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COMPLETED UDYAVAR BRIDGE

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"DESIGN AND CONSTRUCTION OF UDYAVAR BRIDGE"

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CONTENTS

SYNOPSIS

Udyavar bridge is a typical bridge on the West Coast road where the rivers are perennial, having tidal variations and foundation depths varying from 30 to 65 ft. The Authors try to explain in this Paper, the difficulties

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encountered in sinking wells for the foundation, and how the same were surmounted. Details of construction of substructure and superstructure, including the hydraulic data and design are also furnished in the Paper.

1. INTRODUCTION

1.1. West Coast Road

The West Coast road from Bombay to Kanyakumari runs along the coast of Kerala, Mysore and Bombay State. Scheme for the development of the West Coast road has been approved by the Government of India, and will be fully financed by the Centre. The alignment of the West Coast road has also been finally decided, and the work of construction of minor and major bridges, cross drainage works, improvements to the roads, and construction of suitable bye-passes and diversions in the built-up areas are in various stages of progress in different States.

1.2. The length of the West Coast road in the Mysore State is 168 miles. The cost of development of the West Coast road in Mysore State, including the cost of construction of major bridges, will be approximately Rs. 650 lakhs. There are 26 major crossings on this road in the Mysore State of which 7 bridges have already been completed, and the rest are in progress. Well foundations (taken down 30 ft to 65 ft depth) are provided for all the bridges on this road. Superstructures for the bridges are of different types. For the Kulur bridge, the superstructure is of bow-string girder. Hollow box girders have been provided for the bridges across Pavanji, Mulki, Udyavar, Kalyanpur and Mabukal rivers. For Uppunda and Sankadagundi bridges, the deck is of R.C.C. flanged Tee beam-cum-slab. For bridges at Gangavali and Aghanashini, prestressed concrete superstructures are adopted. Of the seven completed bridges on the West Coast road, the Udyavar Bridge is one of the important bridges between Mangalore and Udipi.

1.3. The opening to traffic over the bridge across Udyavar river on the West Coast road in Mysore State, where a ferry service used to operate, fulfilled a long cherished desire for a direct all-weather road between Mangalore, a District Headquarter, and Udipi, a pilgrim centre of all-India importance. By the construction of this bridge and two other bridges; one over river Mulki and the other over river Pavanji, the circuitous route joining Mangalore with Udipi 57 miles long was replaced by a direct link 36 miles long (see Plate I—Key Map). The necessity of constructing these bridges was recognised by the Central Government much before the present West Coast road scheme was envisaged.

2. SELECTION OF SITE

2.1. After detailed investigation, a site ½ a furlong downstream of the existing ferry crossing was selected. The width of both the arms of the river and 60 ft island in between was 865 ft. At this site, the banks were *fairly well* defined, short and straight approaches on either side of the bridge were available compared to long approaches, heavy acquisition of land and construction of culverts, etc., for likely sites (see Plate II—Site Plan).

3. HYDRAULIC PARTICULARS

3.1. Udyavar river has its source in the hills of the Western Ghats, 27 miles east of the bridge site. Fall in the bed of the river from the source to site is about 200 ft. The catchment area above the bridge site is 116 sq. miles (as worked out from contour maps). The discharge at this site as calculated by Ryve's empirical formula taking $C=1500$, works out to 35,060 cusecs. As this is a shallow tidal river flowing between *ill-defined* banks, the method of calculating the discharge by cross section and bed slope characteristics was found inapplicable.

4. WATERWAY

For the maximum calculated discharge of 35,680 cusecs, by Lacy's formula $P = CQ^{\frac{1}{2}}$, taking $C = 2.67$, effective linear waterway works out to 505 ft. But as the width of this tidal river from bank to bank is 865 ft, in order not to restrict the waterway very much, a bank to bank bridge of 9 spans of 90 ft giving waterway of 720 ft ($9 \times 90 - 90$ ft ineffective span opposite the island) was provided. The highest flood level ascertained was 8 ft 3 in. above the lowest tide level in the river. The maximum tidal variation is nearly 4 ft at the bridge site. The velocity that would be developed under the bridge during high floods, assuming that the bed of the stream gets scoured upto total scour level, is 3.68 ft per second.

5. SOIL PARTICULARS

Exploratory borings made in the river bed at intervals of 95 ft along the alignment of the proposed bridge site revealed 8 ft to 15 ft depth of sand over clay and sand layers of varying depths which went down to the rock. Near the right bank, soft laterite was met at about 23 ft depth and hard granite rock at about 45 ft below bed. It was therefore decided to take the foundations down to the hard rock. During construction, soil strata actually met with compared favourably with that of the test boring (see Plate III—General Drawing).

6. FOUNDATIONS

Due to the depth of rock for the foundations being deep and continuous flow of water in this tidal river, it was decided to adopt well foundations. 1:3:6 cement concrete circular wells 9 ft internal and 14 ft external diameter, spaced 3 ft apart under each pier and abutment were considered suitable. The reinforced cement concrete well curb is 2 ft 10 in. high as shown in Fig. 1. The cutting edge consists of 4 in. × 4 in. × ½ in. mild steel angle with one of the 4 in.

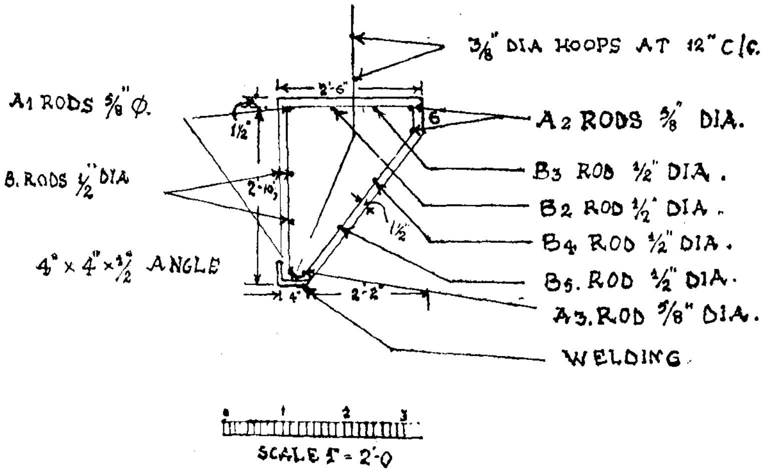


Fig. 1. **Well Curb Section**

side at the bottom. No difficulty in sinking was caused by this arrangement. The weight of the steel used for the reinforcement of one well curb was 600 lb which is equal to 4.33 lb per cu. ft. of concrete (see Plate IV—Details of capping slab over pier, wells and the details of well curb).

7. SINKING OF WELLS

7.1. Sinking of the hollow circular wells due to their having to be sunk through sand and clay to a depth not exceeding 45 ft did

not present much difficulty. Dredging was carried out manually by divers. No costly diving suit or other costly equipment was used. All that the divers had was a simple helmet, sufficiently weighted to counteract the buoyancy. Compressed air at 15 lb per sq. in. from the air compressor was let into the helmet through the only opening at the top through a hose pipe. The volume of compressed air required was on an average 10 cu. ft. per helmet per minute. This pressure kept the water out of the helmet and did not make breathing hard.

7.2. Two divers could conveniently work in a well. The rate of sinking at higher levels in sandy soil was nearly 2 to 3 ft per day and in clayey strata 1 to 1½ ft. Uniform dredging was done to prevent tilting of the wells. To start with, the well sinkers used to dig a pit at the centre and then scoop out alround ; this helped to sink the well gradually and uniformly.

7.3. **Precautions**: During the process of sinking the wells, steining was built up in stages of 3 ft 9 in. Before the addition of a stage of concrete steining it was checked for verticality.

7.3-A. The verticality of the well during sinking operations was checked with plumb bobs held in a number of positions. Irrespective of whether the well developed a cant or not, the building of the steining was in continuation of the stage below it, and no rectification of cant in building of the steining was permitted. The cant, when necessary, was set right while sinking by kentledge or other methods.

7.3-B. When the well curb was approaching the rock bed indicated in the boring charts, test boring in each well was made to accurately assess the level at which hard rock could be expected. In cases of doubt, two or more test bores in a well were made. All the test borings were carried out by the contractors at their expense. Failure to make test borings in time in the case of one particular well resulted in having to chip off considerable height of steining-top laid in excess which was very difficult, costly and involved loss due to wasted material.

7.4. The well foundations of both the abutments and all the piers were taken down to the hard rock. In a number of wells due to the bed rock surface being undulating, perfect seating of the wells on rock at all points could not be achieved. However, excepting the case of two wells, major portion of the periphery of the well shoe was secured in the rock. In the case of the two wells under Pier No. 7, the rock was found to be steeply sloping from north-west to south-east (the flow in the river is from east to west). The downstream side well was sunk 2 ft lower than the upstream well, as there was, a slope of 5 ft in a 14-ft length of the bed. Both the wells could be seated on rock only for a length of about 6 to 10 ft out of the total 44 ft length of periphery. Cutting a trench in the rock to lower the well was attempted in vain.

7.5. In order to prevent the possible lateral movement of the wells under any conditions, it was decided to provide 34 Nos. dowel bars of 1 in. diameter driven 3 ft 9 in. into hard rock and 3 ft 9 in. length projecting into the bottom plugging in each well. 2½ in. diameter holes were drilled by Calyx drill operated by a 3.5 H.P. Lister Engine. The hollow drilling rods worked in casing pipes held in position by means of fixtures. Lead shots revolving under the cutter at the bottom of the drilling rod formed the actual cutting media and the cutter was kept cool by water led into the hollow drilling rods. A 4-ft deep hole could be drilled in 8 working hours. The cost of drilling was Rs 8 per running foot excluding hire charges of the plant. The rock met with was of very hard variety. Immediately a hole was drilled, dowel bar was inserted into the hole and the space around grouted with rich cement mortar. Since this grouting had to be done under water, a cylindrical mild steel jar with screwed lids at top and bottom and a rubber tube with clamp attached to bottom as, shown in Fig. 2, was used. This

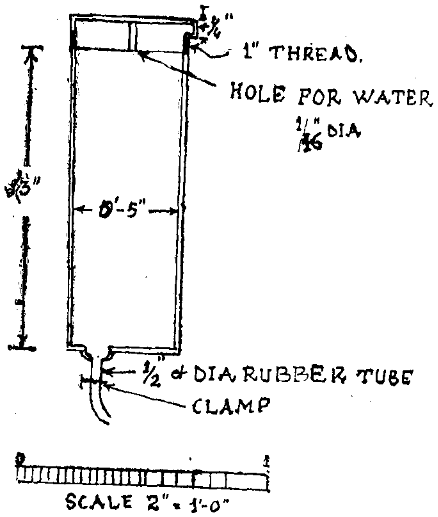


Fig. 2. **Appliance for Grouting**

jar was filled with liquid cement grout, a diver after inserting the other end of the tube right down the bottom of the drilled hole released the clamp of the rubber tube which filled the

hole with the grout. The dowel bar was held centrally until the grout filled and overflowed the hole. Particulars of depth of foundation of each pier, of abutment and the nature of the foundation bed are given in Appendix 1.

7.6. Seating of wells

7.6-A. After ascertaining proper seating of the well for major portion of the periphery of the cutting edge, the gap between the cutting edge and the bed rock was packed with cement concrete held in cement gunny bags. The sloping side of the well curb and the inner side of the wells were roughened by chisel marks for a height of 6 ft to ensure better grip between the well and the bottom concrete plug. After this, the rock bed was cleared of all accumulated silt, etc., before laying the bottom concrete plug. The concrete for bottom plugs had to be laid under water in all the wells, concreting was done with a special plugging box instead of tremmy or chutes. A wooden box 1 ft 3 in. × 1 ft 3 in. × 1 ft 3 in. with a hinged cover at the top and a hinged two-leaves bottom as shown in Fig. 3, was used. The inner sides of the box and the covers were lined with

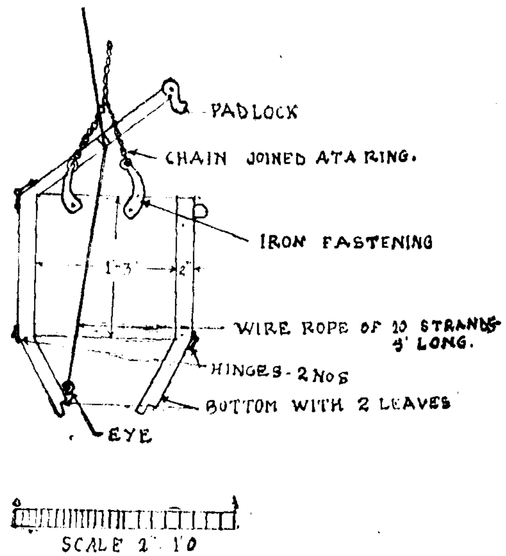


Fig. 3. **Plugging Box**

G.I. sheets and the corners were straightened by means of M. S. flats. Suitable fixtures were provided to facilitate lifting the box with its bottom leaves closed, and to open these when required.

7.6-B. The box was filled with cement concrete 1 : 2 : 4 mix with comparatively less quantity of water and the top lid was closed. The box was lifted keeping the top and bottom lids closed and lowered manually to the bottom of the wells by means of pulleys. Then the catch permitting the bottom to open was released and the concrete deposited by slowly lifting the box. This process of concreting was started near the periphery of the well and gradually worked in towards the centre in concentric circles.

It was found desirable to lay all the 5 ft depth of the bottom plug in one operation. Water from the wells was baled out one week after plugging and almost perfect seal against water was found.

After satisfactory plugging, the wells were filled with clean coarse sand in layers of 1 ft and consolidated thoroughly. The top 2 ft of the wells, was plugged with 1 : 4 : 8 cement concrete.

A capping slab of 1 : 2 : 4 reinforced cement concrete 2 ft and 2 ft 3 in. thick was laid over the pier wells and abutment wells respectively. The bottom of the capping slab was kept at the Low Tide level, and for this, precautions had to be taken to prevent saline seawater during high tide coming into contact within 24 hrs. of laying the slab. The quantity of steel required for the capping slab worked out to $7\frac{3}{4}$ lb per cu. ft. in the case of pier wells and 6 lb per cu. ft. for the abutment wells.

8. SUBSTRUCTURE

8.1. Udyavar being a shallow tidal river, the highest anticipated flood level is 4 ft above the high tide level. Due to the substructure being not very high, Coursed Rubble masonry abutments and piers were built in 1 : 4 cement mortar, face cement pointed. Instead of conventional type of wing walls which would have been very expensive, the abutments were encased with revetments laid to a slope of 1 : 1.

9. ABUTMENTS

The design of the abutments had been based on the Coulomb's theory of Earth Pressure taking into account the Live Load surcharge. In spite of this, suitably reinforced 6 in. thick cement concrete slabs 24 ft wide resting on the back of each abutment and resting onto the road embankment for a length of 10 ft was laid to reduce the earth pressure due to live load on the rear of the abutment. The resultant of all the forces acting on the abutment was calculated to

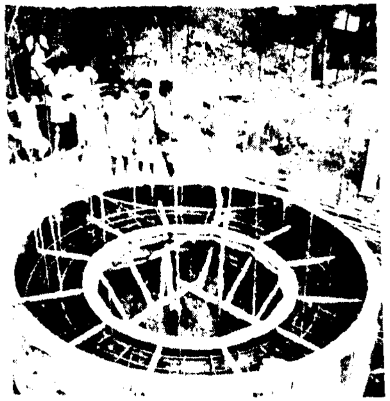


Photo 1

Centering for well curb

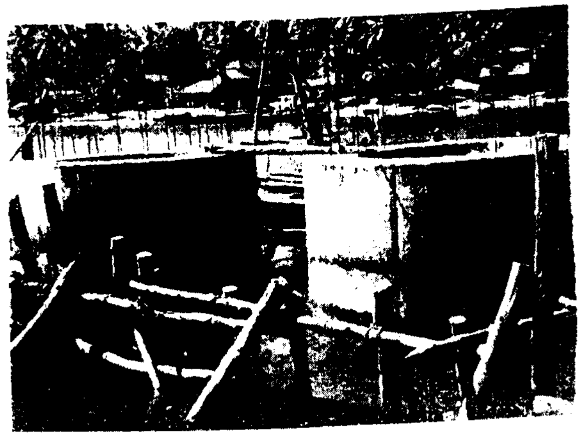


Photo 2

Well ready for sinking

Photo 3

Sinking in progress

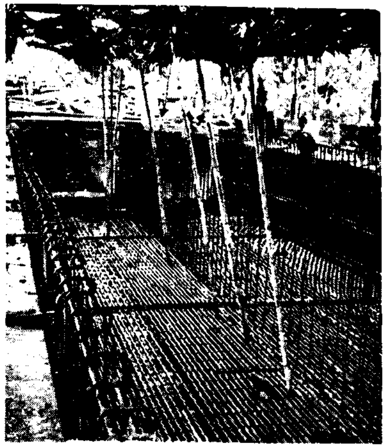


Photo 4. **Reinforcement for soffit slab and webs**

Photo 5. **Reinforcement for intermediate diaphragm**

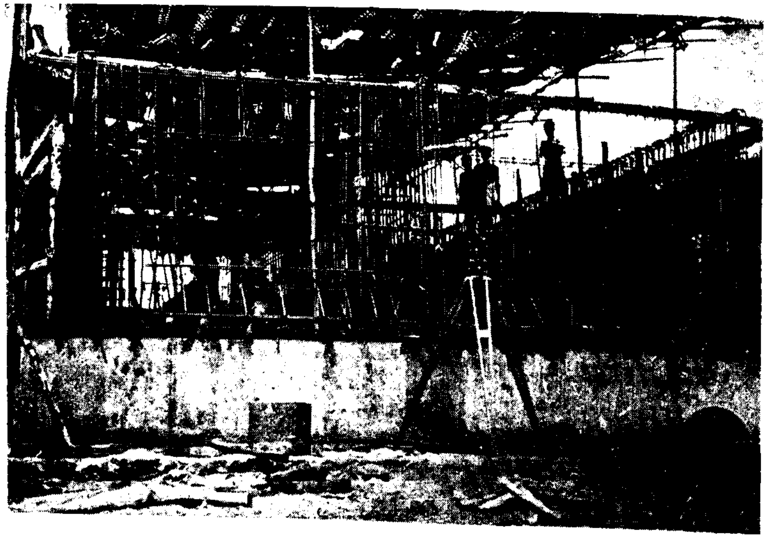


Photo 6. **Reinforcement for end diaphragm**

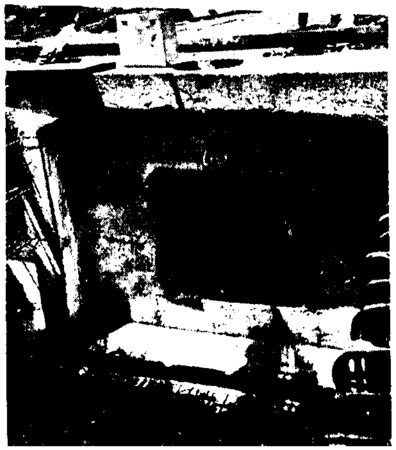


Photo 7

Completed end diaphragm

act within the middle third of the base. Abutment section is 10 ft wide at the bottom and $7\frac{1}{2}$ ft at bearing level with its rear face vertical. The back wall above is 5 ft wide at bearing level and 2 ft at road level. (See Plate III—General Drawing and Plate VII—Details of covered abutment.)

10. WING WALLS

Reinforced cement concrete wing walls cantilevering from the rear face of the abutment ends are provided to retain the road portion above the slope line of 1 : 1 of the conical revetments. The wing walls 8 ft long, 6 ft high and 8 in. thick, shown in Plate IV, are sufficiently long to have an anchorage of 1 ft in the abutment masonry and in the revetment. This was designed to withstand the varying earth pressure acting on it. Detailed design of the cantilever wing walls is given in Appendix 2.

11. PIERS

11.1. The piers are 5 ft wide at top, 5 ft $7\frac{1}{2}$ in. at base and have semicircular cutwaters.

11.2. Pier caps

High grade 1 : 2 : 4 cement concrete pier caps $1\frac{1}{2}$ ft thick were laid over the full width and length of the piers including cutwaters. Helical reinforcement was provided in the portion under the bearings. An additional thickness of 1 ft $1\frac{1}{2}$ in. of concrete was provided under the fixed ends of the superstructure to make up the difference in height of roller bearings provided under the free ends.

12. ROLLER BEARINGS

12.1. The bridge beams are designed as simply supported beams. The expansion end of the spans are carried over cast steel roller bearings as shown in Plate V. The roller is 19 in. long, 4 in. thick and 10 in. high with rounded ends of 5 in. radius. The bearing assembly (from bottom of bed plate to top of top plate) is 15 in. high and 21 in. long. Each one of these is designed to carry a total load of 105 tons. Details of the design of the roller bearings are given in Appendix 3 (also see Plate V—Details of Roller Bearings).

12.2. Fixed end

Under the fixed end of the beam a simple mortar pad 14 in. long, 7 in. wide, $1\frac{1}{2}$ in. thick was provided. Three 1 in. diameter dowel bars embedded in the bed block and projecting into the superstructure were provided to go into each fixed end of the beam (see Plate VI—Details of the Fixed End Bearings). Details of the design of the mortar pad and special reinforcement are given in Appendix 4.

13. SUPERSTRUCTURE

13.1. 90 ft spans were adopted for this bridge after careful study of the economics of alternative spans.

13.2. Normally the cheapest design for a bridge is the one in which the cost of the superstructure is approximately equal to the cost of the substructure and foundations. In the case of the bridges in South Kanara area, economic span is found to be equal to $1\frac{3}{4}$ times the depth from top of pier to the bottom of the foundation. In the case of this bridge, the average depth of foundation from the top of the pier is 54 ft. Thus, the approximate economic span length works out to 94.5 ft. Either nine spans of 90 ft or eight spans of 100 ft were suitable. Bowstring girder superstructure for the 100 ft span and the hollow box girder for 90 ft span were considered, but the latter was adopted on account of the following reasons :

(a) The cost of the hollow box girder bridge was cheaper ;

(b) the superstructure was lighter than the bow string girder deck ; and

(c) the quantity of steel required for the hollow box girder was less than that for the bow string girder.

13.3. **Details:** The hollow simply supported box girder adopted has 90 ft clear span, and 2 ft $5\frac{1}{2}$ in. bearing at either end. It consists of 6 in. thick soffit slab at the bottom, $8\frac{1}{2}$ in. thick road slab carried over 3 webs each 9 in. thick, 5 ft 9 in. high, running right through the entire length of the girder dividing the girder into two cells. The corners at the bottom were thickened with 8 in. by 4 in. fillets, the top corners were provided with 15 in. by 6 in. fillets. Six transverse diaphragms were provided at 18 ft 6 in. centres, the end ones were 12 in. thick and the intermediate ones 10 in. In every diaphragm 4 ft long and 3 ft high openings were provided at mid-height to facilitate removal of centering after completion of concreting for the deck. The bottom soffit slab is 19 ft wide, the road slab cantilevers 3 ft 9 in. on either side of the outer web so as to provide 24 ft clear roadway and 1 ft 3 in. wide kerbs. The cantilever portion of the slab was 1 ft thick at the support and 6 in. at the outer end. The overall depth of the girder was 6 ft $11\frac{1}{2}$ in. Overall widths at bottom and top are 19 ft and 26 ft 6 in. and the

overall length is 94 ft 11 inch (see Plate VIII—Details of Hollow Box Girder for 90 ft span).

13.4. Design features

The design procedure of the girder is similar to that of a 'T' beam, the bottom soffit slab taking the tension, the webs taking the shear and the road slab taking the compression developed in the girder. The soffit slab is heavily reinforced with $1\frac{1}{8}$ in. diameter M.S. rods spaced at 3 in. centres at the centre of the span. The webs were provided with 5/8 in. diameter two-legged stirrups spaced 4 in. apart at the supports, spacing gradually increased to 2 ft at the mid-span. The road slab is designed as supported on all the four sides over the webs and diaphragms. Suitable reduction due to continuity over the three webs in the transverse direction was made. They are reinforced with 3/4 in. diameter M.S. rods at $5\frac{1}{2}$ in. centres at the bottom and 11 in. centres at the top of the slab.

13.4.A. The detailed design calculations of the girder diaphragm, etc., are given in Appendix 5. The compressive stresses developed in concrete are of the order of 830 lb per sq. in. and, therefore, high grade concrete which can safely take up stress of 950 lb per sq. in. was proposed for the superstructure.

13.5. Design of mix for high grade concrete

Though the mix is said to be 1 : 2 : 4, the actual composition of the mix which gives concrete of maximum strength with available aggregate was found to be 1 : 1.9 : 3.7. This mix was adopted for the high grade concrete of the required strength.

13.6. Centering for superstructure

Since the river bed is clayey or sandy, casuarina piles were driven to a depth of 10 to 15 ft below bed at intervals of 3 ft both ways. The dead load of the superstructure to be carried by each of these piles was 1 ton ; some piles in each span were test loaded to 2 tons, no settlement was observed in any case. The piles were interconnected by struts and diagonals. The battens at the top were fitted at the exact height ; the bottom and the vertical boards were fitted to form the end centering for the soffit slab and the outer faces of the outer two webs. The centerings for the bottom of the cantilever slabs and the outside of the road kerbs were also fixed. The required longitudinal camber to allow for the dead load deflection was given in the soffit bottom boards. The reinforcements for the bottom slab and the webs were placed in position exact to the drawings and centerings for the inner face of the outer two webs, both faces of the intermediate web and all the diaphragms were fitted to half the height, namely, 2 ft $10\frac{1}{2}$ in. in order to minimise the drop for the concrete. The centering for the remaining height of the web and the road slab was erected after completing the concreting for the bottom slab and half the height of the web and the diaphragms.

13.7. Concreting for superstructure

Before concreting, the dowel bars projecting from the bed blocks for the fixed ends of the box girder were wrapped in craft paper, bituminous pad $\frac{3}{4}$ in. thick and then enclosed in a copper tube to allow slight local movement for the expansion or contraction caused by changes in temperature.

13.8. Concreting

The total quantity of concrete for the superstructure of each span was 4,700 cu. ft. Concreting was done in the following four stages.

13.8.1. **First stage**: Concreting of the soffit slab 6 in. thick and of webs and diaphragms up to the top of the bottom fillet was completed in 12 hours using two concrete mixers, two pin vibrators, a screed vibrator and about 80 mazdoors. Concreting in the portion of the end diaphragm with spiral reinforcement and also the fillets required special care. To observe flow of concrete into the fillets, windows were kept at frequent intervals in the sloping portion of the inside shuttering of the webs. Quantity of concrete laid was about 900 cu. ft.

13.8.2. **Second stage**: Concreting webs and diaphragms to half the height took 6 hours and was carried out on the next day. Thorough cleaning of the old concrete surface and pouring of cement grout over the old concrete surface was done before starting concreting. Quantity of concrete laid was approximately 900 cu. ft.

During the second day afternoon, night and third day forenoon centering of the remaining height of the webs and the bottom of road slab was done.

13.8.3. **Third stage**: On the third day afternoon, concreting for the remaining height of webs and diaphragms upto the bottom of the top fillets was done in about 6 hours. Quantity of concrete laid was 900 cu. ft. During the third day, night and fourth day, reinforcements for the road slab and road kerbs were placed in position and tied securely.

13.8.4. **Fourth stage**: On the fifth day morning, concreting was started for the road slab, the top fillets and half the portion of the length was completed in about 12 hours working time. On the sixth day, the remaining portion of the road slab was concreted. Quantity of concrete laid in these two days was 1,800 cu. ft. Kerbs

were concreted after centering in the next two days. Thus the concreting of the box girder took one full week.

Six numbers of 6 in. concrete test cubes were cast on each day of concreting, these were tested for compressive strength after 28 days curing. Results obtained in all the cases were quite satisfactory, and are given in Table 1.

Mild steel rods of $\frac{3}{4}$ in. diameter and above were welded and the strength of welds was tested at random, the results of the tensile test are given in Table 2.

13.8.5. **Removal of centering**: Face forms both inner and outer of the webs were removed after a week, the bottom centering of the road slab after a fortnight and the bottom centering of the soffit and cantilever slab removed 28 days after concreting. Since the form work was completely faced with plain G.I. sheets, faces of the concrete were very good. Suitable wooden plugs were provided in each cell of the bottom soffit slab, and at suitable distances near the kerb to provide openings for water spouts.

Thorough curing of the concrete was effected by flooding the soffit and road slabs with water and spraying on the vertical sides of webs.

14. WEARING COAT

14.1. Three in. thick cement concrete ($1:1\frac{1}{2}:3$) wearing surface was laid over the deck. Aggregate consisted of graded granite containing 65 per cent of 1 in.; 25 per cent of $\frac{1}{2}$ in. and 10 per cent of $\frac{1}{4}$ in. size hard granite chippings.

14.2. Wearing coat for each span was laid in 6 bays each 31 ft 8 in. by 12 ft allowing a tar painted construction joint in between both in the longitudinal and transverse directions. Red cement briquettes of the shape of a frustum of a cone $2\frac{1}{2}$ in. high, $1\frac{1}{2}$ in. diameter at top and 3 in. diameter at bottom, were fixed at suitable intervals to indicate the wear of the surface. It will be time for renewal of the wearing coat when the red circles cease to be visible on the road surface.

15. OTHER DETAILS

15.1. **Hand rails**: Barrel shaped reinforced cement concrete handrails have been provided.

TABLE 1

Statement of test results conducted on cement concrete cubes

Sl. No.	Particulars	Size	Weight of cubes in lb	Date of preparation as marked on specimen	Load in *tons* At first crack: Load in tons	At first crack: Stress in tons/sq. in. as calculated	At crushing: Load in tons	At crushing: Stress in tons/sq. in. as calculated	Date of tests and remarks
1	Cement concrete cubes	6 in. × 6 in. × 6 in.	$18\frac{7}{8}$	26–4–1957	43.70	1.214	Not crushed		June 15, 1957
2	Do.	Do.	19		—	—	Not crushed		Do.
3	Do.	Do.	$19\frac{1}{4}$		—	—	Not crushed		Do.
4	Do.	Do.	$18\frac{1}{2}$	3–5–1957	25.72	0.714	48.40	1.344	Do.
5	Do.	Do.	$19\frac{1}{4}$		22.90	0.636	Not crushed		Do.
6	Do.	Do.	$19\frac{1}{2}$		48.54	1.348	Not crushed		Do.

Tested in 50-ton Avery's Universal Testing Machine

TABLE 2

Results of tension test on welded M.S. rods of Udyavar Bridge work

Sl. No.	Diameter	Specimen	Ultimate Load	Stress in tons/sq. in.	Position of Fracture
1	$\frac{3}{4}$ in.	M.S. welded rod	28,500 lb.	28.8	Away from weld
2	$\frac{3}{4}$,,	Do.	28,500 ,,	28.8	Do.
3	$\frac{3}{4}$,,	Do.	28,500 ,,	28.8	Do.
4	1 ,,	Do.	27 tons	34.37	Do.
5	1 ,,	Do.	26.5 tons	33.72	Do.
6	1 ,,	Do.	27.5 ,,	34.99	Do.
7	$1\frac{1}{4}$,,	Do.	37.5 ,,	30.54	At the weld
8	$1\frac{1}{4}$,,	Do.	40 tons	32.58	Away from weld
9	$1\frac{1}{4}$,,	Do.	37.5 tons	30.54	Do.
10	$1\frac{1}{2}$,,	Do.	52 tons	29.41	Do.
11	$1\frac{1}{2}$,,	Do.	48 ,,	27.14	Do.
12	$1\frac{1}{2}$,,	Do.	50 ,,	28.28	Do.

15.2. **Pylons:** Cement concrete pylons of an artistic design with nominal reinforcements are provided at each entrance to the bridge.

A total length of 4 furlongs of new approach roads and a culvert on the Mangalore side approach road was constructed.

16. GENERAL

In spite of dearth of skilled labour and some delays in acquiring land and procuring cement and steel, this bridge was completed within the target period of $2\frac{1}{2}$ years. The construction of the bridge started on 24th December 1955 and the bridge was opened to traffic on the 16th June 1958.

1,380 tons of cement, 360 tons of steel and 154,000 cu. ft. of stone were used in the construction of the bridge.

The cost of the bridge per liner foot comes to Rs 1,113. Particulars of the topographical features, loads, maximum pressure, quantities of work involved, and cost analysis is given in Appendix 6.

List of machinery used is given in Appendix 7.

Appendix 1

Particulars of depth of Foundations, Nature of the foundation bed, etc.

Milage from Mangalore	Description	Openings: No. of spans	Openings: Clear span	No. of piers and abutments	Depth in feet below road level at centre of road bridge (at R.L. 112.71): Bottom of foundation: Up-stream well	Bottom of foundation: Down-stream well	Top of foundation capping slab	Top of sub-structure masonry	Top of bed block	Average river bed	Nature of stratum on which founded	Type of masonry	Details of bearings	Strength of bridge	Depth of girder from road level	Date of commencement and completion
33 miles 4 furlongs	R.C.C. hollow box girder bridge with masonry substructure and well foundations	9	90 ft	S. Abutment	55.42	55.23					Hard granite rock	Coursed rubble II sort for abutments, I sort for piers and R.C.C. cantilever wings	Roller bearings of 10 in. diameter 19 in. for expansion end and for the fixed end mortar pad 14 in. × 7 in. — $1\frac{3}{4}$ in. thick	Designed to carry I.R.C. Class 'AA' single lane loading or 2 lanes of I.R.C. class 'A' loading	7 ft $2\frac{3}{4}$ in.	24-11-1955 and 16-6-1958
				Pier No. 1	61.34	61.29			8.46 for free end							
				Pier No. 2	64.35	56.47										
				Pier No. 3	59.36	62.51										
				Pier No. 4	59.54	59.39	16.71	9.96	7.33 for fixed end	20.01						
				Pier No. 5	55.35	55.96										
				Pier No. 6	59.40	60.38										
				Pier No. 7	46.17	44.64										
				Pier No. 8	52.40	52.00										
				N. Abutment	58.51	56.12										

Appendix 2

Design of cantilever wing walls

Earth pressure acting on the wing wall:

$$P: \frac{wh \sin^2(\theta - \phi)}{\sin^2\theta \sin(\theta \text{ plus } z)} \times \frac{1}{+1\sqrt{\dfrac{\sin(z \text{ plus } \phi)\sin(\phi - d)^2}{\sin(z \text{ plus } \theta)\sin(\theta - d)}}}$$

Where θ : 90°
ϕ : 35°
z : 17°30 min.
w : 110 lb per cu ft.
d : 0.

Therefore $P = 27.06\ h$.

Horizontal component of the earth pressure

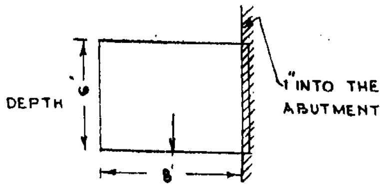
$= 27.06\ h \times \cos 17°30$ min. $= 25.80\ h$.

Cantilever wing wall; R.C.C. 1 : 2 : 4 mix ordinary grade.

Design

(1) No live load will act on the face of the wall.

(2) There is a possibility of the crowd load acting on the face, i.e., 85 lb per sq. ft assumed as 1 ft of equivalent height of earth.



Thickness of slab assumed is 8 in.

(constant throughout to facilitate easy execution).

Intensity of earth pressure in the middle of the bottom strip,

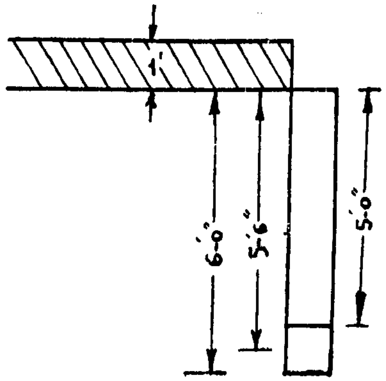
$6.5 \times 25.80 = 167.7$ lb

At 3.5 ft from the top

$= 4.5 \times 25.80 = 116.1$ lb

At top 0.5 ft

$= 1.5 \times 25.80 = 38.70$ lb



Length of retaining wall is 8 ft but 1 ft is inside the abutment.

Therefore effective length for bending = 7 ft

(a) Bending moment at support:

Bending moment at the bottom strip $= 167.7 \times 7 \times 7/2 \times 12 = 49{,}300$ in l

Effective depth required : $\sqrt{\dfrac{49{,}300}{126 \times 12}} = 5.711$ in., say 5.75 in.

Allowing a clear cover of 2 in. and using 1/2 in. diameter bars,

total depth required $= 5.75 + 0.25 + 2.0 = 8.0$. in.

Depth adopted is 8 in. with an effective depth of 5.75 in.

A_s at the bottom $= 49300/18000 \times 0.872 \times 5.75 = 0.5462$ sq. in.

Use 1/2 in. diameter bars at 4 in. centres.

At 3.5 ft from the top:

Bending moment $= 116.1 \times 7 \times 7/2 \times 12 = 34{,}140$ in lb

$A_s = 34140/18000 \times 0.872 \times 5.75 = 0.3783$ sq. in.

Use 1/2 in. diameter bars at 6 in. centres.

At top, i.e., 0.5 ft from the top.

Bending moment : $38.70 \times 7 \times 7/2 \times 12 = 11{,}380$ in lb

$A_s = 11380/18000 \times 0.872 \times 5.75 = 0.1261$ sq. in.

This will be less than 0.1963, use 1/2 in. diameter bars at 12 in. centre as the spacing is limited to 12 in. or 2 d whichever is less.

Bending moment in the middle, i.e., at 3.5 ft from the end;

Bottom strip, i.e., at 5.5 ft from the top

$Wl^2/8$, i.e., 1/4 of the bending moment at the end

= 49300/4 = 12,325 in lb

A_s = 12325/18000 × 0.872 × 5.75 = 0.1366 sq. in.

At 3.5 ft from the top :

Bending moment = 34140/4 = 8535 in lb

A_s = 8535/18000 × 0.872 × 5.75 = 0.0946 sq. in.

Use 1/2 in. diameter bars at 12 in. centres.

Distributors

Distributors of 1/2 in. diameter are provided at 12 in. centres.

Dowel bars

To connect the retaining wall dowel bars are provided. Dowel bars 60 in. in length. i.e., 30 in. inside the retaining wall and 30 in. inside the abutment will be provided. These dowel bars are provided in continuation with the main reinforcements.

Temperature reinforcement

1/2 in. diameter bars at 12 in. centres in both directions are placed in the face of the retaining wall.

Appendix 3

Design of roller bearing for 90 ft span simply supported hollow box (2 cells) girder

C.C. mix adopted for superstructure 1 : 2 : 4 high grade

C.C. mix for bed block : 1 : 2 : 4 high grade

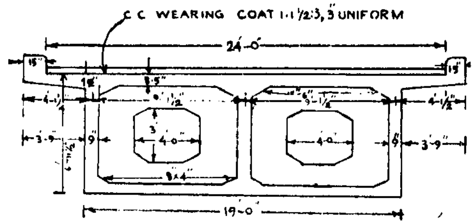
Compressive stress in concrete allowed = .8 (950 plus 50 per cent)

(The concrete will be spirally reinforced)

Stress in cast steel (bending) 9 tons/sq. in.

Shear stress in mild steel = 5 tons/sq. in.

Dead weight calculation :



Of the three webs the central one will take the maximum dead weight of the deck.

Dead weight per foot length :

1.	Wearing coat	9 ft 1½ in. × 3/12 × 140	...	319 lb
2.	Deck	9 ft 1½ in. × 8½/12 × 150	...	970 lb
3.	Bottom slab	9 ft 1½ in. × 6/12 × 150	...	684 lb
4.	Web	5 ft 9 in × 9/12 × 150	...	647 lb
5.	Fillets top	2 × 1/2 × 15/12 × 6/12 × 150	...	94 lb
6.	Fillets bottom	2 × 1/2 × 8/12 × 4/12 × 150	...	33 lb
				2,747 lb

Dead load from half the length of superstructure (excluding diaphragms) on the central web = 47½ × 2747 = 1,30,483 lb

Addition

Intermediate diaphragms = 5 ft 9 in. × 8 ft 4½ in. × 10/12×150 = 6,020 lb

Deductions :

1. Opening in diaphragms = 3 ft × 4 ft × 10/12 × 150 = 1,500 lb

2. Portion covered by fillets = 2 × 1/2 × (15/12 × 6/12 + 8/12 × 4/12) × 10 × 12 × 150 = 106 lb

Net weight of diaphragms = 6020 − (1500 + 106) = 4,414 lb

Weight due to 2 diaphragms = 8,828 lb

End Diaphragms = Weight 5 ft 9 in. × 8 ft $4\frac{1}{2}$ in. × 150 = 7,224 lb

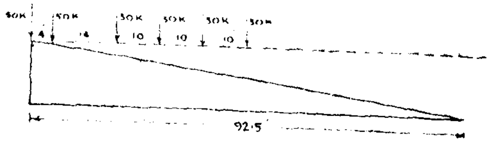
Deductions:

1. Opening 3 ft × 4 ft × 150 = 1,800 lb
2. Portion covered by fillets = 2 × 1/2 (15/12 × 6/12 + 8/12 × 4 × 12) × 1 × 150 = 127.1 lb

Net weight = 7,224 − (1800 + 127) = 5,297 lb

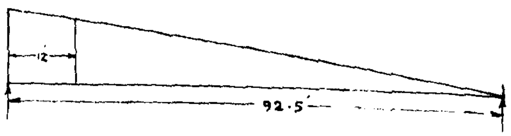
Total dead weight from superstructure = 1,30,483 + 8,828 + 5,297 = 1,44,608 lb

Live load: Class A



= 50 (1 + 88.5/92.5) + 30 (74.5 + 64.5 + 54.5 + 44.5)/92.5 × 1.37 = 1,98,400 lb

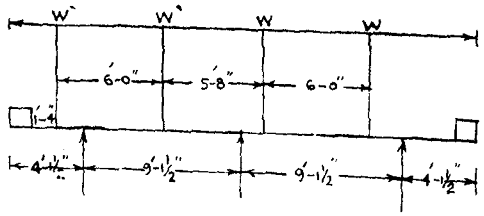
Class AA.



Reaction = 2 × 35 × 1.1 (1 + 0.87)/2 × 2240 = 1,61,300 lb

Class AA gives less, so it is not considered.

Reaction on central web:



= W (8 ft $1\frac{1}{2}$ in. + 2 ft $1\frac{1}{2}$ in. + 4 ft $5\frac{1}{2}$ in.)/9 ft $1\frac{1}{2}$ in. − 1.612 W or $W \times S/5$ where S is the spacing = W × 9.125/5 = 1.825 W.

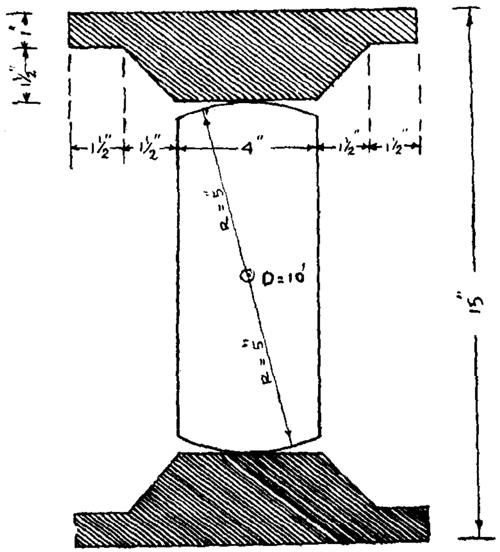
Hence reaction = 1,98,400/4 × 1.825 lb = 90,530 lb

Total dead load + live load = 1,44,608 + 90,530 = 2,35,138 lb or 104.9 tons or say 105 tons.

Design of top plate:

Total load: 105 tons.

Assuming a size of plate = 19 in. × 12 in. stress in concrete in contact with plate = 105 × 2240/(19 × 12) = 1,032 lb/sq. in. which is within the allowable stress of 1,140.0 lb per sq. in. in concrete.



Load per sq. in. = 105/19 × 12 = 0.461 T/sq. in.

Bending moment at centre = 0.461 × 6^2/2 in. tons.

Z required = $\dfrac{0.461 \times 6^2}{2 \times 9}$ = 0.922 in^3.

Thickness required = $\sqrt{6 \times 0.922}$ = 2.352 in. or say 2.50 in.

Adopt $2\frac{1}{2}$ in.

Bending moment at xx = 0.461×2.5^2/2 in tons.

Z required : 0.461 × 2.5^2/2 × 9 = (0.163) in^3.

Thickness required = $\sqrt{6 \times .163}$ = 0.96 in. or adopt 1 in.

The bottom plate also will be of the same size.

Design of roller:

Formula for arriving at the radius for the contact surfaces of the roller: $I/P = I/K$ (I/r plus I/R)

Where P = Pressure per inch length in pounds.

K = Constant depending upon the material employed: 2,840 for cast steel.

R and r = radii in inches of the contact faces.

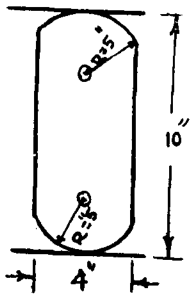
When one face is flat $R : \infty$

$I/P = I/K\ (I/r \text{ plus } I/\infty) = I/Kr. \qquad r = P/K.$

Assuming a roller 17 in. long,
$P = 105 \times 2240/17 = 13{,}840.$

Therefore $r = 13{,}840/2840 = 4.874$ in. or say 5 in.

A roller of 10 in. dia. may be adopted. The width of the roller will be 4 in.



Design of lug in pins (1 in. diameter will be provided).

Longitudinal force due to temperature variation $= 0.03 \times 105 = 3.15$ tons.

Area of 2 lugs at support $= \dfrac{2 \times 22/1^2}{7 \times /4}$
$= 1{\cdot}571$ sq. in.

Stress $= 3.15/1.571 = 2.004$ tons/sq. in. which is within the permissible limits.

Rag bolts, using 4 Nos. 5/8 in. dia. bolts.

Area of bolts $= 4 \times 0.307 = 1.228\ \text{in}^2$.

Shear stress in bolt $= 105 \times 0.03/1.228 = 2.565$ tons/sq. in. which is less than allowable stress. Hence safe.

Spiral reinforcement, nominal spiral reinforcement is provided.

2 spirals of 12 in. dia. with 1/2 in. dia. rods with pitch at 2.5 in. with 1 in. dia. vertical bars will be provided both in the bed blocks and the diaphragm immediately adjacent to the bearing.

Appendix 4

Design of Fixed Bearings - Mortar pad

Maximum dead and live load: 105 tons (Taken from the design of Roller bearings).

Fixed bearing Mortar pad: This will consist of a grout pad of cement sand mortar (1:1). This will be provided with suitable number of through dowel bars of 1 in. diameter anchored in the bed block at the bottom.

Assuming a length of 14 in. along the length of the pier, allowing a pressure of 2,500 lb/sq. in. on the mortar pad, the breadth required along the span will be $105 \times 2240/14 \times 2500 = 6.72$ in. say 7 in.

3 Nos. dowel bars of 1 in. diameter are provided to take up the shearing forces.

Note.—The top surface of the bed block covered by the portion of the grout pad should be roughened to ensure proper adhesion of the grout pad with the bed block surface.

Design of the spirals below and above the mortar pad

Maximum load transmitted by the mortar pad is 105 tons. This is acting over an area of 7 in. $\times$ 14 in. which is about 2,500 lb/sq. in. To take up this pressure, spirally reinforced columns are provided.

The superstructure and the bed blocks are of R.C.C. 1 : 2 : 4 mix high grade.

The ultimate strength of this mix is 3,420 lb.

Since the stress allowed in the mortar pad which is in immediate contact with the concrete is about 2,500 lb/sq. in. a richer mix may be adopted for concrete giving higher value of ultimate strength.

Adopting a mix of 1 : 1 : 2 high grade for the spiral column alone, the factor of safety obtained is about 1.8, i.e., ultimate strength/maximum pressure allowed $= 4500/2500 = 1.8$.

The spiral is designed in accordance with the American Concrete Institute Code.

$P' = 0.45\,(R-1)F'_c/F'_s.$

Where P' = Volume of spiral/volume of concrete core, and

$R = A_g/A_c$ = Gross Area/Core Area.

and F'_c and F'_s = Ultimate stresses in concrete and steel respectively.

In this case $F'_c = 4500$ and $F'_s = 18{,}000$.

Core diameter = 9 in. Gross diameter = 12 in.

$Ag = 22/28 \times 12^2 = 113.1$ sq. in.

$Ac = 22/28 \times 9^2 = 63.59$ sq. in.

$R = Ag/Ac = 113.1/63.59 = 1.778.$

$P' = 0.45(1.778 - 1) \times 4500/45000 =$ 0.035 ft.

Volume of concrete core 1 in. height of column $63.59 \times 1 = 63.59$ cu. in. using 1/2 in. spiral with $2\frac{1}{2}''$ pitch.

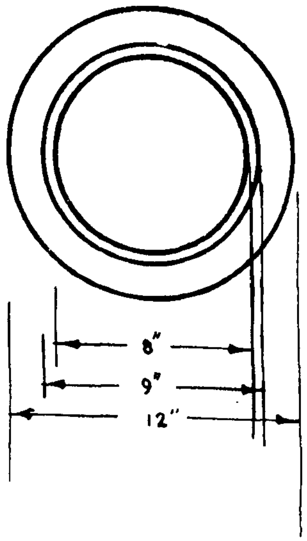
Superload on the spiral produces tension in the spiral column in the transverse direction which must be resisted by the spirals.

The magnitude of the load may be taken as 1/3 of the load coming over each spiral column.

i.e., $105/2 \times 3 = 52.5/3$ tons with 1/2 in. diameter bars (allowing 8 tons/sq. in.)

$52.5/0.196 \times 8 \times 3 = 11.16$ Nos. required.

9 Nos. of spirals with two grid irons are provided.



Percentage of vertical reinforcements.

Percentage: $6 \times 0.7854/63.59 = 7.243$ per cent.

Percentage should not be less than 1 per cent nor greater than 8 per cent which is satisfied in this case.

Strength of the core (according to American Concrete Institute Code)

$P = 0.225\, F'_c \times Ag$ plus $As\, Fs$.

$= 0.225 \times 4500 \times 113.1$ plus $6 \times 0.7854 \times 18000$

$= 199340 = 88.98$ tons.

Hence the total load that can be taken up by the spiral column is about 180 tons while the total load coming over the columns is only 105 tons.

Hence the design is safe.

Appendix 5

Design of R.C.C box girder for 90 ft clear span

(SIMPLY SUPPORTED)

Data

Clear span	...	90 ft 0 in.
Bearing	...	2 ft 6 in.
Roadway	...	24 ft 0 in.
Kerb	...	15 in. $\times$ 12 in.
Wearing coat	...	3 in. uniform.
Loading	...	I.R.C. Class AA single lane or I.R.C. class A 2 lanes (of the two alternatives whichever gives the severe effect will be considered).
Impact	...	Tracked vehicle : 25 per cent for floor system and 10 per cent for main girder.

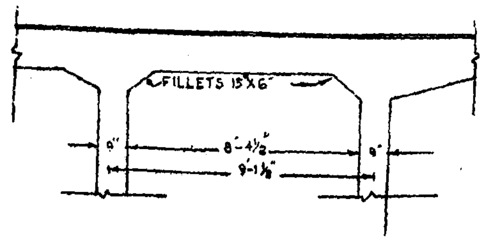
For I.R.C. Class A loading, Impact $= \frac{15}{25 + L}$

Concrete 1 : 2 : 4 (high grade).

(n)	Modular ratio	... 15.
(fc)	Compressive stress in concrete	... 950 lb/sq. in.
(fs)	Tensile stress in steel	... 18000 lb/sq. in.
(v)	Shear stress	... 95 lb/sq. in.
(u)	Bond stress	... 120 lb/sq. in.

The bond stress may be doubled, where the bars are hooked and cranked and where steel is not stressed in bending.

Design of deck slab



Assumed thickness: 8.5 in.

The deck slab is thickened at the ends by fillets 15 in. $\times$ 6 in. As per Clause 329 (e) of I.R.C. Code, the effective span will be measured from the section where the combined depth of slab and fillet is at least $1\frac{1}{2}$ times the thickness of the deck slab.

Effective span = 7 ft 7-3/4 in. or 7.65 ft.

Effective depth of slab = 7.125 in. (with 1 in. cover and 3/4 in. rods).

Clear span of deck in longitudinal direction 18.5 ft — 10 in. = 17.68 ft.

Effective span of deck along longitudinal direction =
17.68 ft plus 7.125 in. = 18.27 ft.

The slab is supported on all four sides by webs and diaphragms and hence Pigeaud's method is adopted for design of slab.

Dead load :	Slab 8.5 in. thick	...	106.25 lb
	Wearing coat 3 in. thick	...	35.00 lb
			141.25 lb

P = shorter span/longer span = 7.65/18.27 = 0.419.

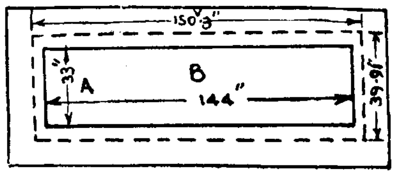
P' = longer span/shorter span = 18.27/7.65 = 2.39.

For a total load of $P = 1$ uniformly distributed

$M\,1 = 0.046 \quad M\,2 = 0.005.$

Moment along shorter span after allowing for Poisson's ratio :—
= (0.046 + 0.15 × 0.005) 7.65 × 18.27 × 141.25 × 12 in. lb = 11,080 in lb

Moment along longer span not considered since it will be less.



Live load : Load on each track including impact = 35 × 1.25 × 2240 = 98,000 lb.

A tyre contact length = 33 in. ... Shorter span.

B tyre contact length = 144 in. ... Longer span.

H thickness of deck = 8.5 in.

D thickness of wearing coat = 3 in.

Width of load spread along shorter span :

$$W = \sqrt{(33 \text{ puls } 6)^2 + 8.5^2} = 39.91 \text{ in.}$$

Width of load spread along longer span

$$V = \sqrt{(144 \text{ plus } 6)^2 + 8.5^2} = 150.3 \text{ in.}$$

$P = 0.42$ shorter span/longer span.

$w/l = 39.91/7.65 \times 12 = 0.435.$

$v/l = 150.3/18.27 \times 12 = 0.686.$

From Pigeaud's Curve :

P	$M\,1$	$M\,2.$
0.40	9.38×10^{-2}	1.17×10^{-2}
0.50	10.18×10^{-2}	2.25×10^{-2}
Interpolating for P : 0.42		
	9.54×10^{-2}	1.39×10^{-2}

Moment along shorter span due to live load after allowing for Poisson correction = $(9.54 + 0.15 \times 1.39) \times 10^{-2} \times 98000 \times 12$ in. lb = 114700 in. lb

Total bending moment due to dead load and live load along shorter span after allowing for continuity :

$$(114700 + 11080) \times 0.8 = 100624 \text{ in. lb.}$$

Effective depth of slab required : $\sqrt{\dfrac{100624}{174 \times 12}} = 6.94$ in.

Effective depth provided = 7.125 in.

Reinforcement :

As : 100624/18000 × 0.86 × 7.125 = 0.9118 sq. in. will be provided.

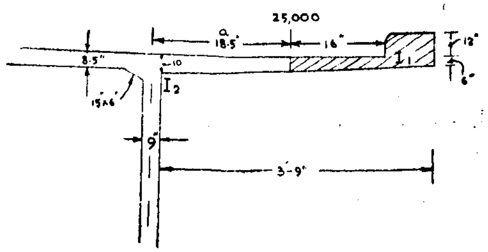
Provide 3/4 in. dr-rods at 5½ in. centre to centre giving 0.964 sq. in.

Distributors : $As = \dfrac{0.9118}{\sqrt{7.65}} = 0.33$ sq. in.

Provide 1/2 in. diameter rods at 7 in. centre to centre giving 0.337 sq. in.

Design of cantilever portion of deck

This is designed for Class 'A' loading.



Live load for one rear axle = 25,000 lb.

Impact : 15/20 plus 3.75 but limited to 0.50.

Live load dispersion as per Swedish formula :

Width of dispersion $2/n$ where $n = \sqrt[4]{\dfrac{C}{4E\,I_1}}$

and $= C\,\dfrac{3E\,I_2}{a^3}$ or $n = \sqrt[4]{\dfrac{3I_2}{4I_1\,a^3}}$

I_1 : M.I. of the shaded portion about its centre of gravity.

I_2 : M.I. of slab at support about an axis perpendicular to the figure.

a : distance of wheel load from centre of support.

Distance of centre of gravity of shaded portion from top of kerb = 11.44 in.

$I_1 = 12{,}738$ in.^{4} units.

$I_2 = 83.33$ in.^{4} units. a : 18.5 in.

$$n \sqrt[4]{\frac{3 \times 83.33}{4 \times 12{,}738 \times 18.5^3}} = 0.0296.$$

Width of dispersion : 2/0.0296 = 67.41 in.

Considering 2 wheel loads total dispersion :

67.41 + 48 in. = 115.41 in. or 9.62 ft.

Load/Ft width including impact = 25,000 × 1.5/9.62 = 3,897 lb.

Therefore live load moment = 3897 × 14 = 54,558 in. lb.

Dead load moments :

1.	Kerb, 15/12 × 12/12 × 150 × 37.5	... 7,047 in. lbs
2.	Hand rails, 70 × 42	... 2,940 in. lbs
3.	Slab, 3.75 × (6 + 10)/12 × 150 × 20.625	... 7,734 in. lbs
4.	Wearing coat : 2.5 × 3/12 × 140 × 15	... 1,312 in. lbs
	Total moment due to dead and live load	... 73,591 in. lbs

As = 73591/18000 × 0.86 × 8.625 = 0.551 sq. in.

Rods available at top 3/4 in. at 6 in. centre to centre will be ample.

Kerb ; Positive moment induced by live load = $P/4\ n$

= 12500 × 1.50/4 × 0.02965 = 1,58,100 in. lb.

Negative moment : $P/19\ n$

12500 × 1.5/19 × 0.02965 : 33,290 in. lb.

A_s required at bottom :—1,58,100/18000 × 0.86 × 16.5 = 0.13 sq. in.

1/2 in. dia. 4 Nos. will be quite ample. In the drawing, 4 Nos. of 1/2 in. dia. have been adopted at bottom and 2 Nos. at top with 3/4 in. dia stirrups at 12 in. centres.

Design of diaphragms

End diaphragms are : 12 in. wide—Intermediate are : 10 in. wide

Reinforcement :—0.3 per cent will be provided and this will be distributed throughout the depth.

Area of end diaphragm = 12 × 69.0 sq. in.

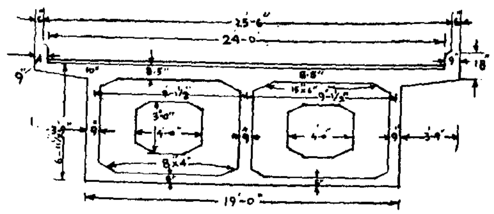
Area of reinforcement = 12 × 69.0 × 0.3/100 = 2.484 sq. in.

4 bars of 1 in. dia. giving 3.14 sq. in. will be provided at bottom,

In addition to this ½ in. dia. bars will be provided within the depth of diaphragms : Area of cross-section of intermediate diaphragms = 10 × 69 sq. in.

As = 690 × 0.3/100 = 2.07. Use 3 bars of 1 in. dia. giving 2.34 sq. in. with ½ in. diameter bars within the depth of diaphragms.

Design of box



1. Dead load uniformly distributed :

1.	Hand rail, 2 × 70	140 lb/ft run
2.	Kerb, 2 × 187.5	375 lb/ft run
3.	Wearing coat, 24 × 0.25 × 140	840 lb/ft run
4.	Top slab, 19 × 8.5/12 × 150	2,019 lb/ft run
5.	Bottom slab, 19 × 0.5 × 150	1,425 lb/ft run
6.	Cantilever portion of deck, 2 × 3.75 × 8/12 × 150	750 lb/ft run
7.	Web, 3 × 0.75 × 5.75 × 150	1,941 lb/ft run
8.	Fillet at top, 4 × 1.25 × 0.5/2 × 150	188 lb/ft run
9.	Fillet at bottom, 4 × 1/2 × 8/12 × 4/12 × 150	67 lb /ft run
		7,745 lbs/ft run

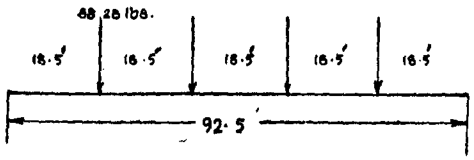
$$\text{Maximum dead load bending moment} = \frac{7745 \times 9.5^2}{8 \times 1{,}000 \text{ ft}} = 8{,}281 \text{ ft kips.}$$

2. Load due to diaphragms :

Self weight of diaphragms : 2 × 8.375 × 5.75 × 10/12 × 150	... 12,040 lb
Deduct for (1) Opening : 4 × 3 × 2 × 10/12 × 150	... 3,000 lb
(2) Portion covered by fillets : 255 × 5/6	... 212 lb
	3,212 lb.

Net weight = 8,223 lb.

(The fillets in the opening have been neglected.)

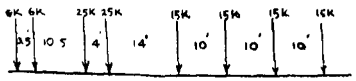


Maximum bending moment due to diaphragms :

: 8828 (2 × 46.25) – (9.25 plus 27.75) = 489.787 ft kips.

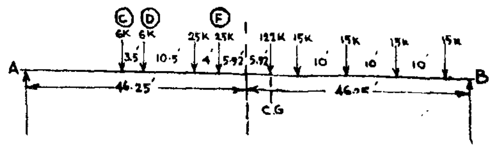
3. Live load : For Class A — Impact factor : $\frac{15}{20+92.5} = 0.133$.

Distance of centre of gravity of wheel loads from first wheel load :



$6 \times 35 + 25\,(14 + 18) + 15\,(32 + 42 + 52 + 62)/122 = 29.84$. ft

Position of wheel load for maximum bending moment :



$R_a = 122 \times 40.33/92.5 = 53.20$ kips.

Maximum bending moment under load (F)

$= 53.20 \times 40.33 - (25 \times 4 + 6)\,(14.5 + 18)$

$= 1742.556$ ft kips.

For 2 lanes including impact $= 2 \times 1743 \times 1.133 = 3{,}950$ ft kips.

Total bending moment $= 8281 + 490 + 3950 = 12{,}721$ ft kips.

Design of section

Bending moment : 12,721 ft kips.

Assumed Jd = 75.5 in.

A_s required $= 12721 \times 1000 \times 12/18000 \times 75.5 = 112.9$ sq. in.

Adopt 66 Nos. $1\frac{1}{2}$ in. dia. bars giving 118.39 sq. in.

Effective depth of beam = 80.5 in.

Depth of N.A. from top of slab :

$$19 \times 12 \times 8.5\;(n - 4.25) + 2 \times 45 \times 8\;(n - 4)^2/2 = 15 \times 118.39\,(80.5 - n)$$
$$n = 33.97 \text{ in.}$$

Centre of gravity of compression from top = 5.07 in.

Lever arm = 80.5 − 5.07 = 75.43 in.

Stress in steel $= 12721 \times 12 \times 1000/118.39 \times 75.43 = 17{,}060$ lb/sq. in.

Stress in concrete $= 17060/15 \times 33.97/46.53 = 830.5$ lb/sq. in.

Stresses are within safe limits.

The beam is divided into 10 equal parts and bending moment and shear calculations are made.

Section I at support : Total bending moment is zero.

Section II at 9.25 ft from centre of support.

(1) Dead load bending moment :

Area of influence line diagram,

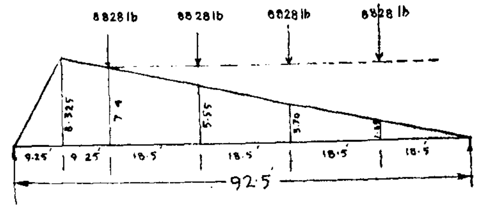
Ordinate $= 9.25 \times 83.25/92.5 = 8.325$.

Area $= 1/2 \times 8.325 \times 92.5 = 385$.

Bending moment : $7745 \times 385/1000 = 2{,}980$ ft kips.

Section II :

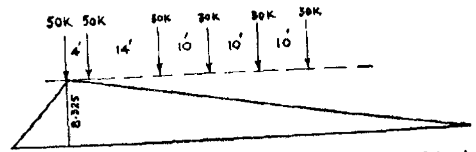
(2) Concentrated load due to diaphragms :



Bending moment $= \frac{8829}{1000}\,(1.85 + 3.70 + 5.55 + 7.40)$ ft kips.

$= 163.3$ ft kips.

(3) Due to live load :



Bending moment : $[50\,(8.325 + 7{\cdot}925) + 30\,(6.525 + 5.525 + 4.525 + 3.525)]\;1.133 = 1605$ ft kips.

Total bending moment : $1{,}605 + 2{,}980 + 163.3$ ft kips $= 4748.3$ ft kips.

Section III :

At 18.5 ft from centre of support.

(1) Bending moment due to dead load as calculated before = 5,300 kips

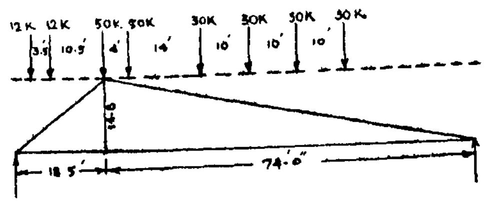
Influence line ordinate : $18.50 \times 74.00/92.5 = 14.8$.

Area : $1/2 \times 14.8 \times 92.9 = 685$.

Bending moment due to dead load $= 7{,}745 \times 685/1{,}000 = 5{,}300$ ft kips

(2) Bending moment due to diaphragms : $8828 \times 2 \times 18.5/1000 = 326.8$ ft kips.

(3) Bending moment due to live load :



Bending moment : [12 (6.4 + 3.6) + 50 (14.8 + 14) + 30 (11.2 + 9.2 + 7.2 + 5.2)] 1.133 = 2,888 ft kips.

Total = 8514.8 ft kips.

Section IV at 27.75 ft from support.

(1) Dead load bending moment :

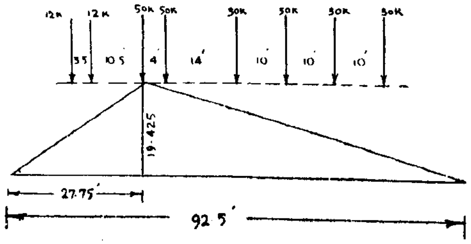
Ordinate of influence line diagram = 27.75 × 64.75/92.5 = 194.25.

Area of influence line diagram : 1/2 × 19.425 × 92.5 = 899.

Bending moment = 7745 × 899/1,000 = 6,951 ft kips.

(2) Bending moment due to diaphragms = 8828 (27.75 × 2 − 9.25) = 408.7 ft kips.

(3) Bending moment due to live load :



Bending moment : [50 (19.425 + 18.255) + 30 (14.025 + 11.025 + 8.025 + 5.025) + 12 (12.075 + 9.625)] 1.133 = 3,730 ft kips.

Total Bending moment = 11089.7 ft kips.

Section at : 37.0 ft centre of support :

(1) Bending moment due to diaphragms :

8828/1000 (2 × 37 − 18.5) ft kips = 490 ft kips.

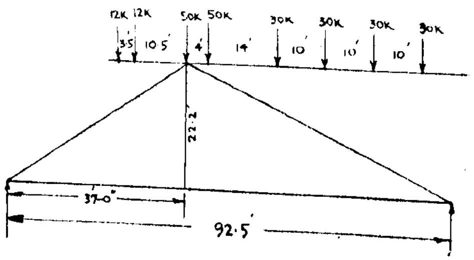
(2) Bending moment due to dead load :

Ordinate of influence line diagram = 37 × 55.5/92.5 = 2220.

Area of influence line diagram = 1/2 × 22.20 × 92.50 = 1026.75

Bending moment = 7745 × 1026.75/1000 = 7948 ft kips.

(3) Bending moment due to live load :



Bending moment = [50 (22.2 + 20.6) + 30 (15.00 + 11 + 7 + 3) + 12 (15.9 + 13.8)] 1.133 = 4,052 ft kips.

Total : 12,490 ft kips.

Section 6 at Mid span :

Total bending moment : Live bending moment at the point for maximum bending.

Moment plus bending moment due to dead load and diaphragms

: 12,721 ft kips.

Resisting moment :

Resisting moment of one bar $1\frac{1}{2}$ in. dia. assuming safe stress of 18,000 lb/sq. in. = 1.767 × 18000 × 75.43/1000 × 12 = 199.9 ft kips.

Total resisting moment of 66 Nos. of $1\frac{1}{2}$ in. diameter bars provided

= 66 × 199.9 = 13,193 ft kips.

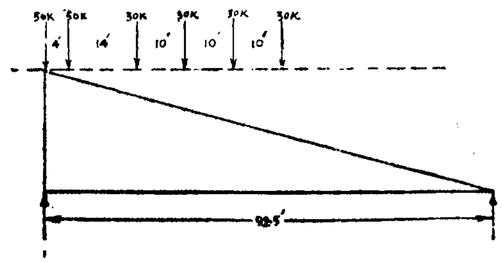
Shear :

Section at centre of support :

(1) Shear due to dead load = 7745 × 92.5/2 = 358,000 lb.

(2) Due to diaphragms = 8828 × 2 = 17,656 lb.

(3) Live load :



[50 (1 + 88.5/92.5) + 30 (74.5 + 64.5 + 54.5 + 44.5)/92.5)] × 1.133 = 1,98,900 lb.

Total : 574,556 lb.

$$\text{Shear stress} = \frac{574,556}{3 \times 9 \times 75.43} = 2,824 \text{ lb.}$$

This is more than allowable stress, hence 2 legged 5/8 in. dia. stirrups are provided.

Spacing = 6 × 0.307 × 18000 × 75.43/574556 = 4.36 in.

Stirrups at 4 in. centres will be provided.

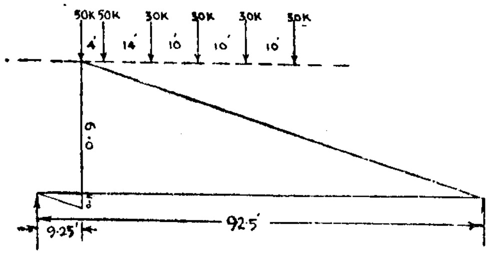
Section II at 9.25 ft from centre of support :

(1) Due to dead load :

7745 (46.25 − 9.25) = 2,86,565 lb.

(2) Due to diaphragms = 17,656 lb,

(3) Live load:



[50 (83.25 + 79.25)/92.5 + 30 (65.25 + 55.25 + 45.25 + 35.25)/92.5] 1.133
100 = 174,000 lb.

Total = 4,78,221 lb.

Using 2 legged 5/8 in. dia. bars

Spacing = 3 × 2 × 0.307 × 18000 × 75.43/478221 = 5.29 in.

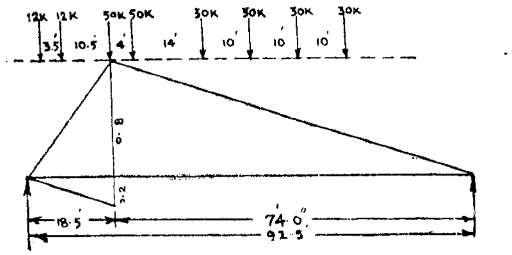
Adopt 5 in. spacing.

Section III at 18.5 ft from the centre of support:

(1) Due to diaphragms: 17,656 lb.

(2) Due to dead load : 7745 (46.25 – 18.5) : 214,800 lb.

(3) Due to live load:



1.133 [50 (74 + 70)/92.5 + 30 (56 + 46 + 36 + 26)/12.5
– 12 (8.0 + 4.5)/92.5] = 1,46,900 lb.

Total shear = 3,79,356 lb.

Spacing of 2 legged 5/8 in. dia. bars
= 3 × 2 × 0.307 × 18000 × 75.43/379356 = 6.59 in

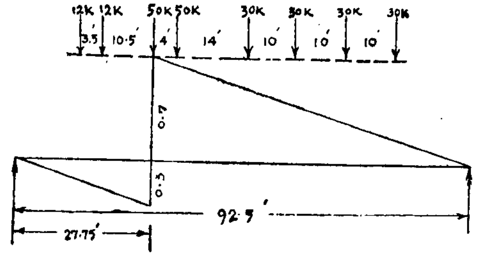
Adopt 6.5 in. spacing.

Section IV at 27.75 ft from the centre of support.

Shear (1) Due to diaphragms: 8,828 lb.

(2) Due to deck: 7745 (46.25 – 27.75) = 1,43,283 lb,

(3) Due to live load:



1.133 [50 (64.75 + 60.75)/92.5 + 30 (46.75 + 36.75 + 26.75 + 16.75)/92.5 – 12 (17.25 + 13.75)/92.5] kips = 1,12,000 lb.

Total = 2,64,111 lb.

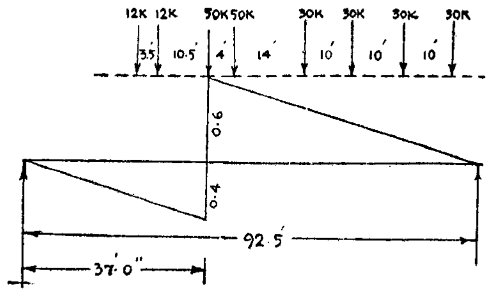
Spacing of, 5/8 in. dia. stirrups = 2 × 3 × 0.307 × 18000 × 75.43/264111
= 9.48 in. – Adopt 9 in. spacing.

Section V at 37 ft from the centre of support:

(1) Shear due to dead load = 7745 (46.25 – 37) : 71,641 lb.

(2) Shear due to diaphragms: 8,828 lb.

(3) Shear due to live load:



[50 (55.5 + 51.5)/92.5 + 30 (37.5 + 27.5 + 17.5 + 7.5)/
92.5 – 12 (26.5 + 23.00)/92.5] × 1.133 kips or 91,320 lb.

Total: 1,71,789 lb.

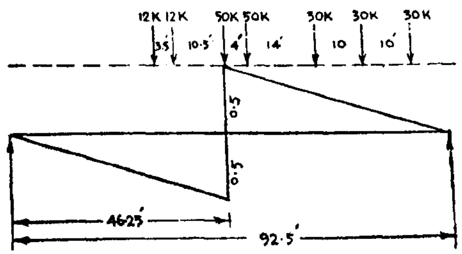
Spacing of 1/2 in. dia. stirrups – 2 × 3 × 0.196 × 18000 × 75.43/171789
= 9.29 in. – Adopt 9 in. centres.

Section VI at Mid span:

(1) Dead load shear : Nil.

(2) Shear due to live load:

[50 (46.25 + 42.25)/92.5 + 30 (28.25 + 18.25 + 8.25)/92.5
– 12 (35.75 + 32.5)/92.5)] × 1.133 = 64,500 lb.



Spacing of 1/2 in. dia. stirrups:

$3 \times 2 \times 0.196 \times 18000 \times 75.43/64500 = 24.76$ in.

Adopt 24 in.

Arrangement of stirrups for the webs:

Diameter	Spacing	Range	
5/8 in.	4 in.	Upto 9.25′ from the centre of support.	
5/8 in.	5 in.	From 9.25′ to 18.5′	do.
5/8 in.	$6\frac{1}{2}$ in.	From 18. 5′ to 27.75′	do.
5/8 in.	9 in.	From 27.75′ to 37′	do.
1/2 in.	9 in. to 24 in.	From 37′ to 46.25′	do.
	i.e., 4×9 in.		
	3×12 in.		
	1×18 in.		
	1×24 in.		

Bond stress—24 bars of $1\frac{1}{2}$ in. dia. will be taken upto support.

Bond stress $= 574556/24 \times 22/7 \times 1.5 \times 75.43 = 67.3$ lb.

SAFE

Appendix 6

1. Topographical Features

1.1. Bridge Site:

The Bridge is situated in plain country, across the perennial rainfed Udyavar river subjected to tidal action of the sea. The banks at bridge site are fairly well defined, the bridge is on a straight reach. The bed of the river consists of medium sand over clay and hard rock.

2. Hydraulic Particulars

Catchment area consisting of lightly covered plateau	... 116 sq. miles.
Maximum theoretical discharge	... 35,680 cusecs.
High flood level	... 11.21 ft below road level.
Highest tide level	... 15.41 ft below road level.
Lowest tide level	... 19.46 ft below road level.
Theoretcial velocity developed under high floods	... 3.68 ft per second.

3. Load

Design of loading	... I.R.C. Class 'AA' single lane or I.R.C. Class 'A' double lane whichever produces worse effect.

4. Maximum Pressure

On bearings	... 1,032 lb/sq. in.
At the base of pier	... 5.97 tons per sq. ft.

Well foundations rest on hard rock in all cases.

5. Quantities of work involved in the bridge

Plain cement concrete	... 82,300 cu. ft.
Reinforced cement concrete	... 59,000 cu. ft.
Masonry work	... 12,600 cu. ft.
Cement used	... 1,380 tons.
Steel used	... 360 tons.

6. Cost Analysis

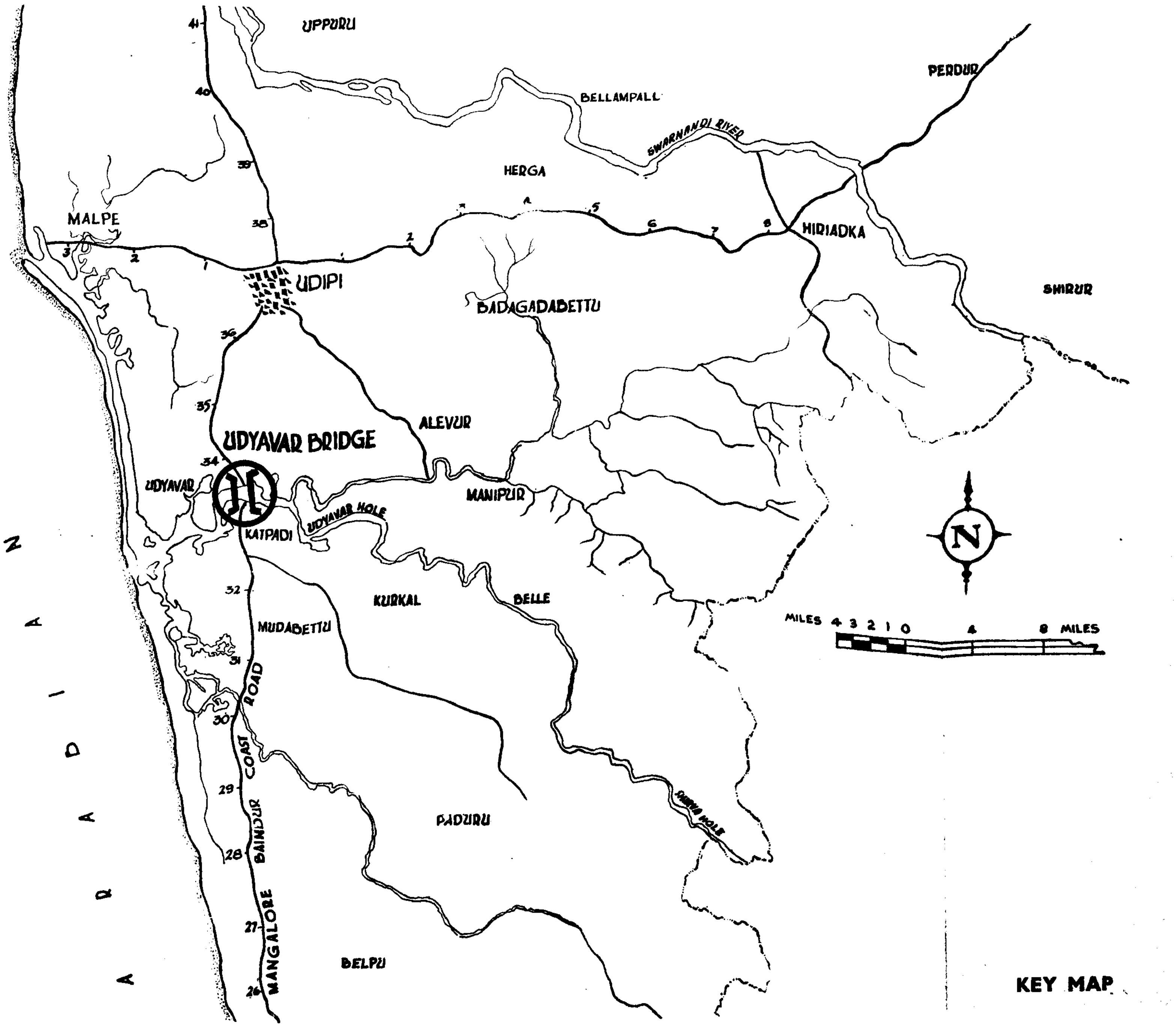
(i)	Total length of the bridge including abutments ...		874 ft
(ii)	Total cost of the bridge (excluding approaches) ...		Rs 9,73,000
(iii)	Cost per linear foot of the bridge	,,	1,113
(iv)	Cost per square foot of the bridge in elevation from bottom of foundation to top of kerb ...	,,	18.50
(v)	Cost per square foot of carriageway (carriageway 24 ft) ...	,,	46.38
(vi)	Cost per cubic foot of bridge (Height reckoned from bottom of foundation to top of roadway) ...	,,	0.70
(vii)	*Break up figures of cost*		
	Cost of foundations		Rs 3,72,000
	Cost of substructure	,,	1,06,000
	Cost of superstructure	,,	4,95,000

Appendix 7

List of heavy machinery used on Udyavar Bridge works

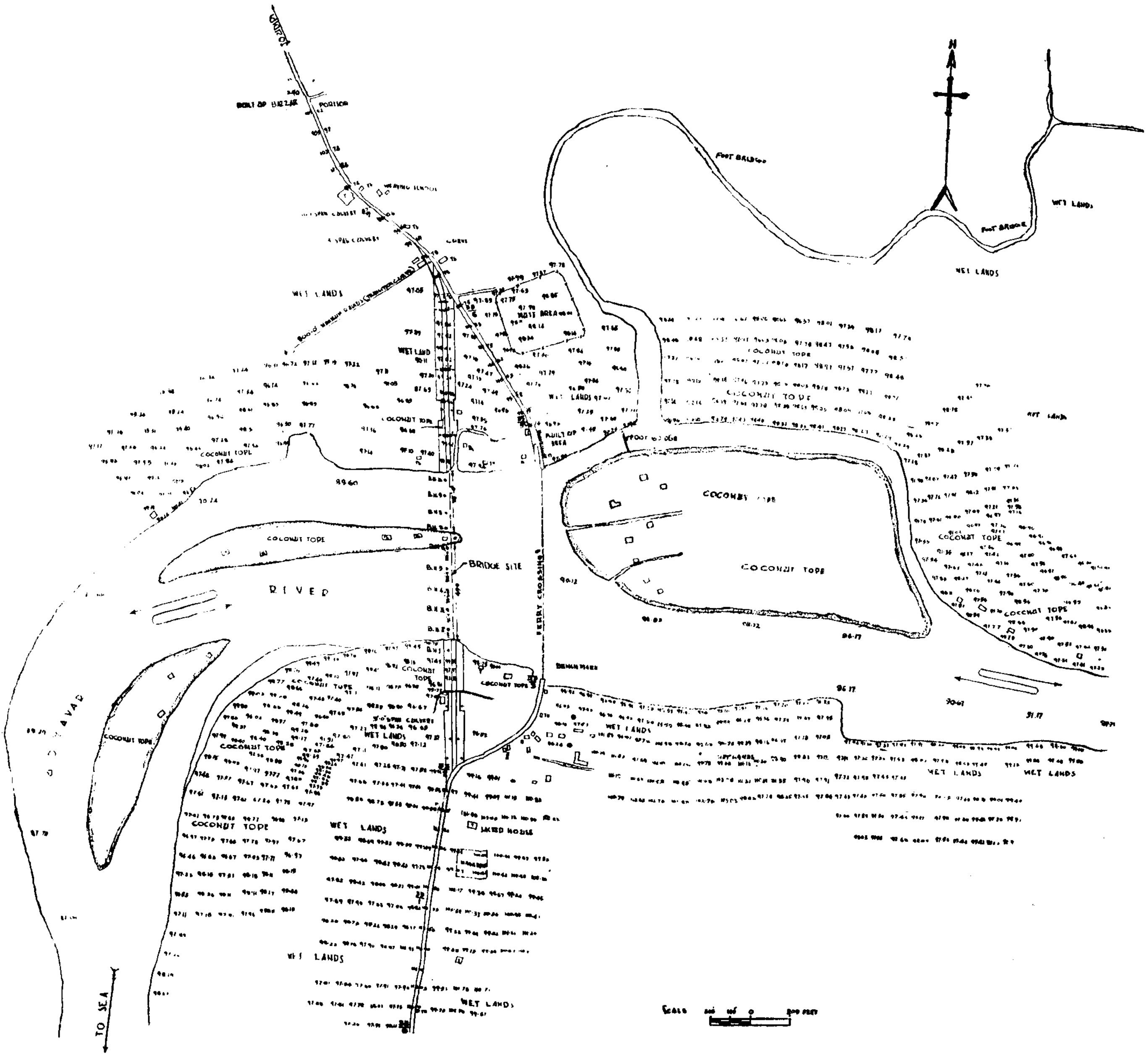
1. 26 H.P. Sentinal Gauz Engine No. 2C/100 coupled to Ingersol Rand (Compressor 80 cu.ft.)
2. 6 H.P. Lister Engine No. 10204514 coupled to Wilson Compressor No. VC. 3422.
3. Parker Mixer coupled to Lister Engine 6 H.P. No. 10377574.
4. Millers Concrete Mixer coupled to 6 H.P. Lister Engine No. 8616514.
5. Marshall Benson Concrete Mixer coupled to 6 H.P. Lister Engine No. C.C. 31623.
6. 10 H.P. Double Cylinder Lister Engine No. 12811 coupled to Mather & Plat Pump (4 in × 3 in.)
7. 5 H.P. Lister Engine No. 96612 coupled to D.B.F. Pump (4 in. × 3 in.)
8. P and H Welding Generator Engine No. 2391128—H.P. No. 10; Spec. No. 109927—Generator No. 13466.
9. Villiers Vibrator—Machine No. 236—No. 015—42907 A. Mark 25—Model III.
10. Villiers Vibrator—Machine No. 236—No. 015 A/42920 A-Mark 25—Model III.
11. Screed Vibrator—Allam Petrol Driven Vibrating Tamper Unit powered $1\frac{1}{2}$ H.P. Villiers Air cooled Petrol Engine No. 952 A 46700—Mark 12 H.S.
12. Sump pump Type 8/600 No. 595101 / 595102 —2 Nos.
13. Ingersol Rand Pneumatic Drill No. I.R. 12 No. 293197.
14. 5 H. P. Lister Engine No. C.S. 44965.
15. Wilson Compressor No. 3164—coupled to 6 H.P. Lister Engine.
16. Wilson Compressor No. 3446—coupled to 6 H.P. Lister Engine.
17. Wilson Compressor No. 3426.
18. Broom & Wade Compressor No. 319185.
19. Calyx Drill coupled to $3\frac{1}{2}$ H.P. Lister Engine No. C.S. 56168.
20. Calyx Drill.
21. Holman S.B. 27 Silver Bullet S.B. 250 D/30051.
22. Atlas Sweedan—R.H. 57 No. 416204.
23. Ripper—No. 70105-25-Z-W-S-Pat. C.P. III.
24. Boring set complete.

PLATE I



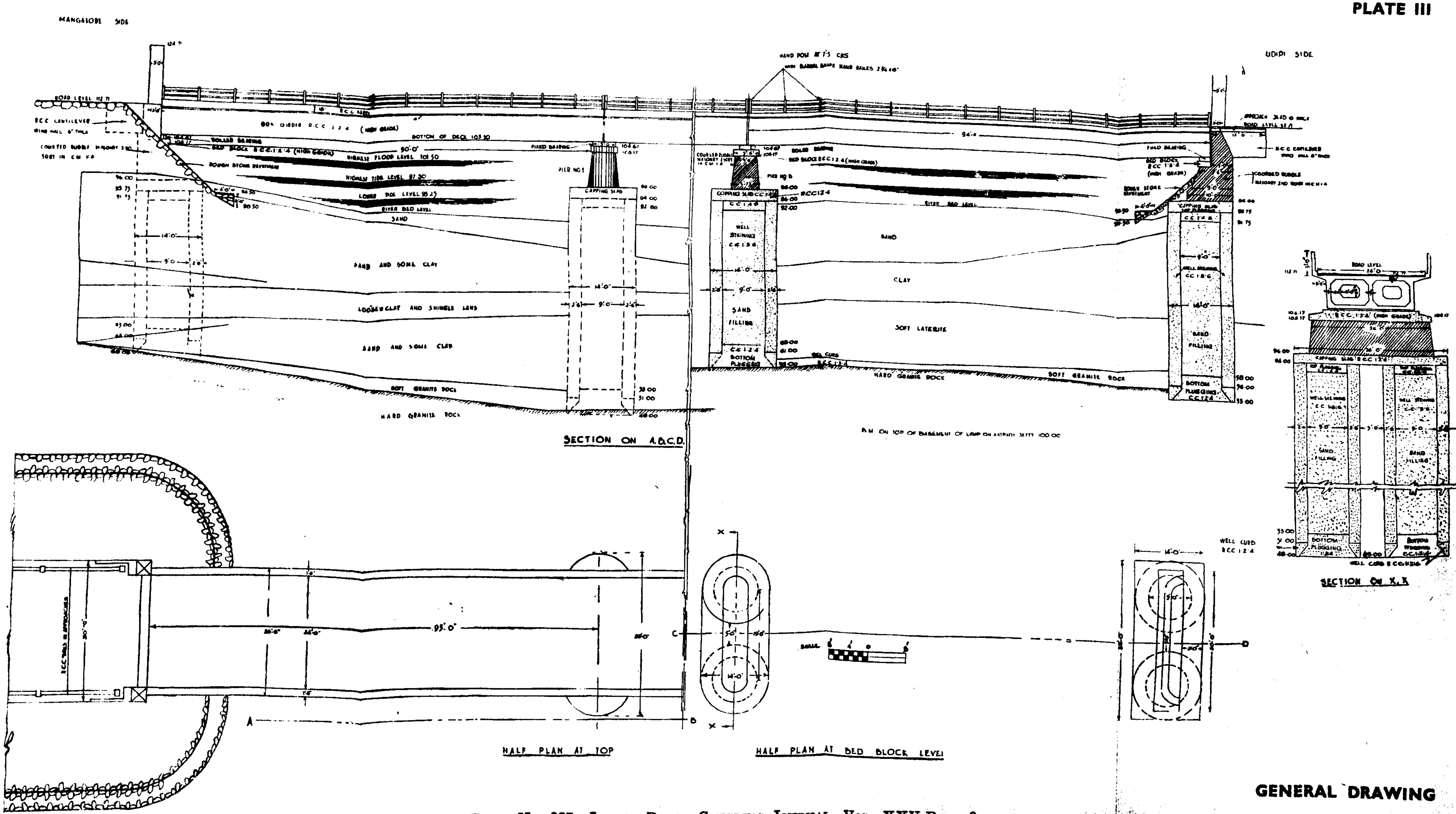
KEY MAP

PLATE II



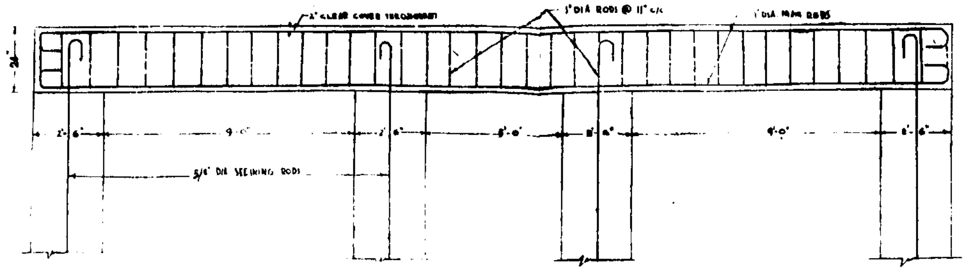
SITE PLAN

PLATE III

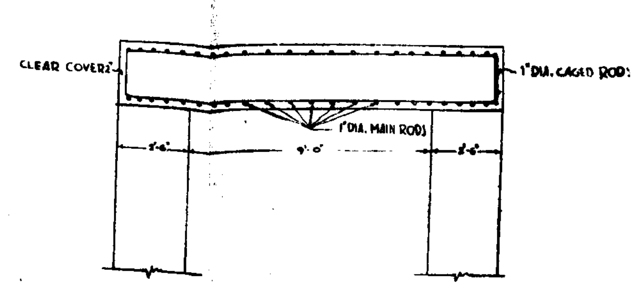


GENERAL DRAWING

PLATE IV



SECTION ON 'AA'



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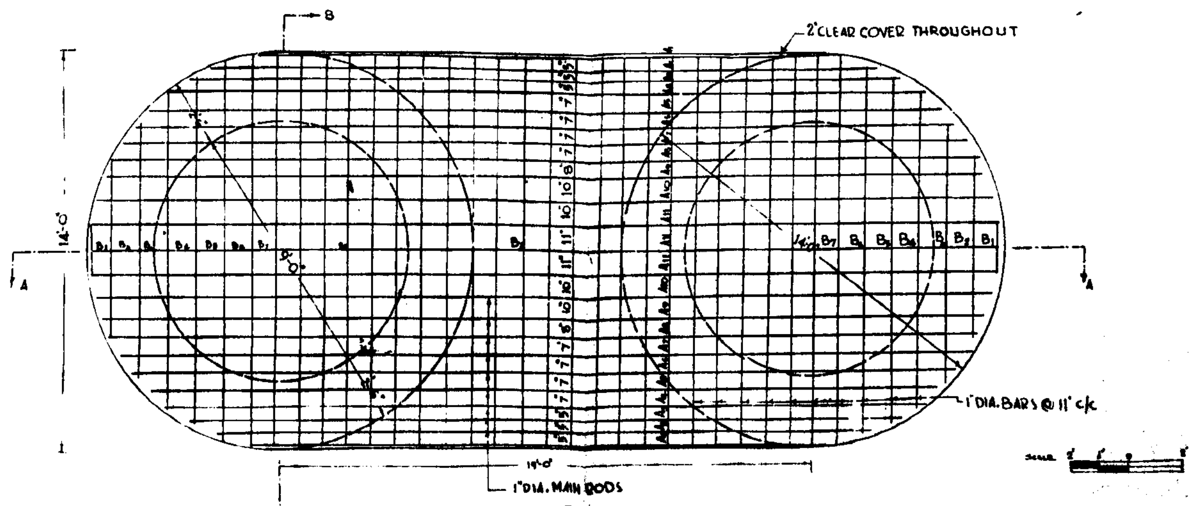
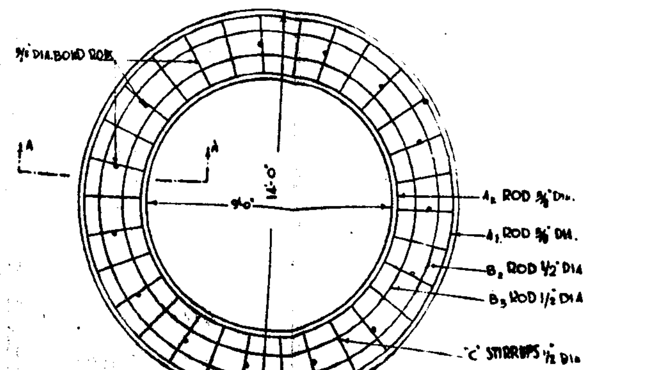


PLAN



PLAN OF WELL CURB

REINFORCEMENT SCHEDULE FOR WELL CAP

NAME	DIA.	NO	LENGTH P	LENGTH a	TOTAL LENGTH	WEIGHT	SHAPE OF BAR
A_1	1"	4	25'-1"	9"	96'-4"		A - RODS
A_2	1"	4	26'-6"	9"	106'-0"		
A_3	1"	4	26'-6"	9"	106'-0"		
A_4	1"	4	27'-0"	9"	114'-0"		
A_5	1"	4	28'-6"	9"	120'-0"		
A_6	1"	4	29'-6"	9"	124'-0"		
A_7	1"	4	30'-6"	9"	128'-0"		
A_8	1"	4	31'-5"	9"	131'-0"		
A_9	1"	4	31'-[illegible]	9"	133'-0"		
A_{10}	1"	4	32'-4"	9"	135'-6"	6569 lbs	
A_{11}	1"	6	32'-8"	9"	205'-0"		
B_1	1"	2	7'-11"	16"	16'-8"		B - RODS
B_2	1"	2	6'-7"	16"	35'-4"		
B_3	1"	2	9'-7"	16"	45'-4"		
B_4	1"	2	11'-6"	16"	54'-8"		
B_5	1	2	12'-7"	16"	57'-4"		
B_6	1"		15'-6"	16"	61'-0"		
B_7	1"	22	15'-6"	16"	600'-10"		

TOTAL ... 6569 lbs
WASTAGE ... 330 ·
BINDING WIRE 71 ·
6970 lbs

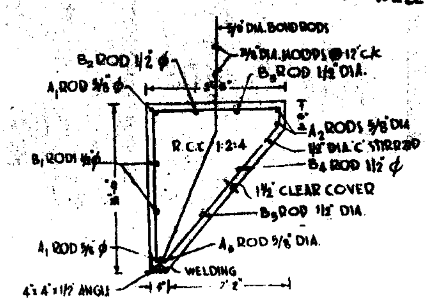
STEEL/CFT. OF CONCRETE = $\frac{6970}{840}$ = 8.29 lbs

REINFORCEMENT SCHEDULE FOR WELL CURB

NAME	DIA	NO	LENGTH	TOTAL LENGTH	WEIGHT	SHAPE OF BAR
A_1	5/8"	2	45'-0"	90'	207 lbs	D - 15'-7½"
A_2	5/8"	2	32'-0"	64'		D - 9'-4½"
A_3	5/8"	1	44'-0"	44'		D - 13'-4"
B_1	1/2"	2	45'-0"	90'	348 lbs	D 15'-7½"
B_2	1/2"	1	41'-0"	41'		D 12'-3"
B_3	1/2"	1	36'-0"	36'		D 10'-9"
B_4	1/2"	1	36'-0"	36'		D - 10'-9"
B_5	1/2"	1	40'-0"	40'		D 12'-0"
C	1/2"	30	9'-4"	279'		

TOTAL ... 555 lbs
WASTAGE 28 lbs
BINDING WIRE 7 lbs
590 lbs

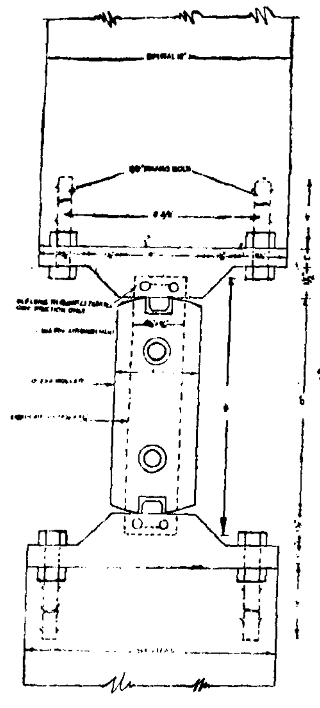
STEEL/CFT OF CONCRETE $\frac{590}{1635}$ = 3.23 lbs



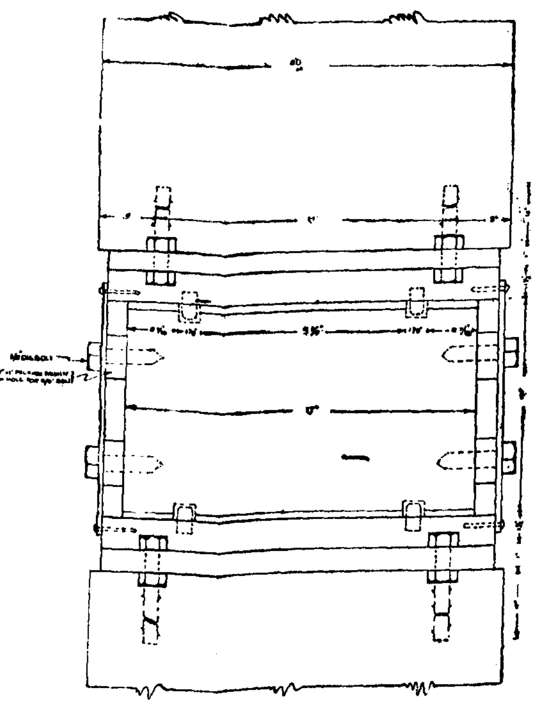
SECTION ON 'AA'

DETAILS OF CAPPING SLAB OVER PIER, WELLS & THE DETAILS OF WELL CURB

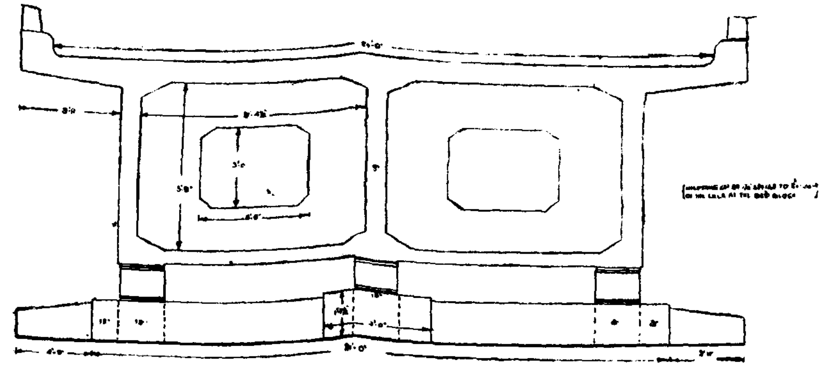
PLATE V



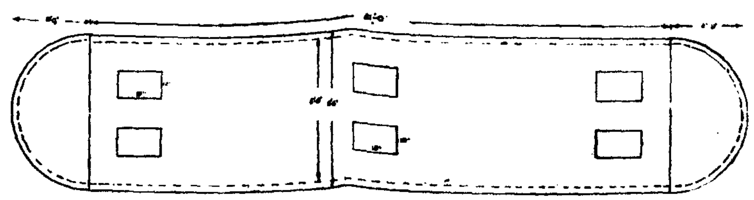
END VIEW OF ROLLER BEARING



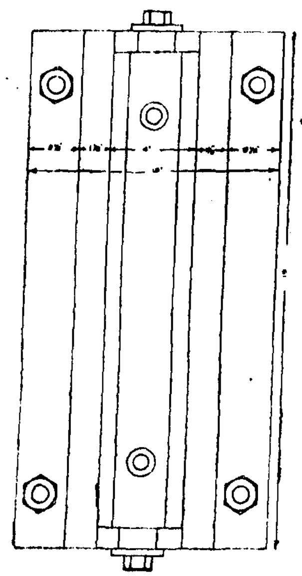
SIDE VIEW OF ROLLER BEARING



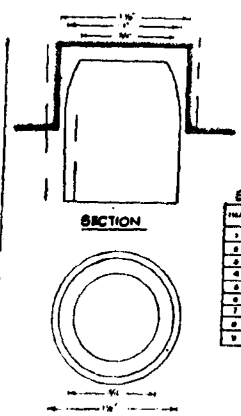
CROSS SECTION SHOWING THE POSITION OF BEARING



PLAN



PLAN.



SECTION

PLAN

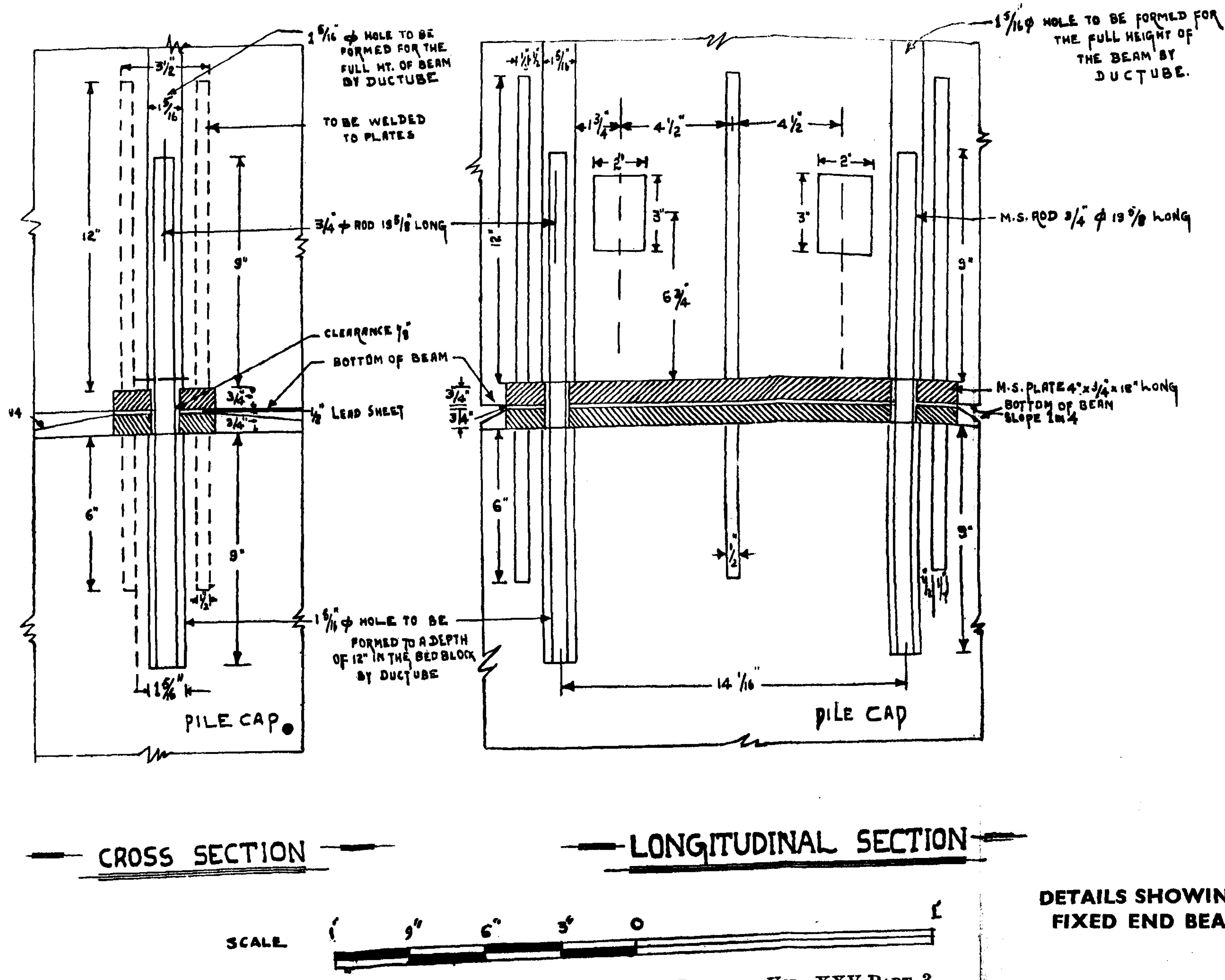
DETAILS OF MILD STEEL PIN

SCHEDULE OF REINFORCEMENTS FOR ONE ROLLER BEARING

Item	Description	No. [illegible]	Remarks	Metal
1	Top plate	1	Complete as shown	Cast steel
2	Bottom plate	1		-Do-
3	[illegible] roller	1		Cast steel
4	End plate [illegible]	8		Mild steel
5	[illegible] dia bolt	4		-Do-
6	[illegible] dia rivets	8		-Do-
7	[illegible] dia rag bolts	8		-Do-
8	Washer [illegible]	4		-Do-
9	1" dia pin	4		-Do-

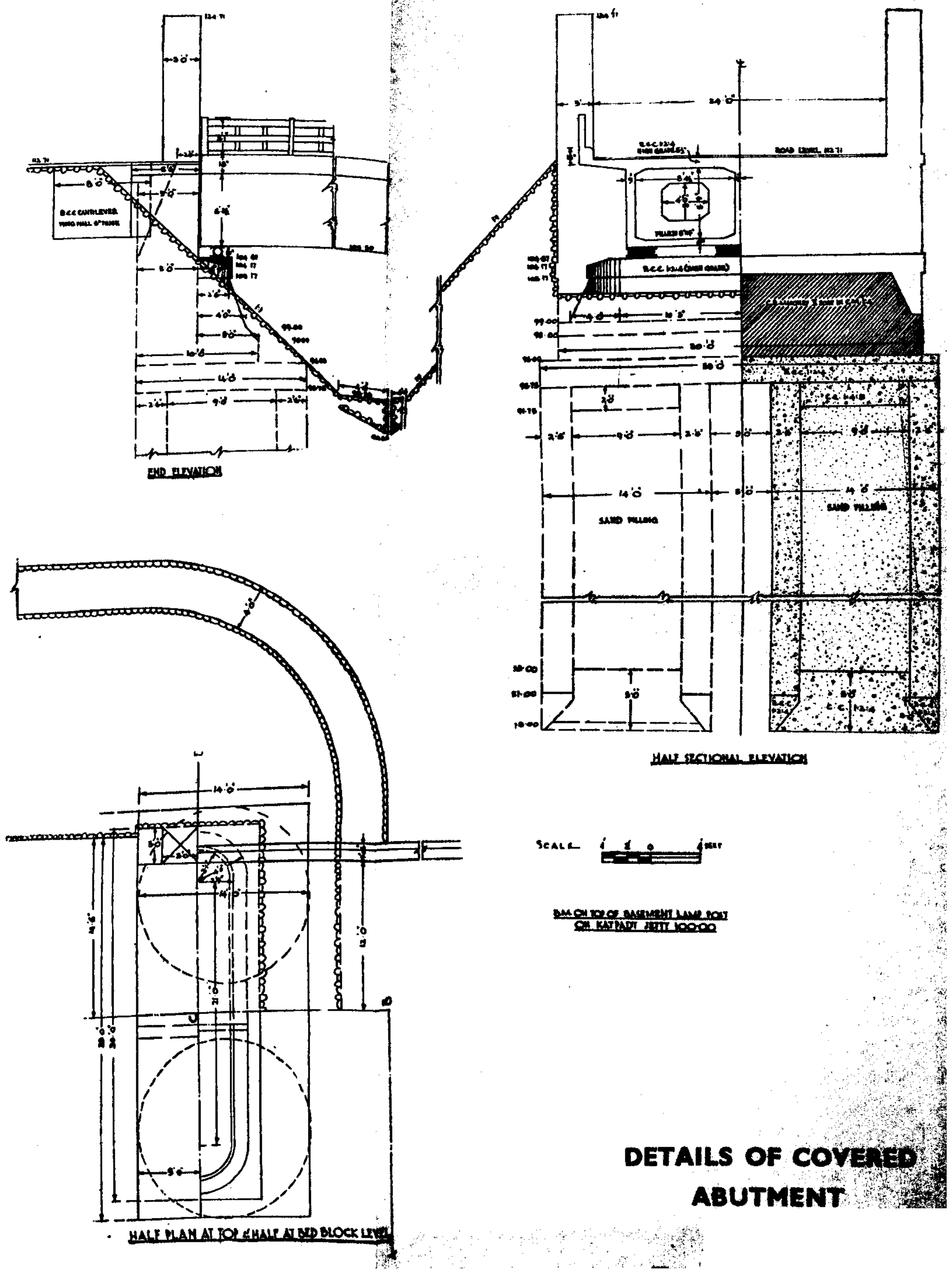
DETAILS OF ROLLER BEARINGS

PLATE VI



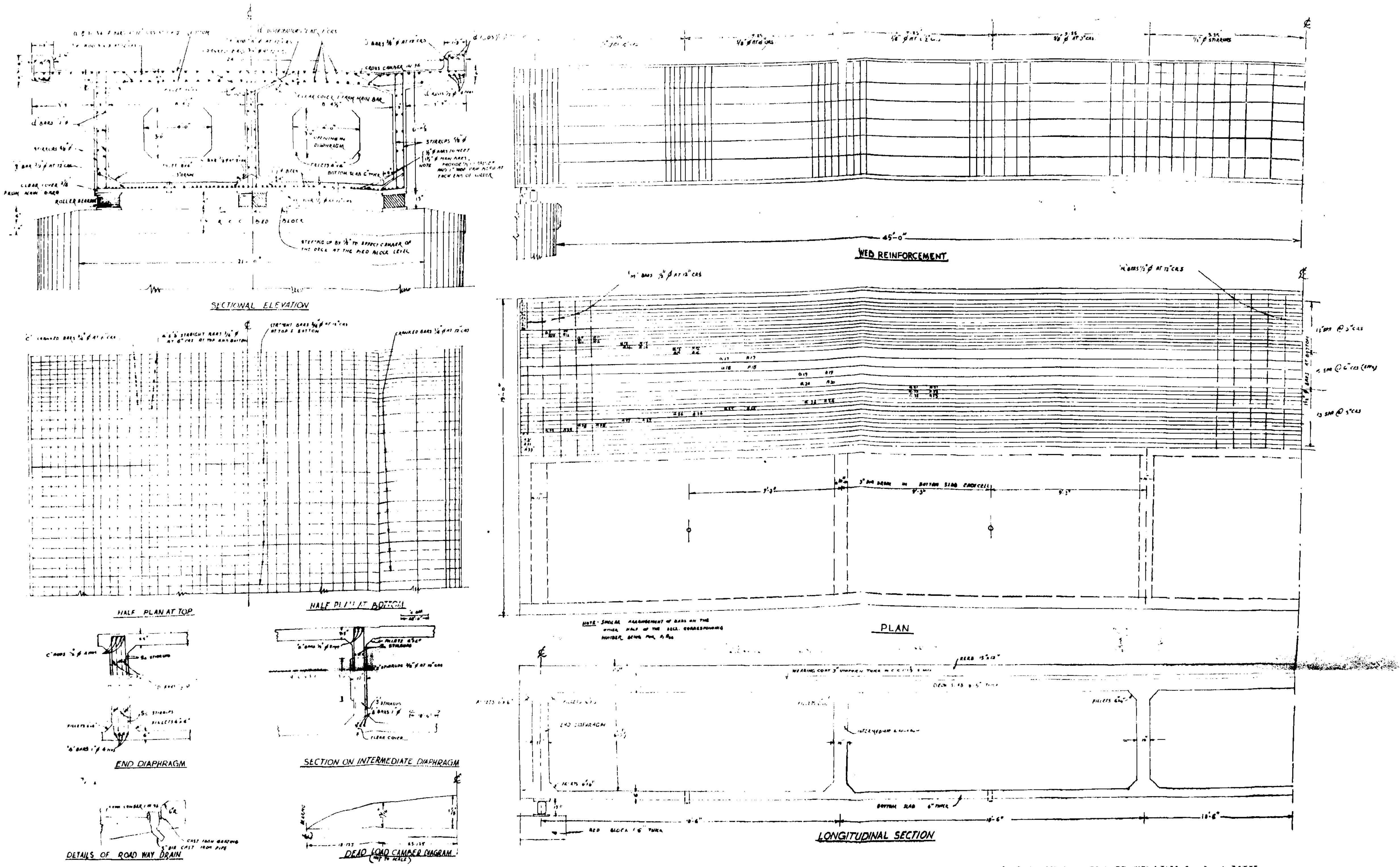
DETAILS SHOWING THE FIXED END BEARINGS

PLATE VII



DETAILS OF COVERED ABUTMENT

PLATE VII-A



SCHEDULE OF REINFORCEMENT FOR BOX GIRDER

NAME	DIA	LENGTH	NOS	TOTAL LENGTH	WEIGHT IN LBS PER RFT	TOTAL WEIGHT	SHAPE OF BARS
a	3/4"	27'-5"	103	2823'-11"	1.502 lbs		26'-3"
b	3/4"	22'-2"	103	2283'-2"	1.502 lbs	11,930 lbs	21'-0"
c	3/4"	27'-10"	102	2839'-0"	1.502 lbs		
d	1/2"	94'-9"	114	10801'-0"	0.667 lbs	7200 lbs	94'-9"
e	3/8"	6'-7"	2×103 = 206	1356'-6"			
f	3/8"	6'-1"	103	626'-7"			
g	3/8"	1'-8"	2×103 = 206	343'-0"	0.375 lbs	1.435 lbs	
h	3/8"	3'-3"	103	334'-9"			
j	3/8"	5'-8"	2×103 = 206	1167'-4"			
k	5/8"	15'-1½"	97×2×3 = 582	8657'-0"	1.043 lbs	9029 lbs	
l	1/2"	15'-1½"	2×9×3 = 54	816'-8"	0.667 lbs	555 lbs	
m	1/2"	19'-6"	103	2008'-6"	0.667 lbs	1339 lbs	18'-9"
A1 To A8, A30 To A37, A59 To A66	1½"	94'-6"	24	2268'-0"			94'-6"
A9, A10, A35 To A36, A57, A58	1½"	89'-6"	6	537'-0"			89'-6"
A11, A12, A28, A39, A55, A56	1½"	85'-6"	6	513'-0"			85'-6"
A13, A14, A27, A40, A53, A54	1½"	79'-6"	6	477'-0"	6.008 lbs	31580 lbs	79'-6"
A15, A16, A26, A41, A51, A52	1½"	73'-6"	6	441'-0"			73'-6"
A17, A18, A25, A42, A49, A50	1½"	67'-6"	6	405'-0"			67'-6"
A19, A20, A24, A43, A47, A48	1½"	57'-6"	6	345'-0"			57'-6"
A21, A22, A23, A44, A45, A46	1½"	44'-6"	6	267'-0"			44'-6"
a9, a10, a19, a38, a57, a58	1/2"	2'-6"×2 = 5'-0"	6	30'-0"			2'-6"
a11, a12, a37, a39, a59, a56	1/2"	4'-6"×2 = 9'-0"	6	54'-0"			4'-6"
a13, a14, a21, a40, a53, a54	1/2"	7'-6"×2 = 15'-0"	6	90'-0"			7'-6"
a15, a16, a26, a41, a51, a52	1/2"	10'-6"×2 = 21'-0"	6	126'-0"	0.667 lbs	656 lbs	10'-6"
a17, a18, a26, a42, a49, a50	1/2"	13'-6"×2 = 27'-0"	6	162'-0"			13'-6"
a19, a20, a24, a43, a47, a48	1/2"	2×18'-6" = 37'-0"	6	222'-0"			18'-6"
a21, a22, a23, a44, a45, a46	1/2"	25'-0"×2 = 50'-0"	6	300'-0"			25'-0"
B	1"	20'-0"	20	400'-0"	FOR DIAPHRAGMS 2.67 lbs.	1.067 lbs.	18'-6"
C	3/4"	23'-0"	20	460'-0"	0.667 lbs	307 lbs	23'-0"
D	1/2"	18'-2"	24	444'-0"	0.667 lbs	296 lbs	16'-6"
S	3/8"	15'-0"	20×4 = 80	1200'-0"			
S1	3/8"	4'-10"	8×4 = 32	155'-0"			
S2	3/8"	5'-8"	8×4 = 32	181'-0"	0.375 lbs	1310 lbs.	
S3	3/8"	14'-10"	20×2×2 = 80	1187'-0"			
S4	3/8"	5'-6"	32	176'-0"			
S5	3/8"	4'-8"	32	149'-0"			
	3/8"	2'-3"	96	216'-0"	FILLET BARS 0.375 lbs	81 lbs.	

TOTAL .... 66765 lbs

WASTAGE & BINDING WIRE } 3235 lbs

70,000 lbs

SCALE 2' 1 0 2'

CONCRETE: HIGH GRADE 1 : 2 : 4 MIX

LIVE LOAD: IRC CLASS 'A' AND 'AA'

LONGITUDINAL CAMBER: SPANS SHALL BE COMBERED FOR DEAD LOAD DEFLECTION WHILE CONCRETING THE DECK.

DETAILS OF HOLLOW BOX GIRDER FOR 90 FT. SPAN

Paper No. 228

"STUDY OF PARKING PROBLEMS—CONNAUGHT PLACE & CONNAUGHT CIRCUS AREA, NEW DELHI"

By

JOGINDAR LAL*

CONTENTS

1. INTRODUCTION

1.1. During the past few years, on account of all round development and continued increase in production and prosperity in the country there has been increase in the number of all types of vehicles, particularly motor vehicles. This has created a parking demand in urban areas. Undefined parking spaces and slack enforcement of parking rules in almost all the big towns, coupled with the increased parking demand have resulted in haphazard parking which impedes the free flow of traffic and contributes towards the increased number of accidents. This study has been carried out with a view to assess the parking demand and to suggest improvements in the layont of parking facilities in one of the busiest centres of New Delhi, keeping in view the present and reasonable future growth of traffic as far as possible and the innate desire of the road users to park their vehicles as close to their destination as possible.

1.2. The area selected for study is shown in Plate I (within the cordon) and includes Connaught Place, Connaught Circus including Service roads, Service lanes and Radial roads, Janpath (from Connaught Circus to Keeling Road), Parliament Street (from Connaught Circus to Hanuman Road) Irwin Road, (from Connaught Circus upto Rivoli Cinema) and Curzon Road (from Connaught Circus upto back side of Scindia House).

* Central Road Research Institute, Okhla, New Delhi-20.

The area has been selected for study on the basis of findings of the origin and destination survey for the Greater Delhi, conducted earlier by the Central Road Research Institute, New Delhi, viz., the Connaught Place area which was found to have the maximum accumulation of vehicles on the area basis.

Due to central location of *Connaught Place, the best shopping centre*, many hotels, restaurants, cinemas, banks, private offices, workshops and garages, etc., are located there resulting in very high parking demand. Due to there being no defined parking spaces, and *impulsive habits of the parkers, haphazard parking has started which* causes irritation to the motorists, inconvenience to both the shoppers and shop-keepers and also impedes smooth and orderly flow of traffic.

2. PROCEDURE

2.1. Field surveys for the assessment of parking demand were carried out in June 1959. For the survey, the area under study was divided into 5 zones, namely (i) Connaught Place, (ii) Service roads and Service lanes, (iii) Radial roads, (iv) Connaught Circus including Parliament Street, Irwin Road, Curzon Road and (v) Janpath.

The area was subdivided into 24 blocks to see the parking demand and the parking spaces available in each block.

2.2. Vehicles were classified into the following two categories :

(i) Private vehicles including (a) private cars, (b) motor cycles, (c) private buses and private trucks and (d) cycles.

(ii) Public transport vehicles including (a) taxis. (b) motor cycle rickshaws, two-seater scooters and (c) tongas.

2.3. There were the following two distinctly correlated steps in the study :

A. Surveys and analysis:

(i) Assessment of maximum parking demand in the area.

(ii) Preparation of physical inventories.

B. Designing the layout for parking spaces and suggesting methods for encouraging the turnover.

3. SURVEYS AND ANALYSIS

3.1. The survey for parking demand of private vehicles was conducted to find out maximum number of short-time parkers*

all-day* parkers and all night parkers. With a view to assess the maximum parking demand for both private and public transport vehicles, direct hourly counts of the vehicles parked on all the 4 sides of the 24 blocks were taken for 12 hours, i.e., from 9 A.M. to 9 P.M. on different days of the week (Monday thro Friday). Separate hourly counting was done on Saturdays for 5 hours, i.e. from 4 P.M. to 9 P.M., the most favourite time for shopping. On Sundays and holidays parking demand is minimum, as such excluded.

All-day parking demand for private vehicles, was assessed on weekdays by noting registration numbers of the parked vehicles at 11 A.M. and 4 P.M., vehicles found parked both at 9 A.M. and 4 P.M. on the same day were taken as all-day parkers. Vehicles found parked at 4 A.M. were taken as all-night parkers.

The data collected was compiled separately for private vehicles, public transport vehicles and cycles. Hourly variation of parking demand on weekdays for private motor vehicles, public transport vehicles and cycles is shown in Figs. 1, 2 and 3.

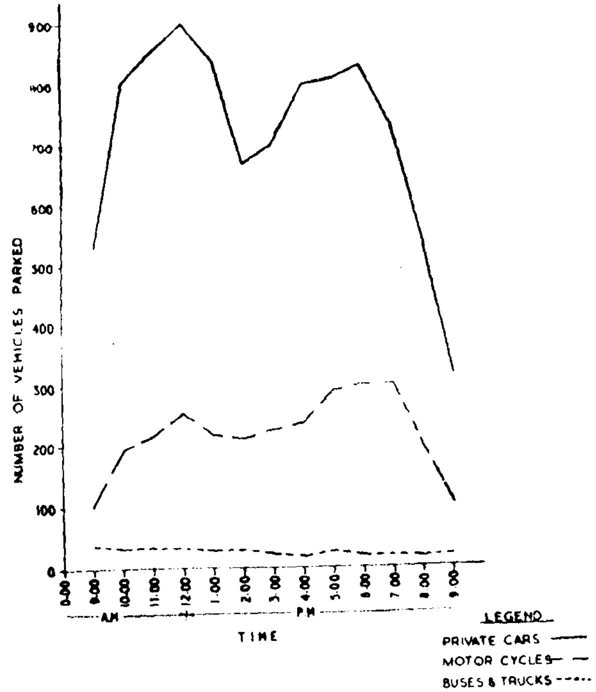


Fig. 1. **Hourly variation of parking demand for private vehicles**

* Less than 5 hours parking classified as short-time, exceeding 5 hours parking were classified all-day parkers.

The maximum parking demand for private vehicles was 901 private cars, including 324 all-day parkers; 327 motor cycles including 112 all-day parkers; and 39 private buses and trucks including 17 all-day parkers. For the public transport vehicles, the maximum parking demand was for 167 taxis, 66 motor cycle rickshaws and 31

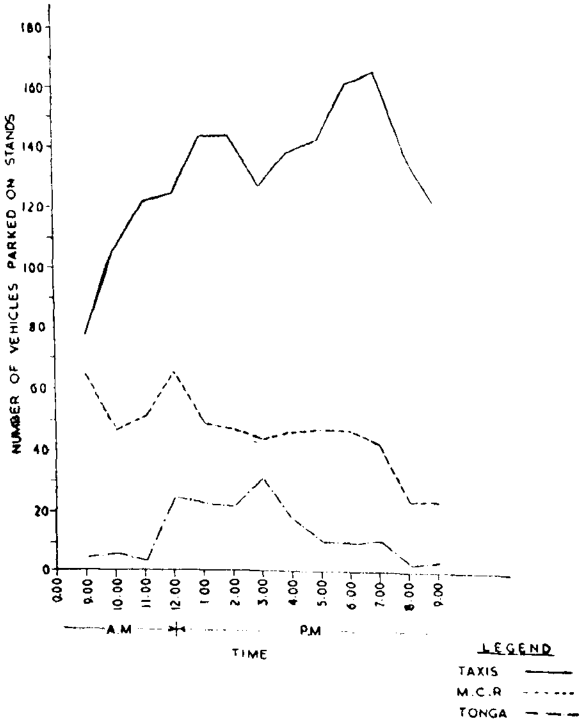


Fig. 2. **Hourly variation of parking demand for public transport vehicles**

tongas. At present there are 15 taxi stands (excluding one DLZ taxi stand near Keeling Road on Janpath), 7 motor cycle rickshaw stands and 3 tonga stands, the maximum number of vehicles that can be parked at each stand is not stipulated. There are 20 cycle stands in the area in which about 1,600 cycles are parked for the whole day. The observed maximum number of cycles parked in these stands was 1,937. Besides the cycles parked in the cycle stands, a large number are parked haphazardly in different places. Exact counts of cycles parked outside the above mentioned cycle stands is not available but it is estimated from origin and destination survey to be nearly 2,000.

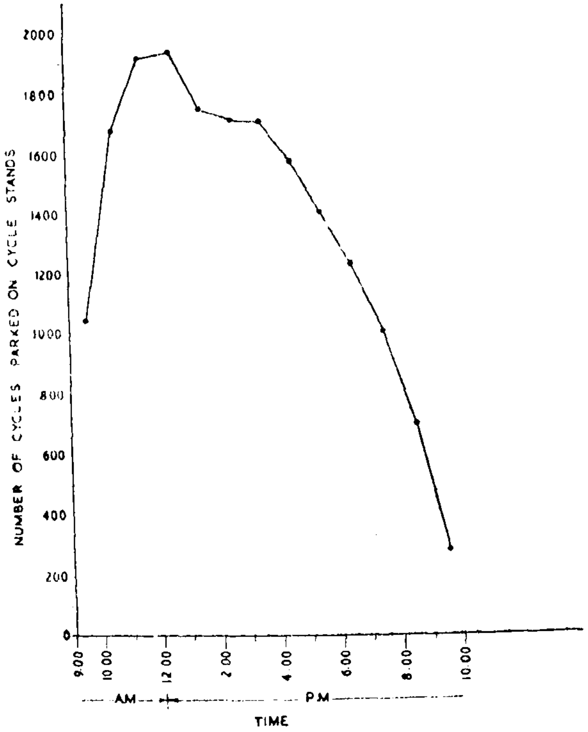


Fig 3. **Hourly variation of parking demand for cycles on cycle stands**

3.2. Physical inventory

Maximum parking demand for private cars and suggested provision of the parking spaces in each of the 5 zones and 24 blocks are shown in Fig. 4 and Plate II.

Physical inventory of the parking space available in the area, after accounting for the spaces with physical obstructions to parking, shows that the space available for parking is sufficient to meet the present day parking requirements and also for sometime to come, if the suggestions in the improvements plan given below are carried out and parking meters installed for enforcement purpose.

The parking meter scheme is likely to pay for itself within 2 years or so and the recurring income thereafter from this source can be utilised for other traffic or parking improvement.

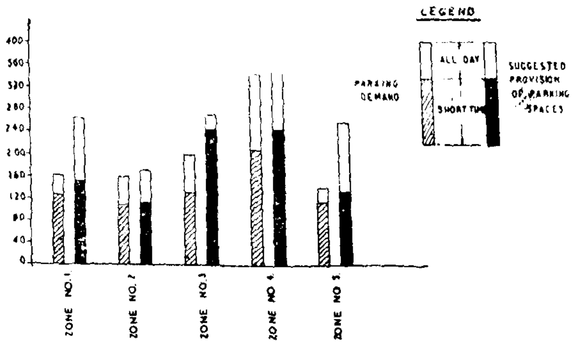


Fig 4. **Parking demand and suggested provisions of parking for private cars in the 5 zones**

4. PROPOSED IMPROVEMENT PLANS

4.1. Some salient features explaining the design for parking are given below :

(i) To make the maximum use of the space available for parking, demarcation of parking stalls for each vehicle be made. This will check the undesirable practice of double parking, parking near intersection, haphazard parking, parking too far away from the kerbs, parking on both sides of the narrow road, parking on side-walks and parking for repair purposes near the workshops, etc., (Photo Nos. 1—4).

(ii) Entrances to and exits from the parking areas to the main roads be kept to the minimum so as to reduce interference with the main traffic and *also increase parking* capacity of the parking lots.

(iii) Separate parking lots be provided for each category i. e. all-day parkers and short-time parkers. The short-time parkers should have lesser walking distance to their destinations as compared to the all-day parkers. Short-time parkers have further sub-categories of those wanting to park for less than 2 hours and those wanting to park for 2 to 4 hours. Proposed parking arrangements for different durations are shown in Plate III.

(iv) The parking meters* (scheme which is *self* paying) be adopted for parking private cars and heavy motor vehicles. Parking charges proposed below to be made only during the period from 9 A.M. to 8 P.M.

*Parking meter is a clock instrument which enables the motorists to buy parking time and the police authorities to take enforcement action if the parking time exceeds the time bought.

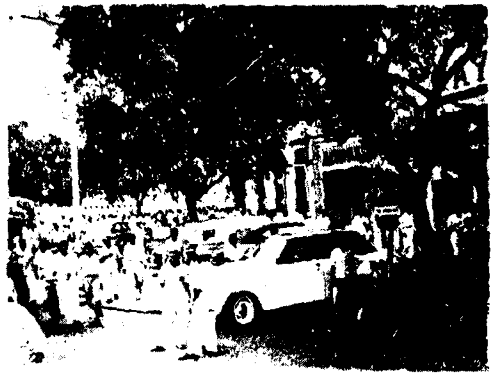


Photo 1

Vehicles are parked on a side walk where "No Parking" sign is installed

Photo 2

Unorganized angle parking on both sides of a narrow road

Photo 3

Vehicles are parked for repair purposes infront of a workshop

Photo 4

Vehicles are parked just near the intersection

Photo 5

Obstruction to traffic while unparking

Photo 6

Mixed parking of cycles and vehicles showing different parking diseases

Photo 7

Haphazard parking leaves little space for the pedestrians to walk

Photo 8

Parking just near the intersection obstructs the sight visibility of the approaching vehicles

Photo 9

Haphazard parking reduces the roadway capacity

Photo 10

Haphazard parking causes obstruction to the motorists pedestrians

Photo 11

Inefficient use of the parking area available

Photo 12

Vehicles are parked on side-walks

Parking Time	Charges
0 – ½ hour	05 nP
½ – 1 hour	10 nP
1 – 2 hours	20 nP
2 – 3 hours	30 nP
3 – 4 hours	40 nP
All-day parkers	50 nP

Expenditure likely to be incurred on parking meters shall be realized with interest in about 2 years time on the basis of charges given above.

The approximate cost of parking meter and the expected income derived during a period of 2 years is given below:

	Rs
Initial cost of a parking meter	350.00
Interest for 2 years @ 4 per cent per annum	28.00
Maintenance charges @ 10 per cent of initial cost	35.00
TOTAL COST:	413.00

Calculated average vehicle hour/meter/day (Fig. 1)—7	
Income/meter/day	70 nP
Income/meter/year (300 days)	Rs 210.00
Total income for 2 years	Rs 420.00

Main purpose of installing parking meters is not as much to raise money as to make people use the parking space for a minimum period and thus permit greater use of space available for parking. Some of the advantages of parking meters are given below:

(1) Reduce duration of parking, thereby making the space available for use by greater number especially for short-time parkers.

(2) Discourage all-day parkers at the kerb and thus permit short-time parkers to park their vehicles closer to their destination or visiting point.

(3) Undesirable parking practices are avoided due to orderly spacing of vehicles. This aids free flow of traffic and reduces parking accidents.

(4) The charges proposed are low compared to the advantages sought for both, the shoppers and the shop-keepers.

4.2. Plate III shows the layout of parking for different types of vehicles in the area under study. It also includes the demarcated areas for public transport vehicles and cycle stands. It also shows the different parking lots for private cars with their respective time durations of 2 hours, 2 to 4 hours and all-day. In Plates III and IV provision for the following parking spaces for each class of vehicles has been made:

(1) **Private Cars**

1,329 parking spaces out of which 423 are for parking upto 2 hours. 479 spaces for 2—4 hours and the remaining 427 for all-day parking.

(2) **Motor Cycles**

643 spaces.

(3) **Heavy Motor Vehicles**

42 parking spaces, out of which 27 are for short-time parking and 15 for all-day parking.

(4) **Cycles**

23 cycle stands with approximate total parking capacity of 2,560 cycles.

(5) **Taxis**

17 taxi stands to accommodate 191 taxis.

(6) **Motor Cycle Rickshaws**

6 motor cycle rickshaw stands with total parking capacity of 83 vehicles.

(7) **Tongas**

4 stands for 41 tongas in all.

Plates V, VI and VII show the maximum space available for parking and the suggested design for parking showing parking stalls, entrances to and exits from the parking lots and the physical changes proposed in the pavements, etc., in the area covering all the 5 zones.

Plate IV shows the maximum parking demand on every side of the 24 blocks and number of parking spaces proposed.

4.3. Zone No. I—Connaught Place

This zone is sub-divided into two groups:

(i) Blocks facing Connaught Place (i.e., Block Nos. A, B, C, D, E and F)

(ii) Central Park.

4.3.1. Block Nos (A, B, C, D, E and F) facing Connaught Place.

Existing Conditions

The roadway is mostly 55 ft wide and carries one way traffic. All the blocks have a setback in the middle except Block Nos C and D. Vehicles are parked in an unorganized manner, which causes obstruction to the free flow of traffic when unparked, (Photo No. 5). Maximum parking demand and the number of parking spaces proposed are given in Plate IV.

Suggested Improvements

(i) Demarcated parking stalls may be provided in front of each block as shown in Plates V and VI. These stalls should be at 45° to the curb near the ends and at 90° at the centre of each block in the setback areas. Block numbers C and D should have stalls at 45° only, this type of stall needs only 10 ft manoeuvring space. Stalls at larger angle require more space for manoeuvring and thus reduce the free width of the main roadway.

(ii) It will be seen from Plate IV that the parking space available is in excess of the existing demand, therefore no parking stalls have been suggested in front of the Theatre Communication building and the adjoining park. This space can be kept reserved for future demand, for the present parking may not be permitted in this area.

(iii) The curb radii joining the radial roads to Connaught Place should be changed to 70 ft to ensure the turning vehicles against coming in contact with the parked vehicles.

(iv) All-day parkers in this zone may be shifted to the Central Park. This will not involve much walking distance to the car parkers.

4.3.2. Central Park

Existing conditions

Available space for parking is 33 ft wide around the park and 36 ft wide on each side of the four radial roads which divide the Central Park into four quadrants. Space around the park is being utilized for short-time parking, all-day parking and for five cycle stands. Out of the 8 kerb spaces on the 4 radial roads, three are used as taxi-stands, two as tonga stands, one as cycle stand and the remaining two are not being properly used.

Suggested improvements

(i) The space facing buildings in Connaught Place around Central Park should be utilized for all-day parking, the stalls may be provided at an angle of 45 degrees. There is enough space to provide 110 parking stalls. Demarcation for stalls be made with bricks projecting about 1 in. above the ground. The projecting portion of bricks be painted white, *or* a pucca surface may be provided and demarcation for the stalls boldly marked.

(ii) The boundaries of the existing 5 cycle stands should be properly demarcated and those not situated at corners be shifted there as indicated in Plates V and VI.

(iii) Three kerb spaces on 4 radial roads within the Central Park area are at present not properly utilized except the one being used as a cycle stand. This cycle stand is recommended to be shifted to the corner of the berm across each block of Connaught Place as shown in Plates V and VI. Three kerb spaces thus available should be utilized for the parking of heavy motor vehicles at an angle of 90 degrees to the roadway, two to be used for short-time parking and the third for all-day parking.

4.4. Zone No. 2—Service Roads and Service Lanes

4.4.1. Existing conditions

The width of the service road is mostly 52 ft including 5 ft side-walks. The road carries one way traffic. Newly constructed three storeyed buildings on both sides of the road are mainly utilized for offices and other small buildings as garages, motor repair-shops and godowns, etc. In this area in addition to parked private vehicles, there is a taxi stand for 10 taxis between Block Nos. F and N and a private cycle stand for 80 cycles between Block Nos. B and H (Plates V and VI). This cycle stand is mainly used by the workers of the automobile workshop situated in the zone. Photo No. 6 shows the present haphazard parking conditions.

4.4.2. Suggested improvements

(i) There is no necessity of a cycle stand at this place, most of the users of the cycle stand are the employees of the nearby workshops; they can use the N. D. M. C. cycle stands which are located not very far from this place. It is, therefore, suggested that the cycle stand between block nos. B and H may be removed.

(ii) Layout of parking stalls for private vehicles may be at an angle of 45 degrees, facing inner blocks of Connaught Place. No parking be permitted on the other side of the road.

(iii) Kerb radii joining the radial roads and the service roads towards the parked vehicles be increased to 70 ft as per the design suggested for reasons mentioned already (vide para 4.3.1).

4.5. Zone No. 3—Radial Road

4.5.1. Existing conditions

There are 8 radial roads, each 40 ft wide, connecting Connaught Place and Connaught Circus (Plates V and VI). On either side of the roads, wide berms are available where vehicles are parked haphazardly, (Photo Nos. 7 and 8), thereby leaving little space for the pedestrians to walk. Vehicles parked just near the intersection obstruct the visibility of the approaching vehicles. Two taxi stands exist to cope with the requirements of the restaurants located on radial road Nos. 4 and 6.

4.5.2. Suggested improvements

(i) The curbs which are bevelled with the roadway may be raised except at the specified entrances and exits.

(ii) Demarcation for private vehicles, taxi stands and cycle stands may be done (Plates V and VI). Vehicles may be allowed to park within the demarcated areas only.

4.6. Zone No. 4—Blocks facing Connaught Circus, Parliament Street, Irwin Road and Curzon Road

4.6.1. Existing conditions

This is the most congested of all the zones and has the maximum parking demand for private vehicles. In this zone there are 7 taxi stands, 7 motor cycle rickshaw stands, 1 tonga stand and 7 cycle stands. Space is available for parking on either side of the 40 ft wide road. Photo Nos. 9 and 10 show the existing parking conditions.

4.6.2. Suggested improvements

(1) There are two unnecessary openings on each kerb, one at the Curzon Road and Scindia House, and the other at Janpath and Scindia House which may be closed. These openings give additional approaches to the intersections, which increases the interference with the main traffic flow, thereby reducing the efficiency of the intersections.

(2) It is suggested that raised side-walks (i) 12 ft wide on the kerb of Regal Building, and (ii) 10 ft wide in front of the park facing the Regal Building be provided.

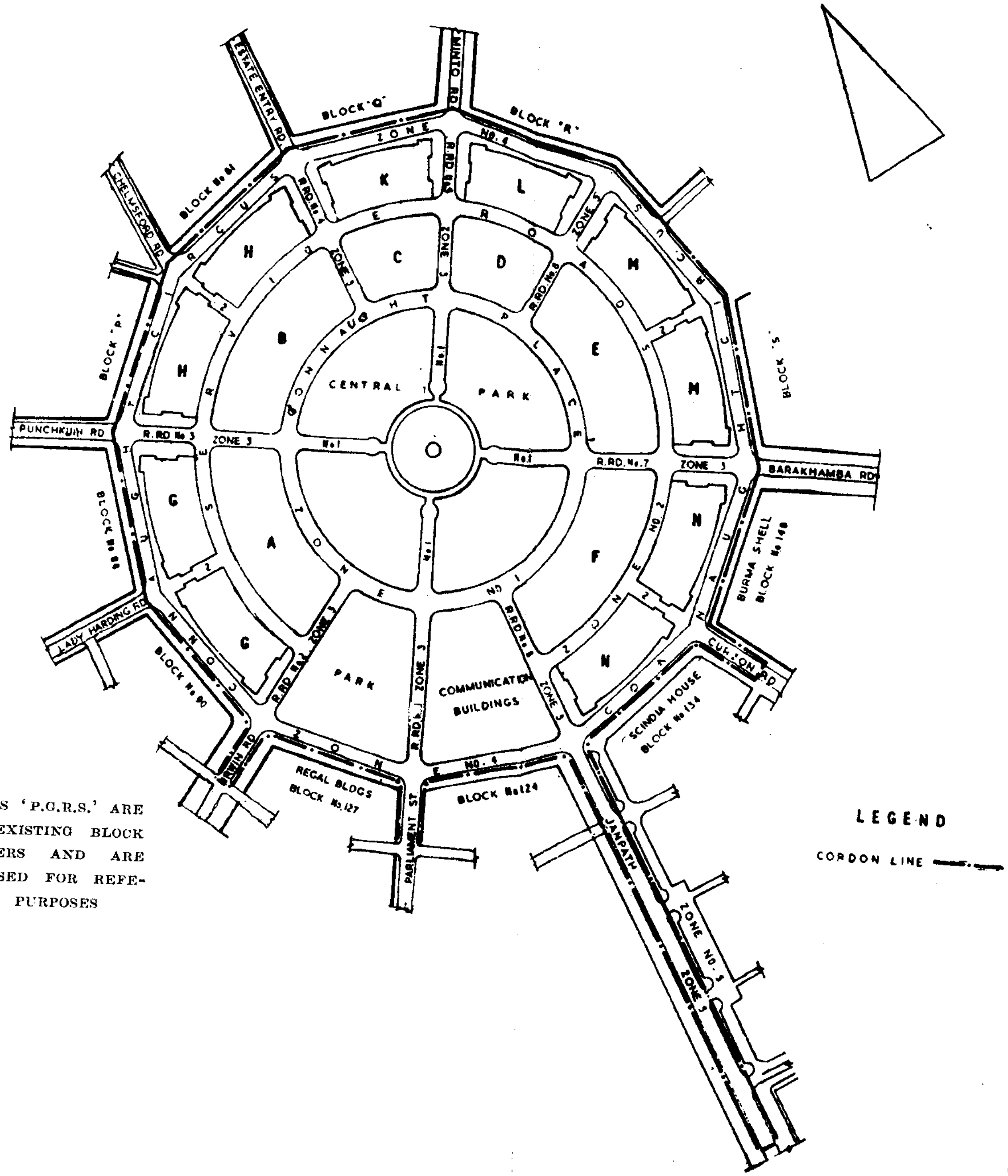
(3) Raised kerb near the park facing the Regal Building in Connaught Circus should be lowered flush with the Roadway and this space may be used as an aisle for the parked vehicles.

(4) A continuous bay for Bus-stops on the kerb space of Block No. N facing Connaught Circus be provided as shown in Plate VI.

(5) Open drains outside Block No. 148 and Block No. S, both facing Connaught Circus, should be covered and the space thus made available be utilized for parking.

(6) Kerbs which are bevelled with the roadway may be raised, except at the entrances and exits that are specified on every kerb

PLATE I

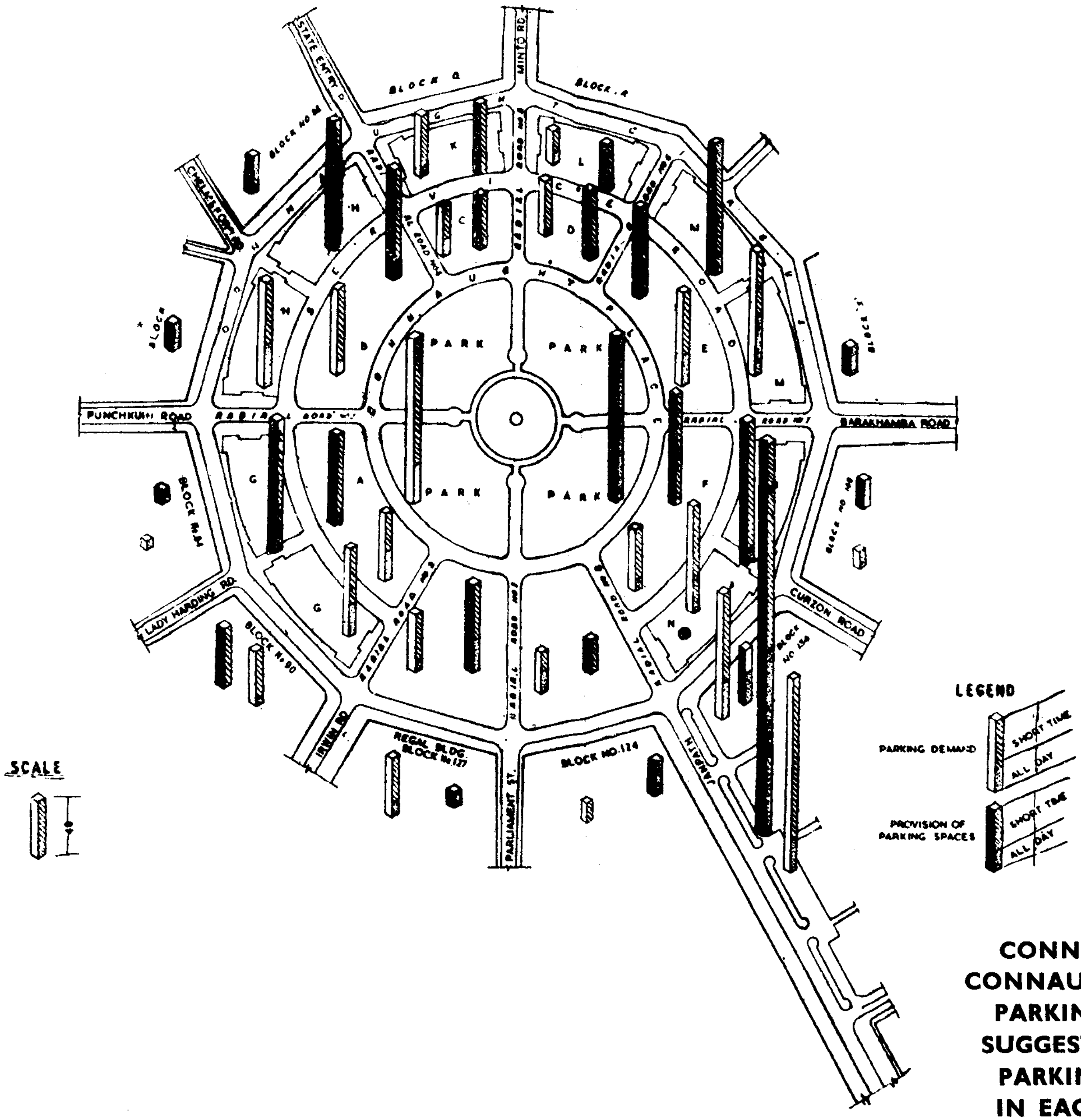


NOTE :—

BLOCKS 'P.G.R.S.' ARE NOT EXISTING BLOCK NUMBERS AND ARE SUPPOSED FOR REFERENCE PURPOSES

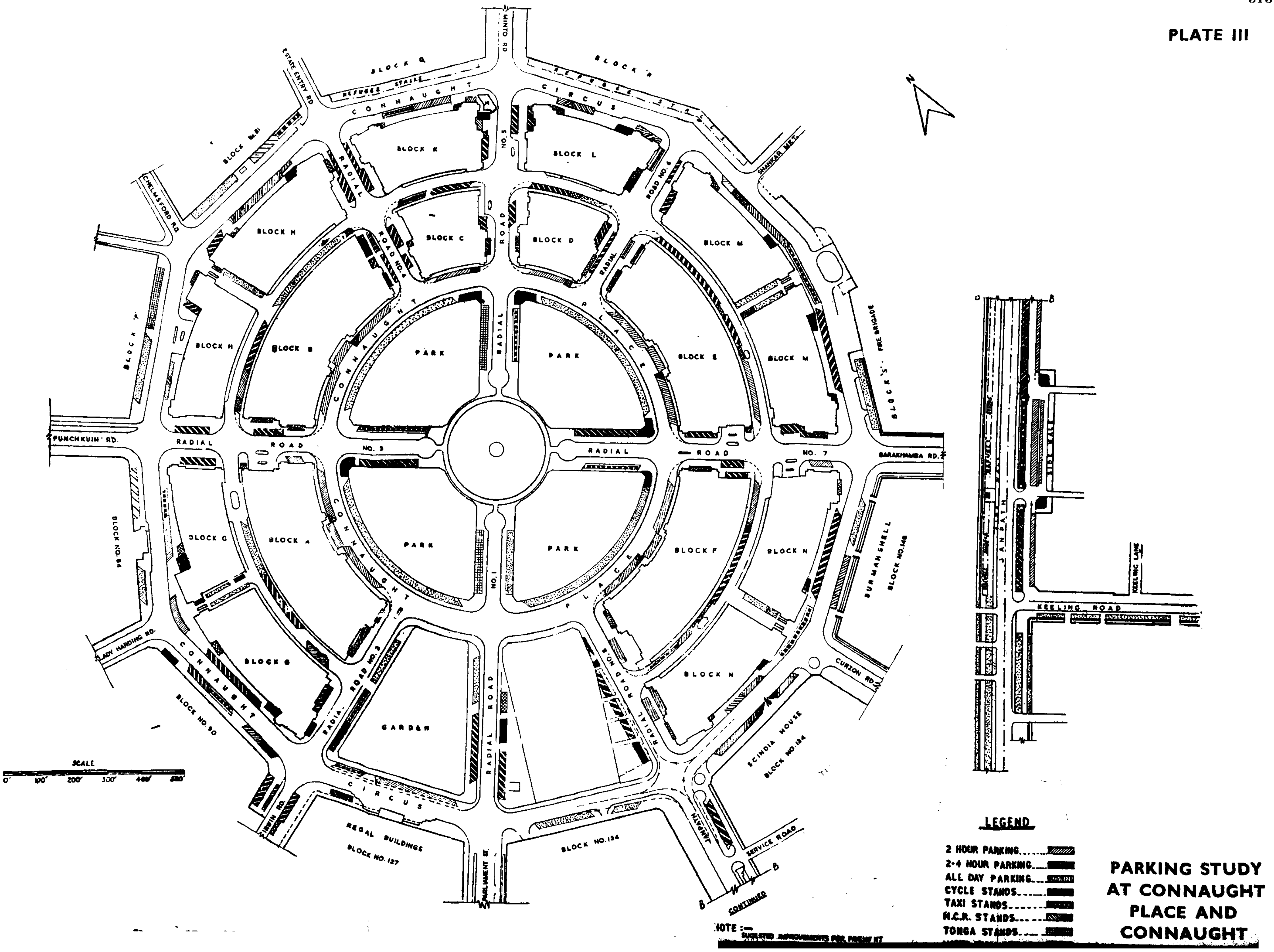
CONNAUGHT PLACE & CONNAUGHT CIRCUS AREA SHOWING CORDON LINE & 5 ZONES

PLATE II



CONNAUGHT PLACE & CONNAUGHT CIRCUS AREA PARKING DEMAND AND SUGGESTED PROVISION OF PARKING PRIVATE CARS IN EACH OF 24 BLOCKS

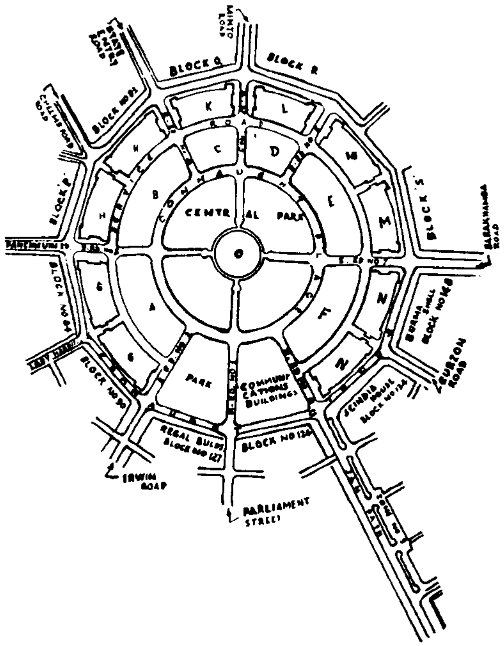
PLATE III



PARKING STUDY AT CONNAUGHT PLACE AND CONNAUGHT

PLATE IV

	PARKING DEMAND																	PROVISIONS FOR PARKING SPACES												
	PRIVATE VEHICLES											PUBLIC TRANSPORT VEH.						PRIVATE VEHICLES							PUBLIC TRANSPORT VEH.					
	SHORT TIME			ALL DAY			ALL NIGHT			CYCLES		TAXIS		M.C.R		TONGAS		SHORT TIME		ALL DAY		M.C	CYCLES		TAXIS		M.C.R		TONGAS	
	P	MC	B	P	MC	B	P	MC	B	NS	N	NS	N	NS	N	NS	N	P	B	P	B		NS	N	NS	N	NS	N	NS	N
BLOCK A FACING C.P	28	5	2	8	5	-	5	-	3	-	-	-	-	-	-	-	-	34	-	-	-	10	-	-	-	-	-	-	-	-
" B " "	41	11	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	10	-	-	-	-	-	-	-	-
" C " "	13	4	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	9	-	-	-	8	-	-	-	-	-	-	-	-
" D " "	14	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9		-	-	8	-	-	-	-	-	-	-	-
" E " "	25	15	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	10	-	-	-	-	-	-	-	-
" F " "	29	8	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	34	-	-	-	10	-	-	-	-	-	-	-	-
CENTRAL PARK - -	87	19	3	24	6	1	2	-	3	5	382	3	49	-	-	2	31	-	23	110	15	-	5	400	3	50	-	-	2	31
ZONE 1 (MAX. DEMAND)	127	29	3	37	12	1	11	-	6	5	382	3	49	-	-	2	31	154	23	110	15	56	5	400	3	50	-	-	2	31
SERVICE RD. A & G	13	5	5	5	2	-	1	-	-	-	-	-	-	-	-	-	-	17	-	21	-	5	-	-	-	-	-	-	-	-
" " B & H	28	9	3	8	2	1	10	-	-	1	80	-	-	-	-	-	-	27	-	21	-	12	-	-	-	-	-	-	-	-
" " C & K	9	-	1	4	1	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	1	8	-	-	-	-
" " D & L	7	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	8	-	10	-	-	-	-	-	-	-	-
" " E & M	41	20	4	25	6	2	16	-	4	-	-	-	-	-	-	-	-	30	-	15	-	16	-	-	-	-	-	-	-	-
" " F & N	42	10	5	8	-	6	4	-	3	-	-	1	10	-	-	-	-	32	4	8	-	20	-	-	1	7	-	-	-	-
SERVICE ROADS (MAXIMUM DEMAND)	110	34	8	51	11	9	34	-	7	1	80	1	10	-	-	-	-	118	4	69	-	83	-	-	2	15	-	-	-	-
RADIAL ROAD NO 1	10	2	-	2	3	-	-	-	-	1	170	-	-	-	-	-	-	39	-	14	-	30	1	170	-	-	-	-	-	-
" " " 2	13	8	2	12	-	-	-	1	-	1	80	1	10	-	-	-	-	17	-	8	-	15	1	80	1	10	-	-	-	-
" " " 3	20	7	-	9	3	-	3	-	-	-	-	-	-	-	-	-	-	35	-	-	-	22	-	-	-	-	-	-	-	-
" " " 4	46	10	1	5	4	1	7	-	-	1	50	1	10	-	-	-	-	40	-	-	-	30	1	60	1	6	-	-	-	-
" " " 5	29	14	-	8	7	-	6	-	-	2	64	-	-	-	-	-	-	31	-	-	-	30	1	60	-	-	-	-	-	-
" " " 6	17	9	1	10	5	1	10	-	1	1	112	1	18	-	-	-	-	32	-	-	-	40	1	120	2	13	-	-	-	-
" " " 7	11	6	3	12	2	-	9	-	1	-	-	-	-	-	-	-	-	30	-	-	-	25	-	-	-	-	-	-	-	-
" " " 8	26	4	9	13	6	1	13	-	7	2	400	-	-	-	-	-	-	34	-	-	-	35	2	500	-	-	-	-	-	-
RADIAL ROADS 1 TO 8 (MAXIMUM DEMAND)	131	33	12	71	30	3	48	1	9	8	876	3	38	-	-	-	-	248	-	22	-	227	7	990	4	29	-	-	-	-
BLOCK G FACING C.C.	18	10	1	16	3	-	13	-	-	1	40	-	-	-	-	-	-	43	-	-	-	25	2	120	1	10	-	-	-	-
" H " "	18	6	1	19	11	-	20	-	3	1	40	-	-	-	-	-	-	30	-	-	-	25	1	80	-	-	-	-	-	-
" K " "	18	5	1	5	4		7	-	-	-	-	1	10	-	-	-	-	13	-	-	-	12	-	-	1	10	-	-	-	-
" L " "	8	7	2	4	1	-	1	-	-	1	67	-	-	1	21	-	-	8	-	-	-	16	1	100	-	-	1	10	-	-
" M " "	26	12	1	19	2		12	-	1	2	131	1	7	1	8	1	5	31	-	-	-	16	2	160	1	13	1	12	1	4
" N " "	20	20	-	12	-	-	6	-	-	1	75	1	23	1	6	-	-	35	-	-	-	30	2	60	1	14	1	7	-	-
COMM. BLDG. " "	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
REGAL PARK " "	34	26	1	3	-	-	-	-	-	-	-	1	16	-	-	-	-	18	-	-	-	-	-	-	1	6	-	-	-	-
BLOCK NO 148 " "	6	-	-	-	-	-	-	-	-	-	-	-	-	1	19	-	-	-	-	13	-	-	-	-	-	-	1	20	-	-
" " 134 " "	41	8	-	18	2	1	2	-	1	-	-	-	-	-	-	-	-	18	-	-	-	10	-	-	-	-	-	-	-	-
" " 126 " "	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-
" " 127 " "	17	24	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-
" " 90 " "	27	10	-	5	3	-	6	-	-	1	230	1	10	-	-	-	-	18	-	-	-	30	1	250	1	10	-	-	-	-
" " 84 " "	5	1	-	1	-	1	1	-	1	-	-	1	10	1	8	-	-	-	-	7	-	-	-	-	-	-	1	22	-	-
BLOCK P " "	8	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	1	6
" 81 " "	3	-	-	-	-	-	-	-	-	-	-	1	7	1	5	-	-	-	-	23	-	23	-	-	1	9	1	12	-	-
" S " "	6	7	2	-	8	1	2	1	-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	-	-
PARLIAMENT STREET	7	3	-	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IRWIN ROAD	17	9	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	10	-	-	-	-	-	-	-	-
CURZON ROAD	24	6	-	4	-	-	5	-	-	-	-	-	-	1	6	-	-	6	-	-	-	10	-	-	-	-	-	-	-	-
ZONE 4 (MAX. DEMAND)	215	106	5	137	37	3	74	2	6	7	584	7	82	7	74	1	5	248	-	188	-	227	9	770	7	72	8	88	3	10
QUEENS WAY (ZONE 5) (JAN PATH)	117	61	2	28	22	2	18	1	2	3	311	1	28	-	-	-	-	133	-	123	-	70	2	400	1	25	-	-	-	-
AREA UNDER STUDY	377	215	22	324	112	17	181	4	30	24	1937	15	157	7	66	3	31	302	27	427	15	643	23	2560	17	191	6	85	4	41

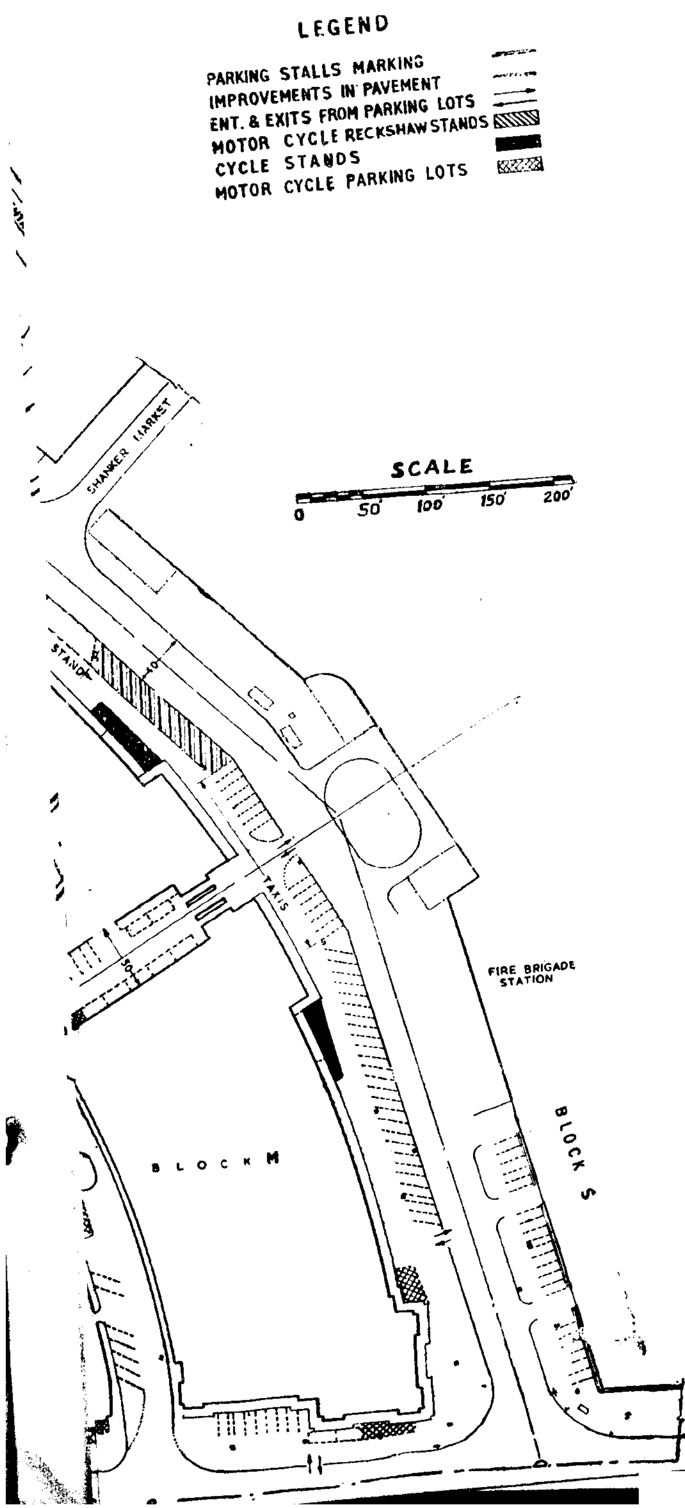


LEGEND

NUMBER OF PRIVATE CARS .... P
NUMBER OF MOTOR CYCLES .... M.C
NUMBER OF PRIVATE BUSES AND TRUCKS ... B
NUMBER OF STANDS .... NS
NUMBER OF PARKED VEHICLES ON STANDS .. N

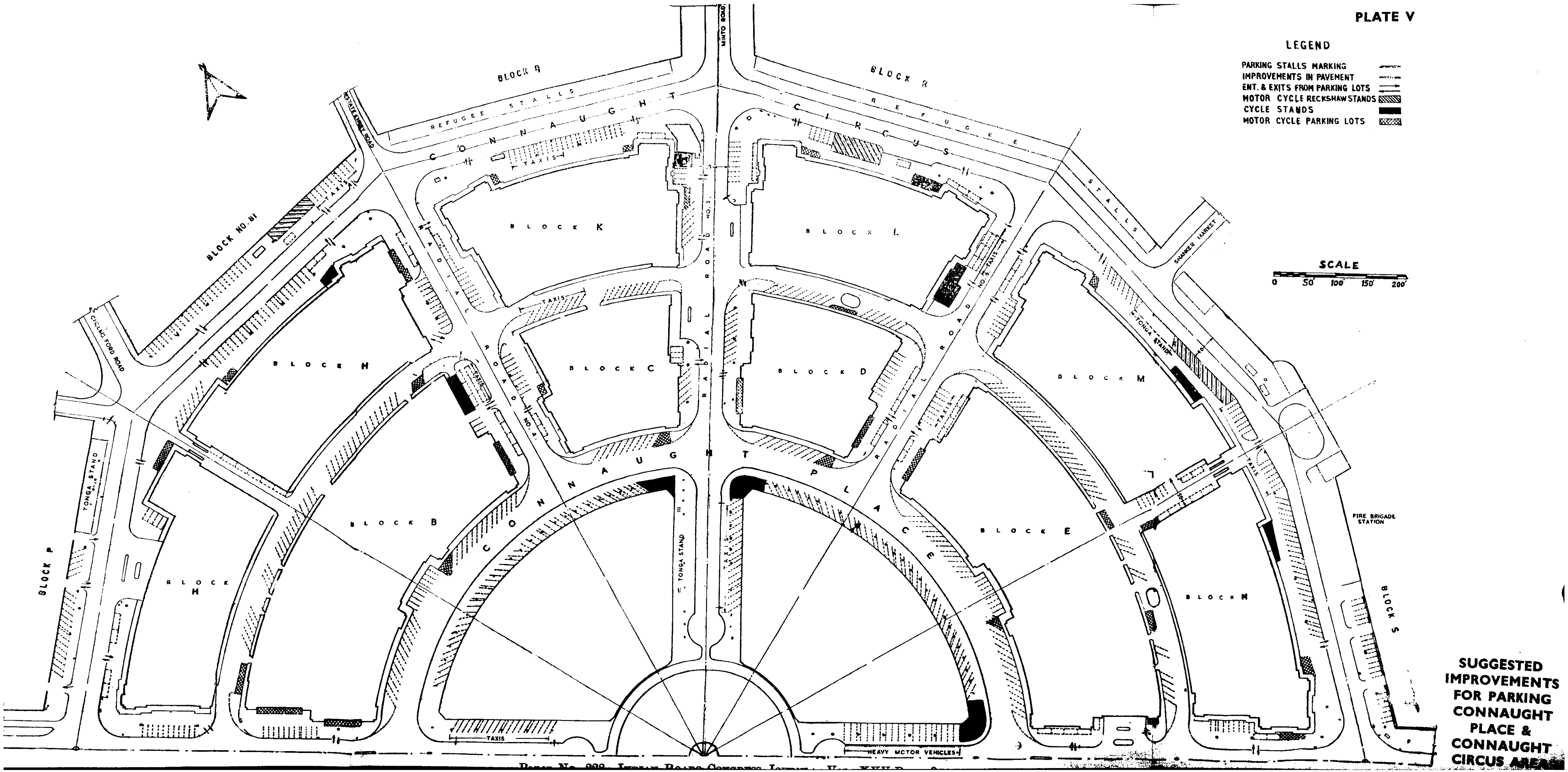
PARKING STUDY AT CONNAUGHT PLACE AND CONNAUGHT CIRCUS AREA

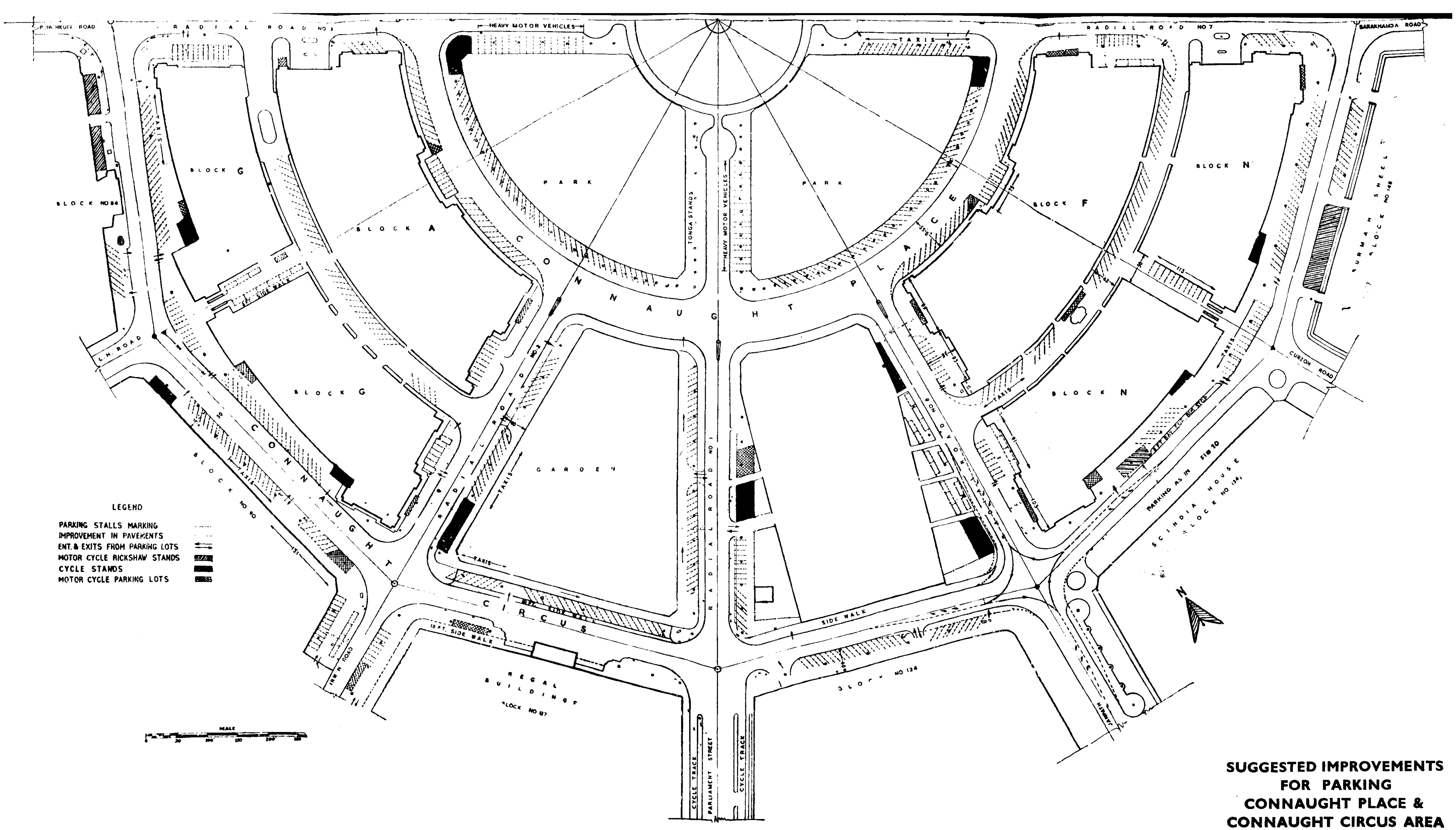
PLATE V



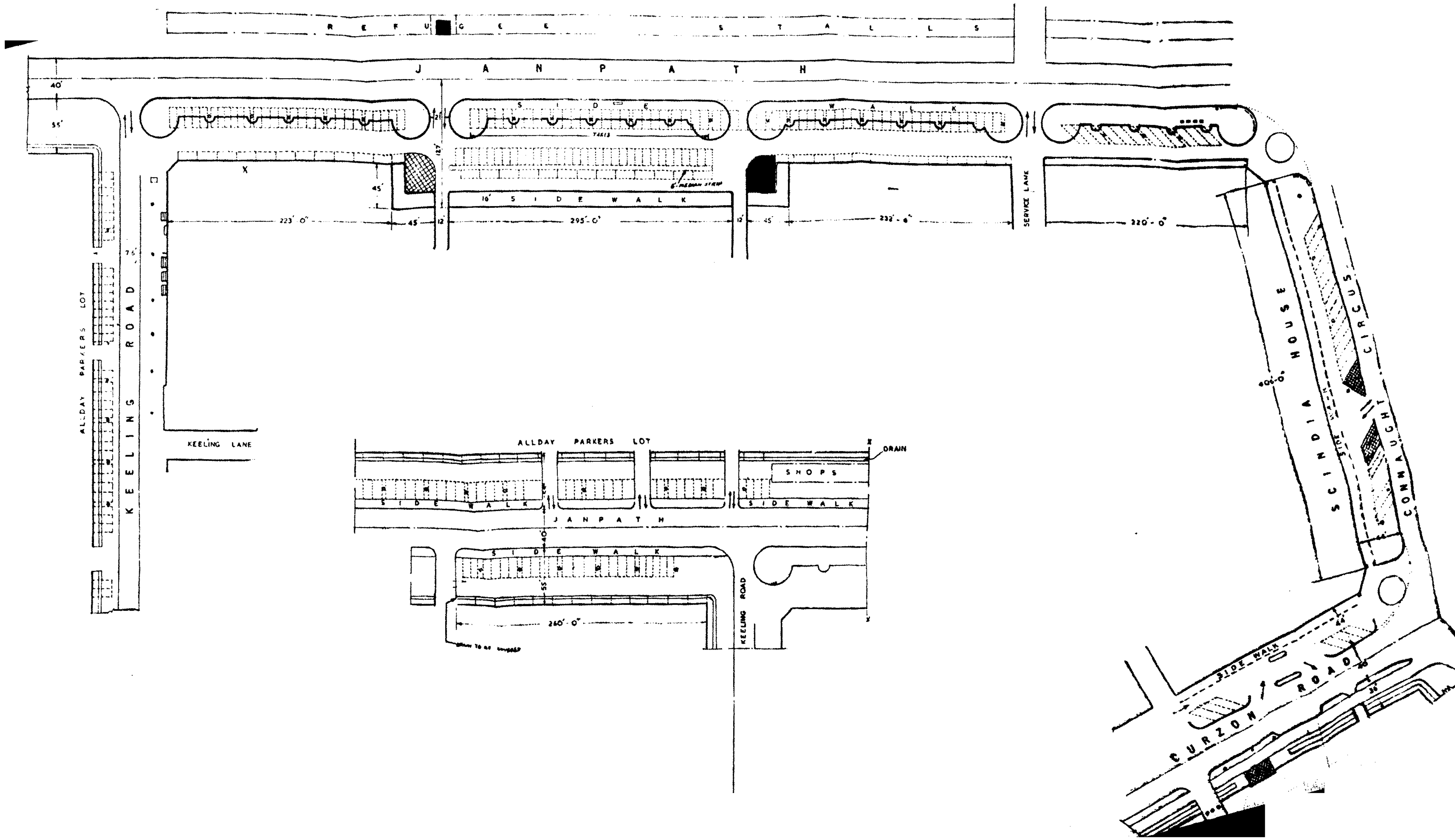
SUGGESTED IMPROVEMENTS FOR PARKING CONNAUGHT PLACE & CONNAUGHT CIRCUS AREA

PLATE V


LEGEND
PARKING STALLS MARKING
IMPROVEMENTS IN PAVEMENT
ENT. & EXITS FROM PARKING LOTS
MOTOR CYCLE RECKSHAW STANDS
CYCLE STANDS
MOTOR CYCLE PARKING LOTS
SCALE
0 50' 100' 150' 200'
BLOCK R
BLOCK R
BLOCK NO. 81
MINTO ROAD
REFUGEE STALLS
REFUGEE STALLS
CONNAUGHT CIRCUS
CONNAUGHT PLACE
TAXIS
BLOCK K
BLOCK L
BLOCK H
BLOCK C
BLOCK D
BLOCK M
BLOCK B
BLOCK E
BLOCK H
BLOCK N
BLOCK P
BLOCK S
RADIAL ROAD NO. 3
RADIAL ROAD NO. 4
RADIAL ROAD NO. 5
TONGA STAND
TONGA STAND
TONGA STAND
SHANKER MARKET
FIRE BRIGADE STATION
HEAVY MCTOR VEHICLES
SUGGESTED IMPROVEMENTS FOR PARKING CONNAUGHT PLACE & CONNAUGHT CIRCUS AREAS



SUGGESTED IMPROVEMENTS FOR PARKING CONNAUGHT PLACE & CONNAUGHT CIRCUS AREA



SUGGESTED IMPROVEMENTS FOR PARKING JANPATH AND SCINDIA HOUSE AREA

GENERAL REPORT

ON

ROAD RESEARCH IN INDIA

1959-60

GENERAL REPORT ON ROAD RESEARCH IN INDIA, 1959-60*

CONTENTS

INTRODUCTION

This year's review of the research work carried out in different parts of the country is significant in that a major part of the work accomplished has shown a definite bias towards actual field experimentation of laboratory findings.

Soil stabilisation techniques, particularly the mechanical, lime, and cement methods are attracting more and more attention in many parts of the country, where these are being tried on a field scale. A greater awareness of the place of scientifically compacted soil in a flexible road crust is also evident in some States.

Systematic work seems to be on hand in some States on pavement failure studies in order to find remedial measures.

* Compiled by the Director, Central Road Research Institute, New Delhi-20

Another encouraging feature is the beginning made in the direction of research on bridges and structures particularly by the Madras Highway Research Station and the Central Road Research Institute, in recognition of which a new section has been started from this year's report on Road Research, to cover the important work done in this field.

All these developments speak of the progressive trend in Applied Highway Research, notwithstanding the fact that the reporting organisations were limited to the States of Andhra Pradesh, Bihar, Madras, Punjab and West Bengal in addition to the College of Military Engineering, Kirkee, and of course the Central Road Research Institute, New Delhi. It is hoped that in course of time more and more States will establish their research and testing centres and add to the usefulness of this contribution.

It is expected that members taking part in the discussion on this report during the I.R.C. Session at Bhopal, will bring out, for the information of delegates, all such items of research which might not have found place in this report due to some of the reports not having been received in time.

As has been the practice all these years, salient points for discussion are given at the end of each section, in an effort to provoke discussion.

I. DESIGN, CONSTRUCTION AND MAINTENANCE

1. RIGID PAVEMENTS

1.1. Design

General

In the field of rigid pavement design, work is being continued by the Central Road Research Institute[1] in connection with the measurement of temperature differentials in concrete pavements. On the basis of measurements so far taken at Delhi, Madras and Hyderabad, a temperature differential of the order of 4°–5°F/in. depth of the concrete slab has been reported. (The gradient now used for design purposes is of the order of 2°).

As the existing pavements in the different parts of the country are mostly 4 in. to 6 in. thick only, it is proposed to cast slabs of a range of thickness from 4 in. right upto 10 in. at each master station, so that temperature differentials can be obtained for different climatic regions at the various master stations for the entire range of thicknesses, which are expected to be adopted in future designs.

1.2. Construction and Maintenance

1.2.1. Field experiments

Pavement for Tracked Vehicles

Further work has been carried out by the College of Military Engineering, Kirkee[2], by laying two types of wearing surfaces over a track 70 ft × 24 ft. The overall thickness of the slabs was 6 in. The lower $5\frac{1}{4}$ in. was laid with a concrete mix of proportions 1 : 1.5 : 3.75 cement sand aggregate by weight, while the top $\frac{3}{4}$ in was laid in two different ways given below:

(a) A mixture of 1 part Hardonate and 4 parts cement by weight was prepared. This mixture was then added to $\frac{1}{4}$ in. size aggregate in the proportion 1 : 2 by volume.

(b) The top $\frac{3}{4}$ in. consists of granolithic concrete of proportions 1 : 1 : 2.5 (cement : sand : aggregate passing $\frac{1}{2}$ in.) by volume.

Results of the performance of the two surfaces are being studied.

Grouted Cement Concrete Experiments

The experimental grouted concrete road construction on Delhi-Mathura road, which was executed by the Punjab P.W.D. in collaboration with the Central Road Research Institute,[1] Concrete Association of India and Ministry of Transport (Roads Wing), has been completed. The data obtained from the observed behaviour of the test track is being analysed.

Quality Control in Pavement Construction

The use of a portable, swing type, weigh batcher for making high quality concrete with a specified flexural strength of 650 psi was resorted to at Bhopal for the construction of the factory roads of the Heavy Electricals Ltd. Control was exercised over the various ingredients of the designed cement concrete mix for their correct quantity, aggregate quality, moisture content and the workability of the concrete. Cubes and beams were cast at frequent intervals and tested at 7 and 22 days. On the whole, about 450 beams were cast during the job and the coefficient of variation of 8.4 per cent was achieved, whereas in a parallel experiment on Delhi-Mathura road where volume batching was resorted to, with similar controls, the coefficient of variation for the various beams cast on the work and tested worked out to 17.

1.3. Laboratory Research

1.3.1. Use of Admixtures in Concrete

Use of Clinker and Flyash in concrete

The Highway Research Station, Madras,[3] has reported that substitution of cement by flyash reduces strength. However, replacement of sand by flyash is reported to give better strengths. Clinker, despite passing the soundness test as determined by pat method, when used to replace the coarse aggregate in concrete, results in lower strength.

1.3.2. Tests on Cement and Concrete

(i) Efficiency of the various methods of mix design

To compare the efficiency of different methods of mix design that are in use to-day, the Central Road Research Institute designed concrete mixes for constant strength and workability by eight different methods and tested these for cube strengths. Further work to recommend a simple method of mix design embodying the important features of the various methods is in progress.

(ii) Relationship between water/cement ratio and compressive strength of concrete made with Indian cements

In continuation of the work reported in the previous year's report, investigation on the relation between W/C ratio and compressive strength on one more cement has been completed by the Central Road Research Institute.

(iii) Partial replacement of sand by soil in cement mortar

"Work at the Highway Research Station, Madras, has revealed that partial replacement of sand by loamy soil to the extent of 30 per cent in cement sand mortar improved the workability and strength. The effect of the replacement on the durability and shrinkage characteristics is under study.

1.3.3. Alkali Aggregate Reaction

Studies at the Central Road Research Institute[1] on the potential reactivity of various rock types, such as granites, basalts, limestones and quartzites have revealed that some quartzites show chemical reactivity with alkalies of cement. A coarsely grained quartzite, if it is intensely fractured or internally strained as a result of metamorphic process, also shows reaction. The reactivity of such quartzites increases with temperature. A study of the potential reactivity of a number of aggregates from different quarries has been taken up.

1.3.4. Resistance to Sulphate Attack

Further work at C.R.R.I. on 15 different clays, calcined at different temperatures, has confirmed the previous finding that clays, calcined at higher temperatures, are more effective in preventing the sulphate attack on concrete. The results have revealed that all types of clays, irrespective of the mineralogical composition and the optimum temperature for maximum reactivity, should be calcined at a temperature of at least about 1000°C for most effective prevention of sulphate attack on concrete.

1.3.5. Use of Foundry Slag in Road Construction

A study of the use of foundry slag for road construction by the C.R.R.I. using the foundry slags available around Delhi has revealed that these slags, which at present are considered a waste product causing problems of disposal in a number of foundries, could be used for soling and for water-bound macadam constructions. Further work on their use as concrete aggregates is being carried out.

1.3.6. Abrasive Resistance of Concrete

Work is in progress in C.R.R.I.[1] on the effect of special surface treatments such as sodium silicate, etc., on the abrasive resistance of concrete surface.

1.3.7. Fatigue of Concrete

With a view to study the effects of air-entrainment, aggregate type, and mix proportions of concrete on its flexural fatigue, a machine has been fabricated at the C.R.R.I. to test beam specimens of 4 in. × 4 in. × 20 in. The machine has an automatic recorder that can record upto 10 million repetitions of load and is provided with an automatic device which stops the machine, after the failure of the specimen.

The Highway Research Station, Madras,[3] has also developed a fatigue testing machine, capable of imposing a load of 1 ton at the rate of 120 cycles per minute.

1.3.8. Joint Sealing Compounds

The work on the manufacture of joint sealing compounds for use in airfields used by jet aircrafts was continued at the C.M.E., Kirkee [2]. A large number of compounds were developed using depolymerised, masticated as well as ordinary rubber, with different grades of road tar in various proportions. However, laboratory tests showed that these were not upto standard in the flow-down and extension tests. Replacing tar with pitch in the above compounds produced no improvement. On the other hand, a set of compounds using a mixture of 20/30 and 80/100 bitumen with masticated rubber has been found to be satisfactory, in so far as extension and flow-down tests are concerned. They are, however, susceptible to softening by jet fuel. A further set of experiments reported to be in progress using bitumen based compounds with a top coat of tar and epicote resin based paint, in order to make the seals jet fuel resistant.

1.3.9. Expansion Joint Fillers from Coconut Pith

A process for binding the coconut pith into sheets which could be used as premoulded expansion joint filler in concrete roads, has been developed by the C.R.R.I. The cost is rather high and efforts are being made to bring it down to a competitive level with imported products.

1.4. Overlays

Laboratory experiments have been conducted at the Central Road Research Institute with bonded overlays in order to find the efficacy of concrete overlays, over old existing concrete pavements as a method of strengthening inadequate pavements. Several bonding media such as neat cement grout, sand cement grout, sodium silicate solution, etc., have been used in casting composite beams. The old surfaces were washed with 20°B (1.02 sp.gr.) HCl acid. After curing for 28 days the beams were tested for flexural strength. Experiments conducted so far indicate that neat cement grout with water cement ratio of 0.4 creates satisfactory bond between the two layers, giving a flexural strength anywhere from 98 per cent to 100 per cent of that of the monolithic beam.

It is proposed to lay experimental overlays both of flexible and rigid type over the Hapur-Garhmukteswar concrete road adopting the various design procedures suggested for such constructions.

1.5. Prestressed Concrete

Laboratory investigations are being carried out in C.R.R.I. to find a suitable method for reducing subgrade friction in prestressed concrete pavement construction. Studies carried out so far have indicated that by placing inflated air bags made with paper covered alkathene between the precast slab (6 ft × 3 ft × 4 in.) and the subgrade, the subgrade friction reduces to a value of about 0.2, whereas the subgrade friction measured with waterproof paper laid on fine grain sand was about 0.4. Further studies with cast in situ slabs are in progress.

Salient Points for Discussion

1. Effect of partial replacement of cement by soil in cement mortar.

2. Advisability of using weigh batching instead of volume batching for cement concrete pavement construction.

3. Strengthening of weak concrete pavements by use of overlays.

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1. Annual Report of Central Road Research Institute, New Delhi, 1959–60.
2. Report on Road Research, College of Military Engineering, Kirkee, 1959–60.
3. Annual Report of Highway Research Station, Madras, for 1959–60.

2. FLEXIBLE PAVEMENTS

2.1. Bituminous Pavements

2.1.1. Design

(i) Pavement Thickness

A comparative study of the C.B.R. method and the Linear Shrinkage method (devised by Australian Highways Department) for the design of flexible pavement thicknesses was reported to have been carried out as a collaborative research problem at the West Bengal Road and Building Research Institute[1] and the Madras Highways Research Station[2]. This problem was initiated by the Ministry of Transport. It is indicated that both the methods yield values for pavement thickness which are quite close except in a few cases. Further work regarding actual correlation between the C.B.R. and the linear shrinkage methods for different types of Indian soils might throw more light on this aspect of study.

(ii) Pavement Performance

This year's reports indicate that pavement performance studies comprising field investigations are being carried out by the various laboratories for finding out the possible causes for failure of some of the roads, to suggest remedial measures in a greater number during the period under review. This trend is very encouraging.

(iii) Design of Dense-graded Mixtures

It is encouraging to find that during the year under review there are indications that the use of dense bituminous mixtures for pavements in suitable cases is attracting attention. One of the major handicaps in its large-scale application seems to be the paucity of machinery required for mixing and laying of such mixtures.

The Central Road Research Institute[3] during the year designed suitable dense mixtures for pavements at Heavy Electricals Ltd., Bhopal, on N.H. 47 in Kerala and for Atomic Energy Commission, Bombay. The Highways Research Station, Madras,[2] designed a dense mixture for Srirangam Municipality using cement as filler.

The Central Road Research Institute studied the possibility of using silt as filler for dense carpet mixtures. Laboratory tests indicate that silt can be used as a filler for bringing the voids percentage below 6 per cent. A test track using silt as a filler in dense carpets is being laid.

The Highways Research Station, Madras, carried out tests using fillers, such as cement, granite dust, lime, flyash and combinations of these in asphaltic concrete mixtures with respect to stability and voids in the compacted mixture. The investigation is in progress.

The experience at the Central Road Research Institute indicates that the use of gradation modulus method[4] aiming at the limiting values 4.5 to 6.5 helps in reducing considerably, the time required for designing the aggregate combination, when compared to the ordinarily used trial and error method.

2.1.2. Construction and maintenance

(i) Field experiments

Surface Dressings

Observations on the performance of the various specifications laid on an experimental test track, conducted by C.R.R.I. during last year, are in progress. The results so far collected indicate the following :

For tar surface dressings, using RT-3 as binder it was found that:

1. Unprimed base of water-bound macadam with 50 lb binder requires either 4½ cu. ft. of graded aggregate in two spreadings or 5½ cu. ft. of single size aggregate in one spreading for 100 sq. ft.
2. If a prime coat of 18 pounds of primer is used, the binder quantity can be reduced from 50 pounds to 40 pounds for 100 sq. ft. keeping the aggregates same as in item 1 above.
3. It was also found that for new water-bound macadam, a prime coat is definitely an improvement as against unprimed surfaces.

Surface Dressing with Precoated Chips

Madras Highway Research Station[2] laid an experimental length with ¾ in. premix carpet on N.H. 45 using a seal coat but with or without a dry sand flushing at the rate of ½ cu. ft. per 100 sq. ft. It has been reported that there is no difference in the surfaces with or without dry sand flushing.

In order to have a comparative study on the surface characteristics, the Madras Research Station has proposed to lay experimental stretches on Madras-Tiruchi-Dindigul road comprising nine different specifications of surface dressings with precoated chippings.

Asphalt Concrete Carpets

A Paper on the design and construction of an asphaltic concrete carpet for a section of road on National Highway No. 2 at Delhi was presented during the Bangalore Session of the Indian Roads Congress. Due to some unfortunate confusion that arose during discussion, doubts were expressed regarding the adequacy of the design procedure adopted for a successful and durable carpet due to the high void content, in certain cases of as much as about 12 per cent allowed in the compacted carpet.

In this connection, it has been stated by the C.R.R.I. that the adopted design procedure for the semi-dense carpet (if it may be so named), presented in the Paper, is not to replace the conventional design criteria laid down for dense carpets but only to prove that the resulting carpet, while costing no more than the conventional sand crete mixes gives considerably higher stability values and a very much better carpet. It is understood, of course, that such a carpet would require a proper mixing plant and laboratory facilities.

This carpet was under continuous observation during the last 20 months. Even though the period under observation is not much when compared to the total probable life of the carpet, the periodical tests conducted by the C.R.R.I. to determine the void content of the carpet indicated that the void content is reduced from about 12 per cent to 7 per cent as a result of traffic consolidation, without any appreciable increase in fines. The design mix as adopted in the already laid carpet was further examined by carrying out tests for absorption and comparing the same with those for a similar mix together with 5 per cent cement as filler. The results are given in Table 1.

TABLE 1

Description	Design mix	Design mix + 5 per cent cement
Swell per cent	0.33	0.1
Water absorption per cent	1.38	0.72
Per cent retained strength	90	94

These values are within acceptable limits.

Further, no deterioration was noticed in the pavement performance from the periodical observations made either by measuring unevenness index using bump integrator, or plotting the cross sections of the pavement at representative locations using an accurate levelling instrument, or by visual examination within the range of the sensitivity possible. The bump integrator readings obtained from time to time are presented in Table 2.

TABLE 2

Bump integrator values—unevenness index, in./mile

Date of observation	Unevenness index
27–8–1959	107
26–2–1960	101
27–8–1960	112
9–9–1960	112

The only significant difference which can be observed on the pavement surface at present is the excess bitumen working out to the top of the pavement at local spots, which is due to working up of the tack coat which was laid rather unevenly by manual labour.

The data collected in C.R.R.I. on the properties of the three different types of mixtures, namely, (a) design mixture, (b) stone-sand 'crete' type of mixture, (c) open graded premix are given in Table 3.

TABLE 3

Comparison of the properties of the mixture

No.	Properties	Design mixture	Stone-sand crete	Open graded premix
1	Percentage of voids	7.4	9.1	25
2	Stability (Marshall)	1286	664	(Sample fails immediately after moulding)
3	Flow	15		
4	Abrasion per cent	0.48		

In view of the data presented above, based on the merits of the three different types of pavement mixtures and in view of the slight variation in cost between them, it is considered that there is no justification to adopt open graded mixes for any carpeting work except in the form of thin precoated surface dressings. Due to the distinct advantage of the designed mix from the various aspects of stability, void content, water absorption and swell characteristics over the stone-sand 'crete' type mix, with insignificant increase in cost, if any, it is considered preferable provided suitable machinery and testing facilities are available to adopt thin carpets with designed mix criteria in place of the stone-sand 'crete' type as a via-media with best possible advantage, till such time that the country can afford to have and the traffic justifies dense carpets involving higher costs and suitable construction machinery.

With the above background, in order to know more about the performance of such thin, semi-dense carpets in different climatic and rainfall conditions, it is proposed to try similar thin semi-dense carpets in different parts of the country using the following design criteria:

1.	Gradation	Crusher run stone, adjusted in grading as required.
2.	Per cent voids in the compacted mixture.	7 to 12
3.	Marshall stability lbs ...	$\leqslant 500$

Mastic Asphalt Surfaces

With a view to evolve suitable surfacing material for tracked traffic, C.M.E., Kirkee,[5] reported the laying of an experimental test-track consisting of mastic asphalt prepared by cooking a mixture of bitumen and fine limestone dust passing 200 mesh or cement. Sand and aggregate are then added and cooking continued. Study is reported to be in progress using different types of ingredients and grades of bitumen ranging from 10/20 to 80/100 penetration. No results have been reported yet.

2.1.3. Laboratory research

(i) Cold Fine Asphalt for Surfacing

M/s. Burmah-Shell in conjunction with Madras Corporation, have developed a hot bituminous mixture consisting of aggregate from 1/4 in. down to quarry fines and 80/100 peneteration bitumen fluxed with light diesel oil. The mix remains workable even after 2 months' storage and it can be laid cold.

(ii) Analysis of Road Tars

In a study on road tars carried out by the Central Road Research Institute[6], it was found that in Indian Tars, pitch/anthracene oil ratio is on the higher side in comparison to the tars produced in Germany. The pitch/anthracene oil ratio of the tars varies from grade to grade.

(iii) Cutbacks

It has been observed in a study carried out by the Central Road Research Institute that to obtain the optimum viscosity of the binder for best adhesion with aggregates in surface dressing work, 2 per cent to 14 per cent of fluxing oil is necessary depending on the pavement temperature. It has been assumed that in India pavement temperature varies from 60°F to 140°F. The intention is that in order to ensure maximum adhesion, only one or two cutbacks should be standardized, and depending on the season in which work is carried out, the necessary additional cutback should be added at site.

(iv) Stripping of Bituminous Binder

Investigations were carried out by B & R Laboratory of Punjab P.W.D.[7] with anti-stripping agents like Adhevia-T, Duomeen-T, Cationic Emulsifier, and Turkey Red Oil. As a result of these investigations it was found that the use of Turkey Red Oil, 1.5 per cent by weight of binder, in conjunction with lime, 1.5 per cent by weight of stone bajri, is most economical in improving adhesion between stone and binder.

Similar work is also reported to be in progress in Madras Highway Research Station with Adhevia-T.

Central Road Research Institute carried out tests and found that Duomeen-T arrests stripping of binder from difficult stones like coarse grained granites.

Experiments are in progress to develop suitable anti-stripping agents with indigenous products with which the bitumen can be doped.

(v) Low-temperature Tar

The Central Road Research Institute[3] has processed the low-temperature tars into two types of road binders by (1) fluxing the low-temperature tar pitch with high temperature tar oils and (2) by blending the low-temperature tar pitch with an equal quantity of hard grade bitumen. The first one resembles standard road tar and the second resembles bitumen in properties. A test track is being planned to evaluate suitability of these binders for surface dressings.

(vi) Sand Bituminous Stabilization

The Highway Research Station, Madras, carried out work on the stabilization of sand by using cutback bitumen with cement and lime as filler. The sand is fairly well-graded. It has been reported that considerable saving will be effected if the conventional method of road construction in coastal areas is replaced by this suggested process.

In an attempt to improve the stability of desert sand, which is of single size, the Central Road Research Institute tried different fillers in the sand-bitumen mix. It was seen that when the sand was mixed with 15 per cent of local kankar dust, the stability of the sand asphalt mixture was doubled.

(vii) Analysis of Road Stones

In the study of road aggregates in the Central Road Research Institute, it has been observed that coarse-grained rocks, poor in mafic mineral content, with coarsely crystalline surface texture show poor adhesion with bituminous binders. Further studies are in progress.

Salient Points for Discussion

1. Advisability of laying semi-dense carpets in different climatic regions to assess their behaviour compared to the conventional "stone-sand crete" type of construction.
2. Use of low-temperature tar as a road binder.
3. Introduction of cutbacks with different percentages of fluxing oils to cater for different temperature conditions.

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2.2. Soil Roads Including Stabilization

2.2.1. General

One of the significant features of this year's work in the different Research Stations appears to be the greater accent given to experiments on soil stabilization on a semi-field scale and full scale. In addition to mechanical stabilization, lime and cement treatment are being tried quite successfully in many of the States, particularly West Bengal, Madras, Punjab and Bihar. The Central Road Research Institute is continuing its pilot projects for the construction of stabilized-soil roads using locally available soft aggregates in different parts of the country. Reports indicate that the service performance of these roads is satisfactory. Soil stabilization techniques are being extended on a field scale to areas subject to waterlogging and high water table after using bituminous primers as capillary cut-offs for preventing the rise of water into bases and wearing courses, and also lime and cement as stabilizers.

2.2.2. Stabilization of Black Cotton Soil

Further research work carried out in the Central Road Research Institute has shown that dolomite lime, which has so far been considered as an inferior lime, can be utilised profitably for stabilization of black cotton soil. It not only cuts down the plasticity but also gives higher compressive strength as compared to commercial lime.

The possibility of improving the black cotton soil by heat treatment was also studied at the Central Road Research Institute in collaboration with Mr. L. R. H. Irwin of Australia, who was in this country as a Colombo Plan Expert. Further work regarding design of a heating machine for adoption in this country is now being looked into.

The Central Road Research Institute has further continued laboratory work on swell pressures in black cotton soils which comprised of a study on the effect of area of loading on the swelling pressure of soil. It has been found that though the total swell pressure increases as the area of loading increases, the swell pressure per unit area of loading decreases as area of loading increases. The formula $\frac{W_1}{W_2} = \left(\frac{A_1}{A_2}\right)^{0.44}$ (where W_1 and W_2 are failure loads on contact areas of A_1 and A_2 respectively in load test) seems to hold good in the experiment of swelling pressure also, where W_1 and W_2 are the total swelling pressures and A_1 and A_2 are the areas of plate on which swelling pressure is measured. The findings suggest that swell pressure tests and load tests are similar in character, the swell pressure test being the reverse of the load test.

2.2.3. Mechanical Stabilization

In Bihar, soil-gravel road construction has been taken up on a large scale during the year under review. On a twenty-mile length of road in Hazaribagh District which passes through a hilly region having rainfall of 50 in. to 53 in., soil-gravel stabilization has been adopted[1]. To improve such specifications against the softening effect due to rain, some of the stretches have also been treated with small concentrations of lime.

The experiments on the improvement of soil-gravel specifications by incorporating small percentages of RC_3, cement and lime have been in progress in the Highway Research Station in Madras.[2] It is claimed that as a result of this treatment, the C.B.R. values of such mixtures do not decrease under soaking.

Pilot plant lengths under the control of the Central Road Research Institute have recently been completed at Srinagar. A length of 3 miles of road is also completed in Bihar[1] using C.R.R.I. recommendation in a region with an annual rainfall of 46 to 50 in. The condition of the road was reported to be satisfactory. Similar work using this method of stabilization is also in progress in West Bengal, Madras and some other States.

2.2.4. Chemical Stabilization

Work is in progress in the College of Military Engineering, Kirkee,[3] on the effectiveness of trace chemicals such as Sodium Tri-Poly Phosphate and Sodium Hexa-Meta Phosphate when used in small concentrations, in improving soil properties. It has been shown that the liquid limit of soils falling in the ML and CL groups of the unified soil classification system are effectively reduced with an addition of as little as 0.4 per cent of these chemicals. The effect of Sodium-Hexa-Meta Phosphate is slightly more pronounced than that of the other chemical, viz., Sodium-Tri-Poly Phosphate. It is also indicated that soils of CH group show very poor response to these chemicals inasmuch as the liquid limit is unaffected, unlike the other two soil groups mentioned above. These experiments have also revealed that for soils in the ML and CL groups pretreatment with these chemicals, prior to admixture with cement

has some beneficial effect. It is indicated that the soil of the CL group pretreated with 0.4 per cent Sodium-Hexa-Meta Phosphate and stabilized with 5 per cent cement showed a crushing strength 100 per cent more than the same soil treated with cement alone. Trials are also in progress in the same organisation using dimethyl dioctadecyl ammonium chloride for stabilization of different kinds of soils.

The work on chemical stabilization of soils, in so far as it relates to the resistance to softening effect of water, has also been conducted in the Central Road Research Institute with chemicals such as Arquad 2HT, Armac-T, Cationic Emulsifier, D.D.B., Silicone, etc.

B & R Research Laboratory, Punjab,[4] has carried out some laboratory investigations using surface active agents like Duomeen T, sodium chloride, barium chloride, etc., for preventing efflorescence in earth construction. It has been reported that Duomeen-T when used in small quantities of 0.11 per cent by weight of soil was found to be very effective in checking penetration of moisture.

2.2.5. Cement Stabilization

Roads and Building Research Institute, West Bengal,[5] reported continuation of road construction work using cement stabilization. An experimental length of road is also under construction in one of the water-logged areas of West Bengal.[5] Cement stabilization is also reported from Madras.[2]

Work conducted in Highways Research Station, Madras,[2] indicates that addition of small percentage of cement to sand bituminous mixes increases the stability of the mix considerably.

Criteria for Cement Content

Based on some field investigations regarding the distress of some roads having soil-cement base, the Highway Research Station, Madras,[2] have reported that, considering the extreme soil moisture variation, with concentrated rainfall that are pronounced in tropical countries like ours, the compressive strength after inundation of the sample for seven days is most important. It is the opinion of the Highway Research Station, Madras, that the criteria of fixing 250 psi for compressive strength is on the low side and that the compressive strength value after seven days moist curing is to be fixed at 400 psi.

Laboratory work conducted earlier in the C.R.R.I.[6] (which was reported in Volume XXII-3) indicated that for some of the types of soil met with in this country a cement stabilized soil developing a strength of 150 psi (tests on cylinders of 2 in. dia. × 4 in. ht.) can successfully stand the moisture absorption, volumetric shrinkage and the wetting and drying cycles as specified in ASTM. A minimum strength of 450 psi was suggested only for zones subject to freezing and thawing.

2.2.6. Stabilization with Lime and Molasses

The use of lime in the stabilization of both alluvial and clayey soils is being taken up very actively in almost all the States where laboratory facilities exist. The B & R Research Laboratory, Punjab,[4] has put up sizeable lengths of roads with soil treated with lime as base course in waterlogged areas and the reports so far received indicate that there have been no cases of failure. It was reported by the same laboratory that silty and clayey soils respond much better to lime treatment than sandy and non-cohesive soils, and that lime treated soils show improvement with lapse of time and after some weathering.

It has been reported from Madras that addition of small percentage of lime to sand bituminous mixes increases the stability considerably. The work started by the Central Road Research Institute[7] with lime and molasses for working out specifications for village roads indicates that soil mixed with 5 per cent molasses and 2.5 per cent lime when stabilized with 40 per cent by volume of a soft aggregate such as brick aggregate, gives a very good riding quality both during wet and dry weather. The length has been under mixed light traffic for about two years and has given service without requiring any maintenance. It has, however, been observed on a similar length that without molasses whereas though lime does provide a certain amount of resistance to softening in the wet weather, its abrasive resistance to traffic in the dry weather is considerably reduced.

B & R Research Laboratory, Punjab,[4] has reported that addition of 3 to 4 per cent of molasses by weight to soil helps greatly in preventing efflorescence in earth construction.

2.2.7. Bituminous Stabilization

Successful stabilization of properly graded gravel with small percentages of bitumen for all weather roads was reported by the Highway Research Station, Madras.[2] It was also indicated that some soil bituminous mixtures and sand bituminous mixtures gave very good stability values after addition of small quantities (about 1 per cent) of lime and cement. Mixtures containing 'modified gravel' + 2 per cent RC 3 + 1 per cent cement or 1 per cent lime were reported to be satisfactory as wearing courses.

In Punjab[4], an experimental stretch of 2 furlongs was completed in a heavily waterlogged area where the waterproofing treatment consisted of laying about 1.5 in. thick layer of bituminised soil (4 per cent bitumen) over the compacted subgrade. The bitumen to be mixed in the cutback was converted into cutback by diluting it with 25 per cent of its weight of kerosine and dissolving in it 1 per cent hard paraffin wax by weight of mixture.

2.2.8. Study of Subgrade Moisture

The subgrade moisture study started by the Central Road Research Institute, details of which were given in the report for 1958–59 is being continued in collaboration with some other State laboratories such as Madras, Andhra Pradesh, West Bengal and Madhya Pradesh. At some of the places situated in these States, observations of subgrade moisture are being taken round the year to study the fluctuations of moisture in relation to seasonal changes and changes in water table.

2.2.9. Low Grade Aggregates

A detailed examination of different types of low grade aggregates from 148 quarries in Bombay State was made by the Central Road Research Institute.[7] As a result of this study it was indicated that most of these low grade aggregates can be very profitably used in sub-base and base-course layers, most of them straightaway and some after minor modifications. Some others are strong enough to be used even for wearing courses, for light traffic roads.

With the inauguration of a number of Steel Plants in this country, it is expected that blast furnace slag which is a waste product of this industry will offer itself as a potential source for road aggregates. Some work on the use of slag in base and surface courses was reported last year by Roads and Building Research Institute, West Bengal. The Central Road Research Institute is taking up this problem with a view to study the suitability of slag for use in base as well as wearing courses for different types of pavements.

2.2.10. Use of Radio Isotopes for Quality Control of highway Fill Construction

The Central Road Research Institute has very recently initiated a study on the determination of in-situ density of soils using radio isotopes.

Salient Points for Discussion

1. Use of lime in base stabilization of alluvial soils and clayey soils.

2. Criteria to be adopted for soil cement construction in the plains.

3. Chemical stabilization of soils.

4. Stabilized-soil roads including gravel roads for light traffic.

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3. BRIDGES AND STRUCTURES

General

Even though more and more imposing bridge structures designed for heavy traffic loads and high traffic densities are coming up on our highways, the load carrying capacity of many of our highways is limited by the old sub-standard bridges and culverts, which are not capable of taking the increased heavy traffic loads of to-day. In order to remove these bottlenecks to the load-carrying capacity of our highways it is essential either to replace old structures by appropriately designed new ones, or to strengthen them so as to make them adequate for present-day needs. A proper appraisal of the load carrying capacity of the existing structures is a pre-requisite for rating them for their adequacy. It is gratifying to note that some interesting work has been done in this direction by the Highways Research Station, Madras, by testing to destruction one old arch bridge.

3.1. Superstructure

3.1.1. Investigation and Testing of Weak Bridges

With a view to gain data as to the strength and load carrying capacity of old bridges, the Highways Research Station, Madras,[1] has undertaken to test some of the old bridges which are theoretically weak, but otherwise show no signs of failure.

The first bridge to be subjected to testing for ultimate load carrying capacity was the arch bridge across Uppodai at mile 343/7 of National Highway No. 7. Three out of seven spans of this bridge were tested to failure. It was concluded from this series of tests that there is considerable slab action in the arch barrel, that the arch behaves elastically till cracking, and that there is a very great reserve of strength between the first crack and ultimate collapse. It was of particular interest that a mere transverse crack at the intrados of the arch at the crown did not constitute a failure. The arch could sustain about 2½ times the load that caused cracks. It was also observed that parapets, pavement fill and spandrel are all contributing to the strength of the structure in various degrees.

A similar load test is proposed to be carried out on the abandoned arch bridge at mile 187/4 of National Highway No. 7 (Madras-Bangalore Road).

3.1.2. Modification to Trautwine's Formula

The Trautwine's formula for the design of cut stone is,

$$W = \{K \times \frac{bd^2}{L} - L/2.\ b/12.\ d/12.\ W_1\}/F_s$$

where W = Safe extraneous central load, lbs

K = Central breaking load for a beam of one sq. in. cross-section and one foot clear span, lbs.

b = Breadth of the beam, in.

d = Depth of the beam, in.

L = Clear span, ft

W_1 = Wt/cu. ft of the stone beam, lbs

F_3 = Factor of safety.

Conventionally, the values of K and F_s, have been assumed as 100 and 10 in the past. However, the value of the constant K actually depends on the structural and geological properties of the stone in question. On the basis of the limited work done so far, it is reported by the Highway Research Station, Madras, that the value of K can perhaps be taken as 200.

3.1.3. Use of Prestressed Slabs and Blocks for Strengthening of Culverts and Small Span Bridges

This aspect of the problem of strengthening old bridges and culverts is also proposed to be taken up for study by the Highways Research Station, Madras, in view of the fact that present pre-stressed concrete units possess special advantages in-respect of ease of transportation and promptness of execution, saving in shuttering, and greater resistance to fatigue.

It is proposed to take up work on the fatigue testing of pretensioned members, as soon as the fatigue testing machine designed for this purpose and proposed to be fabricated by the Madras P.W.D. Workshops is available.

3.1.4. Tests Conducted on Brick Masonry Units

In view of the fact that the strength of brick masonry depends on the strength of brick and the mortar used, and on the efficacy of any additives used for mortars, a series of tests to correlate these variables, were carried out by the Highways Research Station,

Madras. One of the important findings from these tests is that the ultimate strength of brickwork can be increased by the addition of 'Febmix Admix' admixture at the rate of 5 fluid ounces per cwt. of mortar, at the same time increasing the workability and plasticity of the mortar. It was also found that if 50 per cent of cement is replaced by lime in 1 : 3 cement-sand mortar, there is practically no loss in the strength of the mortar.

3.2. Foundations

3.2.1. General

Based on detailed site investigations and tests on foundation soils at bridge sites, West Bengal[2] and Madras Highways Research Station[1], have been designing the foundations using scientific methods for finding bearing capacity.

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II. TRAFFIC AND TRANSPORTATION

1. GEOMETRICS, ECONOMICS, STATISTICS AND SAFETY

General

With the economic development of the country the importance of road transportation and hence traffic engineering is becoming more and more vital. There is a great necessity to make a systematic study of the existing traffic conditions and adopt suitable engineering methods so as to reduce the traffic difficulties and hazards to the minimum possible.

With a view to study the different road traffic problems on a countrywide basis, the various studies carried out have been compiled in the present report.

1.1. Geometrics

1.1.1. Design of Road Intersections

During the period under report, both the Highways Research Station, Madras[1], and the Central Road Research Institute[2] conducted traffic survey for a large number of intersections in Madras and Delhi respectively and suggested suitable designs for free flow of traffic.

(i) Lodhi Road and Lodhi Estate Road Intersection, New Delhi[2]

A manually controlled 4-way right-angled intersection with view obstructed on its arms and having a high volume of cycle traffic on Lodhi Estate road, with majority of cyclists not using the cycle tracks, has been selected. This study aims to see the effect of roughening the pavement at the intersection which may control the speed and deter the cyclists from using the main intersection and divert them to the cycle track.

The design for the pavement roughening is under trial.

(ii) Effect of Central Control Islands[2]

The existing design of intersections is generally provided with a Central Control Island for reducing the speed and guiding the right turning traffic. Heavy motor vehicles on the intersection with such island cannot easily negotiate right turns through the correct lane without a number of to and fro movements.

A few such intersections were selected by C.R.R.I. in order to study the effect of such islands under mixed traffic conditions and to suggest the proper design of such crossings.

(iii) Traffic Rotaries[2]

The traffic at the intersections is mostly controlled either by a traffic-signal or by a rotary. A study to see the comparative effects of signals and rotary under different traffic conditions has been taken up, by C.R.R.I. The field survey of about 70 rotaries has been conducted. Further work is in progress.

1.2. Economics

1.2.1. Economics of Highway Transportation involved in the delays at the road-rail crossings in Delhi

The Central Road Research Institute[2] has taken up the study of the economics of highway transportation involved in the delays at some of the grade crossings of Highways and Railways in Delhi. The effect of delays at the road-rail crossing has been divided under the following heads:

(i) Economic value of the time lost by each sufferer.

(ii) Extra fuel (gasoline and oil) consumed due to delay at the road-rail crossing.

(iii) Extra wear and tear of the tyres, and other parts of the machinery of the different vehicles due to road-rail crossing.

1.2.2. Contribution of Road Transport to the Public Exchequer

This enquiry into the financial contribution of road transport to the Public Exchequer was undertaken by the National Council of Applied Economics Research,[4] New Delhi. The objects of the study are:

To assess the payments made by the industry in the course of its operations to the Public Exchequer, to assess its payments coming out of profits, to correlate the net indices of the performance of the industry, to examine the question of the capital formation in the road transport and to consider the financial eligibility of road transport to increased expenditure under the Third Plan. The report has been published. The gross contribution works out at Rs 133.55 crores for 1957–58. This is made up of operational payments of a specific character amounting to Rs 24.59 crores and operational payments of a non-specific character amounting to Rs 96.35 crores. Further, there were punitive payments amounting to Rs 1.25 crores. The appropriations from profits amounted to Rs 11.37 crores.

But the gross contribution has to be compared with the public costs of roads and road transport, which are termed here cost offsets.

The cost offsets totalled Rs 90.29 crores in 1957-58. The expenditure on road building amounted to Rs 52.29 crores, expenditure on maintenance of roads to Rs 26.56 crores, the cost of establishment of the Engineering Department to Rs 5.85 crores, the expenditure on road transport administration to Rs 1.33 crores, the cost of traffic control to Rs 0.72 crores, the interest on capital in Nationalised Road Transport Undertakings to Rs 1.54 crores and the cost of tax collections to Rs 2 crores.

The net contribution may be put at Rs 95.55 crores for 1957-58 under analytically correct method of analysis in which the cost of road construction has been excluded from the annual offsets on the ground, that it is capital expenditure rather than an annual input debitable to the Revenue Accounts.

1.2.3. Survey of Economic Benefits of Road Construction in Underdeveloped Regions[5]

A comprehensive study has been attempted by the Transport Ministry in December 1959–January 1960, to assess the economic benefits of road construction in monetary terms in underdeveloped regions. The newly-constructed National Highway running from Ramnad to Mandapam, a 21-mile stretch, with its catchment area was selected for the study in the first instance. As a result of this construction, it was stated that there was stability in prices to the same level in the villages around, more cultivation and production and activity in building feeder roads. The cost benefit estimates, allowing for the annual cost of maintenance, also show a return of more than 100 per cent on the initial capital outlay.

1.2.4. Cost of Operation of Motor Vehicles on Different Types of Road Surfaces

In order to study the effect of conditions and types of road surfaces on the cost of operation of motor vehicles controlled experiments are being conducted by the State Transport Undertakings of Uttar Pradesh and Bombay for the last 5 years. The Ministry of Transport has indicated the results of the data so far received show that the change of road surface from bad water-bound macadam to good cement concrete or bituminous surface reduces the fuel cost to the extent of 25 per cent, and that the wear and tear of tyre and consumption of spare parts are also much reduced. In terms of cost per vehicle mile, there is a saving to the extent of 60 to 70 per cent in the consumption of tyre and spare parts when the road surface is good. The scope of this experiment is being extended to hilly regions also. Transport Undertakings of Assam and Himachal Pradesh have already started these experiments on some of their hilly roads.

1.2.5. Operating Costs of Nationalised Road Transport Undertakings in India[5]

During the year under review, the costs of operation statistics received from the various Nationalised Transport Undertakings received upto 31st March, 1958, have been analysed by the economic and statistical division of the Ministry of Transport and a Paper entitled "Operating Cost of Nationalised Road Transport Undertakings in India", has been published. The important findings are that the average cost per seat mile in hilly, city, rural and composite services was observed to be 4.9, 2.3, 2.6, and 2.7 nP respectively which brings out clearly the difference in the conditions of operation in different areas. The cost per passenger mile in plains varies between 2.0 nP and 5.0 nP which, in the hilly region, works upto 7.0 nP. It is clear that this compares favourably with the rate charged (for III class) per passenger per mile, i.e., 2.4 nP for Broad Gauge and 2.6 nP for Meter Gauge by the Railways in 1957–58.

1.3. Statistics and Safety

1.3.1. Parking Study

Parking study in Connaught Place and Connaught Circus area—New Delhi[2]

The parking study in Connaught Place reported last year by C.R.R.L., has since been completed and the following recommendations have been made:

(i) Demarcation of parking stalls.

(ii) Separate parking lots of different type of vehicles and for different parking durations and use of parking metres for time restriction enforcement. The distance of parking spaces from the destination point proposed in the design is in proportion to the length of time for which the vehicle is to be parked.

2. TRANSPORTATION

2.1. Employment Potential of Road Transport

This study undertaken by National Council of Applied Economics Research [3] is a pioneer attempt at a scientific compilation of the employment potential provided by the road transport in India.

The total number of persons who find employment in the road transport industry in its broad sense is about 24 lakhs. The categories of employment included in the computation relate to :

(a) the provision and maintenance of track

(b) vehicular operations

(c) provision and maintenance of terminal facilities

(d) provision and maintenance of vehicle and supply of tractive power, and

(e) transport administration and traffic control.

Employment in the provision and maintenance of track is the largest single item (Rs 9.76 lakhs) accounting for 30 per cent, the provision and maintenance of vehicles and supply of fuel stands third in order of importance and accounts for Rs 5.16 lakhs which is 22 per cent of the total employment. It is of interest to note that the persons engaged in transport administration and traffic control are 0.14 lakhs which is less than 1 per cent of the aggregate number. The employment per commercial vehicle works out at 12.63 persons. The figure per bus is 17.02 and the figure per truck is 11.12.

2.2. All-India Goods Traffic Survey

A pilot sample survey of goods traffic on roads in Delhi was conducted by the Transport Ministry[5] in 1957 and printed reports were sent to the State Governments, Territory Administrations and other interested Departments requesting them to carry out similar surveys in their areas. Some of the main findings of the Delhi Survey are (1) Motor goods vehicles in Delhi handled about 4.5 lakhs maunds of goods per day as against 1.25 lakh maunds by the Railways, (2) motor goods transport is quite economical and offers reasonable rates, (3) the motor goods vehicles remain idle for about 30 per cent of the days in the year and (4) there is ample scope for higher utilisation, if motor transport worked on co-operative basis.

2.3. Estimation of National Income for Road Transport Sector

At the instance of the National Income Committee, the Ministry of Transport[5] have started collecting necessary statistics regarding Transport Undertakings in different States and Territories and are attempting to estimate the contribution of Nationalised Transport Undertakings. As an outcome of this attempt, a Paper entitled 'Nationalised Transport Undertakings and National Income' has recently been brought out. It is estimated that the Nationalised Transport Sector has contributed about Rs 26 crores and Rs 30 crores during the years 1957-58 and 1958-59 respectively.

Salient Points

1. Effect of road roughening on cycle traffic.
2. Parking lots as a measure for relief to parking demands.
3. Effect of various factors on road accidents in Delhi.
4. Employment potential of road transport.
5. Contribution of road transport to the Public Exchequer.

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1. A STUDY OF SOFT AGGREGATES FROM DIFFERENT PARTS OF INDIA WITH A VIEW TO THEIR USE IN ROAD CONSTRUCTION—PART III—BOMBAY

2. TRAFFIC SIGNS

"A STUDY OF SOFT AGGREGATES FROM DIFFERENT PARTS OF INDIA WITH A VIEW TO THEIR USE IN ROAD CONSTRUCTION—PART III—BOMBAY"

By

DR. H. L. UPPAL* & BHUPINDER SINGH*

SYNOPSIS

The study is a continuation of the work published before in the Journals of the Indian Roads Congress Vol. XXI—Part 3-April 1957 and Vol. XXII-Part 2-December 1957.

The State of Bombay now bifurcated into Maharashtra and Gujerat has a big future road construction programme. With a view to economise in the cost of road construction, attempt has been made in this Paper to show the extent to which inferior aggregates such as kankar, moorum and laterite can be used. 148 samples from different quarries were subjected to road aggregate tests. These tests show that a large majority of these samples are fit for use in the sub-base and base course and a few are even strong enough to be used in place of base coat stone metal.

1. INTRODUCTION

In the next twenty years Road Development Plan[1] of the States of Maharashtra and Gujerat, nearly 50,000 miles of roads are to be constructed. Except for about 20 per cent of this milage consisting of the National and State Highway, the rest consists of major district roads, other district roads and village roads.

The specifications generally followed at present for the roads are stone soling, stone metal base coat with or without black topping except for an insignificant length which is built in cement concrete. Construction of roads with the conventional specifications, involve a good deal of haulage of hard stone from long distances, which stands in the way of achieving the targets and is a cause of higher cost. To enable longer lengths of roads to be constructed within the allotted sums allocated it is essential to bring down the construction cost without sacrificing the basic principles of design.

The study of soft aggregates from different parts of India has been in progress in the Central Road Research Institute for some time. The studies of soft aggregates in Rajasthan and laterite from various parts of India have already been published.[2, 3]. The

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present study of soft aggregates from Bombay is similar to those already published.

To find out the engineering quality of the local soft aggregate deposits, such as moorum, laterite, shale, gravel, etc., the P.W.D. authorities were requested to send samples from various quarries in different parts of the State. The location of the quarries from where the samples have been collected is shown in Plate I and the visual observation of the same is given in Table I.

From Plate I, it will appear that the quarries are well distributed throughout the State except for the districts of Aurangabad, Osmanabad, Parbhani and Nander. These districts are, however, rich in gravel deposits which is also a very good road-building material.

From visual inspection it appears that the samples consist of kankar, moorum, shale and other undifferentiated material of disintegrated sedimentary rocks. It further appears that kankar deposits from the divisions of Gujerat and Ahmedabad can be grouped into two classes : (i) nodular, which apparently looks very hard and (ii) calcareous which is in the form of lumps, and appears comparatively less hard. Moorum deposits occur mostly in Aurangabad and Poona Divisions ; shale deposits in Rajkot and Bombay Divisions and undifferentiated disintegrated sedimentary rocks mostly in Bombay Division.

2. EXISTING TECHNIQUE IN VOGUE FOR UTILIZATION OF INFERIOR AGGREGATE

Research work has been in progress in various countries on the use of soft aggregate in road construction. The specifications of some of the techniques which have so far been adopted are described below :

(a) **Use of aggregates as such** : Soft aggregates with negligible percentage of fines have been recommended for use in road construction, according to AASHO[4] procedure based on the aggregate impact value. The limits fixed are :

- (i) Sub-base and base course—Aggregate impact value ranging between 40—60 per cent.
- (ii) Base coat—Aggregate impact value ranging between 30—40 per cent for medium traffic.

The R. R. L. Harmondsworth, however, suggest an aggregate impact value of 13—17 for the base coat for heavy traffic.

(b) **Soil gravel specification** :[5] For such quarried materials where the coarse aggregate is mixed up with fines to the extent of about 50 per cent, soil gravel specification can be advantageously provided used it satisfied the following conditions :

- (i) Grain size distribution conforming to limits laid down by A.S.T.M. D556—40T & D557—40T.
- (ii) Aggregate impact value (A.I.V.) is not more than 40 per cent.
- (iii) Consistency limits : Plasticity index from 0 to 6 for the base course and 4 to 9 for the base coat.

(c) **Soil stabilization with soft aggregate** : In case the percentage of coarse aggregate in the quarried material is relatively smaller than the percentage of fine materials then such mixture can be used according to Mehra's method[6] of soil stabilization provided it can economically be brought to conform to the following specification by blending or otherwise :

- (i) The aggregate soil mixture shall have coarse aggregate ranging between 35—40 per cent. The plasticity index of the soil mortar shall be 9—11 and fraction coarser than 200 U.S. Std. sieve in the soil mortar not less than 33 per cent.
- (ii) Aggregate impact value not more than 50 per cent.

(d) **California Bearing Ratio Test method**[7] : For all such aggregates which are still poorer in strength, and are also mixed with large percentage of fines, their suitability in road pavement under conditions of high water table can be judged by subjecting the compacted mixture to the California bearing ratio test. The exact place, whether sub-base, base or base coat which such mixtures can occupy will depend upon the intensity of traffic and can be worked out from the standard curves[8].

3. LABORATORY INVESTIGATION

There were in all 148 samples received from various parts of Bombay State, Maharashtra and Gujerat to determine their suitability for use in road construction, these were subjected to the following tests :

- (i) Aggregate Impact Value (A.I.V.) (B.S., 812—1951)
- (ii) Los Angeles Test (A.S.T.M. C 131—51)
- (iii) Mechanical Analysis (A.S.T.M. D 422—39)

(iv) Consistency Limits (A.S.T.M. D 423—39) (D 424—39)

(v) C.B.R. Test (U.S. Army Corps of Engineers)

(vi) Soluble Solids (Water Dionic Tester)

(vii) Insoluble Carbonates (Schrotter's Method)

The results of aggregate impact test, Los Angeles Test, consistency limits, soluble solids and insoluble carbonates are given in Table 1. The results of mechanical analysis are shown in Table 2 and those of C.B.R. in Table 3.

Out of the various tests, the Los Angeles test is considered to give the maximum reproductivity in so far as field behaviour of the aggregate is concerned. About 40 samples were tested according to this method and also by the British aggregate impact value test. From the analysis of the data, it was found that there is a definite relationship between the two and it confirmed previous finding of the work carried out in the C.R.R.I. [9] Since Los Angeles is a time consuming test, it was given up in favour of Aggregate Impact Value Test, and the remaining samples of aggregates were subjected to A.I.V. test only.

The test could not be extended to about 10 samples, as the coarse material ran short of quantity required for testing.

4. DISCUSSION OF LABORATORY DATA

4.1. **Use of aggregate as such** : It will appear from the data in Table 2 and graphs in Fig.1 that samples Nos. 4, 55, 80, 84, 109, 121, 122, 124, 126, 127, 128, 134, 138 and 146 which are mostly from Poona and Aurangabad Divisions are almost neat aggregates* without any appreciable quantity of fine material. Their suitability has, therefore, been judged from the impact value. It will appear from the test results that the aggregate impact value varies between 12 to 30 per cent. According to the specifications these materials are fit to be used in the base coat. It appears from the mechanical analysis that the percentage of fines is almost negligible varying from 0-5 per cent. In the absence of harmful salts it is not necessary to remove such small concentration in actual practice. The presence of harmful salt (sodium sulphate) was checked. The analysis of the fine fraction shows that the percentage of sodium sulphate is insignificant. The insoluble material is mostly calcium carbonate which is helpful during wet conditions as it creates resistance to the softening effect of water.

* Retained on 10 mesh U.S. standard sieve.

4.2. **Use of aggregate after screening** : From the data in Table 2 and graphs in Fig. 2 it will appear that samples Nos. 56, 65, 82, 110, 111, 113, 116, 117, 118, 120, 123, 125, 135, 136 and 144 have predominance of coarse material (retained on 10 mesh U.S.

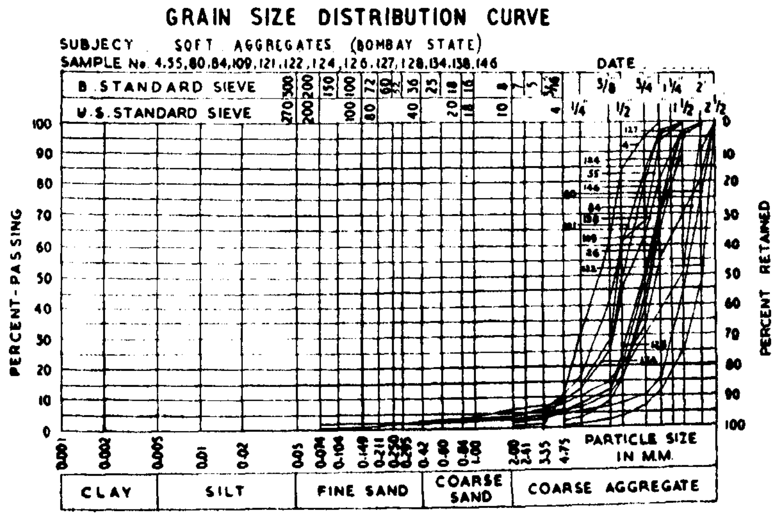

Fig. 1

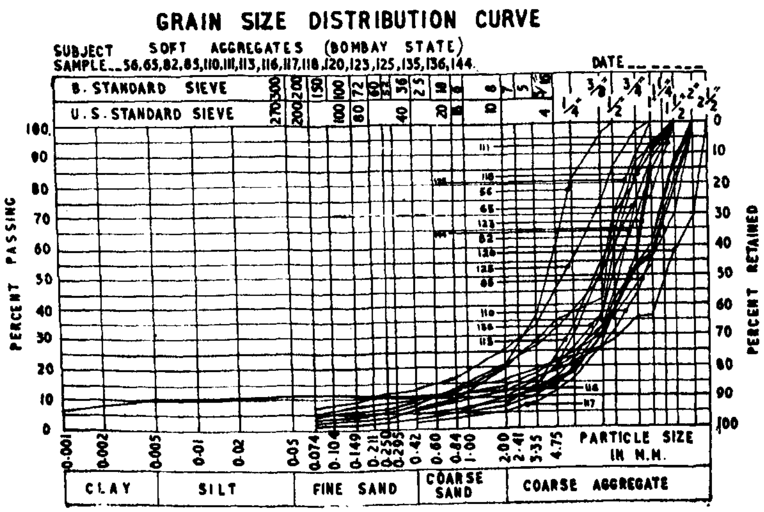

Fig. 2

standard sieve) and the fine fraction varies from 5-20 per cent with large majority of samples having only 5-10 per cent. The coarse fraction when subjected to aggregate impact test, gave a value varying between 20-37 per cent showing thereby that the coarse fraction is fit to be used in the base coat after screening the fine material, as it satisfies the suggested aggregate impact value for medium traffic. There may, however, be some fine fraction still adhering to the aggregate even after screening and it will therefore be necessary to test it for the absence of harmful salt. The chemical analysis of the fine fraction showed that it is not only free from harmful salt like sodium sulphate but also contains a small percentage of beneficial salt, such as calcium carbonate.

4.3. **Use of aggregate mixture according to soil gravel specification**: It will appear from the mechanical analysis of samples Nos. 2, 7, 11, 25, 29, 31, 32, 35, 36, 38, 48, 49, 50, 54, 58, 59, 66, 71, 81 83, 102, 108, 112, 114, 129, 130, 131, 132, 137, 140, 141, 142 and 145 given in Table 2 and plotted in Fig. 3 that the samples are well graded.

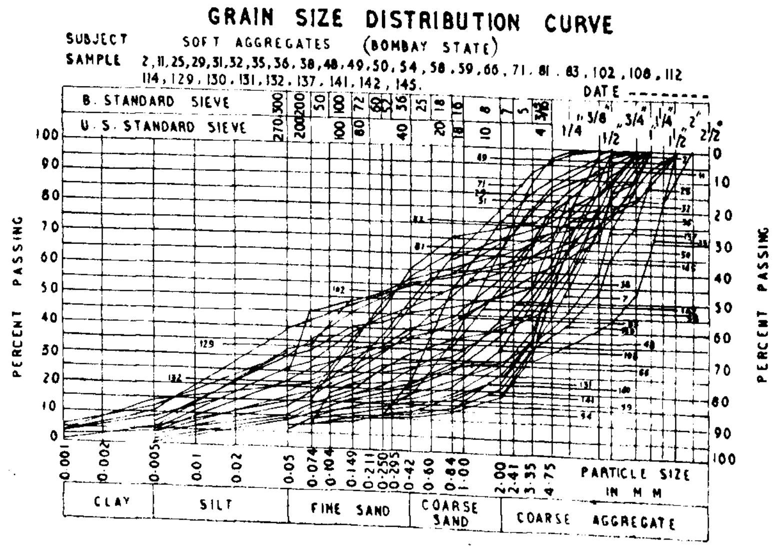

Fig. 3

The plasticity index of the soil mortar fraction for most of the samples varies from 0-12 in such a way that mixtures with higher percentage of coarse fraction have lower plasticity and vice versa. The aggregate impact value varies from 21—40 per cent. Taking

into consideration, the specification required under mechanical stabilization it will appear that a large majority of samples fully satisfy the requirements of particles size distribution, plasticity index and aggregate impact value either for base or base coat, and therefore according to A.S.T.M. standards fit to be used in road pavement as such. The distribution of these samples either as a base or base coat is discussed below in detail.

4.3.1. Out of the abovementioned mixtures, samples Nos. 11, 25, 32, 36, 49, 66, 83, 102 and 112 satisfy the requirements for base course and can therefore be used as such. Samples Nos. 2, 7, 29, 31, 35, 38, 48, 50, 58, 71, 81, 114, 130 & 132 which fully satisfy the requirements of base coat of mechanically stabilized crust can be used as such.

Whereas most of the samples mentioned above can be used as such, either for base or base coat, there are still a few samples, such as samples Nos. 54, 59, 108, 129, 131, 137, 140, 141, 142 and 145 which satisfy the gradation for base course material, but have plasticity index of the finer fraction more than specified. Since the fraction passing 40 mesh varies between 10—33 per cent as against specified, it may not be found economical to add sand to bring down the plasticity index, as this may upset the rest of the grading and therefore such samples require to be treated differently.

4.4. **Use of aggregate mixture on the basis of Mehra's method**: Out of the samples found unsuitable by any one of the methods described earlier, there are about 86 samples which have their coarse fraction varying from 5—45 per cent (Ref. Table 1). It will appear from Table 1 that the aggregate impact value of the coarse fraction of these samples varies from 26—45 per cent and the plasticity index of the soil mortar from 12—50. It will be seen that it is neither economical to screen these materials free of fines to use them as a neat aggregate, nor possible to blend by adding coarse material and fine sand to bring them to proper gradation so as to conform to the specification of soil gravel mixtures. Study of data in Table 2 will, however, show that samples Nos. 12, 13, 14, 15, 17, 21, 24, 26, 27, 41, 52, 72, 73, 74, 76, 79, 133 and 143 have the plasticity index between 12—15 and coarse fraction about 35 per cent. Such samples can be economically brought to the specification of Mehra's Method [10] (stabilization of soil with soft aggregate) by adding about 10—15 per cent fine sand on the basis of original sample. In the same way, samples Nos. 54, 59, 108, 129, 131, 137, 140, 141, 142 and 145 discussed under para 4.3.1 and samples Nos. 69, 75 and 106 discussed under para 4.4 having coarse fraction of about 40 per cent considered unsuitable on account of clay content with high plasticity index can be utilized under this method by adding, on the average, about 20 per cent of fine sand. Such crusts are suitable for being used for light traffic even without surface treatment.

The remaining samples which contain small percentage of coarse fraction and also soil mortar of high plasticity index cannot economically be brought to conform to the specification of the method under discussion and therefore shall have to be utilized according to some other method.

4.5. **Use of aggregate mixture on the basis of their soaked C.B.R. values**: The suitability of different types of material for road construction under adverse moisture condition can be judged by the C.B.R. method, which evaluates the relative strength and consequently the position which such materials can occupy at various depths of the pavement. All those samples which still contain coarse aggregate retained on 10 mesh U.S.Std. sieve varying between 5—30 per cent but were not selected as suitable for road pavement by either one of the methods described earlier, were subjected to the C.B.R. test by compacting them to a dry bulk density of about 90—95 per cent of that of modified AASHO which can readily be achieved in the field for such mixtures. The results of the test are given in Table 3.

It will appear that the C.B.R. under adverse moisture condition varies between 3—70 per cent. From C.B.R. design curves for different classes of road, as evolved by Road Research Laboratory, London, it will appear that for a medium traffic a total thickness of 18 in. of the road pavement is required on a poor subgrade. Since the thickness of about 7 in. of hard crust is normally provided for most of the roads in India, this will require a material of 15 C.B.R. for a base under this crust. It will be seen from Table 3 that samples Nos. 1, 18, 30, 37, 39, 51, 57, 62, 63, 67, 68, 70, 77, 86, 87, 92, 97, 104, 107, 115, 119, 139, 147 and 148 have their C.B.R. varying between 15—70 per cent and therefore strong enough to form a base even under saturated condition. The thickness of hard crust can be further reduced as C.B.R. of the material increases beyond 15 per cent.

It will, however, not be economical to use remaining samples with very low C.B.R., on account of higher thicknesses of hard crust required, involving further treatment.

4.6. **Increasing C.B.R. by treatment with lime**: It was found that in spite of the fact that coarse fraction in the remaining samples varied between 5—30 per cent, the C.B.R. value was very low. This was due to the plasticity index of the fine fraction being between 20—50 per cent.

4.6.1. Research work in different parts of the world has shown that silicious materials react very favourably with lime resulting in a hard mass which resist the softening effect of water. To find out how far the mixtures found unsuitable by either of the methods described earlier could still be made use of, in road pavement, tests were conducted by carrying out C.B.R. test on some of the typical samples from the rejected lot after addition of 2 per cent lime. The results obtained for samples Nos. 14, 28, 60, 64, 94. and 99 are given below :

S. No.	Division	C.B.R. value of sample without treatment	C.B.R. value after treatment with 2 per cent lime
14	Ahmedabad	7.00	24.53
28	Do.	9.50	81.06
60	Bombay	9.50	72.50
64	Do.	14.00	134.40
94	Do.	4.50	61.86
99	Do.	13.00	93.87

It appears from the above that all those samples otherwise considered not fit for use even as a sub-base improved so much in strength as to be fit for use even in the base coat. For actual construction in the field, the concentration of lime shall have to be increased and will vary depending on the efficiency of mixing plant. Only a limited number of samples have been taken, to make out a case. In actual practice, the C.B.R. of each of the samples after treatment with lime, shall have to be determined to find out its place in road pavement. It also makes out a case for lime treatment of those samples which were considered fit for use in the base course only, due to their C.B.R. value being between 15—70 per cent. Such mixtures may require even less than 2 per cent lime.

5. RECOMMENDATIONS

The above study of a sample survey of low grade aggregates indicates that almost all types of quarried material can be profitably made use of in road construction by suitable processing. The use of such material will result in reduction in the cost of roads. This is not a detailed study but it establishes a prima facie case for proper exploitation of quarried material for road construction.

A brief general review of the availability of different types of soft aggregates in various divisions of Bombay and the probable place that each can occupy in the road pavement, is given below.

This could serve as a rough guide to the engineers while fixing specifications of roads in different districts.

Ahmedabad Division

Ahmedabad is generally rich in kankar deposits which are fairly well distributed. Kankar from the districts of Mehsana, Himat Nagar, Broach and Panchmahal is comparatively harder than the kankar available in the districts of Banas Kantha, Kaira, Sabar Kantha and Baroda. The harder quality can even replace stone metal for medium traffic and the inferior quality can form a good base.

Rajkot Division

Disintegrated rock deposits are generally met with in this division. These materials are not very strong and therefore can form only as a base-course.

Bombay Division

The type of aggregates met in Bombay Division are generally poor and get disintegrated under water. These can, after compaction form a suitable base course.

There are, however, some deposits in the districts of Thana and Dangas which appear similar to the disintegrated rock mentioned above but are comparatively stronger.

Poona Division

Districts of Poona, Ratanagiri and Sholapur are rich in moorum deposits. This material can form a good base course after proper compaction.

Aurangabad Division

A good quality of moorum is available in the districts of East Khandesh, Amaravati, Nagpur and Bhandara. This can form a good base course material and at places can even be tried for the base coat in minor roads.

ACKNOWLEDGMENT

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TABLE 1

Physical and chemical characteristics of samples tested

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonates) Per cent
1	Ahmedabad	Mile 13/5 of J.H. Road sub-division, Himat Nagar	Soil-kankar mix	28.6	—	32.80	14.00	14.6	.064	41.60
2	Do.	Mile 1/7, J.H. Road sub-division, Himat Nagar	Do.	24.86	—	26.90	10.30	32.0	.085	48.00
3	Do.	Voh, 11 miles in north of Patan Mehsana Division	Stones with fine grey material	26.75	30.41	Non-plastic		5.3	.144	6.00
4	Do.	Do.	Sand-kankar mixture	23.35	26.75	Non-plastic		99.13	.026	66.80
5	Do.	1 mile in north of Patan Mehsana Division	Disintegrated rock	—	—	34.90	20.30	4.80	.250	12.40
6	Do.	3 miles from Radhan Pur Mehsana Division	Soil-kankar mix with light pink colour	—	—	55.10	26.40	31.9	.1175	52.00
7	Do.	Santalpur Taluq, Mehsana District	Reddish boulders (lime-kankar mix.)	29.8	33.64	31.20	10.30	59.6	.675	1.20
8	Ahmedabad	Ahmedabad - Viramgabad road	Soil-kankar mix	—	—	34.50	16.30	7.1	.0295	17.6
9	Do.	Do.	Do.	—	—	25.84	9.44	22.1	.0265	26.80
10	Do.	Viramgan sub-division	Kankar with fine material	—	—	34.05	17.39	11.7	.41	42.00
11	Do.	Mile No. 9, Orwada-Santpur road, Godhra sub-division	Soil-kankar mix	27.94	31.59	28.64	8.64	39.0	.021	70.80
12	Do.	Shiv Rajpur Section, Halol sub-division, Panchmahal Division	Lime kankar mix	—	—	32.40	15.20	27.40	.0295	68.00
13	Do.	Do.	Do.	32.2	—	35.90	13.90	36.3	.046	40.0
14	Do.	Do.	Soil-kankar mix	—	—	0.9	16.40	25.2	.046	0.80
15	Do.	Do.	Lime-kankar mix	—	—	42.00	15.80	35.3	.046	12.80
16	Do.	Do.	Kankar mixed with reddish material	—	—	42.50	17.90	30.1	.039	0.80
17	Do.	Do.	Lime stone with kankar (sialicious)	—	—	46.90	21.20	33.3	.09	4.80
18	Do.	Do.	Soil-kankar mix	—	—	32.03	12.69	12.1	.035	31,20
19	Do.	Do.	Do.	—	—	26.99	13.79	13.1	.085	
20	Do.	Do.	Do.	—	—	34.16	12.19	1.3	.0325	19.20
21	Do.	Mile No. 3, Sant Ram Pur-Orwada road, Panchmahal district, Godhra	Disintegrated rock	—	—	27.48	12.62	24.7	.035	Nil

TABLE 1—(*contd.*)

S. No.	Division	Location of Quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los angeles Value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonates) Per cent
22	Ahmedabad	Mile No. 9, Sant Rampur Orwada road, Panchmahal district, Godhra	Red soil mixed with kankar	—	—	32.01	12.74	5.5	.0475	Nil
23	Do.	Mile No. 4, Sant Rampur Orwada road, Panchmahal district, Godhra	Disintegrated rock	—	—	32.67	18.20	33.5	0.055	4.0
24	Do.	Mile No. 7, Sant Rampur Orwada road, Panchmahal distt.	Disintegrated rock and kankar mixture	—	—	35.71	13.71	37.1	.035	31.60
25	Do.	Do.	Disintegrated rock	40.13	44.72	25.22	2.47	31.7	.09	19.60
26	Do.	Mile No. 1, Sant Rampur Orwada road, Panchmahal district, Godhra	Do.	35.51	—	36.69	14.99	23.3	.031	39.20
27	Do.	Mile No. 3, Godhra-Lunwal road	Do.	36.90	41.27	33.00	13.40	36.6	.031	26.40
28	Do.	Mile No. 2, Godhra Lumwada road	Dark red soil	—	—	53.3	33.73	15.8	·0275	0.40
29	Do.	Mile No. 90/7, Godhra Pali road	Coarse hard material of red colour	—	—	37.67	10.61	35.0	.0475	2.00
30	**Ahmedabad**	**Mile No. 9½, Godhra Pali road**	Calcareous material	—	—	Non-plastic		11.7	0.055	12.80
31	**Do.**	**Mile No. 97, Godhra Salol road**	Dark brown soil with coarse materials	40.10	—	37.59	10.12	43.4	0.021	0.40
32	**Do.**	**Mile No. 92/6 Godhra Pali road.**	Calcarious hard coarse material	40.90	—	24.36	5.96	30.2	0.03	24.4
33	**Do.**	**Mile No. 3, Orwada Santpur road, Godhra sub-division**	Typical moorum	—	—	38.57	18.40	2.3	0.035	—
34	**Do.**	**Mile No. 4. Orwada, Santpur road, Godhra sub-division**	Soil with disintegrated rock	28.48	32.24	33.90	17.18	28.7	0.0225	—
35	**Do.**	**Mile No. 9, Orwada, Santpur road, Godhra sub-division**	Soil with angular stones	23.65	27.07	32.76	11.44	69.4	0.0225	—
36	**Do.**	**Mile No. 2, Chotta-Udepur - Ferkma road, Chotta-Udepur sub-division**	Typical moorum	—	—	25.90	8.42	24.7	0.012	—
37	**Do.**	**Mile No 10, Chotta-Udepur Bodib-Godhra road**	Coarse sand	—	—	Non-plastic		39.0	0.015	—
38	**Do.**	**Mile No. 4, Chotta-Udepur-Karant road**	Moorum	—	—	31.92	11.53	34.1	0.0165	—
39	**Do.**	**Mile No. 2, Chotta-Udepur Zozkenadi Baria road**	Disintegrated rock	—	—	39.80	17.32	12.6	0.075	—

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonates) Per cent
40	Ahmedabad	Mile No. 12/6, Dhanduka-Darwala road, Dhanduka sub-division	Kankar with dark brown soil	—	—	54.40	20.2	45.4	0.039	78.00
41	Do.	Mile No. 3/7 of above road	Kankar with dark grey soil	—	—	39.81	15.3	28.6	0.0325	29.2
42	Do.	Dhanduka - Fedra road, Dhanduka sub-division	Dark grey sandy soil	—	—	24.49	6.31	1.1	0.035	17.6
43	Do.	Dhanduka-Rampur road, Dhanduka sub-division	Dark grey soil	—	—	43.9	23.0	11.7	0.0433	4.4
44	Do.	Mile No. 13/2 of Dhanduka-Rampur road, Dhanduka sub-division	Soil-kankar mix	—	—	36.42	20.62	18.5	0.8	53.2
45	Do.	Mile No. 59/7, Dhanduka Fedra road, Baria sub-division	Black cotton soil	—	—	66.26	44.84	.7	0.85	20.0
46	Do.	Do.	Soil-kankar mixture	—	—	35.48	13.72	13.2	0.044	31.6
47	Do.	Do.	Disintegrated rock	—	—	41.15	15.03	12.0	0.11	1.2
48	Do.	Do.	Soil-kankar mixture	36.03	40.31	34.10	10.4	35.0	0.049	32.4
49	Do.	Baria sub-division	Lime kankar mixture	35.19	25.14	32.05	8.34	38.0	.044	69.20
50	Do.	Do.	Do.	21.77	25.03	36.81	10.71	49.1	.044	64.40
51	Do.	Do.	Soil-kankar mixture	—	—	41.31	20.29	35.3	.045	60.80
52	Do.	Do.	Do.	—	—	27.79	14.27	35.8	.042	70.40
53	Do.	Do.	Do.	—	—	35.42	19.02	25.8	.085	46.00
54	Rajkot	Mile No. 11/0, Rajkot-Jamnagar road	Slate material	22.40	—	60.6	23.40	75.6	.249	10.8
55	Do.	Rajkot-Jamnagar road, River Und at Dhrol	Do.	30.20	—	28.15	7.50	93.9	.035	12.0
56	Do.	From the bed of Uyyakondan channel	Stony material with white spots	35.50	—	Non-plastic		80.4	.021	13.6
57	Do.	Rajkot-Jamnagar road, mile No. 10/0, 15/0 from Jamnagar site	Grey soil mixed with white quartz	—	—	33.9	18.1	25.20	0.134	8.0
58	Do.	Rajpipla-Dedipada road, 6-7 miles from Rajpipla road	Soft grey stone	36.8	—	30.8	10.30	48.3	.035	12.4
59	Do.	Mile No. 12/5–23/0 of Rajkot-Jamnagar-Veraval road	Grey soil mixed with lateritic quartz	25.80	—	36.60	18.7	73.3	.253	7.6
60	Bombay	Mile No. 3/6 to 3/7 of Maherna-Nihali road, Dangs Division, Surat District	Disintegrated rock	—	—	48.42	24.12	6.2	.0476	22.00

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble sats Per cent	Insoluble salts (carbonates) Per cent
61	Bombay	Mile No. 5/5 to 5/6, Billimora-Gandavi-Gadat road	Typical moorum	32.25	43.75	57.98	29.47	60.7	.018	Nil.
62	Do.	Mile 12/6, Balsar-Dharampur-Nasik road, Dangs Division	Do.	31.40	35.36	45.00	17.21	76.3	.015	Nil.
63	Do.	Mile No. 18/5 of Chikhl - Bansada-Waghai road, Dangs division	Stones with white and black spots	16.14	—	53.33	22.98	35.1	.03	Nil.
64	Do.	Mile No. 161/6, National Highways No. 8, Bombay-Ahmedabad road	Soil with soft lumps	44.88	—	45.00	18.84	20.7	.04	22.50
65	Do.	Deogam quarry, Niphad Taluq, district Nasik	Laminated material with green deposits	26.90	30.52	30.20	15.40	80.3	.148	6.4
66	Do.	Near Nasik Irrigation office	Soft stone with yellow spots	36.00	42.35	29.80	7.20	61.5	.0415	11.20
67	Do.	Do.	Coarse and fine sand mixture	—	—	29.80	10.50	2.5	.0265	10.00
68	Do.	Shalwali village, Palghar Taluq, Thana district	Disintegrated soft material	—	—	54.61	24.58	12.4	.0675	2.80
69	Do.	Mile No. 12/5, Mahim-Manor road, Palghar Taluq, Thana District	Disintegrated rock	—	—	50.21	23.49	51.3	.017	7.60
70	Do.	Mile No. 14/3, Mahim-Manor road, Palghar Taluq, Thana district	Dark red disintegrated material	—	—	55.48	21.38	19.2	.021	2.40
71	Do.	Mile No. 15/4, Mahim Manor road, Palghar Taluq, Thana district	Disintegrated material	—	—	30.26	9.76	20.7	.01	2.80
72	Do.	Mile No. 15/5, Mahim-Manor, Palghar Taluq, Thana district	Do.	41.60	—	38.26	15.25	45.3	.009	2.00
73	Do.	Nandgam village, Palghar Taluq, Thana district	Do.	—	—	43.02	10.53	27.6	.01	1.60
74	Do.	Do.	Do.	—	—	46.08	14.78	29.5	.013	2.40
75	Do.	Aurdhan village, Thana district	Do.	26.40	29.98	55.25	24.28	59.6	.015	Nil
76	Do.	Chilhervillage, Palghar Taluq, Thana district	Do.	35.01	—	40.05	12.91	38.9	.024	9.6
77	Do.	Vada village, Palghar Taluq, Thana district	Do.	—	—	63.88	28.70	19.2	.023	Nil

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate Impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonates) Per cent
78	Do.	Medhavan village, Palghar Taluq, Thana District	Do.	—	—	62.53	33.19	35.2	.023	8.4
79	Do.	Do.	Do.	25.50	30.09	42.79	15.94	62.0	.015	3.60
80	Do.	Tawa village, Dahanu Taluq, Thana District	Disintegrated rock	16.16	19.01	Non-plastic		95.5	.05	2.81
81	Do.	Mile No. 86/4, Tawa village, Thana District	Coarse disintegrated rock.	30.07	34.39	38.35	10.49	39.2	.031	2.40
82	Do.	Mile No. 87/2, Ghol village, Dahanu Taluq, Thana District	Soft stone with white and green deposits.	22.17	—	Non-plastic		90.0	.0167	8.00
83	Bombay	Mile No. 88/7 Varoti village, Dahanu Taluq. Thana District	Disintegrated rock	34.8	39.1	27.59	6.89	48.0	.044	1.60
84	Do.	Mile No. 124/7 Bhilad village, Thana Disdrict	Do.	22.40	25.24	Non plastic		95.4	.017	6.00
85	Do.	Mile No. 3/6 Sanjan Talsoni road, Umbagam Taluq, Thana District	Do.	18.96	22.02	Do.		85.9	.016	1.20
86	Do.	Kurunj village, Unbergam Taluq, Thanna District	Do.	31.60	—	56.85	22.24	48.4	.021	6.00
87	Do.	Bhiwandi quarry Mile No. 42/3 Andheri sub-division, Andheri	Soil sample	—	—	49.25	17.65	1.6	.021	.40
88	Do.	Kashmira quarry B. G. road, Andheri	Disintegrated rock	—	—	61.03	23.98	20.6	.0255	Nil
89	Do.	Mile No. 19, Ghodbundar road, Andheri	Stone pebbles mixed up with grey soil	—	—	74.72	33.06	38.9	.026	Nil
90	Do.	Mile No. 22 B.G. road, Chena quarry, Andheri	Soil sample	—	—	56.69	18.04	4.3	.065	4.40
91	Do.	Gilbert Hill quarry, Andheri	Yellow soil with lumps	—	—	58.00	31.79	1.3	.024	Nil
92	Do.	Mile No. 61/4 (A.H.) Bombay — Agra road quarry	Disintegrated rock	—	—	46.08	10.21	29.8	.015	Nil
93	Do.	Mile No. 59/6 Bombay-Agra road quarry	Do.	—	—	55.45	27.18	6.9	.031	Nil
94	Do.	Kurla, near Nari Sewa Sadan, Bombay-Agra road	Typical moorum	—	—	75.73	41.72	33.5	.0525	0.80
95	Do.	Mile No. 55/4 Bombay-Agra road quarry	Do.	—	—	78.31	57.04	14.3	.013	Nil

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonates) Per cent
96	Bombay	Mile No. 40/4 Bhiwandi quarry, Andheri sub-division	Soft boulders mixed with soil	—	—	48.69	14.57	1.2	.0225	12.00
97	Do.	Mile No. 41/6 Bhiwandi quarry, Andheri sub-division	Soil sample	—	—	61.20	22.04	2.93	.0225	6.4
98	Do.	Mile No. 37/4 Bhiwandi quarry, Andheri sub-division	Do.	—	—	57.10	19.79	2.50	.042	6.00
99	Do.	Mile No. 38/6 Bhiwandi quarry, Andheri sub-division	Do.	—		57.81	18.31	1.5	.031	Nil
100	Do.	Mile No. 39/6 Bhiwandi quarry, Andheri sub-division	Disintegrated rock	—	—	49.55	19.15	8.2	.035	2.80
101	Do.	Mile No. 14/3 Khodala-Mukhada road, Kawal Puda Peta village, Thana District	Medium hard lumps of soil	—	—	77.79	36.78	11.6	.0445	2.40
102	Do.	Mile No. 13/6 Khodala-Mukhada road, Kawal Puda Peta village, Thana District	Stones with cavities and black deposits	31.12	—	Non plastic		40.6	.015	5.20
103	Do.	Mile No. 37/1, Khodala Mukhada road, Kawal Puda Peta village, Thana District	Disintegrated rock	—	—	71.82	25.82	3.7	.021	6.80
104	Do.	Mile No. 28/8 Dhanu Jawhar-Mukhada road, Thana Dist.	Do.	—	—	51.94	18.09	31.7	.011	4.80
105	Do.	Mile No. 29/2 Dhanu Jawhar Mukhada road, Thana District	Soft stone with black and white deposits	—	—	51.35	25.04	23.6	.0105	3.20
106	Do.	Mile No. 24/3 and 24/4 Dhanu Jawhar Mukhada road, Thana District	Disintegrated rock	—	—	50.30	22.80	42.3	.026	9.60
107	Do.	Mile No. 17/6, Dhanu Jawhar Mukhada road, Thana Distt.	Do.	—	—	43.06	19.26	32.7	.0255	5.20
108	Do.	Mile No. 11/8, Talwada Vikram garh road, Jawhar Taluq, Thana Distt.	Do.	31.40	—	49.27	16.07	65.5	.021	2.00
109	Do.	Mile No. 14/6, Dhanu Jawhar Mukhada road, Thana Distt.	Do.	20.74	23.63	Non plastic		96.40	.035	0.40

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Soluble salts Per cent	Insoluble salts (carbonate) Per cent
110	Bombay	Chiplaur sub-division, Ratnagiri District, Bombay State	Do.	28.50	—	Non plastic		88.00	.0175	2.40
111	Do.	Do.	Do.	37.4	41.81	Non plastic		87.6	.01	Nil
112	Poona	N.L.B.C. Mile No.42/2 Hatarna village, Indapur Taluq, Poona District	Sand stone with light violet colour	39.80	—	29.90	8.19	26.70	.026	6.40
113	Do.	Mile No. 42, Hadaspur-Nira road	Laterite stone	23.28	26.54	Non plastic		91.50	.030	1.60
114	Do.	Mile No. 8/5, I.A.S. road, Barda village, Indapur Taluq	Disintegrated rock mixed with fine material	39.00	—	35.40	11.60	80.4	.020	Nil
115	Do.	Mile No. 5/2, I.N. road, Nimgaon Section	Disintegrated rock	19.70	22.77	Non plastic		4.7	.030	7.20
116	Do.	Along (Mutha left bank canal of Yerandavane village)	Do.	34.20	38.37	Do		92.3	.0225	4.00
117	Do.	Along (Mutha left bank canal, Bhamburda village)	Do.	26.80	30.41	Do		94.6	.0165	Nil
118	Do.	Yeshgam quarry and Kopargaon Taluq, Nagar District	Stones with fine grey material	26.75	30.41	Non plastic		81.3	.144	6.00
119	Do.	Quarry at Mirag-Bombay State	Stones with cavities	34.20	38.37	Do.		11.7	.0165	3.6
120	Do.	Quarry at Nirag-Bombay State	Stone boulders with fine material	20.70	—	Do.		84.0	.020	2.8
121	Do.	Mile 115/1 of Mahad-Pandapur road, Malshivas Taluq, Sholapur District	Lime stone mixed up with fine material	17.50	20.40	Do.		95.9	.049	5.2
122	Do.	Mile 115/1 of Mahad-Pandapur road, Malshivas Taluq, Sholapur District	Disintegrated rock	20.54	23.63	Do.		99.21	.039	3.6
123	Do.	Bhilkati village, Phaltan Taluq. North Satara District	Do.	37.43	44.50	Do.		90.40	.0325	2.80
124	Do.	Raodi village, Phaltan Taluq, North Satara District	Do.	11.90	14.38	Do.		98.1	.1175	1.20
125	Do.	Tadavali village, Phaltan Taluq North Satara District	Do.	26.71	30.30	Do.		74.7	.035	14.80
126	Do.	Hillock at Phaltan, Phaltan Taluq North Satara District	Do.	27.70	—	Do.		96.2	.11	7.6
127	Aurangabad	Melarun Quarry one mile from Jalgam city	Brownish stones	24.34	—	Do.		99.1	.10	Nil
128	Do.	Khangaon, Khangaon sub-division Aurangabad Division	Stone pieces (Brownish)	27.90	—	Do.		99.3	—	4.0

TABLE 1—(*contd.*)

S. No.	Division	Location of quarry	Visual inspection	Aggregate impact value Per cent	Aggregate Los Angeles value Per cent	Liquid limit Per cent	Plasticity index Per cent	Coarse fraction Per cent	Solube salts Per cent	Insoluble salt (carbonates) Per cent
129	Aurangabad	Atkal-Madan Road, Akola Beat.	Typical moorum	—	—	53.40	23.70	60.0	.024	0.40
130	Do.	Jail quarry, Akola District, Akola	Black stone mixed up with fine material of dark red colour	40.40	—	26.90	10.40	10.4	.112	5.2
131	Do.	Jalgaon quarry on Amroti Burhanpur road, Amroti District.	Typical moorum	27.40	—	42.80	29.90	83.3	.0465	3.6
132	Do.	Sukli quarry in Amroti Burhampur road, Amroti District	Disintegrated rock	—	—	41.50	13.70	49.1	.095	18.6
133	Do.	Quarry in mile 7, furlong 2, Achalpur-Akalkot road, Amravati District	Do.	—	—	43.60	14.10	22.0	.0415	22.0
134	Do.	Quarry in mile 10, furlong 2, Achalpur-Batul road, Amravati District	Grey stone mixed up with fine material	26.06	—	33.90	11.70	91.2	.0665	5.6
135	Do.	Quarry in mile 5, furlong 8, Amravati, Burhanpur road, Amravati District	Stones	20.30	—	Non plastic		92.1	.02	5.2
136	Do.	Yeotmal sub-division I, P.W.D. Yeotmal	Black stones with soft touch	37.30	—	Do.		84.7	.084	4.8
137	Do.	P.W.D. Division III, Yeotmal	Coarse aggregate with fine material	43.70	—	70.4	37.2	69.1	.049	9.6
138	Do.	Subdivision P.W.D., Wardha	Black stone with soft touch	23.30	—	Non plastic		96.2	0.69	1.2
139	Do.	Boregam quarry, Nagpur	Soft stone with white and grey deposits	—	—	62.80	27.02	18.0	.17	11.2
140	Do.	Bala Ghat Division, Bhandara District	Typical moorum	38.00	—	44.68	21.44	76.6	.11	Nil
141	Do.	Bhandara sub-division, Bhandara	Do.	—	—	70.27	33.27	76.7	.026	Nil
142	Do.	Bhandara sub-division, Bhandara	Do.	—	—	71.16	43.60	71.8	.026	Nil
143	Do.	Chanda sub-division	Chocolate soil with coarse material	38.10	—	28.00	13.70	30.0	.13	2.0
144	Do.	Gangapur Dam site, Gangwadi, Nasik District	Slate material	30.0	33.85	24.60	10.80	92.3	.021	11.60
145	Do.	Do.	Crushed stone with fine material	23.85	—	39.10	22.80	74.8	.0325	12.80
146	Do.	Place not mentioned	Stone samples	17.96	20.94	Non plastic		94.6	.026	Nil
147	Do.	Do.	Stone with cavities	—	—	49.70	11.69	12.8	.03	0.80
148	Do.	Do.	Stone with green deposits	—	—	42.90	7.00	1.8	.03	5.60

TABLE 2

Mechanical analysis of samples tested

S. No.	Per cent passing sieve: 3 in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	¼ in.	$\frac{3}{16}$ in.	⅛ in.	10 mesh	20 mesh	40 mesh	60 mesh	100 mesh	200 mesh	.05 mm.	.005 mm.	.001 mm.
1	—	—	—	—	—	—	100.0	96.5	94.7	92.1	85.4	72.2	66.3	59.2	55.2	47.3	37.62	8.22	2.94
2	—	—	—	100.0	97.4	94.0	93.3	89.2	85.7	78.2	68.0	58.1	54.4	51.8	49.3	44.8	23.67	8.15	4.33
3	—	—	—	—	—	100.0	99.5	97.7	96.7	95.6	94.7	93.2	91.5	89.3	83.1	26.2	20.02	8.41	4.85
4	—	—	—	100.0	95.5	84.5	63.4	31.4	11.7	1.9	.87	.84	.81	.79	.78	.62	Not	done	
5	—	—	—	—	—	—	100.0	98.2	97.3	96.3	95.2	93.6	92.0	89.9	83.2	56.8	47.71	16.15	10.48
6	—	—	—	—	100.0	93.9	91.9	83.2	78.3	73.5	69.1	64.9	58.6	52.7	43.9	33.9	30.39	12.05	7.25
7	—	—	—	—	—	100.0	74.40	54.50	49.17	44.60	40.40	36.05	31.50	26.13	19.31	14.30	9.68	3.96	2.69
8	—	—	—	—	—	100.0	96.0	95.0	94.0	93.2	92.9	92.2	90.2	87.5	84.0	76.6	75.22	10.03	9.70
9	—	—	—	—	100.0	93.9	88.6	83.5	81.5	79.2	77.9	77.1	75.1	69.7	63.7	45.5	35.20	11.70	6.27
10	—	—	—	—	—	—	100.0	97.6	95.8	92.2	88.3	85.7	78.7	74.6	68.8	58.0	45.17	24.79	9.64
11	—	—	—	100.0	91.1	77.0	72.8	67.7	65.6	63.4	61.0	58.2	54.9	50.9	47.6	41.6	40.0	10.1	4.5
12	—	—	—	100.0	95.5	93.3	90.4	85.2	82.2	77.6	72.6	65.6	60.4	56.8	53.4	47.3	47.3	11.33	6.92
13	—	—	—	100.0	96.8	93.5	92.2	84.3	78.9	71.7	63.7	56.2	52.3	49.8	47.4	38.1	32.54	10.31	2.68
14	—	—	—	100.0	91.0	88.5	87.1	81.9	78.8	77.1	74.8	71.5	68.3	65.8	63.2	57.7	55.91	9.02	2.74
15	—	—	—	—	—	100.0	99.2	94.8	89.6	78.3	64.7	48.2	37.7	32.2	27.4	21.8	16.27	7.45	2.78
16	—	—	—	—	—	—	100.0	99.6	97.4	87.2	69.9	50.9	42.9	39.5	36.8	32.9	21.75	12.68	6.03
17	—	—	—	—	—	100.0	99.1	94.9	90.8	80.8	66.7	48.6	38.8	33.6	28.9	23.6	16.52	8.22	4.36
18	—	—	—	—	—	—	100.0	96.6	92.7	90.4	87.9	85.3	83.6	82.3	78.6	51.3	47.5	20.4	10.2
19	—	—	—	—	—	100.0	100.0	97.7	95.6	92.3	86.9	81.1	77.0	75.2	73.8	71.0	68.3	15.3	8.7
20	—	—	—	—	—	—	—	—	100.0	99.7	98.7	93.6	88.2	83.0	77.0	55.0	47.7	20.3	12.4
21	—	—	100.0	93.5	87.3	82.2	79.0	76.9	76.4	75.9	75.3	73.4	66.2	58.4	50.2	34.7	31.5	9.2	7.8
22	—	—	—	—	100.0	98.0	96.8	96.3	96.1	95.6	94.5	90.9	87.9	85.3	82.9	73.7	70.3	13.8	3.7
23	—	—	—	100.0	86.2	72.4	70.3	68.1	66.8	66.7	66.5	65.2	61.8	56.9	53.1	44.0	34.2	4.5	0.3
24	—	—	100.0	92.8	84.6	78.8	76.5	70.7	68.0	65.2	62.9	61.0	59.6	58.1	56.1	48.5	45.8	13.8	5.1
25	—	—	100.0	88.4	82.3	79.5	79.4	74.0	72.2	70.5	68.3	65.0	57.1	47.3	34.5	18.7	16.7	4.1	0.9
26	—	—	—	100.0	96.0	88.4	85.9	83.6	80.9	78.7	76.7	74.0	70.5	67.0	63.5	56.2	54.1	6.4	2.0
27	—	—	100.0	88.2	88.2	79.1	73.7	70.8	68.9	67.0	63.4	54.3	48.0	44.9	42.9	35.4	28.7	11.6	5.2
28	—	—	—	—	—	—	100.0	99.8	99.5	97.8	84.2	54.0	41.9	38.2	35.9	31.9	31.3	22.1	12.8
29	—	—	—	—	—	—	100.0	98.6	96.1	88.8	65.0	34.6	19.1	13.1	9.6	6.6	6.5	3.1	1.5
30	—	—	—	—	100.0	94.5	94.5	92.8	92.0	91.0	88.3	72.4	54.9	40.0	31.2	23.5	23.2	7.2	2.7
31	—	—	—	100.0	95.7	95.7	92.5	86.0	79.4	69.5	56.6	42.0	37.8	34.9	32.8	23.1	22.7	12.1	5.5
32	—	—	—	100.0	90.8	88.8	85.3	80.4	76.7	73.0	69.8	64.5	50.5	37.0	26.8	17.7	17.1	5.0	2.2

TABLE 2—(*contd.*)

S. No.	Per cent passing sieve																		
	3 in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	¼ in.	$\frac{3}{16}$ in.	⅛ in.	10 mesh	20 mesh	40 mesh	60 mesh	100 mesh	200 mesh	.05 mm.	.005 mm.	.001 mm.
33	—	—	—	—	—	100.0	99.4	99.2	99.1	98.5	97.7	95.0	91.0	87.0	84.4	69.3	57.4	10.0	4.2
34	—	—	100.0	78.3	75.0	72.9	72.6	72.3	72.0	71.6	71.3	70.1	67.7	66.1	64.5	61.5	59.3	7.2	1.8
35	—	—	100.0	68.4	52.4	44.4	42.0	36.1	34.2	32.3	30.6	29.2	28.1	26.2	23.2	17.7	16.4	4.6	1.8
36	—	—	—	—	100.0	97.6	97.0	92.7	89.8	84.9	75.3	51.8	22.0	11.5	8.1	6.4	—	—	—
37	—	—	—	—	—	100.0	98.0	95.0	91.4	82.8	61.0	18.2	6.1	4.7	4.2	3.7	—	—	—
38	—	—	—	—	100.0	99.0	96.4	91.0	86.3	78.0	65.9	51.0	39.0	31.5	26.0	21.6	21.0	14.7	3.8
39	—	—	—	—	100.0	97.7	97.3	96.9	96.4	95.0	87.4	69.2	46.7	37.1	29.8	21.5	20.7	14.4	8.7
40	—	—	—	—	—	100.0	98.6	90.0	80.1	67.2	54.6	43.1	38.7	36.6	34.6	32.3	28.54	12.01	5.04
41	—	—	—	—	—	100.0	98.4	93.3	89.1	82.5	71.4	53.6	43.2	34.8	23.0	17.0	12.48	5.32	2.43
42	—	—	—	—	—	—	—	—	—	100.0	98.9	95.8	90.1	83.1	73.4	59.2	32.09	31.64	5.31
43	—	—	—	—	—	—	100.0	98.8	97.3	94.0	89.3	82.4	77.6	73.7	66.4	51.6	51.55	23.74	9.29
44	—	—	—	—	—	100.0	97.8	91.8	87.7	84.6	81.5	77.0	73.2	71.0	68.1	60.8	54.12	27.87	11.82
45	—	—	—	—	—	—	—	—	—	100.0	99.3	98.8	97.6	96.1	92.4	86.4	72.65	37.32	14.34
46	—	—	—	—	—	100.0	98.2	94.7	92.2	89.7	86.8	83.7	81.1	78.8	75.5	60.2	59.7	24.6	12.9
47	—	—	—	—	—	100.0	94.4	90.9	90.0	89.0	88.0	86.2	94.4	81.8	74.2	48.7	45.9	8.1	3.4
48	—	100.0	82.4	82.4	82.4	81.0	78.1	75.8	72.5	68·7	65.0	60.7	55.9	51.1	46.1	35.5	30.9	11.9	5.9
49	—	—	100.0	93.4	87.9	78.9	76.1	69.7	67.1	64.6	62.0	58.3	55.2	52.7	49.3	36.4	32.7	5.3	2.6
50	—	—	—	100.0	89.1	75.8	70.6	65.0	61.2	54.5	50.8	47.5	45.3	43.3	40.5	32.9	30.2	7.2	3.4
51	—	—	100.0	88.1	86.4	79.1	74.7	70.9	68.9	66.8	64.7	62.8	60.5	57.6	54.3	43.6	40.8	17.4	5.8
52	—	—	—	—	100.0	91.7	86.3	76.2	71.8	67.8	64.2	59.9	57.0	54.8	52.6	46.9	40.1	6.9	0.3
53	—	—	—	100.0	95.6	94.6	92.2	85.5	81.4	77.4	74.2	71.0	68.2	65.4	62.6	53.9	48.7	17.7	8.5
54	—	—	—	—	—	100.0	80.9	57.6	45.1	34.4	24.4	17.1	13.7	12.2	10.8	8.8	7.98	4.53	6.8
55	—	—	100.0	84.9	67.2	41.4	27.9	14.8	10.50	7.6	6.1	4.4	3.4	2.8	2.1	1.6	Not done		
56	—	—	—	—	—	100.0	97.79	82.29	59.84	35.89	19.57	11.81	8.78	6.78	5.45	3.88	Do.		
57	—	—	—	—	—	—	100.0	98.2	94.8	87.4	74.8	54.8	44.3	40.0	35.1	24.7	15.07	3.02	1.16
58	—	—	—	—	100.0	97.5	92.0	82.2	76.8	66.7	51.7	34.4	25.4	21.3	17.8	13.6	8.53	2.92	1.04
59	—	—	—	—	100.0	95.7	87.2	66.0	51.2	37.9	49.7	37.3	33.3	31.6	30.3	28.8	23.6	11.34	5.43
60	—	—	—	—	—	—	100.0	99.8	98.4	96.1	93.8	92.2	91.3	90.2	87.9	78.4	66.7	32.3	12.5
61	—	—	—	100.0	93.8	86.8	73.4	62.1	53.7	45.7	39.3	35.0	33.5	33.0	32.6	32.0	31.0	19.5	14.6
62	—	—	100.0	86.7	79.5	75.4	61.8	41.3	34.4	28.4	23.7	20.7	19.3	18.2	16.8	13.8	12.8	4.2	1.8
63	—	—	—	—	—	100.0	99.8	94.1	84.9	78.8	78.3	77.3	76.4	75.6	73.5	51.6	47.2	18.4	8.2
64	—	—	100.0	84.2	84.2	81.9	80.9	79.8	79.4	6.0	5.4	4.2	3.6	3.4	3.3	3.0	—	—	—

TABLE 2—(*contd.*)

S. No.	Per cent passing sieve																		
	3 in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	¼ in.	$\frac{3}{16}$ in.	⅛ in.	10 mesh	20 mesh	40 mesh	60 mesh	100 mesh	200 mesh	.05 mm.	.005 mm.	.001 mm.
65	—	—	100.0	87.2	75.1	60.5	49.7	38.5	32.3	26.3	19.7	12.7	8.5	6.7	5.5	4.4	2.06	.525	.153
66	—	—	—	—	100.0	98.5	85.1	69.7	61.02	50.8	38.5	25.1	20.6	18.7	16.3	11.5	7.04	1.44	.515
67	—	—	—	—	—	—	100.0	99.9	99.8	99.3	97.5	82.5	60.5	48.3	36.4	20.8	16.00	3.085	1.43
68	—	—	—	—	—	—	—	100.0	99.1	95.8	88.0	76.4	66.9	60.7	54.4	44.5	36.8	14.9	5.3
69	—	—	—	—	100.0	96.2	91.7	81.0	72.1	60.8	48.7	37.8	31.7	28.7	26.2	20.6	18.8	4.2	1.4
70	—	—	—	—	—	100.0	99.1	98.6	98.2	96.1	80.8	60.2	55.1	54.0	52.7	42.8	40.0	11.0	3.6
71	—	—	—	—	—	100.0	99.1	97.9	95.7	91.4	79.3	64.5	46.3	35.7	28.4	17.0	14.7	3.0	0.8
72	—	—	—	—	—	100.0	96.8	82.1	71.9	61.8	54.7	48.6	43.1	38.4	33.1	23.0	20.8	3.7	1.3
73	—	—	—	—	—	100.0	99.4	95.8	90.31	82.2	72.4	65.0	60.8	58.2	55.1	44.5	42.6	10.2	3.5
74	—	—	—	—	100.0	92.9	90.4	80.8	78.1	74.07	70.5	67.0	65.6	64.2	58.5	37.4	34.4	6.5	1.7
75	—	—	—	100.0	82.8	84.0	74.1	67.1	60.8	50.1	40.4	33.2	29.4	26.7	23.5	18.5	16.4	3.6	1.6
76	—	—	—	100.0	95.6	94.5	92.9	84.2	79.1	72.4	61.1	46.9	40.1	36.8	33.4	23.5	20.9	2.1	1.5
77	—	—	—	—	—	—	100.0	98.5	96.9	91.1	80.8	69.5	62.9	59.8	56.8	49.9	47.4	16.1	6.1
78	—	—	—	—	—	100.0	98.6	93.1	88.3	78.9	64.8	49.9	43.3	40.9	39.0	34.2	33.6	14.9	6.1
79	—	—	—	—	100.0	84.1	75.0	60.6	54.5	48.1	38.0	28.3	25.7	24.1	22.4	18.8	15.8	8.3	2.2
80	100.0	75.8	47.2	16.6	10.4	8.4	7.0	5.6	5.2	4.7	4.5	4.2	4.0	3.9	3.8	3.5	—	—	—
81	—	—	—	100.0	92.6	83.1	81.0	75.9	72.5	68.5	60.8	59.6	52.0	47.1	42.4	33.5	28.7	5.5	0.9
82	—	100.0	81.7	58.0	53.2	39.1	31.8	24.4	20.6	15.9	10.0	4.9	3.0	2.4	2.1	1.2	—	—	—
83	—	—	—	100.0	94.6	91.8	84.0	72.3	65.3	61.4	52.0	41.8	36.3	33.8	31.6	26.5	23.9	3.9	0.5
84	—	100.0	50.4	38.2	30.5	18.2	11.6	7.2	6.3	5.4	4.6	4.2	3.9	3.7	3.5	3.1	—	—	—
85	—	100.0	83.9	77.5	53.2	35.9	30.2	24.1	21.3	17.9	14.1	11.2	9.3	8.1	6.9	5.0	—	—	—
86	—	—	100.0	95.2	92.8	87.7	83.5	78.4	72.2	61.9	51.6	43.6	40.0	38.5	37.1	34.5	28.0	10.5	3.1
87	—	—	—	—	—	—	—	—	100.0	99.6	98.4	75.9	55.6	42.6	31.8	18.0	17.6	4.5	1.4
88	—	—	—	—	100.0	97.2	96.0	92.4	89.6	86.4	79.4	69.2	62.0	56.3	49.2	36.4	34.0	10.0	3.9
89	—	—	—	—	100.0	93.3	89.5	84.7	79.9	74.6	61.1	43.4	39.3	37.2	35.1	30.1	29.7	14.5	7.2
90	—	—	—	—	100.0	95.8	95.8	95.8	95.8	95.8	95.7	94.8	87.4	79.7	70.4	53.4	49.9	12.1	2.2
91	—	—	—	—	—	—	—	100.0	99.6	99.2	98.7	96.3	88.5	84.5	80.1	71.6	69.8	34.0	14.0
92	—	—	—	—	—	100.0	98.6	92.7	87.4	79.0	70.2	59.4	50.6	47.1	44.0	33.7	31.7	8.1	1.9
93	—	—	—	—	—	—	100.0	99.6	99.5	99.0	93.1	68.2	66.8	61.7	57.6	49.8	47.5	16.6	6.7
94		—	—	—	100.0	99.1	95.0	86.9	82.6	74.5	66.5	60.5	57.7	55.5	53.3	50.0	49.7	36.0	26.1
95	—	—	—	—	—	—	100.0	99.5	97.2	92.3	85.7	79.3	77.7	77.2	77.0	76.3	75.9	50.9	34.3
96	—	—	—	—	—	—	—	—	100.0	99.61	98.85	92.62	80.15	71.66	62.09	44.16	43.53	7.33	1.19
97	—	—	—	—	—	—	—	100.0	99.60	98.34	97.07	95.02	93.46	91.80	88.82	75.85	71.78	13.53	2.77
98	—	—	—	—	—	—	—	—	—	100.0	97.51	95.00	90.79	87.32	81.98	72.38	71.97	17.21	3.02
99	—	—	—	—	—	—	—	100.0	99.86	99.66	98.57	95.22	98.74	82.36	76.38	64.02	63.52	13.50	3.30

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TABLE 2—(*contd.*)

S. No.	Per cent passing sieve																		
	3 in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in.	$\frac{1}{8}$ in.	10 mesh	20 mesh	40 mesh	60 mesh	100 mesh	200 mesh	.05 mm.	.005 mm.	.001 mm.
100	—	—	—	—	—	—	—	100.0	99.41	97.51	91.84	84.97	78.97	71.79	62.20	41.69	39.50	7.44	2.40
101	—	—	—	—	—	—	—	100.0	98.3	94.9	88.4	78.8	71.2	66.9	62.9	55.0	54.5	30.1	17.7
102	—	—	—	100.0	96.8	88.7	83.8	74.8	69.7	64.5	59.4	52.6	46.5	42.7	37.8	27.3	26.1	5.3	1.2
103	—	—	—	—	—	—	—	100.0	99.7	85.8	68.3	50.3	41.2	36.8	32.5	25.9	25.5	5.4	2.1
104	—	—	—	—	—	—	100.0	99.2	95.9	85.7	68.3	50.3	41.2	36.8	32.5	25.9	25.4	5.4	2.1
105	—	—	—	100.0	96.6	94.0	93.8	90.8	87.4	82.7	76.4	67.5	59.5	54.0	49.0	40.7	40.4	11.8	4.8
106	—	—	—	—	—	—	100.0	97.8	92.7	78.0	57.7	38.8	31.2	28.1	25.1	19.0	18.7	3.9	1.4
107	—	—	—	—	—	—	100.0	98.4	95.7	86.8	67.3	48.0	0.7	36.7	31.8	22.5	20.7	5.0	1.4
108	—	—	—	—	100.0	89.8	81.6	67.1	60.1	48.3	34.5	22.1	16.7	14.8	13.3	10.5	10.0	2.5	1.0
109	—	—	100.0	71.3	49.2	20.8	11.3	6.1	5.4	4.3	3.6	3.1	2.7	2.3	1.9	1.4	—	—	—
110	—	100.0	77.9	58.6	41.8	31.4	25.2	20.9	18.8	15.8	12.0	8.2	6.2	4.7	3.6	2.7	—	—	—
111	—	—	100.0	75.9	75.9	44.0	29.8	17.8	14.6	13.1	12.4	11.8	11.6	11.4	11.3	11.0	10.5	6.9	5.0
112	—	—	—	—	100.0	97.3	90.9	82.9	79.2	76.5	74.3	70.0	60.8	48.4	36.2	16.8	13.5	2.0	0.8
113	—	—	100.0	86.0	86.0	61.1	54.5	32.3	22.2	13.0	8.5	5.5	5.5	5.9	4.9	4.2	—	—	—
114	—	—	100.0	63.5	52.8	39.3	33.7	28.2	25.4	22.9	19.6	16.4	14.0	12.0	10.6	9.0	7.9	2.4	1.5
115		—	—	—	—	100.0	99.8	99.4	98.9	98.4	95.3	58.3	21.0	12.2	9.3	7.0	—	—	—
116	—	100.0	85.4	55.9	53.3	40.6	28.1	18.5	15.0	10.7	7.7	5.2	4.0	2.9	2.4	2.0	—	—	—
117	—	100.0	70.1	60.4	53.6	38.9	26.1	15.5	12.4	8.5	5.4	3.4	2.8	2.4	2.0	1.5	—	—	—
118	—	—	100.0	90.1	80.9	67.4	41.9	38.7	34.9	27.9	19.7	10.0	8.2	3.7	2.7	1.6	1.6	.29	.123
119	—	—	—	—	—	—	100.0	99.0	97.5	94.1	89.3	76.4	61.6	47.9	33.5	18.5	17.4	3.0	0.8
120	—	69.1	57.3	35.7	35.7	28.8	26.7	24.5	22.4	19.0	16.0	13.5	11.2	9.4	7.9	6.3	—	—	—
121	—	—	100.0	95.2	84.4	60.4	41.0	17.6	9.9	5.9	4.1	3.0	2.6	2.5	2.3	2.1	Not done		—
122	100.0	49.8	26.0	12.5	7.8	4.7	3.1	1.8	1.1	.82	.79	.54	.40	.36	.33	.29	Not done		—
123	—	—	100.0	89.0	57.0	36.4	28.6	17.9	14.5	11.6	9.6	7.6	6.1	5.0	4.0	3.0	Do.		—
124	100.0	90.3	90.3	70.6	39.7	17.4	8.9	4.4	3.1	2.4	1.9	1.4	1.0	0.87	0.73	0.54	Do.		—
125	—	—	—	100.0	96.4	86.0	74.7	56.3	45.8	33.8	25.3	17.3	13.0	11.0	9.4	7.3	5.04	1.27	.637
126	100.0	81.9	71.5	56.6	33.8	20.3	15.4	11.0	8.2	5.8	3.8	2.2	1.3	.89	.66	.44	Not done		—
127	—	100.0	95.9	65.0	42.2	17.3	8.0	3.0	1.7	1.2	.9	.69	.60	.53	.45	.29	Do.		—
128	—	—	100.0	69.6	51.1	24.4	10.5	3.7	2.05	1.1	0.7	0.5	0.47	0.45	0.4	0.3	Do.		
129	—	—	—	—	100.0	92.7	81.9	61.1	53.8	45.7	40.0	29.9	27.6	25.6	22.9	19.7	17.35	10.31	6.96
130	—	—	100.0	89.8	75.1	64.8	53.9	42.6	37.8	33.8	82.0	77.5	72.0	66.7	56.3	34.3	34.16	7.04	.23
131	—	—	—	—	100.0	92.9	87.8	68.4	52.7	32.3	16.7	11.0	9.9	9.5	9.3	8.8	5.45	3.12	.142
132	—	—	—	100.0	96.7	82.9	75.5	68.1	64.1	58.8	50.9	42.3	36.3	33.0	28.6	20.5	18.56	5.64	.21
133	—	—	—	—	—	100.0	98.6	94.2	90.1	85.1	78.0	69.2	62.2	56.2	45.6	30.6	17.81	10.73	6.12

TABLE 2—(*concld.*)

S. No.	Per cent passing sieve: 3 in.	2 in.	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in.	$\frac{1}{8}$ in.	10 mesh	20 mesh	40 mesh	60 mesh	100 mesh	200 mesh	.05 mm.	.005 mm.	.001 mm.
134	—	—	100.0	92.6	81.7	47.6	25.9	12.8	10.4	9.5	8.8	8.3	8.0	7.9	7.8	7.6	4.10	1.23	.53
135	—	—	—	100.0	89.4	69.4	50.9	29.9	20.7	13.7	7.9	4.4	3.0	2.3	1.6	.7	Not	done	—
136	—	—	100.0	93.5	82.5	56.7	37.4	25.4	21.1	17.7	15.3	12.8	11.6	10.7	9.8	8.4	Do.		—
137	—	—	—	100.0	92.1	74.7	60.6	47.7	41.1	35.2	30.8	26.1	22.6	20.2	18.5	16.8	14.16	7.47	4.63
138	—	100.0	93.7	80.9	61.9	46.9	24.9	13.6	9.5	6.3	3.8	1.9	1.2	0.77	0.65	0.45	Not	done	—
139	—	—	—	100.0	86.2	86.2	85.3	84.5	84.3	83.2	82.0	77.5	72.0	66.7	56.3	34.3	34.16	7.04	.23
140	—	—	—	—	—	100.0	97.78	77.68	56.60	35.27	23.43	15.92	14.76	13.90	13.13	11.93	11.11	7.83	5.59
141	—	—	—	—	100.0	85.44	73.38	56.96	46.71	33.05	23.34	16.63	14.09	12.91	12.01	10.93	10.87	6.36	2.79
142	—		—	—	—	100.0	98.14	85.66	71.06	54.19	39.93	28.22	24.18	22.90	21.88	20.50	20.32	13.62	6.77
143	—	—	—	100.0	96.4	93.3	89.2	84.0	80.3	75.4	70.0	60.9	52.4	37.9	31.50	24.3	18.43	10.2	5.3
144	—	—	100.0	83.8	68.7	51.8	34.6	22.1	16.5	11.4	7.7	5.1	2.2	1.5	1.2	0.8	Not	done	—
145	—	—	—	100.0	97.3	86.5	76.9	59.9	49.0	37.0	25.2	16.8	13.9	12.6	11.3	9.4	6.88	2.35	.906
146	—	—	100.0	72.7	51.8	20.5	13.2	9.2	7.6	6.0	5.4	4.2	3.6	3.4	3.3	3.0	—	—	—
147	—	—	—	—	—	100.0	98.86	96.41	94.35	90.85	87.25	82.47	77.28	70.60	58.39	37.28	34.06	4.30	.984
148	—	—	—	—	—	—	—	—	—	100.0	98.26	95.11	91.88	88.18	77.73	51.30	43.91	3.65	.84

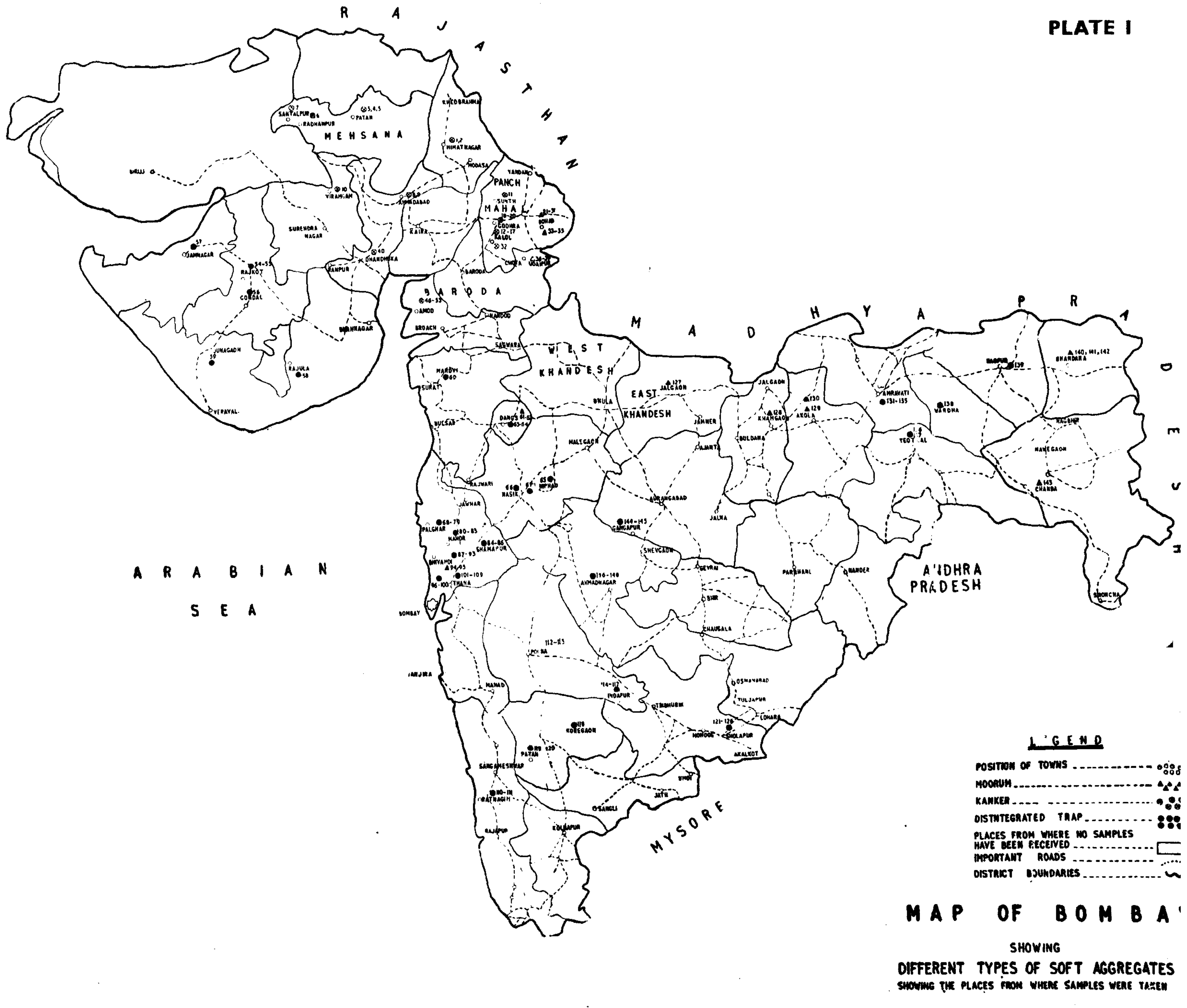
TABLE 3

Showing C.B.R. results of the samples tested

Sample No.	Division	D. B. Density lb per cu. ft.	Saturation moisture content Per cent	C.B.R. at .1″ Per cent
1	Ahmeda-bad	126.4	14.79	22.40
3	Do.	121.20	19.70	11.70
5	Do.	120.60	18.07	7.50
6	Do.	119.07	17.20	10.80
10	Do.	127.13	15.42	8.0
16	Do.	128.9	12.30	7.0
18	Do.	123.32	17.10	18.0
19	Do.	127.80	19.16	11.0
20	Do.	115.20	20.23	6.50
28	Do.	119.8	15.10	9.50
30	Do.	135.7	12.30	32.00
37	Do.	108.90	10.70	42.0
39	Do.	120.04	15.20	26.0
51	Do.	123.40	13.5	25.0
53	Do.	127.10	14.0	11.0
57	Do.	113.6	20.8	33.6
60	Bombay	113.7	22.9	9.5
61	Do.	129.8	17.0	14.0
62	Do.	126.1	16.6	57.0
63	Do.	104.5	27.9	34.0
64	Do.	117.7	21.9	12.0
67	Do.	111.0	15.20	67.0
68	Do.	111.0	20.70	24.8
70	Do.	114.0	25.60	54.5
77	Do.	104.50	20.16	26.00
78	Do.	100.90	24.85	9.00
86	Do.	105.4	25.50	26.00

TABLE 1—(*contd.*)

Sample No	Division	D. B. Density lb per cu. ft	Saturation moisture content Per cent	C.B.R. at .1" Per cent
87	Bombay	117.3	19.60	16.5
92	Do.	118.9	14.80	43.0
94	Do.	110.8	28.1	4.5
95	Do.	120.6	33.2	14.0
96	Do.	113.7	19.8	13.5
97	Do.	103.7	22.2	15.0
98	Do.	108.0	15.0	3.5
99	Do.	110.6	18.8	13.0
101	Do.	87.2	41.8	3.8
103	Do.	83.62	39.04	5.5
104	Do.	114.03	20.1	38.0
105	Do.	80.67	17.02	9.0
107	Do.	115.83	15.9	49.5
115	Poona	102.70	22.9	26.6
119	Do.	99.80	20.00	73.3
139	Auranga-bad	105.1	20.4	26.0
147	Do.	113.4	16.8	57.0
148	Do.	119.8	14.3	39.0



TRAFFIC SIGNS

1. INTRODUCTION

1.1. Traffic signs which have the backing of law in India are incorporated in the Ninth Schedule of the Indian Motor Vehicles Act, 1939. Section 75 of the Act (reproduced in Appendix 1) deals with the erection of traffic signs. The sketches of the signs given in the Ninth Schedule are not fully dimensioned and show only the overall dimensions, colour, width of the border, and the shapes of the symbols. The late Indian Stores Department had prepared detailed dimensioned drawings for the guidance of the manufacturers of traffic signs but these fully dimensioned drawings do not appear to have been published so far. These have now been modified to the metric system and are being published for general information.

1.2. A few paragraphs have been added giving suggestions on the location of the signs, the colours to be used in terms of I.S.I. standards, and the materials to be used in the manufacture of signs and their supports.

2. CLASSIFICATION OF TRAFFIC SIGNS

2.1. According to the Indian Motor Vehicles Act, traffic signs are divided into the following three categories:

(A) *Mandatory signs*, which include prohibitory signs, indicate mandates or prohibitions the compliance of which is compulsory, and the violation of which constitutes a statutory offence.

(B) *Cautionary signs* are used to warn road users of hazardous conditions either on or adjacent to the road. A cautionary sign indicates the approach to a place where caution is required.

(C) *Informatory signs* are intended to guide the road user and to give him such other information as may be of interest or use to him.

2.2. A list of the traffic signs included in the Ninth Schedule to the Act is given below. Detailed dimensioned drawings giving particulars of colours, size, and shape of symbols, etc., are given at pages 402 to 416.

(A) **Mandatory Signs**

1. Speed Limit
2. Weight Limit
3. Total Prohibition
4. Direction Sign
5. No Parking
6. Overtaking Prohibited
7. Use of Sound Signals Prohibited
8. Dead slow—Main Road Ahead

(B) **Cautionary Signs**

General Design

1. Rough Road
2. Zig-Zag (Right)
   Zig-Zag (Left)
3. Cross Roads
4. Level Crossing (Guarded)
5. Level Crossing (Unguarded)
6. Right Turn
   Left Turn
7. School
8. Dead End
9. Side Road (Right)
   Side Road (Left)
10. Steep Hill
11. Ferry
12. Hair-Pin Bend (Right)
    Hair-Pin Bend (Left)
13. Narrow Bridge

(C) **Informatory Signs**

1. Flood Gauge
2. Road Junction Approach
3. End of Speed Limit
4. Parking Sign

3. LOCATION

3.1. **Mandatory signs** No. 2, 3, 4, 5, 6 and 7 should be located in the immediate vicinity of the point where a vehicle is required to observe the mandate or prohibition indicated by the sign and, if necessary, at further points where regulation continues.

3.2. Mandatory signs No. 1 and 8 should be located as indicated in para 3.5.

3.3. **Cautionary signs** should be located as indicated in para 3.5. An additional sign in case of Cautionary Signs No. 7, "School", and No. 13, "Narrow Bridge", should be put up in the immediate vicinity of the school or narrow bridge.

3.4. **Informatory signs**: Informatory Sign No. 1, "Flood Gauge", should be placed on the upstream edge of Irish bridges or causeways at the lowest point and at suitable distances all along the Irish bridge or causeway, keeping in view the longitudinal section affected by flood water on either side of the lowest point. The marking on all the flood gauges on a causeway should indicate the depth of flow at the lowest point on the causeway.

Informatory Sign No. 2, "Road Junction Approach", should be located according to para 3.5. Informatory Sign No. 3, "End of Speed Limit", should be placed at the point where the restriction ends.

Informatory Sign No. 4, "Parking Sign", should be placed at the parking place.

3.5. Unless otherwise indicated in paras 3.1 and 3.4, traffic signs should be fixed at the following distances in advance of the hazards warned against:

(1) **In non-urban locations**:

	In plain and rolling country	In hilly or mountainous country
(i) On National and State Highways	120 metres	60 metres
(ii) On Major District Roads	90 metres	50 metres
(iii) On Other District Roads	60 metres	40 metres
(iv) On Village Roads	40 metres	30 metres

(2) **In urban locations**:

In cities warning signs should usually be placed nearer to the points of hazard than on non-urban roads.

3.6. Location of the signs with respect to the carriageway

3.6.1. On an unkerbed road, the sign should be erected at a distance of 2 to 3 metres from the edge of the carriageway depending on local circumstances, but in no case should any part of the sign come in the way of vehicular traffic.

3.6.2. On a kerbed road, the sign post should not be less than 60 cm. away from the edge of the kerb ; nor should any part of the sign be less than 30 cm. away from the edge of the kerb.

3.6.3. Traffic sign should be fixed on the left side of the road, at right angles to the pavement and facing approaching traffic. This rule, however, does not apply to Informatory Signs No. 1 and 4.

3.6.4. The signs should be so erected that the centre of the definition plate, or device plate or of the main sign when there is no definition or device plate, is 140 cm. above the crown of the carriageway. However, the lowest edge of the sign should in no case be less than 75 cm above the crown of the carriageway.

In locations where they will obstruct pedestrians, the signs should be mounted at a height of not less than 215 cm. to the lowest edge of the sign.

4. COLOURS

4.1. The signs should be painted in colours as shown on the drawings 0given at pages 402 to 416. The reverse side of all sign plates, discs, or triangles should be painted an unobtrusive grey.

4.2. The sign posts should be painted in 25 cm. bands, alternately black and white in colour. The lowest band (next to the ground) should be in black.

4.3. Colours should comply with the following I.S.I. shades given in Indian Standard No. 5—1955 on Colours for Ready Mixed Paints :

Blue	I.S.I. No. 166	French Blue
Yellow	I.S.I. No. 309	Canary Yellow
Red	I.S.I. No. 537	Signal Red
Grey	I.S.I. No. 630	French Grey

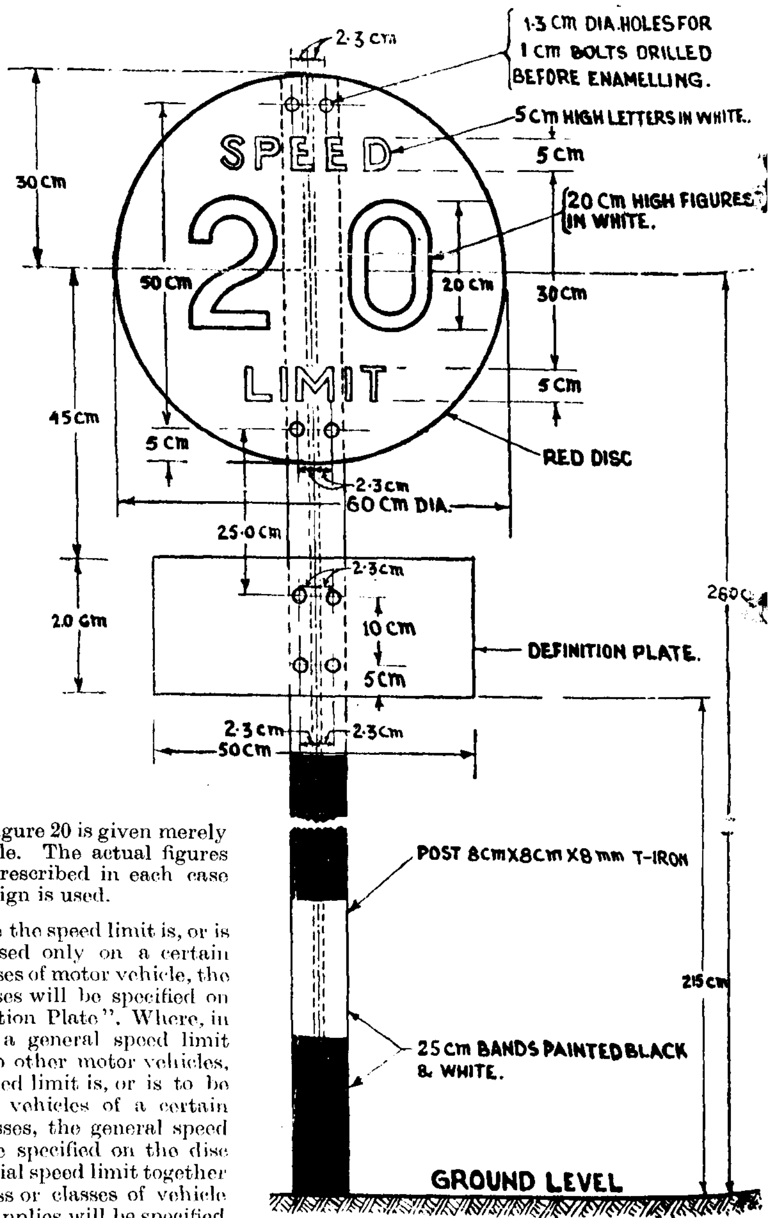
5. MATERIALS

5.1. The traffic sign plates, discs, or triangles may be made of stove-enamelled metal plate, or other suitable local materials like plywood, timber planks with or without metal sheet lining, or reinforced concrete.

5.2. The posts for traffic signs may consist of suitable mild steel sections, galvanized iron pipes (5 cm. dia.), reinforced concrete (10 cm. × 10 cm.) or timber scantlings (10 cm. × 10 cm.).

When pipes are used they should be anchored to prevent turning.

No. 1.



NOTES:

1. The Figure 20 is given merely as an example. The actual figures will be as prescribed in each case where this sign is used.

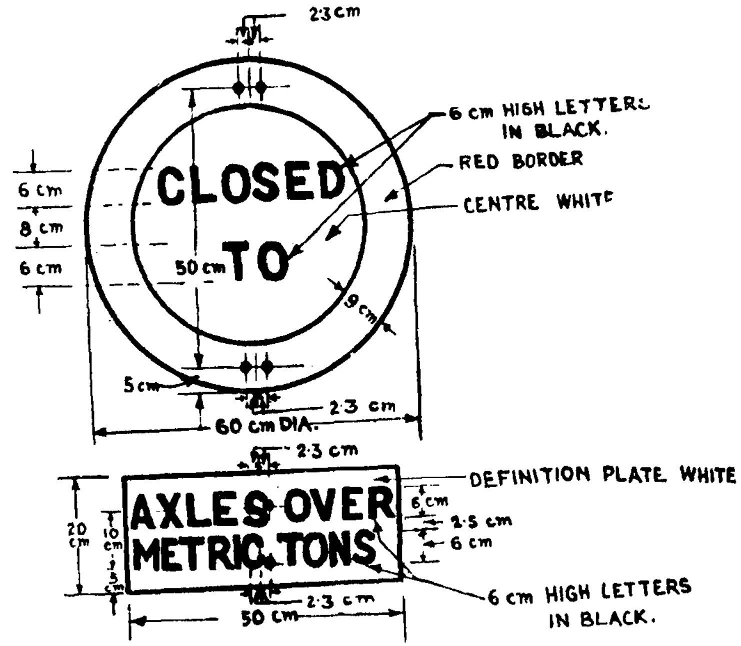
2. Where the speed limit is, or is to be, imposed only on a certain class or classes of motor vehicle, the class or classes will be specified on the "Definition Plate". Where, in addition to a general speed limit applicable to other motor vehicles, a special speed limit is, or is to be imposed on vehicles of a certain class or classes, the general speed limit will be specified on the disc and the special speed limit together with the class or classes of vehicle to which it applies will be specified on the "Definition Plate."

SPEED LIMIT

MANDATORY SIGN

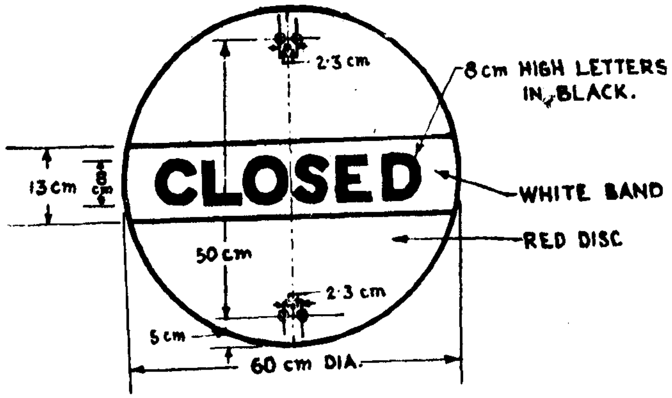
NOT TO SCALE

No. 2.



WEIGHT LIMIT

No. 3.

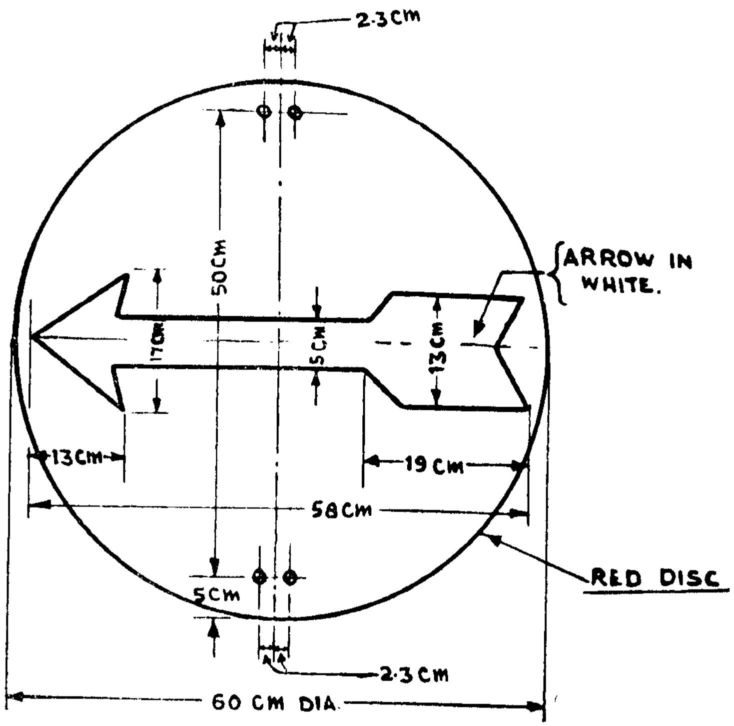


TOTAL PROHIBITION

MANDATORY SIGNS

NOT TO SCALE

No. 4.

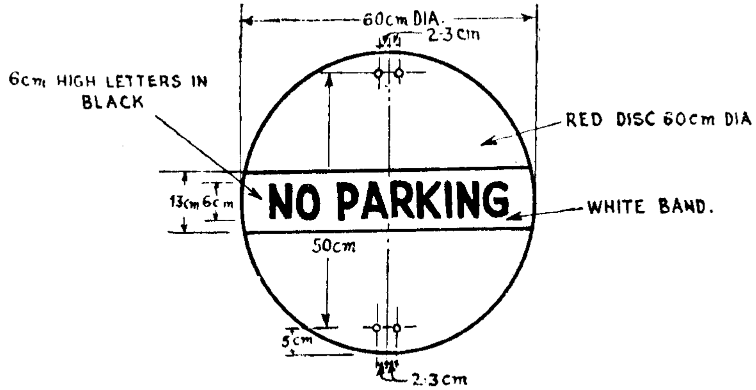


DIRECTION SIGN

MANDATORY SIGN

NOT TO SCALE

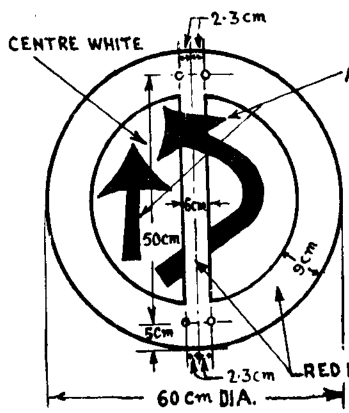
No. 5.



NOTE :—Sign No. 5 as here set forth may be amplified by instructions inscribed upon a definition plate placed below it as in the general arrangement set forth in Sign No. 1 of this part. Upon the definition plate may be set forth the times during which parking is prohibited. In like manner, an arrow-head inscribed on the definition plate will indicate that parking is prohibited on that part of the street or road lying to the side of the sign to which the arrow-head points.

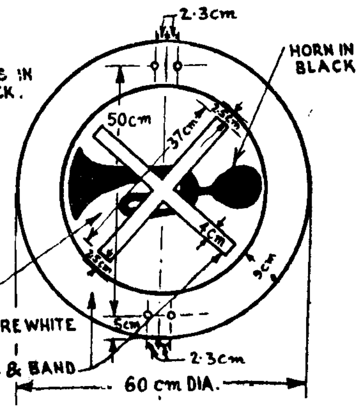
NO PARKING

No. 6.



OVERTAKING PROHIBITED

No. 7.

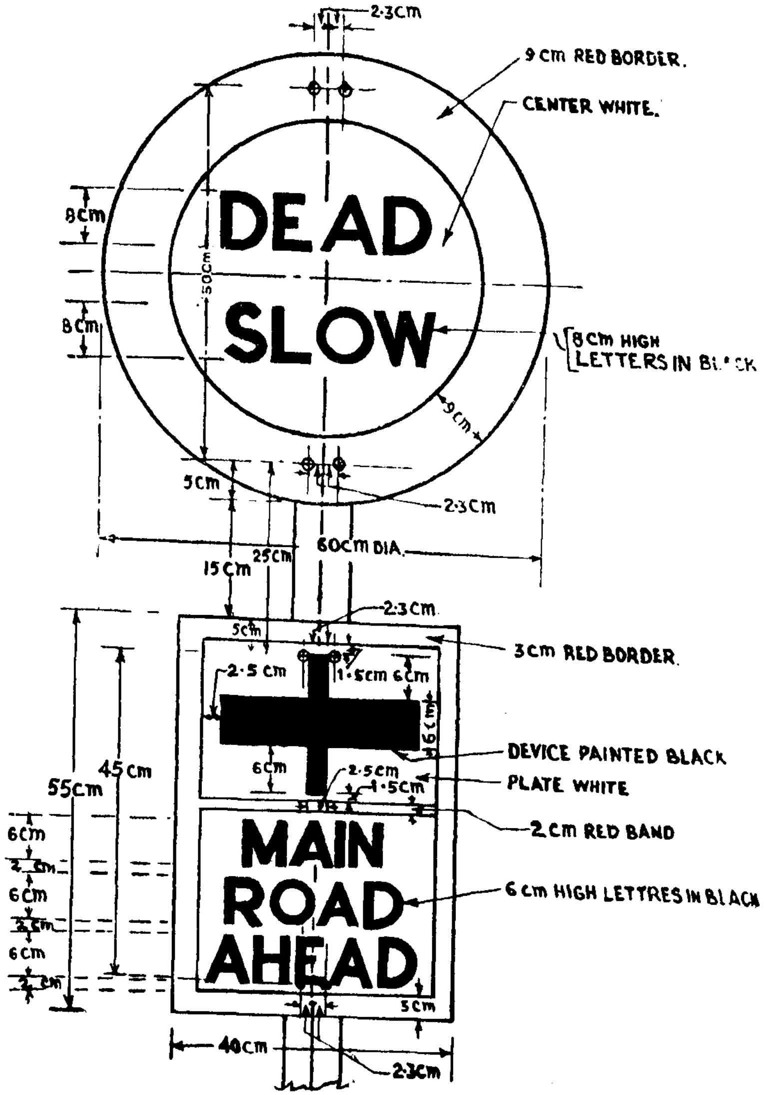


USE OF SOUND SIGNALS PROHIBITED

MANDATORY SIGNS

NOT TO SCALE

No. 8.

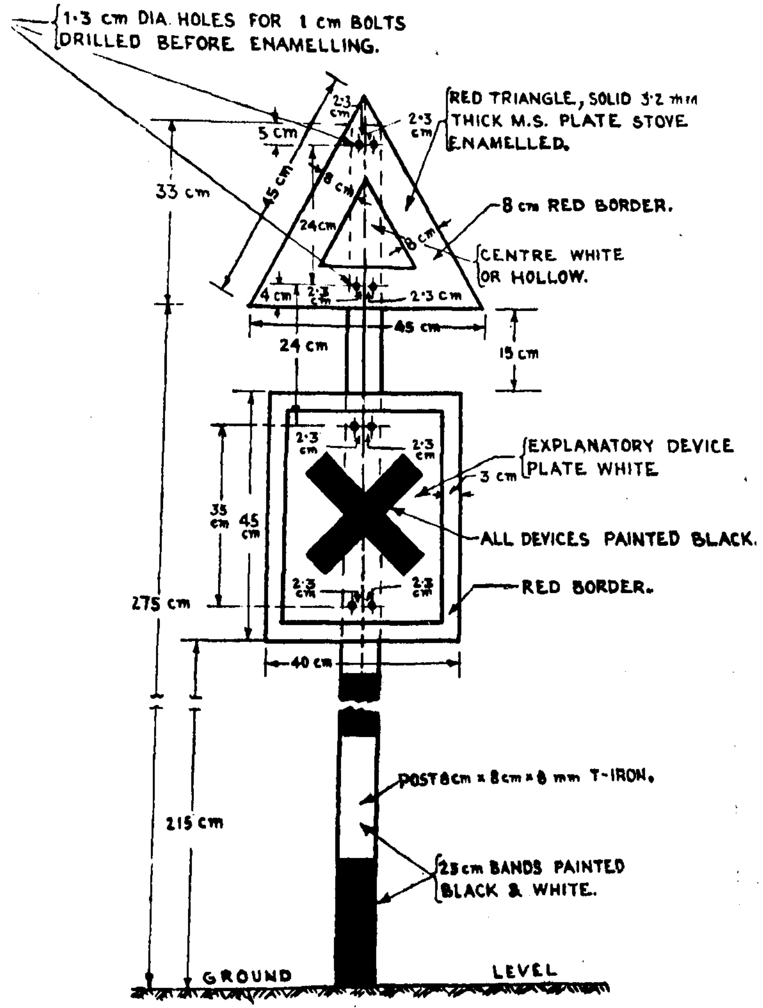


MAIN ROAD AHEAD

MANDATORY SIGN

NOT TO SCALE

CAUTIONARY SIGNS SHALL BE USED IN CONJUNCTION WITH A RED TRIANGULAR PLATE, THE CENTRE OF WHICH SHALL BE EITHER HOLLOW OR PAINTED WHITE, IN THE MANNER INDICATED IN THE GENERAL DESIGN REPRODUCED BELOW.



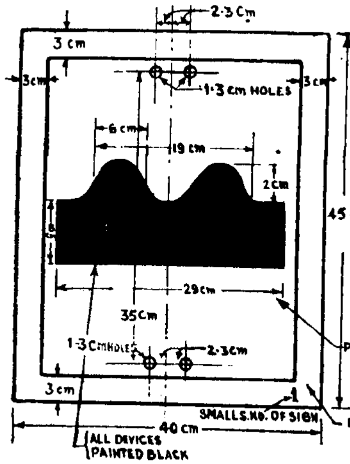
GENERAL DESIGN

CAUTIONARY SIGN

NOT TO SCALE

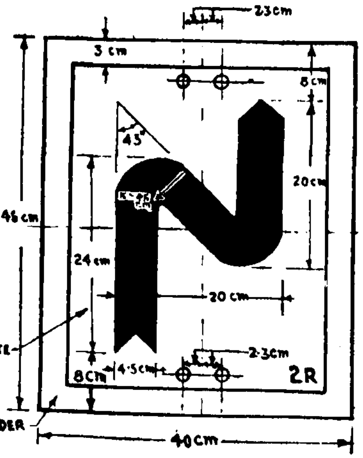
No. 1.

ROUGH ROAD



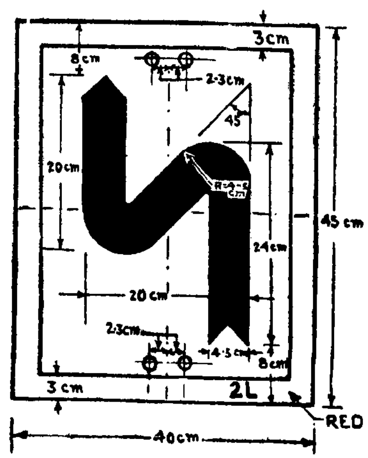
No. 2.

ZIG ZAG (RIGHT)



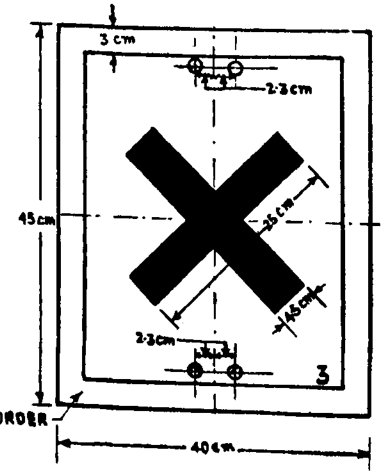
No. 2.

ZIG ZAG (LEFT)



No. 3.

CROSS ROADS



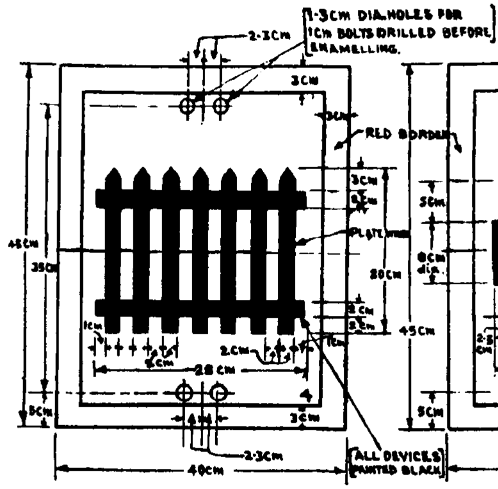
CAUTIONARY SIGNS

NOT TO SCALE

No. 4.

LEVEL CROSSING

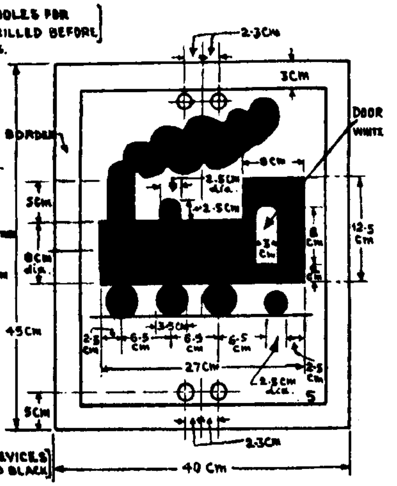
(GUARDED)



No. 5.

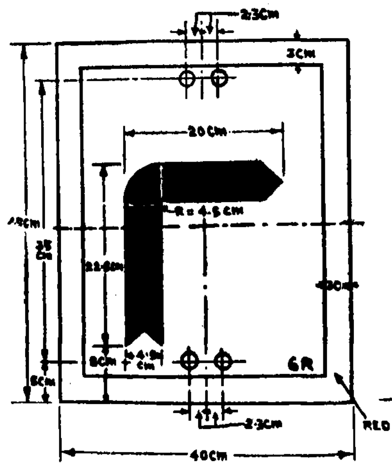
LEVEL CROSSING

(UNGUARDED)



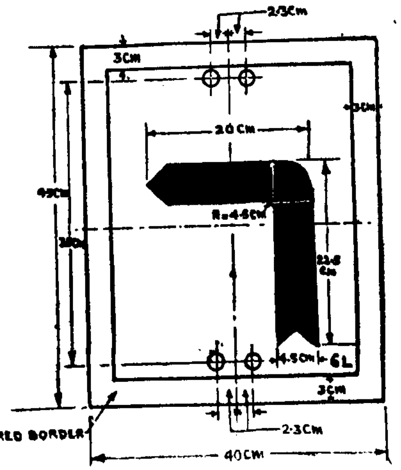
No. 6.

RIGHT TURN



No. 6.

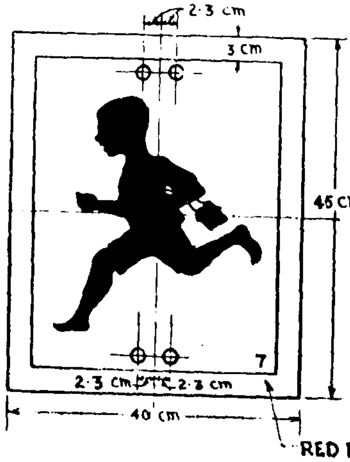
LEFT TURN



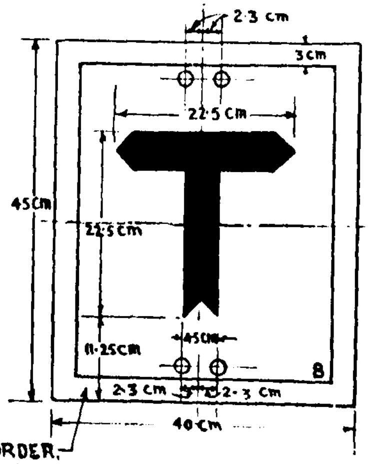
CAUTIONARY SIGNS

NOT TO SCALE

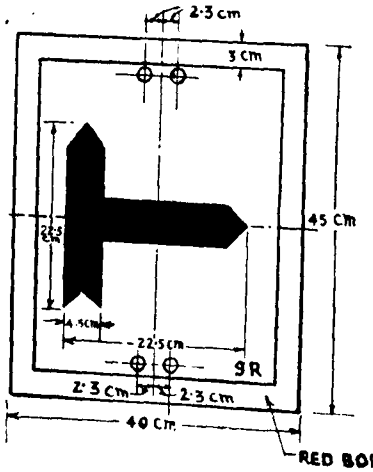
No. 7.
SCHOOL



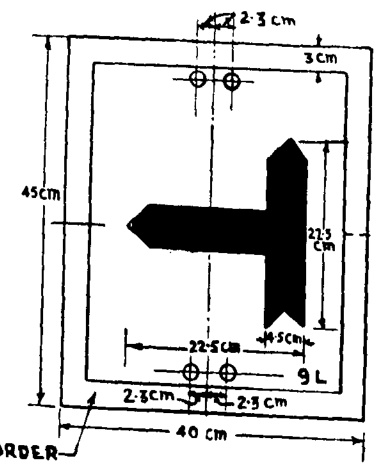
No. 8.
DEAD END CROSS ROAD



No. 9.
SIDE ROAD (RIGHT)

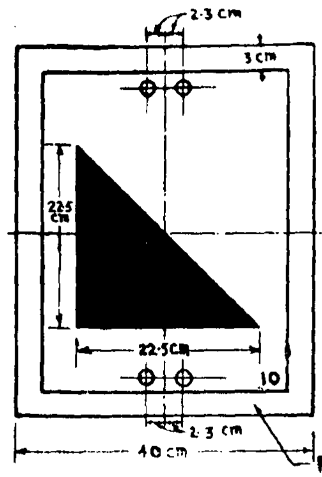


No. 9.
SIDE ROAD (LEFT)

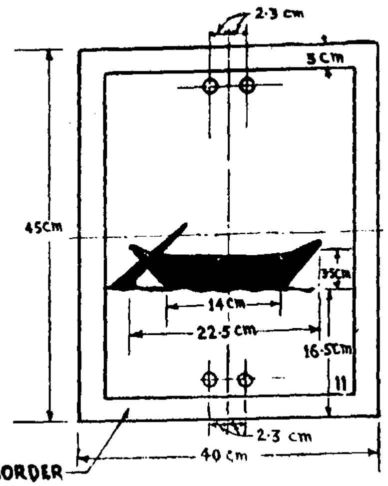


CAUTIONARY SIGNS
NOT TO SCALE

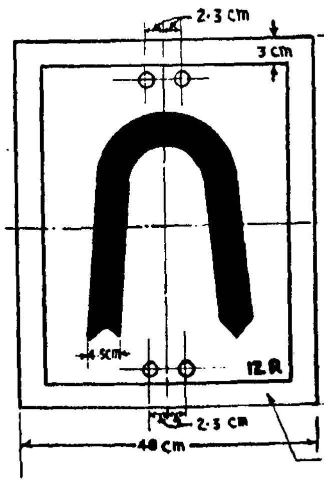
No. 10.
STEEP HILL



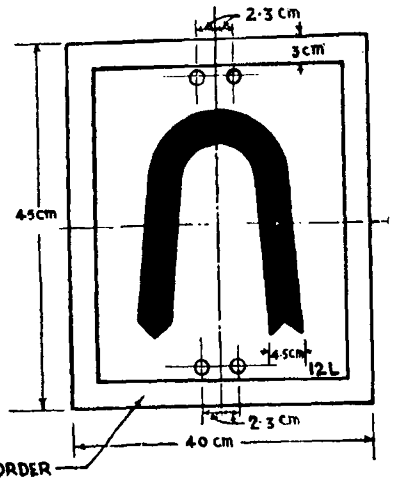
No. 11.
FERRY



No. 12.
HAIR PIN BEND (RIGHT)

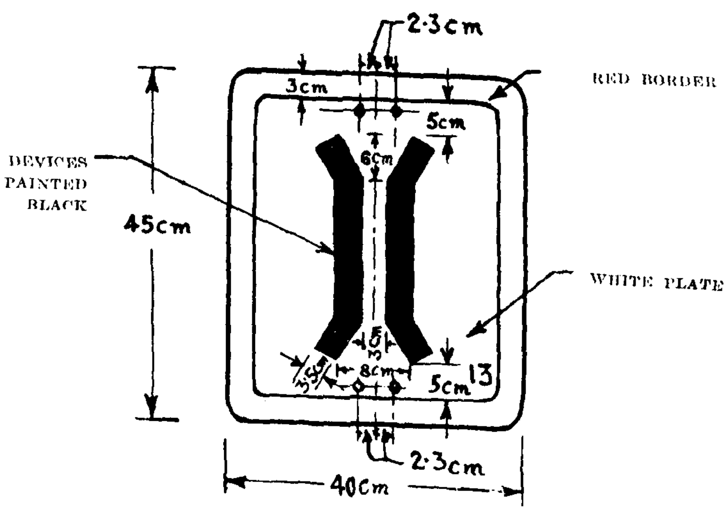


No. 12.
HAIR PIN BEND (LEFT)



CAUTIONARY SIGNS
NOT TO SCALE

No. 13.



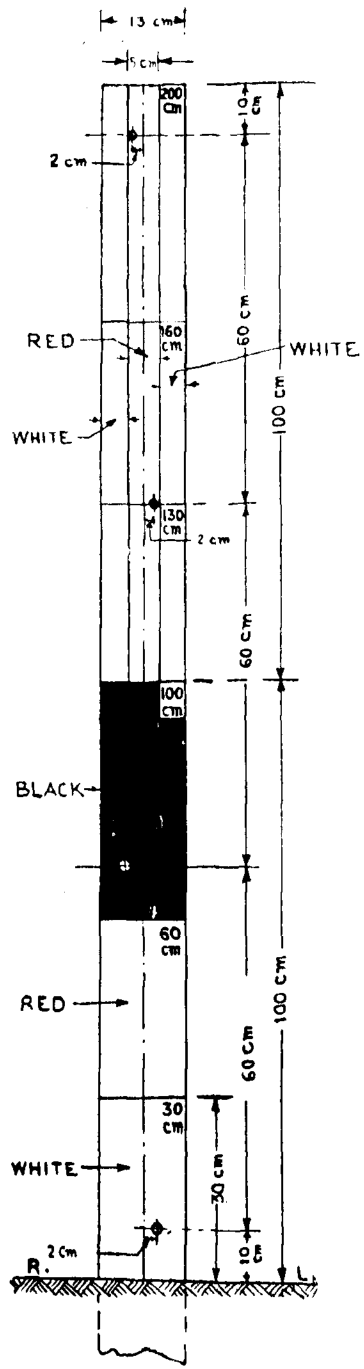
NARROW BRIDGE

THIS SIGN SHOULD BE SPARINGLY USED AND ONLY IN CASES OF REAL DANGER OF THE TWO VEHICLES MEETING ON A BLIND BRIDGE TOO NARROW FOR THEM TO PASS EACH OTHER.

CAUTIONARY SIGN

NOT TO SCALE

No. 1.



FLOOD GAUGE

NOTE:

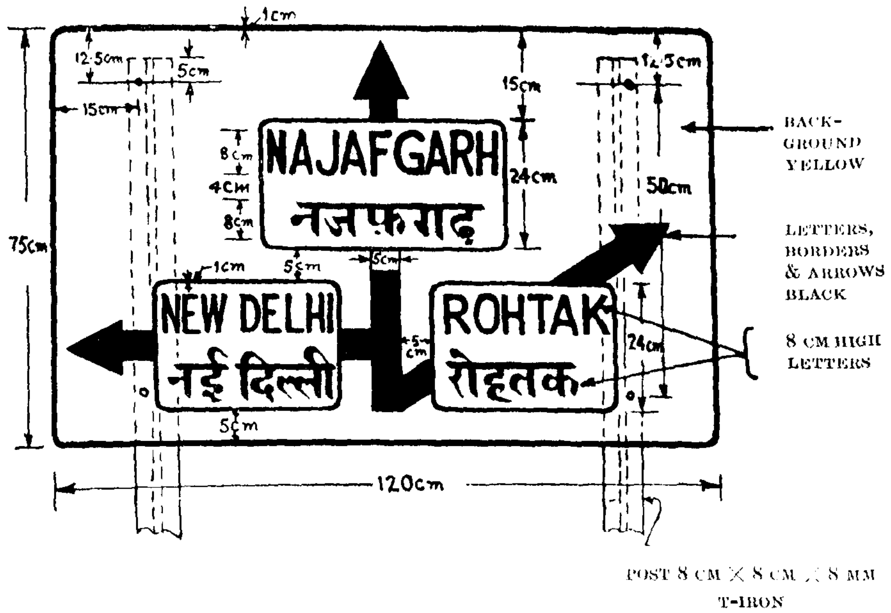
The gauges should be placed on the upstream side of Irish bridges or causeways. They should consist of enamelled iron plates bolted to a 8 cm × 8 cm × 8 mm T iron. They should be 200 cm in height from the deepest part of the gap, the bottom 30 cm should be WHITE, the second 30 cm, RED, the third BLACK and from the top of the BLACK, i.e., from 100 cm above zero to the top the gauge should be WHITE and have a RED line 5 centimetres wide running up the centre.

R. L.:—ROAD LEVEL AT LOWEST POINT OF IRISH BRIDGE OR CAUSEWAYS ETC.

INFORMATORY SIGN

NOT TO SCALE

No. 2.



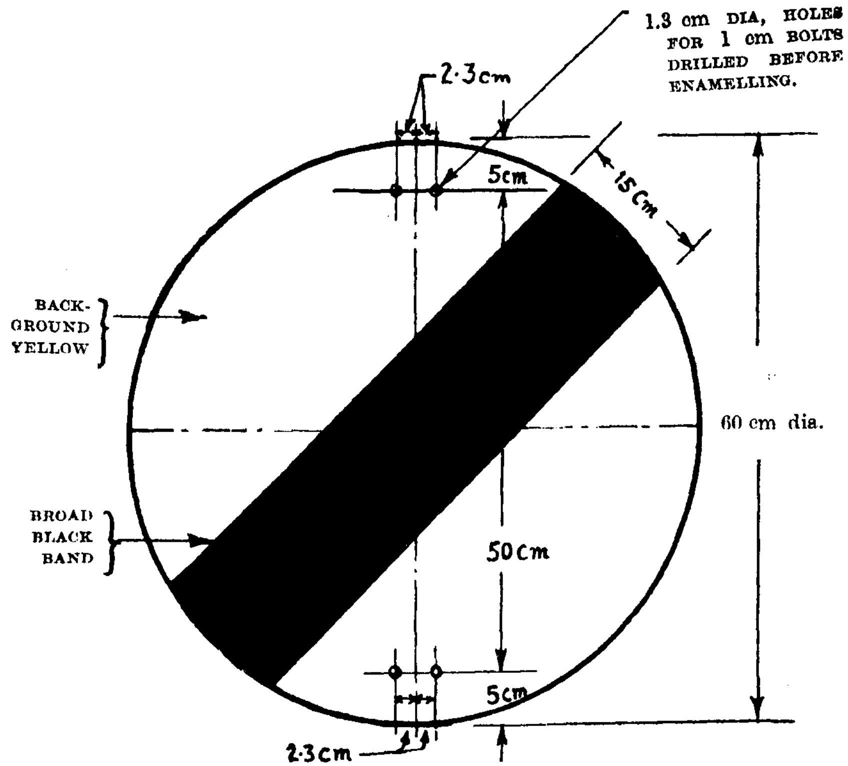
ROAD JUNCTION APPROACH

NOTE :—This sign is intended for use at approaches to important road junctions and should indicate the name of the nearest important towns on each of the roads branching off from the junction and also the angle of bifurcation of the roads. The lettering in the above design is illustrative only.

INFORMATORY SIGN

NOT TO SCALE

No. 3.



END OF SPEED LIMIT

NOTE :—This sign may either

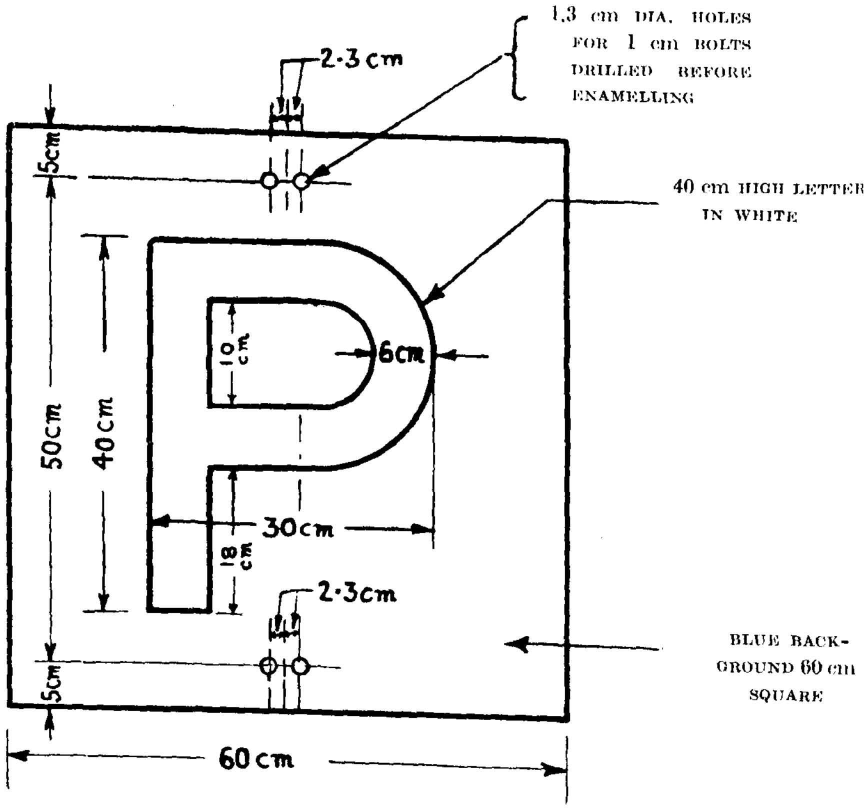
(1) be used as a separate sign to be placed on the left of the road, or

(2) be painted on the reverse of the existing speed limit sign. (Mandatory sign No. 1)

INFORMATORY SIGN

NOT TO SCALE

No. 4.



PARKING SIGN

INFORMATORY SIGN

NOT TO SCALE

Appendix 1

Section 75 of the Indian Motor Vehicles Act, 1939.

Section 75—Power to erect traffic signs—(1) The (State) Government or any authority authorized in this behalf by the (State) Government may cause or permit traffic signs to be placed or erected in any public place for the purpose of regulating motor vehicle traffic.

(2) Traffic signs erected under sub-section (1) for any purpose for which provision is made in the Ninth Schedule shall be of the size, colour and type and shall have the meanings set forth in the Ninth Schedule, but the (State) Government or any authority empowered in this behalf by the (State) Government may make or authorize the addition to any sign set forth in the said schedule of transcriptions of the words, letters or figures thereon in such script as the (State) Government may think fit provided that the transcriptions shall be of similar size and colour to the words, letters or figures set forth in the Ninth Schedule.

(3) Except as provided by sub-section (1) no traffic sign shall, after the commencement of this Act be placed or erected on or near any road; but all traffic signs erected prior to the commencement of this Act by any competent authority shall, for the purpose of this Act, be deemed to be traffic signs erected under the provisions of sub-section (1).

(4) A (State) Government may, by notification in the Official Gazette, empower any District Magistrate or Superintendent of Police (or, in the Presidency-towns, the Chief Presidency Magistrate or the Commissioner of Police) to remove or cause to be removed any sign or advertisement which is so placed in his opinion as to obscure any traffic sign from view or any sign or advertisement which is in his opinion so similar in appearance to a traffic sign as to be misleading.

(5) No person shall wilfully remove, alter, deface, or in any way tamper with, any traffic signs placed or erected under this section.

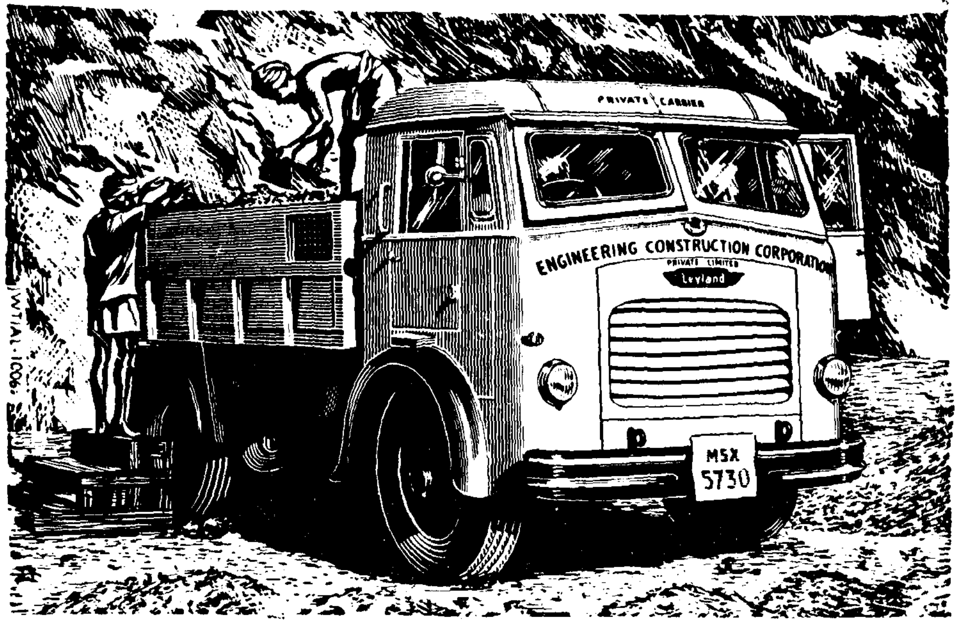
(6) If any person accidentally causes such damage to a traffic sign as renders it useless for the purpose for which it is placed or erected under this section, he shall report the circumstances of the occurrence to a police officer or at a police station as soon as possible, and in any case within twenty-four hours of the occurrence.

(7) For the purpose of bringing the signs set forth in the Ninth Schedule, in conformity with any International Convention relative to motor traffic to which the Central Government is for the time being a party, the Central Government may, by notification in the official Gazette, make any addition or alteration to any such sign and on the issue of any such notification, the Ninth Schedule shall be deemed to be amended accordingly.

"Ashok Leyland COMETS

carry in 5 trips what others would need 7 to clear"

says The Engineering Construction Corporation Private Limited, Madras



"FOR The Madras Harbour Job we shall need upto 500 tons of blue metal a day. All this has to be moved from our Quarries at Pallavaram to the Madras Harbour 15 miles away. Since a lorry can make only a limited number of trips a day, the larger the load it can carry, the more economical it will be for us. That is why we are happy to have Ashok Leyland Comets in our fleet. They carry in 5 trips what others would need 7 to clear. We save on fuel, maintenance and overheads too. Breakdowns? No...None so far!"

Testimonials like this show why LEYLANDS are the most wanted vehicles in over 50 countries in the world. Every vehicle is built to exacting standards of precision and craftsmanship.

The Forward-Controlled Leyland Comet Chassis is designed specially to combine large body space with easy handling. The quick starting, long life Leyland Diesel engine, with its high torque output, combines pulling power with remarkably low fuel consumption. *The Ashok Leyland Comet is the only 7½ ton payload chassis made in India.*

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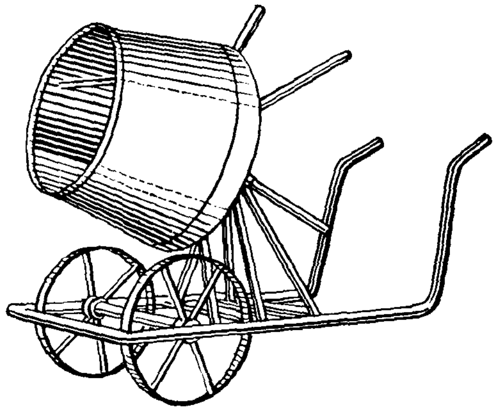
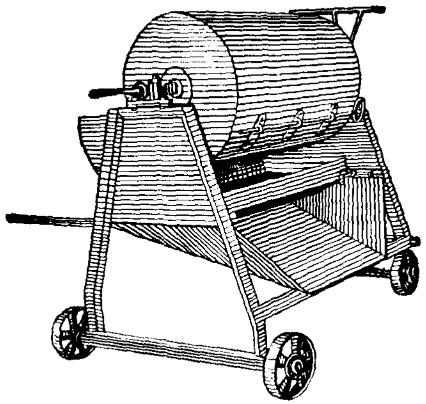
"GARLICK'S MIX"

HAND OPERATED CONCRETE MIXER

Drum Capacity — 1.5 cu. ft





HAND OPERATED GARLICK'S BITUMEN DRUM MIXER

Drum Capacity — 7.5 cu. ft.
Main Shaft — on ball bearings
Mounted — on 3 Nos. or 4 Nos. C.I. Wheels
Turning Circle — 7 ft in radius
Complete with Fire tray and C.I. Grate

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