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Guide to Tools and Equipment for
Labour-Based Road Construction

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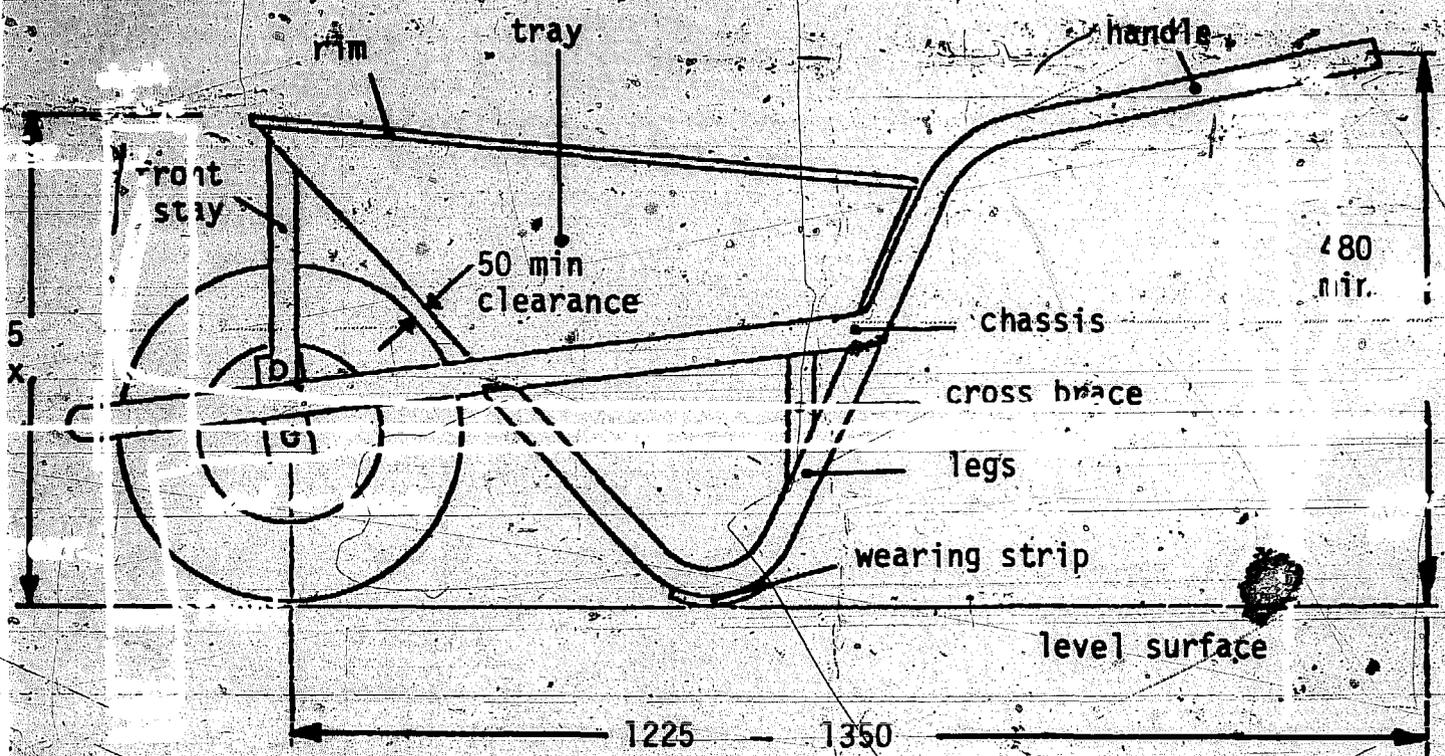
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GUIDE TO TOOLS AND EQUIPMENT

A WEP
study



FOR LABOUR-BASED ROAD CONSTRUCTION



The World Employment Programme (WEP) was launched by the International Labour Organisation in 1969, as the ILO's main contribution to the International Development Strategy for the Second United Nations Development Decade.

The means of action adopted by the WEP have included the following:

- short-term high-level advisory missions;
- longer-term national or regional employment teams; and
- a wide-ranging research programme.

Through these activities the ILO has been able to help national decision-makers to reshape their policies and plans with the aim of eradicating mass poverty and unemployment.

A landmark in the development of the WEP was the World Employment Conference of 1976, which proclaimed inter alia that "strategies and national development plans should include as a priority objective the promotion of employment and the satisfaction of the basic needs of each country's population". The Declaration of Principles and Programme of Action adopted by the Conference have become the cornerstone of WEP technical assistance and research activities during the closing years of the Second Development Decade.

This publication is the outcome of a WEP project.

Guide to tools and equipment for labour-based road construction

International Labour Office Geneva

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PURPOSE OF THE GUIDE

The purpose of this guide is to assist those responsible for the planning and management of labour-based road construction to provide the most suitable tools and equipment for the execution of the work. It does this by presenting information which will allow the reader to:

- specify efficient tools and equipment
- establish acceptance testing procedures for such implements;
- advise local manufacturers on the production of good quality tools and equipment;
- contact sources of supply of good quality implements;
- ensure that tools are used and maintained correctly.

B A C K G R O U N D T O T H E G U I D E

Worldwide there is a growing acceptance that much of the technology transferred from the developed to the developing world has been inappropriate. Too often it has meant both the sacrifice of scarce money and a reduction in the employment prospects of local people. So far as road construction is concerned studies by the International Labour Office and the World Bank have shown that it is feasible to use labour rather than machinery for many activities with a consequent increase in local employment possibilities. For labour-based road construction to be both technically and economically acceptable, it is necessary, among other things, to improve the tools and equipment available.

The use of improved tools and equipment should result in greater productivity, increased tool life, and safer working conditions.

The essential requirements of efficient tools and equipment are that they:

- perform, effectively, the function for which they are intended
- are strong and durable enough to have an acceptable working life bearing in mind the 'normal abuse' to which they will be subjected
- be correctly proportioned to the body dimensions of the operator
- match the strength and working capacity of the operator
- should not cause premature fatigue
- be safe in use
- have initial and maintenance costs as low as possible.

Conditions vary from country to country, but in general existing tools and equipment do not meet most of these requirements. Studies have shown that the main reason for this situation is the purchasing of tools and equipment on the basis of minimum price rather than to an agreed technical specification

One of the major principles of the Guide is that tools and equipment should always be purchased on the basis of technical specifications appropriate to intensive use on construction activities.

- The Guide contains advice on specifications for hand tools and methods of testing ranging from simple visual checks to destructive techniques.

In many countries the present situation could be improved simply by importing better tools and equipment, but this would produce only short-term gains. More permanent benefits will result from local manufacture of improved tools and equipment. Therefore the emphasis in the Guide is on local improvements through better design and manufacture.

- The Guide contains advice on the design and manufacturing techniques for simple hand tools using, where possible, local materials.

There are a range of implements not in current use, largely because they are unknown to the responsible authorities, that could improve the output and safety of labour in road construction:

- The Guide contains advice on tools and equipment that might usefully be introduced on labour-based projects with, where possible, sufficient information for their local manufacture.

The full benefits of improved tools and equipment will only be obtained if correct working methods are used:

- The Guide includes advice on correct tool usage and maintenance.

Examples of hand tools and simple construction equipment available from manufacturers in developing and developed countries are included. The purpose is to illustrate the possibilities for improvement and innovation by imparting more appropriate technology rather than to provide a comprehensive catalogue of sources.

Prices for individual implements have not been quoted. Manufacturers quote prices on different bases, and their publication could be misleading. With the prevailing rapid changes in raw materials costs and rates of exchange, the export prices of goods can change many times per year. In addition, delivered prices will depend on local taxes, customs duty, agents commission, cost of freight and the number of items ordered. These factors will vary from one country to another.

Metric (S.I.) units are used throughout the Guide.

HOW TO USE THE GUIDE

The Guide is divided into twelve sections. Sections 2-12 broadly follow the sequence of operations required to construct a road. At the beginning of each of these sections, there is a list of the tools and equipment that can be used for the operation described, followed by a brief discussion of the factors governing the choice of which tools to use for a particular activity.

In Sections 2-12 the tools and equipment are described under five headings: (i) DESIGN, (ii) MATERIAL, (iii) MANUFACTURE, (iv) OPERATION and (v) SUPPLIERS. In the case of "general purpose" handtools, i.e. handtools which can be used for more than one road construction operation/activity, only their design, material, manufacture and suppliers are described in section 1. Their APPLICATION and OPERATION are described in the relevant sections. Table 1.1 on page 1.3 summarises these sections for each handtool. The list of CONTENTS provides general guidance to the location of information. More specific reference to particular tools or items of equipment is to be found in the INDEX at the back of the Guide.

The information given in each section is that required to obtain an appreciation of the characteristics of each tool or item of equipment. More detailed technical information is given in the TECHNICAL NOTES. References to the technical information will be indicated, as appropriate, by the letters TN followed by a number. For example, (TN 2) means for further information refer to Technical Note 2. References to further information not given in the Guide will be indicated by consecutive numbers, e.g. (4) indicates Reference 4 which will be listed in full at the end of each section.

Most of the tools and equipment are illustrated. The information given covers significant points of design, the materials required for the manufacture of efficient implements and desirable methods of manufacture.

Where appropriate, information is given on sources which can provide the item under consideration, to appropriate national and international specifications. In the individual sections of the Guide, only the trading names of the suppliers are given. Full addresses will be found at the back of the Guide. No attempt has been made to list local agents and distributors, as these can change frequently.

SOURCES OF SUPPLY

Where appropriate, information is given on sources which can provide specific items to appropriate national and international specifications. This is to ensure that it will in fact be possible for organisations responsible for implementing labour-based road construction programmes to obtain the specific items described.

The sources of supply quoted are those which came to our notice as a result of the 160 questionnaires and 600 letters which were sent out to various organisations throughout the world during the preparation of the Guide. We are very much aware that the list of suppliers may not be comprehensive. Consequently, the ILO would welcome applications from suppliers not quoted in the Guide who can produce specific items to the specifications laid down. They can then be included when the Guide is up-dated.

It should be made clear that mention of firm names and commercial products does not imply the endorsement of the International Labour Organisation, nor should any omissions be construed as being in any way representative of the ILO's disapproval.

ACKNOWLEDGEMENTS

This Guide has been made possible through the assistance of the Swedish International Development Authority as part of its financial support to the ILO's programme on appropriate construction technology.

The sources of illustrations and tables are listed in the back of the Guide. The permission of authors and publishers to reproduce these illustrations and tables in this Guide is gratefully acknowledged.

CONTENTS

Section

Page No.

PURPOSE OF THE GUIDE

BACKGROUND TO THE GUIDE

HOW TO USE THE GUIDE

1. HANDTOOLS

Introduction	1.1
Axe	1.5
Brush Hook	1.9
Shovel, Spade and Fork - General	1.11
Shovel	1.15
Spade	1.19
Fork	1.21
Hoe	1.23
Hoe - Forked	1.27
Pickaxe	1.29
Mattock	1.31
Crowbar	1.33
Sledge Hammer	1.37
Stone Breaking Hammer	1.41
Bow Saw	1.43
Cross Cut Saw	1.47
Grass Cutter	1.49
Scythe	1.51
Rake	1.53
Hand Rammer	1.55
Handles	1.57
Axe Handle	1.59
Brush Hook Handle	1.63
Shovel, Spade, Fork Handles	1.65
Hoe and Forked Hoe Handles	1.67
Pickaxe and Mattock Handles	1.69
Sledge Hammer Handle	1.71
Stone Breaking Hammer Handle	1.73
Scythe Handle	1.75
Rake and Hand Rammer Handles	1.77

CONTENTS cont.....

<u>Section</u>		<u>Page No.</u>
2	SURVEYING & SETTING OUT	
	Introduction	2.1
	Application	2.3
	Flexible Tube Water Level	2.7
	Line Level	2.9
	Spirit Level	2.11
	Water Manometer	2.15
	Road Tracer	2.17
	Cowley Level	2.21
	Abney Level	2.23
	Gradient Template	2.25
	Clinometer	2.27
	Cross-staff	2.29
	Surveying Protractor	2.31
	Land Measuring Wheel	2.35
3	SITE PREPARATION	
	Introduction	3.1
	Application	3.3
	Tools and Equipment - Pulling Implements - Manual Plant Pullers	3.7
	Tree Hook	3.9
	Mallet Lever	3.11
	Sheave Blocks	3.13
	Pulling Implements - General	3.17
	Cutting and Felling Implements	3.19
	Grass Cutter	3.19
	Axe/Brush Hook	3.21
	Bow Saw	3.23
	Wedges	3.25
	Breaking Bar	3.29
	Cutting and Felling Implements - General	3.31
	Log Handling Implements	3.35
	Hand Tong and Hook	3.35
	Grapple	3.43
	References	3.45

CONTENTS cont....

<u>Section</u>		<u>Page No.</u>
4	EARTH AND GRAVEL EXCAVATION	
	Introduction	4.1
	Application	4.3
	Tools and Equipment	4.9
	Handtools	4.9
	Ploughs - Design - General	4.13
	Animal-drawn Mouldboard Plough	4.15
	Animal-drawn Tine Plough	4.21
	Tractor-mounted Mouldboard Plough	4.23
	Tractor-mounted Tine Ploughs	4.27
	Ploughs - Operation - General	4.31
	Animal-drawn Earth Scoop	4.33
	Animal-drawn Fresno Scraper	4.37
	Tractor-drawn Earth Scraper	4.41
5	ROCK EXCAVATION	
	Introduction	5.1
	Application	5.3
	Tools and Equipment	5.5
	Pickaxe	5.5
	Crowbar	5.5
	Sledge Hammer	5.5
	Chisel and Tongs	5.7
	Plug and Feathers	5.9
	Machine Breaking and Drilling	5.11
6	ROCK CRUSHING	
	Introduction	6.1
	Application	6.3
	Tools and Equipment	6.5
	Stone Breaking Hammer	6.5
	Sledge Hammer	6.5
	Mobile Crushers	6.7
	References	6.12

CONTENTS cont....

<u>Section</u>		<u>Page No.</u>
7.	HAULING	
	Introduction	7.1
	Application	7.3
	Tools and Equipment	7.9
	Headbasket	7.9
	Mortar Pan	7.13
	Shoulder Pole	7.15
	Measuring Box	7.19
	Western Wheelbarrow	7.21
	Chinese Wheelbarrow	7.27
	Wheelbarrows - General	7.31
	Panniers - Donkey, Pony, Mule	7.35
	Panniers - Camel	7.37
	Animal-drawn Carts	7.39
	Single-axle Tractor and Trailer	7.49
	Four Wheeled Tractor-Trailer	7.53
	Rail Cart	7.67
8.	SPREADING	
	Introduction	8.1
	Application	8.3
	Tools and Equipment	8.5
	Animal-drawn Drag	8.7
	Tractor-drawn Drag	
9.	WATERING	
	Introduction	9.1
	Application	9.3
	Tools and Equipment	9.5
	Filling	9.5
	Bucket	9.7
	Hand and Foot Pumps - General	9.9
	Inertia Pump	9.11
	BRI Diaphragm Pump	9.13
	IRRI Diaphragm Pump	9.15
	Semi-Rotary or Vane Pump	9.17
	Vergnet Diaphragm Pump	9.19

CONTENTS cont

<u>Section</u>		<u>Page No.</u>
9	WATERING cont....	
	Haulage and Dispersal	9.21
	Watering Can	9.21
	Yoke	9.25
	Handcart and Bowser	9.27
	Animal-drawn Bowser	9.29
	Tractor-drawn Bowser	9.31
10	COMPACTION	
	Introduction	10.1
	Application	10.3
	Tools and Equipment	10.9
	Hand Rammer	10.9
	CRRRI Animal-drawn Roller	10.11
	Tractor-drawn Rollers	10.13
11	SOIL STABILISATION	
	Introduction	11.1
	Application	11.3
	Tools and Equipment	11.7
	Handtools - General	11.7
	Animal-drawn Rotary Harrow	11.9
	Animal-drawn Disc Harrow	11.11
	Tractor-drawn Disc Harrow	11.13
	Single-axle Tractor and Rotovator	11.15
	Tractor-mounted Rotovator	11.17
	Tractor-mounted Rotary Harrow	11.19
	Equipment - General	11.21

CONTENTS cont

<u>Section</u>		<u>Page No.</u>
12	BITUMINOUS SURFACINGS	
	Introduction	12.1
	Application	12.3
	Tools and Equipment	12.7
	Bitumen Boiler	12.7
	Cold Emulsion Sprayer	12.11
	Bitumen Can	12.15
	Aggregate Spreading Wheelbarrow	12.17
	Surface Dressing - General	12.19
	Stretcher	12.21
	Batch Heater and Mixer	12.23
	Hand Paver Finisher	12.27

INTRODUCTION

This Section discusses the most useful handtools for labour-based road construction. There are strong national and regional preferences for particular shapes of heads and handles, and even types of tool. This section describes only those types of tool that are likely to be of most general use for road construction.

Information on the following handtools is given:

- axe
- brush hook
- shovel
- spade
- fork
- hoe
- forked hoe
- pickaxe
- mattock
- crowbar
- sledge hammer
- stone breaking hammer
- bow saw
- cross cut saw
- grass cutter
- scythe
- rake
- hand rammer

The application and proper use of each tool - including any variations in design or type required for particular working conditions is described under the activities for which it is recommended. Table 1.1 indicates the sections of the Guide in which specific handtools are referred to.

Field experience has shown that the quality of the handle is crucial to the overall performance of a tool. For this reason the head of each tool is described in detail in the appropriate sub-section. Whilst details of some tool handles are given with the information on heads a separate sub-section is devoted to the specification and supply of handles. Further, more detailed, technical information on handtools is given in the TECHNICAL INFORMATION NOTES at the back of the Guide as follows:

TECHNICAL INFORMATION NOTE TN1: STEELS
 TN2: WOOD
 TN3: TESTING
 TN4: HANDTOOL WEIGHT LENGTH SELECTION
 TN5: MAINTENANCE OF HANDTOOLS
 TN6: SOURCES OF POWER

TABLE 1.1: SUMMARY OF SECTIONS IN WHICH APPLICATION AND USE OF SPECIFIC HANDTOOLS IS DISCUSSED

Tool	Section in which Tool is referred to
axe	3
brush hook	3
shovel	4 5 8 11
spade	3 4
fork	3 4 8 12
hoe	3 4 8 11
forked hoe	3 4 12
pickaxe	4 5
mattock	3
crowbar	4 5
sledge hammer	5 6
stone breaking hammer	6
bow saw	3
cross cut saw	3
scythe	3
grass cutter	3
rake	8 11 12
hand rammer	10

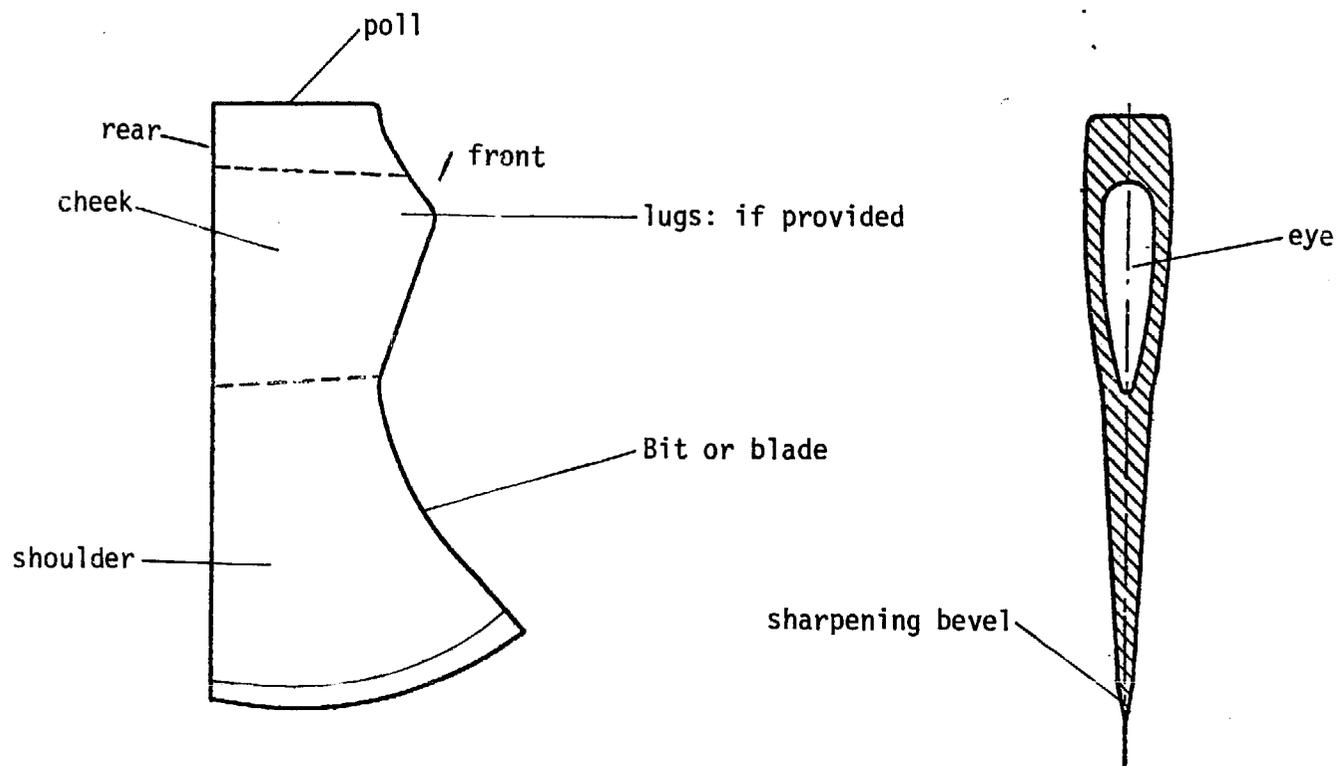


FIGURE 1.1: NOMENCLATURE

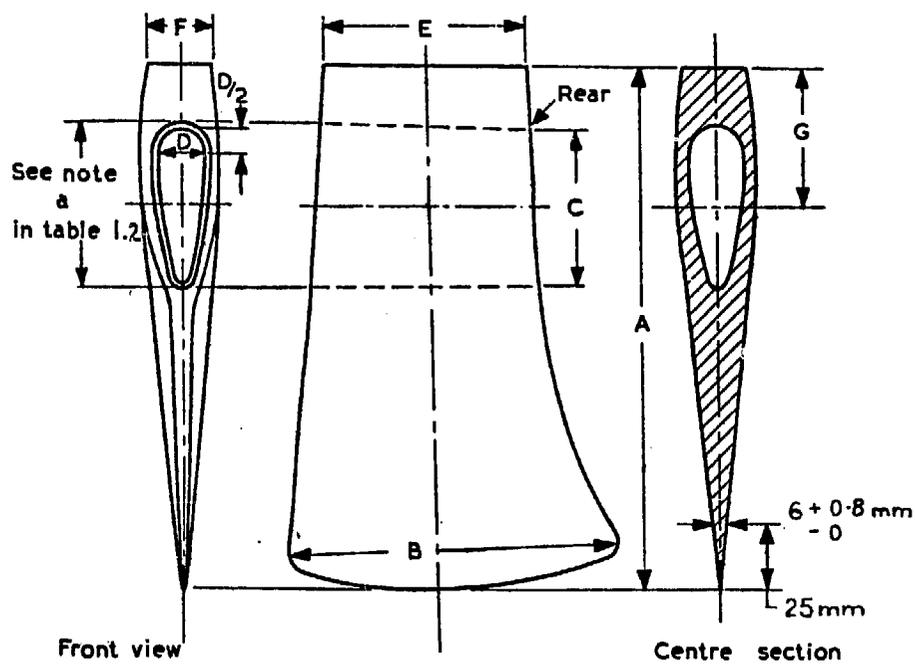


FIGURE 1.2: DIMENSIONS OF WEDGE AXES

AXE

Design : The eye of the axe head should be elliptical as shown and tapered from front to rear: CIRCULAR EYED AXES ARE NOT SATISFACTORY. It is important that the walls of the eye are sufficiently thick to withstand normal working stresses. They should be a minimum of 3mm for axeheads of less than about 1.7kg and a minimum of 5mm for heads in excess of 3.0kg. Wedge type axes are recommended. Table 1.2 gives the dimensions of wedge axes recommended in British Standards.

TABLE 1.2 : SUITABLE DIMENSIONS FOR AXE HEADS (mm)

Nominal weight of head (kg)	HEAD DIMENSIONS: see Figure 1.2							Length of handle (see note d) ±25
	A ±6	B ±6	C ±3	D ±3	E ±5	F ±2	G +0 -6	
1.8	197	118	64	21	81	27	58	813-914
2.3	210	130	64	21	90	29	58	813-914
2.7	222	143	64	21	92	29	58	914
3.2	232	156	73*	23	97	33	64	914

* The limits of tolerance on this size shall be ±5

- NOTE: a. Dimensions C and D apply at the rear of the eye. The dimensions at the front of the eye shall be greater than C and D in all cases.
 b. Dimension D is at a position from the top of the eye of $D/2$.
 c. The handles shall be made to suit the actual eyes.
 d. The alternative lengths are at the discretion of the manufacturer unless one or other is actually specified by the purchaser.

Material : Medium or high carbon alloy steel (TNI)

1. HANDTOOLS

Manufacture : Forged in one piece and heat treated as appropriate (TNI).

Suppliers

- BULLDOG TOOLS
- CYCLONE FORGINGS Pty. Ltd.
- OY FISKARS AB
- SPEAR & JACKSON (TOOLS) Ltd.
- SYNDICAT DE L'OUTILLAGE AGRICOLE ET HORTICOLE
- TROJAN Pty. Ltd.

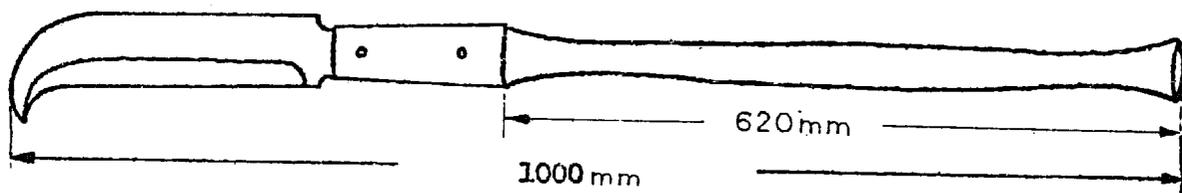


FIGURE 1.3: DIMENSIONS OF LONG HANDLED KRARP BRUSH HOOK

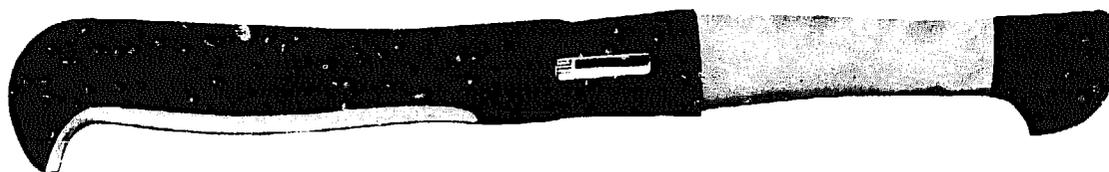


FIGURE 1.4: BLADE AND SOCKET FORGED IN ONE PIECE

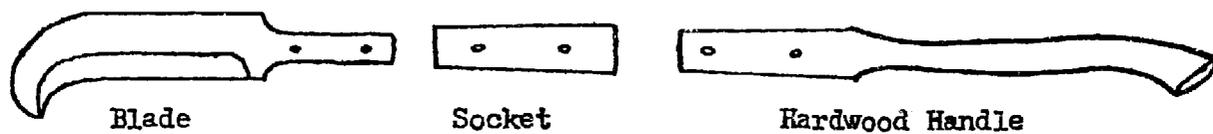


FIGURE 1.5: SEPARATE BLADE AND SOCKET

BRUSH HOOK

Design : There are many traditional shaped brush hook heads. A basic distinction can be made between those with a short handle for single-handed use and those with a long handle to be used two-handed. The long handled type is the most suitable for site clearance activities. Figure 1.3 illustrates the dimensions of such a brush hook.

The blades of Scandinavian brush hooks have weights of 1.3-2.0 kg and lengths of 220-270mm. The characteristic hook shape of the blade helps to prevent small saplings and bushes from being deflected by the force of the cutting stroke. The slightly rounded profile of the blade is to prevent it from jamming in the wood.

Material : Medium or high carbon alloy steel (TN1).

Manufacture : In the best quality brush hooks the socket is forged as one with the blade (Figure 1.4) and heat treated as appropriate (TN1). An alternative, and easier method of fabrication, is to make the socket separate from the blade as illustrated in Figure 1.5 .

Suppliers - OY FISKARS AB
- SKOGSMATERIEL AB

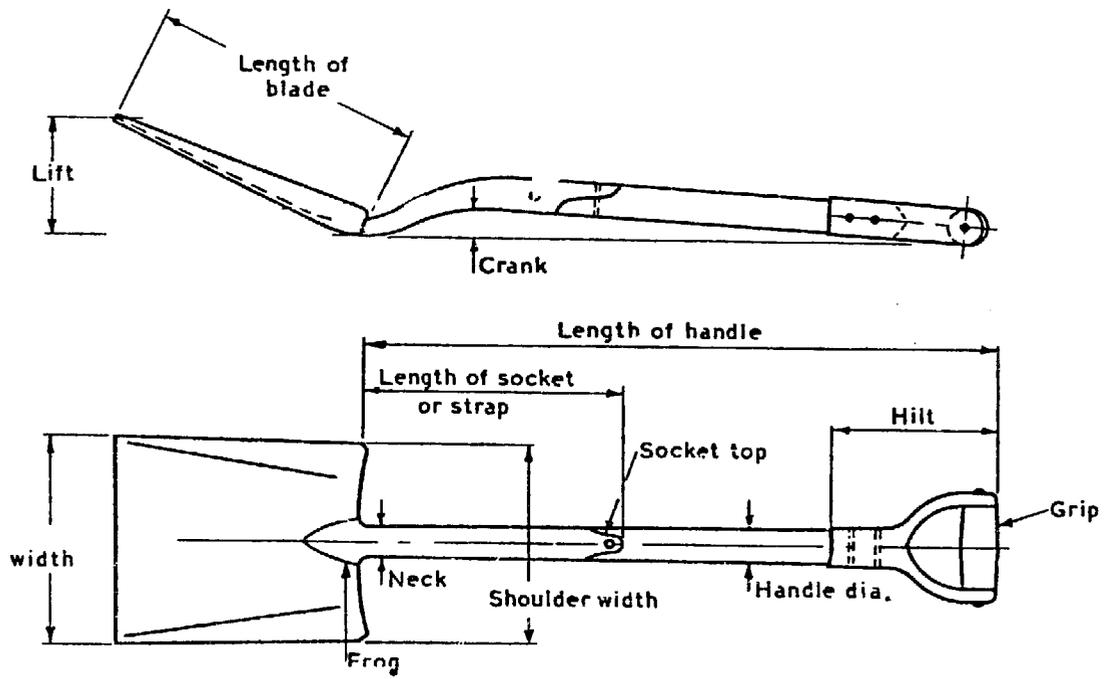


FIGURE 1.6: NOMENCLATURE OF SHOVEL, SPADE AND FORK

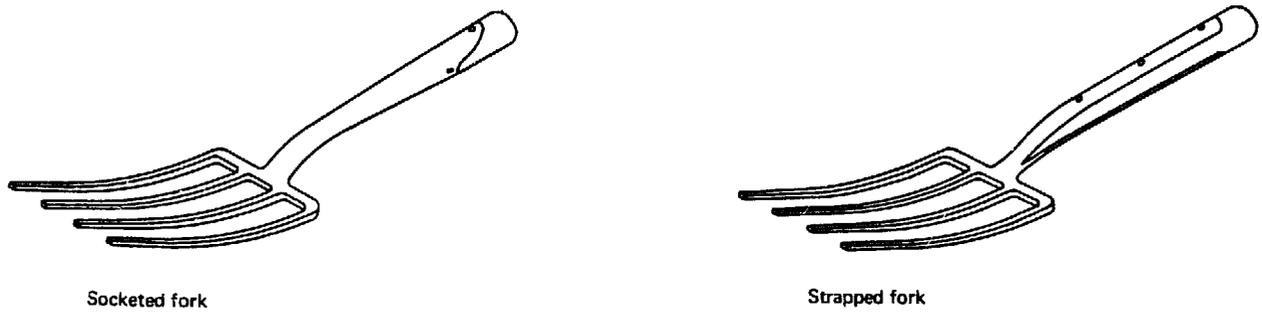


FIGURE 1.7: HANDLE/BLADE CONNECTIONS

SHOVEL, SPADE and FORK

Design : General

The Shovel, Spade and Fork have many common features. In particular the nomenclature used to describe the different parts of the tool, and methods used to attach the head to the handle, are the same.

The *nomenclature* of these tools is given in Figure 1.6

Careful attention to the detailed design of the connection between a fork, spade or shovel head and its handle is necessary to avoid points of weakness and ensure a smooth joint.

The two main types of connection are strapped and socketed (Figure 1.7). In both types the handle may be straight or cranked (bent) at its end. Since tropical woods used for handles are in general not very suitable for bending (TN2) the crank should be designed into the metal head.

For civil construction strapped connections are often preferred, with the strapping extending almost to the hilt since it is difficult to achieve a smooth socketed joint without weakening the handle because of the abrupt change or rapid taper in cross-section that is necessary.

Socketed connections may be solid or split along their length and finished square or, with a lip top. Whichever of these combinations is used gradual tapers rather than abrupt changes in the section of the handle are essential and all metal edges should be rounded to protect the users hands.

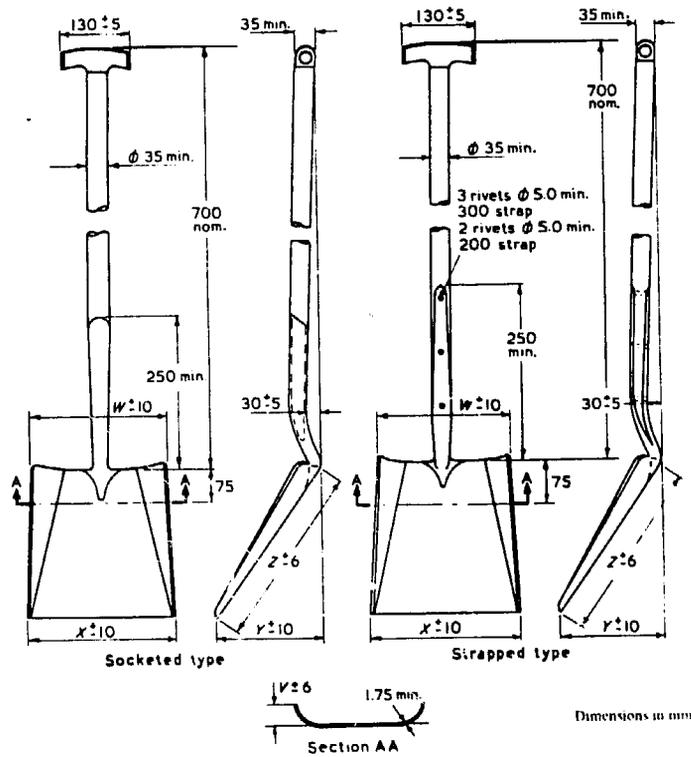
The rivets of strapped or socketed joints must be domed and countersunk so that a smooth handle finish results.

Manufacture : General

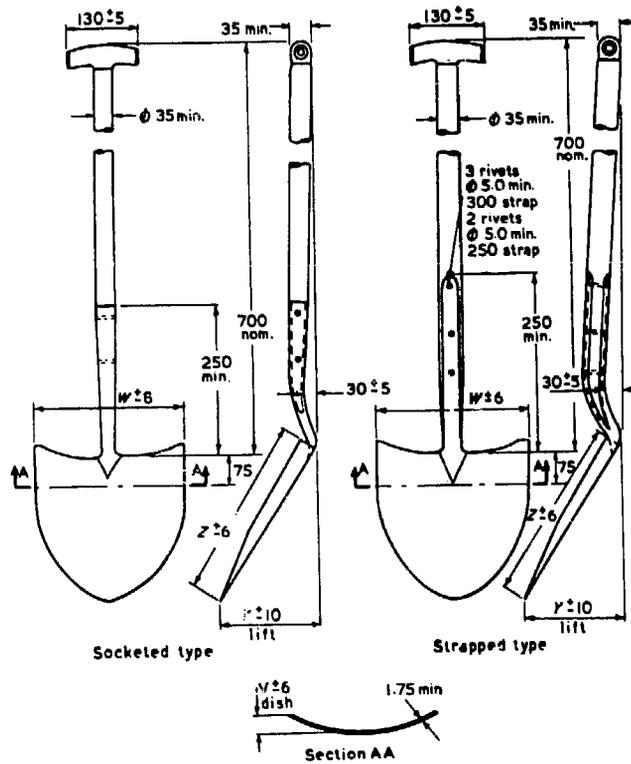
Shovel, Spade and Fork blades can be manufactured in a number of different ways. Following are some of the terms used commercially to describe the different methods of manufacture and their meaning:

- | | |
|------------------------|---|
| Open Socket | : Blade and socket formed from one piece of steel sheet |
| Cofered | : Blade of steel sheet, steel sheet frog and straps welded on |
| Solid Socket | : Blade forged from solid, with socket welded on |
| Solid Socket, Weldless | : Blade and socket forged from solid in one piece |
| Solid Neck, Strapped | : Blade forged from solid, straps welded on |
| Solid Blade, Strapped | : Blade and straps forged from solid in one piece. |

Because of the greater strength conferred forged tools are recommended.



(a) Square Mouth



(b) Round Mouth

FIGURE 1.8: DIMENSIONS OF BRITISH STANDARD SHOVELS

SHOVEL

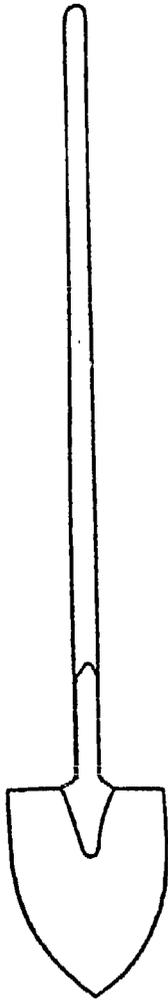
Design : A great variety of shovel shapes and sizes are observed in practice some of which are quite unsuited for road construction activities.

Figure 1.8 illustrates two shovel shapes favoured by British civil contractors. The square mouth shovel is chiefly used for shifting sand and cement, particularly in concrete making, when the straight edge of the head can be used to mix the constituents together. The round mouth is used for shovelling up heavy materials like rubble, and is also sometimes used for digging.

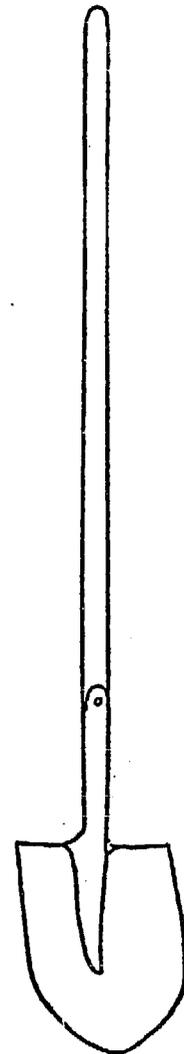
TABLE 1.3: DIMENSIONS OF SHOVEL BLADES (mm)

Size	DIMENSIONS: see Figure 1.8					
	Dish V	Shoulder width W	Mouth width X	Lift Y	Length Z	
Square Mouth	0	20	200	230	160	300
	1	25	220	240	160	300
	2	30	240	250	180	320
	3	30	240	260	190	320
Round Mouth	2	30	260	-	180	320
	3	35	280	-	190	340

Shovel blades are normally curved laterally (dished) and longitudinally. If the curvature is too great then excessive wear will take place on the one or two 'high spots' in contact with the ground. Ideally, the longitudinal section should be almost straight with a slight curve to the blade laterally.



Irish pattern
Blade 240x355
Handle 1230



American miners pattern
Blade 225x305
Handle 1370

FIGURE 1.9: LONG HANDLED SHOVELS (mm)

1. HANDTOOLS

It is important that the blade is sufficiently thick to withstand normal working stresses. It should be a minimum of 1.75mm.

In some countries long-handled shovels of the type illustrated in Figure 1.9 are preferred. They usually have round mouth blades and a handle of 1200-1400mm length.

Material : Medium carbon alloy steel (TNI)

Manufacture : Forged in one piece and heat treated as appropriate (TNI)

Suppliers

- BULLDOG TOOLS
- CYCLONE FORGINGS Pty. Ltd.
- OY FISKARS AB
- SPEAR & JACKSON (TOOLS) Ltd.
- THE STOCKTON HEATH FORGE (Caldwells) Ltd.
- TROJAN Pty. Ltd.

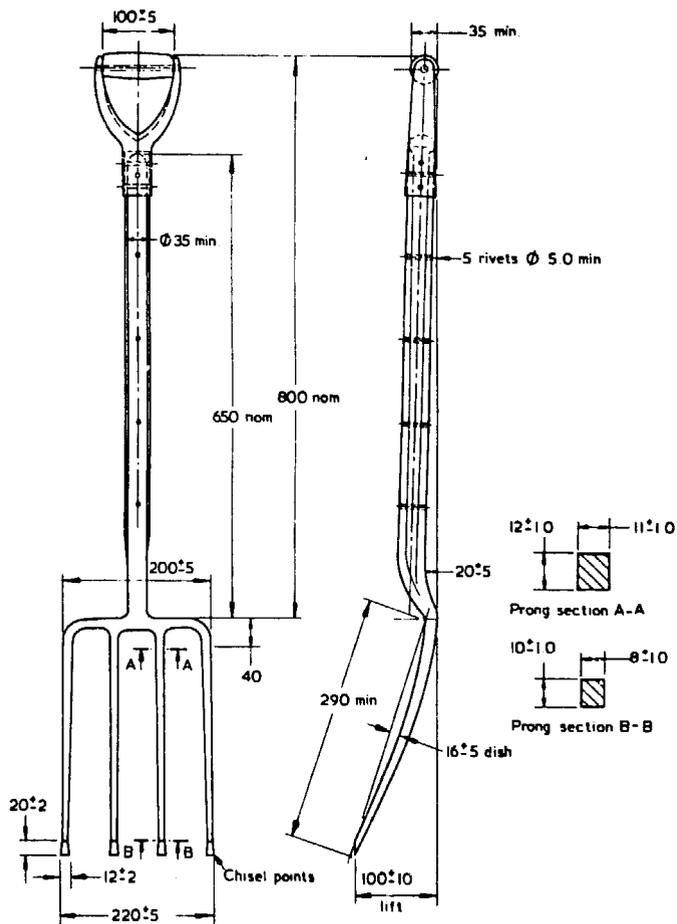
SPADE

Design : Figure 1.10 illustrates the dimensions of a British grafting spade. Spades are designed mainly as digging tools. The blade is normally stronger than that of a shovel and has less of a lift. A spade is normally forced into the ground with the foot which requires that the operator is equipped with stout footwear. The need for stout footwear can be reduced if the spade is given a tread by any one of the means shown in Figure 1.11. Treads do not have to be metal: a broad slotted piece of wood force fitted onto the top of the blade is more suitable for bare foot labour.

Material : Medium carbon alloy steel (TN1).

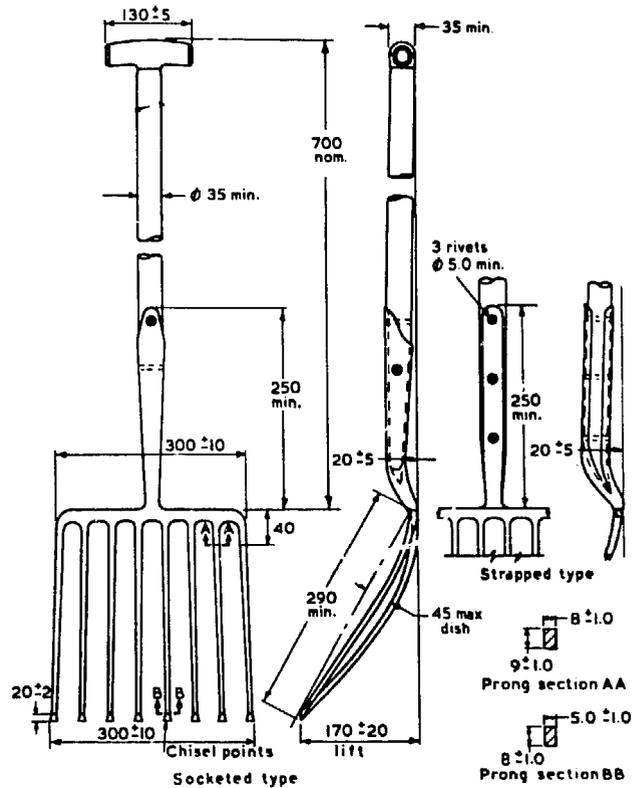
Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers : See SHOVEL suppliers.



Dimensions in mm

(a) Trenching



Dimensions in mm

(b) Ballast

FORK

Design : Figure 1.12 illustrates two forks favoured by British civil contractors. The dish of the prongs is longitudinal rather than lateral and a square section is favoured.

Material : Medium carbon steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1).

Suppliers : See SHOVEL suppliers.

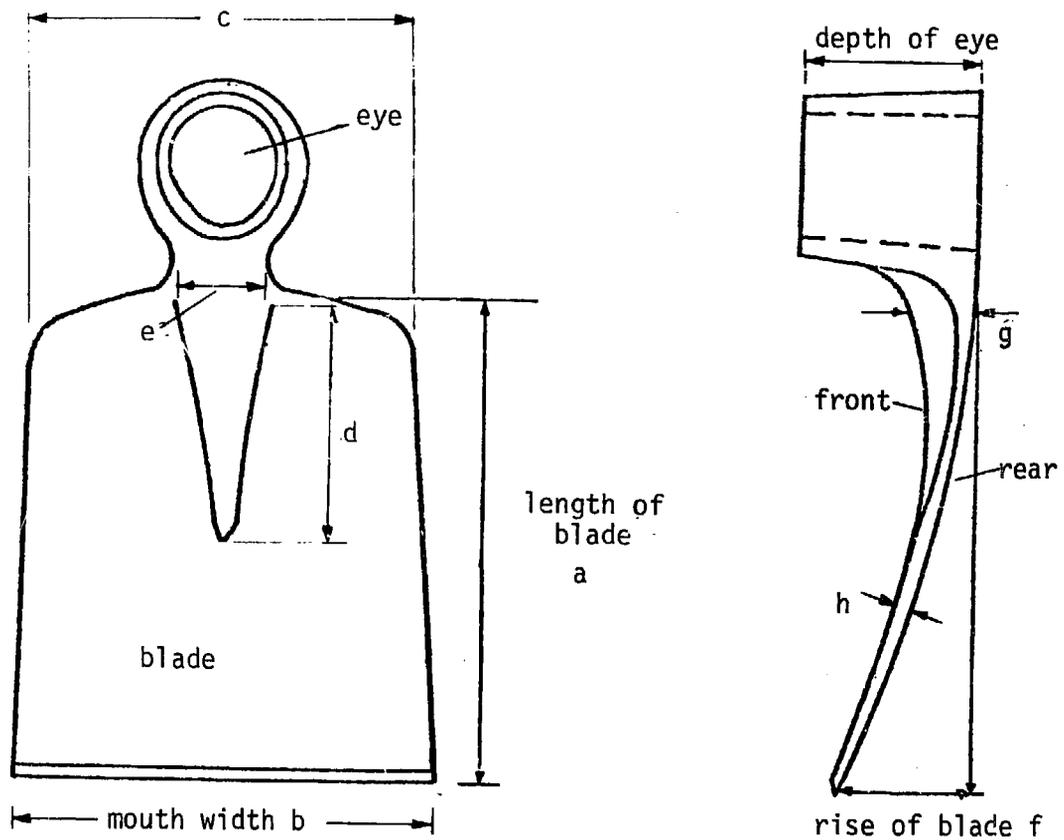


FIGURE 1.13: NOMENCLATURE AND DIMENSIONS OF HOE BLADE

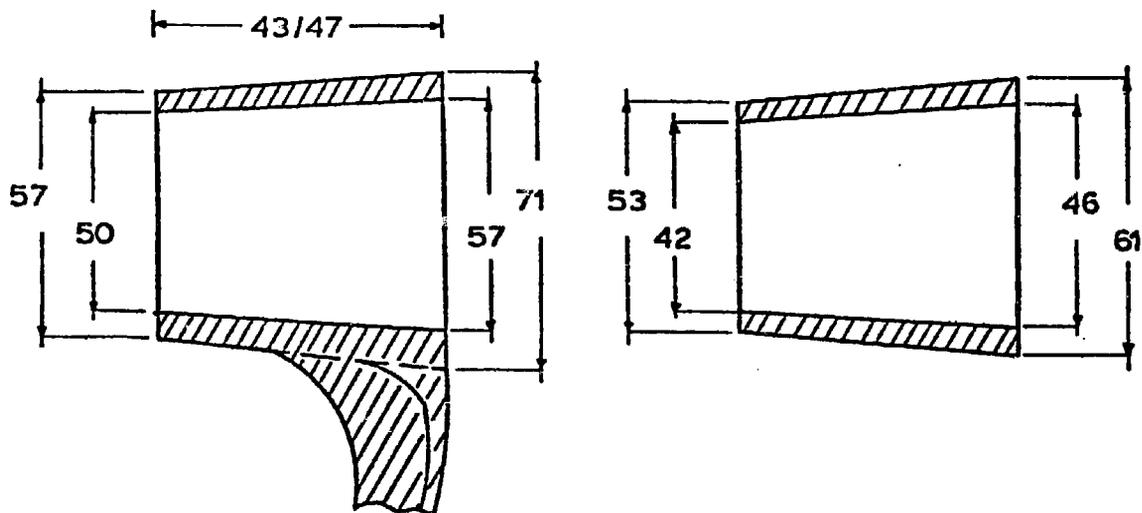


FIGURE 1.14: EYE DIMENSIONS: KRARP HOE

HOE

Design : The eye should be made slightly oval. For very heavy hoes with headweights up to 3.5kg a much larger oval sectioned eye similar to that for a pickaxe (page 1.2a) would be suitable.

The eye section *must* be uniformly tapered from the rear to the front of the blade. There is no available evidence on what is the ideal shape of blade: tapered, flared, rounded or pointed. The consensus of opinion seems to favour a slightly flared blade. A rounded or pointed blade should aid penetration, but might also result in a high rate of wear.

The rise of the blade should be small, so that the blade is almost at right-angles to the handle, giving maximum penetration on impact. Some traditional hoes have a very acute angle between the blade and handle but they are not very effective for digging hard soils.

The edge of the blade should be ground sharp on the *front* face as this will reduce the tendency of the blade to bounce on hard surfaces.

TABLE 1.4: SUITABLE DIMENSIONS FOR HOE BLADE (mm)

	DIMENSIONS: see Figure 1.13								Weight kg
	a	b	c	d	e	f	g	h	
KRARP Hoe	210	150	140	120	30	55	15 min	2.75 min	1.5
Indian National Standard	255 on curve	205	190	115- 180	30	-	-	-	1.8

Figure 1.14 gives suitable eye dimensions for a hoe.

1. HANDTOOLS

Material : Medium carbon steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers

- THE CHILLINGTON TOOL Co. Ltd.
- CYCLONE FORGINGS Pty. Ltd.
- SCOLVIL HOE Co.
- SYNDICAT DE L'OUTILLAGE AGRICOLE ET HORTICOLE
- THE TATA IRON & STEEL Co. Ltd.
- TROJAN Pty. Ltd.
- UBUNGO FARM IMPLEMENTS MANUFACTURING Co. Ltd.

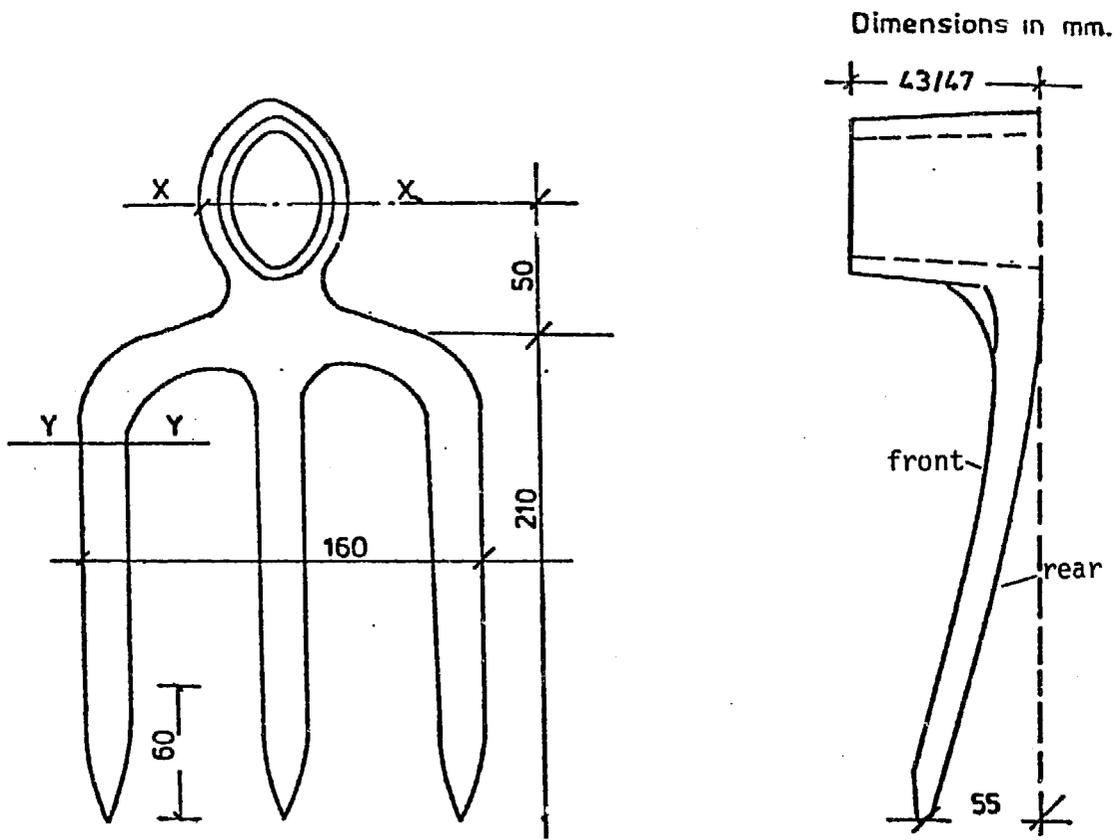


FIGURE 1.15: KRARP FORKED HOE BLADE

HOE - FORKED

Design : The basic principles of design are the same as for the hoe.

The eye is oval and tapered from rear to front. The rise of the prongs is fairly small to give maximum penetration on impact. The edge of the prongs are ground sharp on the *front* face.

Figure 1.15 illustrates the dimensions of the forked hoe blade evolved for use on the KRARP. It weighs approximately 1.5kg. Eye dimensions are the same as for the hoe (Figure 1.14).

Material : Medium carbon steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers : THE CHILLINGTON TOOL Co. Ltd.

PICKAXE

Design : Normal practice is to fabricate the head with one chisel and one pointed end. The chisel end is ground sharp on the *rear* face. The eye is oval and tapered from front to back. The rise of the blade is fairly small at both ends of the head to give maximum penetration on impact. The basic principles for designing the eye and rise of a pickaxe head are similar to that of the hoe, although it is of much more robust construction.

Figure 1.17 and Table 1.5 give dimensions of pickaxe heads. The dimensions are based on the British Standard with additional data from the KRARP design which is very similar. However the width of the chisel on the KRARP pickaxe is only 25mm.

TABLE 1.5: WEIGHT AND BLADE LENGTH OF PICKAXE HEADS

Nominal Weight (kg)	Overall Length (mm) L \pm 50
2.7	610
3.2	660
3.6	686

Material : Medium carbon steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers

- BULLDOG TOOLS
- BURGON & BALL Ltd.
- CYCLONE FORGINGS Pty. Ltd.
- SYNDICATE DE L'OUTILLAGE AGRICOLE ET HORTICOLE
- THE STOCKTON HEATH FORGE (Caldwells) Ltd.
- TROJAN Pty. Ltd.

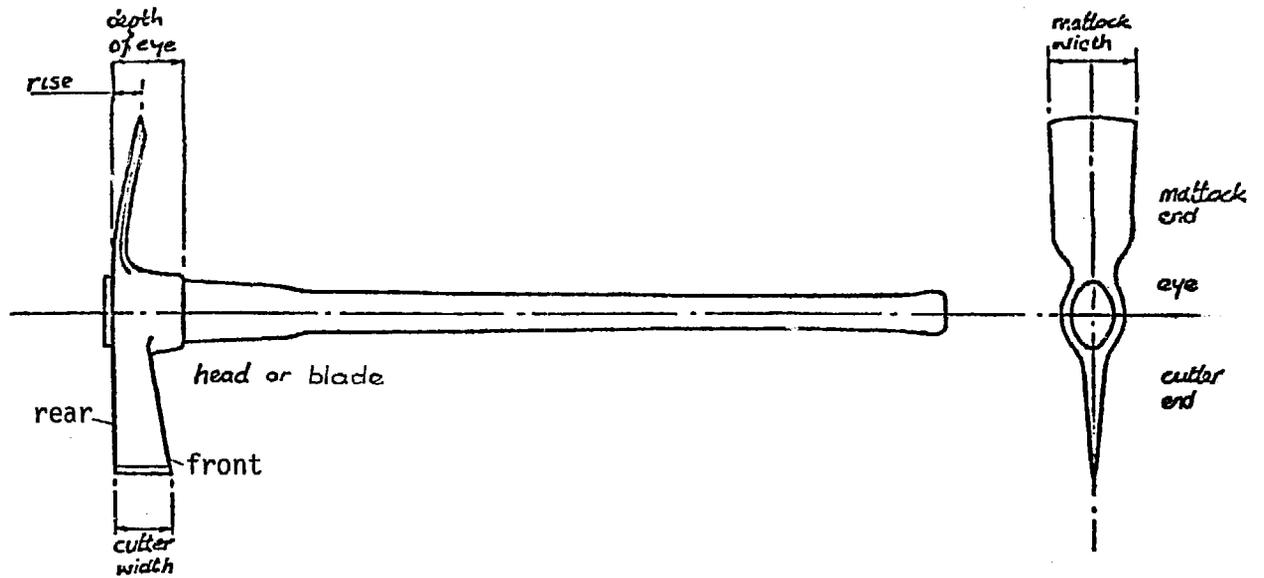


FIGURE 1.18: NOMENCLATURE OF MATTOCKS

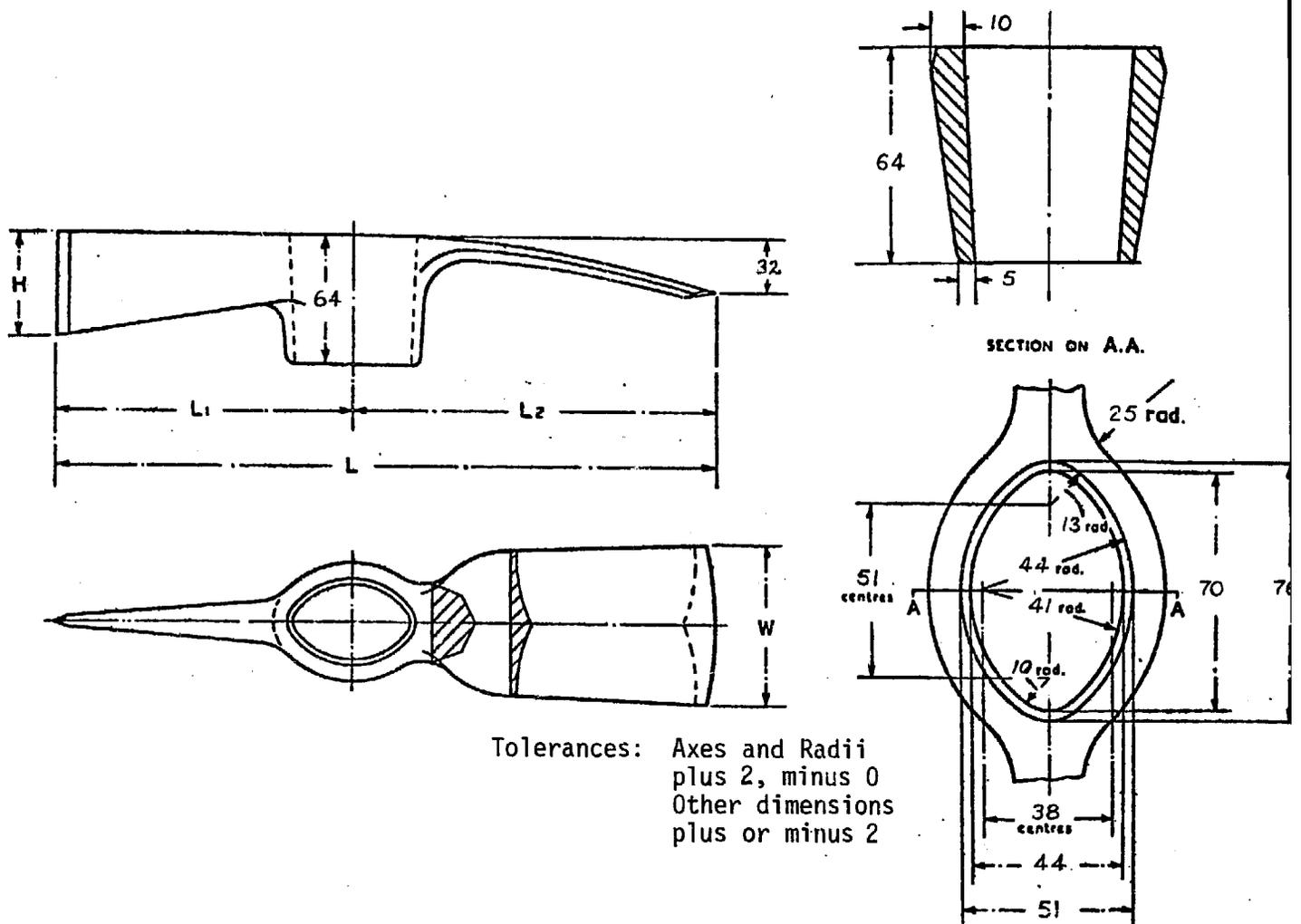


FIGURE 1.19: BRITISH STANDARD MATTOCK HEAD

MATTOCK

Design : Normal practice is to fabricate the head with two chisel edges at right-angles; one for digging and the other for cutting roots. The edge of the mattock part of the head is ground sharp on the *front* face. The eye is oval and tapered from front to back. The rise of the mattock part of the head is fairly small to give maximum penetration on impact. The basic principles for designing the eye and rise of a mattock head are similar to that of the hoe, although it is of much more robust construction.

Figure 1.19 and Table 1.6 give dimensions of British Standard Mattock heads. The KRARP design is essentially the same as the 2.3kg head in the table. However the thickness of the eye wall is a consistent 5mm.

TABLE 1.6: DIMENSIONS OF BRITISH STANDARD MATTOCK HEAD(MM)

Nominal weight kg	Overall length L	Length of cutter L ₁	Length of mattock L ₂	Width of cutter H	Width of mattock W±3
1.8	330	152	178	64	89
2.3	381	178	203	70	102
2.7	432	203	229	70	114

Material : Medium carbon steel (TN1)

Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers : see PICKAXE Suppliers

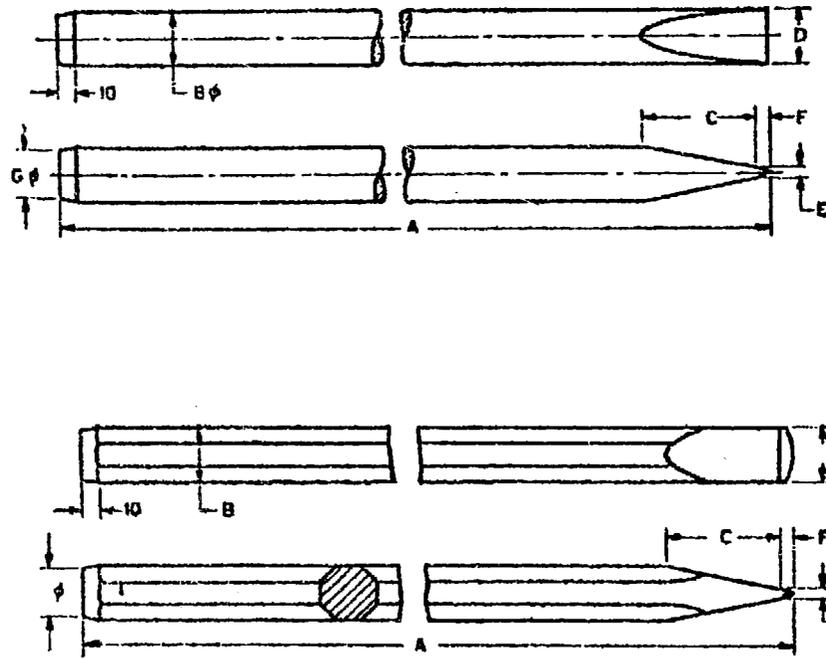


FIGURE 1.20: INDIAN STANDARD CROWBARS

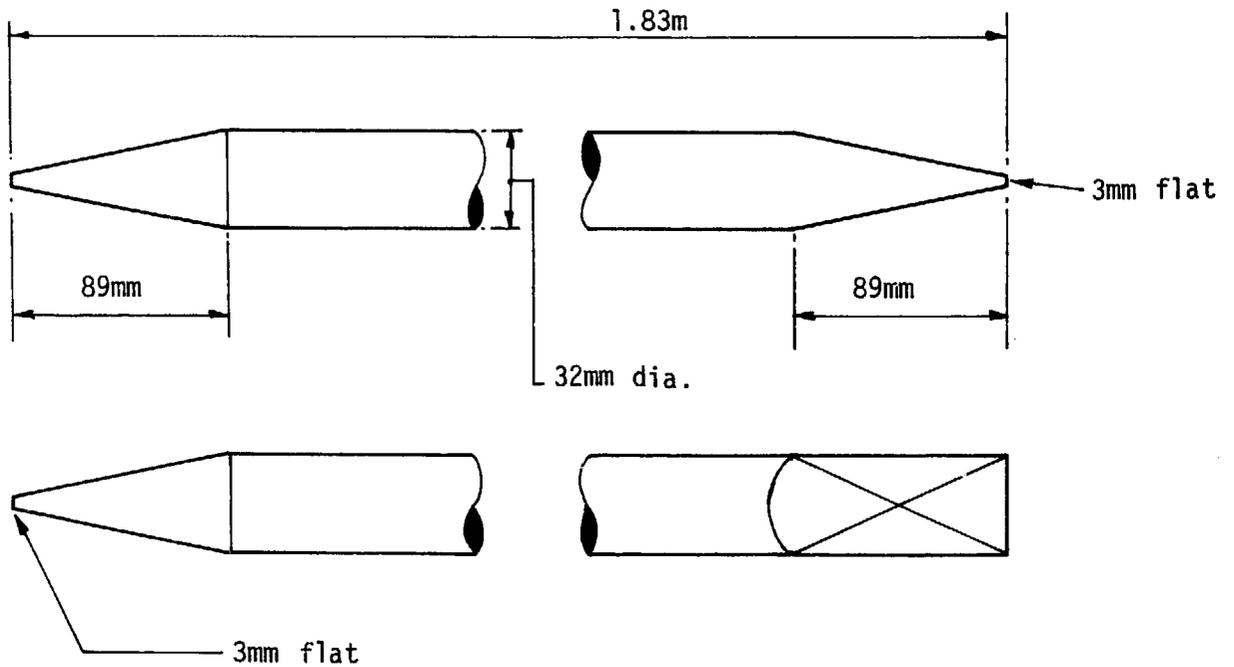


FIGURE 1.21: KRARP CROWBAR

CROWBAR

Design : These are normally manufactured either as round or octagonal sections rods. For road construction a diameter in excess of 30mm is required with a length between 1.5 - 1.8m being most useful. These weigh approximately 7-11kg.

Table 1.7 gives the dimensions of crowbars recommended in Indian National Standards.

TABLE 1.7: DIMENSIONS OF INDIAN STANDARD CROWBARS (mm)

	Nominal weight (kg)	DIMENSIONS: see Figure 1.20						
		Length A \pm 25	Diameter/width across flats B	Length of chisel end C	Width of ground portion D	Thickness at start of cutting edge E	Cutting edge F	Diameter of hammer end G
Round Crowbars	11	1830	30	76	30	6	8	29
Octagonal Crowbars	9	1650	30	70	30	6	8	25
	11	1650	32	75	32	6	8	30

These provide for a chisel and hammer ends. More commonly one end of the crowbar is pointed to aid penetration and the other is given a chisel end for leverage purposes.

Figure 1.21 illustrates such a crowbar evolved for use on the KRARP. It weighs approximately 11kg.

Material : Medium to high carbon steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1)

Suppliers

- BURGON & BALL Ltd.
- FURNIVAL STEEL Co. Ltd.
- THE TATA IRON & STEEL Co. Ltd.
- TROJAN Pty. Ltd.

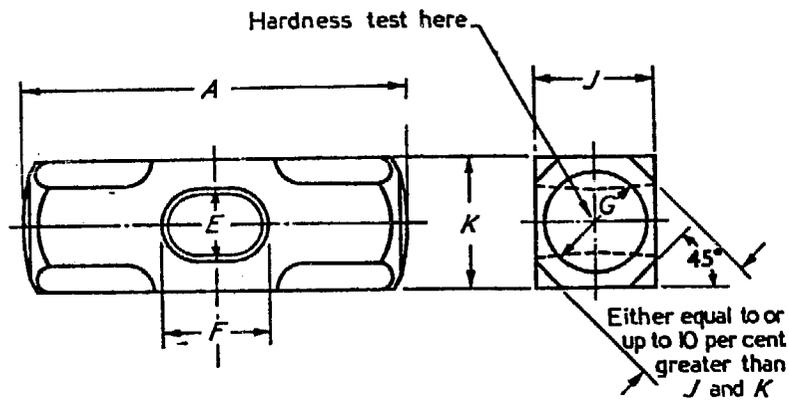


FIGURE 1.22: DOUBLE FACE SLEDGE HAMMER

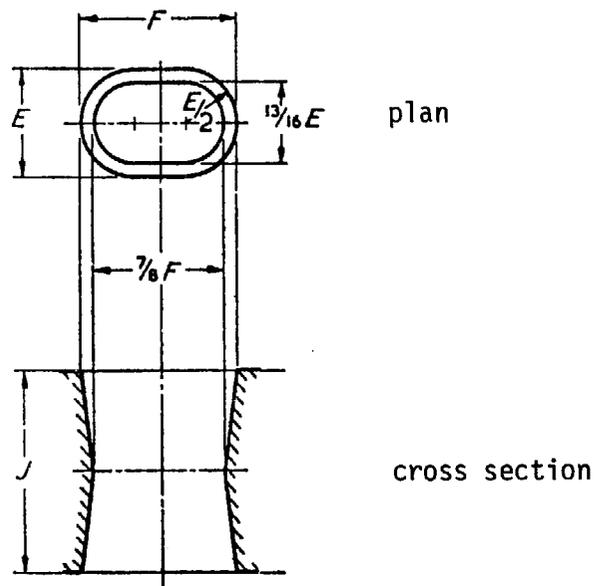


FIGURE 1.23: FORM AND PROPORTIONS OF HAMMER EYES

SLEDGE HAMMER

Design : There are a number of purpose specific sledge hammer heads, but the most useful for road work is the double faced head illustrated in Figure 1.22.

The eye is a characteristic oval shape as illustrated in Figure 1.23. Table 1.8 gives the U.K. method of specifying the dimensions of double faced sledge hammer heads.

TABLE 1.8: DIMENSIONS OF DOUBLE FACED SLEDGE HAMMERS (mm)

Nominal Weight kg	DIMENSIONS:* see Figures 1.22 and 1.23					
	A	E ± 5 per cent	F ± 5 per cent	G	J	K min
1.8	133	22	33	38	46	
2.3	146	22	33	40	48	
2.7	152	25	38	43	51	
3.2	159	25	38	46	54	
3.6	165	28	41	48	57	
4.5	178	29	43	51	64	
5.4	186	29	43	54	70	

* Except for E, F and K, dimensions are mean nominal values calculated to give the weights shown within a tolerance of $+7\frac{1}{2}$ to $-2\frac{1}{2}$ per cent.

Material : Medium carbon alloy steel (TN1)

Manufacture : Forged in one piece and heat treated as appropriate (TN1)
These are highly skilled operations (TN3). If strict adherence to specifications is not maintained the result will be a head that is liable to crack and splinter with consequent danger to the workforce.

1. HANDTOOLS

- Suppliers*
- OY FISKARS AB
 - TROJAN Pty. Ltd.
 - THE TATA IRON & STEEL Co. Ltd.
 - WM. GILPIN SENR & Co. (TOOLS) Ltd.
 - WILLIAM WHITEHOUSE & Co. (ATLAS FORGE) Ltd.

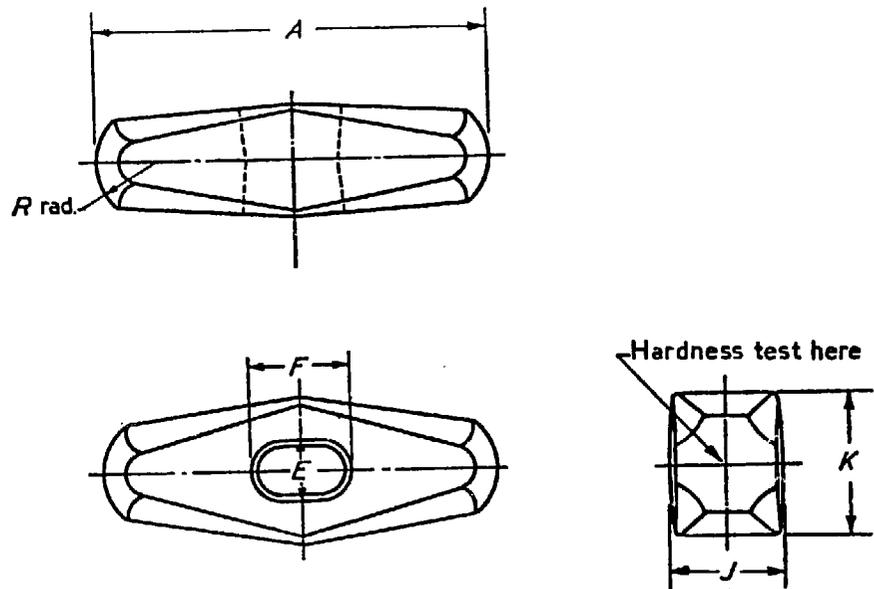


FIGURE 1.24: DIMENSIONS OF BRITISH STANDARD STONE BREAKING HAMMER

STONE BREAKING HAMMER

Design : Figure 1.24 and Table 1.9 give dimensions of British Standard Stone Breaking Hammer heads. Both British and Indian Standards permit oval and circular eyed heads but oval eyes of the form shown in Figure 1.23 and dimensions given in Table 1.9 are preferred.

TABLE 1.9: DIMENSIONS OF STONE BREAKING HAMMER (mm)

Nominal Weight kg	DIMENSIONS:* see Figures 1.24 and 1.23					
	A	E ±5 per cent	F ±5 percent	J	K min	R
0.5	95	19	29	27	43	14
0.6	98	19	29	27	46	16
0.7	106	19	29	32	49	18
0.8	108	25	38	33	49	18
0.9	118	25	38	37	51	19

* Except for E, F and K, dimensions are mean nominal values calculated to give the weight shown within a tolerance of $+7\frac{1}{2}$ to $-2\frac{1}{2}$ per cent.

Material : Medium carbon alloy steel (TN1).

Manufacture : Forged in one piece and heat treated as appropriate (TN1). These are highly skilled operation (TN3). If strict adherence to specifications is not maintained the result will be a head that is liable to crack and splinter with consequent danger to the work force.

Suppliers

- SAMUEL SWIFT Ltd.
- THE TATA IRON & STEEL Co. Ltd.

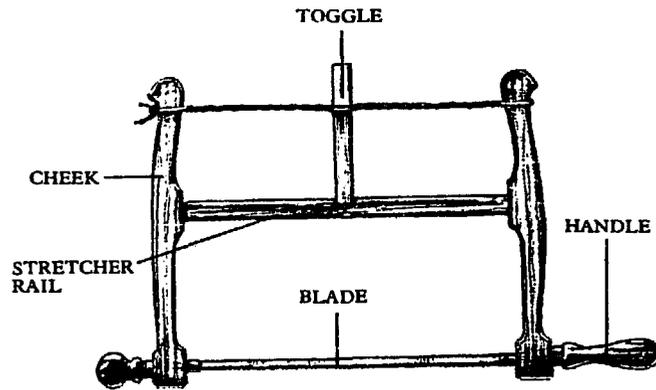
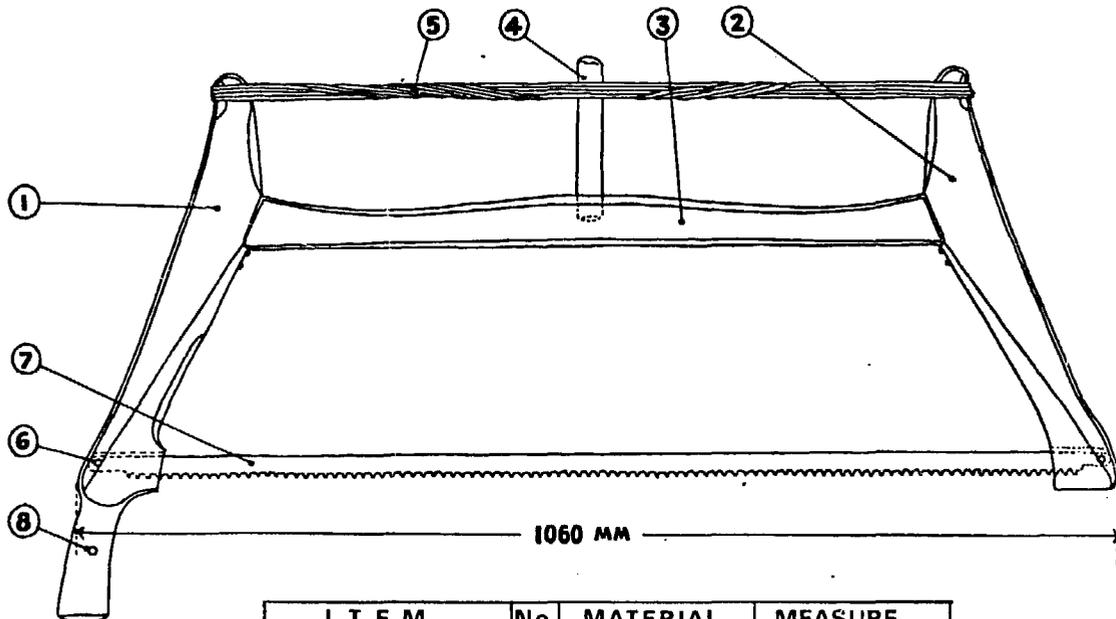


FIGURE 1.25: NOMENCLATURE



ITEM	No.	MATERIAL	MEASURE
Inner support	1	Hardwood	110 X 70 X 600 mm
Outer support	2	Hardwood	110 X 70 X 480 "
Center piece	3	Light wood	70 X 70 X 150 "
Tightening piece	4	Light wood	40 X 25 X 180 "
String	5	manila rope or steel wire	3 mm dia. x 7 metres
Pin	6	Iron	6 mm dia. x 35 mm
Blade	7	Steel	
Wood screw	8	Steel	

FIGURE 1.26: PHILIPPINE BOW SAW

BOW SAW

Design : Figure 1.25 illustrates the nomenclature and design of the traditional bow saw. A relatively narrow blade is held in tension by the side pieces, or cheeks, of the frame, pivoting about their centres on the ends of a stretcher rail. The top ends of the cheeks are pulled toward each other either by a twisted cord and toggle stick or by a threaded rod or a cable tensioned by wing nuts. Figure 1.26 illustrates the design of a modern version of the traditional bow saw produced in the Philippines.

A more recent development has been the tubular steel frame bow saw (Figure 1.27). In modern versions tension is applied by a quick-release lever. The lever combined with an oval sectioned frame provides a comfortable hand grip.

Blades are normally 20-25mm wide and are produced in a range of standard lengths of which the 762 and 914mm are the most useful. They can be supplied with various shaped teeth to suit different types of wood (Figure 1.28). The simplest (a) known as the *peg* tooth, is an evenly spaced row of V-shaped teeth. Each tooth is filed on both edges so that it cuts in both directions. Type (b) has a deep *gullet* between each tooth: while the teeth do the cutting, the sawdust is carried out of the cut in the gullets. This prevents the saw jamming in the cut and is especially important for cutting standing timber. Type (c) has rows of cutting teeth interspersed by unsharpened *rakes* teeth, designed to take the sawdust clear of the sawcut. The *lance* tooth saw (d) has a group of four cutting teeth and a pair of rakers separated by deep gullets. The advice of national forestry organisations is best sought in deciding tooth shapes appropriate to local conditions.

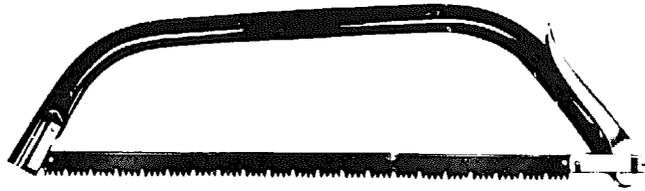
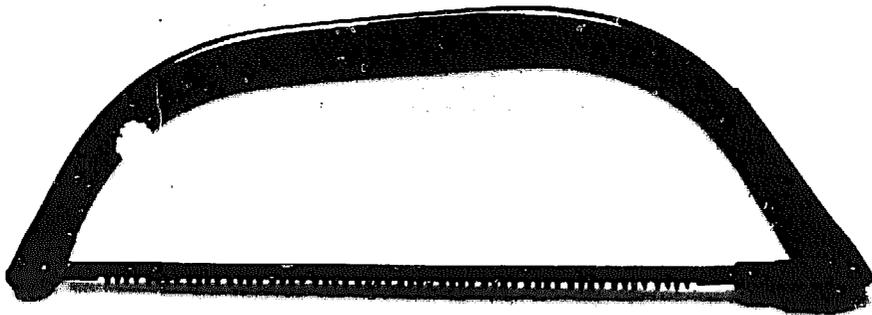


FIGURE 1.27: TUBULAR STEEL FRAME BOW SAW



Peg

(a)



Tooth and Gullet Combination

(b)



Great American

(c)



Lance

(d)

FIGURE 1.28: SAW BLADE TEETH SHAPES

Material : Frame - seasoned wood or mild steel sheet (TN1).
Blade - high carbon alloy steels (TN1).

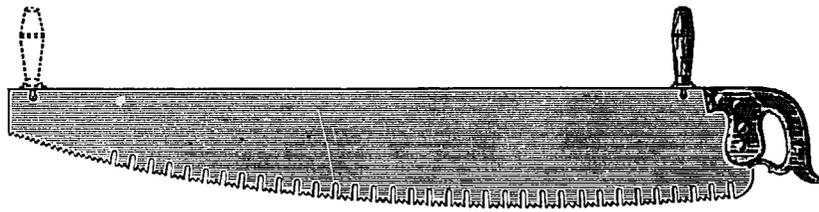
Manufacture : Frame - requires general workshop tools.
Blade - highly specialised cold rolling and heat treatment processes.

Suppliers - EDSBYNS INDUSTRI AKTIE BOLAG (BUSHMAN)
- SANDVIK U.K. Ltd.
- SLACK SELLARS & Co. Ltd.
- SPEAR & JACKSON (TOOLS) Ltd.
- SKOGSMATERIEL AB



Handle ends

(a) Two-man



(b) One-man: occasional two-man

FIGURE 1.29: TWO-MAN CROSS CUT SAWS

CROSS CUT SAW

Design : It is possible to obtain one-man cross cut saws but for tree felling the most useful is the two-man type illustrated in Figure 1.29. It consists of a flat blade, 1.2-2.4 metres long and about 300 mm wide at the mid-point, with cutting teeth on the underside and an upright handle at each end. The shape of the blade is traditional and has no obvious affect on the cutting ability of the saw. Like the bow saw they can be supplied with various shaped teeth to suit different types of wood and advice on this is best sought from national forestry organisations.

Material : Handles - seasoned wood
Blade - high carbon alloy steels (TN1)

Manufacture : Handles - simple wood lathe
Blade - highly specialised cold rolling and heat treatment processes.

Suppliers - E. GARLICK & SON Ltd.

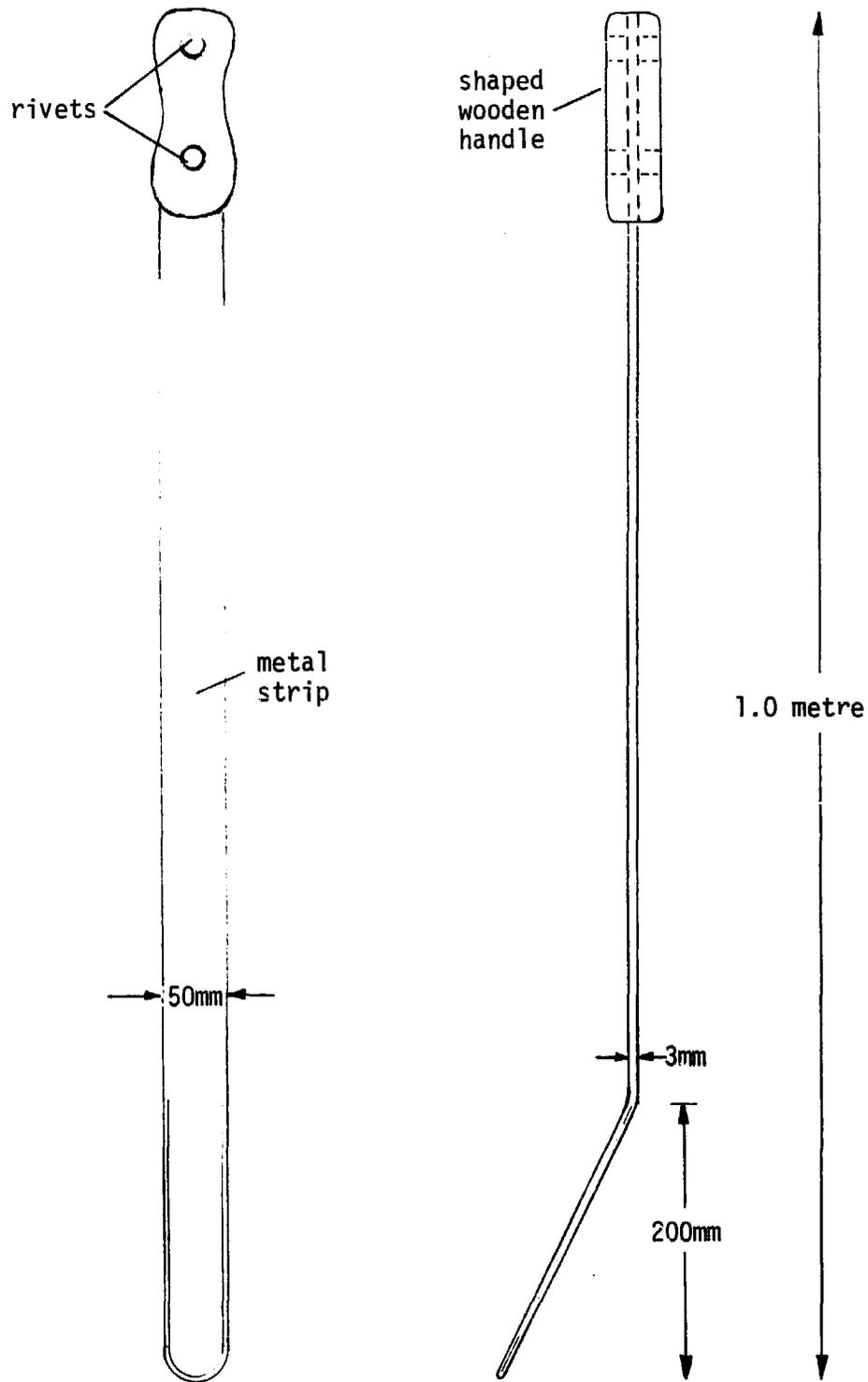


FIGURE 1.30: GRASS CUTTER

GRASS CUTTER

Design : Figure 1.30 illustrates the design of a grass cutter. It consists of a metal strip 50mm wide, 3mm thick and about 1.0 metre long. The bottom 200mm is cranked and sharpened on both edges, and the top end is fitted with a shaped wooden handle rivetted onto the metal strip.

Materials : Handle - seasoned hardwood
Blade - mild steel (TNI)

Manufacture : Requires simple workshop facilities

Suppliers : N/A

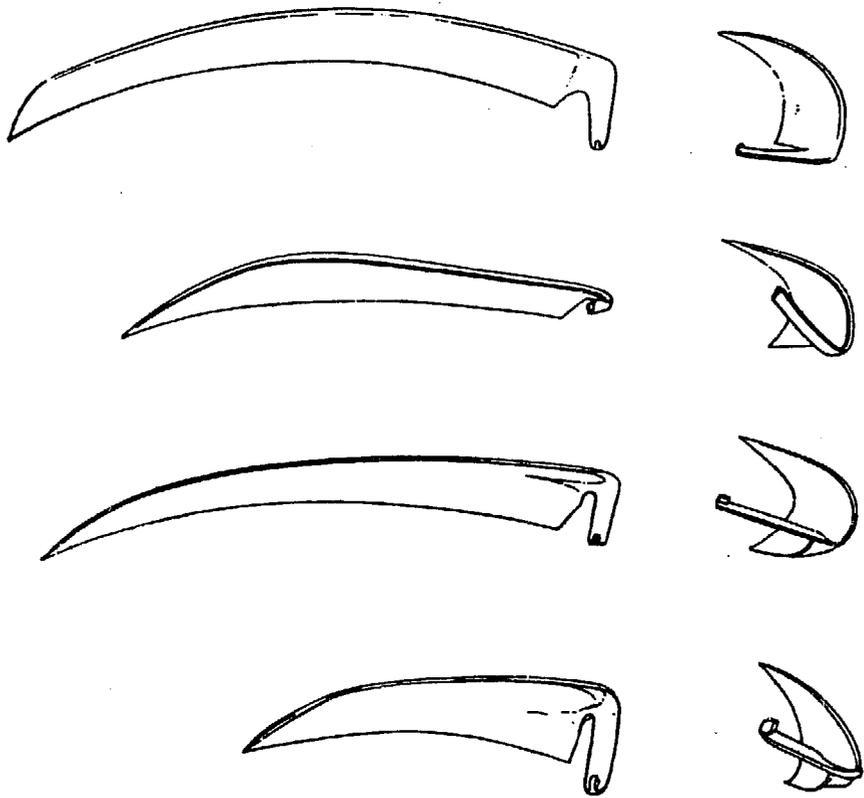


FIGURE 1.31: TRADITIONAL SCYTHE BLADES

SCYTHE

Design: : Figure 1.31 illustrates the design of different types of traditional scythe blade. It consists of a long lightly curving blade sharpened along one edge. The tang at one end serves to connect the blade to a long curved handle (see HANDLES page 1.57) equipped with a metal collar or 'ring connector'.

Two different types of blades are in use: *ground* blades, i.e. blades which are sharpened on a grindstone, and *hammered* blades, i.e. blades which are sharpened with a hammer and small anvil or similar device, thereby drawing out the cutting edge. Both types have the finishing touches given to the edge with a whetstone and are kept sharp in the field by the same method. Ground blades are thicker and thus heavier, and made of steel with a higher carbon content than hammered mild steel blades. Hammered blades are said to be less liable to breakage and less fatiguing to use. The length of blade for grass cutting varies between 700-1000mm and for brush cutting between 400-500mm. A good length for multi-purpose blades is 700-750mm.

Material : Mild or medium carbon steel (TN1)

Manufacture : Requires simple workshop facilities.

Suppliers

- BULLDOG TOOLS
- SPEAR & JACKSON (TOOLS) Ltd.
- SYNDICATE DE L'OUTILLAGE AGRICOLE ET HORTICOLE

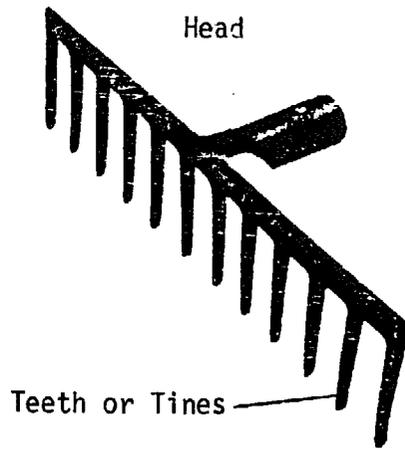
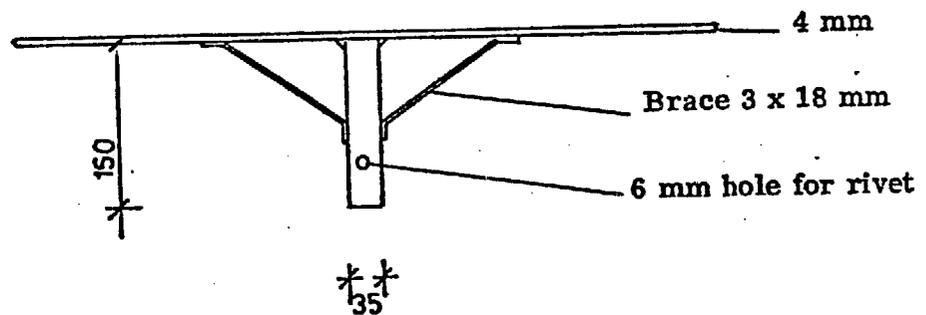
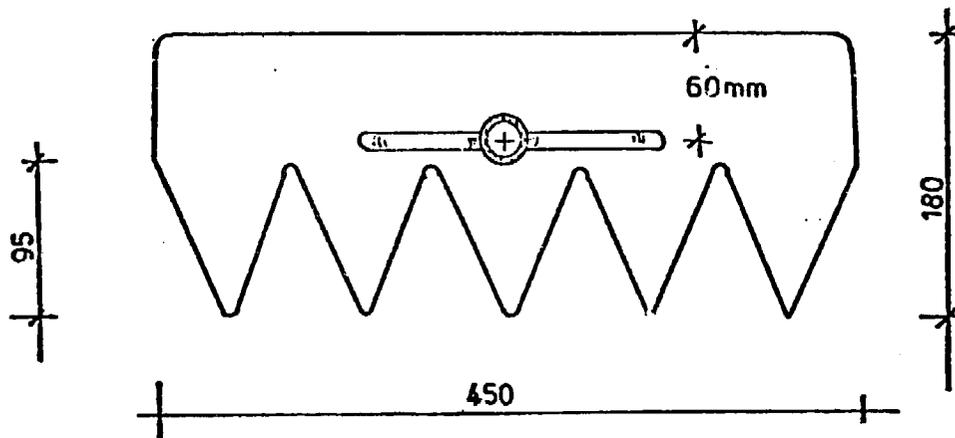


FIGURE 1.32: NOMENCLATURE



To be fitted with a 1500 mm long hardwood handle

FIGURE 1.33: KRARP RAKE

RAKE

Design : The main variations in rake design are caused by the materials to be handled: soil, aggregate or bitumen coated stone.

Commercially produced rakes have 10-16 teeth each about 75-100mm long with an overall width of about 400mm.

Figure 1.33 illustrates the construction of a mild-steel rake (heavy duty spreader) evolved experimentally for use on the Kenya Rural Access Roads Programme. It weighs approximately 3kg and is used for spreading soil, sand and gravel. The dimensions given are nominal and should be subject to confirmation locally.

Material : Mild or medium carbon steel (TN1), or hardwood.

Manufacture : The best metal rakes are forged with the socket, head and flat teeth made from a single piece of metal. However rivetting of round teeth to a forged head and socket can also produce a good quality rake.

Suppliers - Widely available.

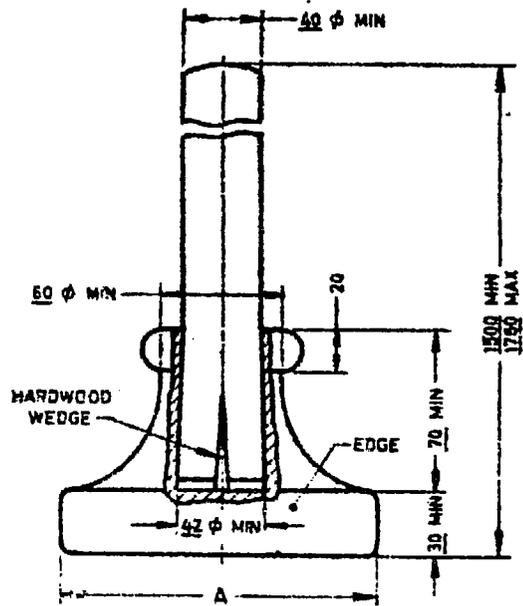


FIGURE 1.34: INDIAN STANDARD RAMMER

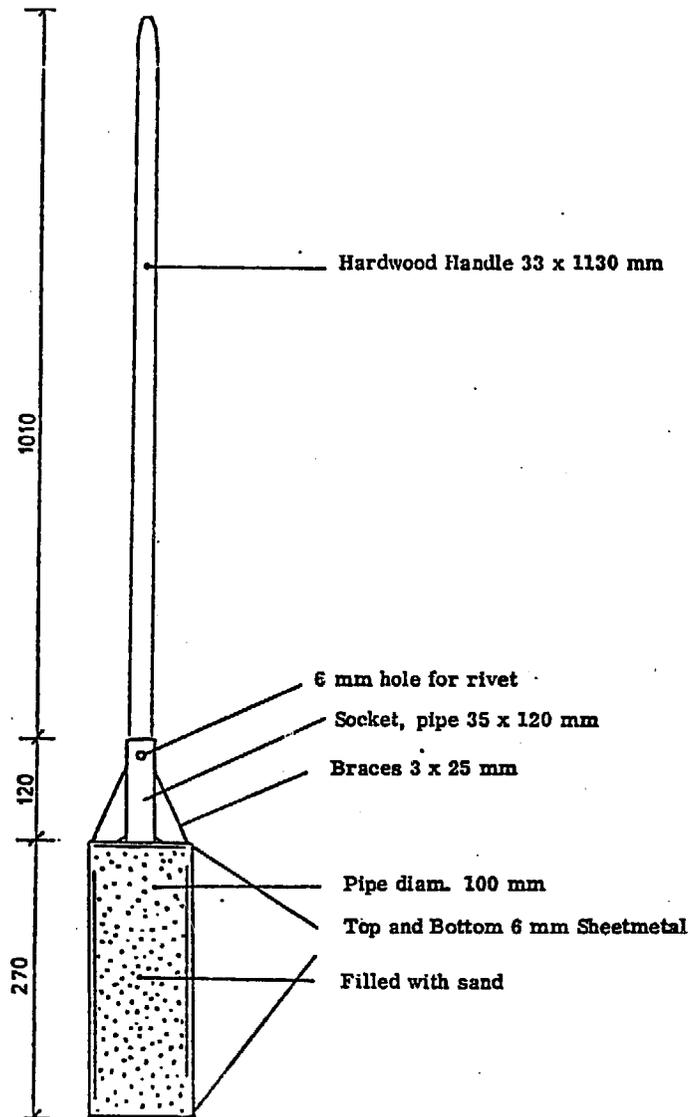


FIGURE 1.35: KRARP RAMMER

HAND RAMMER

Design : The most efficient rammers are the circular or square cross-section metal type which are reasonably heavy without being bulky. Figure 1.34 illustrates the design of Indian Standard Rammers. The socket should be concentric with the periphery and of suitable taper to match with the handle. The relationship between the rammer weight and the size of the base (A) is as follows:

Weight (kg)	Dimension A (mm)
5.0	100
7.5	125
10.0	150

Figure 1.35 illustrates a rammer devised for the KRARP consisting of a simple sand filled cylinder.

Materials : Grey cast iron for the solid metal rammer, mild steel plate (TN1) for the sand filled rammer.

Manufacture : Cast iron rammers require foundry facilities. Other types can be made with simple workshop tools.

Suppliers : N/A

HANDLES

Labour-intensive road construction activities impose very high stresses on the handles of many handtools. These stresses are greatest for the 'striking' tools: axe, hoe, mattock, pickaxe and sledge hammer. If these tools are to perform efficiently it is essential that the handles are well made from materials capable of withstanding the stresses imposed on them. Whilst the handles of forks, shovels and spades are not normally so highly stressed as those of the 'striking' tools, efficient road construction requires them to be used intensively and they should be well made from appropriate materials. Of particular importance is the quality of the finish, since efficient use of most tools requires that one of the operator's hands slides over the surface of the handle. If the surface is left rough the tendency is for the operator to maintain a fixed grip, which greatly lowers working efficiency and accelerates fatigue. High quality tools are usually smoothly sanded and given a final wax, linseed oil or light varnish surface treatment both to improve sliding efficiency and to reduce moisture loss or ingress.

Ideally either hickory or ash wood should be specified for the handles of striking and other handtools respectively, since these woods possess the near ideal characteristics of hardness, toughness and light weight. Unfortunately, they are native only to a few countries and are in very short supply. In most developing countries there are wood species that can be substituted for hickory or ash and these are discussed in TN2. Problems with tool handles in most developing countries are caused by the use of unsuitable, unseasoned wood, poor design and manufacture.

As a relatively low value product it is rare for handles to be purchased other than from local suppliers. For this reason there are relatively few export suppliers of quality handles although most tool head manufacturers will do so on request.

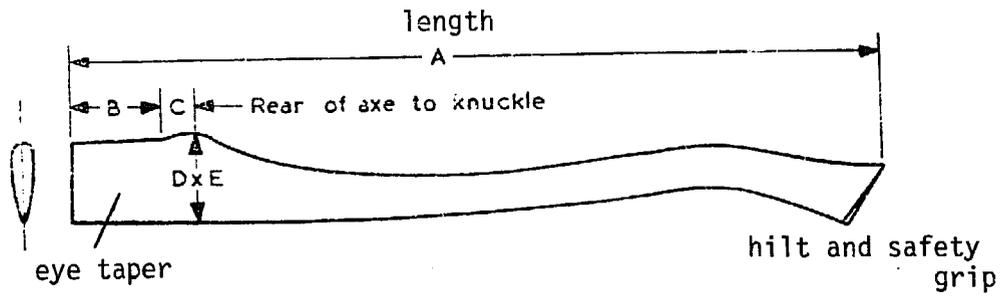


FIGURE 1.36: NOMENCLATURE

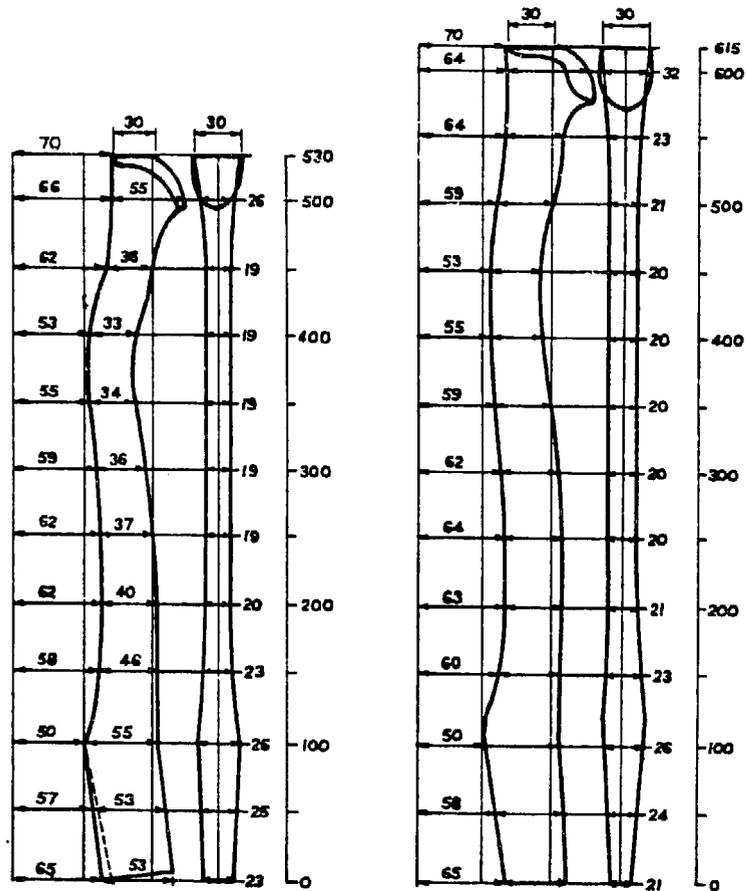


FIGURE 1.37: SCANDINAVIAN AXE HANDLE CONTOUR TEMPLATES

AXE HANDLE

Design : Table 1.10 illustrates the British method of specifying handle shapes for wedge axes. The graphs in Figure 1.37 from Scandinavian sources, illustrate the contour dimensions required. By interpolation from Table 1.10 and Figure 1.37 local axe designs can be derived.

TABLE 1.10 DIMENSIONS OF HANDLES FOR WEDGE AXES (mm)

Nominal weight of head	DIMENSION: See Figure 1.36				
	A ±25	B ±6	C maximum	D* minimum	E* minimum
kg					
1.8	813-914	95	25	67	25
2.3	813-914	95	25	67	25
2.7	914	95	25	67	25
3.2	914	95	25	75	27

* The dimensions of D and E shall always be greater than the maximum dimensions of the appropriate eye

The characteristic shape of a good quality axe handle has been arrived at by lengthy study and experience. The shape ensures that the shock of impact when the head strikes the tree is not transmitted to the worker's body. The angled or curved hilt and safety grip ensure that the operator is able to swing the axe with maximum force without the risk of it slipping out of his hands, and that he need not waste energy gripping the handle excessively hard.

The cross section of the handle is elliptical because this conforms to the natural shape of the hand.

The eye of the handle is normally straight or tapers slightly from the back to the front of the axe-head. On some designs a raised portion or 'knuckle' is created at the end of the tapered eye-section of the handle.

On the best quality axes the head is first wedged with a hardwood wedge, and further secured with a doubly serrated metal cleat as shown in Figure 1.38. The wedge slot(s) should be central and extend to the mid-point of the head.

The grip of the axe-head on the handle can be further re-inforced by adhesive bonding. With modern adhesives there can be a significant improvement in the strength of the head/handle joint at only a small increase in initial tool costs.

Material : Hickory or nearest equivalent quality hardwood (TN2). Long straight-grained wood is essential if weak spots are to be prevented, and the grain must run along the length of the handle.

Manufacture : The complex shape of an axe handle is normally produced using a contour turning lathe. (It should be possible to achieve the same shape by a combination of simple turning, hand shaping and steam bending (TN2)). The handle should be sanded and surface treated.

Suppliers

- G.P. LLOYD & Co. (CARDIFF) Ltd.
- OATES Ltd.
- O.P. LINK HANDLE Co. Inc.

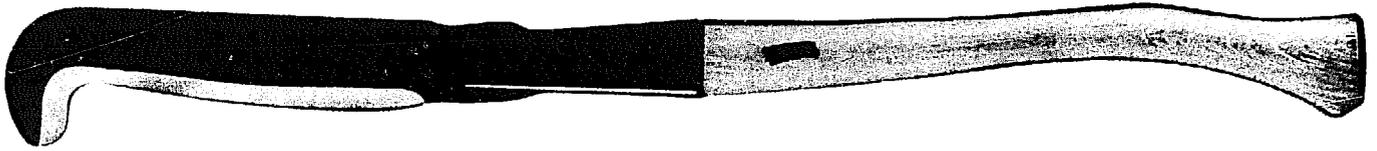


FIGURE 1.39 : SCANDINAVIAN BUSH HOOK HANDLE

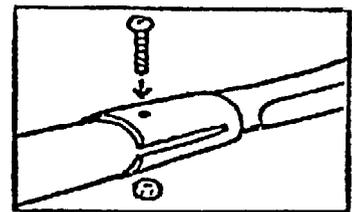
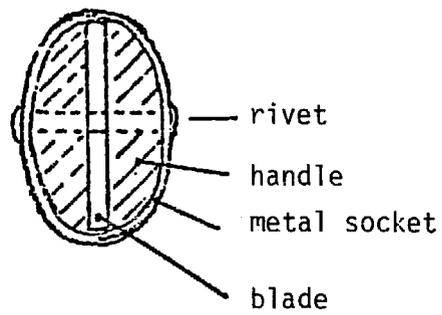


FIGURE 1.40: RIVET AND BOLT METHODS OF FASTENING HANDLE TO BLADE

BRUSH HOOK HANDLES

Design : Most long handled brush hooks are designed with straight handles. They usually have a circular cross-section and some are given a waisted safety grip at the hilt.

The Scandinavian brush hook (Figure 1.39) has a handle very similar to that of an axe. For intensive use this type of design is recommended since, used correctly, it should give the highest productivity. Typical handle length/head weight figures for commercially available brush hooks are: 620mm/1.3kg and 650mm/1.4kg. These figures could be used to derive local designs for brush hook handles by extrapolating the information in Table 1.10 and Figure 1.37.

There are a variety of methods of fitting the handle to the blade. Some designs (Figure 1.4) have a short tapered socket forged in one piece with the blade into which the handle is force fitted. This fit can be re-inforced with an adhesive. In other designs a rivet or bolt is inserted through the handle and tightened (Figure 1.40).

The KRARP brush hook has a separate socket/blade/handle assembly (Figure 1.5) with security bolts.

Unbolted assemblies are to be preferred since any drilling of the handle must weaken it.

Material : Hickory or nearest equivalent quality hardwood (TN2). (see AXE HANDLE)

Manufacture : Straight handles can be produced on a centreless milling machine: the Scandinavian type is made in the same way as an axe handle.

Suppliers - Scandinavian Type
- OY FISKARS AB

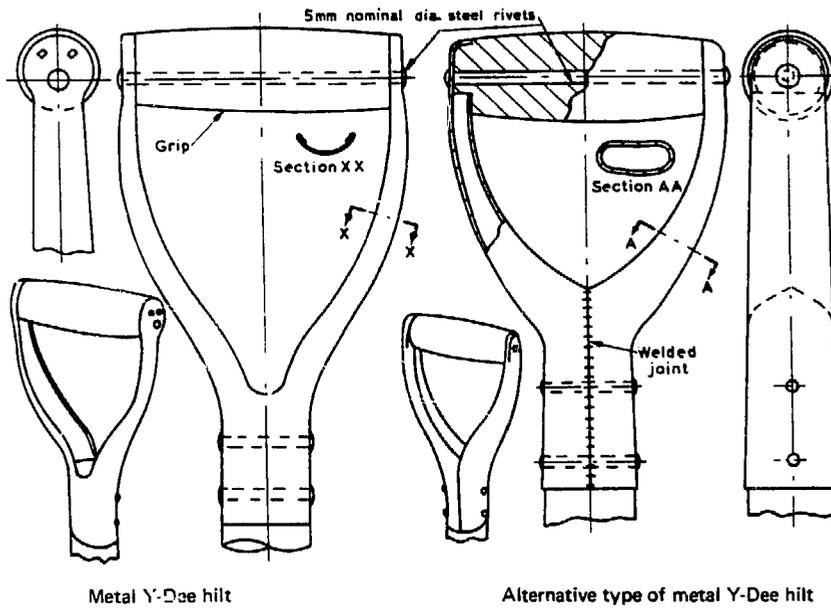
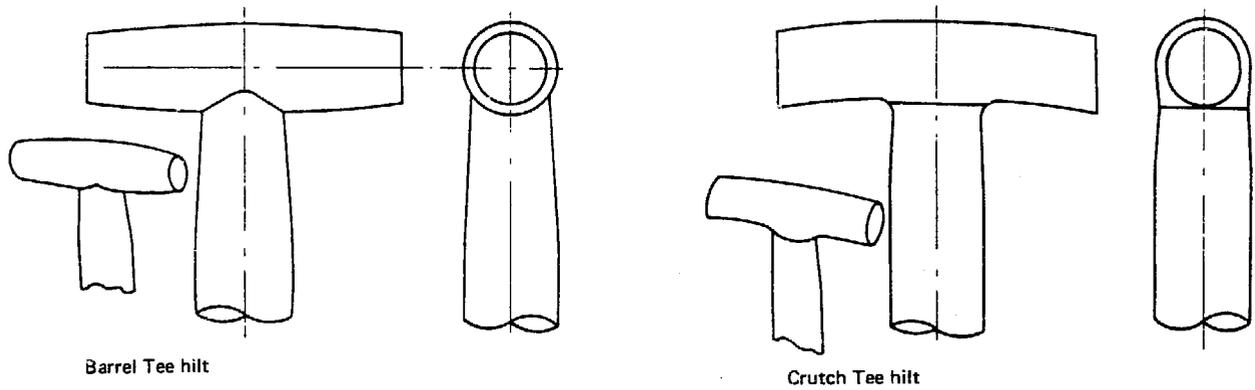


FIGURE 1.41 : COMMON HILT DESIGNS

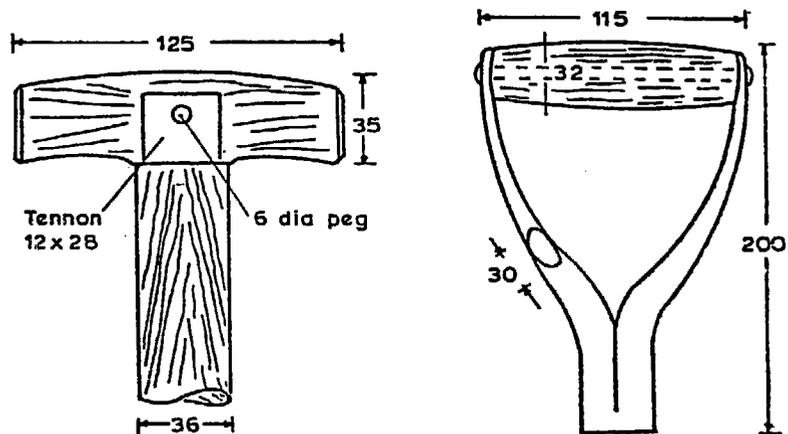


FIGURE 1.42 : KRARP HILTS (mm)

SHOVEL, SPADE, FORK HANDLES

Design : Most national tool specifications allow for considerable variation in the design of tool handle hilts, and in their connection to the metal head.

The most common types of hilt are illustrated in Figure 1.41. The all wood Y-dee is difficult to manufacture from most tropical timbers (TN2) without their subsequently splitting in use. Wooden tee hilts are preferred for local manufacture.

Figure 1.42 illustrates the dimensions of the wooden Tee hilt specified for KRARP handle hilts. In addition to the tenon and peg of the tee hilt it is normal to apply a waterproof adhesive to the joints.

Suitable dimensions for Shovel, Spade and Fork handles are specified in Figures 1.8, 1.10, and 1.12 respectively. Normal handle diameters are in the range 30-35mm.

The handles of straight long-handled shovels may be any of the types illustrated in Figure 1.51.

Material : Ash or nearest equivalent quality hardwood (TN2)

Manufacture : Normal length fork, shovel and spade handles can be turned on a standard centre lathe. The handle should be sanded and surface treated (TN2).

Suppliers - G.F. LLOYD & Co (Cardiff) Ltd.
- OATES Ltd.

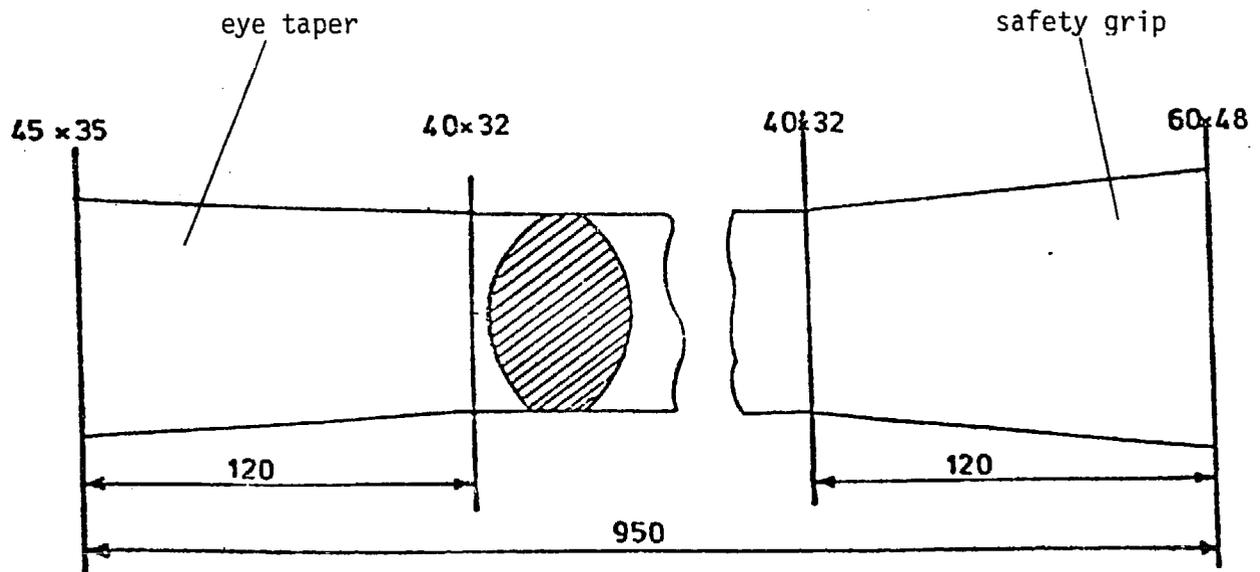


FIGURE 1.43: KRARP HOE HANDLE DIMENSIONS (mm)

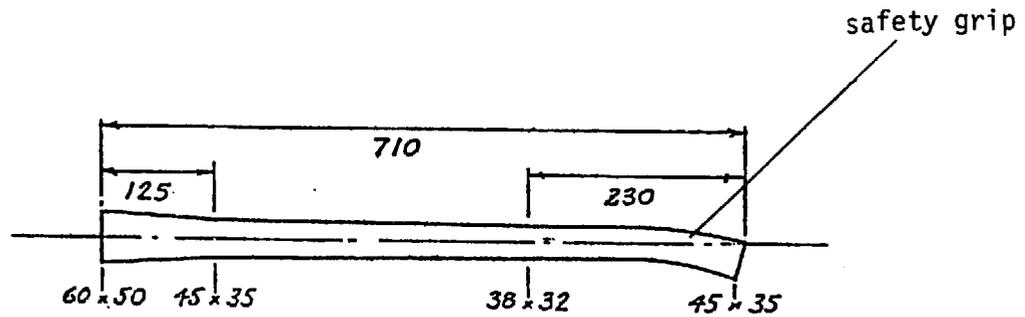


FIGURE 1.44: INDONESIA HOE HANDLE DIMENSIONS (mm)

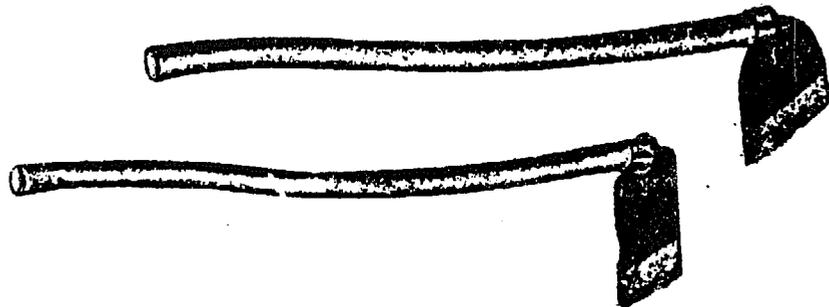


FIGURE 1.45: SCOVIL S-SHAPED HOE HANDLES

HOE AND FORKED HOE HANDLES

Design : The simplest type of handle has, with the exception of the eye, a circular section tapering in a straight line to the heel. This is easy to produce but since the heel is straight there is nothing to stop the operator's hand(s) from slipping off the handle. This wastes energy since the operator has to exert a considerable muscular effort to maintain a firm grip. To prevent this, the handle should have a safety grip (see Figures 1.34 and 1.37). In addition the cross-section of the handle should be elliptical as with the axe, rather than circular (see Figures 1.43 and 1.44).

For a single-edged striking tool, a handle which is straight along its length is undesirable since the impact shocks are transmitted to the operator. Figure 1.45 illustrates that hoe handles have been produced with the S-shape, normally used for axes, which absorbs the shock.

Although it is common to rely on a simple taper to secure the head to the handle, wedging in the manner illustrated for the axe head and/or fixing with an adhesive is recommended.

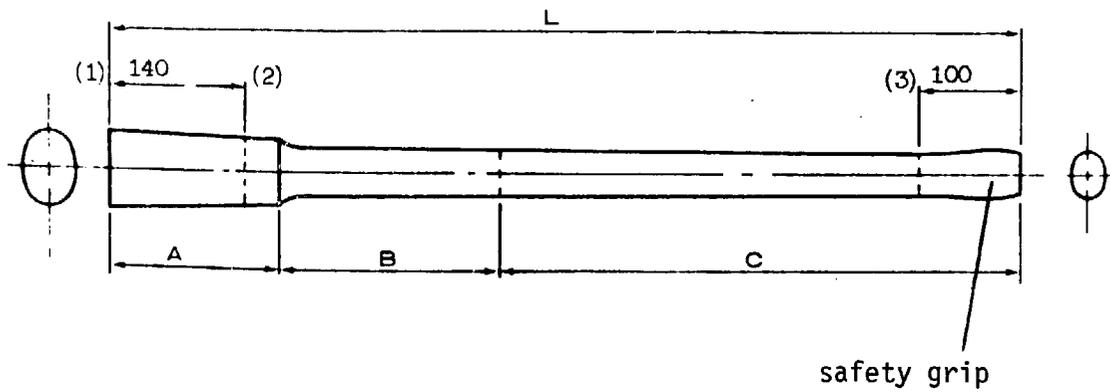
One major international manufacturer of hoes secures the head to the handle with a spiraled nail - not a rivet. This gives the holding power of a screw.

Material : Hickory or nearest equivalent quality hardwood (TN2)

Manufacture : As for axe handles: (It should be possible to achieve the same shape by a combination of simple turning and hand shaping (TN2)). The handle should be sanded and surface treated.

Suppliers

- G.F. LLOYD & Co. (Cardiff) Ltd.
- OATES Ltd.
- SCOVIL HOE CO.



Cross-section			Length			
Point (1)	Point(2)	Point(3)	Head A	Waist B	Grip C	Overall L
52 x 78	40 x 66	30 x 42	165	235	500	900

FIGURE 1.46: HANDLE FOR A PICKAXE OR MATTOCK (mm)

PICKAXE AND MATTOCK HANDLES

Design : As double-edged striking tools it is necessary to have a straight handle with an elliptical rather than circular cross-section. The handle should also be provided with a raised safety grip.

Figure 1.46 illustrates the dimensions of the South African Standard pick-axe and mattock handle.

The grip between the head and handle normally relies just on their respective tapers. The handle is force fit by hammering with a mallet on the tapered end.

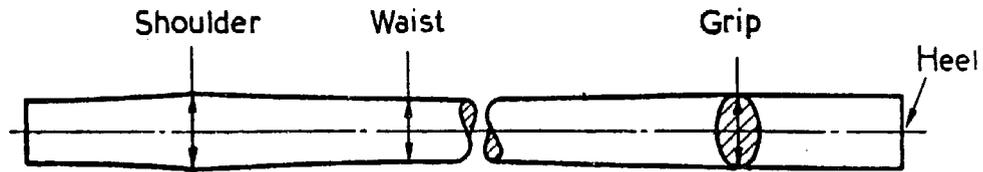
Some specifications require that when tamped home in the eye the handle shall project by not less than 13mm or greater than 40mm.

Material : Hickory or nearest equivalent quality hardwood (TN2)

Manufacture : The handle is normally produced on a contour turning lathe. (It should be possible to achieve the same shape by a combination of simple turning and hand shaping (TN2)). The handle should be sanded and surface treated.

Suppliers

- G.F. LLOYD & Co. (Cardiff) Ltd.
- OATES Ltd.
- O.P. LINK HANDLE Co. Inc.



Nominal weight (kg)	Dimensions of grip (mm)	Overall length (mm)
1.8 - 2.3	38 x 32	760*
2.7	38 x 32	760
3.2	43 x 32	760
3.6 - 5.4	43 x 32	914

* These weights may be fitted with a 610mm handle if required.

- a. The minimum dimensions at the shoulder shall be 5mm larger than the appropriate dimensions for E and F in Table 1.8.
- b. The overall length applies after the fitting of the head and shall be subject to a tolerance of +0mm
-13mm
- c. The grip dimensions apply along the handle to the heel.
- d. The length from the outer end to the shoulder shall be equal to the maximum dimension for J in Table 1.8 according to the nominal weight of the hammer plus an amount sufficient to ensure that wedging is adequate and that the head shall not reach to the shoulder.

FIGURE 1.47: SLEDGE HAMMER HANDLE DIMENSIONS

SLEDGE HAMMER HANDLE

Design : As a double-faced striking tool it is necessary to have a straight handle with an elliptical rather than circular cross-section. The handle should also be provided with a raised safety grip.

Figure 1.47 illustrates the British method of specifying double faced sledge hammer handles.

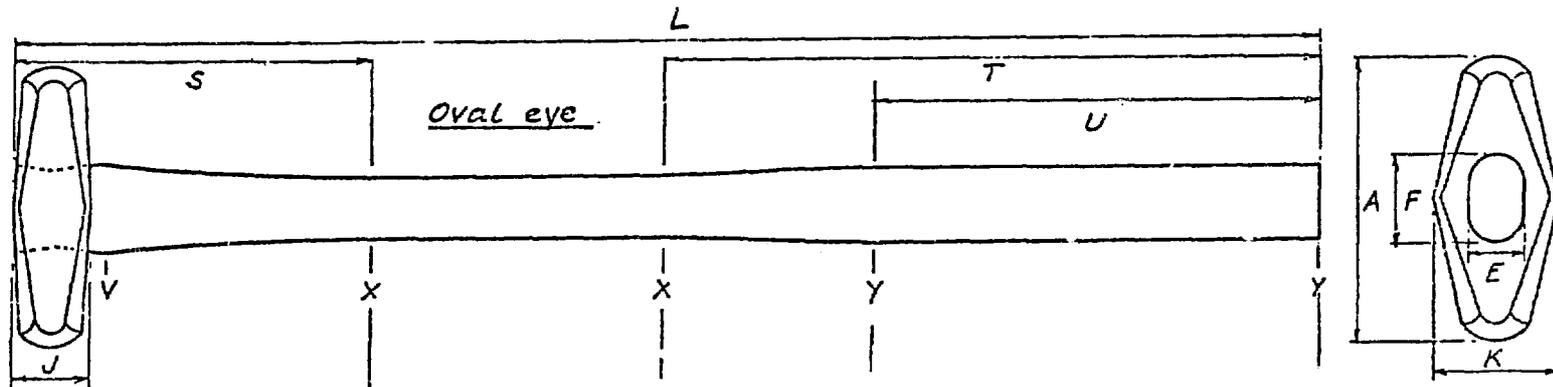
The method of fixing sledge hammer handles and heads is the same as for axes (see Figure 1.38).

Material : Hickory or nearest equivalent quality hardwood (TN2)

Manufacture : The handle is normally produced on a contour turning lathe. (It should be possible to achieve the same shape by a combination of simple turning and hand shaping (TN2)). The handle should be sanded and surface treated.

Suppliers

- G.F. LLOYD & Co. (Cardiff) Ltd.
- OATES Ltd.
- O.P. LINK HANDLE Co. Inc.



Nominal Weight (kg)	E	F	J	L	S	T	U	V	X	Y
0.5	19	29	27	450	125	225	150	32x22	22x16	25x18
0.7	19	29	32	600	167	300	200	32x22	22x16	25x18
0.9	25	38	37	750	208	375	250	41x28	25x18	27x20

FIGURE 1.48 : DIMENSIONS OF STONE BREAKING HAMMER HANDLE (mm)

STONE BREAKING HAMMER HANDLE

Design : Compared with other hammers, the handles of those for stone breaking should be relatively long and slender. Figure 1.48 illustrates a stone breaking hammer handle appropriate to a head with the dimensions given in Table 1.9 and eye illustrated in Figure 1.23.

Materials : Hickory or nearest equivalent quality hardwood (TN2)

Manufacture : The handle is normally produced on a contour turning lathe. (It should be possible to achieve the same shape by a combination of simple turning and hand shaping (TN2)). The handle should be sanded and surface treated.

Suppliers - G.F. LLOYD & Co. (Cardiff) Ltd.
- OATES Ltd.

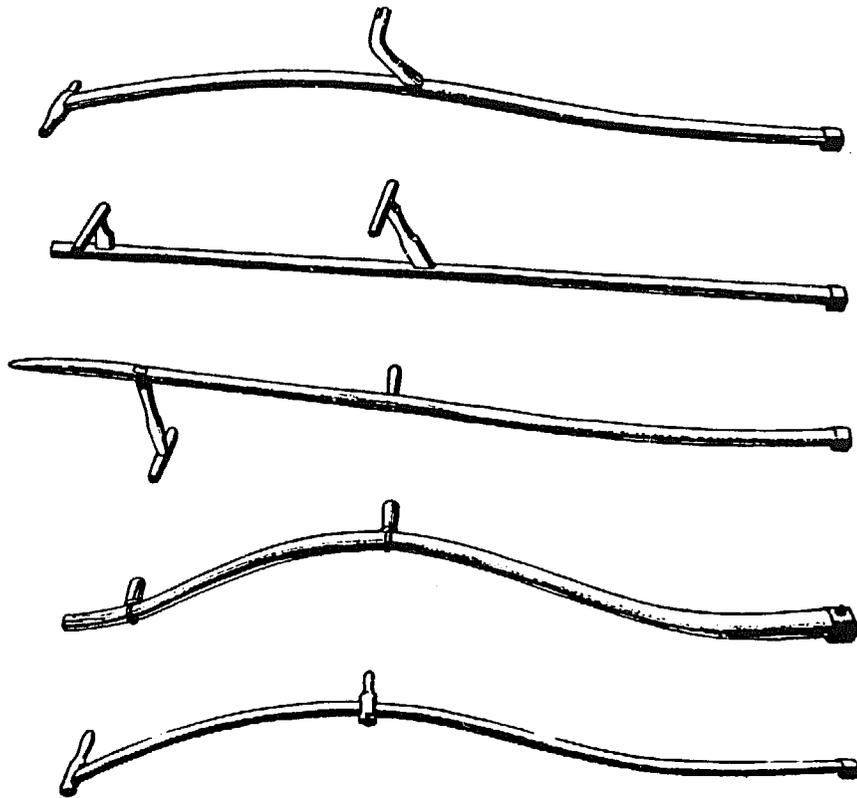


FIGURE 1.49: TRADITIONAL SCYTHE HANDLES

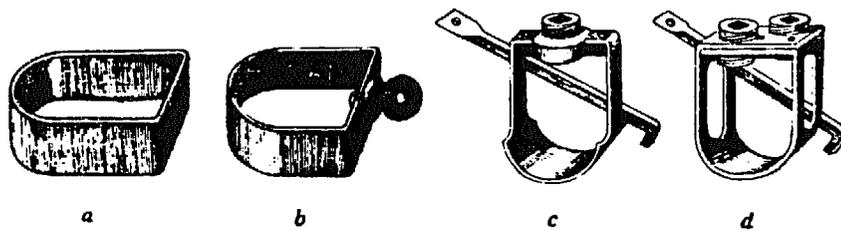


FIGURE 1.50: RING CONNECTORS

- (a) simple ring to be tightened with a wooden wedge;
- (b)-(c) rings with one screw;
- (d) ring with two screws

SCYTHE HANDLE

Design : Most scythe handles are made of wood but light tubular steel is also used. The long handle has a grip in the middle for the right hand, and there is sometimes a second grip at the top. Handles and grips vary considerably but all are designed to enable the operator to work with outstretched arms and both hands at more or less the same horizontal height (Figure 1.49). This is achieved either by curving the handle or on the straight handle by having the middle grip on a separate raised shaft, or with the top grip on a separate shaft pointing down-ward. Whatever the arrangement the aim is to allow the operator to swing the scythe through a wide semicircle without undue strain and with the blade always parallel to the ground.

The length of the handle and the exact position of the grip are determined by the height of the operator. If the scythe is held in a vertical position with the blade on the ground, its top grip should come up to the nose and its middle grip up to the waist of the operator.

The blade is attached to the side underneath the lower end of the handle with a ring connector. The D-shaped ring connector (Figure 1.50) makes it possible to regulate the angle of the blade to the handle.

Material : Hickory, ash or nearest equivalent quality hardwood capable of being steam bent (TN2).

Manufacture : Requires centreless milling machine and steam bending facilities (TN2). The handle should be sanded and surface treated.

Suppliers - G.F. LLOYD & Co.(Cardiff) Ltd.
- OATES Ltd.

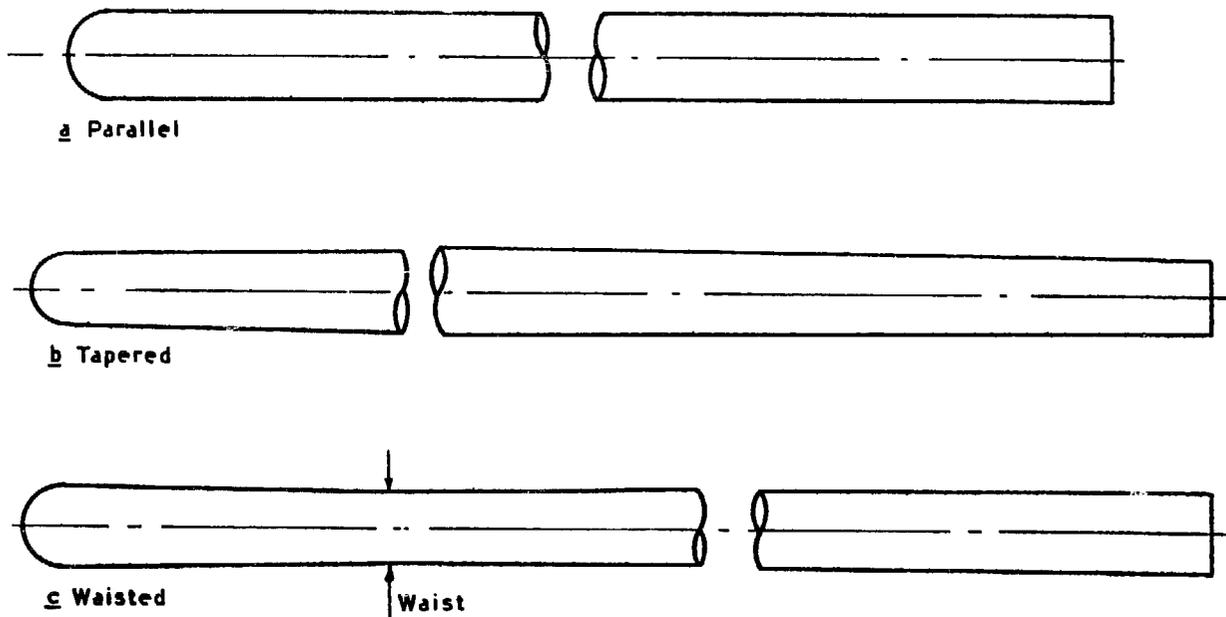


FIGURE 1.51 : RAKE AND HAND RAMMER HANDLES

RAKE AND HAND RAMMER HANDLES

Design : Require only straight handles. Some traditional shapes are illustrated in Figure 1.51.

Materials : A variety of hardwoods can be used (TN2) although some rammer handles are made of metal tube.

Manufacture : Requires centreless milling machine. The handle should be sanded and surface treated.

Suppliers - G.F. LLOYD & Co. (Cardiff) Ltd.
- OATES Ltd.

INTRODUCTION

This Section describes low cost instruments suitable for use in the surveying and setting out of roads. Basic surveying tapes, ranging rods and levelling staffs are not discussed. Information is given on the following instruments:

- Flexible tube water level
- Line level
- Spirit level
- Water manometer
- Road tracer
- Cowley level
- Abney level
- Gradient template
- Clinometer
- Cross staff
- Surveying protractor
- Land measuring wheel

Many of the instruments can be produced locally, and used with an adequate degree of accuracy after a brief period of instruction. No attempt is made to describe surveying methods and techniques since it is assumed that users of the Guide will be familiar with these. Rather the approach is to provide information on simple instruments which have sufficient accuracy for surveying operations on many of the types of road likely to be built by labour based methods.

APPLICATION

The applications of the instruments described in this section are summarised in Table 2.1.

TABLE 2.1: APPLICATION OF SURVEYING INSTRUMENTS

Category	Instrument	Comments
<p>Levels</p> <p>Measurement of vertical angles</p>	Flexible water tube level	Range about 20m. Accurate and simple to use: does not require sighting on a staff
	Line level	Range about 50m. Suitable for slopes greater than 1 in 300. Requires 3 operators: does not require sighting on a staff.
	Spirit level	Range about 10m. Suitable for slopes greater than 1 in 300.
	Water manometer	Range about 10m. Suitable for slopes greater than 1 in 200.
	Road Tracer	Range about 20m. Suitable for slopes greater than 1 in 200. Can be adapted for setting out slopes.
	Cowley Level	All levelling purposes. Can be adapted for setting out slopes.
	Abney Level	All levelling purposes and measurement of vertical angles
	Gradient template	Measurement of gradients over distances of a few miles.

TABLE 2.1 cont....

Category	Instrument	Comments
Measurement of vertical angles  Measurement of horizontal angles Distance Measurement	Clinometer	Measurement of vertical angles
	Cross staff	Setting out of right angles
	Surveying Protractor	Measurement of horizontal angles
	Land measuring wheel	Measurement of distance over land surface: preferred for long distances

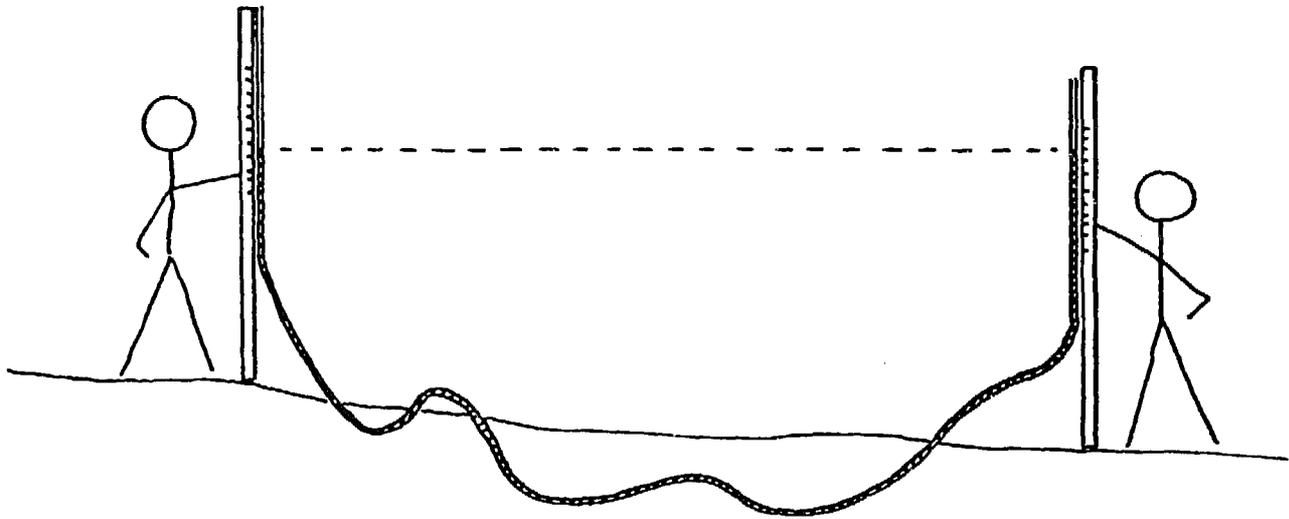


FIGURE 2. 1 : FLEXIBLE TUBE WATER LEVEL IN USE

FLEXIBLE TUBE WATER LEVEL

Design : This level, illustrated in Figure 2.1, consists of a length of clear plastic pipe clipped at each end to a wooden stave. The two wooden staves should be of the same length, about 1.5 m long. A graduated tape is attached to each stave, with the zero level with the top end of the stave. The tube is filled with water until the level is about 1m high from the ground. The ends of the tube are fitted with rubber stoppers to prevent loss of water. The total length of tube, which defines the range of the instrument, is variable, but is usually limited to about 15m by the difficulty of moving the level around.

Materials : Timber and clear plastic pipe.

Manufacture : Can be made with basic carpentry tools.

Operation : The two standpipes are brought together at the starting point, the stoppers removed and the readings taken level with the bottom of each meniscus. The readings should be the same. The head man takes his standpipe to the point being measured and takes another reading. The difference between the two readings is the difference in level.

Range is limited only by the convenience of being able to carry the tube. The two points whose difference in level is being measured do not need to be in sight of one another. The level gives quick accurate results and with care can be used for setting level lines or slopes not less than 1 in 1000.

Suppliers : N/A.

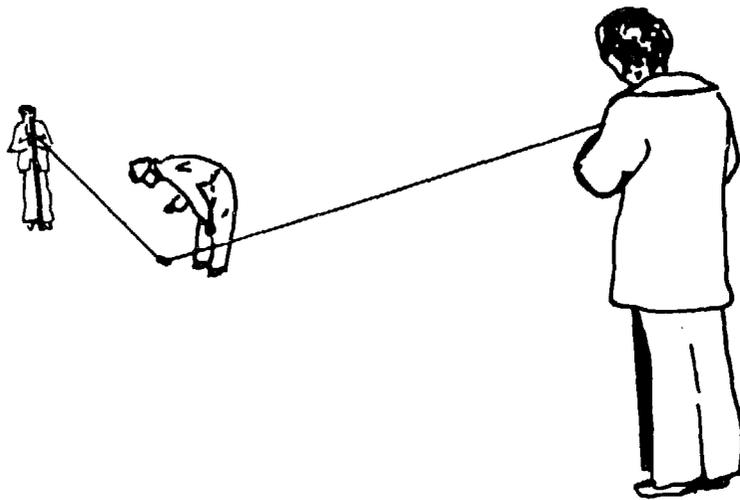


FIGURE 2.2 : LINE LEVEL IN USE

LINE LEVEL

Design : The basis of this instrument, illustrated in Figure 2.2, is a wooden cased spirit level about 250mm long. A threaded eye is screwed into each end of the spirit level. Equal lengths of cord (10m or longer) are tied to the eyes. Two staves about 1.5m long with graduated tapes attached are also required.

Materials : Cheap spirit level
Cord
Suitable timber

Manufacture : Can be made with basic carpentry tools.

Operation : This device requires three operators - one with a staff at each of the cord, the third to watch the spirit level. The head operator moves his cord up or down the staff until the bubble is centred on the spirit level marks. The difference in level between the two points is calculated from the readings on the staves. This instrument has a range of up to about 50m depending upon the length of cord used. It is very portable and, with care, can be used for setting level lines or slopes not less than 1 in 300.

Suppliers : N/A.

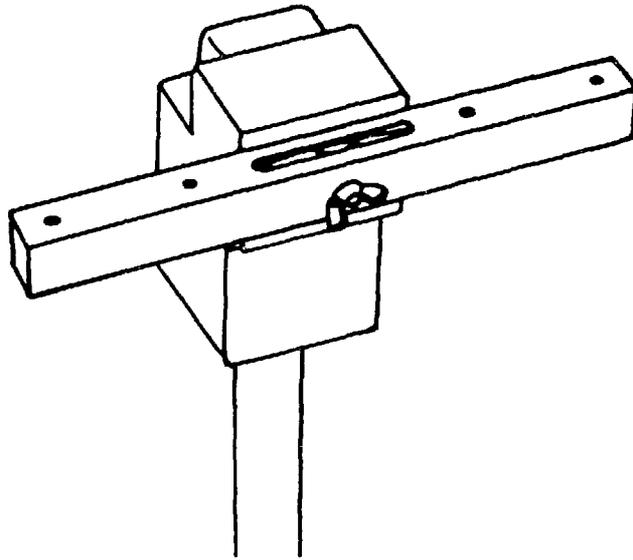
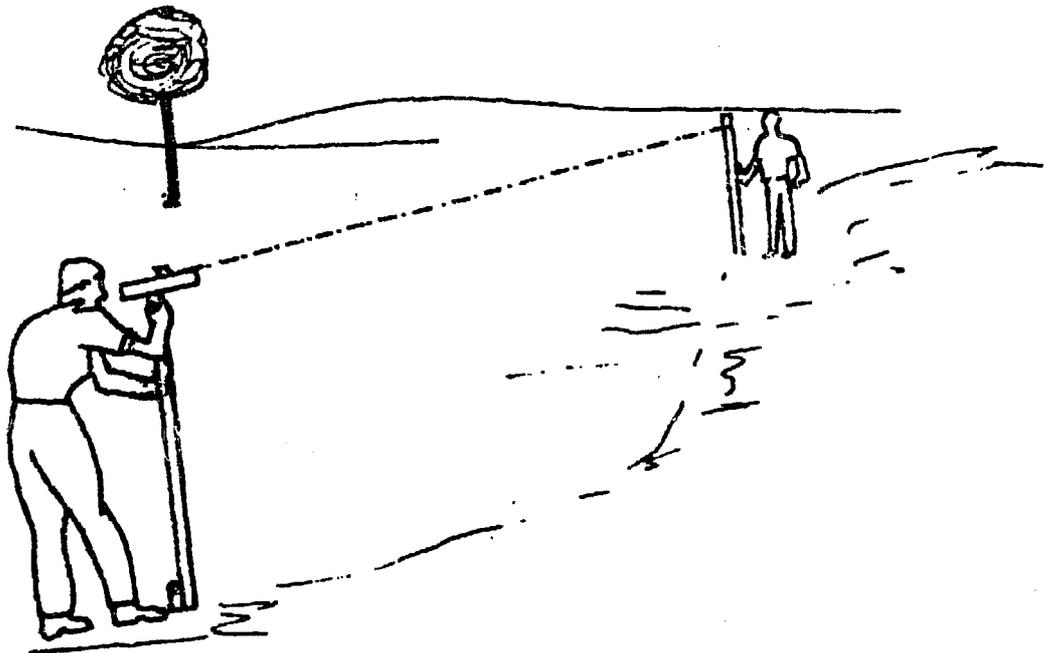


FIGURE 2.3 : SPIRIT LEVEL



SPIRIT LEVEL

Design : This is a very cheap levelling instrument. It consists of a standard spirit level (about 250mm long) clamped onto a pole or tripod. This is done by drilling a hole through the spirit level and attaching it to a support with a bolt and wing nut. If a pole is used, the lower end should be sharpened so that it can be driven into the ground.

Sighting can be along the line of the level, or through a pair of simple sights formed from sheet metal. An angled mirror can be set above the glass tube of the level to check the position of the bubble while viewing through the sights.

Materials : Standard wooden cased spirit level
Suitable timber

Manufacture : Can be made with basic carpentry tools.

Operation : Placed in the ground so that the pole is approximately vertical. The level is adjusted until the bubble is exactly between the centre marks. Sighting is along the line of the level to a staff held by a second operator. Range is dependent on the operator's ability to read the staff and is normally limited to about 10 metres. Taking readings is easier if the operator can sight on a moveable horizontal target on the staff. Figure 2.5 illustrates a simple moveable target.

With care, this instrument can be used for setting level lines or graded lines of slopes not less than 1 in 300.

Suppliers : N/A.

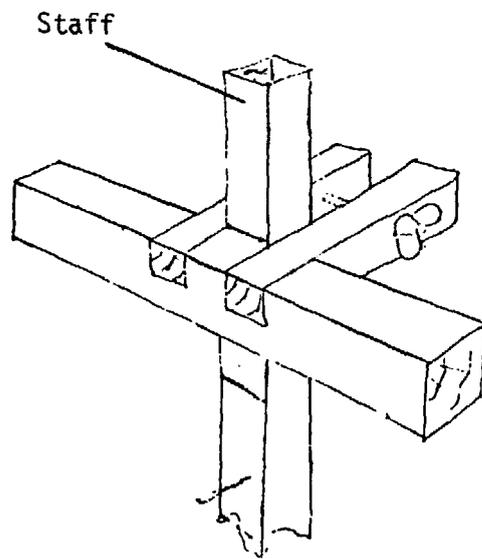


FIGURE 2.5 : MOVEABLE TARGET FOR STAFF

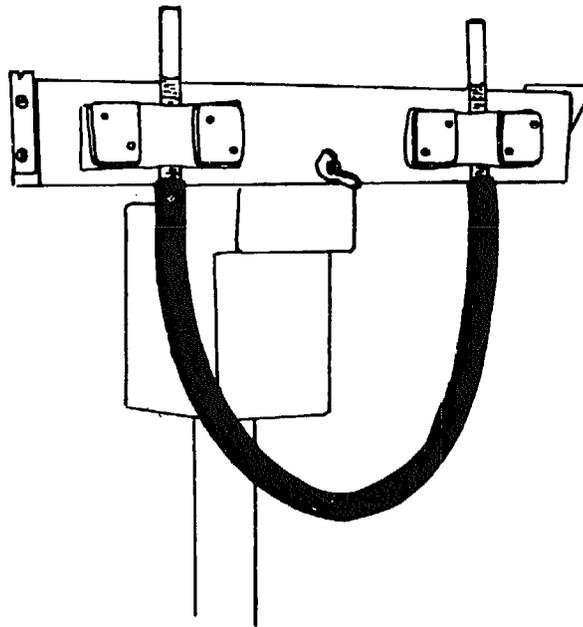


FIGURE 2.6 : WATER MANOMETER

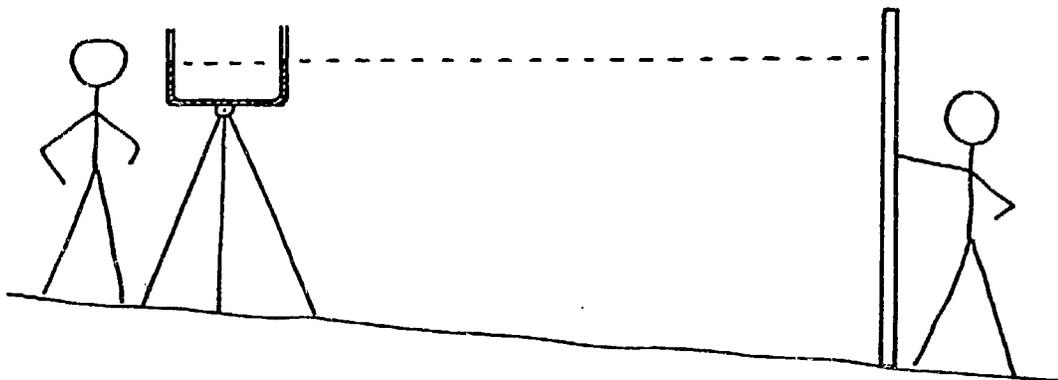


FIGURE 2.7 : USE OF WATER MANOMETER

WATER MANOMETER

Design : This instrument, illustrated in Figure 2.6, consists of a length of rubber tube about 400mm long, with a 100mm long length of glass tube at each end. The two glass tubes are clamped to a piece of wood about 300mm long. The clamps can be made from strips of inner tube nailed to the wood through hardboard pads. Simple sights cut from sheet metal are attached to the ends of the length of wood. The length of wood is attached to a mounting block on top of a pole or tripod by means of a bolt and wing nut. If a pole is used, its lower end should be sharpened so that it can be driven into the ground. The U-tube is filled with water to within about 30mm from the top. The ends may be fitted with stoppers to prevent loss of water.

Materials : See above

Manufacture : Can be made with basic carpentry tools.

Operation : The instrument is placed in the ground so that the pole is approximately vertical. It is levelled by adjusting the angle of the length of wood until the two menisci are exactly level with its top surface. Sighting is along the line of the instrument to a staff held by a second operator. Range is dependent on the operator's ability to read the staff and is normally limited to about 10m. A moveable horizontal target on the staff makes sighting easier (Figure 2.5). With care, this instrument can be used for setting level lines or graded lines of slopes not less than 1 in 200.

Supplies : N/A.

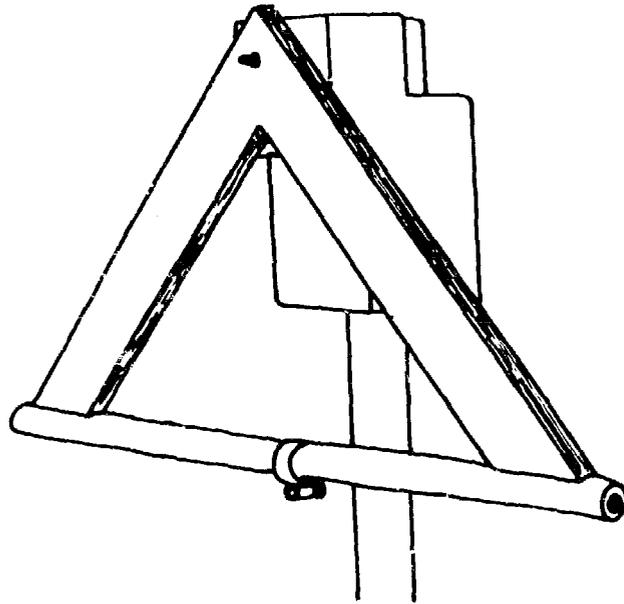


FIGURE 2. 8 : ROAD TRACER

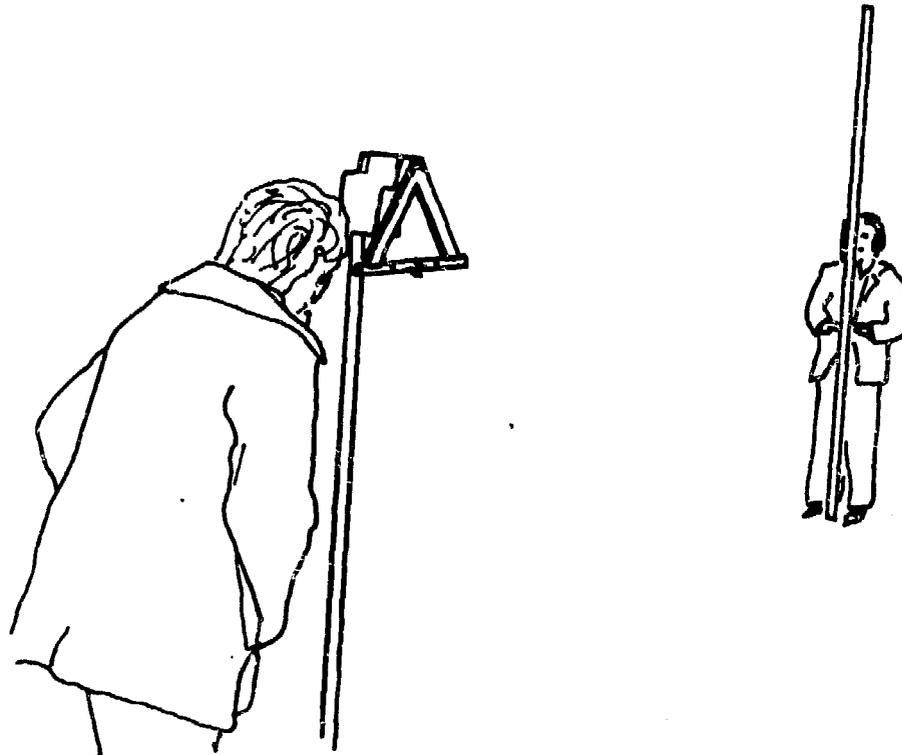


FIGURE 2.9 : USE OF ROAD TRACER

ROAD TRACER

- Design* : This instrument, illustrated in Figure 2.8, consists of a triangular frame, pivotted freely at its apex to a mounting block attached to a pole or tripod. If a pole is used its lower end should be sharpened so that it can be driven into the ground. The base of the triangular frame is a straight steel tube about 450mm long. One end of the tube is fitted with cross wires (thin wire glued into slots cut in the tube) whilst the other is covered with tape, or a thin metal disc, which is pierced to form a viewing hole. A balance weight, which may be a hose clip, is fitted on the tube.
- Materials* : Timber and steel tube.
- Manufacture* : Can be made with basic carpentry and metal cutting tools.
- Operation* : 1. Set the target on the staff at the same height as the cross wires.
2. Locate an area of reasonably flat ground and take the staff a few metres from the road tracer: find the position for the staff where the target lines up with the cross wire when sighted through the tube.
3. Reverse the positions of the road tracer and staff.
4. Sight again through the tube: if the target lines up with the cross wires then road tracer is correctly set, if not the position of the balance weight is adjusted until the error is eliminated. The instrument is then ready for use.

Sighting is along the tube to a staff held by a second operator. Range is up to about 20m and a moveable horizontal target is required (Figure 2.5). Each reading should be checked after swinging the road tracer slightly and allowing it to come to rest. The road tracer should be shielded from any wind. With care this instrument can be used for setting level lines or graded lines of slope not less than 1 in 200.

2. SURVEYING & SETTING OUT

(Note: By attaching a plumb bob to the pivot point, and marking points along the tube corresponding to particular angles, the road tracer can be used to measure and set out vertical angles - the principle is the same as for the 'gradient template' P).

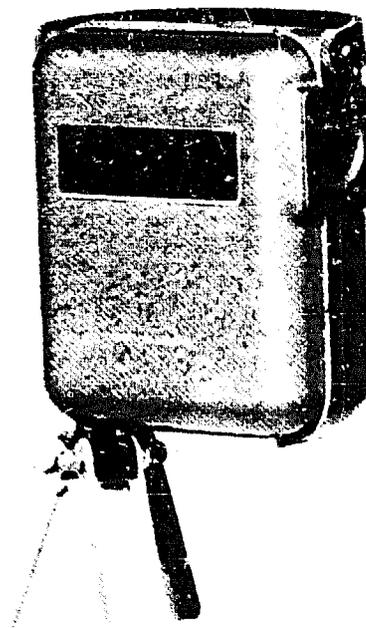


FIGURE 2.10 : COWLEY LEVEL

COWLEY LEVEL

Design : The cowley level, illustrated in Figure 2.10 is a low-cost, commercially available instrument suitable for all levelling purposes. It is simple to use and has an accuracy of 6mm per 30m. It can be fitted with a slope attachment for use where standard slopes are being set out.

Materials : N/A

Manufacture : N/A

Operation : Conventional levelling methods

Suppliers : RANK-PULLIN CONTROLS

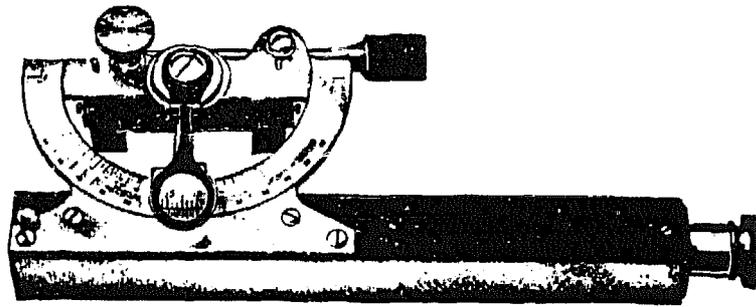


FIGURE 2.11 : ABNEY LEVEL

ABNEY LEVEL

Design : The Abney Level, illustrated in Figure 2.11 is a low-cost, commercially available hand held instrument. It can be used as a normal level, or to set or measure slopes. It consists of a rectangular metal box with an eyepiece at one end and a horizontal wire at the other. Across half the width of the tube is an angled mirror which reflects the view of a bubble level into the eyepiece. The bubble level is pivoted on an arm which pivots around a graduated arc.

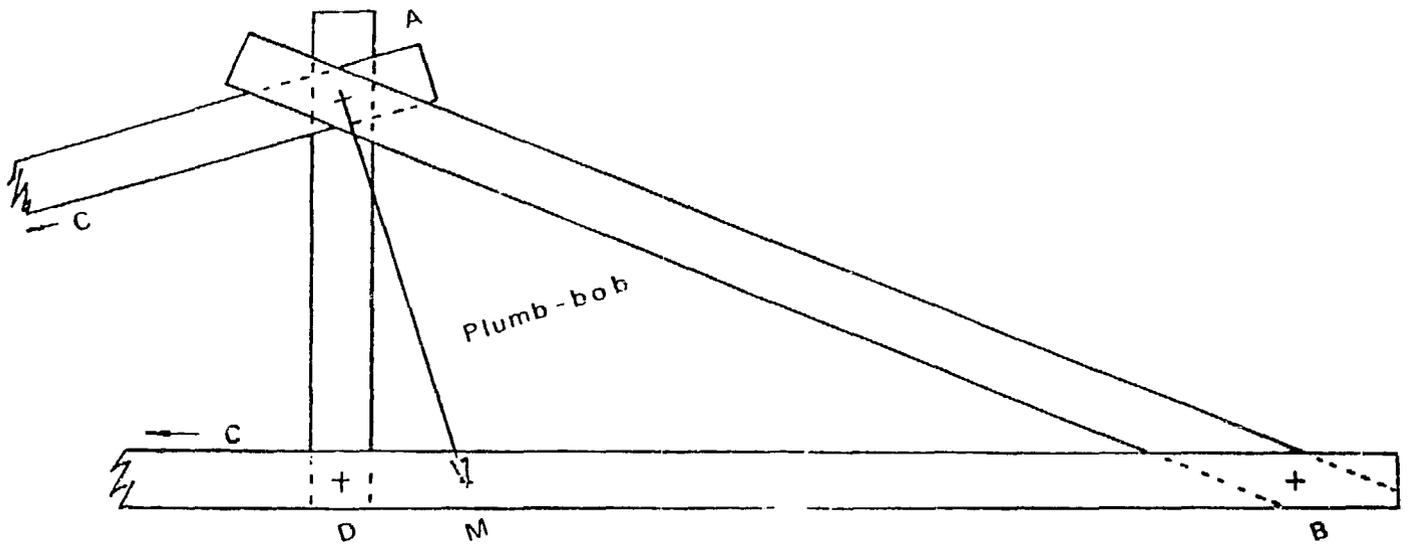
Materials : N/A

Manufacture : N/A

Operation : When used for levelling the arm carrying the bubble level is fixed at the zero position on the graduated arc. The instrument is held at eyelevel and sighted on a staff. The observation consists of noting the reading on the staff adjacent to the cross-hair when the centre of the bubble lies against the cross hair.

To measure the degree of slope a staff, with a target set above its base at the same height as the eye, is held at the point where the sight is to be taken. The level is directed so that the cross-hair intersects the target and the arm is rotated until the bubble lies against the cross-hair. The reading on the graduated arc gives the angle of the slope.

Suppliers : Best obtained from suppliers of surveying equipment.



$AB, AC = 2000 \text{ mm}$
 $BD, CD = 1789 \text{ mm}$
 $AD = 894 \text{ mm}$

FIGURE 2.12 : GRADIENT TEMPLATE

GRADIENT TEMPLATE

Design : Figure 2.12 illustrates and gives dimensions of the gradient template. The nail at A is left proud to attach the plumb bob string. The side BDC must be straight. A series of marks M are made along BDC on either side of D. The positions of point M from D for different slopes are as below:

Slope	Distance DM (mm)
1 in 24	37
1 in 16	56
1 in $12\frac{1}{2}$ (8%)	72
1 in 12	74
1 in 10 (10%)	89
1 in $8\frac{1}{3}$ (12%)	107

Materials : Straight, knot free timber, 50mm x 25mm cross section

Manufacture : The template is of nailed construction. All dimensions to be ± 2 mm.

Operation : Side BDC is laid along the surface whose gradient is to be measured. The slope is read off from the position of the plumb bob.

Suppliers : N/A

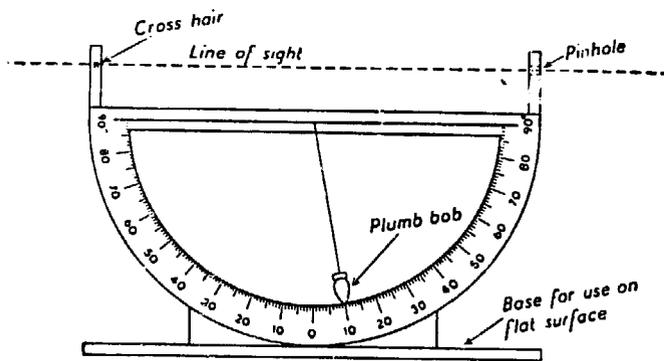


FIGURE 2.13 : DIAGRAMMATIC ILLUSTRATION OF CLINOMETER

CLINOMETER

- Design* : The clinometer is illustrated diagrammatically in Figure 2.13. The simple form of clinometer consists of a sight and cross hairs mounted above a graduated arc. The angle is measured off against a plumb bob or an index mark on an arm pivoted at point A and carrying a spirit level. The clinometer may have a base for use on a flat surface. According to type clinometers may give a reading in gradient and/or angle.
- Materials* : Can be made in wood, metal, or plastic as appropriate.
- Manufacture* : N/A
- Operation* : The clinometer is usually held at eye level and sighted along the slope or vertical angle to be measured. The angle is read off from the arc. If the clinometer is fitted with a base it can be placed on any smooth surface to measure its angle of slope.
- Suppliers* : Best obtained from suppliers of surveying equipment.

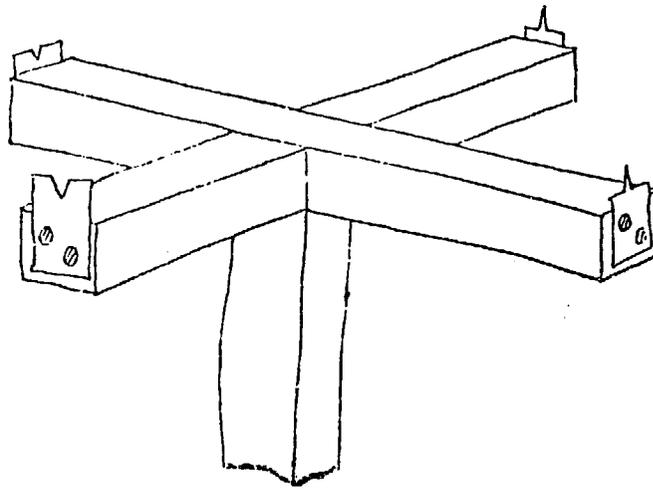


FIGURE 2.14 : CROSS-STAFF

CROSS-STAFF

Design : The Cross-Staff is illustrated in Figure 2.14. It consists of two pieces of timber about 300mm long set at right angles on top of a pole. Each piece of timber is fitted with a sight made up of two pieces of thin metal, one fitted at each end. One piece is cut to a point, the other to a V-slot.

Materials : See above.

Manufacture : The accuracy of the device is checked by comparing a right angle set up with the staff in one orientation, with that in the complementary orientation.

Operation : The pole is placed in the ground so that the sights are level. One sight is set along the surveying line. The line of the other sight sets a right angle.

Suppliers : N/A

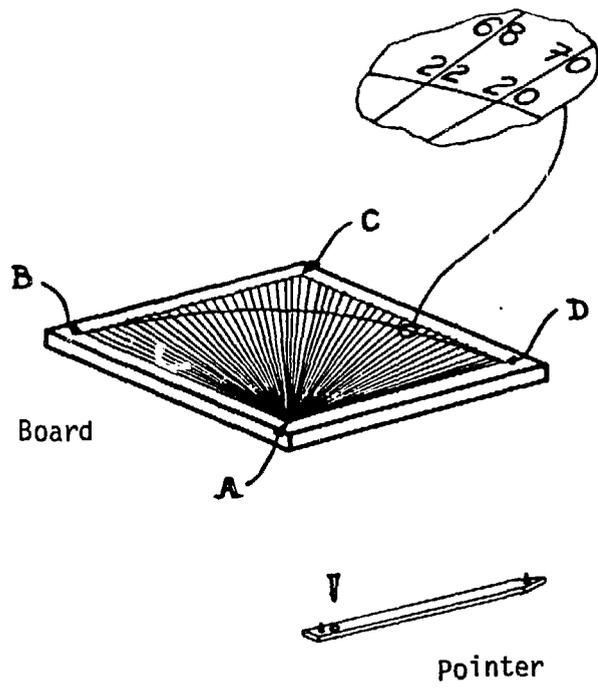


FIGURE 2.15 : SURVEYING PROTRACTOR

SURVEYING PROTRACTOR

Design : The protractor illustrated in Figure 2.15 consists of a board 300mm square marked with a series of lines at 2° intervals, and a pointer pivoted by means of a countersunk screw at the point A from which the lines are drawn. The board is mounted on a pole or tripod by means of a wooden block attached at the centre of its underside. The block has a hole bored in it so that it fits firmly over the pole but allows the board to turn. The pointer has a small nail hammered into it at each end so that the tips protrude about 5mm for sighting.

Materials : The board is made of timber or plywood about 12mm thick.

The pointer is a piece of wood 12mm x 5mm x 275mm long.

The wooden pole is 1200-1500mm long.

Manufacture : The graduations are marked out on the board by drawing a margin 25mm wide all round the board, leaving a 250mm square. Points are marked along the sides BC and DC measuring from B and D (Figure 2.15) at the following intervals:

2. SURVEYING & SETTING OUT

Distance (mm)	Angle (degrees)	Distance (mm)	Angle (degrees)
0.0	0 90	111.3	24 66
8.7	2 88	121.9	26 64
17.5	4 86	132.9	28 62
26.3	6 84	144.3	30 60
35.1	8 82	156.2	32 58
44.1	10 80	168.6	34 56
53.1	12 78	181.6	36 54
62.3	14 76	195.3	38 52
71.7	16 74	209.8	40 50
81.2	18 72	225.1	42 48
91.0	20 70	241.4	44 46
101.0	22 68	250.0	45 45

These points are joined up to A

Operation : The pole is placed straight and secure in the ground, or the tripod if used is set up, so that the board is level. The pointer is set along AB or AD sighting along the survey line. An angle can then be set or measured by moving the pointer to the appropriate position.

Suppliers : N/A

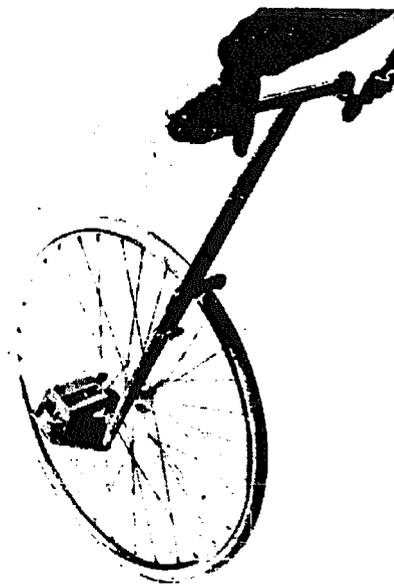


FIGURE 2.16 : LAND MEASURING WHEEL

LAND MEASURING WHEEL

Design : Figure 2.16 illustrates a typical land measuring wheel. It consists of a wheel 600 - 1000mm diameter, preferably fitted with a hard rubber tyre, mounted on a handle. The wheel drives a counter which, on some models gives a direct readout of distance. On other models it records the number of revolutions of the wheel, and a simple conversion allows the distance travelled to be calculated. Some models are fitted with a scraper to prevent a build-up of mud on the tyre.

Operation : Self evident.

Suppliers - GANDY Co
- TRUMETER

INTRODUCTION

This Section discusses implements for clearing vegetation from the areas where road construction activities are to take place.

Information on the following implements is given:

- Pulling Implements : manual plant puller
tree hook
mallet lever
sheave block
- Cutting & Felling Implements : grass cutter*
scythe*
brush hook*
bow saw*
axe*
cross cut saw*
wedge
breaking bar
- Root Excavation Implements : mattock*
hoe*
forked hoe*
spade*
fork*
rake*
- Handling Implements : hand tong and hook
grapple

The technical specifications of those marked with an asterisk * are given in Section 1: HANDTOOLS. This Section discusses only the application and operation of these implements in site preparation. Several of the above implements are used in conjunction with draught animals, tractors or hand-operated winches. The power available from these sources, and efficient ways it can be applied, are described in detail in TECHNICAL INFORMATION NOTE TN6. SOURCES OF POWER.

APPLICATION

Site preparation with labour comprises the *removal* of the vegetation from the ground and its *disposal* by burning or towing to waste or stockpile.

Table 3.1 provides guidance on the tools and equipment likely to be most useful for the removal and disposal of different types of vegetation.

REMOVAL

So long as they are not too firmly embedded, it is possible to pull small plants from the ground using *manual plant pullers*. Larger vegetation can be pulled directly from the ground by animals, tractors or hand operated winches, used in conjunction with pulling aids such as the *tree hook*, *mallet lever* and *sheave block*. The size of vegetation which can be removed in this way depends upon how firmly it is embedded in the ground, and upon the power source. The mallet lever and sheave block both provide a mechanical advantage for the pulling operation. The use of the sheave block, which gives a mechanical advantage of up to four times, requires a secure anchorage point.

Direct pulling of vegetation from the ground is to be preferred since it saves having to dig or grub the roots. Where this method is not possible, vegetation is removed by cutting (grass, undergrowth and small bushes) or felling (trees) and either digging the roots out or, if they are small enough, removing them with the top soil. The most generally useful tool for root excavation is the mattock combining the robustness of the pickaxe with the cutting efficiency of an axe. The narrow hoe-like blade is used to excavate pockets of earth, and the cutter end to sever roots. Soil around the base of the tree trunks should first be loosened with a forked hoe, fork or mattock. This will help locate major roots and pockets of earth. The latter should then be dug out with a spade or hoe exposing the roots to be cut by a mattock cutter blade, axe, or saw as appropriate. For felling trees in excess of about 250 mm diameter wedges and breaking bars should be used.

TABLE 3.1: TOOLS AND EQUIPMENT FOR THE REMOVAL AND DISPOSAL OF VEGETATION

SIZE OF VEGETATION	REMOVAL			DISPOSAL
	Pulling	Cutting and Felling	Root Excavation	
Grass	-	grass cutter scythe	-	rake
Small bushes less than 20 mm diameter	manual plant puller	scythe	hoe	hooks
Small bushes and trees less than 100 mm diameter	pulling aids	brush hook	mattock hoe	hand tongs and hooks
Trees and bushes up to 150-250 mm diameter	pulling aids	brush hook bow saw axe wedges	mattock hoe forked hoe spade fork	hand tongs and hooks grapples
Trees in excess of 250 mm diameter	pulling aids	axe cross cut saw wedges breaking bar	mattock hoe forked hoe spade fork	hand tongs and hooks grapples

3. SITE PREPARATION

DISPOSAL

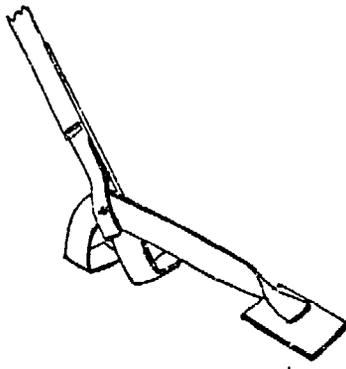
Whenever vegetation is collected and burnt or moved to stockpile the disposal operation involves a significant amount of movement. This can be done manually or with draught animal, tractor or hand operated winch assistance for the larger logs and roots.

The assistance of draught animals is useful for disposing of trees too large to be moved manually, and hauling logs to stockpile. For hauling logs this method is cheaper than motor powered forms of assistance up to haul distances of about 450 metres. [17]

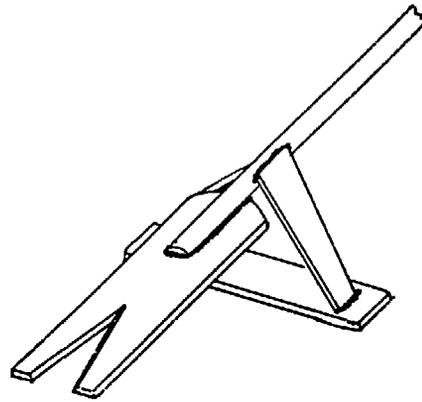
Tractors are a useful means of disposing of tree trunks and roots too heavy to be moved conveniently either manually or with the assistance of draught animals. Providing a suitable anchorage is established, hand operated winches can be used for the movement of the heaviest tree trunks and roots from the immediate road formation.

Hand tongs and hooks are used for handling and carrying vegetation. They are particularly useful with smooth logs and thorny vegetation, both of which are difficult to grip. The use of appropriate aids enables entirely manual methods to be used to dispose of vegetation up to approximately 300 mm diameter logs provided haul distances do not exceed about 25 metres.

Grapples are useful for towing logs whatever means of pulling is used.



(a) Cotton Stalk Puller



(b) Mandypick



FIGURE 3.1: MANUAL PLANT PULLER

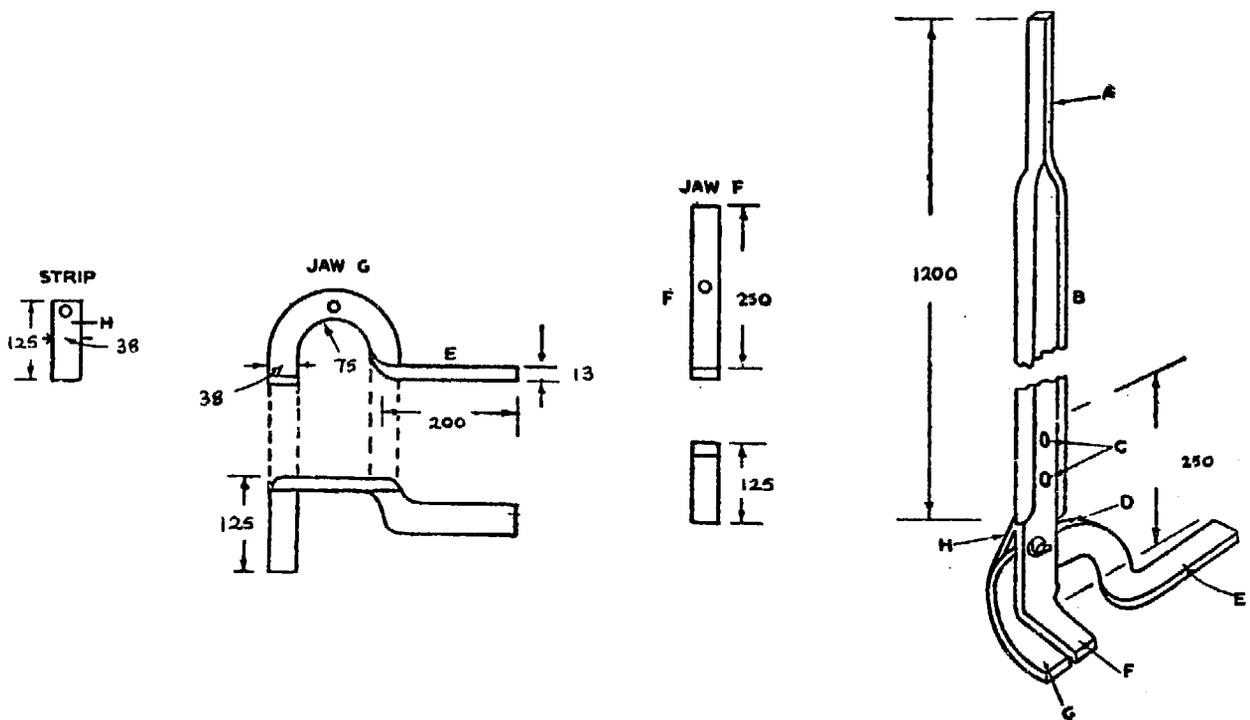


FIGURE 3.2: COTTON STALK PULLER (mm)

TOOLS AND EQUIPMENT
PULLING IMPLEMENTS
MANUAL PLANT PULLERS

Design : Figure 3.1 illustrates two types of simple manual pulling device.

The construction of the cotton stalk puller is apparent from Figure 3.2. Jaw GE is formed from strip 13mm wide, 480mm long. Jaw F is formed from strip 13mm wide, 250mm long. For use in soft ground a flat plate can be welded to the end of Jaw GE to increase the bearing area (Figure 3.1(a)).

Materials : Mild steel. (TN1)

Manufacture : Requires simple metal working facilities.

Operation : Evident from Figure 3.1

Suppliers : N/A

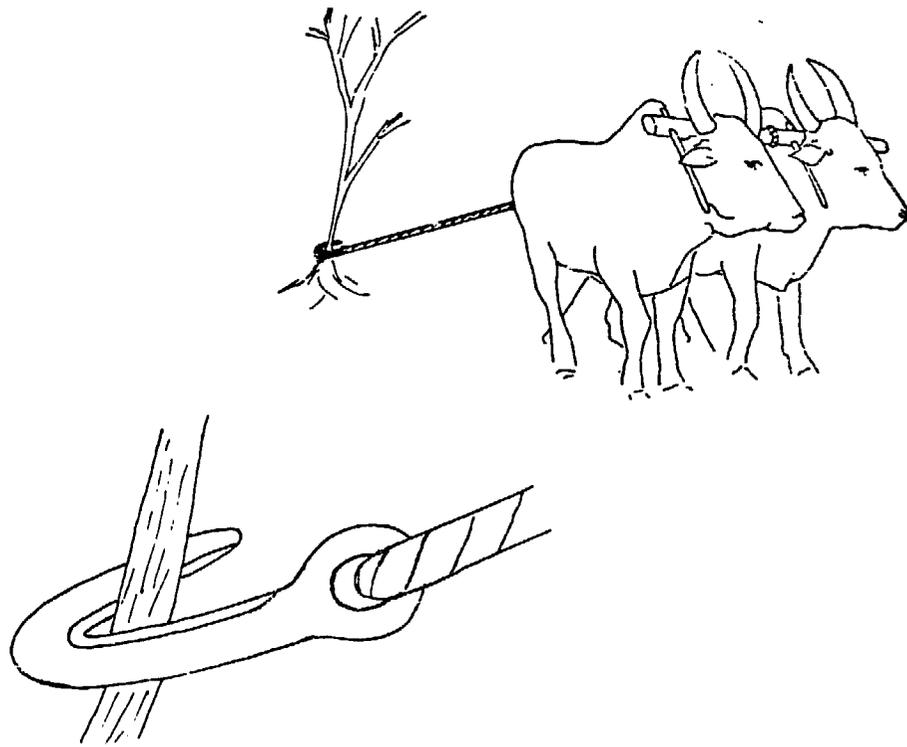


FIGURE 3.3 TREE HOOK : POWER SOURCE, ANIMAL TRACTOR OR WINCH

TREE HOOK

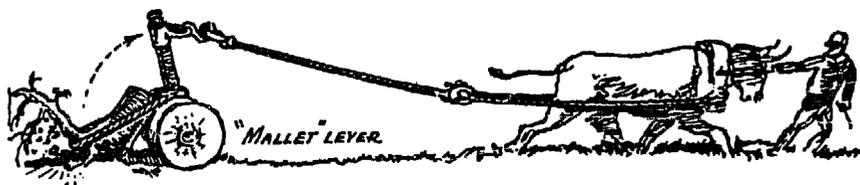
Design : Figure 3.3 illustrates a simple tree hook.

Material : Medium carbon steel (TN1)

Manufacture : Forged, hardened and tempered in a manner similar to that used for axe heads. (TN1). The type of hooks that can be made by village blacksmiths would only be suitable for light vegetation.

Operation : (see page 3.17 for general principles of operation). Evident from Figure 3.3. The tree hook can be sharpened on the inside bend so that it cuts into and grips the tree.

Suppliers : N/A



Power Source: animal, tractor or winch

FIGURE 3.4: MALLET LEVER

MALLET LEVER

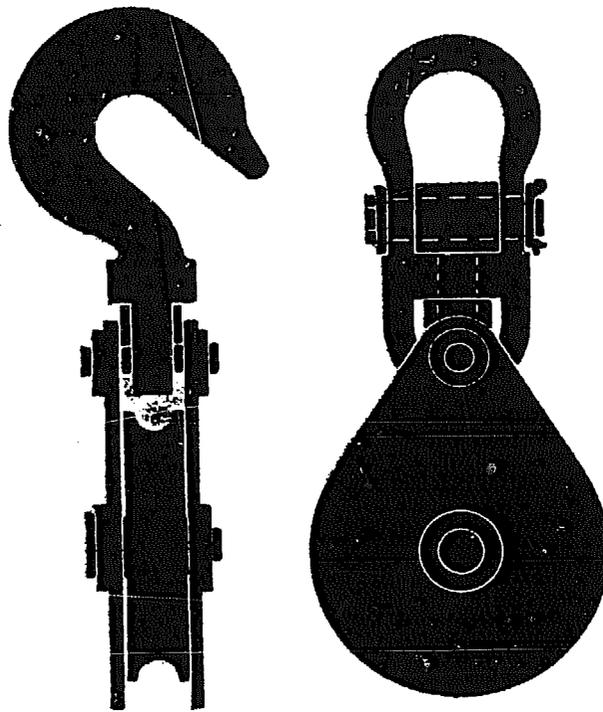
Design : Figure 3.4. illustrates a mallet lever.

Material : Seasoned hardwood. (TN 2).

Manufacture : The lever is best made from a section of tree trunk which has a stout branch stem (at least 200mm dia.) protruding from it on one side. The diameter of the mallet head should be approximately 700mm.

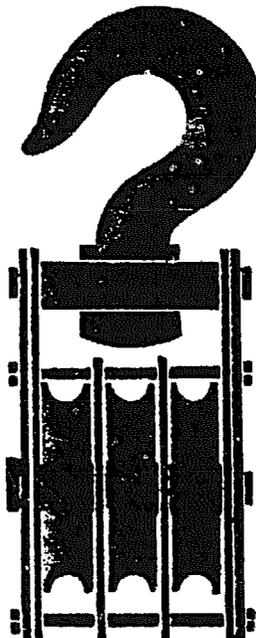
Operation : (see page 3.17 for general principles of operation). A main root of the tree stump is first exposed and a fibre rope, or preferably metal sling, is fed under the root and over the stem of the mallet.

Suppliers : N/A.



Shackle

Pulley wheel



THREE SHEAVE
WITH SWIVEL
HOOK

FIGURE 3.5: SHEAVE BLOCKS

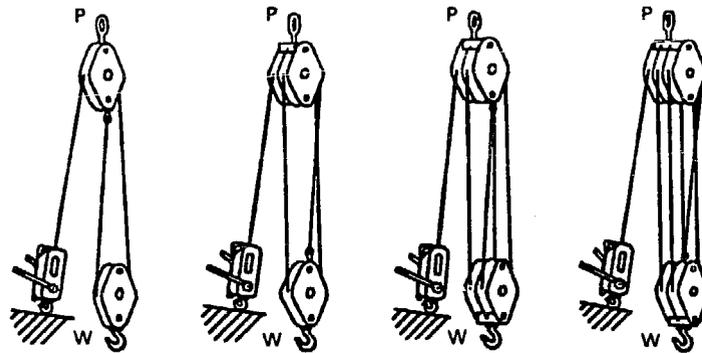
SHEAVE BLOCKS

Design : Figure 3.5 illustrates various forms of sheave block. They can be supplied with hook or shackle and can have 1, 2, 3 or sometimes more pulley wheels (sheaves). Blocks are specified in terms of the number of pulley wheels; the pulley wheel diameter, the rope diameters; and the proof load and ultimate hook load. Typical figures are as follows:-

Rope Diameter (mm)	Pulley Wheel Diameter (mm)	Proof Load (kg)	Ultimate Hook Capacity (kg)
16-25	150	27200	43500
	200/250	27200	43500
		or 36300	or 61200

By arranging sheave blocks with different numbers of pulley wheels in various combinations the nominal pulling force (F) can be magnified several times to give the effective force (W) indicated in Table 3.2. It is also necessary to know the anchor force (P) so that appropriate specifications are used for the anchorage hooks and ropes.

TABLE 3.2 : RELATIONSHIP BETWEEN THE FORCES ON SHEAVE BLOCKS



Block Combinations	1+1	2+1	2+2	3+2
Number of Falls of Rope	2	3	4	5
Nominal Pulling Force	1	1	1	1
Effective Force W	1.8	2.6	3.3	4.0
Anchor Force P	3.0	4.0	5.0	6.0

3. SITE PREPARATION

Materials : The highly stressed components such as hooks or shackles are made from drop forged high tensile strength alloy steels (TN 1).

Manufacture : N/A.

Operation : (see page 3.17 for general principles of operation). The use of sheave blocks is only possible if a firm anchorage in the form of a stouter tree or rock outcrop - can be provided.

Suppliers

- ELIZÄ TINSLEY & Co. Ltd.
- HOLTITE Ltd
- SKOGSMATERIEL AB

PULLING IMPLEMENTS

Operation : General

Pulling vegetation directly from the ground imposes very high stresses on all the equipment used. If any part fails under load then operators and animals are at great risk from fibre or wire ropes. For this reason care is necessary to ensure that all parts of the assembly - ropes, hooks, shackles and sheave blocks - are of a matching strength and adequate for the task being undertaken. MANUFACTURERS RECOMMENDATIONS SHOULD BE ADHERED TO. Safety hooks - those with a spring loaded latch restraining ropes from slipping off of the hook - are recommended at all times.

For the safety of operators and animals it is also important that any rope used be at least twice as long as the tallest tree being extracted. If animals are being used the rope must be as long as possible so that the direction of pull is as near horizontal as possible. This is because animals have difficulty in pulling downwards, particularly where a neck yoke harness is used. If a tractor is used to pull a tree over a steady pull should be maintained and if the cable can be passed through a single sheaf block which is securely anchored to the ground, it will not only help in giving the wheels a better grip, but it will also reduce the risk of the tractor overturning. The wheels should be set out to their widest extent; it is also advisable to add extra weight to the front of the tractor. Where the ground is not level the pull should be *downhill* if possible. The cable should be attached to the tractor drawbar in its lowest position. *Never* hitch above drawbar height; *never* pull at an angle to the direction of the tractor; and *never* pull across a slope - any of these situations could result in the tractor overturning.

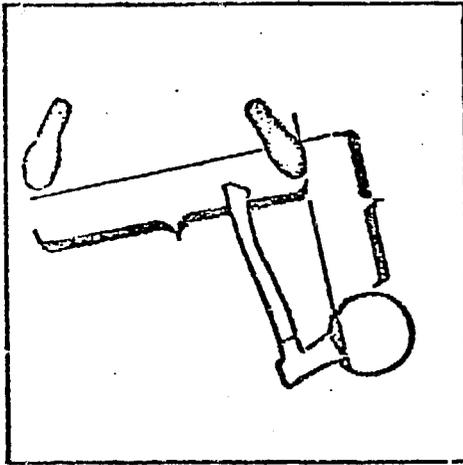
CUTTING AND FELLING IMPLEMENTS

GRASS CUTTER

Operation : The grass cutter should be swung with a loose arm pendulum action. Operators should be taught to work both left and right handed as this makes the most efficient use of their body strength. Efficient working technique can be encouraged if the length of the tool is adjusted to the reach of individual operators.

SCYTHE

Operation : The operator mows grass and brush with a scythe in wide, semicircular cuts from his right side towards his left. He advances in a straight line ahead cutting away from the standing vegetation. The operator should stand with his right foot slightly forward so that his body faces slightly to the left of his advancing direction. The movement of the feet must be in accordance with the cutting swing. The operator's right foot should move about 200mm forward and be immediately followed by the left foot during the backward swing of the scythe. Less swing and narrower cuts are used for brush cutting than for grass mowing. After about 120 cutting swings a blade needs whetting, (sharpening) and this gives the operator a short rest.



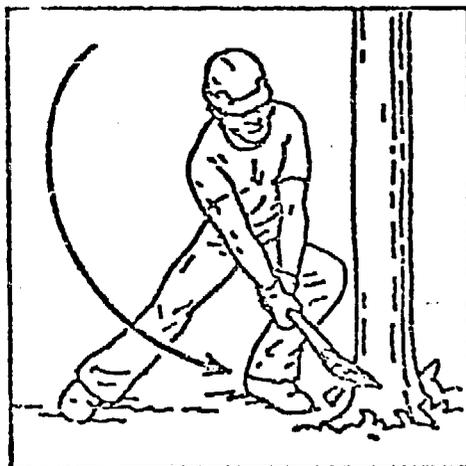
(a) Take the above leg-spread position for efficient and safe working.



(b) The upper hand positions the axe/brush hook.



(c) ... and slides down guiding the handle during the blow ...



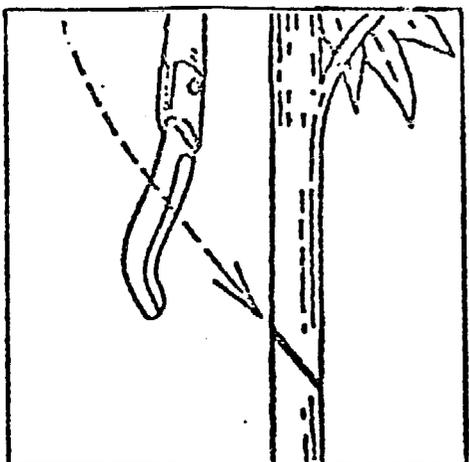
(d) ... until the hands are together when hitting the tree.



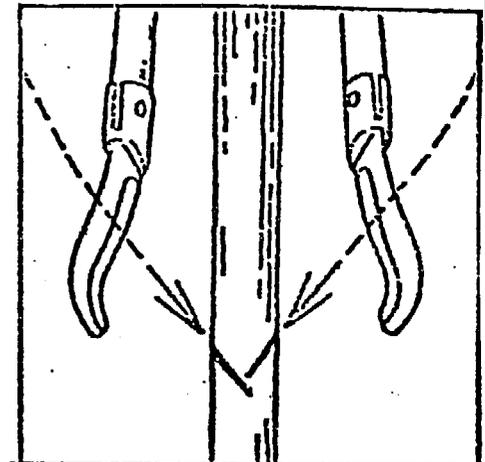
(e) Learn both right hand and left hand grip, which makes work easy and efficient.



(f) The left hand should be in the upper position when cutting from the left side and vice versa when cutting from the right



(g) Brush Hook: cut the small trees with one blow.



(h) Brush Hook: Fell thicker trees with one cut on each side.

3. SITE PREPARATION

AXE/BRUSH HOOK

Operation : (See page 3.31 for general principles of operation). Working techniques with an axe or brush hook are virtually the same and are illustrated in Figure 3.6. All cutting strokes should be away from the body.

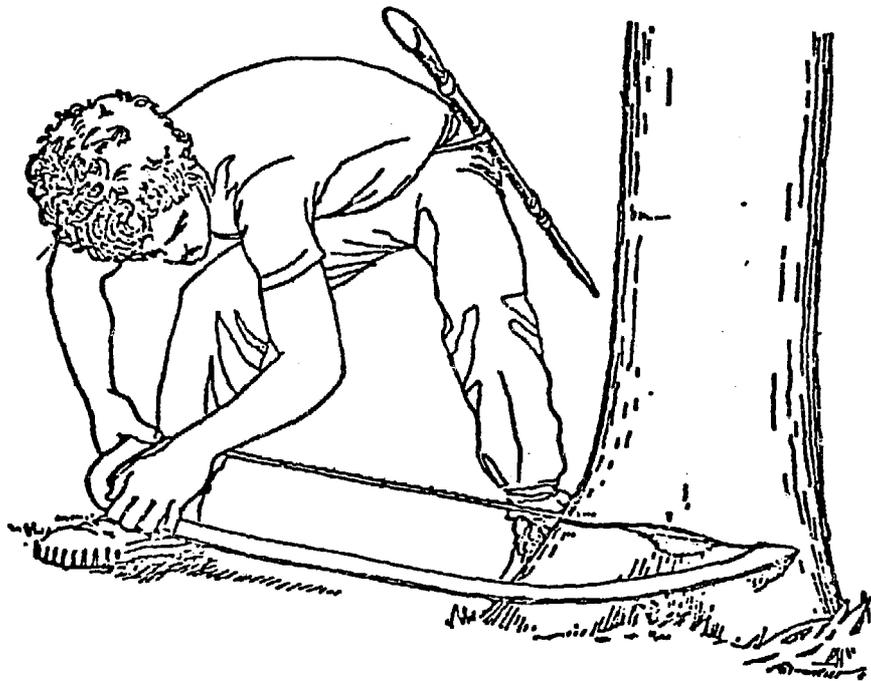


FIGURE 3.7 : WORKING TECHNIQUE - BOW SAW

BOW SAW

Operation : (See page 3.31 for general principles of operation). Use of the saw requires that the worker positions himself low to the ground, parallel to the direction of cut and facing away from the tree. Bending at the waist and with legs widely straddled, he makes long, sweeping strokes. The cutting action is not in the pressure of the saw against the wood, but rather in the smooth push and pull of the saw. This rhythmic gliding motion is produced by shifting the body weight back and forth from one thigh to the other. Figure 3.7.

CROSS CUT SAW

Operation : (See page 3.31 for general principles of operating). For the 2-man cross cut-saw the correct working technique is the same as for the bow saw. There should be a clear understanding between the two men about starting and stopping work, and about who will take the saw when the tree falls. Both men should have a clear unobstructed escape route.

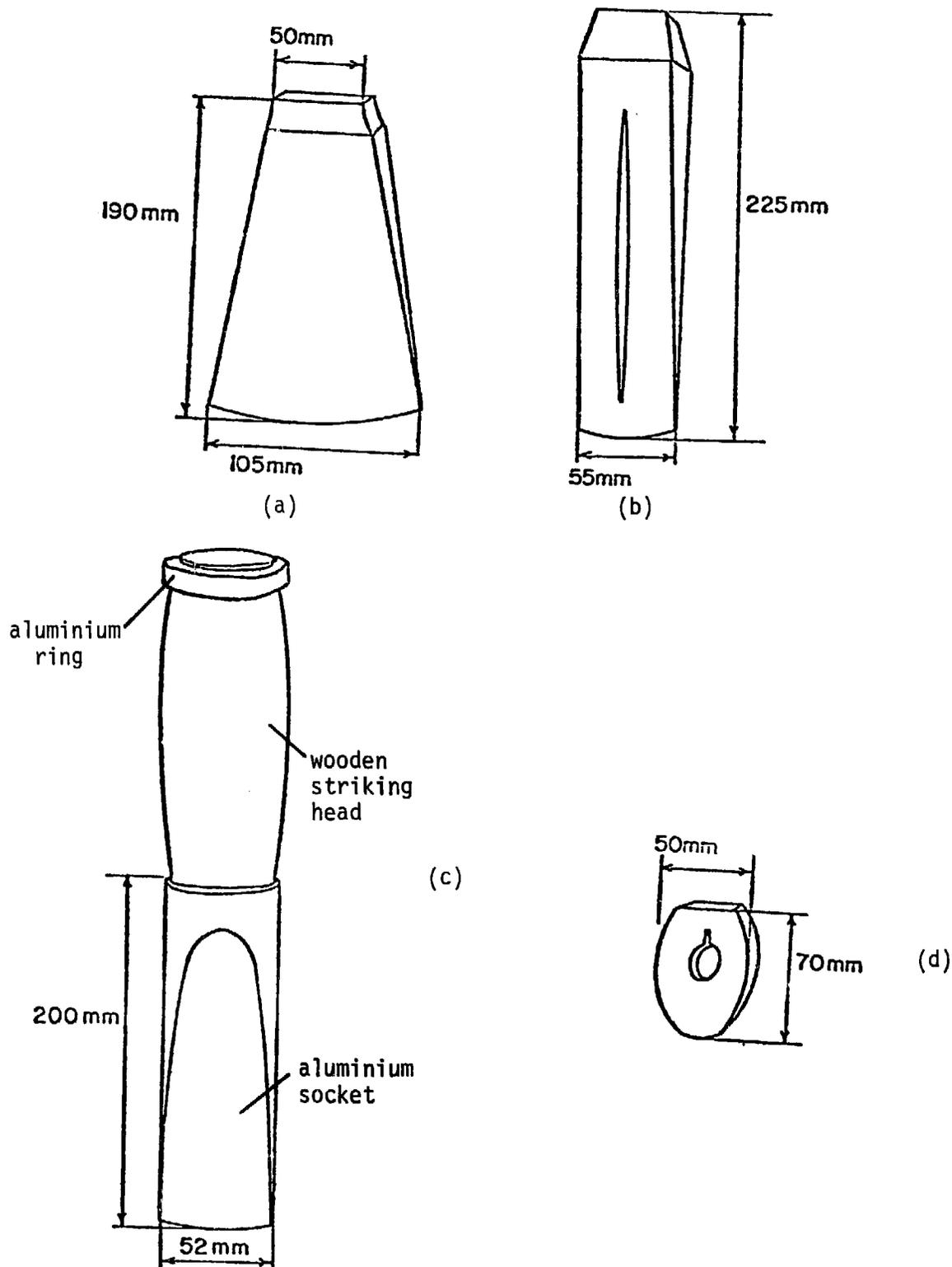


FIGURE 3.8 : DIFFERENT TYPES OF WEDGES

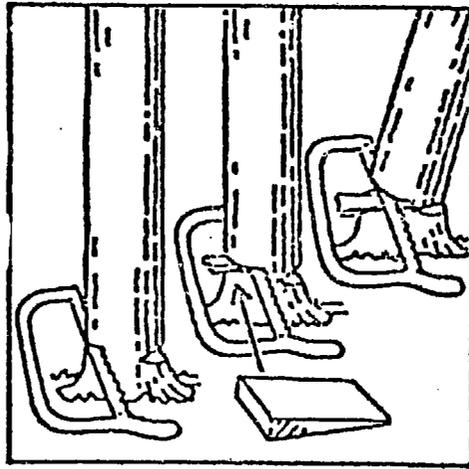
WEDGES

Design : Figure 3.8 illustrates a number of different types of wedge used in forestry activities. Felling wedges (a) are used for directing the fall of the tree and for keeping the saw cut open during felling. They are broad and have a shallow taper. Splitting wedges (b) are narrow and have a steeper taper. Combined felling/splitting or 'socket' wedges (c) consist of a striking head, ring and socket. Cross-cut or 'pocket' wedges (d) are used to keep the saw cut open during cross-cutting.

Materials : Traditionally wedges were made of hardened and tempered medium carbon steel. These are gradually being replaced by hardwood and plastic wedges because with use steel tends to mushroom at the head of the wedge resulting in dangerous splinters flying-off when struck. The striking head socket wedge is made of wood and the ring and hollow socket of aluminium. Cross-cut wedges are made of aluminium.

Manufacture : Wedge sockets are cast in aluminium : the remaining types or components are cut from the solid material.

Operation : The use of wedges for tree felling is illustrated in Figure 3.9.



Use axe hammer for hitting the wedge.
Insert the wedge before the saw jams.

FIGURE 3.9 : USE OF FELLING WEDGE

Suppliers : Aluminium

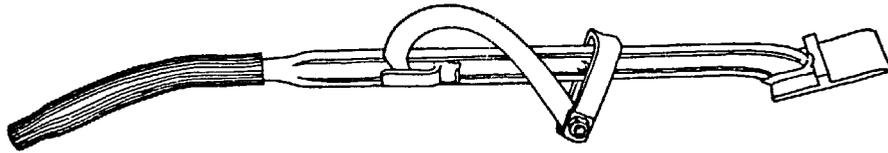
- SKOGSMATERIEL AB

Steel

- BULLDOG TOOLS
- BURGON & BALL Ltd.
- CYCLONE FORGINGS Pty. Ltd.
- TROJAN Pty. Ltd.

Nylon

- SANDVICK U.K. Ltd.
- SKOGSMATERIEL AB



- (a) To use leg muscles and keep the back straight when tilting with the breaking bar.
- (b) To insert the breaking bar as soon as possible. Leave 20-30mm hinge to ensure felling direction.
- (c) Then to continue to cut and lift the bar and push it deeper. When the additional step is inside the tree it will increase the lever force.

FIGURE 3.10 : USE OF BREAKING BAR

BREAKING BAR

Design : The breaking bar consists of a simple lever with a handle at one end and a rectangular wedge at the other. They are between 650-1200mm long, the most useful size being about 800mm, and weigh 1.5-2.5kg. Some are equipped with an auxiliary cant hook.

Material : Medium carbon or alloy tool steel (TN 1).

Manufacture : The blade and cant hook should be forged, hardened and tempered in a manner similar to axe heads. (TN1)

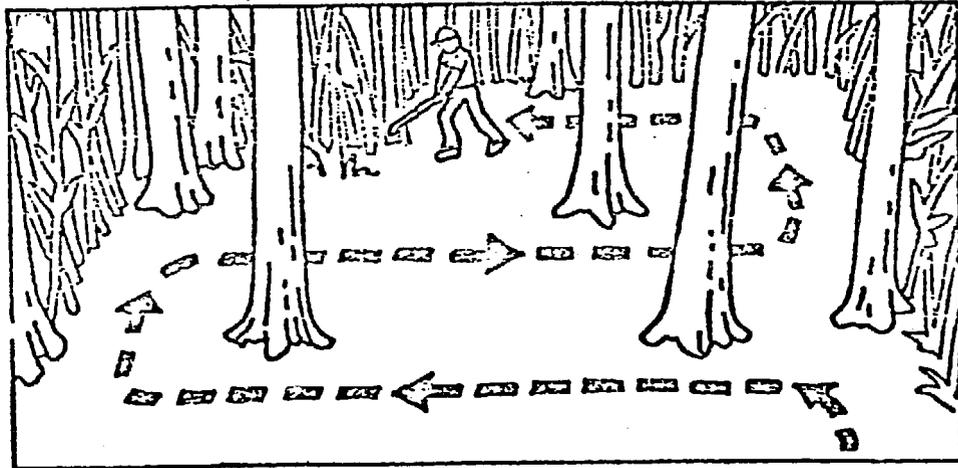
Operation : To use the breaking bar correctly for tree felling workers should be instructed as illustrated in Figure 3.10.

The cant hook on the breaking bar enables it to be used for pulling off felled trees that have become lodged and for trimming logs.

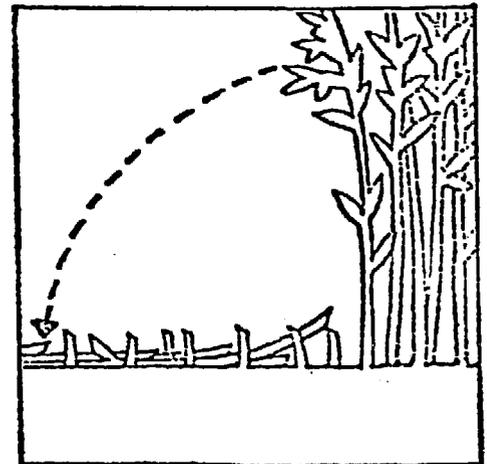
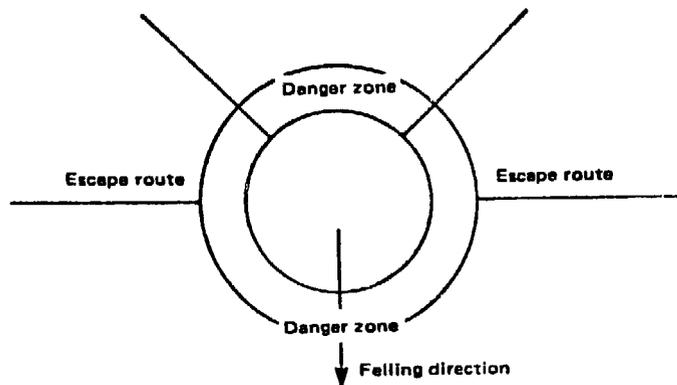
Suppliers

- JAMES JONES & SONS Ltd.
- OY FISKARS AB

- SANVIK U.K. Ltd.
- SKOGSMATERIEL AB



- (a) Clearing the working space prior to work is especially important in dense forests to enable workers to move freely and to avoid injuries from deflected tools: proceed systematically when clearing.



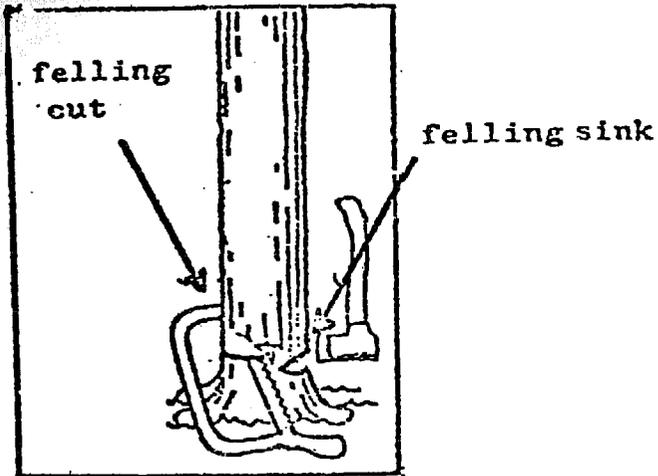
- (b) Clearance of escape routes is needed before a tree is felled.
- (c) To fell trees in 'the cleared area for efficient work'.
- (d) To assess the direction in which the tree will fall, taking into consideration the slope of the ground, distribution of branches and the natural lean of the tree.
- (e) When starting to fell a tree, first cut a 'sink' or 'V' about a quarter of the tree's diameter in the trunk facing the direction in which it is intended the tree shall fall. The 'back' is then cut, or sawn level, from a point a little higher than the 'sink' cut. Provided the tree is evenly weighted or is heavier on the 'sink' side, it should then fall safely in the required direction.

FIGURE 3.11 : FELLING TREES

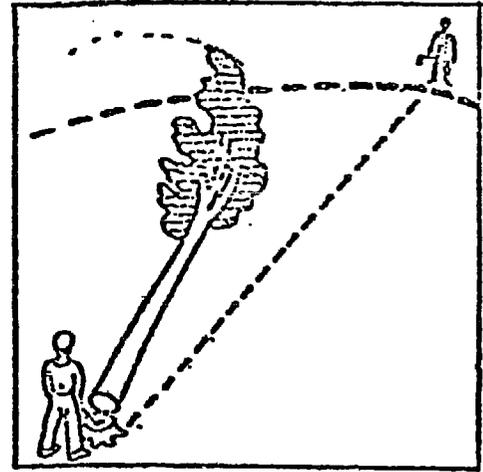
CUTTING AND FELLING IMPLEMENTS

Operation : General

Cutting vegetation and felling large trees requires special working techniques if high productivity is to be obtained WITH SAFETY. For the safety of all workers it is essential, also, that work is very carefully organised and they must be instructed as illustrated in Figure 3.11.

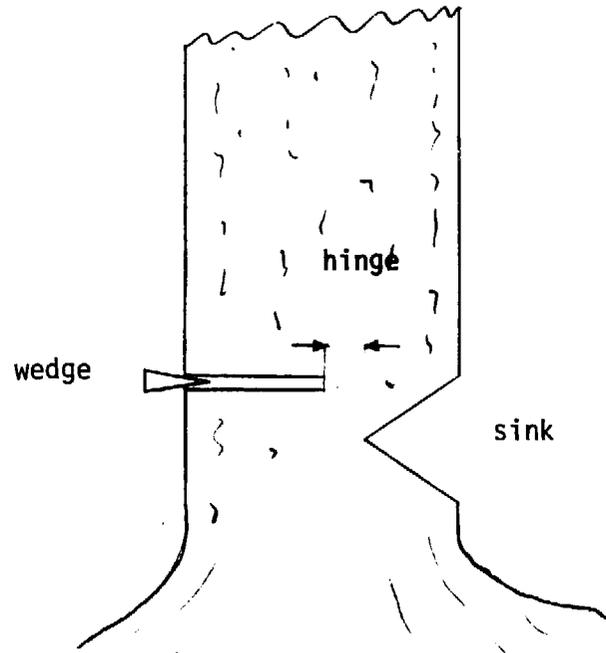


(f) The felling sink determines the direction of fall. Makes the felling cut higher than the felling sink.

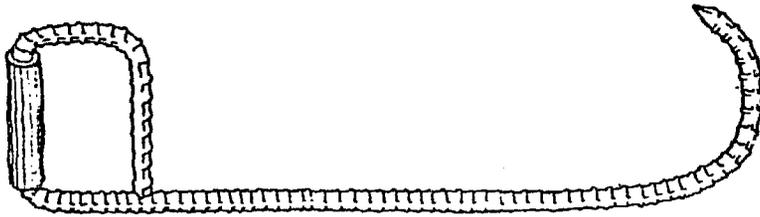


(g) The safe area for other people is outside the circle of twice the length of the felled tree.

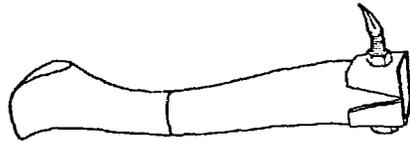
(h) *Never* attempt to fell a tree in a high wind.



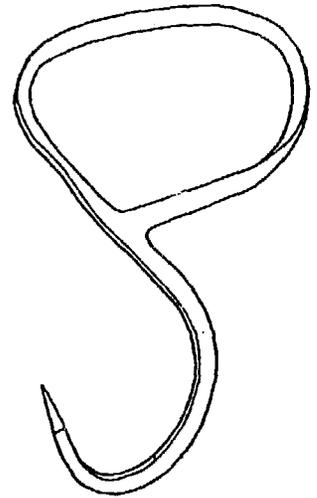
(i) Felling against the wind direction requires a good felling 'sink', a felling hinge and a felling wedge.



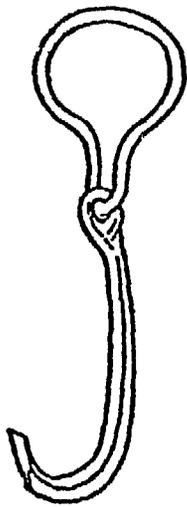
(a)



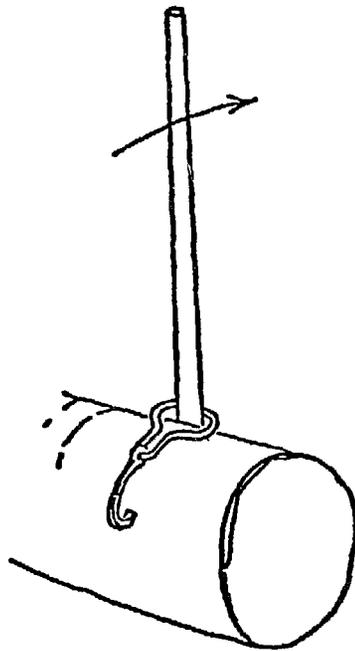
(b)



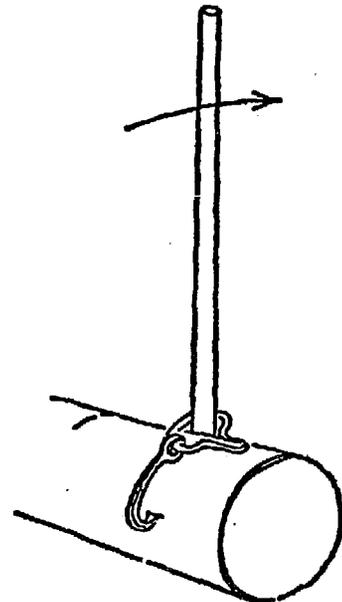
(c)



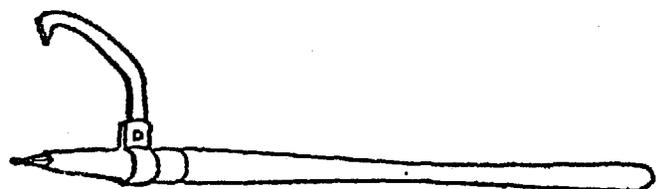
(d)



(e)



(f)



(g)

FIGURE 3.12 : HOOKS FOR LOG HANDLING

LOG HANDLING IMPLEMENTS

HAND TONG AND HOOK

Design : Figure 3.12 illustrates the design of various types of hook for handling logs and thorny vegetation. The *log turner* (d) consists of a steel hook, weight 0.8-1.3kg length 200-350mm fitted to a ring through which a strong pole is put. The special shape of the ring permits use of the hook on larger or smaller trees (e), (f).

The *peavy* consists of a wooden handle the end of which is fitted to a pointed iron tube (g). The hook is attached to this tube.

Figure 3.13 illustrates the design of various types of hand tong for handling logs up to 250mm diameter. The *long-handled timber tong* (c) is used by two men for short distance skidding of poles.

Material : Medium carbon or alloy steel (TN 1).

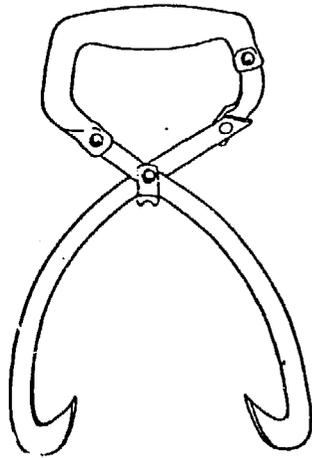
Manufacture : Forged, hardened and tempered in a manner similar to axe heads. (TN1)

Operation : The use of hooks and tongs is very convenient especially in wet weather. The worker is not required to bend down close to the ground when picking up logs or billets. Furthermore, the wood can be held more firmly. Work becomes thus easier and safer. To use hand tongs and hooks for log handling correctly workers should be instructed as illustrated in Figure 3.14.

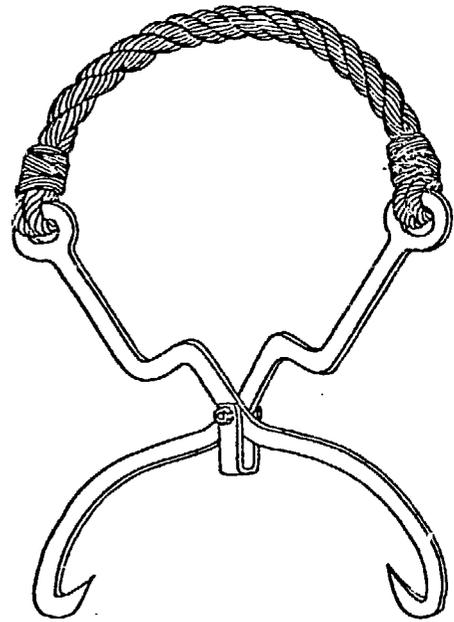
Suppliers

- JAMES JONES & SONS Ltd.
- OY FISKARS AB

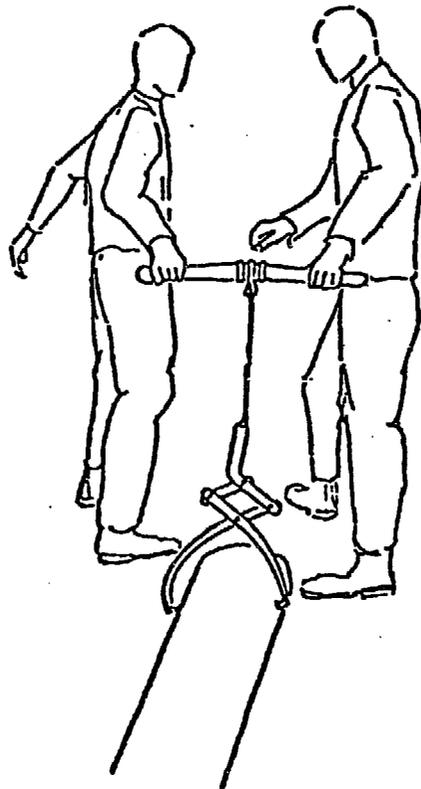
- SANDVIK U.K. Ltd.
- SKOGSMATERIEL AB



(a)



(b)

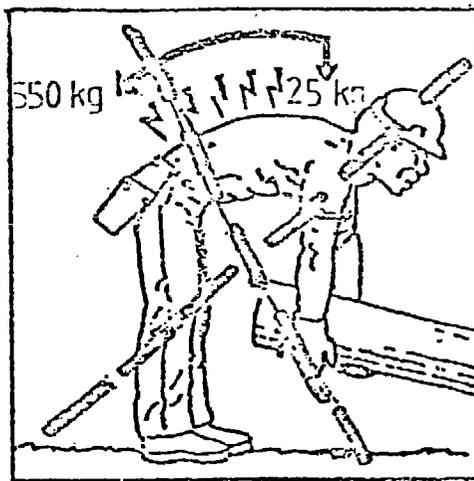


(c)

FIGURE 3.13 : HAND TONGS FOR LOG HANDLING



(a) Use correct lifting technique: the strong leg muscles should do the lifting.



(b) ... not the arms nor the back. Never handle logs with bare hands, always use tools for handling.

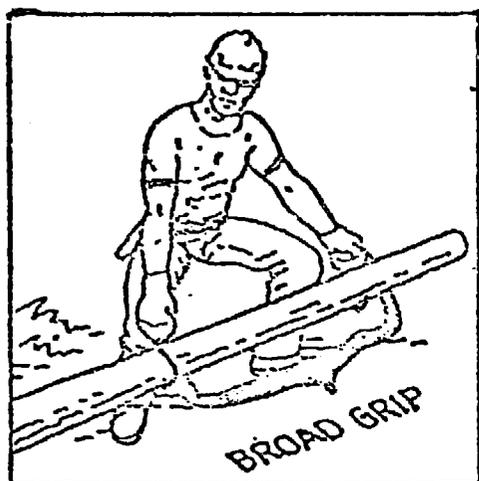


(c) Use tong and leg muscles for lifting...

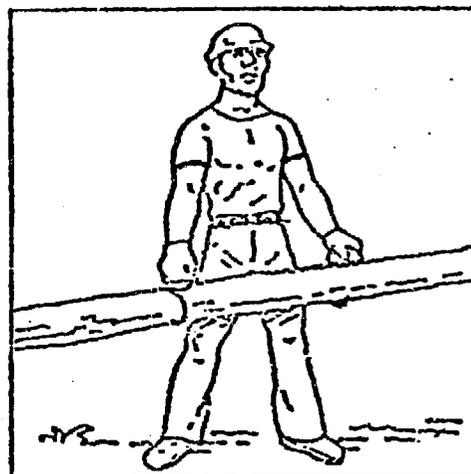
or



(d) Use two hooks and leg muscles for lifting.



(e) Use two hooks and broad grip for carrying.



(f) Carry with straight back - load on legs.



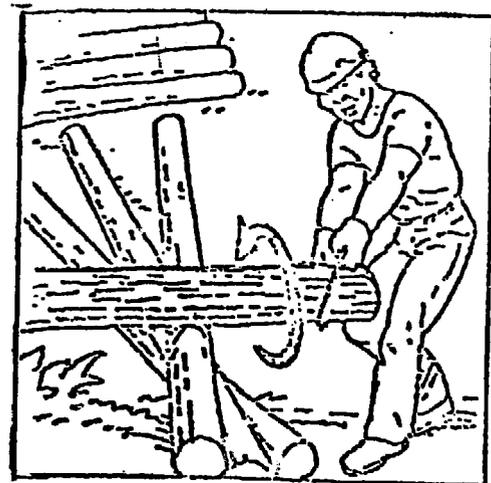
(g) too narrow a grip puts strain on arms and gives poor balance.



(h) Use two hooks for dragging.



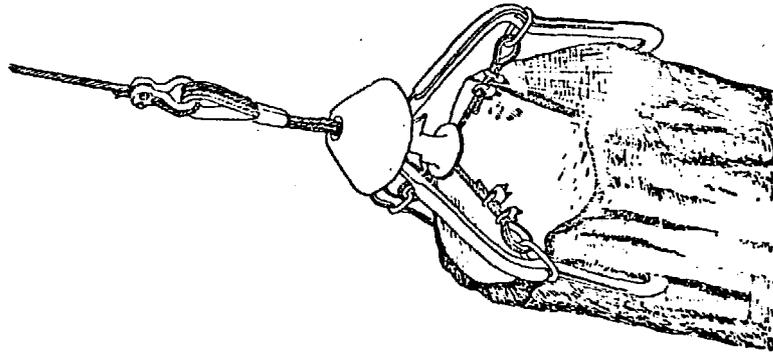
(i) Never twist the body - always use two hooks.



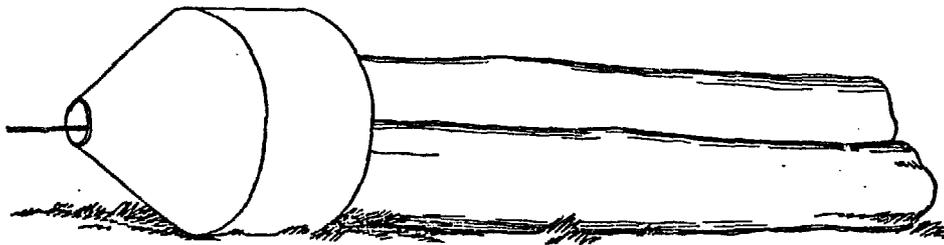
(j) Use hook and the help of other logs for rolling.



(k) Use hook and tong for stacking.



(a) Grapple : small cone

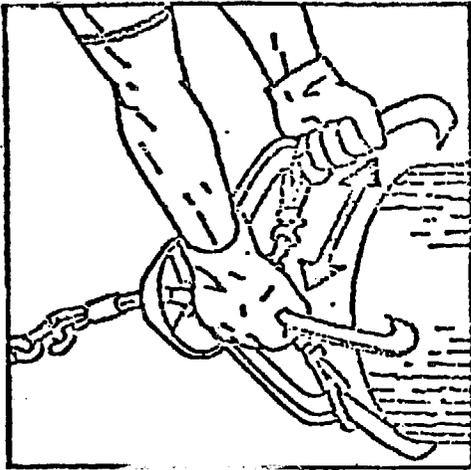


(b) Grapple : enclosing cone

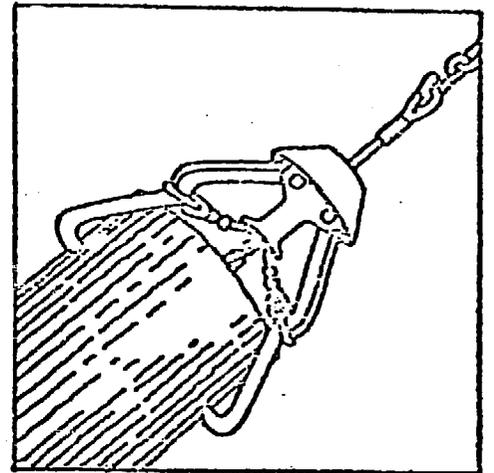
FIGURE 3.15 : GRAPPLES

GRAPPLE

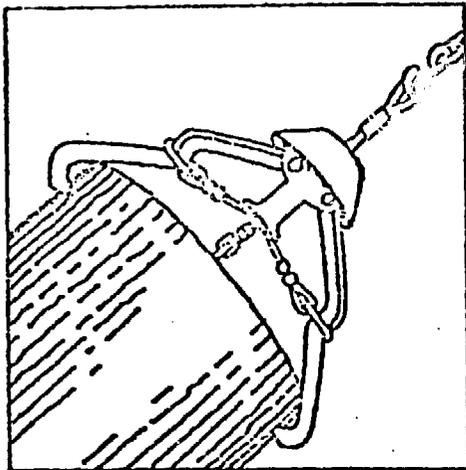
- Design* : Figure 3.15(a) illustrates the design of a grapple for log hauling. It consists of three steel hooks connected to a central pulling wire and weighs about 6kg. The shape of the hooks gives a spring mechanism ensuring a strong grip on the log. The front of the grapple can be fitted with a small or large enclosing cone-Figure 3.15(b) - whose function is to deflect the log around small tree stumps clumps of grass and stone outcrops.
- Materials* : High carbon or alloy steel (TN 1).
- Manufacture* : Forged, hardened and tempered to 42 HRC (TN3).
- Operation* : Grapples can be used to haul logs manually or with animal, tractor or winch assistance. Whatever source of power is employed to use grapples correctly workers should be instructed as illustrated in Figure 3.16. The track along which the trunk is to be hauled should be as free as possible of tree stumps, rocks or other obstructions. The chain, rope or cable should be as short as possible and hitched to either end of the tree so that it is clear of the ground.
- Suppliers*
- OY FISKARS AB
 - SKOGSMATERIEL AB



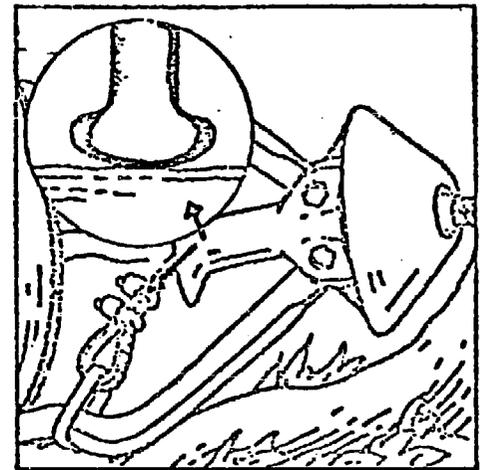
(a) Put the lower hook underneath and push the upper two along the log as far as necessary.



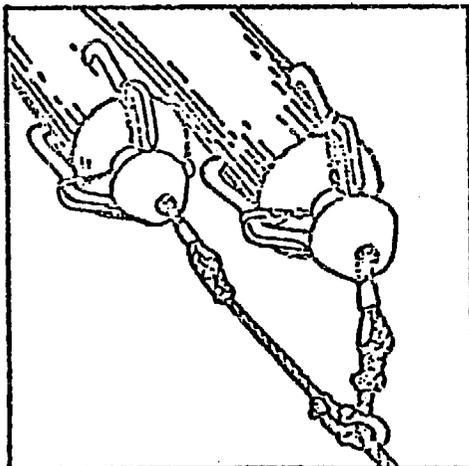
(b) Use the grapple's spring force correctly: push the hooks further up the log when the diameter is small



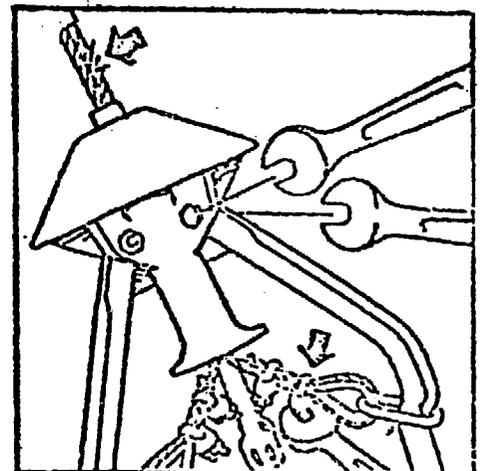
(c)when its large; attach them closer to the top end of the log.



(d) The log end should *never* push against the funnel through which the cables pass. This prevents the grapple from working loose easily.



(e) Two skidding grapples may be choked to each other



(f) Check wearing of the wire and tighten the nuts with two ?

3. SITE PREPARATION

REFERENCES

1. INTERNATIONAL LABOUR OFFICE. Appropriate Technology in Philippine Forestry. Report of Joint Philippine Bureau of Forest Development/ILO/Government of Finland Project, Geneva, 1977 (International Labour Office).

INTRODUCTION

This Section discusses implements for the excavation of top soil from the road alignment or borrow pits; and earth and gravel from borrow pits, cuttings drainage channels and foundations.

Information on the following implements is given:

- crowbar*
- pickaxe*
- hoe*
- spade*
- forked hoe*
- fork*
- shovel*
- animal-drawn mouldboard plough
- animal-drawn tine plough
- tractor-mounted mouldboard plough
- tractor-mounted tine ploughs
- animal-drawn earth scoop
- animal-drawn fresno scraper
- tractor-towed earth scraper

The technical specifications of those marked with an asterisk * are given in Section 1: HANDTOOLS. This Section discusses only the application and operation of these implements in earth and gravel excavation. Coverage of animal-drawn implements assumes the use of bullocks or buffaloes. Donkeys could be used, but their draught capacity, and hence output, is lower.

APPLICATION

The major factor affecting the type of tools and equipment used for earth and gravel excavation is the properties of the material to be excavated. In particular, the cohesiveness and the degree of saturation of the material will control the ease with which it can be penetrated and broken out. Table 4.1 provides guidance on the tools and equipment likely to be most useful for the excavation of different types of material.

After material has been excavated it is often thrown or loaded and hauled away. It is usually efficient to combine as many as possible of these activities into a single operation. It is useful therefore to divide implements for excavation operations into three categories:

Excavate only These implements can only loosen and break down material. The crowbar and pickaxe are normally used where material is too difficult to be excavated and loaded in one operation. Ploughs are only suitable for excavating relatively large, flat, open areas. An important application of the plough is to loosen ground prior to excavation by scrapers.

Excavate and Load These handtools can be used for excavating and loading, usually in one operation. Table 4.2 summarises the loading characteristics of these tools.

Excavate, Load and Haul Animal and tractor drawn scoops and scrapers combine these activities into a single operation. They are only suitable for use in relatively large open spaces. Practical haul distances are up to about 100 metres for animal-drawn devices and 3-500 metres for tractor-drawn. The animal-drawn fresno scraper and the tractor-drawn devices allow a controlled rate of spreading of the excavated material.

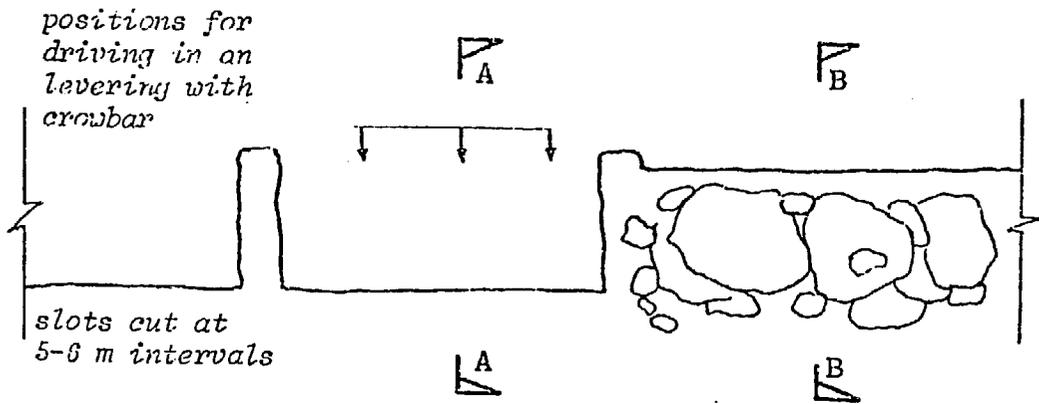
TABLE 4.1: TOOLS AND EQUIPMENT FOR THE EXCAVATION OF DIFFERENT MATERIALS

OPERATION	IMPLEMENT	EXCAVATION MATERIAL
Excavate Only	Crowbar	Dense non-cohesive and stiff cohesive. As a levering tool can cope with materials which are most difficult to break out - heavy wet cohesive.
	Pickaxe	Dense non-cohesive and stiff cohesive. As a swung tool can cope with materials which are most difficult to penetrate - hard dry cohesive.
	Animal-Drawn Mouldboard Plough	Soft or medium cohesive, loose or medium non-cohesive. Preferred for cohesive materials which do not break easily.
	Animal-Drawn Tine Plough	Non-cohesive materials which are relatively difficult to penetrate.
	Tractor Mounted Mouldboard Plough	Most materials up to dense non-cohesive and stiff cohesive. Not suitable for coarse granular materials. Preferred for cohesive materials which do not break out easily.
	Tractor Mounted Tine Plough	Most materials up to dense non-cohesive and stiff cohesive. Not suitable for coarse granular materials. Preferred for hard materials which are difficult to penetrate but break out relatively easily
Excavate and Load	Hoe	Soft or medium cohesive, loose or medium non-cohesive. Not suitable for coarse granular material.
	Spade	Soft or medium cohesive, loose or medium non-cohesive. Not suitable for coarse granular material. Preferred to hoe for wet cohesive material because of greater leverage.

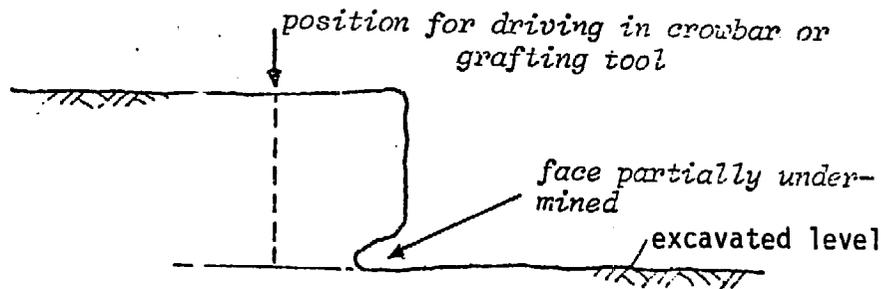
OPERATION	IMPLEMENT	EXCAVATION MATERIAL
Excavate and Load	Forked hoe	Loose coarse granular materials. Cohesive soils such as stiff clay.
	Fork	Coarse but not dense granular materials. Cohesive soils such as stiff clay.
	Shovel	Soft cohesive and loose granular - materials requiring little excavation.
Excavate Load and Haul	Animal-drawn Earth Scoop	Ground that has been loosened by plough
	Animal-drawn Fresno Scraper	Ground that has been loosened by plough
	Tractor-drawn Earth Scraper	Ground that has been loosened by plough

TABLE 4.2 : LOADING CHARACTERISTICS OF HAND TOOLS

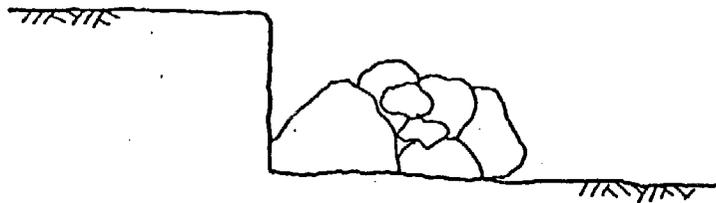
TOOL	LOADING CHARACTERISTICS
HOE	Poor throwing tool, limited range and accuracy, maximum loading height 1m.
SPADE	Good throwing tool, maximum loading height 1.5m. Not suitable for scooping up and throwing since no crank in handle.
FORKED HOE	Can load highly cohesive soils (e.g. soft clay) once they have been broken out. Poor throwing tool, limited range and accuracy, maximum loading height 1m.
FORK	Good throwing tool, maximum loading height 1.5m
SHOVEL	Excellent loading tool, suitable for most materials except wet clay and coarse granular. Maximum loading height 1.5m more for long handled shovel. Maximum range 5m.



Plan of working face in borrow pit



View A-A: Section ready for excavation



View B-B: Excavated section ready for loading

FIGURE 4.1: EXCAVATION OF BORROW PIT USING CROWBAR

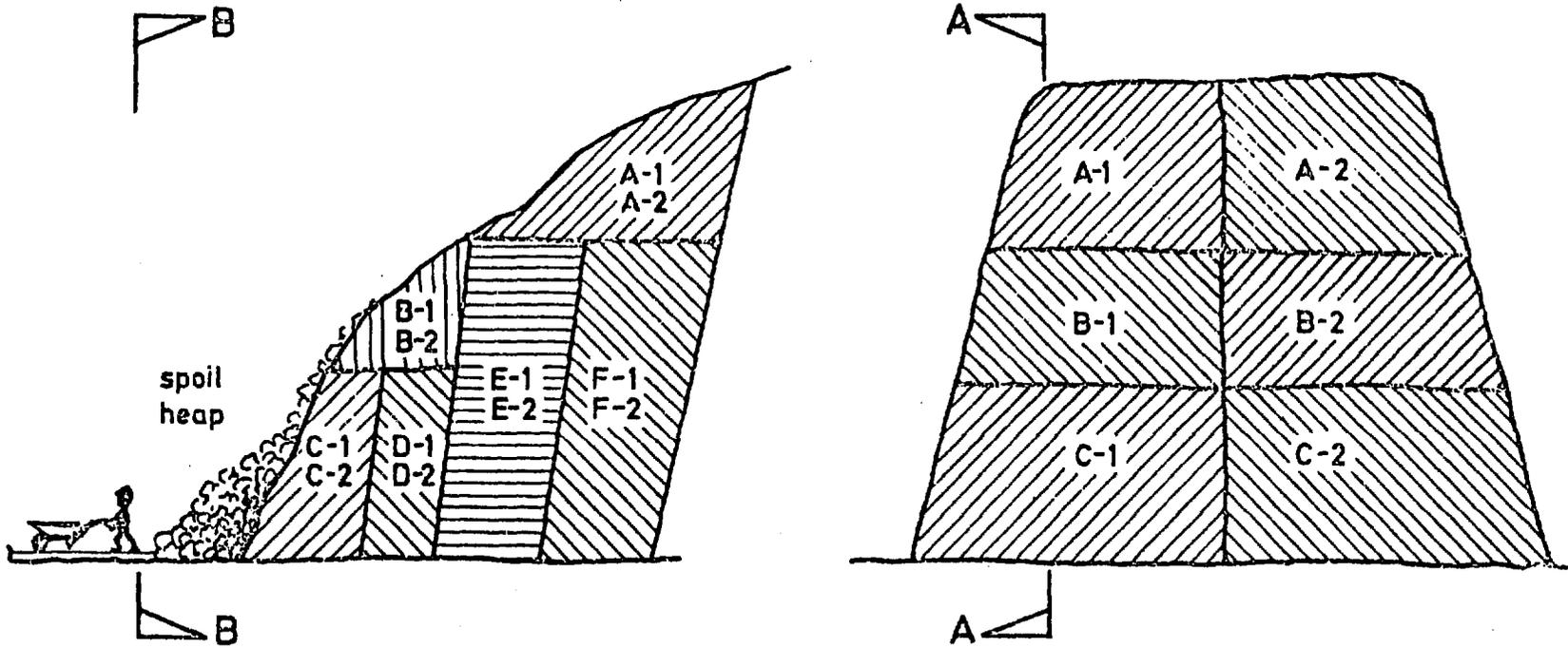
TOOLS AND EQUIPMENT

HANDTOOLS

Operation When excavating with driven tools (i.e. *crowbar, spade, fork*) the operator should stand above the ground to be excavated. This is illustrated for the crowbar in Figure 4.1, which also shows how the excavation face can be undercut to assist in breaking out the material. With swung tools (*pickaxe, hoe, forked hoe*) the operator should stand below the level of the ground to be excavated (i.e. in Figure 4.1 he would stand at the excavated level). When loading with a *shovel* the operator should work at the excavated level, driving the shovel into the pile of loose material.

The maximum productivity will only be obtained from a tool if correct working techniques are used. Good quality tools facilitate correct working practices:

- (i) When raising a swung tool from the ground, one hand is placed at the rear of the handle, the other just behind the blade. As the tool is swung downwards the forward hand slides back along the handle. The swinging force should come from the strong leg and back muscles. To swing the tool using only the arm and shoulder muscles is fatiguing and inefficient.
- (ii) When digging with a spade or fork the operator presses the blade into the ground with his foot. Ideally the operator should wear stout shoes or boots for this but a block of wood can be fitted to the top of the blade to make the operation more comfortable (see page 1.18) To throw the excavated material the operator slides one hand down to the base of the handle. For maximum effectiveness in throwing the material the main thrust should come from the strong back and leg muscles.



CROSS SECTION A-A

ELEVATION B-B

DAY :	1	2	3	4	5	6	7	8	9	10	11	12	13
EXCAVATION	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2	
HAULAGE		A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2

SCHEDULE OF EXCAVATION & HAULAGE

FIGURE 4.2: BENCH METHOD OF EXCAVATION WORKING AT ALTERNATE ENDS

4. EARTH AND GRAVEL EXCAVATION

- (iii) The crowbar is driven vertically into the ground with both hands and then used as a lever to break out the material. In India two/three man crowbars 1800 mm long, 50 mm diameter, weighing 20-25 kg have been used effectively.
- (iv) With the exception of the crowbar, the operation of these tools is 'handed' (i.e. the two hands perform different functions). Operators should be taught to work both left and right handed as this makes the most efficient use of their body strength.

Where material can be worked by 'excavate and load' tools, without the need for crowbars or pickaxes, it is more efficient to combine the two operations so as to eliminate double handling. When it is not possible to combine the excavation and loading operations, because of difficult material or topographical conditions (e.g. on steep slopes), the excavators and loaders should work on separate sections so that they do not interfere with one another. Figure 4.2 illustrates the application of this principle to the excavation of a passing place on a mountain road.

The height to which material has to be loaded has a major effect on the productivity of the operation. Some hauling containers (e.g. headbasket) have a very low loading height. For others (e.g. wheelbarrows, tractor-trailers) measures to reduce the loading height are desirable and, where possible, the containers should be loaded from above. This can be achieved by benching the excavation site.

PLOUGHS

Design

General

The design of ploughs for earthwork excavation in road construction is different from that for agricultural work:

- (i) In road construction the earth to be loosened is often much harder than farmland soil, which is worked regularly.
- (ii) In agricultural work the functions of ploughing are to loosen and invert the soil. The latter function is usually unnecessary in road construction and wastes energy.
- (iii) In agricultural work only limited ploughing depth is required. In road construction it is usually desirable to obtain the maximum possible depth of penetration.

The above suggests the use of some form of tine plough (or ripper) for road construction since these do not invert the soil and allow maximum depth of penetration. However, for materials such as wet cohesive soils which do not break out easily mouldboard ploughs are useful since they cut the material into convenient strips.

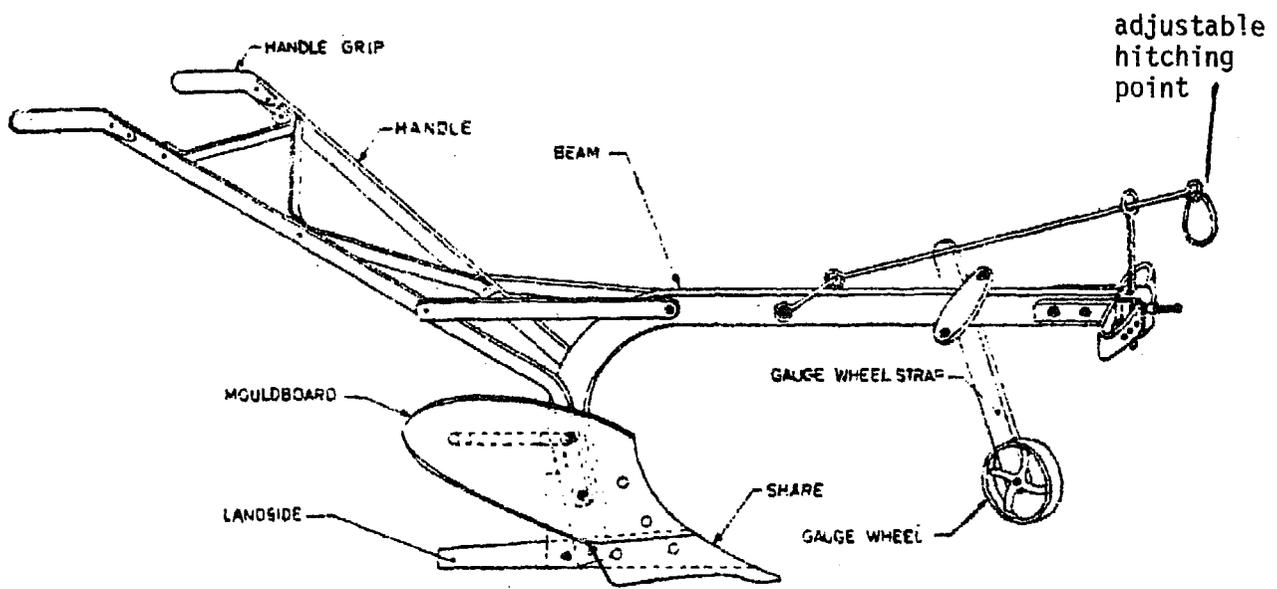


FIGURE 4.3: NOMENCLATURE OF MOULDBOARD PLOUGH (INDIAN STANDARD)

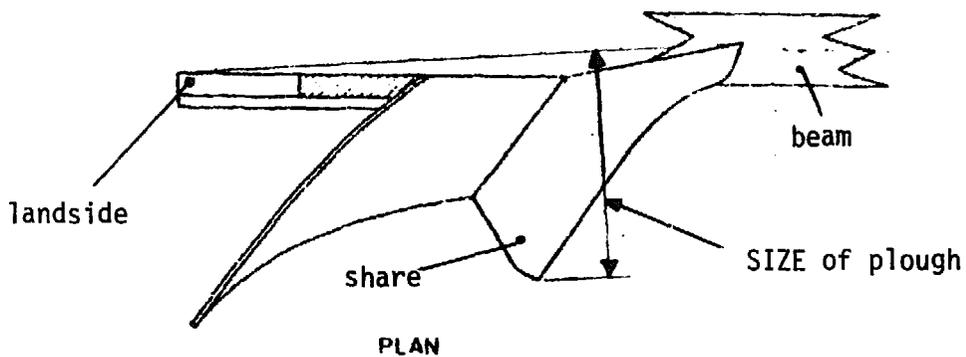


FIGURE 4.4: 'SIZE' OF PLOUGH

ANIMAL-DRAWN MOULDBOARD PLOUGH

Design

Figure 4.3 illustrates the type of animal-drawn mouldboard plough recommended for use in road construction. It has the following features:

Short beam with a hitching point to which the animal(s) are attached. (The methods of attaching them to the plough are covered in TECHNICAL INFORMATION NOTE TN6: SOURCES OF POWER) The hitching point is adjustable vertically and laterally relative to the beam.

Gauge wheel which is adjustable vertically relative to the beam.

The adjustable hitching point and gauge wheel are necessary to allow efficient ploughing of a consistent depth.

The 'size' of the plough, defined as the share width (Figure 4.4) is the major factor determining the draught effort in a given soil. A 'size' of 250 mm is suitable for a pair of medium sized oxen.

The gauge wheel should have a minimum diameter of 150 mm, and a minimum width of 50 mm. For muddy or stony conditions a skid is preferable to a wheel.

Figures 4.3 and 4.5 illustrate two methods of providing the horizontal and vertical adjustment of the hitching point.

The horizontal length of the beam should be about 1200 mm.

The handles should be 900-1100 mm above ground level and adjustable to suit different sizes of operator. The handle grips should be 550-650 mm apart.

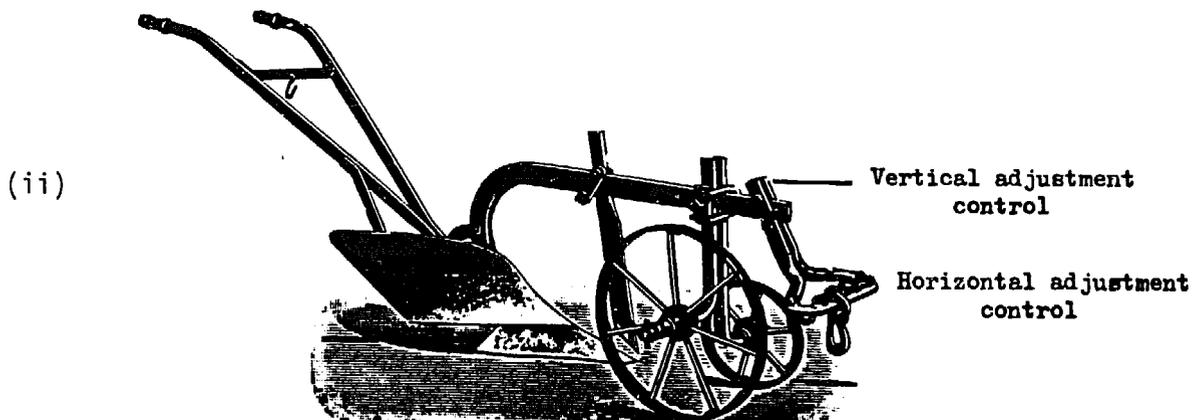
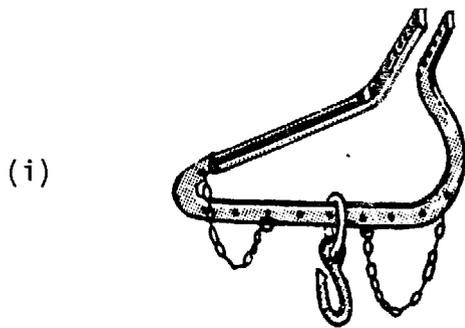


FIGURE 4.5: ADJUSTABLE HITCH POINT

(These two drawings illustrate the principle. They need to be consolidated into a single enlarged drawing of the hitch in (ii)).

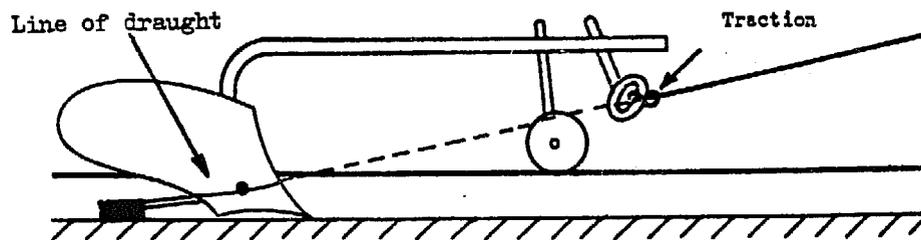


FIGURE 4.6: CORRECT SETTING OF MOULD BOARD PLOUGH

4. EARTH AND GRAVEL EXCAVATION

Materials: Beam - forged steel, mild steel hollow section, or seasoned hardwood.

Share - grey cast iron or high carbon steel heat treated to 39-48 HRC at the cutting edge (see TN3)

Other components - grey cast iron or mild steel.

Operation: (See Page 4.31 for general principles of operation)

The plough is correctly set (see Figure 4.6) when the line of draught from the yoke, the hitching point, and the centre of resistance to forward movement are in a straight line. (The centre of resistance is approximately in the centre of the line joining the mouldboard and the share.) The gauge wheel should be touching the unploughed land, while the tip of the share and the heel of the landside touch the furrow bottom. The basic setting procedure is as follows:

- (i) Set gauge wheel to give the desired ploughing depth. The higher the ground wheel the greater the ploughing depth.
- (ii) Adjust the hitching point vertically to give the correct plough setting (illustrated in Figure 4.6).
- (iii) Adjust hitching point laterally to give desired ploughing width.

4. EARTH AND GRAVEL EXCAVATION

- Suppliers*
- DANDEKAR Bros. (Engineers & Founders)
 - COSSUL & Co. Pvt. Ltd.
 - SISCOMA
 - SOCIETE DES FORGES TROPICALES
 - UBUNGO FARM IMPLEMENTS MANUFACTURING Co. Ltd.
 - DANISHMAND & Co.
 - NEW VIJA INDUSTRIES Ltd.
 - MASSEY FERGUSON
 - GEBRÜDER EBERHARDT
 - PROJECT EQUIPMENT Ltd.
 - ETS TECHINE

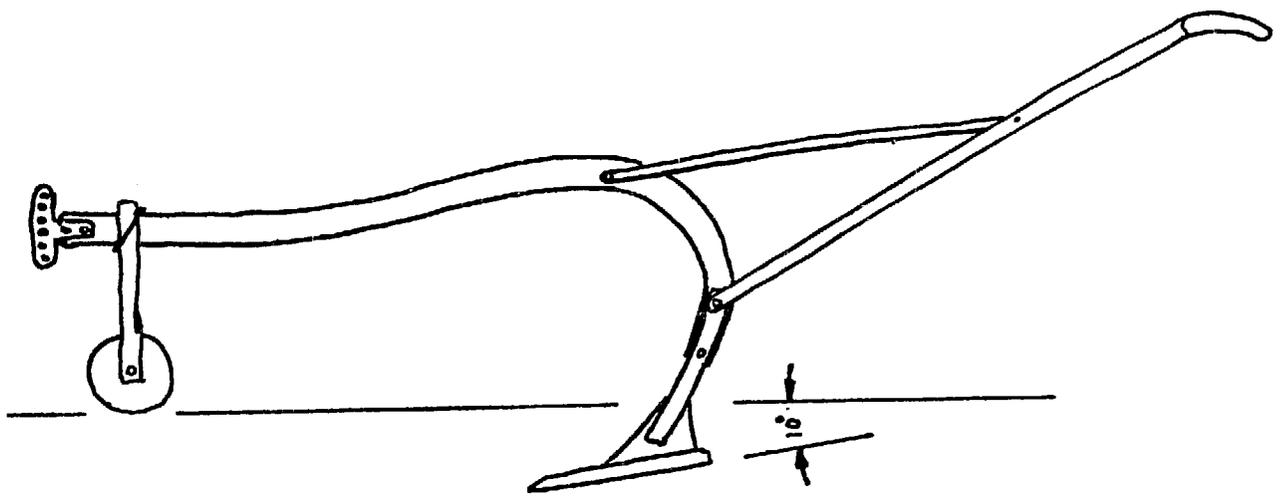


FIGURE 4.7: SHORT BEAM TINE PLOUGH

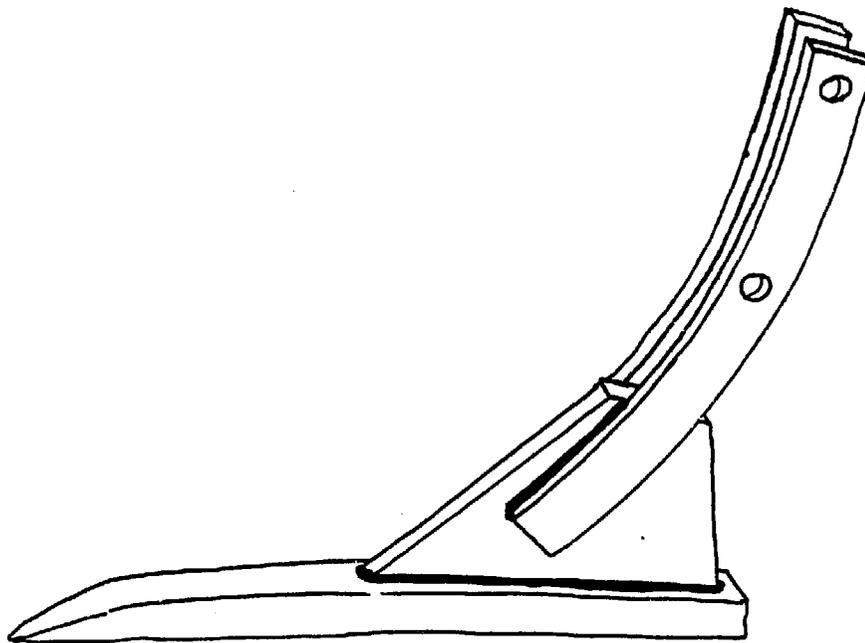


FIGURE 4.8: DETAIL OF TINE AND METHOD OF CLAMPING TO BEAM

ANIMAL-DRAWN TINE PLOUGH

Design: The basic requirements are the same as for the mouldboard plough - short beam, adjustable gauge wheel, and vertically adjustable hitching point (lateral adjustment of the hitching point is not necessary). A single tine is attached to the rear of the beam with a small rake angle to give low draught and good penetration (Figure 4.7).

The tine should be 3-400 mm long. Figure 4.8 shows the shape of the tine and a convenient method of attaching it to the beam.

Materials: Generally as for mouldboard plough.

Tine - Medium carbon steel hardened and tempered to 45-50 HRC (see TN3). A standard tractor chisel plough tine may be used.

Operation: (See Page 4.31 for general principles)

Ground conditions and setting procedure generally as for animal-drawn mouldboard plough, except that there is no lateral adjustment of the hitching point. Since the tine plough does not invert the soil there is more freedom in the method of working than with the mouldboard plough. The major objective should be to minimise the non-productive time consumed turning and walking between successive cuts. Adjacent cuts should be consistently spaced according to the width of material broken out in a single run.

Suppliers: N/A.

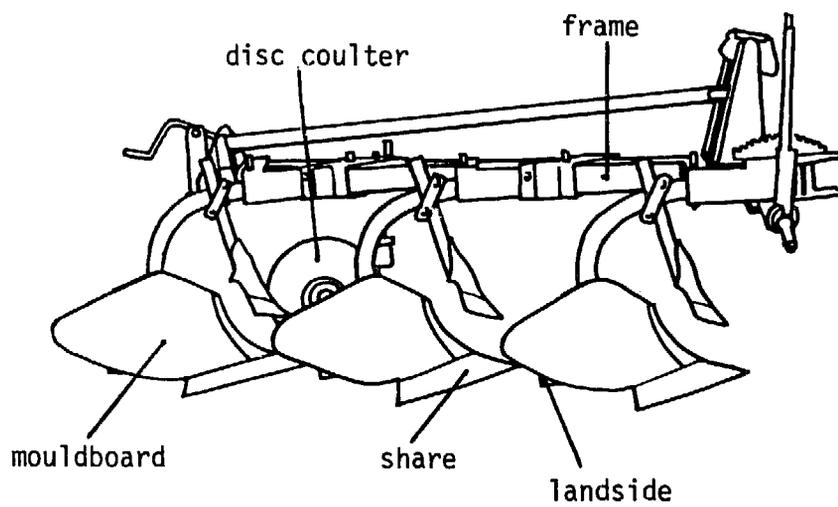


FIGURE 4.9: THREE-FURROW MOULDBOARD PLOUGH

TRACTOR MOUNTED MOULDBOARD PLOUGH

Design: There are many different types of mouldboard plough used in agriculture. The type most suitable for labour-based construction is a very basic three-point linkage mounted plough without depth wheel. Two or three furrow ploughs are likely to be most suitable, depending upon the size of tractor and ground conditions. Ploughs are now available with adjustable furrow width which can give maximum output in different ground conditions.

The main components of the plough are:

Frame which is attached to the tractor.

Share which penetrates and undercuts the soil. The main wearing parts of the share are the tip and cutting edge. These should be replaceable.

Coulter which makes the vertical cut of the furrow.

Mouldboard which inverts the furrow. The leading edge, the shin, should be replaceable. There are different types of mouldboard. The most useful for excavation work are the semi-digger and digger types which allow the greatest depth of penetration and break up the furrow slice.

Landside which presses against the furrow wall.

Operation: (see Page 3.31 for general principles of operation).

When ploughing across a slope, for safety reasons the ground should always be turned down the slope. With the simple type of implement described above, this can only be done in one direction, and consequently productivity is low. Reversible ploughs, which allow ground to be turned down the slope in both ploughing directions, are available but are expensive.

Correct setting of the plough is important, but is a relatively complex, skilled operation beyond the scope of this Guide. The availability of skilled operators is essential to the successful use of tractor-mounted mouldboard ploughs.

Suppliers: Mouldboard ploughs are manufactured by a large number of companies in different parts of the world. The most likely source of supply is through local agricultural equipment manufacturers or distributors.

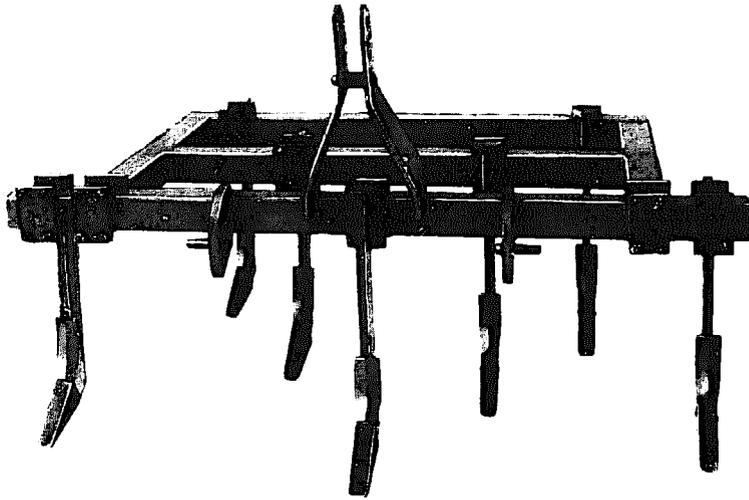


FIGURE 4.10: CHISEL PLOUGH

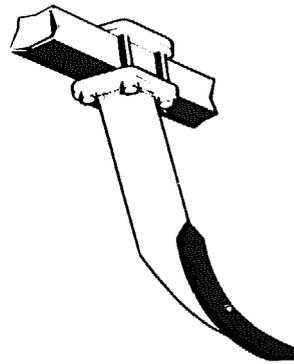
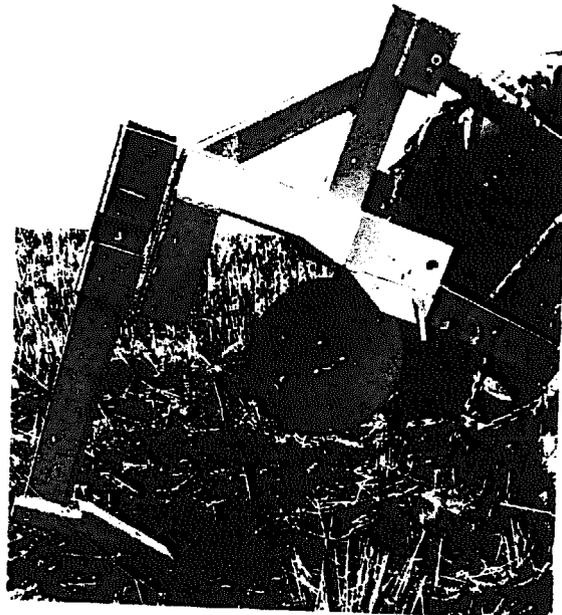


FIGURE 4.11: CHISEL TINE



TRACTOR-MOUNTED TINE PLOUGHS

Design: The two most useful types of tine plough are the chisel and the sub-soiler. Both types have a frame which is mounted on the tractor three-point linkage. A chisel plough has several rigid tines mounted across the frame and penetrates to a depth of up to 300 mm. A subsoiler has a single (for tractors below 50 hp) large tine which penetrates to a depth of about 600 mm.

Figure 4.10 illustrates a typical three point linkage mounted chisel plough without the depth wheel. There are variations in tine design but generally the lower section has a shallow rake angle to give good penetration, while the upper leg is at a much steeper angle (Figure 4.11). The tip is usually replaceable. In some designs the tine mounting incorporates a shear pin to prevent breakage of the tine itself. For tractors below 50 hp 5-7 tines should be fitted.

Figure 4.12 illustrates a typical subsoiler. The tip of the tine is replaceable.

Operation: (See Page 4.31 for general principles of operation)

Suppliers: Chisel Plough

TOWSE OF TIVERTON Ltd.
BROWNS AGRICULTURAL MACHINERY Co. Ltd.
INTERNATIONAL HARVESTER Co. of G.B.
RANSOMES SIMS & JEFFRIES Ltd.
MASSEY FERGUSON (U.K.) Ltd.

Subsoilers

MASSEY FERGUSON (U.S.A.) Ltd.
MASSEY FERGUSON (Mexico)
MASSEY FERGUSON (France)
MASSEY FERGUSON (India)

4. EARTH AND GRAVEL EXCAVATION

COUSINS of AMNETH

W.J. COOPER & SONS Ltd.

RANSOMES SIMS & JEFFRIES

BROWNS AGRICULTURAL MACHINERY Co. Ltd.

PLOUGHS

General

Operation

To maximise the productivity of ploughs the site should be organised to ensure:

- long ploughing runs
- adequate space for turning at the end of the run
- that it is free of obstructions.

With tine ploughs it may be necessary to plough the area more than once, repeat operations being carried out at an angle to the original direction, to produce the maximum loosening effect.

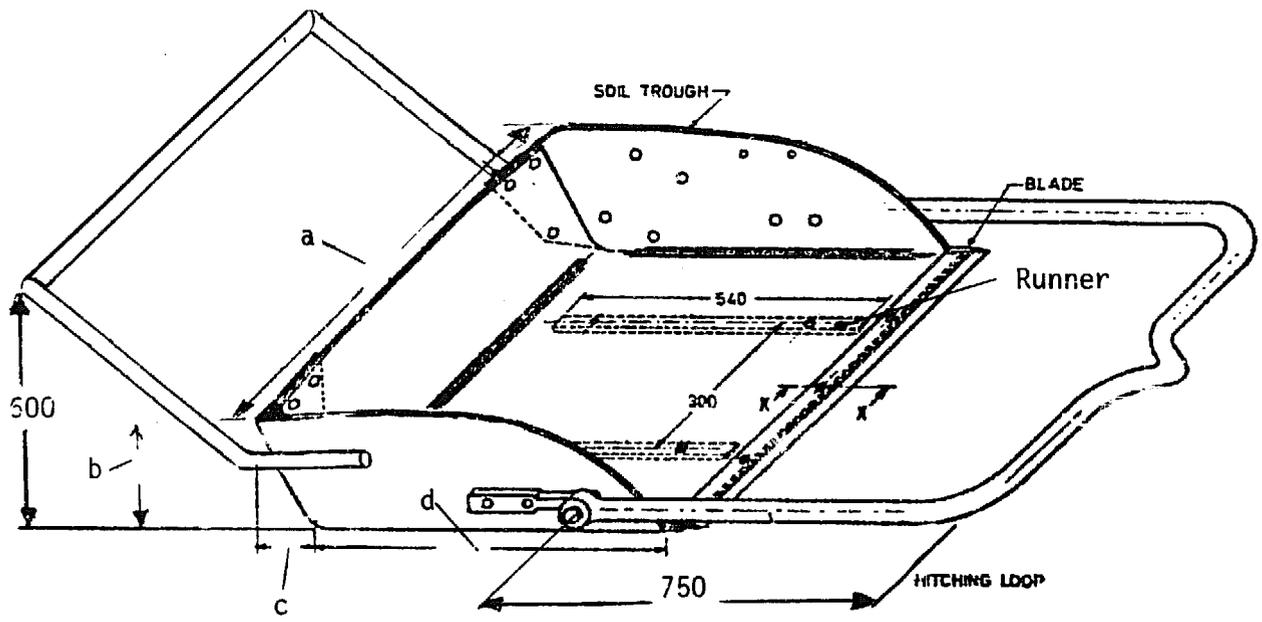


FIGURE 4.13

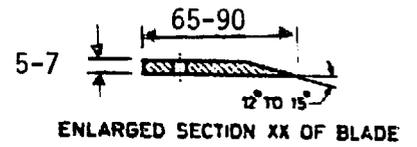
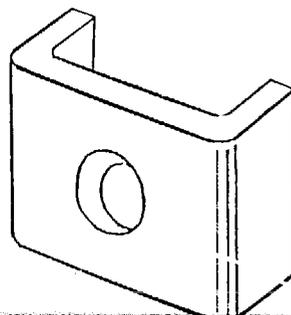


FIGURE 4.14

FIGURE 4.15



ANIMAL-DRAWN EARTH SCOOP

Design: The size of trough is dependent upon the number and strength of animals used to pull it. Table 4.3 gives dimensions for troughs with a loaded capacity of 100-120 kg which can be pulled by two medium sized bullocks or one strong buffalo.

TABLE 4.3: TROUGH DIMENSIONS (mm)

	Dimensions: see Figure 4.14			
	a	b	c	d
Type 1 - Figure 4.14: small corner radii	600	200	95	600
Type 2 - Figure 4.15: large corner radii	730	280	150	500

Type 1 is made by cutting, folding and rivetting or welding the sheet steel. Type 2 is made by forming a single sheet of steel to shape.

The leading edge of the trough should be fitted with a replaceable blade. The base should be fitted with two replaceable runners to prevent wear of the trough itself.

The hitching loop is pivoted on the soil trough. The position of the pivot is critical in ensuring ease of filling, hauling and unloading. Figure 4.13 gives the recommended position and shows one method of forming the pivot. Another method is to weld a component such as that shown in Figure 4.16 onto the side of the trough. The end of the hitching loop is bent to fit into the hole. The methods of harnessing and attaching the animal(s) to the earth scoop are covered in TECHNICAL INFORMATION NOTE TN6: SOURCES OF POWER.

4. EARTH AND GRAVEL EXCAVATION

Materials : Scoop - mild steel sheet 3mm minimum thickness
Blade - high carbon steel (TN1)
Runners - mild steel (or vehicle leaf spring)
Hitching loop - mild steel bar 16mm minimum diameter
Handle - mild steel tube or seasoned hardwood

Manufacture : Blade to be hardened to 39-48 HRC (see TN3)

Operation : The ground should be loosened by ploughing prior to excavation by the scoop. To excavate, the operator raises the handle of the scoop and the blade cuts into the ground, picking up soil in the trough. The position of the handle controls the depth of cut, which should not be too deep since this may cause the scoop to tip over or bring the animals to a halt. The operator brings the loaded scoop into the hauling position by pressing down on the handle. For safety reasons the operator must take care not to have any part of his body directly above the handle. To unload, the operator raises the handle and tips the material out of the trough.

Suppliers - DANDEKAR Bros. (Engineers & Founders)
COSSUL & Co. Pvt. Ltd.
RAJASTHAN STATE AGRO-INDUSTRIES CORPORATION Ltd.

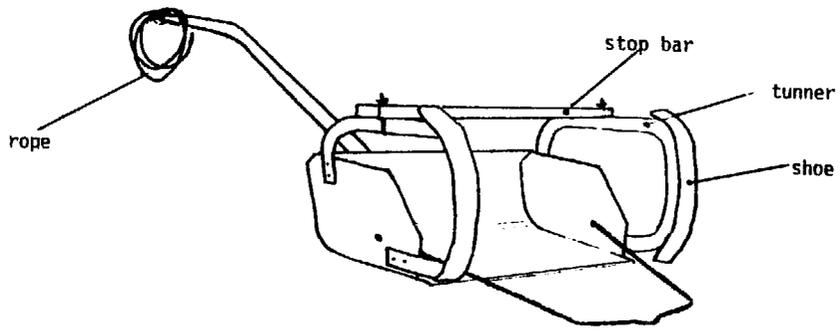


FIGURE 4.16: FRESNO SCRAPER

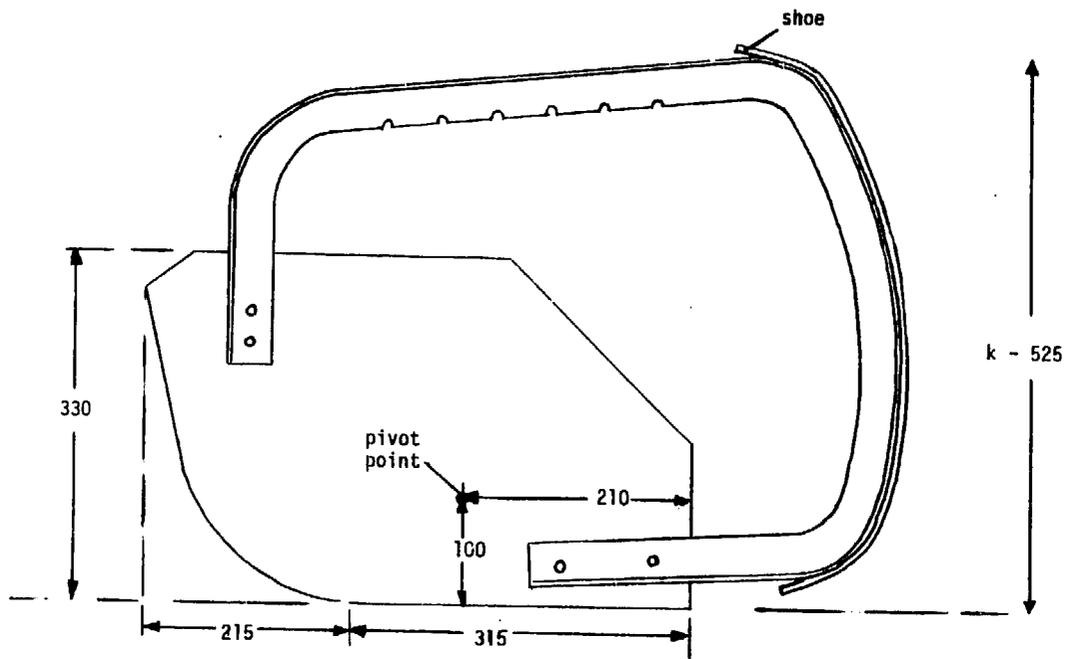


FIGURE 4.17: SIDE OF FRESNO SCRAPER TROUGH AND RUNNER (mm)

4. EARTH AND GRAVEL EXCAVATION

ANIMAL-DRAWN FRESNO SCRAPER

Design: Generally as for earth scoop with the addition of a runner and detachable shoe on each side of the trough. The runners are joined by an adjustable stop bar and a long, central handle is fitted. The runners are welded, bolted or rivetted to the trough. The shoes are attached by counter-sunk screws. The stop bar is clamped by cranked or U-bolts to the notches cut in the runners. The handle should be braced where it attaches to the trough. A length of rope is tied to the loop formed at the end of the handle.

Material: Generally as for earth scoop.
Runner - mild steel angle, minimum dimensions 45x45x6 mm
Shoe - mild steel or vehicle leaf spring
Handle - mild steel 15x50 mm.

Manufacture: Generally as for earth scoop. Handle is hand forged to shape.

Operation: Generally as for earth scoop, but the fresno scraper allows a controlled rate of spreading, giving an even layer of material for subsequent compaction. To unload, the handle is raised so that the trough tips over to stand on the shoes. The position of the stop bar controls the orientation of the trough and hence the rate of discharge (the further forward the stop bar, the slower the rate of discharge). The scraper can be returned to the excavation area running on the shoes. During unloading the operator holds on to the rope attached to the handle. He pulls on this rope to bring the trough back into the excavating position.

Suppliers: N/A.

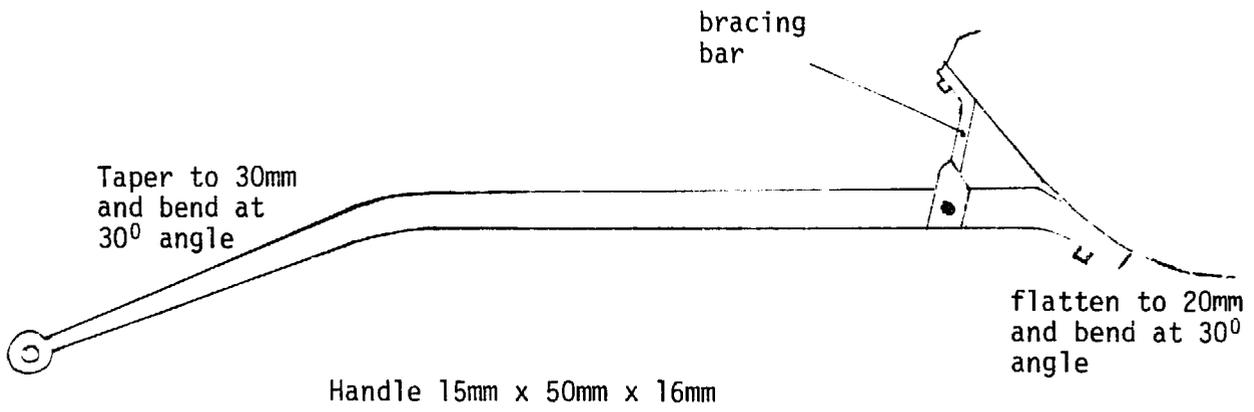


FIGURE 4.18: FRESNO SCRAPER HANDLE

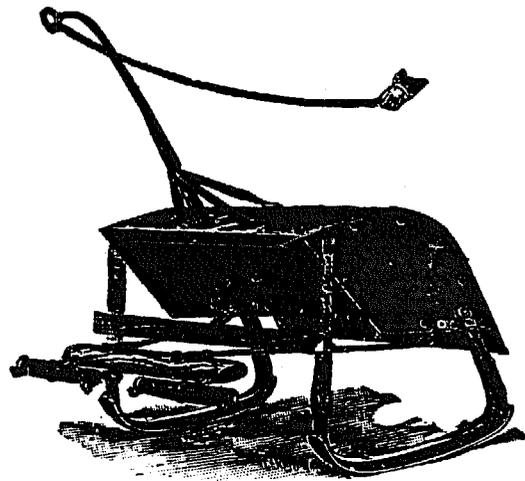


FIGURE 4.19: FRESNO SCRAPER IN UNLOADING POSITION

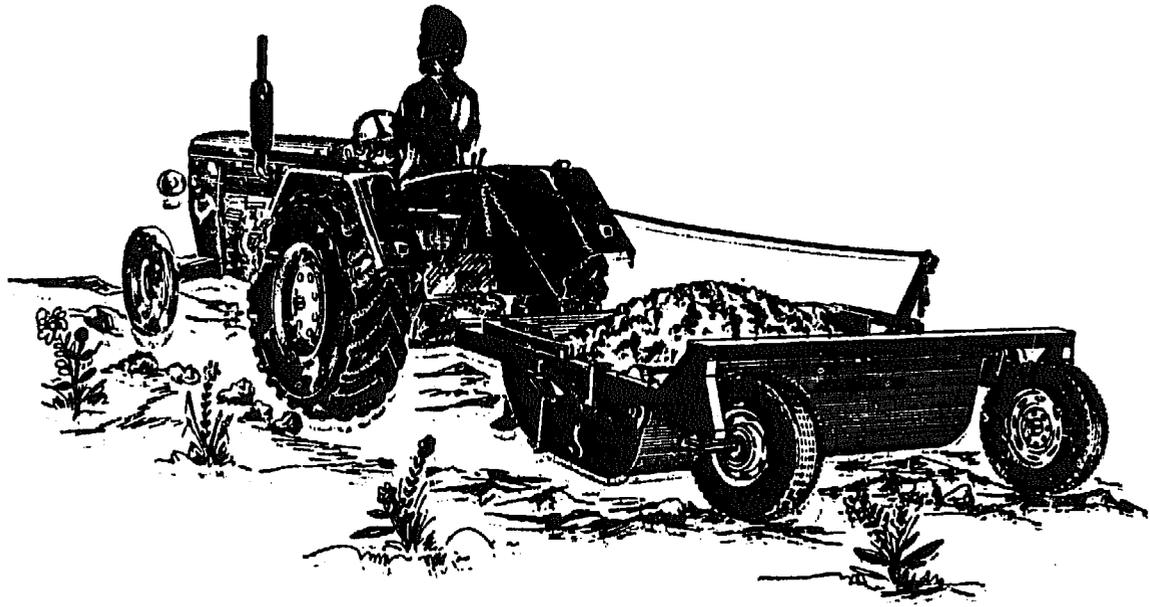


FIGURE 4.20: INDIAN EARTH SCRAPER

TRACTOR-DRAWN EARTH SCRAPER

Design: The scrapers considered here are towed behind the tractor attached to the three-point linkage with which the bucket is raised and lowered hydraulically. The discharging mechanism is mechanically actuated by the driver so no additional hydraulic capacity is required on the tractor.

A bucket capacity of about 1.5 m³ is suitable for a 50 hp tractor. The bucket should be fitted with a replaceable hardened steel blade. The design shown in Figure 4.20 has a gate in front of the bucket which ensures retention of the load during hauling.

Tyres fitted with inner tubes should be specified for road construction work.

Manufacture: A tractor-towed earth scraper can be produced in a well-equipped workshop.

Operation: The ground should be loosened by ploughing prior to excavation by the scraper. The bucket is lowered into the excavating position, and as the tractor moves forward the bucket picks up the soil. When the bucket is full it is raised into the hauling position. A straight loading area about 30 m long is required to give the scraper space to manoeuvre and pick up a full load of soil. These scrapers allow a controlled rate of spread giving an even layer of material. The unloading area should be arranged to give sufficient space for the tractor and towed scraper to turn and manoeuvre.

4. EARTH AND GRAVEL EXCAVATION

- Suppliers*
- MOHINDER & Co. ALLIED INDUSTRIES

 - MASSEY FERGUSON
(their product has a bucket capacity of 0.6m³, and is fitted with a single castor wheel which gives good manoeuvrability).

INTRODUCTION

This section discusses implements for the removal of rock deposits from within the road formation, and the excavation of rock for the production of masonry rubble and aggregates. Drilling equipment for rock blasting is highly specialised and expensive and is not considered here.

Information on the following implements is given:

- pickaxe*
- crowbar*
- sledge hammer*
- chisel and tongs
- plug and feathers
- hydraulic breaker
- electropneumatic breaker and drill
- petrol engined breaker and drill

The technical specifications of those marked with an asterisk * are given in Section 1: HANDTOOLS. This section discusses only the application and operation of these implements in rock excavation.

APPLICATION

The main factor affecting the type of tools and equipment used for rock excavation is the properties of the material itself. The difficulty involved in excavating rock cannot be assessed only in terms of a single property, although its hardness is a major factor; other important considerations are the degree of cementation, weathering and jointing. Some rocks are sufficiently soft to be excavated with a pickaxe (e.g. chalk, coral). Others may be inherently hard, but sufficiently weathered or jointed to be broken up with a crowbar or hammer and chisel.

HANDTOOLS

There is a simple method of using the sledge hammer for clearing isolated rocks from the road formation. A fire is lit on top of the rock and water thrown on the hot ashes. This tends to fracture the rock which can then be broken easily with a sledge hammer.

Sledge hammer driven chisels are normally used on surfaces too rugged to be broken up with a pickaxe, or to puncture the tough outer crust before using a pickaxe. The plug and feathers technique is an extension of the stonemason's practice of driving wedges between pairs of split steel linings (or feathers) inserted into holes previously drilled along the projected line of fracture. Crowbars are normally used to level-out sections of rock that are split. They may also be 'jumped', raised and thrust, against the rock face to bore a hole for subsequent blasting or splitting with a plug and feathers.

MACHINE BREAKERS AND DRILLS

Some rocks may be so hard or cemented as to require machine powered breaking or drilling and blasting. Machine breakers may also be necessary if large amounts must be excavated quickly or to reduce the largest boulders to a size suitable for handtools or removal by hand. Machine drills are required if the plug and feather technique is to be used for rock splitting.

Hydraulic, electropneumatic and petrol engined breakers and drills can be transported in a pick-up and thus are more portable than the traditional pneumatic tools driven from separate diesel engine powered air compressors. Petrol engined breakers and drills, which are completely self-contained and require no external power supply, are the most portable.

TOOLS AND EQUIPMENT

PICKAXE

Operation : The general principles of operation of pickaxes are covered in Section 4: EARTH AND GRAVEL EXCAVATION

CROWBAR

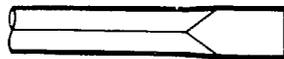
Operation : The general principles of operation of crowbars are covered in Section 4: EARTH AND GRAVEL EXCAVATION. For rock boring heavy weight crowbars of some 20 kg are sometimes used with a team of three men: two jump the bar and the third clears rock fragments from the hole with water and a thin wire hook. There is some evidence that chisel points are more efficient than moil points. (See Figure 5.2)

SLEDGEHAMMER

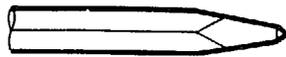
Operation : The correct method of using a sledgehammer is the same as for the axe and brush hook illustrated - Figure 3.6. The upper hand positions the sledge hammer and slides down guiding the handle during the blow until the hands are together as the rock is struck. Workers should be encouraged to use both a right and left hand grip since this makes work easy and efficient. For maximum productivity the height of the surface on which breaking is taking place (i.e. the level at which the hammer face meets the rock should be some 500-600mm above the level on which workers are standing.



FIGURE 5.1: CHISEL AND TONGS



Chisel



Moil

FIGURE 5.2: CHISEL AND MOIL POINTS

CHISEL AND TONGS

Design : Sledge hammer driven chisels are normally 25-40mm square or octagonal section steel bars 250-600mm long. The trade name for the square section chisel is a 'road wedge' and of the octagonal section chisel a 'concrete point'. They can be made with either chisel (Figure 5.2(a) or moil (Figure 5.2(b)) points. Tongs are about 600mm long with a grip forged to fit the section of the chisel being used.

Material : Chisel - high carbon alloy steel or high carbon steel (TNI).
Tongs - mild steel.

Manufacture : Chisels must be forged in one piece and heat treated as appropriate (TNI). The two arms of the tongs are normally forged and then rivetted together.

Operation : One man holds the chisel in the tongs and removes rock fragments from the hole by washing with water or with a thin wire hook, while 1, 2 or 3 men strike the chisel in turn with sledge hammers. The man with the tongs should turn the chisel between blows so that it does not jam in the hole.

Suppliers

- BURGON & BALL Ltd.
- JAMES NEILL (SHEFFIELD) Ltd.
- C.I. JENKINSON & SON Ltd.
- SAMUEL SWIFT Ltd.

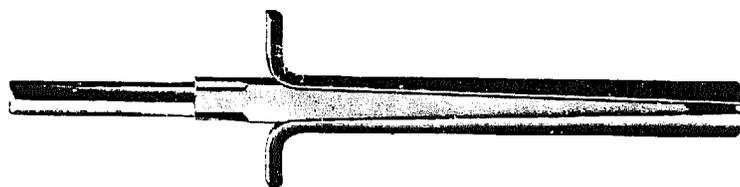


FIGURE 5.3: PLUG AND FEATHERS

PLUG AND FEATHERS

Design : Figure 5.3 illustrates a plug and feathers set. The plug can be driven by sledge hammer or machine rock breakers. The machine sets are normal accessories that are offered in the following range of standard sizes:

PLUG			FEATHERS	
Shank Hexagon size (mm)	Length (mm)	Weight (kg)	Length (mm)	Weight (kg)
28 x 152	610	3.9	305	1.4
" "	760	5.0		
			380	1.6
32 x 152	610	4.4		
" "	760	5.6	460	1.8

Materials : High carbon alloy steel or high carbon steel (TN1).

Manufacture : Must be forged and heat treated as appropriate (TN1).

Operation : A hole should first be drilled about 48mm diameter, the normal limits being 44-51mm, to a depth about 50mm longer than the feathers available. Spacing depends on the size of block, type of material etc.; if an excessive spacing is used, individual fragments may be removed by each wedge leaving the bulk undisturbed. It should in any case be less than the burden; possibly 375-500mm. The steel linings (feathers) are placed inside the hole and the wedge (plug) inserted between them and driven home splitting the rock.

Suppliers

- HOLMAN BROTHERS Ltd.
- PADLEY & VENABLES Ltd.
- STANDALL ENGINEERING Ltd.

MACHINE BREAKING AND DRILLING

Design : General

Machine powered equipment for rock excavation is of two types:

- breakers using a reciprocating chisel bit; and
- hole drills, using a rotating bit which may reciprocate as well.

Some machines can perform both of these functions.

Hydraulic breakers

The hydraulic pressure can be generated by diesel/petrol/propane driven power-packs with equivalent engine ratings of 6-16 BHP. Alternatively, the auxiliary hydraulic drives on some tractors can be used as the power source. Hydraulic breakers are reputedly cheaper to purchase and run than pneumatic tools and it is claimed that they offer greater productivity and less operator fatigue.

Electropneumatic breaker and drill

These have an electropneumatic impact mechanism and are driven by an externally supplied 110 or 240 volts AC supply.

Petrol engined breaker and drill

It is possible to purchase a combined breaker and drill with the ability to switch from one function to the other, or separate breakers and drills. The engine is integral with the breaker or drill so no external power source is required.

Table 5.1 summarizes the characteristics of a number of different makes of breaker and drill.

TABLE 5.1: TECHNICAL CHARACTERISTICS OF MACHINE BREAKERS AND DRILLS

Make and Model	Type	Standard Hexagonal Chuck size (mm)	Weight (kg)	Blow frequency per minute	Power Supply
MACDONALD CTL Breaker	Pneumatic	28/32	38	-	Require auxiliary compressed air supply. 1 breaker unit per 2.8m ³ /min of compressed air.
M303H Drill (RD54)	Pneumatic	22/25	25	-	
WILLIAMS & JAMES Model 240 Breaker	Hydraulic	32	30	1000	Petrol, diesel or propane driven power pack: 16HP Weight 100 kg. Hydraulic flow rate: 15.3 litres per minute at 155 kg/cm ²
RV HYDRATOOLS Breaker	Hydraulic	28	34	1150	Any auxiliary hydraulic supply from a power pack or contractors plant. Hydraulic flow rate: 27-34 litres per minute at 92-112 kg/cm ²
BOSCH Type 11304 Breaker	electro-pneumatic	Standard sizes	27	1060	110V AC supply from mains or power pack. Power Input 1600W

TABLE 5.1 continued

Make and Model	Type	Standard Hexagonal Chuck size (mm)	Weight (kg)	Blow frequency per minute	Power Supply
KANGO 2500 Breaker	electro pneumatic	32	30	1400	110 or 240V AC, 25-60Hz supply from mains or power pack. Power Input 2200W.
950 Hammer drill	electro pneumatic	16-125	11	2000 drilling 2200 Hammering	110 or 240V AC, 25-60Hz supply from mains or power pack. Power Input 900W
PIONJÄR 120 Breaker/ Drill	petrol engine	22	26		Integral 185cc 2-stroke air-cooled petrol engine
130 Breaker	petrol engine	22	24		" " " "
ATLAS COPCO COBRA BBM 47 LA Breaker/ Drill	petrol engine	18-22	25	2100-2600	Integral 125cc 2-stroke air cooled petrol engine

Suppliers : Breaker Bits and Drills

- HOLMAN BROTHERS Ltd.
- OY AIRAM AB
- PADLEY & VENABLES Ltd.
- STANDALL ENGINEERING Ltd.

Pneumatic Breakers and Drills

- JOHN MACDONALD & Co. (P.T.) Ltd.

Hydraulic Breakers

- RV HYDRATOOLS Ltd.
- STANELY POWER TOOLS Ltd.
- WILLIAM & JAMES (ENGINEERING) Ltd.

Electropneumatic Breakers and Drills

- KANGO ELECTRIC HAMMERS Ltd.
- ROBERT BOSCH Ltd., WATFORD

Petrol Engined Breakers and Drills

- ATLAS COPCO AB

Tractor-mounted Compressors

- OY HYDOR AB
- INTERNATIONAL HARVESTER Co. GREAT BRITAIN Ltd.

Hydraulic Power-Packs

- HYDRAULIC BREAKERS (SCOTLAND) Ltd
- STANELY POWER TOOLS Ltd.

INTRODUCTION

This Section discusses implements for rock crushing to produce masonry, pitching and soiling, and aggregate. The dressing of rock into regular blocks for stronger forms of masonry is a highly specialised activity and is not considered here.

Information on the following implements is given:

- stone breaking hammer*
- sledge hammer*
- mobile crushers

The technical specifications of those marked with an asterisk * are given in Section 1: HANDTOOLS. This section discussed only the application and operation of these implements in rock crushing.

APPLICATION

The main factor affecting the selection of tools and equipment for rock crushing is the product required.

MANUAL

Sledge hammers are normally used for the primary reduction of large pieces of rock into 100-200mm aggregate. Stone breaking hammers are used for the secondary reduction into smaller aggregate sizes where this is feasible.

In general it is difficult for manual methods to satisfy the more stringent aggregate requirements laid down for surface dressing, asphaltic concrete etc. While there is some evidence that it is uneconomic to employ labour equipped with handtools to produce aggregate of less than about 20mm size this should be established locally. In many parts of the Indian sub-continent there are no significant rock deposits. All aggregate is produced by crushing and sieving over-burnt bricks. These operations are done entirely by hand.

MACHINE

Machine crushers are used to produce aggregate of precise size or grading less than about 40mm, or where large quantities of these or larger size rock are required rapidly.

TOOLS AND EQUIPMENT

STONE BREAKING HAMMER

Operation : Experimental evidence shows that for maximum efficiency particular care is needed in selecting the correct weight of hammer for the size of aggregate required [1] and the type of rock being worked. The *minimum* weight possible in the range 0.5 - 2.0kg should be determined by trial otherwise productivity will be greatly reduced. Also there is little to be gained from equipping workers with a solid anvil upon which to break the stone. Rubber gloves, made from scrap materials, to protect the fingers of the hand holding the stone and a shallow metal ring to restrain the broken fragments are advantageous. Workers should be encouraged to use the hammer with their left and right hands alternatively since this makes work easier and more efficient. It is important that the correct length handle (Figure 1.48) is used. The long slim handle, coupled with the fairly light weight of the hammer allows a very fast blow to be delivered. This rapid striking action has the advantage of producing a considerable impact which is why it is unnecessary to support rigidly the individual pieces of stone being struck.

SLEDGE HAMMER

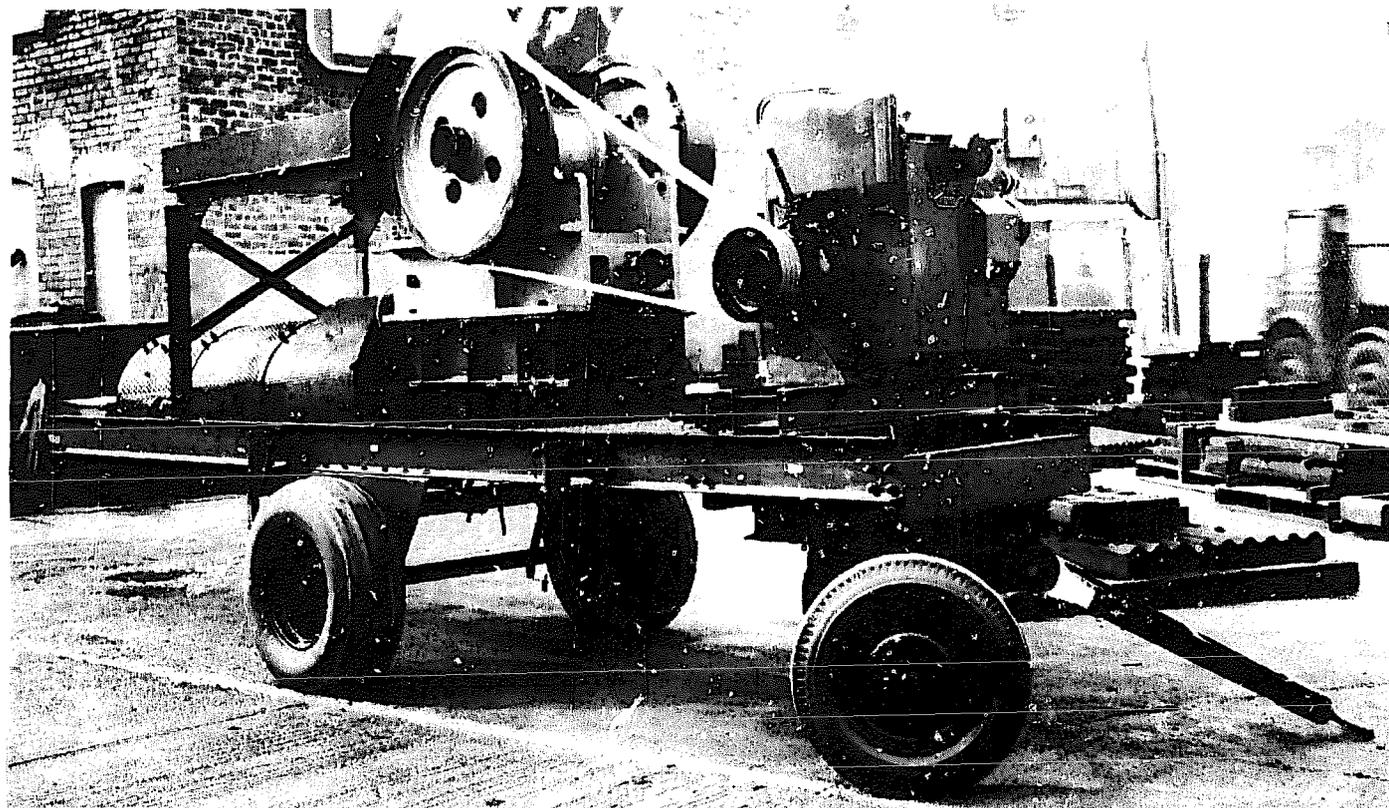
Operation : See page 5.5 for general principles of operation. The weight of sledgehammer giving greatest productivity will vary with the size of rock required and the type being broken and is best determined by trial. It is likely to be in the range 2 - 5kg.

MOBILE CRUSHERS

Design : Three distinct types of machine are used in equipment-intensive rock crushing. The *primary crusher* is the machine which undertakes the initial breakdown of the rock. The *screens* are simply vibrating sheets, or rotating barrels perforated with different sized holes which allow the various aggregates to be separated. The *secondary crusher*, also called *reduction crusher* or *granulator*, is a similar machine to that used for primary crushing except that it is set to produce a particular size material with as little 'waste' as possible.

In the majority of cases it is necessary to determine the size of the crusher by the size of the largest feed material rather than by capacity. The 'size' of a crusher is usually stated to be that of the rectangular feed leading to the crushing chamber. The maximum size of material fed to the crusher should be about 80 per cent of the minimum feed dimension or else frequent jamming of the machine is likely. Thus in a quarry where the stone is to be loaded by hand the crusher(s) can be quite small, say a maximum of 440 x 610mm (i.e. a feed lump size of 350mm) because of the limitation on the size of rock that can be fed. Depending on the size of aggregate produced this will give an output of between 10-30 tonne/hr (7-20m³/hr.)

The design of the actual rock handling and crushing mechanisms is a highly complex subject and there is a considerable choice of types available. However, for fully mobile plant appropriate to labour-based road construction only the most basic machines are suitable.



Crusher* size (mm)	Aggregate size (mm)	Output (tonne/hr)	Weight (tonne)
400x230	-	6	5
400x280	100	8-10	7
	300	25-30	
500x350	150	18-22	9
610x430 m	200	27-30	11

* Can be converted to 800 x 150 or 810 x 200mm granulators with higher outputs

FIGURE 6.1 : DIESEL POWERED MOBILE CRUSHER

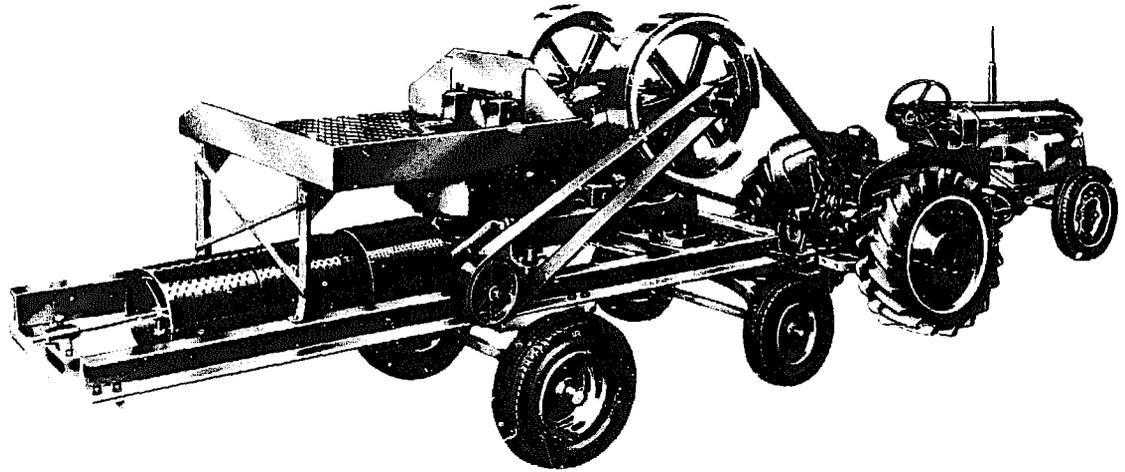
Single-toggle jaw crushers are preferred for both the primary and secondary reduction of rock: these have a reduction ratio of around 7:1. Cone crushers are sometimes used for the second stage crushing particularly if high outputs are required: these have a reduction ratio of around 10:1. For the simpler types of plant, comprising a single crusher, rotary barrel screens are adequate: these have a relatively low capacity, but are very robust.

Mobile plant may comprise a primary crusher and screens, a granulator and screens, or all three items depending on requirements. It is important that pneumatic road tyres are specified rather than simple steel wheels which are only suited to limited 'on-site' movement. Crushers with self-contained petrol or diesel engine power units are obviously more convenient than those requiring an external belt drive or electricity supply.

Figure 6.1 illustrates a typical diesel engine powered mobile crusher, and Figure 6.2 one driven by belt from a tractor power-take off pulley.

- Operation* : Hand loading of crushing equipment has a number of advantages over machine loading. For example :
- clean material, completely free from adherent overburden can be guaranteed provided the men work carefully;
 - correct size of material suitable for the primary crusher can be guaranteed, thereby avoiding delays which otherwise could be caused by jamming;
 - the primary crusher can be very much smaller than would be required in machine loading;
 - no quarry fines will go to the plant, only clean lump stone, therefore no dirt extraction will be necessary.

However, production of material of a manageable size at the quarry face is essential. It is also sometimes difficult to arrange for a crusher to be hand fed with stone at a rate sufficient for efficient operation. This problem can be overcome by (i) stockpiling (ii) use of sufficiently small machine, or (iii) arranging a feed hopper.



Crusher size (mm)	Approximate Output** (tonne/hr)	Weight (tonne)
200x130	4	2
410x230	12	7
510x230	15	10

* can be converted to a granulator : screen sizes to suit requirements.

** 60mm aggregate and under.

FIGURE 6.2 : TRACTOR POWERED CRUSHER**

If a feed hopper is used its capacity should be about twice the capacity of the labour bringing the stone. This allows for delays in transit and assists in keeping the plant evenly fed. The hopper should be designed so as to avoid jamming of the stone. Generally if the end of the hopper near the crusher is square, the tendency is for the stone to move in a turbulent rather than an interlocking manner. The end of the hopper at the loading point should have some accumulation of 'dead' stone on which the dumped material can land. This reduces wear and damage due to impact.

All rock crushing equipment requires regular maintenance if sustained output and acceptable quality aggregate are to result. Wear of the metal parts that do the actual crushing is an inherent problem. Some types of crusher are designed in such a way that adjustments for wear can be made regularly up to the time that complete replacement of the wearing parts is required. With other types it is necessary to build up the worn parts by hard welding fresh material onto the wearing surfaces at regular intervals: this can be required daily if highly abrasive rocks are being crushed, so the necessary maintenance facilities have to be available on site.

- Suppliers*
- MARSHALL, SONS & Co. (MANUFACTURING) Ltd.
 - SAYAJI IRON & ENGINEERING Co.Pvt. Ltd.
 - SHEEPBRIDGE EQUIPMENT Ltd.
 - SVEDALA - ARBRÅ AB
 - W.H. BAXTER Ltd.

6. REFERENCES

- 1 WORLD BANK. Study of the Substitution of Labour and Equipment in Civil Construction. Tech. Memo. 25. *Aggregate Production* June 1976.

INTRODUCTION

This Section discusses implements for the hauling of earth and gravel from borrow pits, and excavated materials from cuttings and other works to fill or waste. The characteristics of draft animals and tractors are covered in TECHNICAL INFORMATION NOTE TN6: SOURCES OF POWER. This Section discusses the attachments used in conjunction with these power sources for hauling.

Information on the following implements is given:

- head basket
- mortar pan
- shoulder pole
- measuring box
- western wheelbarrow
- chinese wheelbarrow
- donkey, pony and mule panniers
- camel panniers
- animal-drawn carts
- animal-drawn earth scoop*
- animal-drawn fresno scraper*
- single-axle tractor and trailer
- four wheeled tractor and trailer
- tractor-towed earth scraper*
- rail cart

The technical specifications and operation of those marked with an asterisk* are given in Section 4: EARTH AND GRAVEL EXCAVATION. This Section discusses only the application of these implements in hauling.

Generally labour-based methods of hauling are only effective up to a maximum of about 5kms: if materials must be hauled further than this then equipment intensive methods will be necessary. Thus in planning the construction of a road by labour-based methods, it is essential to minimise haul distances by careful location both of the road line and borrow pits, and by dumping material from cuttings laterally and obtaining that for embankments from borrow pits rather than trying to 'equalise' cut and fill longitudinally.

APPLICATION

The main factors which affect the types of equipment used for hauling are the haul distance and the condition (gradient, surface, width) of the haul route. Table 7.1 gives guidance on the haul conditions for which different types of equipment are suitable, together with data on payloads. The figures given for haul distance are indicative of the optimum hauling range of a particular implement. However, local conditions (wage rates, implement costs and availability etc) will have an important bearing on the hauling range for which a particular device might be suitable. Similarly, there are several factors (physique of workers, condition and breed of animals etc) which affect the payload of a particular hauling implement; the figures given in the table are indicative of what might be expected.

The major advantage of the *headbasket* and *shoulder pole* is that they are effective in poor haul route conditions. The mortar pan is applicable specifically to the movement of wet materials. The *measuring box* is used in the production of concrete. By moving a specified number of full loads of the different components of concrete their proportions can be correctly measured for mixing. Where route conditions allow, the *wheelbarrow* is the most effective means of employing labour for hauling. Winch assisted haulage can be used on slopes too steep for un-assisted ascent.

The major advantage of *pack-animals* is that they are effective in poor route conditions. Where route conditions allow the most effective means of using animals in hauling is to pull a *cart*. There is little evidence of *single-axle tractors and trailers* being used outside China for labour-based civil construction. However they are potentially very useful, having a similar payload to animal carts but a higher speed.

The major application of *four-wheeled tractors and trailers* is for haul distances beyond the range of human and animal powered devices. They require considerable space for manoeuvring at the loading and unloading sites.

Earth scrapers: Whether animal or tractor powered, can be used where convenient to combine excavation and hauling. Their use requires relatively large open areas of ground.

Experimental studies suggest that *rail carts* offer very high labour productivity. However, because of the time and cost involved in laying the rails they are applicable only to situations where large quantities of material have to be moved along a fixed route.

TABLE 7.1 : CHARACTERISTICS OF HAULING IMPLEMENTS

Implement	Haul Route	Haul Distance (m)	Payload (kg)
Headbasket	Suitable for steep and/or poorly surfaced routes.	0-50	35
Shoulder Pole	Suitable for steep routes but requires reasonable surface.	0-50	35
Mortar Pan	Suitable for steep and/or poorly surfaced routes.	0-50	20
Measuring Box	Suitable for poorly surfaced but not steep routes.	0-50	50 (2 persons)
Western Wheelbarrow	Requires reasonable surface. Can be pushed unassisted up long 12½% slopes.	25-200	120
Chinese Wheelbarrow	Requires reasonable surface. Can be pushed unassisted up long 10% slopes.	50-400	180
Donkey & Mule Panniers	Suitable for steep and/or poorly surfaced routes.	50-300	100-150
Camel Panniers		200-500	400-500
Donkey & Mule Cart	Unsuitable for steep slopes. Requires reasonably smooth and level surfaced route.	100-500	400 (one animal)
Ox-Cart		100-500	1000 (two animals)
Camel Cart		100-500	700 (one animal)
Animal-drawn Earth Scoop/ Fresno Scraper	Unsuitable for steep slopes. Haul route should be free of obstructions.	25-100	100-150
Single-axle Tractor and Trailer	Requires reasonably smooth surfaced route. Slopes should not exceed 10%.	250-1000	1000
Tractor and Trailer	Requires reasonably smooth surfaced route. Slopes should not exceed 10%.	500-5000	4000 (50hp tractor)

TABLE 7.1 : Cont'd

Implement	Haul Route	Haul Distance (m)	Payload (kg)
Tractor-towed Scraper	Slopes should not exceed 10%	200-500	2000
Rail Cart	Unless route is level or downsloping, winch assistance is required.	50-200	1000 (1 person)

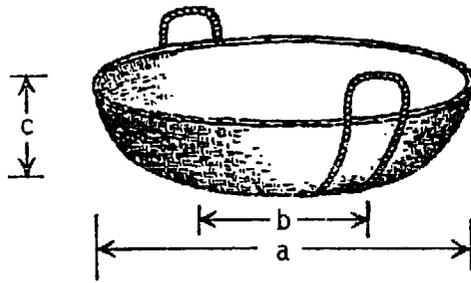


FIGURE 7.1 : INDIAN HEADBASKET

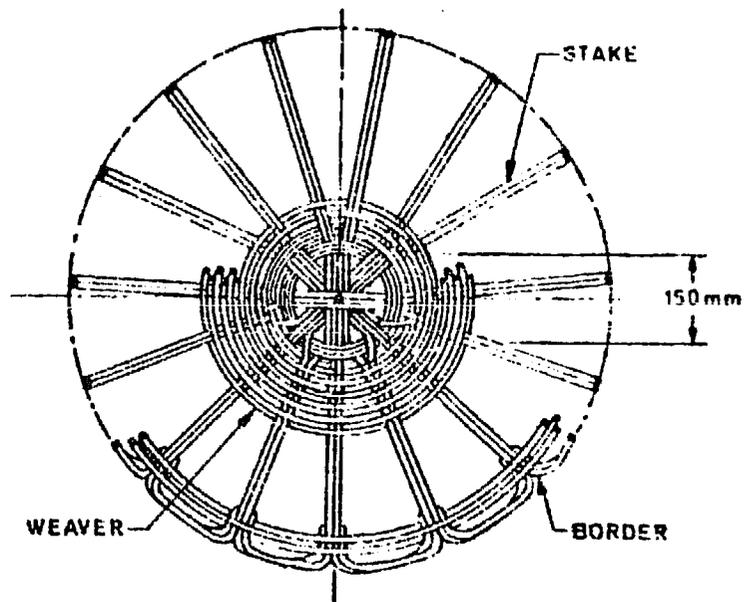


FIGURE 7.2 : INDIAN STANDARD METHOD OF WEAVING HEADBASKET

TOOLS AND EQUIPMENT

HEADBASKET

Design : Table 7.2 gives dimensions of typical headbaskets used in India.

TABLE 7.2 : HEADBASKET DIMENSIONS (mm)

Type	Dimensions see Fig. 7.1		
	Diameter of top a	Diameter of base b	Depth c
A	410	250	135
B	430	220	200
C	450	230	225
D	500	250	250

The headbasket should have sufficient capacity to take the maximum weight of material that the hauler can carry comfortably.

Type A is suitable for carrying broken stone

Type B is suitable for carrying small stones, gravel, heavy earths

Type C is suitable for carrying earth

Type D is suitable for low density materials or for use by the strongest workers

Figure 7.2 illustrates the method of weaving a headbasket as recommended by Indian Standards. The basket should be strengthened with two mild steel strips each of 20mm x 1mm

section passing from one edge, through the bottom of the basket, to the other side. The two strips should be approximately at right angles to one another.

Rope handles can be fitted to facilitate handling of the basket.

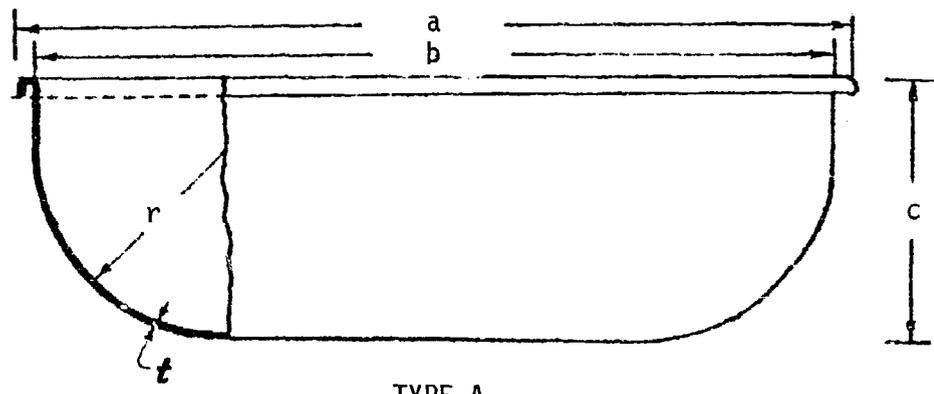
- Material* : Mature cane (Rattan) 6-12mm dia clean and free from any kind of decay or insect attack, capable of being bent to a circle of 150mm dia without showing signs of fracture.
- Manufacture* : The basket should be tightly woven, with all ends trimmed and finished on the inside. Conditioning of the cane for a period of about 4 days at 27⁰C and 65% relative humidity before use will give it better flexibility and longer life.
- Operation* : Headbaskets can be loaded by shovel, spade, fork, hoe or forked hoe. If a hoe is used the loader places the basket between his legs and scoops the material into it. Spare baskets should be used and loaded between arrivals of the haulers. The work should be arranged so that someone assists the hauler in lifting the load onto his head. The load that can be lifted onto the head by one person is only about half that which can be carried comfortably.

The hauler should have a pad of cloth or other soft material on his head to cushion the weight of the basket. For hauls much above about 25m, baskets are best carried by a team operating in relay. Each hauler carries the basket about 25m, then transfers it to the head of the next person and returns with an empty basket. This allows short frequent periods of rest.

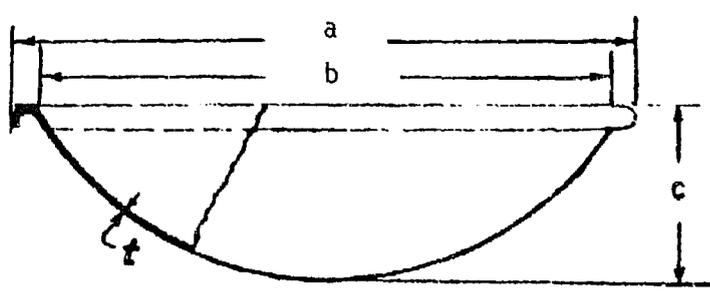
Where height has to be gained on the haul route, then the slope should be as steep as possible up to a maximum of about 30%. A single rising slope is significantly more efficient than the short, interlinked zig-zagging ramps used in some countries.

The hauler unloads the basket by lowering it with both hands and casting out the contents. The basket can be swung to spread the material so that a minimum of subsequent spreading is required.

Suppliers : N/A



TYPE A



TYPE B

FIGURE 7.3 : CROSS SECTION OF INDIAN MORTAR PANS

MORTAR PAN

Design : Table 7.3 gives dimensions of typical mortar pans used in India.

TABLE 7.3 : MORTAR PAN DIMENSIONS (mm)

Type	Dimensions: See Fig. 7.3				
	Outside Dia (a)	Inside Dia (b)	Depth (c)	Corner Radius (r)	Thickness (t)
A	465	450	150	115	1.25
B	400	385	125	-	0.8
	365	350	100	-	0.8

Type A is suitable for carrying rocks and sand

Type B is suitable for carrying mortar, concrete and similar wet materials

The pan should be of seamless construction and have a folded edge all round to resist tearing and protect the user's hands. The Indian Standard specifies that for reinforcement the two largest sizes of pan should have a 6mm diameter wire inside the beaded edge.

Material : Galvanised steel sheet or mild steel at least 2mm thick.

Manufacture : Formed to shape from a single sheet of steel. The mild steel pan should be given an anti-corrosive coating.

Operation : Generally as for headbasket except that with 'wet' material the headload is normally restricted to about 20kg. Hence no assistance is needed to lift the pan onto the head.

Suppliers : N/A

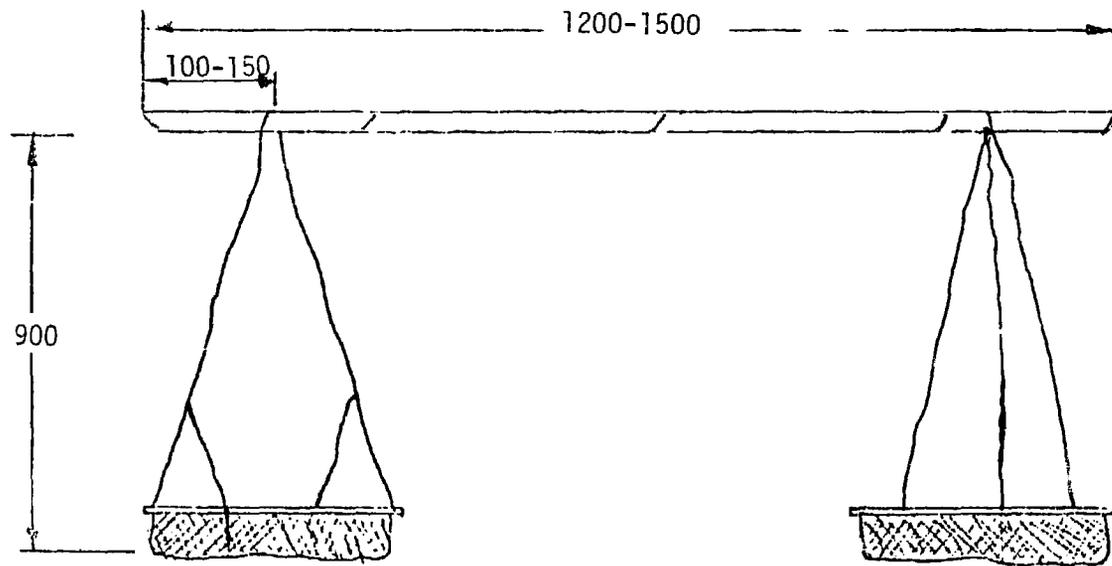


FIGURE 7.4 : DIMENSIONS OF SHOULDER POLE (mm)

SHOULDER POLE

Design : Figure 7.4 illustrates the dimensions for a shoulder pole. The pole is made from bamboo (50-75mm diameter) with a section cut to just less than half its circumference. This gives the pole flexibility and results in the characteristic oscillating motion in use. Notches are cut in the pole 100-150mm from each end to locate the ropes and prevent them sliding. The ropes must provide a stable cradle to support the containers. This can be achieved by two 'forked' ropes (Fig. 7.4 L.H. side) or three ropes (Fig. 7.4 R.H. side). The ropes should pass underneath the containers and not be tied to them. This allows the containers to be loaded onto or removed from the pole rapidly.

The containers can be either cane baskets (see Headbaskets page 7.9) or, for wet materials such as cement, steel pans (see Mortar Pans page 7.13). Headbasket Type A or Mortar Pan Type B would be suitable for use with a shoulder pole.

Materials : Bamboo pole free from decay and insect attack.

Manufacture : Requires simple woodworking facilities

Operation : The containers can be loaded by shovel, spade, fork, hoe or forked hoe. If a hoe is used the loader places the container between his legs and scoops the material into it. The loaded shoulder pole can be picked up by the hauler without assistance.

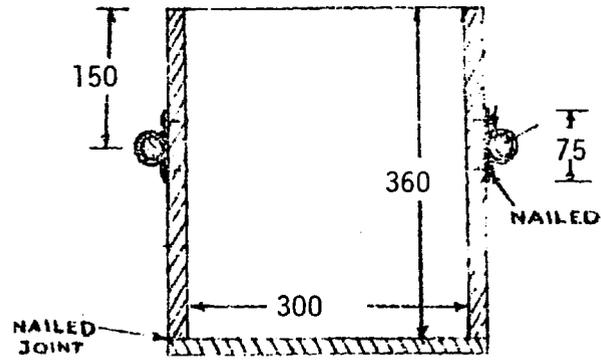
The pole is carried with the smooth outer face resting on the hauler's shoulder and its axis in the line of travel.

The relay chain method of carrying (see Headbaskets) is not normally used with shoulder poles. Thus the route must be wide enough for haulers to pass one another.

The shoulder pole is most effective when the hauler walks in rhythm with the natural oscillation of the pole. This requires a regular pace and is difficult to accomplish if the haul route condition is poor and inconsistent.

The most efficient method of ascending a slope is as for headbaskets.

Suppliers : N/A



SECTION ON A-A

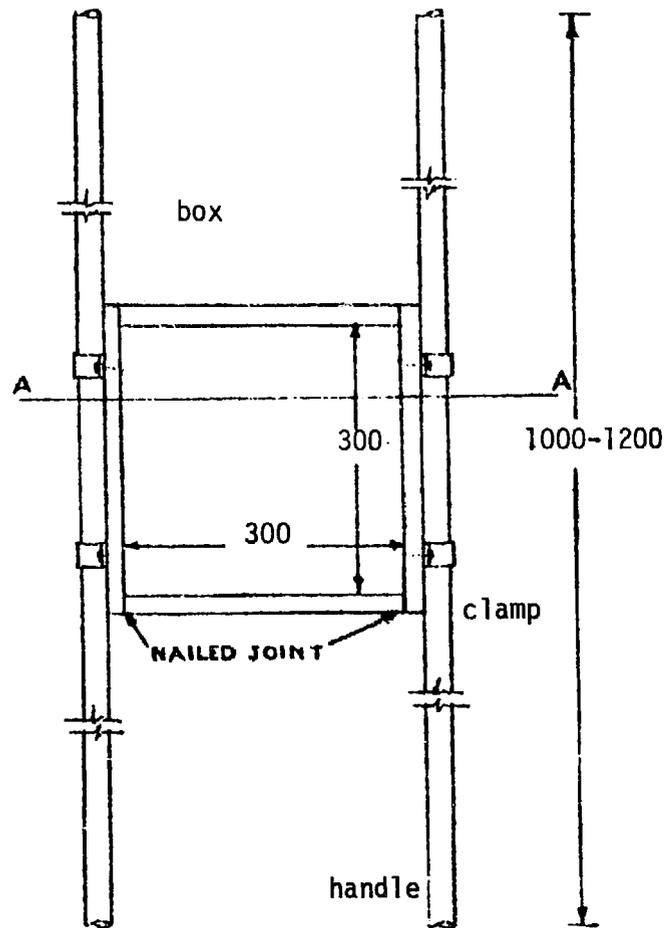


FIGURE 7.5 : MEASURING BOX DIMENSIONS (mm)

MEASURING BOX

Design : Figure 7.5 illustrates the dimensions of a measuring box.

Each handle is attached to the box by two steel clamps nailed or screwed to the wood.

Materials : Box - Seasoned hardwood planks free from defects 20mm thick.
Clamp - Mild steel flat 25mm x 2mm
Handles - Hardwood, bamboo or mild steel black pipe about 35mm diameter.

Note: The box can be made from mild or galvanized steel sheet. This would be somewhat heavier and more expensive but would last longer.

Manufacture : Planks to be finished so that the internal surfaces of the box are smooth.

Operation : The measuring box is used mainly for carrying the component materials of concrete to the point where mixing takes place. By supplying the requisite number of full level loads of the component materials, the correct mix proportions are achieved. Spare measuring boxes should be available and loaded between arrivals of the haulers.

Suppliers : N/A

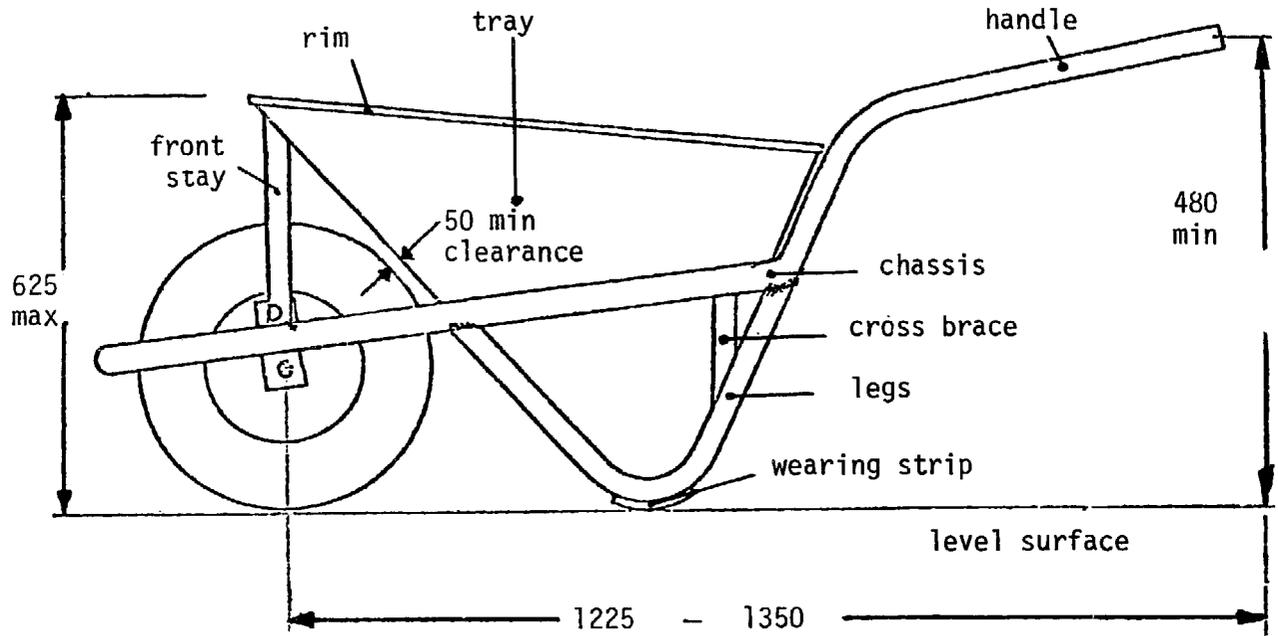


FIGURE 7.6 : NOMENCLATURE AND OVERALL DIMENSIONS OF WESTERN WHEELBARROW (mm)

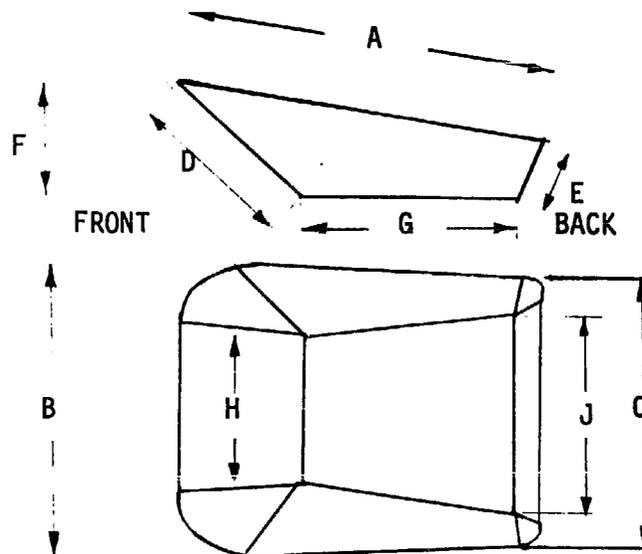


FIGURE 7.7 : TRAY DIMENSIONS

WESTERN WHEELBARROW

Design : Figure 7.6 illustrates the conventional nomenclature and recommended overall dimensions for a western wheelbarrow. The handles should extend rearwards about 600mm from the crossbracing so that the operator can walk freely. There should be about 150mm ground clearance when the barrow is pushed normally, so that the legs do not hit obstacles on the haul route. The centre distance between the handles should be 550-600mm. Approximate weight of wheelbarrow 30kg.

Tray The volume of material that can be carried by the barrow is normally specified by the 'struck capacity' that is the capacity when loaded level with the rim of the tray. Since the load is normally heaped this underestimates the volume that can be carried, but does give a precise measurement of capacity. A struck capacity of 0.07-0.085cu.m. is recommended. Table 7.4 gives data on tray dimensions.

TABLE 7.4 : TRAY DIMENSIONS (mm)

Source	Struck Capacity cu.m.	Dimensions: See Fig. 7.7								
		A	B	C	D	E	F	G	H	J
KRARP Barrow	0.07	940	680	660	530	120	360	410	360	560
U.S. Standard	0.05-0.085	850-1000	640-775	640-740	350-470	150-225	205-350	440-590	325-400	400-500

The tray should be formed from a single sheet of 1.3 or 1.6mm steel. The tray should be reinforced around the full perimeter of the rim by:-

- (i) welding a mild steel band 20mm x 5mm cross section to the outside of the top edge of the tray; or
- (ii) rolling the rim of the tray over a mild steel bar

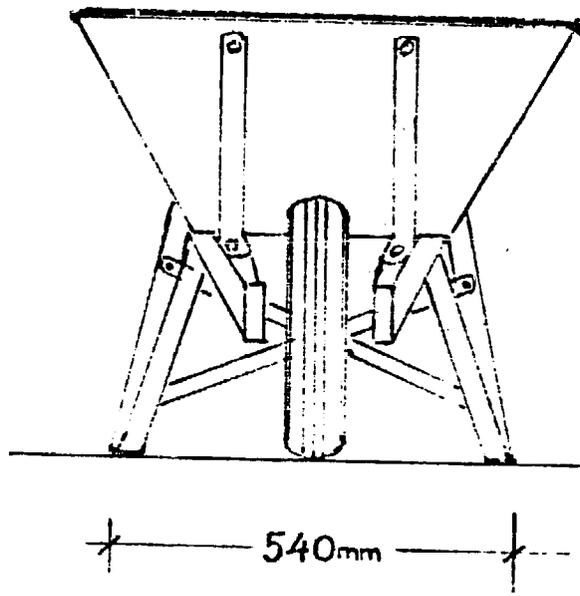
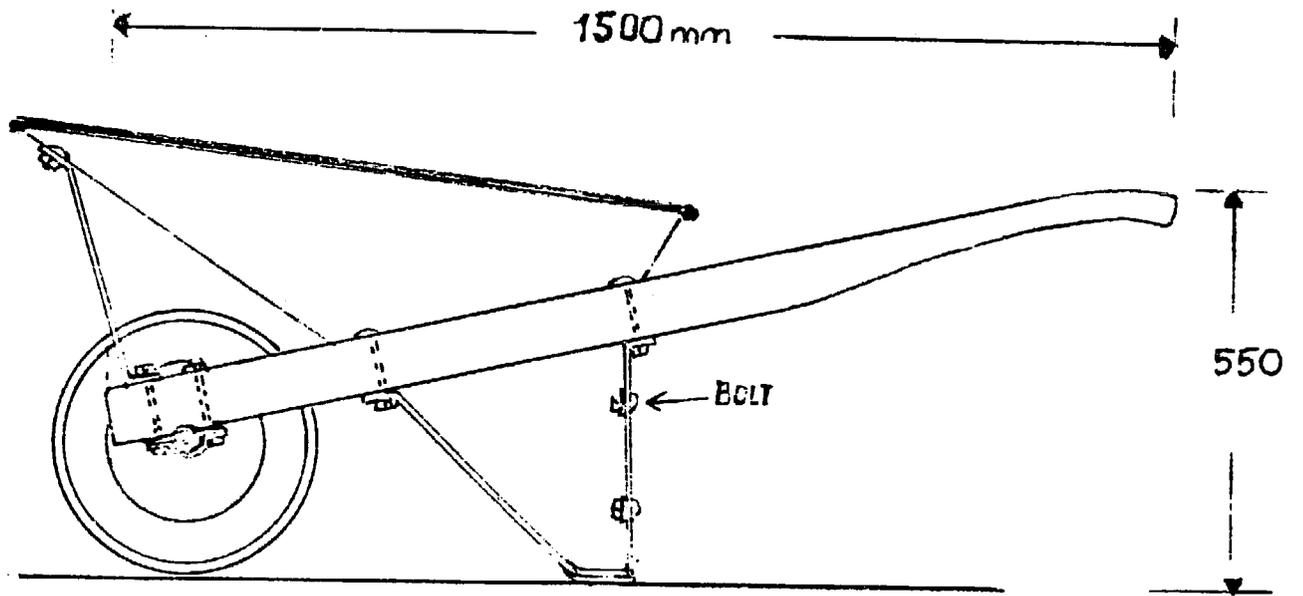


FIGURE 7.8 : KRARP WHEELBARROW

The tray should be attached to the chassis by means of four cup head bolts and square or hexagon nuts so that it can be detached easily. Washers must be fitted under the head and nut of each bolt.

Chassis

The chassis can be made in steel or wood.

Steel : Formed from tube 34mm outside diameter x 2.5mm. There are two recommended methods of construction.

i) Handles and support for body and axle formed from a single length of tube. Each leg formed separately and welded to main tube (as per Fig. 7.6).

ii) Each handle and leg formed from one piece of tube. Support for body and axle formed from one piece of tube.

Wood : Figure 7.8 illustrates the KRARP wheelbarrow which has two wooden main chassis members 40mm x 70mm cross section at the handles.

General : The legs should be strengthened laterally by two diagonal cross braces welded together where they cross and welded or bolted to the legs. The cross-braces should be 32mm x 5mm min. cross section.

The face of the tray should be supported by two front stays 25mm x 6mm minimum cross section bolted to the main chassis.

Wheel/Axle

A solid or pneumatic rubber tyre should be used 350-400mm outside diameter, 75-100 mm wide.

The wheel should be formed from two discs 1.6mm minimum thickness bolted or welded together. The discs should be attached to a hub 63mm minimum width.

Ball or roller bearings, grey cast iron bushes or nylon molybdenum disulphide bushes (as used on the KRARP wheelbarrow) may be used. The bearings may be mounted in the wheel turning on a fixed axle, or on the frame with the axle secured to the wheel. Minimum axle dia. 25mm. Motor Scooter wheel assemblies, which are available in many parts of the world, are suitable for wheelbarrows.

Materials : Metal parts - mild steel
Wooden chassis - seasoned hardwood

Manufacture : Requires simple workshop facilities. Note: Chassis mounting holes for bearing assemblies or axle to be jig drilled to give consistent 'float' to wheel.

Operation : See page 7.31.

Suppliers : Steel barrows

- R.D. MILLES Ltd.
- SLINGSBY
- SOUTH STAFFS CONSTRUCTION Co Ltd.

KRARP Nylon bearings

- ASICOMO A/s (Denmark)

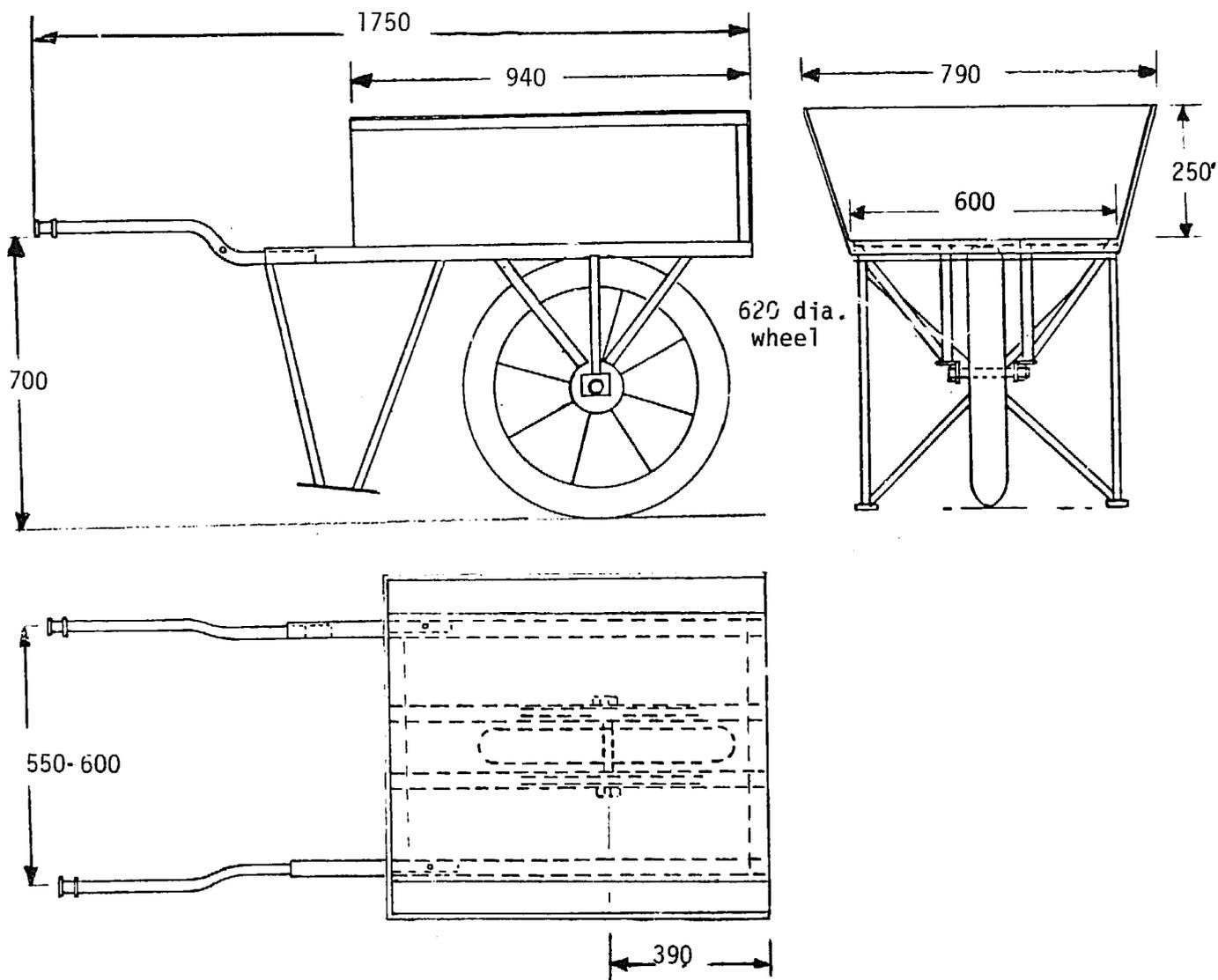
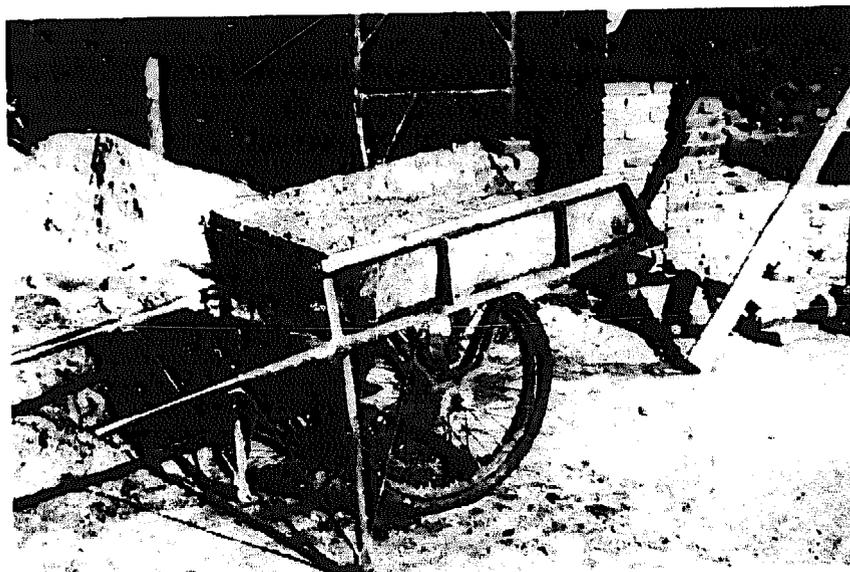


FIGURE 7.9 : DIMENSIONS OF CHINESE WHEELBARROW (mm)



CHINESE WHEELBARROW

Design : This type of wheelbarrow is used extensively in China for labour-based construction. It is potentially a very useful method of haulage because of the high payload. Figure 7.9 gives suitable dimensions for a Chinese wheelbarrow. The handle height is given with the barrow in the operating position. In this position the legs should have about 150 mm ground clearance.

Tray This should have sloping sides so that the material can be discharged easily. The tray shown in Figure 7.9 has a struck capacity of 0.16 cu.m.

The tray should be formed from 1.3 or 1.6mm mild steel sheet, and be reinforced around the full perimeter of the rim. The tray should be bolted to the chassis so that it can be detached (see Western Wheelbarrow for details of rim reinforcement and specification of bolts).

Chassis The chassis shown in Figure 7.9 is formed from angle iron (35mm x 35mm x 5mm) with 30mm diameter mild steel tubular handles. A chassis of similar configuration could be constructed from mild steel tube (Figure 7.10).

The legs should be strengthened laterally by means of two diagonal cross braces.

Wheel/Axle A motor-cycle, moped or heavy-duty cycle rickshaw wheel of 600-700mm outside diameter is suitable. The wheels have ball bearings fitted in the hub running on a fixed axle which is clamped to the chassis.

Shoulder Strap An essential feature of the Chinese wheelbarrow is the use of a strap, attached to the two handles and passing over the operator's shoulders and behind his neck. This assists in supporting the load and balancing the barrow.

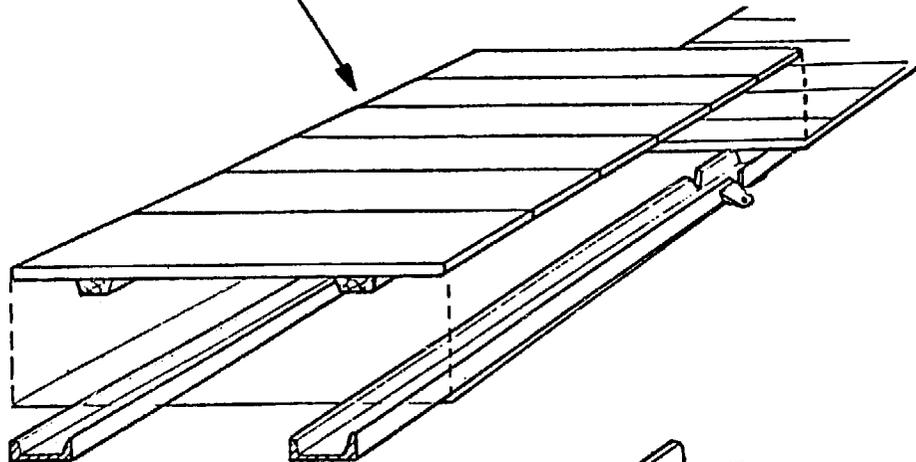
Materials : See above.

Manufacture : Requires simple workshop facilities.

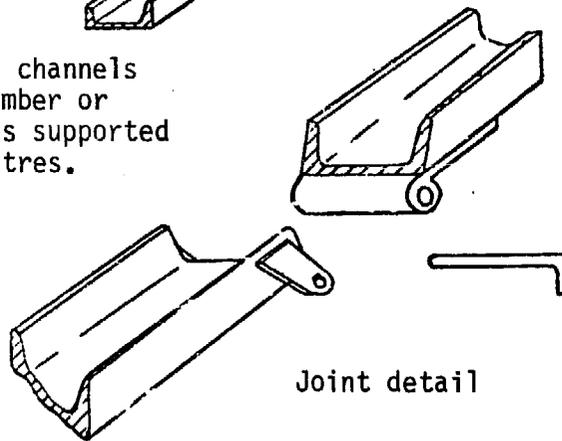
Operation : See Page 7.31.

Suppliers : N/A.

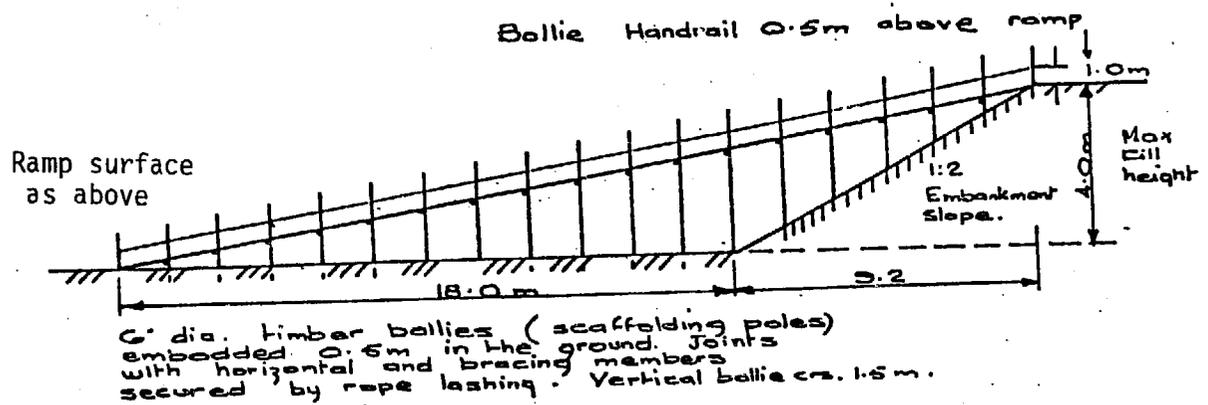
Ramp units 1000x1815mm long prefabricated and dropped into channel bearers



75x40mm steel channels erected on timber or steel trestles supported at 1500mm centres.



Joint detail



WHEELBARROWS

Operation - General

The number of wheelbarrows used should exceed the number of haulers. When the hauler returns to the loading area with an empty barrow there should be a loaded wheelbarrow awaiting him.

The condition of the haul route is an important factor in determining the productivity of wheelbarrow haulage. Anything that can be done to improve the condition of the haul route is likely to be beneficial. It may be sufficient to remove any rocks, smooth out and/or compact the track the barrow will use. In other cases it may be necessary to build a run by bringing in good material and compacting it or by laying wooden planks placed end to end. These planks should be at least 150mm wide.

Many haul routes are likely to include one or more inclined sections (e.g. leading out of a borrow pit, or up the side of an embankment). For short inclines the operator can 'take a run' and allow his momentum to carry him up the slope. In these circumstances a Western Wheelbarrow can be pushed unassisted up a 17% (1 in 6) grade. The equivalent figure for a Chinese Wheelbarrow is 12½% (1 in 8). Thus for the lead out of a borrow pit it is usually sufficient to make a short earthen ramp with a clear approach so that the hauler can 'take a run'.

For long inclines, a Western Wheelbarrow can be pushed unassisted up a 12½% (1 in 8) grade, a Chinese Wheelbarrow up a 10% (1 in 10) grade. There are three methods which can be used to ascend a high embankment:

- (i) Construction of a ramp with maximum grade compatible with the type of wheelbarrow being used. Such ramps are likely to be fairly expensive and their application may be limited to the space available. Figure 7.11 illustrates a ramp supported on scaffolding constructed from bollies (wooden poles or stakes) which has been used experimentally in India.

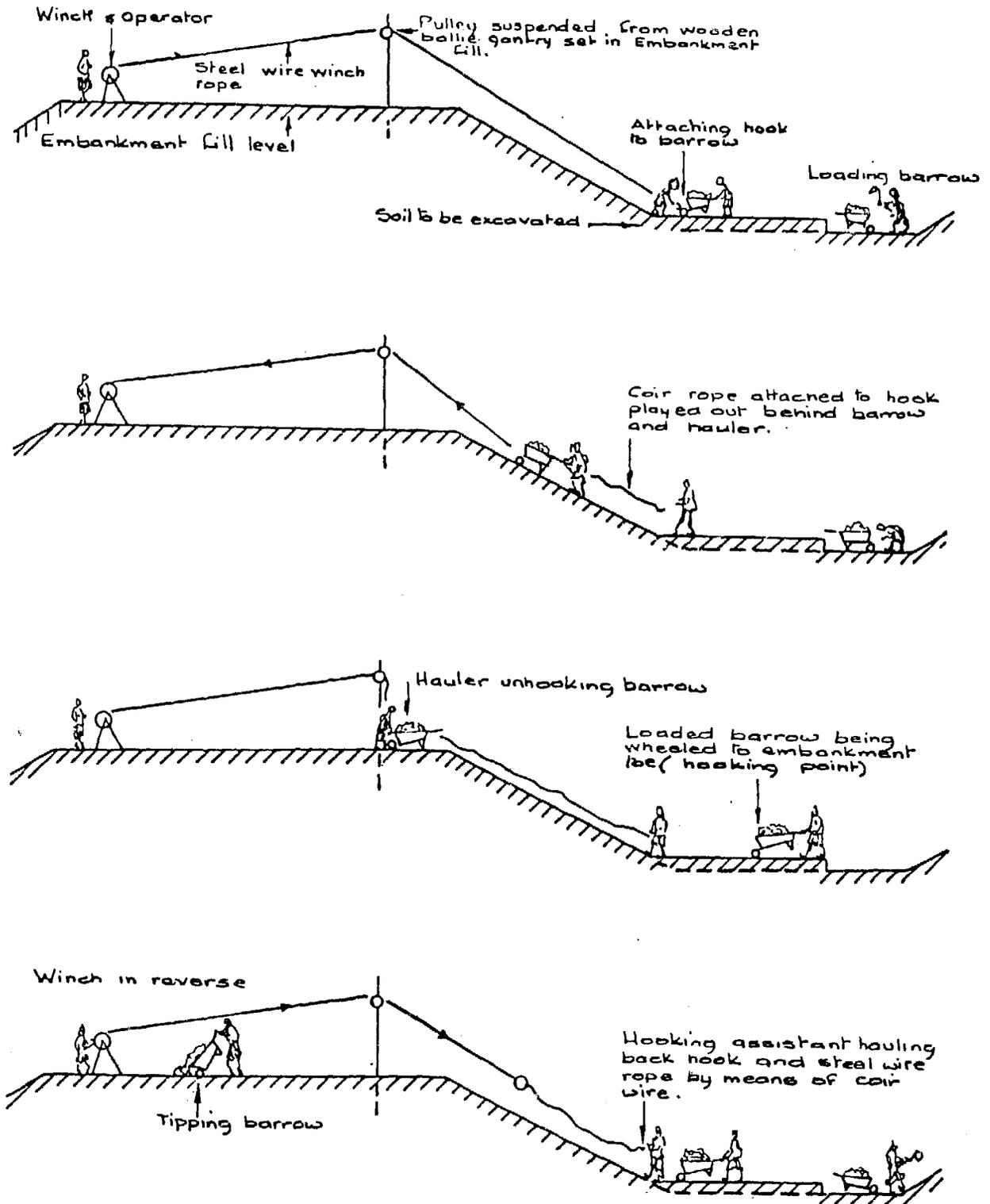


FIGURE 7.12 : WINCH ASSISTED WHEELBARROW HAULAGE

- (ii) The use of an additional puller on the incline. An extra labourer waits at the foot of the incline and when the loaded barrow arrives, attaches a tow rope to its front by means of an S-hook. He pulls the barrow up the incline while the normal hauler pushes from behind. The maximum gradient permissible using this method is about 17% (1 in 6). If the slope is any steeper there is a danger of the haulers losing their foothold.
- (iii) Winch-assisted haulage. This is illustrated in Figure 7.12. Gradients of 50% (1 in 2) are possible using Western wheelbarrows with this method. Chinese wheelbarrows are difficult to balance on such a steep slope.

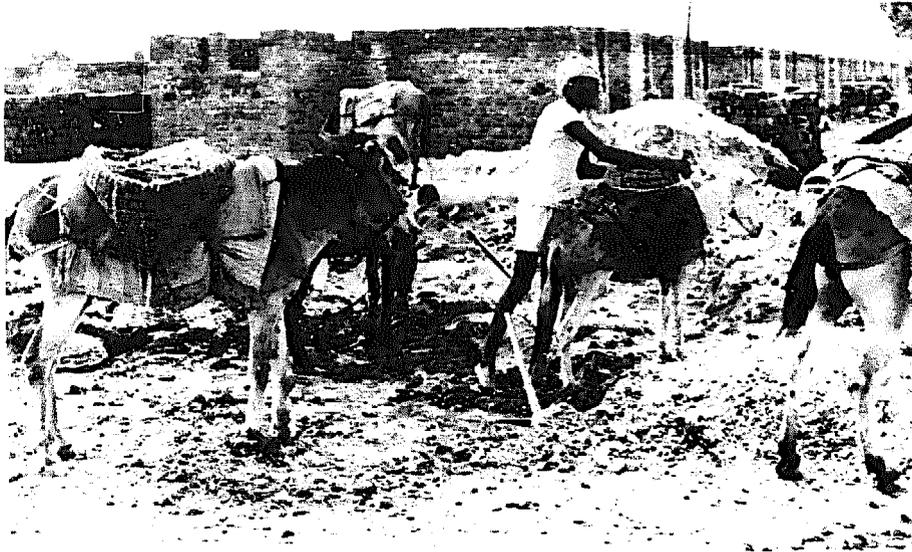
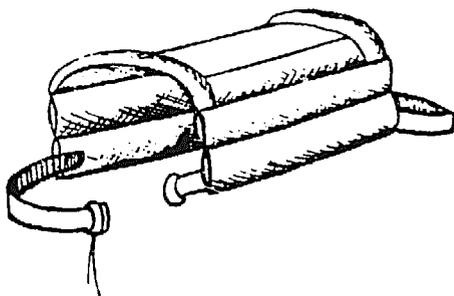
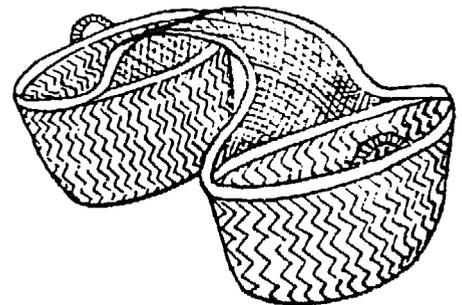


FIGURE 7.13 : DONKEY PANNIERS



(a) Saddle



(b) Container

FIGURE 7.14 : MOROCCAN DONKEY PANNIERS

PANNIERS - DONKEY, PONY, MULE

- Design* : The pannier consists of two components, the material container and a fitting on the animal's back which supports the load comfortably. The fitting may simply be cloth padding to spread the load (visible in Figure 7.13) or it may be a saddle strapped to the animal (Figure 7.14(a)). The container may be a sack which sits on the animal's back and extends down either side (Figure 7.13), or two baskets joined together as in Figure 7.14 (b)). The container should have sufficient capacity to hold 100-200kg of material, according to the strength of the animal. The type of container shown in Figure 7.13 should have a width of about 1m and a depth of 400-800mm. The container should be reinforced around its periphery.
- Materials* : Container - Coir rope, jute/hemp rope, or wickerwork.
Fitting - Cloth padding or saddle made from leather or sacking stuffed with available soft material.
- Manufacture* : Using local skills.
- Operation* : Panniers can be loaded by shovel or hoe, though the shovel is likely to be more effective. Reducing the loading height (e.g. by working the borrow pit so that the animal stands at a lower level than the earth being excavated) will be beneficial. The animals are normally operated in teams of 10-12, with 4-5 labourers to guide and unload them. Unloading is effected by tipping the container off the animal's back.
- Suppliers* : N/A.

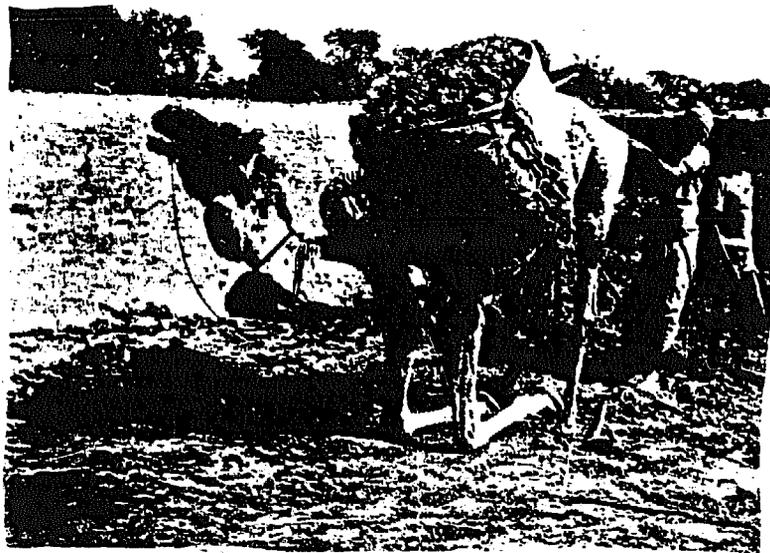


FIGURE 7.15 : CAMEL PANNIER

PANNIERS - CAMEL

Design : A camel can carry a load of up to 500kg on its back. The pannier consists of a bamboo frame, on which sits a large sack, which is strapped to the animal. The sides of the sack are laced (see Figure 7.15) which are undone to unload. This is time-consuming and an improved design would be worthwhile. The sack should be reinforced around its periphery.

Materials : Frame - bamboo
Sack - woven rope, canvas or hessian.

Manufacture : Using local skills.

Operation : The camel kneels down for loading. Consequently the loading height is lower than for donkey, mule or pony panniers. The amount of labour required to guide a team of camels along the haul route depends on how well trained the animals are. Since the load is too great to be tipped off the animal's back the sides of the pannier are unlaced and the material discharged.

Suppliers : N/A.

ANIMAL-DRAWN CARTS

Mules, donkeys, oxen and camels are the most common draft animals. The animals may be used either singly or in pairs. While the payload and hence the size of the cart, will depend on the number and strength of the animals used, the basic design principles remain the same. Data is given here for a cart drawn by one donkey/mule, one camel and a pair of bullocks. This data may be interpolated for other types of cart.

Design : General Two-wheeled carts are preferred for road construction work. Four wheeled carts are expensive, difficult to manoeuvre, and ill-suited to use on rough ground because of the torsional loads imposed on the chassis. The cart should be designed so that, when loaded, there is a small downward force acting on the animals. The cart in Figure 7.16 has the axle mounted slightly behind the centre of the load platform to achieve this. Carts drawn by two animals have a central draught pole to which a double yoke is fitted. Carts drawn by one animal have two shafts leading forward from the platform with the animal harnessed between them.

The weight of the cart should be minimised commensurate with adequate strength. The lower the dead weight of the cart, the greater the useful payload that can be moved.

Wheels/Axle/
Bearings Pneumatic tyred wheels give the lowest rolling resistance in the conditions usually encountered on road construction sites and provide a useful means of indirect compaction. Inner tubes should always be fitted.

Recommended minimum tyre sizes for animal carts are given in Table 7.5.

Table 7.5 : TYRE SIZES FOR ANIMAL CARTS

Type of cart	Payload	Tyre Size*
one donkey/mule	400	5.20x13
one camel	700	5.60x14
pair of oxen	1000	6.00x16

Discarded motor vehicle tyres can be quite satisfactory since the absence of a tread is not important on slow-moving carts. Animal carts have been built using complete motor-vehicle rear axle assemblies, usually obtained from scrap vehicles. This simplifies manufacture but results in an excessively heavy cart. It is preferable to fabricate the axle, which acts as the main structural member of the cart, from square or round section steel tube. Machined stub axles are welded to each end of this to mount the wheels on.

Recommended axle sizes:

Square Section: 35-45mm square, A square section tube can be formed from two lengths of angle iron, welded together

Round Section: 40-50mm outside diameter.

* This is the standard method of specifying a tyre. The first figure is the width of the tyre in inches (on some types of tyre this is now specified in millimetres). The second figure is the bead diameter in inches.

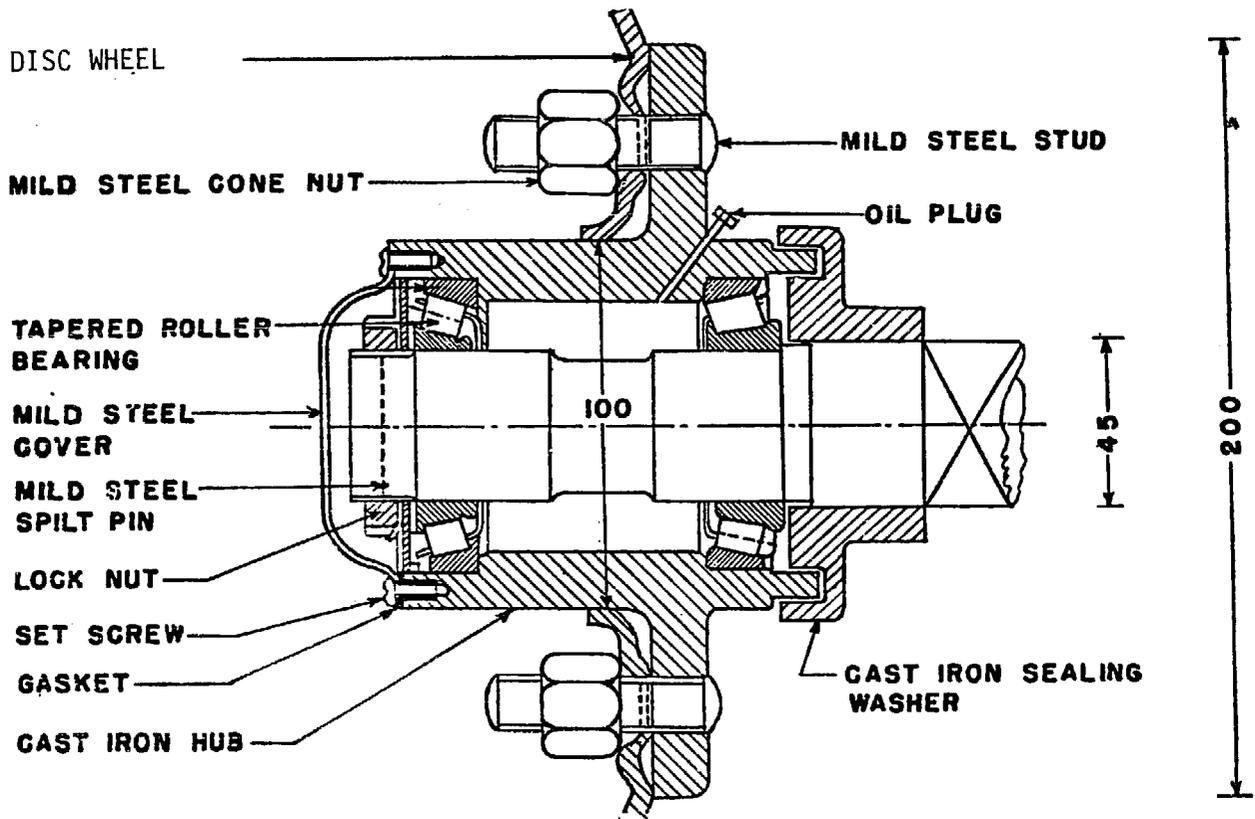
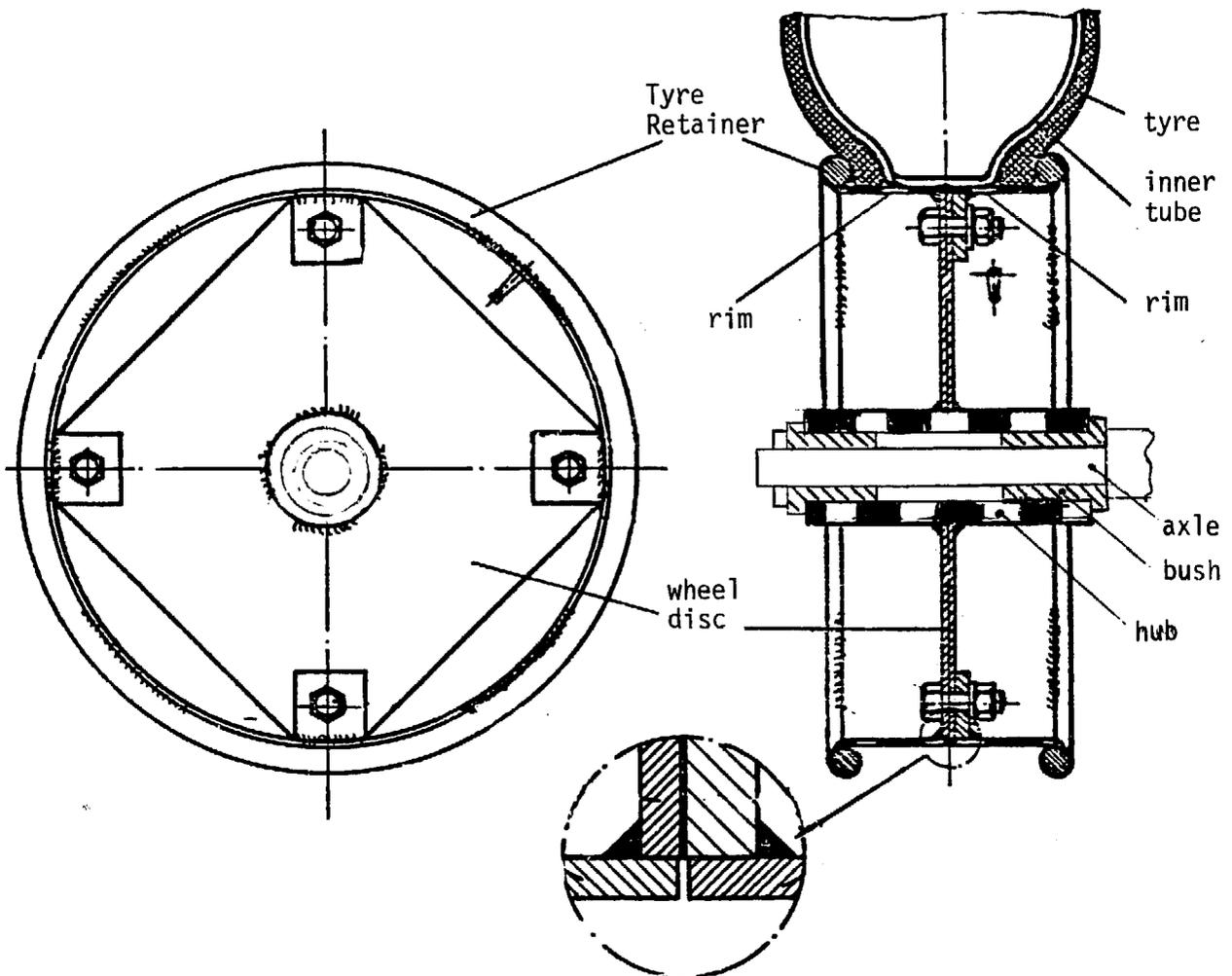


FIGURE 7.17 : HUB FITTED WITH TAPERED ROLLER BEARINGS (mm)



Standard, motor vehicle pressed steel wheels can be used, but may be expensive if purchased new, or difficult to obtain second-hand. Such wheels require a hub which mates with the mounting holes on the wheel and carries the bearings. Figure 7.17 shows such a hub fitted with tapered roller bearings.

Figure 7.18 shows a fabricated wheel which accepts a pneumatic tyre. The wheel rim is in two parts, clamped together. Steel rod is welded around each side of the rim to retain the tyre. The diameter and width of the rim must be matched to the tyre size used.

Rolling contact bearings (ball or roller) or plain bushes can be used. The former are likely to have the longer life, provided that they are properly greased when fitted and well protected, but are relatively expensive. Figure 7.17 shows a hub design using tapered roller bearings. Plain bushes may be of cast iron or phosphor bronze, and regular lubrication is essential to ensure long life. Figure 7.18 shows a hub fitted with plain bushes. (Note: using the design principles demonstrated in Figures 7.17 and 7.18 either type of wheel can be designed to accept rolling contact bearings or plain bushes.

Dunlop India Ltd. manufacture pneumatic tyres, wheels and axles specifically for animal-drawn vehicles.

Load Platform

The axle forms the main structural member of the cart. Supports are attached to each end of the axle and carry the load platform. The supports and load platform can be in steel (Figure 7.16) or wood (Figure 7.19). The size of the load platform should be matched to the capacity of the animals. Typical sizes are:-

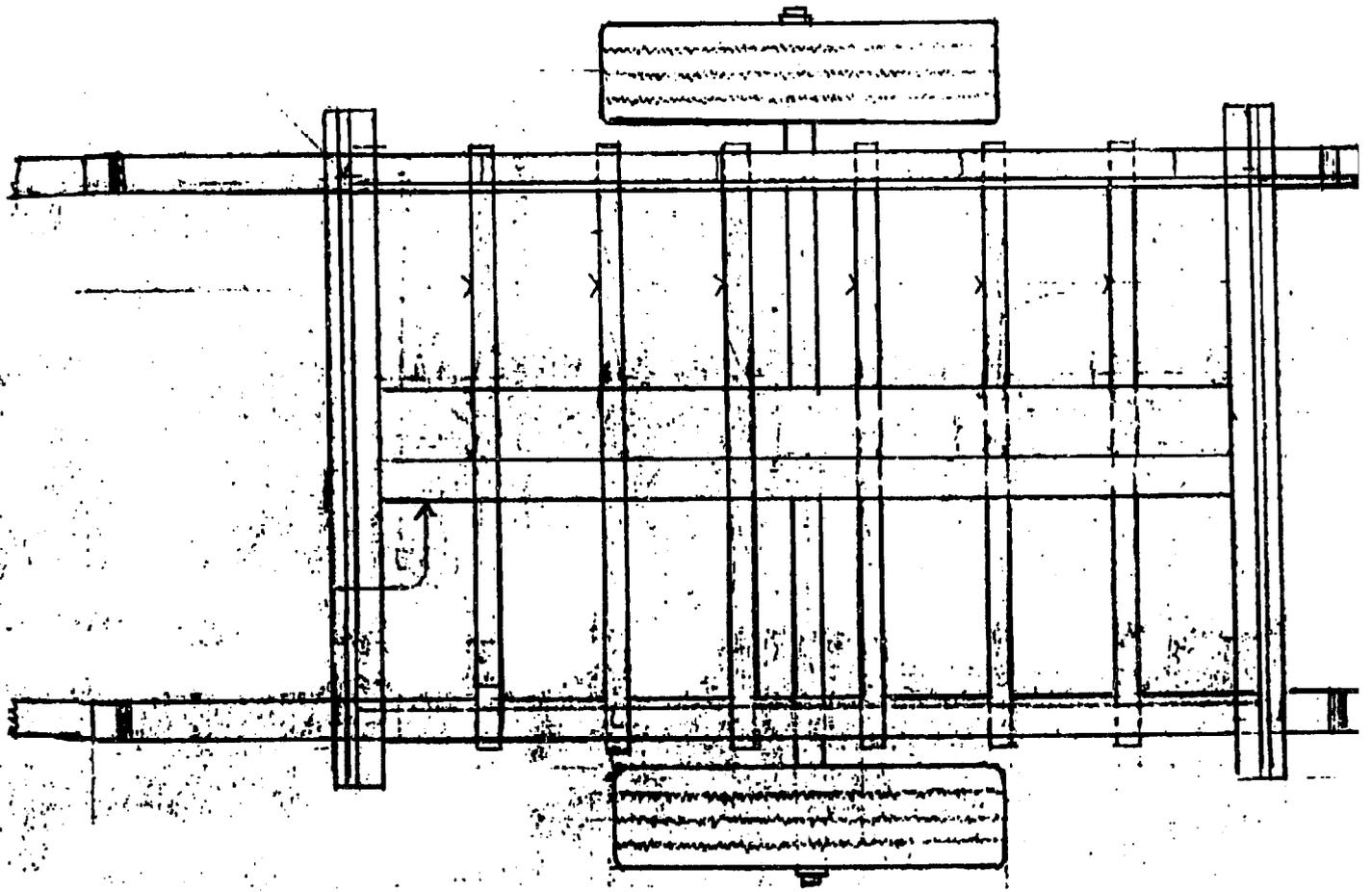
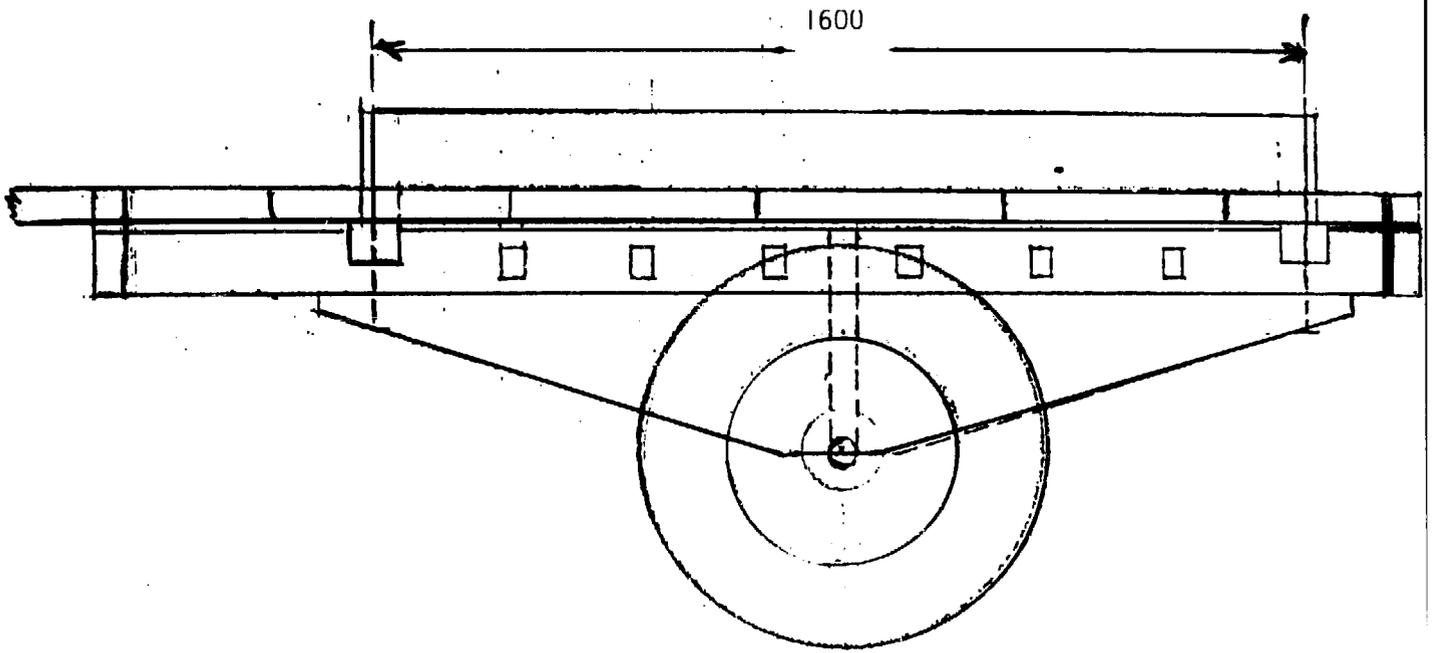


FIGURE 7.19 : WOODEN CART WITH BOTTOM DISCHARGING PLATFORM

cart drawn by one donkey/mule	1.6 x 0.95m
cart drawn by one camel	2.0 x 1.3m
cart drawn by two oxen	1.6 x 1.3m

The platform should have shallow side walls to retain the load without giving excessive loading height.

An important factor in the productivity of animal cart haulage is the unloading time. This can be minimised by appropriate design of the cart:-

- i) Bottom discharge (Figure 7.19). Bamboo mats are placed over the base of the load platform prior to loading. Discharging is effected by pulling out the bamboo mats.
- ii) Tipping cart (Figure 7.20). The draught pole is attached to the cart by means of a pivot just forward of the axle and a latch at the front of the load platform. When the latch is released the cart can be tipped to unload. Another system is shown in Figure 7.21. The harness on the camel's back can be released allowing the complete cart to tip.

Materials : Wooden components should be from seasoned hardwood.

Metal components generally in mild steel.

The hubs can be in cast iron.

Manufacture : The axle/hub assembly requires machine facilities. The remainder of the cart can be built in a simply-equipped workshop.

Operation : Each cart requires an operator who travels on or with the cart, assists with loading and may be solely responsible for unloading.

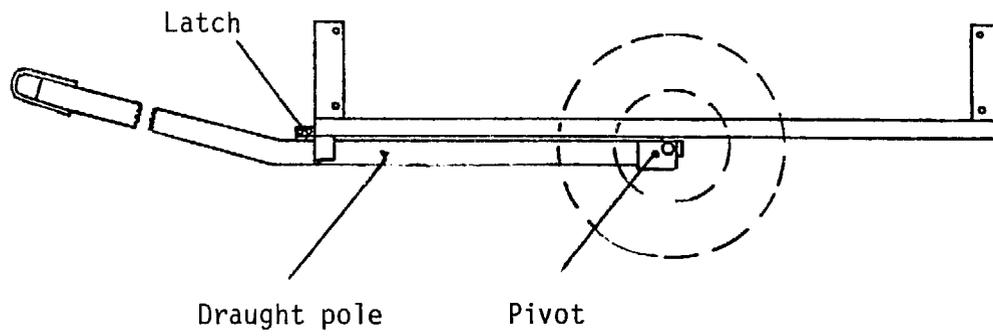


FIGURE 7.20 : TIPPING CART

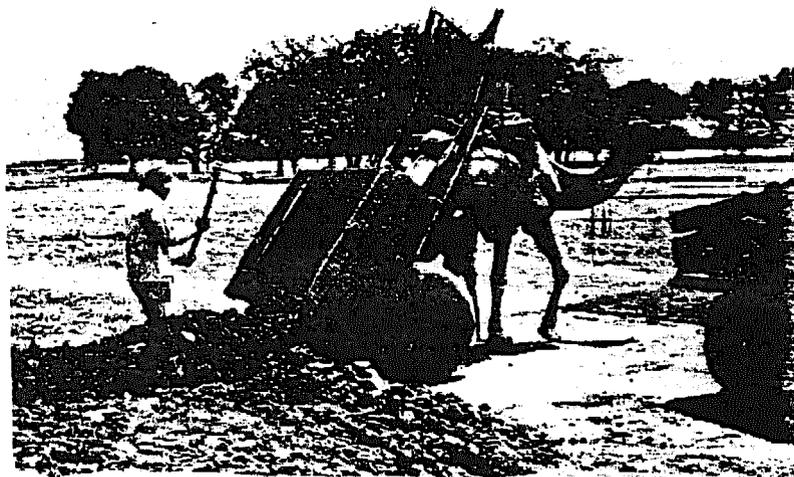


FIGURE 7.21 : TIPPING CAMEL CART

The haul route should be maintained in good condition and steep gradients avoided. As with wheelbarrows organisation of the loading area to reduce loading height is beneficial.

Suppliers : SISCOMA
AGRO PUMPSETS AND IMPLEMENTS Ltd.
SOCIETE des FORGES TROPICALES
TUBE PRODUCTS of INDIA
DUNLOP INDIA Ltd. (tyres wheels and axles only)

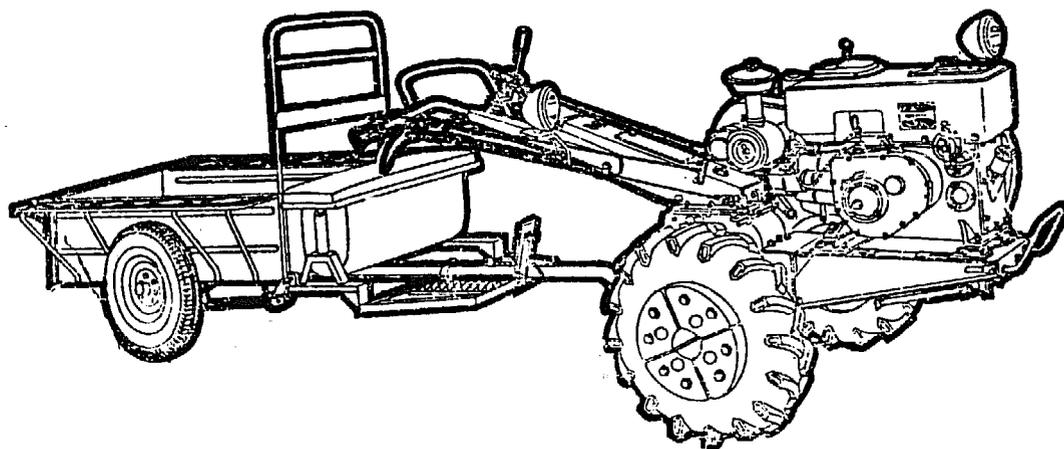


FIGURE 7.22 : SINGLE AXLE TRACTOR AND TRAILER

SINGLE-AXLE TRACTOR AND TRAILER

Design : Many of the design principles can be interpolated from the information given for animal drawn carts and four-wheeled tractors and trailers since the single axle tractor/trailer is intermediate between these devices. Figure 7.22 illustrates a typical single-axle tractor and trailer combination. The payload for the more robust type of tractor suitable for road construction work is 750-1000kg. To drive the combination the operator sits on a seat at the front of the trailer. The trailer should be fitted with foot operated mechanical brakes acting on both rear wheels. The hitch must be compatible with the tractor and the drawbar of the trailer should be fitted with a retractable skid so that when detached from the tractor it can be parked with the load platform level.

The chassis can be fabricated from box and/or channel section steel. A square section (45mm x 45mm) axle would be suitable with pneumatic tyred wheels (6.00x16 for a 1 tonne trailer) running on roller bearings. The animal-drawn vehicle (ADV) axle and wheel assemblies manufactured in India would be suitable.

The bodywork can be of steel or wooden construction, with load platform dimensions of about 2.0m x 1.3m.

A tipping body, using a hydraulic ram and hand pump, is feasible.

Materials : Metal parts generally in mild and hot rolled steel. Wooden parts to be of seasoned hardwood.

Manufacture : Suitable for manufacture in a well equipped workshop.

Operation : Operational principles are likely to be similar to those for the four-wheeled tractor and trailer (including use of additional trailers) though payloads and haul distances will be smaller.

Suppliers : KRISHI ENGINES Ltd.
VST TILLERS TRACTORS Ltd.
IRUSWERKE.
J.K. SATOH AGRICULTURAL MACHINES Ltd.
BOUYER S.A.
CECOCO AGRICULTURAL AND SMALL INDUSTRIAL CENTER
I.R.R.I. (design available for trailer).
DAEDONG INDUSTRIAL Co. Ltd.

FOUR WHEELED TRACTOR - TRAILER

Design : General Two-wheeled unbalanced trailers are the most suitable type for road construction work. Such trailers transfer a proportion of the load to the rear axle of the tractor, thus increasing its traction capability. This is important since, in construction site conditions, tractor pull, and hence payload, is often limited by traction rather than engine power. Two-wheeled trailers are also cheaper, and much easier to manoeuvre, than the four-wheeled type.

The maximum payload for a given tractor depends on a number of factors, including haul route condition and gradient.* The following trailer capacities are recommended as guidelines:

35hp tractor - 3 tonne
48hp tractor - 4-5 tonne

Such tractors are expensive, and trailers relatively cheap; efficient use of this method of haulage requires additional trailers which can be loaded while the tractor is hauling (see 'operation' for further details). Consequently, trailers are repeatedly hitched to and unhitched from the tractor. The tractor should therefore be fitted with a heavy duty automatic hitch which picks up and detaches the trailer hydraulically. (It is arduous and time-consuming to do this by hand).

* A detailed consideration of this complex subject is beyond the scope of the Guide. For further information see World Bank Study of the Substitution of Labour and Equipment in Civil Construction. Technical Memorandum No. 24. The Use of Agricultural Tractor/Trailer Combinations - June 1976.

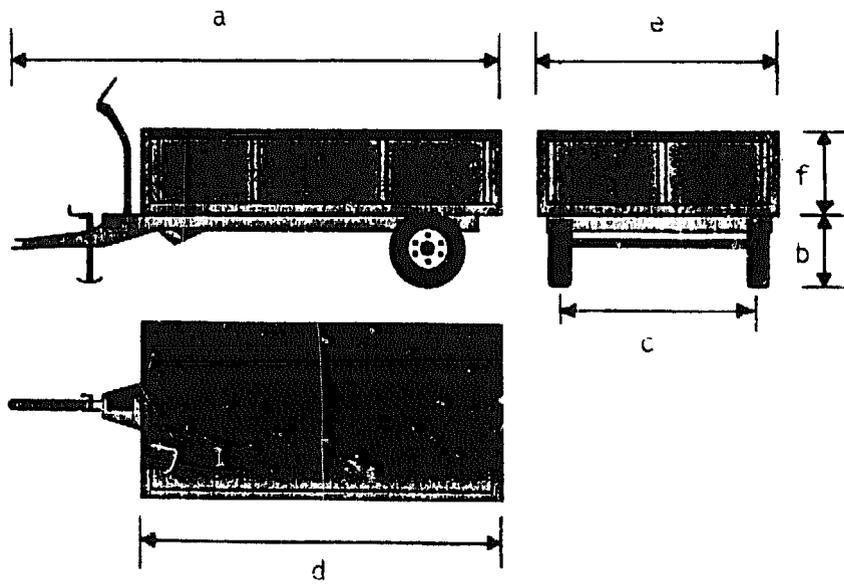


FIGURE 7.23 : TRAILER DIMENSIONS

In specifying a suitable trailer it is essential to ensure that it is compatible with the tractor to be used in terms of capacity, strength and dimensions of towing hitch, hydraulic capacity and fittings, and load transfer. Close liaison should be maintained between the project engineers, tractor suppliers and trailer suppliers.

Suitable overall trailer dimensions are given in Table 7.6

TABLE 7.6 : TRAILER DIMENSIONS (mm)

Payload (tonnes)	Dimensions (see Figure 7.23)		
	Overall Length a	Floor Height b	Axle Track c
3	3800	760	1500
4	4250	840	1500
5	4700	920	1650

The load transferred to the tractor will depend on the position of the axle. The tractor supplier should be consulted on this but as a guide the maximum load transfer is likely to range from 1.2 tonnes for a 3 tonne trailer to 1.5 tonnes for a 5 tonne version. Many manufacturers supply trailers with a choice of axle positions.

Wheel/Axle

Table 7.7 gives suitable minimum dimensions for the tyres, brakes and square cross section of the axle.

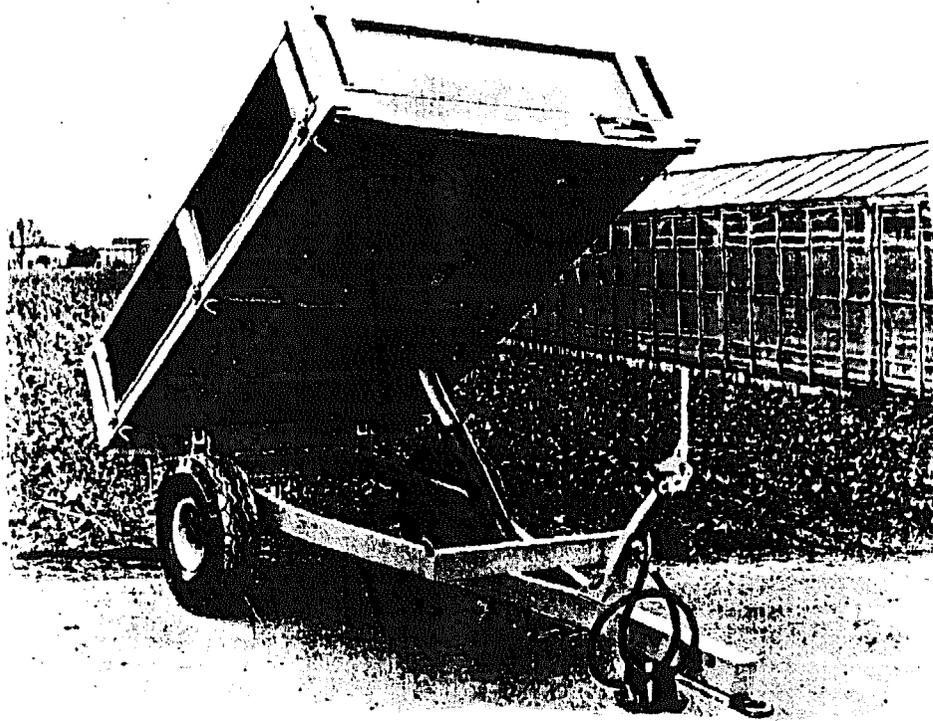


FIGURE 7.24 : TYPICAL TRAILER CHASSIS

TABLE 7.7

Payload tonnes	Tyre Size	Brake Size mm		Axle Section mm
		Dia.	Width	
3	7.50x16 (8ply)	225	40	57x57
4	10.00x15 (8ply)	225	45	64x64
5	11.50x15 (8ply)	255	45	70x70

The tyres should always be fitted with inner tubes.

The trailer should have mechanically actuated drum parking brakes.

Adjustable taper roller wheel bearings are normally fitted.

Chassis

Figure 7.24 illustrates a typical chassis configuration (note that this is a tipping trailer). The main chassis members are of channel section 125x62.5mm for the 3 tonne trailer 150x75mm for the larger versions. The drawbar is welded to the chassis and fitted with a ring hitch for the pick-up hook. The height of the hitch should be such that it is horizontal when attached to the tractor. A robust skid is fitted to the underside of the drawbar to support the front of the trailer when parked.

Body

Table 7.8 gives suitable dimensions for the body.

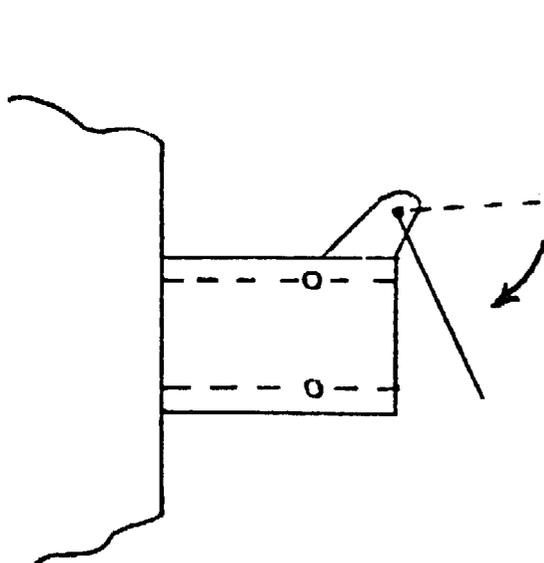
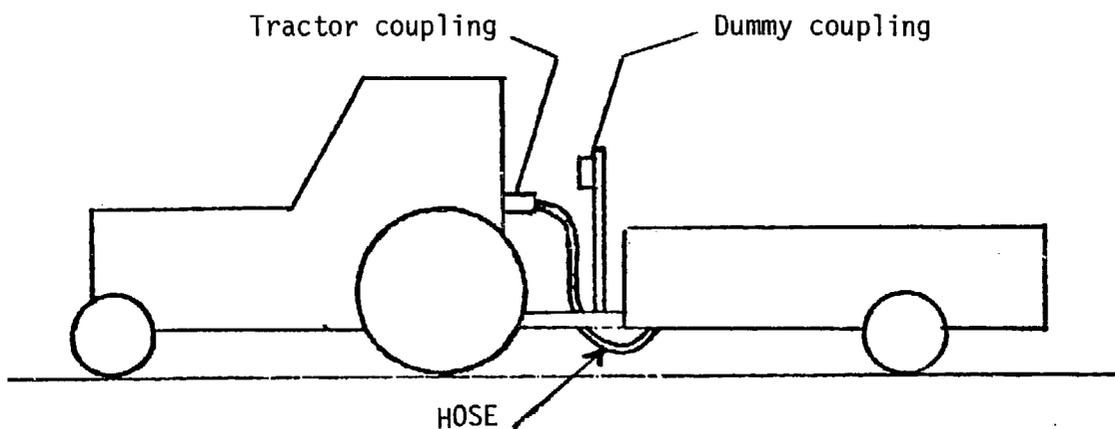
TABLE 7.8

Payload tonnes	Dimensions mm (see Figure 7.23)		
	Length (d)	Width (e)	Height (f)
3	2900	1825	400
4	3200	1825	475
5	3500	2000	550

The body sub-frame is fabricated from steel channels and angles. The panelled floor and sides may be in steel or tongued and grooved timber.

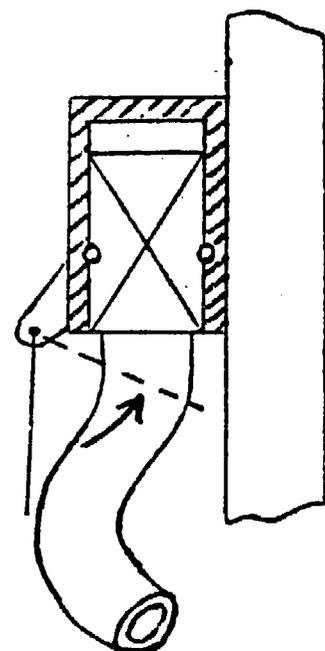
The body may have drop-sides to reduce the loading height but these and the associated latches must be robustly constructed to withstand normal abuse without distortion.

A hydraulically tipping body will minimise unloading time. The hydraulic system must be compatible with the tractor, which must have sufficient hydraulic reservoir capacity. A two-stage hydraulic ram should be used to give a tipping angle of at least 60° . The cross member on which the ram acts should be sufficiently strong to prevent distortion. The body hinge pin diameter should be 35mm minimum. The hydraulic system must be uncoupled each time the trailer is detached from the tractor. To prevent the hose trailing in the dirt a dummy female coupling should be fitted to the trailer into which the



Tractor coupling

When trailer hose is disconnected spring loaded flap closes mouth of fitting



Dummy coupling

After disconnecting from tractor, hose end is pushed into dummy fitting. This is normally sealed by spring flap

FIGURE 7.25 : DUMMY COUPLING ARRANGEMENT

hose can be fitted when detached from the tractor. This and the coupling on the tractor should be fitted with robust spring loaded caps to protect them from ingress of dirt when not in use. (The system is shown in Figure 7.25). A tipping trailer will require a hinged tailgate. This should be hinged from the top and have a robust locking device. The body sides can be extended rearwards to protect the hinges and lock.

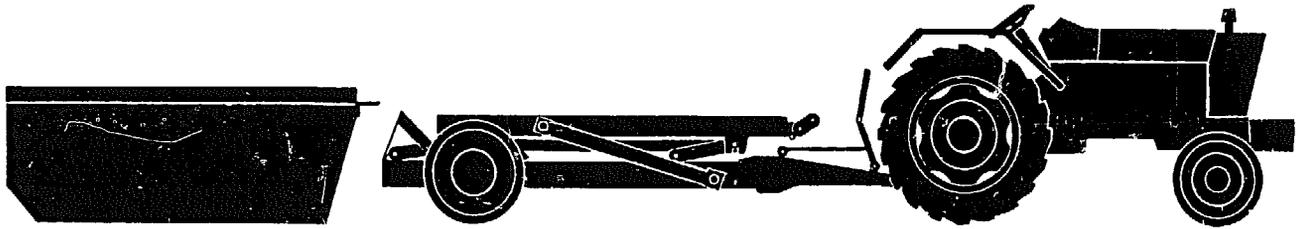
Container
Trailer

Figure 7.26 shows another type of trailer system. This consists of a towed chassis permanently hitched to the tractor, with a container which is picked up and deposited hydraulically. Thus for road construction work several containers would be used with each tractor/chassis unit. An advantage of this system is that the container floor is at ground level which results in faster loading.

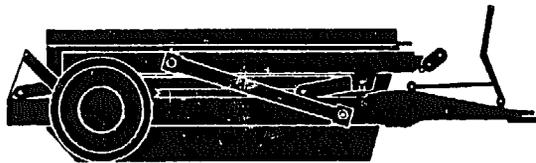
Materials : Chassis, body and subframe : hot rolled mild steel channel.
 Body panels : floor - high tensile steel 2mm thick or
 mild steel 3mm thick
 sides - mild steel 2mm thick or
 seasoned hardwood
 Hitch : heat treated alloy steel

Manufacture : Requires well-equipped workshop.

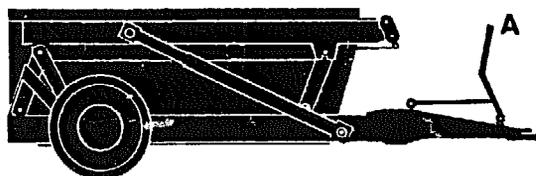
All metal parts should be painted with one coat red oxide primer and one coat gloss paint.



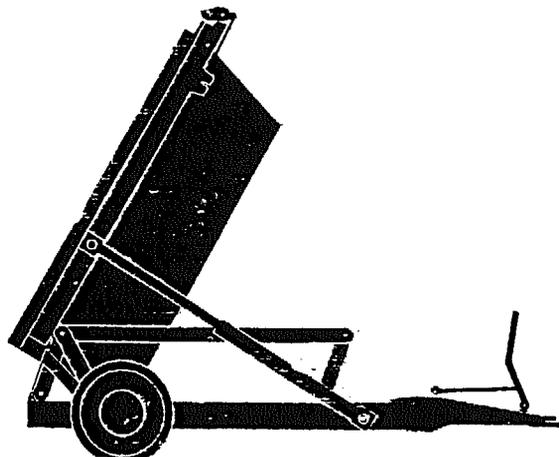
(a) Container on ground, tractor backing up.



(b) Container in the 'Ready for lift' position.



(c) Container in the raised or 'travelling' position.



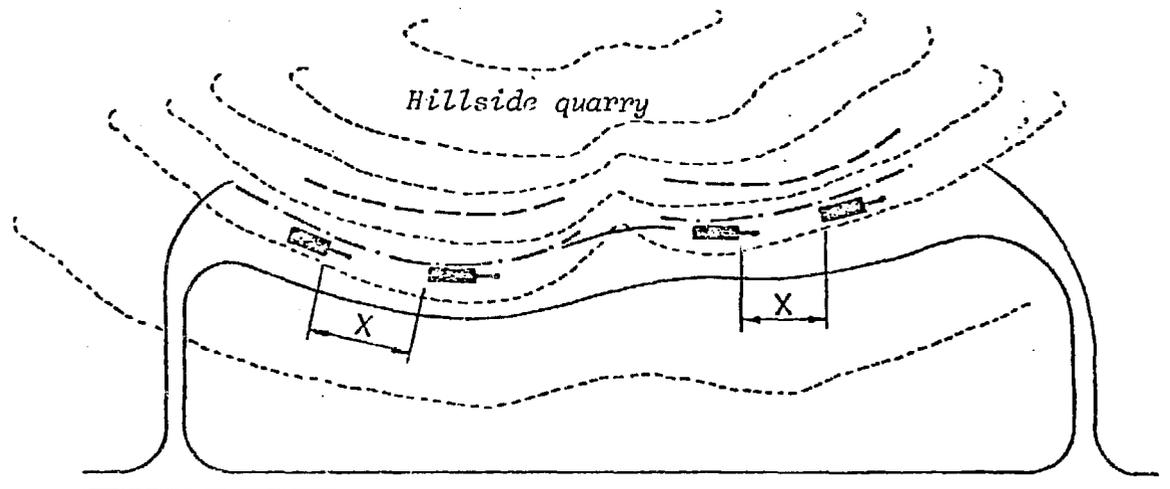
(d) Container in the fully tipped position.

Operation : Good organisation is essential if tractor/trailers are to be used effectively for hauling. The critical factor is to maximise the utilisation of the expensive component - the tractor. Thus, it is normal to use at least two trailers for each tractor. One trailer is hauled and unloaded while the other is being loaded. For haul distances below about 400m where the cycle time is short it may be necessary to use three trailers since the number of loaders that can conveniently work around one trailer may not be sufficient to load it within the cycle time. Organisation of the loading site to minimise loading height is desirable. If a substantial quantity of material is to be moved from one site then it is worth excavating loading benches.

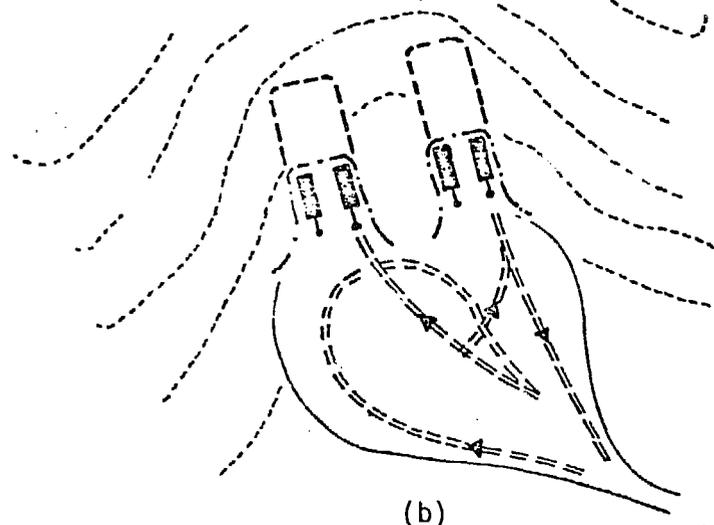
The loading area must be flat, and have sufficient space for manoeuring the tractor/trailers. Figure 6.28 shows two examples, in (a) there is a loop access road to the site which is ideal; in (b) space is required for the trailers to be reversed into the loading points.

The haul route should be maintained in good condition to maximise travel speed and minimise wear and tear on the tractor. Gradients should be limited to about 10%. Steep up gradients will decrease payload while steep down gradients can cause jack-knifing of the tractor/trailer.

A separate team of unloaders should be provided at the end of the haul route. They can be employed in spreading between tractor arrivals (if tipping trailers are used unloaders will not be needed). It is essential that skilled tractor drivers be employed. Training should be given if necessary.



Main road
(a)



(b)

- ==>== *Tractor/trailer manoeuvre (example)*
- ~~~~~ *Roadway*
- - - - *Edge of loading bench*
- - - - *Later position of edge of loading bench (possible)*
- - - - *Contour line*
- ☐- *Possible trailer loading positions*

- X *Minimum distance between trailers, determined by trial (5 to 10m)*

FIGURE 7.27 : TRACTOR/TRAILER LOADING AREA ARRANGEMENTS

Suppliers : MASSEY FERGUSON UK
MASSEY FERGUSON Brasil
RANSOMES SIMS & JEFFERIES Ltd.
INTERNATIONAL HARVESTER Co. Ltd.
F.W. WHEATLEY TRAILERS Ltd.
THE SALOP TRAILER Co. Ltd.
MAHINDRA OWEN Ltd.
TRACTORS & FARM EQUIPMENT Ltd.
WEEKS TRAILERS Ltd.
AVON RUBBER COMPANY (Bridgend) Ltd. - (manufacturers of
axle assemblies.
TELEHOIST Ltd. - (manufacturers of container trailers).

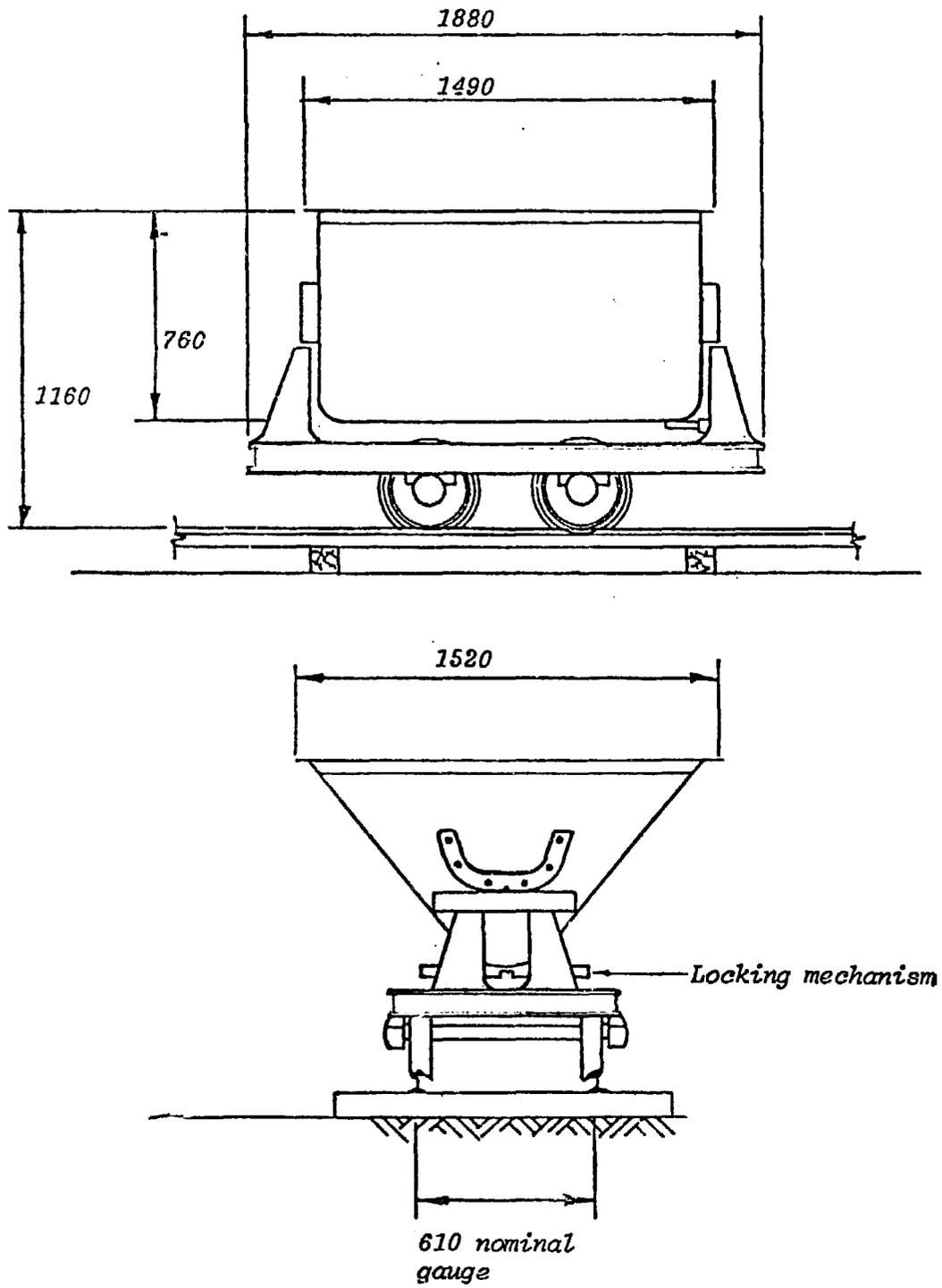


FIGURE 7.28 : RAIL CART

RAIL CART

Design : Rail carts operating on specially laid tracks have the advantage that rolling resistance is very low, so that on level ground large loads can be moved with a small power input. Because of the time and cost involved in moving and re-laying the track, the use of rail carts is limited to situations where large quantities of material have to be moved over a fixed route. In this Guide only manually operated carts will be considered, though animals or internal combustion engines could be used as the power source:

The cart illustrated in Figure 7.28 has been evaluated experimentally in India, where it was found that one man could move a payload of 100kg on level ground. The cart was originally designed for locomotive operation on a narrow gauge railway, and is therefore very robust. For some applications, such as hauling boulders, this robustness is necessary but in other circumstances the tare weight of the cart could usefully be reduced.

There is considerable scope for improving the design of this cart to increase its usefulness in labour-based road construction:

- i) the included angle between the sides could be increased to facilitate discharge of material.
- ii) the loading height could be lowered.
- iii) a pushing bar should be fitted at each end.

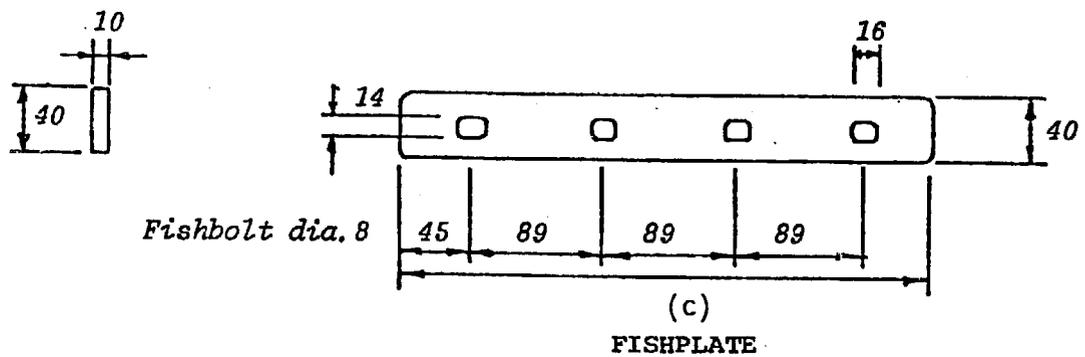
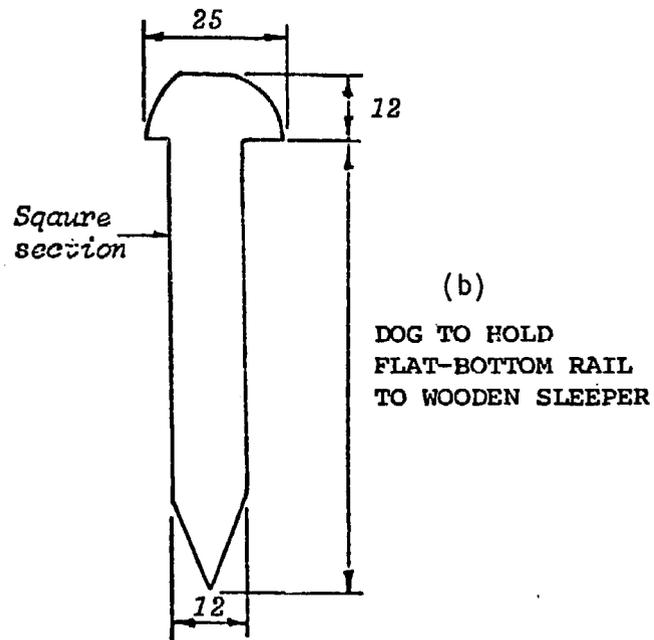
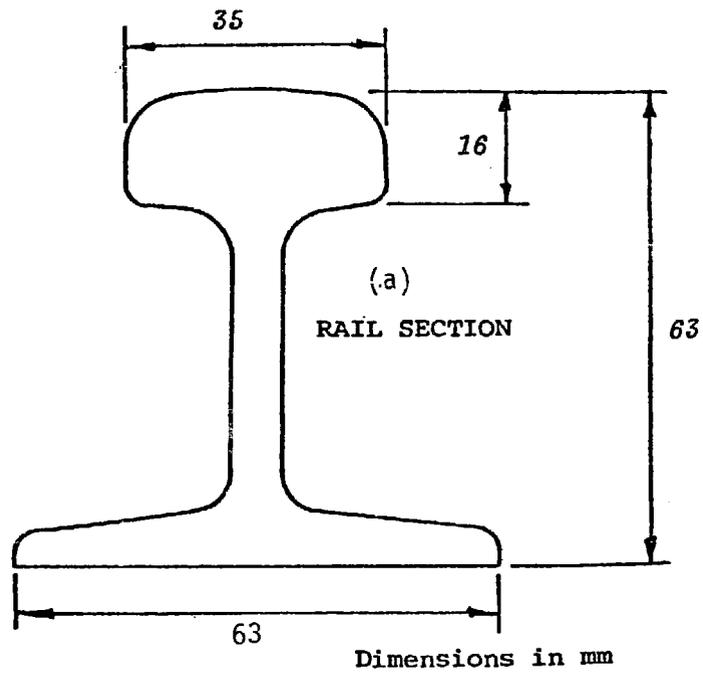


FIGURE 7.29 : TRACK COMPONENTS

- iv) the tipping mechanism could be modified. The tub is retained in the loaded position by a locking mechanism. When this is released the tub can be tipped to either side. The tub pivots and moves sideways during unloading, but the lateral movement tends to lift the cart off the track and de-rail it.

The wheels are fixed to the axles which rotate in plain bearing axle boxes mounted on the perimeter frame.

Figure 7.29 illustrates components of the track. The rails (a) are attached by dogs (b) to sleepers spaced at intervals of about 1.5m. Adjacent sections of rail are clamped together by a pair of fishplates (c).

<i>Materials</i>	:	<u>Cart</u>	Tub	- mild steel sheet 6mm thick
			Frame	- rolled steel channel section 100mm x 50mm
			Wheels	- cast steel
			Axle	- rolled, forged or bright drawn steel. 45mm dia.
		<u>Track</u>	Rail	- rolled steel section
			Fishplate	- mild steel
			Sleeper	- seasoned hardwood 100mm x 100mm cross section 1.25m long.
			Dogs	- mild steel

Manufacture : The cart can be manufactured in a well-equipped workshop. The tub can be fabricated by welding or rivetting but the inside surface should, as far as possible, be smooth and free of obstructions that might trap corrosive material.

Standard wheels and rail sections should be used wherever possible.

The holes in the sleepers to receive the dogs should be template drilled to ensure that correct track gauge is maintained.

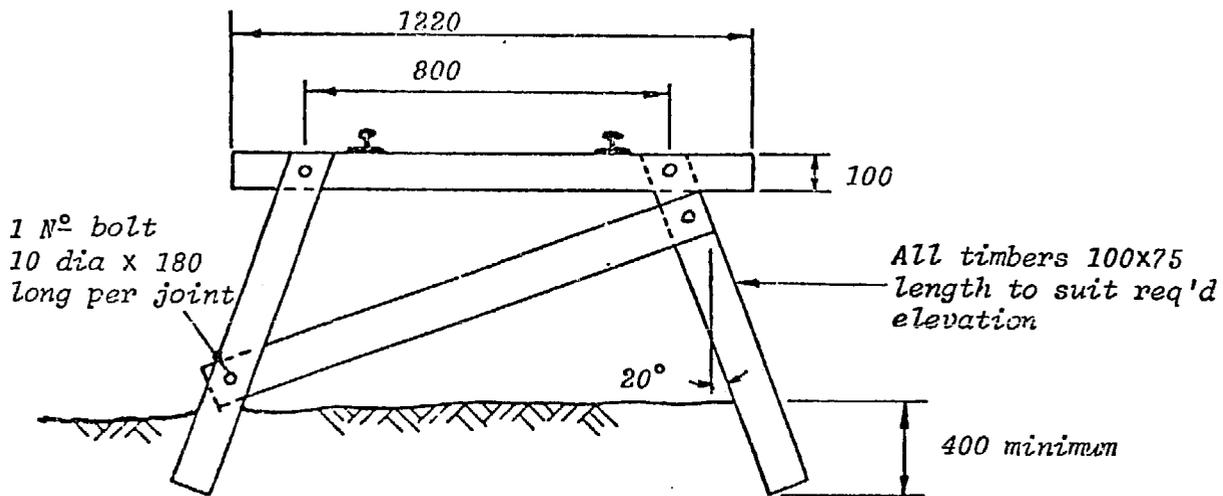


FIGURE 7.30 : TRACK SUPPORT TRESTLES

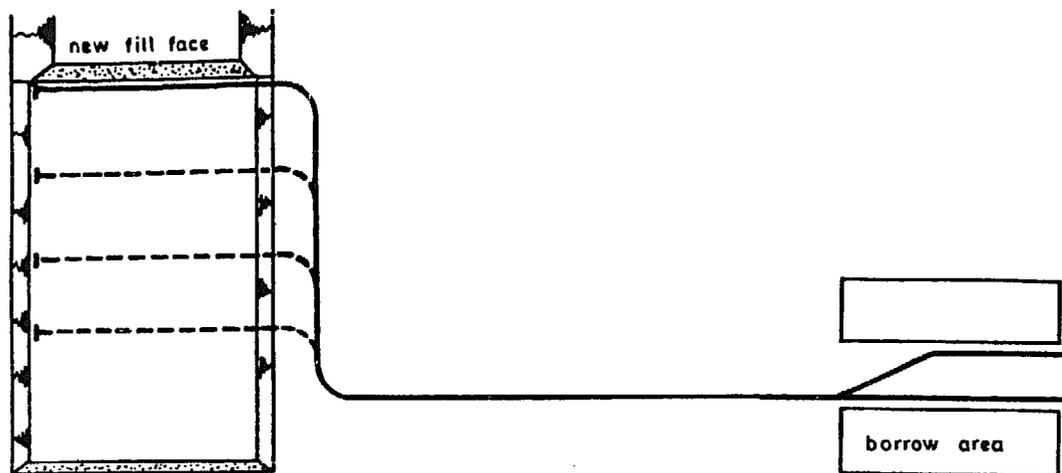


FIGURE 7.31 : TRACK LAYOUT

Operation : The track should be laid on a rough prepared formation. Over rough ground, trestles (Figure 7.30) may be used to ensure a level track.

The simplest layout is a single track from the load area. With this layout only one cart can be used. The addition of a turnout and siding at the load area (Figure 7.31) allows two cart operation, one being loaded while the other is hauled. Figure 7.31 also shows how minor changes can be made to the track layout (e.g. as the unloading position changes) while the major portion of the track remains fixed. Uphill haulage of the loaded cart is difficult using human power, though winch assistance may be used if necessary. However, where feasible the track should be level or have a downward gradient. A down-slope of about 2% is sufficient for the loaded truck to be moved by gravity. The empty cart can be pushed up the slope manually. If gravity haulage is used, then the cart should be fitted with a brake or, alternatively, the unload end of the track can be given a rising grade to slow the cart.

Minor excavation may be required at the loading area to give a level track and reduce the loading height.

Suppliers : Mining and quarrying suppliers. It may be possible to obtain second hand rails, sleepers and carts.

INTRODUCTION

This Section discusses implements for the spreading of excavated and dumped material prior to compaction or stabilisation, or as a finishing operation.

Information on the following implements is given:

- fork*
- hoe*
- rake*
- shovel*
- animal-drawn drag
- tractor-drawn drag

The technical specifications of those marked with an asterisk * are given in Section 1: HANDTOOLS. This Section discusses only the application of these implements in spreading.

Spreading only arises as a separate operation when material is hauled and dumped in piles on the formation or by the side of the road. However, even if spreading has been carried out as an integral part of other operations work is generally required to keep the fill area tidy and, therefore there will usually be some (small) manual input.

APPLICATION

Manual methods of spreading have the advantage that rocks, roots or large lumps of earth can be removed or broken up. The main disadvantage is the difficulty of ensuring a smooth and even thickness layer, although the use of simple camber templates or boards and good supervision will overcome these problems.

Hoe and Shovel: Used with hard materials that have to be both dug and spread and which may require the larger lumps of soil to be broken, or very loose fine soils and sands.

Fork: Used with granular materials such as gravels and crushed brick.

Rake: Used with granular materials such as gravels and crushed brick , and for final spreading of all but very fine materials.

Animal-drawn drag: Used for final distribution and levelling of material previously rough spread by hand. The height of material which it can cope with is normally limited to 25-40mm.

Tractor-drawn drag: Because of the greater power, thicker layers of evenly spread material can be handled than with the animal-drawn version.

TOOLS AND EQUIPMENT

Operation - General

Whenever possible spreading should be carried out as an integral part of other operations such as excavation; unloading; or excavate, haul, spread etc. so as to minimise the cost of construction. Whether this will be feasible or not is primarily a function of haul distance and haulage mode. For example, soil excavated from the sidedrains can be thrown and spread onto the road, and tractor drawn scrapers can excavate, haul and spread in one operation.

It is important that material is spread and compacted *quickly* so that the moisture contained in newly excavated soil is not lost by evaporation since if this occurs additional water may have to be supplied for compaction; and *evenly* so that compaction produces a structure of uniform strength. If spreading is part of soil stabilisation then the need for a layer of uniform thickness is crucial to the success of the operation.

ANIMAL-DRAWN DRAG

Design : Figure 8.1 illustrates a simple animal-drawn drag. Similar devices can be made from scrap lengths of railway line, or steel joists.

Material : Seasoned wooden planking, mild steel plate and metal chain.

Manufacture : Requires simple wood and metal working facilities.

Operation : Two animals are normally required to draw the drag. The depth of cut can be increased up to a maximum of about 40mm by placing ballasting weights on the cross-planks where the animal handler normally rides. The angle at which the drag operates to the centre-line of the road can be adjusted by moving the position of the hitching link.

Suppliers : N.A.

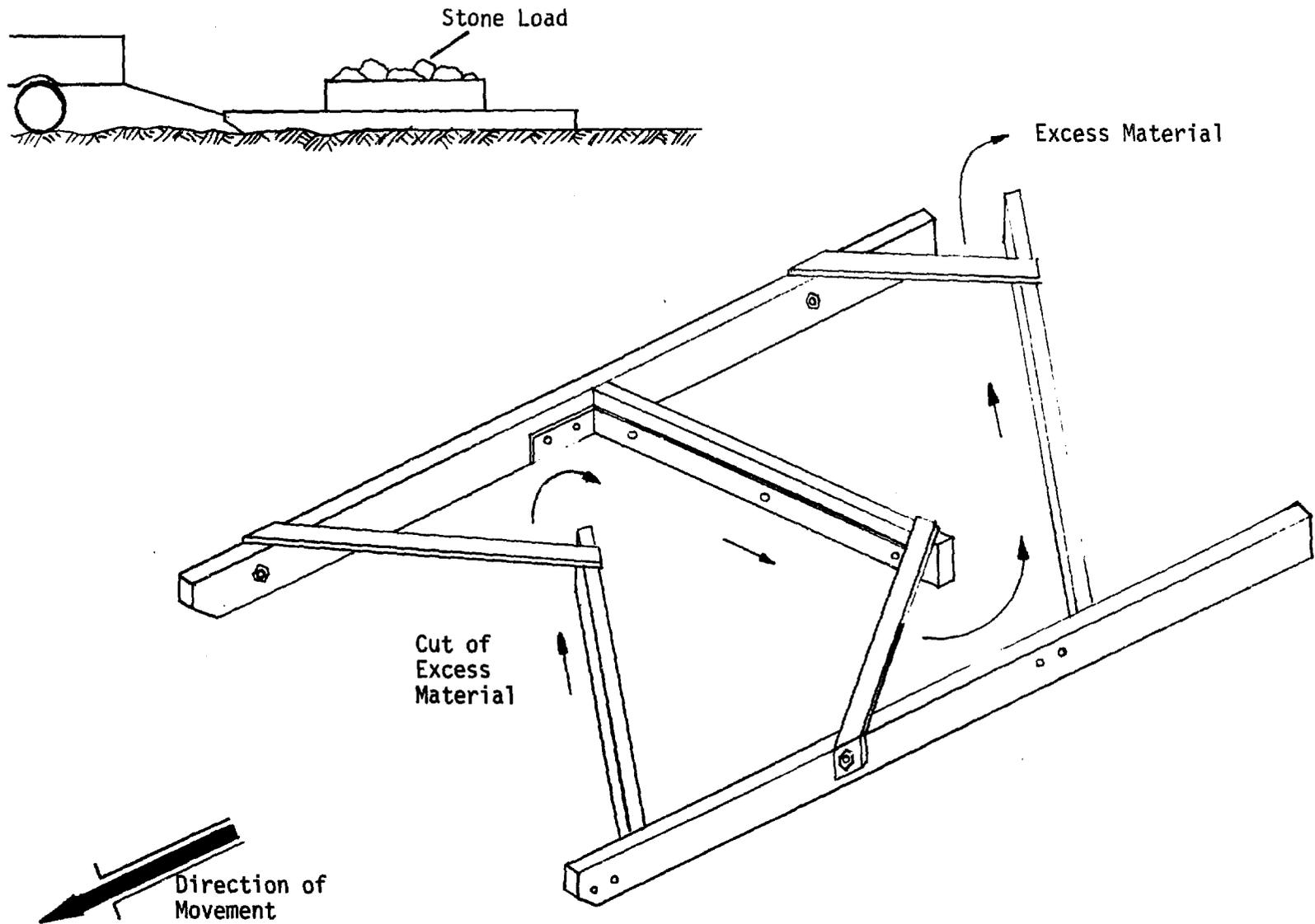


FIGURE 8.2: TRACTOR-DRAWN DRAG: HONDURAS

TRACTOR-DRAWN DRAG

- Design* : The simplest forms of tractor-drawn drag are little different from the animal-drawn type illustrated in Figure 8.1. The greater power of tractors enables higher productivities and greater depths of cut than are possible with animal-drawn drags. Figure 8.2 illustrates a tractor-drawn drag developed for a labour-based road construction programme in Honduras. The overall length is 4300mm and width 1800mm. (A later version, not yet tested will be 6100mm long with 5 diagonal beams). The outlets at the end of each diagonal are about 300mm.
- Materials* : 50x100mm wooden beams with steel plate re-inforcement at the corners of the diagonal beams.
- Manufacture* : Requires simple wood and metal working facilities.
- Operation* : In the Honduran version the drag is towed either by a tractor or a pick-up truck. Stones larger than 25-40mm should first be removed by hand otherwise the drag will lift and an uneven surface result. Excess material is discharged at the side of the road from where it is re-spread by hand. Ballasting to increase the depth of cut, is by stones as illustrated in Figure 8.2. When empty the drag can easily be handled by a gang of 4-6 men.
- Suppliers* : N/A.

INTRODUCTION

This Section discusses implements for the provision of water to road works. Equipment to sink and operate deep boreholes, when surface water is unavailable, is very expensive and is not considered here.

Information on the following implements is given:

- bucket
- hand pump
- foot pump
- watering can
- yoke
- handcart and bowser
- animal-drawn bowser
- tractor-drawn bowser

APPLICATION

The operation of watering comprises the filling of haulage containers, and the haulage and dispersal of the water. The main factors affecting the type of implements used are the amount of water required and the haul distance.

FILLING HAULAGE CONTAINERS

Hand and foot pumps: A major requirement for pumps used in labour based road construction is portability. Such pumps are usually of the low-lift shallow-well type. The practical height that water can be lifted (suction head) is normally 6-8 metres depending upon the efficiency of the installation. With increasing installation altitude reduced barometric pressure will further lower the efficiency of simple pumps. At 3000 metres the loss of head will be about 25 per cent. The Vergnet diaphragm pump does not suffer from these difficulties and, with some loss of portability, can be operated at up to 60 metre heads.

Manual and foot operated pumps suitable for road construction activities are capable of supplying between 600-10,000 litres per hour depending upon the size of the pump and lift required: the greater the lift the lower the output.

HAULAGE AND DISPERSAL

The same implements are normally used for both of these activities.

Watering can: The most simple manual method; capacity is limited to 5-12 litres per filling, and haul distance to 30 metres. Capacity can be approximately doubled and haul distance increased by suspending a can from each end of a *yoke*.

Hand cart and bowser: Used where haul route is reasonably smooth and flat. Capacity is 100-200 litres and practicable haul distance 200-400 metres.

Animal drawn bowser: Capacity 750-1000 litres, practicable haul distance 100-500 metres with an operating speed of 2-3km/h.

Tractor-drawn bowser: Capacity 1000-3000 litres, practicable haul distance up to 2km with an operating speed of 10-25km/h.

TOOLS AND EQUIPMENT

FILLING

Operation : General

The time taken to fill haulage containers either by bucket or pump can have an important effect on the economics of the watering operation. To reduce delays a raised storage tank can be erected at the water supply site. This can be filled continuously by hand and provide a rapid gravity feed through a large diameter main directly into the haulage containers as demands require.

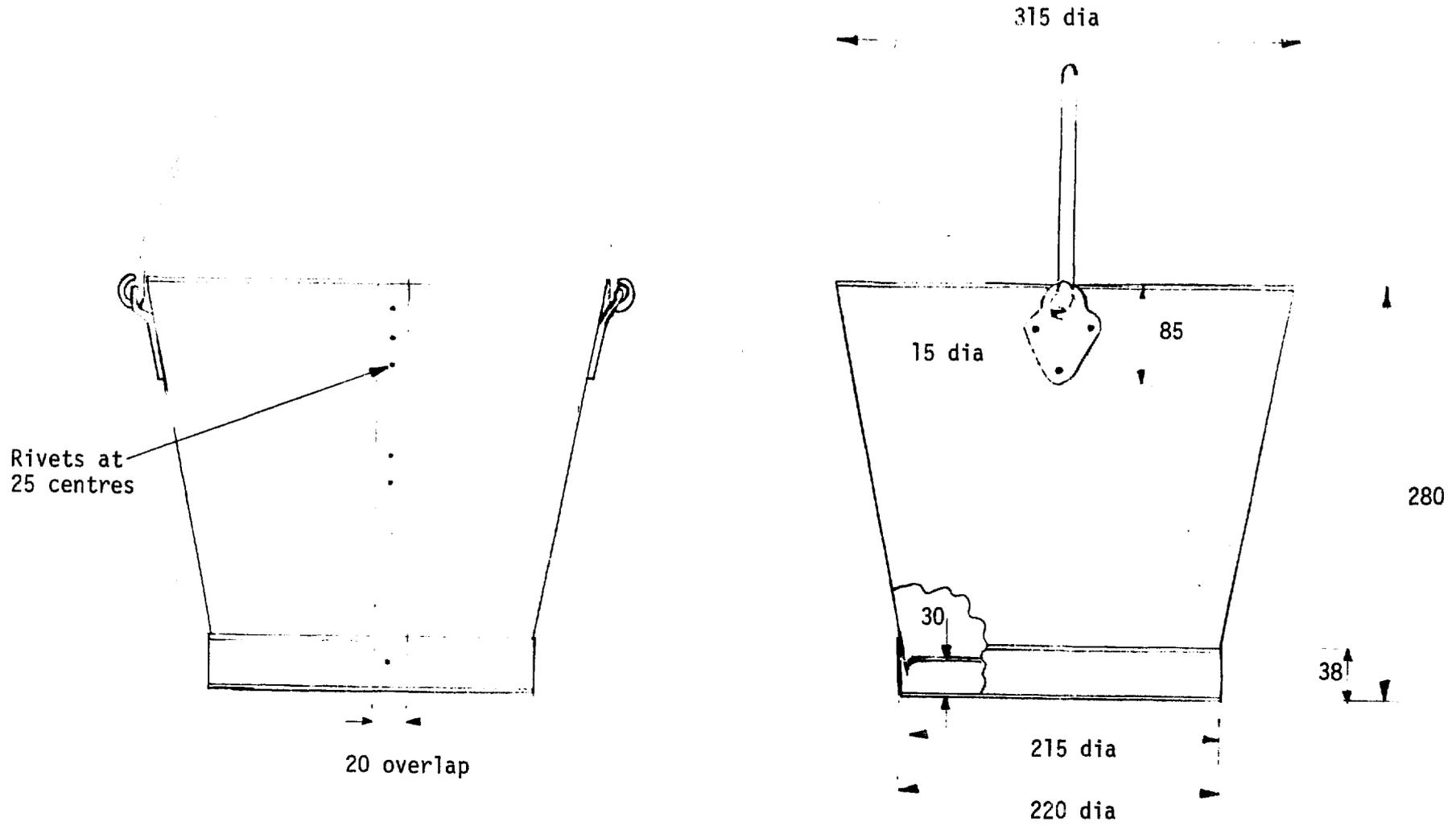


FIGURE 9.1: METAL BUCKET (mm)

BUCKET

- Design* : Figure 9.1 illustrates the dimensions of a metal bucket. The most useful size has a capacity of about 12 litres. The body should be made from one piece joined by an overlapping lock-joint which is rivetted and then soldered. The bottom and top edges are folded over to provide re-inforcement. The handle can be fluted or tubular, and is attached by means of hook clasps formed at each end. These fit into eyelets soldered or rivetted to the body.
- Materials* : Body - galvanized steel sheet at least 2mm thick
Handle - similar material at least 3mm thick if fluted or 10mm diameter bar
Solder - Minimum tin content of 35 per cent.
- Manufacture* : Requires thin metal sheet cutting, bending, rolling, soldering and rivetting equipment.
- Suppliers* : N/A

TABLE 9.1: PERFORMANCE CHARACTERISTICS OF DIFFERENT HAND AND FOOT OPERATED PUMPS

Type	Make	Method of Operation	Inlet/Outlet Pump Diameters (mm)	Head (m)	Output (litres/hour)	Weight (kg)	Remarks
1. Inertia	-	hand	75 100 150	4 2 1	8100 10900 20400	- - -	Suitable for local manufacture
2. Diaphragm	BRR1*	hand	50	5	8200	-	Suitable for local manufacture
3. Diaphragm	IRRI**	foot	100 100	2 1	7200 11400	28 28	Suitable for local manufacture
4. Semi-rotary	KAWAMOTO	hand	32 38 50	7 7 7	1500 2900 5600	12 17 27	
	MEYER	hand	32 38 50	not given " "	4200 5900 10200	13 22 31	Output figures indicate suction head of less than 5 metres
5. Diaphragm	VERGNET	foot	32	25 35 45 60	1400 1250 1000 550	34 50 59 82	Suitable for deep well applications: reasonably portable

* Bangladesh Rice Research Institute

** International Rice Research Institute

HAND AND FOOT PUMPS

Design : General

There are a large number of different types of hand operated pump working on a variety of hydraulic, spring, diaphragm or simple lift principles. Most have been developed for fixed installation deep well applications and are unsuited to road construction operations. Foot operated pumps are usually of the diaphragm type.

Three of the pumps described have been designed for local manufacture. The fourth is one of the commonest and most rugged types of portable hand pump commercially available. The fifth pump described is of special interest because it is portable yet suitable for relatively deep well situations. Table 9.1 gives some figures on the performance of the different types of pump.

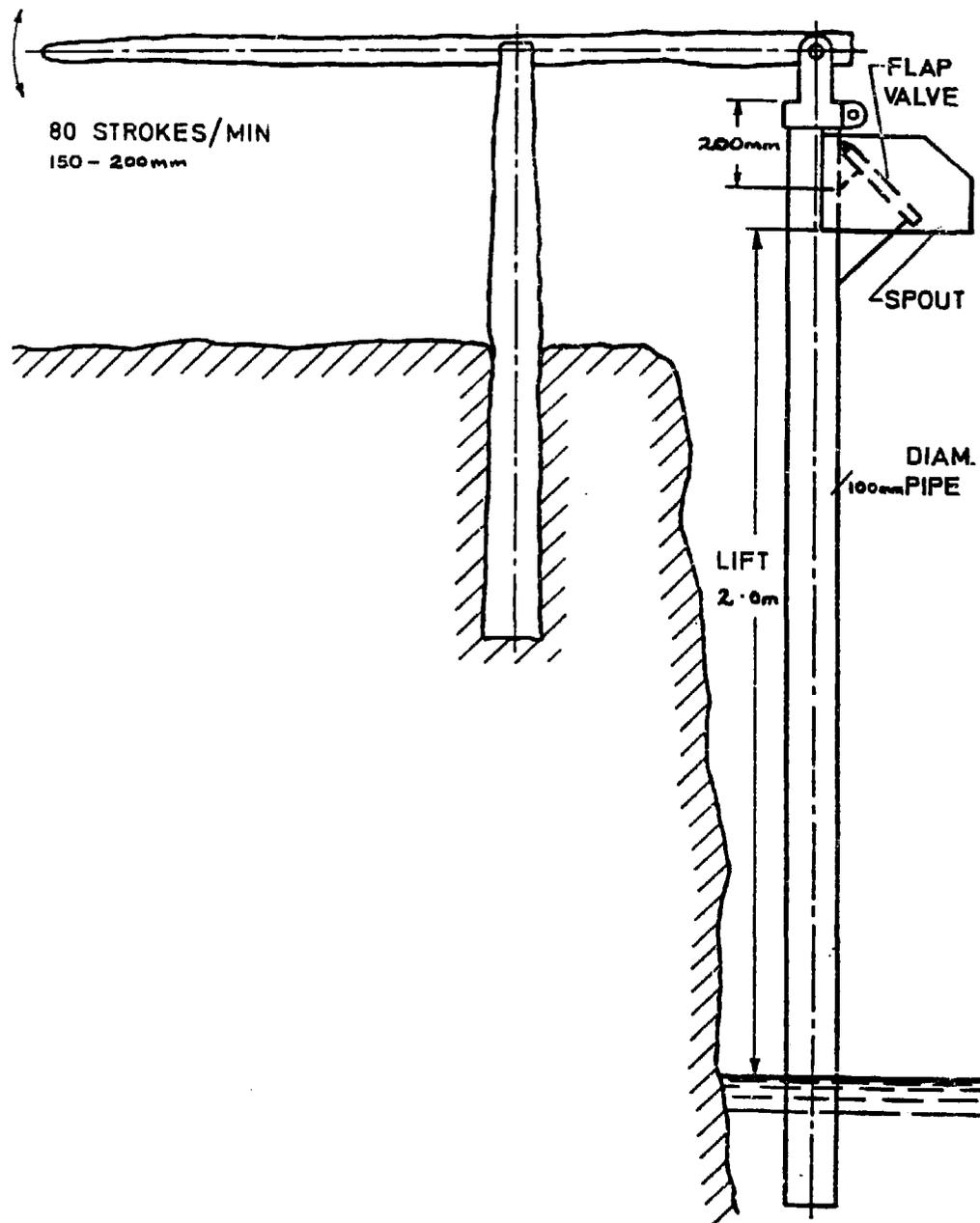
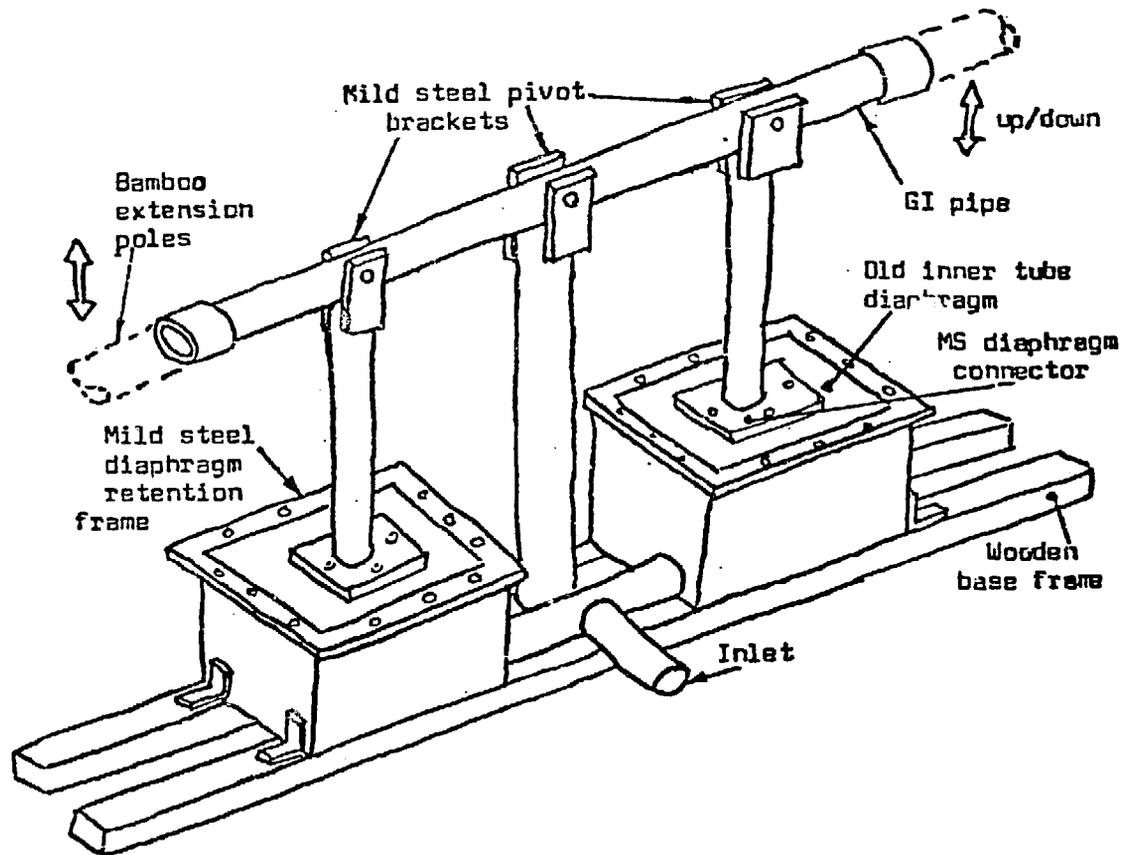


FIGURE 9.2: INERTIA PUMP

INERTIA PUMP

- Design* : Figure 9.2 illustrates a simple inertia pump. It consists of a waist high pole about 2 metres long which is supported and pivoted about a point sufficient to counterweight the rest of the pump. To one end is attached a tube of about 100mm diameter, which has a flap-valve positioned 200mm from the end nearest the pole with the other end of the tube immersed in water.
- Materials* : The pump is normally made of metal, but there seems no reason why it should not equally well be made of bamboo or plastic tubing.
- Manufacture* : Requires simple workshop tools. If made of bamboo the most difficult feature would be the joint between the delivery branch and the main pipe. This might be made by cutting a 90° notch to mate with a similar shaped end of the branch pipe. The two parts could be connected by glueing, binding with tape, a U-shaped metal strap or by a combination of these methods.
- Operation* : The operation of the pump depends on the inertia of the column of water in the pipe, which on the downstroke causes water to be delivered through the flap valve while on the upstroke the valve closes and a fresh volume of water is raised. Very little else is known about this pump although the short 'dead leg' above the valve is thought to serve two functions; the trapped air serving to smooth the flow and helping to 'tune' the system to a particular operating frequency - the performance of the pump is apparently critically dependent on pumping speed.
- If the tube is properly supported, the pump can be operated at a slope.
- Suppliers* : N/A.



Principle of Valve Operation

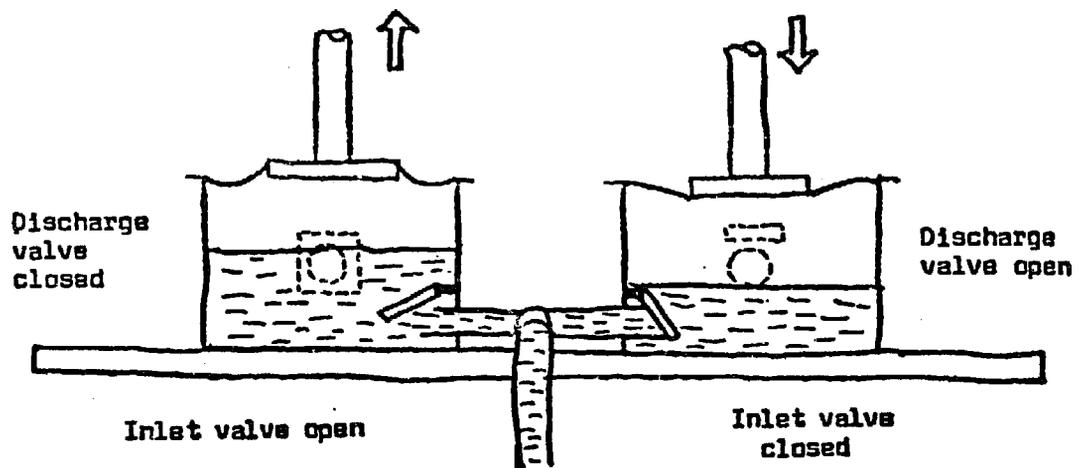


FIGURE 9.3: BRRI HAND-OPERATED DIAPHRAGM PUMP

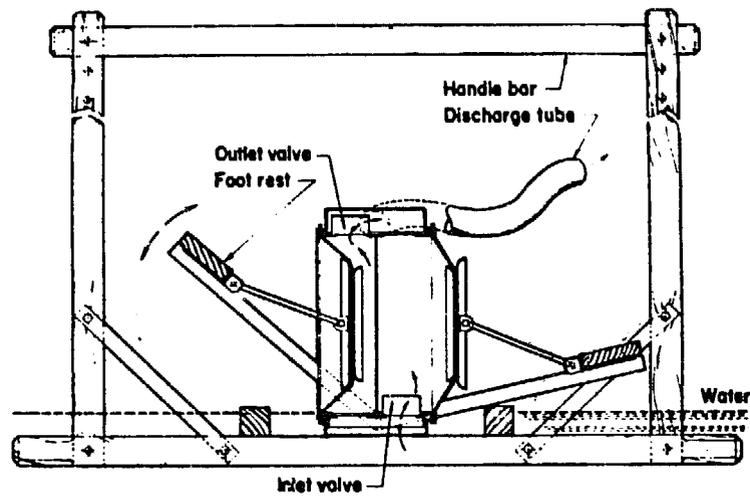
BRRI* DIAPHRAGM PUMP

- Design* : Figure 9.3 illustrates a hand operated diaphragm pump. It consists of two diaphragm operated suction chambers which are inter-connected to a common inlet pipe, but have separate outlet connection: a simple modification could give a common outlet connection. The diaphragms are both connected to piston rods which are reciprocated alternatively as the see-saw over-arm is rocked from side to side on a central pivot. The direction of flow is maintained by four weighted rubber flap (or check) valves, two in each chamber.
- Materials* : 50mm galvanised iron pipe or bamboo; mild steel plate for the diaphragm retention frames; old motor-vehicle tyre inner-tubes.
- Manufacture* : Requires simple workshop facilities.
- Operation* : Most efficiently operated by two persons one on each end of the over-arm which is alternately raised and lowered. The height of the over-arm should be adjusted to be about 100mm below the waist height of the operators so that they can use their body weight efficiently on the power (down) stroke.
- Suppliers* : N/A

* Bangladesh Rice Research Institute : pump designed for irrigation purposes.



FIGURE 9.4: IIRI FOOT OPERATED DIAPHRAGM PUMP



IRRI* DIAPHRAGM PUMP

- Design* : Figure 9.4 illustrates the IRRI foot-operated pump which is shown schematically in Figure 9.5. The pump casing consists of a light sheet-metal cylinder with a central partition to provide two chambers. Rubber flap valves are used on the intake and exhaust ports. The two rubber diaphragms are made from old motor-vehicle tyre inner-tubes and are mounted so that they can be replaced easily.
- Materials* : Wood and steel frame, rubber diaphragms.
- Manufacture* : Requires simple workshop facilities.
- Operation* : The operator stands on the two foot rests and shifts his weight from one foot to the other. This compresses a chamber, forcing water from the outlet valve. By alternately shifting his weight in a rhythmic manner, the operator pumps a continuous flow of water.
- Suppliers* : Drawings can be obtained from the International Rice Research Institute, P.O. Box 933, Manila, Philippines.

* International Rice Research Institute, Philippines.

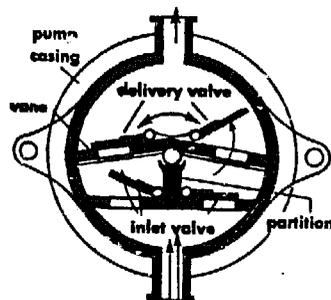
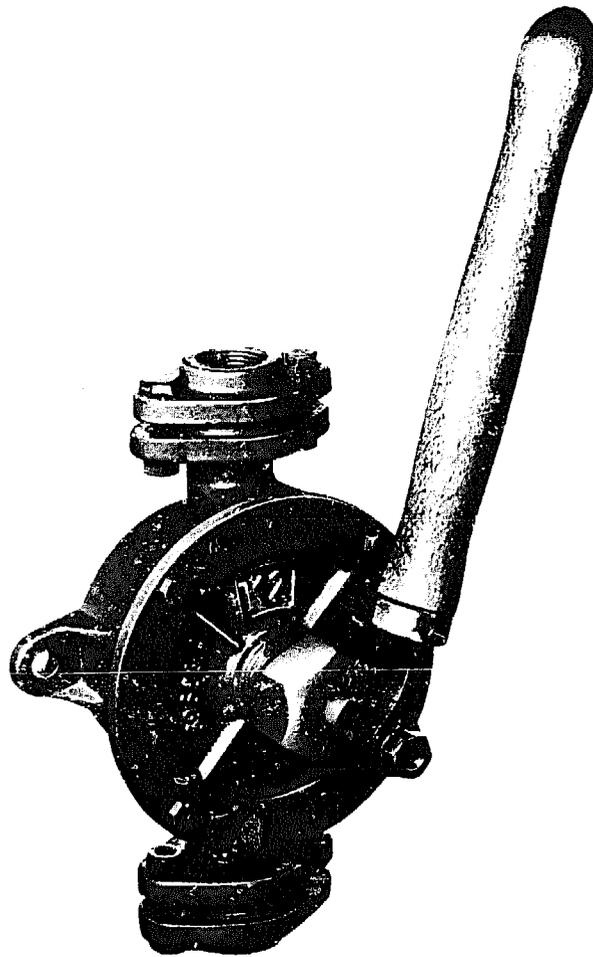


FIGURE 9.6. SEMI-ROTARY or VANE PUMP

SEMI-ROTARY or VANE PUMP

Design : Figure 9.6 illustrates the design of the hand operated vane pump. It consists of a vane or wing cast on the pump spindle; the inlet valves are installed in a fixed partition of the casing, while the delivery valves are in the vane.

Materials : Cast-iron body, brass valve seats and rotor are standard , but can be obtained entirely in brass for handling highly corrosive liquids.

Manufacture : N/A

Operation : Self evident

Suppliers - KAWAMOTU PUMP Mfg. Co. Ltd.
- WILLIAM A. MEYER Ltd.

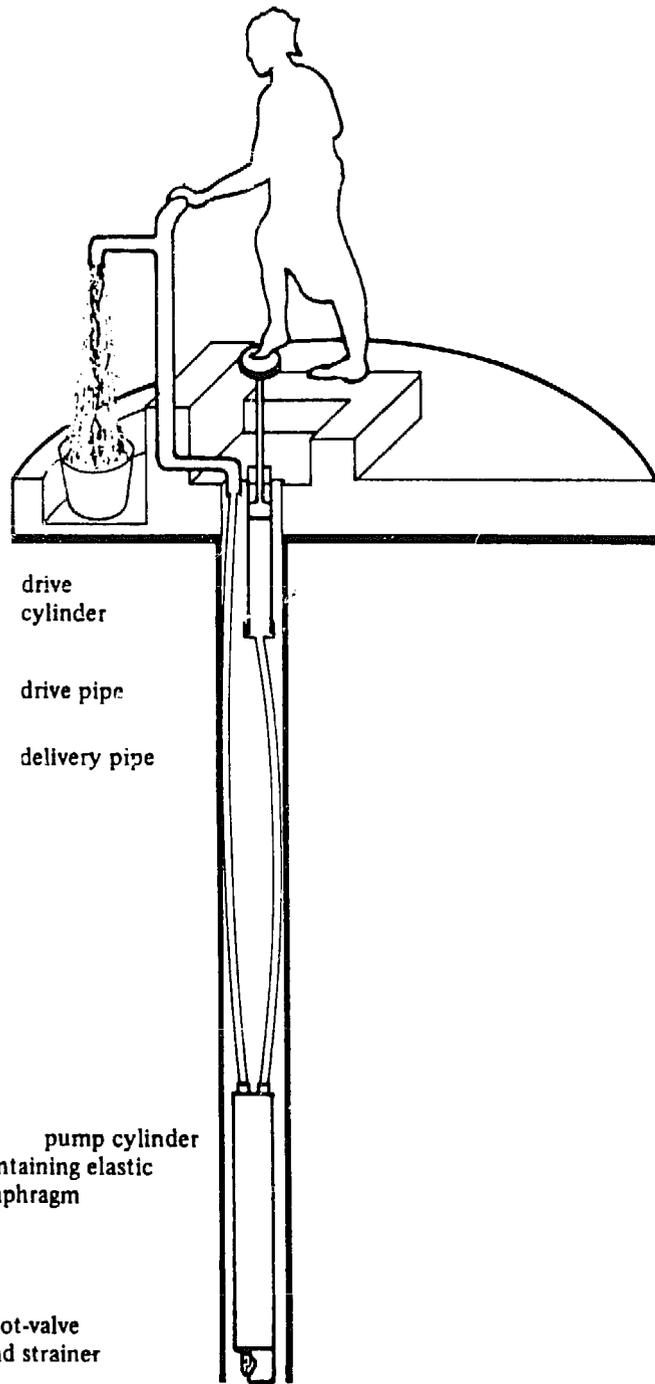


FIGURE 9.7. VERGNET DIAPHRAGM PUMP

VERGNET DIAPHRAGM PUMP

- Design* : Figure 9.7 illustrates the design of the foot-operated Vergnet diaphragm pump. It works on a principle completely different from that of all other manually operated deep well pumps, being effectively a diaphragm pump, with a diaphragm in the cylinder operated by hydraulic action. The pump cylinder is linked to the surface by two pipes, one a driving pipe connected to a drive cylinder containing a foot-operated piston; the other a delivery pipe through which the pumped water emerges.
- Materials* : Drive cylinder and foot pedal - metal or wood.
Piping - plastic.
Pump cylinder - stainless steel.
- Manufacture* : N/A
- Operation* : The whole system is filled with water, the plunger when at rest being in the raised position. The operator presses on the pedal with his foot, and so pushes water through the drive pipe and into the pump cylinder. This has an elastic lining or diaphragm which expands and pushes water out of the cylinder and up the delivery pipe to the surface. When the operator removes his foot from the pedal, at the end of the stroke, the elastic lining pulls back to its original shape, pushing water up the drive pipe and restoring the pedal to its original position.
- Suppliers* : ESTABLISSEMENTS PIERRE MENGIN S.A.

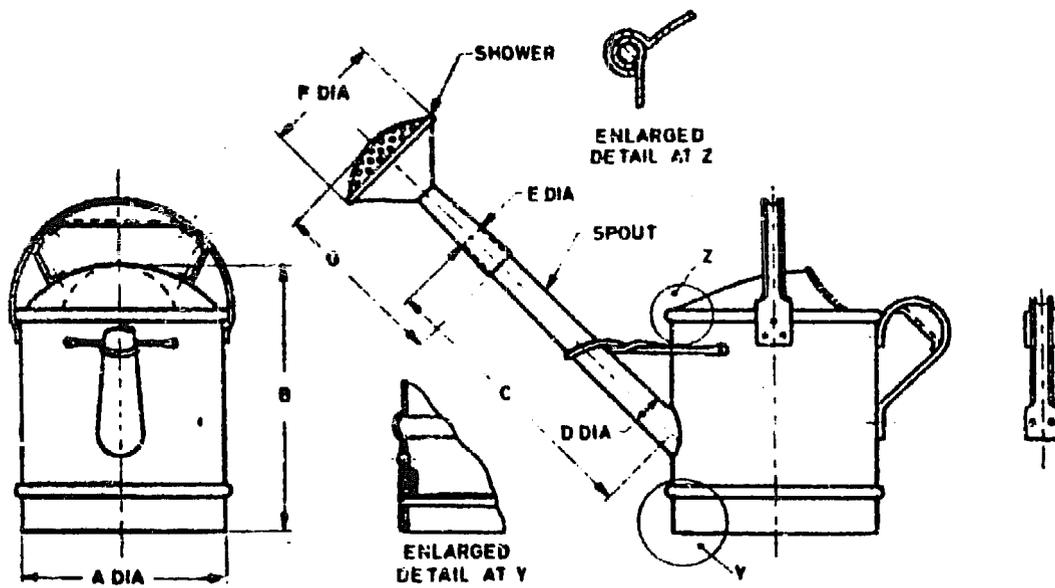


FIGURE 9.8. INDIAN STANDARD WATERING CAN

HAULAGE AND DISPERSAL
WATERING CAN

Design : Table 9.2 gives the dimensions of watering cans recommended in Indian National Standards

TABLE 9.2. DIMENSION (mm) AND CAPACITIES (litres) of WATERING CANS

DIMENSIONS: see Figure 9.8								
Dia- meter of body	Over- all height of body	Length of spout	Diameter of spout		Shower dia- meter	Over- all length of shower	Angle of spout with body	Capa- city. Nominal
A	B	C	D*	E	F	G		
150	200	210	35	20	90	130	45°	5
215	250	260	45	25	110	150	45°	8
250	300	320	50	30	130	150	45°	12

* The dimension shall be measured at a distance of 10 mm from the inner edge.

The body should be made from one piece joined by an overlapping lock-joint which is rivetted and then soldered. The handles can be fluted or tubular and are firmly rivetted to the body. The spout is rivetted and soldered to the body and supported by a wire or metal strip fixed to the body. The bottom ring is rivetted to the body with a lapping of at least 10 mm and its bottom edge is folded inside for extra support where the can contacts the ground.

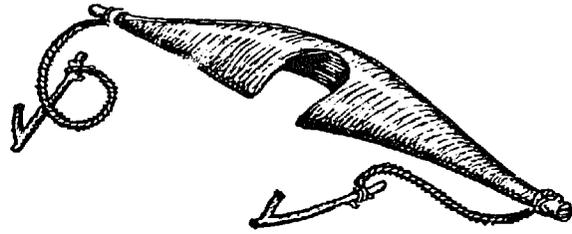
Material : Indian Standards recommend that the body should be galvanised steel sheet at least 0.6 mm thick with the handles of a similar material at least 1.0 mm thickness. This is not stout enough for intensive construction activities and it is recommended that these thicknesses be increased to a minimum of 2 and 3 mm respectively.

Solder - minimum tin content of 35 per cent.

Manufacture : Requires thin metal sheet cutting, bending, rolling, soldering and rivetting equipment.

Operation : Self-evident

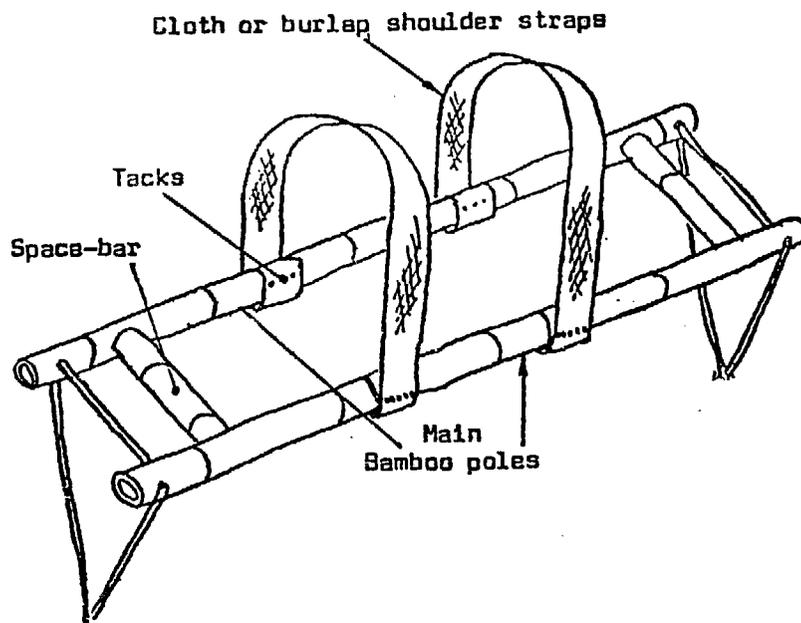
Suppliers : N/A



(a)



(b)



(c)

YOKE

Design : The design of a traditional yoke is illustrated in Figure 9.9(a). It is used in a similar way to the shoulder pole except that it is a rigid member that does not allow the load to oscillate up and down. Thus it is particularly suited to the transport of liquids. The other noteworthy feature is the shoulder collar which is shaped to fit comfortably around the neck. Alternative methods of constructing a yoke are shown in Figure 9.9(b) and (c). Type (b) consists of an elongated hoop of flexible wood or bamboo strip, with two woven material straps over the shoulder. Type (c) is similar except two parallel bamboo beams replace the hoop. To keep the movement of the liquid to a minimum it is useful to make the connection between the yoke and can of wood or stiff metal rod so that flexing does not take place.

Materials : Any reasonably stiff seasoned wood

Manufacture : Simple wood-working facilities

Operation : Self evident

Suppliers : N/A

HANDCART AND BOWSER

- Design* : Consists of a 100-200 litre drum and spray bar fitted to a simple hand cart chassis mounted on two bicycle, or possibly moped wheels. For ease of movement it may be necessary to insert some perforated metal baffles inside the drum. Tests at CRRRI* suggest that the spray bar should be made of 25 mm galvanised steel pipe, with countersunk spray holes of 4-5 mm diameter.
- Materials* : Scrap oil-drum, bicycle or moped wheels, angle-iron or metal tube frame and 25 mm galvanised steel pipe.
- Manufacture* : Requires simple workshop facilities
- Operation* : Self-evident
- Suppliers* : N/A

*

Central Road Research Institute, India



FIGURE 9.10. ANIMAL DRAWN WATER BOWSER: PHILIPPINES

ANIMAL-DRAWN BOWSER

Design : Figure 9.10 illustrates the design of an animal-drawn bowser. It consists of three inter-connected 200 litre metal drums on a single-axle cart drawn by a buffalo. The rear drum is equipped with a spray bar. With two animals a larger cart and 5-6 drums would be feasible giving a capacity of about 1000 litres. The drums should be horizontal rather than vertical to minimise variation in water head and thus rate of spraying.

Materials : See SECTION 7: HAULING (ANIMAL-DRAWN CARTS) pages 7.39-7.47.

Manufacture : Requires simple workshop facilities

Suppliers : Self evident

N/A

TRACTOR DRAWN BOWSER

- Design* : Single-axle trailers are preferred because they are more manoeuvrable than two-axle trailers. These can be fabricated in a range of capacities to suit the power of available tractors.
- Materials* : See SECTION 7: HAULING (FOUR WHEELED TRACTOR-TRAILER) pages 7.53-7.65.
- Manufacture* : Requires heavy workshop facilities
- Operation* : Self-evident
- Suppliers* : N/A

INTRODUCTION

This Section discusses implements for the compaction of earth and gravel used for the road formation. Self-propelled and towed rollers requiring specialised transport between sites are not considered here.

Information on the following implements is given:

- hand rammer*
- pedestrian operated power rammer
- pedestrian operated vibrating rammer
- pedestrian operated vibrating plate
- pedestrian operated vibrating roller
- animal-drawn dead weight roller
- tractor-drawn dead weight roller

The technical specification for that marked with an asterisk * is given in Section 1: HANDTOOLS. This Section discusses only the application and operation of this implement.

Provided appropriate construction and maintenance schedules are adopted experience from the KRARP suggests that direct compaction is often unnecessary on minor roads constructed by labour based methods. Given a suitable period of time indirect compaction - due to rain, and the passage of animals, pedestrians and vehicles - can give densities of the same values as those achieved by direct compaction methods particularly if the traffic is sensibly channeled. In confined spaces such as close to bridge supports and abutments or if there is a risk of rapid soil erosion direct compaction is desirable.

Labour-based road construction programmes involving a large number of relatively small projects favour 'light' plant which can be powered or guided by pedestrians, and transported by small truck.

APPLICATION

Direct compaction can be achieved by impact, vibration and dead weight rolling. Two and sometimes all of these are combined in some types of compaction equipment.

IMPACT

Compaction by impact only can be achieved with hand or power rammers and free falling weights.

Hand rammers: Very cheap to produce and can produce a high degree of compaction if the layers to be compacted are no more than 100-150mm which limits output.

Power rammer: Even relatively light power rammers can produce a high degree of compaction either by using a small area rammer or a relatively fast stroke. Power rammers and falling weight compactors produce great compactive effort at depth, but have an inherently low output. They are used on all types of soil usually for the reinstatement of trenches and compaction in confined areas such as bridge abutments.

VIBRATION

Vibrating equipment is particularly suitable for granular soils. The vibrating effect will be felt to a depth which will depend on the nature of the compacted material and sub-soil, and on the intensity of the vibrations: only with granular soils is the state of compaction sensitive to the frequency of vibration.

TABLE 10.1 : OUTPUT OF LIGHT COMPACTION PLANT¹

Type of Plant	Width compacted by plant m	Speed of rolling m/min	Number of passes required	Area compacted per hour m ²	Depth of compacted layer mm	Output of compacted soil per hour m ³
100kg power rammer	0.05 Area in m ²	60 blows/min	6 blows	25	150	3.8
55kg vibrating rammer	0.28	5	3	23	100	2.3
75kg vibrating rammer	0.28	12	4	42	150	6.3
100kg vibrating rammer	0.40	8	3	53	200	11
200kg vibrating plate compactor	0.38	10	3	63	150	9.5
450kg vibrating plate compactor	0.61	20	12	51	130	6.6
660kg vibrating plate compactor	0.61	15	4	110	200	22
700kg vibrating plate compactor	0.61	15	2	230	150	35
200kg vibrating roller	0.61	10	8	38	80	3.0
350kg vibrating roller	0.71	20	12	59	150	8.9
1.0 tonne tandem vibrating roller	0.81	20	4	200	150	30
2.8 tonne smooth-wheeled roller	1.30	50	8	410	130	53

¹ Compiled from the results of investigations into the performance of compaction plant carried out at the Transport and Road Research Laboratory (U.K.). Data indicates the possible performance of plant under average conditions encountered in the United Kingdom. Outputs have been estimated on the assumption that the machines operate for 50 minutes in each hour.

Vibrating rammer: Also known as Vibro-Tampers. Suitable for all soil types.

Vibrating plate: Equipment less than about 450kg is only suitable for granular soils. Heavier compactors are suitable for most other soils with the exception of heavy clays.

Vibrating roller: Equipment less than about 2 tonnes is only suitable for granular soils. Heavier compactors are suitable for most other soils with the exception of uniformly graded sand. In general a vibrating roller will compact to a greater depth and to a higher degree than will a much heavier dead-weight roller.

ROLLING

Suitable for all soil-types except soft wet clay and uniformly graded sand. Portability considerations will limit the size of roller and thus depth of layer that can be compacted to 150-200mm. Water or sand ballasting of hollow rollers or tanks fitted over them can increase both the weight and depth of compaction.

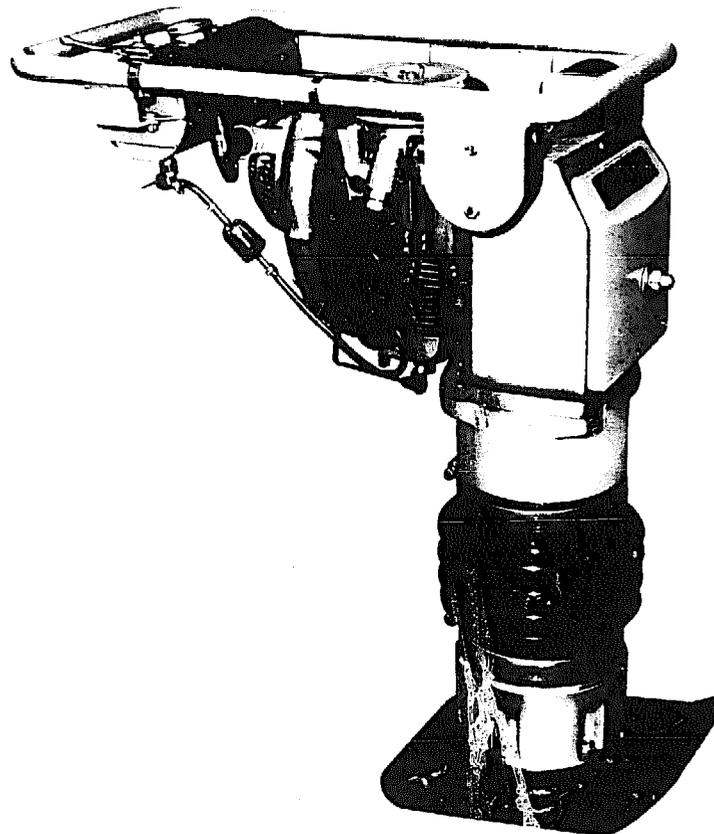
Animal drawn roller: With two oxen, weight will be limited to a maximum of about 1 tonne. At present there is little experience with either the application or design of animal drawn rollers.

Tractor drawn roller: Weight will be limited to between 2-3 tonnes.

Table 10.1 provides guidance on the output of different types of light compaction plant some of which are illustrated in Figures 10.1 to 10.4.



FIGURE 10.1 POWER RAMMER



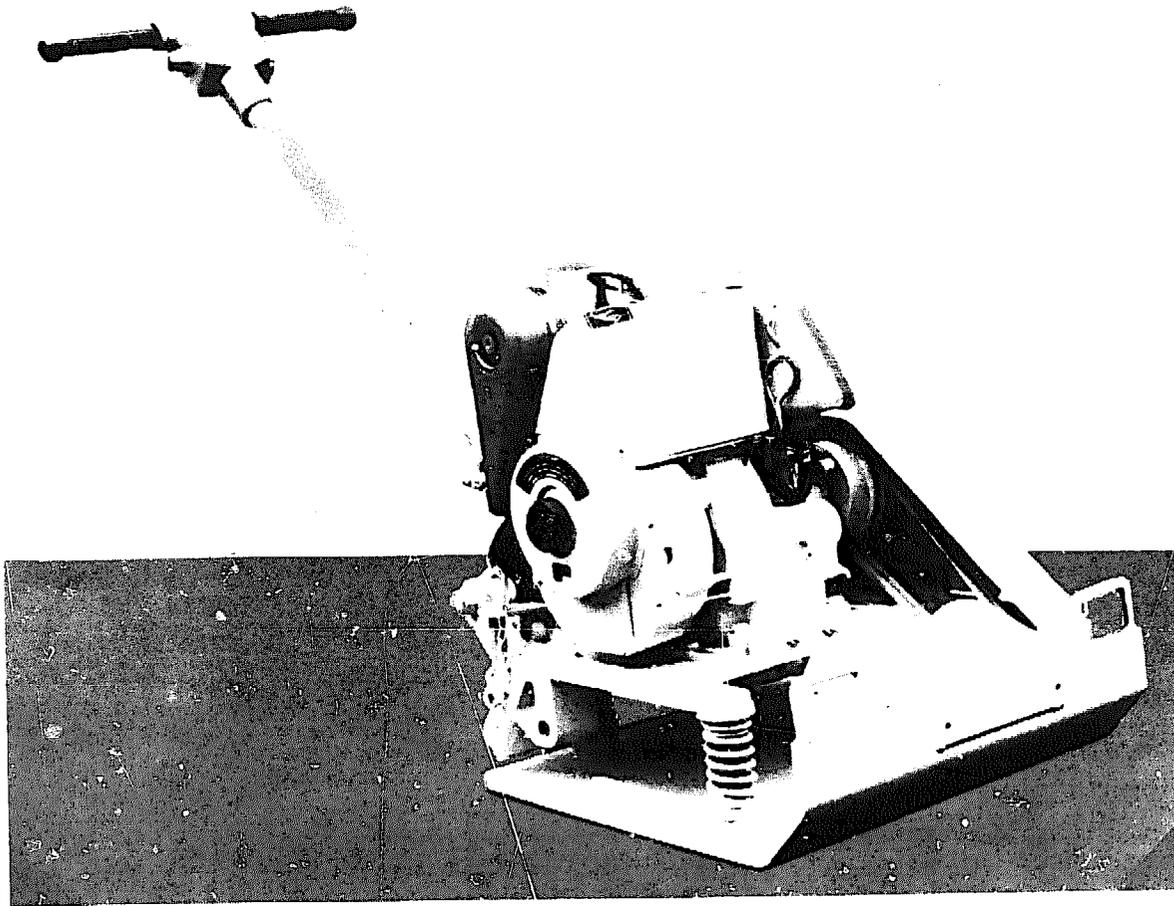


FIGURE 10.3 VIBRATING PLATE COMPACTORS

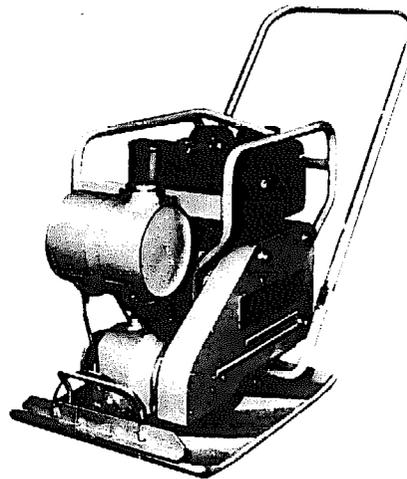


FIGURE 10.3 (*alternative illustration*)

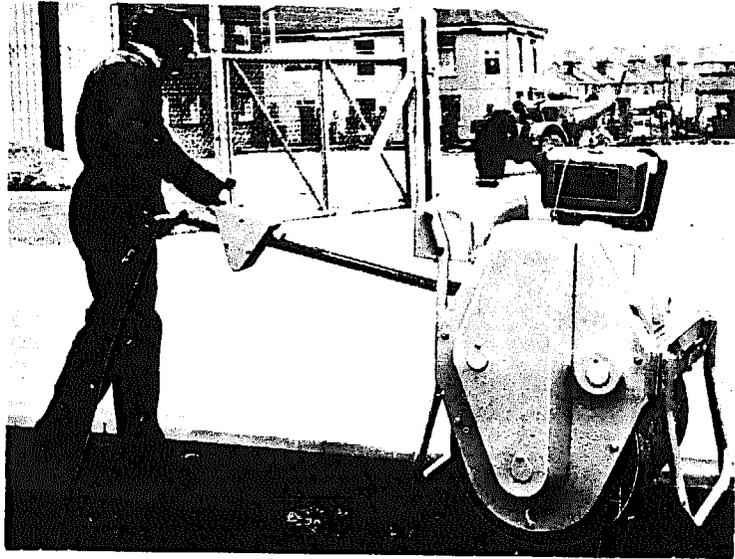


FIGURE 10.4 VIBRATING ROLLERS

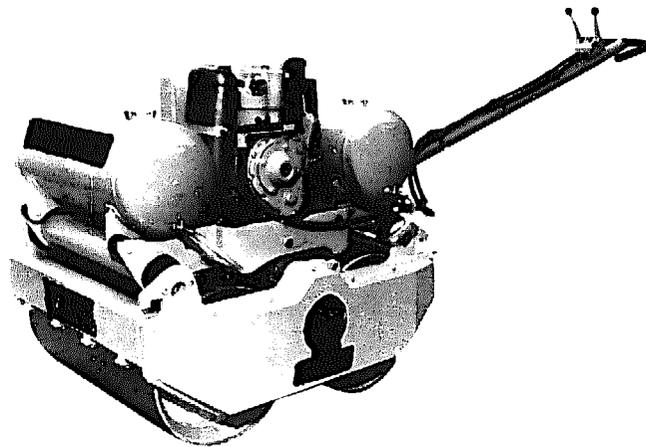
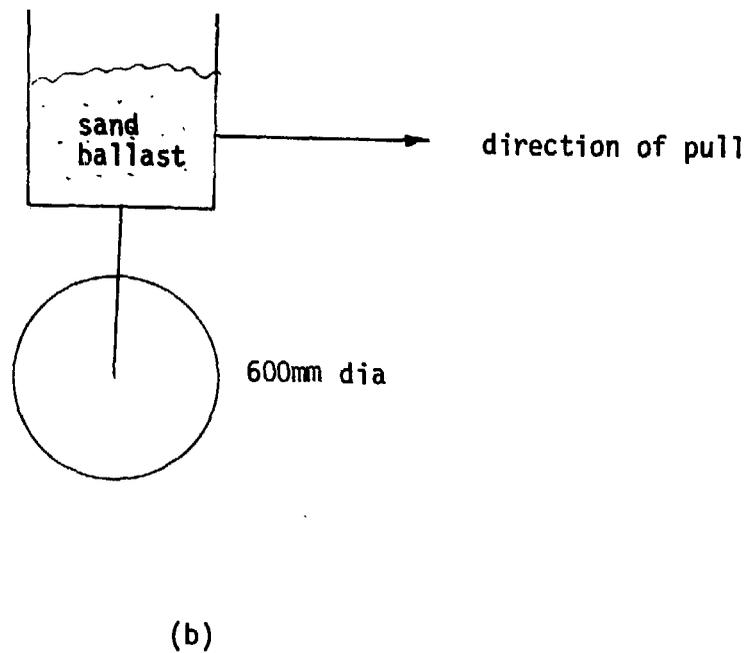
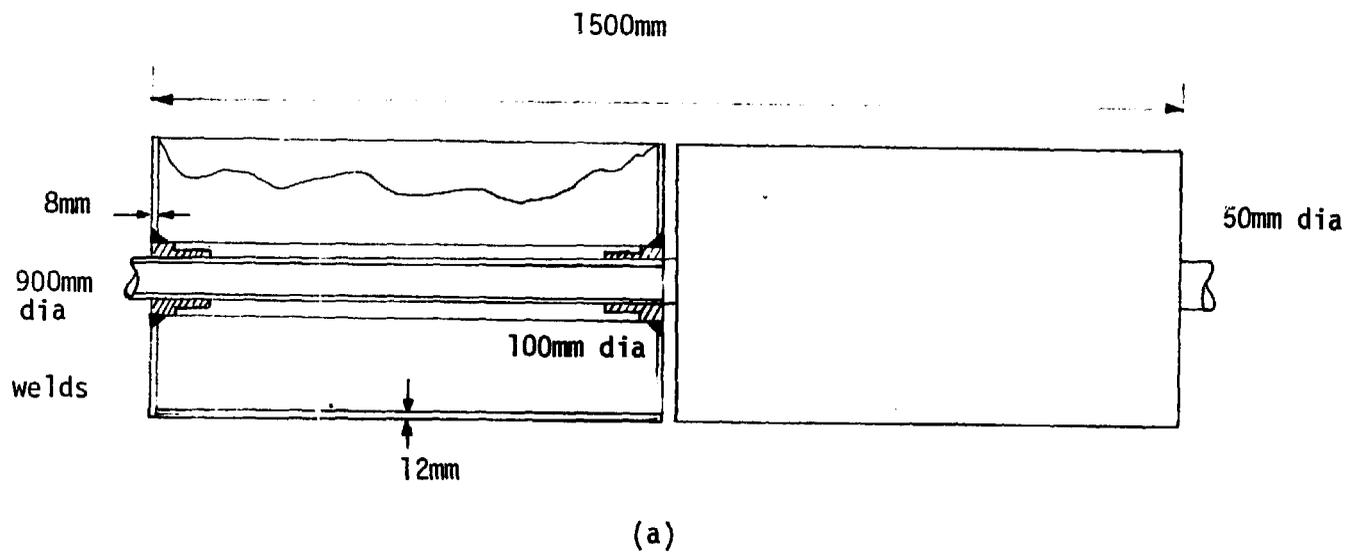


FIGURE 10.4 *(alternative illustration)*

TOOLS AND EQUIPMENT

HAND RAMMER

Operation : Hand rammers are normally used for compacting fairly restricted areas particularly those inaccessible to plant. If it is not possible to transport compaction plant to the construction site then a gang of labourers equipped with hand rammers can be positioned to cover the width of the formation. Effective compaction is possible if the material layers are restricted to a maximum of 100-150 mm.



CRRl* ANIMAL DRAWN ROLLER

Design : The design of CRRl's prototype animal drawn roller is illustrated in Figure 10.5(a). It consists of a 900mm diameter roll 1500mm long, but split into two halves for easy turning. The rolls turn on a hollow 50mm diameter shaft which is supported in plain bearings at both ends of each half roll. The bearings are lubricated by grease injected through nipples into each end of the hollow shaft. The weight empty is 500 kgs, and water or sand ballasting inside the rolls gives an operating weight of 1100 kgs which necessitates using two bullocks.

A second roller is under development with a roll diameter of 600mm (Figure 10.5(b)). This gives a smaller contact area and therefore a higher compactive effort for the same load. Ballasting is effected by means of a sand filled tank fitted above the roll. A further advantage is a reduced empty weight which will improve portability.

Materials : Rolls - steel plate

Manufacture : Requires heavy workshop facilities

Operation : Limited trials to date suggest that the prototype animal drawn roller will achieve a two-thirds reduction of a 150mm soil layer in about 10 passes.

Suppliers : N/A

* Central Road Research Institute, India.

TRACTOR-DRAWN ROLLERS

Design : Portability considerations indicate that the design of tractor-drawn rollers ought to follow similar principles to those used in CRRRI's animal-drawn roller. Empty weight must be kept to a minimum and compactive effort obtained by using a relatively small roll diameter 500-1000 mm and on-site ballasting using sand or water either inside the roll or in a container placed above the roller.

Materials : see Animal-Drawn Roller

Manufacture : Requires heavy workshop facilities

Operation : see Animal-Drawn Roller

Suppliers : GRAYS OF FETTERANGUS (1972) Ltd.

Suppliers : Power Rammers

- WARSOP POWER TOOLS

Vibrating Rammers

- ELBA MEXICANA S.A.
- LOSENHAUSEN MACHINENBAU AG
- ROBERT BASCH GmbH
- STOTHERT & PITT Ltd.
- WACKER (Great Britain) Ltd.
- WARSOP POWER TOOLS

Vibrating Plate Compactors

- ELBA MEXICANA S.A.
- HEINRICH MACHINERY & TOOL Mtg. Co. Inc.
- KOEHRING GmbH
- LOSENHAUSEN MACHINENBAU AG
- MASCHINENBAU B. KALTENEGGER GmbH
- ROBERT BOSCH GmbH.
- S.L. SALOMON Inc.
- STOTHERT & PITT Ltd.
- WACKER (Great Britain) Ltd
- WARSOP POWER TOOLS

Vibrating Rollers

- ELBA MEXICANA S.A.
- KOEHRING GmbH
- LOSENHAUSEN MASCHINENBAU A.G.
- MASCHINENBAU B. Kaltenegger GmbH
- NIS Marketing Ltd.
- STOTHERT & PITT Ltd.
- WACKER (Great Britain) Ltd.
- WINGET Ltd.

INTRODUCTION

This section discusses implements for soil stabilisation with cement, lime or bitumen . The choice of stabilisation agent and the design of mixes is not considered.

Information on the following implements is given:

- shovel*
- hoe*
- rake*
- animal-drawn rotary harrow
- animal-drawn disc harrow
- tractor-drawn disc harrow
- single-axle tractor and rotavator
- tractor-mounted rotavator
- tractor-mounted rotary harrow

The technical specifications of those marked with an asterisk* are given in Section 1 : HANDTOOLS. This Section discusses only the application of these implements in soil stabilisation. Coverage of animal-drawn implements assumes the use of bullocks or buffaloes. Donkeys could be used, but their draught capacity, and hence output, is lower.

APPLICATION

The construction of stabilized road bases involves the proportioning and mixing of the stabilizer and soil and the compaction and shaping of the mixed materials. There are two methods used for incorporating stabilizing agents into the soil: plant mix and mix-in-place.

The static plant-mix method is not considered here since it is unsuited to most road construction projects.

The mix-in-place method is possible with various types of implement. The primary requirement is to achieve an even mixing of the correct proportions of soil and stabiliser. Soil stabilisation is seldom an entirely manual operation because of the difficulty of ensuring an even distribution of the stabiliser throughout the soil. The same difficulty limits the usefulness of graders and some types of agricultural equipment. To mix soil and stabiliser thoroughly it is often necessary to break the former down into a fine tilth.

With enough passes *animal drawn rotary and disc harrows* and the *tractor-drawn discs harrow* will produce the required degree of pulverisation, but they are designed mainly to reduce the soil lumps on the surface only and their depth of penetration is limited. The tractor powered devices operate at a faster rate and produce a greater depth of penetration than those drawn by animals.

The various types of *rotavator* are designed to produce a high degree of pulverisation in relatively few passes. Those mounted on four wheeled tractors operate at a faster rate, and produce a greater depth of penetration, than those powered by single axle tractors.

The most recent development has been the *tractor-mounted rotary harrow* with the soil contacting components attached to a vertical shaft. The vertical rotors are directly followed by a crumbler roller which not only packs the tilth evenly, but controls the harrowing depth. The performance of the rotary harrows for soil stabilisation has not been evaluated, but should be similar to that of a rotavator.

In mix-in-place stabilisation with cement or lime the stabiliser can be spread on the loose soil either by hand or by a mechanical spreader. (see Section 8: SPREADING). To obtain an even distribution when spreading cement or lime stabiliser by manual methods requires strict continuous supervision. When stabilising soils with cement or lime it is usually necessary to add water to the pulverised soil to bring it to the correct moisture content for compaction and provide adequate water for hydration. The water is sprayed on to the loose soil with water bowsers (see Section 9: WATERING) in mix-in-place operations. However, most purpose-made mix-in-place pulverisers have provision for adding an accurately controlled amount of water through a metering pump and spray bar. Similar spraybars are used for adding the bitumen when the mix-in-place method is employed for bituminous stabilisation. Thus mix-in-place bituminous stabilisation is only possible where low viscosity binders, i.e. cut backs or emulsions, are available.

The compaction and shaping of stabilised road bases is carried out with normal plant (See Section 10: COMPACTION and Section 8: SPREADING). Soil-bitumen mixtures are compacted most effectively by the kneading action of rubber or pneumatic-tyred rollers.

TOOLS AND EQUIPMENT

HANDTOOLS

Operation : If spreading of the stabiliser is to be done manually then the boundaries of the area to be stabilised should be set out using pegs and string lines with suitable permanent reference marks placed well clear of the area being processed. Then the bags of cement or lime should be placed at predetermined intervals in a number of longitudinal rows. The positioning of each bag is such that its contents are the correct amount required for the depth of soil layer to be stabilised and the surrounding square area. The bags are split open and the stabiliser raked and shovelled or hoed uniformly over the area being processed.

If mixing is to be carried out manually this should be done by first dividing the soil, spread with stabiliser, into convenient areas of a few square metres. Labour should then be instructed to collect the enclosed material into a heap which is then turned with a shovel or hoe and re-spread. Studies in India show that if the material is heaped and turned a minimum of four times, 70-75 per cent of the strength obtained with machine rotavating can be achieved. Mixing more than four times will further increase the soil strength.

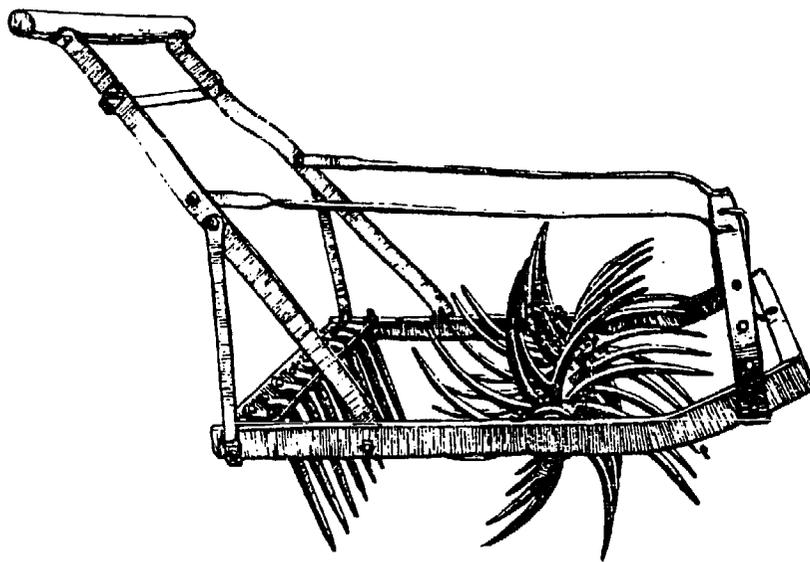


FIGURE 11.1 : ANIMAL-DRAWN ROTARY HARROW

ANIMAL-DRAWN ROTARY HARROW

Design : Figure 11.1 illustrates the design of a traditional animal-drawn rotary harrow. It consists of a series of metal units each having teeth radially fastened to a solid steel hub. All the units, spaced approximately 150mm apart, rotate on a solid axle. The curved teeth are about 250mm in length.

Materials : Frame - mild steel strip
Teeth and Tines - Hardened and tempered medium carbon steel

Manufacture : Requires simple workshop facilities.

Operation : (see page 11.21 for general principles of operation).

Suppliers : N/A

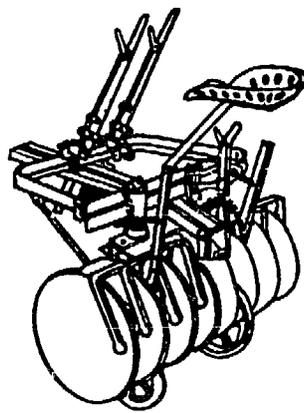


FIGURE 11.2 : ANIMAL-DRAWN DISC HARROW

ANIMAL-DRAWN DISC HARROW

Design : Figure 11.2 illustrates the design of a simple animal-drawn disc harrow. It consists of two shafts each fitted with a row of concave discs with spherical caps. The two shafts carrying the discs are arranged in a wide V open to the front. Each shaft carries 3 to 6 discs mounted vertically which can rotate on roller or ball bearings or on shell or wooden bearings. The discs have a maximum diameter of 500mm and are set 150 to 200mm apart. The depth of penetration can be varied by altering the angle of the discs in relation to the direction of travel. The greater the angle the greater the penetration and the more draft needed to pull them.

Materials : Frame - mild steel
Discs - high carbon alloy steel
Axles - high carbon steel

Manufacture : Requires well equipped workshop

Operation : (See page 11.21 for general principles of operation)

Suppliers : N/A

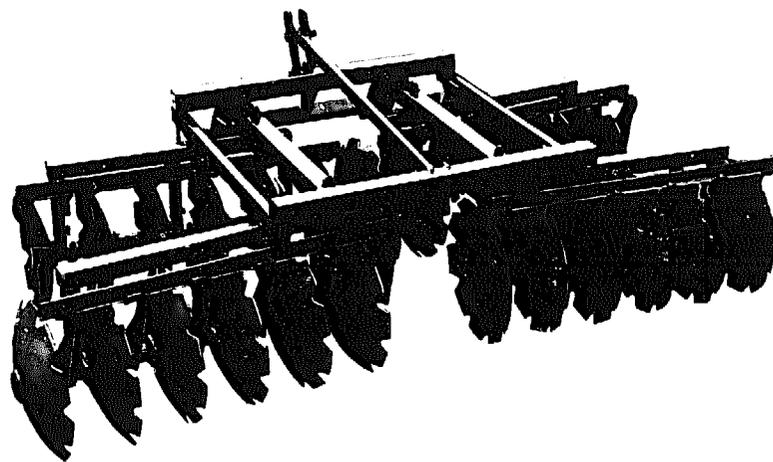


FIGURE 11.3 : TRACTOR DRAWN DISC HARROW

TRACTOR-DRAWN DISC HARROW

- Design* : The basic design principles are the same as for the animal drawn disc harrow. However, the greater power available from tractors and the higher operating speeds have resulted in very much larger and more refined designs. The latter include tandem units, independently adjustable gangs of discs, deeper and more positive depth control, and road wheels for inter-site transport.
- Operation* : (See page 11.21 for general principles of operation).
- Suppliers* : Disc harrows are manufactured by a large number of companies in different parts of the world. The most likely source of supply is through local agricultural equipment manufacturers or distributors.

SINGLE-AXLE TRACTOR AND ROTAVATOR

Design : These are similar in principle to the rotavators fitted to four wheeled tractors. A rotating horizontal shaft driven from the tractor power-take-off carries a set of soil contacting components. A canopy is fitted over the shaft. The soil is thrown against this and pulverised (Note: the canopy is critical to the successful use of this device for mixing. Single axle-tractors with cultivator blades fitted in place of the wheels are not suitable).

Working depth is limited to about 200mm and width 700-1000mm. The speed range is 1-3km/h with the slower speeds used for very hard soils.

Operation : (See page 11.21 for general principles of operation).

Suppliers : The most useful sources of supply are single-axle tractor manufacturers. A list of these is given in TECHNICAL INFORMATION NOTE TN6: SOURCES OF POWER

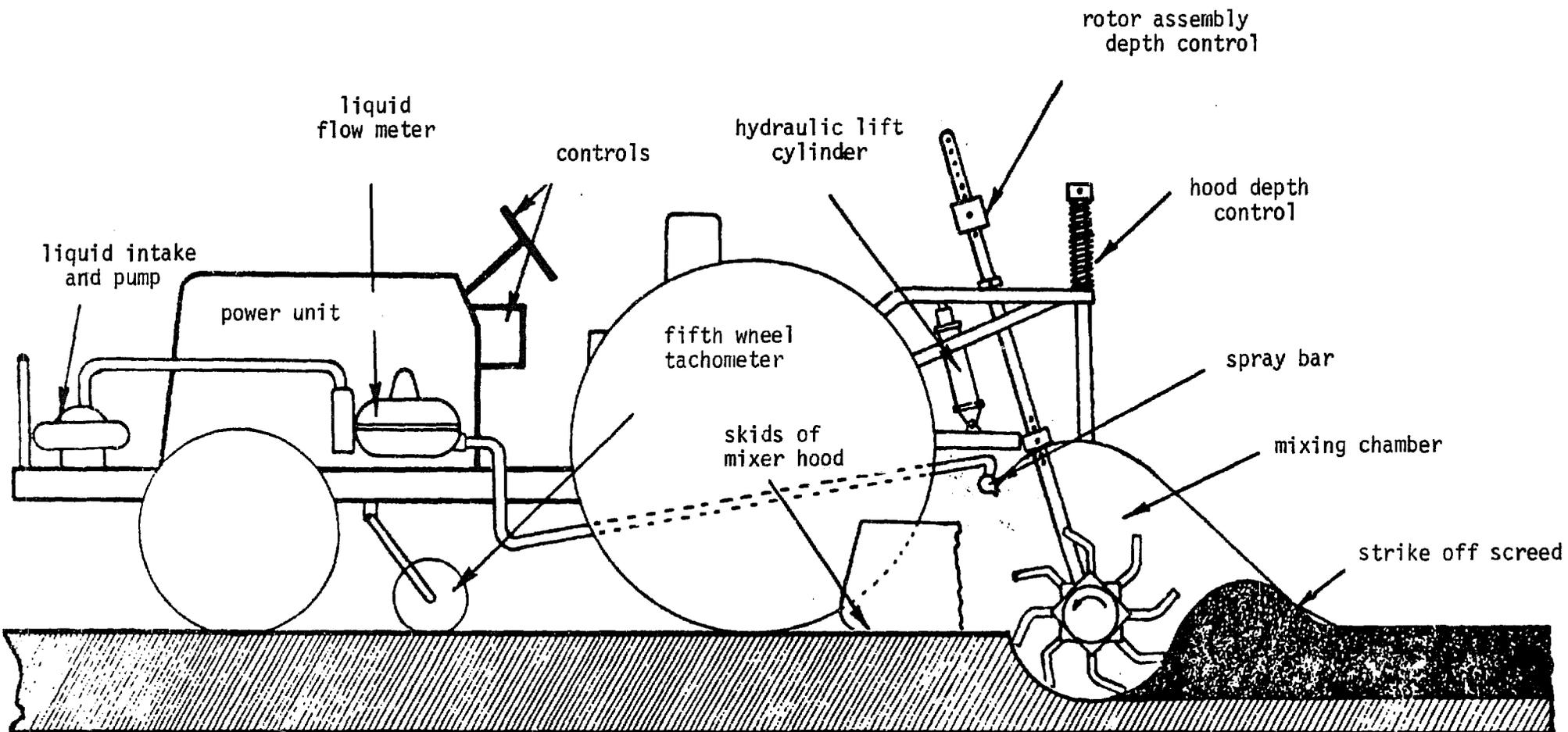


FIGURE 11.4 : TRACTOR-MOUNTED ROTAVATOR (PULVIMIXER)

TRACTOR-MOUNTED ROTAVATOR

Design : Two types are available. The standard units used for agricultural land-preparation purposes, and purpose designed models for soil stabilisation which incorporate built in spray bars and water/bitumen metering equipment. Both types utilise standard 3-point linkage mountings and can be supplied with single or multiple gearboxes.

The basic design of the tractor-mounted rotavator is illustrated in Figure 11.4. The soil contacting components are attached to a horizontal shaft which is driven from the tractor power-take-off through a gearbox and slip clutch. The design of the contacting components varies between machines and is under constant development. The most common consists of a series of L-shaped blades mounted on the shaft. The rotor is covered by a canopy with an adjustable shield at the rear. It is driven in the same direction as the tractor wheels, and the blades chop the soil out in lumps and throw them against the canopy and shield where they break. It produces a deep tilth of small soil particles. The working width is a function of tractor h.p., but typically ranges from 1.3-2.6 metres. The working depth is adjustable upto a maximum of 100-300mm.

Operation : (See Page 11.21 for general principles of operation).

Suppliers : Agricultural rotavators are manufactured by a large number of companies in different parts of the world. The most likely source of supply is through local agricultural equipment manufacturers or distributors.

Purpose Built Soil Stabilisation Rotavators

- HOWARD ROTAVATOR Co. Ltd.
- SATPUDA ENGINEERING INDUSTRIES
(Manufacturers of the 'Rotillor' designed by the Central Road Research Laboratory of India. The licence for manufacture is available from the National Research Development Corporation of India, 61, Ring Road, New Delhi, 110024, India).

TRACTOR MOUNTED ROTARY HARROW

- Design* : Rotary harrows use standard 3-point linkage mountings. The working width is a function of tractor h.p., but typically ranges from 1.0 - 3.5 metres. The working depth is adjustable upto a maximum of 200 - 250mm.
- Operation* : (See Page 11.21 for general principles of operation).
- Suppliers* : Rotary harrows are manufactured by a large number of companies in different parts of the world. The most likely source of supply is through agricultural equipment manufacturers or distributors.

EQUIPMENT

Operation : General With very hard ground it may first be necessary to loosen the soil to the depth to be stabilised. This could be done with handtools or a tine or mouldboard plough (see Section 4 : EARTH AND GRAVEL EXCAVATION). With or without loosening several passes of harrows or rotavators will be necessary to achieve thorough mixing of the material depending on its plasticity. If properly mixed the material should have a uniform colour and consistency.

Disc harrows work the ground more thoroughly as the discs are set more obliquely to the direction of movement, i.e. as their angle of attack is increased. Conversely, they do practically no effective work when the shafts of the two sets of discs are in a straight line; in this case, the harrow rolls over the ground which is the only way the most simple implements can be transported

INTRODUCTION

This section discusses implements for the preparation and laying of bituminous surfacings.

Information on the following implements is given:

	Rake*
	Fork*
	Forked hoe*
Surface dressing :	Bitumen boiler
	Cold emulsion sprayer
	Bitumen can
	Head basket**
	Aggregate spreading wheelbarrow
Pre-mix :	Stretcher
	Batch heater and mixer
	Mortar pan**
	Wheelbarrow**
	Hand paver finisher

The technical specifications of those marked with an asterisk* are given in Section 1: HANDTOOLS; the specifications of those marked ** are given in Section 7: HAULING This section discusses only the application and operation of these implements in the preparation and laying of bituminous surfacings.

APPLICATION

Bituminous surfacing comprises a wide range of materials and treatments, the common element being that they are made of mineral aggregate bound together with petroleum bitumen, naturally occurring asphalts or coal tar. The latter two materials are found in only a few developing countries and will not be discussed further. The two main groups of treatment are the surface dressing in which the binder and the aggregates are applied separately, and the one in which binder and aggregate are pre-mixed and then laid. Both can be carried out almost entirely by machines, which are not discussed here, or mainly by hand with some simple items of equipment.

SURFACE DRESSING

This operation comprises clearing the surface of loose material and dust by brushing; application of a priming and then main coat of bitumen binder and spreading of the aggregate chippings over the binder. The binder may be cold (emulsion) or, more commonly, require heating. Bitumen emulsion is normally used for maintenance operations and other small-scale works so the amount of material required at any one time is limited and pedestrian drawn spraying equipment is adequate. Binder can be heated in temperature controlled boilers, or 'kettles', or simply by lighting a fire under the drums in which the material is usually supplied. For large-scale operations binder and aggregate are applied by lorry mounted bulk distributors. These are specialised units and are not described here. Binder can also be applied from a can or by a hand held or tractor towed spray. Chippings can be spread with handtools, direct from headbaskets, with specially adapted wheelbarrows, or using a mechanical spreader towed behind a tractor-trailer combination from which it is fed by hand. Dust can be removed from chippings by washing with water or, less satisfactorily, by throwing them against an inclined screen. Pneumatic tyred or plain steel dead weight rollers are normally used to compact each layer, but the same effect can be achieved by slowing down and channelling ordinary road traffic. There is no particular advantage in vibrating rollers.

A variation on the standard form of surface dressing is the *penetration macadam*. Repeated spraying is used to form a type of bitumen macadam in-situ. Typically a 75mm layer of 60mm single size stone is laid and compacted with a 10 tonne steel-wheeled roller until thorough interlock is obtained. Heated penetration grade bitumen is sprayed at 4 litres per square metre. A layer of 20mm maximum size stone (*key stone*) is spread at the rate of 25kg per square metre and thoroughly rolled in. Further keystone is spread as rolling continues until firmly embedded. When rolling is complete the surface is brushed to remove surplus keystone and a surface dressing applied. Penetration macadam is particularly suited to labour-based work.

PRE-MIXED SURFACINGS

This operation also requires the surface to be cleared of loose material. In addition to a prime coat of bitumen an appropriate 'tack coat' may be necessary to ensure interlayer adhesion, especially if the mix is of a dense type with no large stones to give a mechanical 'key' to the base. However, the main surfacing of binder and aggregate are not brought together on the road surface; they are mixed in a separate container or on another surface.

Slurry seal pre-mixes - mixtures of fine aggregate, water, bitumen emulsion and occasionally cement - can be mixed cold, but have only specialised uses, mainly as a maintenance treatment for old bitumen surfaces.

The most commonly used pre-mix materials require the bitumen to be hot. The simplest method is to dry and pre-heat the aggregate in a metal stretcher over an open fire, bitumen is added from a 'kettle' and the two are 'raked' together; the same device is then used to carry the mixture to the laying site. With this system temperature and thus product quality control depend entirely on the skill and experience of the operators. Mixing can also be effected with a small motor driven mixer of the type normally used to produce concrete: aggregate can be sun-dried or heated in the same way as for the stretcher method. It will be necessary to experiment with the temperature at which bitumen should be drawn from a kettle so that a satisfactory mix is supplied to the paver. Since they are not designed for

bituminous materials this type of mixer will tend to clog easily and be rendered unfit for normal use. Also, being uninsulated heat losses will be high and product quality difficult to control. They should be used only if more efficient equipment is not available.

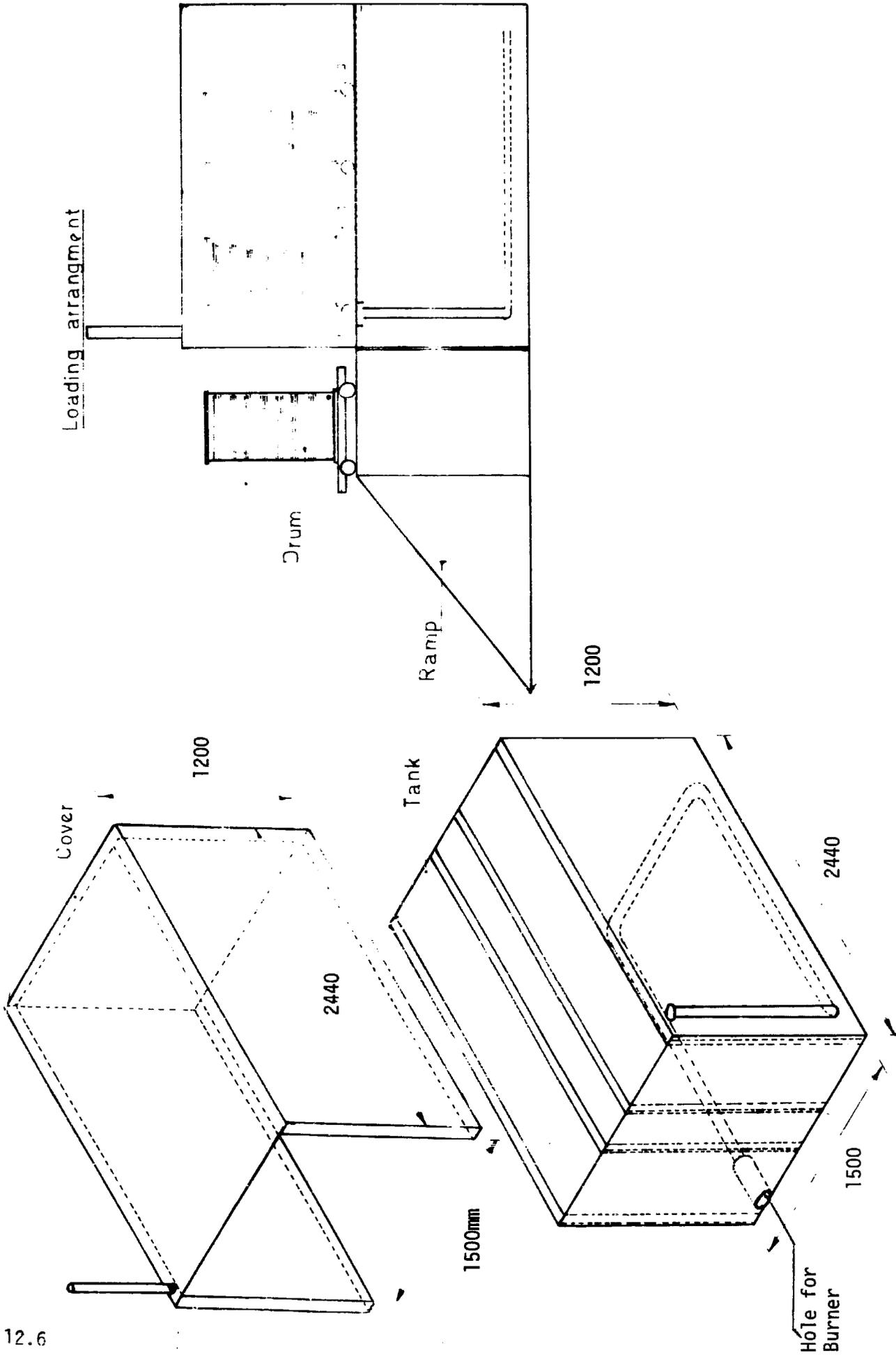
Mobile combined batch heaters and mixers are available with capacities of 150 litres (10 tonne/hr) upwards.

Pre-mix material can also be produced by a technique known as 'road-mix':

- (i) aggregate are windrowed on a suitable mixing site; this is often a new base, old road or a levelled piece of ground which has been sealed with a bitumen spray;
- (ii) the required quantity of bitumen is sprayed by a distributor in several applications and workers with rakes or a blade grader mix the material between applications;
- (iii) the mixed material is then spread.

Unless considerable care is exercised, control of the mix proportions is likely to be poor. Subsequent transport of the material to the laying site can be by mortar pan, stretcher, wheelbarrow, or other metal lined haulage container (See Section 6: HAULAGE). Pre-mixed materials are normally laid by machine, but a hand paver finisher has been developed in India with an approximate paving capacity of 15 tonne/hr. Compaction is as for surface dressings.

Rakes, forks and forked hoes are the most useful handtools for handling surface dressing aggregates and pre-mixed materials.



12.6

FIGURE 12.1 : PORTABLE BITUMEN BOILER (PAKISTAN)

TOOLS AND EQUIPMENT

BITUMEN BOILER

Design : There are a large number of designs for bitumen boilers with different capabilities. The most basic types are static, or fitted with rudimentary steel wheels, and simply supply heat to the bitumen. The most useful are the fully mobile units equipped with road wheels and hand held spraying lances supplied by manual or engine powered pumps. Capacities range from 400 to 4000 litres with the most useful sizes being in the range 500 to 2500 litres.

The boiler has two main functions (i) melting, or 'decanting' the bitumen from the barrels in which it is supplied; and (ii) heating the bitumen to and maintaining it at a specified temperature. Essentially it consists of an insulated metal container into which one or more bitumen barrels can be loaded. Heat, is usually supplied indirectly, either from a wood or coal fire, diesel or gas burner melting from the barrel the bitumen which falls into a reservoir. Figure 12.1 illustrates a portable bitumen boiler of 3600 litres capacity for use in Pakistan. Hot gases from the burner pass through the bottom in a U-tube and are again circulated in the hollow walls of the top cover to provide heat to the drums standing inside. It has a charge of 8 x 164 litre drums which can be decanted in about an hour. The unit was designed to be loaded into a 5 ton truck.

Wood or coal fired boilers are useful for remote locations where gas or diesel supply would be difficult, but the latter forms of heating have the advantage that they can be thermostatically linked to the desired temperature of the bitumen.

Mobile units should be equipped with a hoist or other means of loading the barrels and hand or motor powered spray lances are usual.

Materials : Mild steel plate and tubing

Manufacture : Bitumen boilers can be produced in a well-equipped workshop.

Operation : Self evident

Suppliers

- AEROIL PRODUCTS Co. Inc.
- BRISTOWES MACHINERY Ltd.
- SABARWAL METAL INDUSTRIES
- SALCO MASKIN AB*
- THE PHOENIX ENGINEERING Co. Ltd.*
- THOMAS COLEMAN & SONS Ltd.

* produce tractor-towed boiler and power distributor.



FIGURE 12.2 : COLD EMULSION SPRAYER

COLD EMULSION SPRAYER

Design : The essential features required of a cold emulsion sprayer as illustrated in Figure 12.2, are a sturdy rolled or pressed steel channel chassis sufficient to accommodate the barrel sizes available locally in either the horizontal or vertical positions. The towing or securing handles should convert into a ramp for loading barrels. Either a three or four-wheel configuration is suitable and at least one-axle should be fitted with a brake. Emulsion pumps, whether manual or powered by a small air cooled petrol or diesel engine, are specialist items with flexible impellers to overcome the tendency for the bitumen to seize up the pump. The suction hose should be fitted with a filter and the spray lance with a valve and handle for controlling the rate of spraying.

Larger hand and mechanically towed or self-propelled sprayers are available with capacities of 200 - 430 litres: they are usually equipped with air cooled engine-powered sprayers.

Materials : Chassis - steel channel 100 x 50mm.
 Wheels - pneumatic tyres 200-400mm diameter
 75 - 100mm width.
 Hoses - 3-ply wire lined 30mm suction, 20mm spray.

Manufacture : The simpler sprayers can be made in a well equipped workshop.

Operation : See page 12.19.

Suppliers Pedestrian towed Manually pumped sprayers

- BRISTOWES MACHINERY Ltd.
- THE PHOENIX ENGINEERING Co. Ltd.
- THOMAS COLEMAN & SONS Ltd.
- WALLIS AND STEEVENS Ltd

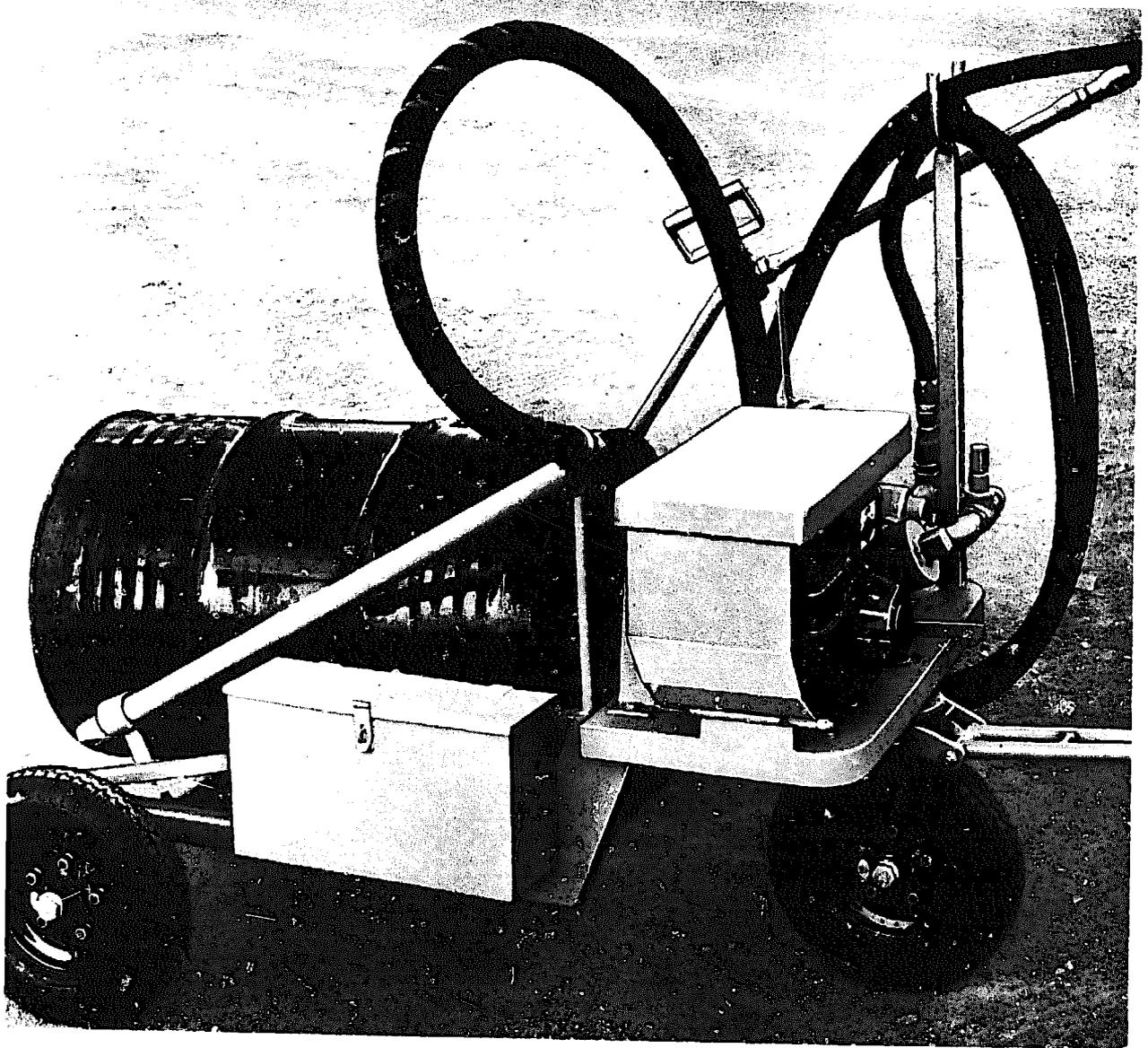


FIGURE 12.2 : COLD EMULSION SPRAYER (*Alternative or additional illustration*)

Pedestrian towed Power pumped sprayers

- BRISTOWES MACHINERY Ltd.
- SALCO MASKIN AB
- THE PHOENIX ENGINEERING Co. Ltd.
- THOMAS COLEMAN & SONS Ltd.*
- WALLIS & STEEVENS Ltd.

Mechanically towed power pumped sprayers

- THE PHOENIX ENGINEERING Co. Ltd.
- THOMAS COLEMAN & SONS Ltd.

Self propelled power pumped sprayers

- THE PHOENIX ENGINEERING Co. Ltd.

* 200 and 430 litre models.

BITUMEN CAN

Design : The design should be interpolated from that of the bucket and watering can described in Section 8: WATERING. The top should be partially enclosed to reduce heat losses. For pouring the bitumen can should be provided with a V-shaped lip, or a spout without the rose used on the watering can. It is also useful if a pouring handle can be fixed to the top or body of the can near to the base. Capacity should be as for watering can 8-12 litres.

Materials : Body - galvanised sheet at least 2mm thick
Handles - similar materials at least 3mm thick
Solder - minimum tin content of 35 per cent.

Manufacture : Requires thin metal sheet cutting, bending, rolling, soldering and rivetting equipment.

Operation : (see page 12.19).

Suppliers : N/A

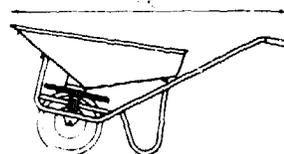
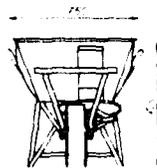
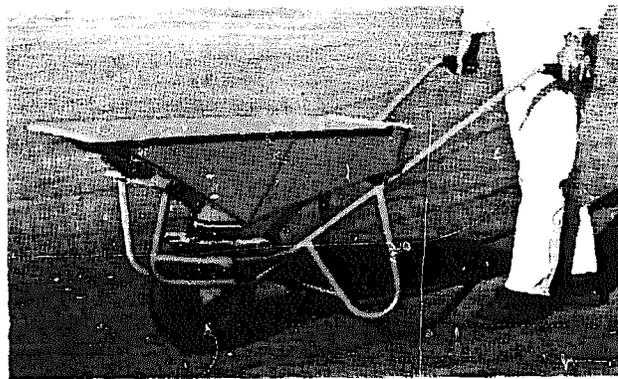


FIGURE 12.3 : AGGREGATE SPREADING WHEELBARROW

AGGREGATE SPREADING WHEELBARROW

Design : Figure 12.3 illustrates the design of an aggregate spreading wheelbarrow. It consists of a standard metal trayed wheelbarrow (see Section 7: HAULAGE) with a discharge shaft about 200mm square in the bottom of the tray. If a sliding plate is opened the aggregate is discharged onto a rotating spreader disc which is connected by a drive shaft and pinion to the main wheel. With the sliding plate closed it functions as an ordinary wheelbarrow.

Materials : see WHEELBARROW Section 7: HAULAGE.

Manufacture : Requires basic workshop facilities.

Operation : Self evident

Suppliers - BRODERNA BRODD AB

SURFACE DRESSING

Operation : General

With all sprayed bituminous work it is essential to obtain an even distribution of binder. Unevenness can be caused by changes in the rate of work of the spray operator, clogged spray jets or variations in the rate of pumping. These problems can be reduced by training and carefully marking out the surface to be sprayed; meticulous maintenance of the equipment; and substituting powered for manual pumping: some manually pumped sprayers incorporate an air chamber to ensure a more even discharge.

With handtools and headbaskets it is difficult to achieve an even distribution of chippings, or to spread them quickly enough to avoid the binder cooling below the temperature at which proper wetting of the stone takes place which leads to loss of aggregate from the surface. These problems can be overcome by carefully placing small piles of aggregate along the side of the road before the binder is applied. The piles should contain more stone than is required and be spread liberally by a gang of workers as soon as the bitumen is applied. Excess stone can be swept off once the surface has been compacted.

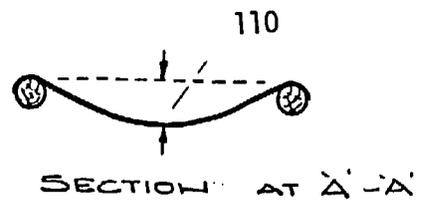
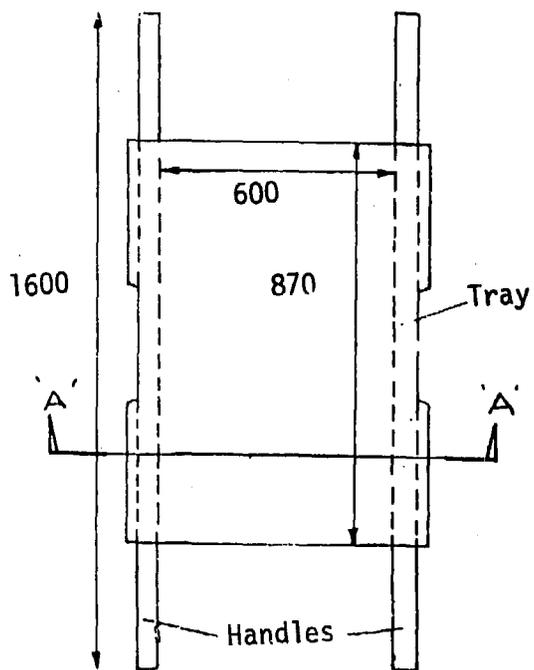


FIGURE 12.4 : STRETCHER DIMENSIONS (mm)

STRETCHER

Design : Figure 12.4 illustrates suitable dimensions for a stretcher. The tray, which may be made from an old oil drum, is dished to retain the material. The sides of the tray are formed over the handles. At the two ends the sides are bent over just sufficient to locate the tray on the handles (Section AA). In the centre, the sides are bent around and under the handles to retain them in place.

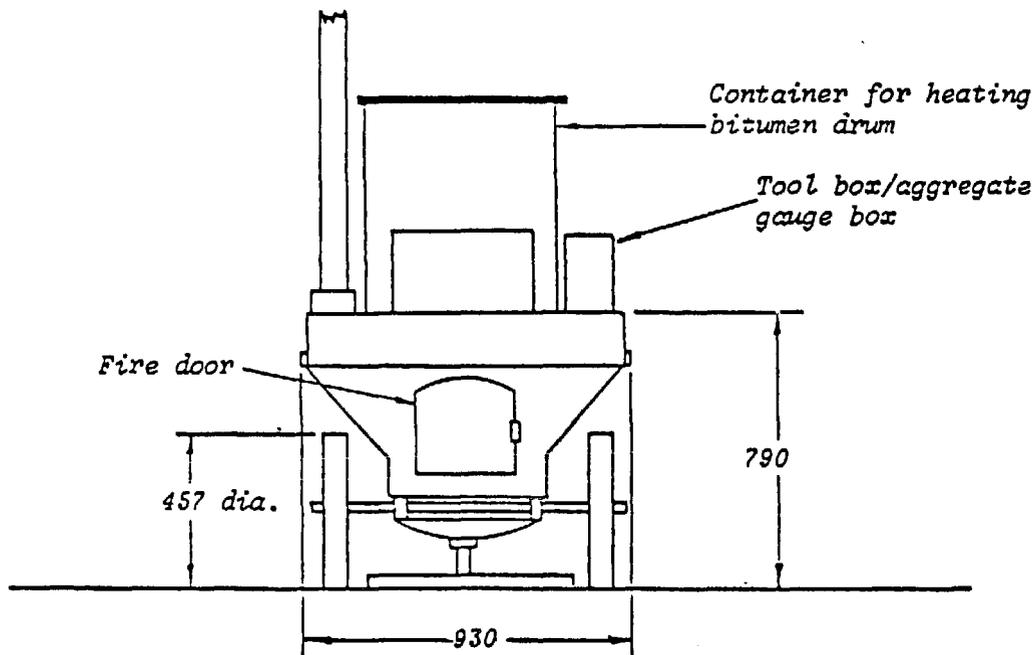
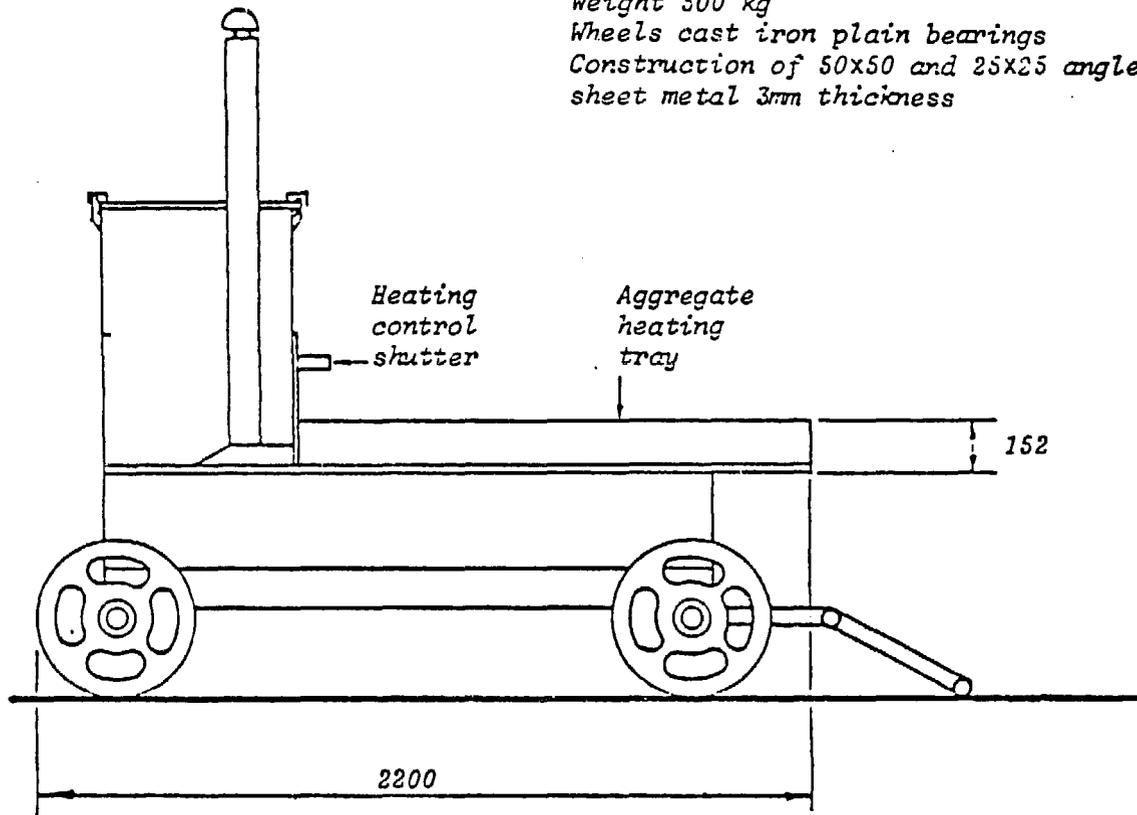
Materials : Tray - old oil drum or mild steel sheet at least 3mm thick.
Handles - mild steel black pipe about 35mm dia.

Manufacture : Tray hand formed to shape.

Operation : see page 12.4

Suppliers : N/A

Tray size 1450x900x150 internal
 Weight 500 kg
 Wheels cast iron plain bearings
 Construction of 50x50 and 25x25 angle,
 sheet metal 3mm thickness



Dimensions in mm

FIGURE 12.5 : 'PATCH KING' BITUMEN HEATER

BATCH HEATER AND MIXER

Design : A large number of different equipment designs are available for the batch production of bituminous pre-mix. One of the simplest, the 'Patch King', is illustrated in Figure 12.5. This is a combined bitumen heating tray mounted on wheels with a fire grate underneath. Mixing is by hand. It has the advantage that the fire is always contained under the tray, giving greater heating efficiency. Being mobile it is possible to keep the haul distance of the mixed material down to a minimum, but the capacity of the machine limits its use to repair work only.

Figures 12.6 and 12.7 illustrate two different types of batch production equipment with machine mixing and positive control over the proportioning and heating of materials.

The equipment in Figure 12.6 has an output of between 9-18 tonnes per hour (5-10 cubic metres). It comprises a two compartment aggregate feed hopper; rotary continuous aggregate drying cylinder feeding to a weigh batch hopper and 270kg capacity paddle mixer. Power is supplied by a 20 HP diesel engine and the burner can be fired by oil or gas .

The equipment in Figure 12.7 has an output of about 12 tonnes per hour. (7.6 cubic metres). It also has a two compartment aggregate feed hopper and separate aggregate drying and mixing sections. Power is supplied by a 15 HP diesel engine and the burner is oil fired.

Suppliers - SIMCO

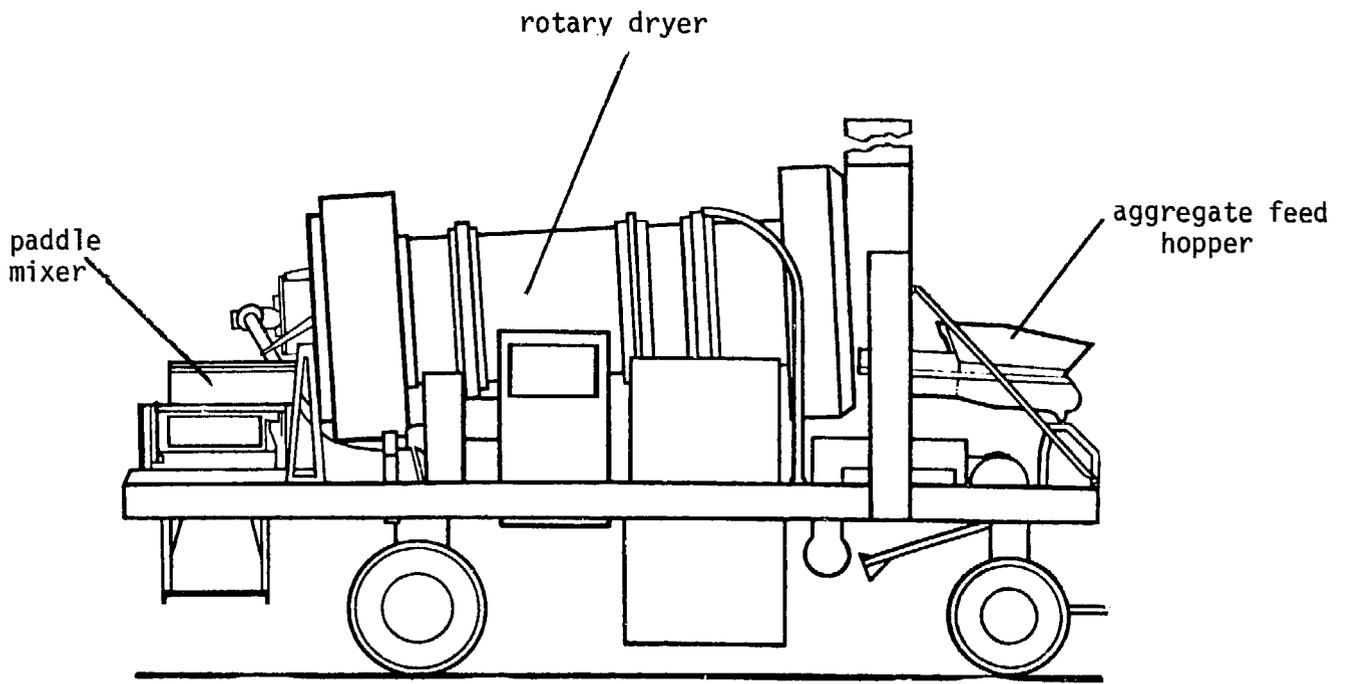


FIGURE 12.6

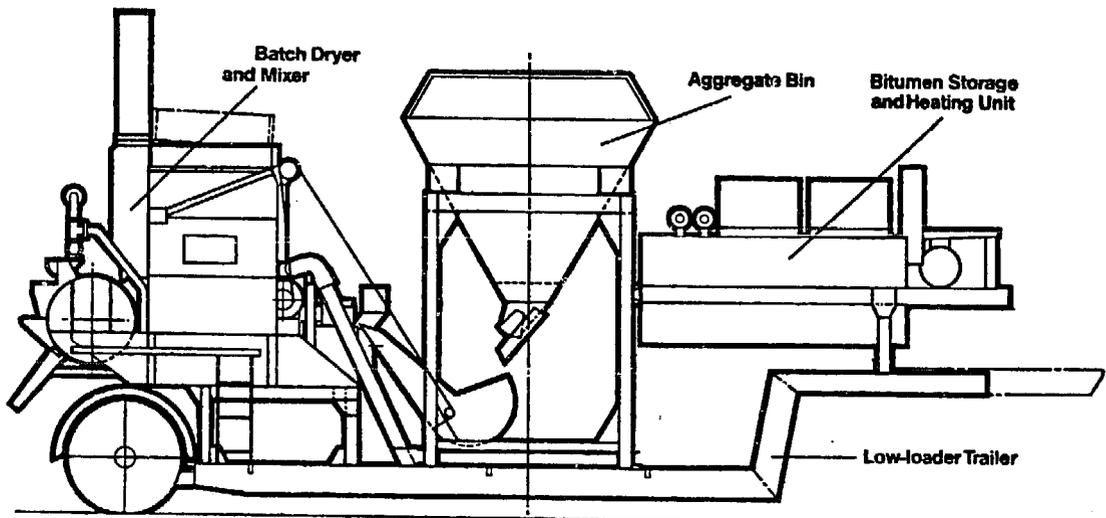


FIGURE 12.7

Mobile Batch Heaters and Mixers

- FREDERICK PARKER Ltd.
- MILLARS MACHINERY Co. Ltd.
- SAYAJI IRON and ENGINEERING Co. Ltd.

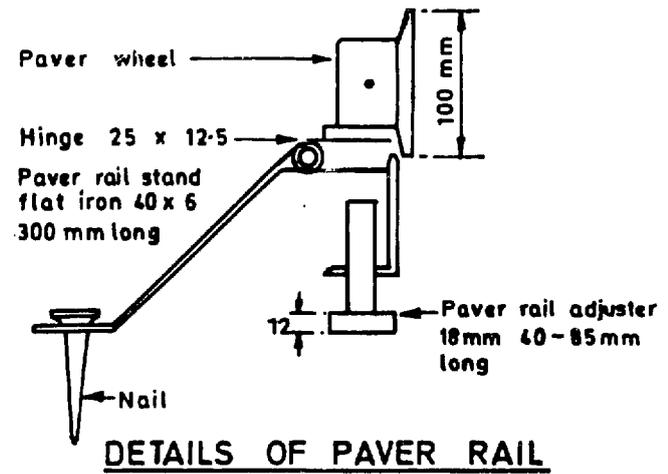
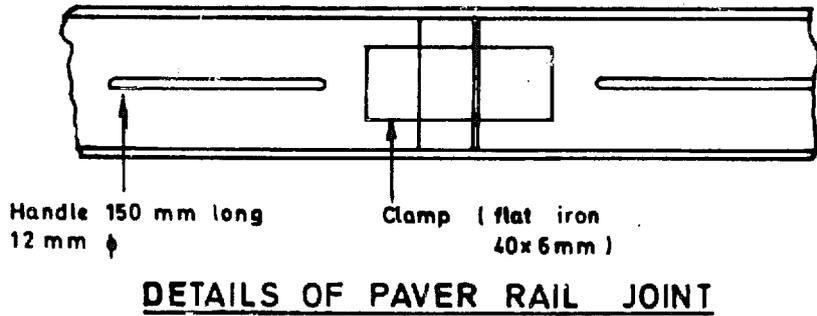
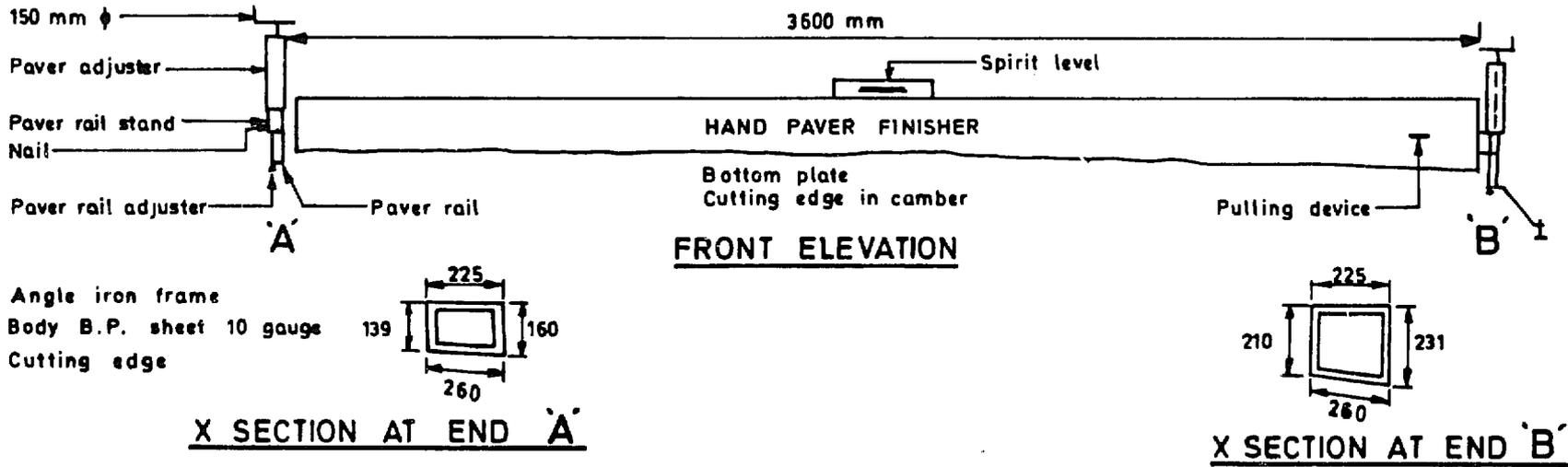


FIGURE 12.8 : HAND PAVER FINISHER

HAND PAVER FINISHER

Design : Figure 12.8 illustrates the design of the hand paver finisher. It is essentially a 3.6 metre screed board with a sharpened cutting edge which is pulled manually along two carefully positioned rails. These are laid in 5 metre sections the overall length depending on the expected daily output: in India 50 metres of rail has been found sufficient for a day's output. The camber of the road is built into the screed board, as can be seen from Sections A and B in Figure 12.8. Each end of the screed board can also be adjusted vertically, up to a maximum of 100mm, for different paving layer thicknesses. This permits further adjustments to the camber or superelevation if required.

Materials : see Figure 12.8 for details

screedboard - 35 x 5mm angle iron
 rail - 100 x 50mm mild steel channel
 pulling handle - 50mm diameter iron pipe 1200mm long.

Manufacture : Requires well equipped workshop.

Operation : The final alignment and levels of the surfacing must first be carefully surveyed and set out. The rails on which the screed board runs are then positioned, adjusted to the required levels and secured in place with nails: see Figure 12.8 (a). This process is assisted if a metal spacer rod, half the width of the road, is used to ensure the rails are correctly spaced and parallel. The screed board is then put in place. Pre-mix is unloaded in front of the screed board, spread and roughly levelled by hand. The screed board is then pulled giving a fine level to the material which is compacted in the normal way: see Figure 12.8 (b).

Suppliers - PRAKASH ENGINEERING WORKS

APPENDICES

TECHNICAL INFORMATION NOTE TN 1 : STEELS

TECHNICAL INFORMATION NOTE TN 2 : HANDTOOL MATERIALS : WOOD

TECHNICAL INFORMATION NOTE TN 3 : HANDTOOL TESTING PROCEDURES

TECHNICAL INFORMATION NOTE TN 4 : HANDTOOL WEIGHT - LENGTH
SELECTION

TECHNICAL INFORMATION NOTE TN 5 : MAINTENANCE OF HANDTOOLS

TECHNICAL INFORMATION NOTE TN 6 : SOURCES OF POWER

LIST OF SUPPLIERS

SOURCES OF ILLUSTRATIONS AND TABLES

INDEX

INFORMATION

The efficiency of many of the implements used in labour-based road construction is critically dependent upon the use in their manufacture of appropriate *materials* and *production methods*. One of the most important materials is steel. If the appropriate steel is not used it will be impossible to achieve or maintain the necessary combination of hardness and toughness for sustained output. This is especially the case with the major cutting and excavation tools such as the axe, shovel, hoe, pickaxe, mattock, crowbar, hammer and the wearing parts of scrapers, graders, etc. This note gives information on appropriate steels and production methods for construction implements. The emphasis is on handtools, but many of the principles can be applied to the wearing parts of construction equipment.

TYPES OF STEEL

Different types of handtools require steels with different properties. A steel's properties can be altered by varying the proportions of its constituent elements and the nature of the production process. The most important elements normally present in a steel, and the broad effect they have on its properties, are as follows:

Carbon : An increase in the carbon content of a steel decreases its ductility, but increases the strength and the susceptibility to hardening when rapidly cooled from elevated temperatures. The amount of carbon in a steel places a limit on the hardness or resistance to wear, that can be achieved. Steels with less than 0.3 per cent carbon can only be surface hardened. The maximum hardening effect is obtained with steels of about 0.7 per cent carbon content. Since most handtools must have a high strength and resistance to wear correct choice of carbon content is important.

Convention broadly recognises the following main types of carbon steel:

Mild Steel (carbon, 0.15 - 0.25 per cent) Rakes, grass slashers, and the sockets and straps of shovels, etc.

Medium Carbon Steel (Carbon, 0.2 - 0.5 per cent). Shovels, spades, forks and some pickaxes, mattocks, crowbars and hoes.

High Carbon Steel (Carbon 0.5 - 1.4 per cent). Axes, brush hooks, chisels, sawblades, pickaxes, mattocks, crowbars, hammers and hoes.

Silicon : Is present in most steels and in small amounts (less than 0.4 per cent) is normally regarded as beneficial. For very highly stressed tools, such as hammers, it is normal to specify 'silicon killed' or 'fully silicon killed' steels. These are steels in which the process of manufacture has been adapted to reduce or eliminate respectively, the silicon content, so as to improve the hardening qualities without the risk of cracks forming.

Manganese : Confers depth of hardening, also a liability to crack in quenching, for which reason high carbon steels, intended to be quenched in water, should contain less than 0.5 per cent. With greater than 0.5 per cent manganese a nitrate quenching solution should be used.

Sulphur : Causes the metal to split when forged, so the proportion is normally limited to about 0.06 per cent maximum.

Phosphorous : For a variety of reasons the phosphorous content is normally kept between 0.02 - 0.06 per cent.

Two other less common, because of their expense, but important elements are chromium and nickel which are used to produce what are called 'alloy' steels. A small proportion - up to 1 per cent - of chromium is sometimes added to steels for the more highly stressed tools, such as axes, to improve their hardness and resistance to wear. Similarly, up to 3 per cent nickel is added to a 0.4 per cent carbon steel to produce a high shock resistance material suitable for the manufacture of the best quality chisels.

Table TN 1.1 gives typical steel compositions for the most commonly used hand tools.

SELECTION OF STEELS

Although it is quite common for tools to be manufactured from scrap materials such as plough shares, motor vehicle suspension springs, railway line or engine crankshafts, the quality of the implements that result cannot be depended upon. A major problem is simply that the composition of the metal is not known precisely and few small-scale manufacturers have the means to determine what it is. For example, the composition of the metals used to make motor vehicle suspension springs is known to vary between manufacturers and with different production batches from the same manufacturer [1]. Unless the metal composition is known to reasonable close limits it is not possible to specify the production methods necessary to achieve the hardness and toughness requirements efficient tools must satisfy. Consistent results are only possible with materials of a known composition.

A particular problem in obtaining supplies of the required raw materials is that there is no internationally agreed method of describing different types of steel. The steel standards of producer countries are generally established on the basis of chemical composition, physical properties, application etc., but the standards even for the same general type of steel differ from one country to another. The International Technical Information Institute, Tokyo has produced a guide to the steels produced in the U.S.A., U.K., West Germany, U.S.S.R, France and Japan [2].

PRODUCTION METHODS

The final properties of a tool, particularly its hardness and toughness, are critically dependent on correct heat treatment.

Heat Treatment

Heat treatment is an operation involving the heating of the solid metal to temperatures, followed by cooling at suitable rates in order to obtain certain physical properties, which are associated with changes in the nature, form, size and distribution of the micro-constituents. Fundamental to all heat-treatment is the ability to determine, and control

within close limits, the temperature of the metal being treated. This cannot be achieved with either open flame heat treatment or the simpler types of furnace: temperature controlled ovens are essential.

There are four main types of heat-treatment used in handtool production: annealing, normalising, hardening and tempering.

Annealing The main purposes of annealing are:

- (i) to soften the steel.
- (ii) to relieve internal stresses induced by some previous treatment (forging, welding).

The operation consists in (a) heating the steel to a certain temperature, (b) "soaking" at this temperature for a time sufficient to allow the necessary changes to occur, (c) cooling at a predetermined rate. Average annealing temperatures are:-

Carbon (per cent)	0.1	0.2	0.3	0.5	0.7	0.9 to 1.3
Average temperature ($^{\circ}\text{C}$)	900	860	830	810	770	760

Normalising Normalising differs from annealing only in that the metal is allowed to cool in *still air*. It is sometimes preferred to annealing because it has a less drastic softening effect.

Hardening Hardening of steel is obtained by heating to the same temperatures used for annealing and then quenching in a liquid, usually water or an oil. Water is one of the most efficient quenching media in commercial use where maximum hardness is required as with hammer heads, but it is liable to cause distortion and cracking of the article unless great care is taken and appropriate steels are used. To prevent steam bubbles forming soft spots, a water quenching bath should be agitated. Where hardness can be sacrificed, mineral, whale or cotton seed oils are used. These tend to oxidise and form sludge, with consequent lowering of efficiency, so they should be changed regularly.

Tempering A quenched tool steel is very brittle and highly stressed, consequently cracking and distortion are liable to occur. These problems can be overcome by re-heating the steel. This is known as 'tempering' and the effects brought about by it are dependent upon temperature.

- heating to 150 - 250^oC in an oil bath immediately after quenching prevents belated cracking and relieves internal stress without softening.
- heating to 200 - 450^oC in a furnace toughens the steel at the expense of hardness.

The reactions in tempering occur slowly and time as well as temperature of heating is important.

Temper colours formed on a *cleaned surface* can be used as a guide to temperature. This is useful for the maintenance in the field of tools that only require the immediate area of the cutting edge to be hardened and tempered. The entire tool is first heated and then the area around the cutting edge that is to be tempered is quenched and quickly cleaned with an abrasive stone. It should not be machine ground clean as this distorts the colour range. The heat from the main body of the tool is allowed to temper the cutting edge to the correct colour, then the whole tool is quenched. The temper colours are as follows:-

Temper Colour	Temperature ^o C
Pale straw	230
Dark straw	240
Brown	250
Brownish-purple	260
Purple	270
Dark purple	280
Blue	300

Metal Forming

Unless considerable effort is put into quality control and heat-treatment tools fabricated by welding or rivetting separately made parts cannot be expected to produce items of an acceptable quality. TOOLS WITH CAST COMPONENTS, SUCH AS TOOL HEAD EYES, SHOULD NEVER BE USED.

To produce efficient hand tools hot forging should be used as the primary means of metal forming because of the desirable properties it confers on the steel. Although 'stamped' hand tools are available from manufacturers they are invariably cheaper and of a poorer quality than the corresponding forged implements. For the more massive handtool heads such as the axe, sledge hammer, pickaxe and mattock, power forging is necessary, although the final shaping is usually done by hand. The forging hammer consists of a substantial weight (known as a 'tup') which is lifted and dropped or forced down on the metal supported on an anvil, weighing about twenty times that of the tup, and cushioned by timber baulks. The rating of the hammer is usually indicated by the weight of the tup and a $\frac{1}{2}$ -1 tonne is required for the larger handtool heads.

The properties conveyed by forging will not occur unless the 'working' of the metal is carried out only between carefully defined temperature ranges. Typical hot forgings ranges in $^{\circ}\text{C}$ are:

Mild steel	900 - 1200
Medium carbon steel	850 - 1000
High carbon steel	725 - 900

TABLE TN 1.1 : Steel Compositions for Handtools (per cent)

Tool (Source of Information)	Carbon	Managanese	Chromium	Silicon	Phosphorous	Sulphur	Remarks
AXE AND BRUSH HOOK							
British Standard	0.45min	0.8max	-	0.35max	0.06max	0.06max	
Indian Standard	0.75-0.85	0.5-0.8	-	0.25max	0.05max	0.05max	
KRARP	0.55min	0.8 max	0.45min	0.35max	0.06max	0.06max	
CROWBAR							
Indian Standard	0.45-0.65	0.55-0.75	-	0.10-0.35	0.06max	0.06max	
KRARP	0.45-0.55		-				
HAMMERS							
British Standard	0.50-0.60	0.50-0.90	-		0.05max	0.05max	fully silicon killed: allhammers
Indian Standard	0.45-0.65	0.55-0.75	-	0.35max	0.06	0.06	silicon killed: stonebreaking hammer
HOES							
Indian Standard	0.45-0.65	0.55-0.75	-	0.1-0.35	0.06max	0.06max	
KRARP	0.40-0.50	0.50-0.80	-		0.05max	0.05max	
PICKAXE AND MATTOCK							
British Standard	0.45-0.55	0.50-0.80	-		0.05max	0.05max	
Indian Standard	0.45-0.65	0.55-0.75	-	0.10-0.35	0.06max	0.06max	pickaxe
KRARP	0.40-0.50	0.50-0.80	-		0.05max	0.05max	

TABLE TN 1.1 : Continued

Tool (Source of Information)	Carbon	Manganese	Chromium	Silicon	Phosphorous	Sulphur	Remarks
SHOVEL, SPADE FORK							carbon and manganese together must not be less than 1 per cent for the blade and prongs: straps and sockets from low carbon shovel only
British Standards	0.35min	0.50min	-	0.40max	0.06max	0.06max	
Indian Standards	0.45-0.65	0.55-0.75		0.10-0.35	0.06max	0.06max	shovel only
KRARP	0.40-0.50	0.50-0.80			0.05max	0.05max	shovel only

¹ Saw blades are generally made from steels in the range 0.65-0.75 per cent carbon, but other alloying elements are added in various proportions depending upon the manufacturer.

² KRARP specification for the heavy duty rake head stipulates a 0.20-0.30 per cent carbon steel.

TN 1 REFERENCES

1 INTERNATIONAL LABOUR OFFICE. Appropriate Technology in Philippine Forestry. Report of Joint Philippine Bureau of Forest Development/ILO/Government of Finland Project, Geneva, 1977 (International Labour Office).

2 INTERNATIONAL TECHNICAL INFORMATION INSTITUTE. Handbook of Comparative World Steels Standards. Tokyo, 1976.

N.B. The annealing and normalising sections may be deleted later if they are not required for other sections of the guide.

INTRODUCTION

This note provides guidance on; the properties required of handtool handles; the identification of species of wood that meet these properties; processing of the raw timber to a state where the production of handles with consistent qualities is possible; manufacturing techniques; and sources of further information.

PROPERTIES OF HANDTOOL HANDLES

The chief properties required of a wood for tool handles are:

- toughness or high shock resistance
- hardness to resist abrasion and indention
- lightness
- resistance to splintering or splitting
- good drying, turning and finishing qualities to minimise the cost of production

Many of these properties are in conflict - for example, strength properties, which are related to the density of the timber, and lightness - so some degree of compromise is inevitable.

The properties of timber can be measured in a number of different ways, but no single property adequately measures suitability for handles.¹ For example, the wood density is a major factor determining the strength of a species; in general species with a high density have high strength properties. However, there may be marked differences in certain specific properties between timbers of the same density. Thus European ash, having the same density and bending strength as European beech, has an energy absorbing capacity approximately 50 percent higher than that of beech, making it an excellent timber for tool handles. Consequently countries that have developed technical standards for tool handles have generally adopted species specifications based upon experience rather than mechanical properties alone.

¹ An attempt has been made to combine four of the mechanical properties of timber (shock resistance, hardness, bending and compressive strength) into a Single Suitability Coefficient for Tool Handles [1]. This coefficient can be predicted from a knowledge of the timber's specific gravity, but the evident variability of the relationship renders its use suspect and it does not seem to have been widely adopted.

In the Americas, England, Australia and some European countries hickory (*carrya* sp¹) and ash (*fraxinus excelsior*) woods have been the basis for national tool handle specifications [2]. Experience has shown that these woods are ideal for tool handles because they possess a near perfect blend of the required properties. Unfortunately they are in short supply and in many western countries other species, laminated wood, hollow steel and fibre glass are being substituted. The last two mentioned substitutes have markedly superior strength and durability properties to any wooden handle, but are more expensive. The advanced technology of these substitutes and licensing problems render them unsuitable for manufacture in most developing countries. Fortunately research has established that most developing countries have hardwood species from which, properly treated, can be manufactured satisfactory tool handles.

IDENTIFICATION OF WOOD SPECIES FOR HANDLES

Two regions with tropical/sub-tropical climates that have investigated wood species for tool handles are India and southern Africa. Tables TN2.1 and TN2.2 give respectively information about the species that have been found suitable for different types of tool handles. Table TN2.3 lists the most useful mechanical properties of the more important woods currently used for tool handles. (The properties are explained in the notes accompanying the Table). Some guidance can be obtained on the suitability of other species by comparing their mechanical properties with those given in Table TN 2.3. Thus, Table TN 2.4 lists the mechanical properties of other wood species that are reported to be used for tool handles, but are not included in either Table TN 2.1 or TN 2.2. It can be seen that many of these miscellaneous species exhibit properties similar to those in Table TN 2.3. However, interpreting the suitability of timber for tool handles requires extensive experience of wood characteristics other than those listed and specialist advice should always be sought. Most national forestry organisations can supply this advice and, just as important, details about availability and the processing of different species to obtain optimum properties.

¹ The main means of identifying wood species mentioned in this note will be the latin botanical name given in brackets and italics, since local names vary widely.

SEASONING

All newly felled timber contains a large amount of water that has to be removed before the wood can give satisfactory service as a tool handle. The process of *seasoning* is the removal of the surplus moisture in a controlled manner as economically and with as little damage to the wood as possible. UNSEASONED WOOD SHOULD NEVER BE USED TO MANUFACTURE TOOL HANDLES.

Wood is a hygroscopic material and at any time will tend to a moisture content which is in balance with the water vapour conditions of the surrounding atmosphere. Thus, for any combination of air temperature and relative humidity there is a corresponding equilibrium moisture content (EMC). Wood is very stable when dried to the EMC of the locality where it will be used. For different climates approximate EMC values for tool handles are as follows:

temperate	: 12 per cent
sub-tropical	: 13 - 14 per cent
tropical	: 14 - 16 per cent

In seasoning wood for the manufacture of tool handles there are advantages in drying to a level 2 or 3 per cent below the EMC of the locality. The dryness will cause the wood to swell as it picks up moisture approaching the EMC of the locality thus producing a tight fit and a strong grip on the eye of the tool.

Seasoning, especially of hardwoods suitable for tool handles, is a skilled process and it is easy to ruin wood completely if correct procedures are not followed. The advice of local forestry organisations should always be sought: the following description provides only basic information.

Timber for tool handles is normally seasoned in rectangular handle length billets with a cross-section slightly larger than the largest effective diameter required.

There are two methods of seasoning timber: air drying; and artificial methods, in which some degree of control is exercised over the rate of flow of air, temperature, humidity or all three.

Air Seasoning

Air seasoning is cheap and simple to carry out, and is a useful method of reducing the moisture content of fresh cut timber. The main disadvantage is that the EMC achieved is unlikely to be below about 17-23 per cent, which is too high for the manufacture of satisfactory tool handles. Also, the times taken to reach EMC vary from 2 or 3 months to 1 or 2 years, depending upon the species and size of the timber. For this reason *some form of artificial seasoning is essential for tool handle materials*, although air seasoning can be used to dry the timber initially.

Timber is stacked on supporting bearers in an open yard with some form of sunproof and preferably waterproof cover. Drying is by circulation of air through the stacks. There is no control of temperature, humidity or rate of air flow other than can be obtained by correct orientation and spacing of the stacks and good methods of stacking.

General requirement for Air Seasoning [9]

Figure TN 2.1 illustrates an appropriate stacking arrangement for the air seasoning of timber.

1. Ground for stacking must be clean, smooth and dry.
2. Bark and wood waste must be removed from the stack.
3. Foundations for the base can be made with brick blocks spaced 400-500mm apart. Longitudinal members of good, seasoned timber - preferably treated against fungi and insects with creosote or other suitable preservative - are placed on these blocks. Logs can be stacked on these members with the help of spacers, 25 x 40mm blocks of well seasoned timber.

4. Spacers, used for separating layers of timber, should be of uniform thickness, placed uniformly one above the other 300 - 600mm apart, sufficient in number to prevent sagging of the stack.
5. The width of the stack should normally not exceed 2.0m
6. As far as possible timbers of the same size and species should be stacked together.
7. There should be a free passage for air to all parts of the stack.
8. Where possible protection should be given against the rain and direct sunshine.
9. If direct protection of the ends of hardwood timber is not possible they should be coated with a moisture proof coating such as wax to prevent end checking or splitting.

Artificial Seasoning

The most common method of artificial seasoning is to use a kiln. There are many designs and degrees of sophistication of conventional kilns, [10] but in all of them the temperature, the humidity and the ventilation are controlled to give optimum drying conditions for any given species of timber. In many developing countries the individual tool manufacturers and timber industries are small and often separated from each other by considerable distances. For small-scale operations even the smallest of conventional kilns pose two major problems: high capital cost and excess capacity. Both problems can be overcome by the use of solar timber drying kilns. A considerable amount of work has been carried out on solar timber drying kilns for developing countries [11] [12].

Figure TN 2.2 illustrates the principle of one solar heated dryer designed for use in developing countries. It is also shown in Plates TN 2.1 and TN 2.2. The solar dryer has a capacity of 7m³, is available in kit form¹ and is about one tenth the cost of a prefabricated conventional kiln of the same capacity.

¹ Complete kits, individual components, or drawings and instructions are obtainable from: Jak Forest Fuels Ltd., 21 Biggar Road, Silverburn, Penicuik, Midlothian EH26 9LQ, Scotland, U.K.

The principle of the solar timber drying kiln is as follows. The stack of green sawn timber is assembled as for air drying and surrounded with polythene envelope supported clear of the stack. The heat required for drying is obtained from incident solar energy collected by simple absorbers. Movement of air, and the water vapour given off from the wood, is effected by electric fans which require an external power supply. Air movement within the kiln is regulated by an internal baffle and exhausting is by means of simple vents. Only a very small proportion of the total air in the kiln is exhausted and most is recirculated, retaining a large proportion of the heat within the kiln.

Characteristics of Solar Kilns

1. Production of seasoned timber in solar kilns has proved in all cases, where costings have been carried out, to be cheaper than conventional kilns.
2. Costs of drying by solar kiln are generally accepted as being as high as, or higher than, air drying.
3. The three major advantages of solar drying over air seasoning are that it is:
 - i) quicker, normally about twice as fast to EMC of air dried timber in the climate concerned.
 - ii) possible to dry timber sufficiently to be suitable for high grade use such as tool handles.
 - iii) almost always superior in quality since humidity is more uniform in all stages of drying.

MANUFACTURE

The simplest handle shapes, such as those of rakes and shovels can be turned from the seasoned billets on an ordinary centre lathe. This method of manufacture can also be adopted to produce a tapered or waisted circular

section handle. These handles are unsuitable for striking tools which require oval or elliptical cross-sections. Oval or elliptical section handles are normally produced on automatic contour turning lathes, but these are expensive (\$8-10,000) and can only be justified if very large numbers are to be produced. Handles for hoes, mattocks and pick axes can be produced labour-intensively by a combination of simple lathe turning and final shaping by hand using templates similar to those illustrated in Figure 1 and a spokeshave. The spokeshave shown in Figure 2.3, also known as a scraper, is specifically designed to finish narrow curved sections of timber. The face is curved for concave shapes or flat for convex curves: both would be required for the manufacture of tool handles. One handle of the tool is held in each hand with the thumbs placed on the back edges to control the angle of the tool. The spokeshave should always be worked away from the body in the direction of the grain of the wood.

The economics of this method of manufacture will depend on the size of orders and whether labour can achieve a satisfactory level of productivity

For the more complex axe and Scandinavian brush hook handles a combination of simple lathe turning, wood bending and finishing by spokeshave should produce the required shape. The technical and economic viability of this form of production remains to be established.

For axe and brush hook handles a critical aspect is the extent to which available hardwoods can be bent to the shape required. Bending is required to ensure that the grain of the wood remains parallel to the handle: so that weak spots are avoided. Most tropical timbers have poor bending properties. Tests have shown [13] that the bending properties of the tropical timbers listed in Table TN 2.5 can be classified as good and moderate respectively.

The actual technique of bending is fairly simple [14] although care is necessary in applying load to the handle slowly. First the wood is softened by steaming, boiling or heating in wet sand. The simplest

arrangement is to have a metal tank of water, that is just boiling, and is slightly deeper than the length of the handles to be bent. The handles are immersed vertically and supported by a 10-15mm square metal wire grid of the type used for concrete floor re-inforcement. Immersion times vary with the wood species but are about 20-30 minutes. The handles are removed and bent, to give the desired shape, either around pegs arranged in a board, or using wooden-vice type clamps positioned vertically against a wall which has concrete blocks shaped to the required handle radii as shown in Figure TN 2.4. The latter method is preferred since the bending stress can be applied gradually. After cooling to room temperature the shape will have set permanently.

FINISH

The finish given to a handle is crucial to the manner in which the tool is used. The efficient use of many tools requires that one or both of the operator's hands slide over the surface of, or rotate around the handle. If the surface finish is so rough that sliding or rotating the hands is painful then the tendency is for the operator to maintain a fixed grip, which greatly lowers working efficiency and accelerates fatigue. Even the maintenance of a fixed grip can be difficult if the surface is left rough and the tool is unlikely to be used effectively. Care is necessary to ensure that the cross-sectional dimensions, and curves of a handle conform to the natural shape of the hand and that the finish is sanded smooth all over. Surface cracks, and rough edges, such as at the end or joint with the head of the tool, should not be permitted. After final sanding to a smooth even finish handles should be lightly waxed: alternatively, they can be treated with linseed oil or a light coat of varnish. (For example, Indian Standards require that immediately after manufacture all tool handles are dipped in hot raw linseed oil at a temperature of about 90°C for one hour and allowed to drain). These treatments assist the sliding and rotating motions of the hand and prolong the life of the handle by resisting the passage of moisture.

STORAGE

If spare tool handles are to retain their properties then they should be stored in cool, dry conditions out of direct sunlight. They should be laid flat, off the ground, on shelves that have a free circulation of air around them. The advice of the local forestry organisation should be sought on suitable preservatives against attack by insects or fungi.

TABLE TN 2.1 - Indian Wood Species for Tool Handles [1][3][4]

Handle Type	Botanical Name	Local Name
Type 1 handles over 750mm in length, for double faced sledge hammer, axe , pick-axe .	<i>Acacia arabica</i> <i>Mimusops</i> sp. <i>Grewia</i> sp. <i>Anogeissus pendula</i> <i>Mesua</i> sp. <i>Heritiera</i> sp. <i>Anogeissus acuminata</i>	Babul Bullet-wood Dhaman Kardahi Mesua Sundri Yon
Type 2 handles varying in length from 600 to 750mm. All the timbers specified for Type 1 Handles are also permitted.	<i>Fraxinus</i> sp. <i>Anogeissus latifolia</i> <i>Hopea</i> sp. <i>Terminalia tomentosa</i> <i>Madhuca</i> sp. <i>Quercus</i> sp. <i>Shorea robusta</i> <i>Ougeinia dalbergioides</i> <i>Dalbergia sissoo</i>	Ash Axlewood Hopea Laurel Mahua Oak Sal Sandan Sissoo
Type 3 handles up to 600mm in length. All the timbers specified for Types 1 and 2 Handles are also permitted.	<i>Amoora</i> sp. <i>Lagerstroemia lanceolata</i> <i>Diospyros</i> sp. <i>Syzygium</i> sp. <i>Morus</i> sp.	Amoora Benteak Ebony Jaman Mulberry
Type 4 handles for shovels, rakes and spades.	<i>Fraxinus</i> sp. <i>Mimusops</i> sp. <i>Grewia</i> sp. <i>Hopea</i> sp. <i>Syzygium</i> sp. <i>Madhuca</i> sp. <i>Quercus</i> sp. <i>Heritiera</i> sp.	Ash Bullet-wood Dhaman Hopea Jaman Mahua Oak Sundri

TABLE TN 2.2 - Southern African Species and Minimum Densities of Wood for Handles

Botanical Name ¹	Local Name	Minimum density at a moisture content ² of 12% kg/m ³		
		Striking tools		Other tools
		Group A	Group B	Group C
		Hammers (length greater than 600mm) Pickaxes	Axes hammers (length less than 600mm)	forks shovels spades
<i>Carva</i> sp.	Hickory	740	670	590
<i>Eucalyptus paniculata</i>	Paniculata	960	830	800
<i>Eucalyptus fraxinoides</i>	Fraxinoides	640	540	500
<i>Eucalyptus citriodora</i>	Citriodora	830	770	640
<i>Eucalyptus globulus</i>	Bluegum	850	800	700
<i>Eucalyptus pilularis</i>	Pilularis	800	720	680
<i>Eucalyptus punctata</i>	Punctata	950	830	740
<i>Eucalyptus diversicolor</i>	Karri	820	690	640
<i>Fraxinus excelsior</i>	European ash	750	640	590
<i>Prunus africana</i>	Bitter almond	900	800	700
<i>Celtis africana</i>	Kamdeboo	750	650	600
<i>Eucalyptus maculata</i>	Maculata	820	720	660
<i>Mimusops</i> sp.		920	800	700
<i>Eucalyptus resinifera</i>	Resinifera	-	820	720
<i>Diospyros whyteana</i>	Swartbas	830	730	600
<i>Eucalyptus microcorys</i>	Microcorys	1 030	880	780
<i>Eucalyptus fastigata</i>	Fastigata	Not suitable for handles of striking tools		650
<i>Albizia adianthifolia</i>	Flatcrown			500
<i>Cassipourea gummiflua</i>	Onionwood	Not suitable for handles of striking tools		550
<i>Eucalyptus sideroxylon</i>	Sideroxylon			800
<i>Eucalyptus obliqua</i>	Obliqua	Not suitable for handles of striking tools		700
<i>Eucalyptus botryoides</i>	Botryoides			850
<i>Funtumia latifolia</i>	Bastard Wild Rubber	Not suitable for handles of striking tools		500
<i>Pinus canariensis</i>	Canariensis			640
<i>Pinus pinaster</i>	Pinaster	Not suitable for handles of striking tools		530
<i>Pinus radiata</i>	Radiata			560

For rake handles the wood may be of any species that has a density of at least 440kg/m³ at a moisture content of 12 per cent [5]

¹ The timbers are listed in descending order of toughness.

² For an explanation of 'moisture content' see the notes accompanying Table TN 2.3.

Notes to Table TN2.3 : Mechanical properties of timber

1. Various factors, such as moisture content¹, density and temperature, affect the values obtained for the strength of timber and quoted results only relate to a standard set of test conditions. Notwithstanding this, it must be remembered that individual pieces of a timber can differ appreciably from the average figures quoted.
2. When comparing the strength of various species of timber it is essential that the moisture content be known. Above the fibre saturation point (25 to 30 per cent) changes in moisture content have no apparent effect on the strength of wood. Below the fibre saturation point, most strength properties increase with decrease in moisture content, although not always to the same extent; the properties of resistance to suddenly applied loads and toughness of some species may show slight decreases as a result of drying. Unless stated otherwise, the strength properties quoted in these Tables relate to a moisture content of 12 per cent.
3. The suitability of timber for tool handles involves consideration of a number of specific mechanical properties the most important of which are as follows:-

Density This gives an approximate indication of a timber's strength. Ash and hickory have outstanding strength properties in relation to their fairly moderate densities (690 and 820 kg/m³ respectively). Whilst similar levels of strength can be found in a few very dense timbers (over 1000 kg/m³, such as Ebony), the use of these materials for handles would probably result in a badly balanced or unduly heavy tool. Densities in excess of 850-900 kg/m³ are unlikely to be suitable for tool handles. Where available the Table gives the mean density and range of values for each species.

Impact Bending This is one measure of the toughness of timber. The test procedure, consisting of a hammer dropped from increasing heights until complete failure occurs, is very relevant to the shock resistance of tool handles. Hickory exhibits exceptionally high values of this property, namely 1.93-2.23 m.

Static Bending From the static bending test procedure a number of important timber properties can be obtained. The *maximum bending strength* is obviously important where handles are used for leverage.

Stiffness is of importance in determining the deflection of a beam under load - the greater the stiffness, the less the deflection. It is usually considered in conjunction with bending strength, as for many uses stiffness is the controlling factor, e.g. shock travelling through the handle and felt as jarring in the hands is a function of the property of stiffness: very generally it may be said that stiff timbers transmit shock waves more readily.

Resistance to shock transmission, is more accurately measured by the *energy consumed in bending*. High values of this property would not be obtained from a material showing sudden brittle fracture, but rather from a prolonged 'stringy' failure. The values obtained for hickory (0.215 N/mm² to maximum load and 0.648 to failure) are again outstanding.

- 1 The amount of moisture in any piece of wood is known as its moisture content. This is expressed as a percentage of the weight of dry wood in the piece, not of the total weight. Thus it is possible to have moisture contents of well over 100 percent.

TABLE TN 2.3 - Mechanical Properties¹ of Important Tool Handle Woods

Species	Density (kg/m ³)	Impact Bending: maximum drop of hammer (m)	Static bending : centre loading			
			Maximum Bending Strength (N/mm ²)	Stiffness (N/mm ²)	Energy consumed in bending (mmN/mm ³)	
					to max load	to total fracture
Hickory (<i>carya</i> sp.)	820 (700-900)	1.93-2.23	139	15000	0.215	0.648
Ash, European (<i>fraxinus excelsior</i>)	690 (510-830)	1.07	116	11900	0.182	0.281
Celtis, African (<i>celis</i> , sp.)	780	1.32	144	15900	0.154	0.272
Birch, European (<i>betula</i> , sp.)	660	1.04	123	13300	0.154	0.259
Beech, European (<i>fagus sylvatica</i>)	690 (670-720)	1.14	118	12600	0.146	0.239

¹ For an explanation of these terms see the notes accompanying this Table. The values have been compiled from [6] [7]

TABLE TN 2.4 - Mechanical Properties of Miscellaneous Wood Species for Tool Handles

Species	Country or Region	Density (kg/m ³)	Impact Bending: maximum drop of hammer (m)	Static bending : centre loading			
				Maximum Bending strength (N/mm ²)	Stiffness (N/mm ²)	Energy consumed in bending (mmN/mm ³)	
						to max load	to total fracture
Pau Marfin (<i>balfourodendron riedeleianum</i>)	Brazil	799 ²	1.55	133	-	0.286	0.592
Mkaratusi (<i>eucalyptus</i> sp.)	East Africa	849 (750-1140)	0.99	118-236	12100-22700	0.170-0.192	0.194-0.346
Msambu (<i>diospyros abyssinica</i>)	East Africa	946 (800-1000)	1.24 (1.19-1.50)	117-189	10700-17700	0.153-0.236	0.387-0.529
Pillarwood (<i>cassipourea malosama</i>)	East Africa	(740-750)	(1.19-1.52)	123	11500	0.190	0.316
Australian Blackwood (<i>acacia melanoxylon</i>)	East Africa	689	1.09	79	16340	0.121	0.225
Agoho (<i>casuarina equistifolia</i>)	Philippines	917 (758-1314)	-	175	21800	-	-
Binggas ¹ (<i>terminalia critina</i>)	Philippines	935 (636-1082)	-	133	15800	-	-
Katilma (<i>diospyros nibidan</i>)	Philippines	892 (739-978)	-	150	18300	0.174	0.266
Ata - Ata (<i>diospyros mindamensis</i>)	Philippines	774 (778-946)	-	125	14900	-	-
Malabayabas (<i>tristania decorticato</i>)	Philippines	1213 (1051-1421)	-	184	19600	-	-
Selangan Batu (<i>shorea superba</i>)	Sabah	833 ³	1.22	143	-	0.159	0.323

¹ considered to be the premier substitute for hickory [8] - ² at 12.9 per cent moisture content

³ at 13.9 per cent moisture content.

TN 2.5 : Bending Characteristics of Tropical Wood Species used for Handles

GOOD

Ebony, African

diospyros crassiflora

Pali

palaquium ellipticum

dichopsis elliptica?

Pillarwood

cassipourea malosana

Karri

MODERATE

Albizia

albizia ferrunginea

Celtis, African

(celtis, sp.)

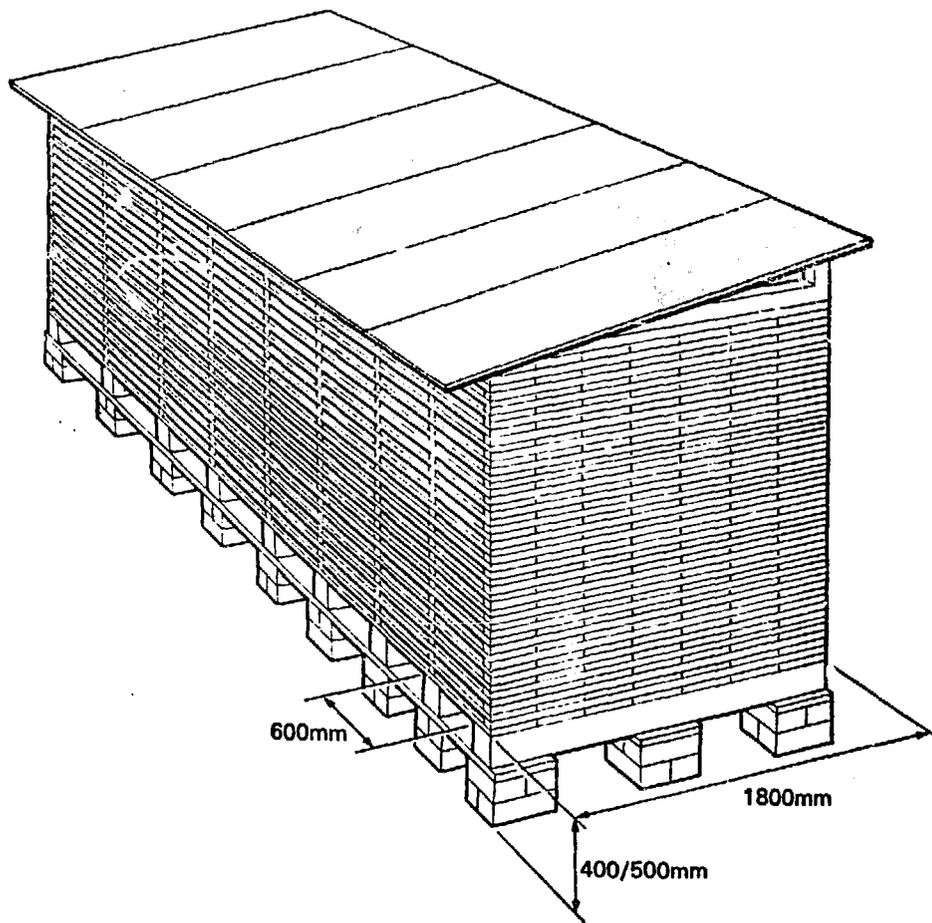


FIGURE TN 2.1 STACK CONSTRUCTION FOR AIR SEASONING OF TIMBER

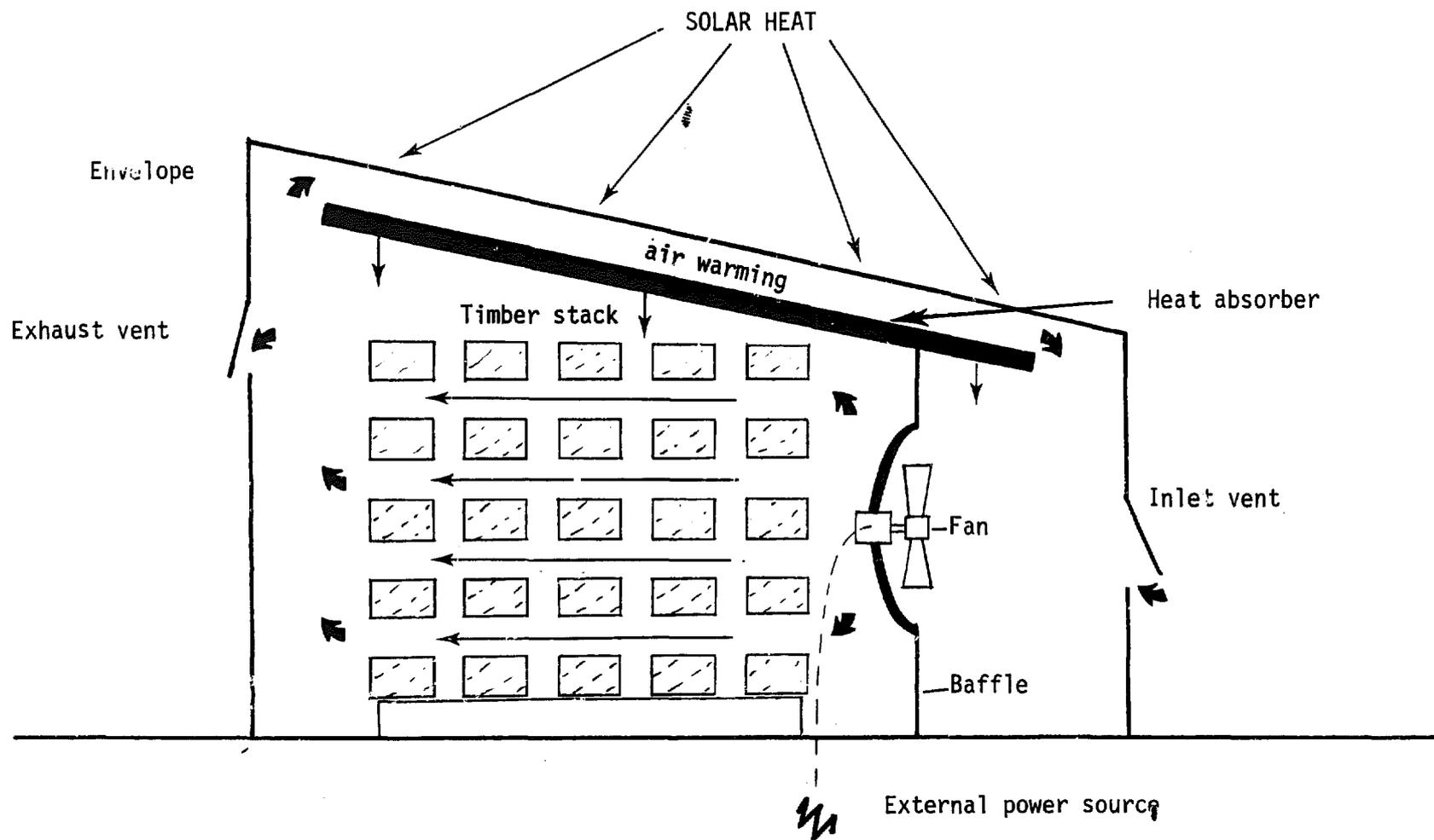


FIGURE TN 2.2 : Solar Kiln

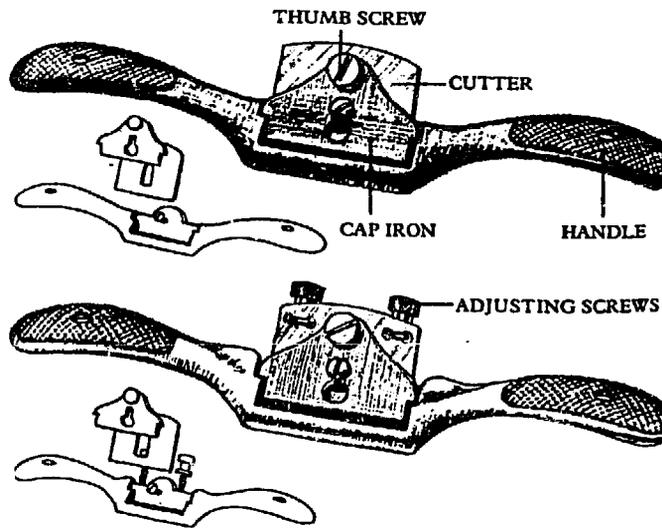


FIGURE TN 2.3 SPOKESHAVE

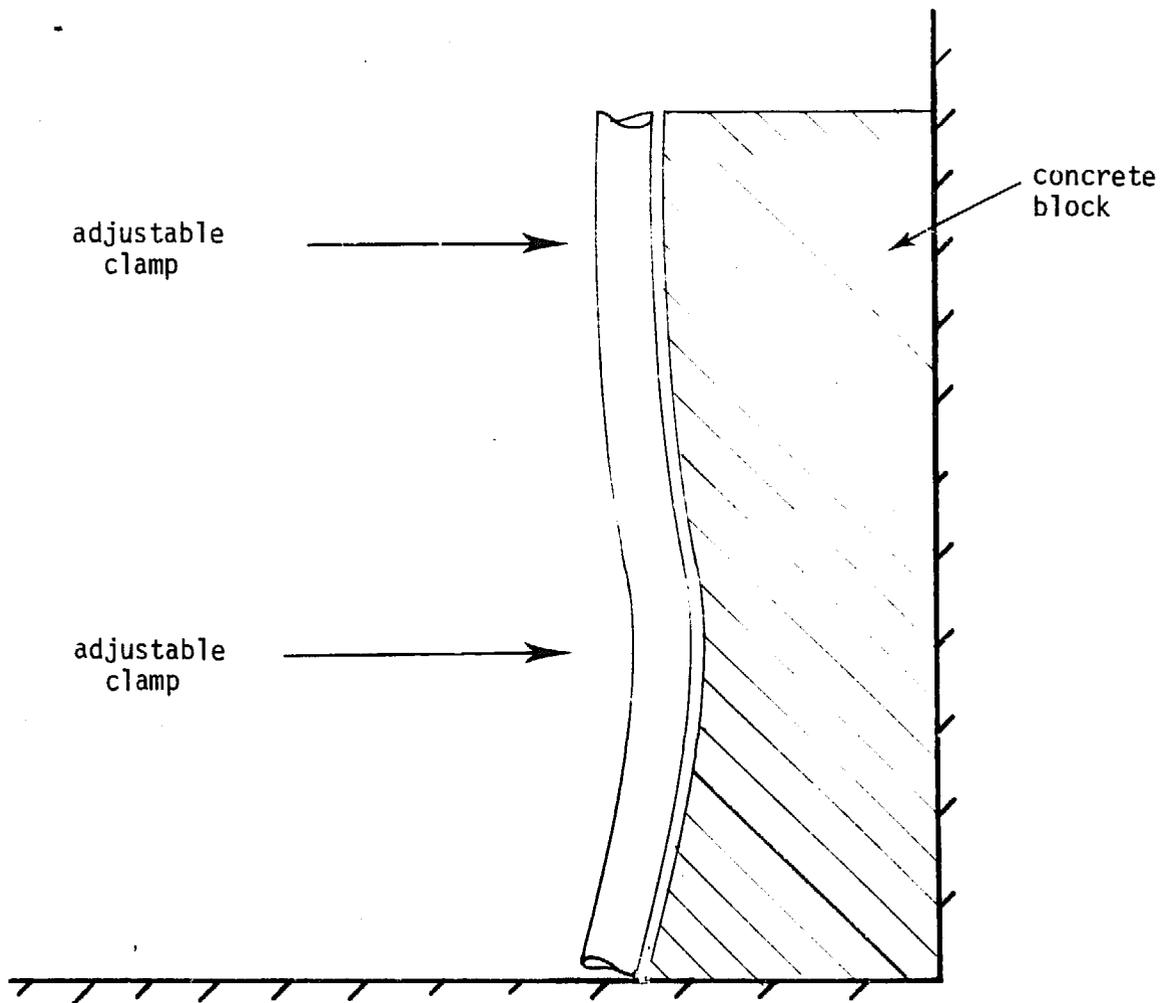


FIGURE TN 2.4 : Concrete Block and clamp
bending of tool handles

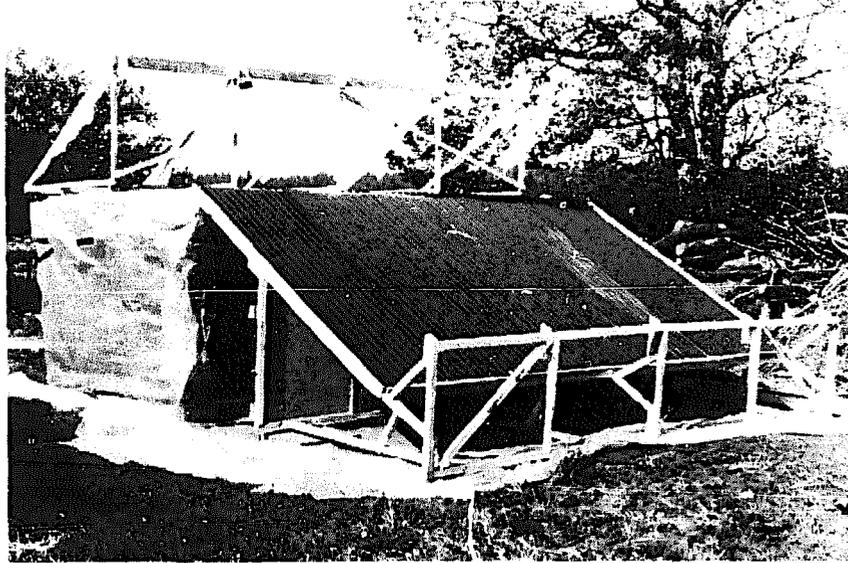


Plate TN 2.1 : Solar Kiln Under Construction Showing Heat Absorber



Plate TN 2.2 : Completed Solar Kiln

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INTRODUCTION

The Guide has emphasised the importance of purchasing only those handtools that satisfy the prescribed technical specifications. To ensure that this is so it will be necessary for the purchaser to carry out acceptance tests upon receipt of any tools from manufacturers. This note describes acceptance or compliance test methods for handtools. It must be emphasised that these tests are neither comparative - they cannot be used to identify the 'best' of a selection of tools, nor do they provide practical information on the working life of the tools. Acceptance tests simply define whether or not a tool meets a particular specification.

The more comprehensive the tests the more expensive and difficult they are to administer, but the more confident a customer can be in what he is purchasing. In practice the extent of tool testing is likely to be decided by the facilities available to the purchaser. For this reason methods are described that progress from the most simple visual checks of the entire tool, through those requiring minimal equipment, to tests on the head/blade and handle separately requiring reasonably sophisticated equipment.

TESTING PROCEDURES

Table TN 3.1 illustrates a progressive testing procedure that can be applied to complete tools or the heads and handles separately as appropriate.

SIMPLE CHECKS

Careful inspection of a tool can be of considerable help in assessing whether it meets the specification.

Metal materials defects

There should not be any cracks, seams, scales, blow holes or discolouration - particularly on the sharpened or polished edges - that might indicate defects in the original material or in its subsequent treatment.

Wooden materials defects

For striking tool handles the inspection should be particularly rigorous. Wood used for tool handles should be straight grained with the grain running parallel to the handle. Any serious deviation in the grain pattern should be examined for possible hair cracks and marked with a soft pencil for scrutiny during and after the bending test. There should not be any decay (rot), centre heart (pith), loose knots or knot holes, borer holes and cracks or splits resulting from incorrect seasoning, or open resinous or gum veins. Discolouration of the wood should not be accepted unless this is a known characteristic of the species which tests have shown not to affect the strength of the handle.

Metal production defects

All sharp edges other than the cutting edge(s) should have been removed. Particular attention should be paid to any bolts or rivets (which should be countersunk), the joint between head and handle, and any parts where the hands grip or slide when using the tool. Any rough edges likely to cause discomfort or injury to the hands are unacceptable.

Wooden production defects

All wooden parts must be free of machine chips or other sharp edges resulting from the production process. The simplest test is to run the hand over the surface: any rough parts are unacceptable.

Check that the head and the cutting edge(s) are in correct alignment with the handle. Also, that head and, where provided, hilt are fixed firmly to the handle.

Finish

Check that the metal parts have been painted, varnished or lacquered as specified: there should be no evidence of rust. Wooden parts should have been waxed or oiled (TN 2).

Manufacturers Identification

Each tool should be plainly marked with some ready means of identifying the source, such as the manufacturer's name or trade-mark. This will enable both satisfactory and unsatisfactory field performance to be reported.

BASIC MEASUREMENTS

It is comparatively simple to check if sample tools comply with specified weights and dimensions allowing for any tolerances on the nominal values. With axe, hammer, hoe, pickaxe and mattock heads particular attention should be paid to ensuring that the eye is central in the width of the head and that the wall thicknesses of the eye are not less than the minimum specified. Any irregularity in the shape of the eye should not be permitted as it requires considerable skill to obtain a secure handle fixing in a poorly shaped eye.

The length, diameter or other cross-sectional elements of handles are simple to check. Checking whether handles have warped is more difficult. Circular handles can be rolled at eye level on any flat surface and the degree of warp observed. More complex handle shapes are best checked against full-scale templates such as those illustrated in Figure 1.37.

PROPERTIES TESTS

Most national specifications follow the same approach to the testing of hand-tool properties, although there is some variation in the detail and extent of the tests applied to individual tools. A summary of some standard test details is given in Table TN 3.2. These have been derived from British Standards (BS), Indian Standards (IS) and those developed for the KRARP.

Bending Test

This test is carried out on assembled axes, hoes, pickaxes, mattocks, shovels, spades and forks, and on crowbars. The implements are clamped at the blade

end and a special load is gradually applied at the handle as shown in Figure TN 3.1 for a predetermined time. The usual test stipulation is that there should be no visible sign of damage or loosening of any component part, nor shall there be any permanent set, or bending, in excess of a specified maximum.

This is a relatively simple test to carry out and provides a useful check on overall quality, without necessarily pinpointing the particular defect in cases of failure.

Under the KRARP the same test has also been applied to the handles of axes, hoes, mattocks, pickaxes, shovels and sledgehammers.

Impact test

Various forms of impact test are carried out on the cutting edges or working faces of axes, crowbars, hoes, pickaxes, mattocks, hammers and cast iron rammers. Either the entire tool assembly is dropped onto a supported hardwood or metal surface a specified number of times from a given height, or the working edge/face is struck with a metal bar or hammer. The usual test stipulation is that there should be no sign of damage in the form of cracks or deformation, or loosening of any component part.

Hardness test

The most accurate method of checking on the heat treatment of tool heads is to determine their hardness. With some tools it is important that parts of the head are hardened to resist wear and compressive stresses whilst other areas are left in their naturally tough condition so as to absorb tensile forces. This can be checked by measuring the hardness values at precisely defined positions on the head: see Table TN 3.2. The most widely employed standard methods for measuring the hardness of metals are the Brinell, Vickers and Rockwell tests. The Brinell method is not regarded as reliable for very hard metals. The Vickers test is the most precise and complex, whereas the Rockwell method is particularly useful for rapid routine testing tests on finished products. All require special purpose equipment.

[1] [2] [3] The values given in Table TN 3.2 are based on the Rockwell C scale for steels, but conversions to appropriate Brinell or Vickers values can be made with the aid of Table TN 3.3 [4].

Crack test

There are various non-destructive methods of determining fine cracks in the surface of highly stressed hammer faces. The two simplest are the magnetic dust and fluorescent tests.

Magnetic dust

This test consists in magnetising the steel article and immersing it in a bath of kerosene containing fine iron dust. If a crack lies across the path of the magnetic flux each side of the crack becomes a magnetic pole which collects iron dust.

Fluorescence

This test, which is not limited to magnetic materials, consists in dipping the article in a solution of fluorescent dye which fills any cracks. The surplus liquid is then removed from the components which, after drying, are examined under ultra-violet light. Cracks are shown up vividly by fluorescence.

Large internal cracks or cavities in hammer heads in excess of 0.5 kg weight can be detected by the ringing test.

Ringing

The head is suspended through the eye on a cord or wire, and struck on the working faces with the ball pein of a 100g hammer. Sound heads will give a clear metallic ring.

Wood quality

We are concerned here with tests on the qualities of wood handles whose acceptability as a suitable species has previously been identified (see TN2). The most important check is to determine if the wood has been seasoned to a moisture content appropriate to the locality. Unless the tool handle is destroyed this can only be determined with an electric moisture meter [5]. These give readings accurate to about ± 2 per cent.

SAMPLING

If large numbers of tools are being purchased it may be impractical to inspect them all so some form of sampling will be necessary. A sampling scheme should specify the number to be selected, process of selection, and the consequences if a proportion of the sampled items fail the given tests.

Sample size

Sample sizes are not generally laid down in national tool specifications this being left to the discretion of the purchaser. Extensive experience of acceptance testing has established certain general principles. For a given lot size the larger the sample the more confidence can be attached to the results of any tests. Also, the larger the lot being purchased the smaller in percentage terms the sample need be for reliable conclusions to be drawn. However, the more difficult the testing procedure the smaller the sample size that will be practicable. Lastly commonsense dictates that the tools of new manufacturers be inspected more rigorously than those that have proved the quality of their products.

Table TN 3.4 gives sample sizes for the acceptance testing of handtools. They have been derived from established procedures in a number of countries and should be regarded as guidelines rather than absolute recommendations.

Selection process

Selection must be random to ensure that the results are free from bias. If sampling requires that 100 tools be inspected from a batch of 1,500 then simply inspect every 15th tool i.e. batch size divided by sample size, etc.

Consequences of rejection

Not all tests are of equal importance. The more crucial to the performance of a tool is the characteristic being tested the fewer the test failures that can be tolerated among the sampled item, perhaps no failures at all. A minor proportion of variations from specification in the dimensions, weight or finish of tools might be overlooked, but, with due allowance for chance elements, almost no deviations ought to be allowed from the stipulated hardness or impact test results on the facts of striking tools, since the safety of workers would be compromised.

TABLE TN 3.1 : Progressive Testing Procedure

PROCEDURE	DETAIL
1. SIMPLE CHECKS	Materials Defects Production Defects Finish Manufacturers Identification
2. BASIC MEASUREMENTS	Weight and Dimension Checks
3. PROPERTIES TESTS	Bending Impact Hardness Crack Wood Quality

TABLE TN 3.2

TOOL		BENDING	IMPACT	HARDNESS
AXE ¹ :	BS	-	<p>(i) Head laid on anvil with hardened portion overhanging the side and unsupported: 3 sharp blows with 1.8kg hammer with normal force on the overhanging hardened part</p> <p>(ii) A series of true, square blows across the grain of a hardwood</p> <p>(iii) Cutting edge is slightly blunted then given a true square blow with a 12-20mm bar of low-carbon steel</p>	Hardness 48-56 HRC up to 50mm from cutting edge and to full depth of blade. Eye left unhardened.
	IS	-	<p>(i) Twelve hard blows across the grain of a hardwood</p> <p>(ii) Handle, only, held horizontally and dropped 10 times from a height of 1.25m onto a concrete surface</p> <p>(iii) Handle only fitted with dummy head of 2kg and 10 blows of reasonable force given to a hardwood surface</p>	

TABLE TN 3.2 continued

TN3 10

TOOL	BENDING	IMPACT	HARDNESS
<p>AXE (continued)</p> <p>KRARP²</p>	<p>(i) Head is clamped firmly so that the handle is horizontal 45kg load applied gradually to end of handle for 2 minutes Permanent set not to exceed 25mm.</p> <p>(ii) Similar test applied to handle only when its larger end is clamped over a length of 100mm</p>		<p>Hardness 48-54 HRC at 50mm from cutting edge, and 25-30 HRC at the eye.</p>

TABLE TN 3.2 continued

TOOL	BENDING	IMPACT	HARDNESS
<p>HOE IS</p> <p> KRARP</p>	<p>-</p> <p>(i) Blade clamped firmly: 45 kg load applied gradually for 2 minutes. Permanent set not to exceed 25mm.</p> <p>(ii) Similar test applied to the handle only with plain end firmly clamped over a length of 120mm and load of 45 kg applied gradually to end of handle</p>	<p>Dropped about 600mm onto a mild steel plate of 25mm thickness, so working edge strikes squarely</p> <p>-</p>	<p>Hardness 39 - 48 HRC measured 12mm from cutting edge</p> <p>Hardness 40 - 46 HRC within 50mm of cutting edge. Hardened zone not to extend nearer than half way to the eye</p>
<p>FORKED HOE KRARP</p>	<p>As for Hoe</p>	<p>-</p>	<p>Hardness 25 - 30 HRC at shoulder increasing along prongs to 45 - 50 HRC within 50mm of the tips</p>
<p>PICKAXE BS</p>	<p>-</p>	<p>(i) Point or cutting edge struck with 25mm bar of mild steel or wrought iron 300mm long, while implement is solidly supported.</p> <p>(ii) Alternative to (i) is a sharp blow by the implement on a slab of mild steel not less than 25mm thick.</p>	<p>Hardness at working end 47 - 54 HRC</p>

TABLE TN 3.2 continued

TOOL	BENDING	IMPACT	HARDNESS
<p>PICKAXE BS (Cont'd)</p> <p>IS</p> <p>KRARP</p>	<p>-</p> <p>(i) Blade clamped firmly : 45kg load applied gradually for 2 minutes. Permanent set not to exceed 25mm</p> <p>(ii) Similar test applied to handle only when its larger end is clamped over a length of 120mm.</p>	<p>(iii) Handle fitted then implement dropped by gravity a minimum height of 460mm onto rigidly supported 25mm mild steel plate.</p> <p>(i) 1500mm handle, fitted then implement dropped by gravity using inverted pendulum testing so that point strikes 25mm mild steel plate.</p> <p>Point or cutting edge struck a sharp blow with bar of mild steel 25mm diameter.</p>	<p>Hardness 46 - 54 HRC</p> <p>Hardness 25-30 HRC at eye increasing to 45 - 50 HRC within 50mm of cutting edges.</p>
<p>MATTOCK BS</p> <p>KRARP</p>	<p>-</p> <p>as for pickaxe</p>	<p>as for pickaxe</p> <p>-</p>	<p>as for pickaxe</p> <p>as for pickaxe</p>
<p>CROWBAR IS</p>	<p>Bar is gripped rigidly and horizontally for not more than 75mm of the straight portion nearest to the working end. A load is suspended from the free end for half a minute. No permanent set is permitted after allowing for an initial set of 6mm. The relationship between weight of</p>	<p>Held vertically at height of 600mm over block grey cast iron at least 150mm thick: dropped 5 times.</p>	<p>Hardness 31 - 42 HRC</p>

TABLE TN 3.2 continued

TOOL	BENDING	IMPACT	HARDNESS
<p>SHOVEL: BS</p> <p>IS³</p> <p>KRARP</p>	<p>Blade clamped firmly as shown in Figure TN 3.1: 40 kg load applied gradually to end of handle for 1 minute. Then 65 kg load applied for 2 minutes. Permanent set not to exceed 25 mm.</p> <p>(i) Blade clamped firmly as shown in figure TN 3.1: 50 kg load applied gradually for 1 minute. Permanent set not to exceed 13mm</p> <p>(i) Blade clamped firmly as shown in Figure TN 3.1: 50 kg load applied gradually for 2 minutes. Permanent set not to exceed 25mm.</p> <p>(ii) Similar test applied to the handle only with plain end firmly clamped over a length of 150mm and load of 45 kg applied gradually to the grip with an offset from the handle centreline of 150mm.</p>	<p>-</p> <p>-</p> <p>-</p> <p>-</p>	<p>Hardness 39 - 47 HRC measured not less than 50mm from the shoulder. If alloy steels are used hardness can be increased providing bending test is satisfied.</p> <p>Hardness 39-48 HRC up to 25mm from the working edge</p> <p>Hardness of blade to be 17 - 22 HRC (This is the 'natural' hardness)</p>
<p>SPADE: BS</p>	<p>as for Shovel</p>	<p>-</p>	<p>as for Shovel</p>
<p>FORK BS</p>	<p>(i) as for Shovel</p> <p>(ii) For trenching forks, the tips of any two adjacent prongs brought together; ballast forks any four adjacent prongs. Following test prongs shall show no sign of permanent set or damage</p>	<p>-</p>	<p>as for Shovel</p>

TABLE TN 3.2 continued

TOOL	BENDING	IMPACT	HARDNESS
RAMMER IS	-	(i) Dropped twenty time from 300mm height onto cast iron or mild steel block (ii) Flat face of rammer given light blows with 0.75kg hammer.	-
BALLAST RAKE IS	Any two adjacent prongs brought together. No permanent set or damage upon release.	-	Hardness 40 - 48 HRC measured at any point beyond 50mm from the shoulder.

Notes to Table TN 3.2 Details of Standard Handtool Testing Procedures

- 1 No tests for Brush Hooks have been located, but it would seem reasonable to model them on those for Axes.
- 2 The KRARP Specification for Axes also describes a test in which 'the head/handle joint shall withstand an end load of 500kg without loosening'.
- 3 Indian Standards also describe a 'flexing test' for shovels. The end of the blade only is clamped firmly and the unsecured part of the blade is flexed through 5-10°, 3 times after which there must be no permanent set or other damage.
- 4 Tests apply to all hammers.
- 5 These tests are for 0.5-1.0kg stone breaking hammers.

Table TN 3.3 : Relationship between Rockwell, Brinell and Vickers hardness Values

Rockwell HRC	Brinell HB 30	Vickers HV 10 and 30
15	195	(205)
20	218	230
25	247	260
30	279	294
35	317	334
40	363	382
45	417	439
50	479	504
55	555	584
60	(663)	698

bracketted values are approximate

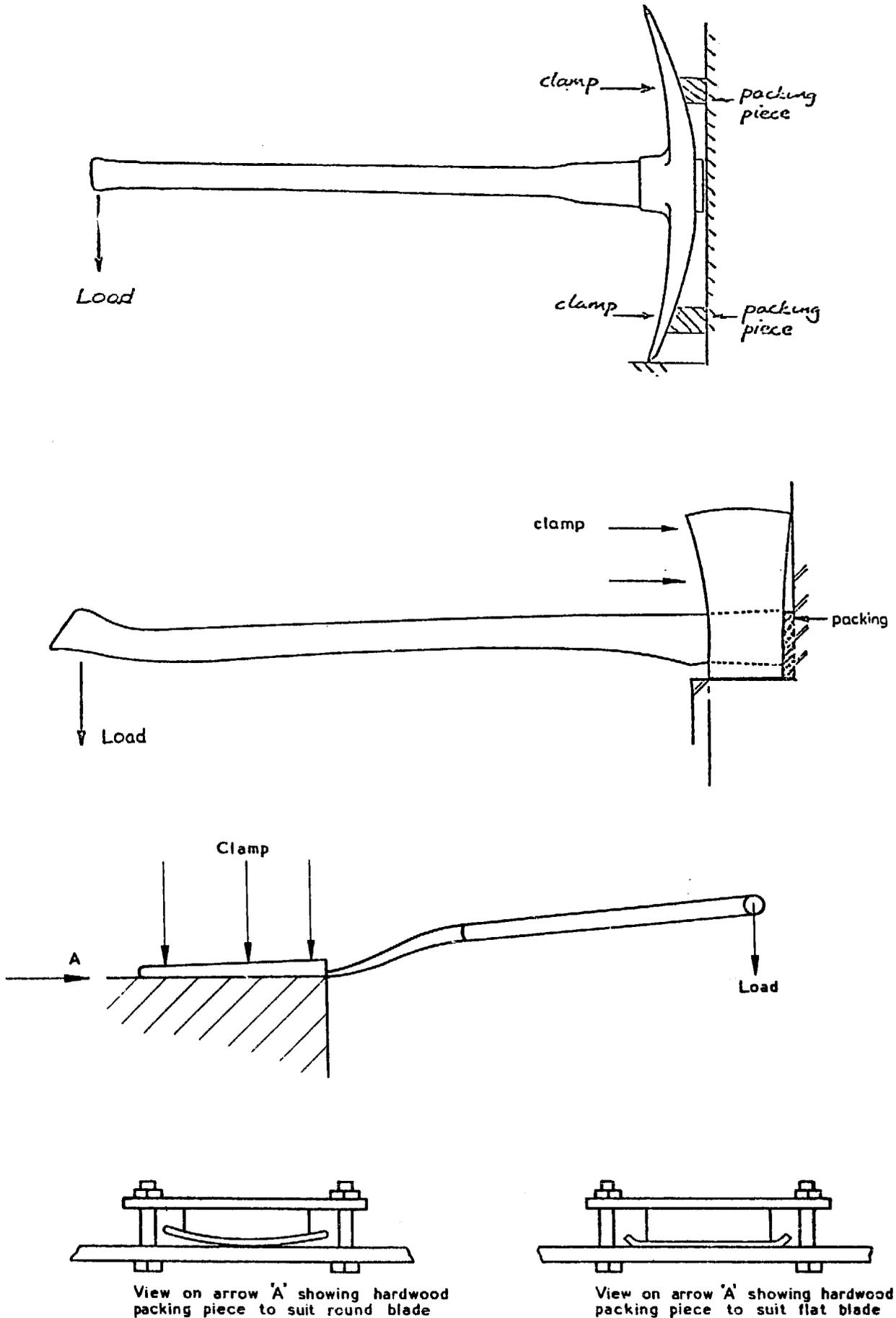


TABLE TN 3.4 : Sample Sizes for the Acceptance Testing of Handtools

Lot Size	Minimum* for Visual Inspection		Weight and Dimensions		Bending, Hardness, Impact and Crack Tests.		Moisture Content (Handles)	
	Sample size	Acceptance [†] number	Sample size	Acceptance [†] number	Sample size	Acceptance [†] number	Sample size	Acceptance [†] number
20 - 70	20	2	15	1	5	0	10	1
71 - 180	40	3	20	2	7	0	15	2
181 - 360	75	4	25	2	8	0	20	2
361 - 600	85	5	30	3	9	0	25	3
601 -1500	100	6	40	3	10	0	30	4

* where possible all to be inspected.

† acceptance number - maximum permissible number of defectives in respect of given requirement.

REFERENCES

- 1 BRITISH STANDARDS INSTITUTION. Method for Brinell hardness test. British Standard 240.
- 2 BRITISH STANDARDS INSTITUTION. Method for Vickers hardness test. British Standard 427: Part 1: 1961.
- 3 BRITISH STANDARDS INSTITUTION. Method for Rockwell hardness test. British Standard 891.
- 4 BRITISH STANDARDS INSTITUTION. Tables for comparison of hardness scale. British Standards 860: 1967.
- 5 PRATT, G.H. (1974) Timber Drying Manual. *Build. Res. Est. Rep.* London, H.M. Stationery Office.

INTRODUCTION

To be used efficiently a tool must be in proportion to the body dimensions of the operator and be suitably adjusted to his strength and work capacity. If the tool is too heavy the worker will tire quickly; if it is too light then he will exert less force than he could and productivity will be lowered. Tools that are too long will be awkward to use reducing efficiency: too short and a cramped working position results again lowering productivity. Commonsense suggests that because of the effort involved in their use tools that have to be swung require greater changes in weight and dimensions, to match variations in the size of operators, than those that are pushed, pulled or levered.

Several studies have shown that experienced workers can use efficiently larger, heavier tools than inexperienced workers. Thus the optimum tools for casually and seasonally employed labour are likely to be smaller and lighter than those for full time construction workers.

Translating these general principles into precise tool requirements is not very easy. For most countries information on the bodyweight and stature or 'size', of operators is difficult to obtain. Also, the relationship of these factors to optimum tool weight and dimensions has received little systematic attention.

This note summarises the available evidence on the tool weight - length combinations suitable for different sized operators.

It should be noted that in many parts of Asia the hoe is a traditional tool used for a variety of tasks from digging hard soil, through the scooping of loose sand or gravel to mixing, loading and the throwing of material. A large number of different head shapes, weights and handle lengths can be observed in practice. However, in most cases the productivity obtained with these tools is very low [1] partly because many are so designed that inefficient working techniques result. In general these tools cannot be regarded as a reliable guide to efficient designs.

TOOL WEIGHT-LENGTH RELATIONSHIPS

Table TN 4.1 and the accompanying notes summarise information on tool weight-length relationships. The 'available range' of tool weights has been obtained from manufacturers. The figures for the 'most useful weight range' have been derived from manufacturer sales records, national specifications and those reported to be used for labour-based road construction. The information on 'typical weight-length combinations' was obtained from national specifications and manufacturers: this data was found to be reasonably consistent from country-to-country.

There appears to have been no direct attempt to relate the *weight* of handtools used in civil construction activities to operator 'size'. However, it is possible to derive such a relationship indirectly.

Investigations of the relationship between 'traditional' *length* measurements for some tools and those established to be the most efficient by tests have found a close degree of correspondence [2.] The results are illustrated in Figure TN 4.1. The length of axe handles determined in this way would not be the same as those given in Table TN 4.1 being measured to the front rather than rear of the axe head. The total spade length is adjusted either to the elbow or to the waist, there being usually, only a few millimetres difference in these heights.

For rakes the length of the head is 3 'spans' or between 550-750mm depending on the force the operator can exert. For exceptionally strong operators it could be made up to 850mm long. The normal distance between the prongs is equal to 2 'digits'. These distances are determined by the material to be gathered; for finer material smaller distances between the prongs are chosen and the number increased from 16-18 to 24.

The length of the handle should be as long as possible (1850-2400mm) so that the operator can draw material from a distance without excessive body movement. For strong tall operators it should be one fist longer than the height of the operator. With populations of relatively short stature the length of handle corresponds to eyebrow height.

These results indicate a way of defining tool lengths in relation to operator size; and, by using the relationships in Table TN 4.1, a method of arriving at appropriate tool head weights.

- (i) Inspection of any one set of national specifications for the handle lengths of striking or 'swung' tools indicates that for a given head weight they are approximately the same for different tools. Thus, the method of estimated axe-handle lengths in relation to operator size given in Figure TN 4.1 (a) could be used also to determine appropriate handle lengths for hoes, pickaxes, mattocks and sledge hammers and hence (Table TN 4.1) suitable length-weight combinations.
- (ii) For shovels, spades and forks the overall height requirements can be estimated as indicated in Figure TN 4.1 (b).
- (iii) Rake dimensions can be estimated as indicated in Figure TN 4.1 (c), except that the handle length be adjusted to eyebrow height for operators of relatively short stature.

TABLE TN 4.1 : Handtool Weight-Length Relationships

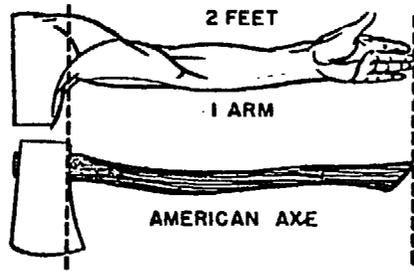
Tool	Head Weight (kgs)		Typical Weight/Length ¹ Combinations		Remarks
	Available Range	Most Useful Range	Head (kg)	Length ¹ (mm)	
AXE	1.1-3.2	2.0-3.0	1.0 1.5 2.0 2.5	600 720 860 910	Australian and Indian Standard : 2.0/815, KRARP Standard : 2.3/920
BRUSH HOOK	1.2-2.0	1.2-2.0	1.3 1.4 2.0	620 650 650	
HOES	0.8-4.0	1.0-2.5	1.5 1.6	950 900:750:450	KRARP Standard Indian Standard : 3 handle lengths allowed
PICK AXE	2.3-4.1	2.5-3.3	3.2 3.2	915 950	Indian Standard KRARP
MATTOCK	1.8-3.0	2.0-2.5	2.3 2.5	915 950	KRARP Standard
SLEDGE HAMMER	1.0-7.5	2.0-5.0	1.8 3.2 4.5 6.3	610 760 915 915	KRARP Handle is 950mm: no head weight specified
CROWBAR ²	3.0-20.0	8.0-12.0	11.0 9.0:11.0 11.0	1830 1650 1830	Indian Standard : round section Indian Standard: octagonal section KRARP Standard: octagonal section

TABLE TN 4.1 : Continued

Tool	Complete Tool Weight (kg)		Typical Weight/Length Combinations		Remarks
	Available Range	Most Useful Range	Head (kg)	Length (mm)	
SHOVEL ³	1.6-3.0	1.6-2.0	Not usually given	750 ⁴ 710 ⁴ 1230-1370	KRARP Standard British Standard Long-handled shovels
FORK ³	1.6-2.2	1.6-2.0	Not usually given	800 ⁴ 710 ⁴	British Standard for Trenching Fork British Standard for Ballast Fork
SPADE ³	2.0-2.7	2.0-2.4	Not usually given	710 ⁴	British Standard
RAMMERS	4.5-10.0	6.0-8.0	8.0 5.0:7.5:10.0	1100 1500-1750	KRARP Standard Indian Standard
RAKE	-	-	3.0	1500	KRARP Standard Heavy Duty Spreader

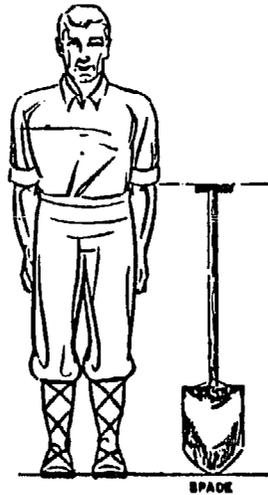
Notes to Table TN 4.1 Handtool weight-length relationships

- 1 For the axe, brush hook, hoes, pickaxe, mattock and sledgehammer the length measurement refers to that of the handle separately or from the top of the assembled tool to the heel of the handle.
- 2 Two man crowbars are used in Afganistan for rock excavation: these have a length of 1000-1500mm and a diameter of 40-50mm. Similarly three-man crowbars are used in India: these weigh 20kg, are 1830mm long and have a diameter of 50mm. Under Indian conditions 7.0kg has been recommended [2] as a comfortable weight crowbar for an individual worker.
- 3 It is unusual to find the weight of shovels, forks or spades quoted and their dimensions are specified in different ways in different countries.
- 4 These dimensions are from the top of the hilt of the handle to the shoulder of the blade/prongs.

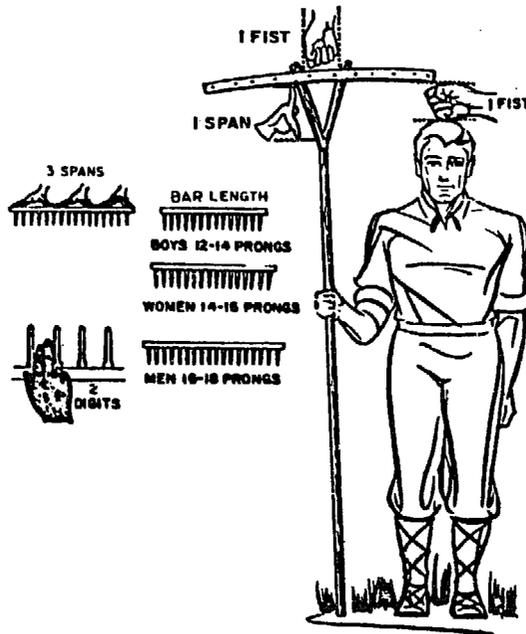


Length of axe handle.

(a)



(b)



Adjustment of the rake.

(c)

TN 4 REFERENCES

- 1 ALLAL, M and G.A. EDMONDS (in collaboration with A.S. BHALLA):
Manual on the Planning of Labour Intensive Road Construction
(Geneva, ILO, 1977).
- 2 DRILLIS, R.J. Folk norms and biomechanics. *Human Factors*
October, 1963. 427-441.
- 3 HOPFEN, H.J. Farm implements for arid and tropical regions.
FAO Agricultural Development Paper No. 91. Rome, 1969.
(Food and Agriculture Organisation).

INTRODUCTION

The working efficiency of tools is greatly reduced unless appropriate maintenance is carried out. Maintenance requirements are of two types: routine and remedial.

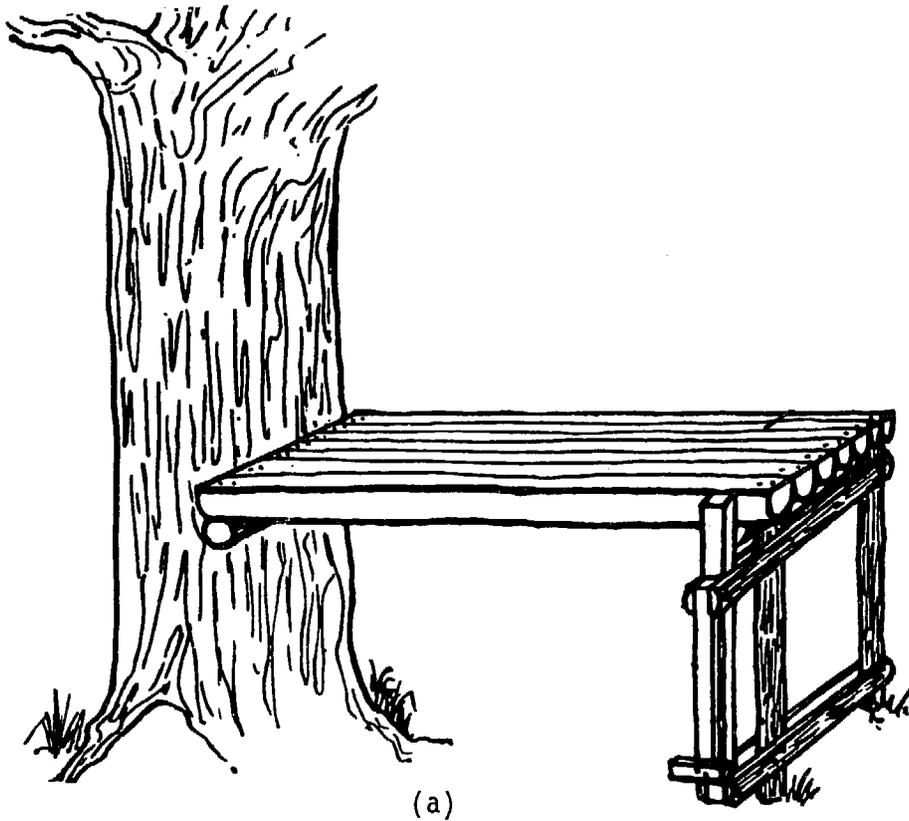
Routine maintenance are those regular but minor operations required to maintain tools in their most efficient working condition: they should be carried out as frequently as is necessary. With most handtools the commonest requirements will be the re-sharpening of cutting edges. For intensively used tools or under arduous conditions such as site clearance and rock excavation, this may be necessary every few hours.

Remedial maintenance is the repair or replacement of broken and worn components: if metal cutting edges are badly worn re-heat treatment may be necessary.

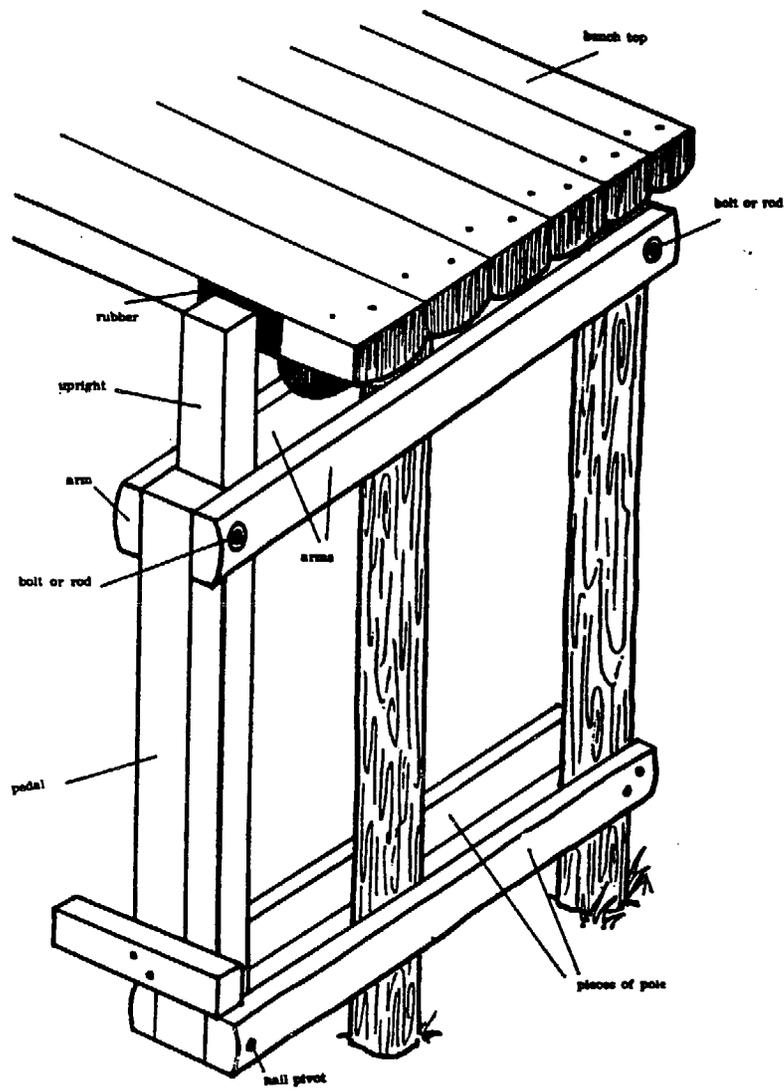
Effective maintenance requires an adequate stock of spare parts, particularly handles, field workshop facilities to effect the necessary operations and staff with basic wood and metal working skills.

SPARES

Replacing the metal parts of well made tools should be such an infrequent occurrence that it should not be regarded as a maintenance operation. It would normally be allowed for in estimating the working 'life' of a complete batch of tools to be replaced en-block. Handle breakages, however, must be regarded as an inherent risk of construction operations and spares should always be readily available. These will need to be stored off the ground in dry airy conditions out of direct sunlight. They should be laid flat to prevent warp and be protected from insect and fungus attack using a preservative suitable to the locality. Advice on this can be obtained from local forestry organisations.



(a)



(b)

FIELD WORKSHOP FACILITIES

The implements required to carry out routine maintenance are usually reasonably cheap and simple to use and should be made available to all field units. Facilities for remedial maintenance are more elaborate but should be easily accessible to all field units.

Routine Maintenance

The fine cutting edges of axes, brush hooks, mattocks, scythes and grass cutters are normally maintained with hand stones. For axes, brush hooks and mattocks the silicon carbide stones should be circular, about 100mm diameter, with a groove around the edge where the fingers grip protecting them from the blade edge. With scythes and grass cutters tubular shaped stones 200-300mm long and tapered at each end to about 20mm diameter are the most convenient. The edges of other cutting tools are best kept sharp by filing as needed and a selection of flat, half-round and round files should be available. For saws small triangular shaped files, with a side about twice the depth of the teeth, are appropriate. After severe blunting it may be necessary to grind a new cutting edge. This is best carried out with a hand or treadle operated rotary grinding wheel. Light sharpening with a stone or file can be carried out with the tool held in the hand, but removal of the heavier burrs is best done with the aid of a workbench and vice. Figure TN 5.1 (a) illustrates the design of a simple method of making a temporary workbench, and (b) gives details of the vice. This is tightened by treading on the pedal with the flat of the foot, and released by upward pressure of the foot. A second standing vice is illustrated in Figure TN 5.2. Both can be made in the field with simple carpentry tools. They will enable handtools to be gripped firmly and filed, planned, drilled, shaped and sawn.

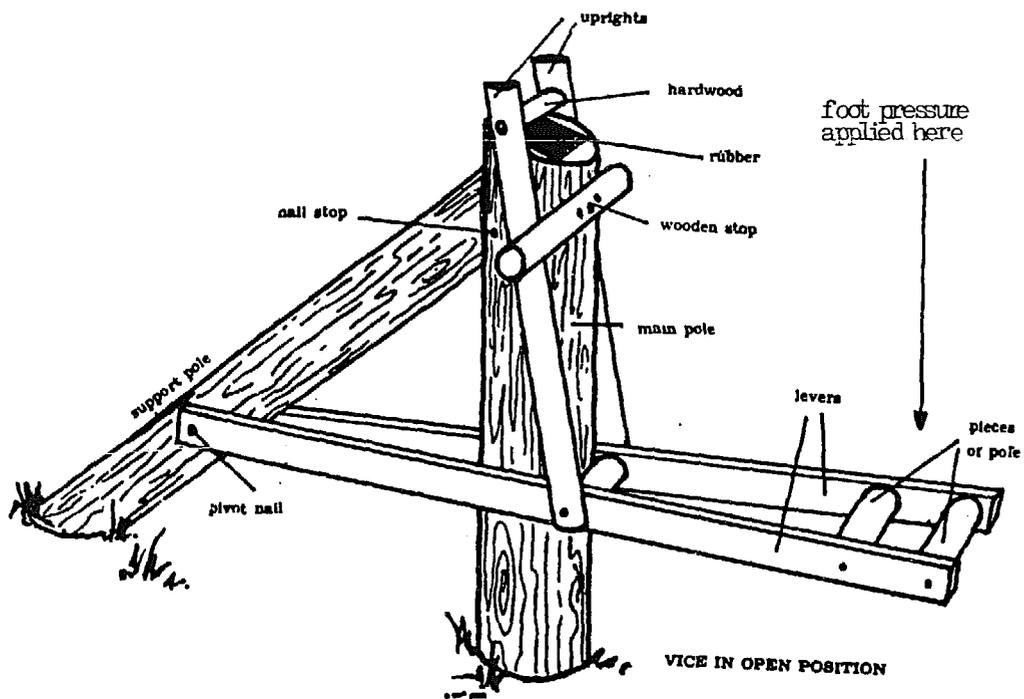


FIGURE TN 5.2 : STANDING VICE

REMEDIAL MAINTENANCE

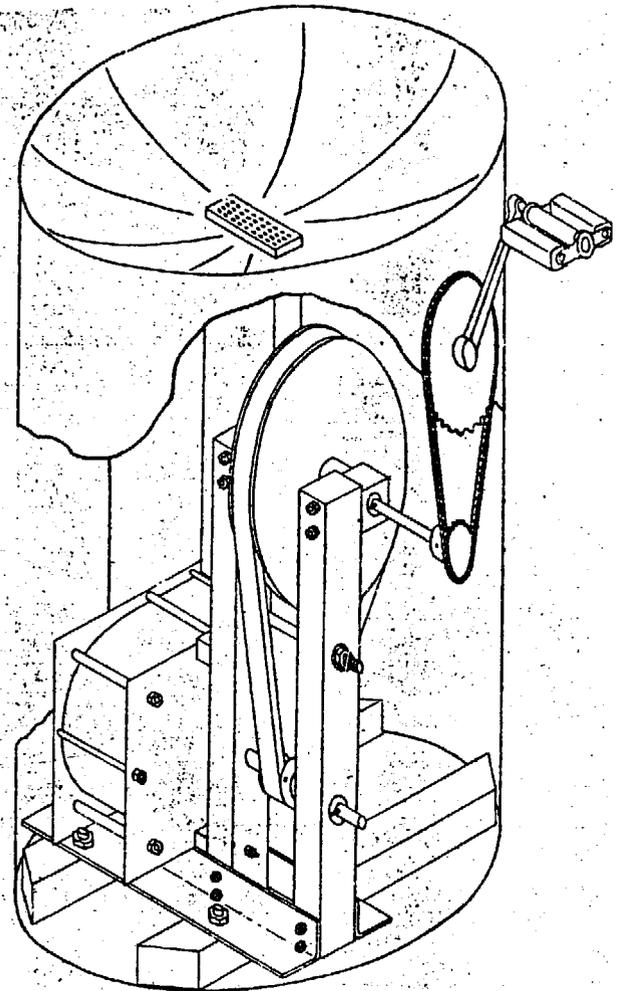
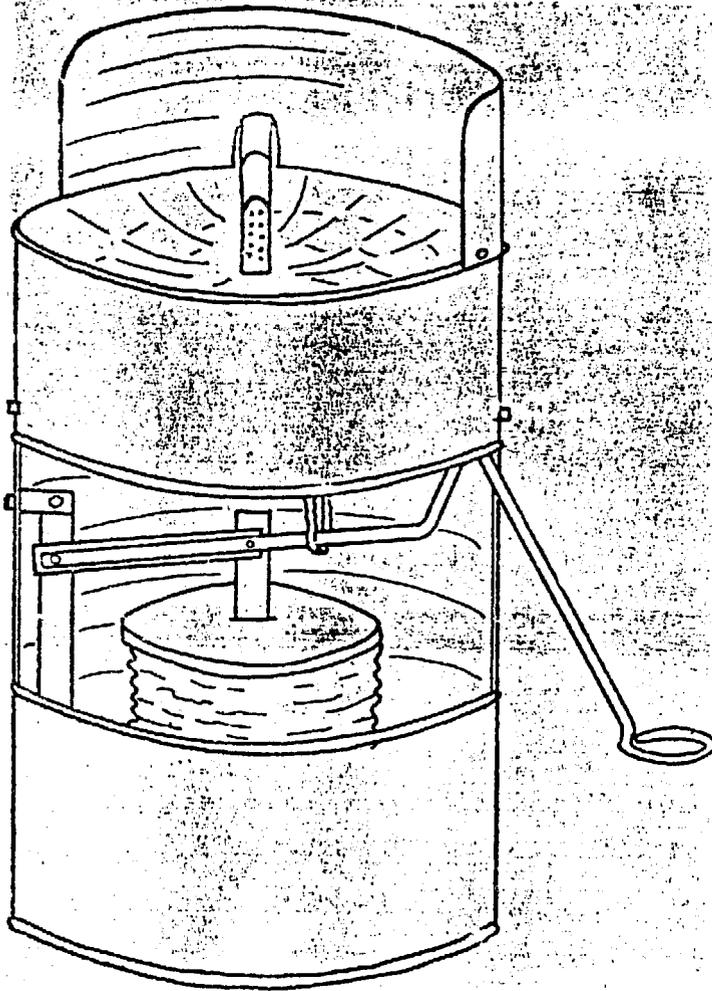
The two main remedial maintenance operations are the replacement of split or broken handles, and the reforging of badly worn cutting edges particularly on chisels and crowbars. Tools that are useful for handle replacement are:

- carpenters claw hammer (1/2kg)
- tenon saw (250-300mm)
- hand drill and set of bits (1-10mm)
- wood rasps or files
- wood chisels

For re-forging chisels, crowbars and other high carbon steel tools it is essential to have a forced draught forge otherwise it will be impossible to achieve the required temperatures (TN1). Figure TN5.3 illustrates two types of forge manufactured from old oil drums. Type A has a foot operated bellows supplying the draught. It can be constructed without either welding or brazing facilities. Type B has a hand cranked fan supplying the draught. Its construction requires access to arc or gas welding facilities.*

Forging also requires the use of an anvil. Commercial anvils weigh from 20-150kg and thus are often not very portable. Figure TN5.4 illustrates an anvil made from a scrap length of railway line. This is adequate for most handtool repairs, but it should be raised to a more convenient working height.

* Complete sets of plans for both of these oil drum forges can be obtained from the Intermediate Technology Development Group Ltd., 9 King Street, London WC2E 8HN (U.K.)



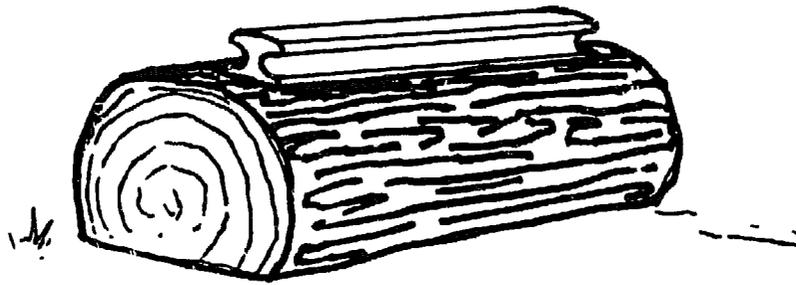


FIGURE TN 5.4 : ANVIL MADE FROM RAILWAY LINE

INTRODUCTION

This Note discusses the characteristics of the major sources of power used in labour-based road construction. The information given complements the data on specific implements in the remainder of the Guide.

Information on the following is given:

- Human Power : winches
- Animals : characteristics of work animals
 - : harnessing methods
 - : operation of work animals
- Single Axle Tractors : design characteristics
suppliers
- Four Wheeled Tractors : design characteristics
operation of tractors
suppliers.

HUMAN POWER

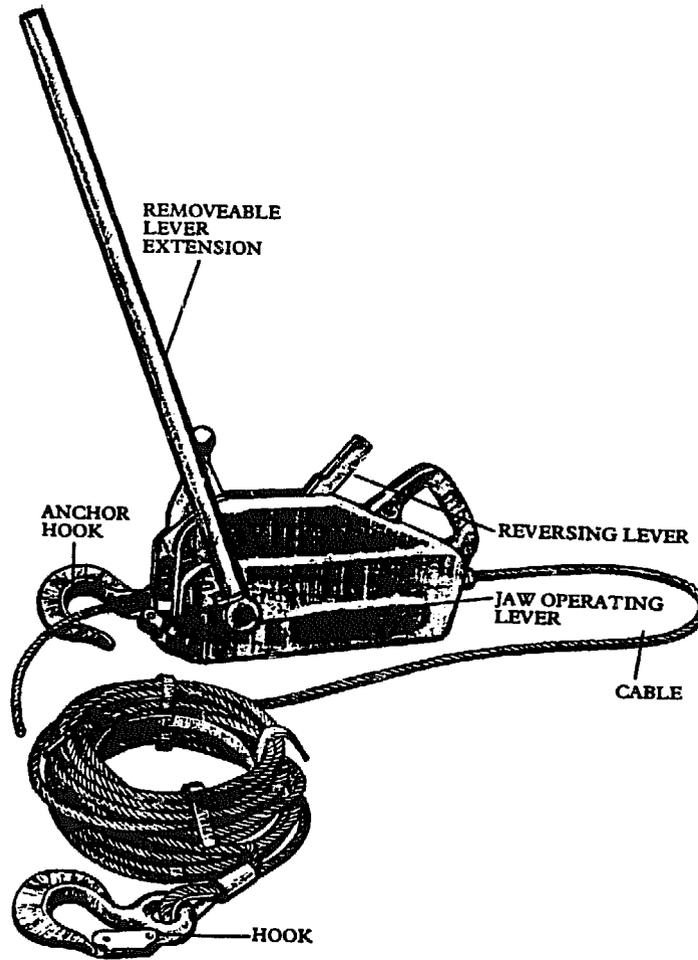
The design and use of handtools and manually operated items of equipment are described throughout the Guide. A useful means of increasing the force which a human being can apply is the winch. The application and operation of winches is discussed in:

- Section 3 : SITE PREPARATION
- Section 7 : HAULING

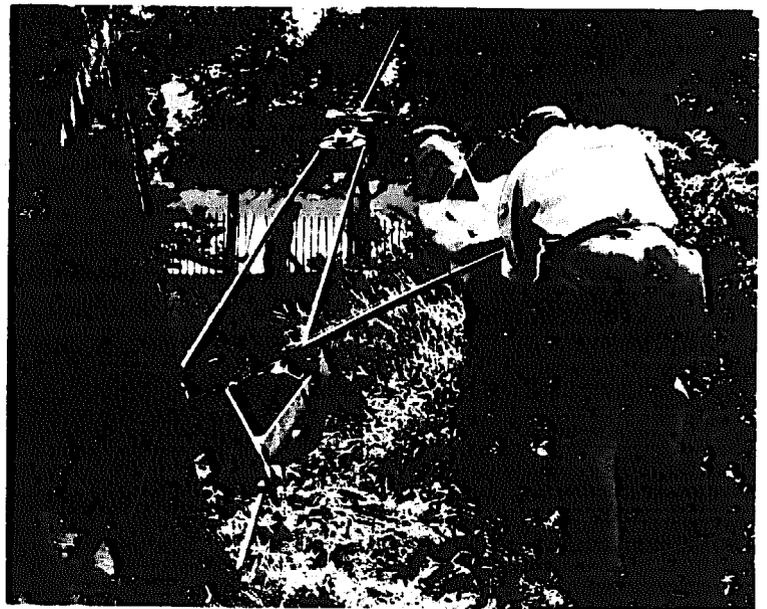
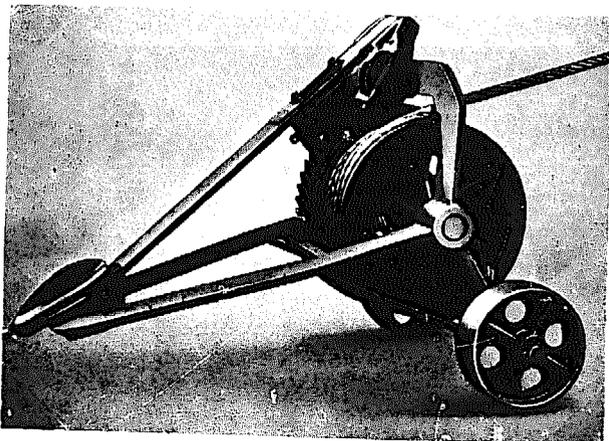
This section describes the characteristics of a range of suitable winches. An important consideration in selecting winches is their portability, particular for site preparation where vehicular access may be difficult. Winches up to about 50kg weight may be carried by operators to the site. Heavier winches will require a pick-up truck for transport. Winches too heavy to be transported by either of these methods are not considered here. Two basic types are considered:

Reciprocating action The operator(s) push or pull the lever rapidly in one direction, causing a small movement of the load at the end of the wire rope. The lever is then returned to its starting position and the operation is repeated. This type of winch allows human beings to apply a very large force, but the rate of movement is slow. It is therefore best applied to Site Preparation operations such as the uprooting of trees.

Rotating action These are operated by turning a lever which rotates a drum carrying the wire rope. They apply a smaller force than the reciprocating type but give a faster and continuous rate of movement of the object being winched. They are best applied to operations such as hauling wheelbarrows up slopes.



(a) Tirfor Pulling and Lifting Machine



(b) Monkey Winch

FIGURE TN6.1 : RECIPROCATING ACTION WINCHES

Reciprocating Action Winches

Figure TN 6.1 illustrates two types of reciprocating action winch and their method of operation:

Type (a) is lightweight, portable winch intended for one-man operation. It works by pulling directly on the wire rope through a pair of jaws which grip the rope in proportion to the load being pulled. It is fitted with two levers which allow the rope to be pulled in either direction. Data for a typical model of this type of winch is given below:

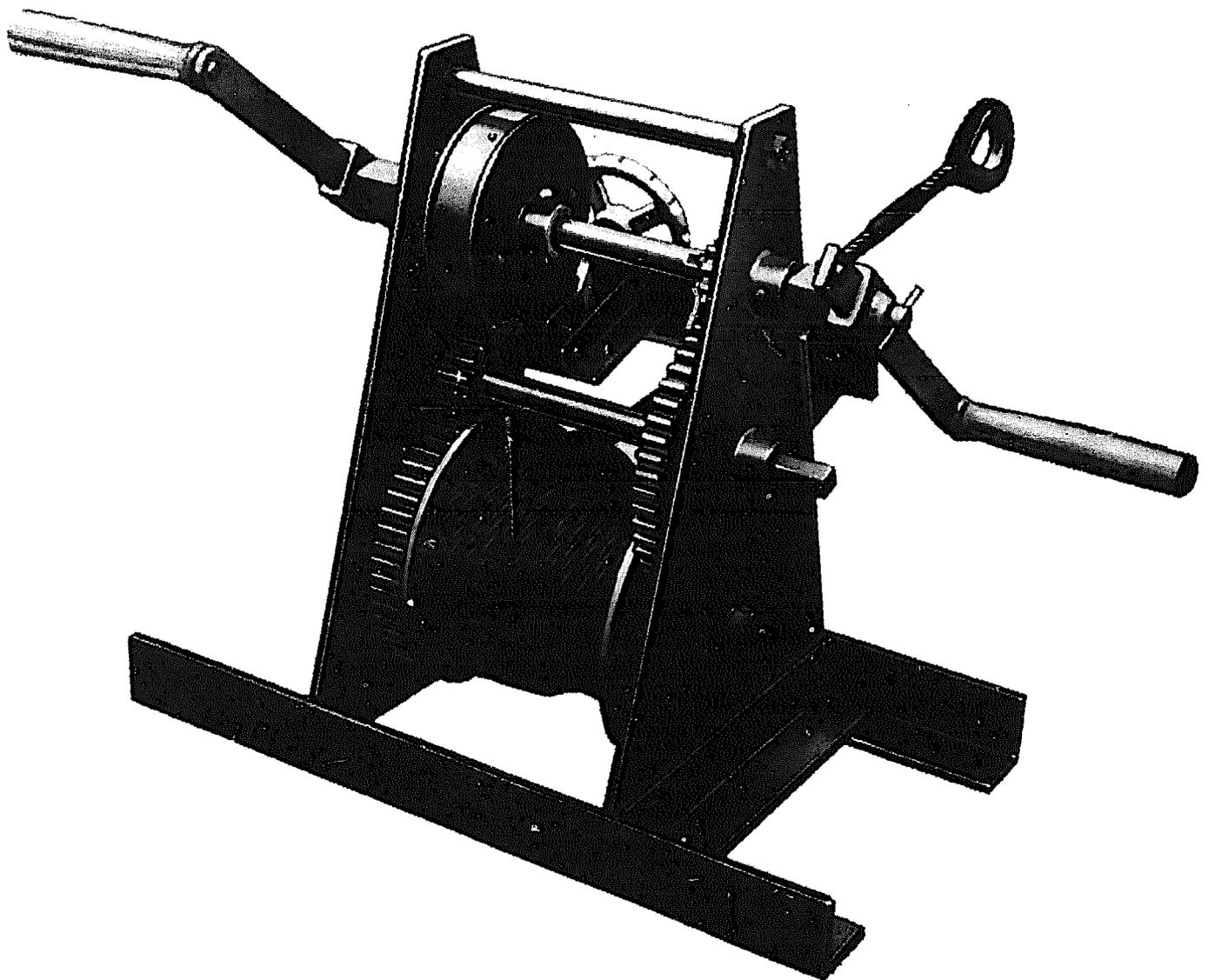
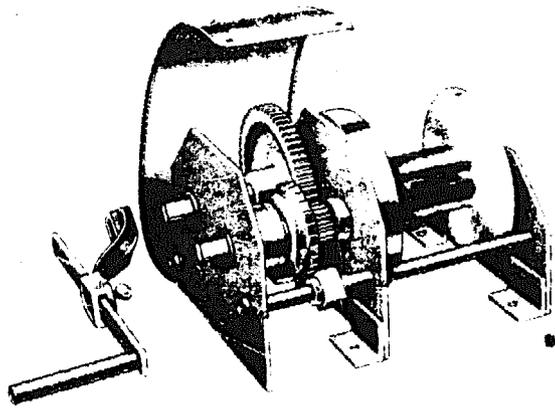
Safer working load (S.W.L) for lifting*	:	1600kg
Mechanical advantage	:	38:1
Rope travel per cycle of operating lever	:	70mm
Weight (without accessories)	:	18kg.

Type (b) is a heavy duty winch for operation by two people. The reciprocating lever turns a drum carrying the wire rope through a ratchet mechanism. Each forward movement of the lever turns the drum a small amount, pulling in the wire rope. It has two positions of the operating lever giving different mechanical advantage ratios. The winch is reversible.

Data for a typical model of this type of winch is given below:

Safe working load (S.W.L.) for lifting	:	5000kg.
Weight (including accessories)	:	118kg.

* Manufacturers specifications usually give the S.W.L. for lifting. The S.W.L. when pulling is somewhat higher.



Suppliers - MATTHIAS SPENCER & SONS Ltd.
- TIRFOR Ltd.
- TREWHELLA BROS. (U.K.) Ltd.

Rotating Action Winches

Figure TN 6.2 shows the typical heavy duty rotating action winches, Type (a) is for operation by one person, Type (b) by two people. The operating handle drives the rotating drum through a series of spur gears. There are two positions of the handle to give different gear ratios; one for quick winding with light loads, the other for winching heavier loads, but at lower speeds. Type (b) is fitted with a friction brake. This is applied by hand and holds the drum in position when there is no load on the operating handles. Type (a) has a ratchet and pawl mechanism, often referred to as automatic or self-actuating brakes, to perform this function.

Data for a typical rotating action winch is given below:

Safe working load for lifting : 2 tonnes
Gear ratios : 17 to 1 and 4 to 1
Weight (excluding accessories) : 62kg.

Suppliers HARVEY FROST & Co. Ltd.
HIGGINSON EQUIPMENT SALES Ltd.
TOYO DIAMOND INDUSTRY Co. Ltd.

Operation of Winches

The need to follow correct procedures to ensure safe operation of any type of pulling equipment is discussed in Section 3 : SITE PREPARATION (page 3.17) These procedures should be followed whenever winches are used. When pulling haulage containers up slopes it is essential to ensure that the winch is firmly anchored to the ground.

ANIMALS

Animals can be used as a source of power for many labour-based road construction operations. Animal powered implements are described in:

- Section 3 SITE PREPARATION
 - 4 EARTH & GRAVEL EXCAVATION
 - 7 HAULING
 - 8 SPREADING
 - 9 WATERING
 - 10 COMPACTION
 - 11 SOIL STABILISATION

Characteristics

The three most common types of animal used in road construction work are the horse family (equines) the ox family (bovines) and the camel.

The horse family includes:

- horse
- donkey
- pony (a small horse)
- mule (donkey/horse half-breed)

The ox* family includes:

- bullock (castrated male ox)
- buffalo (particular breeds of ox)

* Ox is used here as a generic term to describe all bovines. Some references use the term ox to refer to bullocks only.

The breeds and characteristics of horses, oxen and camels vary in different parts of the world. It is sensible to follow local experience in selecting work animals for road construction projects. Major problems are likely to be encountered in introducing;

- types of work animal new to the region; or
- substantially different methods of using the animals.

Table TN 6.1 summarises the performance characteristics of the most useful work animals. These figures are indicative only since there will naturally be variations according to breed, condition, age, etc.

TABLE TN 6.1 : PERFORMANCE CHARACTERISTICS OF WORK ANIMALS

Animal	Weight kg	Approximate Tractive Effort N*	Average Speed of work km/h	Power hp	Working hrs/day
light horse	400-700	600-800	3.5	1.0	6-10
donkey	200-300	300-400	2.5	0.35	3-4 draught 8-10 pack
mule	350-500	500-600	3.2-3.5	0.7	8+
bullock	500-900	600-800	2.2-3.0	0.75	5-6
buffalo	400-900	500-800	2.8-3.2	0.75	5-6
camel	450-650	-	2.8-4.5	-	9-13

In general the tractive effort and power which an animal can produce will increase with its weight . For short periods animals can produce a considerably greater tractive effort than the figures quoted. However, if they are used in this way the total work output over a day will be reduced. When two or more animals are harnessed together there is some

* 1kg = 10N (Newtons)

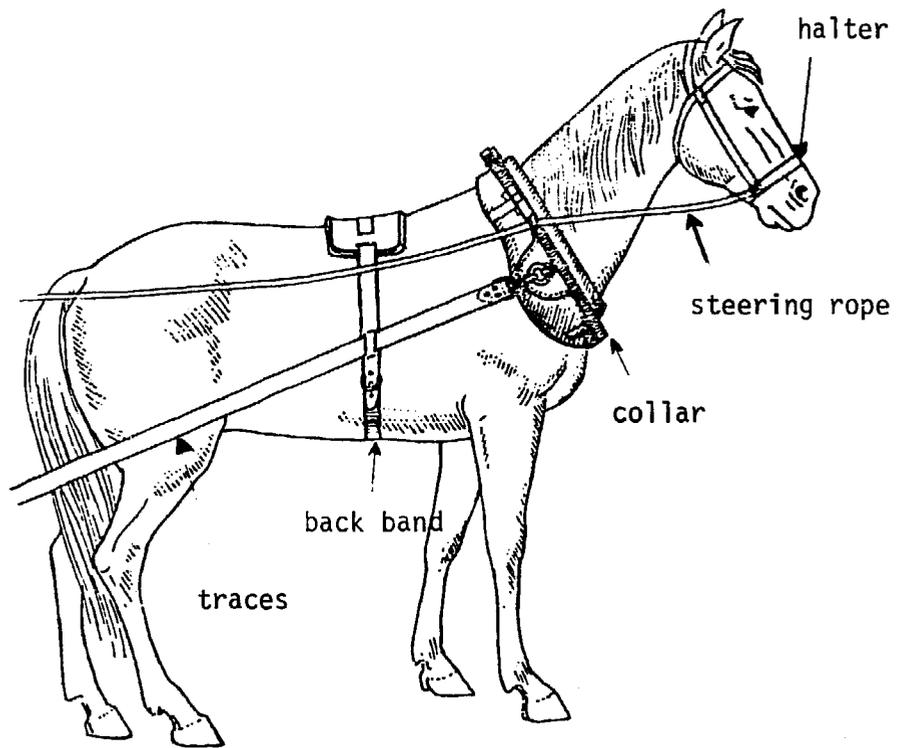


FIGURE TN6.3 : COLLAR HARNESS

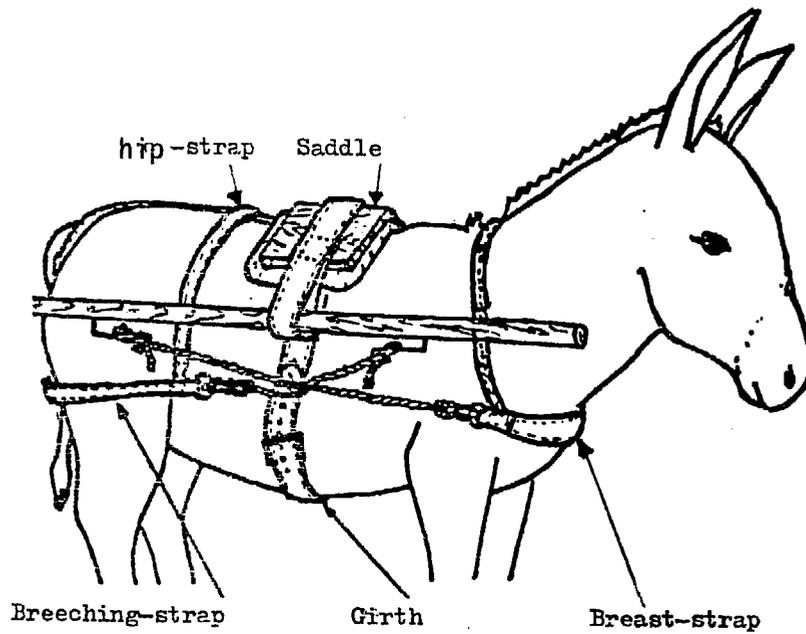


FIGURE TN6.4 : BREASTBAND HARNESS HITCHED TO CART SHAFTS

loss of efficiency. Thus, a pair of oxen will produce about 1.8 times the tractive effort of one animal. In general camels and the horse family can be used for pack (i.e. carrying loads on their back) or draught work. However, the donkey is more effective as a pack than a draught animal. Bovines are generally restricted to draught work.

Harnessing

These are two interrelated aspects to the harnessing of work animals:

- the type of harness fitted to the animal; and
- the hitching of the implement to the harness.

The function of the harness is to transmit the power of the animals efficiently and ensure their easy control.

There are two basic types of hitching arrangement, depending on the type of implement being drawn. Certain implements, notably the two-wheeled cart, require a rigid connection to the harness since;

- i) the animal(s) must support part of the weight of the implement; and
- ii) it may be necessary to reverse with the implement attached.

To achieve this a draught pole or pair of shafts extends forward from the implement and is attached to the harness.

For implements which are self supporting (e.g. two-axled carts) and do not need to be reversed, a loose connection by means of chains, ropes or leather straps (known as traces) is sufficient.

Harnessing of equines

The collar harness is the most efficient type for horses, mules or donkeys used for heavy draught work (Figure TN 6.3). The collar has an oval, wooden

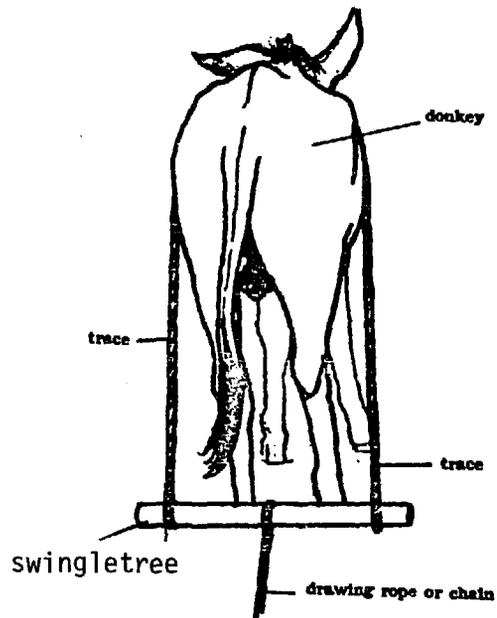


FIGURE TN6.5 : SWINGLETREE HITCHING ARRANGEMENT

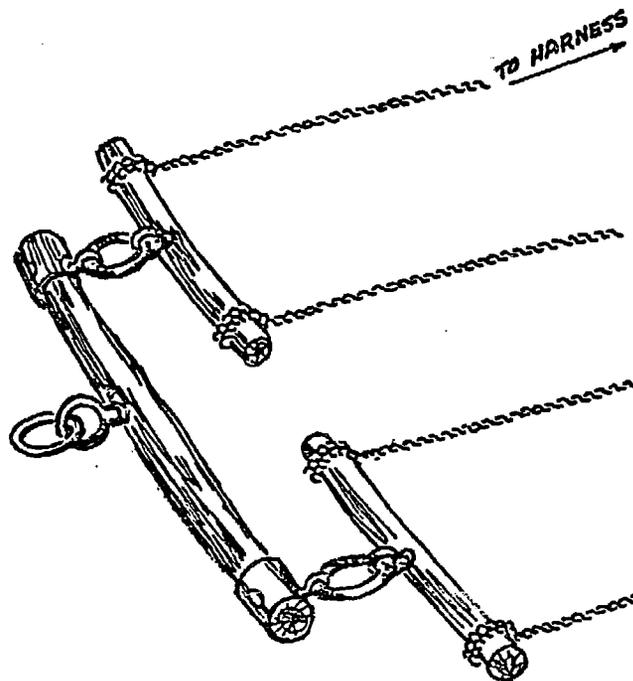


FIGURE TN6.6 : HITCHING ARRANGEMENT FOR DRAUGHT BY TWO ANIMALS

or metal frame called the hame. The collar is usually made in one piece and may be open at the bottom. It should be lined with soft material so as to fit comfortably on the animal's shoulders. The hame has hooks, rings or holes slightly above the joint of the animal's shoulder blades to take the draught traces. The other parts of the harness are the halter, steering rope, and back-band.

The breastband harness is a simpler type suitable for light draught work (Figure TN6 .4). It consists of; a breaststrap made of leather or other soft material large enough to spread the load on the animal and so adjusted as to avoid pressure on its wind pipe; a shoulder strap; and a halter and steering rope not shown in the illustration. Hooks, rings or holes on the ends of the breaststrap provide attachment points for the draught traces.

To draw implements which require only a loose connection traces are attached to the harness (whichever type is used) on either side (Figure TN6 .3). These are joined, at the rear of the animal, by a 'swingletree' or spreader, which keep the traces the correct distance apart and is attached to the implement (Figure TN6 .5). Where two animals are used to draw the implement the arrangement of two swingle-trees and an evener, as shown in Figure TN6 .6 is used.

To draw a cart which requires a rigid connection the animals wear a back strap and saddle made of soft material.

The shafts of the cart are supported by loops attached to the saddle. The traces are also attached to the shafts. Thus, the weight of the cart is supported on the animal's back, while the draught force is transmitted through its shoulders. This system, shown in Figure TN6 .4 applies whichever type of harness is used. The breeching and hip straps allow the cart to be reversed by the animal.

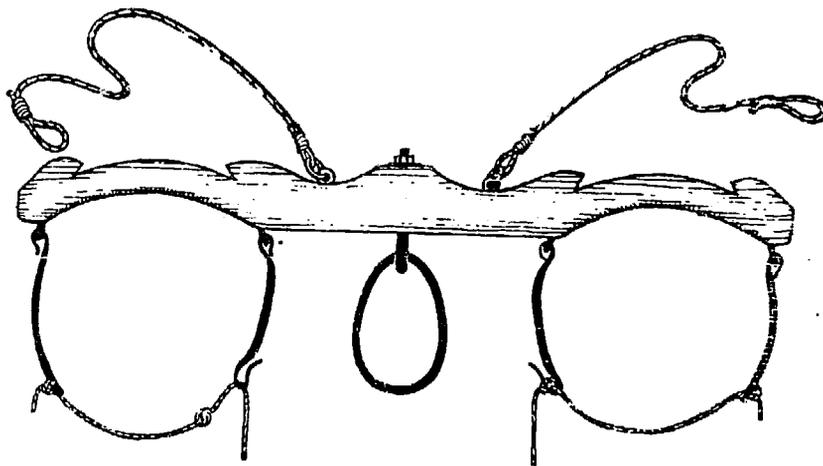
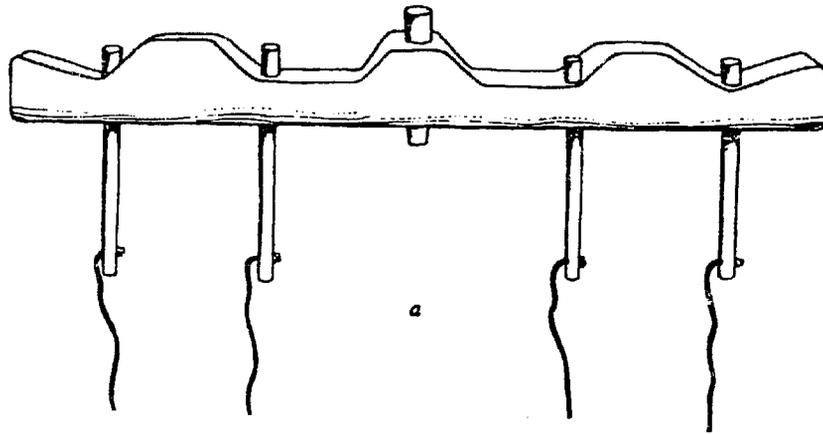
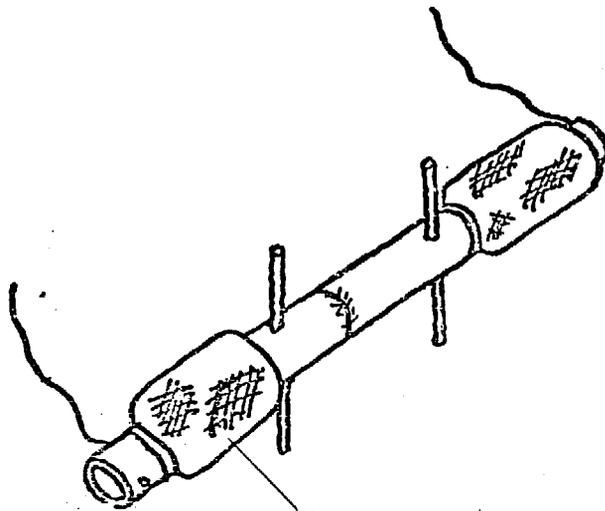


FIGURE TN 6.7 : DOUBLE NECK YOKES



burlap stuffed with padding

Harnessing of Bovines

For draught work bovines are most commonly used in pairs. The traditional form of harness is the double neck yoke. There are a wide variety of different designs but all consists basically of a wooden beam which may be shaped to fit the top of the animal's necks (Figure TN 6.7). It is held in position by wooden sticks inserted on both sides of each animal's neck, or by similarly placed formed iron rods. These are joined by a throat fastening. The centre of the beam carries a ring for implement attachment. The animals are normally fitted with some form of head rope or halter to which attaches the steering rope. This type of harness is cheap but is not very efficient:

- i) when drawing a cart its weight bears on the animals necks;
- ii) the rubbing of the yoke on the neck can cause the animals pain, thereby decreasing their work output. Padding of the yoke above the animal's necks (Figure TN 6.8), and the extension of the padding around the sides of the neck (so that the yoke fits comfortably) is likely to be beneficial.
- iii) the throat fastenings tend to choke the animals, especially when pulling heavy loads. This can be minimised by providing a loose rope or strap connection between the yoke and the heads of the animals. (Figure TN 6.9).

Implements requiring only a loose connection are hitched by means of a rope or chain tied to the yoke ring.

For drawing carts the central draught pole passes through the yoke ring and is retained by a peg or pegs. This allows rotational movement between the yoke and the draught pole (Figure TN 6.9).

Bovines can be used singly for draught work with a single neck yoke (Figure 6.10). The principles and deficiencies of this are the same as for the

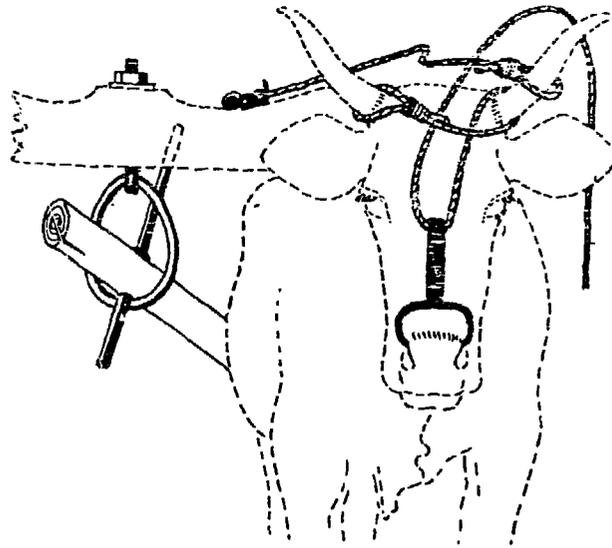


FIGURE TN 6.9 : DETAILS OF YOKING ARRANGEMENT

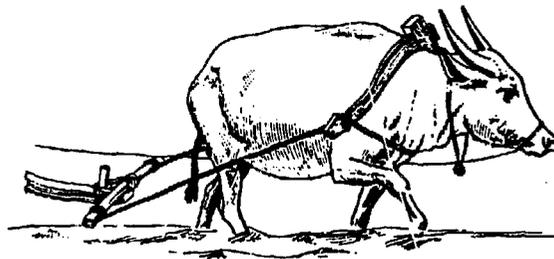


FIGURE TN 6.10 : SINGLE NECK YOKE

double version. For drawing implements requiring only a loose connection the method is exactly the same as for equines - a pair of traces attached to a swingle-tree. To draw a cart the shafts are fixed directly to the ends of the yoke. (Note: there is evidence from China of single buffalo being used to draw a cart with the same hitching arrangement as that employed with equines, i.e. the shafts support by a saddle on the animal's back. This is a more efficient arrangement since it removes the weight of the cart from the animal's back. However, there are many types of bovine that will not accept a weight on their back).

The three pad collar harness for bovines (Figure TN 6.11) was developed in Europe in the 1930's and overcomes some of the disadvantages of the neck yoke. The frame consists of two adjustable wooden hames with padding to protect the shoulders of the animal without impeding their movement. A third pad connects the hames and rests on the neck of the animal. The hames carry rings for attachment of the draught traces. The hitching arrangements with this harness are similar to those for equine collars. As far as is known there is little experience of using this type of harness in developing countries, though it would seem to have considerable potential.

Harnessing of Camels

The withers harness is the most common type for camels. (Figure TN 6.12). It consists of a broad strap made of soft material passing across the upper side of the base of the animal's neck. A retaining strap or rope passes underneath the base of the neck. A halter and steering rope complete the basic harness. For implements requiring only a loose connection traces are attached to the ends of the withers strap, leading back to a swingle-tree. A hip strap may be necessary to support and guide the traces. When pulling a cart the shafts are supported from a saddle (as for equines) or by hump straps (Figure TN 6.12). The traces are attached to these shafts. Figure TN 6.13 shows a harnessing arrangement which allows the cart to be tipped for unloading. The shafts are supported by straps from the saddle, but extend forward to attach to the withers strap. By releasing the strap underneath the neck the complete cart can be tipped. The angle of tip is limited by the saddle straps.

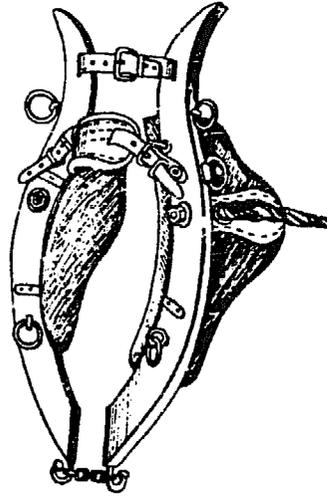


FIGURE TN 6.11 : THREE PAD COLLAR HARNESS

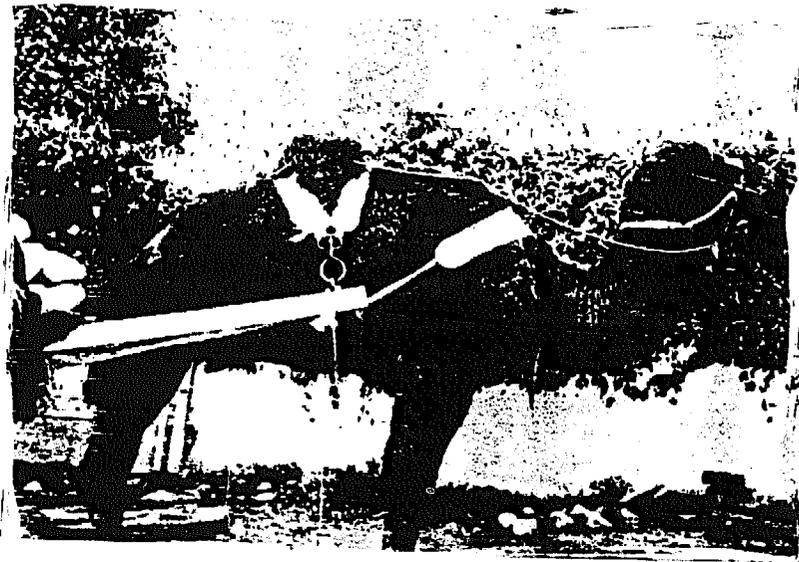


FIGURE TN 6.12 : WITHERS HARNESS

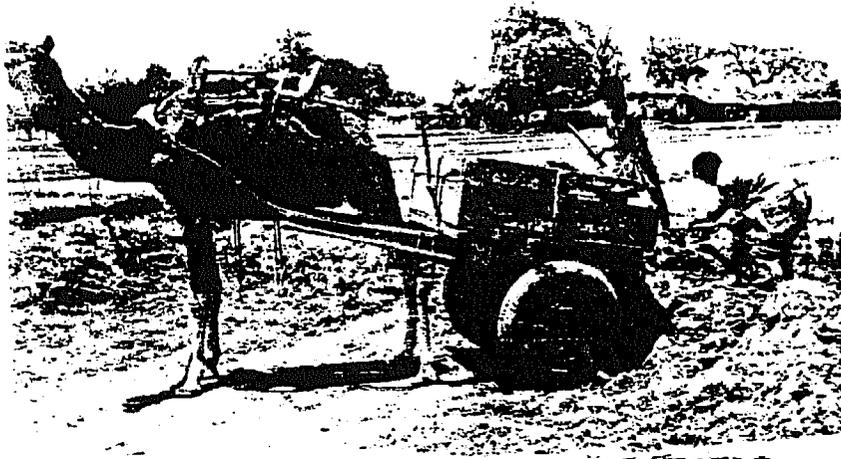


FIGURE TN 6.13 : TIPPING CART WITH WITHERS HARNESS

(Note: Full collar harnesses for camels are known to have been used in Australia. To prevent the collar sliding forward down the neck it must be retained by a rope passing behind the hump).

Operation

Consideration of the training of work animals is beyond the scope of this Guide. Wherever possible animals which are already trained and experienced in draught/pack work should be used. Considerable skill and experience is required to work effectively with animals and it is important to ensure that the labourers concerned have the necessary capabilities.

In some cases the animals will be supplied by local farmers who will operate them and be responsible for feeding, shelter etc. However, it may not be possible to obtain sufficient animals in this way. Furthermore, these animals may not be used to working with non-agricultural equipment such as compaction rollers etc. Where the authority constructing the road has to supply the animals, provision must be made for their feeding (either by use of fallowland and natural pasture, or by bringing in fodder) and shelter. It is important to ensure that the animals are well cared for so as to maximise their work output. Whoever supplies the animals, their care must be taken into account in planning the road construction work.

Donkeys and Mules can work for long hours, but in tropical conditions it is desirable that they be rested during the hottest part of the day. They have fairly modest food requirements and can be fed with coarse fodder.

Oxen are limited to a maximum of about six hours work per day in tropical conditions. Work should be avoided during the hottest part of the day. Water buffaloes need to be 'watered' i.e. allow to wallow in mud or shallow water, for about one hour per day. Oxen can be fed with coarse fodder.

Camels are sturdy animals used to desert conditions and capable of working long hours per day. They thrive on poor pasture but need an enormous range of it.

The overloading or overworking of animals should be avoided since it will, over a period of time, reduce their work capability. The tiredness of an animal is often difficult for an inexperienced person to assess.



FIGURE TN 6.14 : SMALL SINGLE-AXLE TRACTOR WITH ROTAVATOR BLADES MOUNTED ON DRIVING AXLE

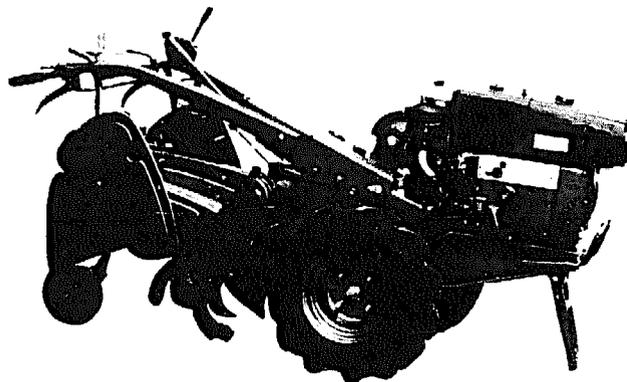


FIGURE TN 6.15 : LARGE SINGLE-AXLE TRACTOR WITH ROTAVATOR MOUNTED BEHIND WHEELS AND DRIVEN OFF PTO SHAFT

SINGLE AXLE TRACTORS

The use of single axle tractors for specific road construction operations is discussed in:

- Section 7 : HAULING
- Section 11 : SOIL STABILISATION

Single axle tractors can also be used, with appropriate attachments, as stationary sources of power for water pumping, electricity generation and sawing of timber. Some single axle tractors can be fitted with moving attachments, in which form they may be useful for road maintenance.

Design Characteristics

There is a wide range of single axle tractors available, with power outputs from 3-18hp. Models in the 7-12hp range are likely to be the most useful for road construction work. Tractors are available with two or four stroke petrol or diesel engines. Some manufacturers offer different engine options for a particular model.

The smaller models generally have a single driven shaft which can be fitted with driving wheels or rotary cultivator blades (Figure TN 6.14). The larger models tend to have a pair of driving wheels with a separate power take-off (pto) shaft to drive a rotary cultivator or other implement (Figure TN 6.15). The latter have greater operational flexibility and are likely to be the most useful for road construction work. The most manoevrable single-axle tractors are those which have independent clutches for each of the driving wheels.

For road construction work it is important to select a single axle tractor which is robust and durable, and to ensure an adequate supply of spare parts. It is also necessary to ascertain that the attachments are compatible with the tractor. Most manufacturers of single axle tractors also supply a wide range of attachments.

Suppliers

J.K. SATOH AGRICULTURAL MACHINES Ltd.

VST TILLER TRACTORS Ltd.

GOLDONI S.P.A.

IRUSWERKE

KRISHI ENGINES Ltd.

GUTBROD

STAUB

CECOCO AGRICULTURAL & SMALL INDUSTRIAL CENTER

DAEDONG INDUSTRIAL Co. Ltd.

PASBO MACHINE AGRICOLE

INDEQUIP ENGINEERING Ltd.

KERALA AGRO MACHINERY CORPORATION Ltd.

MAHARASHTRA CO-OP ENGINEERING SOCIETY Ltd.

BOWYER SA.

MOTOCULTORES PASQUALI SA

GEBRÜDER HOLDER MASCHINENFABRIK

KUBOTA Ltd.

INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI)

- this organisation has developed single axle tractors which are particularly well-suited to local manufacture. Design information, and addresses of manufacturers of these machines in the Philippines, Indonesia, Korea, Sri Lanka and Thailand are available from IRRI.

FOUR-WHEELED TRACTORS

General purpose agricultural tractors can be used as a source of power for many labour-based road construction operations. Tractor powered implements are described in:

- Section 3 : SITE PREPARATION
- Section 4 : EARTH AND GRAVEL EXCAVATION
- Section 7 : HAULING
- Section 8 : SPREADING
- Section 9 : WATERING
- Section 10 : COMPACTION
- Section 11 : SOIL STABILISATION

Throughout the Guide consideration has been restricted to tractors of 50hp or less, and implements compatible with machines of this size. It was necessary to establish a cut-off point, and this encompasses a wide range of basic, general purposes, straightforward tractors. The use of high powered, highly complex tractors, and of those with four wheel drive or of the tracklaying type is not considered relevant to labour-based road construction.

The advantages of using tractors in labour based road construction are:

Flexibility They can be fitted with a wide range of implements to perform a variety of functions, and can be switched fairly rapidly from one activity to another.

Availability Tractors are widely available throughout the developing world, the provision of spares and repair facilities should not provide major problems, and there is a considerable degree of familiarity with their use.

In addition to the major applications covered in specific sections of the Guide, tractors can be used as sources of power for a number of other functions which may be useful for particular construction projects, including material handling and the powering of generators, compressors etc.

Design Characteristics

There is a wide range of general purpose tractors available from a large number of manufacturers. The most important characteristics of tractors used for labour-based road construction are discussed below:

Engine and Drive Train

Tractors are fitted with either 2 or 4 stroke diesel engines.

The transmission system should provide an adequate range of forward and reverse speeds (most tractors have at least six forward and two reverse gears). A synchromesh gearbox, which allows gears to be changed on the move should be specified and is essential for hauling work.

There should be provision for locking the differential in the rear axle to reduce the possibility of the tractor being rendered immobile due to wheelslip.

Tractors are usually available with 4 or 6 ply tyres. 4 ply tyres are suitable for normal use, but 6 ply should be specified for flinty soil conditions. The broader the rear tyres, the greater the pull the tractor can generally exert.

The rear wheel brakes should be capable of independent operation. For normal use the two brakes are latched together, but the facility for independent operation allows very tight turns to be made.

Power Take Off

The transmission system includes a power take-off (pto) shaft which provides a drive for attached implements. The connection point to this shaft is at the rear of the tractor. The p.t.o. on most tractors is operated through the clutch pedal. When the pedal is depressed, initial pressure releases the transmission clutch, disengaging the drive to the rear wheels.

Further pressure on the clutch pedal disengages the drive to the p.t.o. This system is known as a live p.t.o. and allows the p.t.o. to transmit power when the rear wheels are not being driven. Some tractors have a separate hand lever to control the p.t.o., allowing it to be engaged or disengaged while the tractor is in motion. This is known as an independent p.t.o. The p.t.o. should be protected by a cover when not in use.

Hydraulic System

The main functions of the hydraulic system, which is powered by a pump driven from the engine or transmission system, is to operate the three-point linkage. However, it should have several tapings to supply hydraulic power for other operations such as tipping trailers. It is important to ensure that the hydraulic reservoir tank has sufficient capacity to cope with the tasks planned for it.

The three point linkage, illustrated in Figure TN 6.17 is used for attaching and controlling mounted implements. It consists of two lower draft arms and a top link. The linkage is raised and lowered by means of a hydraulic ram. Ball ends are fitted to each end of the three links, the outer set threading over pins on the implement. Three categories of linkage are specified, depending upon the size of the pin. Category I is for the lightest implements and smallest tractors; Category III for the heaviest and largest. It is important to ensure that the implements to be used are compatible with the three point linkage.

The three point linkage can be operated in three ways:

- i) Simple raising and lowering of implements.
- ii) Controlling the depth of soil-engaging implements by means of *draft control*. This system, which transfers the weight of the implement to the rear tractor wheels maintains the draft at a pre-determined level in changing ground conditions and means that efficient use is made of the tractor's power.

- iii) Holding an implement at a pre-determined position relative to the tractor. This is known as *position control* and is normally used for 'above the ground' implements.

Other Features

A robust drawbar or hitch is fitted to the rear of the tractor for the attachment of trailed implements. Adjustable height drawbars are available for some tractors. These allow the drawbar to be set at the correct height for a particular implement. Swinging drawbars allow the position of the hitch to be adjusted relative to the longitudinal axis of the tractors. For use with trailers the tractor should be fitted with a hydraulic hitch. This allows the trailer to be attached and detached hydraulically through the linkage system.

The traction ability of the tractor can be increased by bolting wheel weights to the rear wheels. These weights are usually available in units of 45kg.

When implements are being used which transfer a load to the rear of the tractor (e.g. two-wheeled trailers) it may be necessary to add ballast weights to the front of the tractor to prevent it tipping backwards. These can be attached to the front of the tractor or to the front wheel rims.

The tractor should have a robust front axle and engine chassis with attachment points for front and mid-mounted implements (see Section 8 : SPREADING)

Operation

The tractor, together with the wide range of implements that can be attached to it is a complex machine, and it is beyond the scope of this Guide to discuss its operation in detail. Skilled operators are required for safe and efficient use of tractors, and expert advice should be sought to ensure the correct use of particular implements.

Safe working procedures should be laid down in collaboration with the suppliers of the tractors. Attention should be paid to ensuring that operators understand and adhere to these procedures.*

Regular maintenance and servicing of the tractors and implements will help to ensure long life and safe, efficient operation. The advice of the suppliers should be sought on maintenance schedules. The tractor should be fitted with a proofmeter which records the number of hours the engine operates. This can be used as the basis for planning maintenance schedules.

The use of tractors in labour based road construction depends upon the availability of fuel supplies, spare parts and maintenance facilities.

Wherever feasible it is desirable to use makes and models of tractor which are already available in the region, since this will minimise spares supply and servicing problems. However, in some situations this may not be possible, and therefore a selection of tractor manufacturers is listed below.

Suppliers EICHER TRACTORS INDIA Ltd.
 ESCORTS Ltd.
 HARSHA TRACTORS Ltd.
 HINDUSTAN MACHINE TOOLS Ltd.
 INTERNATIONAL TRACTOR Co of INDIA Ltd.
 KIRLOOKAR TRACTORS Ltd.
 PUNJAB TRACTORS Ltd.
 TRACTORS & FARM EQUIPMENT Ltd.
 INTERNATIONAL HARVESTER COMPANY of GB Ltd.
 DAVID BROWN TRACTORS Ltd.
 VALMET

* A useful reference on the safe operation of tractors is ILO Safe Construction and Operation of Tractors. ILO Codes of Practice. ILO Geneva 1976.

GOLDONI S.P.A.
COMPANHIA BRASILEIRA de TRATORES
MASSEY FERGUSON USA
MASSEY FERGUSON ITALY
MASSEY FERGUSON MEXICO
MASSEY FERGUSON FRANCE
MASSEY FERGUSON BRAZIL
MASSEY FERGUSON ARGENTINA
FORD MOTOR Co. Ltd.

LIST OF SUPPLIERS

AEROIL PRODUCTS Co. Inc.,
69 Wesley Street,
South Hackensack,
N.J. 07606,
U.S.A.

AGRO PUMPSETS & IMPLEMENTS Ltd.,
10-2-3 Intekhab Manzil,
A-C Guards,
Hydelabad 500 004,
India.

OY AIRAM AB,
Kometa Works,
SF-02660 Espoo 66,
Finland.

ASICOMO A/S,
Lerso Parkalle 112,
Copenhagen,
Denmark.

ATLAS COPCO AB,
S-105 23 Stockholm,
Sweden.

AVON RUBBER Co. (Bridgend) Ltd.,
Industrial Estate,
Bridgend,
Glamorgan,
United Kingdom.

W.H. BAXTER Ltd.,
Leeds 12,
United Kingdom.

ROBERT BOSCH Ltd., WATFORD,
Rhodes Way,
Watford WD2 4LB,
United Kingdom.

ROBERT BOSCH GmbH.,
Geschäftsbereich Elektrowerkzeuge,
7022 Leinfelden,
Postfach 1120,
Federal Republic of Germany.

BOUYER SA,
Boite Postale No. 7,
54510 Tomblaine,
France.

BRISTOWES MACHINERY Ltd.,
Jute Lane, Brimsdown,
Enfield, Middlesex EN3 7PL,
United Kingdom.

BRÖDERNA BRODD AB,
S-59600 Skänninge,
Sweden.

BROWNS AGRICULTURAL MACHINERY Ltd.,
Albany Works,
Leighton Buzzard,
Bedfordshire,
United Kingdom.

DAVID BROWN TRACTORS Ltd.,
Meltham,
Huddersfield HD7 3AR,
United Kingdom.

BULLDOG TOOLS,
Clarrington Forge,
Wigan, WN1 3DD,
United Kingdom.

BURGON & BALL Ltd.,
La Plata Works, Holme Lane,
Sheffield S6 4JY,
United Kingdom.

CECOCO AGRICULTURAL AND SMALL
INDUSTRIAL CENTRE,
P.O. Box 8,
Ibaraki City,
Osaka,
Japan.

THE CHILLINGTON TOOL Co. Ltd.,
P.O. Box 45 Hickman Avenue,
Wolverhampton WV1 2BU,
United Kingdom.

THOMAS COLEMAN & SONS Ltd.,
Alfreton Road,
Derby DE2 4AL,
United Kingdom.

COMPANHIA BRASILEIRA DE TRATORIAS,
Av. São Lius, 50-30^o andar,
Sao Paulo - SP,
Brazil.

W.J. COOPER & SONS Ltd.,
Newport Pagnell,
Buckinghamshire,
United Kingdom.

COSSUL & Co. PVT Ltd.,
Industrial Area,
Fazalgunj,
Kanpur,
India.

COUSINS of EMNETH,
The Forge,
Emneth,
Wisbeck,
Cambridgeshire,
United Kingdom.

CYCLONE FORGINGS Pty. Ltd.,
P.O. Box 143, East Bentleigh,
Victoria,
Australia.

DAEDONG INDUSTRIAL Co. Ltd.,
39-3 Dong Ja Dong,
Chung-Ku,
Seoul,
South Korea.

DANDEKAR BROS. (Engineers &
Founders),
Sangli,
Maharashtra,
India.

DANISHMAND & Co.,
Karkhana Bazar,
Lyallpur,
Pakistan.

DUNLOP INDIA Ltd.,
Dunlop House,
57B Mirza Ghalib Street,
Calcutta 700-016,
India.

EDSBYNS INDUSTRI AKTIEBOLAG
(BUSHMAN),
S-82800 Edsbyn,
Sweden.

EICHER TRACTORS INDIA Ltd.,
New Faridabad - 121001,
Haryana,
India.

ELBA MEXICANA S.A.,
Wormser Suiza de Mexico, S.A.,
Km 2 Prolongacion Av. Hidalgo,
Tlalnepantla, Edo de Mexico,
Mexico 1 D.F.

ESCORTS Ltd.,
Farm Equipment Division,
18/4 Mathura Road,
Faridabad,
Haryana,
India.

ÉTABLISSEMENTS PIERRE MENGIN S.A.,
Zone Industrielle d'Amilly,
B.P. 163, 45203 Montargis,
France.

ETS TECHINE,
82400 Valence D'Agen,
France.

OY FISKARS AB,
P.O. Box 235,
00101 Helsinki 10,
Finland.

FORD MOTOR COMPANY Ltd.,
Tractor Operations,
Basildon,
Essex,
United Kingdom.

FREDICK PARKER Ltd.,
Viaduct Works,
Leicester,
United Kingdom.

FURNIVAL STEEL Co. Ltd.,
Attercliffe Road,
Sheffield S4 7WY,
United Kingdom.

GANDY Co.,
528 Gandrud Road,
Owatonna,
Minnesota 55060,
U.S.A.

E. GARLICK & SON Ltd.,
Afric Works, Orange Street,
Sheffield S1 4DW,
United Kingdom.

GEBRÜDER EBERHARDT,
D79 Ulm,
Donau,
BP 204,
Federal Republic of Germany.

GEBRÜDER HOLDER MASCHINENFABRIK,
7418 Metzingen/Württ,
Postfach 66,
Federal Republic of Germany.

WM. GILPIN SENR & Co. (TOOLS) Ltd.,
Churchbridge Works, Cannock,
Staffs NS11 3JP.
United Kingdom.

GOLDONI S.P.A.,
41012 Migliarinadi Carpi,
Modena,
Italy.

GRAYS OF FETTERANGUS (1972) Ltd.,
Fetterangus,
Peterhead,
Aberdeenshire AB4 8HE,
United Kingdom.

GUTBROD-WERKE GMBTH,
Postfach 60,
D-6601 Sbr. Bübingen,
Federal Republic of Germany.

HARSHA TRACTORS Ltd.,
42, Janpath,
New Delhi - 110001,
India.

HARVEY FROST & Co. Ltd.,
P.O. Box 16,
Dunmow Road,
Bishop's Stortford,
Herts,
United Kingdom.

HEINRICH MACHINERY & TOOL Mfg. Co. Inc.,
Sparta Road,
Stanhope, N.J. 07874,
U.S.A.

HYDRAULIC BREAKERS (SCOTLAND) Ltd.,
59/71 Vere Road,
Blackwood ML11 9RR,
United Kingdom.

HIGGINSON EQUIPMENT SALES Ltd., U.K.,
P.O. Box 5011,
Burlington,
Ontario L7R 324,
Canada.

INDEQUIP ENGINEERING Ltd.,
Neer I.T.I. Naroda,
Ahmedabad,
India.

HINDUSTON MACHINE TOOLS Ltd.,
Tractor Division,
1 Jaisingh Road,
Bharat Yuvak Bhawan,
New Delhi 110001,
India.

INTERNATIONAL HARVESTER Co.
GREAT BRITAIN Ltd.,
P.O. Box 25,
259 City Road,
London EC1P 1AD,
United Kingdom.

HOLMAN BROTHERS Ltd.,
Camborne,
Cornwall,
United Kingdom.

INTERNATIONAL RICE RESEARCH INSTITUTE,
P.O. Box 933,
Manila,
Philippines.

HOLTITE Ltd.,
Woods Lane,
Cradley Heath,
Warley,
West Midlands B64 7AW,
United Kingdom.

INTERNATIONAL TRACTOR Co. of INDIA Ltd.,
Akurli Road,
Kandivli (East),
Bombay 400067,
India.

HOWARD ROTAVATOR Co. Ltd.,
West Horndon,
Essex,
United Kingdom.

IRUSWERKE,
7401 Dusslingen,
Federal Republic of Germany.

OY HYDOR AB,
Korso, SF-01450 Vantaa 45,
Finland.

C.I. JENKINSON & SON Ltd.,
Niloc Works, Penistone Road,
Sheffield S6 2FW,
United Kingdom.

RV HYDRATOOLS Ltd.,
South Marston Works,
P.O. Box 77, Swindon SN3 4RA,
Wiltshire,
United Kingdom.

JAMES JONES & SONS Ltd.,
Broomage Avenue, Larbert,
Stirlinshire FK5 4NQ,
United Kingdom.

KANGO ELECTRIC HAMMERS Ltd.,
Lombard Road,
Morden Road,
London SW19 3XA,
United Kingdom.

KAWAMOTA PUMP MFG. Co., Ltd.,
Nagoya,
Japan.

KERALA AGRO MACHINERY CORPORATION Ltd.,
P.O. Athani,
Angamally South,
Distt. Ernakulam,
Kerala,
India.

KIRK DYSON DESIGNS Ltd.,
Leaffield Estate,
Corsham,
Wiltshire SN13 9UD,
United Kingdom.

KIRLOSKAR TRACTORS Ltd.,
Thermal Power Station Road,
Nasik Road 422101,
Maharashtra,
India.

KOEHRING GmbH,
D-5407 Boppard/Rhein,
Postfach 180,
Federal Republic of Germany.

KRISHI ENGINES Ltd.,
A-7 Unit,
Sanatnagar,
Hyderabad 500018,
India.

KUBOTA Ltd.,
22 Funade Cho,
2-Chome Naniwa-ku,
Osaka,
Japan.

G.P. LLOYD & Co. (Cardiff) Ltd.,
Dumballs Road,
Cardiff CF1 6UE,
United Kingdom.

LOSENHAUSEN MASCHINENBAU AG,
P.O.B. 230149, Schlüterstrabe 13-19,
D-4 Düsseldorf 23,
Federal Republic of Germany.

JOHN MACDONALD & Co. (P.T.) Ltd.,
Peel Park Place,
College Milton South,
East Kilbride,
Glasgow G74 5LS,
United Kingdom.

MAHARASHTRA CO-OP ENGG. SOCIETY Ltd.,
PB No. 175,
Shiroli,
Kolhapur,
Maharashtra,
India.

MAHINDRA OWEN Ltd.,
155 Bombay Poona Road,
Pimpri,
Poona 411018,
India.

MARSHALL, SONS & Co.
(MANUFACTURING) Ltd.,
Madras,
India.

MASCHINENBAU B. KALTENEGGER GmbH,
Kurhausstrase 73-79,
5202 Hennef-1,
Federal Republic of Germany.

MASSEY FERGUSON do Brasil S.A.,
Estrada de Campo Limpo, 6197,
CP 40.240,
CEP 01000 Sao Paulo-SP
Brazil.

MASSEY FERGUSON S.A.,
22 Avenue Galilee,
92350 La Plessis Robinson,
France.

MASSEY FERGUSON (India)
Tractors & Farm Equipment Ltd.,
P.O. Box 3302,
Madras 600034,
India.

MASSEY FERGUSON de Mexico S.A.,
Homero No. 1425-7^o piso,
Mexico 5, D.F.,
Mexico.

MASSEY FERGUSON (U.K.) Ltd.,
Banner Lane,
Coventry,
United Kingdom.

MASSEY FERGUSON (U.S.A.) Ltd.,
1901 Bell Avenue,
Des Moines,
Iowa 50315,
U.S.A.

MATTHIAS SPENCER & SONS Ltd.,
P.O. Box No. 7,
Arley Street,
Sheffield S2 4QQ,
United Kingdom.

WILLIAM A. MEYER Ltd.,
9-11 Gleneldon Road,
London S.W.16,
United Kingdom.

MILLARS MACHINERY Co. Ltd.,
P.O. Box 3,
Bishop's Stortford,
Herts CM23 3JZ,
United Kingdom.

R.D. MILLES Ltd.,
6-14 Brasenose Road,
Bootle,
Merseyside L20 8HH,
United Kingdom.

MOTOCULTORES PASQUALI SA,
Poligono Industrial 'Can Jordi',
Calle Haendel S/n,
Apartado Correos 132,
Barcelona,
Spain.

JAMES NEIL (Sheffield) Ltd.,
Napier Street,
Sheffield S11 8HB,
United Kingdom.

NEW VIJAY INDUSTRIES Ltd.,
Vishrambag,
Sangli 416415,
Maharashtra,
India.

NIS MARKETING Ltd.,
Foundry Lane,
Speedwell,
Bristol BS5 7XJ,
United Kingdom.

OATES Ltd.,
Gateford Road,
Workshop 5811 7AP,
Nottinghamshire,
United Kingdom.

PUNJAB TRACTORS Ltd.,
No. 10, Sector 9-A,
Chandigarh - 160011,
India.

O.P. LINK HANDLE Co. Inc.,
Salem,
Indiana,
U.S.A.

RAJASTHAM STATE AGRO-INDUSTRIES
CORPORATION Ltd.,
Virat Bhawan,
C-Scheme,
Jaipur 302006,
Rajasthan,
India.

PADLEY & VENABLES Ltd.,
Callywhite Lane,
Dronfield,
Sheffield S18 6XT,
United Kingdom.

RANK PULLIN CONTROLS,
Langston Road,
Debden,
Loughton,
Essex IG10 3TW,
United Kingdom.

PASBO MACCHINE AGRICOLE,
73041 Carmiano,
Lecce,
Italy.

RANSOMES SIMS & JEFFERIES Ltd.,
Tillage Division,
Ipswich,
United Kingdom.

THE PHOENIX ENGINEERING Co. Ltd.,
Phoenix Works,
Chard,
Somerset,
United Kingdom.

SABARWAL METAL INDUSTRIES,
61 Industrial Estate,
Kalpi Road,
Kanpur 208012,
India.

PRAKASH ENGINEERING WORKS,
Etawah Road,
Sirsaganj,
Mainpuri,
Uttar Pradesh,
India.

SALCO MASKIN AB,
P.O. Box 439,
S-19104 Sollentuna,
Sweden.

PROJECT EQUIPMENT Ltd.,
Industrial Estate,
Rednal Airfield,
West Felton,
Oswestry,
Salop SY11 4HS,
United Kingdom.

S.L. SALOMON Inc.,
151 C. de Jesus,
San Juan,
Rizal,
Philippines.

THE SALOP TRAILER Co. Ltd.,
292 Monkmoor Road,
Shrewsbury, SY2 5TJ,
United Kingdom.

SANDVIK U.K. Ltd.,
Manor Way,
Halesowen,
West Midlands B62 8QZ,
United Kingdom.

J.K. SATOH AGRICULTURAL MACHINES Ltd.,
Kamla Tower,
Kanpur - 208001,
U.P.
India.

SATPUDA ENGINEERING INDUSTRIES,
D-18 Udyog Sadan No. 2,
Andheri (East),
Bombay,
India.

SAYAJI IRON & ENGINEERING Co. Ltd.,
Chhani Road,
Baroda - 390002,
India.

SCOVIL HOE Co.,
P.O. Box 328,
Locust Valley,
N.Y. 11560,
U.S.A.

SHEEPBRIDGE EQUIPMENT Ltd.,
Chesterfield S41 9QD,
United Kingdom.

SIMCO,
Bareilly,
India.

SISCOMA,
BP 3214,
Dakar,
Senegal.

SKOGSMATERIEL AB,
Box 12199,
10225 Stockholm,
Sweden.

SLACK SELLARS & Co. Ltd.,
Sheffield,
United Kingdom.

SLINGSBY,
Kingsway,
London WC2B 6SB,
United Kingdom.

SOCIETE DES FORGES TROPICALES,
BP 706,
Douala,
Cameroun,

SOUTH STAFFS CONSTRUCTION Co. Ltd.,
Powke Lane,
Old Hill,
Warley,
Worcs,
United Kingdom.

SPEAR & JACKSON (TOOLS) Ltd.,
St. Paul's Road,
Wednesbury,
West Midlands WS10 9RA,
United Kingdom.

STANDALL ENGINEERING Ltd.,
Mickley Works,
Dronfield Woodhouse,
Sheffield S18 5XN,
United Kingdom.

STANLEY POWER TOOLS Ltd.,
Nelson Way,
Cramlington,
Northumberland NE23 9JS,
United Kingdom.

STAUB,
25 Boulevard de Verdun,
92402 Courbevoie,
Paris,
France.

TIRFOR Ltd.,
Halfway,
Sheffield S19 5GZ,
United Kingdom.

THE STOCKTON HEATH FORGE (Caldwells) Ltd.,
Warrington,
United Kingdom.

TOYO DIAMOND INDUSTRY, Co. Ltd.,
Tokyo,
Japan.

STOTHERT & PITT Ltd.,
P.O. Box 25, Lower Bristol Road,
Bath BA2 3DJ,
United Kingdom.

TRACTORS & FARM EQUIPMENT Ltd.,
P.O. Box 3302,
Madras 600034,
India.

SVEDALA-ARBRÅ AB,
S-23300 Svedala,
Sweden.

TREWHELLA BROS. (U.K.) Ltd.,
Rolfe Street,
Smethwick,
Warley,
West Midlands B66 2BA.
United Kingdom.

SAMUEL SWIFT Ltd.,
Birley Meadow Steel Works,
Owlerton,
Sheffield,
United Kingdom.

TROJAN Pty. Ltd.,
38 Rayleigh Street,
Footscray,
Victoria 3011,
Australia.

SYNDICAT DE L'OUTILLAGE AGRICOLE ET HORTICOLE,
15 Rue Beaujon,
75008 Paris,
France.

TRUMETER,
Radcliffe,
Manchester 26,
United Kingdom.

THE TATA IRON & STEEL Co. Ltd.,
Jamshedpur 831001,
India.

TUBE PRODUCTS of INDIA,
Avadi,
Madras 600-054,
India.

TELEHOIST Ltd.,
Manor Road,
Cheltenham,
United Kingdom.

TWOSE of TIVERTON Ltd.,
Lowman Works,
Tiverton,
Devon,
United Kingdom.

ELIZA TINSLEY & Co. Ltd.,
P.O. Box 35,
Cradley Heath,
Warley,
West Midlands B64 5JF,
United Kingdom.

F.W. WHEATLEY TRAILERS Ltd.,
Fengate,
Peterborough, PE1 5BD,
United Kingdom.

UBUNGO FARM IMPLEMENTS
MANUFACTURING Co. Ltd.,
P.O. Box 20126,
Dar es Salaam,
Tanzania.

WILLIAM & JAMES (ENGINEERS) Ltd.,
Mercia Road,
Gloucester GL1 2SL,
United Kingdom.

VALMET OY,
Tourula Works,
Jyväskylä,
Finland.

WILLIAM WHITEHOUSE & Co.
(ATLAS FORGE) Ltd.,
Newlyn Road,
Cradley Heath,
Warley,
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WEEKS TRAILERS Ltd.,
Ferry Road,
Hessle,
Humberside HU13 ODZ,
United Kingdom.

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1. Index

An index has been prepared giving page numbers of references to the tools and equipment described in the Guide. The index is not comprehensive in that it does not include every reference to a particular implement, only those which provide useful information. For example, the first page of each Section of the Guide lists the implements covered in that Section but gives no information about them; these references to implements have not been included in the index.

In arranging the alphabetical listing of the index, the following guidelines have been followed:

i) where there are a number of different types of a particular implement, these are listed under the first letter of the name of the implement.

For example, cross-cut saws and bow-saws are listed under S as:

Saw, cross-cut

Saw, bow

ii) Except in these cases, implements whose name consists of more than one word are listed under the first letter of the first word. Thus,

Hand Rammer is listed under H not R.

Grass Cutter is listed under G not C.

Where a reference to an implement is underlined, (e.g. Axe 1.4-1.7) this means that these pages give the main technical description of the implement. References which are not underlined may refer to the application or operation of the implement or, in the case of Technical Note page numbers, give information on material specification, testing etc.

INDEX OF TOOLS AND EQUIPMENT DESCRIBED IN THE GUIDE.

A

Animals. 3.3, 3.5, TN6.8-TN6.11, TN6.20-TN6.21

Anvil. TN5.5, TN5.7.

Axe. 1.4-1.7, 1.57, 1.58-1.61, 3.3, 3.4, 3.20-3.21, 3.30-3.33, TN1.1, TN1.2, TN1.6, TN1.7, TN2.7, TN2.10, TN2.11, TN3.3, TN3.4, TN3.9-TN3.10, TN4.2, TN4.3, TN4.4.

B

Batch Heater and Mixer. 12.4-12.5, 12.22-12.25.

Bitumen Boiler. 12.3-12.4, 12.6-12.9,

Bitumen Can. 12.3-12.4, 12.15, 12.19

Bowser, animal drawn. 9.4, 9.28-9.29.

Bowser, tractor drawn. 9.4, 9.30-9.31.

Breaker (Electropneumatic) and Drill. 5.3, 5.11-5.15.

Breaker (Hydraulic). 5.3, 5.11-5.15.

Breaker (Petrol-Engined) and Drill. 5.3, 5.11-5.15,

Breaking Bar. 3.3, 3.4, 3.28-3.29.

Brush Hook. 1.8-1.9, 1.62-1.63, 3.4, 3.20-3.21, TN1.2, TN1.7, TN2.7, TN4.4.

Bucket. 9.5, 9.6-9.7.

C

Carts, animal-drawn. 7.3, 7.6, 7.38-7.47.

Chisel and Tongs. 5.3, 5.6-5.7, TN1.2.

Clinometer. 2.5, 2.26-2.27.

Cold Emulsion Sprayer. 12.3-12.4, 12.10-12.13, 12.19.

Cross-Staff. 2.5, 2.28-2.29.

Crowbar. 1.32-1.35, 4.3, 4.4, 4.8-4.11, 5.3, 5.5, TN1.1, TN1.2, TN1.7, TN3.3, TN3.4, TN3.12-TN3.13, TN4.4.

D

Drag, animal-drawn. 8.3, 8.5, 8.6-8.7.

Drag, Tractor-drawn. 8.3, 8.5, 8.8-8.9.

E

Earth Scoop, animal-drawn. 4.3, 4.5, 4.32-4.35, 7.5, 7.6, TN1.1.

Earth Scraper, tractor-drawn. 4.3, 4.5, 4.40-4.43, 7.5, 7.7, TN⁴.1.

F

Fork. 1.10-1.13, 1.20-1.21, 1.57, 1.64-1.65, 3.4, 4.5, 4.7, 4.8-4.11, 8.3, 8.5,
12.3-12.5, 12.19, TN1.2 TN1.7, TN2.11, TN3.3, TN3.14, TN4.3, TN4.5.

Fresno Scraper, animal-drawn. 4.3, 4.5, 4.36-4.39, 7.5, 7.6, TN1.1.

G

Gradient Template. 2.3, 2.24-2.25.

Grapple. 3.4, 3.5, 3.42-3.44.

Grass Cutter. 1.48-1.49, 3.4, 3.19, TN1.1.

H

Hammer, sledge. 1.36-1.39, 1.57, 1.70-1.71, 5.3, 5.5, 6.3, 6.5, TN1.1, TN1.2,
TN1.4, TN1.6, TN1.7, TN2.10, TN2.11, TN3.3 TN3.4, TN3.5, TN3.13,
TN4.3, TN4.4.

Hammer, stone-breaking. 1.40-1.41, 1.72-1.73, 6.3, 6.5, TN1.1, TN1.2, TN1.4,
TN1.7, TN2.11, TN3.3, TN3.4, TN3.5, TN3.13, TN4.3.

Handcart and Bowser. 9.3, 9.26-9.27.

Hand Paver-Finisher. 12.4-12.5, 12.26-12.27.

Hand Rammer. 1.54-1.55, 1.76-1.77, 10.3, 10.9, TN3.4, TN3.15, TN4.5.

Hand Tong & Hook. 3.4, 3.5, 3.34-3.41.

Harness, bovine. TN6.11, TN6.14-TN6.18.

Harness, Camel. TN6.11, TN6.17-TN6.21.

Harness, equine. TN6.11-TN6.13.

Harrow, disc (animal-drawn). 11.3-11.5, 11.10-11.11, 11.21,

Harrow, disc (tractor-mounted). 11.3-11.5, 11.12-11.13, 11.21,

Harrow, rotary (animal-drawn). 11.3-11.5, 11.8-11.9,

Harrow, rotary, (tractor mounted). 11.3-11.5, 11.19, 11.21,

Head basket. 7.3, 7.6, 7.8-7.11, 12.3-12.4, 12.19.

Hoe. 1.22-1.25, 1.57, 1.66-1.67, 3.3, 3.4, 4.4, 4.7, 4.8-4.11, 8.3, 8.5, 11.3-11.5,
11.7, TN1.1, TN1.2, TN1.7, TN2.7, TN3.3, TN3.4, TN3.11, TN4.1, TN4.3, TN4.4.

Hoe, forked. 1.26-1.27, 1.66-1.67, 3.3, 3.4, 4.5, 4.7, 4.8-4.11, 12.3-12.5, 12.19,
TN1.1, TN1.2, TN1.7, TN2.7, TN3.3, TN3.4, TN3.11, TN4.3, TN4.4.

L

Land Measuring Wheel. 2.5, 2.34-2.35.

Level, Abney. 2.3, 2.22-2.23.
Level, Cowley. 2.3, 2.20-2.21.
Level, flexible tube water. 2.3, 2.6-2.7.
Level, line. 2.3, 2.8-2.9.
Level, spirit. 2.3, 2.10-2.11.

M

Mallet Lever. 3.3, 3.4, 3.10-3.11, 3.17.
Manual Plant Pullers. 3.3, 3.4, 3.6-3.7.
Mattock. 1.30-1.31, 1.57, 1.68-1.69, 3.3, 3.4, TN1.1, TN1.2, TN1.6, TN1.7, TN2.7,
TN3.3, TN3.4, TN3.12, TN4.3, TN4.4
Measuring Box. 7.3, 7.6, 7.18-1.19.
Mobile Crushers. 6.3, 6.7-6.11.
Mortar Pan. 7.3, 7.6, 7.12-7.13, 12.4-12.5.
Moveable Target for Staff. 2.11, 2.13, 2.15, 2.17.

O

Oil Drum Forge. TN5.5-TN5.6.

P

Panniers, camel. 7.3, 7.6, 7.37-7.37.
Panniers, donkey, pony, mule. 7.3, 7.6, 7.34-7.35.
Pickaxe. 1.28-1.29, 1.57, 1.68 - 1.69, 4.3, 4.4, 4.8-4.11, 5.3, 5.5, TN1.1, TN1.2,
TN1.6, TN1.7, TN2.7, TN2.10, TN2.11, TN3.3, TN3.4, TN3.11-3.12, TN4.3,
TN4.4.
Plough, mouldboard (animal-drawn). 4.3, 4.4, 4.13, 4.14-4.19, 4.31.
Plough, mouldboard (tractor-drawn). 4.3, 4.4, 4.13, 4.22-4.25, 4.31.
Plough, tine (animal-drawn). 4.3, 4.4, 4.13, 4.20-4.21, 4.31.
Plough tine (tractor-drawn). 4.3, 4.4, 4.13, 4.26-4.29, 4.31.
Plug & Feathers. 5.3, 5.8-5.9.
Power Rammer, pedestrian operated. 10.3, 10.4, 10.6, 10.15.
Pump, diaphragm (BRR). 9.3, 9.5, 9.8-9.9, 9.12-9.13.
Pump, diaphragm (IRRI). 9.3, 9.5, 9.8-9.9, 9.14-9.15.
Pump, diaphragm (Vergnet). 9.3, 9.5, 9.8-9.9, 9.18-9.19.
Pump, inertia. 9.3, 9.5, 9.8-9.9, 9.10-9.11.
Pump, semi-rotary or vane. 9.3, 9.5, 9.8-9.9, 9.16-9.17.

V

Vibrating Plate, pedestrian operated. 10.3-10.5, 10.7, 10.15.
Vibrating Rammer, pedestrian operated. 10.3-10.5, 10.6, 10.15,
Vibrating Roller, pedestrian operated. 10.3-10.5, 10.8, 10.15.
Vice. TN5.2-TN5.4.

W

Watering Can. 9.3, 9.20-9.23.
Water Manometer. 2.3, 2.14-2.15.
Wedge. 3.3, 3.4, 3.24-3.27, 3.33.
Wheelbarrow, aggregate spreading. 12.3-12.4, 12.16-12.17, 12.19.
Wheelbarrow, Chinese. 7.3, 7.6, 7.26-7.29, 7.30-7.33, 12.4-12.5.
Wheelbarrow, Western. 7.3, 7.6, 7.20-7.25, 7.30-7.33, 12.4-12.5.
Winches, hand operated. 3.3, 3.5, 7.32-7.33, TN6.3-TN6.7.
Workbench. TN5.2-TN5.3.

Y

Yoke. 9.3, 9.24-9.25.

Other ILO publications on road construction

Manual on the planning of labour-intensive road construction

By M. Allal and G.A. Edmonds, in collaboration with A.S. Bhalla.
ISBN 92-2-101543-2 (limp cover); ISBN 92-2-101544-0 (hard cover)

Even in countries where labour is abundant and capital is scarce, people concerned with the planning and design of roads generally have no clear idea of the scope for the use of labour-intensive methods in road construction. The scope is in fact considerable. To take the fullest advantage of it, however, road investment programmes and road designs, with their associated technological options, must be methodically reviewed in the light of the essential objectives of the national plan and of the roads themselves. The authors first give systematic descriptions of how the choice of technology can be incorporated into planning and design. They then describe how labour-intensive techniques should be analysed, and the range of technological options available. They also show how to analyse road construction costs proper as well as maintenance costs, road users' costs and indirect benefits, and suggest criteria and methods to be used in evaluating different possible combinations of design and technology, both in orthodox financial terms and in terms of shadow prices using cost-benefit analysis. The concluding chapters review the problems of organisation and management in labour-intensive works, and suggest action that should be taken to eliminate capital-intensive biases in fiscal and financial policy, conditions of tender and contract terms, and the attitudes of engineers.

Roads and redistribution

Social costs and benefits of labour-intensive road construction in Iran. By G.W. Irvin, assisted by B. Nilsson, L. Karlsson and R. Eriksson.
ISBN 92-2-101190-9

Equipment versus employment

A social cost-benefit analysis of alternative techniques of feeder road construction in Thailand.
By W.A. McCleary, in collaboration with M. Allal and B. Nilsson.
ISBN 92-2-101501-7

These two books are studies of the real costs and benefits, for society as a whole, of using more labour-intensive methods for the construction of roads in developing countries.

The first book is based on a report prepared at the request of the Government of Iran to elaborate on a suggestion made by a comprehensive employment mission to that country which had been organised by the ILO in 1971-72. It is often argued that, when they leave the land, employment on public works could provide the rural poor with a livelihood until they find more attractive jobs elsewhere. On the basis of a field study of a number of road construction projects in Iran by a team of ILO economists and engineers, the book investigates to what extent the substitution of more labour for some of the machinery used to build roads in that country would be justified in social terms. The payment of a subsidy to contractors willing to employ more labour is suggested as the most practical and direct means of altering the capital-labour ratio.

The second book is a study of the economic case for the use of labour-intensive techniques for the construction of a typical feeder road in northern Thailand. Through interviews with private contractors, consulting engineers and the Highways Department, as well as through direct field observations, technically viable and economically promising alternative techniques were identified for most of the 19 operations involved in the construction of the road. This study is particularly interesting in that it was the first ILO study on road construction work to take account of the effects of the energy crisis on technological choice.

Men or machines

A study of labour-capital substitution in road construction in the Philippines. By Deepak Lal, assisted by A. Heap, H. Boisen, B. Nilsson and L. Karlsson.
ISBN 92-2-101720-6 (limp cover); ISBN 92-2-101721-4 (hard cover)

Is it possible to find labour-intensive methods of road construction that are technically efficient?

Is the adoption of such methods socially desirable?

If so, how can private contractors be encouraged to use the socially optimal method?

What factors affect the large-scale implementation of efficient labour-intensive methods?

These and other related questions are answered in this volume. The implications of using labour-intensive methods are set against their economic background; but this is much more than a theoretical study, since the detailed *ex ante* cost and productivity estimates worked out for a pilot road project in the Philippines are compared with the results of actual experiments carried out on the spot, in which the labour-intensive methods devised by the ILO engineers were tested under field conditions. This practical investigation confirms that, at least in the Philippines, labour-intensive methods of road construction are generally feasible.

The rural access roads programme – Appropriate technology in Kenya, by J. J. de Veen
ISBN 92-2-102204-8

This book describes the "Rural Access Roads Programme", a unique road construction project in Kenya, which represents the first attempt in Africa to implement labour-based methods efficiently on a large scale. After several years of implementation, this programme has demonstrated that labour-intensive techniques may be efficiently used to build low-cost, good-quality roads. All aspects of the programme are described.

GUIDE TO TOOLS AND EQUIPMENT

In recent years it has been shown that labour-based techniques of road construction can be, and often are, preferable to capital-intensive techniques, not only for their reduced cost but also for the additional job opportunities they create. For labour-based techniques to be effective, however, the available tools and equipment need to be improved. The information given in this guide will help those responsible for planning and managing labour-based road construction projects to specify the appropriate tools and equipment for the job, by showing them how to establish test procedures, how to advise local manufacturers on the production of good-quality implements, how to contact sources of supply and how to ensure the correct use and maintenance of the tools and equipment selected.

Whilst the guide is concerned with road construction, it is obvious that the information provided could also find wider application in agriculture, forestry and civil engineering generally.