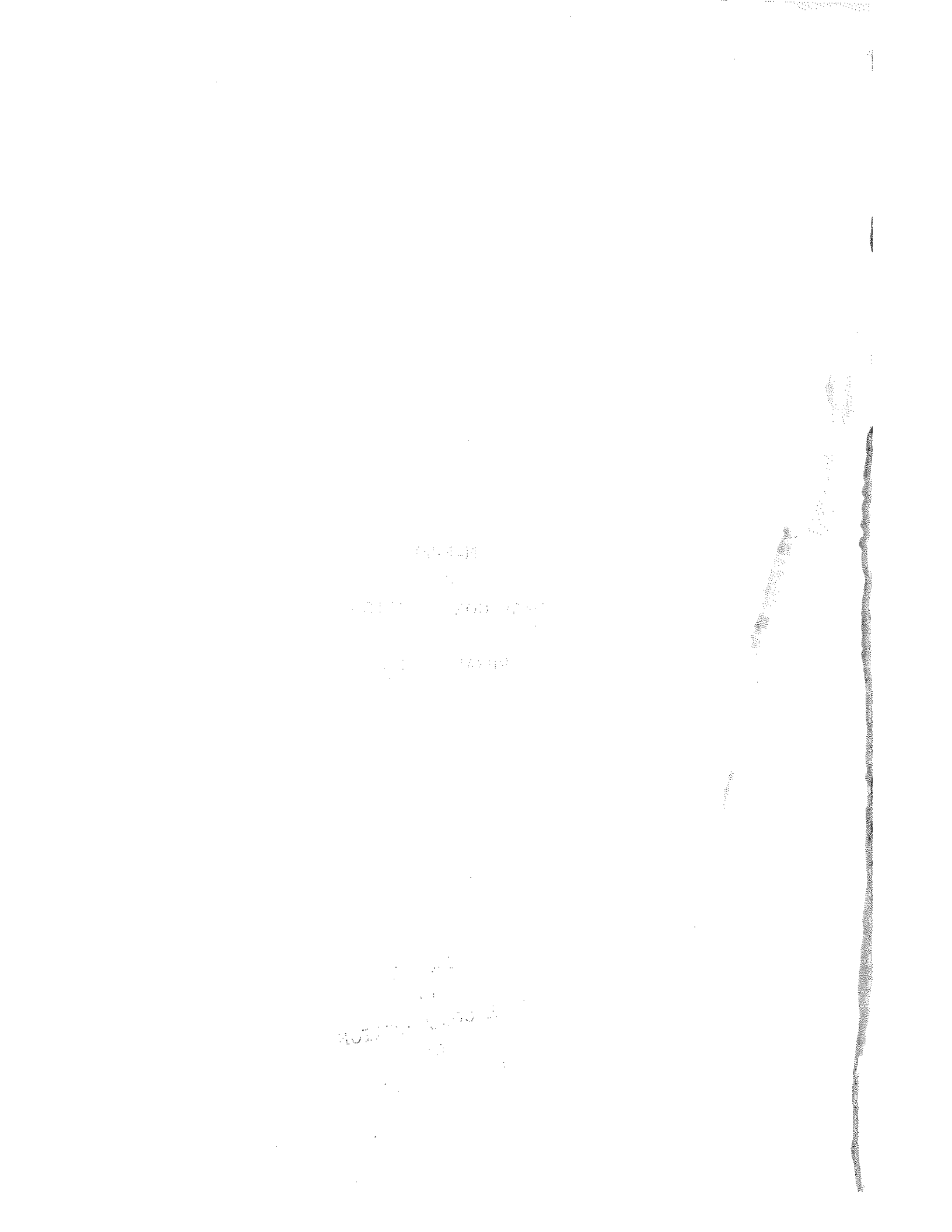
MANUAL
OF
STAGE CONSTRUCTION
OF
RURAL ROADS



G E N E R A L

1. PREAMBLE: The development of agriculture, the distribution of food, the provision of health serviees, and the access to educational services and other forms of communication in rural regions of developing countries, all heavily depend on transport facilities. Rail facilities may play important roles in certain areas, however, a dominant and universal need remains for road system that provides an assured and relatively inexpensive means, for the movement of people and goods. The bulk of this need is for low-volume roads that generally carry only 10-50 vehicles a day and that seldom carry as many as 400 vehicles a day.

2. The planning, design, construction, and maintenance of low-volume roads for rural sector can be greatly ennanced with respect to economics, quality and performance by use of low-volume road technology.

3. AIM: The object of this mannual is to provide useful and practical information for those who have responsibility for construction of low-volume roads.

C O N T E N T S

C H A P T E R - I

4. INTRODUCTION Access and transport are prerequisities integrating rural population. Road access is a popular demand of rural people partly because of read benefits and partly because roads are believed to be the forerunner of other services. Roads provide wider and more flexible coverage of and area than rail and are best suited scattered rural populations.

5. In order to provide as much mileage as possible within usual financial limitations, there is a procedure called stage construction that can be followed in the development and construction of low-volume, low cost roads. Stage construction emphasizes the practical aspects of constructing the most economical and useable road that is adequate to meet the needs of the present and immediate future. As rural development progresses and traffic volume increases, the road can be upgraded or improved in stages in response to these growing needs.

6. STAGE CONSTRUCTION: The terms stage construction is used to describe the betterment of a road in stages through step-by-step improvements. Improvements occur over the time as traffic volume indicate the need. Various stages of construction are carried out over a period of time or may take many years for major works to be undertaken. This upgrading is over and above routine maintenance.

7. Stage construction of roads is appropriate for either of two sets of circumstances:-

a. A path or track proves to be no longer suitable because of increased demand. Stage construction is also best suited for a track or road which under gone some degree of improvement. Such a road may be inadequate in surfacing, width etc and should therefore be upgraded.

b. A road is designed, but it is too costly to be built all at once.

8. Two considerations should not be overlooked. First each stage must be a usable facility. Second, when planning or construction any stage of a project, considerating should be given to each stage. This applies especially to alignment and structures thereon.

9. There are conditions that may warrant stage construction:-

a. Reduced availability of engineering or qualified supervisory staff.

b. The equipment needed may not be available immediately.

c. Construction conditions may sometimes dictate building in stages.

d. Permanent surfaces are usually placed delayed in order to identify and correct soft or unstable areas.

C H A P T E R - II

CONSTRUCTION PLANNING

10. GENERAL: We will consider two classifications of roads:- Class 1 - those with upto 50 vehicles per day (ADT-Average Daily Traffic) and Class 2 - with between 50 and 400 (ADT). These roads are called feeder or tertiary roads, or such as Farm-to-Market roads. These roads carry low volumes of traffic and normally include both motorized and animal drawn vehicles. Typically they are from 5 to 15 km long, but may be upto 100 km.

11. With the decision to provide a road, there must be a decision as to level of service to be provided.

12. Two terms are commonly used to describe further the level of service to be provided by low volume roads. All weather surface describes a road that can be used during all seasons of the year. Streams and rivers can be crossed during normal weather conditions. All weather road, describes a road that not only can be used in all seasons, but streams and rivers are crosseable during and immediately after rains etc.

13. ALIGNMENT: If the construction is a transition from an earth track to an improved road, the extent to which the existing alignment should be employed is usually not difficult to decide. Generally the alignment of the earth track will be

followed. There may be some justification for relocating the road nearer to material sources, providing better access, or eliminating some troublesome maintenance problems.

14. TRAFFIC VOLUME Estimate of volume of traffic to be served is necessary. Movements of produce to marketing centers or movements to and from local village markets will account for most of activity. Where motorable roads already exist, actual traffic counts can be made and estimates of growth can be envisaged.

15. RUNOFF AND DRAINAGE Reliable information on rainfall and runoff plays a major part in the planning and cost of a road project. Information can be obtained by close examination of the site for evidence of high water in trees and brush alongside streams and for deposits on floodplains. The recollections of local inhabitants are always helpful. This information must be analysed to estimate the proper sizes for drainage structures.

16. SOILS AND MATERIALS

a. Soils Most stage construction projects involve soil some is an important factor in planning the work. If the soils are heavy clay, wet, or exceedingly sticky or hard, it not be practical to handle them, and in extreme cases they may not be useable.

b. Other Materials Local materials should be used where possible. Gravel or granular materials can often be

found on or near the roadsides. Local residents often know what other sources are used for various local needs. When gravel sand, or other granular materials are not available within a reasonable haul distance, cement lime, or asphalt may be used. Local rock has a variety of uses in culvert construction, erosion control, retaining walls, and stream crossings.

17. CONSTRUCTION METHODS - LABOR BASED OR EQUIPMENT BASED

The subject choice is decided by government policy, otherwise depends on the economics. A practical approach will probably involve some mix of the two methods.

18. The possibility of using local equipment or animal drawn vehicles for works should not be overlooked. Farm tractors fitted with spreader blades are used for light leveling work, and animal drawn carts can be used for hauling light loads. However, making use of these resources requires more supervision.

19. SCHEDULING Time is required to bring together all the materials, manpower, tools and equipment needed at the work site, and deliveries should be scheduled with the construction season in mind. If the project is contracted, specifications should provide for certain activities to occur within given time frames.

C H A P T E R - III

DESIGN FOR STAGE CONSTRUCTION

20. GENERAL Engineers must design low-volume roads differently from the design of high volume roads. A primary concern is that techniques should be developed for designing low-volume facilities with a minimum of effort and, certainly in most cases, with the use of meager data.

21. Building for 20 years in the future is commonly practiced if sound data is available.

22. SURVEY The requirements depend on field conditions. For new location roads on a foot trail or track improved, a conventional survey follows the trail or track. To improve and existing road, a survey may not be required throughout its entire length. If only improvement of grades, curves, or drainage to be made, it may be adequate to provide survey information for only those locations.

23. STRAIGHT LINE PLANS A straight line plan is adequate when an established road is to be improved. The work is limited to ditching, minor grade alignment and drainage improvements, or surfacing. It requires minimum of survey and design and is u used for determining quantities. The engineer riders the road to be improved. Distances are noted, and correlated with features along the road. For stage improvements to existing

roads, the procedure provides the necessary information at minimum cost. However during construction, survey parties may be required for more exacting work. Other wise a hand level, ruler, marker, and string are the principal tools.

24. DESIGN STANDARDS Standards of the development of low-volume roads should allow for low construction costs. They should be capable of bearing higher volume of traffic through stage development, meeting the needs of the people.

25. DRAINAGE In attention to drainage has caused many low cost roads to fail. Drainage begins by having enough crown or slope (3-5 percent) across road surface. From the surface, the flow is planned to the ditches or down the embankment and away from the road.

26. Several ways to correct this problem are as follows:-

a. Pave the affected section with stone.

b. Intercept the ditch more frequently with transverse culverts.

c. Provide larger ditches and

d. Build narrow channels across the road to collect the water and direct it.

27. Ditches are constructed in various shapes. The most common is the V-shape. A flat bottom ditch may be used to provide a ready source of borrow material. However, lengthy

ditches should be avoided. Ditches may erode when the grade is too steep. The most economical pretection is grass or vegetative cover. Wherever possible, ditches should be laid out without abrupt changes in direction.

28. SURFACES The least costly surfacing for low volume roads consists of shaped natural earth. Most soils provide an adequate surface when they are dry or slightly moist. Under very wet conditions almost all soils except sands and gravels become impassable. The most common practice is placing an appropriate thickness of gravel or granular material on the road. The materials should contain a sufficient amount of fine grained binding soils, i.e. silt and clay. Too little binder results in a loose surface, too much binder results in a soft surface when wet. To provide a good riding surface, the maximum size of stones in the material should not exceed about 20 mm (3/4 inch). For low volume roads, thicknesses of surface stones very from 10cm to 20cm. Bitumen seal coats are often used when traffic volumes reach 140 to 170 ADT depending on local conditions.

29. CULVERTS The term culvert applies to small drainage structures in which water crosses transversely under the road. Culverts are generally required at low points in the terrain wherever the road blocks the flow of water. Local stone is often used for culvert construction. Stone culverts are usually built with a paved botton vertical sides, and a flat

arch top. When local materials are not available, either concrete pipe culverts or corrugated metal pipe culverts are used. Existing culverts should be lengthened with like materials of the same size and without change in the slope of the flow line.

30. WATER CROSSINGS: Low volume roads often cross dry stream beds or low water streams by means of fords, dips and drifts, theoriginal crossings can be upgraded by construction of bridges or culverts on these. The simplest kind of crossing occurs when a stream with a firm bottom is used as a roadway. The approaches should have gentle grades that do not exceed 5 or 6 percent. The surfacing of the approaches should be gravel or other granular materials. The cross slope of a paved ford should not be crowned but should slope downstream.

31. BRIDGES: Bridges or culverts replace ford crossings as a second step in the stage construction of low volume roads. The best possible locations are selected keeping in mind following factors:-

a. The longituinal centre line of the bridge should be at right angles to the direction of the flow of the river.

b. The bottom of the bridge span should be at an elevation above known flood level.

c. Piers and abutments should not impede or interfere with the flow of the stream.

d. Foundations must be on firm bottom.

32. EROSION: Erosion is a major contributor to the deterioration of roads, especially newly constructed roads. Erosion is often experienced in low volume roads where the earthwork has not yet stabilized. Soil erosion is caused by rainfall that displaced soil particles on inadequately protected areas. The causes of erosion suggest some basic principles for erosion and sediment control as follows:-

a. Construct slopes consistent with soil limitations.

b. Reduce the area of unprotected soil exposure.

c. Reduce the duration of unprotected soil erosion during rainy seasons.

d. Protect soil with vegetative cover.

e. Control concentration of runoff.

f. Retard runoff with planned engineering works.

33. Subsurface water is a frequent cause of landslides and other distrubed areas that add to the erosion problem. Where rainfall is adequate, the growth of natural grass in one season will provide erosion protection for average embankments. Where there is need for greater protection sprigs of indigenous creeping grasses are often planted. When drifting sand presents a problem it can be controlled by placing windbreakers on the windward side of the roads. Wind breakers may consist of any material that will break the wind force such as fence trees, brush, or other debris that can be anchored into place.

CHAPTER - IV

ROADS CONSTRUCTION DETAILS

34. MOBILIZATION

a. Materials Before construction begins, arrangements should be made for the delivery of materials, tools, and equipment, and for the mobilization of labour. A convenient site should always be selected for assembling materials and supplies which should be drained, large enough to allow adequate storage space, good traffic circulation and access. Construction equipment should be brought to the site in time to check for acceptability and serviceability. Proper storage must be provided for fuel and lubricants.

b. Scheduling The engineer should analyse his project to determine the logical sequence for construction. He should consider how seasons and weather might affect progress. Labour and local equipment requirements should be anticipated.

35. TOOLS AND EQUIPMENT

a. General The number and types of tools and equipment required for road construction will depend on the nature of the work, local economic conditions, the availability of equipment, and availability of local labour. Some combination of labour-based methods and equipment will

probably be found to be most practical. Hand labour is more productive when soils are easily handled, volumes are small, and hauling distances are short. More equipment is required as soils become more difficult to handle and volumes increase.

b. Tools Labour-based construction requires a variety of hand tools like, shovels, picks, sledges, trowels, wheelbarrows, axes, saws etc. Tools handles, sharpening files, and other micellaneous articles are required to keep hand tools in good repair. In some areas local labour may be more accustomed to local tools that are not universally used like KAHI.

c. Equipment Substantial savings can be realized if local equipment is used instead of more costly imported road building equipment, For example, animal drawn carts can be used for hauling materials when distances are short. Farm tractors with attached blades can be used for spreading loose materials, and soils dug by labour can be loosened by tractors or animal drawn plows.

36. When the work is equipment intensive, the following are normally used:-

a. Dump Truck Most useful for transporting loose materials over longer distances.

b. Motor Grader Very versatile, used for moving small quantities of materials over short distances. It spreads,

levels, and shapes the earth and materials to form roadbeds or other surfaces. It is used to form ditches and cut and dress slopes.

c. Roller - Used to compact soil and other surfaces.

d. Bulldozer - Used to move large volumes of earth for short distances. Its great power is particularly useful for heavy work.

e. Front-end loader - Most useful for loading trucks and for moving large volumes of earth for short distances.

37. SITE PREPARATION AND CLEARING

a. Site Preparation The entire work area should be checked for ponding and wet soils. Later construction problems can be prevented, if the site is drained or exposed to the sun and wind. Borrow or gravel sources should be located and prepared for extraction when needed. They may require access roads or clearing and top soil removel.

b. Staking the Work The construction work must be staked for control of the work. New roads will require staking to locate the centerline, elevations, tops of slopes, and toe of embankments. The information on which staking is based is obtained from the engineering plan and the typical sections.

c. Clearing Clearing consists of removing the existing vegetation in preparation for excavation and the formation of embankments. Clearing consists of one or a combination of the following operations, depending on the type of work and the characteristics of the vegetation.

(1) Felling trees and cutting shrubs.

(2) Undercutting - disposal of undergrowth, grass and weeds.

(3) Grubbing - removal of tree stumps and roots.

(4) Cleaning and burning - cleaning the road area of cleared debris and burning, or otherwise disposing of what cannot be used.

38. SOILS

a. General After the top soil has been removed, the excavation and the formation of embankments, may proceed. The best roadbeds and embankments are built when the soils involved are known and understood. Soils consist of four physical components: gravel, sand, silt, and clay.

b. Natural soils may be composed entirely of one component, but usually consist of two or more. The main physical characteristic used to identify soils is particles size. Gravel, the largest component, ranges in size

from a man's fist to a small pea or bean, and is found in stream bottoms, relatively free of the other components. Sand the next largest, ranges in size from a small pea or bean down to about the smallest size the unaided eye can see. It is found along with gravel and is present in varying amounts in most soils. Silts and clays are too small to be seen by the unaided eye. The clay portion is plastic or putty like. The silt portion is not plastic and behaves more like extremely fine sand.

c. A simple test will determine the approximate amount of each of the components of soil. Place a sample of the soil in a glass jar, fill it to about the one third. Add water untill is about two third fill and shake vigorously. Allow the material to settle untill the water is clear or nearly so. The sand will settle to the bottom and can be distinguished from the silt that will settle on top of the sand. On top of the silt is the clay that is also distinguishable from the silt. The thickness of each layer will indicate its percentage of the total.

d. The ideal material for road building is one that contains gravel and sand with just enough silt and clay to bind it together. Gravel and sand without any silt or clay make good embankments if the embankments can be confined i.e. they can be covered with other

materials to hold them in place. The same may be said for gravel and sand used for surfacing.

e. Soils that are mostly silt and clay generally make satisfactory embankments if they are controlled. Because of economic considerations, the engineer will seldom have much choice in selecting soils for use in low volume road construction. He should select the best of those available and make the best use of those that are available.

f. Compaction of Soils The performance of individual soils as road building materials depends on how they are placed for stability in a road formation as does proper compaction. Cost of compaction is moderate, the means for accomplishing it are varied and generally accessible, and the benefits are substantial.

39. EARTHWORK

a. Removal of Topsoil Topsoil varies from $\pm$0 to 30 cm in thickness, depending on many conditions of growth, soil, and climate. It may not be present in barren rocky, or eroded areas. It is easily recognized by its darker color as compared to the underlying soil. Tracks or old roads often have verying thicknesses of mud or other sediment on their surface or along the road sides. This is extremely poor material, for road building.

To remove topsoil a motor grader is preferred.

b. Excavation After the topsoil has been removed, the roadbed can be formed by cutting high areas, filling low areas, and shaping the roadbed. In flat areas, the forming may consist the roadbed. In flat areas the forming may consist entirely of cutting the ditches and placing the excavated material between the ditches to form the roadbed.

c. If the project is equipment intensive, excation will depend on the kind of equipment that is available. The front end loader for loading. A bulldozer can loosen the harder material and can move it short distances. A grader can also loosen and move soil for short distances, but is is less productive for that purpose than the bulldozer.

d. The work should be planned to take advantage of gravity rather than oppose it. Workers should load to the low side of the hauling equipment and push materials down-grade rather than upgrade.

e. Finishing and dressing of cut slopes are generally done by hand, using shovels, removal of excess materials, and compaction of loose areas will minimize the possibility that the slopes will eventually slide down to obstruct drainage.

f. Embankments Low cost low volume roads will generally have low embankments, perhaps less than a meter above the adjoining terrain. The following engineering principles should be applied to embankment construction:-

(1) Start with a firm base.
(2) Place fill material in layers of moderate and uniform thickness (15-20 cm).
(3) Compact each layer thoroughly, and
(4) Control drainage to minimize wet soils both during and after construction.

g. Before any embankment material is placed, the old road area should be levelled to a reasonable extent, either with hand tools or equipment such as a grader or bulldozer.

40. ROCK EXCAVATION Rock excavation is costly and highly specialised. It should be avoided if there are reasonable alternatives such as changing the alignment or grade. However, it includes following works:-

a. Drilling In this operation, holes are made in the rock for placing explosives. This can be done by hand or equipment, depending on the amount to be done and the equipment available.

b. Placing the Explosives and Blasting Contrary to drilling, this operation requires use of skilled workmen. Experience is of the utmost importance in locating the proper drill sites and in loading the proper drill sites and in loading the holes so that no unnecessary risks are taken with badly placed charges.

c. Extracting and Loading Once the blast has taken place, the shattered rock is picked up and loaded for removal. If the fragmants are too large, they can be broken with mauls or sledge hammers. The fragmented rock may be used in embankment construction. Poorer shaped fragments are useful for erosion protection. Small fragment or chips, even though mixed with soil, can be used in the roadway.

d. Safety Strict safety measures must be employed to avoid accident with explosives.

(1) The fewer men handling explosives, the fewer accident risks.

(2) Never keep explosive and blasting caps together and never allow the same workman to carry both.

(3) Allow only one person to carry, connect the wiring and activate the detonator.

(4) Work should be assigned according to experience.

(5) The work party should have exact knowledge of each individual's duties.

(6) Storage magazines should be surrounded with a protecting earth embankment that contains no rock fragment.

(7) All safety regulations must be observed.

41. SURFACES

a. General Surfacing is a means of providing a more reliable road throughout the year regardless of weather conditions.

The surfacing material may be placed either immediately following the construction of the road formation or as a later stage development. Both methods have advantages and disadvantages. Delaying the surfacing to a later stage has the advantage of lower initial costs. Delaying has the=disadvantage of not providing as reliable a surface initially. It also requires more extensive preparation for surfacing due to the long term effects of erosion and traffic.

b. Staged Surfacing Preparing an older road for surfacing usually requires much more work than is required for a recently constructed road. Roadway shapping is done with a motor grader and some labour support. Either a rubber tired or steel wheeled roler can be used for compaction. If either graders or rollers are available, the work can be done with picks, and shovels.

c. Gravel Surfaces For endurance, a good surfacing material must be stable under both wet and dry conditions and resistant to observe traffic action. In addition, the cost for delivery to the road site should below. The material that meet these requirements are mixtures of gravel, sand slit, and clay. The main resources for surfacing materials are stream and river bottoms, terraces, and alluvial fans and sediments. Time and work can be saved if a laboratory unit and trained

personnel are available to assist in the search and to make preliminary evaluations.

d. The material is hauled from the source to the road and is dumped. Immediately after unloading, the material is spread to the full width of the area to be surfaced.

e. Bituminous Surfacing

(1) A bituminous surface treatment is often applied as a final phase of stage construction when traffic reaches predetermined level. It preserves the surfacing materials, eliminates traffic dust, and provides a smoother and faster riding surface. Equipment intensive such work requires a grader, water sprinklers, asphalt distributors, drags, spreader, steel wheeled or rubber tired rollers and dump trucks. Materials that have previously proven satisfactory under local conditions should be given preference. Depending on local practice, what is available, and the number of coats to be applied, the aggregate should be a clean, hard, crushed gravel, usually ranging in size from 1 to 2.5 cm.

(2) Procedure The road is brought to the proper shapes and grade, depressions are filled and irregularities are leveled. This is best done with a grader. When the bitumen is applied, the surface should be firm, slightly moist, and free of loose materials or dust. The bitumen penetrates the road surface and seals it from the softening effects of moisture. It also serves as a binding

material to hold the stone that is spread on it before the bitumen begins to set or cure.

42. PIPE CULVERTS

a. General Constructing culverts involves preparing the site, or laying the culvert, back filling, and protection from erosion. Culverts are normally installed before the road embankment is placed. Where there is no flow during the construction period, the embankment may be placed first and a trench excavated for placing the culvert. Culverts may be constructed from local materials such as wood or stone, if they are available. If not, either corrugated metal pipe or concrete pipes are commonly used. Concrete pipe may be produced at the site or it may be manufactured at a central location and transported to the site.

Exact placement of culverts should be decided in the field after examining the flow and channel conditions at each location.

b. Building the Culvert Stone Culverts are often built where stone is locally available. Materials are limited to stone, cement, sand, and water. They are best suited to sites where channels are well defined. When concrete pipe is produced at the site, care must be exercised to ensure a good quality product. The pipe should not be handled nor moved until it has aged for a minimum of

seven days under favourable curring conditions. The load that the pipe will support as a culverts is determined to some extant by the way it is bedded. An effective beddings is obtained when the earth is shaped to fit the lower part of the pipe for about one half the diameter of the pipe. If the bottom of the pipe bed is rock or hard clay, space below the pipe should be excavated and replaced with 10-15cm of sand or compacted granular materials. The pipe should never be laid directly on the rock. Backfill around the pipe should be fully compacted because of the susceptibility of backfill toerosion damage and future settlement. The backfill material should be good clean earth, preferably granular, and should be free of lumps, boulders, roots or excessive organic material. It should be placed on each of the pipe with shovels in layers not exceeding 10 cm loose thickness and should be thoroughly compacted with hand tamps. Corrugated metal pipe is sometimes preferred for constructing culverts because it is light in weight, less subject to damage in handling, and easy to assemble using common labour. All the requirements of channel preparation for concrete pipe apply equally to corrugated metal pipe.

c. Erosion Protection Culverts and the immediate area surrounding them are the most likely components of the entire road to suffer from rain damage. Culverts are placed where water flow is most concentrated and

constricted, but economic considerations seldom permit culverts to be designed for the worst possible condition. A mixture of 10-15 percent by weight of cement to soil is usually adequate for obtaining a hard material that is resistant to erosion.

d. Low Water Crossings Fords, dips or causeways are relatively economical to build. They compensate to some extent for the inconvenience of delays caused by highwater. Fords are generally built across shallow or seasonal streams and rivers by placing a concrete slab across the bottom of the stream bed. In some stream beds, erosion becomes an important factor because of the swift flow or the type of material in the stream bed. At these locations, fords should include paved aprons as well as cut-off walls to prevent the structure from being undermined and destroyed.

e. Concrete Bridges Reinforced concrete structures require comprehensive engineering for their design as well as technical skills for their construction. These are not usually built on low cost roads. However, in some locations where streams are swift or deep or where other materials are not available, reinforced concrete may be the only practical means of providing a crossing.

f. The materials and equipment required in addition to those normally used for low-cost roads construction are reinforcing steel, lumber and nails for forms, and a concrete mixer.

g. Foundations are carefully staked out in accordance with the plans. Excavation for the footings is one of the most critical steps in bridge construction. The bottom of the excavation should be horizontal. Footing can be steeped where stopping rock occurs. Forms contain the plastic concrete and provide shapes for the structure components. They are usually built with lumber or plywood but other materials may be used. False work is used is to brace the forms and to hold them in place. The false work is supported by mud sills when the ground is firm or by wooden verticals if the ground is soft. Rainforcing steel roads are placed in the forms to take the tensile stresses developed by loads on the structural members. Proper proportions of cement, aggregate, and water for the concrete are mixed with a concrete mixer. Water contents are carefully controlled. Concrete is moved from the mixer to the forms with wheelbarrows or other containers. The concrete should not be dumped indiscriminately through the reinforcement, nor should it be deposited continusly at one point and forced to flow for considerable distances. When placing concrete in foundations it is sometimes impractical to remove all the water in the foundations. In such cases, it is best to start the placing of the concrete in one corner and continue until it is well above the wter surface.

h. Proper curing of concrete is controlled by humidity, temperature, and protection against disturbance. Concrete must

not be distrubed nor loaded while it is curing. Forms and falsework must not be removed until after curing has occurred and the concerete has gained the necessary strength.

j. Dry Stone Retaining Walls In mountainous terrain, roadways must often be supported by retaining walls. One of the least costly types of walls to build is a dry stone wall. It contains no mortar to hold the stones together. The wall is constructed before the road embankment is placed. Excavation may be required to ensure a firm footing and should be on previously undisturbed ground. The wall should be constructed so that the stones are in contact with each other and so that their longest dimension is perpendicular to the embankment. After completion of the wall, the excavation should be back filled and compacted with 10-15 cm thick layers of soil. The fill immediately behind the wall should consist of stones that facilitate drainage.

k. Gabions Gabions are wire mesh containers, either cylindrical or basket shaped, that are filled with rock. They can be place to act as retaining walls, to control erosion, or to serve other uses. Where rock is available, they are economical to install and lend themselves to maximum use of hand labour.

h. Maintenance A road built in stage development lacks many of the features of a fully completed construction. Some features that would ensure minimum maintenance and long

life for the road are omitted. Once built, the road will probably be required to serve in its newly developed stage long beyond the time originally intended, regardless of increasing traffic needs. any corrections are best noted following the first rainy season after the substantial completion of the project. Particular attention should be given to correction of excessive surface scouring, excessive side-hill runoff, ditch and channel blockage, need for additional culverts, drifts, or bridges.