CPA Series No. 28

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MANUAL

ON

VILLAGE ROAD CONSTRUCTION

Issued by

Community Project Administration
Government of India
1954

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VILLAGE ROAD CONSTRUCTION

1. **Introduction.**—The construction of roads precedes all other activities directed towards the development of any area. Every form of community activity or indeed almost every form of activity in daily life requires the use of a road as a means of communication. It would not be a flight of fantasy to conceive of the "use of the beaten path" as having developed with the beginnings of mammalian life on land. Every hunter in the forest and every explorer of the so-called wilds finds that the creatures of the wild have their own road systems of beaten paths. If one were therefore merely to follow instinct it would not need a lot of argument to convince that roads are for the good of the community. But the "where and how" ideas have grown with the growth of civilisation and science and this Manual tries to keep one abreast of the times.

2. **Early roads in India.**—The great historical epics the Mahabharata and the Ramayana contain not merely references to roads but have portions devoted to road construction. The scientific treatises as the Artha Shastra go further and give specifications for the different classes of roads needed for different purposes.

Archaeological excavations have revealed to us the wonderful system of urban roads in towns and cities of the old.

3. **Roads in the middle Ages.**—Examination of the road systems in the middle ages goes to show that pilgrim routes to the various sacred towns and holy places formed the backbone of a road system. Parts of these still exist and are locally well identified. Indeed one section of a pilgrim route to Rameswaram is now being developed as a National Highway, and another section of a similar pilgrim road to Puri has already been used and developed as part of another National Highway.

4. **Later developments.**—Upto the middle ages rural roads in India were well developed compared to the rest of the world but with the advent of Railways emphasis was shifted from arterial roads to railway lines. Arterial roads thus got neglected.

The arrival of the motor vehicle in the field of communication has again changed the outlook because of certain advantages inherent in the flexibility of road communications. During the present century all advanced countries have taken to development of roads for the better economic development of their countries.

5. **Importance of roads to rural communities.**—The importance of roads to rural communities is obvious and the benefits that the community would derive by the construction of village roads are manifold. Yet to those of us who are habituated to counting of benefits on our finger tips certain brief lists are helpful. Therefore among the most important of the benefits of village roads may be mentioned the following—

(1) Facility for exchange of local produce from agriculture and cottage industry with other goods needed in the village.

(2) Access to welfare services such as medical, sanitary, veterinary and educational.

(3) Development of cultural, intellectual and social activities by making the villages accessible to one another and to the towns.

6. **Origin of the modern road system.**—Under the Government of India Act of 1919 roads were a Provincial subject, and the Provinces made over charge of the major mileage of roads to Local Bodies keeping under their direct charge a small mileage of Trunk Roads. Thus there was no uniform policy of road construction and there obtained also different standards of maintenance depending upon the financial capacity of each local body. The rapid development of motor transport caused a more rapid deterioration in the condition of roads. Public opinion then took a hand and was eventually voiced in a resolution adopted by the Council of States in February 1927 calling for a Committee of both Chambers of the Central Legislature to investigate and report.

As a result, a Committee of both Chambers, the "Indian Road Development Committee", was appointed in November 1927 with Dr. M. R. Jayakar, M.L.A. as chairman. The committee reported in June 1928 and as a result of their report the Central Road Fund was created.

6.1 The Nagpur Plan.—The Second World War brought out sharply the need for a well developed road system for use by the mechanised forces for the defence of the country. As the consequence of the lead given by Lord Wavell active steps were taken for the Post-war Road Development in India. The Government of India convened in 1943 a conference of Chief Engineers of the then Provinces and the major Princely States for the purpose of formulating a comprehensive plan of road development in India. The conference which met at Nagpur in December 1943 drew up for the first time a plan of Road Development for the whole of India and produced a report popularly known as the "Nagpur Report".

6.2 **Road Classification.**—Among the recommendations the conference made is the one on classification of roads into five categories as under —

(1) National Highways: which are the "main" highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of Provinces and/or large States and including roads required for strategic movement for the defence of India—National Highways should be the frame on which should be based the entire road communication system of the country. They must give uninterrupted road communication throughout India and connect the whole structure.

(2) Provincial Highways: which are all main trunk or arterial roads of a State connecting up with National Highways, or highways of adjacent States, district headquarters and important cities within the same State and serve as the main arteries of traffic to and from district roads.

(3) District Roads serving areas of production and markets and connecting these with each other or with highways and railways. District Roads were sub-divided into the following two groups according to importance and traffic intensity.

(a) Major District Roads, and

(b) Other District Roads.

(4) Village roads are roads connecting villages and groups of villages with each other and to the nearest road, main highway, railway or a ferry.

The above classification was accepted by all the State Governments. The administrative classification of roads now current follows the above pattern. This classification has also since been adopted as a standard by the member Governments of the ECAFE.

In any system of road communications each category of road has its own function and a balanced system alone could serve the community in the most efficient manner. For India (excluding Pakistan) the Nagpur Report envisaged the construction of 124,500 miles of village roads against 20,750 miles of National Highways, 53,950 miles of State Highways and 127,800 miles of District Roads. This mileage of roads was based on the principle that every village with a population of 500 and above should be connected by a village road to a road of higher category and that the latter should on an average be within 3 miles of all such villages.

The formulae developed to estimate the needs of any area or State took into account the number of villages with different population densities and provided a factor for the agricultural and industrial development expected in the next 20 years. Roads being a permanent feature this looking ahead is an important element in planning.

7. Alignment principles—surveys, location.—The route that the central line of a proposed road should follow is called the alignment of the road. The fixing of a proper alignment for a road constitutes a very important part of a road project. While selecting an alignment consideration has to be given to the following:

Engineering Aspects:

(1) Gradients.
(2) Nature of the soil.
(3) River or Nallah crossings.
(4) Availability of materials for roads such as moorum or stone metal.

Economic Aspects:

(5) The number of villages served.
(6) Importance of the area served such as cultivated areas or dry land.
(7) Economy of the road alignment.

In planning the alignment for a group of villages three alternative methods are to be considered and their relative merits and demerits assessed. By one method all the villages are strung along one road passing through all of them. By the second method the villages are located at the ends of short branch roads shooting out of a main highway and a third will be a combination of the two. Generally the last will be found more economical.

Even when a village lies on a road, the road should be so aligned that the through road skirts the village and does not go right through the village. Because such a road with houses lying on both sides of it does not give scope for future expansion. One must always look ahead, what may start as a village road may soon become an important main road with lorries and buses plying on it.

Further for sanitary and health reasons it does definite harm to the health of persons living on both sides of a road to have dust raised by all the passing vehicles day in and day out.

The importance to be attached to each of the factors enumerated above can be gathered from the following discussion.

7.1 Gradients affect the ease of travel, speed, haulage power and vehicle operation costs. Easy gradients are very important specially in the village and the other district roads where considerable proportion of the traffic using the road would be low power bullock carts. Also, in the case of earth roads which will form the bulk of village roads steep gradients would allow the rain water to run along the road scouring gullies. Consequently such road would need attention after every rain and thus will be more costly to maintain.

A bullock drawing a cart up an incline has not only to pull the load but has also to lift its own weight and that of the cart. So its pulling capacity on the incline is much less than that on a level. Considering the above it has been laid down that in general for a plain country a gradient of 1 in 30 should not be exceeded in ordinary cases. But under conditions where adoption of a gradient of 1 in 30 would involve excessive cut or fills resulting in undue increase in cost, a gradient of 1 in 20 may be adopted.

In hilly country it is not always possible to secure flat gradients without very heavy excavation involving large expenditure. So a gradient of 1 in 20 is ordinarily allowed where flatter slopes would make the work very costly. In exceptional cases, for short stretches not exceeding 300 ft at a time, gradients of 1 in 15 for main roads and 1 in 12 for others may be allowed. Where gradients are steep it is sometimes necessary to use teams of bullocks to haul a single cart.

7.2 **Nature of the soil.**—A soil which is easily drained and which does not shrink very much when dry, is ideal for a road bed.

In general, moorum soils are good and soils with predominant silt or clay content are not quite suited because of their shrinkage characteristic. So when selecting an alignment it would be necessary to choose, among the alternatives available, the one in which the soil is suitable for embankment construction and has good drainable properties. But it is not always that an engineer is called upon to construct roads in an area where the soil is exactly suited to road construction. While the agriculturist would welcome on to his fields all the rain water he could get, the road engineer would be happy if he could get off all the water from his embankment or road bed.

7.3 **River or nallah crossings.**—Selection of suitable sites for these crossings is very important and it is necessary to fix these before finalising a road alignment. The crossings should be selected so as to cross the streams in straight reaches having confined section and where the banks are not liable to erosion or overflow. It is frequently sufficient, on grounds of economy, to provide only submersible bridges or causeways on the less important roads across big streams. Small streams requiring a waterway of 20 or less should be invariably fully bridged.

For all these works it is necessary to obtain the advice of local engineers.

7.4 **Availability of materials.**—While selecting two or more alternative alignments for a road, consideration should be given to the nearness of quarries from which road materials can be drawn up. Good road materials for village roads are moorums which are formed through disintegration of rocks, coarse gravelly soils, or sandy loams. On clay and sandy soils it is desirable to provide a hard crust. For higher traffic than on an average village road soft stones such as laterite, kankar, or sand stone would suffice if harder material is not available at a reasonable distance.

7.5 **Land acquired or gifted.**—The construction of a road enhances greatly the value of the land on both sides and for this reason it is often easy to persuade landholders to make a free gift of the land required for the road. The width of the land required is in general calculated in the way to be described further below.

With the object of preventing splitting of cultivated fields, owners often offer gifts of strips along the boundaries of fields. This leads to a tortuous alignment and a longer length than necessary, leading to higher cost of construction, high maintenance, greater length of haul and so on. So it is essential to persuade the cultivators to agree to the correct alignments.

Surveys: Plotting of surveys are a pre-requisite for any road project. For village roads and other district roads, when it is decided that a particular village should be connected by a road, survey maps to the largest available scale should be collected; usually village revenue maps to a scale of 16 inches or 8 inches to a mile are available with the village officers and these would prove of invaluable help. Before going out into the field probable alternative alignments should be marked avoiding built-up areas, graves, temples, etc. keeping in view the points mentioned in the previous sections. The officer responsible for the alignment should then walk along the proposed lines taking notes on the soil, stream crossings, probable gradients, availability of road materials and land etc. After completing the reconnaissance, the alignment should be finalised giving due weight to each factor.

8. **Surveys.**—Detailed survey along the route selected should then be undertaken. During the survey information on the following aspects should be collected —

(a) Nature and topography of the country traversed.

(b) Position of intersections with existing roads, railways, canals, their levels and width.

(c) Location of grave yards, temples, mosques, etc. which have to be avoided.

(d) Position of quarries. If there are no quarries details such as distance and ownership, in respect of quarries from where materials of construction could be got.

(e) Normal and high flood levels of streams.

(f) Levels along the central line.

(g) Particulars of the soil.

The levels are then plotted in a longitudinal section. The proposed finished road level is then plotted on the longitudinal sections bearing in mind that gradients should not be excessive and that there should be no uneconomic cut or fill. If the terrain is easy and almost level the plotting of longitudinal sections and marking of gradients may be dispensed with.

Typical cross-section.—A few cross-sections suitable for side long country, hilly country, flat country are shown in Fig. No. 1-A, B, C, D, E and F.

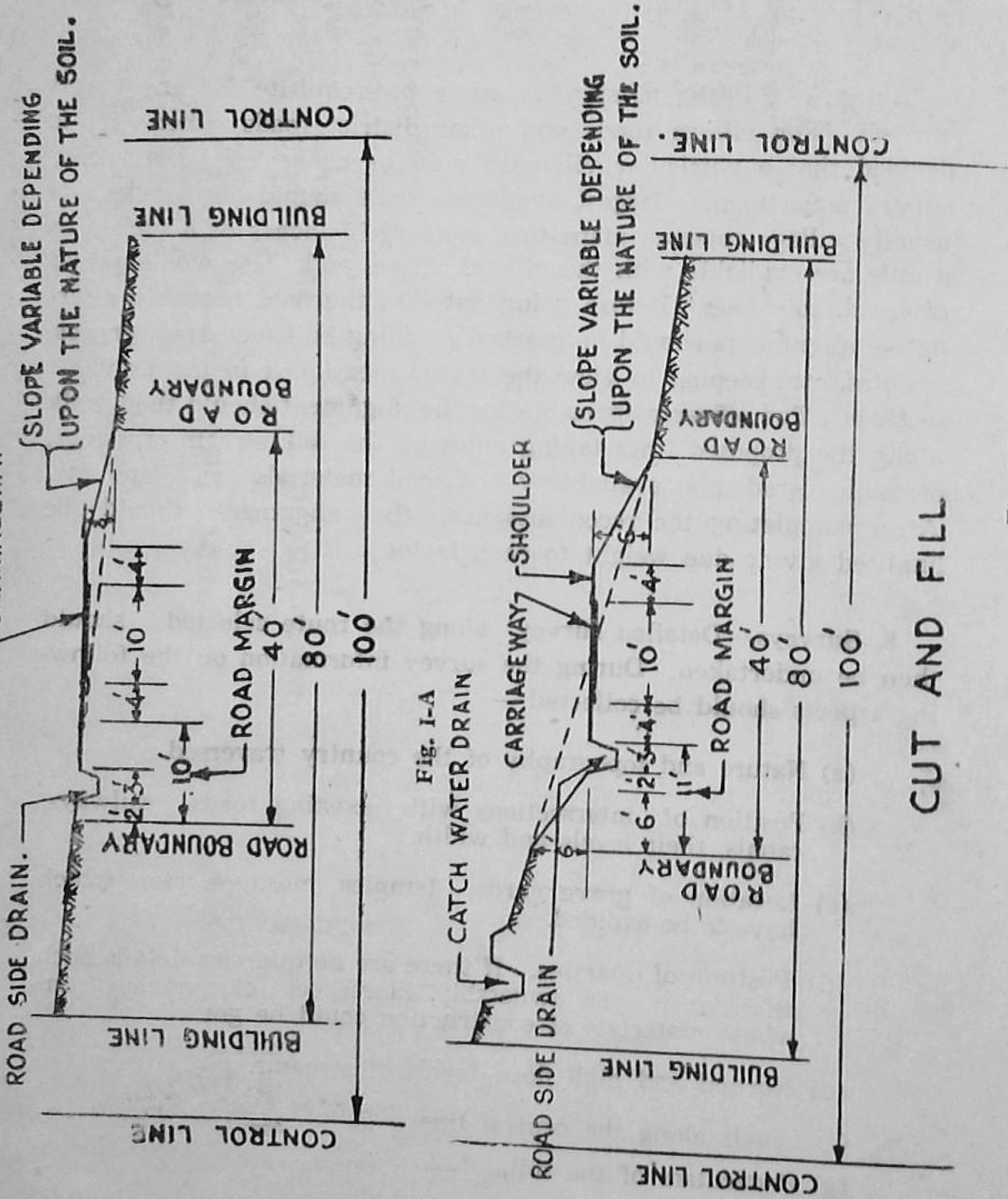


Fig. I-A

Fig. I-B

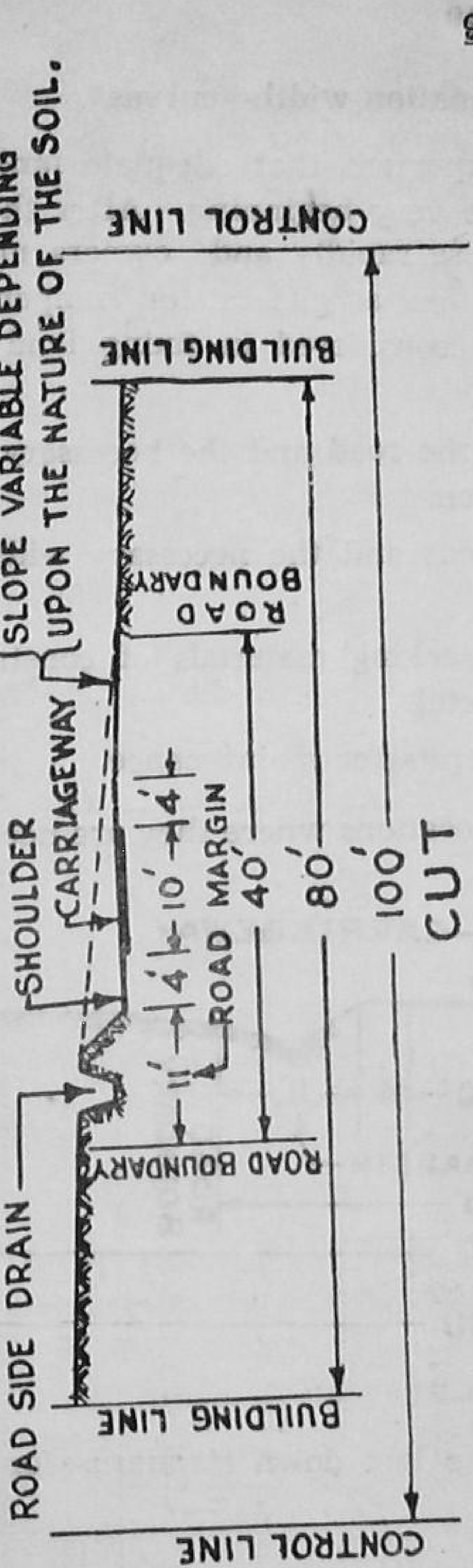


Fig. I-C

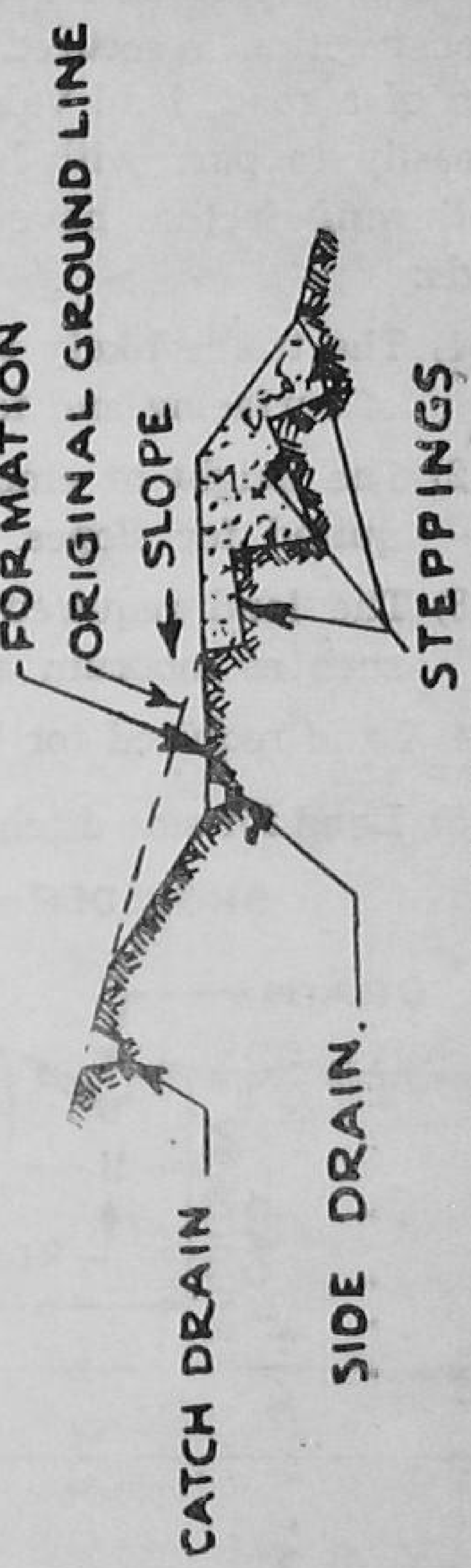


Fig. I-D

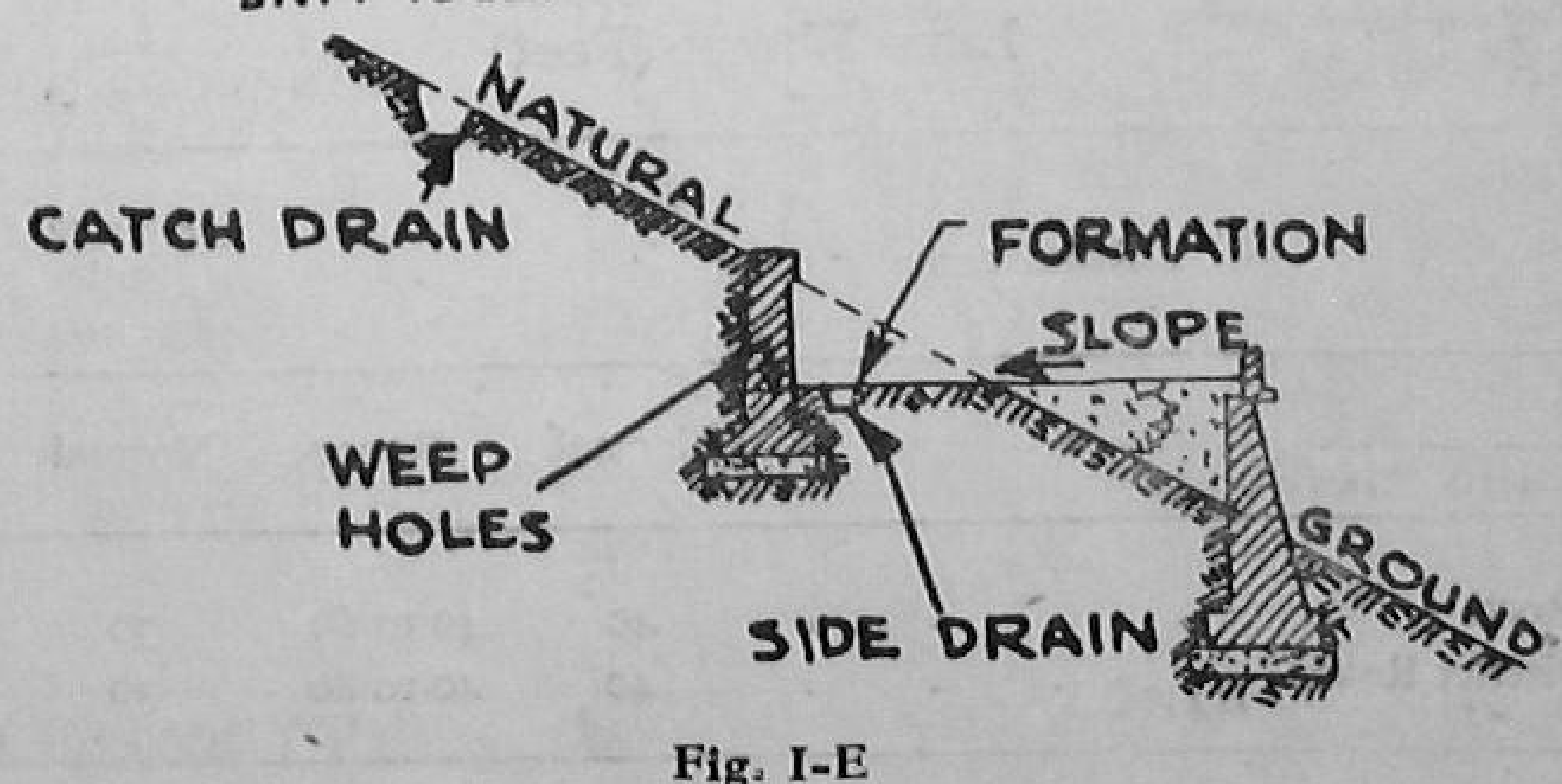


Fig. I-E

9. **Standards.**—Land width, formation width—curves.

9.1 **Land width.**—It is very important that adequate land for a road construction is secured in the very beginning. After the construction of a road, land values rise rapidly and owners may not agree easily to part with land either as gift or for compensation. The following factors have to be considered in fixing land width for roads:

(1) The traffic likely to use the road and the necessary width of surfacing and formation.

(2) The height of embankment and the necessary width required for slopes.

(3) The land required for stacking materials of construction such as moorum and metal.

(4) Land required for borrowpits for maintenance.

(5) Land for side ditches in locations where they are necessary.

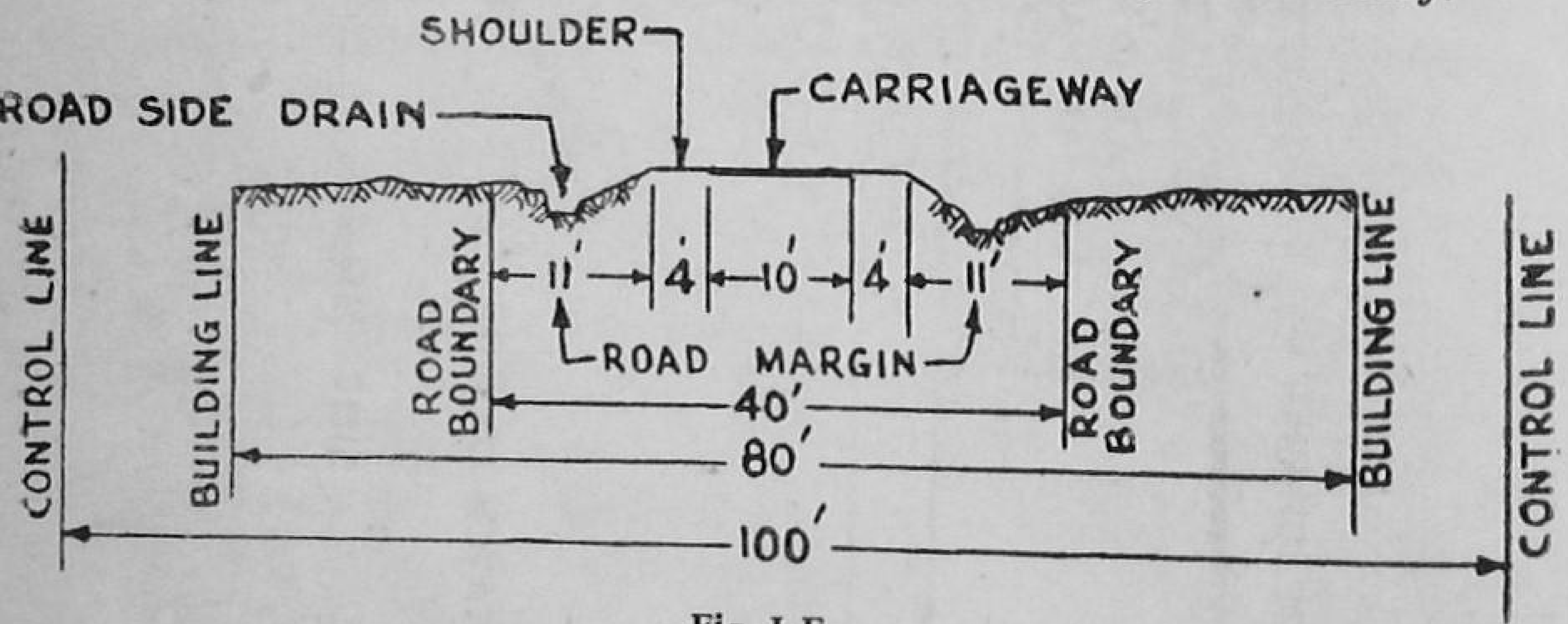


Fig. I-F

The Indian Roads Congress have laid down standards for land width as below:

LAND WIDTH (Feet)

	Rural areas		Urban & Industrial (built up areas)	
	Normal	Range	Normal	Range
Village Road	40	40 to 60	30	30 to 50
Other District Roads	40	40 to 80	30	30 to 50

9.2 Control lines.—Near built up areas where it is likely that buildings would spring up on road side land, experience has shown that it is necessary to control the erection of structure; otherwise intensive construction of building results in ribbon development which interferes with effective use of the road or future expansion.

To prevent such ribbon development, the Indian Roads Congress have recommended control of building operation on both sides of a road in accordance with the following table:

Road	Rural area		Urban or built up area
	Building lines	Control lines	Building line
Village Road	80 ft	100 ft	10 ft strip beyond road boundary.
Other District Road . .	80 ft to 100 ft	120 ft	-Do.-

"Building Lines" indicate the width of land (half the width on either side of the centre line of road) within which no buildings should be allowed to be constructed.

The land between the "Control line" and "Building line" is to be kept under control for all development purposes and only such works should be allowed to be erected which will not interfere with the use of the road by congregations of people, such as markets, cinemas, theatres etc. where large number of people meet.

9.3 Carriageway widths.—Formation width is the overall width of top of embankment, or in other cases where there is no embankment the width between side drains. The carriageway is the width specially prepared for vehicles to travel on. For village roads a minimum formation width of 18 ft and for district roads 24 ft is generally adopted. It is however desirable to have the formation width of the village roads also to be 24 ft. The width of carriageway depends on the maximum width of vehicles using the road and the frequency with which vehicles either cross or overtake each other. Considering that village roads would carry mainly bullock carts a 10 ft carriageway would generally be sufficient for traffic up to 200 tons per day *i.e.*, about 150 laden vehicles per day. When the traffic is more than this a 12 ft carriageway would be requireed. It should be noted here that bullock carts loaded with hay etc. occupy a greater width than others with normal loads.

9.4 Curves.—Changes in direction necessitate the use of horizontal curves. Motor vehicles cannot move at speeds with safety on sharp curves. Considering the condition of the road and the friction that may be developed between the tyres and the road surface, the Indian Roads Congress have laid down the minimum and desirable radii that are safe for Indian conditions and these are given below:

	Design speed in plain country	Desirable minimum radius of curve	Absolute minimum radius of curve.
Other District Roads	30	500	300
Village Roads	20	300	150
Hilly country			
Major District Roads	25	300	100
Other District Roads	20	200	60
Village Roads	15	150	50

In any location the largest possible radius should be adopted. *It is to be anticipated that the areas that are proposed to be developed will very soon be served by motor vehicles both for passenger and goods transport and hence reference to these minima for curve radii.* When a vehicle travels round a curve there is a tendency for the vehicle to be pushed out by the centrifugal force. To counteract this effect the outer side of the road is raised. This is called super-elevating the road. This raising produces a component of the weight of the vehicle in a direction which opposes the direction of centrifugal force.

The Indian Roads Congress formula for super-elevation= $\frac{3V^2}{80R}$ where V is the design speed in miles per hour and R is the radius of the curve in ft.

The help of the local P.W.D. should be availed of in marking out curves.

10. Construction of village roads.

10.1 Dag-belling.—The first step in the construction of a road is to mark the central line on the ground with reference to the final alignment marked on the survey maps. After this is done the full width of the embankment or cutting as obtained from a few cross-sections should be cleared of all trees, scrub, jungle, roots, boulders, rubbish, etc. Then the edge of the formation should be marked by pegs at 100 ft intervals on straight and about 20 ft on curves. The pegs should then be connected by thick coir rope and a V-groove cut in the ground along the line. This cutting of the groove is called Dag-belling.

10.2 Profiles.—Profiles of the road embankment are then to be constructed making due allowance for settlement. Usually thin pieces of timber or bamboo poles are driven into the ground at the proposed ends of formation and strings are tied to the corresponding pegs at the toe of the embankment. In the case of sections in cuttings allowance should be made for accommodating ditches for drainage at the ends of the formation width. In the case of cuttings it would be easier to cut the central rectangular section first and cut the slopes later. When the road passes through wet cultivation the top of formation should be about one foot above the water level in the fields. The top formation in general should be high enough to permit easy draining of the water from the road to the side drains. Usually for village roads a height of embankment of about one foot is sufficient; where the alignment runs on a watershed practically no embankment is needed. The cost of the road work being proportional to the height of the embankment only the minimum height consistent with flood levels should be adopted.

10.3 Side slopes.—The usual side slopes in embankments are $1\frac{1}{2}$ horizontal to one vertical or 2 horizontal to one vertical depending on the nature of the soil.

Modern tendency is to give flat slopes to the sides. This practice is advantageous specially in the lower categories of roads where maintenance does not usually receive much attention. Slopes of 3 horizontal to one vertical or 4:1 involve very little earthwork if the embankment is low. These flat slopes permit of easy and safe drainage without scouring the slopes into gullies. Slopes in high embankment should be turfed or planted with quick growing creepers which take root easily and prevent erosion.

In rock cuttings, and in materials which do not disintegrate from the action of weather, steeper slopes are allowed such as $\frac{3}{4}$ to 1 or $\frac{1}{2}$ to 1.

10.4 Embankment.—When embankments are low, usually side ditches are cut about 3 to 5 ft from the foot of the bank and the earth is used to form the embankment. Although it is advisable that cuts and fills should be balanced physically, longer leads for this purpose *i.e.*, carriage of earth over long distances from a cut to a fill would not prove economical. So it would often be desirable to take earth from borrowpits on the road side land. The inner edge of these borrowpits which should be of regular shape should be as far away from the toe of the embankment as possible.

The pits should be of the same size throughout and tell-tales or witnesses should be left in the excavations. These witnesses should be narrow diagonal strips of the pit for checking measurements by paying officers. The borrowpits should always be connected together by a longitudinal straight drain so as to drain away any accumulation of water in the pits to the nearest natural water course or natural slope. Otherwise the borrowpits collect water during the rains and serve as breeding place for mosquitoes. This is an important anti-malarial operation.

When the earth from a cutting cannot be economically utilised for building an embankment the surplus is dumped on to roadside land and these are known as spoil banks.

The soil from the excavation that is used for embankment shall be free from roots, vegetable matter, etc. It is often possible to conserve separately the top soil, which contains humus and is fertile, and to spread it over the borrowpit area to form a new field at a lower level than before. The area cultivable is thus not affected. No embankment shall be made entirely of sand. When it is necessary to use sand a blanket coat of cohesive soil such as sandy loam or clay about 2 ft thick should be put on all sides of the sand hearting.

The earth when made into embankment usually sinks. So it is necessary that the earth work should be properly consolidated to avoid undue damage. This is done by depositing the earth in layers of not more than 9 in. in thickness, wetting the soil by adding water and rolling. All clods should be broken to powder as clods loosely packed in an embankment settle down later during rain and cause unequal settlement.

In the earlier days water used to be added in large quantities and then the roller drawn over the bank. But a scientific study has revealed that for any method of consolidation there is one particular water content which produces the densest possible embankment. This water content which is known as the *Optimum Moisture Content should generally be adopted when consolidation is done. A rough guide to ascertain this would be as follows.

Take a handful of the soil and try to roll it into a ball. The lowest water content at which it is possible to make a ball is roughly the optimum moisture content. When soil is wet it attains

*See pamphlet on Soils.

a certain colour and consistency. By visual examination alone it is possible to see if the water is in excess or just right.

In view of the fact that settlement takes place over long periods it is desirable to leave the embankment to exposure during one rainy season at least, before attempting metalling of surfacing.

10.5 Aligning grades, and slopes.—The levels between the sets of profiles are checked by what are called boning rods. Boning rods are wooden pieces of exactly equal length with a cross staff fixed at right angles at the top. Two of the rods are held at points of pre-determined level and the third is held at the point whose level has to be checked. The rod is lowered or raised until the top of the rod is in the same line of sight as that joining the other two. The level of the third point will then be on the same gradient line joining the first two. This process is quick and can be effectively used for levelling up earth work to fixed gradients.

10.6 Revetment.—When the embankment is high and near a stream it may be subject to attack from the stream and cause erosion. So dry stones usually one ft in thickness are packed by hand on the slopes. This is called a revetment and serves to protect the slope. Sometimes turfing is also done to protect the slope. The process consists in laying a layer of turfing sods rectangular in shape and not less than 3 inches thick planted side by side to form a continuous surface. The turfing should be done immediately before the rains so that the grass may grow nicely.

10.7 Allowance for settlement.—The settlement that can be expected depends on the nature of the soil forming the bank. Generally it may be assumed that one inch of extra height is required for every foot of the embankment. There would be more shrinkage in clayey soils than in sandy soils.

10.8 Construction on sloping ground.—When the natural ground over which the embankment is to be constructed has a side slope, say, more than one in 15 the surface is cut into a number of steps to prevent the fill earth slipping. This is called benching. (See Fig. 1-D page 9).

10.9 Retaining walls.—In hilly country, where it is difficult to allow the natural slope of the earth to retain the road way because of the large quantity of earth work involved, retaining walls are generally provided. These are constructed either with dry stone or stone in mortar and are given a batter in front and are stepped at the back. Walls upto 10 ft. depth from the road level may have a top width of one ft. 6 in. and a base width of 4 ft. with a suitable foundation going about 2 ft. into the ground.

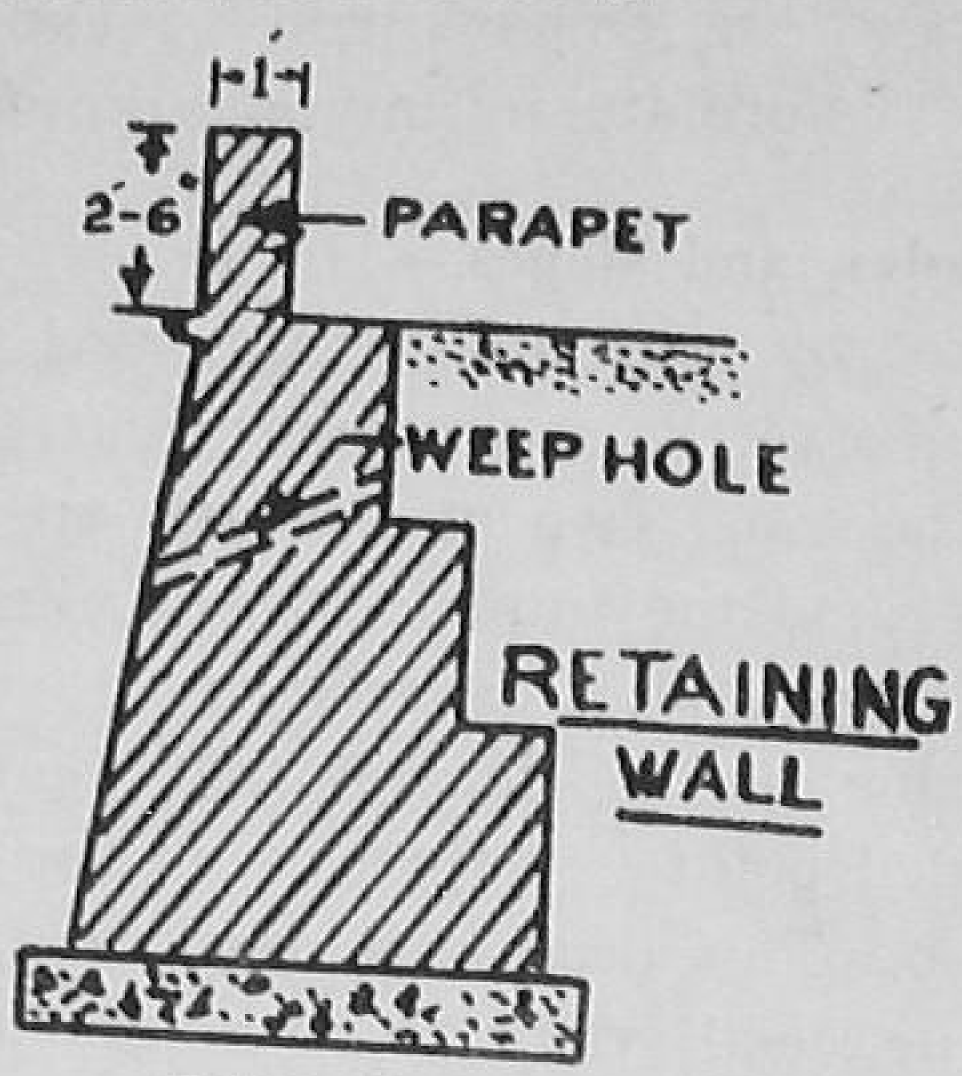


FIG. 2

There should be a parapet of at least one foot wide and 2 ft 6 in. high constructed as a guide to traffic. Care should be taken to leave weep holes in these walls as otherwise accumulated water would cause increased pressure at the back and might result in failure of the wall.

10.10 Dressing up.—All embankments when first built are uneven. After finishing of the earthwork the side slopes should be brought to proper shape by filling in depressions and removing high spots. When the embankment is to be left for the rainy season it is advantageous to give a small slope towards the centre at the top so that the rain water may soak in and hasten settlement, if any. The surface could be dressed to the required cember or slope, before the soling is laid for the foundation of the road surface.

In areas of heavy rainfall more damage is done to roads by the excessive rain than by the normal traffic. While the disposal of surface water is treated in a later chapter on drainage it should be noted here that after dressing up embankment slopes they should be protected with vegetable growth, turf or deep rooted creepers which grow in the particular type of soil of the locality. A look-around would indicate what would grow easily in the wild state without too much care and attention and such growth should be encouraged on the road bank slopes.

10.11 Rock blasting.—There may be some occasions where it would be necessary to remove rock by blasting. In such cases all precautions should be taken to inform the workmen working within a furlong when the charge is fired. Red flags should be displayed to warn any passerby. The blasting should preferably be done at fixed times every day say at 12 noon and 6 p.m. so that the people in the vicinity are aware of the timing.

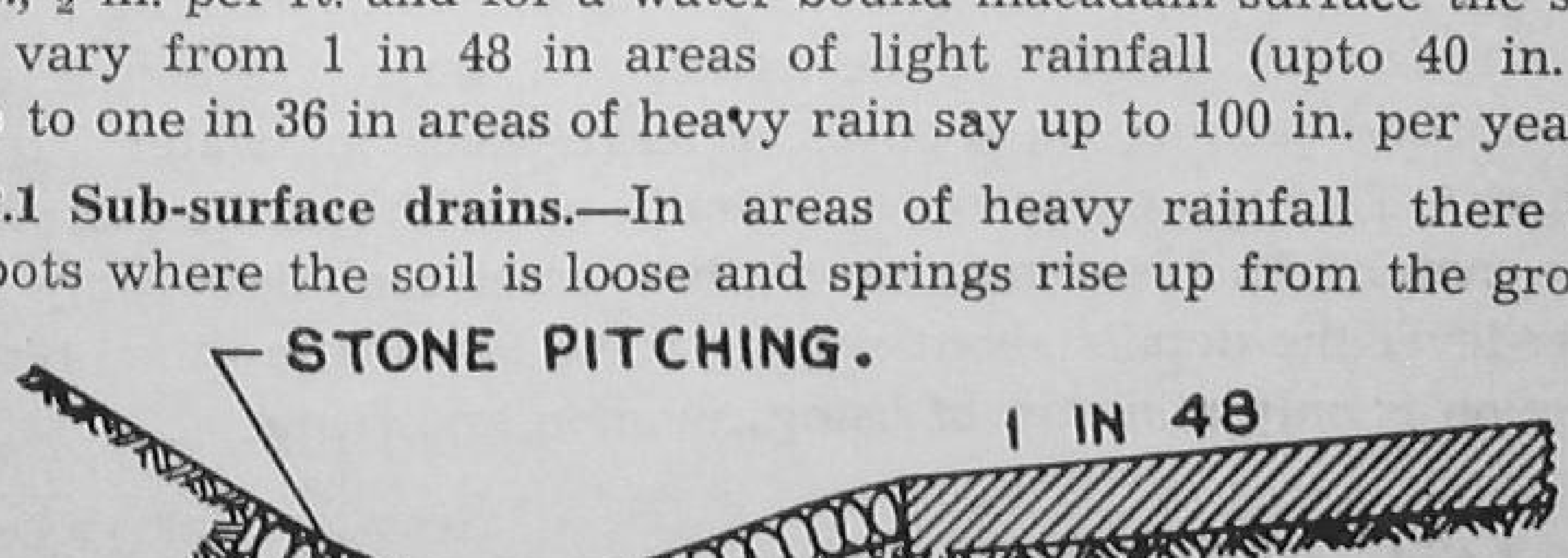
The rock that is blasted is collected and carefully stacked for measurement. In calculating quantities for payment an allowance for voids in the stacking is generally made and is 15 per cent for good packing. In some areas the rate may be for the bulked quantity as stacked. Local practice should be ascertained before payment as this is a costly item of the estimate.

11. Measurements and units of payment.—The unit for payment in earthwork is 1,000 cu. ft. and is paid for by pit measurement. When stacks are measured in exceptional cases a deduction of 12½ per cent is made for shrinkage. Clearing jungle is paid for on 100 sq. ft. It is necessary in this case to take measurements both before and after the jungle is cleared. Blasting rock is paid on 100 cu. ft. usually on stack measurement but some items by measurement of actual excavation where this is possible as in trenches.

12. Drainage.—Maintaining a village road in a serviceable condition all through the year and under all weather conditions depends largely on the efficient draining away of water from the road surface, and the embankment without allowing sufficient time for the water to soak through.

Efficient drainage of the road surface is effected by giving a camber to the road surface. If this convexity is too sharp there is a tendency for the traffic to hug the central portion and wear of road surface will be confined to a central strip, or rather to two ruts on either side of the centre. Thus in balancing between the tendency to rut formation (which depends on the hardness of the surface) and the slope required for drainage, a mean has to be struck. When the surface is not metalled the slope should be one in 24 *i.e.*, ½ in. per ft. and for a water bound macadam surface the slope may vary from 1 in 48 in areas of light rainfall (upto 40 in. per year) to one in 36 in areas of heavy rain say up to 100 in. per year.

12.1 Sub-surface drains.—In areas of heavy rainfall there may be spots where the soil is loose and springs rise up from the ground.



These springs would loosen up the embankment soil and cause a lot of trouble. In such spots sub-surface drains should be laid.

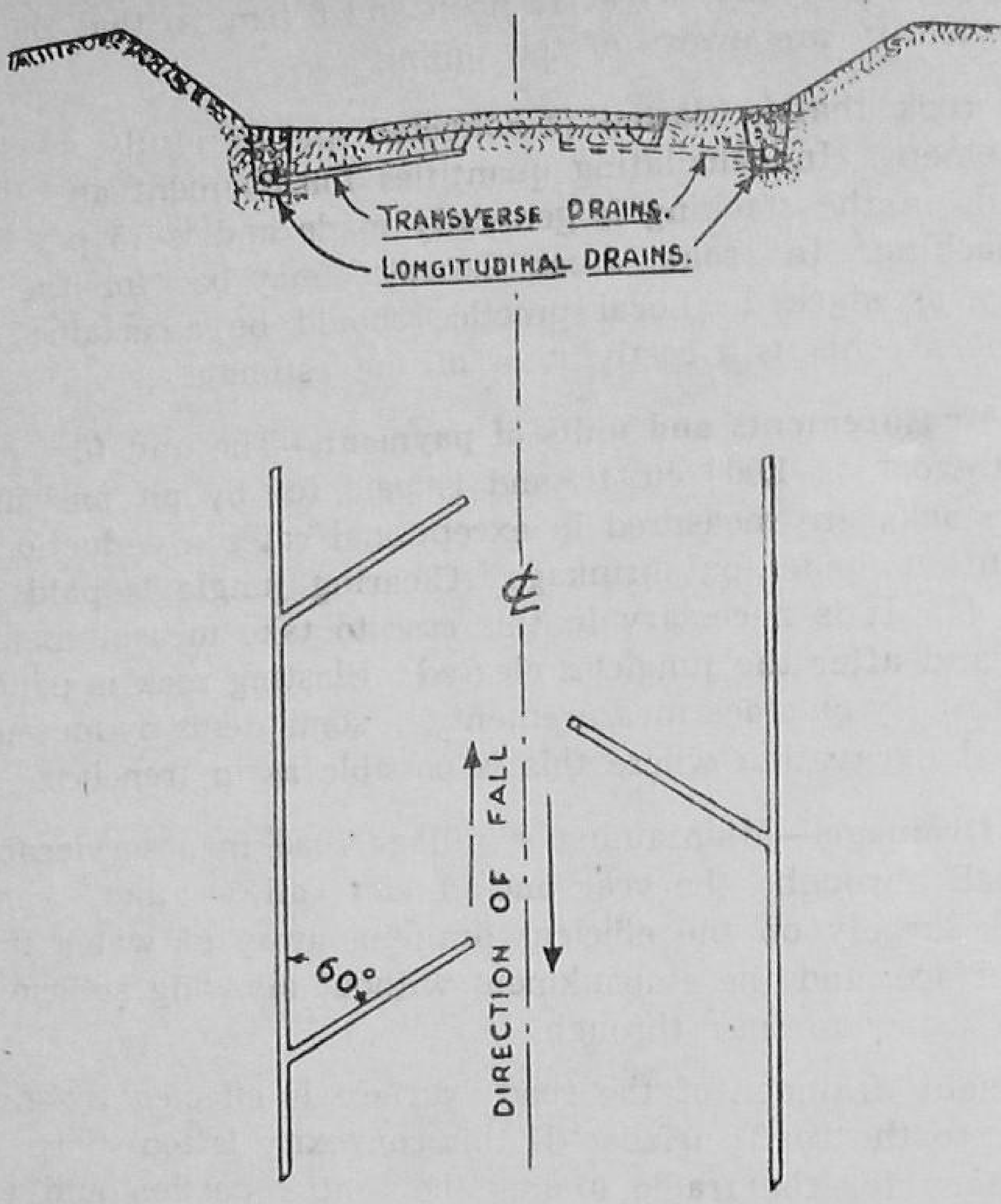


FIG. 3

The water should be led away by means of these sub-surface drains to the side drains which carry all water farther away. The easiest way of constructing these sub-surface drains is by cutting a trench about 1½ ft wide and filling the trench with large size boulders 4 in. to 6 in. size packing them so as to leave voids for water to pass through. The top cover may be built up with packing of graded stone metal. As everyone knows that water can flow only to a lower-level the details about sloping these drains in the required direction is only a matter of using common knowledge.

12.2 Side drains.—This is a very important element in road design. All the watr that falls on the road surface or seeps up through springs in the road bed, is carried away by side drains. Side drains also act as a bulwark against ingress of water from the adjoining land on to the road. It should be taken as a principle that no water should remain for any length of time with its top level within one foot of the top of the road surface. Side drains should be designed with this in view.

Generally in open countryside drains should be 1½ ft wide and about one ft deep. Clearance of these drains of accumulated silt, debris from leaves, etc. should be done at least twice in the rainy season and a careful watch is to be kept to see that the drains do not get choked up by an accidental slips of side earth.

12.3 Catch drains.—When a road runs on a sideway sloping ground there is a tendency for all water to run down from the slope to the road. The side drains are normally not designed to carry off all this water. So a second line of defence is dug higher above on the slope to catch all the water from the slope and carry it away to a natural stream. These are called catch drains. They may be of any requisite size from 3 ft wide upwards and 3 ft deep. If these are made deeper there is a tendency for the water to seep through the soil and reach the road through underground pore channels. Lining these catch channels with local materials may be needed in soils liable to erosion.

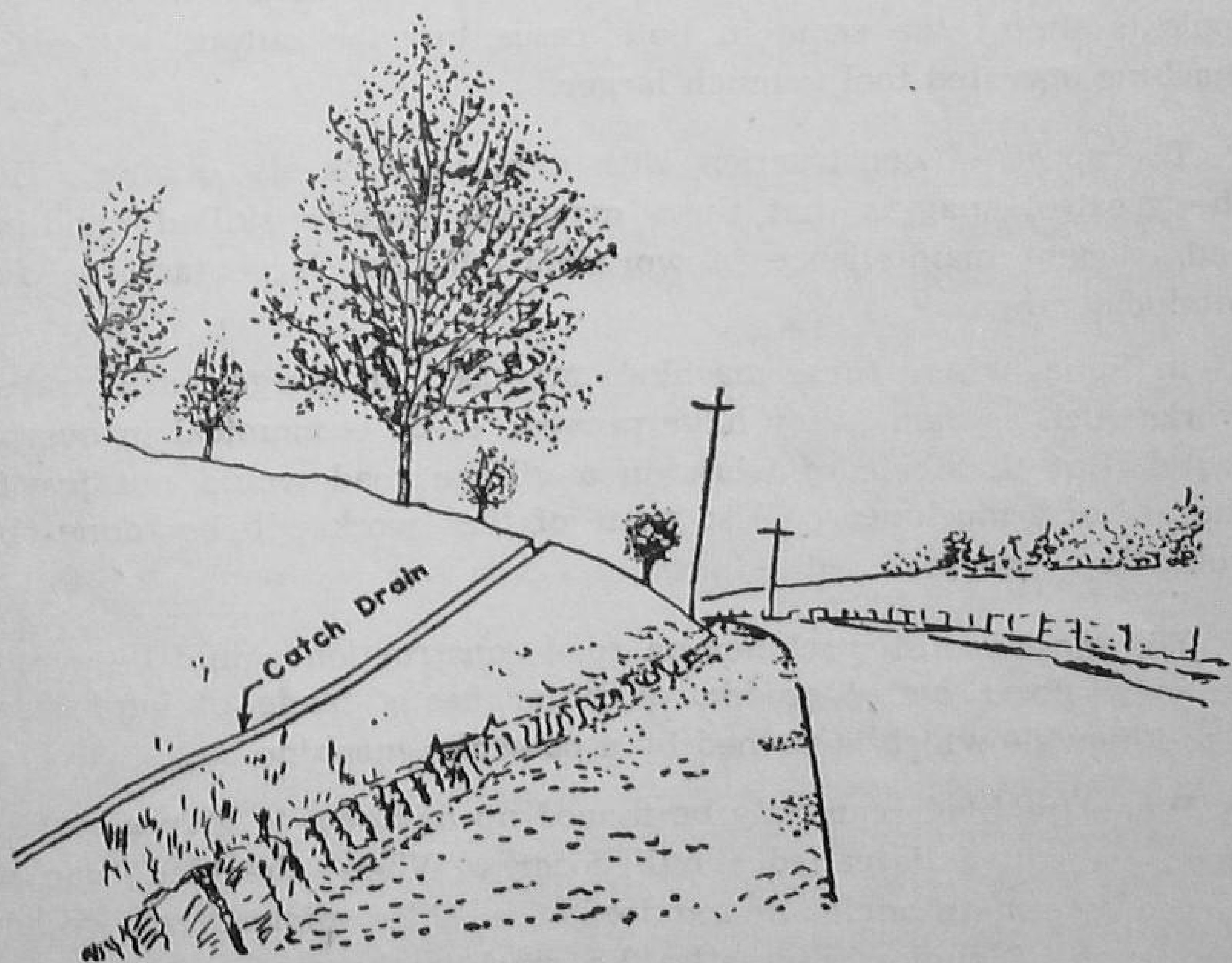


FIG. 4

12.4 Culverts.—Roads have often to cross small streams or nallahs. In some cases a crossing has to be provided for passing water from one side of the road to the other as for example, for irrigating fields. In these cases small bridge like structures are to be constructed. These structures which have a total waterway of less than 20 ft length are called culverts. Because side drains, catchwater drains and road embankments all alter the natural flow characteristics of an area, the discharge through a small stream can be altered considerably after providing these works. It is therefore advisable to determine the size of a vent for a culvert in consultation with a road engineer. There is, however, a minimum width of 3 ft for vents which is fixed so as to enable a workman to enter the vent and do the required repairs.

Having once known the size of vent cement concrete pipes, steel pipes, or plain masonry structures may be built in. The covering in the last case may be of stone slabs 6 in. thick or cement concrete slabs reinforced as advised by the local engineer.

13. Machinery in village road construction.—In the U.S.A. where manual labour is very costly they have developed machines to replace the small tools which our labourer uses. The action of the tools is almost the same in both cases, but the output with the machine operated tool is much larger.

The speed of construction with a machine is also higher. But the greatest snag is that these machines require skilled handling and efficient maintenance in workshops besides large factories for producing them.

In India, where these machines are used on large concentrated works such as dams, they have proved to be economical in overall costs. But the scale of work on a village road would not justify the use of a machine. Also part of the work will be done by voluntary labour.

The most useful machines on road construction would be a bull or angle dozer and a grader. A dozer has a blade of hard steel 6 to 9 ft wide which is pushed by a powerful machine.

When the blade can only be moved up or down to give a certain depth of cut, it is called a bull dozer. When the blade can be turned in certain angles as required it is called angle dozer. When the range of angles is greater the machine becomes a grader.

These machines act as huge mammooties or powrahs scraping up earth and pushing it along to the required place.

There is another combination of a scraper and a carrying box called a carry-all. These are used when earth has to be cut through from a distance more than a furlong.

All these machines have certain limiting conditions for their maximum efficiency and their use may not always be economical. To go into these details would require a greater knowledge of mechanical engineering than we intend to use in these notes.

14. Soil stabilisation.—In recent years the scientific study of soils has enabled the engineer to strengthen a soil in respect of its qualities which are deficient for particular purposes. This strengthening is called stabilisation. Usually stabilisation may be by

1. Mechanical stabilisation.
2. Addition of cement.
3. Addition of bitumen.

Methods 2 and 3 would be costly and are, therefore, not commonly used in India.

In places where stone for the conventional type of soling (foundation of the road) is not available and has to be transported over long distances, or where good bricks also cannot be manufactured cheaply soil stabilisation would be economical and can be used with advantage.

The mechanical process consists in mixing sand with clay available at site or clay if sand is available at site in proportions determined in the laboratory and compacting to a predetermined density. Such foundations have been found to serve very well.

Soil stabilisation to be rigidly and scientifically done requires some laboratory work. But as these aids would not be available at the Community Projects, certain rough and ready methods for determining the mixes of clay and sand would be helpful. These are as follows:

(i) The proportion of sand in a given volume of the mixed soil should be between 50 to 65 per cent of the total. To test this take a wide-mouthed bottle of uniform section (say a marmalade jar) and fill half of it with the soil mixture pressing down as far as possible. Then add copious water to fill and shake vigorously. The sand settles down at the bottom in about five minutes. It can easily be distinguished by the colour. The height of this sand layer to the original total height of soil gives the percentage of sand.

(ii) The mixing should be thorough and should be done by hand when the two soils are in the dry powdered state.

(iii) Compaction of the mix should be thorough and the weight of the compacted soil layer should be about 120 to 130 lbs per cu ft. This can be checked roughly by simultaneously compacting in a wooden box 1 ft x 1 ft x 1 ft a quantity of the same soil as used on the road and weighing it at intervals of compaction.

Degree of compaction can be judged by trying to pierce through with the sharp end of a 3 in. long S.W.G. nail. When fully consolidated the nail should support a 12 lbs load slowly placed upon it without piercing the soil in the dry state and 5 lbs when the soil is soaked for about 24 hours.

When the stabilised soil is further reinforced with the addition of brick ballast to take the abrasion of the wheels, it has been found that it can serve as a wearing course also when the traffic using the road is moderate, *i.e.,* about 50 to 75 bullock carts per day. For village roads when traffic is less and the roads are not liable to flood this method can be used. Building rubbish or the like can also be used for such purposes with great advantage. The brick ballast should be mixed in the proportion of one part ballast to 2 of soil.

15. Maintenance

15.1 Earth Roads.—For efficient service, an earth road must be maintained properly by filling in ruts, pot holes, and dressing the road to proper cambre as soon as these defects appear. This is efficiently done by a grader or a drag (See Fig. 3 on page 16). Mechanical power graders are not available in all places and require specialised maintenance. So for Indian conditions a drag is suitable.

A drag can be made by splitting a log about 8 ft long and 10 inches in diameter into two equal halves. These halves should be braced together about 3 ft apart. A chain should be fixed to one of the pieces, one end being attached to the middle of the outer end and the other being passed over the log and attached to the brace. As the drag is drawn forward the earth cut along the outer edge runs along the log towards the centre, and preserves the camber.

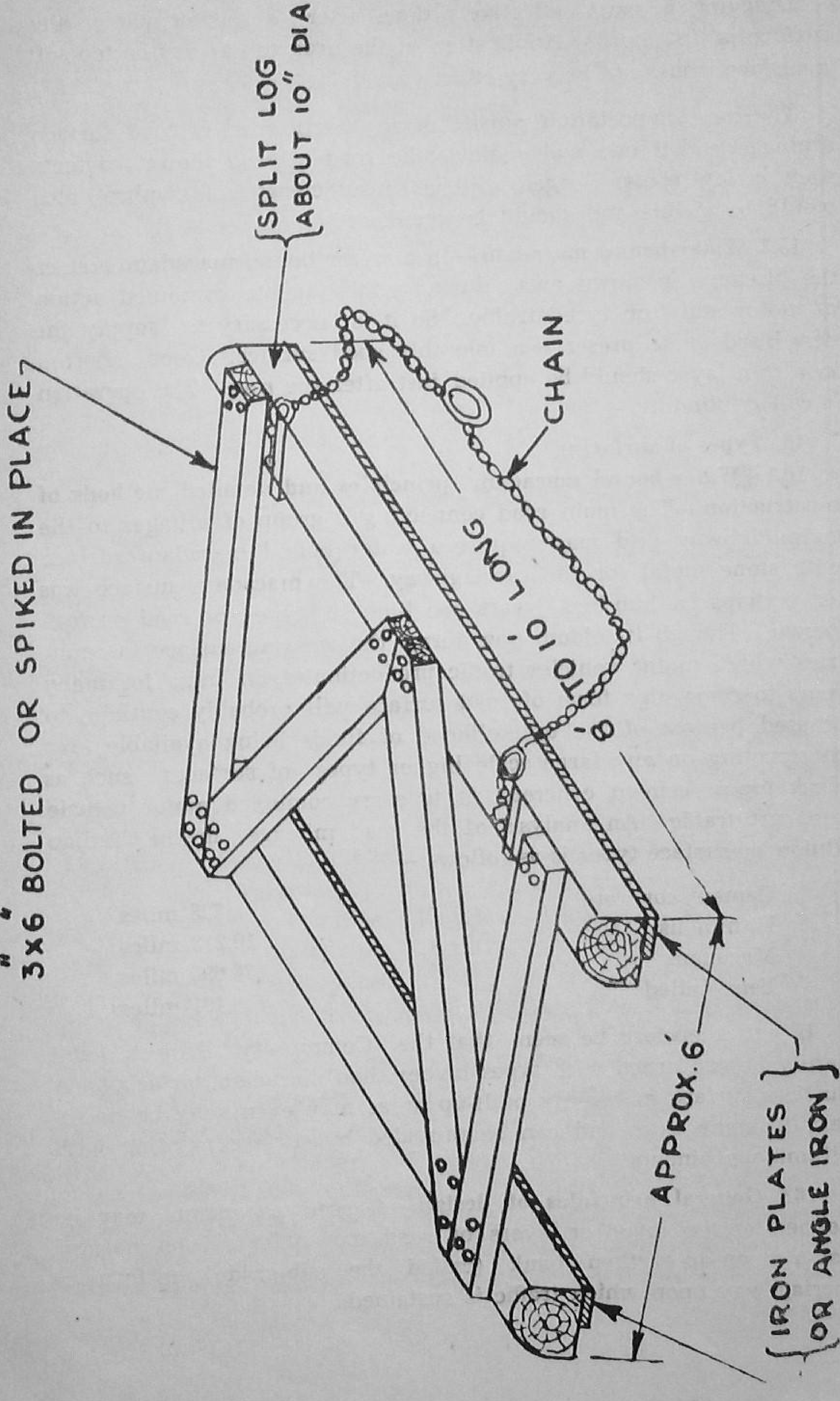

3x6" BOLTED OR SPIKED IN PLACE
SPLIT LOG ABOUT 10" DIA
CHAIN
8' TO 10' LONG
APPROX. 6'
IRON PLATES OR ANGLE IRON

Fig. 5

Dragging is most effectively done after a shower when the surface is just moist. Application of the drag to a dry or too soft a surface would not be very effective.

The most important requisite of any earth road is good surface drainage and if one walks along the road after a shower, defects such as low spots, clogged ditches, insufficiency of cambre etc., would be visible and should be rectified.

15.2 Water-bound macadam.—In a water bound macadam surface the blindage is blown away during winds due to combined action of motor and iron tyred traffic. So it is necessary to supply the new blindage to preserve a tolerably good surface. Good moorum in a thin layer should be applied just after the rain. The operation is called blinding.

16. Types of surfacing

16.1 "Water-bound macadam" principles and detailed methods of construction.—The main road connecting a group of villages to the main highway grid may require a water bound macadam surface with stone metal for the carriageway. The macadam surface was for perhaps a hundred years the highest type of road surface known. Though it seldom now forms the wearing surface in countries where motor vehicles traffic predominates, in India for many years to come, this form of road surface will probably continue to be used because of the unlikelihood of funds being available for constructing on any large scale higher types of surfaces, such as black top or cement concrete, fit to carry combined motor vehicle and cart traffic. An analysis of the road mileage in the Indian Union by surface types is as follows:—

Cement concrete	723 miles
Bitminous	10,213 miles
Macadam	78,690 miles
Unmetalled	156,401 miles

It will therefore be seen that the Community Projects will hardly be concerned with types higher than macadam surfacing. A dustless surface in heavily built-up areas may eventually be necessary in some cases and can be provided by surface painting with bituminous binders.

16.2 General principles of design.—A road pavement may be defined as the layer or layers of road materials laid on natural earth or on an earthen bank (called the sub-grade) to form a carriageway upon which traffic is sustained.

Its main functions are:

(a) to provide a smooth running surface suitable for carrying the class and intensity of traffic anticipated;

(b) to protect the underlying earth from the effects of rains; and

(c) to afford reduction in the live load pressure transmitted by the wheels of vehicles to the underlying earth or natural soil.

A pavement may be "flexible" *i.e.* following the contour of the road subgrade or may be "rigid". To explain further a sheet of rubber if placed on ground would remain in contact with the ground even when it moves down or up according as a load is placed on it or removed, whereas if a thick iron plate were so placed it would not so move but remain rigid. A bituminous pavement is flexible while a concrete surface is rigid.

A semi-flexible pavement of the water bound macadam type consists of:

(i) The wearing coat which directly receives the wheel loads and transmits them to the underlying layers. The wearing coat also imparts a smooth riding surface and serves to protect the other layers from traffic abrasion and surface moisture. It generally consists of one layer of stone metal placed over a base course.

(ii) The base course also known as soling or bottoming is laid direct on the sub-grade, or on an intermediate layer known as sub-base. This base course should transmit the wheel load stresses (See Fig. 7) on the pavement to the underlying sub-base and the sub-grade soil strata without being subjected to stresses greater than it can stand; and

(iii) The sub-grade or the foundation soil upon which the pavement rests and to which the vehicle loads are finally transmitted by the pavement. It may be soil in its natural state or filled material in an embankment improved where necessary to increase its resistance to deformation. Where the sub-grade has a low bearing capacity, it is usual to superimpose a sub-base consisting of coarse gravel or sand to strengthen the loose soil. These parts of a water bound macadam pavement are illustrated in Fig. 6.

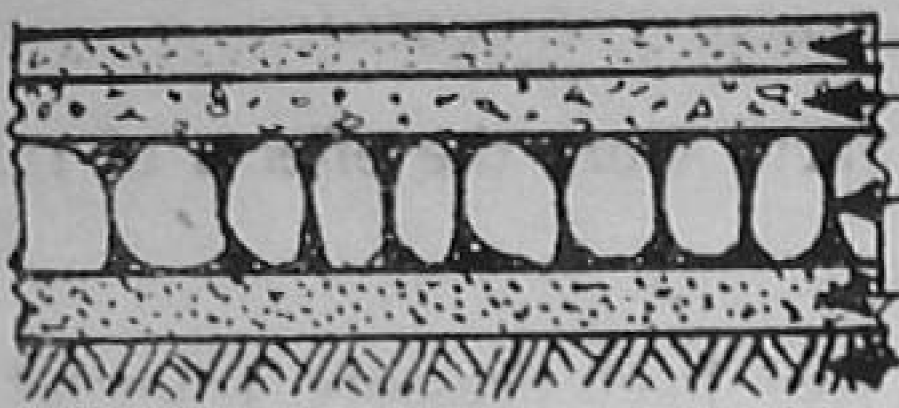


Fig. 6.

16.3 Wearing surface and base course.—The wearing surface should possess the following properties:—

(a) *Shear strength.*—It should possess sufficient shear strength to resist failure by shear under traffic.

(b) *Durability.*—It should resist abrasion under the disruptive action of the traffic (whether wheeled or tracked) and require a minimum of maintenance and repair work.

(c) *Stability.*—It should transmit loads to the base under all weather conditions without undue deformation or creeping occurring, and at the same time it should possess sufficient flexibility to adjust itself to considerable base settlement up to ½ inch without rupture.

(d) *Non-slip character.*—It should not be excessively slippery under normal conditions either to animal or wheeled traffic. The surfacing should retain its non-slip character under the action of traffic and weather; and

(e) *Economy.*—It should serve its purpose with a minimum of material and it should, as far as possible, be made from materials readily available in the vicinity of the work.

For the roads we are now concerned with, the base course may be of any one of the following:—

1. Six in. to nine in. of stone which need not be very hard. Suitable materials are kankar, sand stone, limestone, latrite, disintegrated granite, etc.
2. Nine in. of moorum which is rock disintegrated to a coarse grained pulverised structure.
3. One or two layers of bricks laid flat.

Below the base course lie the sub-base and the sub-grade proper.

16.4 Sub-base.—A sub-base is generally required where the soil has a poor supporting power when wet, such as clay or silt. The sub-base generally consists of locally available granular materials which have a higher supporting value than the compacted sub-grade on which they are placed. They may be sand, gravel, cinders, crusher-run stone, quarry waste etc. Sub-bases are generally required on fine grained soils for the following purposes in addition to the common function of increasing structural strength:—

1. to provide drainage,
2. to minimise the effect of shrinkage,
3. to minimise the effect of elastic rebound, and
4. to minimise the effect of plasticity from excess of moisture.

16.5 Sub-grade.—The sub-grade proper is the natural soil as it exists in place at the site of the work. When the natural soil is predominantly granular the pavement design may not require a sub-base layer and in some instances as for example in moorum soil or in lateritic gravel, the sub-grade may even serve directly as a bases course for the water bound macadam wearing coat. In other cases particularly on fine grained soft soils, both base and sub-base courses will be required.

A road is essentially a hard wearing surface supported from beneath and this surface, whatever its characteristics of strength and hardness, must ultimately conform largely to movements of the sub-grade or natural soil.

All types of road construction have thus to rely ultimately on the bearing power of the soil carrying the road. The wheel loads on the road surface are distributed in turn through the wearing coat, the base course or soiling, and the sub-base to the soil. The surface of the road is the only part which can be seen. Often the faults which develop in the surface are ascribed to the materials of which it is made, but in many cases the trouble is really due to the local weakness in the foundations.

The functions of the sub-grade is to support the base without excessive deformation. The properties of the sub-grade can be measured but not altered and the pavement must, therefore, be designed to suit the sub-grade.

As has been stated, the bearing capacity of the sub-grade is the main determining factor in the designing of the road structures. Different soils have a wide range of supporting power and even in the same soil this varies greatly at different times, depending on its moisture content and degree of consolidation. Road foundation soils fluctuate more in their supporting power than the deep foundation soils of buildings as the former are near the surface and are subject to the effects of rain and the changing action of rapidly fluctuating loads.

To ensure continuous adequate and uniform supporting power, sub-grade should be treated as follows:—

(a) pockets of soft soil should be removed and granular material substituted;

(b) sub-soil drainage should be provided where necessary;

(c) thorough compaction should be effected by sheeps foot or smooth-wheeled roller. Where these aids are not available hand rammers should be used. For a given set of conditions such as (1) the weight of the roller, or rammer, (2) the moisture content in the soil, and (3) a given compacting effort, there is a certain maximum density of soil that can be attained. Speaking in very general terms the maximum density would possibly be attained after 30 to 40 strokes of the rammer on a given spot and further beating has no appreciable effect. So going on beating down indefinitely is waste of effort. Scientific control and direction requires laboratory work but Project Officers may take the above as a rough guide.

A table indicating approximately the safe supporting power of sub-grades of certain Indian soils under normal conditions in their natural state is given below. Soils whose supporting power is not more than 0·5 to 0·75 tons per sq. ft. require the provision of very thick bases and sub-bases. Soils having a supporting power of less than half a ton per sq. ft should be avoided altogether if possible.

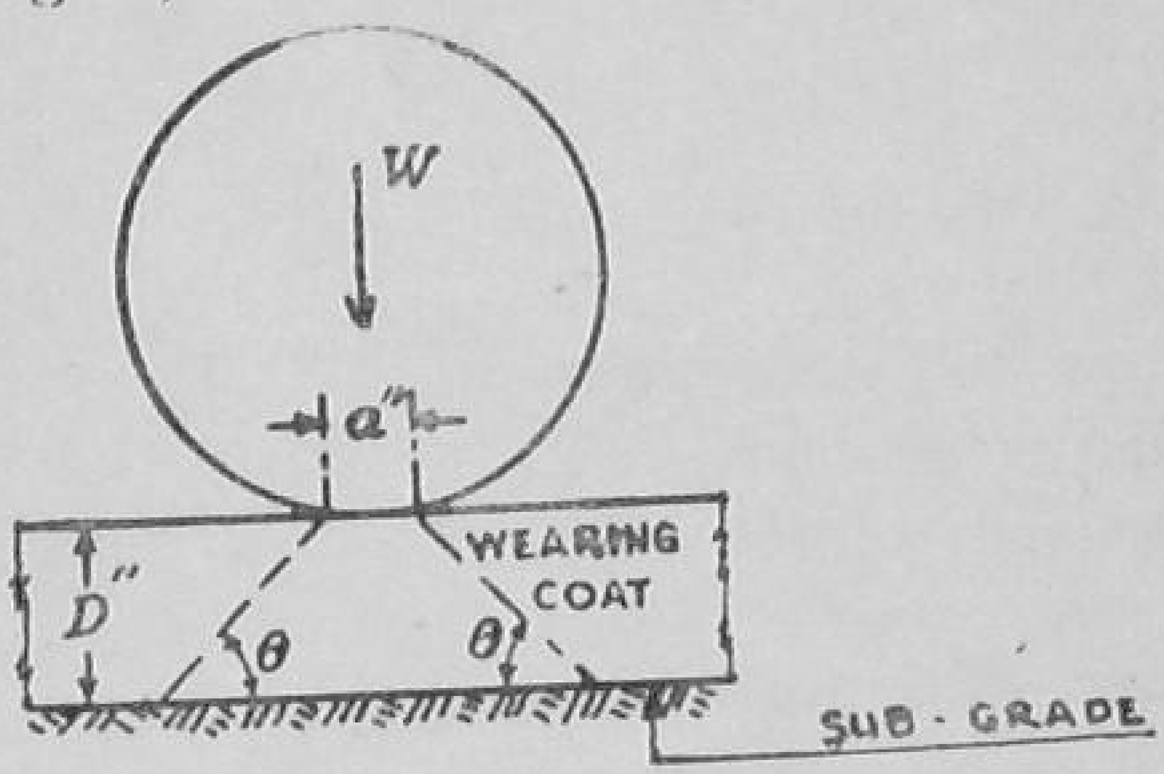
TABLE No. 1

Bearing Power of Soils

Soil	Safe load in tons pe sq. ft.
1. Soft, wet, pasty or muddy clay and marshy clay	0·25 to 0·3
2. Alluvial deposits of moderate depths in wet or damp state	0·2 to 0·3
3. Alluvial clay in wet or damp state	0·3 to 0·7
4. Black cotton soil	0·5 to 0·75
5. Alluvial earth, loams, sandy loams (clay with 40 to 70 per cent of sand) and clay loams (clay with about 30 per cent of sand)	0·75 to 1·5
6. Moist clay	1·0 to 1·8
7. Compacted clay, nearly dry	2·0 to 2·6
8. Solid clay mixed with very fine sand	4·0
9. Dry compacted clay of considerable thickness	3 to 5
10. Compact sand, unconfined	2 to 3
11. Compact sand, confined	5·25 to 7·5
12. Sandy gravel or kankar	2 to 3
13. Firm shale, protected from weather and clean gravel	6·0 to 8·0
14. Red earth	3
15. Moorum	4
16. Compact gravel	7·0 to 9·0

Variation in the moisture content in the same soil affects the bearing power. Well drained soils in embankments comparatively free from the capillary moisture have a greater supporting power than poorly drained soils.

16.6 Thickness of the pavement—Principles.—Various formulae for determining the total depth of water bound macadam pavements to take the maximum wheel loads the road is designed to carry have been evolved by different investigators. The object of these formulae is to deduce a thickness of pavement which will reduce the wheel pressures transmitted to the sub-grade or natural soil on which the road rests to well within its bearing power in all its variation of moisture content. It is assumed in nearly all these formulae that the dispersal of wheel load in well interlocked and consolidated pavements is at an angle of 45 degrees to the vertical. (See Fig. 7).



W = WHEEL LOAD.

a = AREA OF CONTACT IN INCHES

b = BREATH OF CONTACT IN INCHES. (NOT SHOWN IN THE FIGURE)

D = THICKNESS OF ROAD CRUST, INCHES

θ = ANGLE OF DISPERSION, USUALLY TAKEN AS 45 DEGREE

Fig. 7.

The area of the wheel contact is assumed by different authorities in different ways. The area depends upon the width of the tyre and its length of bearing along the surface. In the case of pneumatic tyre, this has got a definite length depending upon the type of the tyre and load, while in the case of a steel rim this length is very small. Without going into these theoretical details it is safe to go by empirical rules based on local experience in providing an adequate thickness of pavement.

16.7 Recommended thickness of pavement.—The wearing coat is usually made 4 in. to 6 in. thick (consolidated thickness) of broken stone. Where gravel or hard moorum is used in the base course and it has been designed to take the total wheel load, the wearing coat need be of only sufficient depth to limit the wheel load pressures on the moorum or gravel to two tons per sq. ft. to avoid rut formation. Where a boulder base course immediately underlies the macadam a minimum thickness of 4 inches of macadam in the wearing coat is recommended. The thickness of boulder soling should generally be 6 in. to 9 in.

The technique of water bound macadam is discussed under the following headings:

(a) Interlocking.
(b) Quality, size, shape, and grading of tones.
(c) Camber.
(d) Spreading and consolidation.
(e) Maintenance.
(f) Corrugations.

16.8 Interlocking.—The term "Macadam" designates properly a road surface in which clean broken or crushed stone is mechanically locked by rolling. The only bonding being obtained by means of stone screening worked into the voids and flushed and "set" with water.

The interlocking is obtained under rolling by the adjustment of the small stone pieces in such a relative position to each other that each stone bears on another to the maximum possible extent with the minimum voids. This adjustment is considerably retarded if any cementing material such as moorum or metal dust is thrown in before the maximum bond is secured. With good angular stones and with proper rolling a completely stable layer can be produced which should ring under an animal's hoofs when the road is dry. When once the interlocking is complete, the remaining surface voids can be filled with moorum or other suitable binder (*e.g.*, sandy clay). This material will also act as a cushion on the macadam surface.

If a binder such as stone dust or moorum is introduced before mechanical bond is effected the result is not a 'macadam crust', but a stablished or 'mud-pie' crust. In this case, each stone is separated from its neighbour by the binder and will have to act for itself though aided to some extent by the friction and cohesion of the binder. There will be no interlocking and once the binder, if it consists of prepared soil, loses its cohesive properties when the road becomes dry or when the road is very wet the surface will fail. Failure in what is thought to be water bound macadam surfaces are thus often caused by mixing binders with the broken stone at the time of laying and consolidation. Such surfaces are really not composed of water bound macadam.

The 'mud pie' or stabilised soil concrete pavement has its uses when it is properly designed so that the main function of the stones or aggregate is to improve the abrasive property of the soil by the addition of angular material. The principles underlying this type of surface are, however, entirely different from those governing water bound macadam.

When the stone is very soft, proper interlocking of the pieces of stone is obtained, the void between the bigger stones being filled by smaller stones themselves interlock, their voids in turn being filled with stone aggregate during consolidation. This indicates that a good grading in size of metal will secure better bond and give a more dense crust than if the stones were not graded. With a uniform size of metal the voids content will be from 45 to 60 per cent, irrespective of the size of the individual stone, but with proper grading this void content will be considerably reduced.

16.9 Quality of stone.—The stone should be tough, hard, possess good cementing properties and have little pore space.

The use of a small quantity of hard limestone nodules (kankar) of ½ in. to ¼ in. size laid on the surface in the final stages of consolidation, after interlocking and compaction are completed, has been found to improve the qualities of water bound macadam roads. Unravelling of stone is prevented, the number of periodical blindings usually necessary with hard types of metal is reduced and the road presents a smooth and even riding surface.

For good road stone for a macadam surface, a combination of the different characteristics of the stone should be considered. For example, vein quartz and quartzite as judged from attrition tests are fairly suitable for road making though as judged from their cementing values they are not so suitable as limestone or laterite. Roads surfaced with quartz stones even after being well rolled produce a harsh surface with loose stones lying about, while those surfaced with limestone or laterite gravel give a smooth and fairly desirable surface provided the traffic is light. The best stones for road making are the medium fine grained, compact, basic rocks with more or less equiangular textures. These include nearly all kinds of trap or basalt (with best stones), some of dolerites and the compact gneisses. Soft rocks like the limestone, shales, laterites and the weaker types of sand stones are not suitable for any but light traffic while vein quartz and quartzites are generally not very suitable. From economic considerations, however, it may often be desirable to use local stone which is less suitable for road work than better quality stone brought from a longer distance. Before deciding to use local stone in these cases, however, one should study roughly the ultimate comparative costs over a period of years of the available types, the cost of renewal, the annual maintenance charges etc.

16.10 Size of stone metal.—Experience indicates that the size of the large pieces of stone metal should be inversely proportional to the toughness of the stone. There is a limiting maximum size indicated by experience of about 2½ inches but 3 inches is permissible for the softer stone and in the case of harder stones like trap, basalt etc. the maximum size should be limited to 1½ in. gauge *i.e.*, all stones should pass through square mesh of 2 in. and retained on square mesh of 1 in.

16.11 Shape of stone metal.—Stone should be angular *i.e.*, possessing well defined edges formed at the intersections of the faces and approaching the cubical rather than the flaky or needle like shape.

16.12 Grading.—By grading is meant that the proportions of each size of stone are so arranged that there is a minimum of void in the mass of the aggregate, resulting in better interlocking and full bond. Pregrading is particularly valuable where thinner coats of metal are used. This would however add to cost of metal unless grading automatically results in the process of normal breaking by hand.

16.13 Camber.—This is the convexity given to the curved cross-section of a roadway. Camber is expressed as the slope of the chord between the crown and the edge of the roadway. In water bound macadam roads, the camber generally adopted varies from 1 in 36 to 1 in 48 depending on the intensity of rainfall experienced in the locality, the higher camber being adopted when the rainfall intensity is great. Where the wearing coat is proposed to be surfaced with a bituminous cover within six months the camber should be reduced to 1 in 60. In actual construction it will generally be sufficient if the camber is given by two straight slopes from the edges joined by a short flat in the Centre. The purpose of the camber is to keep the road surface well drained during rains.

16.14 Preparation of surface.—When a new wearing coat is laid over a base course or added over an old wearing coat, all dirt, mud, loose disintegrated stones etc. should be scraped off and removed. All deep ruts in the old wearing coat should be filled with new metal and the old surface scarified and brought to section. The base course is usually made a foot wider than the wearing coat to secure haunch support to the subsequent wearing coat. Where there is no side support to the new metalling earth shoulders six inches high and about 2 ft wide should be made along the outer edges of the metalling.

16.15 Spreading of metal.—The metal should be raked off the stacks into baskets, screened if dirty, and spread evenly over the surface to make up the full thickness required. The spreading should be done by giving a twisting motion to the baskets to avoid segregation of the stones. The newly spread stone will shrink by interlocking and compacting to an extent of 25 to 30 per cent and due allowance should be made for this reduction in designing the finished thickness of the coat. The thickness of the loose hard metalling that can be properly consolidated by an ordinary power roller is about 3 to 4 inches. Where, therefore, the finished thickness of the metalling exceeds 4 inches the metalling should be done in two stages.

After spreading to the required depth, the loose metal should be hand packed, the bigger pieces of metal being placed below and the smaller pieces in the interstices of the larger. Hand packing is important and should be done by trained coolies. The surface should then be brought to a camber somewhat more than that finally required. The camber should be checked by templates at 25 to 50 ft intervals.

16.16 Rolling.—The surface should then be rolled dry. When the metal is comparatively soft a light roller giving a pressure of 150 to 200 lbs per inch width of roller may be used. The roller should start from the outer edges, overlapping the shoulders and gradually proceed towards the centre. When the broken stone ceases to wave on one side of the road and becomes firm, the roller should be shifted to the opposite side and the operation repeated. After both edges are rolled moderately firm, the roller should be gradually moved towards the centre until the entire surface is covered. On superelevated curves rolling should commence at the lower edge and progress towards the upper edge of pavement. High spots and depressions are corrected by removing the rolled stones or by adding stones in each case the metal being repacked by hand as rolling progresses. When the road metal consists of hard and tough basalt, heavy rolling from the beginning is indicated.

After the preliminary interlocking is completed and the camber and profile checked by templates, final compaction is obtained by a heavy roller weighing not less than 300 to 350 lbs. per inch width of the roller wheel. In the case of hard tough metal like trap and basalts heavier rolling with a pressure of 500 lbs. per inch width of roller and more may be necessary. In this final rolling the roller again starts from outer edge of the road overlapping the shoulders and proceeds gradually towards the centre. (Except on superelevated curves when rolling should commence at the lower edge and progress towards the upper edge.) All the compacting so far described should be done dry rolling only *i.e.*, without spreading any binder over the surface but watering may be done to help the stones to settle down, the rolling being continued until there is no appreciable movement in the metal when walked upon or no appreciable wave in front of an advancing roller. When compaction has been satisfactorily completed a loaded bullock cart should leave no indentation when passing over the rolled work. Another test commonly applied is to place a piece of about one inch gauge metal on the surface and pass the roller over it. If the piece is driven in, the compaction is incomplete, but, if it is crushed, the metal may be considered as compacted.

16.17 Spreading of screening where necessary.—After full compaction of the metal, it is advantageous to spread thinly limestone of kankar nodules of size ½ in. to ¼ in. on the surface even if this involves carting from a distance, when the metal used is of low cementing value. From 250 to 300 cu. ft. of such screenings should be sufficient per furlong of 12 ft width.

If the screenings of lime stone or kankar are not readily available, laterite or hard moorum may be used in the same way.

16.18 Sprinkling with water and finishing with a final topping.—It is only after the spreading and rolling in of the screening has been completed that copious sprinkling of water should be made on the finished surface, and the roller again worked. A final coating or topping consisting of granular moorum or clay soil containing 75 per cent of coarse sand should then be spread evenly to a thin coat (about ¼ in. in depth), and copiously watered and the rolling continued until a paste of this material and water begins to flow ahead of the roller wheels. Watering should be done in front of the roller as it proceeds so that the 'toping' should not stick to the roller and unravel the metal. This portion should now be left to dry.

Next day the surface should be lightly rolled and covered with sand of about 1/4 inch thickness in case the blindage is such as to stick to the wheels. The surface should be kept lightly sprinkled with water for about a week when work is done in dry weather.

16.19 Opening the road to traffic.—After the consolidated surface has set, which will be in 2 to 3 days depending on weather conditions the road should be opened in sections for traffic. For a week after the traffic is let on to the road, an attempt should be made to distribute the traffic over the full width of the metalled surface by placing obstacles in any tracks that may be forming. This is especially necessary where bullock cart traffic is predominant, as the bullocks have a tendency to keep to the tracks used by a previous cart.

16.20 Forming berms.—The berms should be made up on either side with good earth, and preferably moorum if available nearby, sloped to a somewhat greater camber than that of the metalled portion and consolidated by stone rollers when feasible.

16.21 Output of work.—A power roller should be able to consolidate about a furlong length of a twelve feet wide road in a day but the progress depends on the amount of rolling required for the type of stone used, the nearness of water and other factors.

16.22 Diversion.—Before starting the spreading work arrangements should be made for diverting traffic away from the work area.

16.23 Subsequent maintenance.—(a) Periodical spreading of a thin topping of the best binder locally available, especially after very heavy rain or once or twice during dry weather, to fill surface voids will be very beneficial.

(b) The other repair work consists of repair to ruts and pot holes.

(c) Renewal coat of 2 to 3 inches is provided when the wearing coat becomes very thin *i.e.*, after 4 to 5 years depending upon traffic.

16.24 Defects—Corrugations.—A road is said to be corrugated when the surface assumes a wave-like appearance, with ridges and depressions at more or less regular intervals. Corrugations are generally noticed in roads which carry fast motor traffic of one class. Corrugation also occurs in roads in some sandy areas.

The adoption of the following precautions will lessen in most cases the formation of corrugations,

(i) making the sub-grade firm and fairly unyielding,

(ii) securing homogeneity in the top courses and a good bond between the several layer forming the road crust,

(iii) securing proper interlocking of metal by proper rolling and the correction of high and low spots,

(iv) using a roller with a pressure just sufficient for compaction without unduly crushing the metal,

(v) preventing the formation of initial waves during the early stages of consolidation by having the power-roller gearing in good condition to prevent jerky rolling and by taking long runs so as to minimise the stopping and reversing of the roller,

(vi) opening the road to traffic only after the macadam has fully set and not when it is semi-plastic.

This gives in brief the technique of water bound macadam which may be necessary on the major road connecting a group of villages to the main highway system.

17. Flexible Types of pavements

17.1 Surface dressing.—So far as the strength of the road crust for village roads is concerned the water-bound macadam type would generally be sufficient. But where a road passes right through inhabited areas it would be necessary to make the road dust proof. To attain dust proof surfaces the modern higher type surfacings using bitumen or tar or cement concrete should be used.

There are different ways of using bitumen or tar and the cheapest method is called surface dressing, single coat. A bitumen called "Mexphalte 80/100" is the one easily available and generally used in India. In tars a local product by Shalimar's called Road Tar No. 3 is generally used. At present there may be some difficulty in obtaining this product because of the demand being greater than production. The following notes will apply mostly to the use of bitumen.

17.2 Construction.—It is essential to examine the water bound macadam carefully before deciding to surface dress it with bitumen.

The best results will be obtained with a good water bound macadam surface and it is well worth making every effort to obtain the best quality material for the construction of the macadam surface.

17.3 Preparation of the road surface.—The water bound macadam road shall be rendered free from all ruts, potholes or other defects and shall have a camber of 1 in 48 to 1 in 60.

The surface shall be swept clean and free from dust, dirt and deleterious matter, by hand brushing with wire brushes, brass brooms and finally by dusting with gunny bags.

17.4 Collection of stone chips.—Stone chips shall be collected from clean, hard, tough, durable material of uniform quality, free from soft or disintegrated stone or other objectionable matter and shall contain no appreciable amount of dust. Granite stone and quartzite, trap etc. are among the most suitable varieties of stone. The chippings shall be of ½ in. size.

17.5 Application of bitumen.—The bitumen shall be heated in special boilers or drums to a temperature of not less than 350°F. and not more than 375°F. applied to the road surface at about 350°F. It is only when the bitumen is heated to this temperature that the requisite thinness is attained and its properties to adhere to stone brought out.

The bitumen shall be applied to the surface by means of a pressure sprayer at a rate of 40 lbs per 100 sq. ft. To find out at first what this thickness means an area of 100 sq. ft. is marked out and 40 lbs of the heated bitumen is carefully spread over it with a bucket having small holes pierced in its bottom. The thickness is judged from the colour attained by the surface. Experience has to be gained to judge this rate of spread.

The sprayer used for applying the bitumen shall be operated in such a way as will ensure an even and uniform distribution of the bitumen on the road surface. Spraying shall be carried out along lines parallel to the road.

17.6 Spreading of chippings.—Immediately after the application of bitumen, the stone chippings collected should be uniformly and evenly spread at the rate of 5 cu. ft. per 100 sq. ft. over the whole surface which has been spread. It should be noted that this quantity of stone is just sufficient to give a surface layer one stone thick. Precautions shall be taken that the spreading is uniform and that there is no accumulation of chips anywhere. Hand brooming or dragging with rakes or rough brooms may even up irregularities.

17.7 Rolling.—Immediately after the light hand brooming the whole area should be rolled with a power roller weighing 8 to 10 tons and the rolling shall be continued till the chips are thoroughly embedded in the bitumen. The road may be opened to traffic soon after the final rolling.

17.8 Use of road tar.—This same procedure shall apply when tar is used except that some more quantities of tar and stone chips are used. The tar should be spread at the rate of 55 lbs per 100 sq. ft. and chips used at 6 cu. ft. per 100 sq. ft. If the surface is rough some one or two cu. ft. of sand should be spread on top before rolling. The top should never be heated to a temperature more than 220°F.

18. Hill Roads.—The problems one faces in the construction and maintenance of hill roads require some special mention. Briefly they are as follows:

(i) keeping the gradients to the minimum possible,

(ii) limiting the quantity of earthwork required to firm the road,

(iii) preventing rain water from washing away the road surface (see Fig. 8),

(iv) preventing land slides on to the road from upper slopes,

(v) preventing road slips on the down slope side,

(vi) preventing accidents of vehicles running over the side and toppling into the khud.

(vii) giving sufficient view ahead round bends of curves.

All these precautions add to the cost of a hill road, and the weightage to be given to the consideration of each of the problems depends upon local physical condition of soil and climate. However, it would probably help if certain general remedies are discussed.

(i) *Keeping the gradients to the minimum possible*: The main aim should be not to waste effort by giving prominence to local hills and valleys. To explain further one must avoid going up and down a number of times to reach a town or village some distance away. By knowing the total fall or rise between two villages, or other similar obligatory points which should necessarily be touched, the line should be so marked that there is a continuous rise or fall between the two obligatory points. No attempt should be made to rise to the top of an intermediary hill unless the ridge line of that hill range lies right across the straightline joining the obligatories. In this way it is possible to keep the gradients to the minimum.

Following this method might mean making the length of the road too big. So one must have an idea what the theoretical minimum length should be and how far any alternative routes deviate from this length. Suppose the two obligatory points have a difference in level of 1500 ft. With a ruling gradient of 1 in 20 the ideal theoretical line would be 1,500x20 or 30,000 ft. long. So any line which is not far greater than this length should be acceptable. Consider at least two alternative routes and compare them.

(ii) *Limiting the quantity of earthwork required to from the road*: The ideal condition for such economy would obviously be where one could cut all the earth from a ridge and dump all of it to fill a nearby valley. There is however one snag in this. It is much more costly to carry earth say a 100 yards to fill a valley than to cut it from a distance of 20 yds and fill the valley. Thus it would not be economical to carry the earth along the road but it can easily be carried across the road. So what one should do where the hill side along which the road line is taken does not slope more than 30° across, is to cut into the hill for 2/3rd of the width of road required and use that earth to form the rest or 1/3rd on the valley side. Any excess earth on the valley side would allow for some of the earth to be washed away or slip down till it settled down finally.

Where the soil is soft and the hill slope more than 30°, this system may not work. Then one would be tempted to obtain all the road width by cutting into the hill side. This would be unobjectionable were it not for one snag. All hill slopes are cut by a number of water courses from gulleys to wide valleys. So if one were to hug the hill side to obtain the road by mere cutting into it the road would run in and out of these valleys to form a very tortuous road, enough to make one sick, as many often become on some sections of the Kalka-Simla road.

The remedy then would be "to jump" across some of the smaller gulleys or valleys by constructing retaining walls to hold up the filled earth and constructing culverts which would safely carry away the water without dragging the earth away with it.

The problem of balancing this cut and fill is a tricky one, and its importance is all the greater because an initial hill road is rarely abandoned, and all development goes on along the original alignment. No one would dream of suggesting the abandonment of the Kalka-Simla road and building a new one suited to modern traffic. All one does is to straighten a bit here and cut a nose there, possibilities of such future improvements should be kept in mind.

(iii) *Preventing rain water washing away the road*: Normally drainage is an important item to be designed for during original construction and looked into during maintenance of a road. There is probably no other single factor causing the rapid destruction of a road than bad drainage. These statements gain added emphasis where hill roads are concerned. The steps always taken are for the purpose of—

(a) keeping water away from the road,

(b) leading the rain water falling on the road surface away and

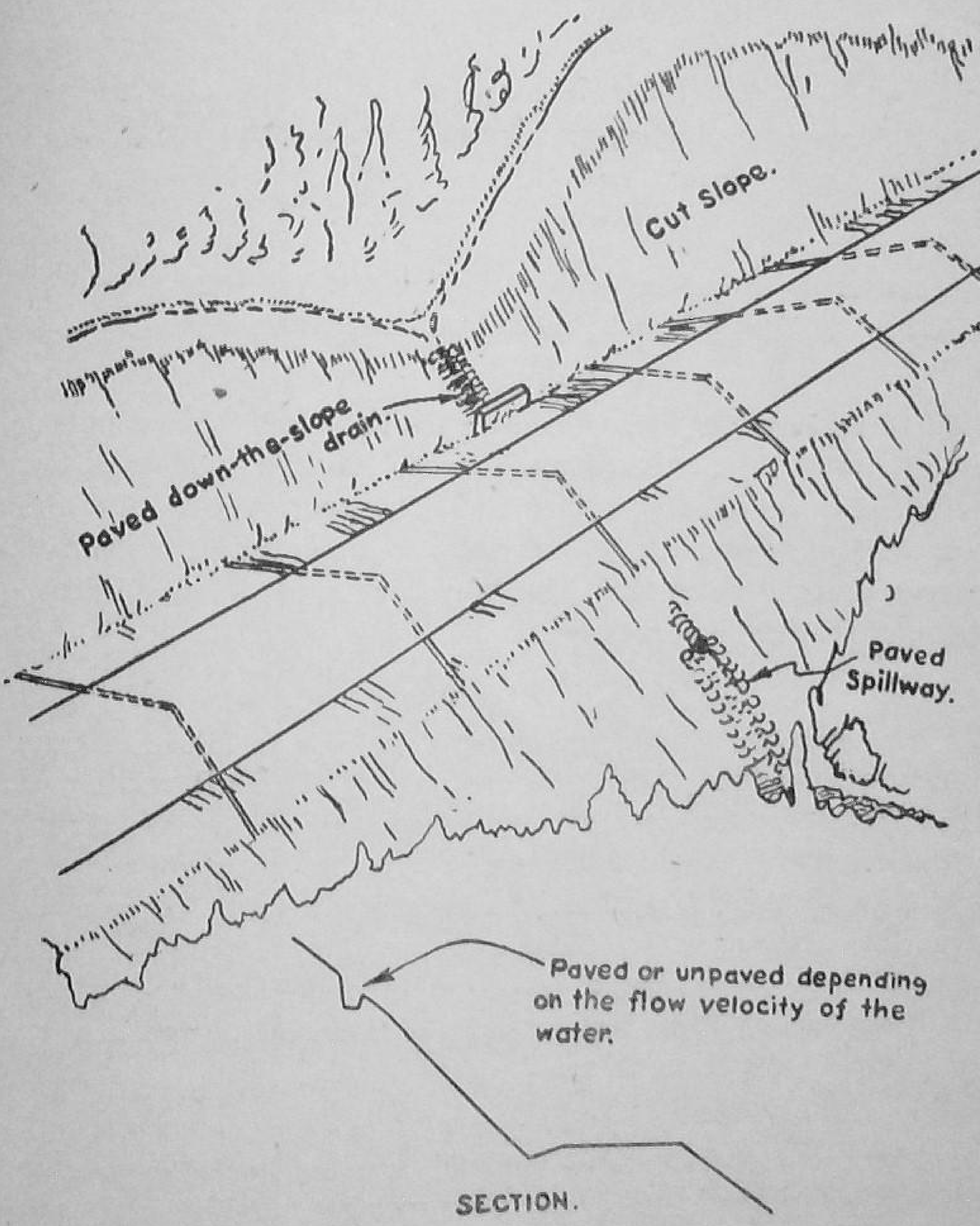
(c) preventing water from running down the slopes along the carriageway or berms.

(a) Water comes flowing on to the road from the upper slopes. To prevent this an intercepting drain is cut parallel to the road on the upper slope. This is called a catch water drain, or simply a catch drain (see Fig. 8). It should be large enough to intercept all the water from the upper side, naturally its size depends on the length of the slope and the distance the water has to be carried till it is discharged across the road and down the valley through a culvert. A 3 ft width and 3 ft depth is generally considered the minimum. The excavated earth is dumped on the lower lip of the trench to form a bund for safety against overflow.

(b) The water that falls on the road surface flows into the side drains. These side drains have generally to be paved with rough stone to prevent scour from the rapidly flowing water.

On hill roads the surface is given a cross slope descending towards the hill side so that all water falling on the road flows towards the side drain cut along the toe of the hill side. It is discharged across the road through culverts. It is not advisable to have less than one such culvert per furlong. Often natural gullies fix the sites of these culverts. In other cases catch pits may be required on the hill side, so that debris etc. may not block the entry to the culvert. Velocities of flow are apt to be high and precautions have to be taken to prevent scours undermining the foundations of the structure.

(c) Bullock carts and other vehicles cut grooves in the metalled roadway or in the soft earthen berms. During rains these grooves in the berms become nice channels for the water to take the steepest slope and the berms easily become eroded and scoured. Thus a road can soon be destroyed. The remedy is to build up bunds, made of gravel and grass sods, at 45° to 60° to the axis of the road and running from the edge of the metalled carriageway to the side drain or where no metalling has been done right from the road centre line to the side drain. Road gangs have to constantly watch and repair these bunds as vehicles cut them down again. (See Fig. 8).



DIVERSION DITCH FOR EROSION CONTROL.

FIG. 8

(iv) *Preventing land slides on to the road from upper slopes*: These land slides mainly depend on the nature of the soil. Where there is a comparatively thin layer of soil on hard rock below the rain water percolates through the upper soil layer in a vertical direction but when it reaches the rock it cannot percolate through but flow along the boundary layer between the rock and the soil. This causes a weakening of the grip of the soil on the rock and causes it to slide down.

In other cases the weakness may lie in the soil itself. When saturated it may become a semi-liquid mass which would slowly move down on the road.

In other cases again the presence of layers of shale and clay would lubricate the soil mass when wet and cause a slide.

In all these cases the best remedy is to draw off the water by a system of drains filled with gravel, coarse sand, shingle etc. and keep the soil mass as dry as possible. The construction of breast walls in masonry can also be resorted to in extreme conditions because they are very costly. The growth of trees, plants, bamboo clumps, etc. should be encouraged.

(v) *Preventing road slips on down slope side*: This is a rarer phenomenon than land slides. Where part of the road width is in fill a line of separation may develop where the fill begins. Cracks may develop which would allow water to seep through and thus cause a slide of the fill portion. Such cracks have to be carefully watched for. This is a maintenance operation. During construction the filled up earth should be properly bonded into the original surface by clearing away vegetation and exposing the natural soil before dumping earth on to it.

(vi) *Preventing accidents of vehicles running over the side and toppling into the khud*: This is easily done by building substantial parapet walls along the edge of the road. All the stones from the spoils of the cutting can be used for this work which may be of kutcha masonry. It would however be advisable to fill up all voids with mud mortar so that reptiles do not infest these parapet walls against which travellers often take rest.

(vii) *Giving sufficient view ahead round bends on curves:* In plains this is clearly a matter of geometric design. On hill roads there is not much scope for adjustments. What could possibly be done is to cut some hedges, protruding branches of trees etc. or in some cases benching on the hill side would give a better view of the road round a bend. It is for this reason too that hill roads are not designed for high speeds.

NOTE ON DESIGN OF VILLAGE ROADS

19. Concluding remarks.—Facility of communication is an essential need for all development projects. For Community Projects, where the work is to be carried out in thousands of villages scattered all over the country, the means of communication in almost all cases, will consist of kutcha village tracks. It will be necessary to improve these tracks as far as possible so that the villages remain accessible throughout the year.

If unlimited funds were available the work of providing all-weather roads would be easy. But the cost of providing pucca roads even with the minimum standard viz., water bound macadam (or moorum) surface after raising suitably the formation of the existing kutcha tracks, would be enormous and would exceed the amount that is intended to be spent on all the works envisaged in the Community Projects. In these circumstances, it is necessary to confine the immediate work to the barest essentials and to plan it in such a matter that future improvements can be given effect to as and when more funds become available.

Principles.—The following principles should be kept in view:

(a) Undertake the least amount of work that would make the track negotiable for most parts of the year.

(b) Reserve sufficient width of land for the road in accordance with its final future character.

(c) Improve the geometrics of the alignment at the very beginning. This will generally consist of straightening tortuous routes and easing the curves and gradients.

(d) Select the most suitable site for drainage crossings.

(e) Prevent ribbon development along the roads.

First Priority to Culverts.—The most pressing work in a village road is the drainage crossings. If the crossings are provided, the village will, except in areas where the soil is heavy clay, become accessible throughout the year apart from short periods of very heavy rain. An attempt should, therefore, be made to construct all culverts, causeways and bridges that may be necessary. These works can be done by the local labour without the use of any new materials. The villagers will be in a position to contribute easily towards the building up of these works and should be persuaded to do so. The Engineering Subordinate employed in the Community Project should direct the villagers in their work and should take technical instructions, where necessary from the State Engineering Department.

A set of general specifications has been given in Appendix I to suit most conditions. It is based on the general practice followed in the overall development of roads in India. The system envisaged in the Community Project Scheme should, therefore, follow the same pattern.

Since the road surface will remain kutcha, the quality of soil will play a very important role in these works. Moorum, Kankar, Kalar and gravelly soils are naturally strong to withstand the normal traffic for village roads. But if the soil consists mainly of sand, silt, or clay, it will not be fit to carry traffic in some periods of the year. Sand, when dry, and silt or clay, when wet, become too soft for traffic.

Such soil will need stabilisation by the admixture of suitable percentage of (1) clay with sand and (2) sand with clay and silt. The percentage to be used has to be worked out by simple experiments which should be entrusted to the State Engineering Department. The use of building rubbish or ballast will also help in stabilisation in certain cases. The extent of moisture present in the soil, while compacting it, plays a very vital role in the ultimate strength attained by the soil. The figure of 'optimum moisture content' (which is a percentage of moisture in the soil that gives the best result) has also to be fixed by simple experiments which can be easily done by the State Engineering Departments.

If the earthwork on the roads is carried out with soil compacted at optimum moisture content and adequately stabilised, where necessary, the road surface would be found to last better, but the surface will still need constant maintenance. In most cases, it would be possible to judge the suitability of soil by visual inspection. As a rough index for optimum moisture a lump of soil with the requisite moisture when shaped by hand into a ball retains its shape without crumbling and will not at the same time leave any free moisture on the palm.

The compaction of the soil can be done by power or hand rollers if available, otherwise by hand rammers.

In the rural-cum-urban units there will be some pucca roads which will no doubt be constructed on the lines of the usual specifications adopted for such roads in the area. Such constructions are quite common and so do not need any special mention.

Maintenance.—A kutcha village road will require more frequent attention to maintenance than a pucca road. But the work involved generally will be dressing the surface so as to remove the ruts. This work can be easily done by manual labour or by the help of a locally made wooden drag (diamond type) pulled by one or two bullocks. A mechanical power grader can be very useful, if available.

Encroachments.—The minimum widths for road land, building lines and control lines are given in the specifications at Appendix I. It is necessary to control development on strips of lands on either side of the road land so as to prevent ribbon development. These strips of land are fixed by the 'building lines' and 'control lines'. The building construction is not controlled beyond the control lines. In between the control lines and building lines, buildings are allowed keeping in view that they do not interfere with traffic. No buildings are allowed between the road land and the building lines. The land can, however, be used for agricultural purposes.

Miscellaneous.—The village roads are generally tortuous as they follow the boundaries of the fields. Such an alignment is very objectionable from the roads viewpoint. A modern road is generally straight for long distances. The straight portions are joined by easy curves to permit ample sight distance. The gradients are also not allowed to be steep. The road system should, not only cope with the requirements at the earlier stages which will generally be limited in the beginning, but should have potential possibilities of being developed as traffic increases in intensity and volume without the necessity of abandoning the earlier established traffic channel. The alignment of road, therefore, must be so selected as to remain useful when the road is fully developed in future. The existing alignment of the village roads will need suitable modification which should not be difficult with the co-operation of the villagers.

The site of drainage crossings which will generally have a permanent or semi-permanent structure should be such that they can serve the ultimate need for the improved road. A wrong site may not only be inconvenient to traffic, but may cost considerably more in construction of drainage works and its protections. It is suggested that all drainage crossings should be provided after consulting the State Engineering Department.

Typical estimates for roads to suit both the village and rural-cum-urban units have been prepared and will be found at Appendices II and III. As per project estimates, on a very rough average, the village unit will need two miles of kutcha road and one culvert. Assuming rates of Rs 4,700 per mile, and Rs 2,000 each respectively (as worked out in the typical estimates), the total cost of one village until will be Rs 9,400+Rs 2,000=Rs 11,400. Taking one-third as the amount chargeable to the project, it will amount to Rs 3,800.

For the rural-cum-urban unit at the scaled provision of road milage, the cost will be:

	Rs
5 miles of kutcha roads at Rs 6,350 per mile	31,750
3 miles of medium traffic roads at Rs 18,800 per mile	56,400
2 miles of heavy traffic roads at Rs 34,000 per mile	68,000
TOTAL	1,56,150

Cost of culverts has not been included in the above figures.

NOTE.—The estimates given above are to be taken as suggestive only. In actual practice they may have to be modified to suit local conditions.

APPENDIX I

SPECIFICATIONS

	Village Units	Rural-cum-Urban Units	
(i) Classification—			
(a) Kutcha Road	Village Road	Other District Road	
(b) Pucca Road	Do.	..	
(c) Medium Traffic Road	..	Other District Road	
(d) Heavy Traffic Road	..	Major District Road	
		Other Road	*Major Road*
(ii) Land width—			
(a) Normal	50 ft	50 ft	80 ft
Range	40-60 ft (40 ft dry areas 60 ft wet areas)	40-80 ft	80-100 ft
(b) Buildings lines	80 ft	100 ft	160 ft
(c) Control lines	100 ft	120 ft	300 ft
(iii) Speed suitability in M. P. H.—			
(a) Plains	20	30	40
(b) Hilly regions	15	20	25
(iv) Radii for curves—			
(a) Plains : Ruling minimum	300 ft	500 ft	800 ft
Absolute "	150 ft	300 ft	500 ft
(b) Hills : Minimum	45 ft	60 ft	60 ft
(v) Section—			
(a) Formation width—			
In plains	16 ft	24 ft	24 ft
In hilly areas	14 ft	22 ft	22 ft
(b) Height :			
In dry areas	1 ft	1 ft	
In wet areas	2 ft	2 ft	
(c) Side slopes	2:1	2:1	
(vi) Surfacing—			
(a) Kutcha roads	Stabilised earth where necessary	Stabilised earth where necessary	
(b) Medium traffic	Moorum or gravel		
(c) Heavy traffic	Waterbound macadam		

APPENDIX II

Typical Estimate for Roads in village unit

	Rs
(i) Road :	
1. Earthwork (average height 1·5 ft for dry and wet areas) @ Rs 25 per 1,000 cu. ft.	
$5280 \times 19 \times 1.5 \times \frac{25}{1000}$	3,762
2. Stabilisation : Assuming one third length requiring to be stabilised in 4 inch thickness with 30 per cent admixture, soil brought from a load of two miles (in full 16 ft width)	
Transport charges @ Rs 50 per 1000 cu. ft.	
$\frac{1}{3} \times 5280 \times 16 \times \frac{4 \times 30 \times 50}{12 \times 100 \times 1000}$	141
Consolidation and Watering @ Rs 6 per 100 cu. ft.	
$\frac{1}{3} \times 5280 \times \frac{16 \times 4 \times 6}{12 \quad 100}$	563
	704
say	700
	4,462
Add 5 per cent contingencies . . .	223
Say Rs 4,700 per mile	4,685
(ii) Culvert:	
Cost of 5 ft span (average culvert @ Rs 400 per r. ft.) . . .	2,000

APPENDIX III

Typical Estimate for Roads in Rural-Cum-Urban Unit.

(With an average height of embankment as $1\frac{1}{2}$ ft and width as 26 ft)

(*i*) *Kutcha Road*—

1. Earthwork in Embankment @ Rs. 25 per 1,000 cu. ft.	Rs
$5280 \times 1.5 \times \frac{25}{1000} \times 26$ . . . . =	5,346
2. Stabilisation as per village unit	700
	6,046
Add 5 per cent contingencies . . .	302
	6,348
	Say Rs 6,350 per mile.

(*ii*) *Medium Traffic Road*—

	Amount Rs
(13 ft width with 6 in. gravel, kankar or moorum) topping at Rs 30 per 100 cu. ft.—	
$5280 \times 13 \times \frac{6}{12} \times \frac{30}{100}$	= 10,300
Rolling say	= 1,000
Raising berms and other misc. items	= 500
	11,800
Add 5 per cent contingencies	590
	12,390
Add cost of earthwork and stabilisation as per (i) above . .	6,3 50
	18,740
say Rs	18,800 per mile

(*iii*) *Heavy traffic road*—

$4\frac{1}{2}$ in. metalling over 6 in. soling

Metal $5280 \times 12 \times \frac{4.5}{12} \times \frac{40}{100}$	= 9,504
Moorum $5280 \times 12 \times \frac{1.25}{12} \times \frac{30}{100}$	= 1,980
Rolling $5280 \times 12 \times \frac{4.5}{12} \times \frac{10}{100}$	= 2,376
TOTAL . .	13,860 per mile
Say Rs	14,000
Berm filling	
$2 \times 5280 \times 5\frac{1}{2} \times \frac{6}{12} \times \frac{40}{1000} = 1,161$ Say	1,200
TOTAL . .	15,200
Add cost of earthwork and stabilisation as per (i) above	6,350
Add cost of soling as per (ii) above	12,390
TOTAL . .	33,740

Say Rs 34,000 per mile.

NOTE.—The estimates given in this chapter are suggestive only. In actual practice they may have to be modified depending on local conditions.

GIPD—13CPA—L—30-10-54 -3,000

SHEET 4 OF 10 SHEETS
LEVELS WITH REFERENCE TO BENCH MARK AT 'A' + 136.06.
MATCHING MARK
N
S
CURVE NO 7.
BRIDGE 1 MILE 3-2200 FT. 6 SPANS OF 30' EACH. CATCHMENT AREA 150 SQ. MILES.
TO L.M.
DRAIN NO. 19 MILE 3-2800 FT. R.C. SLAB CULVERT 6 R.FT. WATERWAY. SILL R.L. 130.2. CATCHMENT AREA 1/2 SQ. MILE.
TELEPHONE LINE TO P.Q.
CULTIVATED LAND DRY
VILLAGE
EXISTING ROAD
WELL
TEMPLE
'A' BENCH MARK
CULTIVATED LAND
LEVELS WITH REFERENCE TO BENCH MARK AT 'A' + 135.06.
CURVE NO. 9.
PALMYRA TREES
RAILWAY LEVEL CROSSING.
CURVE NO. 8.
MOORAM QUARRY
GRAVE YARD
POND
BURIAL GROUND
DRAIN NO. 18 MILE 3-1200 FT. HUME PIPE DRAIN 2' DIA. SILL R.L. 131.2. CATCHMENT AREA 9 ACRES.
FROM X-Y
PLAN
FROM A.B.
CULTIVATED LAND DRY
CURVE NO. | DEVIATION ANGLE | RADIUS FT. | TRANSITION CURVE LENGTH | TOTAL LENGTH OF CURVE
7
8
9
CROSS ROAD FROM A.B. TO P.Q.
GRADIENT
NATURE OF SOIL
1 IN 300
LEVEL
1 IN 500
1 IN 100
1 IN 401
1 IN 125
1 IN 160
V. CURVE
ALLUVIAL
SANDY
MOORUM
DATUM 90.0
DEPTH OF CUTTING
HEIGHT OF BANK
FORMATION LEVELS
GROUND OR ROAD SURFACE LEVELS
DISTANCES IN FEET
MILES
LONGITUDINAL SECTION
SURVEYED BY:-
ESTIMATED BY:-
CHECKED BY :-
SURVEY FIELD BOOK NO.
PAGES ... TO ...
LEVEL FIELD BOOK NO.
ROAD PROJECT NO.
PROVINCE ... DISTRICT
NAME OF ROAD
CLASSIFICATIONS ... N.H, P.H, ETC.
SECTION
LENGTH - MILES ... FROM MILE ... TO MILE
MILE
NO. OF DRAWINGS
REVISIONS
X-Y ROAD
(IMPROVEMENTS)
PLAN
AND
LONGITUDINAL SECTION
SCALES
SIZE BEFORE REDUCTION 13 BY 8 IN