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Paper No. 230

"PARKING IN MOUNT ROAD"

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SYNOPSIS

In Madras City, parking problem is acute on Mount Road which is situated in the heart of the city and is a fashionable shopping centre with show-houses, hotels and other recreational places. A portion of this road, in a heavily built-up area, is now proposed for improvement to provide 84 ft wide carriageway, besides 8 ft wide footpaths on either side for pedestrians to accommodate the increased flow of traffic. In an effort to provide

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this width uniformly throughout the length, it has become necessary to prohibit curb parking in narrow portions and to provide off-street parking spaces. So a survey was conducted to evaluate parking requirements.

The survey was conducted to establish both quantity and character of potential demand of the parking facilities on this road and to meet that demand with economic justification. The survey also aimed at revealing the nature of parking habits. The survey revealed that about 72 per cent of the people park their cars for less than 20 minutes and only 5 per cent of the cars were parked for more than 60 minutes. Long time parking was generally adjacent to the area of important business. The parking facilities provided now by public and private buildings were generally found to be inadequate. The location of taxi stands, bus stops and cycle parking also needed a change.

Recommendations made include thirty minutes curb parking, restriction, marking of stalls and signing of regulations, relocation of taxi stands and bus stops, and enactment of zoning ordinance prescribing parking space provision for the various types of buildings besides amplification of the Motor Vehicles Act as regards method of parking and allied matters.

1. INTRODUCTION

1.1. All roads are primarily dedicated to the purpose of public travel. Any other use must be considered of secondary importance. But mere movements do not accomplish the needs of transportation. Motor vehicles have no utility for their owners unless it is possible to park them on reaching the destination.

1.2. Thus, while parking is not directly a part of the primary use to which streets are dedicated, it is nevertheless an important one. No reasonable private use of the road should be prohibited or restricted, unless public demands for more essential use become pressing. On this principle, parking should be permitted on all roads and streets for as long a period as it does not interfere with requirements of traffic movement.

1.3. Therefore, the curb parking problem involves primarily a study of the supply and demand for parking and for traffic movement and of the best possible balance between the two conflicting uses. Where curb parking is permitted, there is need for studying the most satisfactory regulation. Generally, the justifiable demand for additional parking must be provided by off-street lots or parking garages.

2. GROWTH OF MADRAS CITY

2.1. Madras City, the capital of Madras State, is growing rapidly in area and population. During the recent years various industries have sprung up in and around Madras City. The Madras Harbour, the second largest port on the East Coast of India, is also growing. Consequently, the traffic on the city roads have increased tremendously in recent years. But the improvements to roads have not kept pace with the increase in traffic. Although surface improvements were carried out, very little was done for the improvement of geometrics. A substantial milage of city roads has thus become operationally unsafe. With the rapid increase of automobiles, the problem of accommodating and expediting the movement of fast moving vehicles along with the slow moving cycles, hand-drawn and animal-drawn vehicles has become more important. The existing narrow city roads have not met this demand satisfactorily.

3. IMPROVEMENT OF MAJOR CITY ROADS

3.1. Mount Road, Poonamallee High Road and Wall Tax Road are the three most important roads in Madras City, Plate I. These roads form link to National Highways within the city limits and connect the various industries located in and around Madras City. It is proposed to take up the improvements of these roads with a view to obtain smooth, safe and quick traffic movements. Mount Road, the fashionable shopping centre, is in the heart of the city. Improvement of a short length of Mount Road between Air India Office and Spencer & Co. has been taken up as a pilot scheme.

4. PILOT SCHEME

4.1. The existing width of the carriageway between Air India Office and Spencer & Co., excluding the footpaths, varies from 66 to 102 ft. The pilot scheme for the improvement of Mount Road envisages the widening of the carriageway beyond intersections to 84 ft uniformly to provide additional lanes for the movement of traffic. The 84 ft width of carriageway will consist of two lanes, 8 ft wide each, for cycle track, four lanes, 11 ft wide each, and two lanes, 12 ft wide, for fast moving traffic. Besides this, there will be 8 ft wide footpaths on either side of the carriageway. The traffic survey conducted on 27-7-1960 revealed that the cyclist traffic constituted nearly 50 per cent of the total traffic volume, Plate II. Hence it was decided to segregate the cyclists from the fast moving traffic and to keep them in separate lanes, all along the road and even at the intersections opposite to Wellington and Spencer & Co. At the intersections, the fast and slow moving vehicles are proposed to be sorted out separately into three lanes according to whether they want to turn left, right or go straight. The total width of the carriageway at the intersections will be 94 ft, 52 ft carriage width for the traffic entering the intersection and 42 ft carriage width for the traffic leaving the intersections, Figs. 1 and 2.

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4.2. The principal function of streets and highways being the efficient movement of vehicles and pedestrians, curb parking in Mount Road will have to be prohibited in some narrow places to provide 84 ft wide carriageway to accommodate the increased volume of traffic, Plate III.

In order to assess the actual demand for parking in this area and to make necessary alternate provision for the curb spaces lost due to widening of the carriageway, a parking survey was conducted.

5. PARKING SURVEY

5.1. Parking survey is made to estimate accurately the extent of present parking at the curb and off the street, and to indicate where and how much additional parking space may be needed. Usually, curb parking is considered as reserved for the short time parker—one that requires an hour or less to conduct his business or shopping. Off-street parking is generally considered to be for the long time or all day parker.

6. TYPES OF PARKING SURVEY

6.1. The following parking surveys were conducted :

(a) Compilation of a parking inventory.

(b) Study of usage of parking spaces.

(c) Cycle parking.

7. LOCATION

7.1. The portion of Mount Road taken up for parking survey runs south-west from Fort St. George and is between Air India Office and Victoria Technical Institute. The following roads join Mount Road in the direction indicated against them:

Name of road		Direction
Dams Road	...	West
General Patters Road	...	East
Nellukara Veera Mudali Street (one-way street)	...	East
Woods Road (one-way street)	...	East
Club House Road (dead-end road)	...	East
Binny's Road	...	West
Patullos Road	...	East

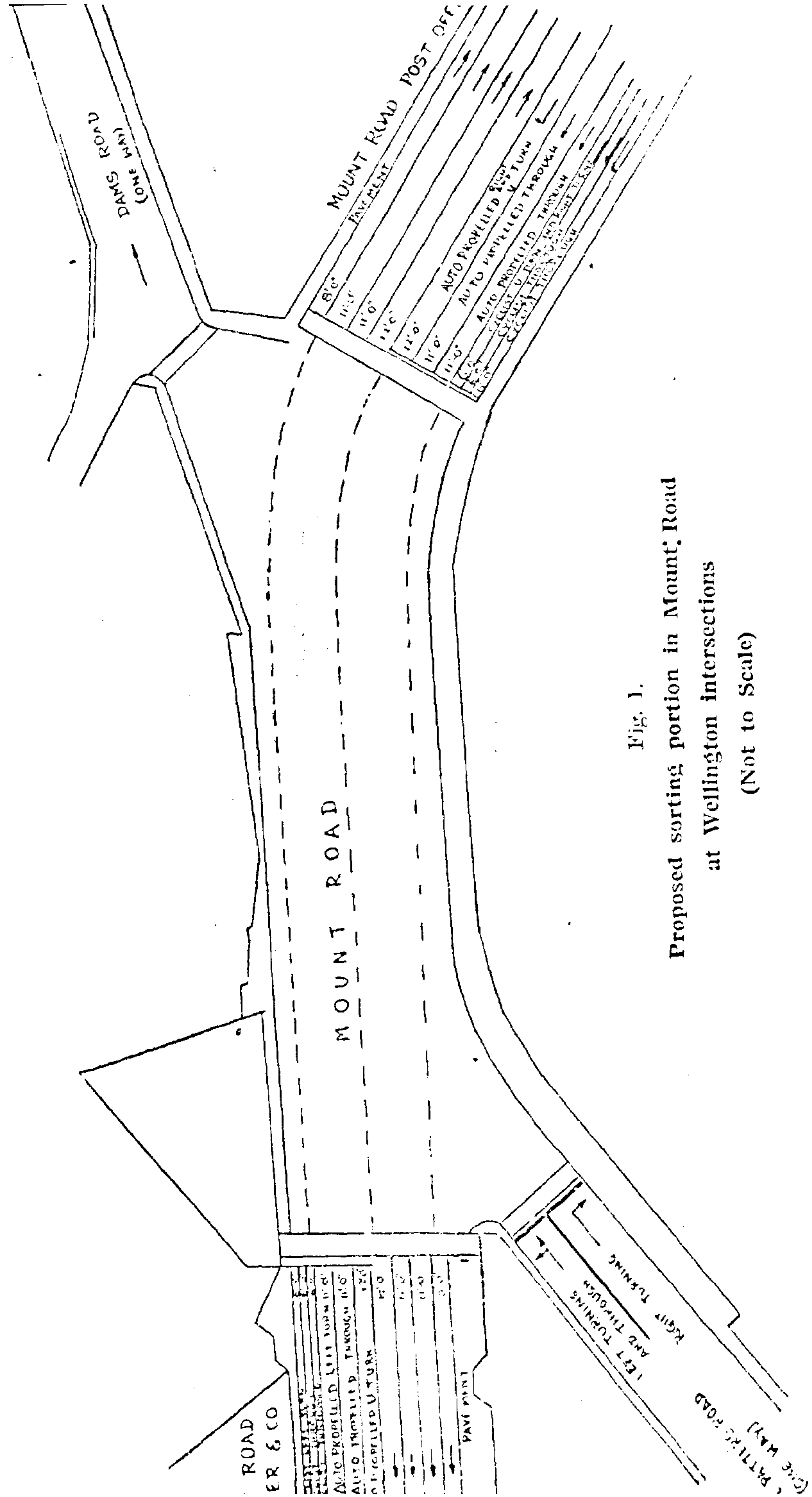


Fig. 1.
Proposed sorting portion in Mount Road at Wellington Intersections
(Not to Scale)

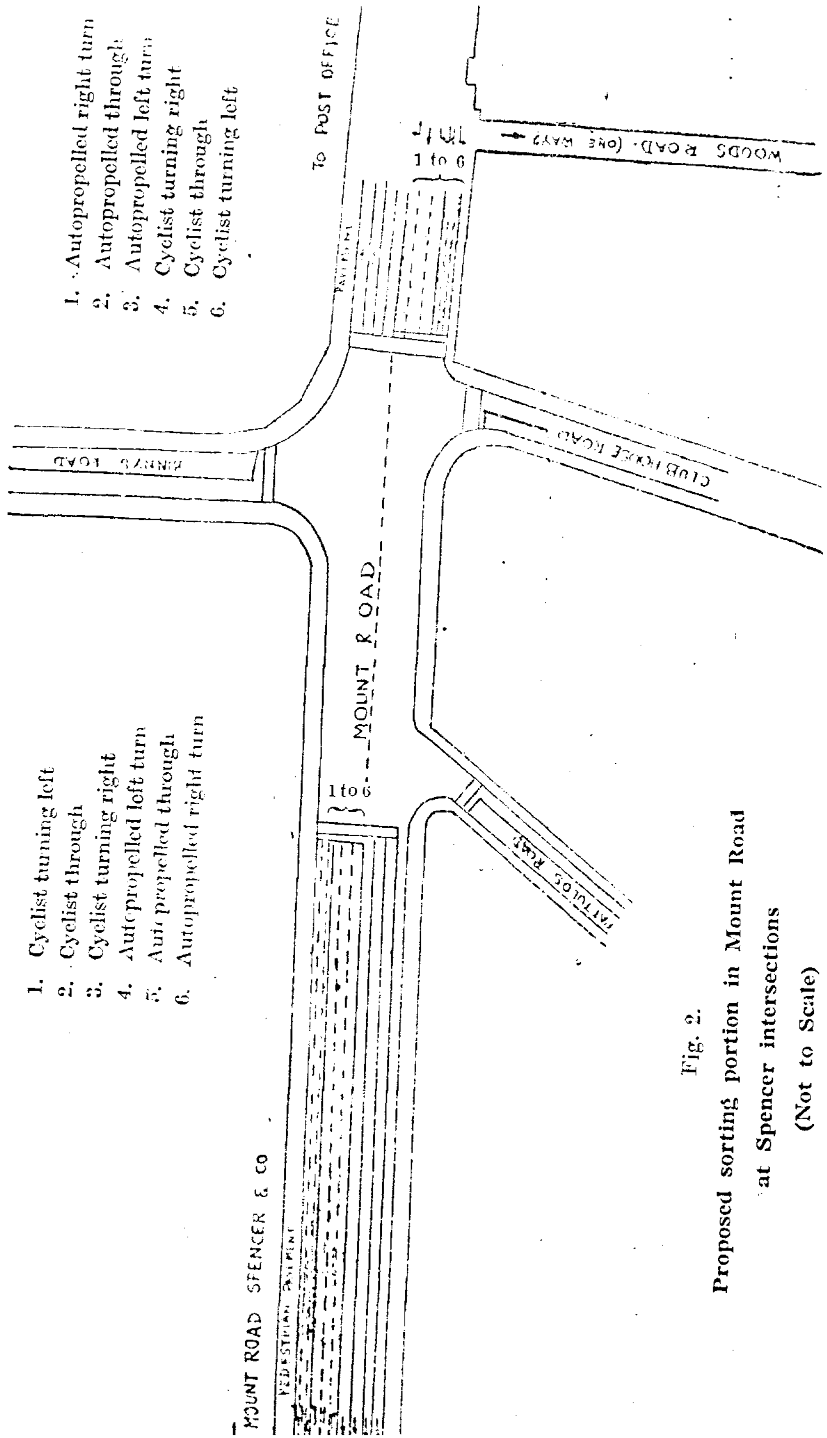


Fig. 2.
Proposed sorting portion in Mount Road at Spencer intersections
(Not to Scale)

7.2. The parking survey also included portions of the above cross roads as far out as were commonly used for parking by the Mount Road traffic. For the purpose of the survey, Mount Road has been assumed to run north-south and all cross roads east-west.

8. TIME AND LENGTH OF STUDY

8.1. The normal practice is to take parking survey for a week. The parking survey taken for a week includes all the days in a week and any special days like Saturday—a half holiday and Sunday—a full holiday. Parking survey is taken for 12 hours between 7.00 a.m. to 7.00 p.m.

Such an elaborate survey was not considered necessary in the present case. Hence it was decided to conduct the survey during a normal working day when all the schools and colleges in the city were open. The parking survey was conducted on Tuesday, 11th October, 1960—a normal working day—from 8.00 a.m. to 12.00 noon and from 4.00 p.m. to 8.00 p.m. The hours of the survey were the same as those adopted for the traffic survey conducted on 27-7-1960.

8.2. The parking survey observations were done at every 10 minute interval. The cycle parking survey observations were done at every 30 minute interval.

9. PERSONNEL

9.1. The parking survey was planned, supervised and analysed by the Traffic section of the Highways Research Station, Madras, in co-operation with the Madras City Traffic Police and the Corporation of Madras.

9.2. The observers for the survey were Traffic Policemen, Photo 4. The traffic regulations on all the roads were also done by the Madras City Police.

10. PRELIMINARY TRAINING

10.1. Prior to the commencement of the parking survey, all the supervisory staff of the Madras City Police and the Highways Research Station were given detailed instructions as regards the parking survey. The supervisory staff in turn gave detailed instructions to the Traffic Policemen.

11. PARKING INVENTORY

11.1. The parking inventory is the assembly of information about the location, extent, capacity, layout, type and operating characteristics of existing parking facilites, both at the curb and off-street.

11.2. Location

The parking inventory was taken in Mount Road between Air India Office and Victoria Technical Institute and all the cross roads branching from Mount Road between these limits as far out as commonly used for parking by the Mount Road traffic.

11.3. Procedure

Every curb face within the selected area was surveyed and inspected and using the curb inventory record form (Form 1), data was collected for every type of space indicated thereon. When the curb parking spaces were not marked, the number of spaces were determined by allowing 20 ft per space for parallel parking and from 8 ft to 16 ft per space for angle parking. In the case of centre street parking, such stalls were marked. All the parking stalls on the curb side and in the centre of the road were marked by means of white paint lines 4 inches wide. The parking spaces in the various roads were divided into 23 sections and each parking stall in a section was given a serial number for easy identification, Photo 1.

In addition to this, an inventory of the existing private parking lot and garages available in this area was also compiled using the off-street parking facility inventory form (Form 2).

11.4. Results

The total curb footage and its break-up for Mount Road between Air India Office and Victoria Technical Institute and other branch roads are shown in Table 1.

11.5. Parking Spaces

The curb side parking spaces available on Mount Road (from Air India Office to Victoria Technical Institute) and other branch

TABLE 1

Showing the breakdown of the curb footage in various roads

	Mount Road		General Patters Road		Nelhukara Mudali st.		Club House Road		Patullos Road		Binny's Road		Dams Road		Woods Road		Total	
	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent	Feet	Per cent
Parking	2,581	30.8	1,810	46.7	228	35.3	573	55.6	—	—	—	—	—	—	—	—	5,192	24.5
Taxi stands	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bus stops	668	8.2	229	5.9	—	—	—	—	35	1.4	150	8.1	—	—	—	—	1,102	5.2
Petrol bunks	646	7.7	82	2.1	—	—	—	—	—	—	—	—	—	—	—	—	728	3.4
Alleys and driveways	927	11.1	312	8.0	22	3.4	94	9.1	338	13.1	90	4.9	100	6.6	82	6.0	1,965	9.2
Corner clearance	1,485	17.7	252	6.5	44	6.8	363	35.3	—	—	229	12.4	—	—	—	—	2,373	11.2
No parking	2,048	24.5	1,195	30.8	352	54.5	—	—	2,199	85.5	1,375	74.6	1,420	93.4	1,277	94	9,866	46.5
Total	8,355	—	3,880	—	646	—	1,030	—	2,572	—	1,844	—	1,520	—	1,359	—	21,226	—

roads are shown in Table 2.

TABLE 2

Showing curb side parking spaces available on various roads

Sl. No.	Name of road	Side of curb	No. of parking spaces: Parallel No.	Parallel Feet	Angle No.	Angle Feet	Total No.	Total Feet	Remarks
1.	Mount Road	East	34	612	124	889	158*	1,501	* 14 parking spaces opposite to L.I.C. are not on curb but on footpath
		West	54	1,080	—	—	54	1,080	
2.	General Patters Road	North	29	580	—	—	29	580	
		South	58	1,090	10	140	68	1,230	
3.	Nellukara Veera Mudali Street	North	10	180	—	—	10	180	
		South	—	—	6	48	6	48	
4.	Club House Road	North	20	359	—	—	20	359	
		South	12	214	—	—	12	214	

11.6. Taxi Stands

There are three taxi stands on Mount Road (from Air India Office to Victoria Technical Institute) as shown in Table 3.

TABLE 3

Showing the location of the taxi stands on Mount Road

Sl. No	Name of road	Side of curb	Location	Capacity No.	Capacity Feet	Remarks
1.	Mount Road	West	Opposite to Mount Road Post Office	4	—	The taxi stands are located on the pedestrian footpaths
2.	Do.	East	Opposite to Cosmopolitan Club	12	—	Do.
3.	Do.	West	Opposite to Govt. Arts College	8	—	Do.

11.7. Bus Stops

There are ten bus stops on Mount Road (from Air India Office to Victoria Technical Institute) and seven in other branch roads as shown in Table 4.

TABLE 4

Showing the location of bus stops on various roads

Serial No.	Name of road	Side	Location	City or mofussil	Curb length occupied in feet	Remarks
1.	Mount Road	East	Opposite to Kashmir Emporium	City or mofussil	129	
2.	Do.	,,	Opposite to Bharat Insurance Co.,	,,	10	
3.	Do.	,,	Opposite to V.S.T. & Co.	,,	50	
4.	Do.	,,	Opposite to D-2 Police Station	City	41	
5.	Do.	West	Opposite to Spencers	,,	39	
6.	Do.	,,	Opposite to Government Arts College	City or mofussil	50	
7.	Do.	,,	Opposite to Industries Emporium	,,	56	
8.	Do.	,,	Opposite to Tarapore & Co.	City	67	
9.	Do.	,,	Opposite to Dhuns Building	Mofussil	40	
10.	Do.	,,	Opposite to Old Post Office building	City	109	
11.	General Patters Road	North	Opposite to Globe Theatre (rear side)	,,	69	
12.	Do.	,,	Opposite to Midland Theatre	,,	50	
13.	Do.	South	Opposite to Byranjung street	,,	60	
14.	Do.	,,	Opposite to Bharat Buildings	,,	50	
15.	Patullos Road	South	Opposite to Good Year & Co.	,,	35	
16.	Binny's Road	North	Opposite to Govt. Arts College	,,	75	
17.	Do.	South	Opposite to Hotel Connemara	,,	75	

11.8. Petrol Bunks and Service Stations

There are six petrol bunks and service stations on Mount Road (from Air India Office to Victoria Technical Institute) and one on

General Patters Road as shown in Table 5.

TABLE 5

Showing the location of petrol bunks and service stations on various roads

Serial No.	Name of road	Side	Location	Name of company	Curb length in feet
1.	Mount Road	East	Adjoining Cosmopolitan Club	Caltex	86
2.	Do.	,,	Adjoining Irani Hotel	Standard Vacuum	74
3.	Do.	,,	Adjoining Globe Theatre	Burmah-Shell	98
4.	Do.	,,	Adjoining George Oakes	Do.	138
5.	Do.	,,	Adjoining the above bank	Stanvac	100
6.	Do.	,,	Adjoining Victoria Technical Institute	Caltex	150
7.	General Patters Road	North	Adjoining Baba Arts near Woods Road	Do.	82

11.9. Corner Clearance

The corner clearance on Mount Road given at the various intersections by the posting of 'No Parking' sign is as shown in Table 6.

TABLE 6

Showing the corner clearance on Mount Road

Serial No.	Name of intersection	Name of road	Side	Clearance in feet
1.	Intersection of Mount Road and General Patters Road	Mount Road	East	91
2.	Do.	,,	,,	154
3.	Intersection of Mount Road and Club House Road	,,	,,	86
4.	Intersection of Mount Road and Patullos Road	,,	,,	62
5.	Intersection of Mount Road and Binny's Road	,,	West	150
6.	Do.	,,	,,	183
7.	Intersection of Mount Road and Dams Road	,,	,,	400
8.	Intersection of Mount Road and Blackers Road	,,	,,	359

11.10. No Parking Zone

In the following places, parking restrictions have been posted in addition to the prohibition at the corner of intersections on the various roads as given in Table 7 :

TABLE 7

Showing the footage of the 'No parking zones' on various roads

Sl. No.	Name of road	'No Parking' zone (feet)
1.	Mount Road	2,048
2.	General Patters Road	1,195
3.	Nellukara Veera Mudali Street	352
4.	Woods Road	1,277
5.	Club House Road	–
6.	Patullos Road	2,199
7.	Binny's Road	1,375
8.	Dams Road	1,420

11.11. Centre Parking

Centre parking is provided in Mount Road alone at two places as shown in Table 8. (Photos 2 and 3.)

TABLE 8

Showing the location of centre parking on Mount Road

Sl. No.	Name of road	Location of centre parking	No. of spaces			Particulars
			Angle	Parallel	Total	
1.	Mount Road	Opp. to Buhari	16	—	16	
2.	Do.	Opp. to Bata Shoe Co.	9	—	9	30-minute parking zone

11.12. Off-street Parking

No public 'off-street parking' is provided in this area. Only private parking to serve the employees and customers in the various public and private buildings has been provided. The details of the available garages and parking spaces in some buildings are given in Table 9.

TABLE 9

Showing the details of private parking in some buildings

Sl. No.	Name of road	Owner of building	No. of garages	No. of parking spaces with aisles	No. of parking space closely packed	Remarks
1.	Mount Road	L. I. C.	11	Nil	Nil	
2.	Do.	Tarapore & Co., Dhun Building	6	—	—	About 40 cars are found parked inside

12. STUDY OF USAGE OF PARKING SPACES

12.1. Perhaps the most valuable information is the supply of and demand for parking space in each block of the Central business zone. Presented both in map form and figures, these findings show clearly the areas of congestion and surplus space and permit a quantitative evaluation of deficiencies.

12.2. Procedure

The curb face in Mount Road from Air India Office to Victoria Technical Institute and other branch roads was divided into 23 sections. The maximum number of parking stalls in a section was 35. Each curb face and each lot was toured by an observer every ten minutes from 8.00 a.m. to 12.00 noon and from 4.00 p.m. to 8.00 p.m. Each observer was assigned no more space than could be covered in ten minutes including his return to the starting point. The parking usage study form (Form 3) was used for this purpose. Depending upon the number of parking spaces, one or more sheets were used for each curb face. The parking usage form had previously added to it in the title space, the date, the day of the week, the time of observation to which the form related and a des-

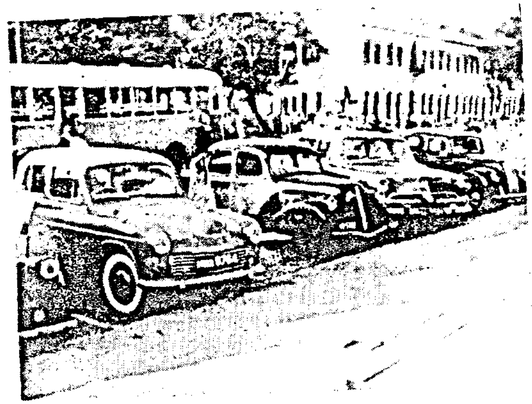


Photo 1

Parking stalls numbered for easy identification

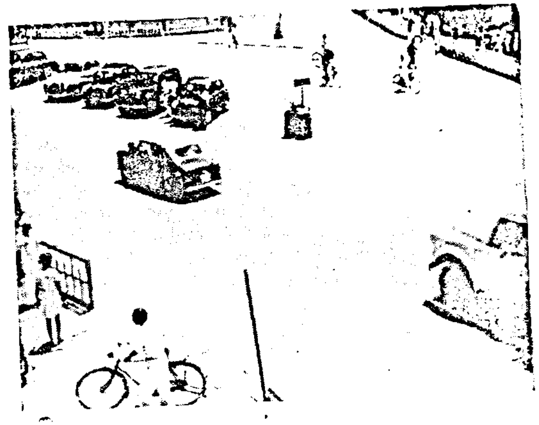


Photo 2

Centre parking in Mount Road opposite to Bata Shoe Company

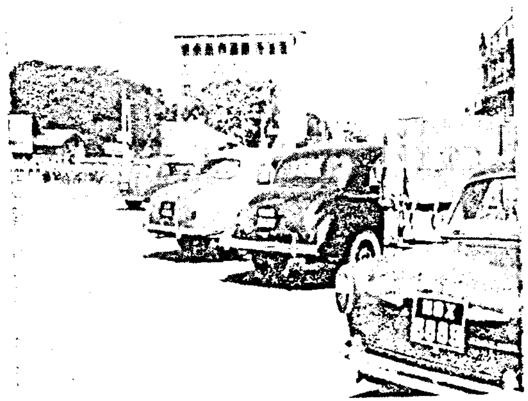


Photo 3

Centre parking in Mount Road opposite to Buhari

Photo 4

Observer (traffic policemen) recording the number of cars parked in stalls

Photo 5

Parallel parking interferes least with movement of traffic—parallel parking in General Patters Road

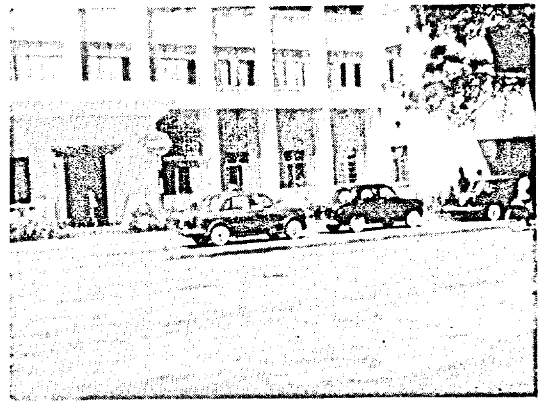


Photo 6

Vehicles parked on footpath in no parking zone

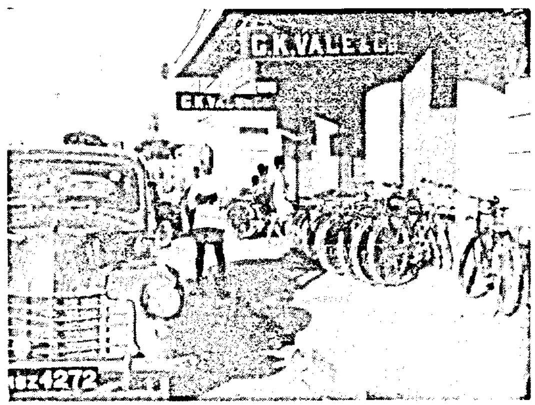


Photo 7

Cycles parked on the pedestrian footpath reducing the usable width of footpath and causing obstruction to the movement of pedestrians

TABLE 10

Length of time vehicles parked on Mount Road

		No. of vehicles parking for								
		0—10 minutes	10—20 minutes	20—30 minutes	30—40 minutes	40—50 minutes	50—60 minutes	1—2 hours	2—3 hours	3—4 hours
V.T.I. to Binny's Road	A.M.	31	11	4	4	1	—	2	—	—
	P.M.	12	6	5	—	—	1	—	—	—
Binny's Road Junction to M.E.S. Road	A.M.	25	9	5	2	—	—	2	1	—
	P.M.	28	9	7	—	—	2	1	—	1
M.E.S. Road Junction to Industries Emporium	A.M.	34	30	6	7	4	4	5	2	1
	P.M.	28	23	8	4	2	4	7	5	—
Industries Emporium to Dams Road	A.M.	5	5	2	3	3	1	—	—	1
	P.M.	14	3	3	1	—	—	1	1	1
Dams Road to P.M.G.'s Office	A.M.	37	30	1	3	—	—	—	—	—
	P.M.	54	26	12	3	—	—	—	—	1
P.M.G.'s Office to Blackers Road Jn.	A.M.	8	10	3	7	—	4	3	1	—
	P.M.	23	12	10	9	4	1	1	—	—
Central Parking opp. to Buhari	A.M.	44	30	7	8	2	—	3	—	—
	P.M.	43	29	21	5	2	5	7	2	—
Central Parking opp. to Bata	A.M.	38	19	11	7	3	1	1	—	—
	P.M.	31	22	8	8	3	2	3	—	—
Air India Office to My Coffee Bar	A.M.	38	14	9	2	4	3	1	1	—
	P.M.	43	17	8	3	3	3	3	—	—
My Coffee Bar to General Patters Road Jn.	A.M.	27	15	6	1	2	2	2	—	—
	P.M.	45	23	7	4	—	3	3	1	—
General Patters Road to State Bank Road	A.M.	32	36	20	9	9	6	3	1	1
	P.M.	48	33	8	6	4	3	2	1	—
State Bank Road to Union Company	A.M.	29	15	3	5	1	—	2	1	—
	P.M.	32	11	4	2	2	—	4	—	—
Union Company to Woods Road	A.M.	40	12	10	4	1	1	5	2	—
	P.M.	41	16	9	3	2	1	2	3	1
Woods Road to Club House Road Jn.	A.M.	12	8	2	1	—	4	1	5	1
	P.M.	12	7	8	2	2	1	4	—	—
Club House Road to Patullos Road	A.M.	14	9	2	2	3	1	2	5	—
	P.M.	13	5	3	1	1	—	5	1	—
Patullos Road Junction to George Oakes	A.M.	25	14	3	2	1	2	1	1	—
	P.M.	14	16	4	3	1	—	2	2	—
Total	A.M.	439	277	94	67	34	29	33	20	4
	P.M.	481	261	125	54	26	26	45	16	4

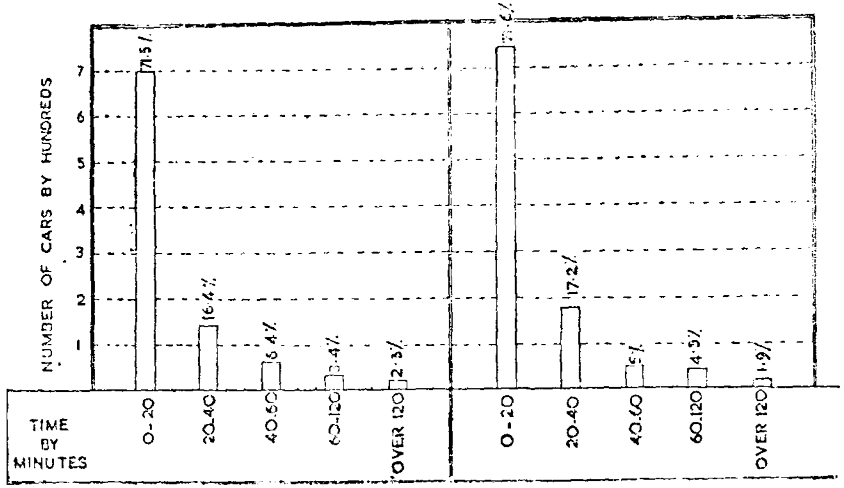


Fig. 3. Length of time parked on Mount Road normal week day
8 a.m.—12 noon 11th October, 1960 4 p.m.—8 p.m.

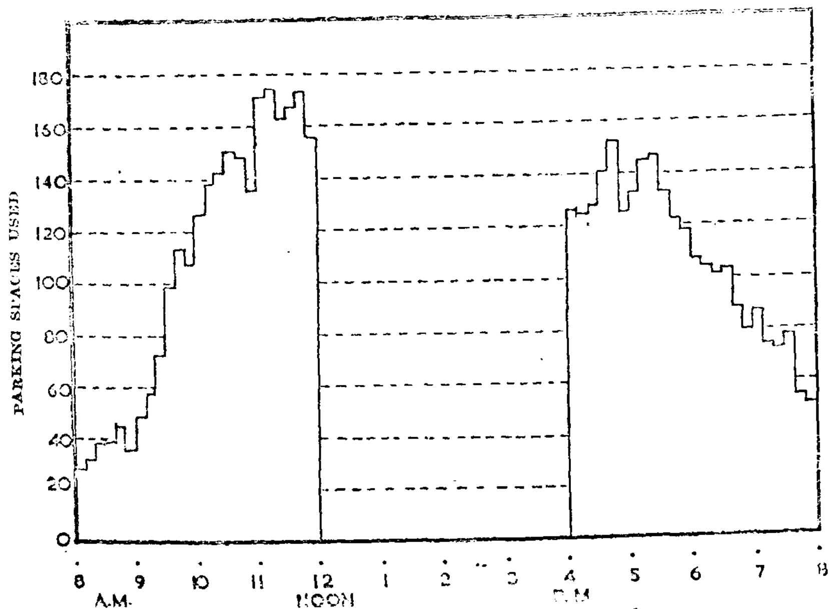


Fig. 4. Curb parking on Mount Road
Movements and Accumulation by 10 Minute Periods.
Normal Week Day, 11th October, 1960. Total parking spaces available 237

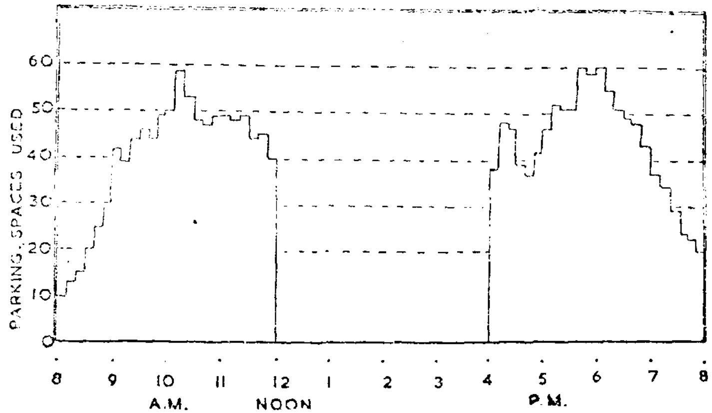


Fig. 5. Street parking in General Patters Road Movement and Accumulation by 10 Minute Periods Normal Week Day, 11th October, 1960.

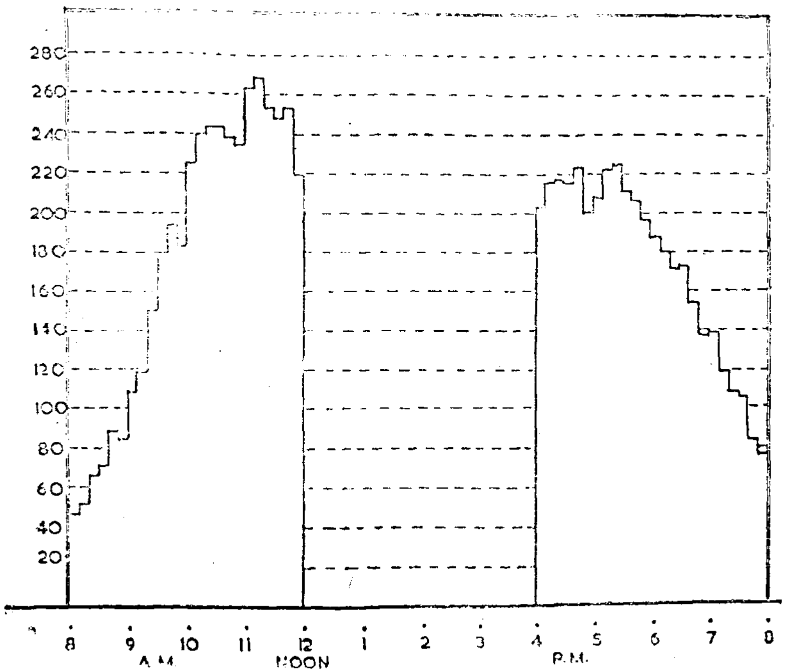


Fig. 6. Curb parking on Mount Road and Branch Roads

Photo 8

Parking garages (11 Nos.) provided for the Life Insurance Corporation building at Mount Road with a floor area of 89,000 sq. ft.

Photo 9

Informal parking space (14 Nos.) opposite to Life Insurance Corporation building at Mount Road. The occupancy rate at this place is very high

cription of the location. One form for each section of the curb face and for every hour was used. Before commencement of the survey, the prevailing weather condition and the name of the observer was also recorded in the form.

The first tour by the observer was started at about 7.50 a.m. since it involved gathering of more details and required upto 20 minutes. On the first tour, the observers recorded every car or truck parked at the curb, whether in a legal space or elsewhere. The form provides one line for each legal space and one or more lines for each of the various restricted spaces that may be present. The line opposite the point where each vehicle was found was used. An exception to this was when vehicles were parked double or in informal spaces. These were recorded in the extra lines provided in the page. An informal space is any space not at the curb and not in an established lot or garage or an irregular and temporary space such as on a sidewalk, lawn or front yard, etc.

On the first tour (beginning at 7.50 a.m.) the registered number of all the vehicles present were recorded in the first column (headed 8 a.m.). All the registration numbers of commercial vehicles were underlined (<u>5349</u>) to distinguish them from other vehicles. In the case of motor cycles and scooters, the letter 'S' was noted.

The first tour—requiring 20 minutes—was completed before 8.10 a.m. All the subsequent tours, one every ten minutes, were started from the same point and following the same path as the 7.50 a.m. tour.

On each subsequent tour using the appropriate column, a check mark (✓) was made for each vehicle found on the preceding tour and was still present; for each new vehicle, the registered number was recorded. The record concerning any vehicle or vacancy on each tour was as seen by the observer at the moment he passed the space. No allowance for what was seen just before or just after passing the space was made. Registered numbers were recorded only to permit an estimate of the demand in terms of time.

12.3. Results

The length of time parked by the vehicles in Mount Road is given in Fig. 3 and Table 10.

The accumulation of vehicles at the curb and centre of street parking in Mount Road, General Patters Road and all the other roads together in this area during the period between 8.00 a.m. and 12.00 noon and from 4.00 p.m. to 8.00 p.m. are given in Figs. 4, 5 and 6, and Tables 11 and 12.

13. CYCLE PARKING

13.1. The accumulation of cycle parking on footpaths opposite to various buildings was noted.

13.2. Location

This study was restricted to Mount Road between Air India Office and Victoria Technical Institute and General Patters Road.

13.3. Time and Length of Study

The cycle parking survey was conducted between 8.00 a.m. and 12.00 noon and from 4.00 p.m. to 8.00 p.m. The cycle accumulation during every 30 minutes was noted.

13.4. Procedure

Mount Road between Air India Office and Victoria Technical Institute was divided into 5 sections and the General Patters Road into one section. The length of each section was such that an observer was able to cover it easily in 30 minutes including his return to the starting point. Each section of the road was toured by an observer every 30 minutes. The cycle parking accumulation study form provided had previously added to it in the title space, the date, the day of the week, the time of observation to which the form related and a description of the location. One form for each section of the road was used. Before commencement of the survey, the prevailing weather condition and the name of the observer was recorded in the form.

The first tour by the observer was started at about 7.50 a.m. since it involved gathering of more details and required 40 minutes. On the first tour, the observer noted the name of the building in column 1 (Form 4) and the number of cycles parked opposite to this building in column 2 (headed 8.00 a.m.). On each subsequent tour, the number of cycles parked opposite to these buildings was noted in columns 3 to 9 headed 8.30 a.m. etc., and so on. No allowance for what was seen just before or just after passing the building was made. The number of cycles was recorded only to permit an estimate of the demand of parking spaces for cycles.

13.5. Results

The accumulation of cycles in Mount Road during the period between 8.00 a.m. and 12.00 noon and from 4.00 p.m. and 8.00 p.m. is given in Fig. 7.

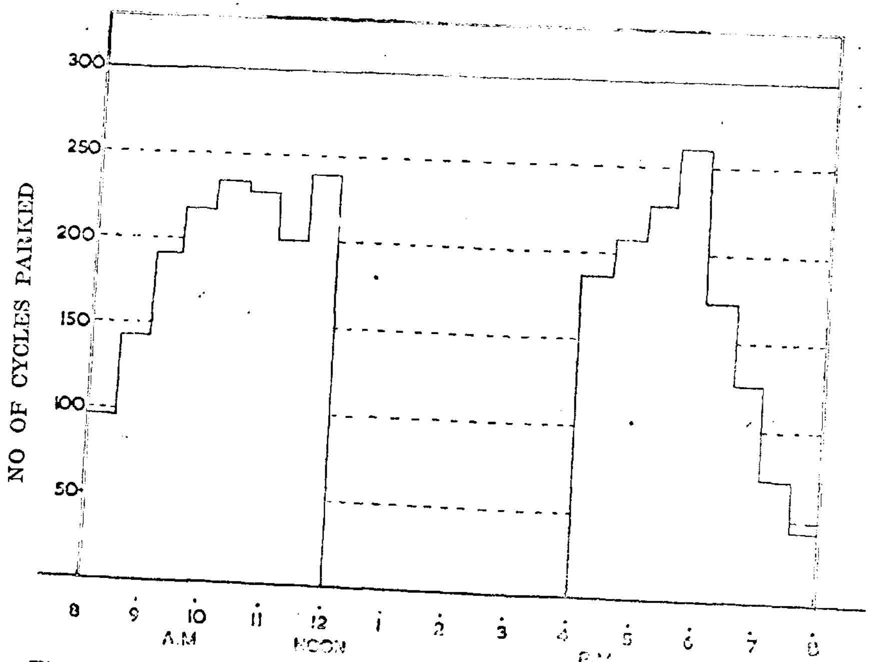


Fig. 7. Cycles Parked on Mount Road Movement and Accumulation by 30 Minute Periods Normal working Day 11th October, 1960.

14. ANALYSIS AND RECOMMENDATIONS

14.1. Curb Parking

14.1.1. In Mount Road, there are 237 spaces for parking. The maximum demand in Mount Road as observed during the survey was for 174 parking spaces, Table 11. By the proposed improvement to Mount Road as provided in the pilot scheme, the parking spaces will get reduced to 100 spaces, Plate IV. Hence alternate arrangements will have to be made for the provision of curb parking or off-street parking to the extent of 74 vehicle spaces. This provision can meet only the present needs. Considering the rapid rate at which the automobile traffic is increasing, the demand for parking may rise to 100 per cent within the next 5 years. Hence it is necessary even now to foresee the future requirements and make adequate provisions. Assuming a 100 per cent increase, the total parking demand will be about 348 vehicle spaces.

14.1.2. It is suggested that the parking demand may be met by:

(a) Restricting the parking time on the curb side in Mount Road to 30 minutes. The traffic survey revealed, Fig. 3, that 72 per cent of the parkers required only about 20 minutes. The long time parkers were generally found opposite to business establishments. It is presumed that they may be employees working in such establishments. The restriction of 30 minutes is proposed to induce the establishments located along Mount Road to make adequate provision themselves for parking for their employees within their own premises.

(b) Provision of curb side parking in the following branch roads:

(i) Club House Road 26 parking spaces

(ii) Binny's Road 20 parking spaces.

(c) provision of off-street parking in the following places:

(i) Open space in front of Cosmopolitan Club, Mount Road 15 parking spaces

(ii) River margin adjoining the Cooum river in Dams Road 40 parking spaces

(iii) Open space in Government Arts College, Mount Road 25 parking spaces.

14.1.3. In General Patters Road (between Mount Road junction to Woods Road junction), there are 29 spaces on the north side and 68 spaces on the south. The maximum demand in this street is for 60 spaces. In the pilot scheme, it is proposed to make General Patters Road a one-way road, allowing only entry of traffic from General Patters Road into Mount Road. This arrangement makes available two lanes of 11 ft each for fast moving traffic and two lanes of 8 ft each for cyclist traffic and one parking lane of 8 ft. It is proposed to allow parallel parking on the southern side of General Patters Road, besides accommodating the bus stops. This arrangement provides for 68 parking spaces as against the maximum demand for 60 parking spaces.

14.1.4. At present, the vehicles are parked in a disorderly manner along the curb, some vehicles parking parallel and some vehicles parking at an angle. The parallel parking, Photo 5, interferes the least with the movements of traffic as compared to angle parking, Figs. 8 and 9. Where there are 'No Parking' restrictions the vehicles are parked on the footpath, Photo 6, causing great inconvenience to the pedestrians. In some places, the vehicles are

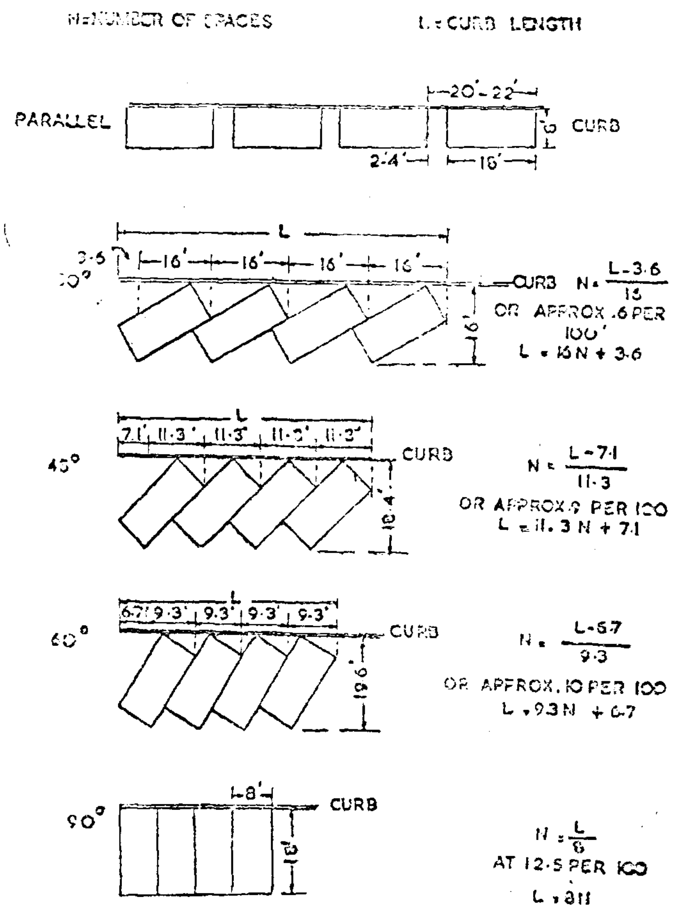


Fig. 8. **Angle parking**

parked across the pedestrian cross-walks also. Section 81 of the Motor Vehicles Act reads " No person in charge of a motor vehicle shall cause or allow the vehicle or any trailer to remain at rest on any road in such a position or in such a condition or in such circumstances as to cause or be likely to cause danger, obstruction or undue inconvenience to other users of the road ".

The above provision in the Motor Vehicles Act is not adequate and specific. Hence it is suggested that a law should be enacted prohibiting stopping, standing or parking of vehicles, on a sidewalk, within an intersection, on a cross-walk, or upon any bridge. Parking of any vehicle for the purpose of displaying such vehicles for

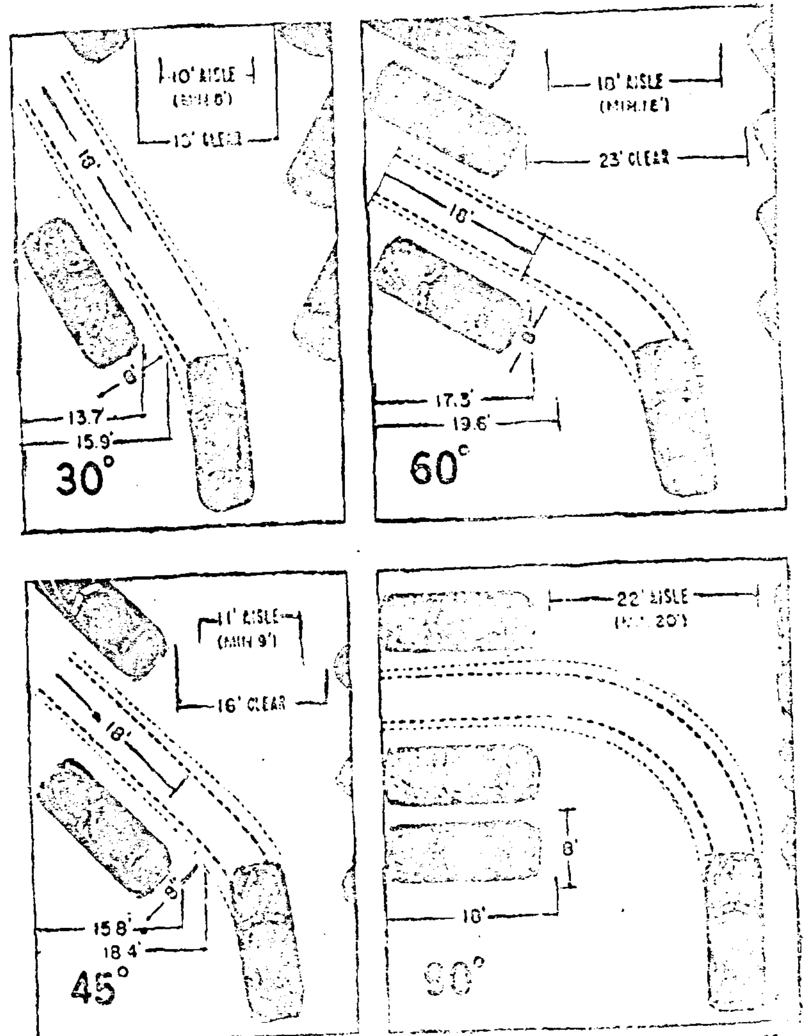


Fig. 9. **Space and aisle requirements for parking at various angles**

sale, or for washing, greasing and or repairing such vehicles, except for repairs necessitated by an emergency, should also be prohibited. No person should be allowed to park a vehicle on a roadway other than parallel with the edge of the roadway, headed in the direction of lawful traffic and with the left-hand wheels of the vehicle within 18 inches of the curb or the edge of the roadway except where angle parking has been indicated. In this connection, Articles XIII, XIV and XVI of Model Traffic Ordinance issued by the Public Roads

Administration, Federal Works Agency, U.S.A., as modified, Annexure 1, are suggested for adoption.

14.2. Cycle Parking

At present cycles are being parked at 90° to the direction of curb on the pedestrian footpath, Photo 7, causing great inconvenience to the pedestrian movement. Consequent on the widening of the roadway to provide for additional traffic lanes, the footpath widths in many of the places have been reduced to 8 ft. On account of the presence of window displays, etc., attracting pedestrians, a footpath width of 3 to 4 ft is also lost for the movement of pedestrians. Hence it is necessary that the pavement parking of cycles on the footpath should be prohibited. In this connection it is also suggested that betel shops and other petty transactions causing obstruction to pedestrians should be located away so as to cause least obstruction to pedestrian movement.

Sufficient attention has not been given to the provision of parking places for pedal cycles while their riders go about their business. Cycles left stationary, often precariously, at the curb side or against a wall or fence, obstruct vehicular and pedestrian traffic and may be a source of danger. For this reason, as also to minimise risk of theft or damages, consideration should be given to the allocation of site equipped with stands or racks, preferably protected from the weather. Such sites may be found in open spaces adjoining shops and other business premises.

14.3. Private Parking

The analysis showed that the parking arrangements provided for the employees and to customers in public buildings, private buildings and theatres located in Mount Road, are woefully inadequate. The newly constructed Postmaster-General's Office is an instance where no parking facilities are provided for the public coming to transact business. So much so vehicles are forced to park on the footpath (where curb parking is prohibited, Photo 6).

The recently constructed L.I.C. Building with a floor area of 89,000 sq. ft. makes provision for only 11 garages for the employee parking, Photo 8. No provision has been made for the parking of customers. At present there are 14 informal vehicle spaces opposite to L.I.C. (Photo 9) and the present occupancy rate is very high. The above instances show that it is necessary to enact zoning ordinances enforcing the provision of off-street parking facilities whenever a new or substantially altered building is provided. In this connection, the parking spaces prescribed for the various buildings in other countries

are given in Annexure 2. Similar zoning regulations are worthy of adoption in big cities like Madras.

14.4. Taxi Stands

The taxi stands are at present located on the pedestrian footpaths. Consequent upon the widening of Mount Road these have to be located away from the road. It is suggested that the taxi stands may be located in the following places in Mount Road by acquiring the required land, Table 13.

TABLE 13

Showing the proposed location of taxi stands

Sl. No.	Location of taxi stand	No. of taxis that can be accommodated	Approximate area required sq. ft.	Remarks
1.	Opposite to Kashmir Arts Emporium	19	3,800	
2.	Corner of Tarapore & Co.	10	2,000	
3.	Opposite to Arts College	22	4,400	

14.5. Bus Stops

The bus loading zone lengths recommended by the American Transit Association are given in Table 14. These standard lengths have been adopted in Mount Road.

TABLE 14

Showing the standard bus loading zones specified by American Transit Association

Approximate bus seating capacity	One-bus stop			Two-bus stop		
	Near side	Far side	Mid block	Near side	Far side	Mid block
25 & less	60	50	85	90	80	115
30	70	50	95	100	80	125
35	75	55	100	110	90	135
40 — 45	80	60	105	120	100	145

It is recommended that the bus stops may be located in the places shown in Table 15 on Mount Road.

TABLE 15

Showing the proposed location of bus stops

Sl. No.	Name of street	Side	Location	City or mofussil	Length of zone (ft)
1.	Mount Road	East	Opp. to Kashmir Arts Emporium	City or mofussil	135
2.	,,	,,	Opp. to Bharat Buildings	,,	145
3.	,,	,,	Opp. to V.S.T. & Co.	City	145
4.	,,	West	Opp. to Govt. Arts College	,,	145
5.	,,	,,	Opp. to Reliance Motor Company	City or mofussil	145
6.	,,	,,	Opp. to Tarapore & Co.	,,	125

At present there are four bus stops on General Patters Road as shown in Table 4. By the conversion of General Patters Road into one-way road, the existing two bus stops on the northern side will cease to function. Hence provision has to be made for the bus stops on the southern side only, opposite to Byranjung street and opposite to Bharat Buildings. It is proposed to provide one bus stop to accommodate two buses opposite to Byranjung street. The bus stop opposite to Bharat Buildings will be removed as it is close to the intersection.

14.6. Petrol Bunks and Service Stations

There are six petrol bunks and service stations on Mount Road (between Blackers Road junction to Victoria Technical Institute) causing interruption to traffic by the vehicles entering and leaving the petrol bunks and service stations. The number of bunks and service stations may be gradually reduced by the stoppage of renewal of licences and by prohibiting the opening of new bunks and service stations.

14.7. Driveways

Driveways and alleys constitute about 11 per cent of the curb spaces. Entrances and exits from Mount Road to adjoining properties

are allowed indiscriminately adding to the traffic hazard. The entrances and exits have not also been properly designed to suit the vehicles using them with the result these vehicles have to cut across other traffic lanes to make an entry into or exit from the adjoining properties. Hence it is recommended that the entries and exits from Mount Road should be limited and properly designed.

14.8. Parking Signs

'No Parking Zone' has to be indicated by means of 'No Parking' signs as specified in the IXth Schedule (item No. 3) under Mandatory signs, Fig. 10, of the Motor Vehicles Act. To this sign, a plate is added indicating the time during which parking is

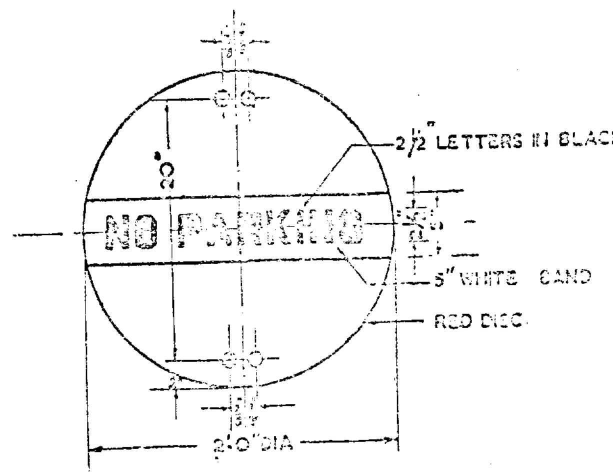
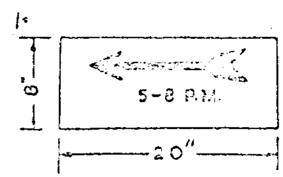


Fig. 10. Parking sign



BACKGROUND WHITE—ARROW BLACK

Note: Arrow may point in either direction. Space below arrow to indicate times during which parking is prohibited if necessary. Letters and figures to be 2 in. high.

To be used in conjunction with Sign No. A-5.

Fig. 10-A. Special parking sign

prohibited. In addition, there is also a single or double headed arrow to indicate the direction in which the regulation is in effect, Fig. 10-A. .The arrows are also added to the main sign (Photo 6). The period during which parking is prohibited is, however, not indicated.

It is suggested that the time during which parking is prohibited may also be noted and parking sign, Fig. 11, standardised for uniform adoption. Where parking is permitted for a restricted time or during certain hours, special signs as shown in Fig. 12 may be posted.

Fig. 11.
Size 12 in. × 18 in.
Background white letters red

Fig. 12.
Size 12 in. × 18 in.
Background white letters red

Parking sign in residence and business districts may be mounted not less than 7 ft nor more than 10 ft above the top of the curb, and with no part of the sign less than 1 foot away from the face of the curb. They may be set at an angle of not less than 30° nor more than 45° with a line parallel to the flow of traffic so as to be visible to approaching traffic, Fig. 13. Where the zone is longer than 200 ft, signs showing a double arrow will be needed at intermediate points within the zone at intervals not exceeding 200 ft.

14.9. Curb Markings for Parking Restrictions

Curb marking may be used to show where parking is prohibited at all times. The curb marking may be of solid yellow colour covering the face and top of the curb. Curb markings are recom-

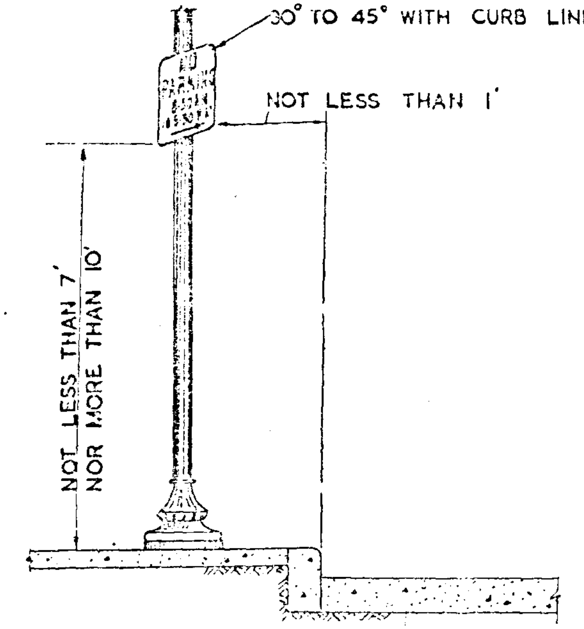


Fig. 13.
Height and lateral location of parking sign

mended only to show that parking is prohibited at all times. Other restrictions should be shown by standard parking signs.

14.10. Marking Parking Stalls

Parking stalls outlined or indicated on the pavement or curb are valuable in promoting orderly parking.

Parallel parking limits may be indicated on the pavement by lines marked perpendicular to the curb and extending into the roadway. The width required by a parked vehicle is usually 8 ft. The zone may be divided into stalls by the use of lines perpendicular to the curb and so spaced that each stall is long enough to accommodate one parked vehicle (usually 20 to 22 ft). In this case, a short line (4 ft long) parallel to the curb may be placed at the end of each stall line indicating the outside boundary of the parking zone, Fig. 14.

Angle parking is generally not desirable though occasionally it may be justified, as for example, on an unusually wide pavement. Where angle parking is permitted, the marking of lines to indicate the limits of the stall enables all drivers to park at the same angle with a minimum of waste space, Fig. 14.

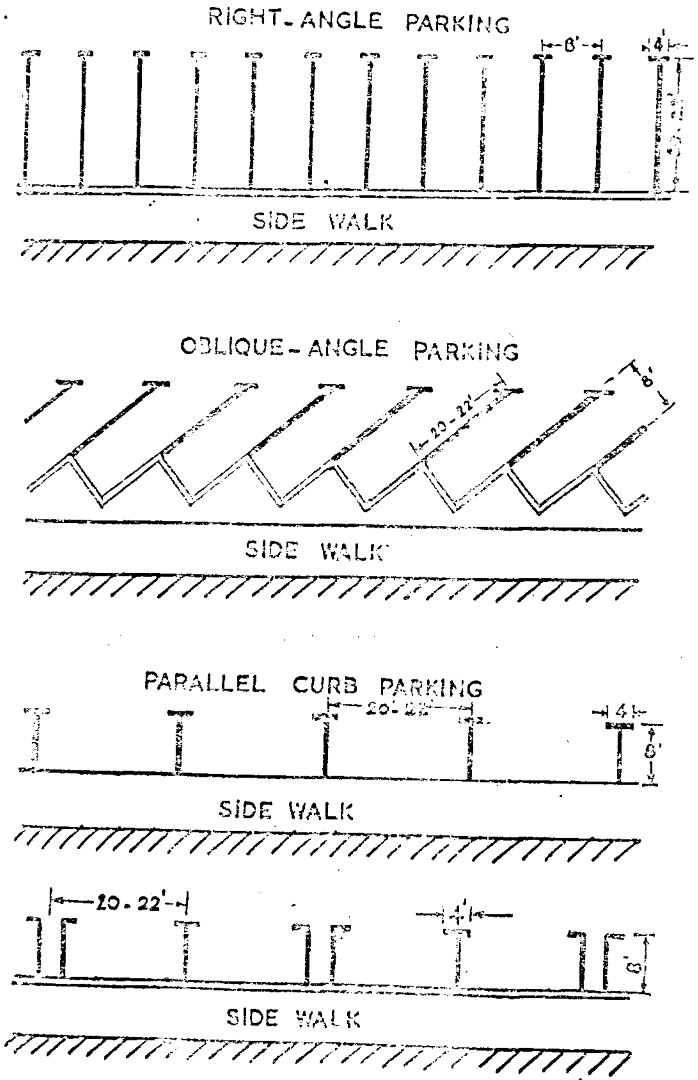


Fig. 14.
Lines indicating parking space limits

All lines for parking spaces may be solid white lines 4 in. wide. The parking stall dimension given is between the centre of the width of the white lines.

14.11. The parking problem is not new. It has been with us and grown in many localities since the rapid rise in automobile use. Faced with rising vehicular traffic and unprecedented needs for off-street parking, merchants and business organizations together with local authorities have in many cities been intensively surveying the situation and studying possible remedies. A limit must be set to the time a vehicle is allowed to wait on the carriage-way while its occupants do business in adjacent premises. Generally the length of this period will not be less than ten or more than thirty minutes. It is, therefore, recommended that curb side parking may be limited to 30 minutes and cars which are required to remain stationary for a longer period should be left in car parks.

14.12. The Corporation should make available in the public car parks sufficient space to meet the whole of the probable demand. This is especially so in Mount Road, where the nature of the development prevents the majority of private enterprises from making provisions within boundaries of their sites. The distribution of car parks should be carefully considered. Motor car owners wish to park their cars as near their destinations as is possible. For this reason, a greater number of small parks is preferable to a few large ones. Car parks may conveniently be combined with service stations and public conveniences. The shape of the site has an obvious bearing on the layout of a car park. It is found that in general the *aisles* take up rather more than one-third of the space available for parking and together with approach roads, account for approximately 45 per cent of the site. Some savings can be made if big cars are segregated, but it will be found that with the open access system, a gross area approaching 200 sq. ft. should be allowed for each car, if due allowance is made for access roads, irregularities in manoeuvring and opening of doors. Four alternate layouts for surface car parks are suggested in Fig. 15.

14.13. A distinction should be made between short time parkers, like shoppers, visitors to offices, etc., and long time parkers. Short time parkers generally need to be closer to their destinations and they can afford to pay the high cost of parking facilities in business areas where the use of high-priced land is involved. Therefore, small parking units for short time parkers may be scattered throughout the business areas or immediately adjacent to them. All-day parking facilities, on the other hand, may be located on less expensive land on the fringe of the business area and since proximity to destination is less important, the units may be of much greater capacity.

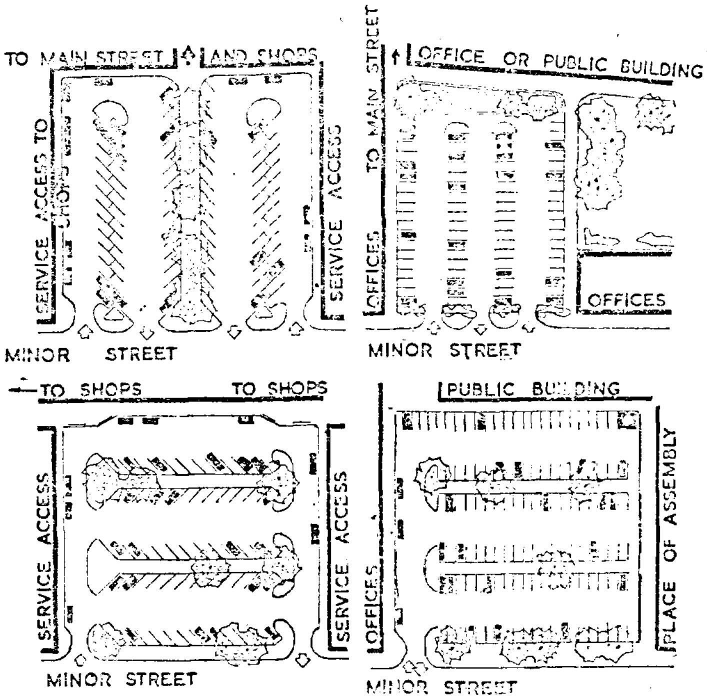


Fig. 15.

Layout of car parks

14.14. Lastly, parking restrictions are only as effective as the efforts to enforce them. Regulations carefully related to parking needs and impartially enforced help to achieve the best use of the existing facility.

ACKNOWLEDGMENTS

The Authors acknowledge with thanks the valuable information furnished by the Madras City Police Department and Corporation of Madras for preparing this Paper. Their grateful thanks are also due to the Director, Highways Research Station, Madras, for his valuable guidance.

The Paper is published with the permission of the Chief Engineer (Highways and Rural Works), Madras.

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FORM 1—(*Contd.*)

Location				Special spaces						Restricted				
Street	Side	Bounding	Streets	Angle or parallel	No. of spaces	Curb length (feet)	Taxi stand (feet)	Bus stop (feet)	Petrol bunks & service stations (feet)	Intersections alleys, drive-ways (feet)	Corner clearance (feet)	No Parking (feet)	Total length (feet)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Club House Road	North	Mount Road	Express Estate	Parallel	20	359	—	—	—	29	131	—	519	
	South	Express Estate	Mount Road	,,	12	214	—	—	—	65	232	—	511	
Patullos Road	North	Mount Road	Whites Road	—	—	—	—	—	—	106	—	1,180	1,286	
	South	Whites Road	Mount Road	—	—	—	—	35	—	232	—	1,019	1,286	
Binny's Road	North	Bridge	,,	—	—	—	—	75	—	12	229	605	921	
	South	Mount Road	Bridge	—	—	—	—	75	—	75	—	770	920	
Dams Road	North	Blackers Road	Mount Road	—	—	—	—	—	—	50	—	700	750	
	South	Mount Road	Blackers Road	—	—	—	—	—	—	50	—	720	770	

FORM 2

MADRAS STATE HIGHWAYS AND RURAL WORKS DEPARTMENT

Off-Street Parking Facility Inventory

1. Lot Garage Located on
   side of street between
   and streets
2. Public Private Free Pay
3. Owner
4. Lot dimensions Area
5. Entrance ft in. from Street
   Exit ft in. to Street
6. (If lot) No. of spaces with aisles clear
   if packed
   (If garage) Clear aisles Packed
   No. of spaces in
   Basement
   Ground floor
7. No. of attendants Open from A.M. to P.M.
8. Rates
9. Approximate total No. of vehicles stored daily (est.)
10. Parking area surface type condition
11. Lighting
12. Sketch layout on back of this sheet, showing aisles, stall arrangements, entrance and exits
13. Field data obtained 196 —196

FORM 1

MADRAS STATE HIGHWAYS AND RURAL WORKS DEPARTMENT

Curb Inventory Records

Location				Special spaces						Restricted				
Street	Side	Bounding	Streets	Angle or parallel	No. of spaces	Curb length (feet)	Taxi stand (feet)	Bus stop (feet)	Petrol bunks & service stations (feet)	Intersections, alleys, drive-ways (feet)	Corner clearance (feet)	No Parking (feet)	Total length (feet)	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mount Road	East	Wallajah Road	General Patters Road	Parallel	34	612	—	129	160	189	91	82	1,263	
		General Patters Road	Nellukara Veera Mudali Street	—	14*	—	—	104	98	148	154	445	949	*Parking is allowed on the footpath.
		Nellukara Veera Mudali Street	Woods Road	90°	63	504	—	50	—	55	—	67	676	
		Woods Road	Club House Road	90°	15	120	—	—	—	—	86	—	206	
		Club House Road	Patullos Road	—	—	—	—	—	—			250	250	
		Patullos Road	Opposite to Victoria Institute	—	—	265	—	44	238	89	62	16	714	
	West	Victoria Technical Institute	Binny's Road	—	—	—	—	39	150	203	150	440	982	
		Binny's Road	M.E.C. Street	Parallel	13	260	—	50	—	53	183	118	664	
		M.E.S. Street	Dams Road	,,	41	820	—	56	—	88	400	259	1,623	
		Dams Road	Blackers Road	—	—	—	—	216	—	102	359	371	1,018	
General Patters Road	North	Mount Road	Irani Hotel	—	—	—	—	69	—	103	—	928	1,100	
		Irani Hotel	Woods Road junction	Parallel	29	580	—	50	82	81	77	—	870	
	South	Woods Road	Byranjung Bahadur I Street	,,	35	630	—	—	—	60	50	—	740	
		Byranjung Bahadur I Street	Mount Road	60° Parallel	10 23	140 460	—	110	—	68	125	267	1,170	
Nellukara Veera Mudali Street	North	Mount Road	General Patters Road	Parallel	10	180	—	—	—	—	44	99	323	
	South	General Patters Road	Mount Road	90°	6	48	—	—	—	22	—	253	323	
Woods Road	South	,,	,,	—	—	—	—	—	—	15	—	657	672	
	North	Mount Road	General Patters Road	—	—	—	—	—	—	67	—	620	687	

FORM 3

MADRAS STATE HIGHWAYS AND RURAL WORKS DEPARTMENT

Parking Usage Study

Date : Day : Time :

Location : District : CITY/Taluk

Weather :

Observer :

Sl. No.	Time	Time	Time	Time	Time	Time	Time	Time
	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked

FORM 3 (a)

Parking Usage Study Page...

Sl. No.	Time	Time	Time	Time	Time	Time	Time	Time
	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked	Regd. No. of cars parked

FORM 4

MADRAS STATE HIGHWAYS AND RURAL WORKS DEPARTMENT

Cycle Parking Study

Date : Day : Time :

Location :

Weather :

Observer :

Location	Time	Time	Time	Time	Time	Time	Time	Time
	No. of cycles parked	No. of cycles parked	No. of cycles parked	No. of cycles parked	No. of cycles parked	No. of cycles parked	No. of cycles parked	No. of cycles parked

Annexure 1

METHOD OF PARKING

(Extract from the Model Traffic Ordinance issued by Public Roads Administration, Federal Works Agency, U.S.A.)

Standing or parking close to curb :

No person shall stand or park a vehicle in a roadway other than parallel with the edge of the roadway headed in the direction of lawful traffic movement and with the left-hand wheels of the vehicle within eighteen (18) inches of the curb or edge of the roadway except as otherwise provided in this article.

Signs or markings indicating angle-parking :

(a) The engineer shall determine upon what streets angle-parking shall be permitted and shall mark or signs such streets but such angle-parking shall not be indicated upon any National or State Highway within the city unless the State Highways Department has determined that the roadway is of sufficient width to permit angle-parking without interfering with the free movement of traffic.

(b) Angle-parking shall not be indicated or permitted at any place where passing traffic would thereby be caused or required to drive upon the right side of the street or upon any street car tracks.

Obedience to angle-parking signs or markings :

Upon those streets which have been signed or marked by the engineer for angle-parking, no person shall park or stand a vehicle other than at the angle to the curb or edge of the roadway indicated by such signs or markings.

Permit for loading or unloading at an angle to the curb :

(a) The engineer is authorised to issue special permits to permit the backing of a vehicle to the curb for the purpose of loading or unloading merchandise or materials subject to the terms and conditions of such permit. Such permits may be issued either to the owner or lessee of real property or to the owner of the vehicle and shall grant to such person the privilege as therein stated and authorised herein.

(b) It shall be unlawful for any permittee or other person to violate any of the special terms or conditions of any such permit.

Lights on parked vehicles :

(a) Whenever a vehicle is lawfully parked at night time upon any street within a business or residence district no lights need be displayed upon such parked vehicle.

(b) Whenever a vehicle is parked upon a street or highway outside of a business or residence district during the hours between one-half hour after sunset and one-half hour before sunrise, such vehicle shall be equipped with one or more lamps which shall exhibit a white light on the roadway side visible from a distance of 500 feet to the front of the vehicle and a red light visible from a distance of 500 feet to rear.

(c) Any lighted headlamps upon a parked vehicle shall be depressed or dimmed.

Stopping, standing, or parking prohibited in specified places :

Stopping, standing or parking prohibited. No signs required.

(a) No person shall stop, stand, or park a vehicle, except when necessary to avoid conflict with other traffic or in compliance with law or the directions of a police officer or traffic control device, in any of the following places:

1. On a sidewalk;
2. In front of a public or private driveway;
3. Within an intersection;
4. Within 15 feet of a fire hydrant;
5. On a cross walk;
6. Within 20 feet of a cross walk at an intersection;
7. Within 30 feet upon the approach to any flashing beacon, stop sign, or traffic-control signals located at the side of a roadway;
8. Between a safety zone and the adjacent curb or within 30 feet of points on the curb immediately opposite to the ends of a safety zone, unless the city traffic engineer has indicated a different length by signs or markings;
9. Within 50 feet of the nearest rail of a railroad crossing;
10. Within 20 feet of the driveway entrance to any fire station and on the side of a street opposite the entrance to any fire station within 75 feet of said entrance (when properly sign posted).
11. Alongside or opposite any street excavation or obstruction when stopping, standing, or parking would obstruct traffic;
12. On the roadway side of any vehicle stopped or parked at the edge or curb of a street;
13. Upon any bridge or other elevated structure upon a highway or within a highway tunnel;
14. At any place where official signs prohibit stopping.

(b) No person shall move a vehicle not lawfully under his control into any such prohibited area or away from a curb such distance as is unlawful.

Parking not to obstruct traffic :

No person shall park any vehicle upon a street, other than an alley, in such a manner or under such condition as to leave available less than 10 feet of the width of the roadway for free movement of vehicular traffic.

Parking in alleys :

No person shall park a vehicle within an alley in such a manner or under such conditions as to leave available less than 10 feet of the width of the roadway for the free movement of vehicular traffic, and no person shall stop, stand, or park a vehicle within an alley in such position as to block the driveway entrance to any abutting property.

All-night parking prohibited :

No person shall park a vehicle on any street for a period of time longer than 30 minutes between the hours of 2 a.m. and 5 a.m. of any day, except physicians on emergency calls.

Parking for certain purposes prohibited :

No person shall park a vehicle upon any roadway for the principal purpose of:

(1) Displaying such vehicle for sale.

(2) Washing, greasing, or repairing such vehicle except repairs necessitated by an emergency.

Parking adjacent to schools :

(a) The engineer is authorised to erect signs indicating no parking upon either or both sides of any street adjacent to any school property when such parking would, in his opinion, interfere with traffic or create a hazardous situation.

(b) When official signs are erected indicating no parking upon either side of a street adjacent to any school property as authorised herein, no person shall park a vehicle in any such designated place.

Parking prohibited on narrow streets :

(a) The engineer is hereby authorised to erect signs indicating no parking upon any street when the width of the roadway does not exceed 20 feet, or upon one side of a street as indicated by such signs when the width of the roadway does not exceed 30 feet.

(b) When official signs prohibiting parking are erected upon narrow streets as authorised herein, no person shall park a vehicle upon any such street in violation of any such sign.

Standing or parking on one-way streets :

The engineer is authorised to erect signs upon the right-hand side of any one-way street to prohibit the standing or parking of vehicles, and when such signs are in place, no person shall stand or park a vehicle upon such right hand side in violation of any such sign.

Standing or parking on one-way roadways :

In the event a highway includes two or more separate roadways and traffic is restricted to one direction upon any such roadway, no person shall stand or park a vehicle upon the right-hand side of such one-way roadway unless signs are erected to permit such standing or parking. The engineer is authorised to determine when standing or parking may be permitted upon the right-hand side of any such one-way roadway and to erect signs giving notice thereof.

No stopping, standing, or parking near hazardous or congested places :

(a) The engineer is hereby authorised to determine, designate by proper signs places not exceeding 100 feet in length in which the stopping, standing, or parking of vehicles would create an especially hazardous condition or would cause unusual delay to traffic.

(b) When official signs are erected at hazardous or congested places as authorised herein, no person shall stop, stand, or park a vehicle in any such designated place.

Stopping, standing or parking restricted or prohibited on certain streets :

Application of articles : The provisions of this article prohibiting the standing or parking of a vehicle shall apply at all times or at those times herein specified or as indicated on official signs except when it is necessary to stop a vehicle to avoid conflict with other traffic or in compliance with the directions of a police officer or official traffic control device.

Regulations not exclusive:

The provisions of this article imposing a time limit on parking shall not relieve any person from the duty to observe other and more restrictive provisions prohibiting or limiting the stopping, standing, or parking of vehicles in specified places or at specified times.

Parking prohibited at all times on certain streets:

When signs are erected giving notice thereof, no person shall park a vehicle at any time upon any of the streets described.

Parking prohibited during certain hours on certain streets:

When signs are erected in each block giving notice thereof, no person shall stop, stand or park a vehicle between the hours specified of any day except Sundays and Public holidays within the district or upon any of the streets described. Stopping, standing, or parking is prohibited during certain hours on certain streets.

Parking time limited on certain streets:

When signs are erected in each block giving notice thereof, no person shall park a vehicle for longer than at any time between the hours of (   ) a.m. and (   ) p.m. of any day except Sundays and Public holidays within the district or upon any of the streets described.

Parking signs required:

Whenever by this or any other Ordinance of this city any parking time limit is imposed or parking is prohibited on designated streets it shall be the duty of the engineer to erect appropriate signs giving notice thereof and no such regulations shall be effective unless said signs are erected and in place at the time of alleged offence.

Annexure 2

Parking space prescribed for the various buildings in other countries

Type of buildings	One parking space required for each		No. of cities represented
	Average	Range of middle 2/3	
Theatres, auditoriums, etc.	7 seats	4-10 seats	24
Retail business	400 sq. ft.	300-500 sq. ft. *	8
Office buildings	400 sq. ft.	400 sq. ft. ** 500 sq. ft. 500 sq. ft.	
Restaurants	(see notes)	50 sq. ft. *** 100 sq. ft. 5 seats	3
Hotels	4 guest rooms	3–4 guest rooms	14
Industrial buildings	3 employees	2-4 employees****	5
	750 sq. ft.	400–800 sq. ft.	4
Single dwellings	1 unit	1 unit	11
Multiple dwellings @	$1\frac{1}{2}$ units	1–3 units	33

Notes:

* Usually square feet of space devoted to sales.

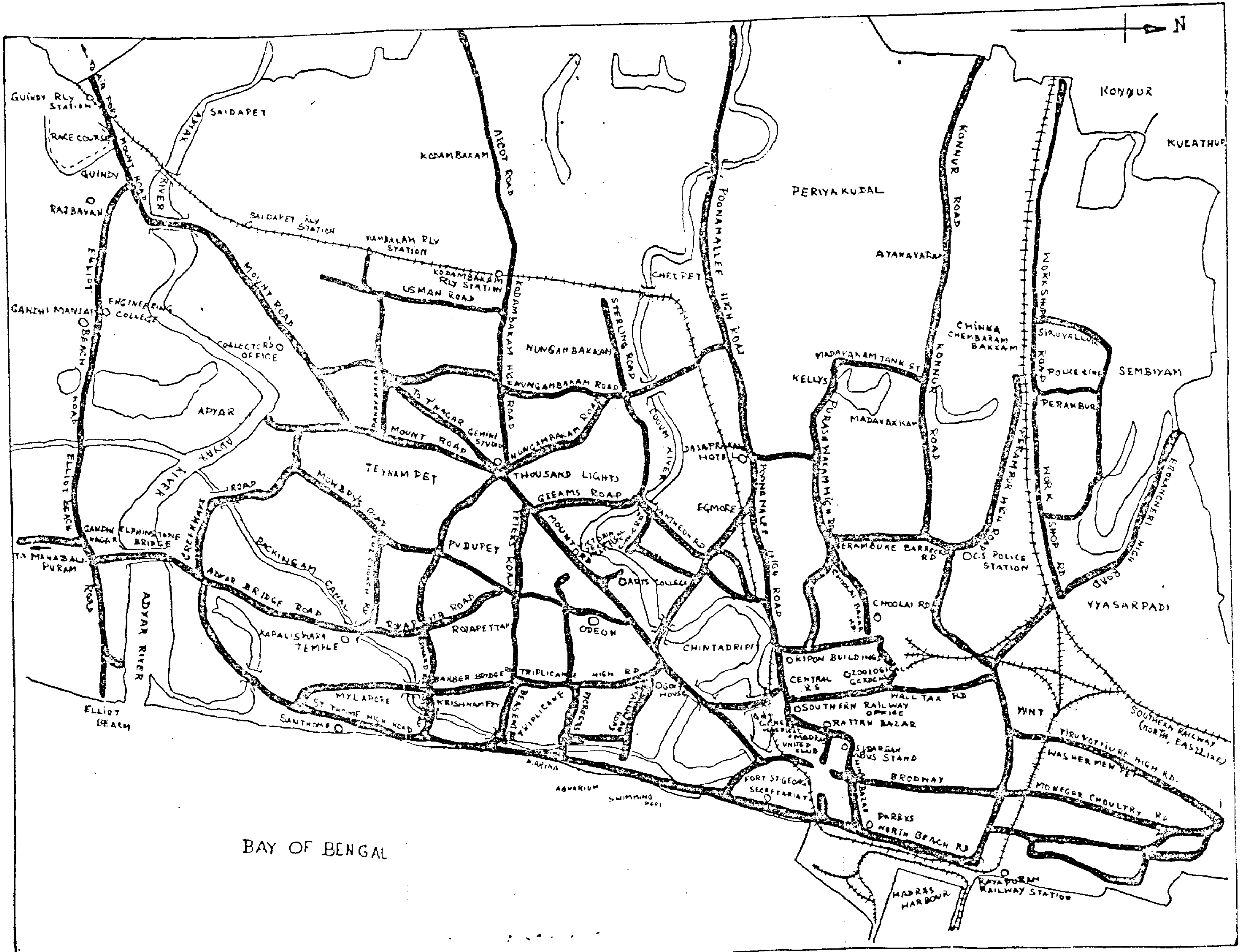
** Represents all three having such requirements.

*** One per 50 square feet devoted to patron use, one per 100 square feet of total floor area.

**** Parking requirements based on number of employees and on gross floor area shown separately.

@ Represents grouping of all areas where multiple dwellings are permitted. Usually more parking space per dwelling unit is required in the higher class dwelling areas than in comparatively low grade areas.

PLATE I



ROAD MAP OF MADRAS CITY

(NOT TO SCALE)

Paper No. 231

"ANALYTICAL STUDY OF SOME BRIDGE ARTICULATION FAILURES"

By

S. N. SINHA*, B. PRASAD** AND P. J. PRASAD***

CONTENTS

SYNOPSIS

The Paper describes the two recent failures, at articulation, of two important bridges in Bihar. One of the bridges was constructed hardly 9 years back while the other was constructed about 19 years back. The nature of the failures, the various causes leading to failure and the remedial measures adopted have been discussed. General principles of design of articulation and certain suggestions relating to both design and construction have also been discussed.

1. INTRODUCTION

1.1. Articulations of bridges are the most vulnerable part of a road bridge and there is every reason to give special attention to their design, construction and maintenance. Every beam structure has some sort of arrangement to allow for movement either due to load or temperature. Generally, therefore, one end of the beam rests on a fixed bearing and the other end is free. A fixed end is fixed in

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position only, it allows angular rotation and translation. From considerations of economy, plate-bearing arrangements are usually provided for short spans as roller and rocker arrangements are costly.

1.2. In bridges of balanced cantilever-*cum*-suspended span type supporting short lengths of suspended spans, plate-bearing arrangements for the suspended spans at the seating of the cantilever end, are very common. Their proper design and construction should be a matter of great importance.

1.3. Recent failures at the articulations (which are also termed by some bridge engineers as "brackets at hinges", or "hinges") of two important high level R.C.C. bridges in Bihar have focussed considerable attention of the engineers of this State to the problem of both design and construction of such articulations. The two bridges are:

(a) *Akharaghat Bridge* over river Burhi Gandak at Akharaghat in the 2nd mile of Muzaffarpur-Sitamarhi Road, in North Bihar constructed during the year 1952-53; and

(b) *Gulsakri Bridge* in mile 281/11 of Grand Trunk Road (National Highway No. 2), constructed during the year 1941-42.

1.4. Both the bridges are of the usual R.C.C. cantilever-*cum*-suspended span type which is popular and suited to the foundation conditions obtaining in several bridges in this State. In North Bihar and major portions of South Bihar, where differential settlement of foundation cannot be avoided, this type of construction is suitable. It has not only better flexibility but due to the provision of cantilevers at both ends, the advantage of economy, afforded by a continuous type bridge, is also achieved to some extent.

1.5. Akharaghat Bridge is one of the largest R.C.C. high level bridges constructed in Bihar. Its salient features could be seen in Appendix 1. The salient features of Gulsakri Bridge are in Appendix 2.

2. TYPE OF BRIDGE

2.1. Akharaghat Bridge

2.1.1. An outline drawing of the bridge has been given in Plate I.

2.1.2. There are no cross girders between the two main girders. Three diaphragm beams are, however, provided in the main span the cantilever portion and two in the suspended portions, one in at the articulation, there are no diaphragms and of course no cross girder.

2.1.3. Bearings

2.1.4. Sliding plate-bearings were provided for the suspended spans having one end free and the other end fixed. Details of sliding and fixed end bearings have been shown in Plate I-A.

2.1.5. Fixed end arrangements consisted of 4 nos. of 7/8 in. diameter dowel bars in two rows. The dowels are 2 ft 3 in. long of which the bottom 1 ft 3 in. length was embedded in the seat for the suspended spans at the ends of the overhanging girders. The top 1-ft length was taken into the suspended girders in 1 in. diameter sleeves. No lead-sheet was provided between the concrete surfaces of the overhanging and suspended girders.

2.1.7. At the free end sliding plate-bearings were provided. The arrangement consisted of a 2 ft × 1 ft 8 in. × $\frac{1}{2}$ in. thick top and bottom mild steel plates with a $\frac{1}{4}$ in. thick copper plate in between. Flats of $2\frac{1}{4}$ in. × $\frac{1}{2}$ in. size were welded to the top plate to restrict any lateral movement. The top and bottom plates were fixed to the suspended girder and overhanging portion of main girder respectively by means of 7/8 in. diameter welded anchor bars of 6 in. length each. There are 4 nos. of anchor bars for each plate.

2.2. Gulsakri Bridge

2.2.1. An outline drawing of this bridge showing the general arrangement is given in Plate II. The arrangement of cross girders is shown in Plate II-A.

2.2 2. Bearings

2.2.3. One end of the suspended span was provided with a sliding bearing while the other end with a fixed bearing. The arrangements are shown in Plates III & IV.

3. BRIEF DESCRIPTION OF DAMAGES

2.1. Akharaghat Bridge

3.1.1. Typical nature of cracks is shown in Fig. 1 and Photos 1 to 7. In all the five suspended spans cracks had developed which were more pronounced at the fixed end bearings of the suspended spans at the articulation. The cracks in the 1st, 3rd and 7th spans from Muzaffarpur end were the very severe, the last being worst. In this span, a width of 15 in. out of the total seating width of 2 ft cracked badly and got detached as shown in Fig. 1 (c) and Photos 4 and 5. The tips of the suspended span also cracked as shown in the Figure. The nature of crack at the articulation of the 3rd span has been shown in Fig. 1(b) and Photos 1 to 3. In this span, a 6 in. thick chunk of concrete at the tip of the cantilever girder, got completely detached and fell down in the river. The crack in the

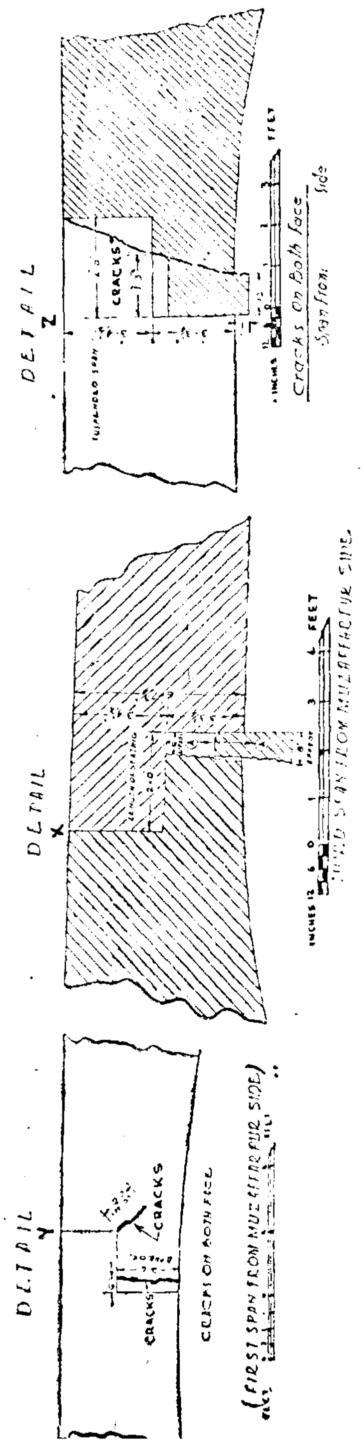


Fig. 1 (a)

Fig. 1 (b)

Fig. 1 (c)

Fig. 1 Typical nature of cracks of Akharaghat Bridge

articulation of the first span is shown in Fig. 1 (a). A vertical crack had appeared for the full height of 2 ft 6 in. and within a distance of 6 in. from the edge of the cantilever. Besides, another diagonal crack extending to a length of about 2 ft and starting from the corner point of the seat also appeared.

3.2. Gulsakri Bridge

3.2.1. Photographs 8 to 10 show the extent of damage. Both the longitudinal girders had cracked at the fixed end bearings. In the supporting girders, cracks had developed both on the up and downstream side whereas the tip of the suspended span had cracked only on the downstream side.

4. GENERAL PRINCIPLES OF ARTICULATION DESIGNS AND ANALYSIS OF FACTORS LEADING TO THE DAMAGE OF THE AKHARAGHAT BRIDGE

4.1. A brief explanation of the principles involved in the design of an articulation would help proper appreciation of the analysis of the damages briefly stated earlier. These articulations, termed also as brackets at hinges, have been treated as vital parts of a bridge structure. There is yet paucity of experimental data on the subject on account of which it is always considered desirable to provide some excess steel and reduce the stresses so that the complex nature is taken care of. This excess steel is a very small part of the total tonnage and does not materially affect the cost of a bridge.

4.1.1. The stresses to be taken care of at an articulation are:

(i) *Bending stress* due to the vertical reaction acting at the centre of the articulation. This would indicate the desirability of limiting the length of seating along the span so that the moment is reduced;

(ii) *Shear stress*: This would naturally mean that the area of the support should be increased so that the stress per sq. in. is reduced.

4.1.2. From the very section of an articulation it would be clear that on account of a sudden reduction in depth of a beam at the seating, high tensile stresses, due to bending, would develop and it would be necessary to determine the inclined plane on which the effect would be maximum. This is determined by arterial method and is briefly explained.

4.1.3. On any plane inclined at an angle θ to the vertical, the effect of the vertical reaction 'R' acting at the centre of the

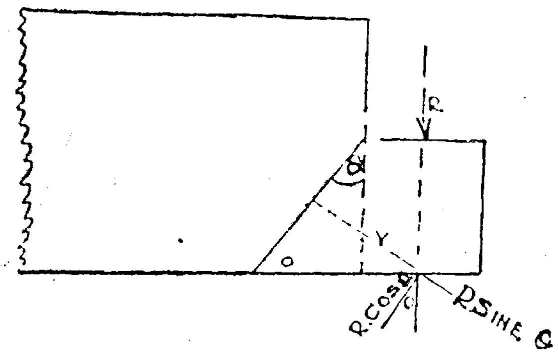


Fig. 2

articulation is :

(a) Bending moment
$M = R \cos \theta \times y$

(b) Normal tension
$N = R \sin \theta$

(c) Shear force
$S = R \cos \theta$

4.1.4. The tension is mainly resisted by the bent up inclined bars. Though these inclined bars are similar in character to diagonal shear bars of the cantilever, they are required mainly from a consideration of the tension across the inclined planes at the corner of the articulation. In order to reduce the shear stress at the articulation section, the concrete section is increased by widening the rib of the beam gradually to a maximum at the articulation. The widening is also necessary from a practical point of view as otherwise there will be no room for accommodating the large number of bars crossing one another in this region. In order to find the worst section, several arbitrary sections are taken at different angles with the vertical through the corner of the articulation and the stresses at these sections are determined assuming the material to be homogeneous. It may be noted that on account of the gradual increase in the width of the web of the beam, none of the inclined sections will have a uniform width. For each section, the width will be maximum at the top and will gradually narrow down, to a minimum, at the bottom. The minimum width at the bottom will again be different for the different sections, being smallest for the section with the greatest inclination. It is, therefore, difficult to compare precisely the stresses with these variations in width. For the preliminary trial section, it is, however, required to know which section will be the worst for tension on the top face in order that the tensile reinforcement may be adequately provided to take up these maximum stresses. The effect of variation in width of a concrete section in bending is only a slight change in the position of the neutral axis, with a consequent change in the dimension of the lever arm. This variation in the lever arm is, however, very small and, within limits, it can be assumed that the steel required for taking up the tensile stress is practically unaffected by the slight variation in the width of the beam. The tensile reinforcement is practically independent of the breadth of the section whereas the stress in a homogeneous section is inversely proportional to the breadth. In order that the calculated values of the stresses in the different homogeneous sections may correctly indicate the comparative amounts of tensile reinforcement, the homogeneous sections may be assumed to be of the same width, though they are actually different. In addition to bending, there will also be some direct tension across the section. The magnitude of direct tensile stress across the section will, however, depend on the breadth. But the effect of this direct tension is so small, compared to tension due to bending, that for practical purposes of determining the position of the worst section, the different sections may be considered to be of the same width.

4.1.5. In the particular case of the Akharaghat bridge, in order to analyse the critical section, a number of trial sections were taken at different angles as shown in Table 1. For a comparison of the stresses, a uniform width was assumed for all these sections. The direct tensile and bending stresses have been shown in columns 13 and 14 and the total tensile stresses in column 15 of that Table. It would appear that section No. 4 inclined at 32° to the vertical is subjected to the maximum tensile stress. For all practical purposes, this section was, therefore, considered as the worst section as regards tension. This section was accordingly checked for determining the area of tensile steel required across the top face of the inclined section. The forces acting at this section are shown in Fig. 3.

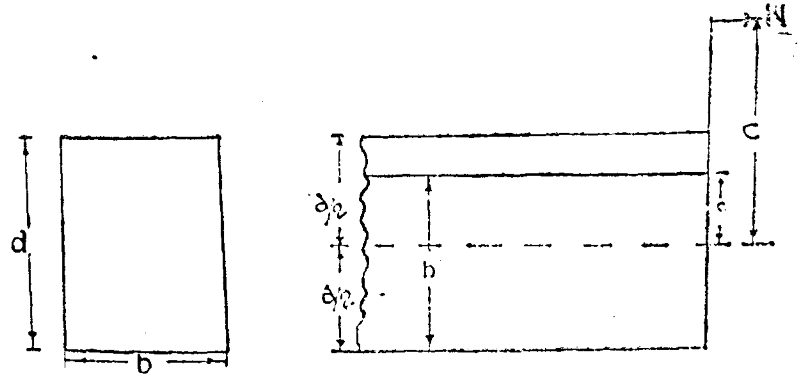


Fig. 3

TABLE 1

Analysis of trial sections taken at different angles—Akharaghat Bridge

Section	Breadth b in in. (assumed uniform for all sections)	Effective depth h in in.	Area F in sq. in. $= b \times h$	$b \times a$ where a is lever arm	Section modulus z in inch units $= \frac{bh^2}{6}$	Distance 'x' in inch	Inclination in degrees α	Sin α	Cos α	$M = R \times X$ (in lb)	$N = -R$ Sin L (in lb)	$S = R$ Cos L (in lb)	Direct tensile stress $= N/F$ in lb	Bending stress $= M/Z$ in lb/□"	Total tensile stress in lb/□" at top	Total compressive stress in lb/□" at bottom	Shear stress $V = \frac{S}{ba}$
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	16.5	39	630	550	4,200	12	0	0	1	2,247,360	0	187,280	0	530	530	530	340
2	16.5	44	730	625	5,300	18	13	0.225	0.974	3,360,000	42,000	183,000	57.5	635	692.5	577.5	291
3	16.5	48	790	680	6,300	22	23	0.391	0.921	4,100,000	73,000	172,000	92.5	650	742.5	557.5	254
4	16.5	54	890	770	8,000	27	32	0.529	.848	5,050,000	99,000	158,000	112	631	743	519	206
5	16.5	58	960	825	9,200	30	36	0.588	.809	5,618,400	110,000	152,000	115	610	725	495	184
6	16.5	68	1,120	965	12,700	36	45	0.707	0.707	6,700,000	132,000	132,000	118	530	648	412	13

This section is subjected to a moment with a direct axial pull. The system of forces can be reduced to a single eccentric pull 'N'. The eccentricity C is such that $N \times C$ = moment 'M'. Near the top, there are two Nos. of $1\frac{1}{2}$ in. dia. inclined "l" bars and 2 Nos. $1\frac{1}{2}$ in. dia. "b" bars as shown in Plate V. To simplify calculations, the two layers of bars were assumed to be in one layer placed midway between the two layers.

Area of 4 Nos. $1\frac{1}{2}$ in. θ bars = 7.068 sq. in.

Angle of inclination of the bars with the normal to the section is $(45° - 32°) = 13°$

Effective area of inclined bars to resist tension across the section = 7.068 Cos 13° = 6.85 sq. in.

b = 19 in. = 48.26 cm.

h = 42 in. = 106.68 cm.

$bh^2 = 48.26 \times 106.68^2$

$= 548{,}000$ cm.^{3}

Normal tension N = 99,000 lb

= 45,000 kg.

Bending moment M = 50,50,000 in. lb

= 58,00,000 cm. kg.

$$c = \frac{M}{N} = \frac{58{,}00{,}000}{45{,}000}$$

= 128 cm.

e = 16 in.

= 40.64 cm.

$C - e$ = (128 − 40.64)

= 87.36 cm.

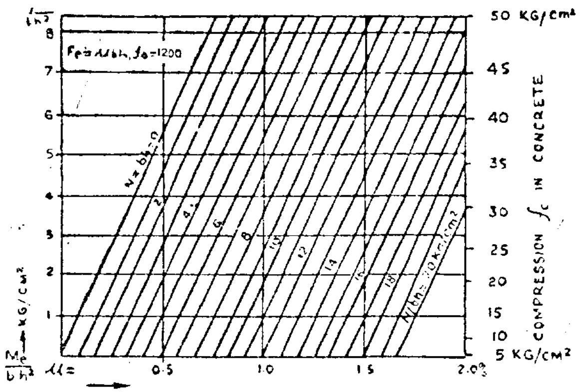
$$\frac{M e}{bh^2} = \frac{N(c\text{-}e)}{bh^2}$$

$$= \frac{45{,}000 \times 87.36}{548{,}000}$$

= 7.2 kg. per cm.^{2}

$$\frac{N}{bh} = \frac{45{,}000}{48.26} \times 106.66$$

= 8.75 kg. per cm^2.



MORSEH CURVE

$fs = 1{,}200\ kg/cm^2 = (=17{,}000\ lbs./in^2)$, $Fe = \mu b.h$

From Morseh curve

for the above values of $\frac{Me}{bh^2}$ & $\frac{N}{bh}$

Maximum compressive stress in concrete

$= 45$ kg. per cm.^{2}

$= 640$ lb per sq. in.

Percentage of steel

required, $m = 1.38$ per cent

Area of steel required $= \frac{1.38 \times 19 \times 42}{100}$

$= 11$ sq. in.

Steel actually provided $= 6.85$ sq. in. ...(i)

Taking into account the effective component of the horizontal steel bars in that plane, the total effective area of steel at this section is $6.85 + 3 \times 1.677 \sin 32°$

$= 7.65$ sq. in. ...(ii)

and, therefore, the provision of steel was inadequate by 3.35 sq. in. ...(iii)

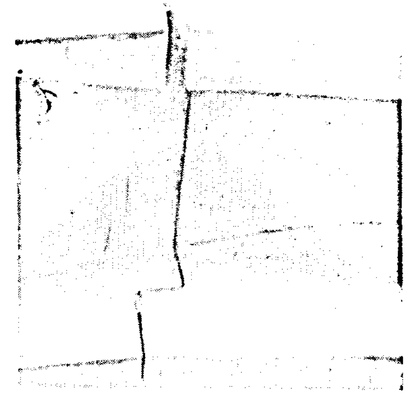


Photo 1

3rd span from Muzaffarpur side (Bottom view showing both beams) (Akharaghat Bridge)

Photo 2

A view of damage in the 7th span from Muzaffarpur side (downstream) (Akharaghat Bridge)

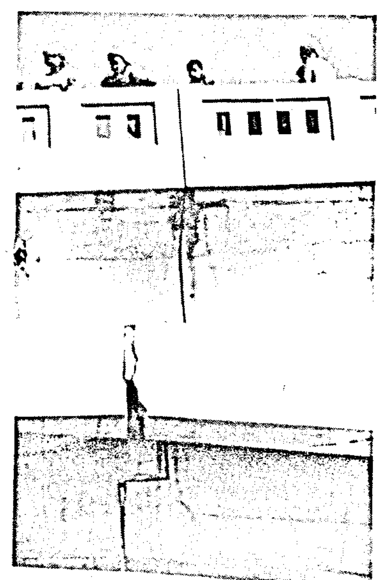


Photo 3

A view of damage in the 3rd span from Muzaffarpur side showing both beams (Akharaghat Bridge)

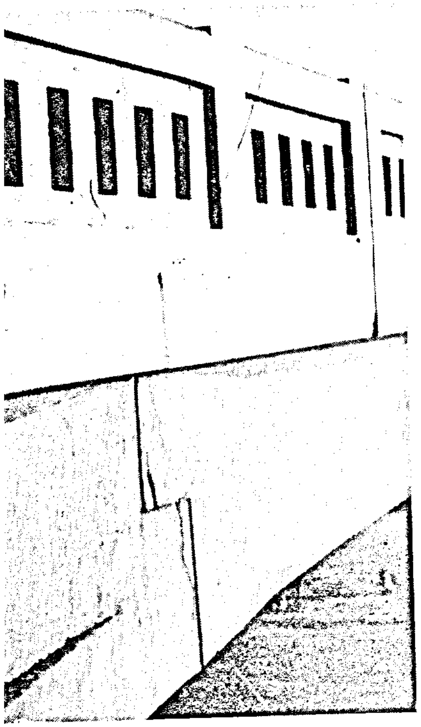


Photo 5

7th span from Muzaffarpur side inner view (downstream) (Akharaghat Bridge)

Photo 4

7th span from Muzaffarpur side (upstream) (Akharaghat Bridge)

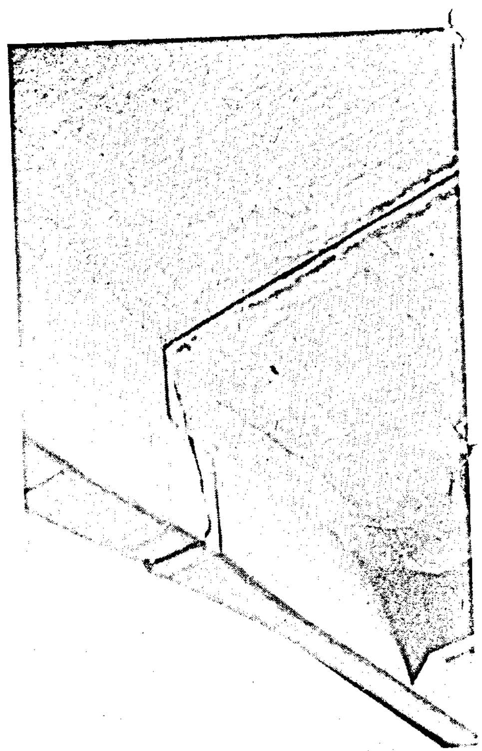
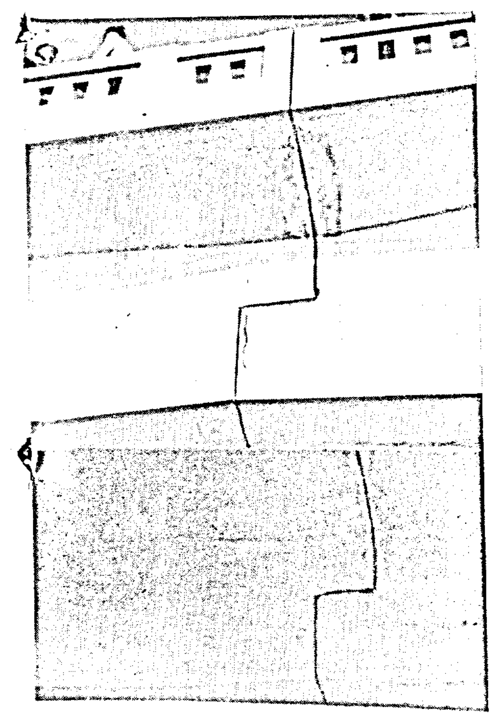


Photo 6

Cracks in the 5th span from Muzaffarpur side (downstream) (Akharaghat Bridge)



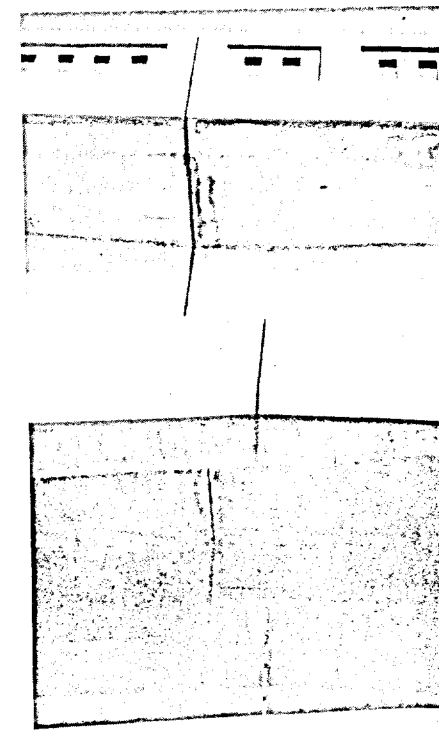


Photo 7

Cracks in the 5th span from Muza side (upstream) (Akharaghat Bridge)

Area of tensile steel required

$$= \frac{0.54 \times 24 \times 39}{100}$$

$$= 5.05 \quad \text{sq. in.} \qquad \text{...(iv)}$$

Area of steel provided

at this section $= 3$ Nos. $1\frac{1}{2}$in. dia. bars

$$= 3 \times 1.767$$

$$= 5.301 \text{ sq. in.} \qquad \text{...(v)}$$

Hence safe.

Maximum compressive stress

in concrete

$$= 25 \text{ kg./cm.}^2$$

$$= \frac{25 \times 2.54^2}{0.4536}$$

$$= 352 \text{ lb/sq. in.} \qquad \text{...(vi)}$$

Hence the vertical section was safe so far as tension and compression were concerned.

Shear :

The maximum shear at the articulation due to dead and live loads was found to be 187,280 lb.

Maximum shear stress

at the section $= \dfrac{S}{bjd}$

$$= \frac{1,87,280}{24 \times 0.872 \times 37}$$

$$= 240 \text{ lb. per sq. in.}$$

Shear taken up by the bent up bars

$$= 2 \times 1.767 \times 1.404 \times 18,000$$

$$= 89,500 \text{ lb}$$

Balance shear to be resisted by stirrups

$$= 187,280 - 89,500$$

$$= 97,780 \text{ lb}$$

Pitch of $\frac{1}{2}$ in. diameter two-legged stirrups

$$= \frac{2 \times 0.196 \times 18,000 \times 0.87 \times 37}{97,780}$$

$$= 2.28 \text{ in.} \qquad \text{... (vii)}$$

The stirrups actually provided were at 5 in. pitch ... (viii)

So even with the most liberal consideration that a maximum portion of the shear was taken by bent up bars and allowing a maximum permissible tensile stress in stirrups as 18,000 lb per sq. in., which according to Taylor, Thompson and Smulski need be greatly reduced, the provision of stirrups was inadequate. The reinforcement used here is intended to resist not only stresses due to loads and variation of temperature or imperfect action of bearings but also the tendency to cracking caused by the sudden reduction in the cross-section.

4.2. Bearing Defect

4.2.1. As has been already explained, sliding type of plate-bearing had been provided over the free ends while at the other end no steel plate or lead sheet was provided and the concrete surface of the suspended span rested directly on the concrete surface of the supporting cantilever span. The anchorage of the suspended span was also done by providing two rows of bars thus restricting rotational movement. It is also apprehended that on occount of the deflection of the suspended span, slope at the fixed end bearing changed resulting in concentrated load acting along one edge, since there was no suitable arrangement to distribute the load. The fixing arrangement also did not permit any rocking action and thus caused splitting of the concrete section. Hair pin mesh reinforcement was also not provided either above or below the bearing surface and thus there was no arrangement to distribute the concentrated stresses.

4.2.2. At the sliding end also, the arrangement provided for a copper plate-bearing sandwitched between two M.S. plates. It has been found that due to the high intensity of pressure at the bearings such an arrangement may result in electrolytic action between the copper and the steel. This electrolytic action leads to sulphating of the copper plate and in course of time restricting the movement of the sliding plate.

4.3. Constructional Defects

On chipping off the concrete and exposing the main bars, it was detected that the cover provided at the cantilever tips was excessive. The cover actually found was as much as 6 to 7 in.

4.3.1. Constructional defect was also detected in placing of the stirrups as shown in Fig 4.

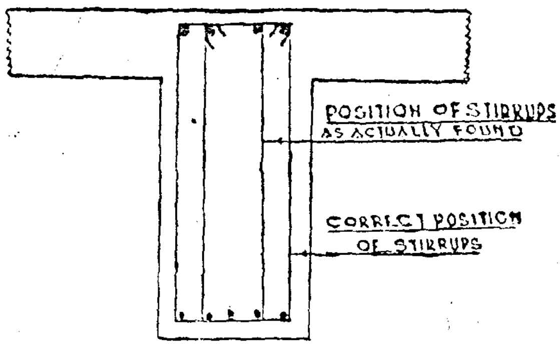


Fig. 4

Out of the 5 main bars at the bottom layer, stirrups were found round only the central three with the result that the two other bars were free and no stirrups encased them.

4.3.2. Defects of a serious nature in the placing of the main inclined bars were also noticed.

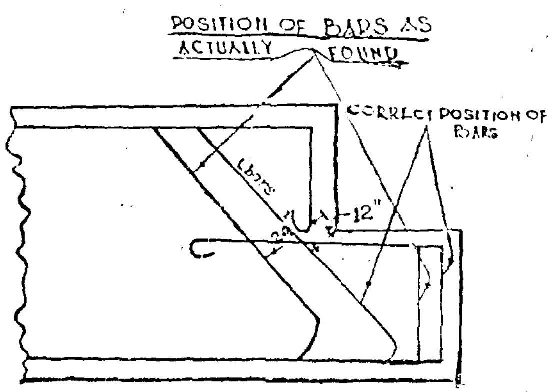


Fig. 5

4.3.3. A typical long. section of the supporting cantilever beam, near the articulation, is shown in Fig. 5. The correct

position of the inclined '*L*' bars should have been 12 in. from the tips of the cantilever end whereas it was found to be 24 in. away. The shifting of position of bars, away from the tips, decreased their effectiveness and resulted in higher stresses.

4.3.4. It could also be seen from the calculations about the intensity of shear, that the bent up bars were expected to resist total shear of 89,500 lb. Actually, however, due to constructional defects in some of the girders the bent up bars did not project into the seat at all with the result that these stresses had to be resisted by the concrete and the stirrups provided therein. The intensity of stresses at the seat, therefore, increased very considerably resulting also in shear failures. As a matter of fact, the position due to thees constructional defects worsened so much, that very roughly the calculated stresses in the stirrups under the seat increased from 18,000 lb to roughly about 50,000 lb per sq. in., thereby stressing the steel almost to the ultimate capacity.

5. REMEDIAL MEASURES FOR AKHARAGHAT BRIDGE

5.1. The following remedial measures were carried out :

(i) Suspended structure was raised by means of jacks to provide sufficient clearance for carrying out repairs, Plate VI.

(ii) All loose concrete, from the cracked portion, was removed.

(iii) Concrete cover from the sides, bottom and top of the brackets was removed. The main reinforcements and stirrups were also exposed by removing concrete around them.

(iv) Additional reinforcement in the form of vertical and horizontal stirrups in accordance with calculations was welded to the existing exposed reinforcement. It was assumed that horizontal forces at the fixed end would be 30 per cent of the vertical shear.

$$\text{Hence horizontal force} = 0.3 \times 1,87,280$$
$$= 56,184 \text{ lb}$$

$$\text{Hence horizontal steel required} = \frac{56184}{12,000}$$
$$= 4.68 \text{ sq. in.}$$

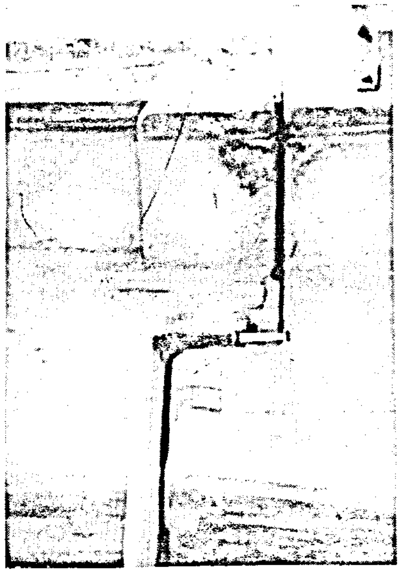


Photo 8

A view of damage at articulation (upstream) (Gulsakri Bridge)

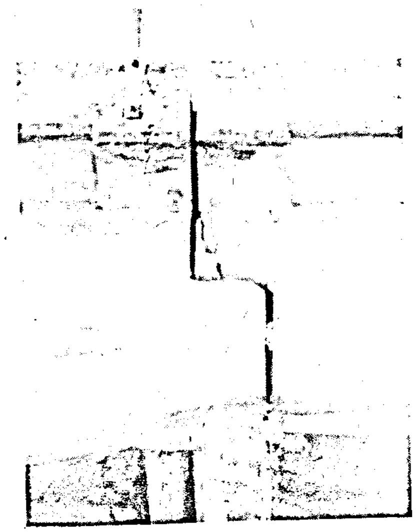


Photo 9

A view of damage at articulation (downstream) (Gulsakri Bridge)

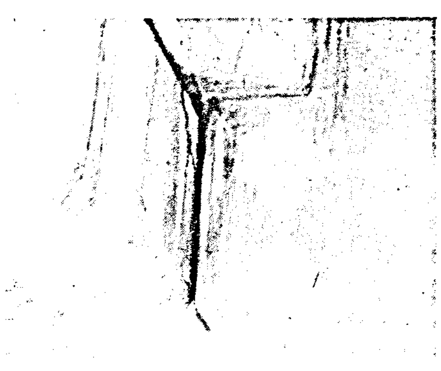


Photo 10

A view of damage at articulation (Bottom side of cross girder) (Gulsakri Bridge)

Checking for the steel at the vertical section of the bracket :

$$b = 24 \text{ in.} = 61 \text{ cm.}$$

$$h = 39 \text{ in.} = 99 \text{ cm.}$$

$$M = 2{,}247.360 \text{ in. lb.}$$

$$= 2{,}556{,}000 \text{ cm. kg.}$$

$$bh^2 = 61 \times 99^2$$

$$= 600{,}000 \text{ cm.}^3$$

Normal tension $= \mu R$ where μ = co-efficient of friction

$$= 0.25 \times 187.280$$

$$= 46{,}820 \text{ lb.}$$

$$= 46{,}820 \times 0.4536 \text{ kg.}$$

$$= 21{,}200 \text{ kg.}$$

$$C = \frac{M}{N} = \frac{2556{,}000}{21{,}200}$$

$$= 121 \text{ cm.}$$

$$e = 18 \text{ in.}$$

$$= 45.8 \text{ cm.}$$

$$C - e = 75.2 \text{ cm.}$$

$$\frac{Me}{bh^2} = \frac{N(C-e)}{bh^2}$$

$$= \frac{21{,}200 \times 75.2}{600{,}000}$$

$$= 2.675 \text{ kg. per cm.}^2$$

$$\frac{N}{bh} = \frac{21{,}200}{61 \times 99}$$

$$= 3.52 \text{ kg. per cm.}^2$$

From the Morseh curve for the above values of $\frac{Me}{bh^2}$ & $\frac{N}{bh}$.

Percentage of steel required

$$\mu = 0.54 \text{ per cent}$$

(Permissible direct tension in steel assumed to be 12,000 lb per sq. in. This was provided by 7 nos. 5/8 in. ϕ 'U' bars and 2×6 nos. $\frac{1}{2}$ in. ϕ bars giving a total area of 6.64 sq. in.

Ignoring the shear to be taken up by existing stirrups pitch for 3/4 in. dia. two legged stirrups reqd.

$$= \frac{2 + 0.442 \times 14000 \times .87 \times 36.5}{1,87,200} = 2.43 \text{ in.}$$

Therefore additional $\frac{3}{8}$ in. dia. stirrups were provided at $2\frac{1}{2}$ in. centre to centre.

After laying the reinforcement cage, the whole surface was gunited. But where the thickness was more, fresh concreting was done with rich mix. The same procedure was followed for repairing the cracks of the suspended span. The reinforcement details for carrying out the repairs have been shown in Plate VII.

(v) *Bearing*: The existing vertical dowel bars were removed by burning them out and $\frac{1}{2}$ in. thick lead sheet was provided in between the concrete surface.

6. PROBABLE CAUSES OF DAMAGE TO GULSAKRI BRIDGE

6.1. The damage to the articulation of the Gulsakri bridge may have been caused due to the following reasons:

(i) Seizing of the sliding plate bearing at the free end. Due to restraint at the sliding plate end on account of formation of copper sulphate on the surface of the plate or on account of any other reason, movement of the fixed end bearing might tend to shear the two 7/8 in. dia. mild steel dowel pins and these in turn would exert a considerable force in the direction of expansion joint and develop high tension in the concrete along the lines of the pin. This high tension may have caused the cracks.

(ii) The damage could have occurred by plastic flow of the $\frac{1}{4}$ in. thick lead plate at the fixed end and the resultant thickness of plate becoming very thin. On account of the increased deflection of the suspended span under full load and concrete surface resting on concrete, the load from superstructure acted as an edge load and thus caused concentration of stresses and ultimately splitting of concrete.

7. REMEDIAL MEASURES FOR GULSAKRI BRIDGE

7.1. In order to carry out necessary repairs and to allow examination of the condition of the sliding plate bearing, the pins at the fixed end were cut by oxy-acetylene flame. The suspended span was lifted up from its seat by means of jacks placed on timber staging.

7.2. Treatment of the Sliding Plate Bearings

7.2.1. On examination, the sliding surface was found to be very smoky. It was also noticed that the thickness of top and bottom copper lining was different. In order to ensure a perfect and good sliding surface, the surface was cleaned by means of fine sand paper. The bottom copper lug was also filed down so as not to be in contact with the top steel plate when lowered on its seat. This would prevent further electrolytic action under stress.

7.2.2. A thin coating of grease was also applied on the sliding surface so that after lowering, the grease might spread and form a seal alround.

7.3. Treatment of the Fixed End Bearing

7.3.1. As pointed out earlier, the lead sheet under fixed end was pressed very thin. A good quality lead sheet $\frac{1}{2}$ in. thick was provided this time. Two $\frac{1}{2}$ in. thick M.S. plates, one above and the other below the lead sheet, were also provided.

7.3.2. In order to improve distribution of stresses, hairpin mesh reinforcement as per sketch was also provided above and below the seating.

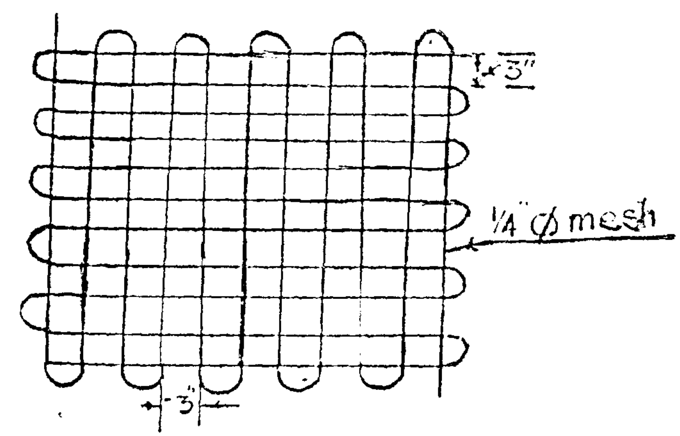


Fig. 6

in these circumstances is rather difficult. Determination of the distribution of the stresses in the solid cross girders will be further complicated with a side shift of the live load. If the load could be assumed to be uniformly distributed over the whole length of the cross girder, the shear stress, with the provision of a 6-in. articulation, solid cross girder and bearing for the entire length of cross girder, was found to be 60 lb per sq. in. only, necessitating no shear reinforcements at all. Discussions with designers revealed absence of any well-defined method of analysing the distribution but experience with hundreds of such articulations has shown that such bearings are functioning very favourably.

The Authors intend to draw the attention of the designers to the necessity of evolving a rational method of design with such an arrangement which could be conveniently applied.

(9) Concreting should be very carefully done simultaneously from both ends so that the bars remain in proper position during concreting.

(10) Concrete of very good quality should be used. It may be necessary to use a slightly wetter mix which has to be vibrated carefully.

9. DESIGN CRITERIA FOR THE CROSS BEAM AT ARTICULATION

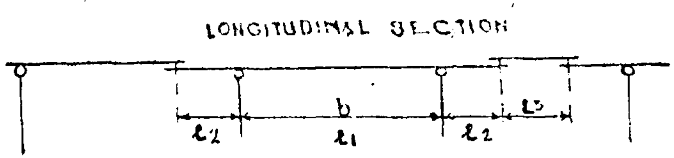


Fig. 9 (a).

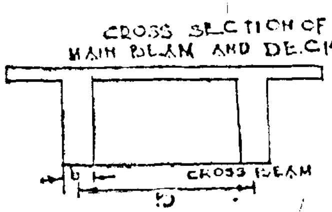


Fig. 9 (b).

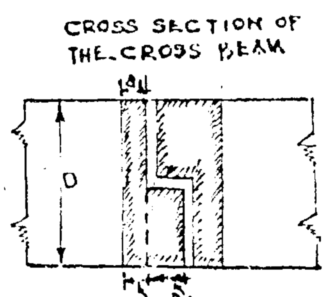


Fig. 9 (c)

Data :

- R Maximum end shear at the joint on one main beam
- R_L Maximum shear at the joint due to L.L. on one main beam
- W_L Maximum L.L. on the overhangs (equivalent uniformly distributed load) per ft run of one main beam
- E Modulus of elasticity
- G_1 Modulus of rigidity
- I_1 Moment of inertia of main beam between supports
- I_2 ,, ,, in cantilever overhang
- I_c Moment of the cross beam at joint
- J_c Polar moment of intertia of cross beam at joint
- A_c Cross-sectional area of the cross beam

9.1. Assuming total maximum shear coming at the two free ends of overhang (from the supported beam) to be effectively transferred through the cross beam.

Total uniformly distributed load per rft of the cross beam

$$= \frac{2R}{B+b}$$

(Since greater concentration of loads near the main beams would give smaller stresses in the cross beam, that condition is not envisaged).

$$\text{Maximum moment at the centre of cross beam} = \left(\frac{2R}{B+b}\right) \cdot \frac{B^2}{8}$$

$$= \frac{RB^2}{4(B+b)} \cdots \quad (1)$$

Note :—Fixity with main beam can be taken into account by considering relative torsional and flexural rigidity of the main and cross beams. Otherwise, partial fixity may be assumed.

The dowel bars anchored into the bottom girders had 1/8 in. play alround in the top girders so as to enable them to have some play for rocking.

8. SUGGESTIONS

(1) While designing articulations, low permissible stresses should be adopted in the steel used in the articulation joint on account of the complex nature of the stress conditions. Taylor, Thompson and Smulski in their book on Concrete Bridges have suggested reducing the allowable stresses even by 50 per cent. Shear per foot run should be provided for fully at this reduced allowable stress in steel.

(2) Solid cross girder should invariably be provided at each of the free tips of the cantilever and at end of the suspended span and these should be load bearing.

(3) It is necessary to reduce the shear stresses at the seating. This is achieved by the horizontal flaring out of the girder so that the area of contact is increased. The practice in this country so far has been to increase the value of 'a' in the width of seating to enable a greater width.

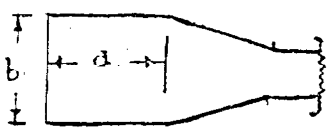


Fig. 7 **Plan of the girder at the Bracket**

(4) Since this increase of width of seat would result in greater moment at the junction where the depth is suddenly reduced, it is essential to find out the critical section and provide the necessary tensile steel.

(5) Lead sheet should be provided at the fixed end bearing arrangement.

(6) Chances of electrolytic action in the sliding plate must be avoided. Properly machined M.S. plates may even be used.

(7) Hairpin mesh reinforcement, preferably in 4 layers, must be provided in the concrete seating so that any edge load which may be inevitable is eventually distributed.

(8) In accordance with the practice of the Highway Deptt., California, U.S.A., the width of seating should be reduced preferably to 6 in. in order to reduce the moment at the articulation joint and to enable reduction in shear per foot width of articulation. The bearing should be provided for the entire length of the cross beams as shown in Fig. 8.

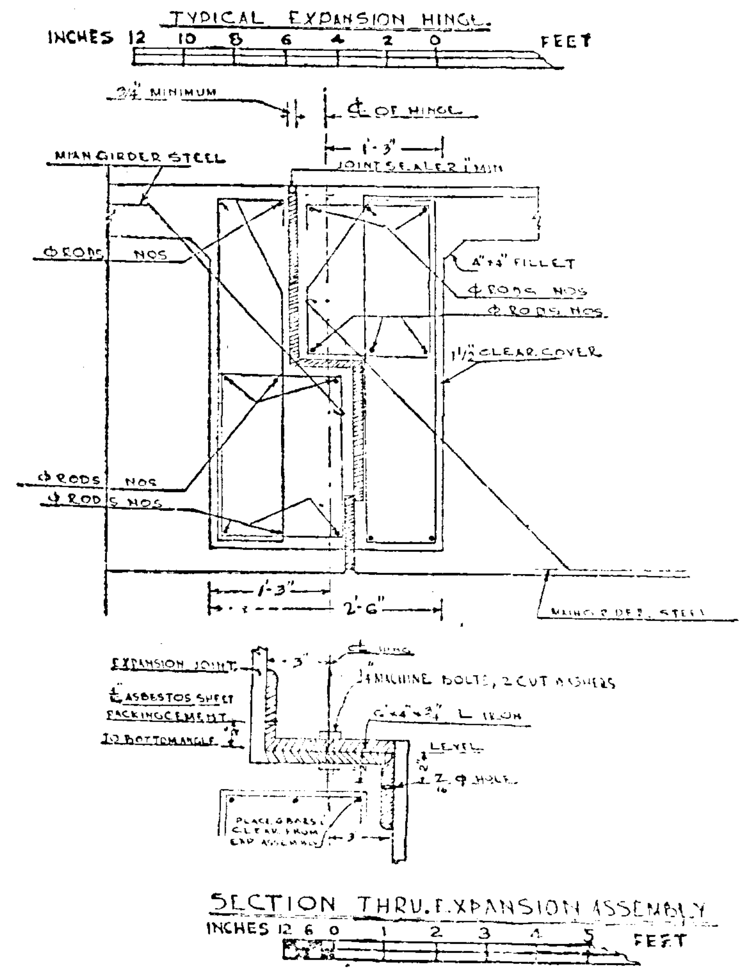


Fig. 8

The moment due to the reaction at the articulation will also be reduced as the reaction per foot is reduced. Calculation of stresses

Maximum shear force at the ends of the cross beam

$$S_1 = \left(\frac{2R}{B+b}\right)\left(\frac{B-b}{2}\right)$$

$$= \frac{R(B-b)}{(B+b)} \qquad \ldots \qquad (2)$$

9.2. The deflection and slope of the ends of the overhangs (of the two main beams) due to dead loads would be equal (because of symmetry). Hence due to the deflection or slope at the ends of overhangs, no stresses or forces would be produced in the cross beam.

However, if the liveload is unsymmetrically placed about the longitudinal axis (i.e., in the worst case the liveload being taken only by one main beam), there will be deflection 'δ' and slope 'θ' of the end of the loaded main beam relative to that of the unloaded main beam.

For monolithic construction of the main beam and cross beam, differential deflection 'δ' would cause end moments and shear in the cross beam and the differential slope 'θ' would cause torsion in the cross beam.

Calculation of deflection 'δ' and slope 'θ' due to L.L. only on one beam

Assumptions :

(a) The most adverse case giving the maximum slope and deflection would be one when it is assumed that (i) the two overhangs have maximum liveload on it. (ii) The liveload reaction from the supported span is also assumed to be carried only by one main beam overhang.

(b) The overhang may have a varying section, and for simplicity the minimum rectangular section at the end would be considered and the beam assumed to be of a uniform section. This would again be on the safe side. However, the effect of variable depth can also be taken into account by graphical construction, if necessary.

(c) The torsion due to a given twist 'θ' is calculated by an approximate formulae applicable for symmetrical rectangular section, which for the cross beam may be taken as $G_1 \times D$.

Considering the overhangs loaded with L.L.

$$L_s = -\frac{W_L L_1 L_2^2}{6EI_1} + \frac{W_L L_1 L_2^2}{12EI_1} - \frac{R_L L_1 L_2}{3EI_1} + \frac{R_L L_1 L_2}{6EI_1}$$

$$L_s = -\frac{L_1 L_2}{12EI_1}(W_L L_2 + 2R_L) \qquad \ldots (3)$$

Deflection at the free end of overhang

$$\delta = \frac{W_L L_2^4}{8EI_2} + \frac{R_L L_2^3}{3EI_2} - \frac{a_s}{\frac{L_1 L_2}{12EI_1}(W_L L_2 + 2R_L)L_2}$$

$$= \frac{W_L L_2^4}{8\,EI_2} + \frac{R_L L_2^3}{3\,EI_2} - \frac{L_1 L_2^2}{12EI_1}(W_L L_2 + 2R_L) \qquad \ldots (4)$$

Slope at the free end of overhang

$$\theta = \frac{W_L L_2^3}{6EI_2} + \frac{R_L L_2^2}{2\,EI_2} - \frac{L_1 L_2}{12EI_1}(W_L L_2 + 2\,R_L) \qquad \ldots (5)$$

[*Note*:—The last terms of equations 4 and 5 represent the deflection and slope due to the slope of the main beam at the support and may be taken as zero if the main beam is assumed to have zero slope at the piers].

9.3. Fixed end moment in the cross beams due to differential deflection 'δ'

$$M_1 = -\frac{6EI_c\delta}{B^2} \qquad \ldots (6)$$

Shear force due to 'δ'

$$\delta = \frac{2M_1}{B} = \frac{12EI_c\delta}{B^3}. \qquad \ldots (7)$$

Torsion in the cross beam due to the relative slope of the ends of the two main beams $= T = \left(\frac{G_1 A_c^4}{40J_c B}\right)\theta \qquad \ldots (8)$

The cross beam is, therefore, subjected to the following 'forces' in the worst case:

1. Maximum span moment $= \frac{RB^2}{4(B+b)} \qquad \ldots (9)$

2. Maximum support moment $= -\frac{6EI_c\delta}{B^2}$

$$= -\frac{6EI_c}{B^2}\left[\frac{W_L L_2^4}{8EI_2} + \frac{R_L L_2^3}{3EI_2} - \frac{L_1 L_2^2}{12EI_1}(W_L L_2 + 2R_L)\right] \quad ...(10)$$

[$\frac{RB^2}{6(B+b)}$ may be added if, for transverse loading, full fixity of the cross beam in the main beam is assumed. Exact solution can, however, be found by considering the effects of twist in main beam and rotation of cross beam].

9.4. **Maximum Shear Force**

$$\delta = \frac{R(B-b)}{(B+b)} + \frac{12\,EI_c\,\delta}{B^3}$$

$$= \frac{R\,(B-b)}{(B+b)} + \frac{12EI_c}{B^3}\left[\frac{W_L L_2^4}{8EI_2} + \frac{R_L L_2^3}{3EI_1} - \frac{L_1\,L_2^2}{12\,EI_1}(W_L\,L_2 + 2\,R_L)\right] \quad ...(11)$$

9.5. **Maximum Torsion** (taking only $G_1 \times D$ retangular section)

$$T = \left(\frac{G_1\,Ac^4}{40\,B\,Jc}\right)\,\theta$$

$$= \left(\frac{G_1\,AC^4}{40\,BJc}\right)\left[\frac{W_L.\,L_2^3}{6EI_2} + \frac{R_L.\,L_2^2}{2EI_2} - \frac{L_1.\,L_2}{12EI_1}\,(W_L\,L_2 + 2\,R_L)\right] \quad ...(12)$$

A cross beam adequately designed as above should be able to function effectively to transmit the loads to the main beam.

9.6. The main beam (one bay) may also be checked for torsion.

Appendix 1

Salient Features of Akharaghat Bridge

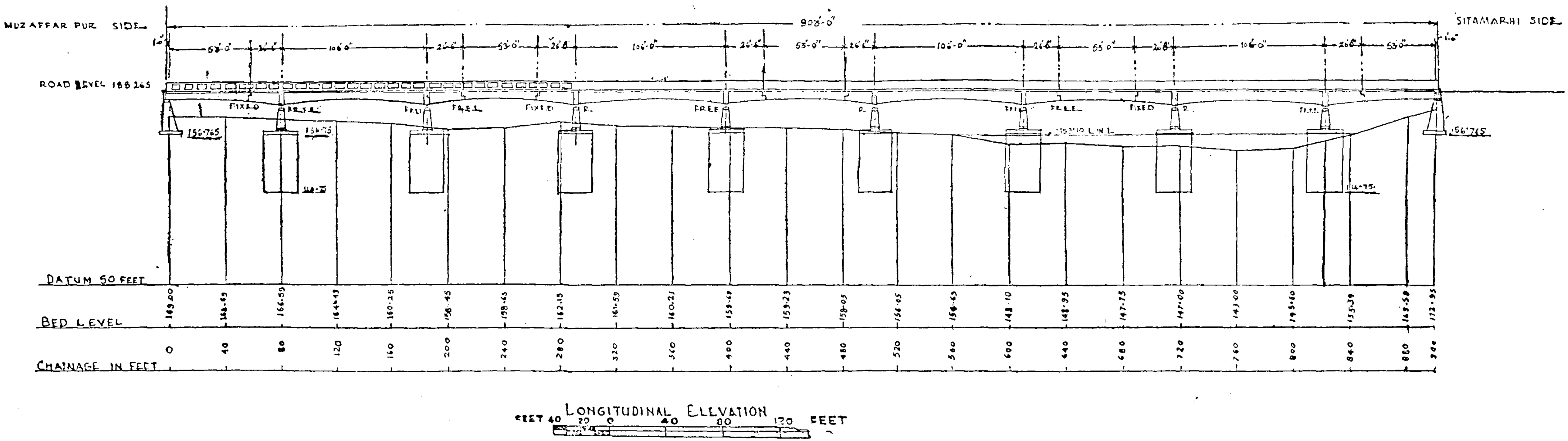
(1)	Width of roadway between kerbs	... 22 ft
(2)	Total number of spans	... 7 of 106 ft each;
		... 2 of 79 ft 6 inch
(3)	Total length of bridge	... 901 ft
(4)	Type of foundations	... (a) Well foundations for all the eight piers
		... (b) Well foundation for Sitamarhi side abutment
		... (c) Open foundation for Muzaffarpur side abutment
(5)	Size of wells	... Single circular well of 24 ft external diameter
(6)	Maximum depth of foundation	... 58 ft below average bed level
(7)	Height of piers	... 16 ft 6 in.
(8)	Size of piers	... 2 ft thick at top with a batter of 1 in 24
(9)	Type of superstructure	... Balanced cantilever type with R.C.C. 'T' beam-*cum*-slab
(10)	Details of superstructure	... (a) Two longitudinal girders at 14 ft centres. Main girders are 106 ft between centres of piers with cantilever projection of 26 ft 6 in. on either end
		... (b) There are 5 suspended spans of 53 ft each including two end suspended spans
(11)	Design live load	
	I.R.C. Class "AA"	... Single lane
	I.R.C. Class "A"	... Double lane
(12)	**Important levels connected with the bridge**	
	(i) Low water level	... R.L. 153.10
	(ii) Bottom of foundation	... R.L. 98.75
	(iii) Lowest bed level	... R.L. 143.00
	(iv) Top of wells	... R.L. 156.75
	(v) Top of capping slab	... R.L. 159.25
	(vi) Top of pier	... R.L. 173.85
	(vii) Top of bed block	... R.L. 175.85
	(viii) Top of road level	... R.L. 188.25
(13)	Wearing coat	3 in. thick R.C.C. road surfacing (1 : 2 : 4)

Appendix 2

Salient Features of Gulsakri Bridge

(1)	Width of roadway (between kerbs)	...	16 ft
(2)	Total number of spans	...	(a) One central span of 57 ft 6 in.
			(b) Two end spans of 52 ft
(3)	Total length of bridge	...	161 ft 6 in. between faces of abutments
(4)	Type of foundations	...	Open type with plum cement concrete (1 : 3 : 6).
(5)	Maximum depth of foundation	...	25 ft below bed
(6)	Height of piers	...	19 ft 5 in. above bed
(7)	Size of piers	...	Two Nos. R.C.C. (1 : 2 : 4.) Columns 3 ft dia. each at 11 ft centres and stiffened by a 3 ft 6 in. × 3 ft 6 in. capping slab at top and 3 ft × 4 ft 9 in. base slab at the bottom
(8)	Type of superstructure	...	Balanced cantilever type with R.C.C. T beam-*cum*-slab
(9)	Details of superstructure	...	(a) Two main longitudinal beams 16 in. × 75 in. at the support and at centre and 16 in. × 50 in. at the cantilevered end including 8 in. thick R.C.C. deck slab
		...	(b) One suspended span of two T-beams 16 in. × 60 in. including 8 in. thick R.C.C. deck slab
(10)	**Important levels connected with the bridges**		
	(i) Bottom of foundations	...	R.L. 50.00
	(ii) Average bed level	...	R.L. 71.00
	(iii) Bottom of pier footing	...	R.L. 74.00
	(iv) Top of pier cap	...	R.L. 93.42
	(v) Top of road level		R.L. 100.00
(11)	Wearing coat		3 in. R.C.C. road surfacing (1 : 2 : 4)

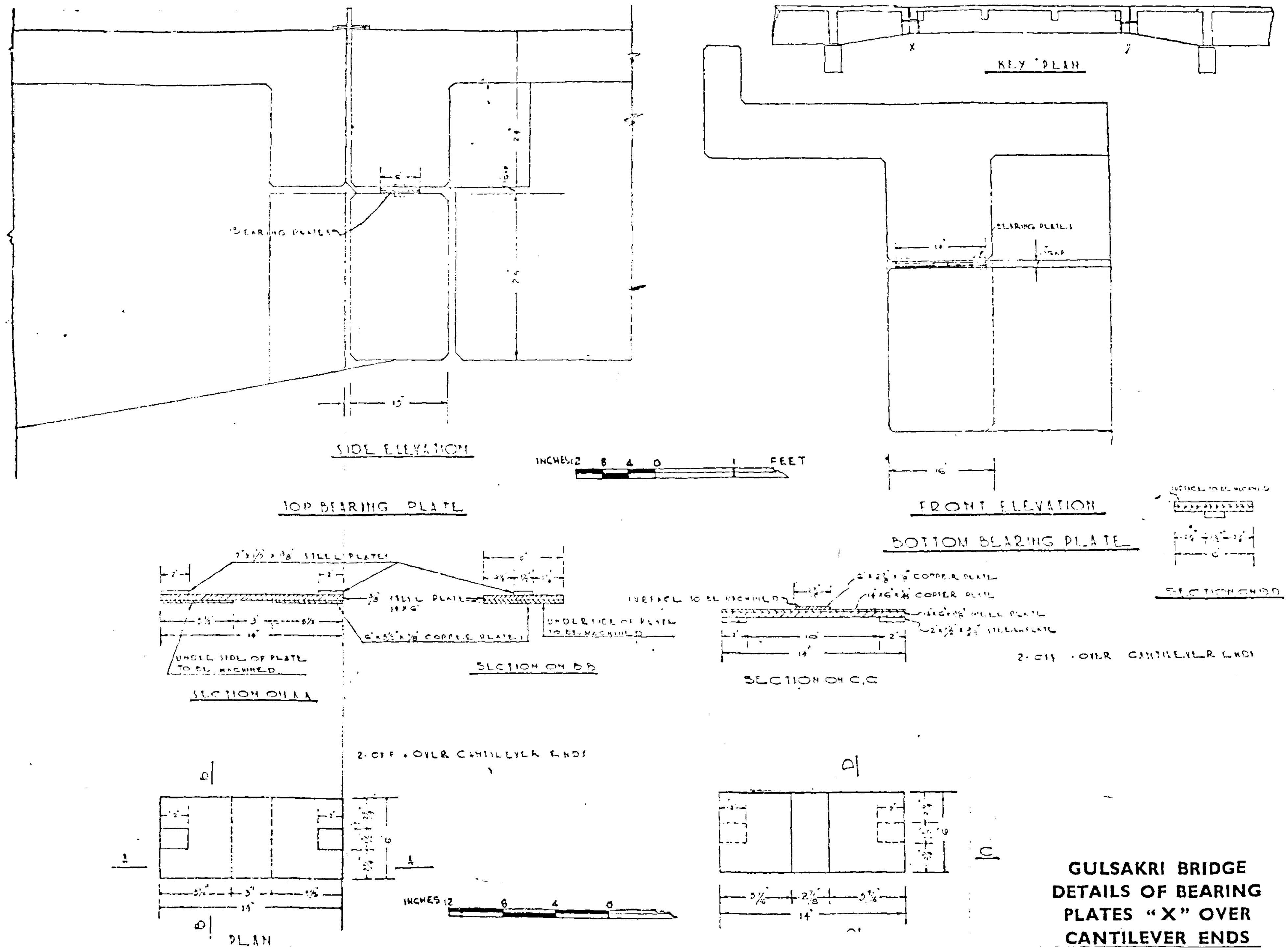
PLATE I



LONGITUDINAL ELEVATION

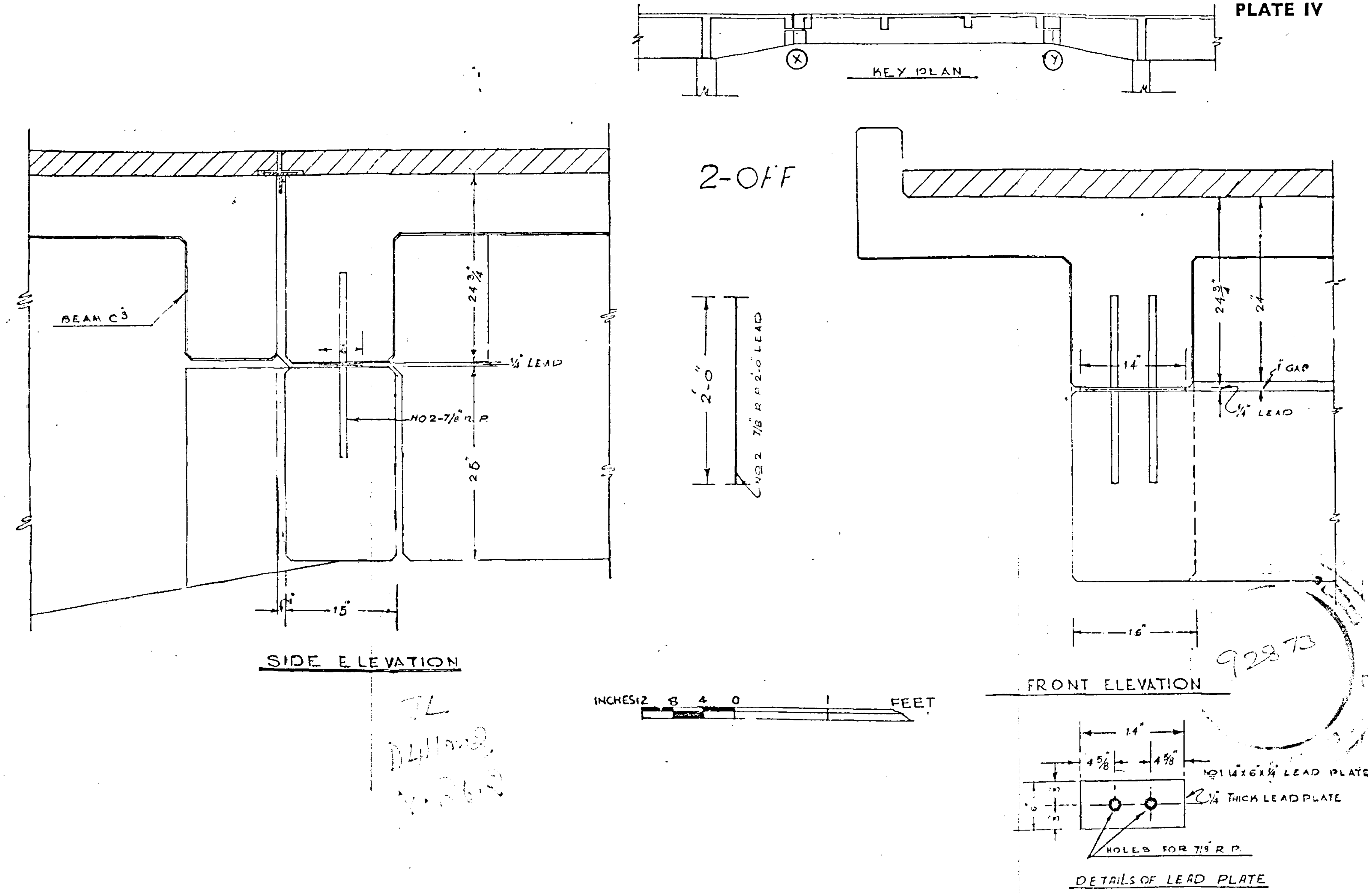
AKHARAGHAT BRIDGE
ACROSS RIVER BURHI GANDAK

PLATE III



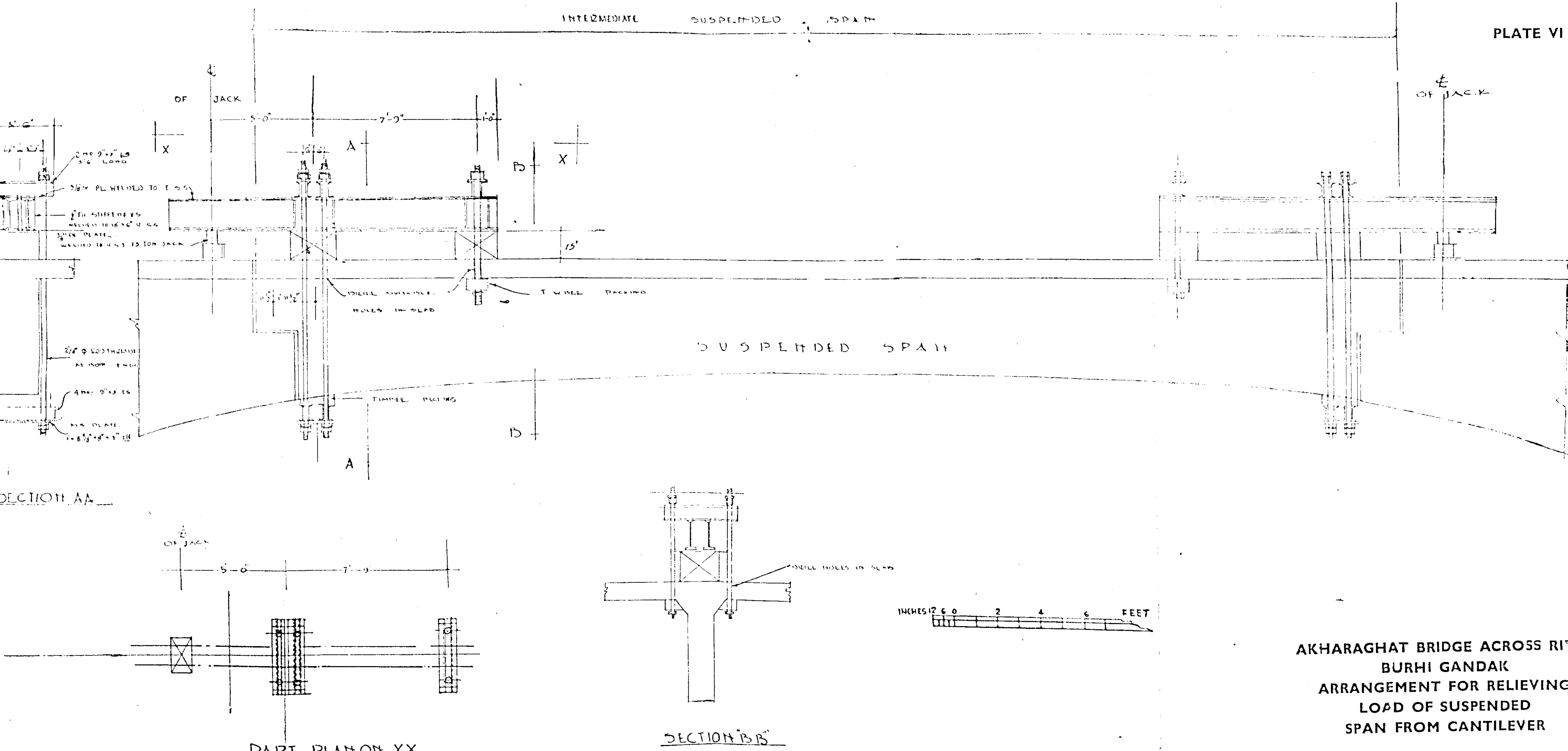
GULSAKRI BRIDGE
DETAILS OF BEARING
PLATES "X" OVER
CANTILEVER ENDS

PLATE IV



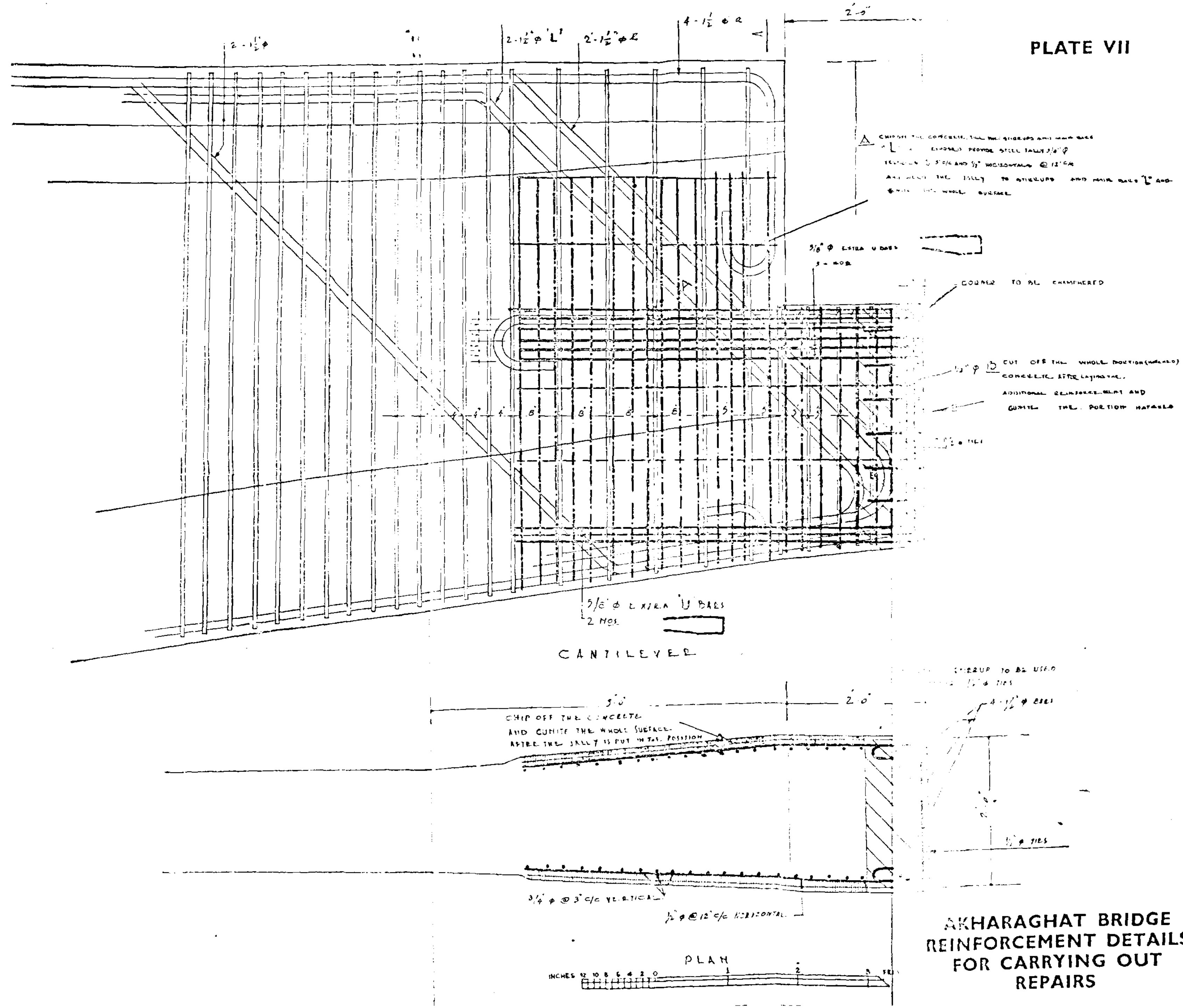
GULSAKRI BRIDGE
DETAILS OF BEARING PLATES
"Y" OVER CANTILEVER ENDS

PLATE VI



AKHARAGHAT BRIDGE ACROSS RI
BURHI GANDAK
ARRANGEMENT FOR RELIEVING
LOAD OF SUSPENDED
SPAN FROM CANTILEVER

PLATE VII



AKHARAGHAT BRIDGE
REINFORCEMENT DETAILS
FOR CARRYING OUT
REPAIRS

Paper No. 232

"DRAFT STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES"

SECTION VI

COMPOSITE CONSTRUCTION FOR ROAD CULVERTS AND MEDIUM SPAN BRIDGES

By

THE BRIDGES COMMITTEE OF THE

INDIAN ROADS CONGRESS

INTRODUCTION

The Bridges Committee of the I.R.C. has prepared draft Standard Specifications and Code of Practice for Composite Construction for Road, Culverts and Medium Span Bridges. Following precedent, this draft of Section VI of the Standard Specifications and Code of Practice for Road Bridges, as approved by the Bridges Committee at their meeting held on the 28th and 29th August 1961, is published for discussion by the members before it is finalised and printed as a Standard.

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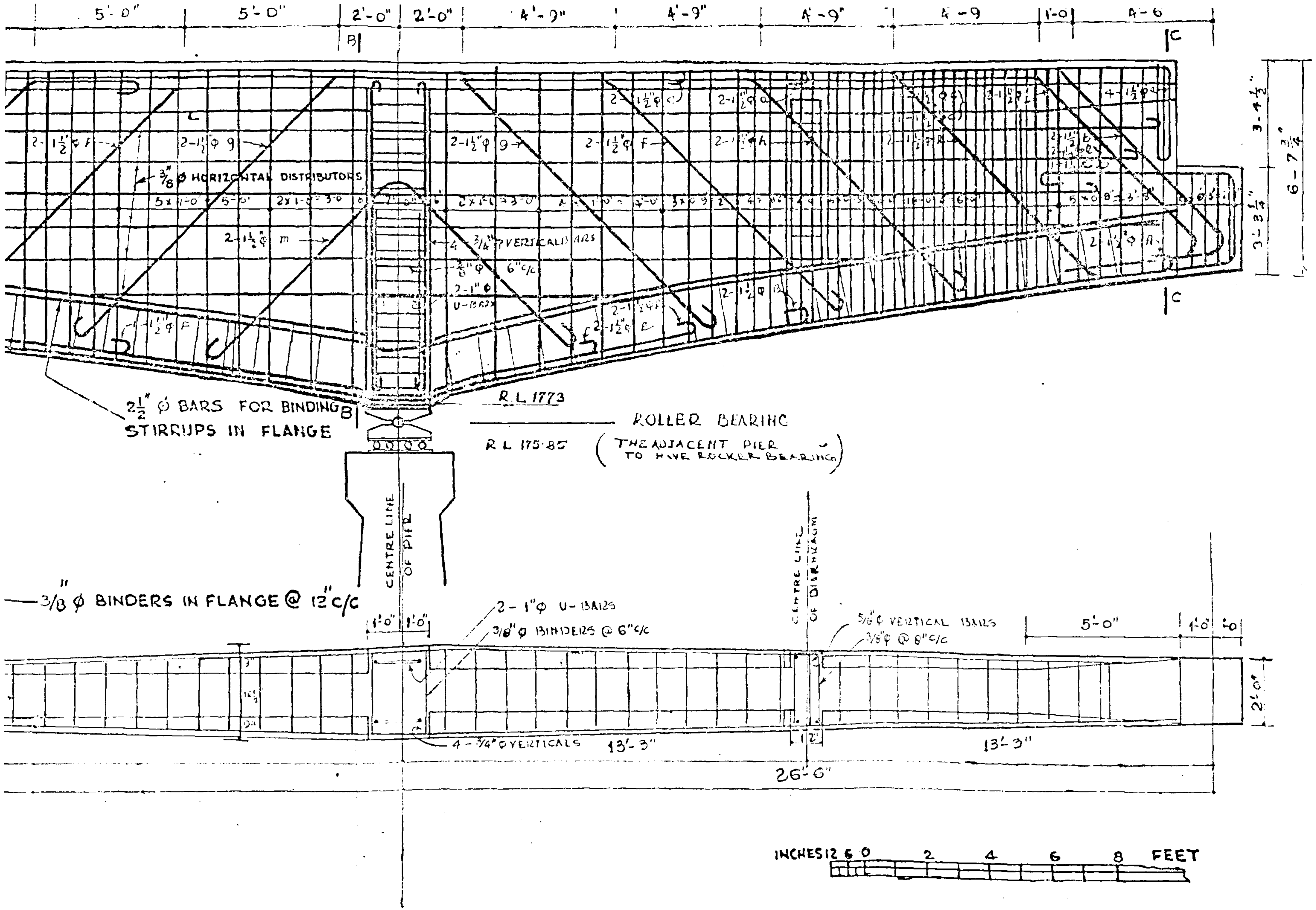
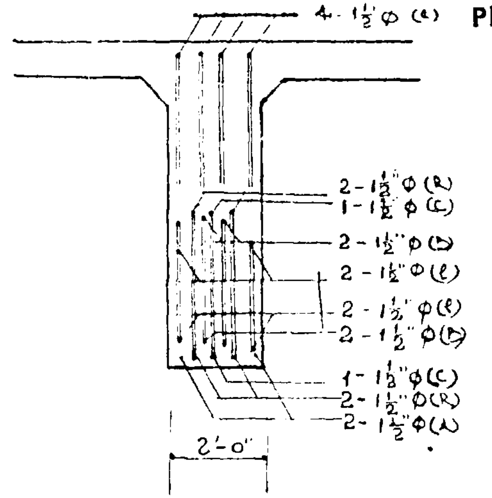
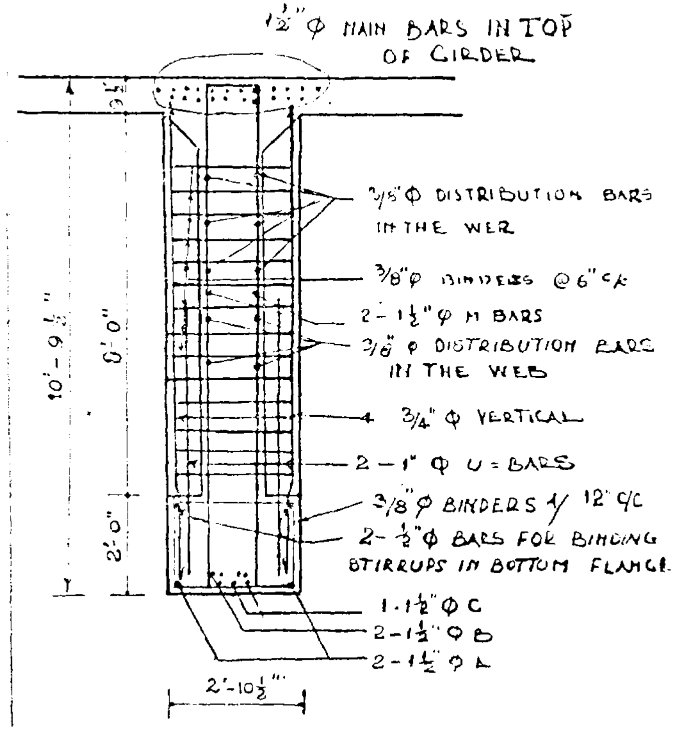
PLATE V





SECTION -"CC"



601. GENERAL

601.1. **Scope**: Until more experience is gained in this type of construction, this Code will apply to bridges of spans not exceeding 20 metres.

601.2. **Types**: Composite beams consist of factory-made or prefabricated beams connected by special structural elements, called "connectors", to reinforce concrete slabs in such a way that they act together as a unit. To ensure composite action, only connectors of an approved type shall be used.

The factory-made or prefabricated beams may consist of:

(a) structural steel beams or girders; or

(b) precast reinforced concrete or prestressed beams.

601.3. Apart from the design requirements specified herein, all other design requirements shall be in accordance with the relevant Steel, Reinforced and Prestressed Concrete Codes of the Indian Roads Congress.

602. DESIGN OF SLABS

602.1. For the design of the slab, stresses caused by composite action may be neglected.

602.2. The effective span of slab shall be equal to the distance between edges of the top flanges of the factory-made or prefabricated beams plus half the width of the flange of the precast unit.

603. EQUIVALENT SECTION

603.1. For prefabricated units in prestressed concrete or reinforced concrete, consideration shall be given to the different modulii of elasticity for concrete in precast and *in-situ* portions.

603.2. For prefabricated units in steel, the effective gross area of concrete shall be converted into the corresponding equivalent area of steel. This shall be done by dividing the effective area of the concrete slab by the modular ratio.

603.3. The modulus of elasticity of concrete shall be assumed as equal to $127{,}000+400\ F_c$ where F_c represents 6 in. cube crushing strength at 28 days in kilogrammes per sq. cm.

604. FLANGE WIDTH

604.1. The width of slab considered effective in the design of the composite "T" beam (except edge beams) shall not exceed any of the following:

(a) the distance centre to centre of beams;

(b) twelve times the least thickness of slab; and

(c) one-fourth of the span of the beam.

604.2. The effective slab width for the inner and outer part (measured from the centre line of the beam) to be taken in the case of edge beams shall not exceed any of the following:

(a) 1/12th of the span of the beam (for either part);

(b) six-times the slab thickness (for either part);

(c) half the distance to the adjoining beam (for the inside part); and

(d) actual width (for the outside part).

604.3. Any openings, which exist, are to be deducted from the calculated width of the slab.

605. DESIGN REQUIREMENTS

605.1. For purposes of design, the prefabricated unit shall be considered as sustaining its self load, the load of the form work and *in-situ* concrete. The composite section shall be designed to carry the additional loads imposed after the *in-situ* concrete has attained its 28-day strength.

If the prefabricated unit is adequately supported before placing of *in-situ* concrete, it shall be designed to sustain self load only. The prefabricated unit shall be considered to be adequately supported if at least three supports at quarter points of the span are provided.

605.2. The composite section shall be proportioned in such a way that the neutral axis of the composite section is located below the *in-situ* concrete slab.

If the neutral axis is located inside the concrete slab, the portion below the neutral axis shall not be considered effective for computing moments of inertia or resisting moments except for deflection calculations. Also, if the neutral axis is located within or just below the slab, the steel sections shall be investigated for stability during the time the concrete is in place and before it has hardened.

605.3. Composite action will be considered to be effective only after the *in-situ* concrete has attained at least 75 per cent of its 28-day strength.

605.4. Where a supporting fillet is provided between the prefabricated steel section and the concrete slab, its section shall be ignored in computing the total composite section.

605.5. With steel prefabricated units, the depth of the steel section shall preferably be not less than 1/30th of the span and the depth of the composite section shall not be less than 1/25th of the span. The span of continuous beams shall be the distance between the points of contraflexure caused by the dead load. If depths smaller than these are used, the sections shall be adequate to limit deflections to the values obtained with the limiting depths.

605.6. With prestressed concrete prefabricated sections, the design of the composite beam shall be based on the following two critical conditions :

(1) when prestress is maximum and the load causing the bending moment is minimum; and

(2) when prestress is minimum, i.e., after deduction of all losses and when the load causing the bending moment is the maximum.

605.7. Adequate prestressing steel shall be provided in the prefabricated section to equal the total tensile force at ultimate load.

606. SHEAR CONNECTORS

606.1. Shear connectors shall be designed to take the full horizontal shear at the contact surfaces of the prefabricated and *in-situ* portions. For design of shear connectors, the horizontal shear at the plane of contact of the prefabricated and *in-situ* units shall be determined from :

$$S_h = \frac{Vm}{I};$$

where S_h = horizontal shear at the junction of the slab and the top flange of beam ;

V = vertical shear, acting on the composite section ;

m = statical moment of the transformed concrete area about neutral axis of the composite section or the statical moment of the area of reinforcement embedded in the slab ;

I = moment of inertia of the transformed composite section.

In structural steel beams or steel girder composite beams, vertical shear shall be considered as resisted by the steel web only.

606.2.1. Shear connectors with steel prefabricated unit shall consist of :

(1) studs welded to the contact surface of the steel section,

or

(2) channels similarly attached,

or

(3) a bar spiral welded at each loop to the steel.

606.2.2. The safe shear resistance value 'Q' in kilogrammes of the connectors shall be taken as follows :

606.2.2.1. For welded stud connectors

(i) For ratios H/d less than 4.2

$$Q = 34\ \frac{H}{d}\sqrt{F_c}$$

(ii) For ratios H/d equal or greater than 4.2

$$Q = 22\, d^2 \sqrt{F_c}$$

606.2.2.2. For channel connectors

$$Q = 12\,(h + 0.5t)\ W \sqrt{F_c}$$

606.2.2.3. For spiral connectors

$$Q = .333d\ \sqrt[4]{F_c}$$

where

Q = Safe shear resistance in kilogrammes of one shear connector or one pitch of a spiral bar ;

h = the maximum thickness of a channel flange in cms. measured at the face of the web

t = the thickness of the web of a channel shear connector, in cms.

W = the length of a channel shear connector, in cms.

F_c = 6 in. cube crushing strength at 28 days in kilogrammes per sq. cms.

d = diameter of studs or of the round bars used in helical connectors (spirals), in cms.

H = height of stud in cms.

606.2.2.4. The value of 'Q' shall not exceed 1,130 kilogrammes.

606.3.1. The strength of the welds connecting the shear connectors to the steel prefabricated section shall be adequate to withstand the shearing forces.

606.3.2. Welding shall be permitted only, if the steel used is of weldable quality.

606.3.3.1. Welding of studs is a specialised job. Hence stud connectors shall be used only when the necessary equipment is available.

606.3.3.2. To permit welding of studs, the gap between the heads of two adjacent connectors shall not be less than 1.5 cms.

606.4. Shear connectors with steel prefabricated units shall not be spaced further apart than 60 cms. and the distance between the edge of shear connector and the edge of the top flange of the steel section shall not be less than 2.5 cms. The concrete cover over the top of the shear connector shall be not less than 2.5 cms. in all directions.

606.5. For mild steel spiral shear connectors, rods of spiral less than 1.25 cms. diameter shall not be used unless very careful welding is assured because welding heat may cause brittleness in the rods. It is also recommended that the rod diameter for spiral shall not exceed 2.0 cms., because the horizontal shear which requires spirals of large cross-section may produce pressures on the concrete near the welds in excess of permissible values.

606.6. The developed length of the shear-spiral rod per pitch shall not be less than 15 times the rod diameter and the ratio of the spiral pitch to spiral diameter S/d shall not be less than 0.7 and more than 4.0.

606.7. The shear spiral pitch shall not be less than 10 cms. nor greater than 40 cms. for practical reasons.

606.8. In concrete (R.C.C. and prestressed) prefabricated units, the connection between the precast and *in-situ* concrete shall consist of:

(1) shear bars projecting from the precast unit and,

(2) castellations in the precast unit.

606.9. For shear bars, the shear stress 'f_{sh}' at the contact surface shall be obtained from the formula:

$$f_{sh} = \frac{Vm}{Ib}.$$

Where 'V', 'm' and 'I' are as defined in Clause 606.1 supra and 'b' = width of section.

606.10. Castellations shall be invariably provided and these shall be at least 1.25 cms. deep and shall be provided throughout the length of the precast member. These shall be placed at suitable intervals.

606.11. The contact surface of the precast (R.C.C. or prestressed) element shall be finished as rough as possible.

606.12. Shear Connection for Slab on Precast Reinforced Concrete Beams.

606.12.1. All stirrups in the web of the beam shall be extended into the cast-*in-situ* slab.

606.12.2. Mechanical anchorage in the form of vertical ties to prevent separation of the component elements in the direction normal to the contact surfaces shall be provided. Spacing of such ties shall not exceed four times the thickness of slab nor 60 cms. A minimum cross-sectional area of the ties in each length of 30 cms. of span of 0.15 per cent of the contact area but not less than 1.350 sq. cms. is recommended. It is preferable to provide all ties in the form of extended stirrups.

606.13. Shear Connection for Slab on Precast Prestressed Concrete Beams.

This shall be according to the provisions under Clause 606.12 supra.

606.14. Shear Connection in Regions of Negative Moments (moments producing tension at top fibres)

606.14.1. When the negative moments are to be resisted by the prefabricated section alone, shear connection between the prefabricated beam and the slab need not be provided in the regions of negative bending moments.

606.14.2. When the negative moments are to be resisted by the composite section, shear connection must be provided throughout the full length of the beam, but the concrete on the tension side of the neutral axis shall not be taken as effective except as a device to develop the reinforcing steel embedded in.

607. DEFLECTION

607.1. The deflection shall be determined under the following heads:

(i) The deflection due to self weight. (To this weight shall also be added the weight of *in-situ* concrete provided the prefabricated units are not shored during casting of the slab).

(ii) The deflection caused by the imposed load based on the composite section.

(iii) For prestressed prefabricated units, the deflection due to prestress shall be computed with the section of the precast unit.

607.2. Deflection shall be limited to (i) 1/600 in case of steel prefabricated units and to (ii) 1/800 in case of reinforced or prestressed prefabricated units.

608. SHRINKAGE AND CREEP OF CONCRETE AND DECK SLAB

Effects of differential shrinkage and creep of concrete of the cast-*in-situ* deck slab on the prefabricated unit shall be taken into account when the prefabricated unit consists of prestressed concrete in order to ensure that no tensile stresses are caused in the bottom fibres of concrete, even when the effects of shrinkage and creep of the deck slab are considered. In other cases, when the prefabricated unit consists either of reinforced cement concrete or of steel, the effects of shrinkage and creep can be ignored.

RESEARCH SECTION

"IMPROVING THE STRENGTH CHARACTERISTICS OF GRAVEL"

By

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AND

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CONTENTS

1. THE PROBLEM

1.1. Progressive stage construction in which the road is improved with successively higher type of surfaces, as required by increasing traffic, is an economic and safe method of improving highways. It avoids investment in excess of traffic requirements.

In the first stage of development of roads, according to the practice in Madras, gravel is extensively used. Usually, it is laid in 4 to 6 inches loose thickness and then compacted and is not satisfactory as surface course due to lack of supporting power. Gravels, as occurring in nature, have a wide range of supporting power and even the same gravel varies greatly at different times due to variations in moisture content. Gravel surfaces get cut up or rutted and ravel under traffic loads and abrading effect of wheels. Yet, gravel continues to be used for low type roads.

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The use of gravel for road pavements either as bases or wearing course will not prove economical, unless the strength characteristics are improved upto the desired level.

1.2. Gravel soils are widely distributed[1] over Madras State, Fig. 1. They consist of aggregation of small stones more or less worn and rounded by water action and varying in size from that of a pea to a pebble, from 'one half inch to over an inch in diameter', and finer material that acts as a binder to hold the stones

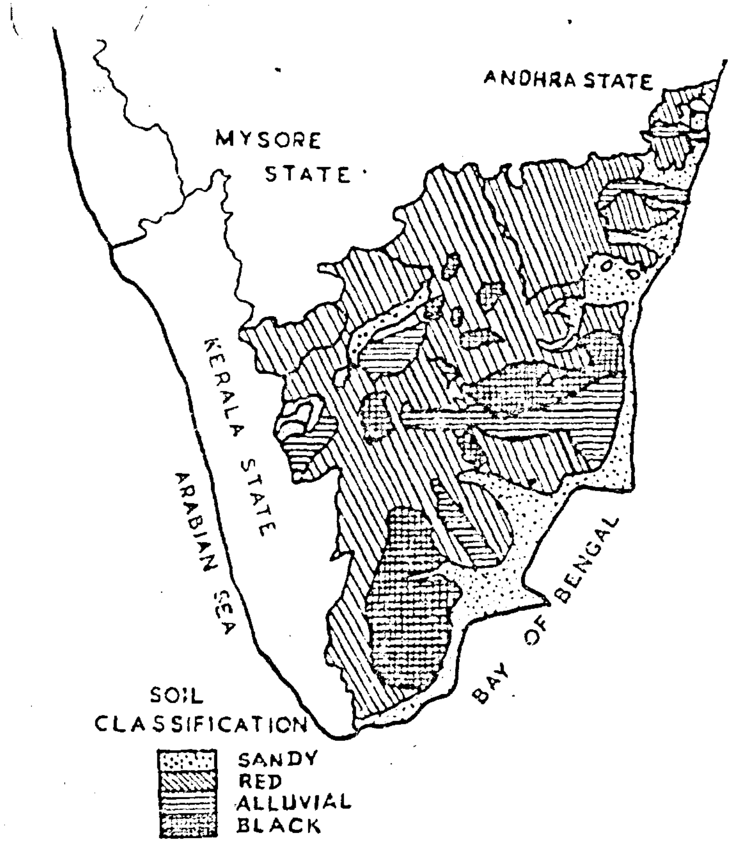


Fig. 1. Soil map of the Madras State

together. Generally, the binder soil is in excess of the voids in the coarse fraction. So, when climatic conditions are favourable, this forms a very satisfactory blend, while in hot and dry weather, lack of moisture causes the materials to become loose. In wet weather, the soil becomes soft with the coarse particles going down

In order to be suitable as a surfacing material for roads, the aggregate and binder content should be present in suitable proportions. Also, the binder should have desirable characteristics for obtaining maximum stability value. But such graded material rarely occurs in nature. Therefore, the effects of varying the proportions of coarse fractions and fines of gravel soils on the strength of the resulting mixes have been studied and reported in this Paper.

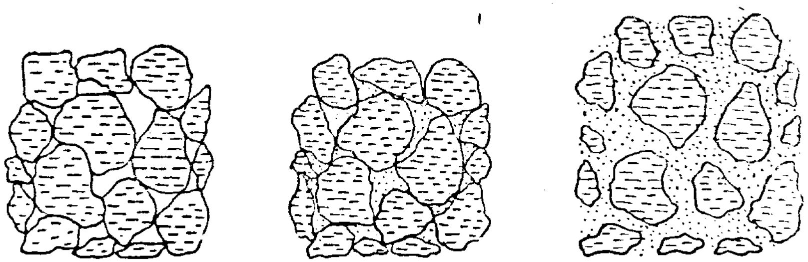
2. APPROACH TO THE PROBLEM

2.1. The best mixture of soils to form a stabilized material obviously depends on its strength and incompressibility characteristics. Both these properties are very much influenced by the density of the mixture and it is a well-known fact that generally the strength increases and compressibility correspondingly falls down with increase in density. On this basis, the design of the best mix resolves itself into the determination of the mix which yields the greatest compacted density to bring about the maximum stability.

2.2. Increase in density of a soil may be obtained either by the use of efficient compaction methods or by incorporating additional coarse or fines fraction to the soil as the case may be. The compaction method has got its own limitations, since it involves the use of costly compaction machinery. Also, even when maximum density is attained, the stability of the soil in adverse moisture conditions will depend upon the inherent properties of the chief constituent of the soil. Hence, the second method, namely, increasing the density by incorporating additional coarse fractions, appears to be the best method.

2.3. In mechanical stabilization, maximum density is generally obtained by ideal gradation. A quantity of largest particles is arranged in their most dense state. The voids in them are filled with the next smaller size grains, the voids of which are filled in turn with grains of smaller size. Each succeeding smaller size is that which will fit into the voids between the next larger grains. If this process is continued to infinity, the result will be a solid mass[2]. But this ideal gradation concept becomes hopelessly complex when widely varying and different particle shapes like that occurring in gravel are met with. Sometimes even some external materials have to be added to achieve anything approaching an ideal mix. Definitely the above process will not be economical and cannot be successfully employed in practice.

2.4. Hence, the study reported here is based on the aggregate binder concept. The soil is considered to be made up of two components, the aggregate, composed of the coarse grains and the binder consisting of finer grains and clay. The fine fraction has comparatively low unit weight, good supporting power when dry, high plasticity, low supporting power when it contains excessive water and a high degree of cohesion. On the other hand, the coarse fraction has high unit weight, is not affected greatly by moisture, has excellent drainage properties and a high angle of internal friction. The two fractions taken separately have, therefore, varying properties and the properties of the combinations of those two materials obviously depend upon their relative proportions in the mix. The best combination will be one which gives the maximum stability characteristics. The fundamental principle involved in this ideal combination is that the coarse material forms the main skeleton of the soil mass and the voids in between are gradually filled up with the fines. The coarse fraction should be compacted to its densest state. The voids between the grains are filled with compacted binder to produce maximum density. Recent research[2] has shown that maximum stability is obtained by proper grain to grain contact. Fig. 2 shows three general states of soil-aggregate mixtures. It can be seen that the maximum stability is obtained



Aggregate with no fines.	Aggregate with sufficient fines.	Aggregate with large amount of fines.
Grain to grain contact.	Grain to grain contact with increased resistance against deformation.	Grain to grain contact destroyed—aggregate floating in soil.
Variable density.	Increased density.	Decreased density.
High stability if confined. Low if unconfined.	High stability in confined or unconfined conditions.	Low stability.

Fig. 2.

by grain to grain contact with increased resistance to deformation offered by sufficient fines. Whenever an excess of fines is used, the contact between individual grains is destroyed with resulting loss of stability. From this, it is also obvious that though generally stability increases with increase in density, density and stability are not necessarily related and the quantity of fines is extremely important. It is also clear that the optimum quantity of fines does not merely function as a filler of voids but also serves as a supporting medium within the structure formed by the coarse and in addition to maintaining the grain to grain contact, offers resistance against deformation, depending largely on the characteristics of the fraction.

The grading and plasticity of the soil mortar are relatively of less importance[1].

3. TEST CRITERIA

3.1. An important aspect of the investigation was the selection of the test methods for measuring the strength characteristics of the soils. Of all the methods in current use, the California Bearing Ratio test seemed to be a convenient and suitable test. In spite of criticisms, that the design based on the test is conservative, it is a valuable index type of test, by means of which a rough evaluation of the strength characteristics of a soil can be made[3]. The C.B.R. test has the advantage that it can be performed in the laboratory without cumbersome equipment and the *in-situ* C.B.R. tests can be easily arranged as field control tests so that the field test results may be correlated with the laboratory values and necessary modifications effected then and there. Hence, the C.B.R. test value has been taken as the main criteria in the present study.

3.2. Swelling and moisture absorption and the unconfined compressive strength tests which are necessary for evaluating the strength characteristics have also been conducted for each mix.

3.3. In addition to the above strength characteristics, an important factor that has to be considered in the load carrying capacity is the stability value of the road sections. In any flexible type of road pavement, it is essential that the superimposed layer should have sufficient mechanical stability to spread the load so that it could be carried by the subgrade without any deformation. Hence, the principal problem of design consists of preventing detrimental shear in the subgrade, base course and wearing surface. If sufficient plastic shear develops in any one or more of these three elements of the road structure, rutting and upheaval of the surface will occur. Serious plastic shear of the subgrade is prevented by an adequate overlying thickness of base course and surface. So the base course material should possess the required stability (resistance to plastic shear) under-imposed stress. From the Mohr's diagram[6] which provides a fundamental basis for defining the term stability as applied to granular and cohesive materials, it may be stated that the stability of the materials depends on their capacity for carrying a greater applied vertical load V, for a given lateral support L. Consequently for a specified value of lateral support L, the most stable material is that for which the value of $(V-L)$ is greatest for the equilibrium conditions established by the Mohr envelopes for the material under comparison. For materials with both granular and cohesive properties, it has been found that the stability value $(V-L)$ depends upon the magnitude of the lateral support, the cohesion C, and the angle of internal friction ϕ. This factor has been worked out from the geometrical and the trigonometrical relationship and is given below:

$$V-L = \frac{2\,L \sin\phi}{1-\sin\phi} + 2C\sqrt{\frac{1+\sin\phi}{1-\sin\phi}}$$

Hence, the stability value $(V-L)$ has also been considered for the different combinations taken up for the tests from the corresponding C and ϕ values obtained by the Triaxial compression tests.

4. LABORATORY STUDIES

4.1. Two typical gravel soils, one obtained from a quarry near Madras (Velachery) and the other from Palayamcottai quarry in South Arcot District, were taken up for detailed tests and for modifying their strength characteristics. The particle size analysis and other physical properties of these gravels are given in Table 1.

4.2. The coarse fractions of the gravels were separated from the fines. Considering that the aperture size (0.0949 in.) of B.S. Sieve No. 7 (I.S. Sieve No. 240) forms an approximate boundary between gravel and sand, silt and clay fractions as per the textural classifications and also taking into account the fact that this aperture size is approximately equal to that of the sand screen which is commonly used in road works, the B.S. Sieve No. 7 was selected as the limit between the coarse and fine fractions. The materials retained on B.S. No. 7 sieve form the coarse fraction and that passing through it are fines. Photos 1 to 3 show samples of the natural gravel from Velachery quarry and also the separated coarse and fine fractions.

The particle sizes of the coarse and fine fractions were then determined individually and the grading curves are shown in Figs. 3 and 4.

TABLE 1

Physical and chemical properties of the gravel soils tested

Serial number	Name of test	Gravel from Velachery quarry	Gravel from Palayamcottai quarry
1.	P.R.A. classification	A-2-6	A-2-6
2.	Liquid limit	40.9	19.9
3.	Plastic limit	16.3	8.7
4.	Plasticity index	24.6	11.2
5.	Per cent passing B.S.S. No. 7	27	24
6.	,, ,, ,, ,, 36	20	20
7.	,, ,, ,, ,, 200	15	17
8.	Proctor density lb per cu. ft.	130.5	132.0
9.	Optimum moisture, per cent	11.0	9.6
10.	California Bearing Ratio per cent (after 4 days soaking)	39.0	37.3
11.	Unconfined compressive strength test (wet) lb per sq. in.	3.0	3.8
12.	Moisture absorbed by capillary action, per cent	17	12.5
	Chemical Tests		
1.	Loss on ignition per cent (including moisture)	6.31	9.10
2.	Silica (SiO_2) per cent	40.71	43.04
3.	Mixed oxides (R_2O_3) per cent	45.58	45.10
4.	Iron oxide (Fe_2O_3) ,,	34.65	31.54
5.	Titania (TiO_2) ,,	4.00	0.89
6.	Lime (Cao) ,,	1.41	—
7.	Magnesia (Mg O) ,,	—	0.51
8.	Alkalis ,,	3.13	0.91

4.3. Then different mixes were obtained with varying coarse and fine combinations. For proportioning the coarse and fine fractions, two procedures were adopted. One was by adding different percentages by weight of the coarse fractions, (i.e., 12.5, 25, 37.5, etc., upto 100 per cent to the natural gravel). In the second, fines in small percentages (by volume) varying from 5 to 30 were added to the coarse fraction.

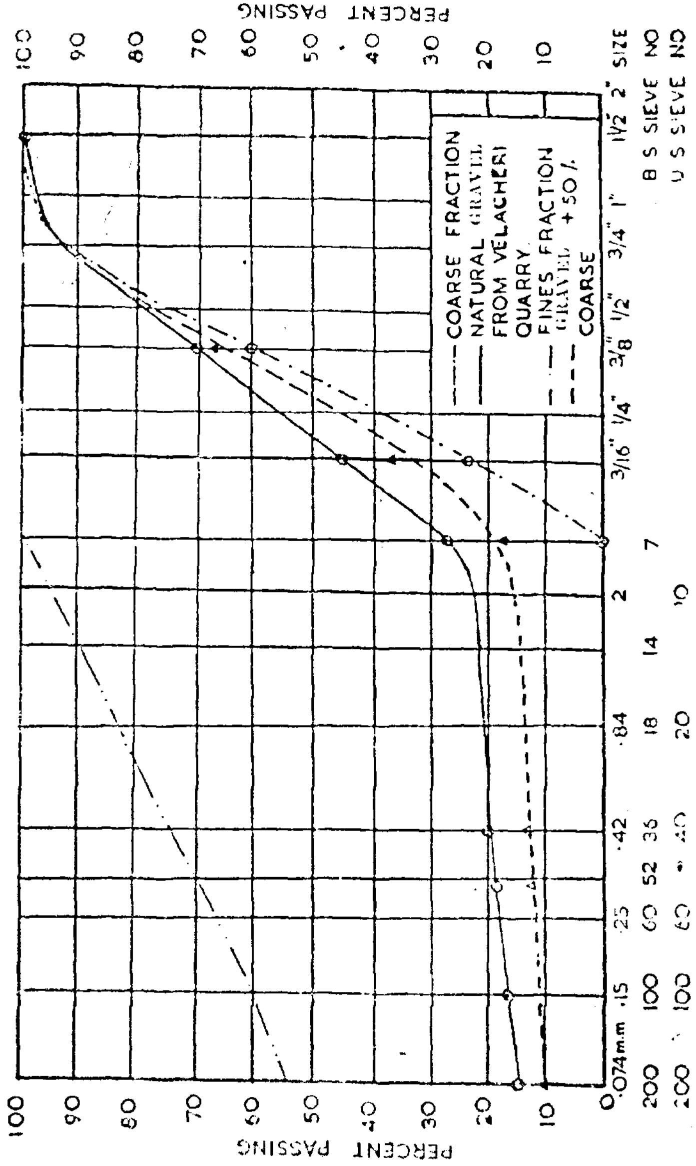


Fig. 3. Grading curves of natural gravel from Velachery quarry and the mix gravel + 50 per cent coarse fraction

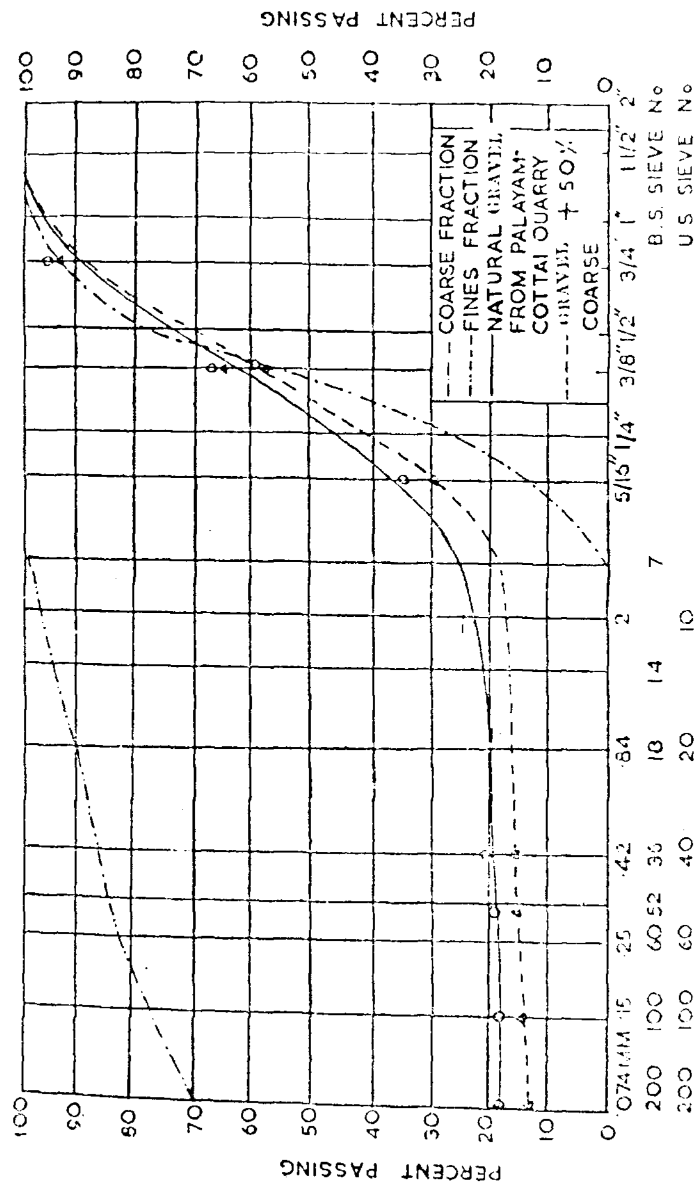


Fig. 4. Grading curves of natural gravel from Palayamcottai quarry and the mix gravel + 50 per cent coarse fraction

4.4. Suitable proportion of sand was also added to the natural gravel for improving the grading characteristics. The resultant mixes thus obtained were subjected to compaction and other strength tests. The California Bearing Ratio test was conducted as per standard procedure [7,8]. The test blocks for the C.B.R. tests were prepared at optimum moisture content and soaked for four days. The C.B.R. value was determined by causing a cylindrical plunger 3 sq. in. end cross section to penetrate the test block at the rate of 1/20 in. per minute and measuring the loads to cause a penetration of 0.1 or 0.2 in. The percentage of swell and the moisture absorption for the period of 4 days soaking were also determined.

4.5. For determining the unconfined compressive strength values, test specimens of size 2 in. dia. and 4 in. height were compacted to maximum density at optimum moisture content.

4.6. For determining the stability values $(V-L)$, test specimens of size 4 in. dia. and 8 in. high were prepared at optimum moisture content and maximum density. The specimens were then subjected to triaxial tests with lateral pressures of 0, 10 and 20 p.s.i. and the corresponding C and ϕ values were determined by drawing the Mohr's envelopes, Fig. 5. The stability value $(V-L)$ was then worked out using the C and ϕ values, thus obtained.

4.7. The effect of the addition of coarse fractions on the voids content of the resulting mix was also determined in the laboratory in respect of Velachery gravel. The change in the voids content for the different mixes both in the normal state and in the compacted state was determined separately. Assuming that the coarse fractions form the skeleton of the resulting mix, the degree of compaction of the fines were determined for each proportion. The fines were then compacted separately to the determined compactive values and the C and ϕ values for the corresponding mixes were determined from the direct shear tests.

5. DISCUSSION OF THE TEST RESULTS

5.1. From the physical properties, the two gravels tested may be classified as A-2-6 as per the P.R.A. Classification and may be considered as fair subgrade materials. Considering the plasticity index values, the Velachery gravel is highly plastic and the Palayamcottai gravel is medium plastic. As regards the chemical constituents, both the gravels are essentially hydrated oxides of iron and silica with quartzitic and schisty nodules.

5.2. The standards now adopted in Madras State for road materials for use in the base and wearing courses are indicated in

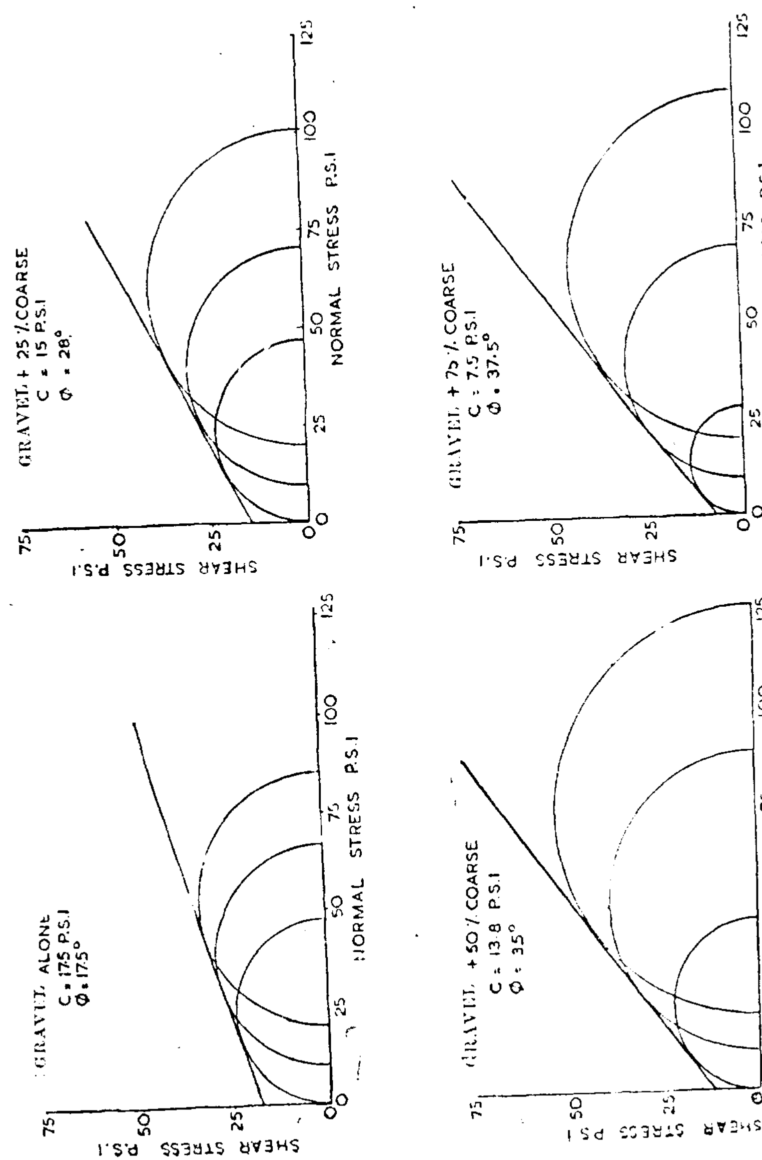


Fig. 5. Mohr's envelopes for gravel and gravel plus coarse fractions

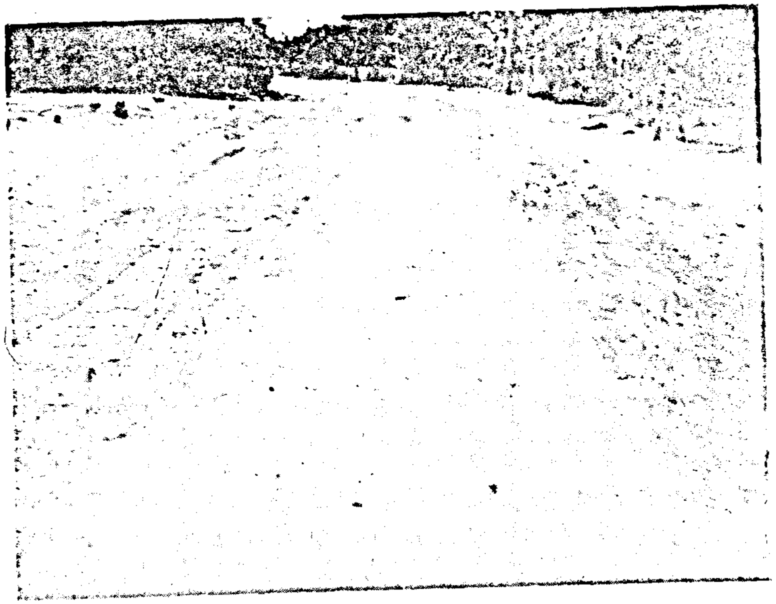


Photo 4. **Portion of the experimental reach where the mix gravel plus 50 per cent coarse fraction has been used as wearing course (after 1 year of service)**

Photo 5. **Portion of the reach where natural gravel has been used as wearing course (after 1 year of service) Note the development of wheel tracks**

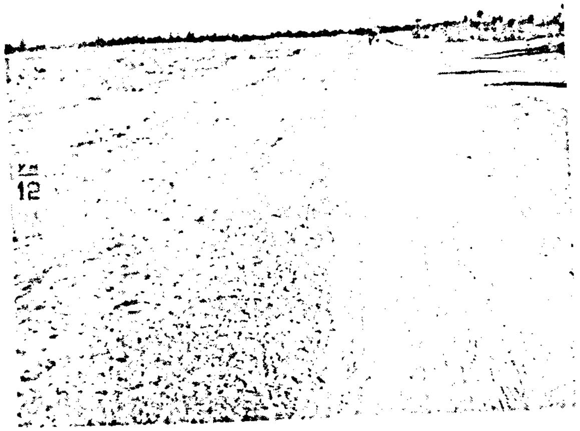
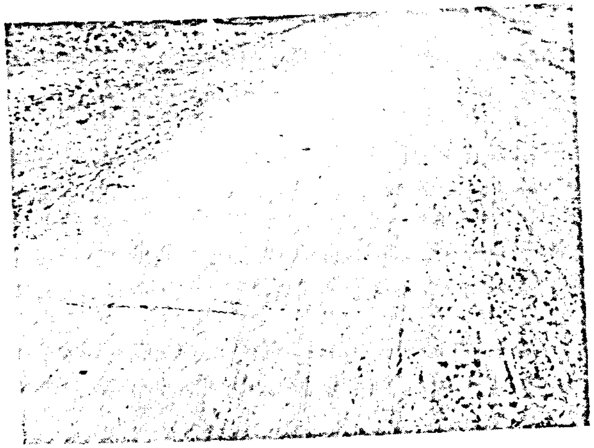


Photo 6

Photo 7



Photos 6, 7 & 8

Portions of the exper mental reach where the mix gravel plus 50 per cent coarse fraction has been use as wearing course (after $1\frac{1}{2}$ years of service)

Table 2. The two types gravel whose index value do not satisfy the standards may be considered not suitable for base course in their natural state. Also, it should be noted that the coarse fractions

TABLE 2

Standards for base and wearing courses in Madras State

1. Grading (for maximum size $1\frac{1}{2}$ in as per AASHO T.27 & B.S. 410)			
$1\frac{1}{2}$ in.	B.S. Sieve	...	100
1 in.	-do-	...	70 – 100
$\frac{3}{4}$ in.	-do-	...	60 – 90
$\frac{3}{8}$ in.	-do-	...	45 – 75
3/16 in.	-do-	...	30 – 60
No. 7	-do-	...	20 – 50
No. 36		...	10 – 30
No. 200		...	5 – 15
2. Liquid limit per cent		...	Maximum 25
3. Plasticity index		...	Maximum 6
4. California Bearing Ratio per cent :			
Good base		...	60 to 80
Best base		...	above 80

For wearing course, the plasticity index should not be less than 4 or more than 9 and the liquid limit should not exceed 35 per cent.

alone give a maximum dry density value of 125 lb per cu. ft. while the fines alone have a value of 122 lb per cu. ft. But by proper coarse fine combination, a maximum dry density of 134.5 lb per cu.ft. is obtained which is about 11 lb higher than the average. It is also seen that with the increase in the percentage of the coarse fractions, the void content is reduced gradually upto a certain value and beyond that stage the void content increases with the increase in the percentage of coarse fractions. At this stage, dry density and the C.B.R. values are also found to be the maximum and as such that particular ratio of the coarse and the fines may be taken as the optimum value for the particular gravel. The relationship between the maximum density and the proportions of aggregate and binder indicate that the maximum density is produced for the combinations of about 18 per cent fines and 32 per cent coarse fractions by weight in respect of Velachery gravel, Table 3.

5.3. Though a maximum density is got by the addition of sand, it is to be noted that a higher C.B.R. value is not obtained with the mere addition of an optimum percentage of sand fractions, Tables 3 and 4. The C.B.R. value (after 4 days soaking

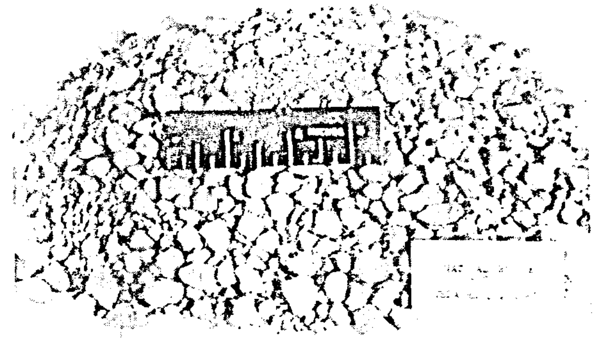


Photo 1

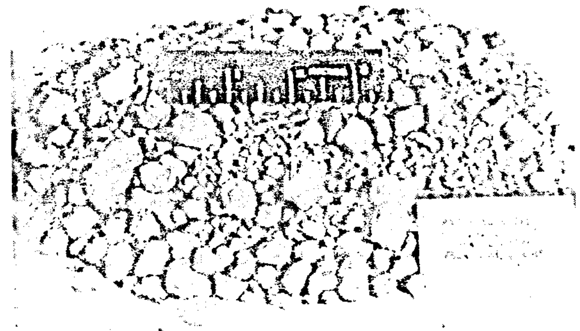


Photo 2

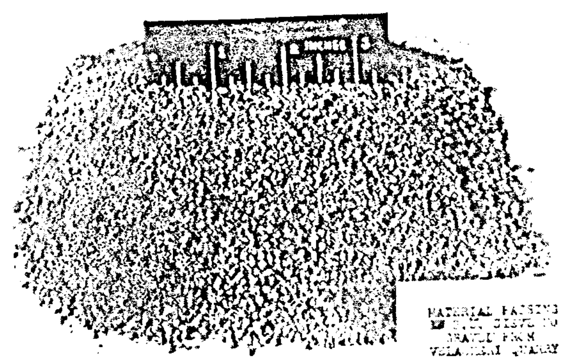


Photo 3

Photo 9

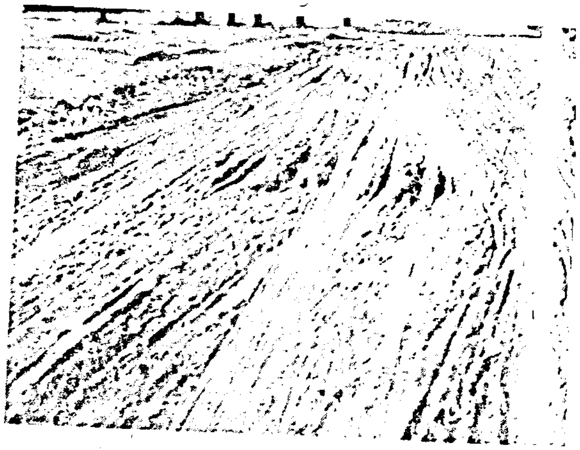


Photo 10

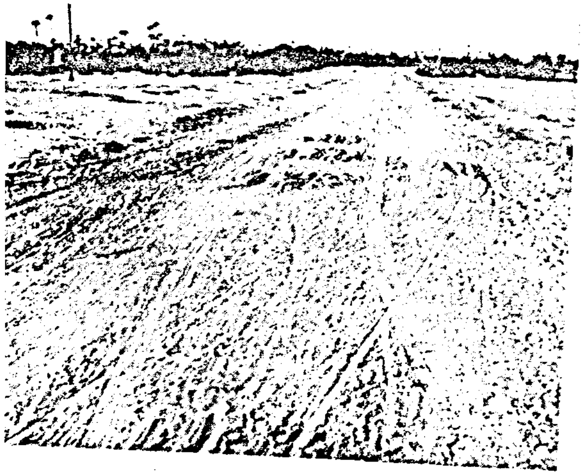


Photo 11

Photos 9, 10 & 11

Portions of reaches where natural gravel has been used as wearing course (after 1½ years of service)

TABLE 3

Effect of addition of coarse fractions on the strength characteristics of the natural gravel from Velachery quarry

Material	Per cent Coarse + 7 B.S.S.	Per cent Fines − 7 B.S.S.	Per cent Volume of voids in the compacted mix	Moisture density relationship: Density lb per cu.ft.	Moisture density relationship: Optimum moisture per cent	C.B.R. per cent	Unconfined compressive strength lb per sq. in.: Wet	Unconfined compressive strength lb per sq. in.: Moisture absorbed by capillary action per cent	($V-L$) in lb per sq. in.: Lateral pressure 0 lb per sq. in.	($V-L$) in lb per sq. in.: Lateral pressure 10 lb per sq. in.	($V-L$) in lb per sq. in.: Lateral pressure 20 lb per sq. in.
Coarse material alone	100	0	31	125.0	16.5	...	...	...	...	...	...
Natural gravel alone	73	27	25	130.5	11.0	30	3.0	17.1	49	57	65
-do- + 12.5 per cent Coarse	76	24	24	131.2	10.8	46	5.2	15.6	...	...	...
-do- + 25 ,,	78	22	24	132.5	10.7	52	7.0	14.0	51	69	87
-do- + 37.5 ,,	80	20	24	133.0	10.8	70	8.0	13.0	...	...	...
-do- + 50 ,,	82	18	23	134.5	10.3	82	8.3	10.2	52	78	104
-do- + 62.5 ,,	83	17	24	132.5	10.8	63	8.0	11.5	...	...	...
-do- + 75 ,,	85	15	25	130.3	10.6	49	6.1	15.7	30	61	92
-do- + 100 ,,	86	14	27	127.0	11.2	37	5.0	19.0	...	...	...
-do- + 25 per cent sand	58	42	24	131.2	10.9	45	4.0	15.8	...	...	...
-do- + 50 ,,	49	51	23	131.9	10.5	53	4.5	13.6	...	...	...
-do- + 75 ,,	42	58	21	133.5	10.0	58	4.8	12.0	...	...	...
-do- + 100 ,,	36	64	21	135.0	9.0	69	6.4	11.6	...	...	...
-do- + 150 ,,	29	71	20	133.0	10.9	50	4.0	16.0	...	...	...

TABLE 4

Effect of addition of coarse fractions on the strength characteristics of the natural gravel from Palayamcottai quarry

S.No.	Material	Per cent coarse +7 B.S.S.	Per cent Fines −7 B.S.S.	Per cent Volume of voids in compacted mix	Moisture density relationship: Density lb per cu. ft.	Moisture density relationship: Optimum moisture	C.B.R. per cent	Unconfined compressive strength lb per sq. in.: Wet	Per cent moisture absorbed by capillary action
1.	Coarse material alone	100	0	29	130.0	14.1	...	...	...
2.	Natural gravel ,,	76	24	25	132.0	9.6	37	3.8	12.5
3.	Natural ,, + 25 per cent coarse	81	19	20	140.0	8.8	84	7.8	9.7
4.	,, ,, + 50 ,,	84	16	22	136.0	10.2	75	7.0	11.5
5.	,, ,, + 75 ,,	86	14	23	135.5	10.8	71	6.7	12.0
6.	,, ,, + 100 ,,	88	12	24	134.0	10.9	69	6.0	12.0
7.	,, ,, + 50 per cent sand	64	36	23	134.0	9.0	67	7.0	11.5
8.	,, ,, + 100 ,,	56	44	24	131.2	9.2	50	3.0	12.0

of the natural gravel alone is found to be 39 per cent and by adding the optimum percentage of the coarse fractions, a C.B.R. value of about 82 per cent has been obtained while with the addition of an optimum percentage of sand, say, 100 per cent, the maximum C.B.R. value is found to be only 69 per cent (Table 3 and Fig. 6). But, for the tentative wearing course which will ultimately become the upper base course material, the C.B.R. value should be in excess of 89[7,9] per cent. Hence, it is now clear that the desired standard could be easily achieved by adding the optimum proportion of the coarse fractions while, by the addition of sand, even though the plasticity characteristics are reduced considerably, the C.B.R. value is improved only to standards required for ordinary base courses. Similar results are obtained for Palayamcottai gravel (Table 4 and Fig. 7) where addition of about 25 per cent of the coarse fractions gives best results. With the addition of 25 per cent fractions, the voids and the percentage of moisture absorption are found to be minimum while the unconfined compressive strength is found to be maximum.

5.4. Fig. 8 shows the stability values $(V-L)$ for Velachery gravel treated with 0, 25, 50 and 75 per cent coarse fractions obtained for the three lateral pressures 0, 10 and 20 p.s.i. From the Figure it is seen that the stability values $(V-L)$ for the different lateral pressures increase gradually upto the addition of 50 per cent coarse and then decrease. This again indicates that the addition of optimum percentage of coarse fractions, i.e., 50 per cent, gives the maximum stability also for the various lateral pressures. From these test results, it is obvious that suitable coarse fine combination not only produces maximum density and C.B.R. values but the stability values are also increased with the result that a greater vertical load can be applied for a particular lateral pressure.

Table 5 shows the test results for different mixes obtained by adding 5 to 30 per cent fines (by volume) to the coarse material. The compacted coarse fractions form the skeleton framework and the voids in them are assumed to be filled up with the fines on compaction. On the above assumptions, the state of compaction of the fines for the various proportions has been worked out. The corresponding C and ϕ values for the fine fractions are given in columns 9 and 10 of Table 5. It is seen that the dry density value (in other words, the state of compaction) and the C and ϕ values of the fine material increase with the increase in the fines content upto the optimum proportions (*i.e.*, natural gravel 50 per cent coarse) and then drops down appreciably. From this, it is clear that with the increase in the fines content not only the voids are gradually reduced but the fines themselves get compacted by the compactive effect and offer the necessary bearing resistance to the coarse

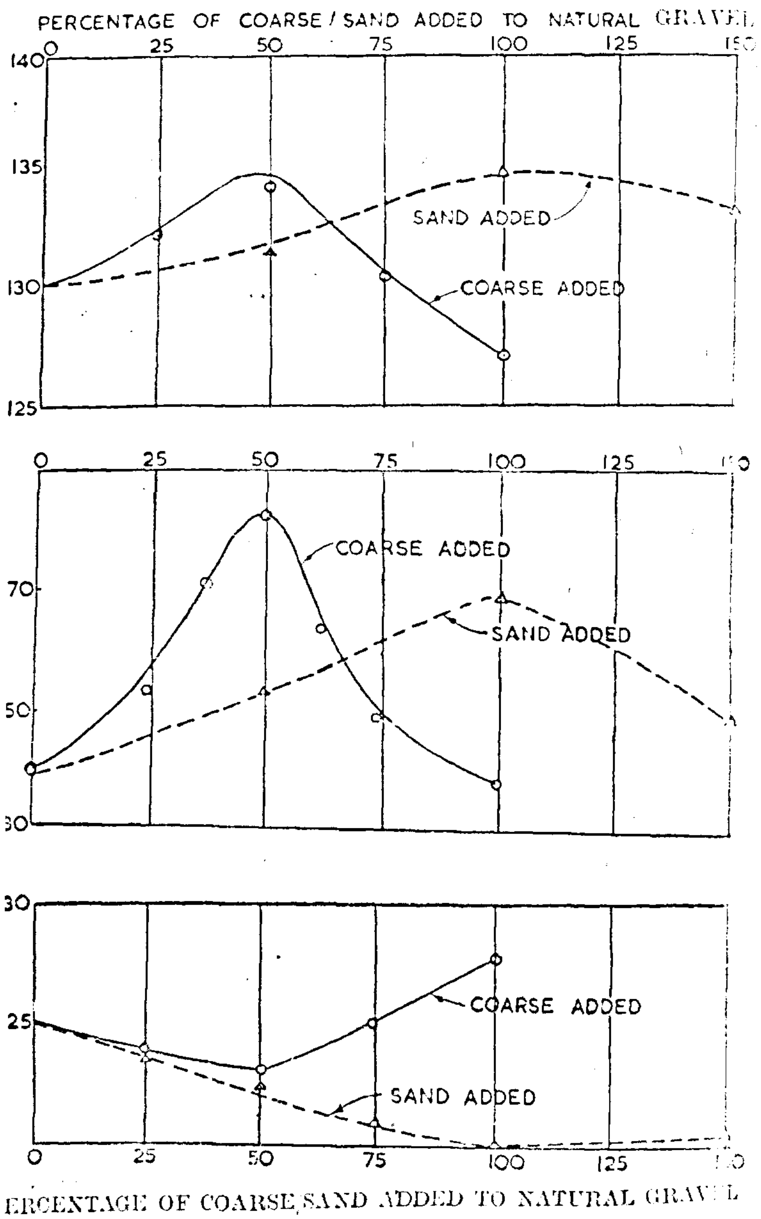


Fig. 6. Test results for gravel from Velachery quarry

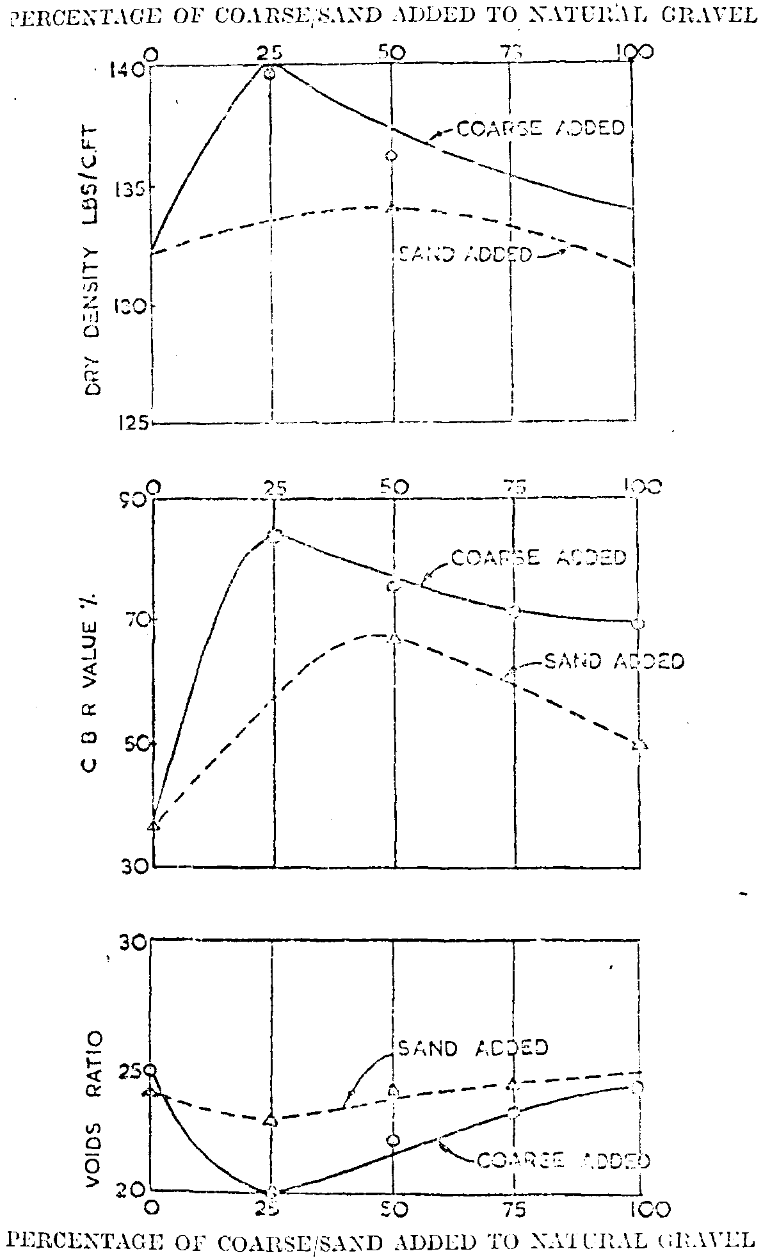
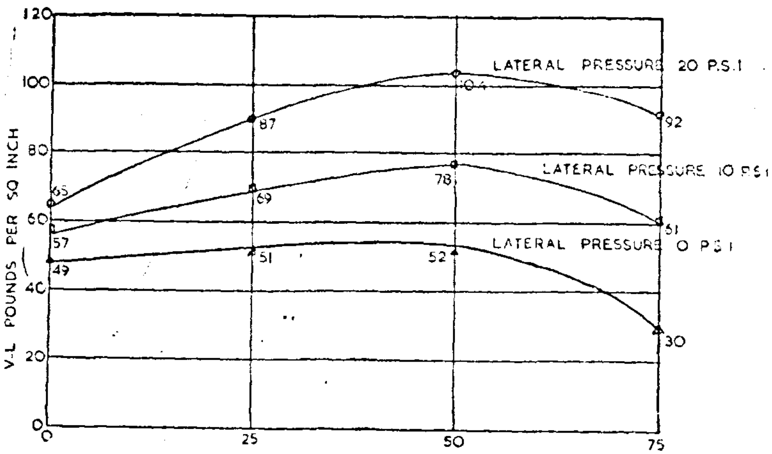


Fig. 7. Test results for gravel from Palayamcottai quarry



% OF COARSE MATERIAL ADDED TO NATURAL GRAVEL

Fig. 8. (V-L) Stability values for gravel with and without additional coarse fraction at different lateral pressures

skeleton. Thus the state of compaction of fines and the low voids content give the best mix which is far superior than that obtained individually. So, it is evident that the strength characteristics of the material will be improved considerably when the correct proportions of fines and coarse particles are present. The volume of voids in the coarse fractions and the volume of compacted fines occupying the same are given in columns 6 and 7 of Table 6 for the different mixes. From the perusal of the test results, it may be observed that the voids in the compacted coarse material are gradually filled up with the increase in the percentage of fines. Considering the mix "coarse + 5 per cent fines", the volume of voids in the compacted coarse is 1.35 units while the volume of fines occupying this is only 0.24 units leaving a balance voids of 1.11 units. Now with the increase in the percentage of fines, the volume of the fines in the mix is approximating to the volume of voids in the coarse and the critical condition (as shown in Fig. 2) for the mix "natural gravel + 50 per cent coarse" giving a net void of 0.03 units is attained. But on further increase in fines, the volume of fines is more than the volume of the voids in the coarse i.e., the fines are in excess and the grain to grain contact in the coarse will be lost. This is the condition in which the coarse aggregates will float in fines and thereby the stability is lost.

From the above discussion, it is now obvious that the strength and stability characteristics of the natural gravel are improved considerably by the addition of optimum percentage

TABLE 5

Test results for different mixes obtained by adding different percentage of fines to the coarse material

S. No.	Soil mix particulars	Loose state		Compacted state					
		Loose dry density lb per cu. ft.	Per cent voids as determined by laboratory test	Compacted dry density lb per cu. ft.	C.B.R. per cent	Per cent voids in compacted specimen (calculated)	Calculated dry density of fines in the mix lb per cu. ft.	Direct shear test values for fines compacted to the corresponding densities as in col. 8: Cohesion T sq. ft. per	Angle of internal friction ϕ
1	2	3	4	5	6	7	8	9	10
1.	Coarse + 5 per cent fines	100.5	47	127.0	36.4	27.5	57·0	0	9
2.	,, + 10 ,, ,,	101.5	45	129.5	39.2	26.0	74·5	0·69	13
3.	,, + 15 ,, ,,	102.5	41	131.0	41.0	25.0	104·7	0·44	17
4.	,, + 20 ,, ,,	102.5	39	133.5	48.5	23.5	103·5	0·51	19
5.	,, + 25 ,, ,, *	113.5	36	136.5	81.0	22.0	122·0	1·25	30
6.	,, + 30 ,, ,,	108.0	42	134.5	67.2	23.5	117·0	0·54	25
7.	Natural gravel (coarse + 12 per cent fines)	94.0	46	130.5	39.0	25.5	117·0	0·42	16
8.	Coarse (retained on B.S.S. No. 7)	92.0	59	125.0	32.7	28.5	—	—	—
9.	Fines (passing B.S.S. No. 7)	80.0	53	117.0	8.4	27.0	—	0·33	25

* Equivalent to natural gravel + 50 per cent coarse.

TABLE 6

Effect of addition of fines to the coarse on the voids in the coarse

Sl. No.	Mix particulars	Increase in volume when coarse fractions are added to 1 cu.ft. of natural gravel to make the proportion shown in Col. (2)	Actual volume after compaction (experimentally determined) cu.ft.	Volume after compaction (calculated with respect to coarse alone) Col. (3) × 0.79	Calculated volume of voids in the compacted coarse Col. (4) × $\frac{23+5^{**}}{100}$	Volume of compacted fines, occupying the voids of the compacted coarse	Balance of voids in the coarse after filling up with fines Cols. (6) − (7)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Coarse + 5 per cent fines	6.0	4.75	4.74	1.35	0.24	1.11
2.	,, + 10 ,, ,,	3.2	2.48	2.52	0.71	0.25	0.46
3.	,, + 15 ,, ,,	2.2	1.72	1.74	0.49	0.26	0.23
4.	,, + 20 ,, ,,	1.7	1.30	1.34	0.37	0.26	0.11
5.	,, + 25 ,, ,, *	1.2	0.995	0.918	0.28	0.25	0.03
6.	,, + 30 ,, ,,	1.1	0.89	0.87	0.25	0.27	Volume of voids filled up and excess fines. Hence, grain to grain contact in coarse destroyed.
7.	,, + 40 ,, ,, (Natural) gravel	—	0.72	0.79	0.20	0.30	
8.	,, Retained on B.S.S. No. 7	—	0.79	—	0.225	—	
9.	Fines (passing in B.S.S. No. 7)	—	0.69	—	—		

* Equivalent to natural gravel + 50 per cent coarse

** Percentage of voids in the compacted coarse

of the coarse fractions of its own. Such proportions of the coarse and fine combinations correspond to the ideal mix with grain to grain contact and a minimum voids content and can be obtained very easily at very little extra cost. A rough method of fixing this optimum proportion of the coarse and fine fractions in the field is given in the Appendix.

6. FIELD EXPERIMENTS

6.1. Encouraged by the findings of the laboratory experiments to study the behaviour of the modified gravel under field conditions, an experimental stretch of about 12 furlongs was taken up in miles 7/4 to 9/0 of Tiruvanmiyur-Muthukadu Road very near to Madras city. The subgrade soil is medium to fine sand throughout (for grading of sand, vide Fig. 9). Good gravel soil is available at Velachery quarry for an average lead of about 12 to 15 miles. The average rainfall is about 45 inches and the road embankment is well drained on either side.

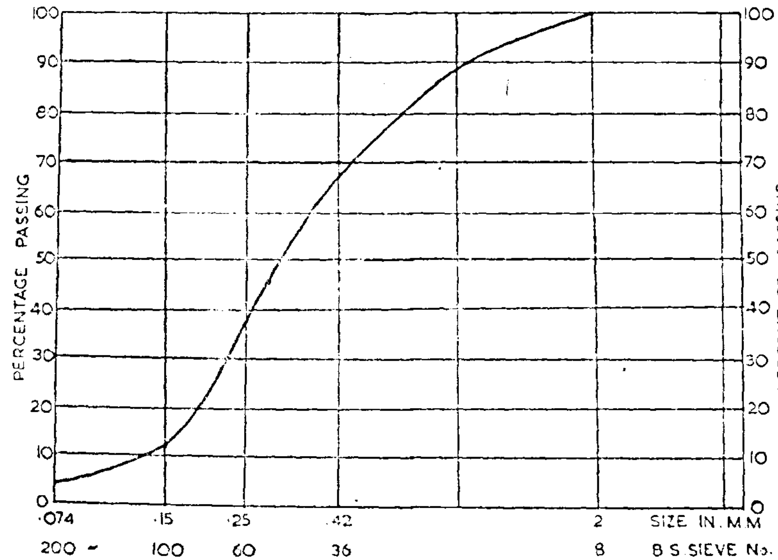
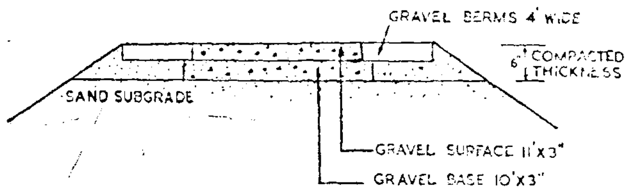
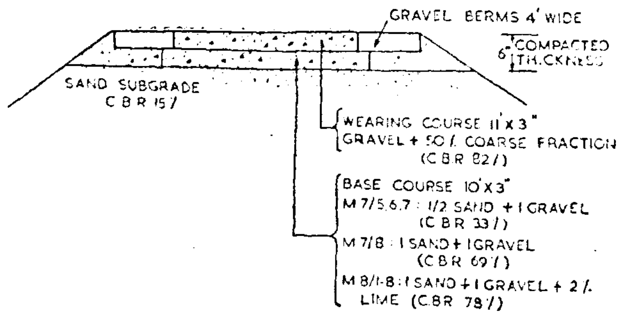


Fig. 9. **Grading curve of the subgrade sand of Thiruvanmiyur-Muthukadu Road**

6.2. **General Specifications :** Except the experimental reach the entire road is constructed with gravel laid in two layers of 4 inches loose compacted to about 3 inches thick over the sandy subgrade. Typical cross section of the road is given in Fig. 10.



CROSS SECTION OF THE ROAD IN GENERAL REACHES



CROSS SECTION OF THE ROAD IN EXPERIMENTAL REACHES

Fig. 10. **Thiruvanmiyur-Muthukadu Road**

6.3. **Specifications for Experimental Portion with Modified Gravel**: (Miles 7/5 to 9/0) For the experimental reach, gravel modified by adding an optimum percentage of coarse fractions of its own has been used. The coarse fractions are obtained by sieving the natural gravels on B.S.S. No. 7 (I.S. No. 240) equivalent roughly to the sand screen used in the field. The material retained on this sieve is added in suitable proportion to modify the natural gravel.

The principal factor controlling the stability of the mechanically stabilized soil aggregate mixture is the proportion of the soil to aggregate. But the natural gravel as it occurs, contains excess of fines. Hence, by addinga suitable quantity of coarse fractions, an ideal aggregate binder combination is obtained wherein maximum stability is attained by grain to grain contact. Though maximum density is obtained by the proper design of sand gravel combination, the required C.B.R. value could not be obtained by addition of sand. But by modifying the natural gravel with the addition of its own coarse fractions, its C.B.R. value which is only about 35 per cent increases to about 80 per cent. Hence, it is considered that it can be used even as a surface course for secondary roads.

The typical cross-section adopted is shown in Fig. 10. Sand gravel mix was used for the base course. Modified gravel with addition of about 50 per cent of coarse has been used for the wearing course. The specifications adopted in different stretches are given in Table 7.

TABLE 7

Reach	Length	Subgrade	Base course 3 in. compacted thickness	Wearing course 3 in. compacted thickness
7/5, 6, 7	3 × 660 ft	Sand C.B.R. 15 per cent	½ sand + 1 gravel (C.B.R. 53 per cent)	Gravel + 50 per cent coarse fraction (C.B.R. 82 per cent)
7/8	660 ft	-do-	1 sand + 1 gravel (C.B.R. 69 per cent)	-do-
8/1-8	1 mile	-do-	1 sand + 1 gravel + 2 per cent lime (C.B.R. 78 per cent)	-do-

6.4. **Design Criteria**: The design of the mixes was mainly based (i) on the values of the California Bearing Ratio in soaked condition, (ii) unconfined compressive strength, and (iii) maximum proctor density value. Variations in plasticity index and grading limits were not considered in the design.

6.5. **Method of Construction**: The sandy subgrade was formed to the required camber. The required quantity of the coarse fraction was added to the natural gravel soil and mixed well. The calculated quantity of water was added, wet mixed, then spread uniformly and compacted to the required thickness and camber.

6.6. **Cost per mile**

		Rs
(1)	Base course (sand gravel mix) 4 in. loose thick and 11 ft wide	6,000 per mile
(2)	Wearing course stabilized soil using gravel and 50 per cent coarse fraction (retained on B.S.S. No. 7) 4 in. loose thick and 10 ft wide ...	9,300 per mile
(3)	Base course of gravel 4 in. thick (loose) and 11 ft wide (normal specification) ...	7,549 per mile

6.7. **Behaviour of the Road**: The road where the main traffic at present consists of iron-tyred vehicles has completed one cycle of summer and rainy season and Photos 4 and 5 taken after more than one year of laying show the condition of the road with improved gravel and natural gravel. Photos 6 to 11 show the condition of the stretches with modified gravel and natural gravel respectively after $1\frac{1}{2}$ years of service. The improved gravel wearing surface continues to be in a very good condition and the field studies on this experimental work so far made are very encouraging and indicate larger field experimentation, under different conditions. If this modified gravel is surface treated with bitumen, it would preserve the surface and increase the life of the surface considerably. Further field experiments in this regard are indicated.

It may be mentioned here that the modified gravel surface offers a cheap and yet durable surface for medium traffic in areas where gravel is available. As may be seen from Fig. 1, large areas of the Madras State have gravel soil. Hence, the surface treated with modified gravel seems to be ideally suited for the bulk of rural roads. And when traffic develops, the modified gravel would serve as a good base for higher type of surfacing.

7. CONCLUSIONS

7.1. From the study of the laboratory test results and field observations of the experimental stretch, the following conclusions are arrived at:

(1) The strength characteristics of gravel can be increased very much by introducing an optimum proportion of coarse fractions (retained on B.S. Sieve No. 7) obtained from the same soil.

(2) For each sample of gravel, there is an optimum percentage of coarse fraction to be added so that the voids will be minimum and the strength values maximum.

(3) With the addition of optimum percentage of coarse fraction, the importance of the plasticity characteristics of soil mortar vanishes and the quality of the resultant material depends more on the properties of the coarse fraction.

(4) This type of improved gravel may be successfully used in base courses of pavement with high grade surface. It can also serve as a wearing course where stage construction is proposed.

(5) Though the required maximum density is obtained by adding optimum proportion of sand, the C.B.R. value of a mix could not be raised to standards required for the base below the wearing surface.

7.2. In concluding this study, it is to be mentioned that this type of surface cannot replace the higher types of surface. It is only hoped that it may ultimately prove to be an ideal low cost road for areas where gravel is available locally.

ACKNOWLEDGMENTS

The work described in this Paper was carried out in the Soils Section of the Highways Research Station and thanks are due to Sri K. V. Lakshmidhar, B.Sc., Research Assistant, who carried out the laboratory portion of the work described and to Sri R. Ranganathan, Assistant Engineer (H) for the valuable co-operation provided in carrying out the field experiments.

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Appendix

Field Method of Mixing the Optimum Proportion of the Coarse Fraction

The optimum proportion of the coarse fraction to be added to the natural gravel can be easily found out in the field by the following method. A known volume of the natural gravel is taken in a graduated jar and tamped well such that there is no further decrease in volume and the quantity is exactly measured. To this a certain measured quantity of kerosene is added and the total volume as indicated by the kerosene level in the jar is noted. The difference between the sum of the volumes of the natural gravel and the kerosene on one side and the resultant volume of gravel filled with kerosene on the other will give the volume of voids. The coarse fraction obtained by sieving on number 7 B.S. sieve is then added in different proportions, say, starting from 5 per cent onwards to the natural gravel, and the volume of the voids is determined for each mix separately as explained previously. It will be seen that with the addition of the coarse fractions upto a certain percentage, the voids content decreases. But by adding additional percentage of coarse fractions beyond that limit, the voids content increases. Hence, that turning point gives the optimum percentage of the coarse that is to be added for obtaining a mix that will contain the minimum amount of voids.

INFORMATION SECTION

"AN ANALYSIS OF 1958 DELHI TRAFFIC ACCIDENTS"

By

MISS D. V. HINGORANI*

1. INTRODUCTION

1.1. The number of traffic accidents and the number of persons killed are increasing considerably every year in Delhi. Every year brings about an additional 1,000 accidents on the police records. The number of accidents has risen from 1,127 in 1956 to 2,838 in 1958, i.e., from 3 accidents to 8 accidents per day, within a short period of three years, even though the number of motor vehicles has not doubled during the same period. In 1959 and 1960, the number of accidents as reported by the Delhi Traffic Police were 3,721 and 4,814 respectively which brought the number of accidents per day to 10 and 13 respectively.

1.2. The increasing frequency of traffic accidents and the resultant high death rate due to these accidents show that this accident problem shall have to be treated scientifically.

1.3. The purpose of this Paper is to investigate scientifically the traffic accidents which occurred in Delhi in 1958.

1.4. The accidents have been classified according to (i) severity of accident, (ii) place of accident, (iii) type of vehicles involved in accidents, (iv) accidents involving pedestrians, cyclists and slow-moving vehicles during different hours of day and night, (v) seasonal daily and hourly variation in accidents, (vi) type of accidents, (vii) age and driving experience of drivers, (viii) age and sex of pedestrians killed and injured, and (ix) surroundings such as built-up and non-built-up area, road conditions, surface conditions, weather conditions, light and traffic conditions.

1.5. The details of traffic accidents for 1958 were collected from the records maintained by the Delhi Traffic Police. The data were analysed by the Hollerith Punch Card System, using a convenient system of coding to facilitate sorting and tabulation.

2. ANALYSIS

2.1. The total number of traffic accidents in Delhi in 1958 was 2,838. These accidents were classified by the police into fatal,

* Central Road Research Institute, New Delhi.

non-fatal, injury and property damage accidents. The number of fatal, injury and property damage accidents was 118, 915 and 1,805 respectively. The number of persons killed and injured was 126 and 1,074 respectively, Table 1.

2.2. The sense the terms like fatal, non-fatal, injury and property damage accidents is defined below :

(a) **Fatal accident** is a serious injury accident in which death occurs either at the spot or later provided the cause of death is the injury received in the accident.

(b) **Non-Fatal injury accident** is an accident in which a person is hurt, slightly or severely, but no death occurs.

(c) **Property damage accident** is a collision type of accident in which nobody is killed or injured.

2.3. **Fatal Accidents**

There were in all 118 fatal accidents in Delhi in 1958. A detailed study of Delhi traffic accidents revealed that New Rohtak Road topped the list. There were 9 fatal accidents on New Rohtak Road, 7 on Grand Trunk Road (Karnal), 7 on Najafgarh Road, 5 on Elgin Road, and so on. Among the intersections, 3 fatal accidents occurred at Mori Gate Chowk, 2 at Chatta Rail Chowk (Queens Road-Elgin Road crossing) and so on.

2.4. The list of fatal accidents on various roads and intersections on which even one fatal accident occurred is given in Table 2. This Table also shows injury, property damage and total number of accidents on these roads and intersections. Various roads and intersections are shown in Delhi Road Map in Plate I, which also shows roughly the areas indicating development that has taken place in Delhi.

2.5. Table 3 shows different types of vehicles involved in fatal accidents.

The vehicles running on Delhi roads are classified into (i) fast-moving vehicles, (ii) slow-moving vehicles, and (iii) cycles.

Fast-moving vehicles included private cars, taxis, D.T.U. buses, private buses, trucks, motor-cycles and scooters, motor-cycle rickshaws and scooter rickshaws, etc.

The slow-moving vehicles included tongas, rehras, bullock-carts, hand-carts, etc.

The number* of fast-moving and slow-moving vehicles running on Delhi roads in 1958 was 23,754 and 13,299 respectively.

Table 3 shows that the worst killers on Delhi roads were trucks with 49 fatal accidents which accounted for about 42 per cent of the total number of fatal accidents. The worst sufferers in fatal accidents were pedestrians and cyclists, numbering 35 and 10 respectively.

3. INJURY ACCIDENTS

3.1. Total number of injury accidents in 1958 was 915. Of these, 36 injury accidents occurred on Grand Trunk Road (Shahdara), 31 on New Rohtak Road, 29 on Qutab-Mehrauli Road, 26 at Chandni Chowk, 24 on Elgin Road, Table 2. Some accidents occurred at the intersections also. Those were 7 at Mori Gate Chowk, 5 at Chatta Rail Chowk (Queens Road-Elgin Road crossing), and 5 at Delhi Gate Chowk, Table 2.

Table 2 shows injury accidents on only those roads and intersections on which fatal accidents occurred.

3.2. Table 4 shows different types of vehicles involved in injury accidents.

As in fatal accidents, the pedestrians and the cyclists in injury accidents also were the worst sufferers, involving 399 pedestrians and 331 cyclists. Here private cars were mainly responsible for most of the accidents.

4. PROPERTY DAMAGE ACCIDENTS

4.1. Total number of accidents involving property damage was 1,805. Of these, 76 occurred in Connaught Circus, 74 on New Rohtak Road, 57 on Qutab-Mehrauli Road, 42 in Chandni Chowk, and so on, Table 2. Property damage accidents occurring at the intersections were 25 at Chatta Rail Chowk (Queens Road-Elgin Road crossing), 17 at Mori Gate Chowk, 17 at Delhi Gate Chowk, 17 at Ajmeri Gate Chowk and so on, Table 2.

Table 2 shows property damage accidents on only those roads and intersections on which fatal accidents occurred.

* This information was also collected from Delhi Traffic Police.

5. TOTAL ACCIDENTS

The total number of accidents in 1958 was 2,838. Table 5 shows the various roads on which the total number of accidents was more than 10. Only that length of the road between the two extreme points at which the accidents occurred, has been measured.

The rate of accidents was 276 per mile in Faiz Bazar, 120 on Duffrin Bridge, 115 on Elgin Road and so on.

6. PEDESTRIAN ACCIDENTS

6.1. There were 465 accidents involving pedestrians. Of these, there were 66 fatal accidents and 399 injury accidents.

6.2. Out of 66 fatal accidents, 35 occurred with the trucks, 10 with D.T.U. buses, 7 with private cars and so on, Table 3.

6.3. About 60 per cent accidents involving pedestrians occurred during day time, i.e., from 6 a.m. to 6 p.m., 26 per cent during night time, i.e., from 6 p.m. to 6 a.m. and in 14 per cent accidents, the time of occurrence was not stated.

Accidents involving pedestrians during different hours of day and night are shown in Table 6.

7. CYCLE ACCIDENTS

7.1. From Table 7, it will be observed that the total number of accidents involving cyclists was 741. Of these, the number of fatal, injury and property damage accidents was 31, 331 and 379 respectively.

7.2. Most of the fatal accidents involving cyclists occurred with heavy motor vehicles, 10 with trucks, 9 with D.T.U. buses, 4 with private buses and so on, Table 3.

7.3. About 64 per cent accidents involving cyclists occurred during day time, i.e., from 6 a.m. to 6 p.m., 26 per cent during night time, i.e., from 6 p.m. to 6 a.m., and in 10 per cent accidents, the time was not mentioned.

Table 7 shows accidents involving cyclists during different hours of day and night.

8. ACCIDENTS INVOLVING SLOW-MOVING VEHICLES

8.1. As shown in Table 8, there were 479 accidents involving slow-moving vehicles, the number of fatal, injury and property damage accidents being 11, 131 and 337 respectively. Out of 479 accidents, tongas were involved in 373 accidents, bullock-carts in 75 and hand-carts in 31 accidents.

8.2. The percentage of accidents involving tongas, bullock-carts and hand-carts during day and night are shown below:

Slow-moving vehicles	Accidents		
	During day time (6 a.m. to 6 p.m.) (per cent)	During night time (6 p.m. to 6 a.m.) (per cent)	Time not stated (per cent)
Tongas ...	57	31	12
Bullock-carts ...	49	36	15
Hand-carts ...	52	39	9

Table 8 shows accidents involving slow-moving vehicles, during different hours of the day and night.

9. ACCIDENTS INVOLVING FIXED OBJECTS

9.1. Table 9 shows the accidents involving fixed objects.

9.2. There were 108 accidents with fixed objects, out of which about 42 per cent accidents occurred with the electric poles.

10. AREAWISE DISTRIBUTION OF ACCIDENTS

10.1. Greater Delhi is divided into three districts: (i) Northern, (ii) Central and (iii) Southern.

The number of accidents in various districts is shown in Table 1. Out of 2,838 accidents, 676 occurred in Northern District, 778 in Central and 1,384 in Southern District.

The various districts are shown in Delhi Road Map in Plate I.

11. PLACE OF ACCIDENTS

11.1. There were 2,157 accidents on carriageways and 681 at intersections, i.e., about 76 per cent accidents occurred on carriageways and 24 per cent at intersections.

11.2. Number of fatal accidents on the carriageways and at intersections was 102 and 16 respectively, the percentage being about 86 and 14 respectively.

11.3. About 80 per cent accidents involving pedestrians occurred on carriageways and 20 per cent at intersections, Table 6.

11.4. About 79 per cent accidents involving cyclists occurred on carriageways and 21 per cent at intersections, Table 7.

11.5. About 78 per cent accidents involving slow-moving vehicles occurred on carriageways and 22 per cent at intersections, Table 8.

12. SEASONAL TREND OF ACCIDENTS

12.1. Accidents do not occur uniformly throughout all the months of the year, days of the week and hours of the day. Analysis of accidents of some more years is necessary before arriving at a definite conclusion whether the month, day and the hour have anything to do with the occurrence of accidents.

The list showing the number of accidents during various months of the year is shown in Table 10.

The graphs showing the seasonal trend of fatal and total number of accidents are drawn in Fig. 1.

12.2. From Table 10 and Fig. 1 it is clear that there are two main seasons according to the variation in the number of accidents:

(i) Summer season from April to September

(ii) Winter season from October to March

Sumer season includes rainy season also, i.e., from July to September.

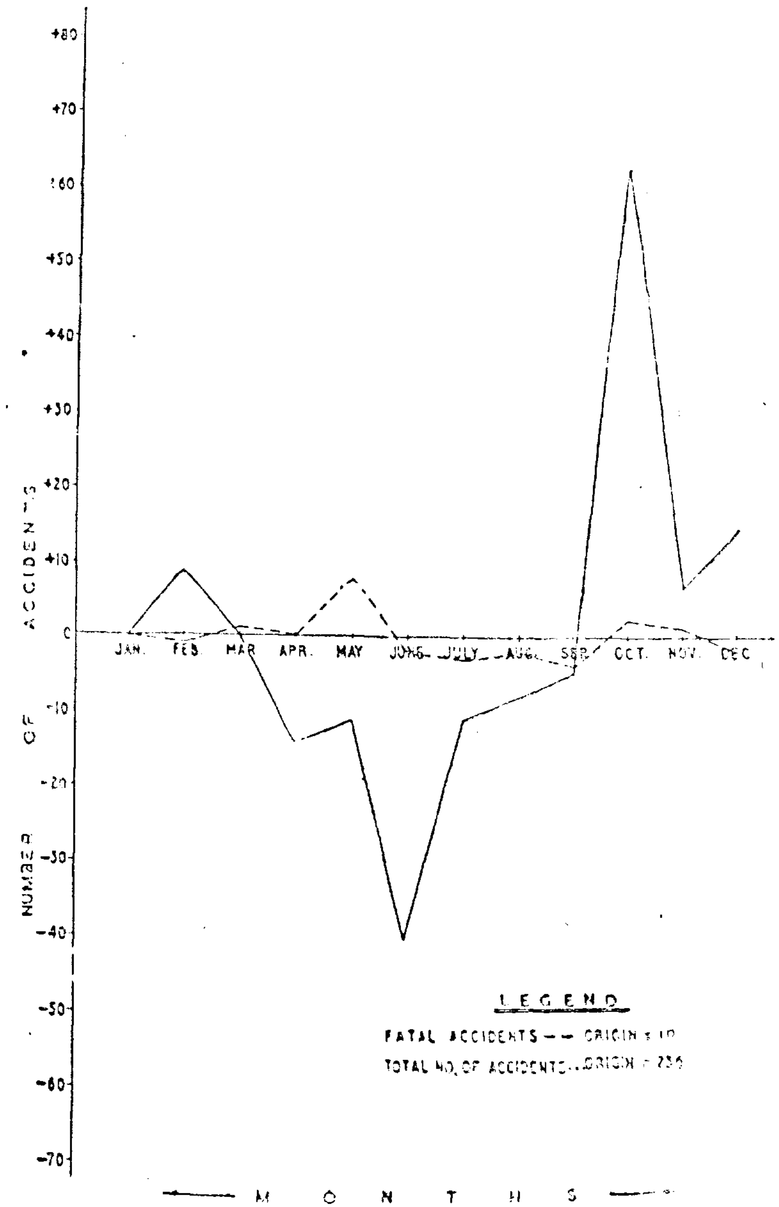

Fig. 1. Seasonal trend of accidents

12.3. In summer season, the deviation from the mean is on the negative side, the maximum being 40 in the month of June. This means that the number of accidents was less in summer season, the least accident month being June.

This may be due to less traffic volume on the roads in summer.

12.4. In winter season, the deviation from the mean is on the positive side, the maximum being 63 in the month of October, meaning thereby that the number of accidents in winter season was more which may be due to greater traffic flow in that season.

12.5. In case of fatal accidents, the deviation from the mean is the greatest (8) on the positive side in the month of May which can be taken as the highest fatality month.

13. DAILY VARIATION IN ACCIDENTS

13.1. Table 11 shows variation in accidents on different days of the week. A graph showing daily variation is drawn in Fig. 2.

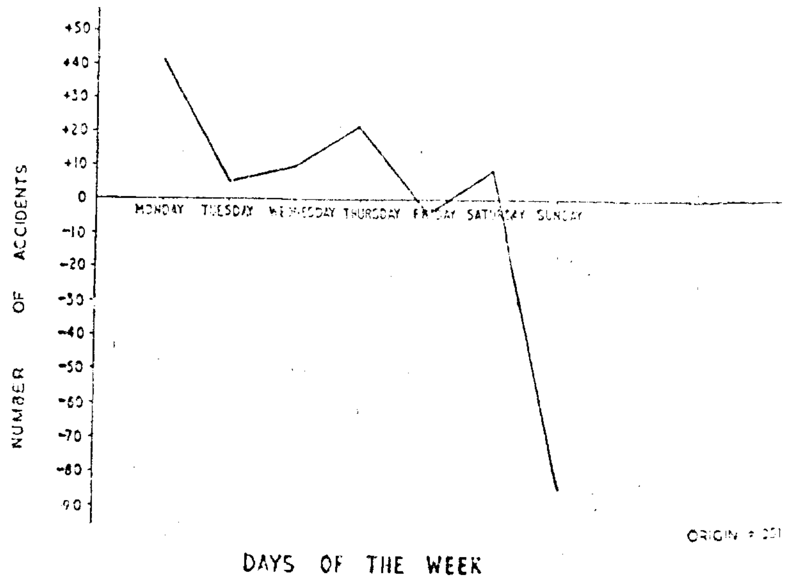

Fig. 2. Daily variation in accidents

The Table and the graph show that the deviation of accidents from the mean is the greatest (85) on the negative side on Sundays, i.e., the number of accidents on Sundays was minimum. Apparently the reason for this is that offices, firms, schools, and some business centres are closed on Sundays.

On Mondays, there is great deviation (41) from the mean on the positive side, i.e., the number of accidents was maximum on Mondays.

14. HOURLY VARIATION IN ACCIDENTS

14.1. Accidents classified according to various hours of the day are shown in Table 12.

14.2. The graphs showing fatal, injury, property damage and total number of accidents are drawn in Fig. 3.

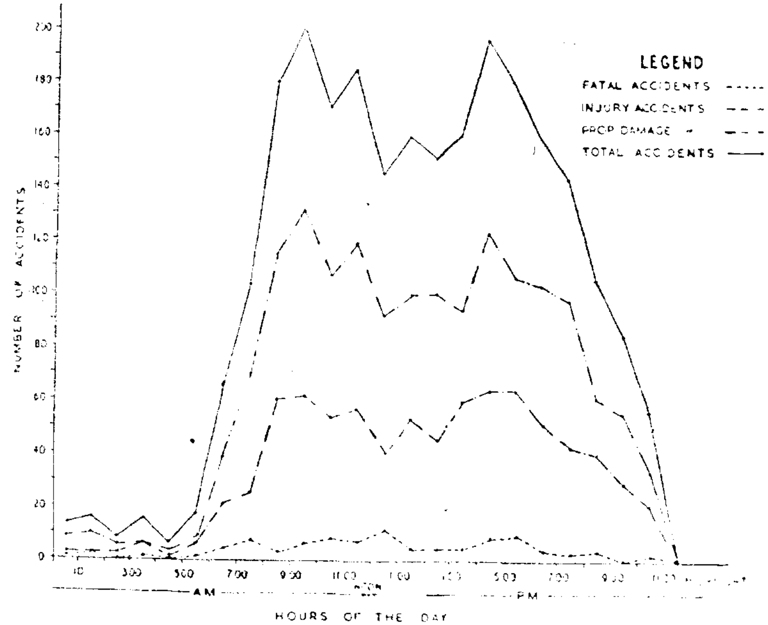

Fig. 3. Hourly variation in accidents

From all the graphs, excepting that for the fatal accidents, it is found that there are two perceptible peaks—one in the morning from 9 a.m. to 10 a.m and the other in the evening from 4 p.m. to 6 p.m. There is more traffic flow on the roads during these periods.

14.3. The number of fatal accidents was maximum during the period 12 noon to 1 p.m.

15. TYPE OF ACCIDENTS

15.1. Table 13 shows the accidents classified according to the type.

A chart showing the percentages of fatal and total number of accidents according to type of accident, is given in Fig. 4. This shows that out of 1,210 accidents in which the type of accident was known, about 49 per cent accidents occurred as a result of collision of one vehicle with another vehicle and rear-end collision ranked high, followed by head-on collision.

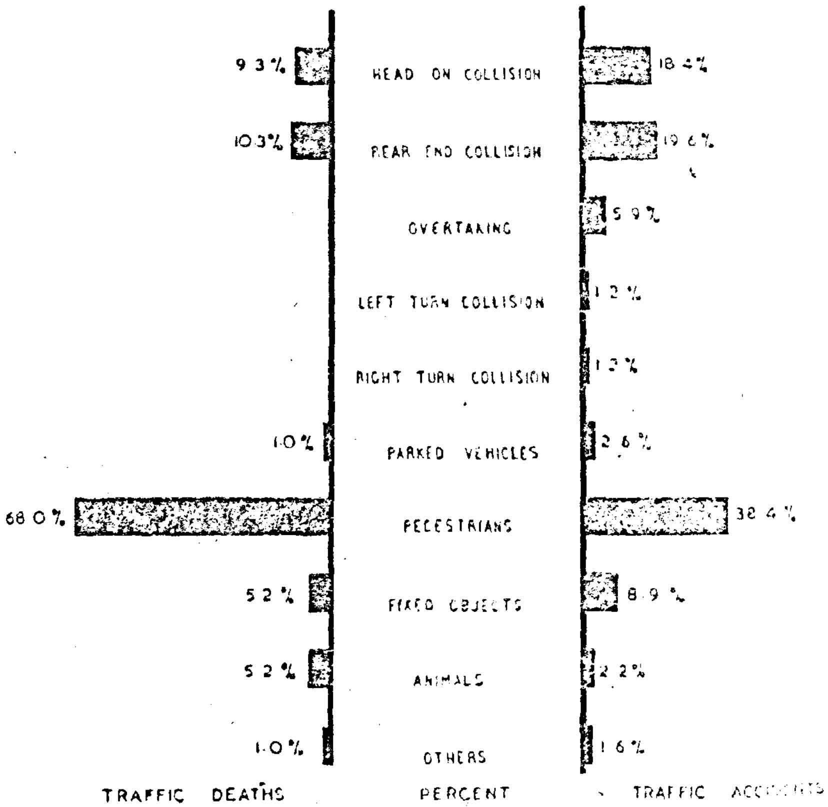

Fig. 4. **Type of accidents**

Photo 1

Head-on collision

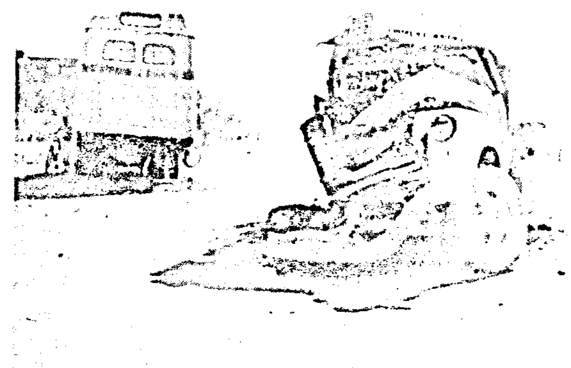

Photo 2

Head-on collision

Photo 3

Accident with fixed object (tree) due to overtaking

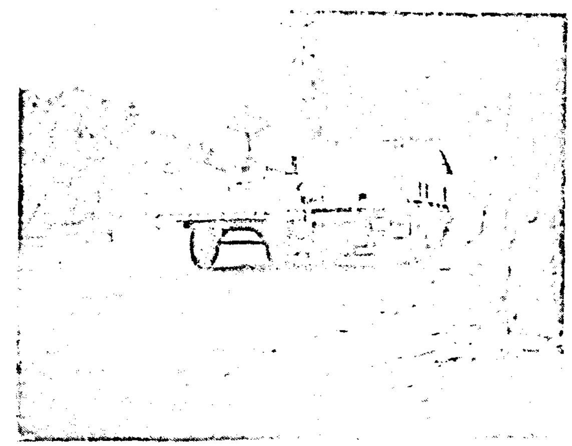

Photo 4

Accident with fixed object (tree) due to overtaking

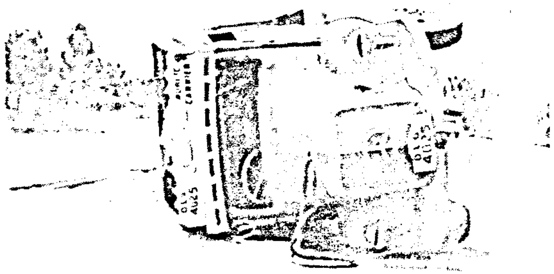

Photo 5

Overturning at a road-curve due to over-speeding

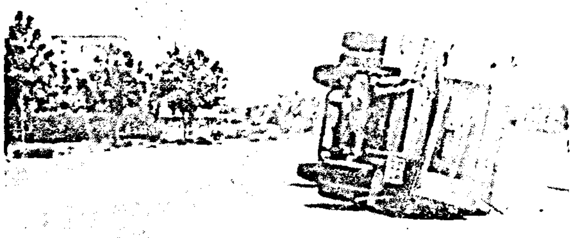

Photo 6

Overturning at a road-curve due to over-speeding

15.3. Of 97 fatal accidents in which type of accident was known, about 68 per cent accidents occurred with the pedestrians, 10 per cent due to rear end collision, 9 per cent due to head-on collision and so on.

16. AGE AND DRIVING EXPERIENCE OF DRIVERS

16.1. Table 14 shows the age and driving experience of the drivers.

16.2. Full particulars regarding the age and driving experience of the drivers were not available for all the accidents. In the absence of such knowledge, it is not possible to come to any conclusion regarding the relationship of age and driving experience to accident proneness.

However, from whatever statistics it was seen, the drivers within the 25—29 years age group and those with 8—10 years driving experience produced more accidents than any other group.

17. AGE AND SEX OF PEDESTRIANS KILLED AND INJURED

17.1. Table 15 shows the age and sex of pedestrians killed and injured. Although the statistics regarding the age of pedestrians killed and injured were not available in more than 50 per cent accidents, it was observed from whatever data was available that the maximum fatality percentage and maximum injury percentage occurred in the age group of 5-14 years.

18. SURROUNDINGS

18.1. Built-up and Non-Built up Areas

Accidents classified according to built-up and non-built-up areas are shown in Table 16. About 94 per cent of the total accidents occurred in built-up areas and 6 per cent in the non-built-up area, the percentage of fatal accidents in built-up and non-built-up areas being 81 and 19 respectively.

18.2. In non-built-up area, about 19 per cent accidents occurred due to overtaking whereas in built-up area only 8 per cent accidents occurred due to the same reason. This is perhaps due to the fact that in non-built-up area, there is less traffic volume on open roads. Therefore, the drivers are tempted to overtake the other vehicles.

18.3. The percentage of accidents with the pedestrians in built-up and non-built-up areas was about 22 and 28 respectively in spite of the fact that there is less number of pedestrians on roads in non-built-up area. The reason may be high speed on the part of drivers as the traffic flow on the roads in non-built-up area is light.

19. ROAD CONDITIONS

Accidents classified according to road conditions are shown in Table 17. About 85 per cent of the total accidents occurred on straight roads, 12 per cent on curved roads and 3 per cent on hilly roads. About 28 per cent accidents on straight roads and 48 per cent accidents on hilly roads occurred due to rear-end collision whereas about 31 per cent accidents on the curved roads occurred due to head-on collision.

20. WEATHER CONDITIONS

20.1. Table 18 shows accidents classified according to weather conditions.

20.2. In clear weather, the percentage of accidents was about 91 and in rainy and cloudy weather only 9. The reason for this may be that rainy season in Delhi lasts for only 2 to 3 months in a year, i.e., from July to September and even during these 3 months, it is not raining continuously.

20.3. The number of fatal accidents in clear weather was 46 as against 1 in rainy season. Fatal accidents mostly occurred with the pedestrians and cyclists. In rainy season, the number of pedestrians as well as cyclists on the roads is less. People, instead of going to their offices on bicycles, like to go by buses.

21. LIGHT CONDITIONS

21.1. Table 19 shows accidents classified according to light conditions.

21.2. About 76 per cent of the total accidents occurred during day-time, 20 per cent during night time and 4 per cent at dusk.

21.3. The percentage of accidents with the fixed objects at dusk and during dark hours was much more than the percentage of accidents during day-time. The reason for this may be that the fixed objects are not distinctly visible during dark hours.

21.4. The percentage of accidents due to head-on collision during dark hours on roads with poor and no street light was about 38 and 42 respectively whereas during day, dusk and dark with good street light, the percentage was about 22, 19 and 17 respectively. This may be due to the fact that the driver of one vehicle could not have seen the other vehicle due to improper road lighting or due to dazzle caused by the other vehicle.

21.5. Out of fatal accidents, night fatalities accounted for about 18 per cent.

22. TRAFFIC CONDITIONS

22.1. Accidents classified according to traffic conditions are shown in Table 20.

22.2. About 22 per cent of the accidents occurred on the roads with dense traffic, 29 per cent on the roads with moderate traffic and 49 per cent on the roads with light traffic.

22.3. On roads with dense traffic, the percentage of accidents with fixed objects was about 2 as against 7 and 9 in case of roads with light and moderate traffic respectively.

22.4. The percentage of accidents with the pedestrians was about 30 on roads with light traffic, 20 on roads with moderate traffic and 18 on roads with dense traffic. This could be attributed to higher speed of the vehicles on roads with light traffic.

23. CONTROLLED JUNCTIONS

23.1. The percentage of accidents due to rear-end collision at junctions with dense traffic was about 36, with moderate traffic 46 and with light traffic 22.

23.2. The percentage of accidents due to overtaking was about 17 and 15 at junctions with dense and moderate traffic respectively but there was no such accident at the junctions with light traffic.

23.3. The percentage of accidents with fixed objects at junctions with light traffic was about 22 as against 4 and 8 at junctions with dense and moderate traffic respectively.

24. UNCONTROLLED JUNCTIONS

24.1. The percentage of accidents due to rear-end collision at junctions with dense, moderate and light traffic was about 37, 23 and 27 respectively and those due to overtaking were 10, 11 & 3 respectively.

25. RECOMMENDATIONS

25.1. The limited study of one year traffic accidents indicates that during 1958, 70 pedestrians were killed and 423 injured, i.e., about 56 per cent of the total number of persons killed and 39 per cent of the total number of persons injured were pedestrians. Therefore, considerable reduction in the number of pedestrian accidents could be affected by providing side-walks on either side of the roads and making suitable provision for them to cross the roads.

25.2. Cyclists were involved in 741 accidents, i.e., about 26 per cent of the total accidents. Cycle traffic should, therefore, be segregated from the motor-vehicle traffic wherever possible and cycle tracks should be of such quality that cyclists may feel attracted to use them.

25.3. There were 108 accidents with the fixed objects.

Fixed objects should be far removed from the roads wherever possible and, where not possible, they should be made distinctly visible both during day time and during night time. About 42 per cent of the accidents involving fixed objects occurred with the electric poles which points out the necessity of keeping road shoulders clear of the poles or else making them distinctly visible with black and white paint or by some other means.

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TABLE 1

Accidents in Delhi in 1958—classified according to districts

District	Accidents						
	Fatal	Injury	Property damage	Total	Persons killed	Persons injured	Total
Northern	39	257	380	676	39	298	337
Central	46	236	496	778	53	276	329
Southern	33	422	929	1,384	34	500	534
Total ...	118	915	1,805	2,838	126	1,074	1,200

TABLE 2

Showing fatal, injury and property damage accidents on various roads and intersections where even one fatal accident occurred (1958)

Name of the road		Accidents			Total
		Fatal	Injury	Property damage	
New Rohtak Road	...	9	31	74	114
Najafgarh Road	...	7	20	23	50
G.T. Road (Karnal)	...	7	17	23	47
Elgin Road	...	5	24	37	66
G.T. Road (Shahdara)	...	4	36	35	75
Old Rohtak Road	...	4	7	5	16
Mori Gâte Chowk	...	3	7	17	27
Gurgaon Road	...	3	5	5	13
Chandni Chowk	...	2	26	42	70
Ring Road	...	2	19	20	41
Subzi Mandi	...	2	10	22	34
Chatta Rail Chowk (Queens Road-Elgin Road Crossing)	...	2	5	25	32
Bela Road	...	2	6	15	23
Pusa Road	...	2	5	13	20
Gandhi Nagar	...	2	8	7	17
Link Road	...	2	5	9	16
Mutiny Memorial Road	...	2	4	9	15
Sadar Bazar	...	2	2	6	10
Kalkaji	...	2	0	0	2
Connaught Circus	...	1	16	76	93
Qutab-Mehrauli Road	...	1	29	57	87
Deshbandhu Gupta Road	...	1	2	18	21
Mall Road	...	1	10	9	20
Chelmsford Road	...	1	2	17	20
Patel Road	...	1	4	15	20
West Patel Nagar	...	1	4	9	14

TABLE 2 (*Contd.*)

Name of the road		Accidents			Total
		Fatal	Injury	Property damage	
Dufferin Bridge	...	1	5	12	18
Asaf Ali Road	...	1	5	11	17
Kitchner Road	...	1	8	7	16
Reading Road	...	1	8	7	16
Tis Hazari	...	1	4	11	16
Bahadurgarh Road	...	1	2	12	15
Kishanganj Road	...	1	5	8	14
Jamna Bazar	...	1	4	6	11
Raj Path	...	1	3	7	11
Minto Bridge	...	1	4	5	10
Faiz Road	...	1	1	7	9
Court Road	...	1	1	7	9
Chitra Gupta Road	...	1	4	3	8
Vinay Marg	...	1	3	4	8
Jheel Kuranja	...	1	4	2	7
Station Road	...	1	1	3	5
Hastings Road	...	1	1	3	5
Boulevard Road	...	1	2	2	5
Idgah Road	...	1	1	3	5
Calcutta Gate	...	1	1	2	4
Shakur Basti	...	1	0	3	4
South Avenue	...	1	1	2	4
Paschmi Marg	...	1	0	2	3
Lukhnow Road	...	1	0	1	2
Village Buwana	...	1	0	1	2
Chirag Delhi	...	1	0	1	2
Mondi Road	...	1	0	0	1
Kesho Road	...	1	0	0	1
Village Mitrou	...	1	0	0	1

TABLE 2 (*Contd.*)

Name of the road	Accidents			Total
	Fatal	Injury	Property damage	
Kabul Nagar ...	1	0	0	1
Village Kerala ...	1	0	0	1
Perperganj Road ...	1	0	0	1
Dhansa Road ...	1	0	0	1
Jatekara Road ...	1	0	0	1
Delhi Gate Chowk ...	1	5	17	23
Ajmeri Gate Chowk ...	1	2	17	20
Minto Circus ...	1	2	11	14
Lodi Road-Lodi Estate Road No. 1 Crossing ...	1	0	4	5
Gurdwara Road Crossing ...	1	1	2	4
Mathura Road-Okhla Road Crossing ...	1	2	0	3
Akber Road-Mansingh Road Crossing ...	1	0	0	1
Bahadurgarh Road-Old Rohtak Road Crossing ...	1	0	0	1
Najafgarh Road-Shadipur Crossing	1	0	0	1
Ring Road-Lancer Road Crossing	1	0	0	1
Alipur Road-Ring Road Crossing	1	0	0	1
Alipur Road Crossing near Kashmeri Gate ...	1	0	0	1
Madan Road Crossing ...	1	0	0	1
Total ...	118	384	771	1273

Note:—Only those intersections where fatal accidents occurred, are shown separately but other intersections where injury and property damage accidents occurred, are included in the major roads.

TABLE 3

Fatal accidents involving different types of vehicles

	P. car	Taxi	D.T.U. bus	Private bus	Truck	Motor-cycle	Rickshaw	Slow-moving vehicles	Bicycles	Pedes-trians	Others	Not stated	Total
P. car	2	0	0	0	1	0	0	1	2	7	3	2	18
Taxi	0	0	0	0	0	0	0	0	1	4	0	0	5
D.T.U. bus	0	0	0	0	0	0	1	2	9	10	1	0	23
Private bus	0	0	0	0	0	1	0	1	4	4	1	0	11
Truck	0	0	0	1	0	0	0	1	10	35	0	0	47
Motor cycle	0	0	0	0	0	0	0	1	0	2	0	0	3
Rickshaw	1	0	0	0	1	0	0	1	1	1	0	0	5
Slow moving vehicles	0	0	0	0	0	0	0	0	2	2	0	0	4
Bicycles	0	0	0	0	0	0	0	0	0	1	1	0	2
Total ...	3	0	0	1	2	1	1	7	29	66	6	2	118

Note:—Rickshaw is carriage-driven by a motor-cycle or a scooter and is used for passenger transport.

TABLE 4

Injury accidents involving different types of vehicles

	P. car	Taxi	D.T.U. bus	Private bus	Truck	Motor-cycle	Rickshaw	Slow-moving vehicles	Bicycles	Pedes-trians	Others	Not stated	Total
P. car	7	3	2	0	6	17	10	14	100	102	2	0	263
Taxi	3	1	0	0	0	2	1	4	23	39	1	0	74
D.T.U. bus	3	0	1	0	1	3	5	13	27	36	3	0	92
Private bus	1	0	0	0	0	1	2	4	5	14	1	0	28
Truck	1	1	1	1	5	2	5	19	51	50	5	1	142
Motor cycle	3	1	1	0	4	0	2	2	36	49	2	0	100
Rickshaw	6	1	1	0	1	4	4	9	44	49	2	1	122
Slow-moving vehicles	0	0	0	0	1	1	0	7	16	39	1	0	65
Bicycles	1	0	0	0	2	2	1	1	0	21	1	0	29
Total ...	25	7	6	1	20	32	30	73	302	399	18	2	915

TABLE 5

Table showing the rate of accidents on various roads during 1958

Name of the road	Total No. of accidents	Length in miles	Rate of accidents, i.e., No. of accidents per mile
Faiz Bazar	69	0.25	276.0
Dufferin Bridge	18	0.15	120.0
Elgin Road	98	0.85	115.0
Pul Mithai	11	0.13	84.6
Janpath	76	1.20	63.3
Minto Road	35	0.58	60.3
Parliament Street	37	0.65	56.9
Barakhamba Road	25	0.53	47.2
New Rohtak Road	114	2.65	43.4
Old Rohtak Road	17	1.00	17.0
Panchkuin Road	50	1.25	40.0
Chelmsford Road	20	0.50	40.0
G.T. Road (Shahdara)	75	2.10	35.7
G.T. Road (Karnal)	47	4.43	10.6
Tis Hazari	16	0.43	37.2
Irwin Road	45	1.20	37.5
Queens Road	58	1.68	34.5
Malkaganj Road	27	0.80	33.8
Curzon Road	31	1.00	31.0
Mathura Road	146	4.80	30.4
Bahadurgarh Road	15	0.52	28.9
Thompson Road	12	0.43	27.9
Arya Samaj Road	21	0.80	26.3
Church Road	17	0.65	26.2
Shahjehan Road	13	0.50	26.0
Pusa Road	20	0.80	25.0
Alipur Road	25	1.00	25.0
Mansingh Road	11	0.45	24.4
Naya Bazar	19	0.80	23.8
Lothian Road	14	0.60	23.3
Reading Road	16	0.70	22.9

TABLE 5 (*Contd.*)

Name of the road	Total No. of accidents	Length in miles	Rate of accidents, i.e., No. of accidents per mile
Kishanganj Road	14	0.63	22.2
Circular Road	24	1.08	22.2
Qutab-Mehrauli Road	87	4.00	21.8
Najafgarh Road	51	2.50	20.4
Patel Road	20	1.00	20.0
Mall Road	20	1.05	19.1
Asaf Ali Road	17	0.93	18.3
Bela Road	23	1.33	17.3
Hamilton Road	14	0.83	16.9
Hardinge Avenue	13	0.80	16.3
Gurdwara Road	11	0.73	15.1
Prithvi Raj Road	16	1.10	14.6
Roshanara Road	12	0.85	14.1
Deshbandhu Gupta Road	21	1.6	13.1
M.M. Road (Mutiny Memorial Road)	15	1.2	12.5
Ashoka Road	11	0.90	12.2
Wellesley Road	11	0.93	11.8
Link Road	16	1.45	11.0
Ajmal Khan Road	12	1.10	10.9
Rajpath	11	1.05	10.5
Jamna Bazar	11	1.05	10.5
Rajpur Road	12	1.20	10.0
G.B. Road	11	1.20	9.2
Kitchner Road	16	1.83	8.7
Ring Road	43	5.40	8.0
Shankar Road	13	1.80	7.2
Lodi Road	12	1.80	6.7
Gurgaon Road	13	2.00	6.5

Note:—The accidents which occurred at the intersections have been assigned to Major Roads while calculating the rate of accidents, e.g., the accidents on Elgin Road also include the accidents which occurred at Chatta Rail Chowk.

TABLE 6

Accidents involving pedestrians during different hours of day and night

Time	Intersection			Carriageway			Grand total
	Fatal	Injury	Total	Fatal	Injury	Total	
6.00 A.M. — 7.00 A.M.	0	0	0	1	2	3	3
7.00 ,, — 8.00 ,,	0	2	2	3	17	20	22
8.00 ,, — 9.00 ,,	0	3	3	3	11	14	17
9.00 ,, — 10.00 ,,	1	3	4	0	14	14	18
10.00 ,, — 11.00 ,,	1	8	9	4	21	25	34
11.00 ,, — 1.00 P.M.	1	8	9	6	33	39	48
1.00 P.M. — 2.00 ,,	1	9	10	4	8	12	22
2.00 ,, — 4.00 ,,	1	14	15	5	41	46	61
4.00 ,, — 5.00 ,,	1	1	2	1	22	23	25
5.00 ,, — 6.00 ,,	1	2	3	5	22	27	30
6.00 ,, — 7.00 ,,	3	3	6	4	15	19	25
7.00 ,, — 8.00 ,,	0	0	0	5	17	22	22
8.00 ,, — 9.00 ,,	0	4	4	2	16	18	22
9.00 ,, — 11.00 ,,	1	8	9	1	21	22	31
11.00 ,, — 6.00 A.M.	1	4	5	5	10	15	20
Not stated	0	10	10	5	50	55	65
Total	12	79	91	54	320	374	465

Fatal accidents = 12 + 54 = 66
Injury ,, = 79 + 320 = 399

Total 465

TABLE 7

Accidents involving cyclists during different hours of day and night

Time	Intersection				Carriageway				Grand total
	Fatal	Injury	Property damage	Total	Fatal	Injury	Property damage	Total	
6.00 A.M. — 7.00 A.M.	0	0	0	0	0	3	2	5	5
7.00 ,, — 8.00 ,,	1	6	3	10	0	7	8	15	25
8.00 ,, — 9.00 ,,	1	1	2	4	2	10	10	22	26
9.00 ,, —10.00 ,,	0	9	6	15	2	21	20	43	58
10.00 ,, —11.00 ,,	2	5	1	8	2	16	22	40	48
11.00 ,, — 1.00 P.M.	1	11	11	23	3	36	32	71	94
1.00 P.M. — 2.00 ,,	0	0	2	2	4	13	17	34	36
2.00 ,, — 4.00 ,,	0	5	13	18	1	27	38	66	84
4.00 ,, — 5.00 ,,	0	7	2	9	2	13	16	33	42
5.00 ,, — 6.00 ,,	1	5	6	12	1	21	24	46	58
6.00 ,, — 7.00 ,,	0	3	4	7	2	14	26	42	49
7.00 ,, — 8.00 ,,	0	4	4	8	2	16	20	38	46
8.00 ,, — 9.00 ,,	0	2	4	6	3	16	8	27	33
9.00 ,, —11.00 ,,	0	7	5	12	0	11	21	32	44
11.00 ,, — 6.00 A.M.	0	1	3	4	1	4	11	16	20
Not stated	0	8	10	28	0	27	28	55	83
Total	6	74	76	156	25	257	303	585	741

Fatal accidents = 6 + 25 = 31
Injury ,, = 74 + 257 = 331
Property damage = 76 + 303 = 379

Total No. of accidents 741

TABLE 8

Accidents involving slow-moving vehicles during different hours of day and night

Time	Intersection	Carriageway	Tongas Fatal	Tongas Injury	Tongas Prop. damage	Tongas Total	Bullock carts Fatal	Bullock carts Injury	Bullock carts Prop. damage	Bullock carts Total	Hand carts Fatal	Hand carts Injury	Hand carts Prop. damage	Hand carts Total
6.00 A.M. — 7.00 A.M.	0	2	0	1	0	1	1	0	0	1	0	0	0	0
7.00 ,, — 8.00 ,,	1	6	0	1	4	5	0	0	2	2	0	0	0	0
8.00 ,, — 9.00 ,,	8	11	0	2	13	15	0	0	3	3	0	0	1	1
9.00 ,, — 10.00 ,,	6	27	0	7	22	29	0	3	1	4	0	0	0	0
10.00 ,, — 11.00 ,,	5	31	0	11	21	32	0	0	2	2	0	0	2	2
11.00 ,, — 1.00 P.M.	12	43	1	12	30	43	1	3	5	9	0	1	2	3
1.00 P.M. — 2.00 ,,	4	14	0	2	11	13	0	2	0	2	0	1	2	3
2.00 ,, — 4.00 ,,	12	33	1	6	27	34	2	0	6	8	0	1	2	3
4.00 ,, — 5.00 ,,	3	12	0	2	8	10	0	0	2	2	0	0	3	3
5.00 ,, — 6.00 ,,	7	28	1	7	22	30	0	1	3	4	0	0	1	1
6.00 ,, — 7.00 ,,	6	22	1	9	13	23	0	2	1	3	0	1	1	2
7.00 ,, — 8.00 ,,	8	17	0	5	14	19	0	1	3	4	0	1	1	2
8.00 ,, — 9.00 ,,	8	29	0	4	29	33	0	1	0	1	0	0	3	3
9.00 ,, — 11.00 ,,	6	35	1	11	16	28	0	2	8	10	0	1	2	3
11.00 ,, — 6.00 A.M.	8	16	0	1	12	13	2	6	1	9	0	1	1	2
Not stated	9	50	0	16	29	45	0	6	5	11	0	0	3	3
Total	103	376	5	97	271	373	6	27	42	75	0	7	24	31

Fatal accidents : = 5 + 6 + 0 = 11
Injury ,, : = 97 + 27 + 7 = 131
Property damage : = 270 + 42 + 25 = 337
TOTAL 479

TABLE 9

Accidents with fixed objects

Fixed object	Accidents Fatal	Accidents Injury	Accidents Property damage	Accidents Total	Percentage of total accidents
Electric pole ...	0	9	36	45	41.7
Traffic islands ...	1	3	12	16	14.8
Fence ...	0	5	11	16	14.8
Tree ...	3	0	4	7	6.5
Building, Gate, Wall	1	0	6	7	6.5
Miscellaneous ...	0	1	16	17	15.7
Total ...	5	18	85	108	100.0

TABLE 10

Accidents classified according to month of the year

Month	Accidents Fatal	Accidents Injury	Accidents Property damage	Accidents Total	Deviation of fatal accidents from the mean	Deviation of total No. of accidents from the mean
January	10	80	146	236	0	0
February	9	75	161	245	− 1	+ 9
March	11	79	146	236	+ 1	0
April	10	72	140	222	0	− 14
May	18	63	144	225	+ 8	− 11
June	8	57	131	196	− 2	− 40
July	7	73	145	225	− 3	− 11
August	8	61	159	228	− 2	− 8
September	6	85	140	231	− 4	− 5
October	12	103	184	299	+ 2	+ 63
November	11	78	155	244	+ 1	+ 8
December	8	89	154	251	− 2	+ 15
	118	915	1805	2838		

For fatal accidents, Mean = 10 For total No. of accidents, Mean = 236

TABLE 11

Accidents classified according to day of the week

Day of the week	Accidents				
	Fatal	Injury	Property damage	Total	Deviation from the mean
Monday ...	10	140	242	392	+ 41
Tuesday ...	18	116	222	356	+ 5
Wednesday ...	20	100	241	361	+ 10
Thursday ...	17	123	233	373	+ 22
Friday ...	11	107	229	347	− 4
Saturday ...	22	124	214	360	+ 9
Sunday ...	7	100	159	266	− 85
Not stated ...	13	105	265	383	
Total ...	118	915	1805	2838	

For total No. of accidents, Mean = 351

Note:—While finding the mean, the column 'not stated' has not been taken into consideration.

TABLE 12

Accidents classified according to hours of the day

Hours of the day	Accidents			
	Fatal	Injury	Property damage	Total
0 – 1.00 A.M.	2	3	9	14
1.00– 2.00 A.M.	3	3	10	16
2.00– 3.00 A.M.	0	3	6	9
3.00– 4.00 A.M.	2	7	7	16
4.00– 5.00 A.M.	1	2	4	7
5.00– 6.00 A.M.	2	7	9	18
6.00– 7.00 A.M.	5	22	39	66
7.00– 8.00 A.M.	8	26	70	104
8.00– 9.00 A.M.	4	61	115	180
9.00–10.00 A.M.	7	62	131	200
10.00–11.00 A.M.	9	54	107	170
11.00–12.00 Noon.	8	57	119	184
12.00– 1.00 P.M.	12	41	92	145
1.00– 2.00 P.M.	5	54	100	159
2.00– 3.00 P.M.	5	46	100	151
3.00– 4.00 P.M.	5	60	94	159
4.00– 5.00 P.M.	9	64	123	196
5.00– 6.00 P.M.	10	64	106	180
6.00– 7.00 P.M.	4	51	103	158
7.00– 8.00 P.M.	3	43	97	143
8.00– 9.00 P.M.	4	40	61	105
9.00–10.00 P.M.	0	29	55	84
10.00–11.00 P.M.	2	21	33	56
11.00–12.00 Mid-night	0	0	3	3
Not stated	8	95	212	315
Total:	118	915	1,805	2,838

TABLE 13

Accidents classified according to type

Type of accident	Accidents				Percentage of fatal accidents	Percentage of total accidents
	Fatal	Injury	Property damage	Total		
Head-on collision	9	75	138	222	9.3	18.4
Rear-end ,,	10	72	155	237	10.3	19.6
Overtaking	0	14	57	71	0	5.9
Left turn ,,	0	6	9	15	0	1.2
Right turn ,,	0	6	9	15	0	1.2
Perked vehicle	1	5	26	32	1.0	2.6
Pedestrian	66	399	0	465	68.0	38.4
Fixed object	5	18	85	108	5.2	8.9
Animals	5	21	0	26	5.2	2.2
Other causes (over-turning, ran off etc.)	1	6	12	19	1.0	1.6
Total	97	622	491	1,210	100.0	100.0

Note :—In only 1,210 accidents out of 2,838, the details regarding type of accidents were known.

TABLE 14

Accidents classified according to age and driving experience of the drivers

Age in years	No. of drivers involved in accidents	Accidents				
		Fatal	Injury	Property damage	Total	Percent-age
15 — 19	9	0	7	2	9	1.6
20 — 24	58	3	31	24	58	10.3
25 — 29	200	10	88	102	200	35.6
30 — 34	167	22	50	95	167	29.8
35 — 44	90	4	35	51	90	16.0
45 — 54	34	3	9	22	34	6.1
55 — 64	2	0	2	0	2	0.4
65 — 74	0	0	0	0	0	0
75 years and over	1	1	0	0	1	0.2
Total	561	43	222	296	561	100.0

Driving experience

1 year	19	0	12	7	19	5.6
2 years	25	0	14	11	25	7.3
3 ,,	22	0	7	15	22	6.4
4 ,,	21	1	12	8	21	6.6
5 ,,	35	2	10	23	35	10.3
6 — 7 years	79	3	28	48	79	23.2
8 — 10 ,,	104	12	31	61	104	30.5
11 — 15 ,,	14	2	6	6	14	4.1
16 years onwards	22	2	14	6	22	6.0
Total	341	22	134	185	341	100.0

Note :—The statistics of ages of only 561 drivers and driving experience of only 341 drivers out of 2,838 accidents were available.

TABLE 15

Showing age and sex of pedestrians killed and injured

Age group in years	No. of pedestrians killed					No. of pedestrians injured				
	Male	Female	Child	Total	Per cent	Male	Female	Child	Total	Per cent
0 — 4	2	4	1	7	16.7	4	2	1	7	7.4
5 — 14	5	8	2	15	35.7	23	14	1	38	40.4
15 — 24	5	1	0	6	14.3	10	2	0	12	12.8
25 — 44	3	3	0	6	14.3	16	7	0	23	24.5
45 — 64	3	2	0	5	11.9	3	6	0	9	9.6
65 & above	2	1	0	3	7.1	2	3	0	5	5.3
Total	20	19	3	42	100.0	58	34	2	94	100.0
Not stated	17	5	6	28		239	54	36	329	
Grand total	37	24	9	70		297	88	38	423	

Note :—While finding out the percentage, the column 'not stated' has not been taken into consideration.

TABLE 16

Accidents classified according to surroundings

(Built-up and non-built up area)

Area	Type of collision	Accidents				Percentage of total accidents
		Fatal	Injury	Property damage	Total	
Built-up area	Head-on collision	2	55	86	143	23.1
	Rear-end ,,	3	54	120	177	28.6
	Right turn ,,	0	4	7	11	1.8
	Left turn ,,	0	4	4	8	1.3
	Overtaking	0	9	41	50	8.1
	Parked vehicle	0	3	17	20	3.2
	Pedestrians	24	110	0	134	21.7
	Fixed object	2	8	37	47	7.6
	Animals	4	10	0	14	2.3
	Others	0	5	9	14	2.3
	*Not stated	9	77	130	216	—*
	Total	44	339	451	834	100.0
Non-built up area	Head-on collision	2	2	2	6	16.7
	Rear-end ,,	2	3	1	6	16.7
	Right turn ,,	0	0	1	1	2.8
	Left turn ,,	0	0	1	1	2.8
	Overtaking	0	4	3	7	19.4
	Parked vehicle	0	0	1	1	2.8
	Pedestrians	5	5	0	10	27.7
	Fixed objects	0	0	3	3	8.3
	Animals	1	0	0	1	2.8
	*Not stated	0	6	11	17	—*
	Total	10	20	23	53	100.0
	Grand total	54	359	474	887	

Note :—*1.* In only 887 accidents out of 2,838, the details regarding 'built-up' and 'non-built up' areas were known.

2. * While calculating the percentages, the column 'not stated' has not been taken into consideration.

TABLE 17

Accidents classified according to road conditions

Road condition	Type of collision	Accidents: Fatal	Injury	Property damage	Total	Percentage
Straight & flat road	Head-on collision	3	49	69	121	22.4
	Rear-end ,,	5	42	104	151	27.9
	Right turn ,,	0	3	6	9	1.7
	Left turn ,,	0	4	4	8	1.4
	Overtaking	0	10	38	48	8.9
	Parked vehicle	0	2	14	16	3.0
	Pedestrians	25	99	0	124	22.9
	Fixed object	2	7	32	41	7.5
	Animals	5	10	0	15	2.8
	Others	0	3	5	8	1.5
	*Not stated	7	68	110	185	—
	Total	47	297	382	726	100.0
Curve or bend in road	Head-on Collision	1	4	18	23	30.7
	Rear-end ,,	1	6	7	14	18.6
	Right turn ,,	0	1	1	2	2.7
	Left turn ,,	0	0	2	2	2.7
	Overtaking	0	3	3	6	8.0
	Parked vehicle	0	0	2	2	2.7
	Pedestrians	2	12	0	14	18.6
	Fixed object	0	1	7	8	10.7
	Others	0	2	2	4	5.3
	*Not stated	1	5	18	24	—
	Total	5	34	60	99	100.0
Hilly road	Head-on collision	0	1	2	3	14.3
	Rear-end ,,	0	5	5	10	47.6
	Parked vehicles	0	1	1	2	9.5
	Pedestrians	0	3	0	3	14.3
	Fixed object	0	1	1	2	9.5
	Others	0	0	1	1	4.8
	*Not stated	0	6	2	8	—
	Total	0	17	12	29	100.0
	Grand total	52	348	454	854	

Note:—1. In only 854 accidents out of 2,838, the road conditions were known.
2. *While calculating the percentage, column 'not stated' has not been taken into consideration.

TABLE 18

Accidents classified according to weather conditions

Weather	Type of collision	Accidents: Fatal	Injury	Property damage	Total	Percentage
Clear	Head-on collision	2	51	64	117	21.9
	Rear-end ,,	5	44	102	151	28.2
	Right turn ,,	0	3	5	8	1.5
	Left turn ,,	0	4	5	9	1.7
	Overtaking	0	8	33	41	7.6
	Parked vehicle	0	2	17	19	3.6
	Pedestrians	24	98	0	122	22.8
	Fixed object	2	7	31	40	7.5
	Animals	5	9	0	14	2.6
	Others	1	5	8	14	2.6
	* Not stated	7	68	114	189	—
	Total	46	299	379	724	100.0
Raining	Head-on collision	0	4	8	12	24.5
	Rear-end ,,	0	3	7	10	20.4
	Right turn ,,	0	1	1	2	4.1
	Overtaking	0	3	4	7	14.3
	Parked vehicle	0	0	1	1	2.0
	Pedestrians	1	5	0	6	12.3
	Fixed object	0	0	9	9	18.4
	Animals	0	1	0	1	2.0
	Others	0	0	1	1	2.0
	* Not stated	0	7	9	16	—
	Total	1	24	40	65	100.0
Cloudy	Head-on collision	0	0	1	1	25.0
	Rear-end ,,	0	0	1	1	25.0
	Pedestrians	0	1	0	1	25.0
	Animals	0	1	0	1	25.0
	* Not stated	0	0	2	2	—
	Total	0	2	4	6	100.0
	Grand total	47	325	423	795	

Note:—1. In only 795 accidents out of 2,838, the weather conditions were known.
2. * While calculating the percentage, the column 'not stated' has not been taken into consideration.

TABLE 19

Accidents classified according to light conditions

Light condition	Type of collision	Accidents				Percentage of total accidents
		Fatal	Injury	Property damage	Total	
Day-Light	Head-on collision	4	46	66	116	21.8
	Rear-end ,,	7	40	102	149	28.0
	Right turn ,,	0	4	7	11	2.1
	Left turn ,,	0	3	6	9	1.7
	Overtaking	0	11	35	46	8.6
	Parked vehicle	0	3	16	19	3.6
	Pedestrians	24	108	0	132	24.8
	Fixed object	2	5	22	29	5.4
	Animals	4	5	0	9	1.7
	Others	1	3	8	12	2.3
	* Not stated	5	71	139	215	—
	Total	47	299	401	747	100.0
Dusk	Head-on collision	0	1	5	6	18.8
	Rear-end ,,	1	3	5	9	28.1
	Overtaking	0	1	2	3	9.4
	Pedestrians	2	6	0	8	25.0
	Fixed object	0	0	4	4	12.5
	Animals	0	1	0	1	3.1
	Others	0	0	1	1	3.1
	*Not stated	0	1	5	6	—
	Total	3	13	22	38	100.0
Dark with good street light	Head-on collision	0	6	12	18	17.0
	Rear-end ,,	0	14	16	30	28.3
	Left turn ,,	0	1	1	2	1.9
	Overtaking	0	1	7	8	7.5
	Parked vehicle	0	1	3	4	3.8
	Pedestrians	5	16	0	21	19.8
	Fixed object	0	3	14	17	16.1
	Animals	0	3	0	3	2.8
	Others	0	2	1	3	2.8
	*Not stated	3	15	28	46	—
	Total	8	62	82	152	100.0

TABLE 19 (*Contd.*)

Light condition	Type of collision	Accidents				Percentage of total accidents
		Fatal	Injury	Property damage	Total	
Dark with poor street light	Head-on collision	0	4	5	9	37.5
	Rear-end ,,	0	1	4	5	20.8
	Overtaking	0	1	0	1	4.2
	Parked vehicle	0	0	1	1	4.2
	Pedestrians	2	3	0	5	20.8
	Fixed object	0	1	1	2	8.3
	Animals	1	0	0	1	4.2
	*Not stated	0	3	8	11	—
	Total	3	13	19	35	100.0
Dark with no street light	Head-on collision	0	2	1	3	42.9
	Rear-end ,,	0	2	0	2	28.5
	Fixed object	0	0	1	1	14.3
	Animals	0	1	0	1	14.3
	*Not stated	0	3	4	7	—
	Total	0	8	6	14	100.0
	Grand total	61	395	530	986	

Note:—(1) In only 986 accidents out of 2,838, the details regarding light conditions were available.

(2) * While finding the percentage, the column 'not stated' has not been taken into consideration.

TABLE 20

Accidents classified according to traffic conditions

Traffic conditions	Type of collision	Accidents				Percentage of total accidents
		Fatal	Injury	Property damage	Total	
Dense traffic	Head-on collision	0	3	13	16	25.8
	Rear-end ,,	1	4	14	19	30.6
	Overtaking	0	3	6	9	14.5
	Parked vehicles	0	0	2	2	3.2
	Pedestrians	3	8	0	11	17.8
	Fixed object	0	1	0	1	1.6
	Animals	1	2	0	3	4.9
	Others	0	1	0	1	1.6
	* Not stated	1	12	25	38	—
	Total	6	34	60	100	100.0
Dense traffic controlled junction with manual operated signals	Head-on collision	0	1	12	13	24.5
	Rear-end ,,	1	1	17	19	35.8
	Right turn ,,	0	0	2	2	3.8
	Overtaking	0	2	7	9	17.0
	Pedestrians	0	6	0	6	11.3
	Fixed object	1	0	1	2	3.8
	Animals	1	0	0	1	1.9
	Others	0	0	1	1	1.9
	* Not stated	1	1	7	9	—
	Total	4	11	47	62	100.0
Dense traffic uncontrolled junction	Head-on collision	0	4	4	8	11.4
	Rear-end ,,	0	9	17	26	37.1
	Right turn ,,	0	1	1	2	2.9
	Overtaking	0	0	7	7	10.0
	Parked vehicles	0	1	3	4	5.7
	Pedestrians	0	11	2	13	18.6
	Fixed object	0	1	5	6	8.6
	Animals	0	3	0	3	4.3
	Others	0	0	1	1	1.4
	* Not stated	0	9	13	22	—
	Total	0	39	53	92	100.0

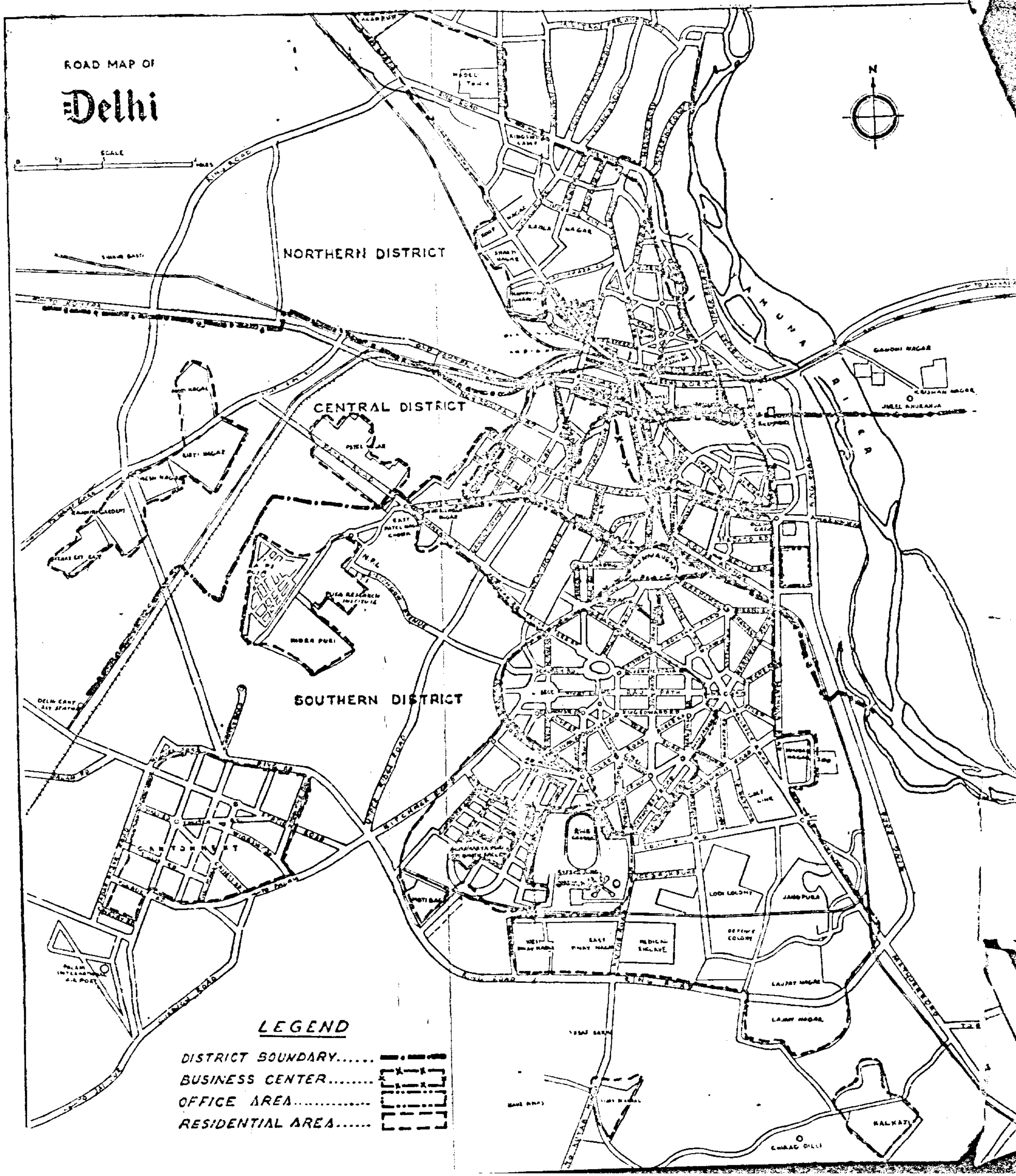
TABLE 20 (*Contd.*)

Traffic conditions	Type of collision	Accidents				Percentage of total accidents
		Fatal	Injury	Property damage	Total	
Moderate Traffic	Head-on collision	0	10	15	25	25.5
	Rear-end ,,	1	10	20	31	31.7
	Left turn ,,	0	0	1	1	1.0
	Overtaking	0	0	6	6	6.1
	Parked vehicles	0	2	1	3	3.1
	Pedestrians	5	15	0	20	20.4
	Fixed object	0	2	7	9	9.2
	Animals	0	1	0	1	1.0
	Others	0	0	2	2	2.0
	*Not stated	2	17	15	34	—
	Total	8	57	67	132	100.0
Moderate Traffic controlled junction with manual operated signals	Head-on collision	0	0	3	3	23.1
	Rear-end ,,	1	0	5	6	46.1
	Overtaking	0	0	2	2	15.4
	Pedestrians	1	0	0	1	7.7
	Fixed object	0	1	0	1	7.7
	*Not stated	1	3	3	7	—
	Total	3	4	13	20	100.0
Moderate Traffic uncontrolled junction	Head-on Collision	0	10	9	19	23.7
	Rear-end ,,	0	6	12	18	22.5
	Right turn ,,	0	1		12	2.5
	Left turn ,,	0	0	1	1	1.2
	Overtaking	0	4	5	9	11.4
	Parked vehicles	0	0	2	2	2.5
	Pedestrians	2	19	0	21	26.2
	Fixed object	0	1	5	6	7.5
	Others	0	2	0	2	2.5
	*Not stated	0	5	15	20	—
	Total	2	48	50	100	100.0

TABLE 20 (*Contd.*)

Traffic conditions	Type of collision	Accident: Fatal	Injury	Property damage	Total	Percentage of total accidents
Light traffic	Head-on collision	1	23	21	45	25.7
	Rear-end ,,	2	12	21	35	20.0
	Right turn ,,	0	1	2	3	1.7
	Left turn ,,	0	3	1	4	2.3
	Overtaking	0	2	10	12	6.9
	Parked vehicles	0	0	5	5	2.9
	Pedestrians	11	42	0	53	30.3
	Fixed object	0	2	11	13	7.4
	Animals	0	3	0	3	1.7
	Others	0	0	2	2	1.1
	*Not stated	0	18	37	55	—
	Total	14	106	110	230	100.0
Light traffic-controlled junction with manual operated signals	Head-on Collision	1	0	3	4	17.4
	Rear-end ,,	0	2	3	5	21.7
	Right turn ,,	0	0	1	1	4.4
	Left turn ,,	0	0	1	1	4.4
	Parked vehicles	0	0	1	1	4.4
	Pedestrians	0	2	0	2	8.7
	Fixed object	0	1	4	5	21.7
	Animals	0	1	0	1	4.3
	Others	0	0	3	3	13.0
	*Not stated	0	2	4	6	—
	Total	1	8	20	29	100.0
Light traffic-uncontrolled junction	Head-on collision	0	6	6	12	17.6
	Rear-end ,,	0	10	8	18	26.5
	Right turn ,,	0	1	0	1	1.5
	Left turn ,,	0	1	1	2	2.9
	Overtaking	0	2	0	2	2.9
	Parked vehicles	0	1	3	4	5.9
	Pedestrians	4	11	0	15	22.1
	Fixed object	1	0	8	9	13.2
	Animals	3	1	0	4	5.9
	Others	0	1	0	1	1.5
	*Not stated	3	10	16	29	—
	Total	11	44	42	97	100.0
Grand total		49	351	462	862	

Note :—(1) The terms dense, moderate and light traffic have been used by Police department as per observations made at accident spot.
(2) In only 862 accidents out of 2,838, the details pertaining to traffic conditions were known.
(3) While calculating the percentage, the column 'not stated' has not been taken into consideration.


ROAD MAP OF
Delhi
SCALE
MILES
NORTHERN DISTRICT
CENTRAL DISTRICT
SOUTHERN DISTRICT
YAMUNA RIVER
N
MODEL TOWN
KAMLA NAGAR
GANDHI NAGAR
PATEL NAGAR
EAST PATEL NAGAR CHOWK
MOTI NAGAR
KIRTI NAGAR
RAJENDRA NAGAR
PUSA RESEARCH INSTITUTE
INDRA PURI
N.P.L.
CANTONMENT
RAJ PATH
LODI COLONY
JANGPURA
DEFENCE COLONY
LAJPAT NAGAR
KALKAJI
CHIRAG DILLI
MEDICAL ENCLAVE
WEST VINAY NAGAR
EAST VINAY NAGAR
DELHI CANT RLY STATION
PALAM INTERNATIONAL AIR PORT
RING ROAD
MATHURA ROAD
LEGEND
DISTRICT BOUNDARY......
BUSINESS CENTER........
OFFICE AREA..............
RESIDENTIAL AREA......