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"ROADSIDE DEVELOPMENT IN MADRAS STATE"

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CONTENTS

SYNOPSIS

The Paper embodies the principles and practices recommended for roadside development in Madras State.

The necessity for having adequate road land width has been brought out and details of how the road can be made to harmonize with the landscape are given. The desirability of having flat side slopes is stressed.

Planting schemes, namely, conventional avenues and alternatives such as group planting and informal planting etc. are discussed. Different species of trees, their habits, and their suitability for avenue plantation are enumerated. Suggestions in regard to raising nurseries, care of seedlings, and plantation by the roadside are given in great detail.

Under the heading, Maintenance of Avenue trees, practical hints on pruning, removing parasites and unhealthy branches etc. are given.

The section on Roadside Drainage puts forth a rational method of designing roadside drains by the use of charts. A worked out example is included.

1. INTRODUCTION

1.1. In the past, Highway Engineers, fixed by the limited funds at their disposal, have devoted all effort to the extension of milage in road construction. Little or no attention has been paid to aesthetic features. Highway traffic, to some extent, is recreational and the tourist seeks routes of beauty. People from the city and the village are attracted by the varied charms of the open country and appreciate roadsides, harmonizing with natural beauty. Moderate expenditure on roadside improvements is, therefore, justified and should be included in schemes for road construction and maintenance. Much roadside improvements can be accomplished without material increase in costs.

1.2. In general, landscaping includes a variety of measures which aim at fitting the road into the landscape, enhancing its appearance, safety and utility and increasing the pleasure of the public using the road. Good landscape design will preserve the natural character of the roadside as far as possible, and as trees are the dominant units in landscape work, will conserve existing vegetation. Where it is necessary to supplement by new planting, it should be done with native material arranged in an informal manner to merge smoothly into the natural landscape.

1.3. Improved appearance should not be the sole objective of roadside improvement. It should emerge from improved highway design particularly with reference to erosion control such as rounding of surfaces, and improved drainage. As the highway is intended primarily to carry traffic, improvements of geometric elements such as curvature, grade and sight distance are even more essential than any ornamental planting or other embellishments, but it must not be forgotten that utility, and safety require due regard for the basic principles not only of engineering but also of sound landscape design.

1.4. The prevailing ecological conditions of sea-coast and inland valley, forest and delta, and mountain and wasteland control the design and the methods of landscape planning. Climate and soils of the area influence it. It is a field of work that is at present undeveloped, and methods and practices must be evolved suitable to the locality. Standardization is neither necessary nor desirable, since variety and change are the essence of roadside charm. Satisfactory roadside improvement and modern highway landscape design require the collaboration of the highway engineer and the trained landscape architect. However, Engineers can apply many of the principles of landscaping in the planning and execution of highway projects.

1.5. Roadside development is discussed under the following headings:

(1) roadland width and the landscape;
(2) the highway alignment and the landscape;
(3) the highway cross-section and the landscape;
(4) roadside planting; and
(5) roadside drainage.

A. LANDSCAPING

2. ROADLAND WIDTH AND THE LANDSCAPE

2.1. Adequate roadland width is perhaps the most important item for good highway landscaping. No other single element will solve as many landscape problems. Land width should be adequate (a 100 ft or more) to allow for:

(i) the provision of a continuous strip of trees or shrubs to shut out undesirable views;

(ii) the shifting of electric transmission lines etc. away from the border trees;

(iii) the provision of roadside parking places;

(iv) flat side slopes of the embankment to increase safety and to ensure a satisfactory transition of the embankment into the natural contours of the country;

(v) the avoidance of unsightly borrow pits; and

(vi) look out points for scenic views.

3. THE HIGHWAY ALIGNMENT AND THE LANDSCAPE

3.1. Highway alignment is greatly improved by the provision of curves of as large a radius as possible, supplemented with spiral transitions which produce a pleasing landscape effect. Since the safety of traffic must take precedence over landscaping, building in adequate sight distance is essential. Roads that lead to tourist centres should be so located as to afford the maximum opportunity for seeing pleasant views. The alignment selected from engineering considerations such as grade, etc., may also be made to afford access to pleasing vistas where the extra cost is within reason.

3.2. The proper combination of profile and alignment is important for landscape design and traffic operation. The beauty of line may be lost, if grade and line are not properly related. Thus a horizontal curve should not begin at a summit ; it is better to suggest the change of direction before the road goes out of sight. Lines " flowing with the country " with carefully placed profile changes and properly designed vertical curves are essential.

3.3. Poorly placed grade changes can distort an otherwise beautiful curve. Thus a hump in the profile of a curve, whose concave side is visible across a broad valley, may mar the entire line of the highway. Jerky changes of the longitudinal profile should be avoided and near scenic vistas the grade should be flattened. Bearing in mind the desirable combination of grade and curvature for safe operation, the landscape aspect of the gradient should receive consideration. Sometimes it may be desirable to design the grade and curvature for sudden bursts of scenery or for spectacular effects.

4. THE HIGHWAY CROSS SECTION AND THE LANDSCAPE

4.1. Steep Slopes Undesirable

The steep side slope of $1\frac{1}{2}$ to 1 adopted for cuts and fills, irrespective of the nature of soil and the country traversed, is not desirable. It is unsightly and difficult to maintain. Steep slopes reduce visibility in cuts and necessitate erection of guard rails in embankments. Flatter slopes are needed to prevent erosion, to permit seeding and sodding, and to improve appearance. Edge bunds should not be put up in any circumstances as a measure of erosion control.

4.2. Gentle slopes and rounding of the top and bottom

Gentle slopes and rounding of the top and bottom of slopes is desirable. In order to encourage the growth of grass

and other groundcover which is the best insurance against erosion, the side slopes of cuts and fills should be as gentle as possible. Slopes steeper than 2 horizontal to 1 vertical should never be used even though structurally stable. Ease and safety of driving require that the motorist should be able to see where the embankment merges into the ground ; with the majority of vehicles this is not possible if the side slope is steeper than 3 to 1 (Fig. 1). So from the point of view of the motorist any slope steeper than 3 to 1 is undesirable. The slight increase in cost that may arise from the adoption of gentle slopes will be more than offset by the ultimate saving in maintenance.

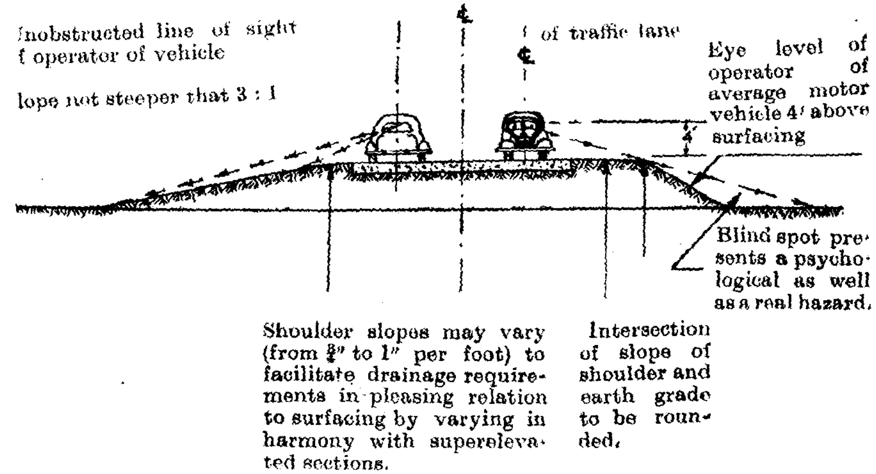


Fig. 1

Showing desirable side slopes

4.3. The aim should be to make the surfaces of cuts and

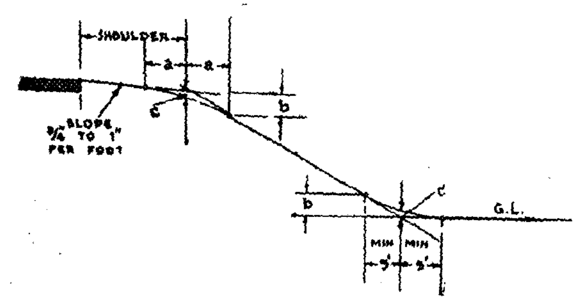


Fig. 2

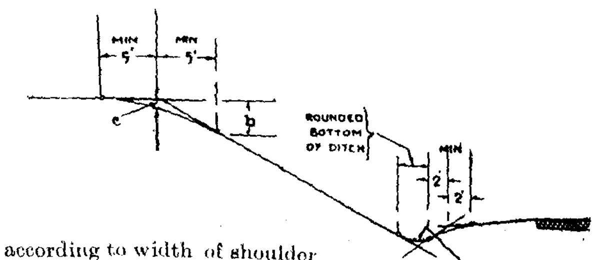
Rounding of Fill Slope

a = 2' to 4' according to width of shoulder

$$c = \frac{b}{4} = \frac{n(g' - g)}{4}$$

in which g' and g are the slopes of intersecting lines, of same sign.

fills flow into the natural ground contours with as little break in grade as possible. The top and bottom of fills and cuts should be rounded as shown in Figures 2, 3 and 4. Such work is best finished by hand. The existing steep slopes, where the embankment height does not exceed 8 or 10 feet, may be reduced to 2 to 1 or less with such rounding. The surplus materials removed by rounding the top may be used to round slopes at the bottom. A "transition" or "warped" surface is necessary as cut changes to fill. The rounding should not be too stereotyped, a natural or "weathered" effect being desirable.



$a = 2'$ to $4'$ according to width of shoulder

$$c = \frac{b}{4} = \frac{n(g'-g)}{4}$$

in wich g' and g are the slopes of intersecting lines, of same sign.

Fig. 3. **Rounding of Cut Slope**

4.4. The highway cross-section in general must be adopted to the roadland width and designed for progressive development to the section required for ultimate traffic. Wherever extensive landscape treatment is to be carried out on the finished slopes, the grading of the section should be carried to the final future width, so that the investment in planting will be saved.

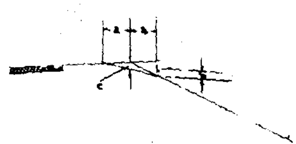


Fig. 4 **Rounding of Fill Slope at Superelevations**

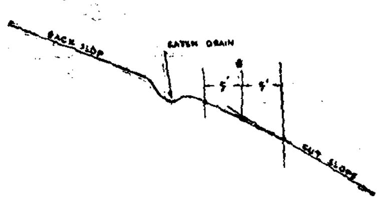


Fig. 5. **Catch Drain to Protect Cut Slope**

4.5. Catch Drains and Side Ditches

In cuttings where the slope continues to a high elevation and where the drainage from adjacent land flows over the cut slope in enough volume to start or aggravate erosion, a catch drain as shown in Figure 5 should be provided. The size of these drains

will be governed by the area to be drained and the permissible velocity as explained in Section 15 "Roadside Drainage".

4.6. Side ditches in all cuts should be designed to carry the volume of water as explained in Section 15. The bottom should be rounded as shown in Fig. 3, since a rounded section is less conducive to erosion than the trapezoidal or V-shaped section. It is not necessary that the side ditches be always parallel to the road or have uniformly sloping banks. Ditch banks in favourable soils can have very flat slopes so as to be almost unnoticed.

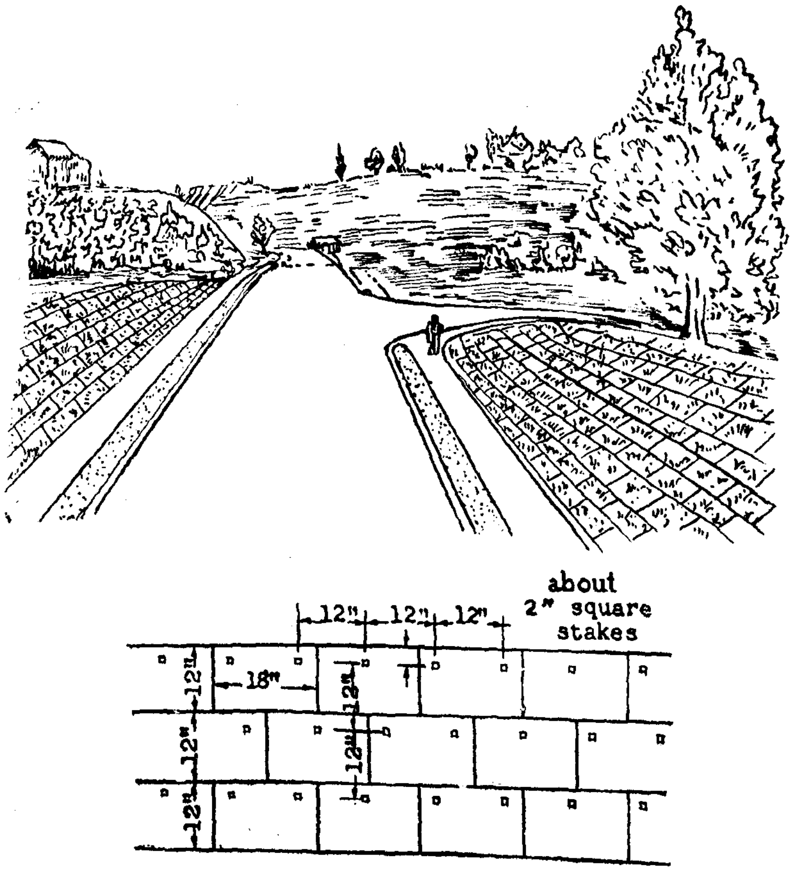
4.7. Ground Cover

In all new formations and existing cut or fill slopes where erosion is in evidence, it is necessary to encourage the growth of ground cover. This may be done by seeding, turfing, or planting creepers and low growing shrubs. To avoid artificiality, the use of native varieties of grass, creepers, and shrubs should be preferred and natural growth preserved.

4.8. Turfing

Turfing is recommended for bank of extremely erodible soil.

After the slopes have been rounded as shown in Fig. 2, the earth should be loosened to a depth of about 3 inches, and if soil conditions are adverse to plant growth, a fresh layer of soil containing a high percentage of clay, 2 in. deep, should be spread over the area and worked into the existing soil. It should preferably be taken from the same locality as the sod used for turfing. Any raking of the ground for loosening the soil and mixing soil should be done parallel with the contours. Sod should be lifted in a thickness of $2\frac{1}{2}$ inches and cut to 12 in. by 18 in. pieces. The strips should be placed on the prepared slope parallel to its contours starting at the bottom. When the top is reached the edge of the sod should be turned into the surface and a thin layer of earth placed over the edge and compacted so as to divert water over the edge and on to the top of the sod. Successive strips should be neatly matched and all joints should be staggered. The sod should be staked in staggered lines on all slopes of $1\frac{1}{2}$ to 1 or steeper and compacted by tamping lightly so that it becomes incorporated with the soil bed. The stakes should be about 12 inches long and about 2 inches by 2 inches in section and may be of any locally available material such as bamboos, avenue cuttings, country wood, etc. The method of turfing is illustrated in Fig. 6.



Detail for Staking

Fig. 6. **Turfing**

4.9. Planting of Shrubs and Creepers

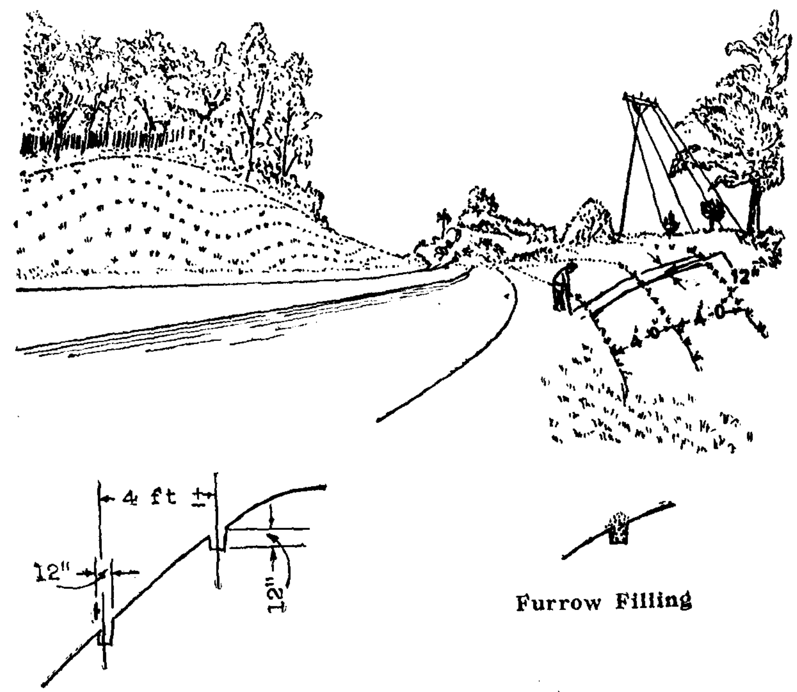
For deep cuts and high falls in certain conditions of climate and soil, this type of ground cover will be the most suitable.

After the rounding of slopes as shown in Fig. 2, plant furrows about 12 in. deep should be dug along the contours of the slope, on a grade not exceeding 3 per cent ordinarily and one per cent in the case of erodible soils. The furrows should be about 4 ft apart centre to centre along the slope on fairly stable soil and about 3 ft apart in erodible soil and should be filled with good soil to form a proper seed bed. Saplings or

cuttings of native stock such as *Mudar*, *Tanner's Cassia Bandrike*, *Goats Foot*, etc., should be planted in the furrows (See Appendix II for habits and suitability of various plants). The plants should be spaced suitably so that the entire surface may be covered in course of time.

Where low growing shrubs are used as ground cover they are better planted in irregular groups or colonies rather than furrows.

The method of slope planting is illustrated in Fig. 7.



Furrow Section for Slope Planting

Fig. 7. **Slope Planting**

All planting operations should be carried out during favourable weather. Where necessary, watering should be done to assist the establishment of ground cover.

All planted areas are to be mulched down with roadside cuttings, leaf mould, etc., to assist in retaining moisture.

4.10. Other Routine Items

The blasting of rock which might cause damage to trees should be controlled. Small boulders must not be left piled in

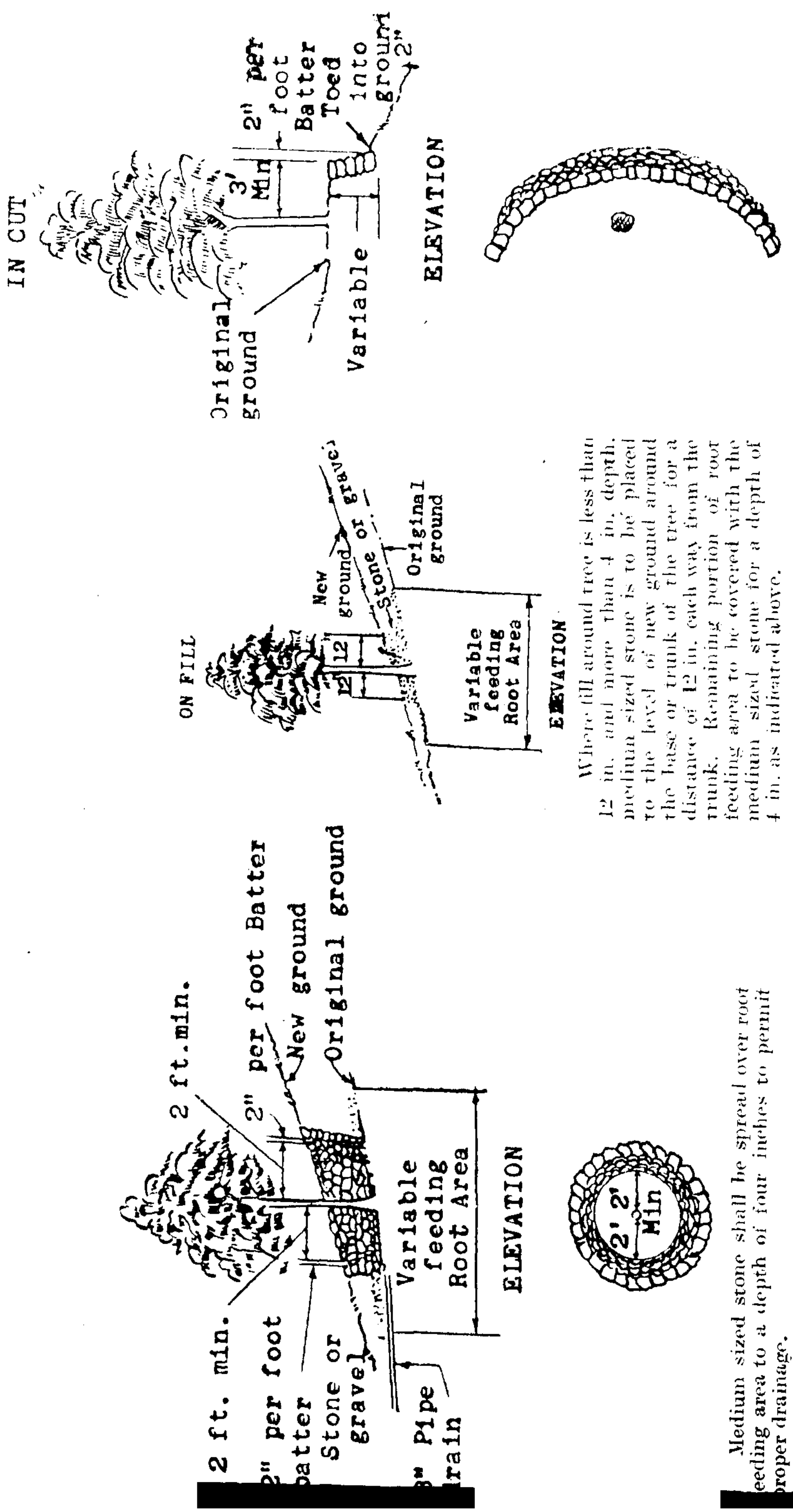


Fig. 8. Masonary Tree Guards

rows on top of shallow cuts. Larger boulders can be salvaged and used for guard rails. In high embankments, dry stone masonry retaining walls are often required to prevent undue lengths of fill slope.

Specimen trees can be preserved in a fill by the use of masonry " wells ", illustrated in Fig. 8.

Clumps of grass once started will catch much fine, eroded material and retard wash.

Concentrated ditch water and culverts that function under head start erosion. Protective pitching should be provided in such cases.

On completion of work the site should be thoroughly cleaned up. Ragged slopes and ugly borrow or gravel pits are unsightly.

As far as possible no borrow pits should be allowed within the roadland. In unavoidable cases where borrow has to be taken from within the roadland area pits should be as far out as possible and hidden from the roadway.

B. ROADSIDE PLANTING

5. ROADSIDE PLANTING AND MAINTENANCE

5.1. The primary object of planting trees along the highways is the provision of shade, as in India the sun is unbearably hot for at least six months in the year. Well planted trees also appeal to the aesthetic sense because of the beauty of their foliage, flowers and shape. Further, fruit bearing trees are a source of income. Therefore, it should be the aim of every officer to plant and rear up as many trees as possible and to see that proper care is bestowed on the young plants. This Section deals briefly with the items that are essential for the sound planning and execution of roadside planting.

5.2. Planting Programme

As soon as planting is decided upon, a complete scheme should be prepared showing the nature and cost of work to be done each year till the trees are mature as well as a calendar of duties to ensure attention in time.

5.3. Procedure in New Roadside Tree Planting

Experience indicates that the following procedure should be carefully followed:

(1) Make a list of trees known to be climatically suitable for the district, preferably those that have already been tried and have proved suitable for roadside planting.

(2) Examine the site closely, especially in respect of moisture conditions, depth and type of soil, and the extent of exposure to winds.

(3) Take account of the conditions at the site and select from the list the type of tree to be planted.

(4) Provide tree-guards or fencing and prepare the ground thoroughly.

(5) Plant in the correct season.

(6) Include an item in the annual maintenance programme to cover the care and maintenance of trees.

(7) Ensure proper care and maintenance and set up a proper organization of trained personnel. If trained men are not available, select employees who display a special interest in trees, and train them.

5.4. Avenue Plantation Versus Group Planting

The success of tree planting is judged not by healthy tree growth alone, but also by the general landscape effect created. The following are some of the points to be considered.

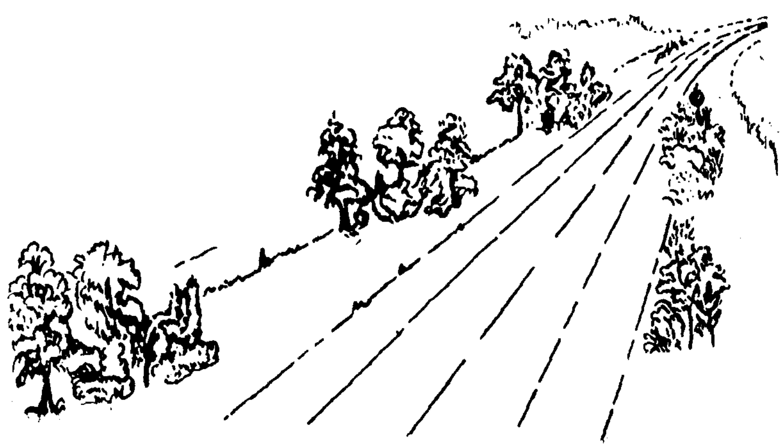


Fig. 9 Group Planting

As the rural landscape is essentially unorganized, the planting of formal avenues should generally be confined to the approaches to towns, large bridges or other man-made features. Long avenues tend to become monotonous. Where travel speeds are high, regularly spaced trees lacking variety may become irritating to the eye and induce drowsiness.

A better alternative to avenue planting is group planting (See Fig. 9), which requires roadland width of at least 200 feet which is seldom available. When land is less than 200 ft group planting is possible if advantage is taken of local widenings.

Group planting provides an opportunity to introduce contrast and variety by the use of exotic trees not similar to the background trees. Groups should not be planted in regular rows, but to a scheme the essence of which is informality and which will take into account the growing habits of the trees. For example, smaller growing trees might be placed on the fringes of the group, creating a pyramidal effect. Stagging the groups on opposite sides of the road, as shown, produces a good effect. The group of trees may be omitted wherever desirable growth exists on or near the road bed.

Group planting has the advantage that it is flexible and the types of tree can be selected to suit the exact conditions at each site. Further, group planting may be undertaken on as small a scale as desired and yet give pleasing results. Also such areas can be developed as picnic spots.

Another alternative to formal avenue planting is informal planting (Fig. 10) which is suitable for rural areas. A natural and free arrangement of native plants to fit into the informal character of the open country should be the aim. Transition from the informal to the formal planting should create a fade out effect, see Fig. 10.

Mixed Planting.

Much of the monotony of avenue trees can be relieved by selective planting of different varietiessuch as tamarind, mango, eluppai, wood apple, etc., as illustrated in Fig. 11. Mixed planting has the following advantages:

(1) The plants flower and bear fruit in different seasons and, therefore, the avenue lessee is induced to take some interest in them throughout the year.

(2) In storms and gales, at least some of the harder varieties survive.

(3) The shedding of leaves takes place in different parts

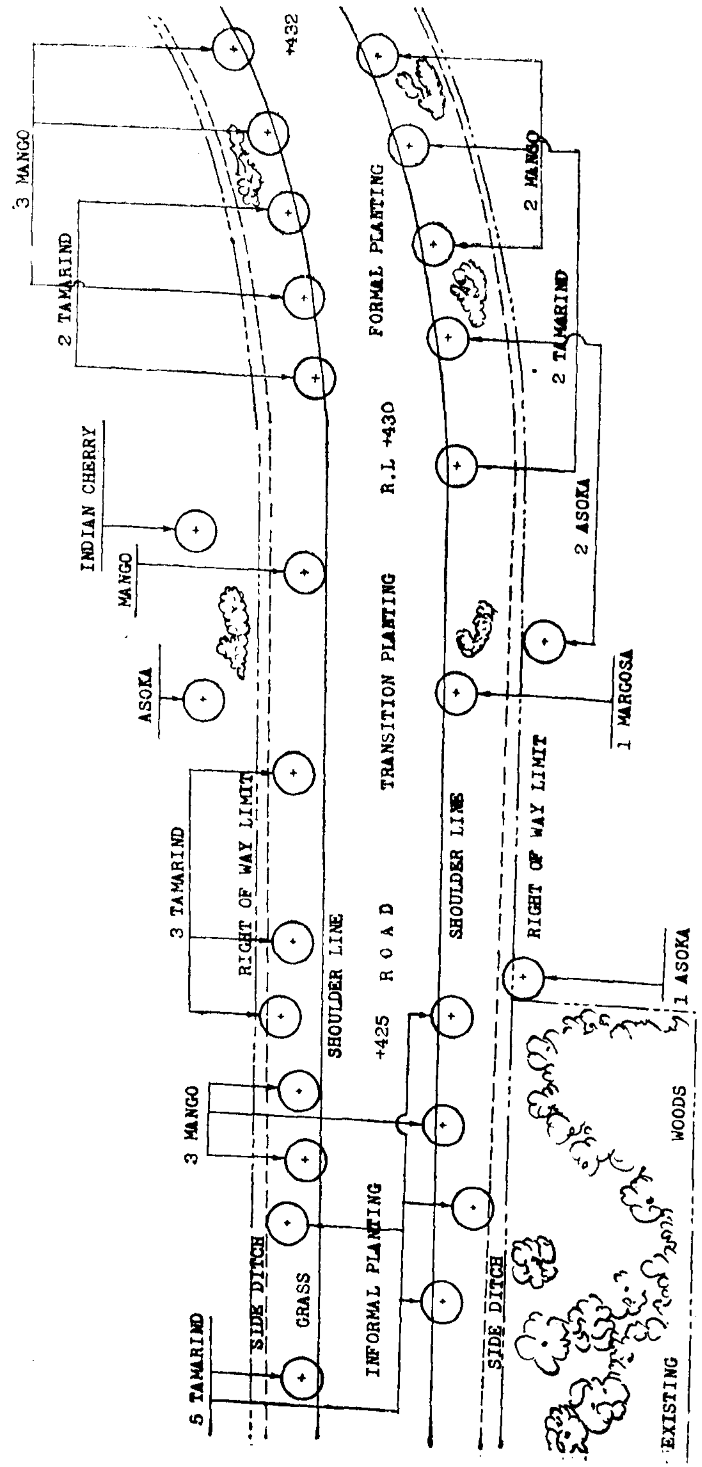


Fig. 10.
Informal Planting.

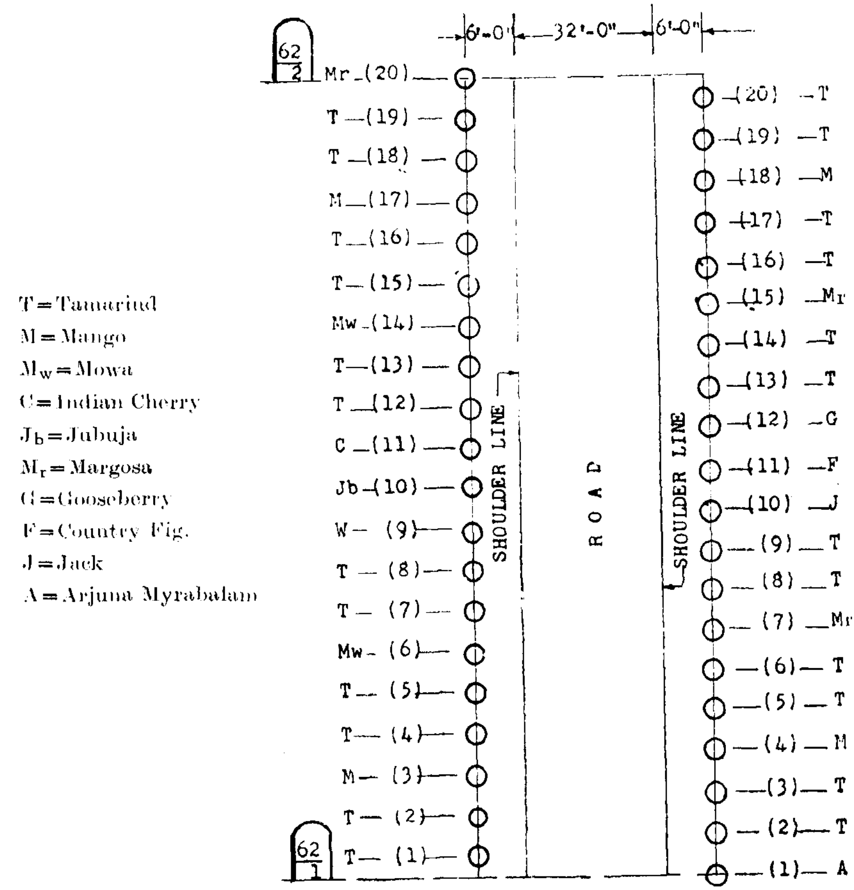


Fig. 11.

Selective Mixed Planting

of the season, thereby avoiding completely bleak appearance and too much of dry leaves at one time.

(4) Tall growing varieties with straight stems such as Arjuna Myrabalam may be planted at selected spots to serve as effective landmarks.

6. CHOICE OF TREES

6.1. An avenue tree must have certain basic qualities :

(1) It must be hardy and robust and should need little attention once it has attained a certain stature.

(2) It must suit the soil and rainfall of the place.

(3) It must appeal to the eye *en masse*.

(4) A spreading, evergreen crown is essential, but it must not be of too rank a habit, for a tree that will grow right on to the roadway will never do.

6.2. The nature of the road should be taken into consideration in selecting the type of trees for planting. For example, if the road is of a suburban character or is a new road in the neighbourhood of which it is proposed to build houses moderately close to the road, it is obviously unsuitable to plant large trees of the forest type as these will grow up close to the houses and block the view, darken the rooms, and generally be a nuisance to the householders. They will have to be severely pruned and this will damage them.

6.3. The choice of species must be governed by the following considerations:

(1) The species must be either truly evergreen such as the mango, nearly evergreen such as the Margosa, or be in leaf during the height of summer.

(2) The species should be capable of developing a straight and clean bole up to a height of 8 to 12 feet from the ground level, beyond which it must develop a spreading and reasonably dense crown. In general, two types of branching may be distinguished: heliotropic, i.e., with side branches growing with an upward or horizontal tendency, and geotropic, i.e., with side branches growing outwards and downwards or with a definite drooping habit. Of these, trees of the former type such as the Indian Cherry are more suitable for highways than trees of the latter type.

(3) The species must be fairly hardy, fast growing and wind-firm. Too rapidly growing trees should be avoided because these are invariably short-lived and have very brittle branches.

(4) The tree should be deep rooted. Shallow spreading roots injure pavements for they crawl underneath pavements and break them up and by absorbing moisture from the subgrade in detrimental amounts during times of draught cause instability of the road structure.

(5) The trees should not harbour pests or in any way injure agriculture in the neighbouring fields.

6.4. Many ornamental flowering trees such as Gulmohar, Cassias—native and exotic, Jarul, Indian Cork, and the Rain-tree lend colour to the drabbest surroundings when in bloom, but their proper place is in parks and gardens not on the roadside, for they are softwooded and top heavy. Pinari belongs to the same class and has the further disadvantage of attracting caterpillars.

6.5. Where they can be cultivated, the Champak and Magizh would both provide cool and fragrant avenues of exceptional charm.

6.6. The Indian Beech is a sturdy, evergreen, quickgrowing tree that stands lopping well, and whose foliage finds ready sale as green manure. Another tree of very near size and colour is Portia.

The long-leaved Asoka is a magnificient tree when full grown, but like other lofty trees with thick, mastlike boles, it dwarfs the highway if allowed to pursue its nature, and if pollarded, needs periodical attention and loses its grandeur.

6.7. The Margosa has many virtues as an avenue tree. In the hottest months, when shade is most welcome, it is in thick leaf, and its clean-smelling neighbourhood is said to be health giving, probably because of the antiseptic properties of its oil. It has a stately presence and the sweep of its branches has a decorative quality.

6.8. No tree, however stately or picturesque, can equal the Tamarind for the road. It needs careful planting, but once grown is the hardiest of trees and no wind bothers its tough, supple boughs. Its deep round crown, some ten feet above the ground, has ample breadth and substance. Its economic worth should more than offset what little damage its acid leaves may do to crops grown directly under its foliage.

6.9. The Banyan has all that one can ask of a tree in appearance or shade, but has the habit of spreading all over the place over its prop roots, and when these prop roots overhang the road they chute down water damaging the surfacing.

6.10. The Peepul though majestic has no shade and is soon turned into a little shrine by local people. It should not be used for roadside planting.

6.11. The charming Fig tree (Ichi) with the chaste green of its foliage and the grace of its outflung, slender limbs, adds refinement and an air of peaceful repose to any highway.

6.12. The best principle to follow in the selection of trees is to select those species which are thriving under similar conditions. Generally trees with small sized thin leaves like the Tamarind and the Margosa stand droughts very well as they need much less supply of water than the large and thick leaved varieties.

As a general rule, all species of trees having large and thick leaves should be avoided as avenue trees for the following reasons:

(1) They require more moisture than the small-leaved varieties.

(2) Dripping during rains will be very severe.

(3) The noise made by the blowing of wind through the foliage of such trees and by the impact of falling leaves is unpleasant and positively nerve-racking on a lonely road.

Appendix I gives the names of trees and shrubs of Madras suitable for roadside planting.

Brief descriptions of the habits, peculiarities of shape etc., of the species listed in Appendix 1 are given in Appendix II.

7. THE IMPORTANCE OF PLANNING

7.1. The Importance of Planning

Roadside planting is no routine job. It calls for knowledge, care and ability to select the right species of trees to harmonise with the local setting and a plan for proper attention during the early stages of growth.

One distinguishing feature of avenue planting is its great length without breadth which increases the cost of rearing the plants. Expenditure and extra effort in hastening their growth and advancing the time of their being out of danger tend to economy in the long run. Besides, a fast growth necessarily requires a uniformly healthy condition and trees so grown will develop a pleasing shape and appearance. A slow or stunted growth at the beginning accounts for the shapeless forms of trees so frequently seen.

8. THE NURSERY

8.1. Nursery

Although trees may be raised by means of direct sowings or cuttings, in practice it is found more economical to transplant nursery culturd seedlings two or three years old when their root system is well developed so as to get established

into the soil. Such plants come up vigorously and stand drought well and need care for a shorter period, ultimately reducing the cost of plantation. Nurseries for raising seedlings are therefore indispensable for any programme of tree plantation.

The seedlings in the nursery should be raised from seed, but species which do not seed freely and hybrids must be raised from cuttings or layers of graftings.

8.2. Selection of Site

A good site for a nursery must be (i) conveniently situated in regard to areas it is to supply with seedlings and to the exercise of supervision; (ii) on good soil; and (iii) abundantly irrigated.

Generally it is found convenient to locate nurseries in the compound of inspection bungalows and to place the bungalow watchman to be in-charge. For important schemes the best situation is the Section headquarters. As a rule, there must be a nursery at every Section headquarters.

8.3. Size of the Nursery

This depends on the number and the age of the seedlings to be supplied annually. Area required depends on the number of the years for which it is intended to keep the young plants in the nursery. For example, if the seedlings are to be planted out after three years, space must be sufficient for three years' stock of seedlings. Additional area for pathway between the beds is also necessary.

8.4. Laying out the Nursery

The ground must be cleared of all stumps, roots of trees and stones, and must be ploughed deep and levelled. A platform of 2 feet height made of light soils or sandy loam must be raised over this prepared ground. This will permit the full and unhampered development of the root system and facilitate easy removal of the plants from the beds. The platform, as far as possible, must be rectangular in shape to facilitate laying out the beds conveniently. The slopes of the platform all round must be stabilized by grass sodding. The platform should be fenced round leaving a 3 ft wide pathway round it. Four and a half feet high trellis work in split bamboos carried on casurina posts, spaced at 6 ft intervals, will serve the purpose. Separate areas with pathways all round should be reserved for each kind of plant. A satisfactory arrangement is to divide the platform into 3 ft wide beds in the transverse direction with 2 ft wide pathways in between to facilitate watering and other nursing activities. The beds on which the posts are to be arranged or seeds sown, as the case may be are covered with leaf mould to a depth of about 6 inches to retain the moisture. If platform is large, a central pathway along the length should be left.

9. SEEDS AND SEEDLINGS

9.1. Selection, Extraction and Storage of Seeds

It should be made sure that genuine seed is obtained from selected plants which are the best of their kind in shape, profusion of leaf and fruit. For seed extraction the fruits must be ripe to ensure that the seeds are well developed. When this is done it is astonishing that their vitality is preserved under the most trying circumstances. The methods of extraction vary with the kind of trees. However, any means without affecting the embryo inside the seeds can be adopted.

9.2. Ripeness in dry fruit is usually accompanied by loss of succulence, gain of a peculiar colour, and opening of the fruit. In pulpy fruits ripeness is indicated by colour and softness.

9.3. Dry fruits when ripe are spread on paper in the sun until they open, when the seeds are removed by hand. Those fruits that open explosively are put inside muslin bags till they open so that the seeds are not ejected to a distance and lost. The seeds should then be thoroughly dried by exposing them to the sun for three successive days, storing them in air-tight tins in the intervening nights. After the final drying the seeds should be put in dry air-tight tins along with a ball of napthalin and the lid soldered or waxed on. Glass bottles with the corks sealed in are as good as tins if perfectly dry.

9.4. Pulpy fruits should be gathered when showing signs of over-ripeness and allowed to rot. When the pulp is rotten, squeeze and wash it away from the seeds and dry the seeds on blotting paper in the shade for three days, and in the sun for three more days. The seeds are then stored as described above.

9.5. If seeds are kept in envelopes or some such receptacles, they are liable to the attacks of insects and the effects of moisture.

9.6. The seeds of different plants differ very much in the length of time for which they may be stored. Most of our annuals will keep a year, but mango and citrus seeds keep only a month or at most six weeks.

Naphthalin is a most effective means of keeping insects from attacking seeds. One-fourth of a naphthalin ball in a cigarette tinful of seeds will kill all existing insects and prevent further attack.

9.7. Seed Sowing

The best method of sowing will depend on the kind of seed to be sown.

Certain seeds, especially some belonging to the classes leguminosae (pod-bearing kind) and malvaccae (cotton class) have extremely hard-coated seeds. If these are sown in the ordinary way they will not germinate. Such seeds should be soaked in cowdung water for about 24 hours prior to sowing.

9.8. If the seed can stand storing, the best time for sowing will be the beginning of monsoon or, failing that, July to September, as this reduces the cost of maintenance to the minimum. The seeds which have to pass through a dormant stage before germinating should be stored. Seeds which are short-lived and which germinate satisfactorily immediately after extraction are best used fresh. Very large seeds should be sown directly into pots and very fine seeds in crates or pans in sandy soil covered with sawdust or finely chopped leaf mould. Very obdurate seeds such as Gulmohar should be soaked in water for one or two days before sowing or the hard seed coat should be peeled out without injuring the hilum.

9.9. Pots having a thin shell, well burnt, preferably double-burnt, conical in shape, plain and without rims or curves, 6 inch diameter at top and 4 inch diameter at bottom, 15 to 18 inch deep, and open at bottom are found satisfactory. The pots are filled up full with sand-silt mixture in equal proportions and watered to permit setting. The seed is then sown and covered with sand and sawdust or chopped leaf mould with about ½ inch of free space at top to admit watering. Only one seed should be sown in each pot.

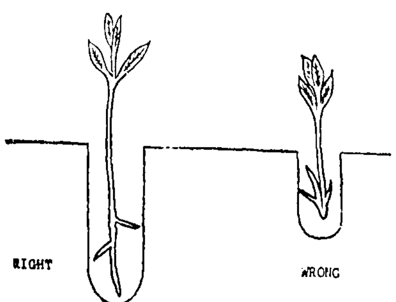
9.10. When pots or seed-pans are used, the best soil is one part leaf mould, one part common garden earth, and an eighth part sand, mixed well. A light soil for covering the seeds may be made of equal parts of coarsely pounded charcoal and leaf mould. If the seeds remain long before they germinate, the charcoal will have the tendency to keep the soil from becoming green and sour, as it often happens due to continued watering.

9.11. The depth at which a seed should be sown is roughly equal to its diameter. The bigger the seed the deeper should it be sown. Small seeds are sprinkled on the surface of the seed bed immediately after drenching the soil. If proper attention be given to drainage, moist soil softens the hard integument of the seed and enables it to germinate speedily.

9.12. Seeds need warmth to assist their germination and should not therefore be denied the heat and light of the sun.

When light comes from one side only the seedlings lean over towards that side and become long and leggy. A light roof of split bamboo is a first-class protection, giving a certain amount of shade and no side light. If seedlings do not get plenty of light they grow up into weak-stemmed plants which soon topple over and die.

9.13. The watering of beds and pots in which seeds are sown needs special care. Where the seeds are very small and sown in pans, the best way is to stand the pan in a dish of water and let the water rise up in the soil by capillarity. An alternative method is to protect the surface of the pot with fine-leaved twigs which will break the force of water drops. The watering-can should have a fine "rose" and be held high in the air.



TRANSPLANTING FROM SEED BED TO PITS

Fig. 12

9.14. Seedlings from fine seeds raised in special crates or beds are removed and pricked into the pots singly. In transplanting, care should be taken to ensure that no part of it is injured, that the stem is vertical, and that the roots point downwards in their natural direction without twisting or turning, Fig. 12.

The pots are embedded in rows over the platform, 3 to 4 rows to a 3 ft wide bed, and spaced closely.

9.15. Care of Seedlings

The plants should be allowed to remain in the nursery until they have become sufficiently hardy to withstand planting. Having remained in the nursery for one or two seasons and developed a well established root system, they will be ready for transplantation to roadside when they are 3 to 5 ft high. During the two years the plants remain in the nursery, they should not be disturbed. Plants should not be allowed to remain so long in the nursery as to have their root system unduly cramped for space. For the normal period required in most cases, the use of the open bottom pot described above virtually eliminates this danger while avoiding the necessity of changing into larger pots. Weeding should be done as often as necessary. Watering which should not be profuse and should be done every day, preferably in the evenings even during the rainy season when there has been no rain. If this is regularly and judiciously done, there will be no water collecting at the surface. Two mazdoors, are necessary to raise up to 10,000 seedlings.

9.16. About 10 to 20 per cent seedlings more than the number of plants required should be grown to provide for casualties.

10. PREPARATION OF PITS FOR PLANTING

10.1. Spacing of Pits

The optimum distance between adjacent trees in the rows will depend on the species, and no hard and fast rules can be laid down. Where space permits it, the distance from tree to tree should be equal to the diameter of the crown of a fully developed tree, and the distance from the margin of the road should be half the diameter. The position of telegraph and electric wires, side drains, curvature of the road, etc., should be considered in fixing the spacing. On curves the trees on the inner side may either be set back for clear vision or trees with high crowns may be planted. On the inside of sharper curves trees may be omitted if they are likely to obstruct vision; on the outside, however, they indicate the curve direction, especially at night, and are therefore useful. On vertical curves, tall trees visible over the hill may indicate changes in direction.

For ordinary trees the minimum distance apart may be 30 feet and the distance from the edge of formation may be at least 15 feet.

The trees in formal avenue planting should be planted in rows on either side of the road with a staggered pitch so that any tree in a row is opposite the centre of the space between two trees in the opposite row.

10.2. Preparation of Pits in Ordinary Soil

The pits should be dug well in advance of planting so that they may get sufficiently weathered. Dimensions depend on the nature of soil. Normally, 3 ft by 3 ft by 3 ft should be sufficient. In hard soil they may be 5 to 6 ft in diameter. Top soil not exceeding a foot in depth should be stored on one side and the sub-soil kept separately. A few days in advance of actual planting, the pits should be refilled with top soil mixed with manure and rich silty soil in 1 : 4 proportion. Additional top soil, if required, may be obtained by digging around the edge of the pit. Depressions so caused by the stripping of top soil should be made up with the sub-soil. The loose filling should be allowed to settle by one or two showers or the pits may be irrigated once or twice before planting. The filling in should slope upward 6 to 9 inches towards the centre.

10.3. Preparation of Pits in Rocky Ground

Avenue trees are most needed in rocky and barren areas of hard soil where it is difficult to rear them. In such areas a large pit should be dug and filled with arable soil. If necessary, the pit may be opened by blasting. If blasting is done, sufficient time should be allowed to elapse before backfilling is done to permit noxious fumes to escape. A pit thus prepared may give a sufficient start to the plants and if a proper selection of a hardy variety were made, the trees may be able to send their roots into the rock. Where the rock gets hardened by weathering, the backfilling should be done as soon as the pits are opened. In some cases, the spoil may be useful for road repairs. Where loose soil is difficult to obtain, the side drain, silt should be stored till it is sufficient to fill in one pit, or suitable soil should be transported from the nearest source.

An alternative method is as follows: A shallow pit is first opened by removing the over-burden and disintegrated rock at the top. The bottom of the pit thus opened is next shattered by blasting so that several planes of cleavage are opened up through which the roots can develop. The pit is then filled with loose soil and a mound with a level top about 3 ft high raised over it with the same soil. The side slopes of the mound are preferably protected by grass sodding.

11. PLANTING

11.1 The best time for planting at the roadside is when light showers have heralded the approaching monsoon so that when the monsoon actually breaks, a month or so later, the plants will have sent their roots into the ground and established themselves. In the north-east monsoon areas, about the middle of August is the proper time, and in the south-west monsoon areas about the middle of May.

11.2. The plants are removed from the nursery along with the pots without disturbing the tap root which is very likely to have gone down through the open bottom of the pots. In the centre of the roadside pit a hole large enough to take in the cone of earth inside the pot and deep enough to allow the tap root to go down vertically is scooped out. The pot is then broken and removed gently tapping it with a light scythe. The plant along with the cone of soil holding its root system is then planted in the prepared hole, making sure that the tap root has gone down vertically and the stem is vertical. Any space left in the hole after the planting should be back filled with top soil and manure.

11.3. Only one sapling should be planted in each pit. If the plant is liable to attack by white ants, one aloe plant may be planted in each pit. This will effectively prevent white ants.

12. FENCING

12.1. Immediately after the planting, fencing should be provided to protect the plant from grazing animals. Willow wattle woven guards, 15 to 18 in. diameter and $4\frac{1}{2}$ ft high, last for 2 to 3 years and are simple and effective. They should be erected in the following manner: Three bamboos, each about 10 ft long, are first driven firmly into the pit spaced in such a manner that the tree guard can be readily inserted around them. The tree guard is then inserted and firmly tied to the three supporting bamboos with its bottom raised about 6 to 9 inches from the surface of the pit and neatly enclosing the plant. The larger end of the guard should be at the bottom and the smaller end should point upwards. It is essential to keep the bottom 6 to 9 in. raised from the bed in order to prevent damage to the tree guard by water, white ants, etc., see Fig. 13.

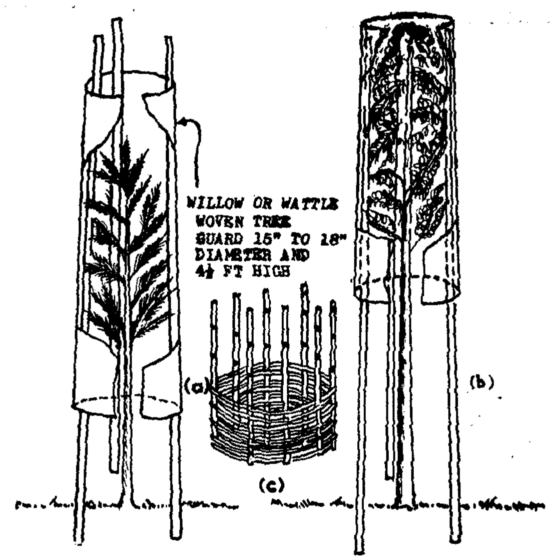


Fig. 13.

Tree Guard

(a) Details of Planting in roadside pit showing tree guards bamboo props, pots for irrigation etc.

(b) Raising of tree guards to protect foliage as plant groups.

(c) Tree Guard.

13. TENDING OF PLANTS

13.1. Tending of seedlings transported into roadside pits consists of periodical watering, digging around plants and removing weeds, mulching, and general care of the plant till it has fully established its growth. These items are dealt with in the following paragraphs.

13.2. Watering

Regular watering is required during the period between planting and the breaking of the monsoon.

Watering is required, say, once in 3 days during April, May, June; once in 5 days in January, February and March, and once a week from July to September if there has been no rain.

Proper supervision is essential.

Water is really required a little below the surface. The pot system of irrigation described below, see Fig. 14, helps to achieve this and renders the work foolproof.

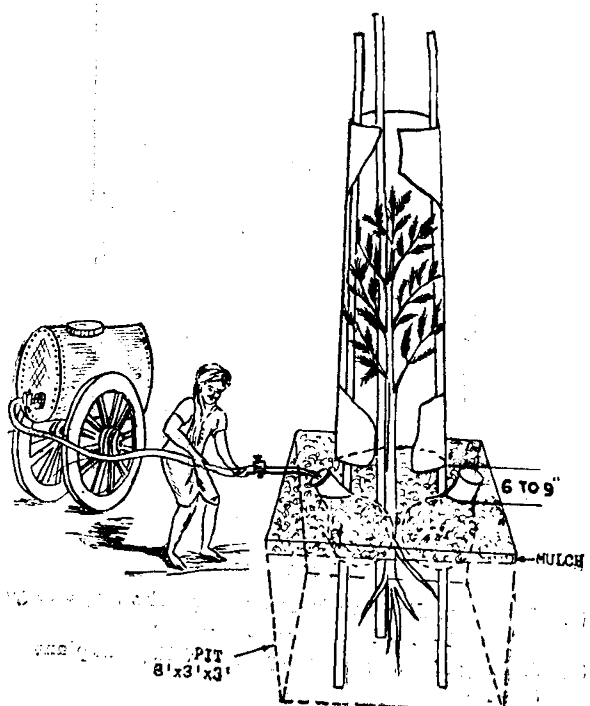


Fig. 14. The pot System of Irrigation

13.3. Pot System of Irrigation

Two pots of 3 to 4 gallons capacity will be put in at the roots inside the pit with the neck of the pots kept clear of the ground. The pots can be filled once in a week or 10 days as necessary.

Pots will be specially manufactured with long straight neck to prevent loss and misuse. Water will be supplied by hand carts and the pots will be filled up by flexible hose.

Once a year the pots may have to be changed if they get broken or leaky or if the pores get closed. The old pots should be scooped out without disturbing the root system and the hole backfilled with a mixture of top soil and manure. The new pots must be set in holes dug on a line at right angles to the line of the pots removed.

Direct irrigation being liable to be abused is not recommended till the plants are at least two years old and well developed.

The ground should be periodically raked and made up with a heaped cone at the stem and a watering channel all round about half way between the stem and the periphery of the pit.

13.4. Digging Round Plants and Removing Weeds

It is important to prevent the soil around the plant from hardening. It should therefore be kept raked from time to time. No grass, weeds or any kind of vegetation should be allowed to grow near the plant.

Even after the plants have developed into trees and are out of danger, the ground round them should be dug both at the beginning and end of the monsoon. In the first digging, it may be sufficient if the clod is broken and overturned; in the second, it should be pulverised. With the first digging necessary manure may be added.

Appendix III gives details about the various types of manures and hints on their application.

13.5. Mulching.

As soon as the dry season commences, the soil round the stem, two feet wider than the shadow at noon, should be covered to a depth of about 3 inches with leaf mould. Watering should be done over this mulched soil. The moisture will then be retained much longer and the soil will neither cake nor crack and the tender roots will not be injured.

13.6. General Care

One person should be employed to remove the caterpillars or other insects that injure the plants and see that all causes that hinder growth are promptly removed. A system of reward depending on the healthy growth of plants will act as a powerful incentive for good work.

As the plant grows up, the tree guard should be raised from time to time to keep the foliage well protected, see Fig. 13.

After the plant has reached safe stake, a ring bund should be put around it to help retain rain water. This is specially necessary in steeply sloping ground. Care should be taken to see that the top of the bund is level; and it may be crescent shaped to admit the inflow of surface water from above.

14. MAINTENANCE OF AVENUE TREES

14.1. The proper maintenance of avenue trees consists of a digging all round, removing parasites and unhealthy branches, and judicious pruning to keep up balance and form.

14.2. Digging Round Trees

A digging, as described in para 13.4 should be done round all young trees for a radius of about 5 ft round the stem both at the beginning and at the end of the monsoon.

14.3. Removing Parasites

Parasite plants, i.e., plants which have established themselves on trees, should be traced to their origin and completely removed, root and all. The wounds caused by the removal of the parasite, if more than 2 in. in diameter, should be covered with tar to prevent decay. When a branch of the tree is severely infected it may have to be cut off so that the rest of the tree may be saved from the growth of parasite.

14.4. Removing Unhealthy Branches

Branches that are dead, damaged, or are severely infected by parasite plants and insects, should be removed. For removing, a cut should be made with a sharp saw close to the intersecting branch and as nearly parallel to it as possible, leaving no stub of the amputed branch on the good limb or the tree trunk.

Large limbs should be removed in portions, always making undercuts to prevent the tearing of the bark on the good portion of the tree when the limb is removed, see Fig. 15.

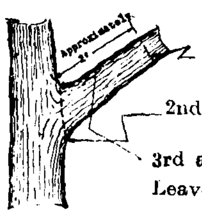


Fig. 15. **Removing Large Limbs**

All cuts of one inch or larger should be treated thus: Stripped bark should be traced to sound cambium and smeared with a solution of lac in methylated spirits. The central woody portion should be painted with a dilute solution of any good wood preservative such as creosote or coal tar.

The methods explained above are illustrated in Figs. 16 to 18.

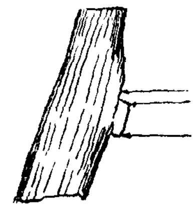


Fig. 16. **Ledge Cuts**

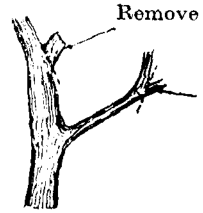


Fig. 17. **Stubs**

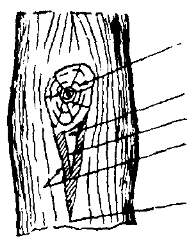


Fig. 18.

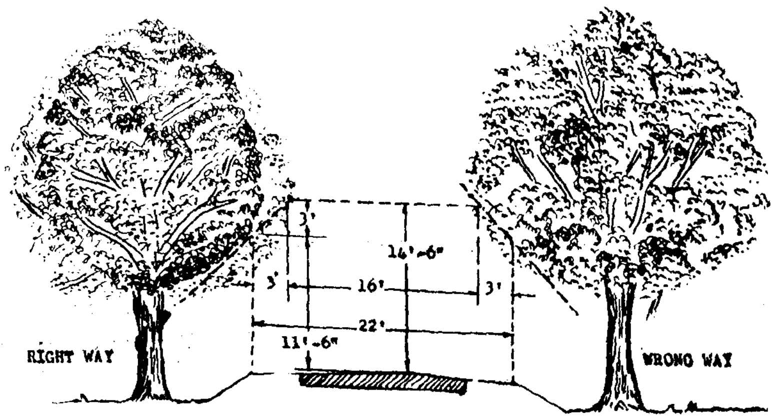
Treated Stripped Bark

14.5. Pruning.

Trees should be pruned whenever necessary but preferably during their dormant period. The pruning should preserve the natural contour of the tree. The habits of the species to which the tree belongs should be borne in mind in deciding the extent of pruning. Sharp tools should be used and the cuts should be made clean and flush with the limb or branch forks. In removing limbs to lighten heavy branches, only the under limbs should be removed.

Some species of trees such as the Rain Tree which grows very fast require pruning early in their life in order to ensure a balanced and healthy growth.

Pruning for roadway clearance should conform to dimensions shown in Fig. 19.



Prune to Retain Natural Shape of foliage as far as possible

clearance required minimum horizontal clearance 22' for single lane road for each additional lane increase clearance by 10 feet.

Fig. 19. **Pruning for Clearance over Roadway**

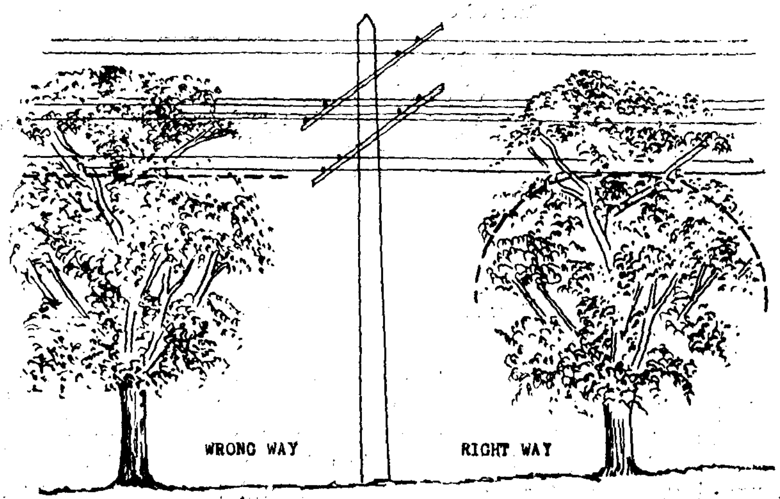


Fig. 20. **Pruning for Clearing Utility Lines**

Pruning for utility lines should be as in Fig. 20.

All such clearances should be obtained by pruning each year according to the tree's growth and in proportion to its size.

14.6. Planting of Gaps

Gaps occurring by removal and fall of trees should be systematically filled in by re-planting.

14.7. Numbering of Avenue Trees

Numbering should be done every 5th year, furlong by furlong, and in the direction of increasing milage, first on the left side and then on the right side. Scraping the bark for painting should be done so as not to peel it off ; only the dry scales should be scraped for an area 6 inches by 6 inches at 4 ft above the ground level and facing the road. The lettering should be stencilled in black paint after painting the background in white.

14.8. Removal of Dead or Dangerous Trees

Old trees which are precariously balanced and those that are dead should be promptly removed.

14.9. Protection of Roots

When roots are exposed by erosion of soil they should be protected by heaping up soil around the trunk. Care should be taken not to leave a benching at the top of the heap. Protection to roots will be particularly necessary if the trees are standing on sloping ground.

14.10. Filling cavities

Where a cavity has been formed in the trunk due to careless pruning, further damage should be prevented by cleaning and filling it up. This is best done as follows:

Carefully scrape out all dead wood. Wash the hollow thoroughly with a strong solution of permanganate of potash and fill it with 1 : 2 : 4 cement concrete rammed well and finish off with a little neat cement a little below the level of the bark. When the concrete has set hard, pare back the dead bark to induce fresh growth which will cover the fringe of the patch.

C. ROADSIDE DRAINAGE

15. DESIGN OF CHANNELS

15.1. Efficient surface drainage is an important element in the safe, convenient, and economical use of a highway. The procedure for designing channels to avoid future difficulty and abnormal expense in maintaining the drainage system consists of:

(i) estimating the peak rate of run-off from the area contributing to the discharge;

(ii) checking the ability of these channels to carry the estimated discharge without eroding or overflowing; and

(iii) designing protection against erosion or designing modified channel sections for increased capacity where necessary.

15.2. Requirements of Drainage Channels

The primary function of the roadside drainage channel is to provide efficient removal of surface run-off from the roadway and the adjoining country or area draining on to the road. It should have adequate capacity to carry the normal peak rate of run-off without over flowing. For ultimate economy, the channel should retain this capacity during the life of the road without excessive maintenance costs. This means that the channel should not erode or silt up. Also the drainage channel should have gently sloping sides and a slightly rounded bottom so that a vehicle forced off the roadway can run down into the channel without overturning. In hilly or mountainous country, considerations of economy in first cost will limit the extent to which this ideal cross-section may be attained. Roadland width should not restrict the width of channel necessary from hydraulic consideration.

15.3. Traffic safety and good landscape design demand a wide, shallow roadside drainage channel. The ideal cross-section of an earthen roadside drain should have a slope from the shoulder of at least 4 : 1, a rounded bottom at least 4 ft wide, and a back slope not steeper than 4 : 1. The depth should vary from a minimum of about 1 ft below the edge of shoulder in regions of low rainfall intensities to a minimum of $1\frac{1}{2}$ ft in districts of high rainfall. Depths and widths should be increased to provide additional capacity where the run-off analysis indicates that peak run-off rates from the drainage areas are of such magnitude that the

water is likely to rise above an elevation 0.3 ft below the shoulder of line. When the ideal cross-section results in an excessive amount of excavation which cannot profitably be used in the construction of embankment the width of the bottom may be reduced and the backslope steepened to not more than 2 : 1, provided the discharge capacity remains adequate. The slope from the shoulder may also be increased to a limit of 3 : 1. Considering all aspects, three cross-sections, Figs. 21 to 23, are proposed.

15.4. In rock cuts, the backslope will necessarily be very steep, approaching the vertical in the extreme case. In such

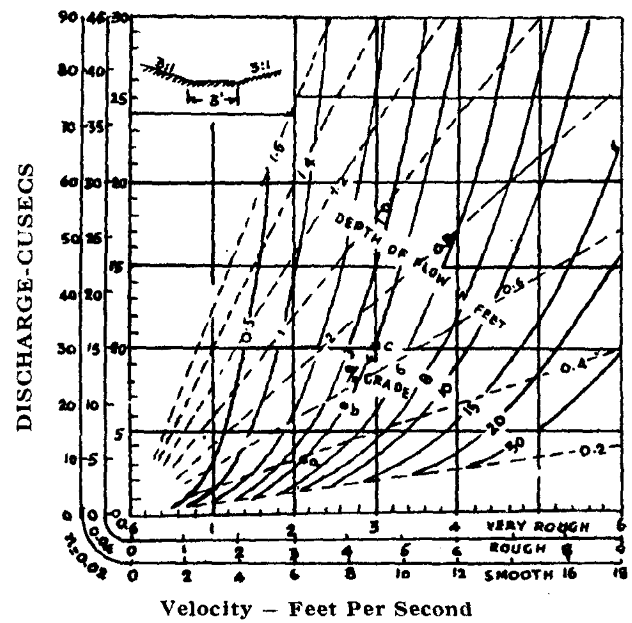
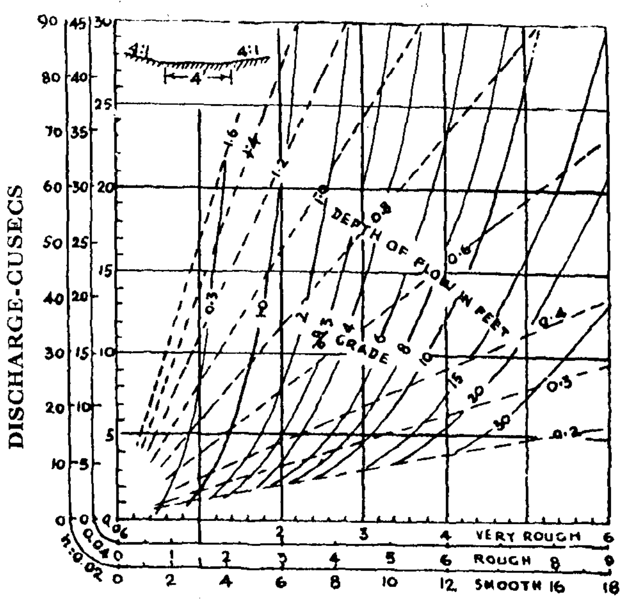


Fig. 21.

Relations between grade depth, discharge, and velocity for a channel 3 feet wide at the bottom and having 3 : 1 side slopes, for various linings,

instances the drainage channel may have a narrow V-shaped cross section just large enough to carry the peak run-off without overflowing.



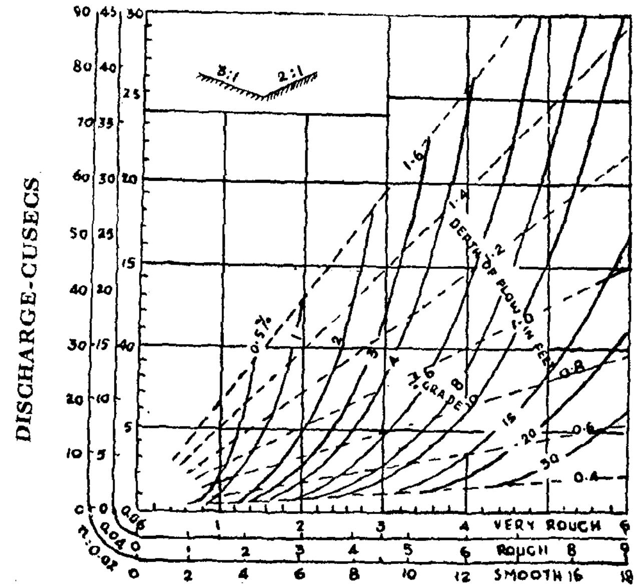
Velocity — Feet Per Second

Fig. 22.

Relations between grade depth, discharge, and velocity for a channel 4 feet wide at the bottom and having 4 : 1 side slopes for various linings.

15.5. Erosion in Drainage Channels

Control of erosion is fundamentally a matter of controlling the velocity of flow or of treating the material so that it will withstand the velocity likely, to occur. The velocity of flow in a channel depends on its grade; size and shape of its cross section, the roughness of channel lining; and the rate at which water is delivered to the channel. Curves in Fig. 21 to 23 can be used for finding the velocities in the channels of cross



Velocity — Feet Per Second

Fig. 23.

Relations between grade depth, discharge, and velocity for a V shaped channel having 5 : 1 and 2 : 1 side slopes for various linings.

section shown therein. The curves are computed from the Manning formula:

$$Q = A.\frac{1.486}{n} R^{\frac{2}{3}} . S^{\frac{1}{2}}$$

in which Q is the discharge in cusecs,

A the drainage area in acres,

S the slope in feet per foot,

R the hydraulic mean depth of the channel in ft,

n the co-efficient of roughness.

Table 1 gives the values of roughness for different types of linings and table 2 allowable velocities.

TABLE 1

VALUES OF ROUGHNESS FOR DIFFERENT TYPES OF LININGS.

Type of Lining	Scale	Value of n in the Manning Formula
Ordinary earth, smoothly graded	Smooth	0.02
Jagged rock, or rough rubble	Rough	.04
Rough concrete	Smooth	.02
Smooth rubble	Smooth	.02
Well-maintained grass, depth of flow over 6 inches	Rough	.04
Well-maintained grass, depth of flow under 6 inches	Very Rough	.06
Heavy grass	do	.06

NOTE.—Use roughest condition likely to exist for estimating capacity, and smoothest condition for estimating velocity.

15.6. Use of charts

Problem: Check the velocity for an earth channel: peak discharge is 10 cusecs, slope 4 per cent, cross section, Side slopes 3 : 1, and Bottom width 3 ft.

Since the channel is in earth, use the smooth scale. Move along the 4 per cent grade curve in Fig. 21 to the point "a" where discharge equals 10 and read 6.8 per second on the velocity scale. This velocity is excessive for earth, see Table 2. So either pitching or flattening of the grade by drops or ditch checks is necessary. Where soil and climate facilitate the easy establishment of grass, use the "rough" scale ($n = 0.04$) for the checking of velocity; from the curve for 4 per cent grade at "b" read velocity equal to 4 feet per second. This velocity is allowable for good sod.

If grasses and weeds are allowed to grow rank, the resistance to flow is increased and the velocity is decreased. Decrease in velocity entails an increase in cross sectional area if the given peak discharge is to be carried otherwise the channel may overflow. To check on this condition the depth of flow should be investigated as follows:

Dotted lines in Fig. 21 to 23 are drawn through points of equal depth of flow on the discharge curves. Thus in the preceding example water would flow about 0.4 foot deep in a bare earth channel (point "a"), or about 0.55 ft deep in the sodded channel (point "b"). If grasses are allowed to grow rank the flow will be approximately as shown on "very rough" scale ($n = 0.06$), viz., point "c" where the depth of flow is approximately 0.67 ft. A free board of at least 0.3 ft should be provided above the maximum depth of flow to allow for silting, for wave action, and for a factor of safety against an under estimate of peak run-off. See the worked out examples at the end.

TABLE 2.

ALLOWABLE VELOCITIES IN DIFFERENT TYPES OF LININGS.

Type of Lining	Allowable Velocity Ft per Sec.
Well-established grass on any good soil:	
Bermuda grass (Cynodon Dactylon. Tamil: Arugam Pillu. A creeping perennial)	5
Blue grass (Panicum Longiflorum. Tamil: Sellai pithu. A creeping perennial)	5
Buffalo grass (Panicum Barbinode. A coarse, hairy, spreading grass with long, trailing, thick stems).	4
Sudan grass (Sorgum Ludanese. Tall, quick growing, mostly annual.)	3
Earth without vegetation:	
Fine sand or silt, non colloidal	1-2
Ordinary firm loam.	2-3
Stiff clay, very colloidal	4
Clay and gravel	4
Coarse gravel	4
Shale	5

15.7. Increasing Discharging Capacity

In any channel with fixed side slopes the discharge capacity may be increased by increasing the grade, the bottom width, the depth, or by providing a smoother lining and thereby decreasing resistance to flow. Increasing the grade is frequently impracticable. Increasing the bottom width has little effect on velocity and is therefore desirable where the velocity is close to the limit. Increasing the depth increases velocity and is the simplest way of increasing the capacity. It requires less overall width and should be resorted to where road land is restricted or expensive. Smoothing of the channel lining increases capacity but this can generally be accomplished only at the considerable cost.

15.8. Instead of providing additional capacity in a given channel it is sometimes possible to divert part of the run-off into another channel as by the construction of an intercepting ditch on top of the cut slope.

On gentle grades the design of a channel is governed by the required capacity. As the grade is steepened the velocity increases but it cannot be allowed to exceed the maximum allowable non-scouring velocity. For a given rate of discharge and a fixed grade the velocity may be kept within reasonable limits by increasing the bottom width of the channel or by flattening the channel slopes. Both methods lead to a substantial increase in the overall width of the channel. Where it is feasible to provide a sodded channel slightly higher velocities than allowed on bare earth are permissible. Where sodding is not feasible, the channel may be paved: velocity is then no longer the governing factor. The capacity of a channel of given section may be doubled by changing the lining from well-maintained sod to concrete or masonry, or tripled if the initial lining was a rank grass.

Outfall channels carrying water collected from cuttings frequently involve steep grades which cause excessive velocities. In such cases the channel should be paved or its bottoms width increased. The required bottom width may be approximately found by the following formula:

$$b_2 = b_1 \times \frac{S_2}{S_1}$$

In which b_2 is the required bottom width, b_1 is the width of the standard section, S_2 is the proposed grade and S_1 is the grade on the standard section at which the given discharge produces the maximum allowable velocity.

If high velocities are developed in paved channels, provision must be made for stilling the velocity at the outlet unless the channel discharges into a pool of water of appreciable depth. This may be done by providing a wide apron with projections or baffle walls on the surface or by a low sill at the end, creating a stilling pool.

16. ESTIMATING RUN-OFF

16.1. Design of Roadside Channels

(a) Drainage areas are measured in the field while taking cross sections, and plotted on a drainage area map drawn to a reasonable scale.

(b) The run-off is estimated by either of the methods described below:

Ryve's Formula

$$Q = CM^{2/3}$$

in which Q = run-off in cusecs.

M = area drained in sq. miles.

C = 450 in flat tracts along the coast.

560 in tracts with greater slope and at a distance of 15 to 100 miles from the coast.

675 in limited areas near the hills.

1,000 for West Coast Districts.

As areas of a few acres only are generally involved in the design of roadside drains, the hourly rainfall is significant and the local characteristics are more clearly defined than in large areas.

The Burkli-Ziegler formula which takes account of these factors should be used.

$$Q = MRc \sqrt[4]{\frac{S}{M}}$$

in which Q is the run-off in cusecs,

M is the drainage area in acres,

R the average rate of rainfall in inches per hour during the heaviest rainfall,

S the average of slope of ground, in feet per 1000 ft and

c a coefficient depending upon the character of the surface drained and determined approximately as follows:

Description of area	Values of C
Paved streets and heavily built up areas	0.75
Ordinary residence areas	0.55 – 0.65
Sparsely built up areas	0.35 – 0.45
Villages with open spaces	0.30
Farmlands	0.25
Parklands, etc., covered with sod	0.20

Fig. 24 shows a graphical solution of Burkli-Ziegler formula for slopes from 1 to 400 ft per 1000 ft. This diagram is based on $R = 1$ inch and $C = 1$. To obtain run-off for other values of R and C multiply the discharge by the appropriate values.

(c) After peak rates of run-off have been estimated, the appropriate chart, Figs. 21 to 23, according to the standard cross sections adopted, may be used to estimate the resultant velocity and the depth of flow. Critical conditions will necessitate special study to develop economical designs.

16.2. Example

Fig. 25 shows the alignment of a road SP along with contours at intervals of 10 feet. Design the drainage channel.

Suppose it has been decided to have a 4 per cent grade from chainage 85 plus 90 to chainage 95 plus 90.

The road is not affected by the surface water on the left side.

All water on the right of AB goes directly into the valley and that to the left of AB is intercepted by the road, and therefore a suitable drainage ditch is needed on the right side to divert it to the lowest point at about chainage 96 plus 00 where a culvert will be required. CB shows the probable ridge. The roadside ditch will have to deal with all the run-off from the area ABC.

Area ABC is 0.01 sq. mile approximately.

The peak run-off from this area will be 26 cusecs (by Ryve's formula) assuming $C = 563$.

The worst affected section is at A.

To check the velocity in bare earth:

$n = 0.02$ from Table 1.

Graphical Solution of Burkli-Ziegler Formula

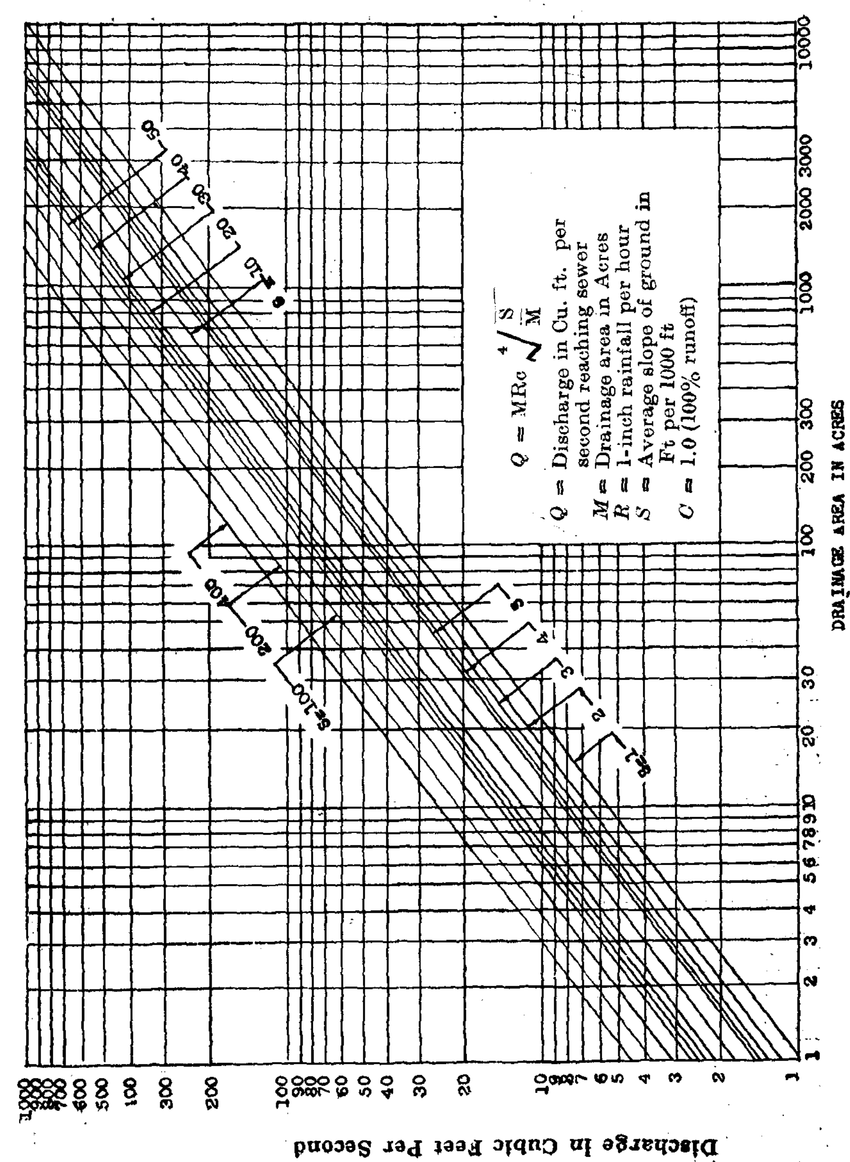


Fig. 24.

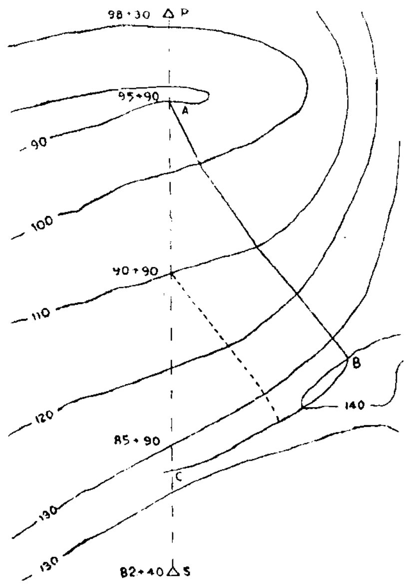


Fig. 25.

Move along the curve for 4 per cent grade till discharge equals 26 cusecs and read 8.7 ft per second on velocity scale (for $n = 0.02$). This velocity exceeds the permissible velocity for the soil in the area (4 ft per second, Table 2), so either pitching or flattening of the grade by drops or ditch checks will be needed.

If velocity is proposed to be controlled by drops, the gradient between drops should be such that the velocity does not exceed 4 feet per second.

If it is possible to provide sodding, the velocity will be 5.2 ft per second ($n = 0.04$ scale) which is permissible for well established grass.

The depth of flow will be about 0.9 ft and allowing 0.3 ft free board the required depth of channel will be 1.2 ft.

Section at A will be the worst affected. Intermediate points may be checked to ascertain at which point sodding may be stopped. For example, at chainage 90+90 where the discharge is 10 cusecs, for bare earth the velocity is 6.8, again too much. So sodding will have to be continued even beyond this point. With sodding the velocity is reduced to 4 feet per sec,

Appendix I

NAMES OF TREES AND SHRUBS SUITABLE FOR ROADSIDE PLANTNIG

S. No.	English	Latin	Tamil	Telugu	Malayalam	Kanarese	Hindi
1	2	3	4	5	6	7	8
1	Alexandrian Laurel	Gallophyllum Ionophyllum	Punnai	Punnagamu	Punna	Surahonnae	Undi
2	Aloe	Aloe Vera	Kathalai	...	...	...	...
3	Arjuna Myrabalam	Terminalia Arjuna	Vella Maruthu	Maddi	Marutha	Kaidaryavu	Arjuna
4	Asoka	Polyalthia Langifolia	Asoka	Asoka	Nedunar	Pungu	Asok
5	Bamboo	Bambusa arundinacea	Mungil	Bongu, veduru	Mola	Biduru	Banse
6	Bandrike	Dodonea Vicosa	Virali	Bandara	Varali	...	...
7	Banyan	Fiscu Bengalensis	Ala	Marri	Aal	Alada	Bargad
8	Cashewnut	Anacardium Occidentale	Munthri Andimangottai	Jidimamidi	Parangimavu	Tarukageru	Hijjali bodam
9	Coconut Palm	Cocos Nucifera	Thenga	Kobbari or Tenkaya	Thenga	Tengina	Nariyal

S. No.	English	Latin	Tamil	Telugu	Malayalam	Kanarese	Hindi
1	2	3	4	5	6	7	8
10	Country Fig.	Ficus Glomerata	Atthi	Medi	Atthi	Atthi	Gular
11	Date Palm	Phoenix Dactylifera	Perichchu	Karjuramu	Tenichcha	Kharjura	Khajur
12	Elengi	Mimusops Elengi	Magizh	Pagada	Mukuzha	Ranji	Mulsari
13	Goats Foot	Impomes Pescaprae	...	...	...	...	...
14	Golden shower	Cassia Fistula	Konnai	Rela	Konna	Kakke	Amaltas
15	Gulmohur	Poinciana Regia	Mayirkonrai	Erra-turayi	Alarippu	Kodanchi	Gul Mohur
16	Indian Beech	Pongamia Glabra	Pungu	Ganuga	Punga	Honge gida	Kanji
17	Indian cherry	Eugenia Jambolana	Nagai	Neredu	Naval	Nerula	Jaman
18	Indian Cork tree	Milligtonia hortensis	Maramalli	Akasamalli	Katesam	Biratumara	Akas Nim
19	Indian Gooseberry	Phyllanthus Emblica	Nelli	Usirika	Nellikay	Nellikai	Amlika
20	Jack	Artocarpus Integrifolia	Pala	Panasa	Pilava	Halasu	Kathal
21	Jujuba	Zizyphus Jujuba	Ilandai	Regu	Llanda	Bogari	Baer

S. No.	English	Latin	Tamil	Telugu	Malayalam	Kanarese	Hindi
1	2	3	4	5	6	7	8
22	Mango	Mangifera Indica	Maru	Mamidi	Mavu	Mavina	Am
23	Margosa	Melia Azadirachata	Vembu	Vepa	Veppa	Berina	Neem
24	Mowa	Bassia Longifolia	Illuppai	Ippa	Irippa	Ippegida	Mohva
25	Mudar	Calotropis Gigantea	Erukku	Jilledu	Erukka	Yakkeda	Akan
26	Palmyra palm	Borassus flabelliformis	Panai	Thati	Pana	Pane	Thar
27	Portia	Thespesia populnea	Puvarusu	Gangaregu	...	Hawarasi	Dumbla
28	Rain tree	Enterolobium Saman	Mazhamaram	Nidaraganneru	...	...	...
29	Red silk-cotton	Bombax Malabaricum	Mulilavu	Mundlaburaga	Pula	Mulluburaga	Ragaisemal
30	Screw Pine	Pandamus tectorius	Thazhai	Mogili	Kaitha	Mundigi	Ketgi
31	Siamese Cassia	Cassia Siamea	Ponnavarai	Sinna Thangedu	...	...	...
32	Small Date	Phoenix Farinifera	Ech-chu	Eetha	Chiteen thal	Esala	Samdola

S. No.	English	Latin	Tamil	Telugu	Mala-yalam	Kanarese	Hindi
1	2	3	4	5	6	7	8
33	Tama-rind	Tamarind-us Indica	Puli	Chinta-manu	Puli	Huna-Scehunnu	Imli
34	Tanner's Cassia	Cassia Auriculata	Avarai	Than-gedu	Avara	Avara	Tarvar
35	Teak	Tectona Grandis	Thekku	Tekko	Thekka	Tegu	Saguna
36	Wom-an's Tongue	Albezzia Lebbeck	Vagai	Dirsa-nam	Vaga	Bage	Siris
37	Wood-apple	Farnia Ele-phantum	Vila	Velaga	Vilavu	Baelada	Dharkth Kaveet

Appendix II

DESCRIPTION AND IMPORTANT HABITS OF TREES AND SHRUBS SUITABLE FOR ROADSIDE PLANTING

(Numbers refer to Serial number in Appendix I).

1. **Allexandrian Laurel** is a tree of considerable size, native of India, commonly found near the sea coast, with white scaly bark and foliage of large, elliptical, rich, polished dark green, thick leaves. It bears in June, drooping racomes of large, white delightfully fragrant flowers, and brings forth numerous marble-size seeds, from which it may be easily propagated. The seeds are ready during July-August and must be sown absolutely fresh without removing the rind or cracking the shell.

The roots take any shape according to location and the tree is particularly useful for conserving channel banks.

2. **Aloe.** A stemless succulent plant with large variegated leaves with spiny edges. Propagated by suckers. Not found in moist districts.

3. **Arjuna Myrabalam** is a large white tree; grows very tall, and girth upto 40 feet are not uncommon. The trunk and branches are smooth and white with practically no scaly bark. With its great size and foliage of lanceolate leaves it makes a magnificient avenue tree. Not much shade, and no fruit value, and does not damage adjoining crops. Gives very good timber.

The tree blossoms in March and the fruits, which are of the size of an arecanut, of a light tawny colour and feathery stuff, ripens in June.

Comes up in any rich soil. Can be propagated by seed which are scattered by wind. On the day preceding sowing, the seeds are soaked in cow-dung water. The seedling attains 2 to 3 feet height in 3 months and grows to 8 ft in one season. Does not require attention after about two years.

4. **Asoka** is a handsome truly evergreen tree with long tapering, lanceolate, shining leaves. Its chief ornament is the foliage and symmetrical form. The new flush of leaves is completed by April when the tree assumes an extremely attractive appearance. Flowers creamy-green. Fruit in clusters all over the branches, not unlike Coffee berries.

Easily raised from seed which are ready in July-August.

An excellent choices for a shady town-avenue, also for clumps and for planting singly.

5. Bamboo. Bamboos for the most part like a fairly moist climate. A very large number of varieties belong to low, damp country even though some grow at a height of 3,000 feet above sea-level.

Old stumps should be cut at the nodes, for if cut between nodes the hollow stems will form receptacles for rain water, where mosquitoes will breed.

Bamboos flower after a very long period, which may be up to fifty years or more, after flowering the parent clump dies.

It takes a long time for a clump to form. The first year the suckers usually give rise to two stems, often thin, solid and twisted. Subsequent stems are normal, and double in numbers each year.

Bamboos are best propagated in rainy weather by long suckers, with roots. The ground should be dug well before planting. The sucker should be put into the soil at a slant, and the cut top protected with a dab of mud and cowdung paste.

6. Bandrike is an exceedingly pleasing, evergreen, large bushy shrub. Flowers are pale green. It thrives well in any soil and climate, can stand long periods of draught. Its large expanse of cheerful, green, fine, twiggy foliage is very refreshing to the eye.

Propagated by seed, which it bears abundantly throughout the year. Seedlings are raised in seed beds and planted in prepared furrows on slopes for prevention of soil erosion. It is extensively used for hedges.

7. Banyan is a large, spreading, smooth-barked tree with large, leathery, shiny, ovate leaves. Remarkable for its aerial roots, which hang from the branches and on reaching the ground rapidly take root and develop into independent stems supporting one immense head, resembling a number of trees.

Easily propagated by cuttings.

Eminently suited for camping grounds, but not for highway avenues, as it gives a rather low and dense shade, and eventually becomes unwieldy. May be planted at locations such as river banks, approaches to shandies etc. where large numbers of carts and draught animals camp or take shelter.

8. Cashewnut is a medium sized tree with a fine ornamental foliage of oval, blunt, alternate leaves. The fragrant, rose-coloured flowers are borne in panicles during March—April. The multi-coloured fruits consisting of the pyriform, fleshy peduncle

on which the nut is seated ripen in June-July. It is very common on the west coast of the peninsular India, and thrives best in sandy soil though it does not dislike gravelly soil. It is ideal for preventing sand dunes or wind erosion because of its low drooping branches and thick foliage. Not suitable for avenues, but may be planted on sandy slopes.

Easily propagated by seed which stand storage. Large, ripe seed nuts are selected and soaked in cowdung water for 24 hours when the shell becomes soft. It may be planted in situ or seedlings may be raised in pots and transplanted. Does not need any tree guard as leaves are not touched by goat.

9. Coconut Palm. The ideal conditions for the coconut are (1) proximity to the sea, (2) a temperature ranging between 55° and 90° F, (3) rich but very porous and friable soil, (4) a rainfall of 50—80 inches, well distributed. Coconuts, however can be grown at considerable distances from the sea and, under artificial irrigation, in regions of low rainfall. They must, however, always have a light rich soil, and will not tolerate great extremes of temperature.

Coconuts are propagated by their nuts. For seed purposes nuts should be selected from trees of good growth and producing nuts of desirable size and quality. The nuts should be gathered when half full of " milk " and placed in a nursery to germinate. It is a common and reprehensible practice to let the nuts sleep in a well till they germinate. The seed nuts should be laid one foot apart under half shade in well cultivated and enriched soil, and almost covered with the soil. The nuts should be watered every second day if there is no rain, and the seedlings with nuts attached transplanted in pits 25 feet apart each way in the field when from 6 to 12 months old.

10. Country Fig is a medium sized tree with a whitish trunk and branches covered with light scaly bark and green ovate leaves. Flowers are rarely seen. Puts forth clusters of fruits all over the trunk and branches, practically throughout the year. The fruits are green, when raw and turns brick-red when dry.

Can be propagated by root shoots or tender cuttings. Seeds appear to have a dormant period and are indifferent to germination.

11. Date Palm. The Date flowers and fruits in June and is propagated from seeds which may be dried and kept. The seeds are sown direct in the pits.

It affords good protection against soil erosion.

12. Elengi. The tree is indigenous to the moist Indian forests and is widely cultivated. A moderate-sized, flow growing evergreen tree with a dense crown of shiny, small leaves with somewhat undulate margins. A delightful fragrance diffused by numerous clusters of white, star-shaped flowers which appear during March-April. The tree is also very attractive when its round berries turn bright-orange on ripening.

Propagated from seed obtained from the edible fruit which ripens in August. The seeds may be sown straight or kept stored for later use.

Very suitable for small shade avenues and for planting singly.

13. Goats Foot is a wild trailing plant growing abundantly by the sea-side, with curious two-lobed fleshy leaves ; produces in the hot season numerous large rose-coloured flowers. Can also be grown on river banks, and in any sandy and light soil.

Propagated by clippings with roots. Requires watering for a few days.

It is an excellent sand binder and therefore useful for stabilising sandy slopes.

14. Golden shower. The epithet *Fistula* in the botanical name *Cassia Fistula* means a pipe and refers to the shape of the pod. It is a moderate sized, deciduous tree, somewhat unsymmetrical unless properly trained by timely pruning. The flowers appear on bare branches, or as the new foliage is about to come out during April-June. They are large, bright-yellow and borne in long, pendulous, inverted-cone clusters, fully justifying the name Golden Shower. Some of the long brown pods of the previous year, which still persist on the trees, hanging in clusters, only further enhance the beauty of the tree by their rich contrast against the golden yellow flowers and the bright-grey branches. The fresh leaves are of a rich coppery colour turning later to bright-green.

The tree is not exacting as regards soil and does not mind the heat.

Propagated from seeds which are hard and take a few weeks to germinate. Seeds available July-August. Seedlings stand trans-planting well provided the root-system is not damaged ; slow growing to begin with, they develop rapidly after a year.

The tree is leafless during February-March, and is attached by shoot borers in the rains, which at times kill entire branches.

The new foliage is also very much susceptible to attack by defoliators. Hand picking of the catterpillars is the best remedy. The tree is an excellent choice for small avenues, for flower clumps and for planting singly. There is a late flowering variety with shorter racemes of somewhat paler flowers which are deliciously scented. The pods of this variety are longer and thinner. No timber or fruit value.

15. Gulmohur is a native of Madagascar which is widely and successfully planted in India. A medium-sized, fast growing tree with an umbrella-like crown of finely-cut, bright-green foliage. Its chief ornaments are its flowers, which appear when the tree is completely leafless in April-May, covering the crown in its entireity with dazzling, large, flaming-red flowers, making it a most conspicuous object in the landscape. *Leafless from March to May.*

Usually grown from seed, which are somewhat obdurate to germinate ; but it can also be raised from cuttings. The seeds are obtained by splitting open, the swordlike fruits. The growth is rapid and trees begin to bear in four or five years. If too near water the tree begins to develop young foliage before the flowering season and does not flower prolifically. It should therefore be planted in a dry locality. The tree has superficial roots which compete with flowering plants and shrubs under it or near it. It is therefore best planted well away from these.

Very suitable for town avenue, for planting singly, and in large flowering clumps in wayside parks and inspection bungalow compounds.

No timber or fruit value.

16. Indian Beach is a moderate-sized, nearly evergreen, fast-growing tree with a spreading, shady crown of shining, dark-green leaves. It bears racemes of palmauve flowers in great profusion in June, which however are not very attractive. Prefers moist localities but would grow in the driest place.

Easily raised from seed which should be sown directly in May. It is apt to get malformed if not pruned from time to time and when seeds are ready in September or October.

Seed has a thick shell which should be broken without injuring the kernal and its thin covering prior to sowing. The seeds can be preserved with the heavy shell on. The seed will be light yellowish green if fit for germination. If the colour is changed it is unfit for germination.

Wood is useful as timber, oil is obtained from seeds and foliage is used as green manure.

17. Indian Cherry is a large timber-tree with fine shady, verdant foliage of dark-green shiny leaves, very common in all parts of india; moisture-loving and somewhat slow-growing. The tender leaves are copper-coloured. Bears a juicy kind of fruit, with a stone in the centre, with a flavour peculiarly its own. There are two well-known varieties; the first blossoms in February-March, bears fruit in September-October, and the fruits are round; The second variety with leaves slightly larger, blossoming in January and bearing somewhat larger elongated fruits in May-June. The second has better market value.

Propagated by sowing the stone during the rains. Seeds must be sown fresh, and need careful handling.

As the bark is a popular remedy for stomachache it is liable to be stripped by pilferers. The fruit is edible. Very suitable for shade avenues in towns, especially if alternated with a flowering tree.

18. Indian Cork tree is a lofty tree with exceedingly beautiful Neem-like foliage of deep-green decompound leaves looking remarkably handsome in the cold season with its numberless panicles of large, pure white fragrant flowers. During November-December the tree is covered with drooping masses of fragrant, which flowers filling the surrounding air with their perfume.

The tree is extremely brittle and shallow rooted and must be planted well away from electric and telegraph wires. Graceful as on occasional plant or in small clumps, or as avenue trees in town and village limits very hardy and unmindful of soil.

Easily propagated from root-suckers which appear in troublesome profusion all round the tree. May be raised from seed also.

19. Indian Gooseberry is a medium-sized rather handsome tree with smooth, silvery-grey trunk and branches and graceful foliage of small leaves. The tree flowers in July-September and puts forth small, round light green fruits during December to March. In the core of the fruit is ribbed nut or stone about 3/8 inch diameter which contains the seeds.

Propagated by seed sown in the rains. The nuts are callected when the fruit gets a rosy tinge, dried and preserved. For sowing, the nuts are cracked and broken open along the ridges and the small seeds collected. One or two seeds are sown in each

pot, and the seedling will be ready for transplantation in about 6 months. Comes up in any soil and grows to a fairly large size if the soil is good. Not a very shady tree.

Wood is excellent for fuel.

20. Jack. The tree grows to a considerable size, has a thick foliage or dark green leaves of the size of a man's palm. In story soil it grows short and thick; in sandy ground tall and spreading and if the roots happen to come in contact with water the tree will not bear fruit.

There are two varieties:

(1) The hard kind, distinguished by the large size of the edible pulp, and by the abundance and thickness of its juice. The exterior of the fruiet is fairly smooth to the hand, and green, and the nuts or seed comparatively small. The leaves are of a rounder form than those of the second variety.

(2) The soft kind, is reckoned a much inferoir fruit, with the inner pulp small in quantity and its juice scanty, thin, and watery. The fruit is much smaller that that of the first variety with a rough exterior, and with large seeds.

The jack-fruit is not borne, as most other fruits are, from the ends of branches, but upon stout footstalks projecting from the main trunk and the thickest branches of the tree. In no other way, indeed, could its ponderous weight be sustained. The situation of the fruit, moreover, is said to vary with the age of the tree, being first borne on the branches, then on the trunk, and, in old trees, on the roots. Those borne on the roots, which disclose themselves by the cracking of the earth above them, are held in highest estimation.

The tree blossoms and sets its fruit in November, and continuous to do so even until March. The flowers give out a sweet, agreeable smell.

The tree requires a deep, rich, light soil for its best growth. The heavy rainfall and moist air of coastal districts suits it, but it can be grown in sheltered situations also by irrigation in any place with a suitable temperature. The tree bears fruits from the fifth to eightyear.

The tree is propagated either by planting the seeds in groups of 4 or 5 in well manured pits 30 feet apart and then keeping the strongest seedling, or by raising seedlings in the nursery and transplanting 30 feet apart in the field. The seeds should be sown absolutely fresh without injuring the membrane covering it.

The tree has both timber and fruit value.

21. Jujuba. A small, very thorny tree, blossoms in the rains by the end of September and its fruit ripen b. end of January.

The fruit, which is usually borne in unbounded profusion, is perfectly round, of the size of a very large cherry, smooth, shining, of a tawny yellow colour and rather acid in flavour.

The tree is extra-ordinarily rapid in growth ; When cut down after fruiting, it will spring up again to the height of fifteen feet, and be covered with an amazing crop of fruit, by the following season.

Propagated from seed, and requires no care for its cultivation. The seeds are collected, and stored for the dormant period which is from January to June. The seeds are sown in August, preferably on roadside pits directly. It may take some weeks for the seeds to sprout.

Not grown on Hills.

The timber is used for structural purposes. Fruits have market value.

22. Mango is a common, large, evergeen tree with a dense round crown of dark-green leathery leaves. Essentially a shade tree, which owes its popularity to the edible fruit it produces. When the tree renews its foliage annually during February—April not all the leaves are shed simultaneously, with the result that when the new flush is appearing the tree presents a vivid display of colour as the leaves are coppery to begin with, then turn yellowish-orange, and later pale green and finally assume their dark-green colour. It will grow on practically any soil but for best development moisture and good soil are essential. Very long-lived tree. Bears fruit during March to June.

Mango tree is easily raised from seed. There are innumerable varieties good and bad. Tall growing varieties should be selected.

The nut should not kept for more than a month before sowing. The seed should in any case be sown before the kernel dries. In sowing, the seed should be placed flat. The tree grows fast but should be carefully pruned in early life to get a clean bole of at least 12 feet and to prevent interlacing of branches. Highly cultured variety do not attain large size and they are not suitable for roadside planting.

Mango tree is used for timber purposes, especially for planks.

With age the tree is liable to develop hollows.

23. Margosa. The tree stands a very dry climate and is a good roadside tree in dry districts, but is a comparatively slow to

grow. Not suitable for waterlogged areas. There are examples of huge trees with 39 feet high trunks and 15 to 20 feet girth in the black cotton soil of Cuddappah.

Propagated by seed. When the ripe seeds drop down in May —June they are collected and sown during July—August. As the seed has oil it will not stand much storage.

Very good timber ; oil is obtained from seeds.

24. Mowa is a very common large the milky variety of the plains of India. Leaves fall gradually from February to April and new leaves appear in April-May either with or shortly after flowers which scent the air heavily. It affords good shade it is an excellent choice for avenues and village camping grounds. The tender leaves are coppery and a conspicuous sight in March-April. The fruit ripens from June to August. Propagated by seed which should be sown absolutely fresh and directly in pots. Bats eat the ripe fruits and seeds may be collcted from such fruits which drop down to the ground. The seeds should be removed without injuring their shells. The plants may be put out when about 12 months old.

The corollas known as *Mahua* are a food of the poor people. They are also distilled into a spirituous liquor. Oil is also extracted from the nut and the cake is the poor man's soap. Wood is used for structural purposes.

25. Mudar. These are unquestionably very handsome flowering shrubs of medium height 10-15 feet with white stem and thick, large, green leaves with shades of white. Put forth white and light violet flowers.

Propagated by seeds. The plant flowers and bears fruit almost throughout the year. The fruits are about 6 inches long and resemble the Silk Cotton fruit. The fruits are collected when they turn brown and dried inside muslin bags to prevent the seeds escaping when the fruit dries up and opens explosively. The seeds are preserved and sown in August.

Foliage is used as green manure.

26. Palmyra Palm. This palm is well known and is of unquestionable economic worth, every part of the tree being useful in some way or other. Propagated from seeds. Trees with luxuriant large leaves, long stems and sturdy trunks are selected for seed nuts. The palm flowers in February to March and puts forth its fruits in April and May and matures then in about July and August. Generally luxuriantly growing trees are taken up for tapping juice and the tapping season begins from February

and lasts till June. Only untapped palmyras bear fruits; tender fruits are cut for the pleasant end refreshing jelly like pulp in hot weather. So arrangements should be made well in advance with owners of selected groves for ripe fruits for obtaining seed nuts.

Counting of the nuts when the requirements are large is a tedious job. After extensive trials it has been found that one hundred of seed nuts with the fibrous casing weighs about 44 lbs and just fills up a cement bag or about 5,000 seeds go to a ton at an average. Therefore, weighed out and packed in cement bags and transported from groves to stores or to site of plantations.

The mature fruits when ripe vary in colour from light golden to black, are globular in shape 6 to 8 in. in diameter, soft, luscious, and emit a fragrant smell as the ripe ones fall off from the trees. The fruits carry within the core 1 to 3 stones or seed nuts 2 inches size, flat, heart, shaped and fibrous outside.

The period during which the fruits are obtained is short. They are stored and heaped up in shade for extraction of nuts. After a few weeks the pulp ferments and dries up leaving the nuts loose in the moist fibrous casing. By mere handling these seeds are separated from the fibrous stuff and are ready for planting. Nuts even from boiled or packed fruits germinate.

Cultivation. The palm is propagated by direct sowing as the seedlings do not stand transplantation well. A moist climate is necessary during sowing period. It grows well in good loam, leaf mould and sand. The spot where the palmyra is to grow is turned over and loosened with a spade and the seed is buried under the loosened earth, say 6 inches below ground surface. In harder soils the holes are to be made deeper and filled up with sandy or light soils for the seed to put forth its shoot down unobstructed. When the nut begins to germinate the cream coloured substance of the consistency of cheese is formed inside the shell. From this the root of the germ or the young plant protrudes and sends a shoot downwards to a depth of 3 feet to 4 feet and then from the bottom of this shoot, the bud which forms the stem is developed. Within two months from germination, the tender shoot 12 inches to 15 inches long is found beneath the surface, about 1 inch thick and tapering off to a point.

If this shoot is cut across, it will be found to enclose the first loaf in a small oval hollow about $\frac{1}{8}$ in. diameter extending from bottom. When these shoots are about 9 to 12 months old they put forth two leaves. These are $1\frac{1}{4}$ in. broad and 2 to 3 feet long with a few folds in each leaf. Then the leaves issue from the ground no part of the stem is seen; but a succession of leaves sprout, increasing in breadth and thickness for about six year

when the stout stem at the ground surface becomes visible. Easily 95 per cent of seeds planted germinate and put forth leaves in about 9 months.

Protection. The seed nuts are sown in about October to November and the tender edible roots are ready only by January or early in February. The main difficulty experienced is protection against cattle and goats. The first few leaves put forth are tender and need protection. If these are protected, the plant develops vigorously and puts forth thick leaves which are self-protective. As soon as the tender leaves appear on the ground surface, the spot is heaped with prickly pear or other thorny vegetation to afford necessary protection against goats and cattle.

27. Portia is a small, evergreen, rapidly growing tree with a dense foliage of cordate-acuminate leaves. The yellow flowers with dark-purple blotch at the centre, fading to rosy-violet, are borne throughout the year.

Propagated from seed or cuttings, mostly the latter.

Not recommended for avenues because of its twisted trunk and tendency to develop hollows.

28. Rain Tree is a large tree of extraordinary rapid growth. An excellent shade tree for roadsides up to a certain age, but in hot, moist regions, at low elevations, assumes a great size, with large spreading surface roots, often becoming top-heavy after the age of 40-50 years.

Easily raised from seed which may be preserved for use. May be raised from cutting also.

May be planted where there is a fair amount of subsoil water, but not in cyclone areas where they are easily uprooted. Wood is valuable.

29. Red Silk-Cotton is a fast growing tall tree with a straight cylindrical bole and branches in whorls. The large, bright, reddish-pink flowers appear in March when the tree is leafless and make the tree a conspicuous object of beauty.

Grows best in light rich soil with a high water table. It is planted singly or intermingled with coconut palms along fringes of garden lands or wet fields.

Propagated by seeds which are collected in August and which may be preserved. Sown directly on a sandy seed bed and grows to a height of 6 to 8 feet in 3 months, when it is lifted and planted on the roadside. It does not require much nursing beyond the 1st or 2nd year. Begins to bear fruit in the 4th year.

May be raised from cuttings also but such trees do not bear fruit.

Though a short-lived (about 20 years) it is a tree of great economic worth. The timber is used for kattamarams, country boats and for planking.

30. Screw Pine is a large shrub 15 to 20 feet. Indigenous, and common in swampy places; named in reference to the curious screw-like arrangement of its long, spine-edged, sedge-like leaves on the summit of the stems. It extends over a large space by sending down aerial roots from its branches. Blossoms during the rainy season with panicles of large, white, sheath-like leaves, enclosing spongy-looking bundles of closely packed minute flowers. The tender white leaves of the flowers chiefly those of the male, yield that most delightful fragrance for which they are so universally and deservedly esteemed.

It appears to thrive best in low, swampy ground and hence is admirable for planting near toes of embankments through swampy ground or along tanks and ponds. Occasional flooding does not harm it.

Propagated readily by cuttings put down in the rains. In rather wet situations these plants can be grouped with grand effect.

31. Siamese Cassia. The specific nane refers to the fact that the species is a native of Siam (Thailand). Widely planted as a roadside tree. A large, fast growing evergreen tree with a somewhat malshaped bole and very brittle branches. It is strikingly attractive during September—October with its bright-yellow flowers borne in erect, terminal pyramids. It thrives best on moist soils. Very easily propagated from seed. Best suited for quickly concealing an unsightly background and for mixing with other flowering trees planted in large clumps.

32. Small Date. This is similar to the Date-palm, but on the name indicates, is smaller, growing to a height of 5 to 8 feet. Propagated like the date palm.

Affords good protection against soil erosion.

33. Tamarind. Tamarind is a fairly big tree growing to a height of 80 feet and a girth of 25 feet. It is drought resistant and can thrive in any soil. It dislikes high altitudes and water-logging. It is a very good avenue tree and is very extensively used. It flowers in six to seven years. The flowers are small, variegated yellow and red, appearing during May-June. Fruits ripen during January–March in South India.

Plants are always raised from seed but whether the varieties may be depended on to come true to their seed, it is impossible to say. Seeds should be obtained in the ripening season from first class fruits–Sour, pulpy, long and multi-podded. The fruits may be stored in bags and the seeds separated from them in the sowing season, or else the seeds separated soon after collection of the fruits and safely stored away.

Produces hard wood, good fuel, and valuable fruit.

34. Tanner's Cassia is a small, with dense, agreeable foliage, easily distinguished by the ear like appendage between each pair of leaflets; ornamental when in blossom with its abundant large yellow flowers in the cold season. An inhabitant of dry salt land. Its bark is used for tanning. Propagated by seed which are usually ready in March–April. Seedlings are raised in seed beds; planted before the rains in rows 3 feet apart and at 3 feet intervals in prepared furrows.

Very hardy plant which affords excellent ground cover against erosion because of its matty roots.

35. Teak is gregarious tree which yields one of the most important commercial timbers of the tropics. Teak is considered best when produced on calcareous soil. Grows tall with a straight cylindrical bole and foliage of large leaves which does not give much shade.

Best propagated by root-shoots obtainable from the Forest Department.

On the roadside they are best planted in clusters for column effect.

36. Woman's Tongue. The Americans have called this tree "The Woman's Tongue Tree" because of the clattering noise of its dried pods in a breeze. Believed to be wild in the sub-Himalayan tracts, and widely planted throughout India. A large, handsome tree with a straight bole and a broad-topped crown with spreading limbs. The flat, rather wide pods are characteristically straw coloured and strikingly attractive against the dark-green, fresh foliage. Leafless during January–March. The fragrant flowers appear during March-April and the masses of of greenish-yellow blossom borne in globuler heads are conspicuous against the new foliage.

Easily raised from seed which are available July–August Pods are stripped open to obtain the seeds which may be pre served if necessary.

Suitable for highway avenues. Fairly fast growing and highly valued as timber. Its hardness makes it eminently suitable for making hubs of wheels.

37. **Wood-Apple.** A common jungle tree of this country. Not a very shady tree and has sharp shines. The fruit is round, of a pale-green colour, and about the size of a cricket-ball.

When the hard shell-like rind is cracked the interior is found full of a brown, soft, meally kind of substance, rather acrid, having a strong smell of rancid butter. It ripens in October.

The tree may be propagated by seed or by cutting and planted in the rains. The pulp of the ripe fruit may be washed to collect the seeds, and the seeds may be preserved for sowing. The tree comes up in any soil and does not require much nursing and after care.

Not grown on the hills.

Appendix III

MANURES

1. Manures may be classified as follows :

   (i) Those supplying mainly nitrogen such as Cow-dung, horse-dung, sheep-dung, goat-dung, leaf-mould, green manure, groundnut husk, oil cake, night-soil, nitrates of sodium, ammonium sulphate, calcium cyanamide, etc.

   (ii) Those supplying mainly phosphorus—bones, calcium superphosphate, fish.

   (iii) Those supplying mainly potash—ashes, sulphate of potash.

A complete manure must contain nitrogen, phosphorus, and potash, and hence a mixture of the three groups is recommended.

The function of nitrogen is to increase vegetable growth. Excess of nitrogen means plenty of wood and leaves and little flower or fruit.

Phosphorus hastens maturity and assists the ripening of fruits.

Potash is essential to the plant for the proper manufacture of its carbon-compounds, starch, sugar, and cellulose.

2. Some of the common manures used in roadside planting are described below :

Farmyard Manure. Cowdung is the oldest and best general manure. Solid dung contains from .05 to 1 per cent of nitrogen in a gradually available form, about 0.3 per cent of potash, and 0.3 per cent of phosphoric acid. Horse-dung is somewhat less rich in these elements, and sheep and goat dungs are richer. The urine of cows, sheep, goats and horses is also rich in manurial value and hence the bedding of stables and byres mixed with the solid dung, is an excellent manure. Farmyard manure of this type protected from rain is best used after it has been allowed to remain for sometime in a pit, and occasionally forked over to aerate it.

Leaf-Mould. Fallen leaves of avenue trees, particularly at the time when mangoes and other fruit-trees shed their leaves, should be collected and thrown into a deep pit, dug for the purpose. In about a year and a half after the pit is filled, the leaves thrown into the pit will have been converted into invaluable manure. If the pit is thoroughly soaked two or three times in the hot season the decay will be hastened. It will be found to contain worms and other vermin which should be carefully removed before it is used.

Charred Turf. An excellent material for general potting purposes may be obtained by charring turf, which should be exposed to the sun, with the green part undermost. In a few days it will become thoroughly dry, and could be roasted for use.

Compost. A compost is a mixture of dung and earth with other organic materials. A simple method of making compost is to sun-dry the organic matter in the air and place it in a pit with a little earth sprinkled over the top and lightly watered. Further layers of organic matter and earth follow until the pit is full. In a cold place the compost may take 4 to 6 months to mature but in a hot place it will be ready in 2 to 4 months. The micro-organisms of the soil actually convert the organic matter into manure.

Rules of Manuring. The followiug are a few simple rules to be observed in the application of manures:

(i) Never put raw manure of any kind in direct contact with the plant. Always mix it well with the earth.

(ii) It is better to manure little and often than much and seldom.

(iii) For profusion of leafy growth add nitrogen, for plenty in flowers and fruit reduce nitrogen and increase phosphorus and potash.

(iv) Do not apply easily soluble manure just before heavy rain.

(v) Apply manures other than soluble ones during the rains and at seasons when the tree is in rapid growth.

Paper No. 170

GLOSSARY OF HIGHWAY ENGINEERING TERMS

By

THE SPECIFICATIONS & STANDARDS COMMITTEE OF THE INDIAN ROADS CONGRESS.

[Following precedent the recommendations of the Specifications and Standards Committee on "Glossary of Highway Engineering Terms" are published in the Journal. Members are requested to send their comments in writing not later than the 1st November, 1954.]

1. For purpose of easy reference, the terms of the Glossary have been grouped into the following eight Sections:

SECTION 1. **Highways - general, classification.**

SECTION 2. **Preliminary operations.**
- 2.1. Location.
- 2.2. Surveying.
- 2.3. Setting out.

SECTION 3. **Preparatory works.**
- 3.1. Earth works.
- 3.2. Soils.
- 3.3. Drainage.
- 3.4. Structures.

SECTION 4. **Surface construction.**
- 4.1. Surfacing types.
- 4.2. Construction details.

SECTION 5. **Materials.**
- 5.1. Classes.
- 5.2. Properties and tests.

SECTION 6. **Plant and Machinery.**

SECTION 7. **Traffic.**
- 7.1. General terms.
- 7.2. Signs and directions

SECTION 8. **Miscellaneous.**

2. Sections 1 and 2, and sub-section 3.1 were presented to the Congress as Paper No. 146 and discussed at the Bombay Session. Sections 3.2 to 5.2 are included in this Paper. As soon as all the Sections have been finalized, the Glossary will be published as a book.

3. To facilitate reference to published literature, as classified in libraries, the Universal Decimal Classification numbers have been given wherever it has been possible.

4. The use of terms given within brackets is deprecated.

5. Explanations, wherever necessary, are included in brackets along with the definitions.

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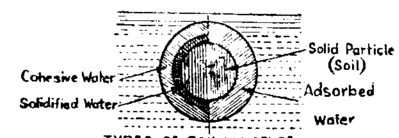
SECTION 3—PREPARATORY WORKS

3.2 SOILS

Definition No.	U. D. C. No.	TERM	DEFINITION
32.01		ABSORPTION	The entry of a fluid into a body through the pores of the latter.
32.02		ADSORPTION	The phenomenon that causes attachment of a fluid to the surface of a solid particle owing to a form of molceular attraction.



TYPES OF SOIL MOISTURE

32.03		BASE EXCHANGE	A property by virtue of which certain minerals, notably the Zeolites can exchange ions of, say calcium for sodium, magnesium, potassium, or any element of the alkaline earth group, when in a suitable environment. [The reaction is essentially of a chemical or ionic character.] 2. An exchange of bases. [Refers to the reaction which certain insoluble constituents of soils undergo when they are brought in contact with a salt solution. The cations* of the salt replace the bases from the soil.]
32.04		BINDER	The fine cohesive soil (clay) fraction inherent in or added to sandy and gravelly soils. *(Also see 51.07).*

* **Cation**—(as opposed to **anion**) — The ion is an electrolyte which carries the positive charge and which migrates towards the cathode under the influence of a potential difference.

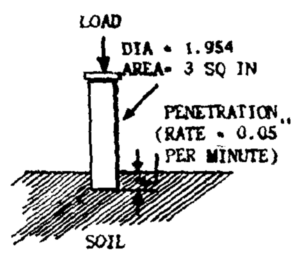
Definition No.	U. D. C. No.	TERM	DEFINITION
32.05		BLACK COTTON SOIL[1]	Soil formed by the decomposition of rocks like trap, granite, gneiss, basalt, or limestone, by long continued weathering. The clay content (particle size less than 0.002 mm.) is from 40 to 50 per cent. [It is black or blue-black and is found in tropical countries.]
32.06		BROWNIAN MOVEMENT	The state of constant unordered motion, of solid particles in a fluid medium, visible under the microscope, which is due to the fact that each particle possesses an electrical charge which causes it to repel other particles similarly charged.
32.07		CALIFORNIA BEARING RATIO* (C. B. R.)	It is a measure of the shearing resistance of a soil to penetration under carefully con-

1. It is claimed that this soil *contains 4 to 8 per cent humus*, 32.34. It has great affinity for water and attracts it (water) from all directions and by capillarity, is extremely sticky when wet and has a high coefficient of shrinkage. It has a high bearing capacity when dry, but becomes almost a fluid when wet. Generally suitable for cotton crop, but very unsuitable as a foundation for road pavements, and structures, because of the great volume change and requires special treatment.

* Unit-load values for various depths of penetration into the standard sample are standardized and given in the Table :

STANDARD VALUES

Penetration inches	Unit Load P.S.I.
0.1	1000
0.2	1500
0.3	1900
0.4	2300
0.5	2600



Definition No.	U. D. C. No.	TERM	DEFINITION
32.07		CALIFORNIA BEARING RATIO (*Contd.*)	trolled density and moisture conditions. [The ratio is expressed as a percentage of the unit load required to force a standard piston into the soil at a rate of 0.05 inch per minute divided by the unit load required to force the same piston the same depth at the same rate into a standard sample of crushed stone.]
32.08		CAPILLARITY	A phenomenon associated with surface tension and angle of contact, by which the surface of a liquid where it is in contact with a solid, (as in a capillary tube) is elevated or depressed. [Capillarity depends on the relative attraction of the molecules of the liquid for each other and for those of the solid. In soil stabilization, capillarity is the ability of the soil to transmit moisture in all directions regardless of any gravitational force.]
32.09		CENTRIFUGE MOISTURE EQUIVALENT (C. M. E.)	The moisture content, expressed as a percentage by weight of oven-dried soil, retained by a soil which has first been saturated with water and then subjected to

$$\text{C.B.R.} = \frac{\text{Test unit load}}{\text{Standard unit load}} \times 100.$$

The C.B.R. used in design is the 0.1 or 0.2 inch penetration value, whichever is greater. For most soils the 0.1 inch penetration value is the greater.

The C.B.R. is used with empirical curves for designing flexible pavements.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.09		CENTRIFUGE MOISTURE EQUIVALENT (C. M. E.)) *(Contd.)*	a centrifugal force equal to one thousand times the force of gravity for one hour.
32.10		CLAY	(a) Colloidal fine complex silicates formed by the natural decomposition of igneous rocks; (b) In the mechanical analysis of soils, clay is defined in the International Soil Classification System, as composed of particles smaller than 0.002 mm. (See also 31.07.)
32.11		COHESION	(a) The internal molecular attraction which opposes the rupture of a material. (b) The property of a material on which its degree of stability depends.
32.12		COHESIVE WATER	Outer film of adsorbed water surrounding soil particles in colloidal suspension (See Fig. in 32.02).
32.13		COLLOIDS	(1) Soil particles of size less than 0.001 m. m. (2) The finer clay particles which show pronounced brownian movement (See 32.06) when suspended in water.
32.14		COMPACTION	The process of inducing a closer packing of particles in a mass of loose material, by blows, or by other external pressure.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.14		COMPACTION *(Contd.)*	[This term is generally used in Laboratory Tests.]
32.15		COMPACTION, DEGREE OF	A ratio given by the equation $D_d = \frac{(\text{Void Ratio of Sample}) - (\text{Void ratio in densest state})}{(\text{Void ratio in loosest state}) - (\text{Void ratio in densest state})}$
32.16		CONSISTENCY INDEX	The ratio of the difference between the liquid limit and the natural water content to the Plasticity Index.
32.17		CONSOLIDATION	The process of reduction in the volume of a soil, with a corresponding increase in density, such as can be produced by the expulsion of water or air from the pores of the soil under application of external force (Same as 31.09).
32.18		DENSITY, DEGREE OF (D_d)	See Compaction, Degree of, 32.15.
32.19		DUST	Fine, dry, pulverised soil particles that can be lifted and carried by wind.
32.20		DUST RATIO	$\frac{\text{Percentage of material passing sieve No. 200 (A.S.T.M. \& B.S.)}}{\text{Percentage of material passing sieve No. 40 (ASTM) or sieve No. 36 (B.S.)}}$
32.21		EFFECTIVE SIZE (E.S.)	The size of the particle that is coarser than 10 percent by weight of the material, i.e. 10 percent of the material will consist of particles smaller than the effective size and 90

Definition No.	U. D. C. No.	TERM	DEFINITION
32.21		**EFFECTIVE SIZE (E.S.)** *(Contd.)*	percent consists of larger particles. [Thus, if a sand is said to have an effective size of 0.4 m.m., it means that 90 percent of the sand grains are more than 0.4 m.m. in diameter. The effective size, however, does not give any indication of the degree of variation or uniformity of the particles composing 90 percent of the material.]
32.22		**EXPANSION LIMIT, LINEAL**	The increase in one dimension, expressed as a percentage of that dimension at the shrinkage limit, of a soil mass when the water content is increased from the shrinkage limit to the field moisture content.
32.23		**EXPANSION, LINEAL**	The increase in one dimension, expressed as a percentage of that dimension at the shrinkage limit, of a soil mass when the water content is increased from the shinkage limit to any given water content.
32.24		**FIELD MOISTURE EQUIVALENT**	The minimum moisture content expressed as a percentage of the weight of the oven-dried soil at which a drop of water placed on a smoothed surface of the soil will not immediately be absorbed but will instead spread out over the surface and give it a shiny appearance.
32.25		**FLOCCULATION**	The coalescence of a finely divided precipitate into larger particles.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.26		**FLOCCULATION RATIO**	The void ratio of a soil when it is in the condition of a deflocculated sediment.
32.27		**FLOCCULATION LIMIT**	The water content of a soil, when it is in the condition of deflocculated sediment.
32.28		**FLOW CURVE**	The locus of points obtained from a standard liquid limit test (mechanical method) and plotted on a graph representing water content as ordinates on an arithmetic scale and number of shocks as abscissa on a logarithmic scale.
32.29		**FLOW INDEX**	The slope of the flow curve.
32.30		**FREE WATER**	The water that moves in a soil under the force of gravity without being retained by the soil.
32.31		**FRICTION, ANGLE OF**	The angle between the normal to the contact surfaces of two bodies, and the direction of the resultant reaction between them, when a force is just tending to cause relative sliding.
32.32		**GRAIN DIAMETER**	The size of grain, usually in millimeters, as determined by sieve analysis or wet mechanical analysis. (Hence, not a true grain diameter except for spherical grains).
32.33		**GRAIN SIZE**	Same as Grain Diameter, 32.32.
32.34		**HUMUS**	A dark brown amorphous substance formed usually in the soil, due to partial or complete decomposition of vegetable matter; the organic component of the soil.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.35		HYDROSTATIC PRESSURE RATIO	A term used in earth pressure computations to represent the ratio between the normal component of pressure at a point on a given plane and the pressure which would exist at the same point if earth were substituted by a liquid of the same unit weight.
32.36		LEACHING	The process of the washing through of soils by water.
32.37		LIQUID LIMIT (L.L.)	That moisture content expressed as a percentage by weight of oven-dry soil, at which the wet soil will just begin to flow when jarred slightly. [The Liquid Limit is the upper limit of the plastic state of the soil.]
32.38		LOAM	A loam is a soil having relatively even mixture of the different grades of sand and of silt and clay. [It is mellow with a somewhat gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled freely without breaking.
32.39		MARL	An earthy mixture of minerals consisting of quartz, clay, calcite, and sometimes glauconite sands. Quite often found in swamps and lakes. Same as 31.23. Some loamy soils contain a considerable proportion of organic matter.] Same as 31.22.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.40		MODULUS OF ELASTICITY (E)* (Contd.)	The ratio of stress to strain for a given material under given load conditions. [In soil mechanics, it is assumed that the soil is isotropic and homogeneous and follows Hookes' Law strictly.]
32.41		MODULUS OF INCOMPRESSIBILITY	The ratio of the developed pressure to the volume change in a soil mass of unit volume.
32.42		MODULUS OF SUBGRADE REACTION (K)	A measure of the ability of a given subgrade to exert reacting pressure against a pavement slab when the slab is subjected to flexure. [This ability or the stiffness of the subgrade is expressed in lbs per sq. inch of area, per inch of deflection, i.e., in lbs in. 3**].
32.43		MODULUS OF SUBGRADE REACTION DYNAMIC	The modulus of subgrade reaction determined by dynamic or vibrator tests.

* Subscripts may be used to differentiate moduli under different load conditions.

** This modulus of subgrade reaction, is a soil property that can be readily determined by loading tests in the field and is closely related to the modulus of elasticity. The pressure required to press a circular disc into the soil for about 0.05 in. is determined and the modulus of subgrade reaction is defined as the pressure to produce one inch deflection. The indentation is purposely kept small so as to limit the effect of a permanent set.

If r = the radius of the disc

E = the modulus of elasticity of the soil

then $E = 1.5\ K.r$ (if the pressure on the soil is uniform)

or $E = 1.18\ K.r$ (if the deflection is constant over the loaded area, i.e. the disc is rigid).

It is necessary in quoting figures for the modulus of subgrade reaction that the size of the plate employed should be mentioned. For airfield work, this is usually 30 inches but for roads this is 18 inches, and the figures for a given subgrade using the two sizes will usually be different.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.43		MODULUS OF SUBGRADE REACTION DYNAMIC (*Contd.*)	[This modulus is considerably larger than that obtained by static load tests, and represents the dynamic equivalent of the coefficient of subgrade reaction.]
32.44		MOISTURE CONTENT	The ratio, expressed as a percentage, of the weight of water in a given soil mass to the dry weight of solid particles.
32.45		OPTIMUM MOISTURE CONTENT (O.M.C.)	The moisture content expressed as a percentage by weight of the oven-dry soil at which the maximum density is produced in a soil by a *specific amount of compaction*.
32.46		MOISTURE INDEX	The ratio of the plasticity index to the difference between the natural water content and the plastic limits.
32.47		OVERBURDEN	The layer of soil or other material which overlies a deposit of rock or sand gravel.
32.48		PEAT	Dark fibrous spongy soil showing evidence of vegetable origin. (Same as 31.24.)
32.49		PERCENT FINER	The percentage of particles by weight, in a given soil, having diameters smaller than the given grain diameter.
32.50		PERMEABILITY	The property by virtue of which fluids can pass through materials, defined by the rate at which fluid passes under unit pressure gradient. [Permeability is usually expressed in terms of velocity of

Definition No.	U. D. C. No.	TERM	DEFINITION
32.50		PERMEABILITY (*Contd.*)	flow per unit head loss, assuming the area of flow at any section to be equal to the cross-sectional area of both the void spaces and the soil particles; i.e., the area of the entire mass. The actual velocity of the percolating water through the void spaces is considerably greater than the value of the permeability coefficient. It is a property of the soil mass and not of individual particles, although its value is very much dependent on the nature of those particles and the voids between the particles.]
32.51		PERMEABILITY COEFFICIENT	The discharge velocity of flow of a fluid through a porous mass under a unit hydraulic gradient. [If v = Velocity of water flowing through soil, in centimeters per second; K = Coefficient of permeability; h = difference in elevation between sub-drain and highest ground-water level, in centimeters; b = horizontal distance in centimeters from drain to point at which h is measured.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.51		PERMEABILITY COEFFICIENT (Contd.)	then, $v = K.\frac{h}{2_h}$; $\frac{h}{2}$ is assumed as the average head causing flow of water to sub-drain. The value of the coefficient K depends on the type of soil. The common values are— Coarse sand ... 2×10^{-2} Fine sand ... 1×10^{-3} Diatoms ... 5×10^{-5} Clay ... 2×10^{-7}]
32.52		pH VALUE*	The logarithm to the base 10, of the reciprocal of the concentration of hydrogen ions in an aqueous solution. [It is a convenient method of expressing small differences in the acidity or alkalinity of nearly neutral solutions.]
32.53		PLASTICITY INDEX	The difference between the Liquid Limit and the Plastic Limit. [It is the range of moisture content (expressed as a percentage of the oven-dry soil) over which the soil is *plastic*.

* Chemically Pure water contains an equal number of hydrogen (H) ions and hydroxyl (OH) ions and therefore is neither acid nor alkaline but is referred to as neutral. When there is an excess of hydrogen ions, the solution is said to be acid, and when hydroxyl ions are in excess, the solution is said to be alkaline. One litre of chemically pure water or any neutral solution contains 1×10^{-7} of a gram of hydrogen ion. On the pH scale the figures run from 0 to 14 with the midpoint 7 referring to $1/10^7$ gram which is the weight of (disassociated) hydrogen ions in a neutral solution. The numbers less than 7 refer to acid solutions and the numbers greater than 7 to alkaline solutions.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.53		PLASTICITY INDEX (Contd.)	It is a measure of the cohesion of the soil under damp conditions.]
32.54		PLASTIC LIMIT	The lowest moisture content expressed as a percentage by weight of oven-dry soil at which the soil can be rolled into threads 1/8 inch in diameter without breaking into pieces. [It is the lower limit of the Plastic State]
32.55		POROSITY	The ratio, expressed as a percentage, of the voids in a given soil mass to the total volume of the soil mass.
32.56		REMOULDING INDEX	The ratio of the modulus of elasticity (or deformation) of a soil in the undisturbed state to the modulus of elasticity (or deformation) of the soil in the remoulded state.
32.57		REPOSE, ANGLE OF	The angle between the horizontal plane and the natural slope at which earth or other loose material stabilizes without tending to slide.
32.58		SAFE BEARING CAPACITY	The load which may be applied over the soil without causing it to settle to an extent detrimental to the structure over it.
32.59		SAND	A cohesionless soil composed of granular, gritty and loose grains of siliceous origin of sizes ranging between 2.00 m. m. and 0.02 m. m.
32.60		SAND, COARSE	Sand of grain size varying from 2.00 m.m. to 0.20 m.m.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.61		SAND, FINE	Sand of grain size varying from 0.20 m.m. to 0.02 m.m
32.62		SATURATED SOIL	A soil which has absorbed the maximum amount of moisture it can hold without being disturbed or remoulded. In saturated soils, the moisture just fills the voids.
32.63		SATURATION, DEGREE OF(S)	The ratio expressed as a percentage of the moisture content in a given soil mass to the total volume of intergranular space (voids).
32.64		SHALE	A compressed and laminated clay not so hard as slate, with or without associated organic matter (same as 31.29).
32.65		SHRINKAGE LIMIT (S.L.)	The maximum moisture content expressed as a percentage by weight of the oven-dried soil at which a reduction in moisture content will not cause a decrease in volume of the soil mass, but at which an increase in moisture content will cause an increase in volume of the soil mass. [It represents the moisture content at the point where the soil passes from the semi-solid to a solid state.]
32.66		SHRINKAGE LIMIT, LINEAL	The particular *linear shrinkage* (32.67) pertaining to the Field Moisture Equivalent (32.24).
32.67		SHRINKAGE, LINEAL (L.S.)	The decrease in one dimension, expressed as a percentage of that dimension originally, of

Definition No.	U. D. C. No.	TERM	DEFINITION
32.67		SHRINKAGE LINEAL(L.S.) (*Contd.*)	a soil mass when the water content is reduced from the original percentage to the shrinkage limit (32.65).
32.68		SHRINKAGE LIMIT, VOLUMETRIC	The decrease in volume expressed as a percentage of dry volume, of a soil mass when moisture content is reduced from the Field Moisture Equivalent (32.24) to the shrinkage limit (32.66).
32.69		SHRINKAGE RATIO(R)	The ratio between a given volume change, expressed as a percentage of the dry volume, and the the corresponding change in water content above the shrinkage limit, expressed as percentage of the weight of the oven-dried soil. (It is numerically the same as the bulk specific gravity of the dried soil.)
32.70		SHRINKAGE, VOLUMETRIC	The decrease in volume, expressed as a percentage of the dry volume, of a soil mass, when the moisture content is reduced from a given percentage to the shrinkage limit (32.65).
32.71		SILT	Mud consisting of fine, barely visible grains, with grain size between 0.02 m.m. and 0.002 m.m., with little or no plasticity, and no cohesion, usually deposited as a sediment in water. (See also 31.31)
32.72		SOIL	A mixture of earthy materials with particles differing phy-

Definition No.	U. D. C. No.	TERM	DEFINITION
32.72		SOIL (*Contd.*)	sically in size, shape and cellular structure, varying in chemical composition and surrounded, at times, with water containing varying amounts of chemicals in solution.
			[Soil is of secondary origin and is produced by decomposition of various kinds of rocks intermingled more or less with organic matter, resulting from the growth and decomposition of animal matter or vegetation (Same as 31.33)]
32.73		SOIL MORTAR	Soil fraction passing sieve No. 40 (A. S. T. M.) or sieve No. 36 (B.S.)
32.74		SOIL STABILISATION	The process of treating a soil in such a manner as to improve or alter its physical properties so as to serve a specific purpose.
32.75		SOIL WATER. ADSORBED	Water held on the surface of a solid particle as a result of attractive forces.
			[The water held may be under pressures of several thousand atmospheres and in a solid form. (See Figure under 32.02).
			Soil-water hygroscopic (32.78) is a particular type of soil water, adsorbed].
32.76		SOIL WATER, CAPILLARY	Water held above the water-table (32.93) by adhesion and surface tension forces as a film around particles and in the capillary spaces.

Definition No.	U. D. C. No.	TERM	DEFINITION
32.76		SOIL WATER, CAPILLARY (*Contd.*)	[Moves in any direction in which capillary tension is greatest.]
32.77		SOIL WATER GRAVITATIONAL	Same as Free Water, 32.30.
32.78		SOIL WATER, HYGROSCOPIC	Water which is adsorbed from an atmosphere of water vapour and held on the surface of particles by forces of adhesion.
32.79		SUB-SOIL	The undisturbed strata lying below the natural top soil. (Same as 31.38).
32.80		SURFACE TENSION	A property possessed by liquid surfaces whereby they appear to be covered by a thin elastic membrane in a state of tension, measured by the force acting normally across a unit length in the surface.
			[The phenomenon is due to unbalanced molecular cohesive forces near the surface].
32.81		SURCHARGE	The load superimposed above the level of the top of the retaining wall on the earth bearing against it.
32.82		SURCHARGE, ANGLE OF	The angle between a horizontal plane, and the sloping face of a surcharge of earth.
			[This angle may be equal to or less than the angle of repose.]
32.83		TOP SOIL	Commonly, the organic surface soil suitable for cultivation.
32.84		TOTAL ACTIVE EARTH PRESSURE	The total force exerted by or through a mass of earth against a medium of lateral

Definition No.	U. D. C. No.	TERM	DEFINITION
32.84		TOTAL ACTIVE EARTH PRESSURE (*Contd.*)	support, or against a given area thereof.
32.85		TOTAL PASSIVE EARTH PRESSURE	The total externally applied lateral force which a given mass of earth is capable of resisting over a given area, at the point of sliding.
32.86		TOUGHNESS INDEX	The ratio of the plasticity index to flow index.
32.87		UNIFORMITY COEFFICIENT (U.C.)	The ratio of the size of the particle that is coarser than 60 per cent by weight of the material to the *effective size* (32.21) of the material. [Thus, if 60 per cent of a sand having an effective size of 0.44 m.m. passes a 0.64 m.m. screen, the uniformity coefficient is $\frac{0.64}{0.4} = 1.6$]
32.88		VOID RATIO	The ratio of the volume of intergranular space voids to the volume of solid particles in a given soil mass without regard to the proportions of liquid, air, or gas which may occupy the space. (*Cf. Porosity, 32.55*) [If I = void ratio V_v = total volume of voids in a mass of soil V_s = Absolute volume of soil particles then $I = \frac{V_v}{V_s}$]
32.89		VOID RATIO-CRITICAL	The void ratio of a cohesionless soil at which continuous

Definition No.	U. D. C. No.	TERM	DEFINITION
32.89		VOID RATIO-CRITICAL (*Contd.*)	shearing deformation can take place without change in void ratio.
32.90		VOLUMETRIC CHANGE	Same as Shrinkage, Volumetric, 32.70.
32.91		WATER CONTENT	See Moisture Content, 32.44.
32.92		WATER GRADIENT	The surface below which, except for relatively small quantities of dissolved or entrapped air, water fills the voids in soil or rock. [Its level can be found by measuring the elevation to which water rises in a well sunk below the surface at any location. Water table will vary with the season and the soil. Where the water-table rises above the ground-level a body of stagnant water exists.]
32.93		WATER-TABLE	Same as Water Gradient, 32.92.

SECTION 3. PREPARATORY WORKS

3.3 DRAINAGE

Definition No.	U. D. C. No.	TERM	DEFINITION
33.01		AFFLUX	The rise above the normal surface of water in a water-course caused by an obstruction to flow.
33.02		AQUEDUCT	An artificial channel through which water flowing with a free surface is taken across a valley, drain, canal, river, road or railway.
33.03	532.55	BACKWATER	The water in a stream rising above its normal level due to some obstruction to flow.
33.04		BACKWATER CURVE	Particular form of the surface curve of a stream, which is concave upwards.
33.05	532.55	BACKWATER LEVEL	The level of the backwater surface at any specified point.
33.06		BOX CULVERT	A monolithic drainage structure rectangular in section.
33.07	625.735	BOX-DRAIN	A covered drain of rectangular section.
33.08	625.735	BOX-GUTTER	A gutter of rectangular section.
33.09		BREACHING SECTION	A lowered section of a road, specially designed to permit the escape of abnormal floods, without damaging any important road or bridge structures nearby.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.10		BRIDGE	A drainage structure, with a total lineal opening of more than 20 ft, erected for carrying traffic across a natural or artificial water course, a railway track, another roadway, or any other obstruction. [For structures with a lineal span of 20 ft and less see Culvert, 34.28.]
33.11		BUOYANCY	The loss in weight of a body, immersed partly or wholly in a fluid, due to the resultant upward pressure exerted on it by the fluid.
33.12	625.735	CATCH-WATER DRAIN	A drain excavated on the upper slope of a hill road to intercept and collect water flowing towards the road, and to lead it to a point where no damage will result to the road.
33.13	551.437.3	CATCHMENT AREA	(1) The area drained by a water course at any section. (2) Area from which the rainfall flows into (a) a drainage line at any specified section on (b) a reservoir.
33.14	551.437.3	CATCHMENT BASIN	Same as Catchment Area, 33.13.
33.15	625.745.456	CATCH-PIT	A pit excavated on a chamber constructed below the normal bed level of a ditch, drain, stream or sewer to trap bed silt and solid matter.
33.16	625.735	CATCH-DRAIN	See Catch-water Drain, 33.12.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.17		CAUSEWAY (Irish Bridge)	1. A paved dip in a road across a shallow drainage course, at or about the bed level. 2. A paved road crossing at or about the ground level, a water logged or marshy area.
33.18		CAUSEWAY, RAISED	A paved dip appreciably above the bed level of a stream, usually provided with vents to pass low water flow (Cf. Submersible Bridge, 33.79).
33.19		COEFFICIENT OF CONTRACTION	The ratio of the most contracted sectional area of a stream, jet or nappe, beyond the plane of the orifice or notch, through which it issues, to the uncontracted sectional area. (Nappe is a sheet or a curtain of water flowing over a dam, weir etc.).
33.20		COEFFICIENT OF DISCHARGE	The ratio of the actual discharge to the theoretical discharge calculated according to a specific formula.
33.21		COEFFICIENT OF ROUGHNESS OR RUGOSITY	A reduction factor which has to be applied in formulae, such as the Kutter, Manning, and Bazin Formulae, when calculating the discharge of a stream, to allow for the frictional and other losses engendered by the characteristics of the wetted perimeter.
33.22		CRITICAL VELOCITY	The mean velocity of flow in a channel of given depth which will just keep the bed of the channel free from either

Definition No.	U. D. C. No.	TERM	DEFINITION
33.22		CRITICAL VELOCITY *(Contd)*	silting or scouring, when the water is running fully charged with silt.
33.23	625.745.2	CULVERT	A structure used for purposes similar to that of a bridge, but having a total lineal opening of 20 ft or less.
33.24	69.022.5	CURTAIN WALL	A thin wall used as a shield or protection against scouring action.
33.25	624.022.21 532.685	CUT-OFF WALL	A wall, collar, or other structure intended to cut off or reduce percolation of water along smooth surfaces, or through porous strata.
33.26	625.735	DITCH	A trench cut in the ground for the purpose of receiving and conducting drainage water.
33.27	625.735	DRAIN	A conduit or channel, either artificial or natural, for carrying off surplus ground water or surface water. [*Cf. Ditch, 33.26 and Gutter, 33.40*]
33.28	625.735 & 625.731.8	DRAINAGE	1. The interception and removal of water from, over, or under an area. 2. The water so removed.
33.29	551.437.3	DRAINAGE BASIN	See Catchment Area, 33.13.
33.30		EROSION	The process of removal of matter from the banks of a stream by the action of flowing water.
33.31	625.745.21	FLOOD ESCAPE	A section of a road specially designed to permit the flow

Definition No.	U. D. C. No.	TERM	DEFINITION
33.31		FLOOD ESCAPE *(Contd)*	over it of flood water rising over a specified level. [Cf. Breaching Section, 33.09]
33.32	621.646 627.51	FLOOD GATE	A movable obstruction placed across a water course for impounding, excluding or diverting flood water.
33.33	625.745.21	FLOOD WAY	See Flood Escape, 33.31.
33.34		FLUSH CAUSEWAY	A causeway at bed level of a stream [See Causeway, 33.17]
33.35	624.034.5 625.7	FORD	A shallow crossing where a stream or river can be crossed by wading through.
33.36	625.745. 455.4	GRATING	A metal grid to keep out debris at the entrance to a drain.
33.37		GROYNE	An obstruction of stone, timber brushwood, or other material constructed from the bank of a canal or river and projected into it, for diverting the current.
33.38		GUIDE BANK	A protective and training bank constructed at the site of a weir; bridge, etc., to guide the river through the waterway provided in the structure.
33.39	625.745. 456	GULLEY	1. The erosion formed on road shoulders by rain water. 2. A receptacle of stone-ware, concrete, cast iron, or other material provided with a grid, placed at the side of the road to receive drainage from a gutter or channel.

Definition Fo.	U. D. C. No.	TERM	DEFINITION
33.40	625.735	GUTTER	A water carrier constructed along the sides of a carriageway to carry away water drained from the surface of the pavement.
33.41	625.731.3	HERRING-BONE DRAIN	A system of interconnected drains, commonly used for sub-soil drainage, and laid out in the pattern of a herring-bone (Zig zag pattern).
33.42		HIGH LEVEL CAUSEWAY	See Raised Causeway, 33.18.
33.43		HYDRAULIC GRADIENT	The slope of the hydraulic gradient line.
33.44		HYDRAULIC GRADIENT LINE	1. The line joining the levels to which water rises in pressure pipes (manometer tubes) erected at points along a flowing conduit. 2. The waterline along an open channel. 3. The line of saturation in the earth section of an embankment, dam, tank, bund or other earth structures for retaining water.
33.45		HYDRAULIC MEAN DEPTH	1. A function of depth obtained by dividing the cross-sectional area of a stream of water by the length of its periphery in contact with water. 2. The ratio of the area of the flow section of a stream or pipe to the wetted perimeter.
33.46		HYDRAULIC MEAN RADIUS	Same as Hydraulic Mean Depth, 33.45.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.47	532.685	INFILTRATION	The passage of water from the sub-soil into a water-bearing stratum or to a drain. [This is a particular case of Seepage, 33.68].
33.48	551.577.213	INTENSITY OF RAINFALL	The rainfall in a unit of time usually expressed in inches per hour.
33.49	625.735	INTERCEPTING DRAIN	See Catchwater Drain, 33.12.
33.50		INVERT	The lowest portion of the internal surface of a drain, sewer or culvert.
33.51		INVERTED SIPHON (Siphon Culvert)	A water conduit crossing a depression or under a highway, railway, canal etc.
33.52	625.735	KERB INLET	Apertures formed in a kerb to let in surface water from the pavement to a gully.
33.53	625.735	LEADER DRAIN	A principal drain by which the branch drains are connected to an outfall or ditch.
33.54	625.735	LEADING DRAIN	Same as Leader Drain, 33.53.
33.55		LEAD OFF DRAIN	A drain to lead away roadside drain water from convenient points to prevent accumulation of water, and side sewer.
33.56	625.745.4	MAN-HOLE	An underground chamber constructed for giving access to a drain, sewer, or other underground services.
33.57	532.685	PERCOLATION	The slow passage of water through soil or a porous solid under the action of gravity.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.57		PERCOLATION (Contd)	[*Cf. Seepage, 33.68, Infiltration, 33.47*]
33.58	625.735 1.643.2	PIPE DRAIN	A drain constructed with pipes or in the form of a pipe.
33.59		PIPING	The phenomenon of water flowing under or round a structure built on permeable foundations and carrying away with it the finer material of the foundation soil.
33.60		PUDDLE	1. Clay material kneaded and placed to form a compact mass to reduce percolation. 2. To place such a material.
33.61		PUG	To pack with clay or similar material generally for the purpose of checking leakage or to render the surface water tight.
33.62	551.577	RAINWATER	The quantity of atmospheric water falling during a certain period over an area and measured as the average depth of water in inches of percipitation.
33.63		RAISED CAUSEWAY	See Causeway, Raised 33.18.
33.64		RATE OF RUN-OFF	Run off in a unit time (usually a second) and expressed in cusecs (cubic feet per second).
33.65	625.735 691.21	RUBBLE DRAIN	A drain constructed by excavating a trench to the required level and filled in with selected rubble or stone through which water can percolate.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.66	551.579.1	RUN-OFF	The total quantity of precipitated water from a catchment area, reaching a given point within a given time.
33.67		SCOUR	The process of erosion and removal of matter by the action of running water on the stream bed.
33.68		SEEPAGE	Percolation of water into or from the soil. [Seepage into a soil is termed Influent Seepage and that away from a soil as Effluent Seepage].
33.69	625.745.4	SEWER	An underground conduit or duct formed of pipes or other suitable construction for the conveyance of sullage water and/or rain water.
33.70	625.755	SIDE DRAIN	An open drain along the side of a road.
33.71	625.745 455	SOAKING PIT	An excavation or pit to which drains are led and from which the collected water passes into the surrounding sub-soil by seepage or percolation.
33.72		SOAKAWAY	Same as Soaking Pit, 33.71.
33.73		SPILLWAY	A surfaced apron or trough for conducting water down a relatively steep slope.
33.74		SPUR	Same as Groyne, 33.37.
33.75	551.77.37	STORM WATER	That portion of the precipitation which runs off the surface of the ground during a storm and for a short period

Definition No.	U. D. C. No.	TERM	DEFINITION
33.75		STORM WATER *(Contd)*	following it when the flow exceeds the normal or ordinary rate of run-off.
33.76		STORM-WATER DRAIN	A drain which carries storm water, street wash, or other wash waters but excludes sewage.
33.77	625.735.691. 21	STONE DRAIN	Same as Rubble Drain, 33.65.
33.78	625.731.3	SUBGRADE DRAIN	A drain to draw away water from the subgrade.
33.79		SUBMERSIBLE BRIDGE	A bridge designed to allow normal floods to pass through its vents but allowed to be overtopped during high floods.
33.80	625.731.3	SUBSOIL DRAIN	A drain below the ground surface to drain away subsoil water.
33.81	625.745.455	SUMP (Sump well)	A well or cistern, sunk below the working level, into which water may be drained from other portions of the work.
33.82		UPLIFT	The upward water pressure on the base of a structure.
33.83		VIADUCT	A structure which carries a road or railway across a wide and deep valley.
33.84		WASTE WEIR	Same as Spillway, 33.73.
33.85		WATER CUSHION	A pool of water maintained to absorb the impact of water flowing over a dam, chute, drop or other spillway structure.
33.86	551.431.3	WATER SHED	The line of separation between adjacent catchment areas.

Definition No.	U. D. C. No.	TERM	DEFINITION
33.87		WEEP HOLE	A small opening left through soil retaining structures to drain away percolation water.
33.88		WETTED PERIMETER	The periphery of the cross sectional area of a stream in contact with water.

SECTION 3.—PREPARATORY WORKS

SECTION 3.4—STRUCTURES

Definition No.	U. D. C. No.	TERM	DEFINITION
34.01		ABUTMENT	An end support of the superstructure of a bridge or similar structure generally sustaining the pressure of the abutting earthwork.
34.02		ABUTMENT PIER	A pier designed to withstand heavy unbalanced inclined thrust from the superstructure.
34.03		AFFLUX	The rise above the normal surface of water in a water course caused by an obstruction to flow. (Same as 33.01.)
34.04		AQUEDUCT	An artificial channel through which water flowing with a free surface is taken across a valley, drain, canal, river, road or railway. (Same as 33.02.)
34.05		ARCH	A structure having a curved axis.
34.06		ARCH BRIDGE or CULVERT	A bridge (or culvert) with a superstructure that depends for its stability on the principle of the arch.
34.07		ARCH STONE	The wedge shaped structural component of a stone arch.
34.08		BARRIER	An obstruction temporarily placed to prevent access to a particular area.
34.09		BEAM	A load bearing structural member spanning a gap and supported at both the ends either by resting or fixing the ends into other members.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.10		BEARING	The support for a beam or a girder.
34.11		BOWSTRING GIRDER	A girder consisting of a curved rib or arch, having a horizontal tension member arranged as a chord and connected to the rib by hangers.
34.12		BOX CULVERT	A monolithic drainage structure rectangular in section. (Same as 33.06).
34.13		BRACING	A member used to stiffen or strengthen a structure, but not to take a direct stress.
34.14	625.745.1	BRIDGE	A drainage structure, with a total lineal opening of more than 20 ft, erected for carrying traffic across a natural or artificial water course, a railway track, another roadway or any other obstruction. [For structures with a lineal span of 20 ft and less see Culvert, 34.28.] (Same as 33.10.)
34.15		BUTTRESS	A structure built against a wall to strengthen it for lateral stability.
34.16	625.745.9	CABLE FENCE	A fence consisting of one or more metal cables carried on posts.
34.17		CAISSON	A water tight box like structure constructed of wood, steel or concrete used for laying foundations below water level. [*Cf. Coffer-dam, 34.23*].
34.18		CANTILEVER	That part of a structure or a structural member that extends beyond its support.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.19		CAUSEWAY (Irish Bridge)	1. A paved dip in a road across a shallow drainage course, at or about the bed level. 2. A paved road crossing at or about the ground level. A water logged or marshy area. (Same as 33.17.)
34.20		CAUSEWAY, RAISED	A paved dip appriciably above the bed level of a stream, usually provided with vents to pass low water flow. [*Cf. Submersible Bridge, 33.79*] (Same as 33.18.)
34.21		CENTRING (False work)	Temporary supports to the shuttering of a structure which is in the process of formation to the required shape and strength. [*Cf. Shuttering, 34.64*]
34.22		CLEARANCE	(i) The vertical distance between maximum flood level of a stream and the lowest point on the soffit of the superstructure of a bridge or a culvert. (ii) The distance between the extreme points of a loaded vehicle designed to pass through a bridge and the adjacent face of a structural member of the bridge superstructure.
34.23		COFFER-DAM	A temporary box like structure or enclosure formed to isolate the area which it encloses for excluding water therefrom.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.24		COLUMN	An upright compression member the length of which exceeds three times its least lateral dimension.
34.25		CONTINUOUS GIRDER OR BEAM	A girder or beam having more than two supports.
34.26		CORNICE	The horizontal moulded projection generally at the top of a structure.
34.27		CROSS GIRDER	A girder placed across from one truss or main girder to another.
34.28	625.745.2	CULVERT	A structure used for purposes similar to that of a bridge, but having a total lineal opening of 20 ft or less. (Same as 33.23).
34.29		CURTAIN WALL	A thin wall used as a shield or protection against scouring action. (Same as 33.24.)
34.30		CUT-WATER	The upstream nose of a pier shaped to reduce obstruction to smooth flow of water past it. [*Cf. Easewater, 34.33*]
34.31	625.745.1	DECK BRIDGE	A bridge in which the carriageway is built at or near the top level of the main supporting members of the superstructure.
34.32		DECK LEVEL	The level of the crown of the carriageway over the deck.
34.33		EASE-WATER	The downstream nose of a bridge pier designed to promote smooth merging of the water flowing out of the adjacent openings of a bridge cut-water. [*Cf. Cut-water, 34.30*]

Definition No.	U. D. C. No.	TERM	DEFINITION
34.34		EXTRADOS	The outer surface of an arch.
34.35	625.748.32	FENCE	A permanent obstruction erected or planted to separate plots of land and to prevent access to an area.
34.36		FLOATING BRIDGE	A bridge having pontoons or barges as its supports.
34.37		FREE BOARD	The vertical distance between the maximum flood level and the road surface level.
34.38		GIRDER	A principal horizontal beam or a compound structure acting as a beam, and supported at both ends.
34.39		GROYNE	An obstruction of stone, timber, brushwood, or other material constructed from the bank of a canal or river and projected into it, diverting the current. (Same as 33.37.)
34 40	625.738	GUARD RAIL	A side barrier or protection consisting of a rail supported on posts to constrain traffic.
34.41		HAUNCH	That part of an arch lying midway between the crown and the skewback.
34.42		HEAD-WALL	A retaining wall built at the inlet end of a culvert or a sluice.
34.43		IMPACT	The sudden application of a load to a structure producing stresses in excess of those induced by the same load applied statically.
34.44		INTRADOS	The inner surface of an arch.

Difini-tion No.	U. D. C. No.	TERM	DEFINITION
34.45		KEYSTONE	The central voussoir at the crown of an arch.
34.46		LIVE FENCE	A fence formed of live plants.
34.47	625.745.1	OVERBRIDGE	A bridge that enables one form of land communication over the other.
34.48		PARAPET	A low or a breast-high wall built along the edge of a bridge, a culvert etc.
34.49	625.738	PEDESTRIAN GUARD RAIL	A guard rail so placed on foot-paths as to constrain the movement of pedestrians.
34.50		PIER	An intermediate support between the end supports of a bridge or a culvert.
34.51		PILE	A column driven or screwed into or formed in the ground in order to consolidate the soil or to transmit the weight or the thrust of a structure to firmer zones of the sub-soil.
34.52		PITCHING	A protective course or layer of stones or the like laid on slopes, banks, or river beds to prevent erosion by currents, waves or winds.
34.53		PLATE GIRDER	A girder built of structural plates as main components.
34.54		PONTOON BRIDGE	Same as Floating Bridge, 34.36.
34.55		REINFORCEMENT	Rolled Sections, bars, rods, wire or fabric, usually of

Difini-tion No.	U. D. C. No.	TERM	DEFINITION
34.55		REINFORCEMENT (Contd.)	steel or other suitable material, embedded in concrete, masonry or brick work for the purpose of resisting definite stresses.
34.56	625.737	RETAINING WALL	A wall constructed to maintain in position material capable of exerting lateral pressure, generally a mass of earth.
34.57		RETURN WALL	A retaining wall built parallel to the centre line of a road and in continuation of an abutment or wing, to retain the embankment.
34.58		REVETMENT	A facing of stone or other material laid on a sloping face of earth to maintain the slopes in position.
34.59		ROAD-RAIL BRIDGE	A bridge that carries both a railway and a road.
34.60		ROCKER BEARING	A bearing or a support which permits slight angular movement in the supported ends of a bridge superstructure.
34.61		ROLLER BEARING	A bearing assembly, consisting mainly of rollers with suitably designed top and bottom plates, which permits of slight longitudinal movements in the supported ends of a bridge superstructure.
34.62	625.748.32	SAFETY FENCE	A fence placed with the object of preventing a vehicle out of control from leaving the formation.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.63	625.748.32	SHEET PILES	Flat piles driven into the ground alongside of each other with their edges in close contact, or interlocked to resist hydrostatic or earth pressure. [*Cf. Pile, 34.51*]
34.64		SHUTTERING	Temporary timber or metal forms used to mould the structure to shape. [*Cf. Centring, 34.21*]
34.65		SKEW-BACK	That part of a pier which immediately supports an arch.
34.66		SKEW-BRIDGE OR CULVERT	A bridge or culvert of which the centre line is oblique to the axis of the crossing.
34.67		SLAB BRIDGE OR CULVERT	A bridge or a culvert having slabs only as its superstructure.
34.68		SLIDING BEARING	A bearing which permits slight sliding of a girder end under expansion or contraction.
34.69		SOFFIT LEVEL	The level of the soffit of an arch intrados.
34.70		SPANDREL	The space extending from the top of a masonry arch to the top of the carriageway.
34.71		SPANDREL WALL	A wall built upon the extrados of an arch upto the top level of the carriageway.
34.72		SPRINGING LINE	The line of intersection between the intrados and the supports of an arch.
34.73		STOCK SUBWAY (Cattle Creep)	A shallow subway constructed to permit passage of cattle underneath a road or a railway.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.74		STRIKING	The releasing or lowering of centring.
34.75		SHIPPING	(i) The removal of shuttering after a structure has *been completed.* (ii) The displacement of tar or bitumen from coated aggregrate.
34.76		SUBMERSIBLE BRIDGE	A bridge designed to allow normal floods to pass through its vents but allowed to be over topped during high floods. (Same as 33.79).
34.77		SUBSTRUCTURE	That part of a bridge or culvert which lies above the foundation and below the superstructure seats, or below the springing line of arches.
34.78		SUBWAY	An underground passage or tunnel to permit the movement of traffic or to accommodate public utilities such as service pipes, cables etc.
34.79		SUPERSTRUCTURE	That part of the structure which lies above the bridge seats or above the springing line of arches.
34.80		SUSPENSION BRIDGE	A bridge with its deck suspended from chain or wire cables, usually carried over massive towers and suitably anchored.
34.81	625.745.1	THROUGH BRIDGE	A bridge in which the roadway is at or near the bottom chord level of the main supporting members.
34.82		TOE WALL	A small retaining wall constructed at the foot of an earth slope.

Definition No.	U. D. C. No.	TERM	DEFINITION
34.83		TRESTLE BRIDGE	A bridge composed of pilobents or towers carrying the deck.
34.84		TRUSS	A framed or jointed structure designed to act as a beam.
34.85	625.745.1	UNDER BRIDGE	A bridge that enables the construction of one form of land communication under the other.
34.86		VIADUCT	A structure which carries a road or railway across a wide and deep valley. (Same as 33.83.)
34.87		VUSSOIR	Same as Arch Stone, 34.07.
34.88		WING WALL	A splayed extension of an abutment of a bridge or a culvert to retain the adjacent embankment.

SECTION 4—SURFACE CONSTRUCTION

4.1 SURFACING TYPES

Definition No.	U. D. C. No.	TERM	DEFINITION
41.01		BITUMEN CONCRETE SURFACING	A type of construction in which coarse and fine mineral aggregates are mixed with bitumen and laid hot to desired thickness.
41.02		BITUMEN OR TAR MACADAM	A type of construction in which the fragments of coarse aggregate are bound together either by bitumen or tar applied either by the premix or the grouting method.
41.03		BLACK-TOP SURFACE	A general term applied to wearing coats or surfaces of roads in which tar or bitumen is used as a binder.
41.04	625.821.2/3	BRICK PAVING	A paving composed of bricks laid in regular courses.
41.05	625.855.41	CARPET	A surfacing obtained by laying bitumen or tar concrete to a thickness of more than an inch.
41.06	625.844	CEMENT-BOUND MACADAM	A surface in which a matrix of a cement-sand mixture is interposed between two layers of road metal spread on the road and the whole mass is watered and consolidated so that the mortar works into the interstices of the road metal to produce a compact mass.
41.07	625.75	CEMENT CONCRETE SURFACING	A surface obtained by placing and consolidating cement concrete to required thickness.
41.08	625.81	EARTH ROAD	A road with the carriageway composed of natural soil.

Definition No.	U. D. C. No.	TERM	DEFINITION
41.09	625.814.3	GRAVEL ROAD	A road with the carriageway composed of a consolidated layer or layers of gravel.
41.10	625.859.3	GROUTED MACADAM	A macadam crust in which the stone aggregate is bound together by a binder applied to penetrate to the desired depth.
41.11		KANKAR ROAD	A road with the carriageway formed of a macadam composed of Kankar stone.
41.12		LATERITE ROAD	A road with the carriageway formed of a macadam composed of laterite stone.
41.13		LIME STONE ROAD	A road with the carriageway formed of a macadam composed of lime stone.
41.14		MOORUM ROAD	A road with the carriageway composed of a consolidated layer or layers of moorum.
41.15	625.8	PAVEMENT	The superficial covering of a carriageway, a cycle track or a footpath.
41.16	625.8	PAVING	A wearing coat consisting of separate blocks or units fitted closely together and having joints between them.
41.17	625.82	STONE-SETT PAVING	A paving of rectangular blocks of stone setts laid in regular courses.
41.18	625.82	STONE-BLOCK PAVING	A form of paving in which stone blocks (usually larger than setts) are laid flat with the vertical faces carefully dressed so as to give fine joints.

Definition No.	U. D. C. No.	TERM	DEFINITION
41.19	625.75 & 625.855.4	SURFACING	A wearing coat laid upon a prepared foundation in the form of a continuous surface layer.
41.20	625.752/4	SURFACE DRESSING OR PAINTING	The surfacing resulting from the application to a road surface of a film of bitumen or tar, on which has been spread a layer of chippings or other fine mineral aggregate.
41.21		TAR CONCRETE SURFACING	A type of construction in which coarse and fine mineral aggregates are mixed with tar and laid to desired thickness.
41.22		TOP COAT	Same as Surfacing, 41.19.
41.23	625.863.2	WATER-BOUND MACADAM	A type of surfacing in which stone fragments are first interlocked by rolling and then bound with smaller stone, gravel, etc. which is forced into the interstices by brooming, watering and rolling.
41.24		WEARING COAT (Wearing Course)	Same as Surfacing, 41.19.
41.25		WEARING SURFACE	Same as Pavement, 41.15.
41.26		WOOD-BLOCK PAVING	A paving formed of rectangular blocks of wood laid in regular rows on a prepared foundation.

SECTION 4—SURFACE CONSTRUCTION

4.2—CONSTRUCTION DETAILS

Definition No.	U. D. C. No.	TERM	DEFINITION
42.01	625.731.7 625.731.8	**BASE COAT**	An intermediate course between the base course and the wearing coat.
42.02		**BASE COURSE**	That part of the construction resting upon the sub-base, or in its absence the subgrade, and through which the load is transmitted to the subgrade or the supporting soil.
42.03	625.733 & 626.35	**BERM**	A horizontal ledge or margin formed at the top or bottom of an earth slope. (*Cf. Shoulder, 42.45*).
42.04		**BLINDING**	(a) The process of applying a loose layer of fine material to fill the voids or interstices in a water-bound macadam surface. (b) The material so used
42.05		**BLOTTER**	A covering of a suitable material to absorb excess binder or to overcome bleeding.
42.06		**BOTTOM COAT**	Same as Base Coat, 42.01.
42.07		**CENTRAL RESERVE**	A median strip in a dual carriageway system, a part of which can in future be utilized for widening the carriage way.
42.08		**CONSOLIDATION**	The process or operation of making loose or disturbed material more dense by vibrating, or by rolling with a heavy weight. [*See Consolidation, 32.17 and Cf. Ramming, 42.35*]

Definition No.	U. D. C. No.	TERM	DEFINITION
42.09		**COURSE**	(a) Blocks of material, such as bricks, laid to form a single layer, one unit in height. (b) Prepared material placed to form a continuous layer of desired thickness.
42.10		**CRETEWAYS**	A carriageway in which a cement concrete wearing surface is provided for the wheel tracks only.
42.11		**CUSHION (Sub-crust)**	An intermediate layer acting as a cushion between the wearing surface and its foundation.
42.12		**DIVIDING STRIP**	A narrow longitudinal mark or construction to separate different streams of traffic.
42.13		**EDGING**	Blocks of concrete, bricks, stones or the like embedded along the edges of a pavement to protect them from damage caused by traffic.
42.14		**EXPANSION JOINT**	The self adjusting connection formed between two parts of the same structure, and so designed as to permit small relative movements under thermal changes without destroying continuity or structural properties.
42.15		**FENDER**	A replaceable device for protecting costlier not easily replaceable structures from damage caused by impact from floating bodies.
42.16		**FLUSHING**	The act of applying a material in liquid state to fill up joints or to connect shallow

Definition No.	U. D. C. No.	TERM	DEFINITION
42.16		FLUSHING (*Contd.*)	surface irregularities of an area, as with cement or bituminous grout; used in the sense of "filling up" to the top.
42.17		FOOT PAVEMENT	The paved portion of a street or a road reserved for use by pedestrians. (See Footpath 11.11.)
42.18		FORMATION	(a) The preliminary earthwork in grading and shaping a road to line and level prior to its actual construction. (b) The surface of the ground in its final shape and level after completion of earthwork.
42.19	625.731.812	FOUNDATION	(a) Natural:—The firm earth, rock or other material lying below the formation. (b) Structural:—The portion of the work constructed to distribute or transmit to the natural ground the weight of the structure together with any superimposed load. (c) Road:—The base course which sustains the wearing coat and distributes the weight of the traffic over the sub-base or subgrade.
42.20		GRITTING	The operation of spreading small broken stones, chippings, or small gravel.

Definition No.	U. D. C. No.	TERM	DEFINITION
42.21	625.067	GROUTING	The action by which a fluid cementitious binder is made to penetrate into joints, fissures, or cracks between stones or blocks, or void spaces in mineral aggregates, either under the action of gravity or by applied pressure.
42.22		IMPROVEMENT	Reconstruction in whole or in part to a higher standard of strength, efficiency or quality. [*Cf. Renewal, 42.37 and Resurfacing, 42.40*]
42.23		INTERMEDIATE COURSE	A course between the base course and the wearing coat. [Also see Base Coat, 42.01]
42.24		JOINT	The space between the adjacent faces of blocks, units or courses.
42.25		KERB	A continuous or semi-continuous raised edging of a carriageway placed so as to prevent encroachment by or to secure the constraint of wheeled traffic.
42.26	625.76	MAINTENANCE	The upholding of a construction to a definite standard of efficiency and quality over a stated period of time.
42.27		MARGIN	The narrow strip adjoining the main carriageway of a road.
42.28		MEDIAN STRIP	A dividing strip in the middle of a roadway.

Definition No.	U. D. C. No.	TERM	DEFINITION
42.29		PATCHING	Repairing or restoring to a definite standard of quality small isolated areas of a structure.
42.30		PICKING	The systematic loosening of the top surface of a road by pick axes or similar tools.
42.31		POT HOLES	Marked local depressions in a surface layer, roughly circular in plan, arising from the displacement or wearing away of material by traffic or other causes.
42.32		PRE-COATING	The process of coating individual pieces of coarse or fine aggregate with a binder prior to laying at site.
42.33	625.068	PRE-MIXING	The process of mixing of coarse or fine aggregate, with a binder prior to laying at site.
42.34		PRIME COAT	The initial application of a binder of low viscosity to an absorbent highway surface prior to the construction of a wearing coat. [*Cf. Tack Coat, 42.53.*]
42.35		RAMMING	Compaction of loose material by repeated blows.
42.36		RECONDITIONING	Replacing of old and worn out parts by new materials to obtain a surface as efficient as when originally constructed.
42.37		RENEWAL	Replacing the whole of the old and worn out surface by new materials to obtain a surface as efficient as when originally constructed.

Definition No.	U. D. C. No.	TERM	DEFINITION
42.38	625.768	REPAIRING	Restoring the wear and wastage of time and use.
42.39		RE-PAVING	Renewal of a paving.
42.40		RESURFACING	The complete renewal of an old wearing surface by new materials.
42.41		SAND PAPER SURFACE	A rough surface texture for road surfacing produced by the pressure of protuberant sharp particles of mineral aggregate which are not larger than about $\frac{3}{16}$ in. size.
42.42		SCARIFYING	The systematic loosening of the top surface of a road by mechanical or other means.
42.43		SEALING COAT	A binder applied as a thin film to close the surface voids in a wearing surface so as to render it water proof.
42.44		SHAPING	A general operation involved in bringing a surface to conform to a required shape or contour.
42.45		SHOULDER (Haunch)	The portion immediately beyond the edges of a carriageway on which vehicular traffic may pass occasionally. [*Cf. Berm, 42.03*].
42.46		SLEDGING	The operation of reducing large blocks of rock by means of sledge hammers into smaller pieces.
42.47		SPRAY	(*a*) To distribute under pressure in the form of atomized particles a liquid over a surface.

Definition No.	U. D. C. No.	TERM	DEFINITION
42.47		**SPRAY** (*Contd.*)	(*b*)—A liquid in the form of atomized particles.
42.48		**STAGGERED JOINT**	The arrangement of blocks or units of one series with respect to an adjacent series such that the transverse joints are discontinuous.
42.49		**SUB-BASE**	A layer of material placed between the base course and the subgrade. [Usually for a special purpose such as for drainage, or for offsetting any undesirable qualities of the subgrade.]
42.50		**SUB GRADE** (**Road Bed**)	The natural earth foundation as prepared and shaped to receive the actual road structure.
42.51		**SURFACE**	The external or exposed top face of the wearing course.
42.52		**SURFACE TREATMENT**	A general term for work carried out to improve the quality or behaviour of a wearing surface.
42.53		**TACK COAT**	The initial application of a binder to an existing surface given to ensure thorough bond between the new construction and the existing surface.
42.54		**TEMPORARY DIVERSION**	An improvised track laid on adjacent ground to permit the passage of traffic while the carriageway is temporarily closed.

Definition No.	U. D. C. No.	TERM	DEFINITION
42.55		**TRACKWAYS**	A carriageway in which an improved wearing surface is provided on the wheel tracks only.
42.56	625.774.6	**TRIMMING**	Cutting to shape by removing excess material.
42.57	625.732	**VERGE**	Same as Dividing Strip, 42.12.
42.58		**WHEEL GUARD**	An installed fixture or built in device projecting out at the inner face of a parapet wall or a railing, as a protection against damage by the projecting parts of vehicles.

SECTION 5—MATERIALS

5.1—CLASSES

Definition No.	U. D. C. No.	TERM	DEFINITION
51.01	625.8.07	**AGGREGATE**	The inert mineral fragments or pieces of broken stone, slag, gravel, sand or the like. (*Cf. Ballast, 51.05 ; Road Metal, 51.72.*)
51.02	625.8.06	**ASPHALT**	A natural or artificial mixture in which bitumen is associated with inert mineral matter. [The word asphalt should always be qualified by indication of its origin or nature.]
51.03		**ASPHALTITE**	A natural mixture of bitumen with organic materials insoluble in carbon disulphide.
51.04	625.8.06	**ASPHALTIC CEMENT**	A mixture of bitumen with a fine mineral aggregate, prepared for use as a binder.
51.05	625.8.07 625.731.813	**BALLAST**	(a) Small stones or gravel with grit, sand and clayey materials, of which the major proportion of the particles retained on a standard sieve having 4 square meshes to the linear inch and which when consolidated yields a coherent layer. (b) Stone or gravel of irregular unscreened sizes which may contain smaller material and sand too. (*Cf. Aggregate, 51.01; Road Metal, 51.72*).

Definition No.	U.D.C. No.	TERM	DEFINITION
51.06		**BASALT**	A dark-coloured, fine-grained basic, igneous rock composed essentially of calcic plagioclase, augite, and iron ores usually with olivine. (Some basalts are lavas, others are hypabyssal.]
51.07	625.8.06	**BINDER**	An adhesive material used for the purpose of holding together mineral particles and for assisting in their cohesion. (Also see 32.04.) (*Cf. Cement, 51.14, and Mortar, 51.55*).
51.08	625.8.061	**BITUMEN**	A non-crystalline solid or a viscous material having adhesive properties, derived from petroleum, either by natural or refinery processes, and which is substantially soluble in carbon disulphide. [Bitumens are black or brown in colour. Though they may occur naturally, they are usually obtained as the last residual products from the distillation of, or as extracts from, selected petroleum oil.]
51.09		**BITUMEN EMULSION**	A liquid product in which substantial amount of bitumen is suspended in a finely divided condition in an aqueous media and stabilized by means of one or more suitable reagents.
51.10	625.8.06	**BITUMINOUS MATERIAL**	A material containing bitumen as an essential constituent.

Definition No.	U.D.C. No.	TERM	DEFINITION
51.11		**BLINDAGE**	A material, such as moorum, earth, etc., used for covering the top of a water-bound macadam surface.
51.12		**BLOWN BITUMEN**	A bitumen the properties of which have been modified by the passage through it of air under pressure at a high temperature.
51.13	553.58 625.731.81	**BOULDER**	A detached and rounded or much worn mass of rock.
51.14	691.54 or 666.942	**CEMENT**	A medium employed in a liquid, powdery or a plastic condition which, upon hardening by cooling or hydration, will unite adjacent solid substances of a particular nature. [Also see Hydraulic Cement, 51.46.] (*Cf. Binder, 51.07 and Mortar, 51.55*).
51.15	625.8.072	**CHIPPING**	Angular fragments of crushed or broken stone, of size between 0.2 inch and $\frac{3}{4}$ inch.
51.16	668.73	**COAL TAR PITCH**	The black or dark brown solid or semi-solid fusible and agglomerative residue remaining after partial evaporation or fractional distillation of coal tars.
51.17	625.8.072	**COARSE AGGREGATE**	A relative term to denote the larger mineral fragments usually limited to a size greater than 3/16 inch.
51.18	691.32 & 666.972	**CONCRETE**	A mixture of mineral aggregate with a binding or cementing agent which on chemical action or temperature change forms a solid mass.

Definition No.	U.D.C. No.	TERM	DEFINITION
51.19		**CONGLOMERATE**	A cemented clastic rock composed of rounded pebbles of various rocks, of sedimentary or volcanic origin.
51.20	668.736.34	**CREOSOTE**	A coal tar fraction distilling mainly between 200° C. and 350° C, of which suitable fractions are used for preserving timber and for diluting bitumen.
51.21	668.73	**CRUDE TAR**	A product viscous or liquid resulting from the destructive distillation of organic materials and having adhesive properties. [The word tar should be preceded by the name of the material from which it is produced, *e.g., coal, shale, peat, vegetable matter, etc.* Its mode of production too should be indicated.]
51.22	625.8.072/3	**CRUSHER-RUN STONE**	Rock or other analogous material as broken by the crusher unsorted and unscreened.
51.23		**CURING (Rapid, Medium or Slow)**	An index of the time required for the cut-back bitumen to set or stabilise by the loss of volatile matter and by the hardening resulting therefrom and due to weather effects.
51.24	625.8.062	**CUT-BACK BITUMEN**	A bitumen whose viscosity has been reduced by a volatile dilutant.
51.25		**DIORITE**	A plutonic rock consisting essentially of oligoclase or andesine, together with horn blende, augite or biotite.

Definition No.	U. D. C. No.	TERM	DEFINITION
51.26		DOLOMITE	A rock composed mainly of the mineral dolomite, the double carbonate of calcium and magnesium.
51.27	625.8.074	FILLER	A very finely divided inert powder employed to give body to a bituminous binder or to fill the voids of a sand.
51.28	625.8.073	FINE AGGREGATE	A relative term to denote the smaller mineral fragments and particles passing through 3/16 in. square mesh.
51.29	668.734	FIXED CARBON	The carbonaceous residue remaining after distilling an organic material out of contact with the air in a standard form of apparatus and under standard conditions of heating.
51.30		FLINT	Rock or boulder consisting of very fine crystalline (cryptocrystalline) silica and sometimes showing remains of sponges and other organisms. Has a Conchoidal, glassy fracture.
51.31		FLUXING AGENT	A substantially non-volatile material used for reducing the consistency of a bitumen.
51.32	668.734	FREE CARBON	The carbonaceous portion of tar, pitch, etc., that is insoluble in a specific liquid, such as benzene, toluene, carbon disulphide, pyridine, etc.
51.33		GNEISS	Banded or foliated rock of metamorphic origin having the mineral composition of granite.

Definition No.	U. D. C. No.	TERM	DEFINITION
51.33		GNEISS *(Contd.)*	[The principle minerals contained are quartz and feldspar, with a black or white mica, forming irregular streaks nearly parallel to one another.]
51.34	625.8.071	GRADING	The act of proportioning the various particle sizes in a material.
51.35	625.8.071	GRADED MATERIAL	Material composed of definite proportions of screened sizes.
51.36	553.521 625.8.07	GRANITE	A coarse grained, holocrystalline, plutonic rock, composed of quartz, orthoclase, subordinate plagioclase, a ferromagnesian mineral, and accessories.
51.37		GRANULITE	Medium to fine grained equigranular metamorphic rock, consisting principally of quartz and feldspar with some biotite, etc.
51.38	625.8.073 553.624.1	GRAVEL	Small stones, usually water worn sometimes mixed with finer materials occurring in natural deposits. (*Cf. Shingle, 51.81*).
51.39	625.8.073	GRIT	Fine sharp-edged aggregate or coarse sand.
51.40	625.731.812	HARD CORE	A consolidated layer of rubble.
51.41	666.942.5	HIGH ALUMINA CEMENT	A material made by fusing aluminous and calcareous materials to a completely molten state and grinding the resulting clinker to a fine powder, and containing a specified percentage of alumina.

Definition No.	U. D. C. No.	TERM	DEFINITION
51.42		HIGH EARLY-STRENGTH CEMENT	A Portland cement which, by an adjustment in the chemical composition and grinding to a finer powder than the ordinary portland cement has the property of hardening more rapidly than that cement.
51.43		HORN-BLENDE	A metamorphic rock, consisting of horn-blende with small proportions of feldspar, biotite, epidote, etc.
51.44		HORN-BLENDE SCHIST	A foliated metamorphic rock consisting of hornblende, with various proportions of feldspar, biotite, epidote, etc.
51.45	624.131.26	HUMUS	A dark brown amorphous substance formed usually in the soil, due to partial or complete decomposition of vegetable matter; the organic component of the soil. (Same as 32.34).
51.46	666.941	HYDRAULIC CEMENT	A finely ground powder, which upon hydration, sets into a hard, rock-like substance. (Also see Cement, 51.14).
51.47	666.94.11	LAITANCE	Finer particles of cement and/or inert material which accumulate at the top of a concrete surface and form a thin crust after the concrete has hardened.
51.48	625.8.061	LAKE ASPHALT	A solid or semi-solid natural asphalt, existing in well defined surface deposits.
51.49	553.57	LATERITE	A mixture of red and yellow residual soils or surface

Definition No.	U. D. C. No.	TERM	DEFINITION
51.49		LATERITE (*Contd.*)	products that have originated in situ from the atmospheric weathering of rocks and infiltration of iron compounds.
51.50	553.551.1	LIME STONE	A rock consisting essentially of calcium carbonate.
51.51		MARBLE	A limestone re-crystallized by heat or pressure. [The name is applied to ornamental limestones too.]
51.52	625.8.06	MASTIC ASPHALT	Asphalt or bitumen heated and mixed with mineral fillers sand and/or chippings as to form a coherent voidless impermeable mass solid. or semi-solid under normal temperature, but sufficiently fluid when brought to a suitable temperature to be spread by means of a hand float.
51.53		MEDIUM CUT-BACK BITUMEN	A cut-back which sets or stabilises neither very quickly nor very slowly.
51.54		MOORUM	A gritty silicious material with lumps or stones not exceeding $\frac{3}{4}$ in. in size and with a natural admixture of clay of calcareous or laterite origin, preferably the former.
51.55	691.52 or 666.93	MORTAR	A mixture of cementitous material and fine mineral fragments, like sand. (*Cf. Binder, 51.07. Cement, 51.14*)
51.56	624.131.27	MUCK	Soft mud containing much vegetable matter.

Definition No.	U. D. C. No.	TERM	DEFINITION
51.57	625.8.061	**NATURAL ASPHALT**	A mixture occurring in nature in which bitumen is associated with inert mineral matter.
51.58		**NORMAL-SETTING CEMENT**	A cement in which the initial set occurs not earlier than a specified period, usually not less than thirty minutes, after mixing with water.
51.59		**PEGMATITE**	Very coarsely crystalline vein rock, consisting of quartz, feldspar, mica, tourmaline, etc.
51.60	691.2: 624.137.4	**PITCHING STONE**	A stone of a size shape, and quality suitable for use in pitching.
51.61	553.624.1	**PIT-RUN GRAVEL**	The material obtained from a natural deposit of gravel without separation into various sizes.
51.62		**PORPHYRY**	An igneous rock characterized by comparatively large porphyritic crystals or phenocrysts (generally of soda potash feldspar) in a finer ground mass of feldspar, quartz, etc.
51.63	691.54 & 666.942	**PORTLAND CEMENT**	A material made by intimately mixing together calcareous and orgillaceous, materials, and/or other silica, alumina and iron oxide bearing materials, burning them at a high temperature and grinding the resulting clinker to a fine powder.
51.64		**PRIMER**	A binder of low viscosity which on application to a surface, other than a black-top surface, is completely absorbed.

Definition No.	U. D. C. No.	TERM	DEFINITION
51.64		**PRIMER** *(Contd.)*	[Its purpose is to water proof the existing surface and prepare it to serve as a base for the construction of a black-top surface.]
51.65	553.621	**QUARTZ**	A mineral rock composed entirely of silica.
51.66	553.50/4	**QUARTZITE**	A metamorphosed quartz sandstone, formed by the deposition of secondary silica between the original grains so that the rock is more firmly cemented and less porous than before and tends to break across the grains.
51.67		**QUICK-SETTING CEMENT**	A cement in which the initial set occurs earlier than in the normal-setting cement.
51.68		**RAPID CURING CUT-BACK BITUMEN**	A cut-back bitumen which sets or stabilises rapidly.
51.69	666.942.112	**RAPID-HARDENING PORTLAND CEMENT**	Same as High Early-Strength Cement, 51.42.
51.70	625.8.06	**REFINED ASPHALT**	A natural asphalt from which water and the coarser mineral matter have been separated by the application of heat.
51.71	691.328.2 666.982	**REINFORCED CONCRETE**	Cement Concrete strengthened within its mass by metal rods, bars or other suitable material.
51.72		**ROAD METAL**	Crushed or broken stones of regular sizes below 3 inches for road construction (*Cf. Aggregate, 51.01 and Ballast, 51.05*)

Definition No.	U. D. C. No.	TERM	DEFINITION
51.73		ROAD STONE	Same as Road Metal, 51.72.
51.74	668.73 625.8.06	ROAD TAR	A product prepared by treating high temperature coal tar in such a way that it conforms to a specification which defines its applicability for some branch of road work.
51.75		ROCK ASPHALT	A natural rock formation, usally of lime stone or sand stone, impregnated with bitumen throughout its mass.
51.76		RUBBLE	Pieces of stone, brick or concrete of irregular sizes and shapes.
51.77		SAND STONE	A stone formed by consolidation of sand, predominantly of quartz.
51.78		SCHIST	Foliated metamorphic rock in which the minerals are arranged in sub-parallel bands of streaks and in which platy minerals such as micas are prevalent.
51.79	625.8.07	SCREENINGS	The small size stone particles sieved through the lowest mesh of 0.2 inch prescribed for chipping sizes.
51.80		SHALE	A compressed and laminated clay not so hard as slate, with or without associated organic matter. (Same as 31.29 and 32.64).
51.81	553.624.2	SHINGLE	Rounded or water-worn stone of irregular shape and size occurring in river beds or open beaches (*Cf. Gravel, 51.38*).

Definition No.	U. D. C. No.	TERM	DEFINITION
51.82		SLATE	Clay rock in which fine cleavage has arisen by earth pressure, producing fissility.
51.83		SLOW CURING CUT-BACK BITUMEN	A cut-back bitumen which sets or stabilises slowly.
51.84		SYENITE	A holocrystalline intrusive igneous rock, consisting principally of alkali-feldspar, with hornblende, biotite, or augite.

SECTION 5—MATERIALS

5.2—PROPERTIES AND TEST

Definition No.	U. D. C. No.	TERM	DEFINITION
52.01		ABRASION	The removal of material from the surface of a solid by grinding or rubbin gaction. [*Cf. Attrition, 52.09*].
52.02		ABSOLUTE VOLUME	The actual weight divided by the absolute weight.
52.03		ABSOLUTE WEIGHT	The weight of a unit volume of a dry material if all voids were actually filled by the material itself.
52.04		ABSORPTION	The entry of a fluid into a body through the pores of the latter. (Same as 32.01).
52.05		ACTUAL VOLUME	The volume of a material including voids.
52.06		ACTUAL WEIGHT	The weight of a unit volume, including voids, of a dry material.
52.07		ADHESION	The property by means of which a fluid or plastic substance sticks to the surface of a solid body.
52.08		ANGLE OF REPOSE	The angle between the horizontal plane and the natural slope at which earth or other loose material stabilizes without tending to slide. (Same as 32.57).
52.09		ATTRITION	Mutual rubbing or grinding within the mass of mineral fragments under the action of
52.09		ATTRITION (*Contd.*)	traffic thereby producing an alteration in their shapes and/or sizes. (*Cf. Abrasion, 52.01*).
52.10		BOND	(a) The force tending to resist the separation of two materials or units. (b) The property of mechanical interlock between particles arising from their shape and disposition relative to each other (*Cf. Cohesion, 52.14*). (c) The pattern of internal placement of units in masonry, brickwork, etc., with break of joints both in rows and courses.
52.11		BULKING	(a) The increase in the original volume of a mass of material due to disturbance or excavation. (b) The increase in the actual volume of a mass of fine granular material, such as sand due to the addition of a liquid, usually water, and subsequent handling.
52.12		BULK DENSITY	The weight of a unit volume of a loose sub-divided material.
52.13		CEMENTING VALUE (of an Aggregate)	An index of binding value assessed by the number of blows required to break under standard conditions a cylinder made of paste obtained by grinding in a specified manner the aggregate in a ball-mill.

Definition No.	U. D. C. No.	TERM	DEFINITION
52.14		COHESION	(a) The internal molecular attraction which opposes the rupture of a material. (*Cf. Bond, 52.10*). (b) The property of a material on which its degree of stability depends. (Same as 32.11).
52.15		CONSISTENCY	A general term for the rheological state of a semi-liquid or a plastic material associated with its resistance to deformation or flow.
52.16		CREEP	A slow non-elastic movement of a material caused by stress.
52.17		CRUSHING VALUE (of Aggregate).	A measure of the resistance to abrasion of an aggregate.
52.18		CURING	The process or method of protecting from too rapid drying new concrete or other made-up surfaces during the period of hardening. (*Cf. Curing, 51.23*).
52.19		CURING PERIOD	The period during which a surface is cured.
55.20		DENSITY	The weight of a unit volume of a substance at a known temperature.
52.21		DUCTILITY	(a) The physical property of a material which permits permanent distortion without rupture. (b) The amount by which a material can be elongated before fracture when tested under prescribed conditions.

Definition No.	U. D. C. No.	TERM	DEFINITION
52.22		ELASTICITY	That property of a material which permits the strain resulting from an applied stress to disappear entirely upon the removal of the applied stress.
52.23		EQUIVISCOUS TEMPERATURE (of Tar)	Temperature in degrees Centigrade at which the viscosity of tar is 50 seconds as measured by the specified tar viscometer.
52.24		FINAL SETTING TIME (of Cement)	The period elapsing between the time when water is first added to neat cement to form a paste and the time when that paste has solidified or set to a certain degree as indicated by the specified conditions of test.
52.25		FINENESS	The degree of sub-division of small particles.
52 26		FINENESS MODULUS	A measure of the mean size of graded aggregates. [It is 1/100 of the sum of the percentages of an aggregate retained by each separate standard sieve of a specified series.]
52.27		FINENESS TEST	The determination of the characteristics of sub-division of a dry powder under specified conditions of test.
52.28		FLASH POINT	The lowest temperature under specified conditions of test at which the vapour of a substance momentarily takes fire but does not continue to burn.

Definition No.	U. D. C. No.	TERM	DEFINITION
52.29		FLOW-TABLE TEST	A method of ascertaining the workability of concrete by measuring the amount by which a heaped sample will spread under standard conditions of test.
52.30		FRENCH CO-EFFICIENT OF WEAR	A measure of the resistance of a stone to wear.
52.31		HARDENING PERIOD (Cement Mortar or Cement)	The period during which a mortar or concrete continues to increase in strength or hardness to about the maximum limit.
52.32		HYDRO-METER	A float which by the depth of its immersion in a liquid indicates the specific gravity of that liquid.
52.33		IGNITION POINT	The temperature at which the vapour of a substance takes fire and continues to burn under specifed conditions of test.
52.34		INITIAL SET	The preliminary phenomenon in which the liquid or plastic nature of the cement paste in a mortar or concrete begins to disappear; it represents the beginning of the crystal formation in the mortar or concrete.
52.35		INITIAL SETTING TIME (of Portland Cement)	The period elapsing between the time when water is first added to neat cement to form a paste and the time when that paste ceases to be fluid and plastic to a specified degree under the specified conditions of test.

Definition No.	U. D. C. No.	TERM	DEFINITION
52.36		MECHANICAL ANALYSIS	The determination of the particle sizes of a granular material by sieving, sedimentation, elutriation, or other means (*Cf. Sieve Analysis, 52.49*).
52.37		MELTING POINT	The temperature at which a solid substance liquifies under standard conditions of test.
52.38		MESH	An aperture in a sieve.
52.39		ORGANIC IMPURITY	Matter of vegetable or animal origin the presence of which in a material is detrimental to its functional qualities.
52.40		PENETRATION (MEASUREMENT OF)	The vertical distance passed through by the point of a standard needle entering a material under standard conditions of applied weight, time and temperature.
52.41		PERMEABILITY	The property of a material by virtue of which fluids can pass through it and defined by the rate at which they pass under unit pressure gradient. (Same as 32.50). [Permeability is usually expressed in terms of velocity of flow per unit head loss, assuming the area of flow at any section to be equal to the cross-sectional area of both the void spaces and the soil particles; i.e., the area of the entire mass. The actual velocity of the percolating water through the void spaces is considerably greater than

Definition No.	U. D. C. No.	TERM	DEFINITION
52.41		PERMEABILITY (*Contd.*)	the value of permeability coefficient. (See 32.51).
			It is a property of the soil mass and not of the individual particles, although its value is very much dependent on the nature of those particles and the voids between the particles.|
52.42		PLASTICITY	The property of the material by virtue of which it is permanently deformed when stressed above its yield point.
52.43		POROSITY	The ratio, expressed as a percentage, of the voids in a given soil mass to the total volume of the soil mass (Same as 32.55).
52.44		PROPORTIONING	The adjustment by measure of all the constituents in a mixed material. (*Cf. Grading, 5134.*)
52.45		QUARTERING	The process of obtaining a reduced quantity as sample from a mass of material by dividing a heap into four roughly equal parts, removing opposite quarters and then repeating the same process with the remainder until the desired quantity is obtained.
52.46		RESILIENCE	The property of a solid whereby it will sustain shock load without permanent deformation.
52.47		SAMPLING	The selection by a specified method of a representative portion of a material for the

Definition No.	U. D. C. No.	TERM	DEFINITION
52.47		SAMPLING (*Contd.*)	purpose of ascertaining the quality and nature, of the whole.
52.48		SEDIMENTATION TEST	A method of determining under specified conditions of test the sizes of fine particles by deposition during specified intervals of time through a liquid at rest.
52.49		SIEVE ANALYSIS	The determination of the particle sizes of a granular or fragmentary material by means of a series of standard sieves. (*Cf. Mechanical Analysis, 52.36*).
52.50		SLUMP	The vertical depth through which wet portland cement concrete subsides from its standard moulded height when tested by the standard method.
52.51		SLUMP TEST	The determination of the slump under specified conditions of test.
52.52		SOFTENING POINT	The temperature at which a substance attains a particular degree of softness under specified conditions of test.
52.53		SOUNDNESS	The homogeneity of a solid indicated by its freedom from cracks, flaws, fissures, irregular quality or variations from an accepted standard.
52.54		SOUNDNESS TEST	The method of determining under specified conditions the soundness of a material.

Definition No.	U. D. C. No.	TERM	DEFINITION
52.55		SPECIFIC AREA	The surface area per unit weight, usually expressed in sq. centimeters per gram, of all the particles in a material.
52.56		SPECIFIC GRAVITY	The ratio of the weight of any given volume of a substance to the weight of an equal volume of pure water, the temperature of both the substance and the water being specified.
52.57		TENSILE TEST	The determination of the properties of a specimen in tension under specified conditions of test.
52.58		TOUGHNESS (of Road Stone)	The resistance to fracture under shock or impact.
52.59		TOUGHNESS INDEX (of Road Stone)	A measurement of the resistance of a stone to fracture under impact.
52.60		VISCOSITY	The external indication of the internal friction between the molecules or particles of a fluid when the velocity of flow is proportional to the stress applied.
52.61		VOIDS	The total space between the particles of a given volume of a granular or a fragmentary material.
52.62		WATER-CEMENT RATIO	The ratio of the weight (or volume) of the water to the weight (or volume) of the cement in a portland cement concrete.
52.63		WORKABILITY	The degree of ease of manipulation of concrete, mortar or

Definition No.	U. D. C. No.	TERM	DEFINITION
52.63		WORKABILITY (Contd.)	the like, with the minimum loss of homogeneity, before setting has commenced.
52.64		YIELD (of Concrete)	The factor obtained by dividing the volume of the mixed concrete as laid and measured in situ by the volume of the coarse aggregate used. Sometimes expressed as the volume of concrete per unit quantity of binder.
52.65		YIELD POINT	The upper limit of elasticity of a material.

RECOMMENDED PRACTICE FOR LOCATION AND LAYOUT OF ROADSIDE MOTOR-FUEL FILLING STATIONS

INTRODUCTION

The following principles have been laid down by the Specifications and Standards Committee of the Indian Roads Congress for general adoption after carefully considering the views of the representatives of the major distributors of motor fuels. Where local conditions necessitate any deviations from these Standards, these should be permitted after very careful consideration.

2. **The Basic Principle.** The governing consideration is to minimise, as much as possible, interference by vehicles using the amenity with the normal flow of traffic on the road.

3. **Road Authority must be consulted.** The sanctioning authority, if it is not the road authority, should consult the appropriate road authority before finally approving the site and the layout.

4. **On which side of the road should the station be sited?** On heavily trafficked roads it is proper to have one station on each side of the road so that vehicles do not have to cut across the road. On roads carrying light traffic, where the installation of two pumps, one on each side, is not warranted or is not possible for want of space, the pump can be sited on either side, provided the site is not close to a junction.

5. **Siting at Junctions.**

5.1. The siting of stations close to road junctions should not be permitted except in special cases where no other suitable site is available away from the junction.

5.2. When approving a site close to a junction, it should be ensured that sufficient space is left for future improvements to the junction.

5.3. The distance from the "stop line" (existing or likely to be put in future when the carriageway is widened) of the road to the tangent point on the curve of the exit or the entrance, (whichever is nearer to the intersection), measured in a direction parallel to the centre line of the road (Drawing I) should *not* be less than (i) 200 ft on main roads, and (ii) 150 ft on other roads. The intention is to prevent hazards caused by decelerating vehicles turning into the station and to allow standing space for about 10 vehicles during traffic hold-ups.

5.4. When the layout illustrated in Drawing II has to be adopted to enable one concern to operate two pumps, a smaller distance than that prescribed above may be allowed subject to the absolute minimum distance of 50 ft between the tangent points of the curves as shown in Drawing II. Such layouts should not be readily permitted (see para 5.1). The construction of the fencing or the low wall AB is essential to prevent vehicles cutting across.

6. **Frontage.** For easy flow of vehicles into and out of the station, the site should permit construction of wide entrance and exit with easy curves. It is, therefore, desirable to have the longest possible frontage, the minimum being 100 ft (Drawing I).

7. **Visibility.** Vehicles entering or leaving the station should be fully visible to the traffic using the main road. This is best done by selecting a site where there are no obstructions to the view between the pump and the road.

8. **Layout of Exit and Entrance.** The entrance and exit should be at least 30 ft wide and have the easiest curves, the ruling radius being 100 ft and the absolute minimum 35 ft. This is illustrated in Drawing I.

9. **Kiosk and other buildings.** The kiosk or other buildings shall not be located less than 12 ft beyond the fuel filling pump.

10. **Buffer strip.** A buffer-strip at least 40 ft long and 10 ft wide, or as wide as the foot and cycle paths, where they exist, whichever is greater, should be provided.

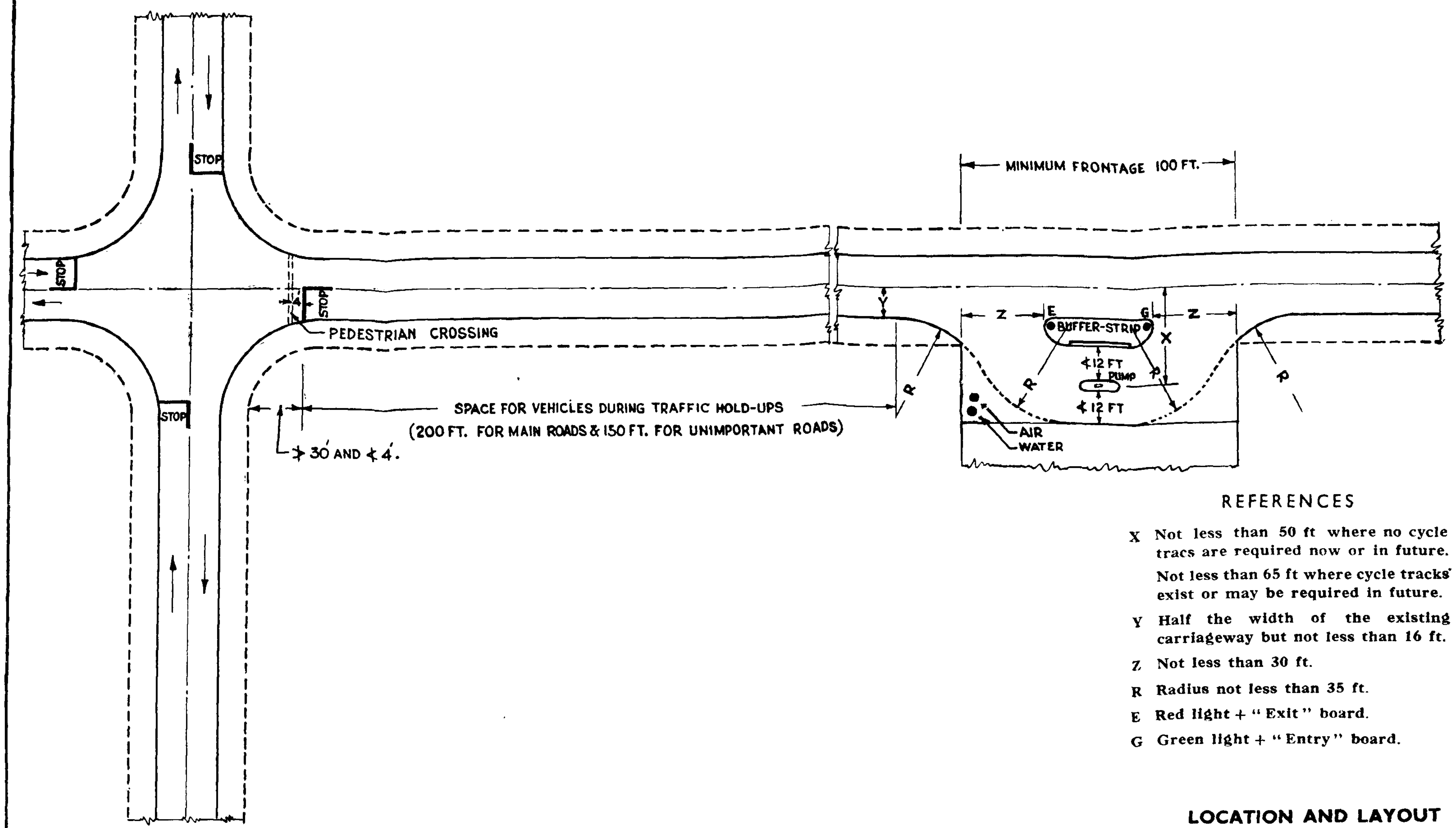
11. **Distance of the Pump from the carriageway.** The distance of the pump should not be less than 50 ft from the centre line of the road where cycle tracks are not likely to be required in future. But if cycle tracks are likely to be required in future, this distance should not be less than 65 ft.

12. **Space inside the station.** There should be sufficient standing space inside the station for vehicles to wait for their turn. In order to reduce the number of waiting vehicles it is desirable to have oil, air, etc., installed at some distance from the fuel filling pump so that vehicles which have refuelled can immediately be drawn away from the pump.

13. **Signboards and Lights.** "Entry" and "Exit" signboards should be put up to guide vehicles during the day and green and red lights to guide them at night.

14. **Typical Plans.** Drawings I and II are attached to illustrate the standards recommended above.

DRAWING No. I



REFERENCES

X Not less than 50 ft where no cycle tracs are required now or in future.
Not less than 65 ft where cycle tracks exist or may be required in future.

Y Half the width of the existing carriageway but not less than 16 ft.

Z Not less than 30 ft.

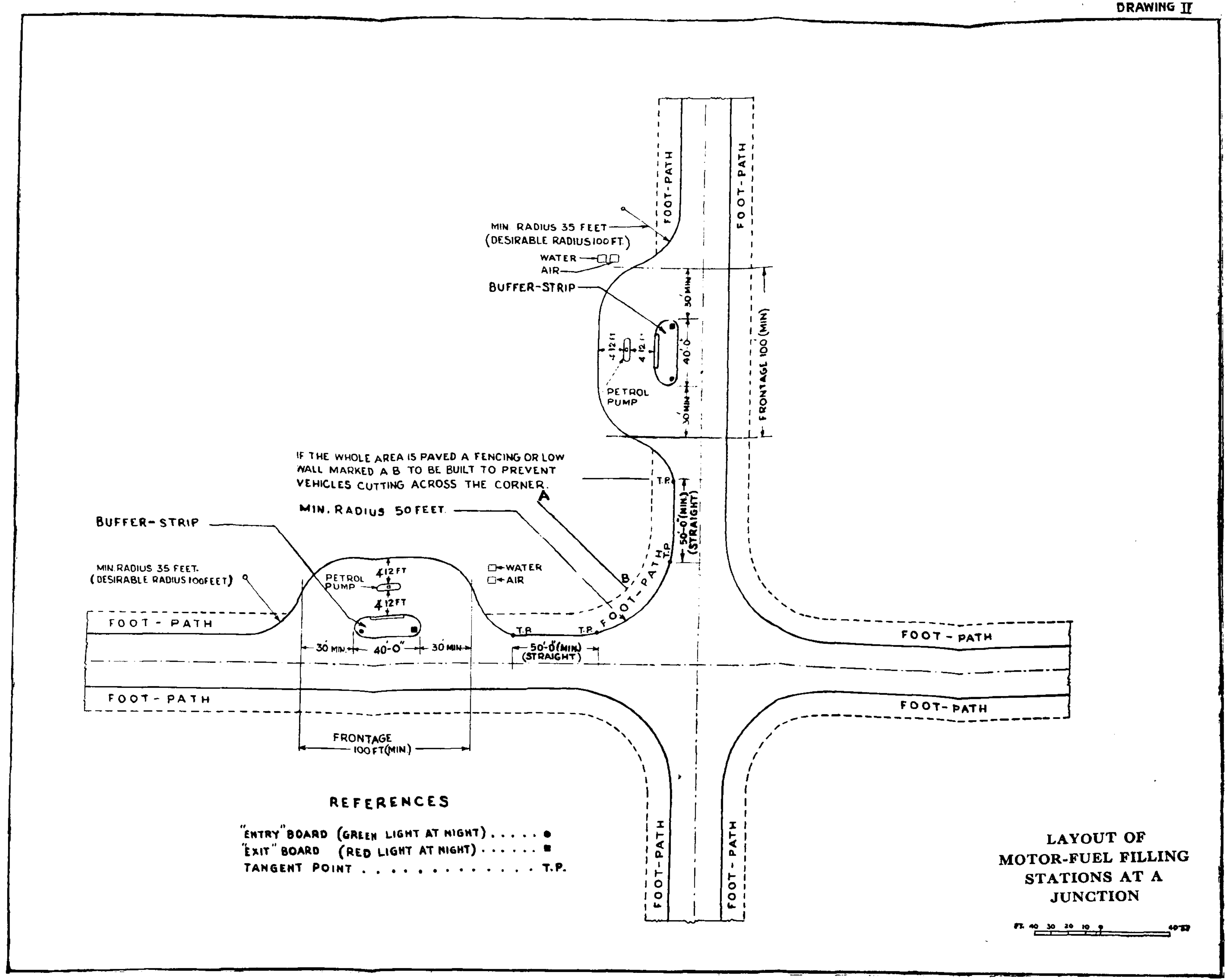
R Radius not less than 35 ft.

E Red light + "Exit" board.

G Green light + "Entry" board.

LOCATION AND LAYOUT OF A MOTOR-FUEL FILLING STATION

DRAWING II



LAYOUT OF MOTOR-FUEL FILLING STATIONS AT A JUNCTION

INFORMATION SERVICE

THE ROLE OF ROAD TRANSPORT IN THE NATIONAL ECONOMY

It is hardly necessary to emphasize the importance of transport as a vital factor in present day civilization. Efforts made to assess the economic part played by any form of transport are therefore bound to be of considerable value in evaluating economic progress. From this point of view, considerable interest attaches to an item of research work carried out by the Road Research Laboratory of the Department of Scientific and Industrial Research in the United Kingdom for estimating the expenditure on road transport in Great Britain, the results of which have been presented in a Paper by Earnest Rudd to the Royal Statistical Society and published in its Journal.* The conclusions of outstanding interest are commented upon in the following paragraphs, but the whole Paper is full of interesting information and will amply repay close study.†

As pointed out by Mr. Menzler during the course of the discussions on the paper, "the more developed, industrialized, and prosperous is a country, so the proportion of its resources devoted to ancillary activities, such as transport, is higher. It is obviously one of the features which distinguishes a primitive rural community from a more developed economy. It is, in short, the price of civilisation. The White Paper on national income and expenditure shows that the distributive trades (including a transport element) rank only after manufacturing, as regards share of the national effort. In fact, transport and the distributive trades together account for, roundly, a quarter of the national effort."

The following are the salient facts which emerge from the Paper.

(1) Transport and the distributive trades together account for, roundly, a quarter of the national effort.

(2) About three quarters of the nation's expenditure on internal transport in 1949 and 1950 was on road transport.

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* Estimates of Expenditure on Road Transport in Great Britain by Ernest Rudd. Journal of the Royal *Statistical Society, Series A* (General) Part II 1952, Vol. CXV page 179-198.

† A copy of the paper has been added to the Library of the C.E. (R.D.) and can be obtained on loan by members of the I.R.C.

(3) Road transport absorbed about 10 per cent of the nation's available resources against 3½ per cent absorbed by the railways.

(4) The expenditure on road transport and on the upkeep of roads compared as follows:

Expenditure	1949	1950
	(£ million)	
On Road Transport	1060	1220
On Roads	80	90
On accidents (estimated)	40	50
Total	1180	1360

The breakdown of expenditure on transport of goods by road is somewhat as shown in the following table:

Item	1949	1950
	Percentages	
1. Licences	4.5	4.1
2. Driver's Wages	34.2	31.7
3. Garages*	3.0	2.8
4. Insurance of Vehicles	3.2	3.0
5. Fuel	13.9	17.7
6. Lubricants	1.3	1.3
7. Tyres	4.9	5.6
8. Maintenance	15.0	14.5
9. Depreciation	9.4	9.7
10. Interest on capital invested in vehicles	1.1	1.1
11. Administration and other expenses including profits	9.6	8.4

(* Rents and rates of garages only)

It is difficult to resist comparison with Indian conditions, but unfortunately no authoritative figures are available. Prof. Madhava's essay on Road Transport Economics* contains figures of twelve transport companies as well as an "official" estimate made by a Technical Adviser of a Province and a "non-official" estimate made by a non-official Association, but the figures relate to a period more than ten years ago. Since then prices of vehicles and costs of operation have increased substantially, taxes have also increased and compulsory insurance has come into force. Moreover, some of the companies were operating extensively on producer gas. To add to all this, all the twelve companies had not given the split-up of the figures on a uniform comparable basis and the figures were also not all above suspicion. Bearing these limitations and qualifications in mind there are striking differences in the incidence of costs of fuel, tyres and tubes and wages of running staff as is evident from the table below:

Item	U. K. 1950	Prof. Madhava		
		12 Companies†	"Official"	"Non-official"
		Percentages		
Fuel, Charcoal or petrol	17.7	33.4(12)	38.1	43.9
Lubricants	1.3		1.2	1.9
Tyres and Tubes	5.6		18.2	10.9
Repairs and Maintenance	14.5	21.5(10)	16.0	5.4
Salaries and Wages	31.7	17.7(10)	6.8	6.5
Direction and development§	...	5.3(12)	3.8	8.3
Taxes and insurance	7.1	6.5(11)	3.3	9.5
Depreciation and interest	10.8	6.7(12)	12.6	13.6
Profits	11.2$	11.7(12)	—	—

* Journal of the I.R.C. Vol. XI-1, Nov. 1946.

† The number of companies on whose returns each percentage based is shown in brackets.

§ Shown together with "garages" under "Profits".

$ Including Administration charges and garage rents and rates.

The causes for the great discrepancies shown can be matters of speculation only. In the U. K. the salaries and wages of running staff seem to be very high, but conversely fuel and tyres cost for too much in India. The former can perhaps be explained as due partly to the difference in the standards of living between the two countries and partly to the heavy increase in cost of living in the post-war period. The explanation for the discrepancy in the other direction in fuel and tyres and tubes is not so obvious. Doubtless, the bad condition of roads in India is causing considerable reduction in tyre life, but does this factor reduce the life of tyres to one third? Can the difference in fuel cost (to the extent of being more than double in India, allowing for differences in taxes, cheapness of charcoal etc.) also be explained by the same cause?

Or can it be that, as petrol must give nearly the same milage in the U. K. and in India, road transport is managed on a much more luxurious scale in U. K. compared with India? Or conversely, is it inadequately supervised and tended in India?

Only research can give the answers to these questions. But they do bring into relief important problems whose solution can save lakhs and perhaps crores of rupees to the country. They also show the necessity for collecting reliable and up-to-date data regarding the cost of operation of vehicles in this country and for making a thorough study of the various factors relevant to road transport operation.

AN INTERESTING PROBLEM

A very interesting economic problem relating to road-rail relations was posed by Prof. Jones during the course of the discussions on the Paper. In his own words, " we have on the one side a railway system which once enjoyed a virtual monopoly of transport operation in this country. During the depression of the early 1930's the rail transport industry suffered very severely, partly on account of the universality of the industrial depression, and partly on account of the increasing competition of road transport. At the present time we are again suffering, or appearing to suffer, from a very heavy cost of idleness on the railways, and it is quite clear that if we could fill the railways with work within the limits of its present structure the railway industry would be benefiting from the operation of the law of increassing returns. On the other side, we have a rapidly growing road transport system which is already imposing a severe strain upon the roads of the country. It is perhaps true that, looking forward, say, five years, road transport in congested areas will be suffering

from the operation of the law of diminishing returns. Thus the law of increasing returns is operating on the one side and the law of diminishing returns on the other, and I feel pretty sure that one of the major tasks in the very near future will be to decide what constitutes a square deal as between two systems of transport.

That, I think, is the significance of the figures presented in this Paper. The importance of the Paper lies in the fact that at last we have, I believe for the first time, a comprehensive and conservative estimate of the statistical importance of road transport in the whole national economy ".

Another matter of interest is the justification for further expenditure on roads. As pointed out by Mr. Menzler in the discussions, it is difficult to say whether the high proportion of national effort expended on transport, viz., one-seventh, is a matter of satisfaction or alarm. Here clearly is a wide field for economists to exercise their minds. Unlimited scope also offers for research in many directions. In one of its aspects the heavy cost to the community of traffic congestion could be relieved in considerable part by road improvements—and it has been suggested that London Transport alone would save £2 millions a year if bus speeds increased on the average by one mile per hour.

Mr. Menzler in this connection also recalls Mr. Valentine's Presidential address to the Institute of Transport wherein it was mentioned " it could be proved that the expenditure of a given sum on road improvements would produce a bigger and quicker dividend in the saving on man-hours, equipment, and resources than an equal expenditure by almost any of the major industrial users of capital today.

One well-known authority had expressed privately the conviction that such an investment on roads could be shown, if the facts were all properly established and marshalled, to yield a return in increased national productivity perhaps three times greater than the return obtained from the same capital spent on oil or steel, or even electricity, and about equal to the return from similar expenditure on coal mining ". Here is food for thought for financiers who want economic justification for road expenditure on a 'yield' basis!

The figures in the Paper showed that, while before the war, £ 3 5 sh. 3 d of every £ 1000 of national income had been spent on new or improved roads, the expenditure since was only

7 sh. 4 d. In India the corresponding figure would be between Rs 2 and Rs 3 per Rs 1000 of national income.

The above paragraphs give an outline of some of the interesting results contained in the Paper and the discussions. The Paper was originally submitted as a report to the Economics Committee of the Road Research Board who decided that it should be given as wide a publicity as possible.

ABSTRACTS

ROADS IN GENERAL

1. 625.8 "Ideal Road Surface yet to come"—by 'Observer'—Highways and Bridges, 7th May 1952, pp. 1 & 3).

While observing that road surfacing techniques have been changing like fashions without really giving an ideal surface, the 'Observer' ends by saying that "the ideal surface must be permanently non-skid in all weather conditions except freezing sleet, and should never require gritting except during the formation of ice films or in snow; it should be light enough in colour to give ample luminosity with head lights in the dipped position, but no glare in blazing sunshine; it must be homogeneous and require no joints; it should have a low tractive resistance, but high adhesion for braking, even in worst weather conditions; it should be cheap in first cost and the road surveyor would like it to last for ever."

2. 625.8 "New Road Testing Machine" developed by Shell Research (Highways and Bridges, 12th March, 1952, p. 10).

Mention is made of a machine used for studying the behaviour of road structures under dynamic or moving loads. The machine is also used to ascertain the effects of traffic vibrations on the strength of the road.

3. 625.8 "Highway Research Board Meeting"—Highways and Bridges, 30th January, 1952, p. 4.

Synopses of papers on the following which came up before the Highways Research Board Meeting at Washington in January 1952 are given: Stability and durability of plant-Mixed macadam; Group pile loads in plastic soils; Parking turnouts and rest areas; Tyre design; Vehicle design and vehicle mobility; and Load distribution on highway bridges having adequate transverse diaphragms.

4. 625.7 "Adoption of Aerial Surveys for Highways" by W. T. Prior; (Highway Research Abstracts, Volume 23 (5), May, 1953).

A brief history of the adoption of aerial surveys by highway engineers in the United States of America is given. The advan-

* Universal Decimal Classification Numbers.

tages of adopting aerial surveys are explained. It is shown how aerial photographs give soil information for aligning a highway and siting its structures.

The article discusses in brief the following four stages of highway alignment and the use of aerial surveys in them:

(1) Reconnaissance of a broad area to determine all feasible alternate routes from one terminal point to another.

(2) Reconnaissance of the feasible alternate routes to compare them and select the best route.

(3) Preliminary survey of a band of topography along the best route for designing the highway location on it.

(4) Location survey, namely, the actual staking on the ground of the highway alignment (centre line), grades, cross sections, structures, and rights-of-way.

Cost data of a recently completed project are included.

5. 625.8 "Why America Builds Better Roads" Lt. Col. E.W.W. Richards (Journal of the Institution of Municipal Engineers, December, '52).

This is an interesting article on the technical and administrative policies of American road building in recent times. dealing with the importance of highway transportation and its effect on American life in economic, financial and international spheres. The extent to which private finance was made use of in improving roads to suit traffic development is also explained. Methods adopted to reduce traffic hazards and accidents are illustrated. The importance of planning and proper execution is also discussed. Engineer-Contractor relationship is also discussed. The progress of highway engineering in America is explained to be due in no small measure to the system of financing adopted in that country. The question of equitable distribution of highway taxation among the various sections of the community is considered difficult to solve, but the principle of applying the funds contributed by road users wholly to their construction and improvement is followed. Reference is also made in some detail to the training given to the graduate-recruit engineer by the U. S. Bureau of Public Roads. Summing up, the American highway development is stated to involve complex factors such as considerations of operational cost and efficiency, human safety, materials and traffic research, employment conditions, financial and administrative structures, aesthetics of highway design, and contract procedure.

SOIL ENGINEERING AND DRAINAGE

6. 624.131. Proceedings of the Third International Conference on Soil Mechanics and Foundation Engineering (1953), Organizing Committee, Gloriastrasse 39, Zurich 6.

Volume I.

Section 1—Theories and Hypotheses of General Character, Classification, Engineering Geology. The more important papers are:

(1) Influence of Vegetation on Soil Moisture Contents and Resulting Soil Volume Changes by E. J. Felt of U. S. A.

(2) Relation between the Mean Grain Size, the Size Factor and the Optimum Moisture Content of Compacted Soils by M. S. Youssef of Egypt.

Section 2—Laboratory Investigation, Including Compaction Tests, Improvement of Soil Properties. The following papers are of particular interest:

(1) Stable Density by C. L. Dhawan and 4 others of India.

(2) Experimental Determination of the True Cohesion and True Angle of Internal Friction on Clays by R. E. Gibson of England.

(3) The "Hydration" Method, A New Process of Stabilizing Soils by Inorganic Agents by K. F. G. Keil of Germany.

(4) The Shearing Resistance of a Fine Closely Graded Sand by K. L. Nash of England.

(5) Determination of Swelling Pressure of Black Cotton Soil—A Method by R. M. Palit of India.

Section 3—Field Investigation, Technique of Field Observations including Compaction Control, Soil Stabilization. The more interesting papers are:—

(1) Quality Control of Earth Embankments by F. J. Davis of U. S. A.

(2) The Compaction of Soil for Earth-works and the Performance of Plant by W. A. Lewis of England.

(3) Investigation of Some Problems in Soil Stabilization by D. J. MacLean of England.

(4) Soil Stabilization in Tropical Areas for Mass Construction of Cheap Permanent Housing by S. R. Mehra of India.

(5) Field Compaction Tests on Lean Clay Soil by W. J. Turnbull and W. G. Shockley of U. S. A.

Section 4—Foundation of Buildings and Dams, Bearing Capacity, Settlement Observations, Regional Subsidence. The following are some of the interesting Papers :

(1) Settlement Studies on the National Museum Building, Ottawa, Canada by C. B. Crawford of Canada.

(2) Settlement Observations in Finland by K. V. Helenelund of Finland.

(3) Building Settlement Measurements—Oregon State College by G. W. Holcomb of U. S. A.

(4) The Use of Sand Drains Under Buildings at Port Newark by J. M. Kyle of U. S. A.

(5) The Bearing Capacity of Foundations under Eccentric and Inclined Loads by G. G. Meyerhof of England.

(6) Settlement and Permissible Bearing Pressures by E. Schultze of Germany.

(7) The Foundations of the Bank of China Building, Hong Kong by M. J. Tomlinson and J. B. Holt of England.

(8) Soil Movement and Weather by W. H. Ward of England.

Volume II.

Section 5—Piles and Pile Foundations, Settlement of Pile Foundations, contains 18 Papers, of which the following deserve special mention :—

(1) Investigations of Values of the Dynamic Penetration Resistance to Model Piles in Sand and Clay, obtained from Tests by H. Grasshoff of Germany.

(2) An Investigation for the Foundations of a Bridge on Dense Sand by G. G. Meyerhof of England.

(3) The Problem of Pile Driving by N. Nanninga of Netherlands.

Section 6—The paper on Roads is interesting.

(1) The Design of Road Foundations by D. C. MacLean and M. D. Armstrong of England.

Section 7—deals with Earth Pressure, Retaining Walls, Tunnels and Pits in Soils. The following are some of the interesting papers :

(1) Measurements of Loads and Strains in Earth Supporting Structures by L. F. Cooling and W. H. Ward of England.

(2) A General Earth Pressure Theory by J. Brinch Hansen of Denmark.

(3) The Behaviour of the Concrete Bridge Built at Klosters by the Rhaetian Railway Company, Switzerland under the Influence of Soil Creep Pressure by R. Haefeli, Ch. Schaerer and G. Amberg of Switzerland.

Section 8—deals with Stability and Deformation of Earth Slopes etc. The following papers are interesting :—

(1) Landslides in Japan by Masami Fukuoka of Japan.

(2) Applications of Soil Mechanics in River Structures (India) by K. L. Rao of India.

(3) Recent Research into the Coastal Landslides at Folkestone, Warren, Kent, England, by A. H. Toms of England.

7. 624.131. Annual Report (1951) of Concrete Research Laboratory, Chepauk, Madras. The work done in the laboratory is presented in two sections : (1) Soil Mechanics and (2) Building Research.

In the section on Soil Mechanics, routine tests for ascertaining the bearing capacity of the soils for the foundation of the bridge across Bharatpuzha and Upputeru are presented.

Reports on research studies on the variation of cohesion and the angle of internal friction of black cotton soils from Madurai at different moisture contents and various degrees of compaction are included. The main conclusions of the study, which is still in progress are: (i) that the angle of internal friction is inversely proportional to the moisture content and (ii) that cohesion has an optimum value similar to the dry density but occurs at a moisture content below the moisture content for maximum dry density.

The section on Building Research deals with :

(1) Use of sea sand in construction work.

(2) Chemical studies of surkhi.

(3) Strength of cement mortar with various admixtures.

(4) Accelerated curing of concrete.

(5) Various dimensions of the specimens on the strength of concrete.

(6) Design of mix with reference to strength and workability.

8. 625.745. "Some Recent Foundation Research and its Application to Design." By G. G. Meyerhof (The Structural Engineer, June, 1953).

In the past, foundation design was essentially empirical and based largely on permissible bearing pressures or loads to avoid failure of the ground. The study of foundation behaviour in the field amplified by laboratory research has led to a more rational approach in which the results of a site exploration and soil tests form the basis of an analysis of the stability and probable movement of the proposed foundation and superstructure. The present paper is mainly concerned with recent research on foundation behaviour and indicates how the results may be applied to structural analysis.

The paper shows how the soil, the foundation and the structure can be considered as one integral unit and discusses in general terms the main aspects of this approach. Since foundations form the link between the superstructure and the soil, they have to fulfil two main interrelated functions: First, the stability of the foundation soil must be assured with an adequate margin of safety and, second, the movement of the foundation must be within limits that can be tolerated by the superstructure.

The bearing capacity of shallow and deep foundations under a central load is briefly discussed, and the effects of eccentricity

and inclination of the load are indicated. The total and differential settlements of foundations are estimated in relation to the soil and foundation characteristics and the stiffness of the structure. The settlement stresses in foundation and superstructure are considered, and recent observation on brick walls and cladded building frames are analysed. The lateral movement and tilting of foundations are estimated and illustrated by the results of some loading tests on model portal frames on clay and sand.

9. 625.731.3 Highway Subdrainage. By the Physical Research Branch, Bureau of Public Roads, U. S. A. (Public Roads, February 1952.)

The Report presents test data on permeability and drainability of soils and their applicability to highway subdrainage. The data are utilized to illustrate methods of calculating vertical capillarity flow, flow into horizontal drains, and lateral drainage of base courses.

The apparatus used are illustrated. The inter-relation of drainage, density and gradation of soils is also discussed.

The tests show that small gradients generally obtained for lateral drainage are not effective for the rapid drainage of dense graded materials on impervious subgrades.

10. 631.4–A New Concept—Using Chemicals for Soil :—C. L. Swanson (Journal of Soil and Water Conservation, Vol. 7, No. 2, April 1952).

How the use of Krilium in soils high in clay content improves their structure, increases their porosity and permeability making them easier to work with while reducing cracking and crushing of the soil surface is described. Soil and berm erosion can also be controlled by its use.

11. 624.138.–";Coquina" Asphalt Street in Florida L. J. Ritter. (American Highways, Vol. XXXI No. 2, April 1952, pp. 14-15 and 25-27).

Describes work done in 1949 for the City of Jacksonville Beach to aid the design and construction of low cost streets with local materials since conventional aggregates for the stabilization were scarce and very costly. After preliminary investigations, local sand (top soil), Coquina, and hardpan were experimented with. The chief purpose was to " develop a sort of mixture which would serve either as a combined base and wearing surface or as a base which would require only a very thin surface treatment to withstand the abrasive effects of traffic." Results of tests are tabulated.

Large-scale field experiments are described as conducted between 14th December 1950 and 3rd January 1950. Results as observed in August 1951 under moderately heavy traffic and occasional very heavy loads are stated to be satisfactory. Rapid-curing cut-back asphalt (R. C. - 1S) was used for the stabilization. Calcium chloride was used in one of the sections to aid compaction in obtaining a higher density.

12. 625.731.3. "Oklahoma Turnpike" — (Highways and Bridges, 18th June 1952, pp 1 & 3).

Design details of an 88-mile flexible paving are given. Subgrade was of special soil, with a C. B. R. value 10 or more, P. I. less than 9, obtained by mixing non-plastic granular soils with 20 to 40 per cent of soils having P. I. greater than 8 and less than 15. Final subgrade material was made to pass 2 in. sieve.

The stabilised aggregate, base course was obtained by blending coarse aggregate, sand, stone dust, or other inert fines of mineral matter and soil binder.

13. 625.81. "METHODS OF SOIL STABILIZATION AND THEIR APPLICATION TO THE CONSTRUCTION OF AIRFIELD PAVEMENTS." by D. J. Maclean, and P. J. M. Robinson. (Proceedings of the Institution of Civil Engineers, Part II, Volume 2, Number 2, June, '53).

Consideration is given to the use of stabilized soil for constructing the bases of airfields of the permanent or of the temporary military type. As shown in the Appendix, a fairly large number of airfields have already been constructed with stabilized soil, the techniques employed being usually extensions of road practice.

14. 625.81. "SPECIFICATIONS FOR ROAD GRAVELS AND SAND-CLAYS". (Main Roads, June 1952, pages 101—109).

The article discusses the use and properties of gravels and sand-clays in pavement construction. Standard for material for soil-aggregate sub-base, base, and surface courses with reference to typical mixtures of materials available in New South Wales are discussed. Grading curves and tables are given. While the

A. A. S. H. O. does not prescribe any grading restriction for size below No. 200 sieve size, it was found necessary that the grading should be extended down to a much smaller grain size.

CONCRETE ROADS

15. 625.84 "CONCRETE ROAD DESIGN AND CONSTRUCTION" by Civil Engineer—(Highways & Bridges, 16th April 1952, pp. 4, 12 & 18).

Discussing the Westergaard's formula for design thickness it is mentioned that intelligent consideration of subgrade conditions and experience ought to be the guiding factor rather than empirical or theoretical formula and that uniform thickness seems to be universal. Spacing of expansion joints in reinforced concrete roads is generally at 120 ft with dummy joints 30 to 40 ft apart. So far as American practice is concerned all expansion joints are dowelled and use of reinforcement appears to be common. A case is described where joint failure had to be prevented and adjacent slabs had to be reinforced with dowels.

16. 625.84. "Evaluation of concrete curing methods" by Melville and R. W. Czaban—(Highways and Bridges, 9th April 1952, p. 6).

This briefly describes the object of curing. Electrical methods were chosen to secure the desired data. The following order of effectiveness to maintain low and uniform temperatures was noticed : liquid membrane seal with whitewash, damp burlap, waterproof paper, no cure, liquid membrane seal.

17. 625.71. Factors Affecting The Riding Qualities of Machine-Laid Concrete Roads by R. H. H. Kirkham ; Proceedings of The Institution of Civil Engineers, Part II, Vol. 2, Number 3, October 1953.

Measurements made by the Road Research Laboratory had shown that the riding qualities of machine-laid concrete roads are generally not as good as that of hand-finished work. This study revealed that better results might be expected from closer control of various constructional operations. Therefore studies were made during the construction of two roads in which two different spreading and two different finishing machines were employed.

The Paper gives the details of construction and tests made with a profilometer specially designed to record irregularities of the concrete surface after each pass of the finishing machine. During these tests the accuracy of setting formwork and its deflexions under machines were also studied.

Some of the important conclusions given in the Paper are :—

(i) The evenness of the finished surface depends upon the evenness of spreading. Existing spreading machines do not give concrete of uniform density and it is necessary to control the method of their operation carefully.

(ii) The effectiveness of the finishing machines for removing irregularities left by the spreading depended upon the weight, shape, and method of mounting the oscillating screed.

(iii) Even with high quality workmanship and good supervision the forms were sometimes as much as 3/8th of an inch out of alignment when set by boning. Settlement under the machines on some subgrades may increase the amount of unevenness.

(iv) Unevenness at dummy joints is the least.

18. 625.84. The Design of Concrete Mixes, J. D. McIntosh. (Journal of the Institution of Municipal Engineers, March 1953).

Concrete mix design and a review of the characteristics of concrete that go to make for its strength and durability combined with workability are dealt with. The method of estimating suitable mix proportions, using the tables and charts furnished by the Cement and Concrete Association in their Research Note 4, is explained. The importance of designing laboratory trial mix first and then a full-scale trial mix is stressed. Based on laboratory and full-scale trials variations are recommended to be made so that while laying the quality of concrete does not vary in the field.

19. 625.84. Compaction of Concrete Slabs by Vibrators: (Highway Research Abstracts, October 1952, Vol. 22, No. 9)

Test Results of experiments conducted at Road Research Laboratory, London. Small variation of workability affects surcharge required and depth of compaction, and so effect of method of compaction alone was studied. With constant acceleration and vibration numbers, increased compaction resulted in increased depth of compaction. Change of acceleration alone did not affect depth of compaction. Depth of Compaction varied inversely with speed of travel. Depth of compaction is unaffected by acceleration if amplitude and number of vibrations be constant, but is related to the product of amplitude and number of vibrations with a limiting value depending on concrete mix and vibrator characteristics. Vibration with constant acceleration is to be adopted with large amplitude and low frequency. High frequency results is the best surface finish.

MAINTENANCE OF HIGHWAYS

20. 625.76. SURFACING AND OTHER WORKS IN STRETFORD: R. Moody (Highways and Bridges, 5th March 1952 p. 5).

The successful use of cold asphalt in road works like surface dressing and precoated chipping carpet, and reconditioning of R. C. Structures by the use of cement gun are explained.

BRIDGES

21. 624.21 Expediting Overstress Analysis in Highway Bridges :—J. Trueman Thompson and Bernhard H. Booke. III. (American Highways, Vol. XXXI No. 2, April 1952, pp. 8–13.)

Describes the method employed to quickly ascertain the overstress in old bridges due to the maximum effects produced by legally permitted load and axle arrangements. For expeditious work approximate methods were adopted by taking average values of axle spacing, and loading ; but the placements of the dead, live, and impact loads were according to the Standard Specifications for Highway Bridges.

Graphs are worked out for centre line bending moment, relationship of live and impact load moment and reactions in floor beams for different load classes.

22. " Prestressed concrete footbridge tested to destruction "—(Highways and Bridges, 14th May 1952, p. 4).

The bridge, consisting of plain beam construction supported on columns 76 ft apart with 12 ft wide deck, was designed and built according to the Freyssinet system, the prestressing being with 24 Nos. 12-wire cables and wire anchorage in precast cement concrete blocks, to carry a load of 35 tons. The testing was for the design load at first and then for a 25 per cent overload, next for a 50 per cent overload which was left overnight, and then the whole weight released next morning and loading done that day up to 70 tons and the next day up to destruction. The actual load at collapse was 85 tons as against 90 tons predicted and provided for at site. A view of the bridge at moment of collapse is also published.

23. 624-68. THE PORTAL FRAME BRIDGE: J. J. Leeming (Journal of the Institution of Municipal Engineers, September, 1952).

Discusses the advantages of the portal frame and its general principle and method of design. Temperature, shrinkage and deflection are also considered, and the practical case of a bridge of the type used for construction in Dorset is quoted as an illustration.

24. 624.68 "Bridge on East-side Approach Road at Borough Boundary, Swansea." B. Eriksen (Journal of the Institution of Municipal Engineers, October 1952).

Design and construction of a road over-bridge, of skewspan 64 ft 3 in. with pin jointed R. C. portal frame are described. The design was to take the Ministry of Transport's (London) new heavy loading, comprising two knife edge loads of 150,000 lb. each on a width of 10 ft and 25 ft apart.

25. 518.6 : 624.624 A Numerical Method for Analysis of Two-Hinged Elastic Arches by Deflection Theory—Dr. P. N. Chatterjee (Journal of the Institution of Engineers, India, December, 1952, pages 125-161).

Analyses the action of a two-hinged elastic arch by the deflection method. Formulae have been developed for calculating bending moment. The results of a model test on a two-hinged arch carried out at the Bengal Engineering College, Howrah are also included. This numerical procedure is recommended by the Author for use in designing arches both by the ordinary and deflection theory.

26. 624.6—Indeterminate Frame Analysis by the Method of Equivalents—by M. R. Saha (Journal of the Institution of Engineers, India—March 1952, pages, 67-92).

Describes a method of dealing with frames consisting of members of uniform cross-section and fully restrained against lateral sway. It involves evaluation of final rotation of joints under the influence of equilibrating moments and is known as the method of equivalents. The principle involved is based on replacement of complex frames by equivalent simple ones and is derived from the fundamental equilibrium equations of elastic joints.

The theory is dealt with first and then the practical aspect. Computation procedure with a summary of formulae is given. An example is also worked out.

27. 624.22—The Protection of Steel Structures in Salt Atmosphere:—H. C. Bright (Main Roads-December, 1952, pages, 53-59).

Experiments were conducted by cleaning and painting all the faces of plates by various processes and exposing them to atmospheric action by suspending them, so that one face was exposed to sunlight and the other shaded. The conclusions are that the surface preparation of steel by sand blasting is the best, scraping and wire brushing next best and flame cleaning and wire brushing is the least effective; Redlead is a better rust-inhibiting primer than zinc chromate for imperfectly cleaned steel, and Tung oil phenolic paint vehicle provides a more water-proof paint than an alkyd vehicle. For exposure in salt atmosphere zinc paints failed but aluminium was extraordinarily good on grit-blasted surfaces.

TRAFFIC MARKINGS SIGN AND SIGNALS

28. 625.746.5 "Traffic Paint Development in California" E. D. Bots (Highway Research Board Bulletin 57, 1952, pages 1-8).

Based on Laboratory experiments, large-scale experimental trials of five different kinds of white line marking paints were carried out. The formulations tried were (1) the D. B. B. chinawood oil; (2) Alkyd; (3) Dispersion resin; (4) Chinawood oil-pentalyn varnish-chlorinated rubber; (5) Modified phenolic resin-castor oil-chlorinated rubber. All of these were tried with reflectorisation beads.

Type (4) gave the best results under all conditions of traffic (30,000 vehicles per day) and weather (alternate wet and dry).

Experiments are in progress to perfect this material. Another formulation which promises good results is "Pliolite" with a mixture of chlorinated paraffins for use in cross walks in unbeaded lines.

TAR AND BITUMEN

29. "New Adhesion Agent for Surface Dressing"—(Highways and Bridges, 18th June, 1952).

Mention is made of a new agent, D. S. 2274, for use in bitumen surface dressing in wet weather, tested at the Road Research Laboratory and found satisfactory and recommended in place of 'cetyl pyridinium' which is at present very much in short supply. D. S. 2274 is stated to be in adequate supply and is to be applied as a solution in creosote either by mixing with chips or sprinkling over bitumen-sprayed surface before application of chippings.

30. "Research into the ageing of Bitumens"—(Highways and Bridges, 28th May, 1952).

This refers to research made by sensitive methods and reported to the 'Institute Technique due Batiment et des Travaux Publics' by M. Dubrise. Experiments at temperatures between 65 and 110 deg. C. disclosed oxidation of bitumen, besides the increase in the rate in case of asphaltenes (very rapid at 115 deg. C. slow at 65 deg. C. and much slower at lower ordinary temperatures). Products insoluble in toluene formed at 115 deg. C. Experiments showed ageing of bitumens to be due to oxy-polymerization.

31. 625.858—Tar Macadam by A. R. Lee ('Road Tar,' September 1951, pages 7-13).

The article deals with the types of tar macadam and tar carpets that are in use to meet present traffic in Great Britain, and the specifications adopted in their construction. The use of aggregates from soft stones as limestone, igneous rocks and rounded stones and the effects of oxidation of tar are also discussed. The importance of low volatility and oxidation of tar is stressed. Results of experiments on the use of tar-bitumen mixture are included. The essentials of a 'dense tar surfacing' are explained.

32. 625,754—The Mechanisation of Road Maintenance operations with particular reference to Hot Surface Dressing by C. R. Chadwick ('Road Tar', September 1951, pages 15-17)

How the use of machines results in increased outturn and how to match economically the general purpose and special plants on a job are briefly explained. The effects of site and weather conditions are also discussed.

33. 625.754—The Use of Precoated Chippings for Surface Dressing by L. F. Cantlay ('Road Tar,' September 1951, pages 20 & 21).

An experimental surfacing with tar precoated chippings, carried out at a roundabout in September 1949 at the commencement of Croydon Bypass is described.

Type 'A' tar of 44 E. V. T. with wetted and unwetted stone chippings was used.

34. 625.736—Preparation of Gravel Pavements for Bitumen Surfacing: H. C. Macready, Divisional Engineer, Department of Main Roads (Main Roads, December, 1952, pages 35-40).

This article gives details of field methods used for obtaining a good bitumen-surfaced pavement out of gravel surfacing. Details of preliminary operations to correct the alignment, profile and surface irragularities, depending on type of gravel, time of year, rainfall, plant available and other factors, are given. The processes of grading, watering, compaction, and maintenance grading are described.

35. 625.8.072 : 620.60—Stripping of Bitumen from Aggregates (Main Roads, March 1952, pages 90-95.)

The method adopted in New South Wales to test a large number of aggregates by subjecting them to "Immersion-Compression Test" is described. The procedure followed for the tests was slightly different from the test procedure prescribed by the U. S. Bureau of Public Roads.

An appendix of the test procedure adopted is given.

BOOK REVIEW

"PUBLICATION OF THE INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING" VOL. XII, 1952, issued by the International Association for Bridge and Structural Engineering, Swiss Federal Institute of Technology, Zurich, pages 324 ; price not stated.

The publication contains 17 Papers, presented to the Association, on various subjects. Eight are in English, four in French, and five in German.

The following Papers are in English.

(1) "Partially Prestressed Concrete Constructions, Built in the Eastern Region of British Railways 1948—52" by P. W. Abeles.

The Paper deals with partial prestressing, its economy and usefulness. Routine tests to investigate the quality of prestressing are described and examples of practical application to 16 road bridges over railways of spans 20 to 50 ft built as composite partially prestressed slabs are given.

(2) "The Design of Small Railway Underbridges with Special Reference to Erection and Maintenance under Traffic" by P. S. A. Bridge.

The Paper explains the present practice in the design and maintenance of various types of railway bridges after discussing the design loadings and calculations for impact effects due to hammer blows, rail joints and lurching. The use of water proofing layers between the ballast and the deck slab is discussed. Comparative costs of various types of construction, for a double deck of 40 ft span, are given. The choice between welding and riveting for fabrication is touched upon and reference is made to current practice in painting steelwork.

(3) "Approximation Following from the Maximum Condition Applied in Theories of Plasticity and Earth Pressures" by Hermann Craemer.

The Paper deals with the Plastic Theory as applied to beams, frames and plates in the higher ranges of stresses when the Elastic Theory has ceased to apply. The effects of movements in the critical sections are described and it is shown how approximations in computing the maximum stresses do not generally result in appreciable errors by the use of this Theory.

(4) "Shear Deflections in Latticed Structures" by Charles Doveton Crosthwaite.

(5) "Statics of the Vierendeel Girder" by Prof. I. A. el Demirdash.

(6) "Model Verification of the Classical Flutter Theory as Adapted to the Suspension Bridge" by Prof. F. B. Farquharson.

(7) "The Fabrication and Erection of the "Dome of Discovery" by J. D. Vaughan.

The Paper describes the fabrication and the erection of the Dome of Discovery built for the 1951 Festival of Britain. This structure has an overall diameter of 365 ft and is probably the largest dome in the world. The curved latticed girders, tubular struts, and bolts and nuts were of steel and the remaining parts of aluminium. Approximately 138 tons of steel and 234 tons of aluminium were used in the construction.

(8) "Mathematical Prediction of Suspension Bridge Behaviour in Wind from Dynamic Section Model Tests" by George S. Vincent.

The following Papers are in French :

(1) "Corrosion problems of Concrete" by Pierre Chevrier and Robert Houbas.

The Paper deals with the effects of pure water, salt water, and frost on concrete hydraulic structures in France.

(2) "Tests concerning Creep and Shrinkage Losses in Prestressed Concrete" by Guy Dawance.

The Paper describes the use of a simple testing device to ascertain the creep of steel and concrete, as shrinkage in concrete progresses as it occurs in prestressed concrete girders, and gives the results of a few tests.

(3) "The Sectional Method in Slab Theory" by R. L. Hermite.

In this Paper the Author describes a method of calculations for slabs and flat coverings with free edges from theory of intersectional slabs supported freely at the edges.

(4) "Adoption of Superelevation in Concrete Slabs of Mixed Constructions in Steel, and Concrete" by M. Oudotte and M. Guerin.

The design of bridges comprising the structural steel frame with concrete deck has been the subject for research for many years. When the beams are continuous there is a tendency for the slabs to crack over the supports. To prevent the slab from cracking, a compressive stress is produced in it by raising the inner supports of the continuous beam before casting the slab and lowering the beams to the original level after the concrete has hardened. The slabs are bonded to the steel beams by means of bars in the form of helices welded to the flanges of the beams and embedded in concrete. The adoption of the method during reconstruction of three bridges in France is also given.

The following are in German :

(1) " Prefabrication in Steel-Concrete—Special Constructions " by Prof. Fr. Baravalle-Brackenburg.

(2) " Continuous Cylindrical Beams of Prismatic Cross-Section " by Ernst Gruber.

(3) " The Two-Dimensional Problem in the case of Periodically Altering Temperature Effects " by Prof. Pierre Lardy.

(4) " Regarding the Influence of Frictional Forces and Bearing Pressures in Connection with Prestressing in Steel-Concrete Structures " by W. Swida.

The volume has been well got up with numerous drawings, charts, and photographs. At the end of each of the Papers in French and German a summary of the Paper in English is included.

BSY-750

THICK STUFF - BITUMEN !

Here's a familiar sight—this gentleman is pouring Bitumen on to a road surface to bind and strengthen it. It is no exaggeration to say that the economy of the country as a whole depends upon good roads. When Bitumen is used in their construction they can withstand present day traffic and monsoon rains.

• • • •

For irrigation schemes too, Bitumen is important as it is used for canal linings to prevent seepage and corrosion. It is also used to build airfield runways, to insulate electrical cables, for damp-proof courses and for refrigeration purposes.

• • • •

So, next time you are driving along a well-kept road, trying to overtake a heavily-laden lorry or a train of bullock carts, console yourself with the thought that it is really the road surface that's taking most of the strain. Think of Bitumen, and think of Burmah-Shell.

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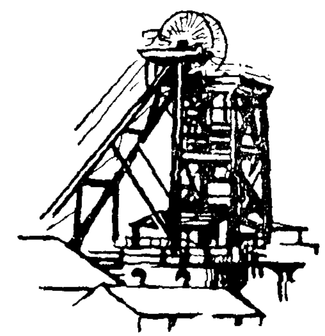

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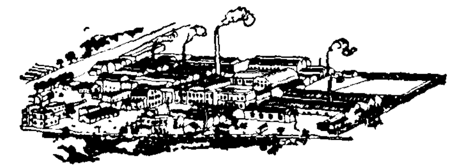

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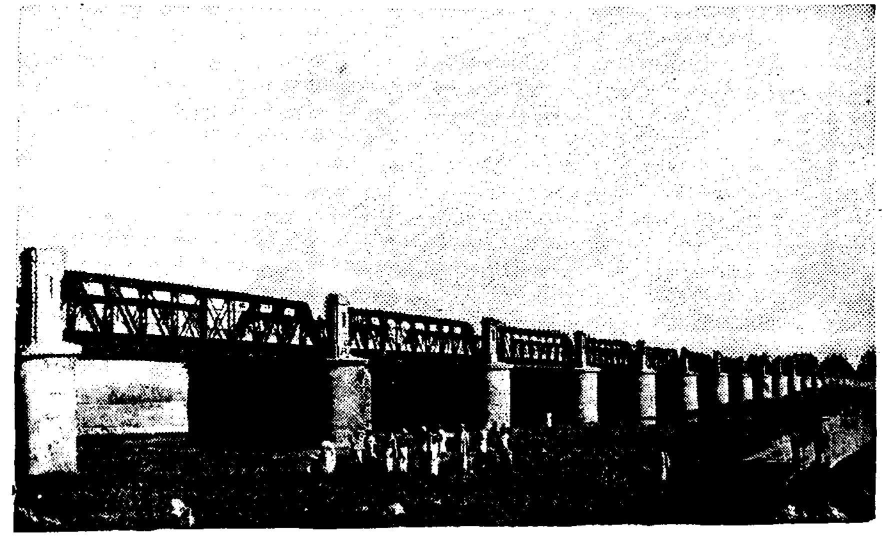

Calercon Road Bridge, Trichinopoly District,
24 spans of 100-feet on Masonry Piers.