Indian Road Congress I

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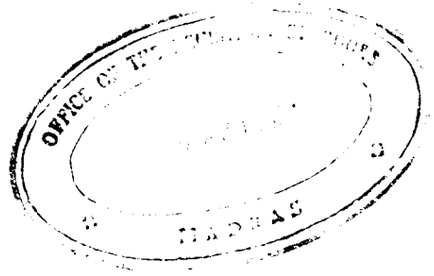

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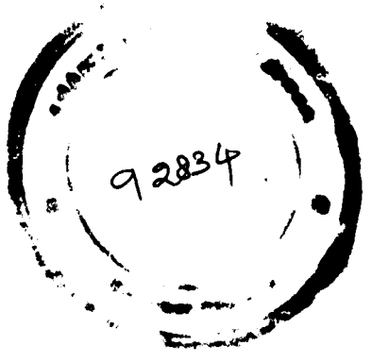


INDIAN ROADS CONGRESS

NOTICES AND ANNOUNCEMENTS

215

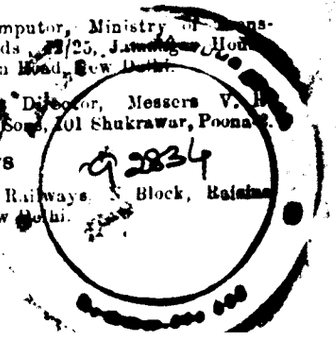
I. New Admissions

LIST OF THE MEMBERS OF THE INDIAN ROADS CONGRESS ENROLLED FROM 22-6-1950 to 27-11-1950.

Serial No.	*Roll No.*	*Name.*	*Address*
1377	1521	C. N. Shukla	Executive Engineer, Provincial Division, Jhansi. (Uttar Pradesh).
1378	1522	M. P. Apte	Resident Engineer, 1226/6 Deccan Gymkhana, Poona-4.
1379	[redacted]	B. Venkatachalam	Municipal Engineer, 20/152, Mulapet, Nellore, (Madras State).
1380	1524	Anand Singh Bishnoi	Assistant Engineer, (Bridges, Bridge & Planning Division, U.P., P.W.D. B & R Branch, Lucknow.
1381	1525	D. C. Chaturvedi	Assistant Engineer, Bridge & Planning Division, P. W. D., B & R Branch, Lucknow.
1382	1526	T. Satchidananda Rao	Assistant Engineer (Highways), Srungavarappukot, Visakhapattanam District.
1383	1527	M. L. Champhekar	Chief Engineer, P.W.D. Bombay, P.W.D. Secretariat, Bombay.
1384	1528	B. B. Patkar, (L.M.)	Deputy City Engineer, Bombay Municipality, Prakash Road. No. 3, Shivaji Park, Bombay-28.
1385	1529	L. Kuttalanathan	Supervisor, Coleroon Bridge Works Vallampadugai. (Madras State).
1386	1530	K Yoganarayana	Supervisor (Highways), 12, Mahalakshmi Street, T. Nagar, Madras-17.
1387	1531	Mohd. Abdul Ala	Assistant Engineer, P.W.D., T.R.S. Hyderabad Roads Division, Near Moazzamjahi Market, Hyderabad-Deccan.
1388	1532	Parmanand T. Sobra	Project Computor, Ministry of Transport (Roads [illegible]/25, Jantar Mantar Road, Shahjahan Road, New Delhi.
1389	1533	J. Y. Ranade	Engineer & Director, Messers V. [illegible] Ranade & Sons, 101 Shukrawar, Poona-2.

Associate Members

1	43	Central Standards Office for Railways	Ministry of Railways, N. Block, Rafsina Road, New Delhi.



II. Addresses Wanted

Communications addressed to the following members have been returned unclaimed by the Post Office. Members able to give information regarding the present address of any of those concerned are requested to forward particulars to the Secretary, Indian Roads Congress.

Serial No.	*Roll No.*	*Name of Member.*	*Last known address*
1	1371	Damodaram. A. M.	Municipal Engineer, Guntur. (Madras State).
2	125	Dasgupta, N.	C/o. Mr. K. R. Sen, Calcutta Insurance Co., Ltd., 90/8, Connaught, Circus, New Delhi.
3	652	Gurnaswamy, S. (L. M.)	No. 8, Apparawami Koil Street, P. O. Mylapore, Madras.
4	178	Kidar Nath	32, Kaonli Road, Dehra-Dun.
5	24	Korni, M. A.	114, Regent Estate, Tollygunj, Calcutta.
6	681	Krishnamurthy, B.	Assistant Engineer, Bridges, Gandhi Nagar, Bellary.
7	1219	Mehta, Vasant V.	Assistant Engineer, Amarnath Vishwanath Building, near Gutaiya Market-Tower, 113/109, Swarup Nagar, Kanpur. (Uttar Pradesh).
8	1128	Paul, J. D. Bayliss.	Professor, Engineering College, Jubbulpore (Madhya Pradesh).
9	720	Shaw, M. (L.M.)	Executive Engineer, C. P. W. D., Indore.
10	228	Simbaiya, N. Lakshminara.	Minister, P. W. D., Kotah State, Kotah.
11	1842	Sinha, L. U. C.	Student Engineer, C/o. Shriyut Jagdish Narainlal B.A., LL.B., Nayatola-Bhagalpur. (Bihar).
12	141	Sundaresan, T. V.	C/o, Pipe Line Superintendent, Pipe Line Installation, Saltpan Road, Siwri P.O., Bombay, 15.

Paper No. 153.

"Some Examples of Planning Surveys."

By

R. P. Chanda, B.E., A.M.I.E. (India)*

CONTENTS

SYNOPSIS

This Paper describes some planning surveys undertaken in West Benga for the purpose of :

(i) locating rural roads;

(ii) selecting a suitable alignment for a bye-pass for a heavily trafficked road serving the suburbs of Calcutta, and

(iii) improving traffic flow inside Calcutta.

The location survey is described as being mainly an economic survey and the Author recommends that instead of touching the individual important villages a road should pass through the "centres of gravity" of groups of mutually dependent villages.

In the second part of the Paper the Author raises the important question as to which traffic figure—very high but comparatively rare, or the not-so-high but much more frequent—should be used for designing a highway. He suggests that standard practice should be evolved for this purpose.

In the last part, the traffic surveys in Calcutta (in progress at the time of writing) are briefly described. Peak hour counts were being taken at most of the road junctions in and about the city and origins and destinations of traffic were being noted down, the object being to rationalise traffic flow in that congested city.

1. INTRODUCTION

1.1. In the State of West Bengal considerable preliminary investigations were carried out during the years between 1935 and 1938 under Mr. A. J. King, then Superintending Engineer in the Indian Service of Engineers. Existing road systems were methodically examined and extensive statistics and particulars relating to all factors having a bearing on the question of communications by roads were collected. The items thus investigated included the roads and bridges existing at the time, physical features, extent of flooding, drainage conditions, crops

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* Prepared under the guidance of Sri S. N. Chakravarti, Special Chief Engineer—Roads, West Bengal.

grown, "hats" (periodical markets) and "melas" (fairs), manufactures and industries, ferries, loads and types of traffic by means of census) and so on. Accurate skeleton road maps were prepared. Standard forms were devised to obtain systematic and classified information on the various matters detailed therein. A traffic census was taken at each of nearly 400 stations. Truly, Mr. King's voluminous published reports and the unpublished data collected by him can be regarded as an asset to the State. On the basis of these investigations, a comprehensive scheme for road development was formulated by him. Even the cost of individual projects were worked out approximately.

1.2. Since the publication of these voluminous reports, no further planning surveys have been undertaken here until recently. After the partition of the State, the Government started afresh to draw up their First Five-Year Plan to meet the requirements of this truncated State. Simultaneously actual work began, throughout the State, on projects which found place in Phase I of the plan. A separate executive organization was established in 1948 to handle the programme.

1.3. The principal trunk roads of the State and the main roads in the districts were fairly well-known or well-fixed and it seemed comparatively easy, at that initial stage of development, to plan and fix priorities. It is now apparent that, even at that stage, surveys would have been really helpful in fixing priorities, selecting the best locations and approving designs. As regards roads of lower categories, such as Other District Roads and Village Roads, not many were selected initially as it was felt that some sort of planning surveys would be necessary if the programme was to have a basis which could not easily be challenged. Demands for the inclusion of more roads in the programme started pouring in large numbers from the public soon after the advent of independence, whereas only a few of these road works could be taken in hand for execution at a time. Experience has now established the necessity of planning surveys beyond doubt. So far, some pilot surveys have been carried out here and these are expected to help in finalising the methods and details of procedure, so as to get reasonably accurate but quick results. The efforts made so far and the summaries of results obtained and recommendations are described in this Paper.

1.4. At the present stage, planning surveys are considered mainly under two heads viz., economic surveys and traffic surveys. Fiscal studies have not been undertaken yet.

1.5. Much has already been written about the basis and fundamentals of highway planning in the Indian Roads Congress Journal. No attempt will be made to repeat these. But here, it may be useful to note the objects of planning surveys as, without a proper understanding of these, it may not be possible to get the best results with limited funds. Planning surveys do not include engineering surveys as we understand them though making road inventories or determining inadequacies of existing roads require some technical knowledge. The purpose of planning surveys is briefly stated below :

(*1*) *Justification for developing or improving a highway between two given points, say A and B:* If sufficient data are available, it should be possible to rate projects according to "benefits to cost" ratio. Benefits may be calculated from the savings in distance and time, the grades and curves improved, increased safety etc. Another way of judging the necessity for improvements is the use of sufficiency rating methods. The least perfect sections should receive the first priority for inclusion in the programme.

(*2*) *Fixing layouts between A and B:* The problem of routing has to be properly considered apart from any requirements of engineering.

(*3*) *Design of road widths and layout:* These depend on the expected volume of traffic, on the speed permissible and on the proportion of slow and fast vehicles.

(*4*) *Pavement design*, depending on the expected axle loads and traffic volume.

1.6. It may be generally assumed that future developments will have to be foreseen from economic studies rather than from traffic statistics as, in undeveloped areas, much traffic is likely to be induced or generated following economic development. But traffic surveys may also act as a check on results apparent from economic studies.

2. AN EXAMPLE OF AN ECONOMIC SURVEY

2.1. A case arose in 1948, when the Dignagar 'Palli Kalyan Samiti' (Village Welfare Society) submitted a petition to the District Board as well as to the Works and Buildings Department, West Bengal to adopt a scheme for the improvement of the local existing kutcha roads, one of which was to go from Badkulla village to Nabadwip, via Dignagar (Plate I). After the partition of the State, it is claimed, the areas served by this alignment had become more important, because of large settlements of refugees.

2.2. In July 1949, after receiving a deputation of the Samiti members, the Government decided to undertake an economic survey to examine properly the needs of the area, around the location Badkulla-Dignagar-Depara-Bhaluka-Nabadwip (Plate I).

2.3. Information was collected by a survey party, headed by an assistant engineer, first in "Village Note-Books" and then tabulated in the specially devised form shown in Table 1. Most of the information was gathered from villagers and from the presidents of the various Union Boards, as very few useful records were available in the Union Board offices. The enquiry was fairly broad-based, and had usefulness also for purposes other than that of road planning. Summaries of the data collected are shown in Table 2. In spite of some possible errors and discrepancies, the survey gave a fairly detailed economic picture of the area.

2.4. The detailed surveys were conducted by a party consisting of an assistant engineer, two overseers and four surveyors. About 36 square miles were covered in this area which comprised 57 villages having a population of about 38,000. About 71 per cent of the area is agricultural, of which 60 per cent is under food crops. A considerable area has been brought under sugar farming and is managed by two firms, who operate four tractors for the purpose. At Badkulla, there are four brick fields, a husking mill and a saw-mill. There is a market every day at Bhaluka and twice a week at Badkulla. Of the 57 villages, eleven are situated by the side of a road, 15 are within a mile of a road, and 13 villages are more than three miles from any road. Thirty-one villages are more than three miles away from any market. Figures of professional bullock carts shown in Table 2 under "carts other" may indicate the commercial importance of a village.

2.5. There are many uses for the statistics collected: but for road planning, it would be most useful if it were possible to determine the relationship, if any, between population density, area under crops, number of bullock carts, and exports and imports. The values of these items have been shown graphically for each village (Plate II). No doubt the density of population influences the other features to some extent but because of the shifting of population for various reasons or the starting of industries (small or large), the relationship between population and other economic facts is bound to be altered from time to time. A village with a small population may have a larger number of carts than a more populous village in the neighbourhood. In such a case the surplus carts in the smaller village will be hired to serve the bigger village. When there is more area under agriculture around a village than is required to satisfy its own needs, there will be exports to deficit areas. Hence it would appear that, in a defined area, villages could be regarded as a group, each group being more or less self-sufficient in these matters. Instead of aligning the road to touch only the more populous villages it would seem more desirable that it should pass through the "centre of gravity" of the population centres in a group. In other words, it is suggested that villages which make up each others' deficiencies, should be grouped together on the basis of the survey data collected and that the proposed route should pass through the "centres of gravity" of such groups in respect of their population.

2.6. A map of the area surveyed was drawn (Plate I) on a scale of one inch to a mile and this was divided into squares, each one mile by one mile, for the purpose of showing visually the density of population, the extent of agricultural area, the exports and imports, and the number of carts for each square mile. From this map (Plate I) it is possible to choose a good location for the proposed road. The route recommended by the Samiti is marked A, B, C, D, E, F, G. It will be seen that this alignment covers all the important villages except those between E and F, where it should be differently routed to touch more villages. Incidentally, the existing kutcha road coincides with the proposed alignment between D and E again between F and G. Between D and E there is a trackway passing by E_2, whereas in this portion, the investigating officer has recommended the D, E, E_1 and F as a more desirable alignment. The other alternative E_2D also passes through a well populated area but E_1 is preferable because of the large export and import figures in square 19.

2.7. The best alignment from D to B will be DC_3B, as this will serve the squares with a higher population density in this area than those served by the alternatives C_1, C_2, and C_4.

2.8. It must be admitted, however, that the surveys have not really covered all areas which should have been considered in this connection. The important area lying between the river ghat near Nabadwip and Krishnanagar Municipality has not been so surveyed. There is an existing road connecting these two places, which brings large traffic from the surrounding areas on to the district headquarters at Krishnanagar. The improvement of this road, together with that of the feeder road from Bhaluka (square No. 6), may be a better proposition than developing a road between Nabadwip and Dignagar (square No. 17). It seems that a traffic census would have been helpful, but unfortunately this was not taken. Subsequently a census was taken on the entrance to Krishnanagar city on the Provincial Highway from Calcutta, in which "origins and destinations" were also noted. From this, a fair indication of the relative importance of the villages served by the Provincial Highway has been obtained. But simultaneous counts on the Nabadwip-Krishnanagar road and on important feeder roads should also have been taken. Only then would it have been possible to judge the relative merits of the alternative schemes which might have suggested themselves once

the analysis had been completed and the results placed together conveniently.

3. TRAFFIC CENSUS IN RURAL AREAS

3.1. In October 1949, it was decided that traffic census should be taken on some of the important highways in charge of the Works and Buildings Department, West Bengal. Though this undertaking was not meant to be a part of any systematic planning survey, it was considered that, at least for some important routes, the Government should have information on items like daily and hourly traffic variations, types of vehicle in use, principal commodities transported, origins and destinations of traffic, and so on. If similar observations are repeated in future years at the same places, the trends of growth of traffic on these arterial highways would be clearly seen.

3.2. Eleven stations were selected for the purpose. These are shown on the map in Fig. 1 and the census form used in Table 3. The census was taken continuously, day and night, for two weeks. The staff at each station, employed in three shifts, consisting of two to three men with a "work-sarkar-in-charge" (mate) in each shift. The cost was charged to the maintenance grants for the respective sections of the roads. A barrier was set up at each census point, with warning posts half a furlong away on either side, inscribed "Stop, Census Point Ahead." At the barrier, a sign board was put up saying "Kindly stop and give information required in the prescribed form. Thank you" both in English and Bengali. The co-operation of the local police was sought and obtained. Hardly any practical difficulty arose during the whole of this period.

3.3. During the actual surveys it was realised that the symbol "I" or "O" should be marked against each count, to indicate readily whether a vehicle was incoming or outgoing in relation to the nearest city or municipal area. It would be laborious to get such information from maps. It was also realised that in busy streets, a better arrangement would be to take counts on separate sheets for incoming and outgoing traffic. A line was drawn at the end of each hour for convenience of subsequent tabulation. Wherever possible hourly totals were drawn up by the field staff themselves. An improvement of the form would be that against each class of traffic Origin and Destination should be shown separately. This would reduce the quantity of forms used. As the proportion of slow and fast traffic has an important bearing on the design of a road, it would be better still if separate forms were printed, say in two parts, for slow and fast traffic. With these arrangements, subsequent tabulation and analysis would be

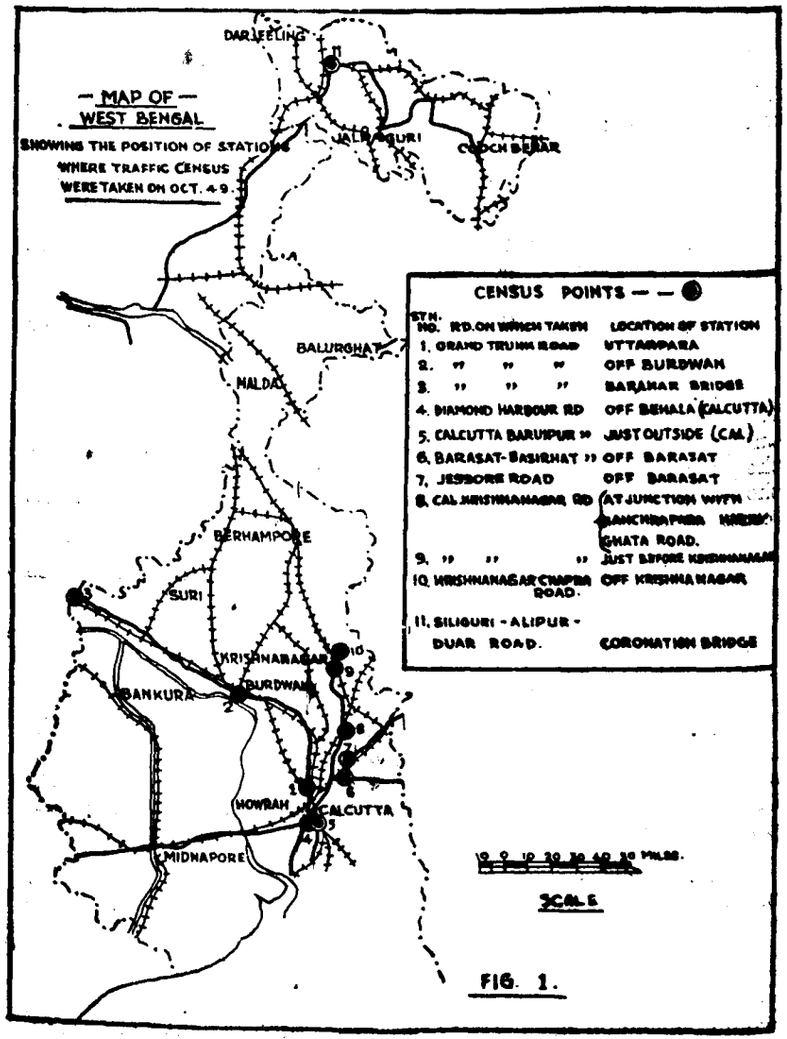


FIG. 1.

comparatively quicker. During the period of the census the officers of the Statistical Directorate, West Bengal, rendered valuable assistance with their advice and supervision.

3.4. On the completion of observations record forms were sent to the Statistical Directorate for analysis. For only one station viz., that at Uttarapara on the Grand Trunk Road (National Highway No. 2) near Calcutta, the following features were tabulated:

(a) Average and total number of vehicles passing in a particular hour, by classes (carts and motor vehicles).

(b) Average and total number of motor vehicles by hours and by commodities.

(c) Average and total number of carts by hours and by commodities.

3.5. Graphs were prepared showing daily and hourly variations for different categories and classes. Such detailed analyses would make available a wide field for study. But for the purpose of road design and planning, it was decided to reduce the analyses for the other stations to the following characteristics (omitting all references to categories):

(a) Average number of vehicles passing per hour for each day during the whole period;

(b) Total number of vehicles passed, by days;

(c) Peak traffic for each hour, during the whole period.

3.6. A set of graphs for one station can be seen in Plate III. A final summary of the statistics collected for all stations is shown in Table 4. A further breakdown showing the proportion of fast slow traffic would have been useful but has not been prepared so far.

3.7. Besides giving information regarding present-day traffic, this table would be useful for various other studies. During the census fortnight the daily traffic volume varied by as much as 100 per cent and the peak hourly traffic by as much as 300 per cent. This would indicate that the selection of the time of the year for taking observations is an important matter. This timing would depend on the object of the census which might be to obtain figures of the highest volume of traffic that might occur only once in a year and last for two or three days, or to get figures for occasional heavy traffic, smaller than the annual maximum figure but occurring more frequently, say once or twice every month.

For which of these figures—the high but rare figure or the somewhat smaller but much more frequent figure—should a higway be designed? The Author is of the opinion that the latter would provide a better basis for design and suggests that a standard practice should be evolved for this purpose.

3.8. Traffic figures can be used to decide when the full capacity of the road has been reached and congestion conditions prevail, justifying further improvements. The traffic capacity of a single lane highway has to be determined first, with the assumption that earth shoulders are available to allow crossing or overtaking. To cross or overtake a bullock cart travelling at 3 miles per hour we may assume that the car has to slow down to 15 miles per hour where shoulders are formed of clay only. In such an event, it may take about half a minute for the car to overtake and come back on to the centre of the road in a distance of about 650 feet. Allowing for a minimum sight distance of 300 ft, about 250 motor vehicles could pass a bullock cart in an hour. The capacity of the road would be much reduced if bullock carts were also met coming from the opposite direction. On this basis a volume ranging between 200 to 250 vehicles an hour could be regarded as fair traffic on a single-lane highway. Beyond this volume, two lanes with adeqate shoulders would be indicated. By this standard, at all the places where the census was taken the road width was found to be adequate. But in the case of the Grand Trunk Road at Uttarapara, with a volume of nearly 150 vehicles an hour travelling within a width of 20 feet congestion conditions definitely existed. Besides, this width was not sufficient for two heavy-type trucks passing or meeting each other. This is so because both sides of the road are fully built up and a part of the roadway is most of the time occupied by pedestrians, cyclists, cycle rickshaws, etc., and the full 20-ft width is not available for vehicular traffic. Widening of the road at Uttarapara would appear to be an immediate necessity.

3.9. The analysis of origins and destinations was found to be very laborious, as many places declared by vehicle drivers as the origins or destinations of their journeys were obscure villages, not easily detected on maps. All localities around an important village or market were therefore grouped together, for the purpose of tabulation. It is intended to draw maps showing diagrammatically the traffic volume of different locations. Such a map showing travel lines as observed at three stations on the Grand Trunk Road is reproduced in Plate IV. It will be seen that traffic originating from or going to Calcutta falls off considerably beyond Chandernagore. The road up to this place passes through heavily built-up areas and is perpetually congested on account of through and local traffic. The Author would go so far as to say that this section of the road abounds with death-traps

The Government of India have actually taken a decision to bye-pass the whole area by selecting altogether a different route from Howrah joining the existing road at Memari. Land acquisition for this new alignment of the National Highway has been completed and works would start as soon as funds are made available. But the traffic diagrams tend to demonstrate that the proposed construction will not solve most of the problems in this stretch unless link roads are built to the bye-pass road.

3.10. It may be worthwhile to discuss this specific matter here in a little more detail. It seems that the new route will take off only that part of the traffic which goes "through." Benefit will accrue to long range traffic only, whereas the congestion arising from local traffic will remain. On the other hand, the diagram itself suggests better solutions as alternatives. For example, if a new road is taken across the river Hooghly from near Chandernagore, not only will a greater volume of traffic be diverted to this crossing but the bottlenecks existing near the approaches to the Howrah bridge will also be removed. The Howrah Bridge is so congested even at present that a new bridge at a fair distance above will be of real service. On the east bank of the Hooghly there would have to be a wide arterial route going on to Calcutta via Barrackpore. The important item to consider in this connection will be the cost of the new bridge. Another solution suggested is to bring the diversion road much nearer to the Grand Trunk Road and to provide a sufficient number of short links between the Grand Trunk Road and the proposed bye-pass. This suggested alignment should pass along the outskirts of the industrial areas concerned. This new diversion need not have to start from as far off as Memari; Hooghly might be a better point for taking off. However, any further detailed discussion of this alternative would appear to be beyond the scope of the present Paper. But it is interesting to note that these considerations have been suggested by the Traffic diagram. This diagram also confirms a general assumption in planning viz., that road traffic is mostly short-ranged and it is not enough to take care only of long-range through traffic. Circumferential routes are the best solution for clearing congestion around industrial areas.

3.11. Assuming that similar observations will be taken in the future years also, such repeated surveys will yield information on the following matters :

(i) The trend of traffic growth by volume, by types of vehicle and by destinations;

(ii) Whether at present, or at any future date, the capacity of existing roadway is adequate to take the volume of traffic rolling over it ;

(iii) Suitability of pavement design in relation to traffic volume or weights ;

(iv) Relative importance of various feeder roads as can be judged from "origin and destination" surveys.

3.12. In the case of the main highways, which are already fairly well developed and are important charges for this Department the information as suggested above should be of incalculable value. A fortnight's observation every year at a few chosen points will enable the Department to feel the pulse, as it were, of the State's transportation facilities.

4. TRAFFIC STUDIES IN URBAN AREAS

4.1. Recently the State Government have appointed a Committee to study the transportation problems in and around the city of Calcutta and to suggest remedial measures. The terms of reference of this Committee contain, among others, the following items:—

(i) To undertake thorough investigations on the congestion of traffic at the outlets and inlets of the city and on points within the city itself as regards nature, intensity, and duration.

(ii) To draw up proposals for relieving congestion at all points, where this actually exists and in a manner commensurate with hardships involved.

(iii) To draw up a road plan for better traffic movements in and around Calcutta.

(iv) To work out the rough costs of suggested projects and to determine priorities.

4.2. It is common knowledge that numerous bottlenecks exist in and around the city at present. Unless something can be done, it is apprehended that the future growth of traffic will almost certainly be strangulated in greater Calcutta's inadequate road system. Also, unless better facilities of transport are made available, the prospects of establishing satellite towns, some distance away from Calcutta, are poor. As a first step, traffic censuses are being taken at selected points along the main arterial routes. Traffic census forms, devised separately for internal and external stations, are shown in Tables 5 and 6. For internal surveys no attempt is being made to interfere with the flow of traffic in order to make enquiries regarding origins and destinations. But such information will be collected at external stations, in order to assess the

volume of traffic bound for different parts of the city as well as for zones beyond it. Such information would be helpful in proving the necessity, as well as in deciding the best location, of any bye-pass route which might be proposed.

4.3. The traffic census now in progress is being taken for each station only during the daily peak periods, lasting from six to eight hours. A notable feature of these surveys is that records are kept of the durations of traffic blocks caused by traffic signals and the number of motor vehicles detained. For important crossings in the city counts are being taken simultaneously on all the connected roads. Hourly totals are being abstracted and the peak figures are noted in data sheets (Table 7) along with other useful particulars for the road. These sheets together with a variety of traffic plans are expected to show up clearly locations and degrees of congestion existing and whether some new facilities are really necessary. For one important intersection abstracts of hourly traffic volume and a plan of flow may be seen in Fig. 2 and Table 5.

4.4. Other surveys proposed include pedestrian crossings at important places, accident records, registration of vehicles, etc. Also it is desired to make a series of observations of time taken to travel to different points outside the city from a focal point in the business district. This investigation will take the form of trial runs along important routes to determine the time required to traverse different sections of these routes. Such data may help in ascertaining the average duration of traffic blocks at different junctions due to congestion and traffic regulations. A time-contour map with regard to this focal point might be prepared.

4.5. These investigations are now in progress and it may take three to four months more to complete the collection of data and to analyse these fully. Besides this, investigations are also in progress with regard to the development works or improvements actually in progress or with regard to projects recommended by the various authorities interested in the matter. The authorities who are so concerned are the Irrigation & Waterways Department, the Works and Buildings Department, the Calcutta Corporation, the Calcutta Improvement Trust, the Port Authorities, the East Indian Railway, the Bengal Nagpur Railway, the Director General Transportation, the Calcutta Police, various municipal authorities surrounding Calcutta, and the Calcutta Tramways. Each of these organizations may have its own schemes and ideas. These have to be collected together and examined to find out whether such diverse schemes are adequate and suitable in consideration of the future traffic requirements of Calcutta and whether suggested priorities are acceptable to the authorities concerned.

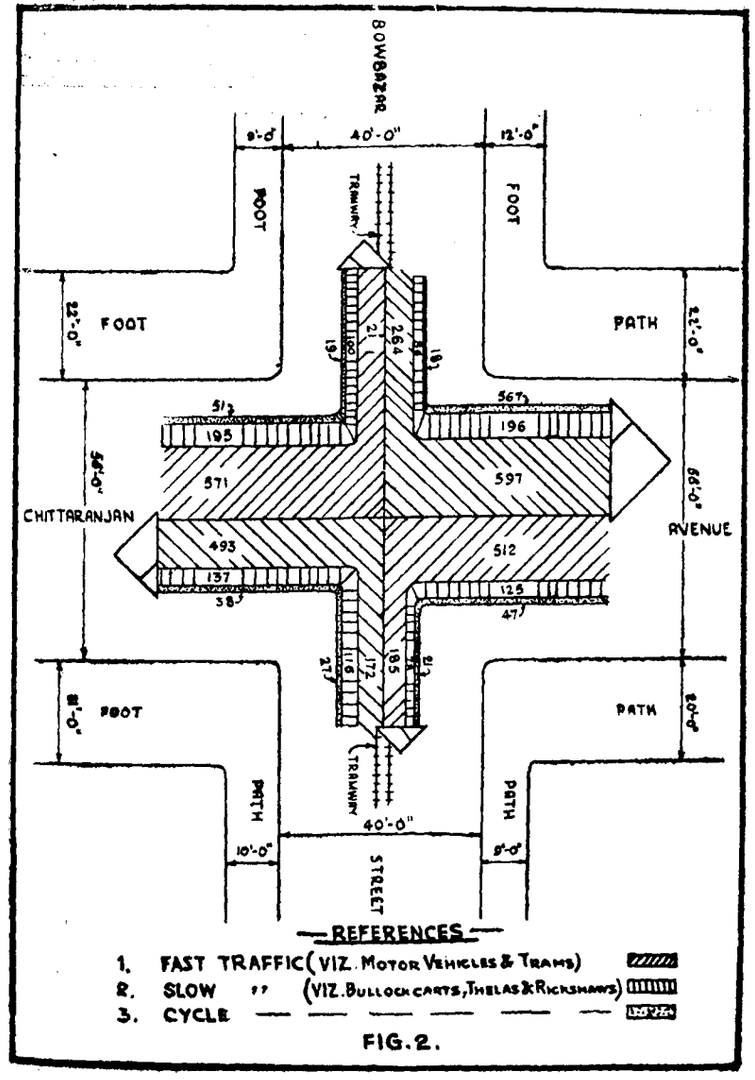


FIG. 2.

4.6. Suggestions from members of the Indian Roads Congress are invited with regard to procedure, forms to be adopted, the approach to the problems, etc. It is hoped that these brief notes will be helpful in designing similar studies elsewhere. Traffic problems are certain to become more urgent and increasingly difficult to solve with the expected growth of traffic in the near future, specially in and around big cities.

Table 1

Proforma used for Economic Surveys

3			5	
Population			Agricu ilies engaged dustries	
	Minors	Total	For paddy & other eaving food grains	Other
ıle	Male / Female			

	7		
ıches and cars		Distance from nearest metalled or un-metalled road	rt Dis fı ne ma Other agricultural and miscellaneous articles
Total no. of working bulls	Agricultural carts / Professional carts		

2	13			17
ıulars eriodical ts and nd the e no. of oing & per day	Passenger Traffic			REMARKS:
	Average traffic per day from and to (Badkulla)	Average traffic to and from (Rly. Stn.)	Average traffic to and fro (Krishna-nagar)	

Table 2—*(contd.)*

ral er	Total agricultural area	Carts			Working bulls
		Agricultural	Other	Total	
0	725	40	20	60	200
0	480	4	6	10	60
5	526	30	10	40	160
0	610	10	5	15	70
0	915	25	10	35	140
0	210	12	8	20	80
0	615	30	12	42	122
0	710	30	20	50	200
0	1010	40	24	64	192
0	805	29	22	51	152
0	612	31	18	49	150
0	2700	124	140	264	1188
0	50	—	—	—	8
0	525	31	21	52	204
7	487	31	10	41	164
0	410	17	15	32	98
3	11330	484	341	825	3208
0	2375	120	30	150	500
0	4300	75	25	100	600
0	1450	22	8	30	200
5	1000	—	—	—	140
0	480	17	3	20	70
0	7500	180	20	200	970
0	800	50	10	60	125
0	460	—	—	—	70
0	1300	30	10	40	220
0	280	10	—	10	45
0	2500	65	10	75	350
0	750	25	5	30	110
0	1200	35	5	40	175
0	1650	35	5	40	230
0	400	15	—	15	70
0	800	8	2	10	100
0	800	20	5	25	120
0	800	35	10	45	117
5	28845	742	148	890	4212

127

Table 4

ds in Comparison with Available Highway Facilities (October 1949).

nents	Total Daily Counts for 15 days			Total Hourly Counts		Special Remarks
	Maximum observed	Average of 15 days	Minimum observed	Peak hour volume total	Maximum, on average of 15 days	
	5	6	7	8	9	10
maca-	1,860	1,675	1,370	147	116	Capacity is limited as road passes through a built-up, congested area. Road is the centre of marketting and commercial activities (URBAN TRAFFIC). This is a Bottle-neck.
	567	450	298	62	33	Beyond Municipal Area.
	649	512	366	123	55	On the Barakar Bridge Approach.
with and facing	170	133	93	24	13	This road is being developed as a main Highway connecting Calcutta with N. Bengal. A large increase in traffic is expected in future.
; with and facing	134	100	670	21	8	This is part of a long border road, now under development. A large number of refugees are being re-habilitated here. On completion, much more traffic may be generated.
e over	650	472	358	86	40	Much increase in traffic volume is expected—This road links up Assam with the rest of India (HILL SECTION).
over se	1,921	1,574	1,353	160	117	There is a fair volume of night traffic. There are tramway tracks (URBAN TRAFFIC).
cadam urface	327	260	197	34	20	Narrow Gauge Railway Line running alongside —on the same embankment. This tends to restrict traffic and make drainage of the road most difficult. Maintenance is difficult and expensive.
on an cadam	274	225	169	36	17	
treat- and 6" bound)	217	149	73	34	10	
metal k over base	2,065	1,758	1,624	196	137	URBAN TRAFFIC—This is NE outlet of the city of Calcutta. The level crossing is a bottle-neck here. Large colonies of refugees are being established and traffic is growing.

Table 7

DATA SHEET for Street Traffic.

1.	Name of the Street	Chittarajan Avenue (Northern portion)
2.	Name of nearest Junction	Chittarajan Avenue & Bowbazar Street
3.	Census Sub-stations Nos. (Up and Down Traffic)	D/a & D/b
4.	Road Section (average)	
	(i) Carriageway width (total)	56′ 0″ Ft. (surfaced).
	(ii) Footpaths (with conditions i.e., whether paved/partly paved/unpaved)	22′ 0″ Ft. (on Upside). 20′ 0″ (on Down side). Partly paved Partly paved.
5.	Any special feature causing obstruction.—	
	(i) to vehicular traffic	Very often it has been observed that vehicles park on either side at the carriageway causing obstructions to traffic.
	(ii) to pedestrian traffic	Nil
6.	(i) Tramway routes using this road	Nil
	(ii) Bus routes using this road	32 Esplanade–Dakshineswar, 32A Baranagar–Esplanade, 13 Bengal Chemical-Dalhousie Sq., 14 Ultadanga-Esplanade, 2C Shambazar-Kalighat.
7.	Period under consideration (excluding cycle traffic from census).	15 to 16 hours.
8.	Traffic at the peak hours :	
	(i) Passenger vehicles	489 in Up 419 in Down
	(ii) Buses & trucks	100 ,, 82 ,,
	(iii) Total fast moving vehicles	597 ,, 512 ,,
	(iv) Total slow moving vehicles (excluding cycle traffic)	196 ,, 125 ,,
	(v) Cycle traffic	56 ,, 47 ,,

(vi) Total Blocks (in minutes)	17 m. 30 sec
(vii) Total no. of vehicles (Fast moving only) held up in these blocks	175
(viii) Average duration of road-blocks	28·37 Sec.
(ix) Principal causes of these road-blocks	Traffic Signal.

9. Characteristic of traffic in this peak hour :

(i) Percentage of Trucks to total Fast moving vehicles	12·40 per cent 9·97 per cent	in Up in Down
(ii) Percentage of Trams to total Fast moving vehicles	nil in Up	nil in Down
(iii) Percentage of Bullock-carts to total vehicles (excluding cycles).	0·25 per cent 0·31 per cent	in Up in Down

10. Whether volume of Pedestrians crossing the Road is remarkably high. If so what is the volume at peak Period — High between 9 & 11 hours and 17 & 18 hours.

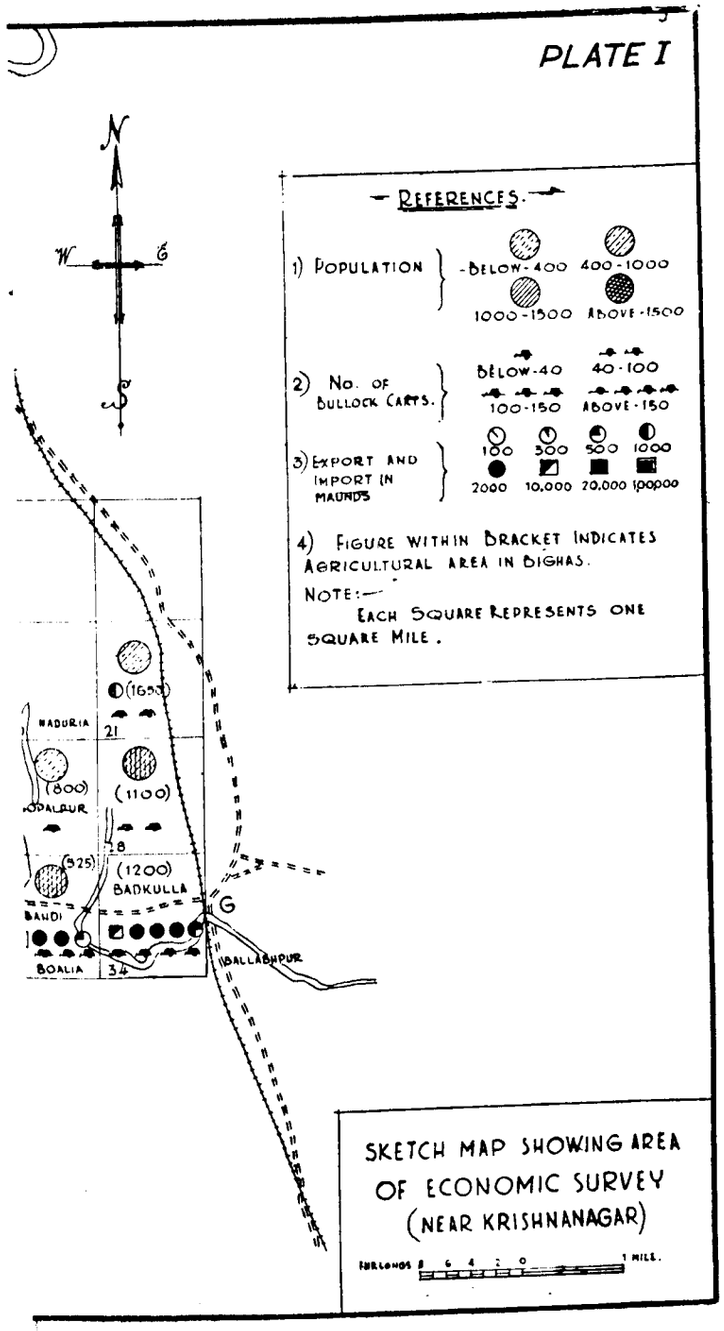
11. Any special feature of traffic such as one way route for Bus or Trams. — Nil

—do— for all vehicles

(Mention the duration)

12. Remarks .....

.....



ET 3.

PLATE II

"URAL AREA,
"ION, EXPORT
VILLAGES.
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a.

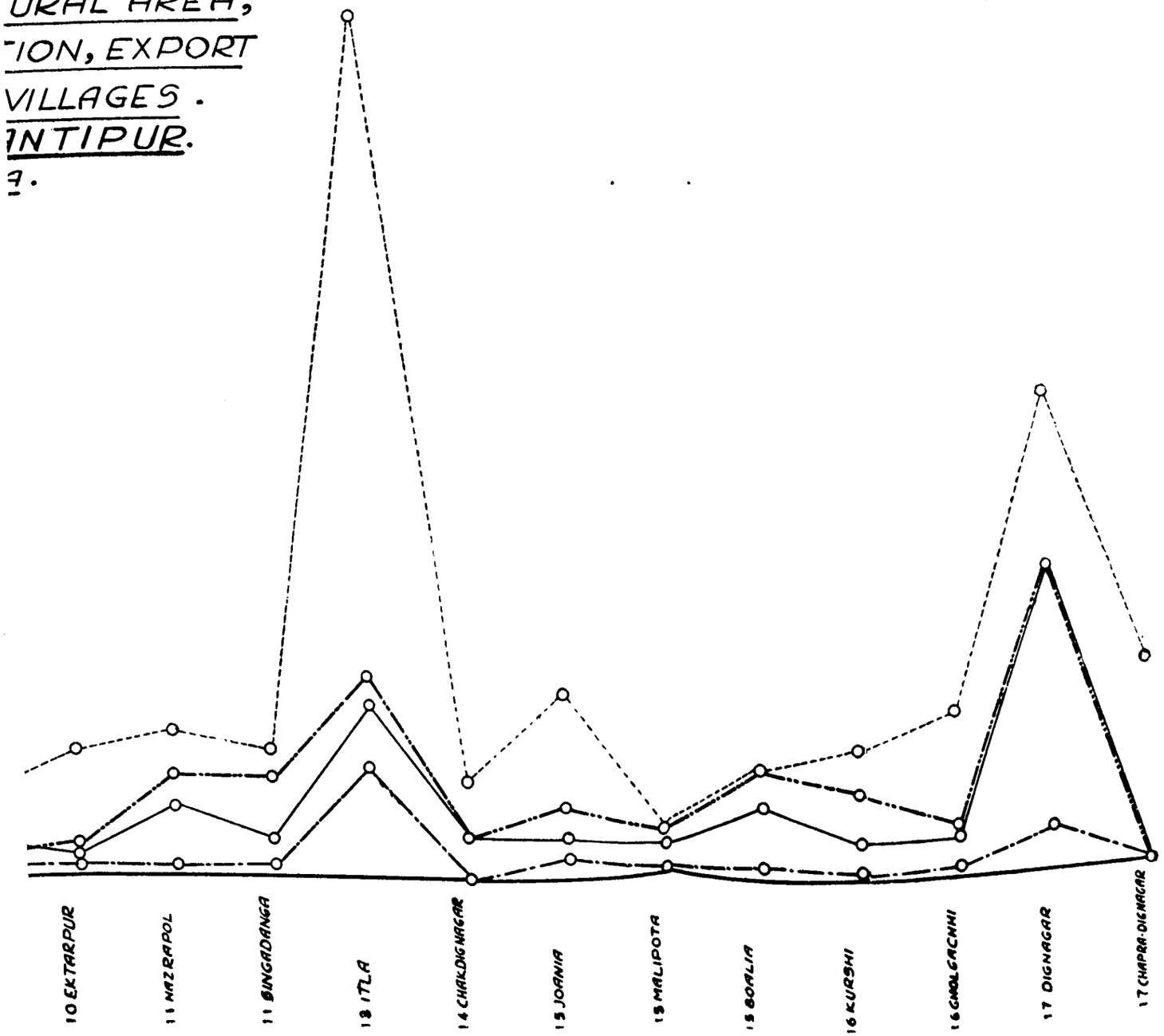

PLATE III

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ND BEHALA
AD.)

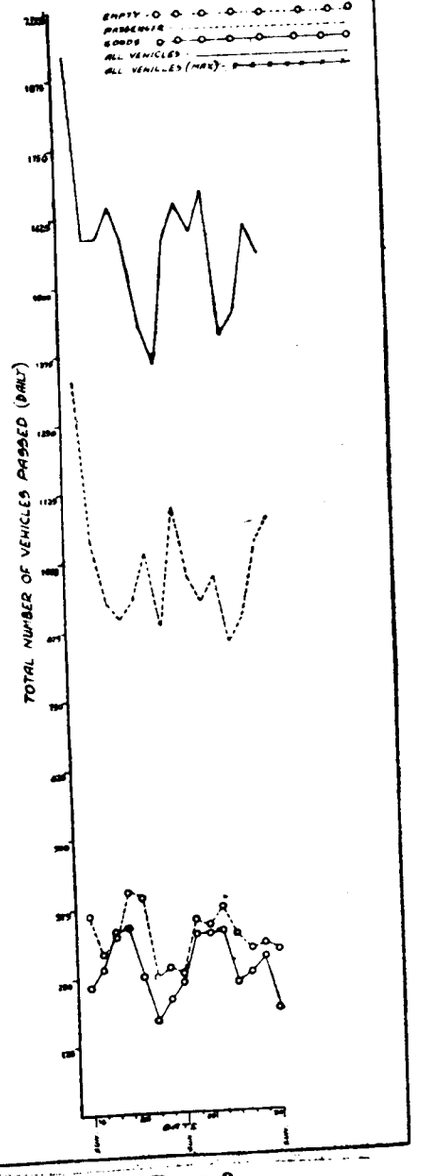
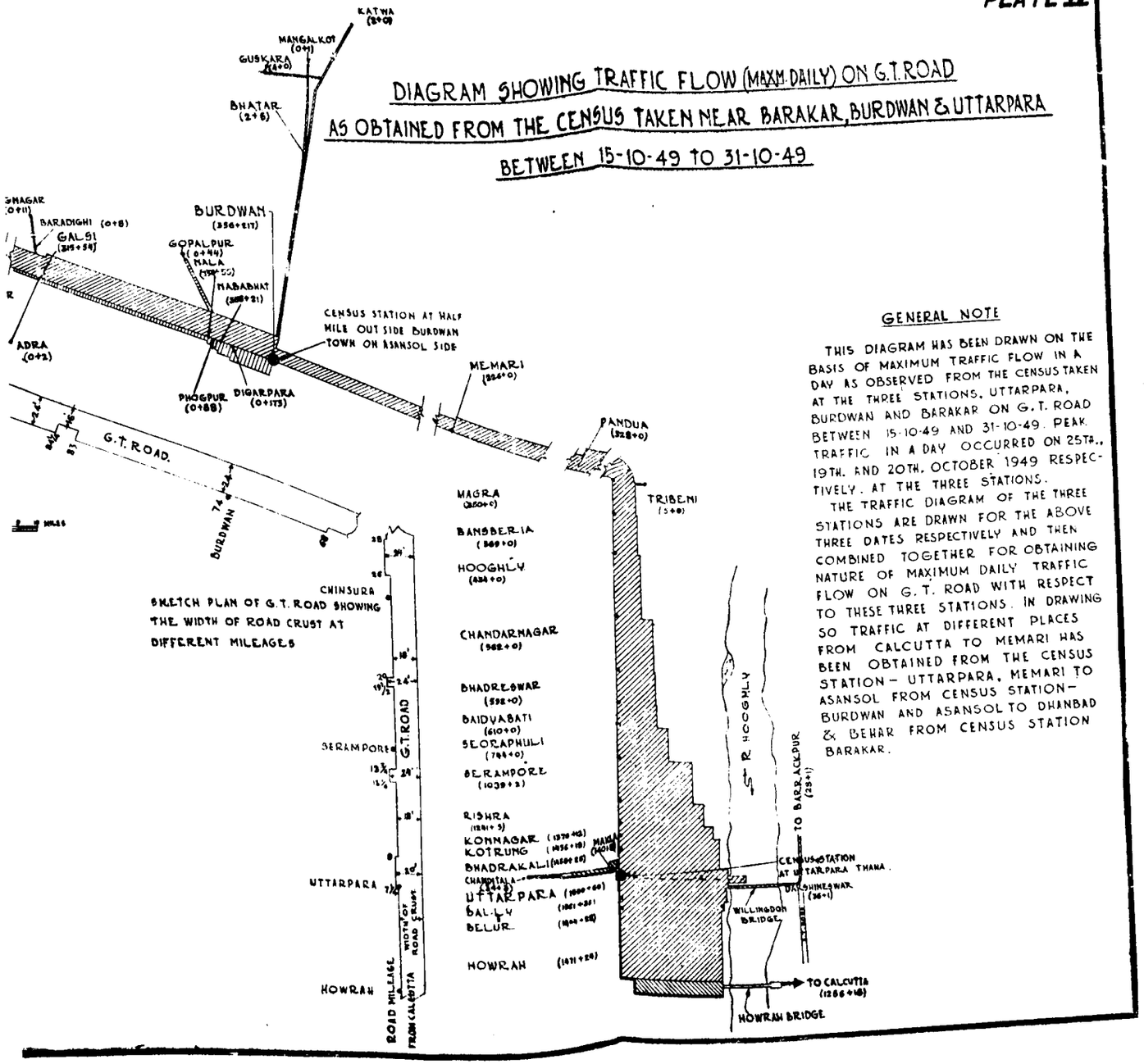


PLATE II

DIAGRAM SHOWING TRAFFIC FLOW (MAXM. DAILY) ON G.T. ROAD AS OBTAINED FROM THE CENSUS TAKEN NEAR BARAKAR, BURDWAN & UTTARPARA BETWEEN 15-10-49 TO 31-10-49



GENERAL NOTE

THIS DIAGRAM HAS BEEN DRAWN ON THE BASIS OF MAXIMUM TRAFFIC FLOW IN A DAY AS OBSERVED FROM THE CENSUS TAKEN AT THE THREE STATIONS, UTTARPARA, BURDWAN AND BARAKAR ON G.T. ROAD BETWEEN 15-10-49 AND 31-10-49. PEAK TRAFFIC IN A DAY OCCURRED ON 25TH., 19TH. AND 20TH. OCTOBER 1949 RESPECTIVELY. AT THE THREE STATIONS.

THE TRAFFIC DIAGRAM OF THE THREE STATIONS ARE DRAWN FOR THE ABOVE THREE DATES RESPECTIVELY AND THEN COMBINED TOGETHER FOR OBTAINING NATURE OF MAXIMUM DAILY TRAFFIC FLOW ON G.T. ROAD WITH RESPECT TO THESE THREE STATIONS. IN DRAWING SO TRAFFIC AT DIFFERENT PLACES FROM CALCUTTA TO MEMARI HAS BEEN OBTAINED FROM THE CENSUS STATION – UTTARPARA, MEMARI TO ASANSOL FROM CENSUS STATION – BURDWAN AND ASANSOL TO DHANBAD & BEHAR FROM CENSUS STATION BARAKAR.

Paper No. 154.

"Behaviour of Brick Metal in Tar Carpets."

By

K. C. De, B.Sc.

CONTENTS

SYNOPSIS.

The behaviour of brick metal in tar carpets is, it is suggested, an important matter for investigation in places where stone metal is scarce or comparatively costly.

The load bearing capacity of the untreated brick metal examined, as described in this Paper, was found to vary with the degree of burning from about 0·87 ton per square in. in the case of "2nd class" bricks to about 1·13 tons per square in. when the bricks were over burnt. The same categories of brick metal when soaked in High Viscosity Road Tar gained in strength and attained a more or less uniform load bearing capacity of about 1·3 tons per square inch. The soaking had a toughening effect also on the brick metal.

When the brick metal treated in the above described manner was enclosed in a cushioning bed of tar-mixed sand, its load bearing capacity was further increased by as much as 200 per cent.

In actual field tests, the tar treated brick metal laid in a tar-mixed sand bed was in no way inferior to a similar carpet containing stone metal.

1. INTRODUCTION

1.1. Stone metal is very costly in localities where it does not occur in nature and has to be brought from great distances by rail, road, or boat. As a result the milage of road that can be improved in such localities is proportionately small. Many ambitious schemes for road improvement have, therefore, had to be dropped as the available funds were generally limited.

1.2. On the other hand, if some material available locally could be used in place of stone and could be brought to site at minimum transport costs, and at the same time if it gave satisfactory results, a far greater mileage of good roads could be built with the funds available.

1.3. One such substitute for metal is broken burnt brick or broken "jhama" (over burnt brick). These can be burnt at the site nearly everywhere in Bengal. Even if that is not possible, these materials are almost always available within a short distance from the road site.

1.4. On account of its low cost, brick metal has been extensively used in Bengal and North Bihar in the soling and in the wearing course of water bound macadam roads which do not carry very heavy traffic. The reason for preferring brick metal is entirely a matter of economics as stone metal has to be brought to these areas from far off places. It has also been found that, if a bituminous wearing coat is provided with stone grit, waterbound macadam roads of broken brick or brick jhama are able to carry quite heavy traffic.

1.5. It had been frequently observed that, as a result of painting the surface of a brick metal waterbound macadam road with road tar, the attrition and crushing of the metal under steel-tyred traffic had been considerably reduced. It was assumed, therefore, that the absorption of road tar by the brick metal had toughened it. It was further assumed that, if such metal were placed in an elastic or a cushioning bed, it would be able to carry fairly heavy traffic although it did not follow that the metal would prove to be as hard as stone metal.

1.6. Before going into the question of how toughening could be achieved, it would not be out of place to mention that, when speaking of brick metal, it is generally assumed that at least 70 to 80 per cent of it would consist of over-burnt or vitrified material. In practice, however, this is not always so. The bulk of the supply consists of under-burnt or insufficiently burnt bricks. It is, therefore, obvious that it is almost impossible to get good results from the use of a material of such variable and unknown quality. If one were to insist that the metal should contain vitrified material only, it would be impossible to obtain large quantities to this standard and the price would be comparatively very high.

1.7. In burning bricks, even with all possible care and attention, one cannot normally expect to obtain uniform quality under local conditions. Even if uniform in appearance, all the bricks will not be of the same strength. If a certain percentage of

alkaline sodium salt (soda ash) is incorporated in the soil and coal used in excess of the usual quantity, a large percentage of over-burnt vitrified bricks may result but, here again, the quality of such bricks may not be uniform. Even in the same brick, a portion may be well vitrified and the rest less vitrified and porous.

2. INCREASING THE LOAD BEARING CAPACITY OF BRICK METAL BY SOAKING IN TAR.

2.1. The degree of toughness or hardness of a brick increases with burning and an under-burnt brick is much softer than a properly burnt brick. Therefore, a process or method would have to be found so that a road built of brick metal consisting of pieces that had been subjected to widely varying degrees of burning, i.e., from vitrified to under-burnt pieces, should have a more or less uniform load carrying capacity throughout.

2.2. It was suggested that this could be achieved if the softer pieces of the metal were toughened by soaking them in road tar. Road tar with its great penetrating power can soak deep into the pores of bricks from which all moisture has been excluded by drying and thus toughen them. The undernoted experiments were carried out in the laboratories of M/s. Bengal Chemical & Pharmaceutical Works Ltd., Calcutta, to find the extent of penetration of road tar into and the consequent increase in strength of ordinary bricks.

2.3. Bricks were classified for the purpose of the test as under. This classification is intended to categorise bricks by their degree of burning so as to give some indication of their load bearing capacity :

Table I

	Description	Classification
1.	Vitrified or overburnt Bricks	Jhama Brick
2.	Well-burnt Bricks	1st Class Brick
3.	Fairly well-burnt Bricks	2nd Class Brick
4.	Under-burnt Bricks	3rd Class Brick
5.	Insufficiently burnt Bricks	4th Class Brick

The last two categories are commonly known as "ama" or "pilla" bricks.

2.4. Bricks for the tests were selected according to the above given classification. Pieces of size 5 in. by 3 in. by 3 in. cut from each class of brick were heated in an air oven to drive out

moisture from their pores and then immediatly transferred to a trough containing High Viscosity Road Tar (H.V.R.T.) heated to 260 degree F and were soaked there for an hour. After that the brick pieces were taken out and allowed to cool to room temperature and thereafter all excess tar was removed from their surfaces.

2.5. Each piece of brick soaked in the tar was then cut into two pieces longitudinally at right angles to the 5 inch by 3 inch face and the depth to which the tar had penetrated from the surface was measured with a scale and recorded as under. (Also see graph in Fig. 1).

Table 2.

Class of brick (vide Table 1)	Size of piece	Depth of penetration of Road Tar into the bricks (inches)	Percentage of penetration of Road Tar into the bricks.
Jhama (overburnt)	5″ × 3″ × 3″	1 8	10 % approx.
1st Class Brick	,, ,,	3/4	50 %
2nd Class Brick	,, ,,	$1\frac{3}{16}$	80 %
3rd Class Brick	,, ,,	1/2	33 %
4th Class Brick	,, ,,	1/8	10 %

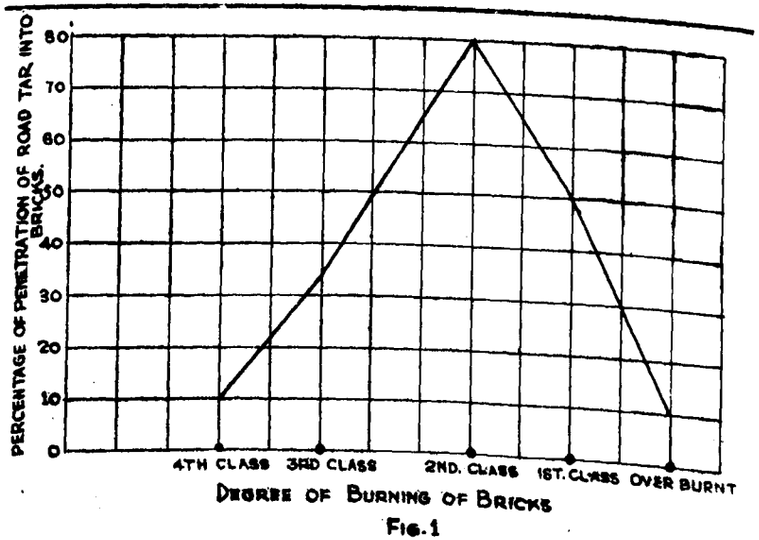


FIG. 1

2.6. It may be seen from the above that up to a limit the less the degree of burning of the brick the more the tar it can soak, the maximum soaking being 80 per cent in the case of second class bricks and the minimum i.e., 10 per cent in the case of both " jhama " and the fourth class bricks.

2.7. An experiment, as described below, was also conducted to find the percentage absorption by weight by different categories of bricks.

2.7.1. Samples of size 2 in. by 1 in. by 1 in. were prepared from the three classes of bricks, dried in an air-oven to drive out the moisture from the pores of the samples, and then cooled to room temperature in a desiccater and weighed.

2.7.2. The weighed pieces were then soaked in tar (H.V.R.T.) heated to a temperature of 260 degree F. The samples were examined at intervals to find the amount of soakage. After $2\frac{1}{2}$ hours it was observed that the maximum soakage of the tar had taken place. The samples were kept in the tar for another half an hour and then removed and allowed to cool. After removing the excess of tar from the surface of the samples by scraping with a hot spatula, the samples were weighed and the weight of the tar absorbed by the samples found.

2.7.3. The results are tabulated as under :

Table 3.

Size of piece.	Class of brick.	Weight before treatment.	Weight after treatment.	Difference.	Percentage of Tar soaked.	Average percentage of Tar soaked.
2″ × 1″ × 1″	Overburnt	90 gms.	94 gms.	4 gms.	4·4 %	
2″ × 1″ × 1″	1st Class	80 gms.	94 gms.	14 gms.	17 %	16 %
2″ × 1″ × 1″	2nd Class	70 gms.	99 gms.	19 gms.	27 %	

2.8. If the increase in strength is directly proportional to the degree of soaking, we may expect to obtain uniformity in a quantity of brick metal consisting of mixed pieces burnt to different degrees down to second class by treating them with road tar. In order to find the increase in strength of the various classes of brick in relation to the road tar soaked up by them, the following experiment was carried out.

2.8.1. One piece each of jhama, first, and second class bricks was selected and cut into two pieces, each of size 5 in. by 3 in. by 3 in. No brick below second class was selected for this test as it was found from the previous test that the penetration of road tar in the third and fourth class bricks was low and consequently the desired increase in strength could not be expected.

2.8.2. Each piece was then heated to exclude moisture from the pores, and then saked for three hours in road tar heated to 260 degree F in the same way as in the previous experiment. They were then cooled down to room temperature and all excess road tar on the surface was removed.

2.8.3. The 5 in. by 3 in surfaces of all the samples were properly levelled with plaster of paris and then subjected to a load test. The results are tabulated below.

Table 4.

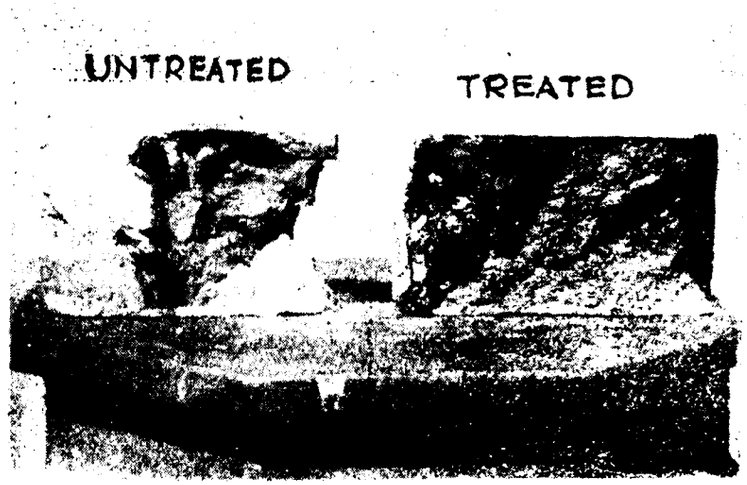
Soaked or Unsoaked	Particulars of sample of size 5″ × 3″ × 3″.	Crushing Load on the 5″ × 3″ face	Average crushing load	Percentage of increase in strength
Unsoaked	A. Overburnt Brick	17 tons.		
	B. 1st. Class Brick	15 tons.	15 tons.	
	C. 2nd Class Brick	13 tons		
Soaked	A. Overburnt Brick	20 tons.		17·6 per cent
	B. 1st Class Brick	19·25tons.	19·5 tons.	28·3 per cent
	C. 2nd Class Brick	19·25 tons.		48·1 per cent

After crushing, sample 'C' was found completely impregnated with tar. (Photograph No. 1)

2.8.4. The above results indicate that —

(i) there was an overall increase in crushing strength on all types of the selected samples after soaking in road tar;

(ii) the inferior classes of samples, by absorbing a greater quantity of tar, acquired approximately the same strength as those of superior quality.



Photograph 1.
Photo of Untreated and Treated Bricks Crushed Under Load.

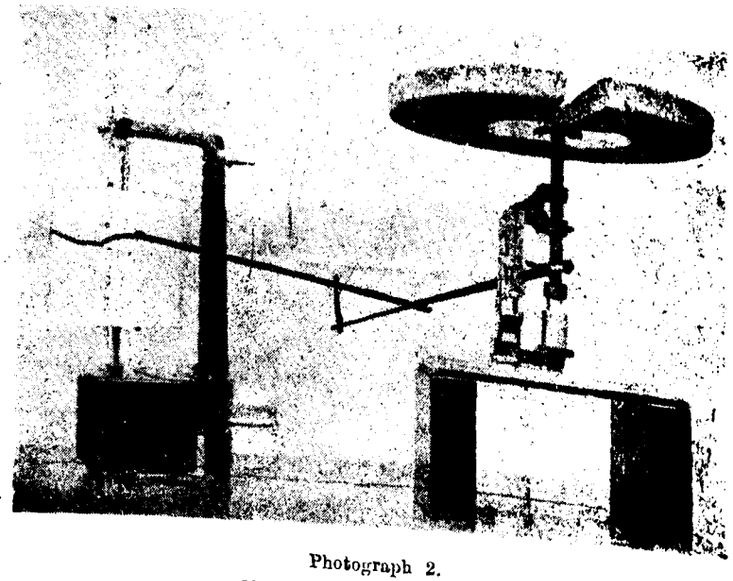
3. INCREASE IN LOAD BEARING CAPACITY OF METAL WHEN ENCLOSED IN A TAR-MIXED SAND BED.

3.1. Apart from the toughening of the brick metal on account of the absorption of road tar, it was expected that its load bearing capacity would be greatly increased if it were placed in a bed of sand premixed with road tar and if the load were applied through the same medium i.e., if there was another layer of tar-premixed-sand between the load and the brick metal. This effect would be due to uniform transmission of the load through the elastic medium provided by the tar mixed with sand.

3.2. The elastic properties of such a bed was tested in the following manner.

3.2.1. A given volume of sand premixed with road tar (H. V. R. T.) at 7 lb per cu. ft of sand was placed in a cylinder and well compacted. Thereafter the sample was allowed to cool down and mature for two days. The load bearing test was carried out at room temperature (80 degree F) by placing the load on the plunger and increasing it in stages. The corresponding yields were measured on a magnified scale on a kymographic recorder. (Photograph No. 2). The load was then decreased in the same

stages and the corresponding recovery noted. It was observed that the recovered level was almost the same as the original level indicating that the premixed sand-bed in which the metal was proposed to be placed in the brick-metal tar-carpet was sufficiently elastic.



Photograph 2.
Kymographic Recorder.

3.3. For finding the increase in load bearing capacity of the brick metal when enclosed in premixed sand-bed, two sets of samples were prepared and two iron rings of 8 inches diameter and three inches in height, made out of 3 in. by ¼ in. flat iron, were kept ready.

Sample No. 1

3.3.1. Graded brick metal consisting of equal proportion of overburnt, first, and second class brick metal were premixed with road tar (H. V. R. T.), heated to 260 degree F at 6 lb per cu. ft of metal.

This mix was placed in one of the rings and well compacted and kept for seven days to mature.

Sample No. 2

3.3.2. Graded brick metal as above was premixed with road tar (H. V. R. T.), heated to 260 degree F at 6 lb per cu. ft of metal and dry sand, (sand equivalent to 50 per cent of the volume of metal, having been added and mixed with the premixed metal).

This mixture was then placed in the other ring and well compacted and kept for seven days to mature.

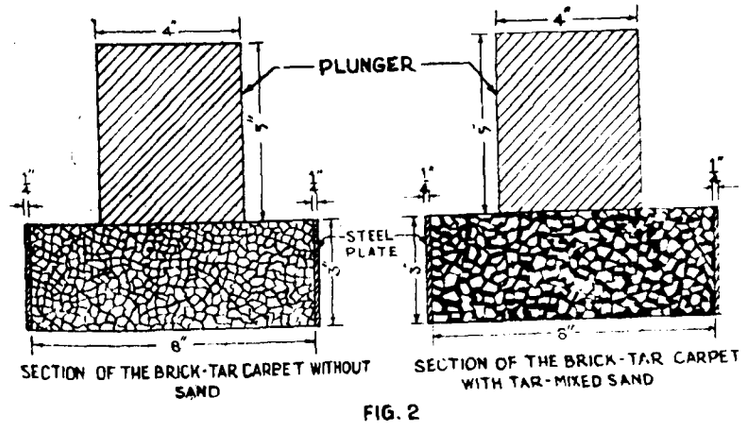


FIG. 2

3.3.3. The samples were tested for crushing strength in a standard crushing-strength testing apparatus employing a four inch diameter steel plunger (Photograph No. 3 and Fig. 2).

3.3.4. The depth of penetration of the plunger was measured at 5-ton load intervals. In the case of sample No. 1, i.e., the one without sand, the crushing load was found to be 14 tons. At this stage the individual pieces of metal were found to be completely crushed.

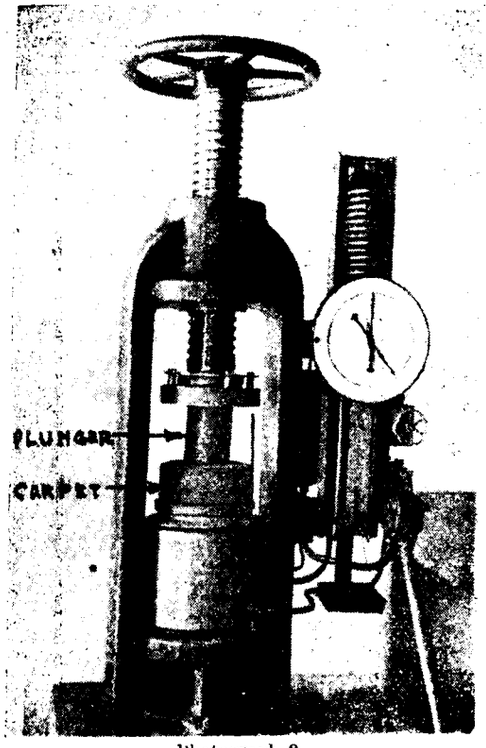
3.3.5. Sample No. 2, i.e., the one incorporating tar-mixed sand, failed at 45 tons i.e., at more than three times the crushing load of the first sample. Further, on examination, it was found that the individual pieces of brick metal were all intact, the

failure having taken place only on account of the movement of the elastic layer which started to squeeze out of the ring around the plunger.

3.3.6. Three sets of test were made on each type of mix and similar results were obtained in each case. The results are tabulated below :—

Table 5.

Carpet of Jhama & Brick metal without sand.					Carpet of Jhama & Brick metal with tar-mixed sand.				
Load in Tons.	Distance between two plates of the machine (inches).			Average penetration. (inches).	Load in Tons.	Distance between two plates of the machine (inches).			Average penetration (inches.)
	North Reading.	South Reading.	Average.			North Reading.	South Reading.	Average.	
0	6·812	6·781	6·796		0	7·031	7·062	7·046	
5	6·625	6·562	6·593	·203	5	6·968	7	6·984	·062
10	6·312	6·281	6·296	·297	10	6·937	6·968	6·953	·031
14	—	—	—	Carpet failed to resist.	15	6·875	6·906	6·890	·063
					20	6·750	6·812	6·781	·109
					25	6·687	6·750	6·718	·063
					30	6·625	6·687	6·659	·059
					35	6·562	6·625	6·593	·066
					40	6·437	6·500	6·468	·125
					45	6·312	6·375	6·343	·125



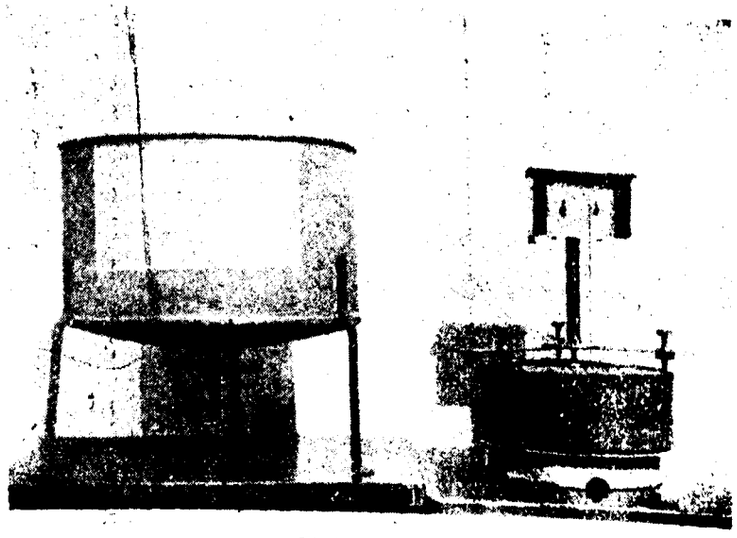
Photograph 3.
Standard Crushing-Strength-Testing Machine.

3.4. The tests described above confirmed what was assumed previously that the cushioning effect of an elastic base can increase the bearing power of brick metal considerably and also that sand, premixed with road tar, forms a very satisfactory cushion.

3.5. The road tar used in premixing, it would appear, fills the voids in the sand and the sand in its turn fills the voids in the brick metal, thereby obtaining a voidless carpet which, by excluding access of water, should increase its life considerably. As a result a minimum surface of the brick metal is exposed to the atmosphere and thereby the life of the carpet is also lengthened.

3.6. To test that the mix becomes voidless and is unaffected by water, a sample like No. 2 above was prepared in the 8-inch

diameter ring and kept under water in a trough. A recorder (Photo No. 4), specially designed by the Author and capable of recording 1/3600 of an inch change in height, and consequently in volume, was placed over it. Immersion for 48 hours did not show any change. The experiment was repeated three times on the same sample but no swelling or increase in weight was observed. The sample was then put to a load test which gave the same result as in the similar test described above.



Photograph 4.

The Recording Apparatus Placed on the Carpet to Measure Increase in Height.

4. FIELD TESTS.

4.1. It has been shown in the above described tests that brick metal can withstand a considerably heavier load when surrounded by elastic material. It will be seen from the experiments desoribed below that brick metal when soaked in tar can also stand abrasion or attrition much better. The resistance of brick metal to attrition resulting from the toughening of brick metal by absorption of road tar, however, will be inferior to that of stone metal but a cushioning layer of premixed sand on the top of the brick metal can help considerably by preventing traffic coming in

direct contact with the brick and this will enable the brick metalled road to withstand heavy traffic satisfactorily. The cushioning layer will be subject to abrasion which will of course have much less effect on it as the sand particles are harder than the stone and the sand layer can be easily and cheaply renewed when necessary by application of an ordinary coat of painting with road tar blinded with sand (seal coat). This will also prevent the entry of moisture into the brick metalled road.

4.2. Prior to the above laboratory test, actual road trials were made eleven years ago, in 1939, on the main approach road of Messrs. Bengal Chemical and Pharmaceutical Works factory at Panihati. Apart from finding out the suitability or otherwise of the use of brick metal in tar carpets, this experiment also aimed at ascertaining the comparative behaviour of brick and Pakur stone metal under identical condition of sub-grade, rainfall, and traffic.

4.3. Two sections, each 100 ft long and 15 ft wide, one using brick metal in the wearing course and the other using stone metal, were laid on the main approach road to Panihati factory of Messrs. Bengal Chemical and Pharmaceutical Works. Both these sections were again sub-divided into two sub-sections, one having a seal coat and the other without it. Detailed specifications are given below :

Table 6.

Section	Base Course	Wearing Course
1 (a)	Consolidated Jhama-metal waterbound macadam, 6 in. thick, laid over one brick flat soling.	Two inches thick standard 'Tarcrete' carpet using brick metal consisting of a mixture of over-burnt, 1st and 2nd class brick metal. No seal coat provided.
1 (b)	Do.	Do. With Seal coat.
2 (a)	Do.	Same as in 1 (a) but using Pakur stone metal. No seal coat.
2 (b)	Do.	Do. But with seal coat.

4.4. Specification for 2 in. "Tarcrete" Carpet

(i) *Using Brick Metal* :

(a) Brick metal consisting of 1st and 2nd class brick metal, size 1½ in. to 1 in.	16 cu. ft	per ⅝ s. ft.
(b) Medium dry sand	8 cu. ft	Do.
(c) High viscosity road tar (H. V. R. T.)	136 lb	Do

(ii) *Using Pakur Stone Metal* :

(a) Pakur stone metal size 1½ in. to 1 in.	16 cu. ft	per ⅝ s. ft.
(b) Medium dry sand	8 cu. ft	Do.
(c) High viscosity road tar (H. V. R. T.)	120 lb	Do.

Sixteen pounds extra tar was used in the case of the brick metal carpet to allow for the absorption of the binder by the brick metal in order to toughen the weaker pieces.

4.5. The ingredients were mixed in a mechanical mixer, laid on the prepared base course, and rolled with a 10-ton steam road roller.

4.6. No description of the laying of the base course is necessary as this is a process known to all engineers. The sequence of mixing charges for the "Tarcrete" carpet, especially that using brick metal, is important and is given here :—

4.6.1. "Tarcrete" with Brick Metal

(a) Four cu. ft of brick metal was put in the mixer and 24 lb of tar heated to 260 deg F was added to it. These materials were mixed until the metal was well coated on the surface.

(b) Two cu. ft of dry medium sand was then added and mixing continued for half a minute when 10 lb of tar heated to 260 deg F was put in and mixed well till the sand was thoroughly coated.

The mix, when ready, was emptied into a wheel barrow and spread on the road so that each charge covered 25 sq. ft of road surface. Rolling was started after a sufficient area had been laid.

4.6.2. "Tarcrete" with Stone Metal

The procedure was the same as for brick metal except that 16 lb of road tar was added to the stone and 14 lb to the sand.

4.7. If the above sequence of mixing is followed, the result will be that each piece of Jhama or stone will have, adhering to it on all sides, a fair amount of sand coated with tar so that the placement of the metal in a cushioned bed will be ensured.

4.8. The cross slope or camber given was 1 in 60 and the usual procedure of rolling a bituminous carpet was followed.

4.9. Forty-eight hours after the rolling had been completed, half the length of each section as already stated, was sealed with 18 lb of road tar (No. 3A) and blinded with two cu. ft of dry sand per 100 sq. ft (Fig. No. 3)

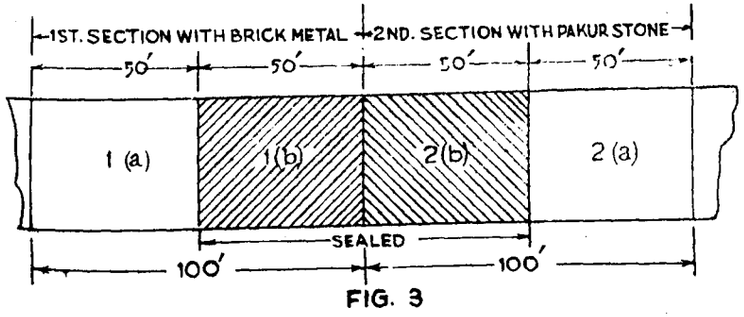


FIG. 3

5. TRAFFIC ON THE ROAD.

5.1. As the Panihati Factory has no railway siding, the raw materials and the entire out put of the factory are carried over this road by bullock carts and heavy lorries.

6. BEHAVIOUR.

6.1. End of 1st year (1940): No appreciable change took place on any of the sections excepting that both the unsealed sections 1 (a) and 2 (a) worked up under traffic so that the surface of the exposed metal on top became partially covered with premixed sand.

Sealed sections viz., 1 (b) and 2 (b) remained unaltered.

Photograph 6.

The Road at Panihati Factory as it stands now.

6.8. From the above it was concluded that brick metal up to second class can give as good a road as stone metal, provided the correct specification is adopted.

7. EXTENSIVE TESTS.

7.1. There is one difference between the traffic on this factory approach road and a public road, namely that the traffic speed is low on the former. A further experiment on a public road carrying heavy fast traffic of mixed variety was, therefore, indicated.

7.2. The Works and Buildings Department of the West Bengal Government was, therefore, approached to give an extensive trial to this specification on their roads in the State.

7.3. On the suggestion of the Chief Engineer, instead of using a mixture of brick metal of all grades, the different grades were separately used in order to observe their individual behaviour in the "Tarcrete" carpet.

7.4. Accordingly, a section of the Strand Road opposite Fort William was selected for this purpose.

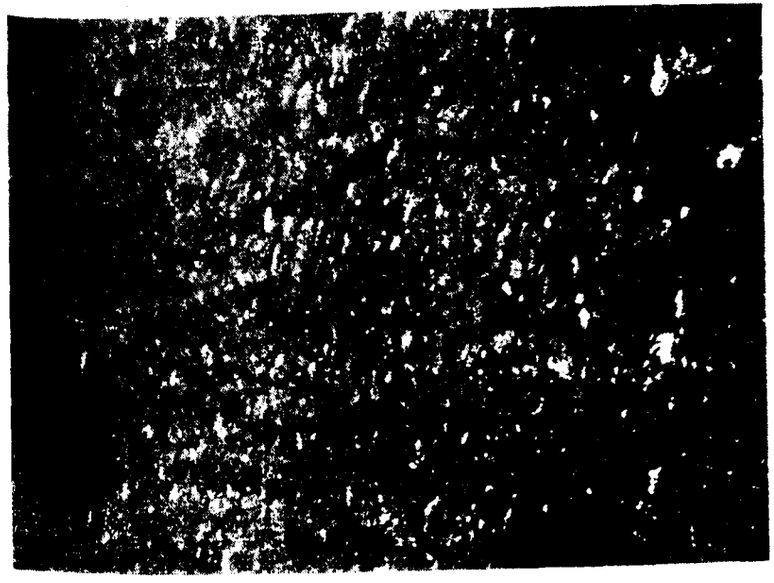
Four sections were laid after removing approximately 2 in. to 3 in. of the existing surfacing over the stone metal waterbound macadam.

Section 'C' — 2½ in. to 3 in. "Tarcrete" with stone metal.

Section 'B' — 2 in. "Tarcrete" with a mixture of overburnt and 1st class brick metal (Photographs 7 and 8).

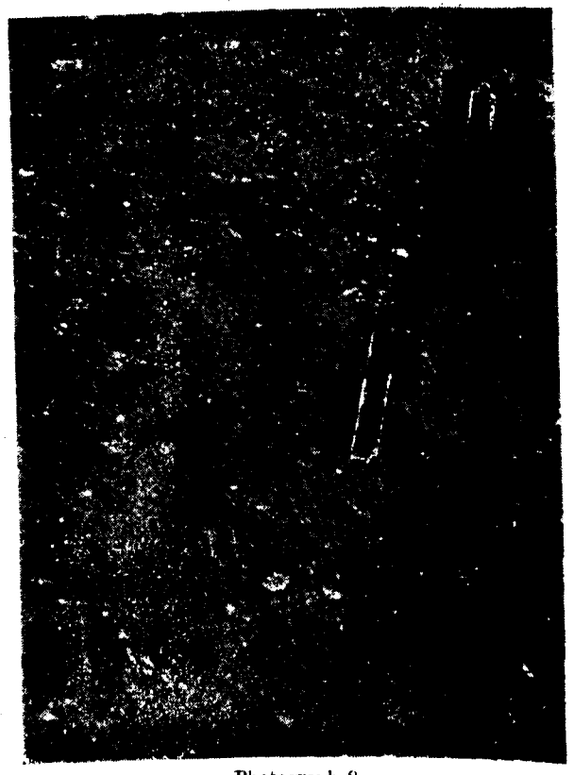
Section 'D' — 2 in. "Tarcrete" with a mixture of 1st and 2nd class brick metal.

Section 'A' — 2 in. "Tarcrete" with a mixture of 2nd and 3rd class brick metal.



Photograph 7.

Surface texture of the section 'B' immediately after laying.



Photograph 8.

Surface texture of the section 'B' after a fortnight under traffic.

7.5. No seal coat has been applied on any section. The sections were laid in November 1949 in the same way as those laid in Panihati Factory and have been kept under observation ever since.

7.6. This portion of the road carries all types of traffic. bullock carts and hand carts forming the major portion. There is no speed restrictionon this road and all types of moor vehicles, including heavily loaded lorries, traverse this section at high speeds (varying from 30 to 50 miles per hour).

7.7. It is now almost a year since the experimental sections were laid. All the sections are in good condition (Photograph No. 9).

Photograph 9.

Strand road opposite Fort William, Calcutta.

7.8. A further observation to be made in this connection is that the bulk of the traffic is unidirectional owing to the position of the section and the width of the road which has at least four traffic lanes.

7.9. No thorough traffic census could be arranged for 24 hours but a partial one for three hours (from 12-40 p.m. to 3-40 p.m.) was taken for four consecutive days soon after completion of the work and the results are recorded below.

Table 7.

Traffic Census on Experimental Section of Strand Road Opposite Fort William. Time 12-40 to 15-40 hours.

Average of 4 days

1.	Loaded bullock carts	(Average load 40 mds.)	107 Nos.
2.	Unloaded ,, ,,	(,, ,, 10 ,,)	40 Nos.
3.	Loaded hand carts	(,, ,, 10 ,,)	114 Nos.
4.	Unloaded hand carts	(,, ,, 2 ,,)	48 Nos.
5.	Loaded lorries	(,, ,, 6 tons)	64 Nos.
6.	Unloaded lorries	(,, ,, $2\frac{1}{2}$,,)	22 Nos.
7.	Motor buses ..	(,, ,, 5 ,,)	25 Nos.
8.	Motor cars ,,	(,, ,, 1 ,,)	22 Nos.
9.	Motor cycles ,,	(,, ,, $\frac{1}{8}$,,)	16 Nos.
10.	Push cycles ..	(,, ,, 2 mds.)	92 Nos.
11.	Hackney carriages	(,, ,, $\frac{1}{2}$ ton)	46 Nos.
12.	Rickshaws loaded	(,, ,, $\frac{1}{8}$,,)	22 Nos.

(Note : One ton = 28 mds.)

8. CONCLUSION.

Brick metal when used in water-bound macadam in the usual way is unable to stand heavy traffic. But the same metal when soaked in High Viscosity Road Tar and placed in a bed of tar-mixed sand with a seal coat of tar and sand can withstand fairly heavy traffic to the same extent as a stone metal "Tarcrete" carpet of the same thickness laid under identical conditions. This fact should be of great interest to road authorities operating in localities where stone metal is scarce and comparatively costly.

9. ACNOWLEDGEMENTS.

The Author expresses his grateful thanks to Shri T. Mitra, R. N. Chatterjee, S. K. Ghose, S. N. Gupta, K. C. Roy, P.B. Sarker, P.N. Sen Gupta, and S.P. Sen for their help, advice, and ready co-operation which alone made the investigations possible.

Photo No. 1
A view of the completed Kuakhai Bridge.

Paper No. 155.

Construction of the Kuakhai Bridge.*

By

SUDHINDRA NATH GUPTA, B.SC., B.E.

CONTENTS

SYNOPSIS

This Paper, published in abstract form, describes the construction of a bridge over the Kuakhai river in Orissa during 1948—50. The total length of the bridge is 1,696 feet with 15 equal spans of 106 feet and a 53-foot cantilever span at each end. This bridge carries a 24 ft carriageway and two 6-ft footpaths. The foundations are two circular wells, 13½ ft diameter under each pier. The superstructure is of the reinforced concrete balanced cantilever type and consists of three R.C. girders spaced 11 ft centre to centre connected with a 9 in. thick R. C. deck slab. The reinforcement was welded.

The Paper includes cost details which show that the cost of the superstructure per running foot was Rs 360.

1. INTRODUCTION

1.1. The *raison d' etre* of the Kuakhai bridge has already been given in I.R.C. Paper No. 144† relating to "Well Foundations of the Kathjuri Bridge." The Kuakhai Bridge is the second of a series of four bridges required for developing the Mahanadi

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* Ordered by the Council to be printed in abstract form. The original Paper with drawings etc. may be seen in the Indian Roads Congress Office, Shahjahan Road, New Delhi.

† Paper No. 144 published on pages 153 to 192 of Vol. XIV-2 and discussed on pages 507 to 522 of Vol. XIV-4 of the Journal of the Indian Roads Congress printed in December, 1949 and June 1950, respectively.

delta near Cuttack. Construction work was started on this bridge in November, 1948 and, except for some minor details, the bridge was completed in August, 1950.

2. SELECTION OF SITE

2.1. The river Mahanadi, which is the parent river of the Kuakhai, traverses very hilly country throughout its course of about 500 miles. Immediately after it enters the plains through the narrow width (about 2,800 feet only) of the Naraj Gorge (Plate I), it bifurcates into branches called the Mahanadi on the left and the Kathjuri on the right. The town of Cuttack was built on the delta formed by this bifurcation. Soon after passing the town, these two main branches are further subdivided, the Birupa originating on the left from the Mahanadi branch and the Kuakhai on the right from the Kathjuri. Within a distance of about 16 miles, the Kuakhai subdivides itself into the Kushbhadra and the Bhargavi Rivers. There is still further subdivision of all the branches lower down in the delta as is usual with deltaic rivers.

2.2. The discharge passing down the various branches of the Mahanadi varies from year to year. Sometimes only one branch takes the main discharge and a few years later this branch gets sluggish and tends to silt up while another branch becomes active. The observed record discharge of the Kuakhai was 3.40 lakh cusecs in 1896. Since then the highest recorded discharge was only 2.53 lakh cusecs in 1937. About the year 1896 when a railway bridge was constructed over the Kuakhai at a site some miles upstream of the road bridge described in this Paper, the opinion of the railway engineers, based on a comparison of surveys and other records dating back to 1847 and earlier with the surveys made in 1896—97, was that

> "the whole tendency of the river appears to be to convert the Kuakhai into the main channel.....
> The Kathjuri river is slowly but surely cutting away the right bank at Chargurriah Point, and the further advance of this erosive action downstream will surely, unless checked, result in the Kuakhai becoming the main channel for the discharge of the Kathjuri waters. It presents the shortest route to the sea by several miles....."

2.3. Levels taken in recent years show that the bed of the Kuakhai River has tended to be considerably higher than that of the Kathjuri and, in 1947, the difference in levels was reported to be of the order of 17 feet. With such changes in the regime of the river, the selection of a suitable site for a bridge across the Kuakhai presented a difficult problem for solution.

2.4. The intricacy of the problem is illustrated by the fact that various experts favoured construction of the bridge in four different locations on the river spread over a range of about 15 miles starting from a short distance upstream of the existing railway bridge near Cuttack up to near its bifurcation into the Kushbhadra and Bhargavi rivers. Further, for each possible location there was some difference of opinion about the most suitable site. In view of these divergent opinions a joint inspection by all concerned was arranged by the Consulting Engineer to the Government of India (Roads) in March 1947. As a result of this joint inspection a site near Balianta was finally approved (Plate I). It was also decided to determine by model experiments the most suitable length of waterway required for the bridge and to determine the design of training works, if any, required.

2.5. The results of the model experiments (which were carried out at the Central Waterways, Irrigation, and Navigation Research Station, Poona) confirmed that the site as finally selected was the most suitable and the length of waterway as already tentatively decided upon correct. As a matter of interest it might be mentioned that the site finally selected for the bridge was also considered to be an excellent site about 50 years ago by the B. N. Railway Engineers when they were surveying the river in connection with a railway bridge over the Kuakhai, although this fact was not known at the time the 1947 decision was taken.

2.6. The nature of the strata met with at 50 feet upstream of the centre line of the bridge as constructed is shown in the Boring Chart (Plate II).

3. DESCRIPTION OF THE BRIDGE

3.1. The Kuakhai, like the Kathjuri bridge, was designed as a reinforced concrete balanced cantilever structure with suspended spans in alternate bays (Plate III) as this was found to be the most economical type in the conditions prevailing at the site. The piers are founded on concrete wells, two separate circular wells under each pier being provided instead of a twin well as at the Kathjuri bridge.

3.2. The total length of the bridge is 1,696 feet, comprising fifteen equal spans of 106 feet each and two end spans of 53 feet each. A 24-foot wide carriageway has been provided with two 6-foot wide footpaths, one on either side.

3.3. **The Substructure**. The foundation under each pier consists of two separate circular cement concrete wells of 13 ft 6 in. outer diameter with a 2 ft 6 in. thick steining, and a 3-foot

thick vibrated R. C. well cap on the top (Plate IV, Fig. 1, and Photo 2). All the wells were carried to a depth of R. L. – –15.00.

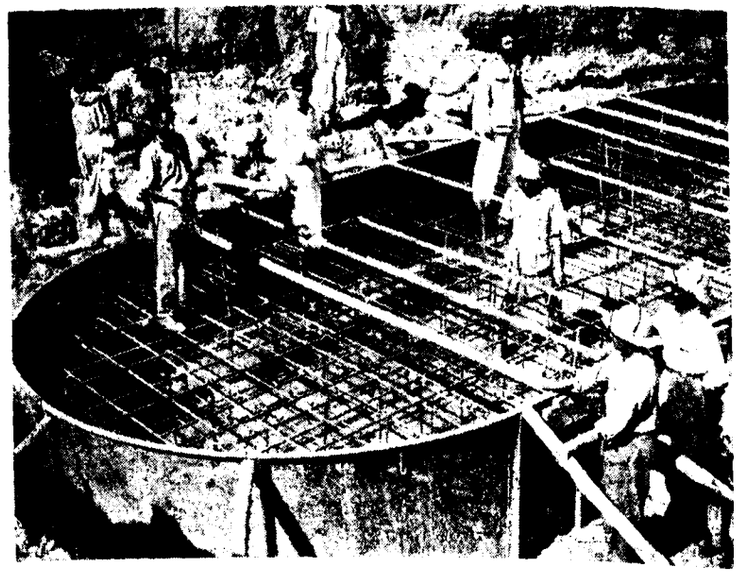


Photo No. 2

Well cap shuttering and reinforcement work is in progress and almost ready for concreting.

3.4. **The Piers** are in lightly reinforced 1 : 3 : 6 cement concrete with plums. The abutments are reinforced concrete retaining walls with counterforts (Plate IV, Fig. 2) and are designed only for earth pressure and traffic loads but not to take any load from the bridge. As a result, the abutment foundations were not taken down very deep (R. L. +54.00).

3.5. **The Superstructure.**—The superstructure consists of three R. C. girders, spaced 11 feet centre to centre, with a 9-inch thick R. C. deck slab (Plate III). The wearing coat on the deck slab is a 3-inch layer of 1 : 2 : 4 cement concrete.

3.6. The depth of the **girders** is 13 feet 3 inches at the support and 6 feet at the centre. The central girders have been made two inches higher throughout their length so as to provide a cross slope for drainage, keeping the thickness of the deck slab

and the wearing coat uniform over the cross section. The girders are of web and flange type construction with a web thickness of 9 inches. The thickness of the flange varies from 7 inches at the centre of the span to 15 inches at the support.

3.7. **Roller bearings,** each having four rollers of 4 inches diameter, have been provided at the free ends of the supported spans, and rocker bearings at the fixed ends. See Plate IV, Fig. 3. The bearings have been designed for a load of 240 tons.

A report of the physical and chemical tests of the metal used in the bearings can be seen in Appendix III, Table 1.

3.8. **The sliding bearing** at the free ends under each of the three girders of the suspended spans consists of two $\frac{1}{2}$ inch mild steel plates, each 2 ft 6 in. by 2 ft $4\frac{1}{2}$ in. in size, with a $\frac{1}{4}$ in. thick copper plate in between (Plate IV, Fig. 4). At the fixed end each girder has four vertical dowels, each 12 in. long and 1 in. diameter, embedded half in the cantilever and half in the suspended span.

3.9. Provision for expansion in the the roadway has been made at the free ends of the suspended spans. Two angles, 2 in. by 2 in. by $\frac{1}{4}$ in., as shown in the Plate IV, Fig. 5, have been embedded in the wearing coat with their top $\frac{3}{8}$ inch below the road surface, so that when a $\frac{3}{8}$ in. thick iron plate is placed on the angles the top of the plate is in level with the road surface. On one side the plate is welded to one of the angle irons whereas the other side slides freely over the other angle iron. A clearance of $\frac{3}{8}$ inch provided between the free end of the plate and the concrete of the wearing surface is filled with bituminous expansion material.

3.10. **Two footpaths** (Plate IV, Fig. 6) are provided, one on each side of the carriageway, the surface being formed by four precast concrete tiles, each $16\frac{3}{4}$ in. by $16\frac{3}{4}$ in. by in. thick.

In the original design sand filling was provided underneath the precast slabs but it was later decided to paint the top surface of the cantilever portions with a water-proofing bituminous coat because fine shrinkage cracks appeared in the cantilever transverse to the bridge and to replace the sand support with three 4-inch walls to carry the floor tiles. (Plate IV Fig. 6).

3.11. The parapets are of panelled reinforced concrete construction, with expansion joints carried up from the road.

4. CONSTRUCTION

4.1. **Materials.** Sand was taken from the river bed. Coarse aggregate was brought from the same quarries which supplied

aggregate for the Kathjuri bridge and are described in Paper No. 144. Steel was received from Tatanagar and Burnpur, and cement, at the beginning, from the Kistna Cement Factory, Madras, and later on from Chaibasa. The timber for the work was obtained mainly from the State's own forests, only a small quantity being imported from Madhya Pradesh.

4.2. The bridge site, being low lying, was unsuitable for the storage of materials during the monsoon. Construction materials were, therefore, stored near the Bhubaneswar railway station at a distance of about 4½ miles from the bridge site. After the monsoon the materials were shifted to the site of work.

4.3. **Proportioning of the Concrete Mix.** Before the superstructure work was taken in hand, test cubes were made to ascertain the strength of concrete made with aggregates from different sources. Hard granite stone metal from the Tapang and Haridaspur quarries and gravel from the Hindol Road quarry were found suitable. Selected, broken gravel was, however, also allowed in the superstructure mixed with 50 to 60 per cent of broken granite. During actual construction two to three test specimens were taken every day from the mix used in the work, and later on tested to see whether the ultimate strength conformed to the specification. A chart showing some of the test results can be seen in Appendix III Table 2.

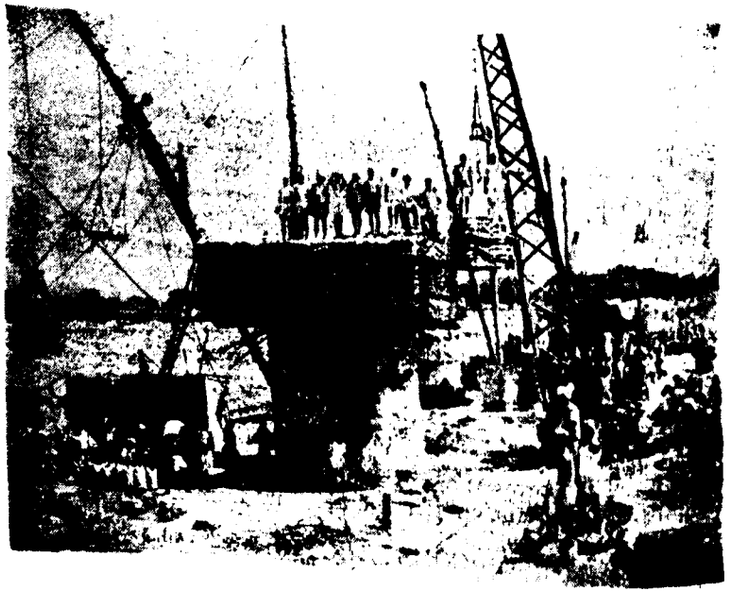


Photo No. 3

Sinking Devices : Kentledge loading on one well and dredging in progress on another.

4.4. Sand was tested for bulking every day of concreting in a tin cylinder 12 in. long and 3 in. in diameter. Figures for percentage reductions ranged from 22 per cent to 27 per cent. An adequate proportion of extra sand was used to compensate for this bulking.

4.5. **Sinking Devices.** When it was found that dredging had become ineffective owing to the wells coming on to extremely stiff clay which could not be penetrated, a special chisel cutter made locally out of rails assembled together, as shown in Plate IV, Fig. 7, was tried. This was operated by a derrick and winch, the chisel being dropped from a height of 15 to 20 feet. In this way the stiff clay soil was loosened to some extent and dredging again became possible.

Other devices used were de-watering, blasting, kentledge loading, and so on. See Photographs No. 3 & 4.

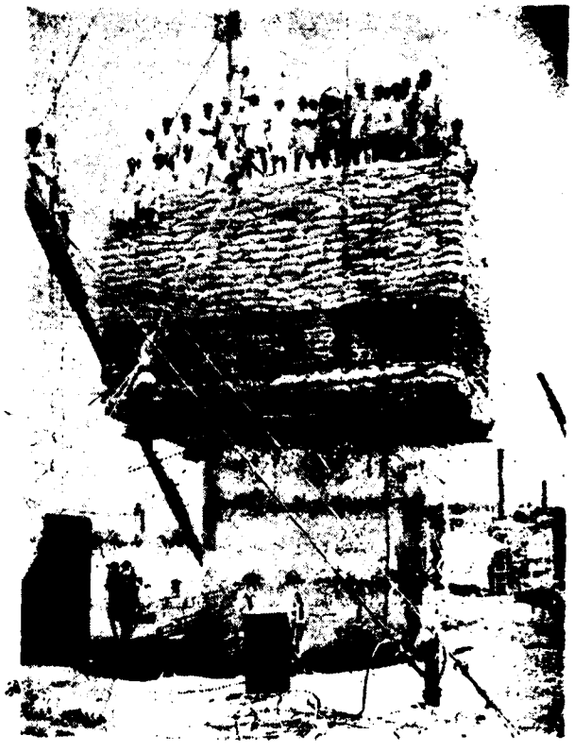


Photo No. 4

Well No. 13. Unable to sink even after sufficiently loading, the diver is being sent down to examine the substrata.

4.6. **Shift and Tilt**. Out of the thirty-two wells forming the foundations of this bridge only seven sank absolutely straight. The shift and tilt of the remaining 25 wells is shown in Plate V. It will be seen that the shift and tilt both varied from $\frac{1}{4}$ in. to about $1\frac{1}{2}$ in. in the worst cases. Photo No. 5 shows eccentric loading, which was one of the devices used to rectify tilt.

Photo No. 5

Concreting is being done in one well while the other is being loaded eccentrically at the intial stage to rectify cant.

The sinking of the wells was considered quite satisfactory and the piers were constructed in the designed positions.

4.7. While sinking was in progress a regular day-to-day progress chart was maintained, a specimen of which appears in Plate VI. The chart shows also the nature of the strata pierced through.

4.8. Starting on the 7th of November, 1948, the aggregate length of wells cast and sunk in a working season of six months was 1,775 feet. In addition, one abutment and all the 16 piers (total height 256 feet) were completed before the work was closed down for the monsoon in June, 1949. Work was again resumed in November, 1949.

4.9. **Abutment**. As the foundations for the abutments were shallow (see para. 3.4), open excavation was made to R. L. 53.75 and a 3-inch seal coat of 1:4:8 concrete was put in. Reinforcement was then laid in the proper position and concreting with a 1:2:4 mix was done in 4-foot lifts. See Photo 6.

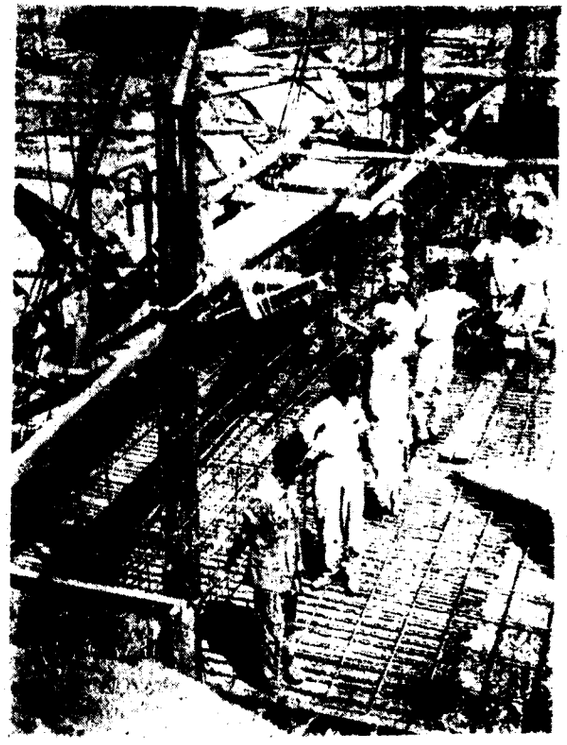


Photo No. 6

Fixing of bottom reinforcement of the base of the left abutment is in progress.

4.10. **Superstructure**. The construction of the superstructure was taken in hand early in November, 1949, the first concrete being placed in position on the 21st December.

4.11. During the monsoon the construction of the staging and the fabrication of the shuttering was done in the contractors' workshop near the Bhubaneswar Railway Station. The reinforced

concrete slabs for the bases of the trestles were cast at site at the end of monsoon. These slabs were 5 ft by 5 ft by 4 in. with top and bottom reinforcements and four hooks to facilitate handling. They were placed in position and tested with a 30-ton load. If there was any sinkage it was made up by inserting steel packing pieces under the trestles. The amount of sinkage noticed under 30-tons was $\frac{1}{4}$ in. to $\frac{1}{2}$ in. only. Some slabs gave way under this load and were replaced.

4.12. After slabs had been tested, **trestles** were placed over them by means of a crane. Each trestle was built up of four wooden columns latticed with wooden battens (Plate VII). Three trestles were placed in one span. Of these eight rows of trestles, four i.e., two rows at either end near the piers, were not so high as the others their tops being 6 in. below the top of the pier cap. The second row of trestles was cross-braced with the third, the fourth with the fifth, and so on.

4.13. **Horizontals** built up of two rolled steel channel sections, 6 in. by 3 in., with one inch gap between, ran along the length of the bridge over the columns. The horizontals passed over the first and second trestle and rested on a seat by the side of the third trestle (Plate VII) whose height was more than that of the first and second trestles. See also Photo No. 7.

4.14. **Vertical timber frames** were then fixed on the built up steel horizontals by means of bolts and nuts. These vertical frames carried the soffit centering and shutters. The level of the timber frames could be adjusted by means of threaded bolts.

4.15. An **angle bent** to the proper shape of the main reinforced concrete bridge girders ran along the full length of each span and was kept in position by means of angle cleats which fixed it to the vertical frames.

4.16. **Reinforcement.** Reinforcement was first arranged over the side shuttering, tied and then gradually lowered into position.

4.17. It will be evident from Plate IV, Fig. 8 that there was no space for lapping the rods. The joints were, therefore, electrically welded. Numerous tests were made both at site by cutting the joints and at Alipore Test House on test specimens to check tensile strengths. It was found by cutting that only five per cent of the joints showed any weakness and that too only at the start of the work when the welders were paid on piecework, the output

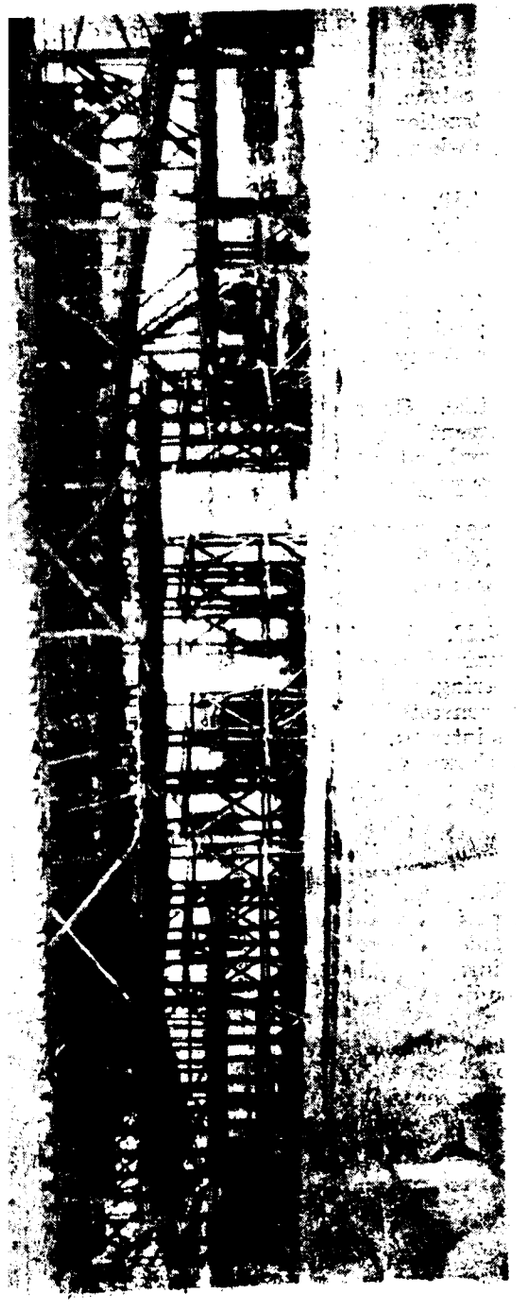


Photo No. 7

The trestle, staging and shuttering are being erected between piers No. 15 & 16.

being 12 to 16 joints per welder per day. The piecework system was subsequently abandoned and payment made by time. The output fell to 8 to 10 joints per day per welder but the work was better done. The quality of work continued to improve during construction and no defects or weakness was discovered at a later stage when 20 joints were cut for inspection.

4.18. The tensile and X-ray tests (Appendix III Tables 3 & 4) showed very good results. In most cases the parent material gave way before the welded joints.

4.19. In placing the reinforcement, the welded joints were staggered and not more than 10 per cent of the rods had welded joints at any particular cross section.

4.20. **Concreting of the Girders and Slabs.** When the reinforcement had been fixed in position, concreting was started. Internal and external vibrators were used during concreting to ensure proper consolidation.

4.21. When concreting an R. C. Girder, starting from the piers, the full length of the flange was concreted first and then the web was concreted in layers.

4.22. A period of four to five weeks was required to finish one unit of superstructure including the erection of the trestles, shuttering, and concreting. The three main girders of each span were concreted in three days and the deck slab concreted after one day's interval. This one day interval was given as experiments had shown that an undisturbed interval of 8 to 24 hours made for better strength in the case of vibrated concrete.

5. COSTS

5.1. During concreting, statistics were kept on the cost of construction as well as the quantity of materials required for the different units of the superstructure. The charts for labour, machinery, and the approximate costs of each item are given in Appendix IV.

5.2. The cost of the superstructures per lineal foot worked out to Rs 360/-. Cost per 100 cu. ft. of reinforced concrete work including the shuttering etc., came to Rs 628/-. The cost of labour and machinery only (excluding the cost of the shuttering) came to Rs 30-14-0 per 100 cu. ft. of reinforced concrete.

Appendix I

Extract from the specifications and data for the design of the bridge.

The Specifications were similar to those adopted for the Kathjuri Bridge which were published with Paper No. 144. Only those clauses are retained here which are peculiar to the Kuakhai Bridge.

* * *

(c) Levels and heights on the bridge :

(i) Finished level of caps of piers and the lowest part of the span bearings—not lower than R. L. 68·5.

(ii) Finished level of the lowest edge or face of the superstructure at the middle of the 106 ft spans—not lower than R. L. 74·5.

(iii) Finished level of lowest edge or face of the superstructure at the middle of 53 ft spans—not lower than R. L. 72·00.

(iv) Finished level of the crown of the road over the main 106 feet spans as low as practicable but not lower than R. L. 81·00. The roadway along entire length of this part of the bridge shall be kept at the same level.

(v) Finished road level over the abutments, as low as practicable but not lower than R. L. 76·25.

(vi) The slope of the road from the ends of the central and level portion of the bridge towards either abutment shall not exceed 1 in 50 and suitable vertical curves shall be provided at the meeting of grades.

* * *

(x) Base of well foundations for all piers : R. L. – 15·00.
Base of abutments : R. L. + 15·00.

* * *

(e) The design shall be good for the following standards of loading, stresses, physical conditions and other paraphernalia of design practice :—

(i) Hydraulic and site data :

Peak H. F. L.—R. L. 66·00
Maximum discharge—260,000 cusecs.
Estimated average velocity in unobstructed channel. — 5 ft per second.
Estimated scour level at the piers in the main stream. — R. L. + 6·0
Estimated scour at other points — Twice the depth of flow at H. F. L.

* * *

Pressure intensity on foundation soil at R. L. minus 15·00 : 6 tons per square foot.

* * *

Appendix II

Materials Tools, and Plant used in the Construction of Kuakhai Bridge.

Serial No.	Items.	Number or Quantity.
	A. Materials.	
1.	Cement ...	3,000 Tons.
2.	Steel ...	1,172 Tons.
3.	Coal ...	1,864 Tons.
4.	Stone chips, metal and plum stone ...	4,20,000 cft
	B. Transport.	
1.	Wagons ...	1,500 Nos.
2.	Trucks ...	12 Nos.
	C. Tools and Plant.	
1.	Crane with steam Boiler (4 tons & 7 tons) ...	2 Nos.
2.	Derrick Set ...	6 Nos.
3.	Winch—5 ton capacity (Steam) ...	4 Nos.
4.	Boiler ...	4 Nos.
5.	Pumps ...	
	(a) Sump pump ...	2 Nos.
	(b) Air lift pump ...	2 Nos.
	(c) Pulsometer pump ...	4 Nos.
6.	Air Compressor—200 lb ...	1 No.
7.	Concrete Mixer, 6 H. P. (7/10 capacity) ...	3 Nos.
8.	Diver's Pump ...	1 No.
9.	Screw Jack ...	2 Nos.
10.	Water supply pump with engine 12 H. P ...	1 Set.
11.	Electric Generating Set. (220 V, 23 Amp & 5 K. W.) ...	1 Set.
12.	Welding Set ...	1 Set.
13.	Stone Crusher ...	3 Nos.
14.	Gravel Washer (10 H. P.) ...	1 No.
15.	Workshop Machines ...	
	(a) Lathe ...	2 Nos.
	(b) Drilling machine ...	1 No.
	(c) Band Saw ...	2 Nos.
	(d) Screw Cutting machine ...	1 No.
	(e) Hacksaw ...	2 Nos.
16.	Ram Pump and Centrifugal Pump ...	2 Sets.
17.	Rail Chisel Cutter ...	1 No.
18.	Lorries ...	10 Nos.

Appendix III

Table 1

test of roller and rocker bearings.

gs in Cast Steel.

Phos.	Yield	Ultimate Stress in tons/Sq. inch	Elongation (per cent)	Bend	Brinell
.038	20.8	40.0	14.625	O.K.	187
.033	20.8	48.8	25%	Satisfactory	187
	20.4	37.6			
.037	18.8	38.4	21.875%	Satisfactory	180
.029	16.4	32.4	17.187	Satisfactory	179
	20.4	39.6			183
gs in Rolled Steel					
0.033	19.6	37.80	17.187%	O.K.	187
0.034	20.0	37.80	15.65%	O.K.	187
0.032	19.2	37.60	23.437%	O.K.	197
0.032	17.20	36.4	21.975%	O.K.	197
0.035	23	47.0	19%	—	—

lcation (Provisional) for Cast Steel Bearings (1950)

Bend	Hardness (Brinell)	Tolerance			Thickness of Castings
		Roller Dia.	Between dia. & pin & dia. of knuckle or bearing	Height of components	
—	180–200	0.003 in.	0.02 in.	.02 in. No minus tolerance.	The edges of all ribs shall be parallel throughout their length.

Appendix III—(*contd.*)

Table 2

Chart showing Compressive strength of Test Cubes taken during construction.

Serial No.	Description of materials & works.	Proportion of mix.	Date of casting.	Period of curing.	Cross sectional area.	Ultimate crushing load in tons.	Ultimate crushing stress in lbs/Sq. in.		Remarks.
1.	Well curb with chips.	1 : 2 : 4	11-12-48	28	36.60	63	3855	Tested at Alipore Test House, Calcutta.	Broke with a pyramidal fracture. A few pieces of aggregate also broke.
2.	Well steining.	1 : 3 : 6	28-1-49	17	37.82	36	2132		
3.	Flange of girder with chips.	1 : 2 : 4	20-2-50	28	36	80	4978	Tested at Site by Avery Testing machine.	—Do—
4.	—Do—	1 : 2 : 4	21-2-50	28	36	87	5413		—Do—
5.	—Do—	1 : 2 : 4	22-2-50	28	36	84.5	3257		—Do—
6.	Web of girder with chips.	1 : 2 : 4	22-2-50	28	36	87.5	4200		—Do—
7.	Deck slab with 50% chips and 50% shingle.	1 : 2 : 4	24-2-50	28	36	67	4167		—Do—
8.	Flange of girder with chips.	1 : 2 : 4	28-2-50	28	36	82	5102		—Do—
9.	—Do—	1 : 2 : 4	21-2-50	28	36	85.5	5320		—Do—
10.	—Do—	1 : 2 : 4	22-2-50	28	36	77.5	4822		—Do—

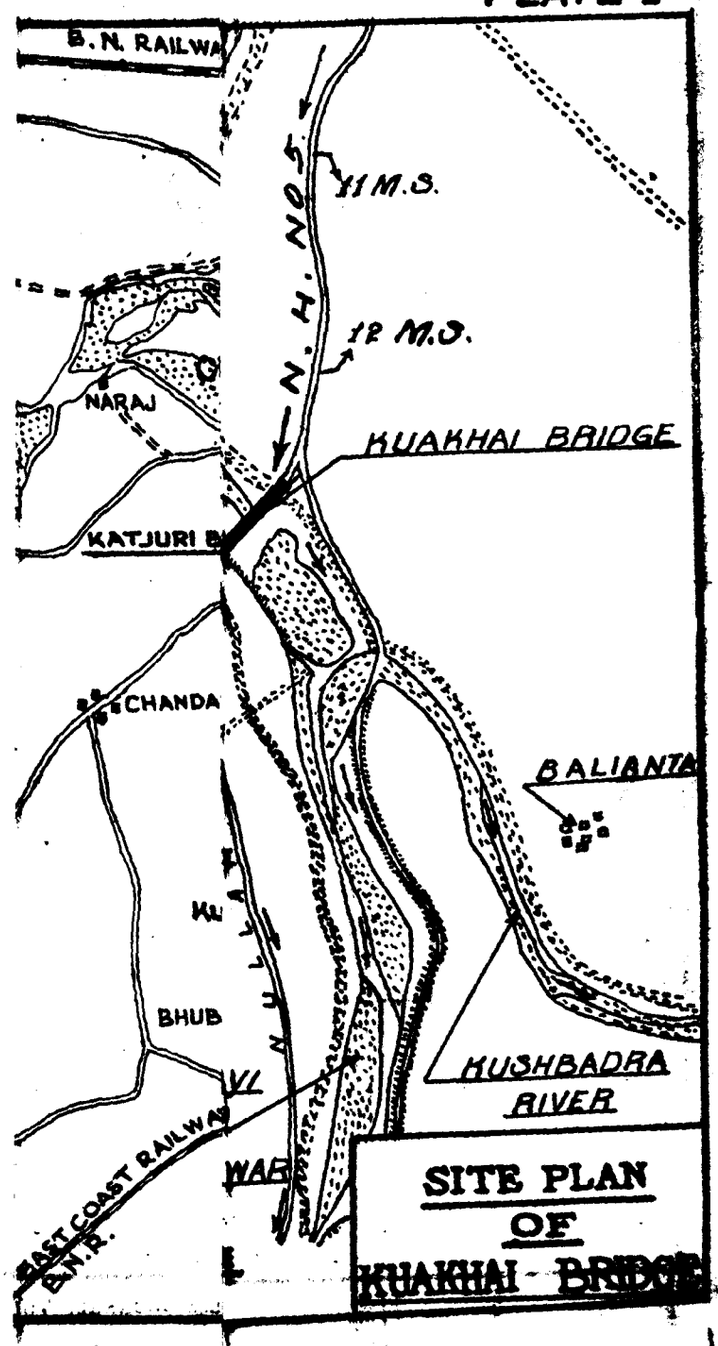
ır, materials anuigth 185′—6″)

LABOU		Quantity of Steel	Average time per Rft.	Remarks.
se th Skilled	ials			
N r drivers-2 m e driver-1 r-1 s-3 asies-12 ns-3 Nenter-1 madars-2 I	Asstgate- Coal 0 Cft Cool-665 Cft. t-266 bags	76.2 tons for the full unit	2 mins.	
r drivers-2 wie driver-1 r-1 s-3 asies-14 Dns-6 enter-1 adars-2	Asstate- Coal Cft. Cool-1365 Cft. t-545 bags		2.95 mins.	
G. P. r drivers-4 e driver-1 r-1 s-4 asies-14 ns-8 enter-1 adars-3	Asstate- Coal Cft. Cool-2578 Cft. t- bags		5 mins.	

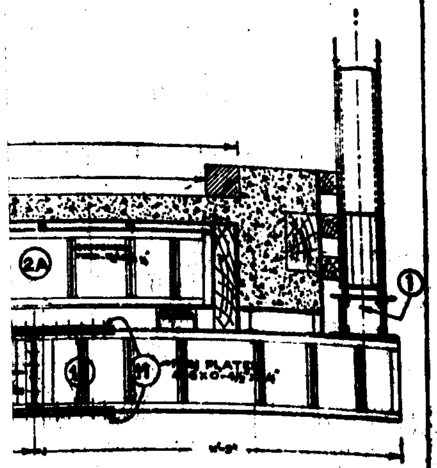
ours, materials and mac gth—53 ft)

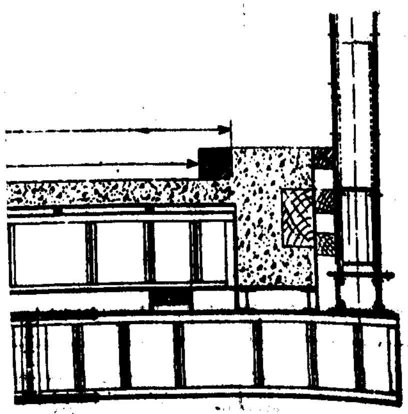
Labour.			
Skilled.	crete rials.	Quantity of steel.	Average time per Rft.
Mixer driver - 1 Crane ,, - 1 Masons - 3 Mates - 4 Khalasies - 12	Asst. te- 930 Cft. Coalm - 465 ,, Coolies - 185 bags.	17 tons for the full unit.	2.83 mins.
Mixer drivers - 2 Crane ,, - 1 Masons - 3 Mates - 5 Khalasies -10	Asst. te -1580 Cft. Coalm - 800 ,, Coolies - 315 bags		10.3 mins.

PLATE I


B.N. RAILWA
N.H. NO.5
11 M.S.
12 M.S.
NARAJ
KUAKHAI BRIDGE
KATJURI B
CHANDA
BALIANTA
KU
BHUB
VI
WAR
EAST COAST RAILWAY
E.N.R.
KUSHBADRA RIVER
SITE PLAN
OF
KUAKHAI - BRIDGE

ANY

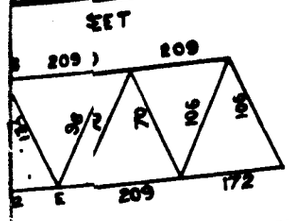




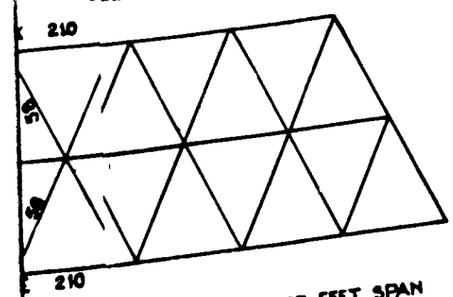
PROVIDED

NAGIENTBING

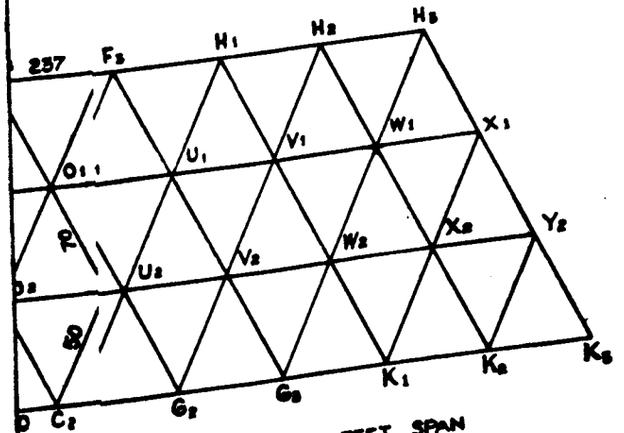
PLATE V



MARKED FOR 85 FEET SPAN



5 MARKED FOR 125 FEET SPAN



IN TOES MARKED FOR 150 FEET SPAN

RESEARCH PUBLICATIONS

I. USE OF STABILIZED SOIL IN ENGINEERING CONSTRUCTION

Section V.

A. Thermal Expansion of Compacted Soils.

B. Thermal Conductivity of Compacted Soils.

By S. R. Mehra & H. L. Uppal.

Soil Research Laboratory, Karnal.

Solids expand when heated, a phenomenon which plays an important role in all practical engineering.

With the object of studying from all angles the use of stablized soil in engineering construction, experiments were conducted to see how a compacted soil mass behaves under changes of temperature.

The four types of soil used in the experiment are described n Table 1.

Table 1

Analysis of Soils used in the Study

Soil No.	Description	Liquid limit	Plasticity index	Sand content	Optimum moisture	pH	Exchangeable		Total soluble salts
							Ca, m. e/100 gms	Na+K m. e/100 gms	
1	Sandy loam	21.8	4.9	65.6	13.0	8.65	4.2	0.9	Negligible
2	Silty loam	27.5	8.7	18.8	12.0	8.6	7.0	1.8	„
3	Silty clay loam	37.0	17.3	8.4	12.0	8.85	14.8	1.10	„
4	Loam	24.7	9.5	43.89	11.	8.10	8.7	1.14	„

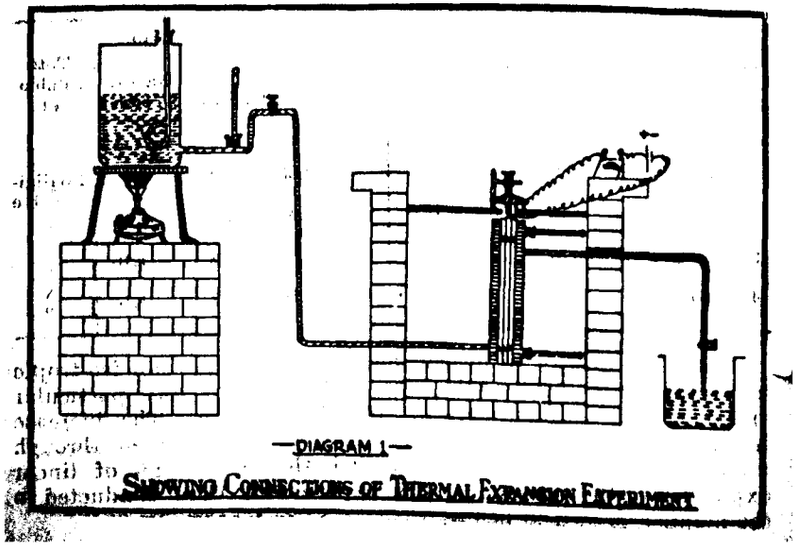
A practical way of measuring the expansion of an iso-tropic material, independent of the size and shape of any particular specimen of it, is to measure its linear expansion. The increase in length of a unit length of the material when heated through unit rise in temperature is called the co-efficient of linear expansion of the substance. The experiments were conducted in the manner described below.

Soil sticks were cast about 15 inches long and $\frac{3}{4}$ inch in diameter. The casting of soil sticks of so small a diameter presented some difficulty because shrinkage on drying was not large enough to enable the dry soil stick to be pushed out of the cylindrical mould without damage. The difficulty was, however, overcome by forming the metallic tube in three equal segments tightly taped together during compaction of the soil. After compaction, the tape was unwound and the three segments of the tube carefully pulled away from the soil sticks, which were then allowed to dry. The compaction was effected with an iron rod $\frac{1}{2}$-inch diameter and uniformity of compaction was maintained by compacting about 2 inches depth at a time.

APPARATUS FOR MEASURING LINEAR SHRINKAGE

The soil stick prepared as above was dried in the oven to constant weight. To measure linear shrinkage the soil stick was placed vertically in a brass tube provided with a jacket round it for circulation of a liquid at different temperatures. To ensure vertical movement of the loosely fitting soil stick within its brass tube, the ends of the soil sticks were fitted with ebonite caps.

For electrical connections the top end of the tube was fitted with a flat top pin to the side of which was soldered an electric wire connected to a spherometer. The detailed connections are given in Diagram 1 and also shown in Photo 1. Since a thermo-



—DIAGRAM 1—

SHOWING CONNECTIONS OF THERMAL EXPANSION EXPERIMENT

couple was not available the exact temperature of the soil stick could not be recorded. This was, however, determined indirectly by fitting a thermometer in the middle of the stick and finding out the time after which the temperature of the stick was the same as that of the liquid circulating in the jacket. It was observed that the compacted soil stick attained the same temperature as the circulating liquid in about 20 minutes. In actual experiment, the expansion was recorded after the liquid had been in circulation for 30 minutes at a definite temperature.

Photo 1.

Apparatus for measuring linear expansion.

The linear expansion attained with different soils is given in Table 2 and reproduced in Fig. 1.

It will appear from Table 2 that the rate of expansion was constant and independent of degree of temperature, that is, its expansion was uniform.

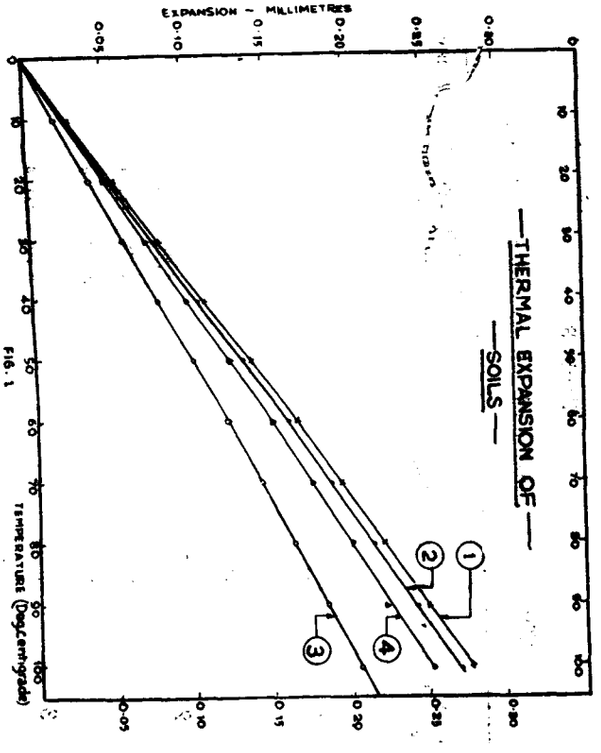
It will also appear that, for the same density, the sandy loam soils had the highest thermal expansion and the silty clay loam had the lowest.

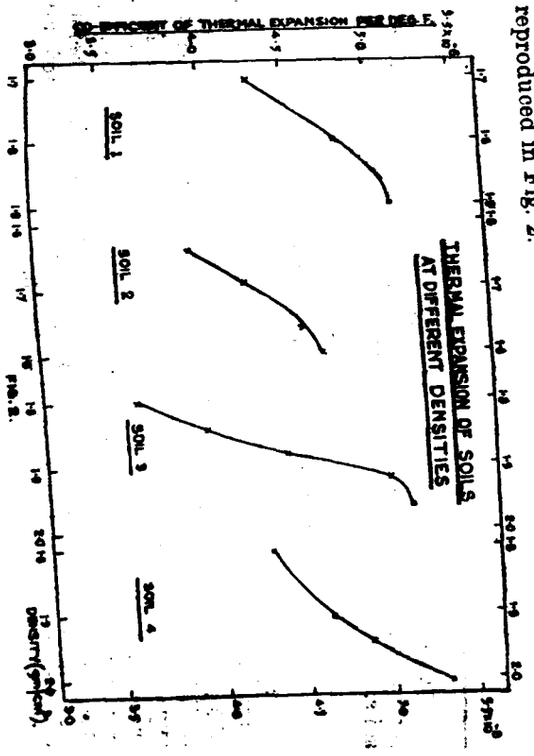
Table 2

Thermal expansion of compacted soils

Soil No.	Density	Reading of Spherometer—Division											Total expansion in mm. (L_{100} - Lo) x	Length of the stick in mm. (Lo)	Co-efficient of Thermal Expansion per degree F $\alpha = \frac{Lt - Lo}{Lo \times t \text{ in. degree F}}$
		0°F	10	20	30	40	50	60	70	80	90	100			
1	1.80	0	29	58	87	114	142	169	196	223	250	277	277×10^{-3}	322	4.81×10^{-6}
2	1.80	0	27	54	81	108	135	162	189	215	242	269	269×10^{-3}	325	4.60×10^{-6}
3	1.80	0	20	41	62	82	103	123	143	164	184	204	204×10^{-3}	320	3.54×10^{-6}
4	1.80	0	25	50	76	101	126	151	177	202	227	252	252×10^{-3}	322	4.30×10^{-6}

Note: One division of the Spherometer = 10^{-3} mm.





With the object of finding out any sustaining relation between density and expansion, all the four soils mentioned were compacted into sticks of increasing densities. The results of linear expansion tests on these sticks are given in Table 3 and reproduced in Fig. 2.

Table 3

Thermal expansion of soil at different densities

Soil No.	Density of the sticks	Co-efficient of Thermal Expansion per degree F $\alpha = \frac{Lt - Lo}{Lo \times t \text{ in deg. } F}$
1	1.71	4.30×10^{-6}
	1.80	4.80×10^{-6}
	1.88	5.10×10^{-6}
2	1.69	4.20×10^{-6}
	1.76	4.55×10^{-6}
	1.80	4.64×10^{-6}
3	1.80	3.54×10^{-6}
	1.88	4.40×10^{-6}
	1.96	5.14×10^{-6}
4	1.80	4.30×10^{-6}
	1.90	4.64×10^{-6}
	2.00	5.32×10^{-6}

It will appear that the thermal expansion of these soils increased as the density increases and this may be true of all soils.

CEMENT SOIL MIXTURES

It has been shown in the earlier parts of these notes that an addition of cement to soil increased the water resisting qualities of the resultant mass. With the object of finding the effect of the addition of cement to a soil on its thermal expansion, all the four types of soils in Table 1 were compacted into sticks with an increasing percentage of cement. The sticks were cured for a week under wet sand and then allowed to dry in the shade before they were finally dried in an oven. The results obtained are given in Table 4 and reproduced in Fig. 3.

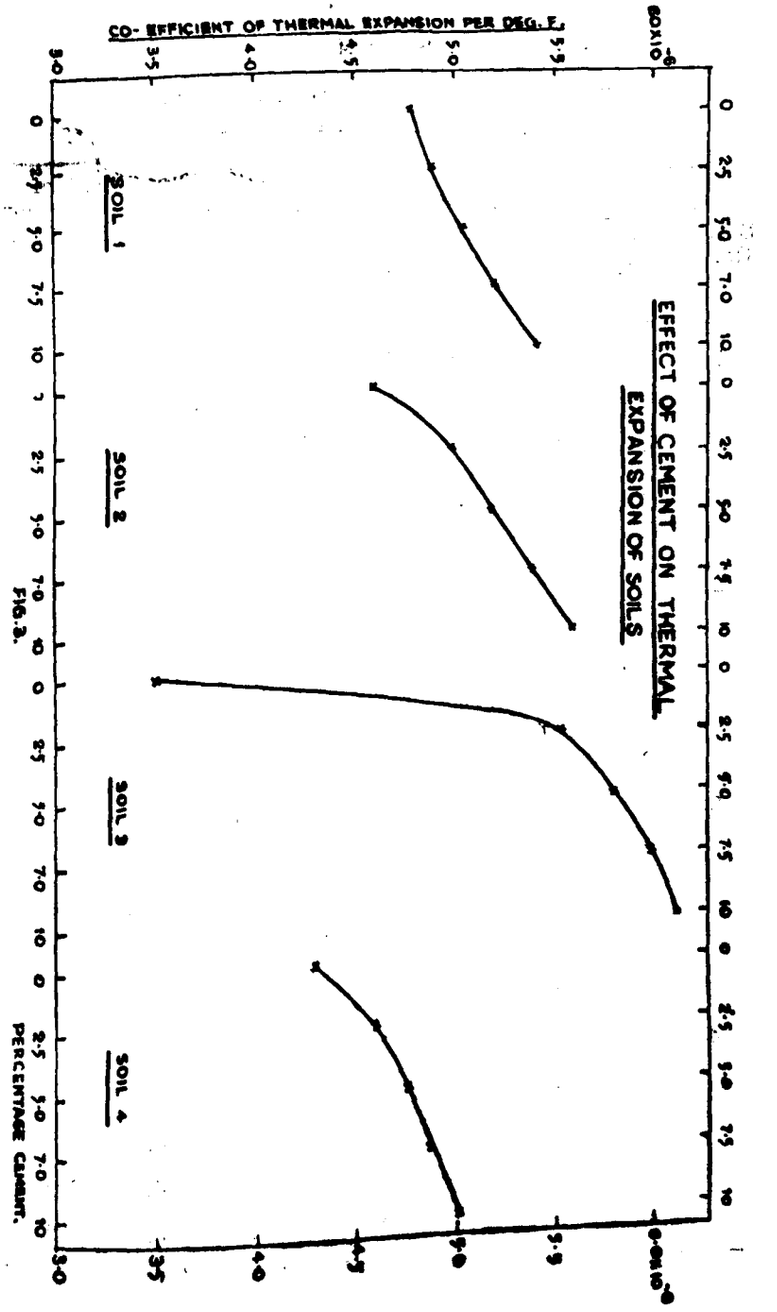


FIG. 3.

(48)

Table 4

Effect of increasing concentration of cement on the thermal expansion of soils

Soil No.	Percentage of cement	Density	Increase in length of stick in mm. ($L_{100} - Lo$)	Original length of stick Lo.	Co-efficient of Thermal expansion per degree F. $a = \frac{Lt - Lo}{Lo \times t \text{ deg. } F}$
1	0	1.80	279×10^{-3}	322 mm.	4.81×10^{-6}
	2.5	1.81	287×10^{-3}	324 ,,	4.91×13^{-6}
	5.0	1.81	295×10^{-3}	322 ,,	5.08×10^{-6}
	7.5	1.80	305×10^{-3}	324 ,,	5.22×10^{-6}
	10.0	1.80	317×10^{-3}	324 ,,	5.43×10^{-6}
2	0	1.80	269×10^{-3}	325 mm.	4.60×10^{-6}
	2.5	1.80	296×10^{-3}	322 ,,	5.01×10^{-6}
	5.0	1.80	302×10^{-3}	322 ,,	5.20×10^{-6}
	7.5	1.80	313×10^{-3}	321 ,,	5.42×10^{-6}
	10.0	1.80	325×10^{-3}	321 ,,	5.61×10^{-6}
3	0	1.80	204×10^{-3}	320 mm.	3.54×10^{-6}
	2.5	1.80	324×10^{-3}	322 ,,	5.50×10^{-6}
	5.0	1.80	340×10^{-3}	323 ,,	5.83×10^{-6}
	7.5	1.80	350×10^{-3}	324 ,,	5.98×10^{-6}
	10.0	1.80	362×10^{-3}	325 ,,	6.18×10^{-6}
4	0	1.80	256×10^{-3}	322 mm.	4.30×10^{-6}
	2.5	1.80	270×10^{-3}	324 ,,	4.62×10^{-6}
	5.0	1.80	275×10^{-3}	321 ,,	4.75×10^{-6}
	7.5	1.80	284×10^{-3}	325 ,,	4.85×10^{-6}
	10.0	1.80	295×10^{-3}	323 ,,	5.07×10^{-6}

It will appear from Table 4 that, for the same density, the thermal expansion increased as the quantity of cement increased. The increase in thermal expansion with increasing percentage of cement was more rapid in the case of silty clay loam soils than for any other soil.

For the same percentage of cement in a soil, it is sometimes necessary to compact the mass to increasing densities, depending upon the strength required of the structure in which the soil is to be used. It was therefore essential to know the corresponding change in thermal expansion when a certain cement-soil mixture was compacted to increasing densities. The results of tests conducted with all the four types of soils with increasing densities are given in Table 5, and reproduced in Fig. 4.

It will appear that, for the same concentration of cement, the thermal expansion of a cement-soil mixture increased with the density.

By comparison of the Tables of thermal expansion (Table 4) it will be seen that the thermal expansion, for a temperature range of about 100 to 120 degrees F. (the maximum range which is generally experienced in tropical countries) was less than the resultant shrinkage produced on drying. It may, therefore, be safely assumed that for a cement soil mixture of the type tested, the thermal expansion would be taken up by the gaps caused at the joints as a result of shrinkage on drying and therefore, beyond the provison of shrinkage joints, no provision for thermal expansion would be necessary.

CONDUCTIVITY

One of the important requirements of a material for building construction is that it should allow as little heat to pass through it as possible. This is all the more important in tropical countries, where the thickness of the wall has sometimes to be increased to reduce the passage of heat. The conductivity of different soils, which were selected for the study, was tested and the results are given in Table 6. All the four types of soil were compacted at optimum moisture to a density of 1.7 to 1.8, which is generally required for all round stability, and their thermal conductivity was determined by the Searle's method.* The results of the conductivity tests are given in Table 6 in B.T.U. per hour square foot per inch per degree F. It appears that there was no appreciable difference in conductivity of different soils when compacted to the same density.

* Method of determination of conductivity by G. F. C. Searle. Cavendish Laboratory, Cambridge.

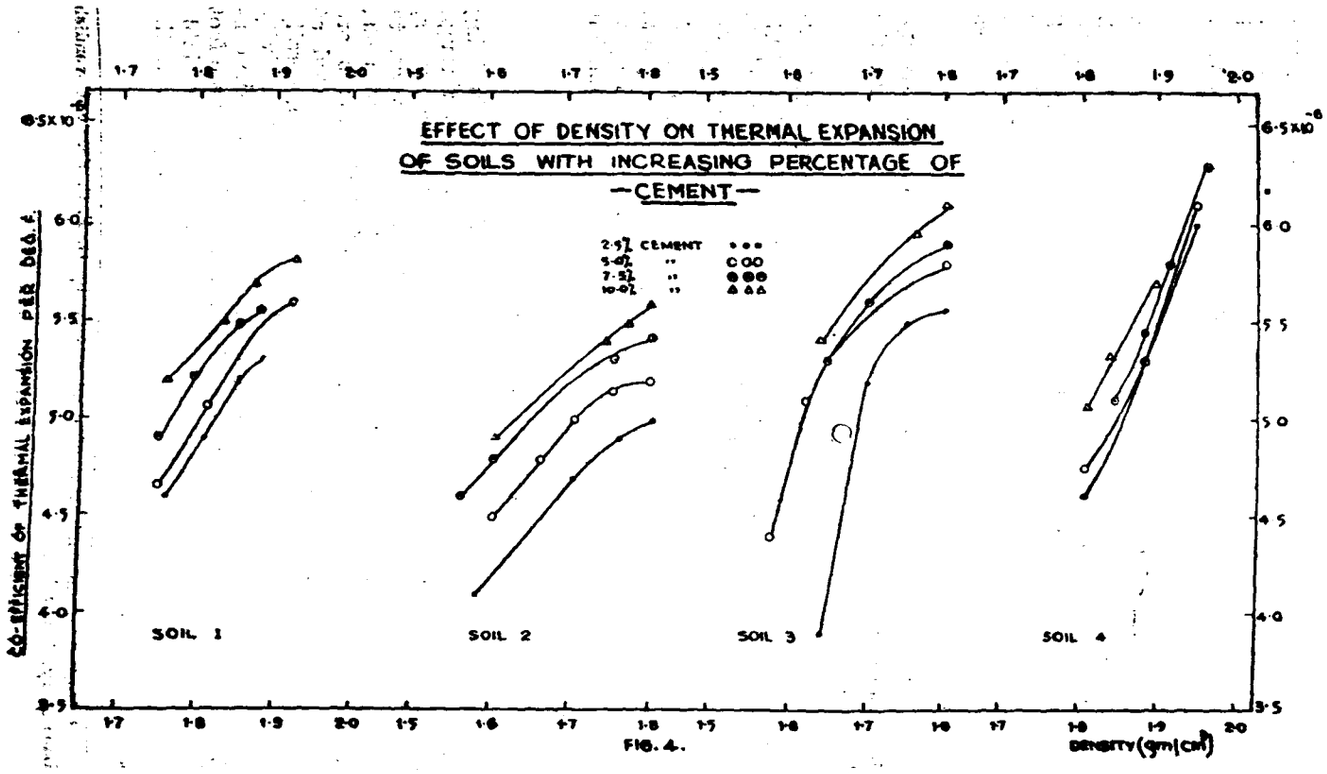


FIG. 4.

Table 5

Thermal Expansion of various soils with increasing percentage of cement and varying densities. (Range of experiment 0 deg. C to 100 deg. C)

Soil No	2.5 per cent cement		5.0 per cent cement		7.5 per cent cement		10 per cent cement	
	Density	Co-efficient of Thermal Expansion per deg. F	Density	Co-efficient of Thermal Expansion per deg. F	Density	Co-efficient of Thermal Expansion per deg. F	Density	Co-efficient of Thermal Expansion per deg. F
1	1·76	4.6×10^{-6}	1·75	4.65×10^{-6}	1.75	4.9×10^{-6}	1.76	5.2×10^{-6}
	1·809	4.9×10^{-6}	1·81	5.08×10^{-6}	1.79	5.2×10^{-6}	1.835	5.5×10^{-6}
	1·85	5.2×10^{-6}	1·92	5.6×10^{-6}	1.85	5.5×10^{-6}	1.87	5.7×10^{-6}
	1·884	5.3×10^{-6}			1.876	5.55×10^{-6}	1.92	5.8×10^{-6}
2	1·58	4.1×10^{-6}	1.60	4.5×10^{-6}	1.56	4.6×10^{-6}	1.60	4.9×10^{-6}
	1·703	4.7×10^{-6}	1.704	5.0×10^{-6}	1.60	4.8×10^{-6}	1.74	5.4×10^{-6}
	1·76	5.0×10^{-6}	1.75	5.15×10^{-6}	1.75	5.3×10^{-6}	1.77	5.5×10^{-6}
	1·80	5.1×10^{-6}	1.80	5.2×10^{-6}	1.80	5.42×10^{-6}	1.80	5.6×10^{-6}
3	1·64	3.9×10^{-6}	1.576	4.4×10^{-6}	1.65	5.3×10^{-6}	1.64	5.4×10^{-6}
	1·70	5.2×10^{-6}	1.645	5.1×10^{-6}	1.70	5.6×10^{-6}	1.76	5.94×10^{-6}
	1·75	5.5×10^{-6}	1.70	5.4×10^{-6}	1.80	5.9×10^{-6}	1.80	5.17×10^{-6}
	1·80	5.55×10^{-6}	1.80	5.8×10^{-6}				
4	1·80	4.6×10^{-6}	1.80	4.75×10^{-6}	1.84	5.1×10^{-6}	1.80	6.07×10^{-6}
	1·88	5.3×10^{-6}	1.88	5.3×10^{-6}	1.88	5.45×10^{-6}	1.83	5.33×10^{-6}
	1·94	6.0×10^{-6}	1.94	6.1×10^{-6}	1.91	5.8×10^{-6}	1.89	5.70×10^{-6}
					1.96	6.3×10^{-6}		

Table 6

Thermal Conductivity of Soils at 90° C.

Soil No.	Density	Thermal Conductivity in B.T.U.
1	1·80	3·112 calories
2	1·80	3·070 ,,
3	1·80	3·000 ,,
4	1·80	3·300 ,,

Since the loam soil was generally recommended for construction on account of its all round superiority over the other soils, the effect of increasing density on the conductivity of this soil was carried out and the results are given in Table 7 and reproduced in Fig. 5.

It will appear from Table 7 that the conductivity of a compacted soil increased as the density increased and, therefore, from the insulation point of view, a low density should be preferred, provided other structural properties at that density are not materially affected.

It will be interesting to know how thermal conductivity of various building materials compares with that of compacted soil. The figures collected are given in Table 8.

Table 7

Thermal Conductivity at 90° C. of loam soil with increasing density

Sample No.	Density	Thermal Conductivity in B.T.U.
1	1·60	2·80 calories
2	1·72	3·22 ,,
3	1·80	3.30 ,,
4	1·90	3·60 ,,
5	2·00	4·00 ,,

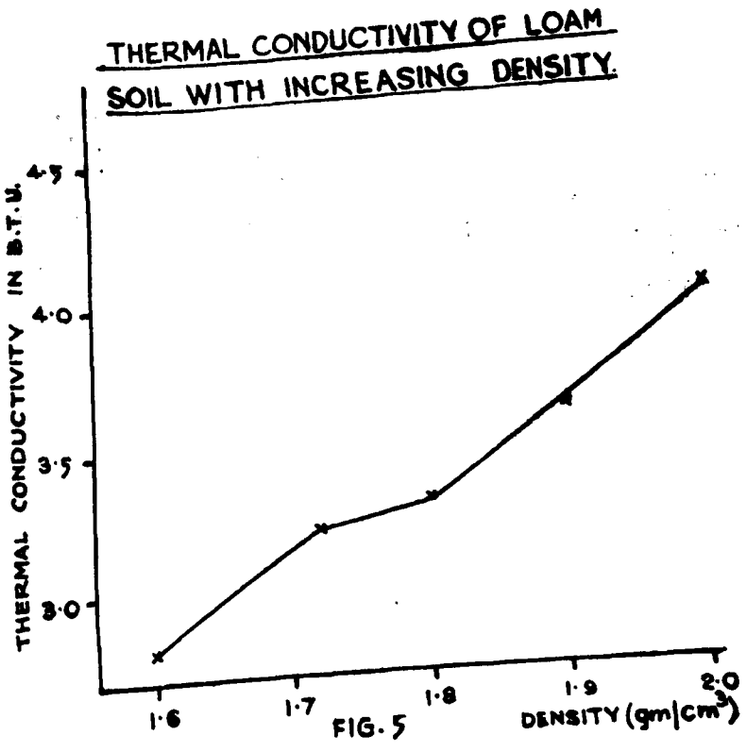


FIG. 5

Table 8

Thermal Conductivity of Different Building Materials

Serial No.	Material	Temperature	Thermal Conductivity in B.T.U.
1	Brick	90° C	6.0
2	Concrete	90° C	8·5
3	Soil	90° C	3·3

It will appear from the above Table that the thermal conductivity of soils is fairly low as compared with that of other building materials such as concrete and brick.

SUMMARY

It has been shown that the thermal expansion of certain soils and also of certain cement-soil mixtures increased as the density increased and, for the same density, the thermal expansion increased as the concentration of cement increased in the cement-soil mixture. It has also been shown that the use of certain stabilized soils in engineering construction can be justified not only because the structural qualities like compression strength, etc., are suitable but also because of their better thermal insulation properties.

II. USE OF STABILIZED SOIL IN ENGINEERING CONSTRUCTION

Section VI—Adhesion of Plasters on Stabilized Soil Walls.

BY S.R. MEHRA, H.L. UPPAL & LABHU RAM

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The outer surface of the walls of a building built with stabilized soil is generally finished by giving it a coat of plaster. This gives it a smooth finish besides providing an increased protection from damage by rain. Experiments were therefore made to study the adhesion of different plasters applied to stabilized soil surfaces and the results are given below.

Stabilized soil walls were divided into two classes for the purpose of this study.

1. Stabilized soil walls containing cement.
2. Stabilized soil walls without cement.

ADHESION OF PLASTER ON A STABILIZED WALL CONTAINING CEMENT

It has been shown in previous articles of this series that an addition of 2.5 per cent of cement to certain soils increased the water resisting quality of the resultant mass. Experiments were therefore carried out to examine the adhesion of cement-sand plaster to stabilized soil walls containing 2.5 per cent cement.

A loam soil, a detailed analysis of which has already been given in an earlier publication of this series, was used in this study for making specimens of stabilized soil walls, because of the general superiority of loam over the other soils tested. A number of blocks were made by compacting 200 gm. of cement-soil mixture at optimum moisture to a density of 1.9 to 2.0. These were cured for seven days under wet sand, and then allowed to dry in the shade. These blocks represented specimens of the wall.

Two such blocks were joined together by interposing a layer of plaster of cement-sand about $\frac{1}{2}$ in. in thickness, thereby providing a sandwich of the plaster between the two blocks. The blocks thus joined were cured for a week and then dried in the shade before finally drying them in an oven at 50 deg. C.

The adhesion of the sandwiched plaster to the blocks was tested by pulling the blocks apart. This was effected by attaching a clamp to each block, and pouring sand into a bucket hung from the lower clamp, till the blocks were pulled

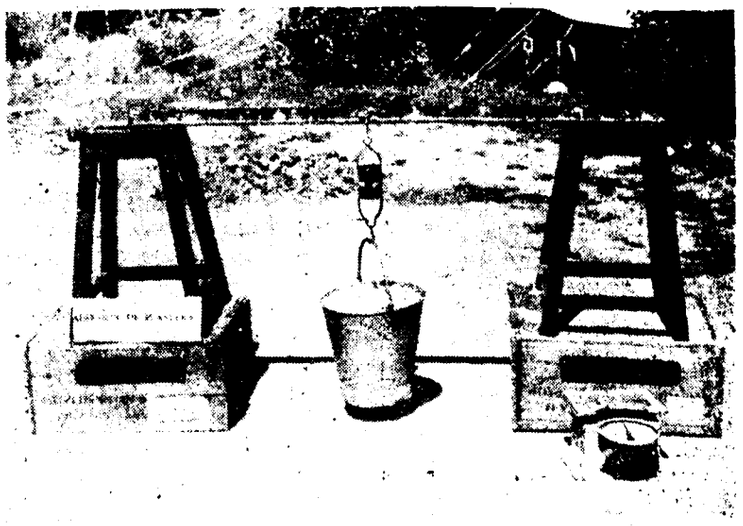

Photo 1.

Apparatus for measuring adhesive strength of plaster.

apart. The arrangement used for the test is shown in Photograph 1. The weight of the bucket and the sand in it was recorded, and the pull per unit area was calculated. The tests were repeated with plasters containing different proportions of cement. The results are given in Table 1.

Table 1

Adhesion of plaster with varying concentration of cement when applied to cement-soil compacted block (Density = 1.9) without cement wash.

Cement sand ratio in plaster.	Adhesive strength lb per sq. in. Average of three tests	Remarks.
1 : 3	7.0	Analysis of sand used in the plaster
1 : 4	7.4	
1 : 5	5.1	Passing 40 mesh (U.S. Standard) = 97.07 per cent.
1 : 6	3.3	
1 : 8	3.2	—Do.—200 mesh—Do.— = 8.8 per cent.
1 :10	2.2	

It appears from Table 1 that the adhesion of plaster to the blocks increased as the quantity of cement in the plaster increased. It will also appear that a concentration of cement higher than 1:5 did not materially add to the adhesion. It was noticed that even the maximum adhesion attained was not sufficient to warrant the use of this kind of plaster in outdoor work. Compared to the adhesion of 1:5 cement sand plaster to burnt brick, which is about 12 lb. per sq. inch, this adhesion of 5 lb was considered too low.

TACK COATS

In an effort to provide a tack coat, different treatments, such as lime wash, surkhi wash, and soda silicate wash in varying concentrations were tried on the blocks before applying a plaster of cement-sand. It was found that none of the treatments increased the adhesion materially. Then the effect of a cement wash was tried. A concentration of 1 : 3 cement-water slurry was applied before applying the usual plaster and the adhesion with cement-sand plaster containing increasing percentage of cement was studied. The results are given in Table 2. For want of adequate equipment, the tests could not be carried to ultimate failure and therefore the figures for adhesion in some cases are given as beyond a certain limit. Adhesion was, however, tested separately for these blocks and it was found that it was of the order of 35 to 45 lb per square inch.

Table 2

Adhesion of plaster with varying concentration of cement when applied to cement-soil compacted block (Density = 1.9) with a primary coat of cement wash.

Cement sand ratio in plaster	Adhesive strength lb per sq. inch Average of three tests
1 : 3	Beyond 20 lb
1 : 4	,, 20 ,,
1 : 5	,, 20 ,,
1 : 6	,, 20 ,,
1 : 8	14.7 ,,
1 : 10	10 ,,

By a comparison of the results given in Tables 1 and 2, it will appear that the adhesion of cement-sand plaster over stabilized soil walls containing 2.5 per cent cement increased tremendously when a tack coat of cement wash was applied to the surfaces before plastering.

Since a cement wash was found to increase the adhesion of the plaster, different concentrations of cement, varying between 1 : 10 to 1 : 2 in the wash, were tried under a 1 : 5 cement-sand plaster.

A 1 : 5 cement-sand plaster was alone experimented with, because, together with high adhesion, it has a sufficiently hard surface, and is not unreasonably expensive. It was observed that the concentration of the cement wash did not make any difference, so long as the wash covered the entire surface and set properly. It may be pointed out that in the case of very rich mixtures of cement and sand in plaster, a small quantity of cement goes in suspension and automatically gives a cement wash which improves the adhesion.

EFFECT OF WEATHERING ON ADHESION OF PLASTER

Effect of wetting and drying on the adhesion of cement-sand plaster to stabilized soil walls containing 2.5 per cent cement was then tried. The joined blocks were subjected to an increasing number of wetting and drying cycles. The adhesion at the end of 25 cycles was determined and it was noticed that the adhesion remained unaffected. For want of proper apparatus the actual figures could not be determined.

It is to be pointed out that the adhesion of plaster will depend upon the density or the firmness of the surface of the wall on which it is applied. If the wall has a low density, then the plaster, during its shrinkage, will peel off bringing with it a part of the loosely compacted surface of the soil wall.

To find the minimum density required for a reasonably good adhesion of plaster, blocks with increasing densities were made, and joined together with 1 : 4 cement-sand plaster and tested for adhesion in the manner already described. The results obtained are given in Table 3.

Table 3

Adhesion of 1 : 4 cement-sand plaster applied to 2.5 per cent cement soil block, compacted to different densities with a primary coat of cement wash.

Soil	Density	Adhesive strength lb per sq. inch
Loam	1.4	Block gave way while fitting
	1.5	3.3
	1.6	5.4
	1.7	9.3
	1.8	18.5 lb
	1.9	Beyond 22 ,,

It will appear from Table 3 that a cement soil mass has to be compacted to a density of at least 1.8 for successful adhesion of plaster. The process of applying plasters as discussed in the foregoing pages has been successfully employed in the construction of 4,000 stabilized cement soil houses.

ADHESION OF PLASTER TO STABILIZED SOIL WALLS CONTAINING NO CEMENT

The construction of cement soil walls finished with a subsequent plaster is rather costly in villages where houses are mostly constructed with local soil only. To protect such houses from rain, a plaster consisting of clayey soil and chaffed straw is usually kept soaked for a number of days, with frequent mixing, and then applied on a wall. It is sometimes finished with a soil mixed with cow dung, locally called "gobri leeping". It has been experienced that the plaster not only peels off but also gets washed away during rains and has to be re-applied frequently. Trials were made to obtain a more stable plaster. This was tried by mixing with a loam soil (Soil No. 4 of Table 5) increasing percentages of cement. The plaster was applied to compacted loam soil blocks. The results for adhesion with increasing percentages of cement are given in Table 4. Since cement wash was found quite successful in increasing the adhesion of cement-sand plaster, it was also considered worthwhile to try the effect (on the adhesion of cement mud plaster) of giving a prior coat of cement wash on the wall. The results are given in Table 4.

Table 4

Adhesion of cement soil plaster applied to loam soil blocks with increasing concentrations of cement in the plaster.

Soil	Percentage cement in the cement plaster	Adhesive strength without cement wash lb/sq. inch.	Adhesive strength with cement wash lb/sq. inch	
Loam	5.0	3.2	10.2	Average of four tests
	10.0	5.0	11.8	
	15.0	7.0	13.8	

It will appear from the above that adhesion increased as a result of cement wash. Similar results as in Table 4 were also obtained by giving a thin coat of cement-soil slurry before plastering. The object is to get a firm surface before applying the plaster.

CEMENT-SAND PLASTER

It was noticed that when a cement-soil is used for plasters, a number of hair cracks developed. These were then covered by another thin coat. This cracking in the final surface was avoided at places where good sand was locally available, by using a cement-sand plaster. Adhesion of 1 : 5 cement-sand plaster was tried on blocks compacted with loam soil, and the results obtained were of the order of 10 to 12 lbs per sq. inch. The adhesion also increased as in other cases by giving a coat of cement wash.

When the plastered blocks mentioned in the preceding pages were subjected to rise of moisture through capillarity, it was noticed that the plaster was showing signs of separating out and, therefore, could not be safely relied upon to have long life. The reason was that the surface of the plaster being pervious to water, the moisture penetrated down to the surface of the blocks and softened it considerably. During drying the soil surface shrank considerably and the plaster got detached from the block. Frequent repetition of the process resulted in the plaster breaking loose from the wall. It is, therefore, essential that the surface of the wall to which plaster is to be applied should remain hard in the presence of water and this is not possible in the case of ordinary compacted soil walls. The only alternative is to prevent the moisture penetrating through the plaster, and to this end the plaster should not only be non-erodable but also be impervious to water.

WATER-PROOFING PLASTER

Attempts were therefore made to water-proof the plaster by mixing a number of materials, like rosin dissolved in alcohol, calcium stearate mixed finely with cement, shell primer No. 3 and Snowcem, a patented cement pigment compound. Though satisfactory results were obtained with Snowcem it was found that the cost was high and incompatible with the principle of low cost construction.

It was therefore considered that the final solution lay in water-proofing the skin of the compacted wall. After a number of experiments with oils, sodium silicate, and metallic soaps, the following process of primer treatment was finally adopted.

Proposed Method

A soil wall is to be compacted to a density of 1·8 at least. It should then be allowed to dry and the loose soil particles brushed off. Cold penetration bituminous material No. 3 warmed to about 50 deg. C. is to be spread over the wall by means of a spray pump, at the rate of 10 lb per 100 sq. ft. This is to be allowed to penetrate the skin for about 2 to 3 days. When the bituminous material has penetrated and the surface is dry and reasonably hard, a solution of 40 per cent sodium silicate (63°^{Be}) in water is to be spread over the treated surface by means of a spray pump. It is to be allowed to dry for a couple of hours when the surface will be ready for a lime wash.

Experiments carried out on a field scale showed that it was advisable to give a wash with a mixture of 1:5 cement-lime, which set much better and protected the primed surface more thoroughly than if lime alone were used.

A small length of wall prepared according to the method described above was subjected to a continuous spray of water at a velocity of about 10 feet per second for 72 hours. It was observed that no moisture travelled through the treated surface.

ADHESION OF MORTAR TO CEMENT SOIL BLOCK MASONRY

Another case where adhesion plays an important part in building work is the laying of cement soil blocks with mortar for wall construction.

Since a soil mortar without cement is likely to get washed out by rain in unplastered block masonry, cement was added to the soil mortar in different proportions. To find out how far the nature of the soil affected the adhesion, four different soils, the physical characteristics of which are given in Table 5, were selected for the study. The results obtained for adhesion with increasing percentages of cement are also given in Table 6. A working consistency of cement-soil mortar could be obtained with 30 to 35 per cent moisture.

Table 5

Analysis of soils selected for the study.

Soil No.	Liquid limit	Plasticity index	Sand content percentage
1	27·2	8·0	38·0
2	27·5	8·7	18·9
3	34·8	14·8	8·4
4	25·6	9·6	37·1

Table 6

Adhesion of different soil mortars with increasing percentages of cement.

Soil No.	Percentage of cement	Adhesive strength lb per sq. inch without cement wash	Adhesive strength lb per sq. inch with cement wash
		Average of Three Tests	
1	5·0	1·0	5.9
	7·5	2·2	10·2
	10·0	3·0	11·0
2	5·0	1·3	6·1
	7·5	2·8	9·2
	10·0	3.3	13.3
3	5·0	0·8	7·7
	7·5	1·8	8·0
	10·0	3·6	8·9
4	5·0	2·4	12·6
	7·5	2·8	12·9
	10·0	4·6	13·3
Sand	5·0	1·2	3·1
	7·5	2·2	7·4
	10·0	3·4	10·1

It will appear from Table 6 that an addition up to 7·5 per cent of cement to soil had no effect on the adhesion of mortar to soil block masonry. Even when the concentration of cement was raised to 10 per cent there was no appreciable improvement in adhesion. Further experiments were therefore carried out to improve the adhesion by giving a coat of cement wash to the sides of the blocks before applying cement soil mortar. The results obtained for adhesion are included in Table 6. It will appear that the adhesion after giving a cement wash increased almost 5 to 6 times of the adhesion without cement wash, when 5 and 7·5 per cent cement was used, and about 3 time[illegible] centration of 10 per cent cement, as compared to adhesion without a cement wash.

It can therefore be concluded that a mixture of 1 : 10 cement-sand or cement-soil can safely be used as a strong mortar in case of soil block masonry containing 2·5 per cent cement, when applied after giving a cement wash to the blocks. If sand is locally available, cement-sand mortar should be preferred to cement-soil on account of its low shrinkage.

SUMMARY

It is shown that the adhesion of cement-sand plasters to stabilized soil walls containing 2·5 per cent cement was greatly improved by giving a cement wash, so much so that the adhesion was twice as much as that between burnt bricks and 1 : 5 cement-sand plaster. It is also shown that a stabilized soil wall can be made fully resistant to water with a coat of cold penetration bituminous material followed by a spray of sodium silicate and a lime-cement wash.

III. WATER-PROOFING OF ALKALINE SOILS BY LINSEED OIL-CAKE

By

B. R. Sen & Manohar Lal.

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1. INTRODUCTION

1.1. In road construction it is essential that bases and subgrades of fine-grained soils should be stable when laid and this stability should be subsequently maintained. It is well known that the stability of a road subgrade depends to a large extent on its moisture content. Hence it is desirable that the moisture content of subgrades should remain throughout the life of the road as near as possible to the appropriate moisture content adopted at the time of construction.

1.2. One of the principal ways in which changes in moisture content can occur in the subgrade is by capillary rise from the water table. Recently several road failures arising from this cause have occurred in the Meerut and Bulandshahar Districts of Uttar Pradesh State. In England a method has been developed of limiting and retarding the increase of moisture content in the subgrade by mixing water-proofing agents with soil. Clare (1) has reported the water-proofing action of vinsol resin when used with acid soils. The present note describes some laboratory experiments on the water-proofing of alkaline soils by means of oil-cake. While it is possible to water-proof such soils by the use of anionic soaps, their use might not be economical. The work described herein is of an exploratory nature and was under-taken to find suitable means of water-proofing alkaline soils cheaply in view of the wide occurrence of such soils in Uttar Pradesh.

2. THE SOIL

2.1. The soil for the experiment was collected from the Lucknow District. It was found to belong to group A-4 of the Classification adopted in the U.S.A. Public Road Administration and contained silty-clay materials, more than 35 per cent passing No. 200 sieve.

(1) Clare, K. E., Journal of the Society of Chemical Industry—1949, 68, page 69—76.

Group A-4 has the following characteristics : (2)

Sieve Analysis Per cent passing No. 200	...	36 min.
Characteristics of fraction passing No. 40		
Liquid limit	...	40 max.
Plasticity index	...	10 max.
Group Index (3)	...	8 max.
Usual Types of Significant Constituent Materials	...	Silty Soils.
General Rating as Subgrade	...	Fair to Poor.

The sample was dried, powdered and passed through a 2 mm sieve before the various water absorption tests were carried out. Particle size analysis, plasticity (4) and compaction (5) charateristics were determined and are given in Table 1.

(2) See Proceedings of the Highway Research Board—1945, page 377.

(3) Group Index calculated by the formula :

Group Index = 0.2a + 0.005ac + 0.01 bd.

In which

a = That portion of percentage passing No. 200 sieve greater than 35 and not exceeding 75, expressed a positive whole number (1 to 40).

b = That portion of percentage passing No. 200 sieve greater than 15 per cent and not exceeding 55 per cent expressed as a positive whole number (1 to 40).

c = That portion of the numerical liquid limit greater than 40 and not exceeding 60, expressed as a positive whole number (1 to 20 .

d = That portion of the numerical plasticity index greater than 10 and not exceeding 30, expressed as a positive whole number (1 to 20).

(4) Tentative method of Test for Moisture — Density Relations of Soils, A.S.T.M. Designation : D 698—42 TP. 1180—82 Part 3, 1946 Edition of A.S.T.M. Standards.

(5) Standard methods of Test for Liquid Limit, Plastic Limit and Plasticity Index of Soils A.S.T.M. Designation : D 423-39 and D 424-99 P. 1168-67, A.S.T.M. Standards Part 3, 1949.

Table 1

Particle Size Analysis.		
Coarse sand	(2.00 mm – 0.2 mm)	5 per cent.
Fine sand	(0.2 mm – 0.02 mm)	57 per cent.
Silt	(0.02 mm – .002 mm)	22 per cent.
Clay	(0.002 mm)	16 per cent.
Plasticity Tests.		
Liquid Limit	...	23
Plastic Limit	...	15
Plasticity Index	...	8
Public Road Administration Classification		A-4
Compaction Test.		
Optimum moisture content — per cent	...	15
Maximum Dry Density lb per cu. ft	...	120
pH	...	8.1

3. WATER PROOFING AGENT

3.1. Various oil seed cakes were studied but particular attention was given to linseed cake. The cake used was obtained after the extraction of oil by an oil expeller and was found to have the following composition :

Moisture	10.5 per cent
Oil	7.4 ,,
Albuminoids	31.0 ,,
Carbohydrates	36.5 ,,
Fibre	10.5 ,,
Mineral Matter	4.1 ,,
	100.00

4. CAPILLARY WATER ABSORPTION TEST

4.1. The Standard Compaction Test was made on the soil sample and the same test was repeated after mixing the linseed cake content in the middle range, i.e., 2.5 per cent, as the stabilizer used in the investigation was only upto 5 per cent. Two curves, one for the treated and the other for the untreated soil, were drawn showing dry densities at standard compaction with different proportion of moisture. (Fig.1). A 10 per cent Air Void Content line

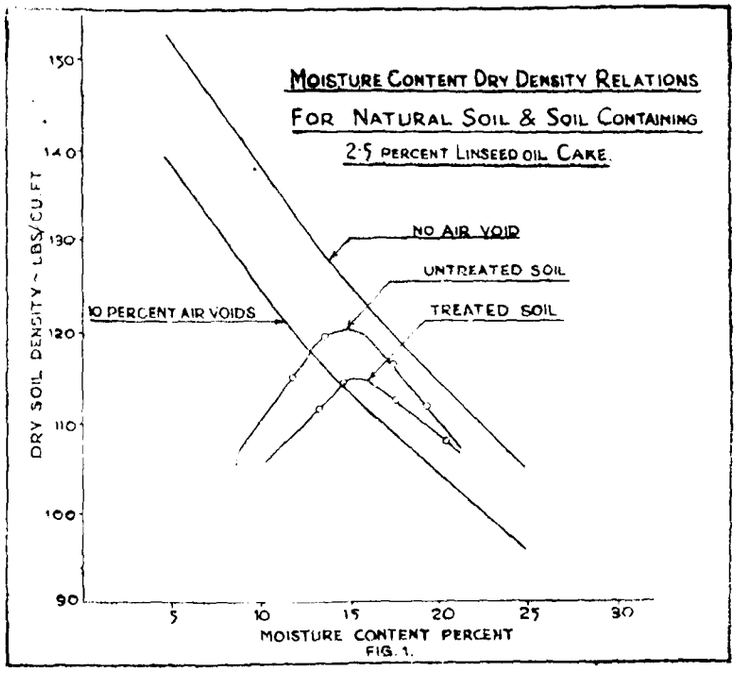
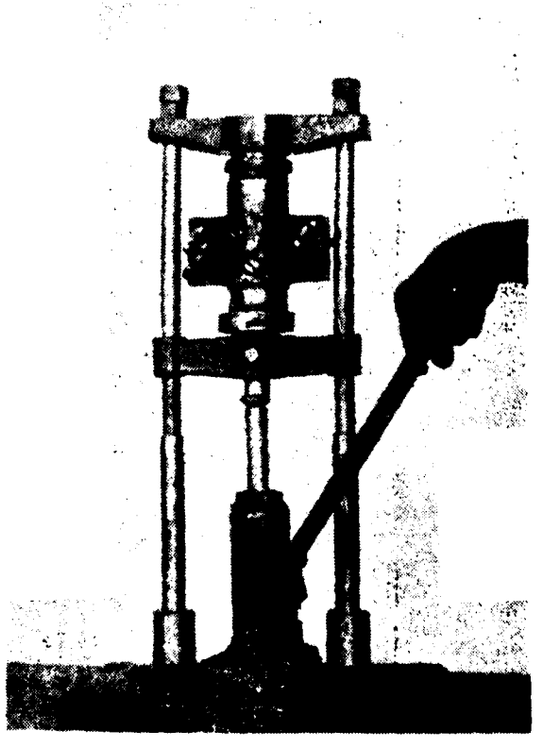


FIG. 1.

Photograph 1.
Split Cylindrical Mould.

was also drawn on the same figure. This was necessary for determining the dry density and the moisture content to study the water absorption of the treated soils, with 10 per cent Air Voids. The co-ordinates of the point at which the 10 per cent air void line intersected the relevant compaction curve were noted. The use of the 10 per cent air content ensured a condition in which the untreated soil absorbed water.

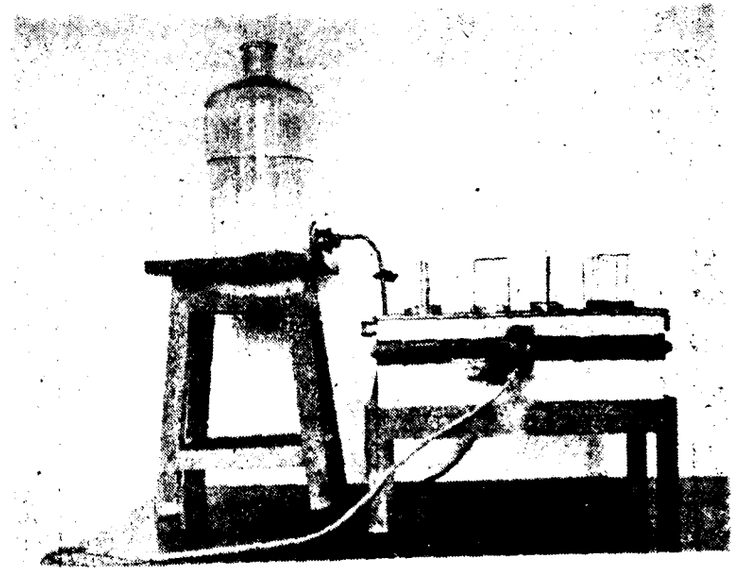
4.2. *Specimens in duplicate were then made in the Split Cylindrical Mould*, shown in Photo 1, which had a known internal volume (3 inches long & 2 inches in diameter). A predetermined weight of soil with appropriate moisture content, so as to ensure 10 per cent air voids after compaction, was placed in the mould between the top and bottom plungers which were then pressed in the soil compaction machine shown in Photo 2. By this means a specimen of the required dry density was obtained.



Photograph 2.

Compaction Machine for Making Specimens.

4.3. The specimens under test were then kept in a moist closet, having 90-95 per cent humidity, for three days for curing in order to develop properly the requisite film at the air-water interfaces which is believed to be the probable cause of the waterproofing of soil. (It is proposed to discuss this aspect of the problem in a subsequent note). The specimens were then subjected to the Capillary Water Absorption Test. (6). The curved surfaces of the specimens were coated with parafin wax and they were weighed and stood in about 2 mm depth of water in a tank fitted with a constant water level device, as shown in Photo 3. The amount of water absorbed was determined by weighing the specimens after 1, 3, 7, and 14 days.



Photograph 3.

Water Absorption Tank with Constant Level Device.

4.4. Since the specimens were made up to a contant volume (154 cc) and had a fixed air void contents (10 per cent), it followed that the volume of the air voids was 15.4 cc. This was also the volume of water required to saturate each specimen, if it was assumed that water entered all the air voids and that no swelling took

6) Report on tests for soil stabilization by the Soil Stabilization Panel of the Institute of Petroleum J. Institute. Petrol. 1944 30 251; 327-48.

place. The volume of air voids left unfilled at the end of the test was used as a criterion by which the efficiency of the water proofing agent was tested.

5. WATER PROOFING PROPERTY OF LINSEED CAKE

5.1. The soil under test was treated with varying percentages of powdered linseed cake, specimens prepared, and water absorption tests performed, as described in para 4.3. The results are shown in Fig. 2. It can be seen that the water absorption of the soil decreased with the increase in the quantity of linseed cake used, till at 3 per cent it became fairly constant (Fig. 2). The dotted horizontal

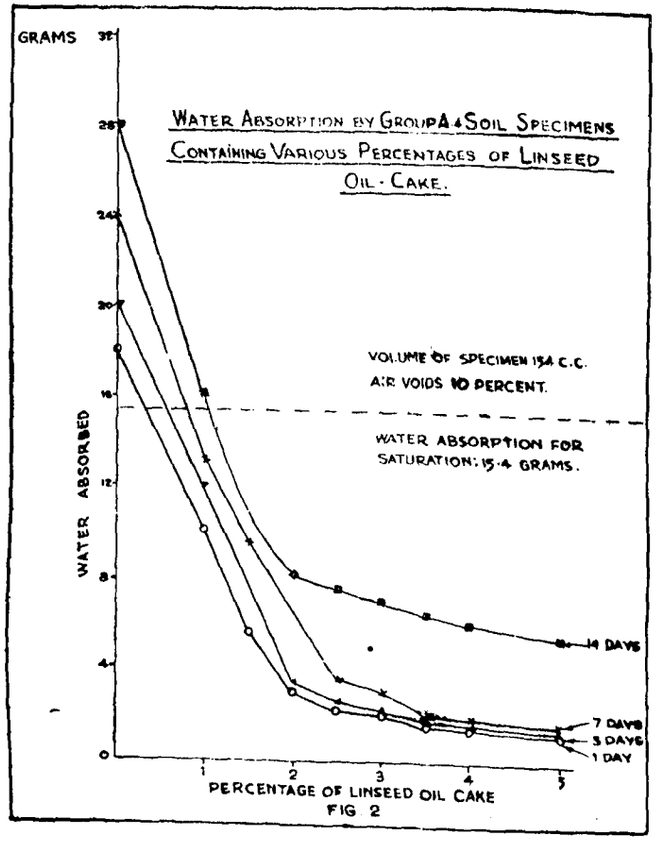
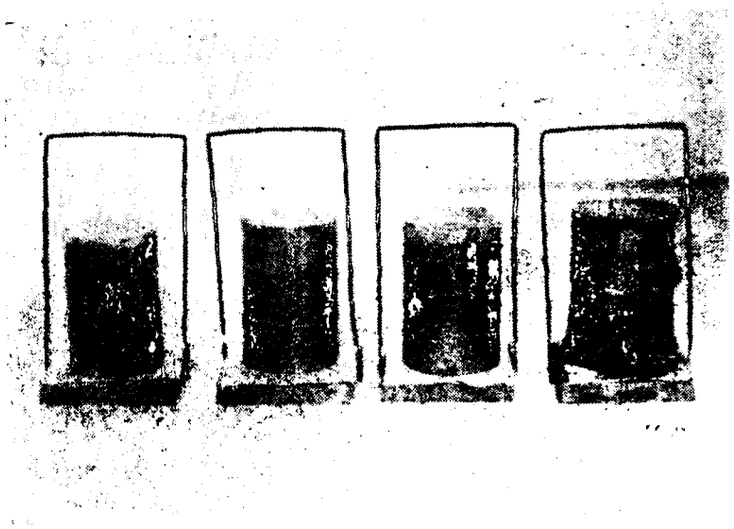


FIG. 2

line in Fig. 2 indicates the amount of water required to fill the air voids in the specimens, calculated with the assumption that no swelling occured during the absorption process.

5.2. Untreated soil specimens tested in the laboratory absorbed 18 grams of water in one day, 20 grams in three days and 24 grams in seven days, whereas specimens treated with three per cent linseed oil-cake absorbed only 2 grams, 2.5 grams and 3 grams in one, three and seven days respectively. The results given in Fig. 2 show that the ability of the soil to absorb water was not completely inhibited by the treatment, but that the rate at which absorption occurred was considerably reduced.



Photograph 4.

Untreated Soil Block (extreme right) shows swelling and breaking of the wax coating whereas the Soil Block Treated with 3% Linseed Cake (extreme left) shows no swelling.

6. CONCLUSIONS

6.1. The experiments showed that it should be possible to reduce for a time the ingress of moisture into a subgrade caused by a rise in the water-table.

6.2. Under laboratory conditions, 3 per cent of linseed cake by weight added to a fine-grained soil imparted for all practical purposes the maximum degree of water proofing to an alkaline soil. (Photo 4).

6.3. The addition of 2.5 per cent of linseed cake to fine grained soil reduced the maximum dry soil density obtainable under standard compaction by 5 lb per cu. ft. The optimum moisture content increased by 1 per cent above that of the untreated soil (Fig.1). Further study on this subject is in progress and will be published later on.

7. ACKNOWLEDGMENT

7.1. The work is being carried out in the Research Station of Uttar Pradesh, Public Works Department, Buildings and Roads Branch, Lucknow and is being published with the kind permission of the Chief Engineer.

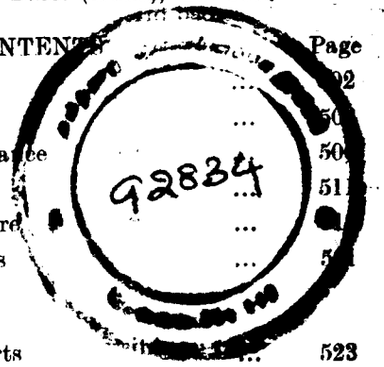
PLANT, MACHINERY, AND APPARATUS SECTION

Technical Note No. 4

ON

DIESEL ROAD ROLLERS MANUFACTURED IN INDIA

By R. S. BHALLA, B.Sc. (HONS), LONDON.



CONTENTS

SYNOPSIS

In the Indian Roads Congress Journal Vol. XII — 4 a note on road rollers, with particular reference to steam road rollers, was published. This is a similar note dealing with diesel road rollers made in India. It refers to the previous article for common features and deals only with the special features of the diesel roller. The specifications to which the rollers have been manufactured are included, as well as lubrication charts, plans of the engine and roller, and lists of "do's" and "don'ts".

1. INTRODUCTORY

1.1. Road Rollers are used for consolidating embankments, bases, subgrades and most types of wearing coats and surfacings. Many types of road rollers have been designed to suit different kinds of materials and conditions of work e.g., the hand or bullock drawn **Cylindrical Roller,** the **Sheeps foot Roller, Wheeled Rubber-Tyred Roller,** the **Three Wheeled Roller** (Steam or Diesel) and so on. The various types of road rollers and their functions have been described briefly on pages 108 and 109 of the I.R.C. Journal Vol. XII — 4, while the Three Wheeled Road Roller (steam) has been dealt with at considerable length. The present article deals with the Three Wheeled (Diesel) Road Roller.

1.2. The main advantages and disadvantages of the Steam and Diesel rollers are listed below. The two types are very much alike, the difference being mainly in the power unit.

The Diesel Road Roller.	**The Steam Road Roller.**
1. It uses a fuel which, at present, has to be imported and often has to be carried long distances by rail.	1. It uses coal or wood fuel which are indigenous products. Special road-side trees are often grown to supply fuel for these road rollers.
2. It is subject to heavier wear and tear than the steam road roller because the engine travels faster (1000 r.p.m. against 200 r.p.m.) and works at higher temperatures ; gear reduction to the slow speed of the roller is correspondingly greater, resulting in more gear wear ; Owing to its design, the engine parts are more in number (seven hundred against a few score) and less substantial in make which again makes for shorter life and heavier maintenance charges. The torque characteristics are not as satisfactory as those of a steam roller.	2. The engine is composed of a few heavy parts which move comparatively slowly; the gearing is simpler and more substantial ; there is no clutch ; no change of gear is required in ordinary running as speed is adjusted by steam pressure ; and reversing is simple.
3. The engine is susceptible to damage from the dust laden air often encountered in road work.	3. Not appreciably affected by dust in the air.
4. The diesel road roller can be started up and shut down in a few minutes and does not consume fuel when standing temporarily idle on a job. It is, therefore, particularly suitable for black-top road work.	4. The steam road roller takes an hour to start up and cannot be temporarily shut down.
5. It is not so dependent on good water as a steam roller and is not dangerous to work.	5. It is dependent on a good water supply and is subject to steam hazards.
6. It is more expensive but, under present Indian conditions, less troublesome to overhaul and can generally be repaired much quicker than a steam road roller.	6. It requires a "boiler certificate" every year which may entail extensive stripping. Overhaul takes time.

1.3. The use to which the three wheel type of road roller can be put and its operation and management are described in detail in Sections 4 and 5 of the note on Steam Road Rollers. Those remarks apply equally to the Diesel Roller and should be carefully studied. That article also includes a note on the compaction produced by various types of rollers on clayey gravel (or hoggin).

2. DESCRIPTION

The Diesel Road Roller

2.1. This type is now manufactured in India to a standard specification drawn up by the Roads Organization of the Ministry of Transport in consultation with experts from abroad. Similarly a Steam Road Roller is now being manufactured in India to a standard specification drawn up by the same authority. In both cases, the rollers can be described as GENERAL PURPOSE rollers since, although only one model of each type is manufactured weighing a little over 9 tons empty, adjustable weight devices are fitted to each model so that the rolling pressure per inch width of rim can be varied to suit different consolidation requirements. The ground pressure per inch width of rim is a more important consideration than the total weight of the roller, as it is the intensity of pressure which determines the crushing or consolidating effect on the road metal.

2.2. Some of the advantages of having one model only built to a standard design for each type are described below:

(a) Quickness and cheapness of manufacture in India since one set of jigs only is required for each type.

(b) Ready interchangeability of parts and a reduction in the stocks of spare parts.

(c) Simplification of inspection and supervision of repairs when on the road.

(d) Quicker overhaul and carrying out of major repairs.

(e) Greater facilities for training drivers and greater opportunities for drivers and fitters to require skill in handling and repairing the rollers since only two models have to be dealt with.

A further advantage of the standardization achieved is that the charts for routine adjustments, maintenance, lubrication, and fuel oil can be standardized.

2.3. In the Indian-manufactured diesel road roller, the ground pressure per inch width of the rolls can be varied from 150 lb to 280 lb on the front rolls and from 350 lb to 470 lb on the hind rolls by traversing the sliding weight forward or backward as required and by adding detachable weights in set positions. The variations obtainable are described below:

Position of Ballast weights	Ground Pressure in lb per inch width of rolls	
	Front	Hind
(a) Sliding weight at rear—no detachable weights	160	400
(b) Sliding weight at front—no detachable weights	240	350
(c) Sliding weight at front and detachable weights at rear	240	390
(d) Sliding weight at rear and detachable weights at front	230	400
(e) Sliding and detachable weights at rear	150	470
(f) Sliding and detachable weights at front	280	350

2.4. A one-ton sliding ballast weight is integral with the roller and is never removed. It consists of cast iron weights. Each one is mounted on small cast iron rollers running on mild steel axles, the track being inside the main frame channel. It is essential to keep the track clean and greased so that the weight can be moved with ease. When engaged on heavy work,

the sliding weight must always be at the rear of the roller. The sliding weight must never be moved when the roller is on a gradient.

2.5. Twenty-eight detachable ballast weights, each of ½ cwt, are supplied for use on front or rear of the roller as required.

2.6. The following are the leading details of the Indian-manufactured diesel road roller:

I. ENGINE

Make	Ruston & Hornsby Ltd.
Number of cylinders	4
Diameter of each cylinder	4½ inches.
Length of stroke	4½ inches.
Revolutions per minute (normal)	1,200
Horse Power (at normal R.P.M.)	36 B. H. P. rated output at 30 inches mercury and 62 deg. F.
Grade of Fuel	High Speed Diesel oil.
Consumption of Fuel	Full load 0.44 lb/B.H.P./hr. ¾ load 0.46 lb/B.H.P./hr. ½ load 0.50 lb/B.H.P./hr. under normal working conditions.
Capacity of Fuel Tank	20 gallons

II. ROLLER

Wheel base	10 ft 8¼ in. between axle centres.
Overall length	20 ft 3 in. approx.
Overall height	10 ft 1½ in.
Front roll diameter	3 ft 11 in.
Front roll width (each)	1 ft 5 in.
Front roll rim thickness	1¼ in.
Rear roll diameter	5 ft 3 in.
Rear roll width	1 ft 6 in.
Rear roll rim thickness	1¼ in.
Total rolling width	5 ft 4 in.
Turning circle minimum radius	19 ft.
Maximum grade roller will climb	1 in 5
Number of speeds	4

Speed forward, high gear (2 speeds)	4 and $2\frac{3}{4}$ m.p.h. on level ground.
Speed forward, low gear (2 speeds)	$1\frac{1}{4}$ and $\frac{7}{8}$ m.p.h. on level ground.
Speed, reverse	4 speeds as for forward movement.

III. WEIGHTS

Weight in working order but without detachable ballast	9 tons 6 cwt approx.
Weight in working order with ballast	10 tons approx.
Ground pressure per inch width of rolls:	
Front rolls	150 to 280 lb
Rear rolls	350 to 470 lb

3. OPERATION AND MAINTENANCE

3.1. **Pre-Starting Inspection.** Before starting the roller, inspect it thoroughly and see that all bolts are tight. Study the lubrication chart and instructions (Plate I) and then carefully grease or oil all bearings and working parts and see that all operating units are free and move easily.

3.1.1. Fill the radiator with clean, soft water. Hard water must not be used as it forms heavy scale deposits and chokes the water circulation system.

3.1.2. Fill the fuel tank by pouring fuel through a strainer. Fill the engine lubricating sump up to the upper mark of the dip-stick with clean lubricating oil (for temperate climates, shell "CY1" or "Dervoil-light" and, for tropical climates, "CY2" or "Dervoil-medium" are recommended) and allow time for the oil to find its way into the sump and pockets inside the chamber.

3.2. **Starting a New Roller or one that has been standing for some time.** The cylinder head cover of the engine should be removed and some lubricating oil poured over the valve stems and tappets. Also pour about three tea-spoonfuls of lubricating oil over the piston through the counter sunk hole leading to the air-intake port on the top of each cylinder head. **Care should be taken not to pour more than the above-mentioned quantity of oil on the top of pistons as more oil may cause severe damage to the engine.**

3.2.1. Remove the crank case inspection door. Smear the cylinder walls with lubricating oil by hand and also put some oil on the moving parts inside the crank case. Take care that no dirt or anything undesirable (such as a cleaning rag, a tool, etc.) is left inside the crank case. Also observe that all the bolts, nuts and pins are intact. Then replace the inspection door.

3.2.2. The fuel system must be primed. Open the main cock on the fuel tank and move the fuel pump cut-out lever to the running position. Unscrew and ease the air vent screws on the top of the fuel oil filter and fuel pump and retighten them as soon as oil begins to trickle out without any air bubbles. De-compress the engine and give a few turns to the flywheel until a creaking sound of the nozzle inside the cylinder is heard; if no creaking sound is heard, disconnect the fuel delivery pipe union on the injector and give a few more turns to the engine until fuel flows freely out of the pipe without any air bubbles. Now retighten the union and wait for the creaking noise as before. Similarly air must be expelled from the other pump injectors in turn. Do not give the engine more turns than necessary as excess of oil in the cylinder will cause difficulty in its starting. Open the drain cocks on the tappet chambers to allow waste fuel to drain off.

3.3. **To Start Engine.** Oil should be filled in the rocking lever lubricating cups and applied on other external moving parts by means of an oil can. See that the fuel pump cut-out lever is placed in the "running" position and the de-compressing gear levers of the engine are lifted. Press the spring plunger of the over load stop.

3.3.1. See that the starting handle boss is clean and oiled, and that the starting handle can be quickly engaged and disengaged into the crank shaft end. Give the engine a few sharp turns and, while still turning, release the de-compressing gear levers and continue turning the engine until it starts firing. Immediately withdraw the starting handle. Note that turning of the engine slowly will be of no use. A fairly rapid traverse of the compression period is of vital importance, as it stores up sufficient momentum in the flywheel and assists in jerking the engine. When the engine attains full speed, look to the oil pressure which should be 10 to 15 lb. If it is found correct, put the engine gradually on load. **Never run the engine on no-load or on light load for a long period.**

3.4. **Starting during cold weather or under adverse conditions.** Cold makes the oil stiffen in the cylinder tightening the piston and thus renders starting difficult. The engine should be given a few turns with the handle after de-compressing it. Remove the cylinder head cover and pour about three teaspoonfuls of lubri-

cating oil through the counter sunk holes on the cylinders to the air inlet ports. Give a few turns to the engine until it revolves easily, keeping the fuel cut-out lever on the "off" position during these operations. Now the engine should be started as described previously.

3.4.1. Easy starting of the engine is also assisted by pre-heating which is done by circulating hot water in the water cooling system and also by warming the crank case oil by taking it out, heating it, and putting it back.

3.5. **Attention during initial running**. After starting the engine for the first time or after repairs, run it slowly under load for some time. The speed of the engine should be reduced by altering the governor controlling wheel. But before making any such alteration, however, check and mark the existing position of the governor so that it may be restored to that position, the normal position, without any difficulty. Watch that the oil pressure is 10 to 15 lb per square inch.

3.5.1. After running the engine under load for about **half an** hour, stop it and check the oil level in the sump ; if necessary add more oil to bring it up to the correct mark on the dip-stick. Open the crank case inspection door and check all the bolts, nuts and pins etc. If any are found loose, tighten them with a suitable tool. Replace the cover and restart the engine as usual.

3.5.2. At the end of a two-hour run under load, clean the lubricating oil filter by giving a turn to the top handle and expel the dirty oil by opening the drain plug. Clean it again at intervals until all the initial dirt is eliminated.

3.5.3 After the engine has run about 50 hours, again check it thoroughly. Adjust the tappet clearance which should be 0.007 inch. Check bolts, nuts and pins etc. inside the crank case. Never let the engine run on a loose bearing or a loose flywheel key. Check the oil level.

3.6. **To stop the engine**. Take off the engine load and move down the fuel pump cut-out lever to the stop position. De-compress the engine just before it is on the point of stopping. **Never stop the engine by shutting the fuel supply main cock, otherwise it would be necessary to prime the fuel system again for the next start.**

3.6 1. Open the tappet chamber drain cock to allow any waste fuel to drain off. Clean the engine on the outside, wiping off dirt, oil, and grease. The water in the cooling system should be drained out completely in frosty weather.

3.7. **Parking brake**. The hand brake on the roller is normally used as a parking brake, although it can be used to assist the foot brake on steep gradients. When the brake is correctly adjusted, the handwheel can be turned about eight complete revolutions from the "full off" to the "full on" position. **The hand brake must be fully released under normal working conditions**.

Warning: The road roller MUST NOT be worked with the hand brake even partially on as doing so is bound to cause trouble.

3.8. **Maintenance of the roller**. The cost of maintenance will be largely reduced if the roller is always kept clean internally as well as externally. Wipe the roller down after every shift. Do not allow any grease, oil, or dirt to accumulate on the roller. Do not allow any of the bright parts on the roller or any tool in the tool kit to get dirty or rusty. Keep them always clean. Take care that there is no leakage in any part of the water, fuel and lubricating systems. Nothing looks worse than patches of rust or stains caused by leaking joints.

3.8.1. Besides the usual tools it is advisable to have the following:—

(a) A sheet-iron tray say about 2 feet square and 4 inches deep for use when draining the oil sump, washing filter elements, etc.

(b) Two-gallon, one-gallon, and quarter-gallon measure and pouring spouts for filling oil into the fuel tank and lubricating the oil sump.

(c) Oil cans.

(d) Strainers for fuel and lubricating oils.

All these should be kept clean and be readily available. In addition, it is desirable to have a nozzle testing apparatus and a thermometer reading temperatures up to 1,000 deg. F.

3.9. **Periodical attention.**

After every 8 running hours:

(a) Check the lubricating oil level, the water level and the fuel supply.

(b) Clean the lubricating oil filter by giving about one turn to the top handle.

(c) Drain the Valve Tappet Chamber.

After 50-60 Running Hours:

(a) Drain the deposits from the Fuel Oil Filter.

(b) Check if there is any leakage in the cylinder head jointing and tighten nuts if necessary.

(c) Clean the air inlet filter by withdrawing the element and rinsing it in paraffin or kerosine oil. Afterwards dip it in clean lubricating oil, allow it to drain, and replace.

After 250 Running Hours:

(a) Remove the nozzle and test if spraying is proper, otherwise clean them carefully according to instructions mentioned later.

(b) Check the injection timing and tune up the engine.

(c) Change the engine oil after cleaning the sump.

(d) Clean the air filter element.

(e) Clean and wash the fuel filter element in petrol or paraffin.

(f) Check all bolts and nuts inside the chamber and tighten if found loose.

(g) Check the valve clearance and adjust, if necessary.

(h) Check that all points are being lubricated.

(i) Test the fuel system to see that all lines are solid.

After 500 Running Hours:

(a) Remove the cylinder heads, decarbonise the interiors and tops of pistons. Check the condition of the inlet and exhaust valves and grind them lightly, if necessary. Adjust the tappet clearance.

(b) Clean the lubricating oil filter.

(c) Ensure that the exhaust system is free from excessive carbon deposits.

(d) Check all bolts and nuts of the moving parts inside the crank case and ascertain by feel that no bearing is loose.

(e) Wash the air intake filter.

After 1,500 Running Hours:

(a) Remove the pistons, and take off the rings, clean them and the grooves in the pistons.

(b) Examine the water jacket and remove any scale or deposit.

(c) Examine the gaskets and replace them if found damaged.

(d) Examine the main, big-end and little-end bearings and reduce or replace them if necessary.

(e) Wash out the lubricating pipe line and passages. Remove any fins or obstruction in the oil holes in the bearings. Clean and wash the lubrication oil sump.

(f) Drain out the fuel oil tank and clean it well.

(g) The radiator should also be drained and washed thoroughly to remove any dirt or sediment accumulated in it.

4. GENERAL REPAIRS

4.1. **Grinding in Valves.** In the beginning it is most desirable to inspect the valves at the end of about 100 working hours. Later on, the period may be extended to 600 hours. The cylinder head is removed, the key withdrawn and the spring released. Now take out the valve to examine the line of contact on the seat and, if this is bright all round, the valve is in good order and can be replaced after wiping the spindle clean. But if the valve or seat is blackened or rusted in places or pitted with small black holes on the line where the seat should be, the valve must be reground.

4.1.1. The valve should be soaked in paraffin or kerosine oil for sometime and then the carbon deposits should be brushed or scraped off lightly without damaging the valve seat. The valve seat should then be smeared over with lubricating oil and a fine grinding powder spread over it evenly. The valve is then put back on its seat and rotated to and fro with a screw driver (a special rubber device, generally used for grinding the valves of automobiles is very useful for this purpose). Do not grind more than is necessary to remove pitting and to polish the face. If the seat on the cylinder head has become very wide and irregular, it should be faced down with a special cutting tool. The seat should be between 1/32 in. and 1/16 in. wide.

4.1.2. After grinding, ensure that every particle of the grinding paste etc. has been removed from the valves, cylinder head, and guides. The best way to check the bedding of the valve seat while grinding is to draw pencil marks across the valve seat, then replace it gently and give it a quarter turn with a slight pressure. Take out the valve and observe. If the pencil marks have been rubbed off, the seat has been ground correctly otherwise it requires further grinding.

4.1.3. Exhaust valves generally require more grinding than inlet valves. When the pits are deep, take a fine cut on a lathe and then grind. When replacing the valves, care should be taken that the springs of the inlet valve are not exchanged with those of the exhaust valve.

4.1.4. After the valves have been put in, the clearance both of the inlet and the exhaust valves must be readjusted. Bring the crank to the top dead centre of its compression stroke by turning the flywheel slowly. The clearance between the lever end and the valve stem should be 0.007 inch. Check it with a gauge and adjust, if necessary, by means of the tappet adjusting screws.

4.1.5. Serious pitting of the valve is due to the following reasons:—

(a) Tappet clearance not correctly adjusted.

(b) Deposit of scale in the water jacket on account of the use of hard water or on account of running the engine with abnormally hot water.

(c) Fuel pump incorrectly timed; nozzles dirty or out of adjustment; or use of unsuitable fuel.

(d) Choked silencer or restriction of the diameter of the silencer.

(e) Poor compression due to worn out pistons and/or loose rings.

(f) Nozzle spring pressure requiring adjustment.

(g) Air filter requiring cleaning.

4.2. **De-compression Gear.** After the valves have been ground, it is necessary to readjust the clearance between the plunger of the de-compression gear and the exhaust valve lever. This should be 0.030 inch when the valve is closed and the de-compression gear lever is horizontal.

4.3. **Cleaning the Water Jackets.** Chocking of jackets is caused by the use of hard water for circulation and also by the engine being run on abnormally hot water. Unless this is dealt with promptly, the deposits will obstruct the water passage and cause overheating, resulting in rapid and excessive wear of valves, pistons, and cylinder liners as well as loss of power.

4.3.1. Inspection plugs are provided on each cylinder head as well as in the main body of the engine. These should be removed and the water passages cleaned by scraping and by forcing in water under pressure. If the deposits are too hard to chip off, water mixed with hydrochloric acid, caustic soda, or washing soda, should be poured into the jackets and allowed to remain there for some time till the deposits get dissolved and become soft. Then the jackets should be thoroughly cleaned with clean water before reassembling.

4.3.2. Deposits of sediment caused by hard water can be reduced by occasionally adding washing soda to the circulating water while the engine is running and then replacing the water when the engine stops.

4.4. **Decarbonising the Piston and Cylinder Head.** The cylinder head should be removed after every 400 to 500 running hours and should be well examined and cleaned. To remove the cylinder head, dismantle all the pipes and other obstructing mountings but, before doing so, bring the particular piston to the top of its stroke by turning the engine. This will enable the piston to be cleaned easily. Take care to block all other openings with clean cloth to prevent any loose nuts etc. falling into them. Scrape off any carbon deposited on the top of the liner and cylinder head. Dismantle the valves with the special tool meant for this purpose, and clean and grind them if necessary. Take care that no similar parts i.e., rods, valves or springs get exchanged with each other; it is a good plan to mark them clearly and carefully.

4.4.1. When the cylinder head is replaced, care should be taken to examine the gasket thoroughly; if damaged, it should be replaced with a new one. The holding down bolts should be tightened diametrically and equally. These should be again tightened when the engine has run for some time and become warm. Never tighten the bolts with undue or unequal force. The clearance between the end of the piston and the underside of the cylinder head must be checked and should be 0·031 inch. Pipe connections and other mountings may now be replaced.

4.5. **Piston Rings**. These should also be checked when it is observed that the consumption of lubricating oil is abnormal and the engine does not take full load. The piston is withdrawn after the cylinder head has been removed. The rings should be eased with kerosine oil and removed one by one from the piston by sliding them on thin strips of iron placed at four places around the piston at right angle to the rings. Grooves and oil holes must then be well cleaned. Check the condition of the rings; if worn out, replace them by new ones of the correct size. These may be put back on the piston by sliding them over iron strips as before. But before mounting them on to the piston, check their clearance by placing them inside the cylinder. The clearance should not exceed 0.004 to 0.005 inch. The head and other mountings should now be replaced.

4.6. **Piston Liner**. When the engine is opened for repairs and it is noticed that a liner is worn out or scratched, it should be taken out for reboring or replacement. Care should be taken while replacing to see that the shoulder of the liner is clean and that the rubber joint ring is not nipped in. If a new liner is to be fitted, see that its top face projects above the top of the crank case 0·002 to 0·004 inch and all the top faces of the liners are level with each other, otherwise the piston head will not fit in properly and will create further difficulties for the mounting.

4.7. **Connecting Rod**. Care of the connecting rod big end and small end bearings is very important. These must be occasionally attended to. If tight, the bearings will become hot whereas knocking will occur if they are loose. Knocking may cause serious damage to the engine and therefore, when knocking is heard, the engine must be immediately stopped for observation. The bolts of the bearings, etc., should be carefully examined to ensure that their split pins are not broken. The head of the split pin should be driven into the castellation of the nut and the sides of the pin bent vertical, one side to be flattened over the nut. Never use a split pin once it has been removed. Use only dead-size split pins. Bolts must be renewed after about 12,000 running hours of the engine, and only genuine (maker's) bolts should be used for replacement. **Never use ordinary iron bolts.**

4.8. **The Lubricating System**. The main bearings and crank pins are lubricated automatically by the pump but the piston liners and the connecting-rod small-end bearings receive oil by splash when the engine is running.

4.8.1. For the economical consumption of the lubricating oil as well as satisfactory working of the engine it is most desirable that correct oil pressure i. e., 10 to 15 lb per square inch must be maintained. It can be adjusted by tightening or easing the relief valve on the pump.

4.8.2. If the pressure increases or falls abnormally when the engine is running, examine at once whether the pipe line or some oil passage to the bearing is blocked or whether, alternatively, there is a leakage at any of the joints or wearing out of bearing metals.; also check the oil sump and see that it is clean and free from sediment. The defect should be remedied before restarting the engine.

4.9. **Fuel Pump Cleaning**. When dismantling the pump, see that the surrounding area is free from dust and splinters, etc. **It is absolutely inadmissible to grind the plunger or barrel with any grinding tool**. If either of these is found damaged, both should be replaced. All parts should be well washed in kerosine or paraffin oil, then dipped into clean lubricating oil and replaced carefully. Take care that no dirt or dust gets in. Never use cloth as it leaves fibres.

4.10. **Timing the Fuel Pump**. If the fuel pump has been disturbed or if a new pump is to be fitted, it should first be air vented. Then place the fuel pump cut out lever in the running position. Turn the engine until the piston is roughly at the top of the compression stroke. Disconnect the fuel injection pipe from the pump and remove the delivery valve and spring and replace the delivery valve holder and tighten it up. Decompress the engine and turn the flywheel backward and forward until a position is found in which the fuel ceases to flow through the pump. This should be done carefully, and the top of the valve holder wiped to see that the exact position at which fuel ceases to flow is obtained. This position will be approximately 25 degrees before the top dead centre.

4.10.1. When the pump is correctly readjusted, the special mark on the flywheel should be in line with the similar mark on the crank case. If they are not in line, a correction must be made by means of the adjusting screw on the fuel pump tappet. Turning the tappet screw to the right advances the point of injection. See that the lock nuts are tightened after adjustment. Replace the delivery valve and spring after washing them in paraffin or fuel oil and reconnect the injection pipe. Prime the fuel injection pipe as instructed previously. Each cylinder must be tried in a similar manner in turn.

4.11. **Setting the Fuel Pump Connecting Links and Tuning up the Engine.** An equal load on each piston in a multi-cylinder engine is very important. This can be done by equal distribution of fuel and, to ensure this, the fuel pump connecting links are carefully set and marked by the manufacturers.

4.11.1. When re-assembling the fuel pump after repairs or cleaning, care should be taken that the mark cut on the link should coincide with the corresponding end of the fork that pump.

4.11.2. When replacing a new pump or link proceed as follows:

(a) Move the rack rod to the right hand (towards the governor) and adjust the fuel pump as described previously.

(b) Deal with the fuel pump at the governor end first.

(c) Put the stop lever in its stop position and move the rack-rod fully towards the left hand and then pull back again 1/16 of an inch. Now lock the connecting link to the governor lever with the rack in this position. Repeat the process for each cylinder in turn, working from the governor end.

4.11.3. This will give an approximately correct setting but the best results can only be obtained by tuning the engine for equal load on each cylinder. Remove the exhaust piping and run the engine for a short time on no load at slow speed, noting the beat of the exhaust on each individual cylinder. If these beats are not similar and well balanced, make final adjustments by slightly (not more than 1/32 inch) altering the position between the governor lever and the first pump and/or the links between the individual pumps.

4.11.4. It must be noted that any adjustment made on a link must be balanced by a corresponding adjustment in the opposite direction on all links to the left of the one adjusted. Mark finally all the links when the beat of the engine is well balanced.

4.12. **Timing of the cam shaft gear wheel.** When the crank shaft is taken out for repairs and replaced, it is most important to see that the positions of the cam shaft and crank shaft gear wheels are absolutely correct, otherwise the engine will never run satisfactorily.

4.12.1. The cam shaft gear wheel is marked with an "O" on one of its teeth which engages between the two teeth of the crankshaft gear also marked 'O'. When replacing the end covers care should be taken not to distort the oil seal rings, otherwise the oil will leak through. Tighten the screws of the cover equally and carefully.

4.13. **Cleaning and care of the injector.** One of the most vital factors in the successful running of the engine is maintaining

the nozzle valves in perfect order. In the beginning the injector should be cleaned after 50 to 60 hours but later on the period may be extended to 80 to 100 hours. Cleaning is carried out as under:

(a) Remove the overflow pipe and take off the nozzle holder from the engine. Hold the body in a large wrench or vice to remove the cap nut.

(b) Try to extract the nozzle valve with the finger and put it in a clean and safe place. If it sticks, then extract the nozzle body first from the cap nut by hand pressure or with a slight blow with a piece of wood or a copper rod. Take care not to damage the pintle point of the valve.

(c) Extract the valve from the nozzle body and soak both of them in petrol, kerosine or fuel oil. Clean thoroughly with a tooth brush. The interior of the nozzle body should be cleaned by means of a wooden manicure stick dipped in petrol, or paraffin. A special fine broach can be obtained for cleaning the nozzle.

After cleaning, rinse the valve, body etc. again in petrol. Now place the valve in the body. The valve should rotate and slide perfectly freely without any stiffness. When assembling make certain that the polished face on the top of the nozzle body and the lower face of the nozzle holder are both perfectly clean. Their corresponding holes should coincide.

4.13.1. After the injector has been completely assembled its spraying may be tested on its piping outside the cylinder. A lot of time is saved by trying thus to detect any fault outside rather than inside the engine.

4.13.2. Do not use a metal tool, unless made of soft brass for cleaning or scraping the nozzle. No emery or carborundum should be used. The fuel system should be air vented.

4.13.3. When replacing the nozzle holder in the engine, do not forget the copper washer.

4.13.4. Occasionally it may be found, after reassembling the injector, that it does not give a satisfactory spray. This, in most cases, can be overcome by slacking back the injector plug one turn, giving the nozzle a slight tap with a copper drift and again tightening the plug.

4.13.5. If the injector needle shows signs of sticking this can be remedied by covering the needle valve with clean lubricating oil and inserting it again into its guide and giving several turns.

4.13.6. The injector filter should be cleaned after about 500 working hours. To do this, remove the pump delivery pipe on the injector and remove the filter body. Extract the filtering element and wash it with clean paraffin or petrol. Also check that the copper joint of the delivery pipe is in good condition. Now replace the filter body and the element in position.

To keep the injector in good condition, it is essential that clean, well strained fuel is used.

4.14. **The nozzle testing apparatus** consists of a hand pump for applying high pressure (about 2,500 to 3,000 lb per sq. inch), a pressure gauge to indicate the nozzle pressure, a nozzle holder, and a shut off valve.

3.14.1. The nozzle of the engine for test should be coupled to the pressure pipe union of the apparatus and clean fuel oil filled in the small oil container. Work the operating handle a few strokes to expel the air in the line. Now work it further and note the pressure at which the spray of the nozzle breaks, which should be 2,500 to 3,000 lb per sq. in. If the pressure is not within the range, it should be adjusted by means of the top screw on the nozzle. The pressure of the nozzle can be increased or decreased by tightening or slackening respectively the top screw on the nozzle. The spray should now be observed for its uniformity at a rate of pumping of about 20 strokes per minute by the operating handle. The nozzle should make a fine spray and the pintle point of the nozzle should remain dry and no drip should come from it. If the nozzle does not give a correct spray, it should be opened and examined for defects.

4.15. **General Faults in Nozzles and Their Remedies :**

(a) Dirt between nozzle valve and its seating — Clean valve and seating.

(b) Crack in nozzle body — Replace it.

(c) Broken nozzle valve control spring — Replace it.

(d) Nozzle valve sticking in its guides — Clean it.

(e) Dripping of the nozzle — Clean or replace.

(f) Too much oil escapes at the leak off pipe of the nozzle — Possibly due to much play of the nozzle (not being correctly tight). Tighten the nut or renew the nozzle and the needle, if necessary.

5. CAUSES OF ENGINE FAILURE

5.1. **If Engine Fails To Start** the reason may be :

(a) The correct method of turning the engine may not have been acquired.

(b) Throttle not fully functioning or its position incorrect.

(c) Faulty nozzle valve or its pressure incorrect.

(d) Poor compression or starting under adverse conditions.

(e) Unsuitable lubricating oil and thus stiffening of the cylinders.

(f) Fuel pump not correctly tuned.

(g) Unsuitable fuel.

(h) Timing of valves not correctly adjusted.

(i) Fuel system not correctly air vented.

5.2. **If Engine Fails To Develop Full Power** this can be due to any of the following reasons :

(a) Any of the faults detailed above.

(b) Oil pressure not correct.

(c) Overheating of bearings ; shortage of oil in the sump or choking of oil system.

(d) Water cooling system choked due to accumulation of sediments.

(e) Choking of exhaust piping.

5.3. **Failure of Lubricating Oil Pressure** may be due to :

(a) Insufficient oil in the sump.

(b) Filter choked.

(c) Sludge at the bottom of the oil sump.

(d) Suction feed of oil pump choked.

(e) Oil pressure gauge defective.

(f) Oil pressure release valve not correctly adjusted.

(g) Some bearing damaged.

4.13.5. If the injector needle shows signs of sticking, this can be remedied by covering the needle valve with clean lubricating oil and inserting it again into its guide and giving several turns.

4.13.6. The injector filter should be cleaned after about 500 working hours. To do this, remove the pump delivery pipe on the injector and remove the filter body. Extract the filtering element and wash it with clean paraffin or petrol. Also check that the copper joint of the delivery pipe is in good condition. Now replace the filter body and the element in position.

To keep the injector in good condition, it is essential that clean, well strained fuel is used.

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3.14.1. The nozzle of the engine for test should be coupled to the pressure pipe union of the apparatus and clean fuel oil filled in the small oil container. Work the operating handle a few strokes to expel the air in the line. Now work it further and note the pressure at which the spray of the nozzle breaks, which should be 2,500 to 3,000 lb per sq. in. If the pressure is not within the range, it should be adjusted by means of the top screw on the nozzle. The pressure of the nozzle can be increased or decreased by tightening or slackening respectively the top screw on the nozzle. The spray should now be observed for its uniformity at a rate of pumping of about 20 strokes per minute by the operating handle. The nozzle should make a fine spray and the pintle point of the nozzle should remain dry and no drip should come from it. If the nozzle does not give a correct spray, it should be opened and examined for defects.

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(a) Dirt between nozzle valve and its seating — Clean valve and seating.

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(g) Unsuitable fuel.

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(i) Fuel system not correctly air vented.

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(c) Sludge at the bottom of the oil sump.

(d) Suction feed of oil pump choked.

(e) Oil pressure gauge defective.

(f) Oil pressure release valve not correctly adjusted.

(g) Some bearing damaged.

5.4. **Engine Becomes Overheated.**

(a) Bad lubrication.

(b) Cooling system choked.

(c) Loose compression; valve-adjustment incorrect; piston rings worn out or broken.

5.5. **Engine Knocking.**

(a) Loose or worn out bearings; loose key of flywheel. **(Take immediate action).**

(b) Over-loading of the engine.

(c) Cooling water too hot.

(d) Piston begins to seize; lubricating oil level too low.

5.6. **Hissing Of The Engine.**

(a) Cylinder head packing damaged.

(b) Piston rings broken.

5.7. **Excessive vibration.**

(a) Faulty timing.

(b) Fuel supply insufficient.

(c) Governor not working properly.

(d) Cooling water level too low.

(e) Valves in bad condition.

(f) Any one of the cylinders not functioning.

(g) Water in fuel.

5.8. **Smoky exhaust.**

5.8.1. If the exhaust smoke is black, then the exhaust valve is not tight. If the smoke is bluish, there is too much oil in the crank case and this oil is being expelled from it to the cylinders; or the adjustment of the valves is incorrect; or the nozzles are dirty.

5.8.2. The exhaust piping and silencer should be examined after about 500 working hours. These should be thoroughly cleaned and replaced if badly pitted and eaten up by heat. A choked exhaust will create many troubles in the running of the engine; it should not, therefore, be neglected.

6. INSTRUCTIONS FOR DRIVERS

6.1. **Observation during operation and general care.**

(a) See that the cooling water temperature remains between 120° and 180° F.

(b) Watch that the lubricating oil pressure is between 10 to 15 lb per sq. in.

(c) Lubricate the external parts of the engine during each shift.

(d) Periodically manipulate the fuel and lubricating oil filters.

(e) Observe that there is an adequate supply of fuel and lubricating oils, and note their consumption.

(f) Take periodical readings of all the pressures and temperatures including those of the exhaust gases.

(g) Note any point demanding attention after "shut-down" of the engine and maintain a proper record of repairs.

(h) At once look into and examine the condition of the piston, piston rings and valves if the engine consumes more fuel or lubricating oil or both than it should.

6.2. **DON'TS For Drivers.**

(a) DON'T use inferior fuel or lubricating oil.

(b) DON'T allow the fuel tank to run empty.

(c) DON'T stop the engine by turning off the fuel cock.

(d) DON'T use hard water for cooling.

(e) DON'T run the engine without cooling water or on very hot water.

(f) DON'T run the engine on loose bearings or a loose flywheel key.

(g) DON'T prolong idling of the engine.

(h) DON'T use cloth on any internal part of the engine. Cloth leaves small fibres on iron.

(i) DON'T fail to inspect and clean the nozzles and filters at regular intervals.

(j) DON'T disturb the setting of the fuel pump or tinker with the nozzles if you do not understand their functions properly.

6.3. The ability of the driver of the roller is judged by his ability to keep his roller clean and his machinery in such good

order that it may be corrected. Excessive fuel consumption is the sign of a bad driver and so is a roller that uses too much fuel or lubricating oil.

7. LOG BOOK

7.1. Every roller should have a log book in the form suggested at Plate II.

7.2. The log book should give the daily history of the roller throughout its life time. The following information should be recorded in the log book :—

(a) Name of driver.

(b) Times of starting up and closing down work every working day.

(c) Details of stoppages with dates when the roller is laid up and restarts work.

(d) Details of minor and major repairs carried out.

(e) Details of stores issued.

7.3. A separate register for recording repairs to be carried out during the shut down period and the actual repairs subsequently carried out should be maintained properly.

7.4. The log book and the repair register should be kept permanently on the roller and regularly inspected by the subordinates and the engineer responsible for the work. These Officials should make it a practice to inspect the log book and the register as often as they check the muster roll.

8. BONUS FOR DRIVER

8.1. The system of paying bonuses to drivers is recommended as it will give an impetus to drivers to take pains in their work. The bonus should be substantial and should not in any case be less than 25 per cent of the drivers' pay per month.

8.2. Full bonus should be paid monthly —

(a) If the driver works not less than 25 days in the month. DEDUCT PRO RATA whether idleness is his fault or not.

(b) If there are no breakdowns. DEDUCT if parts are broken and replaced — at discretion.

(c) If there are no bad reports during the month. DEDUCT if there are bad reports, excessive use of stores, dirty roller, etc. — at discretion.

(57)

Appendix I.

SPARE PARTS FOR THE INDIAN MANUFACTURED DIESEL ROAD ROLLER

I. Schedule I

[Parts to be kept as spares by the user]

Part No.	Description	No. to be kept in stock.
V.O.970	Atomiser Nozzles	Four for each roller
2-BH.4347	Manifold Gasket ...	One " " "
VO.6850	Valve Spring (Outer) ...	One " " "
VO.46	Valve Spring (Inner) ...	One " " "
4 VPH.118	No. 2 Fuel Filter Element ...	One " " "
4 VPH.118	No. 5 / No. 6 / No. 10 / No. 12 — Set of joints for Fuel filter ...	One set " "
GDQ.2107	Clutch-lining with rivets ...	Four " " "
GDT.2102	Clutch driving bolts ...	Six " " "
GDQ.11174	Bottom Water connection ...	One " " "
GDQ.115	Top Water Connection ...	One " " "
	Links ⅜" whittle fan belt ...	Six " " "
GDT.11144	Hose connection for Auxiliary pipe ⅝" dia. × 4" long ...	One " " "
GDT.1206	Roll clips & Banding for GDT. 11144 ...	Two " " "
GDQ.10636	Set Brake linings with rivets	Two " " "
95 P 4	Kingfisher Lubricator	One " " "
95 P 6	Kingfisher Lubricators ...	Two " " "
H.29	Tecalemit Grease Nipples ...	Eight " " "
H.A.39	" " " ...	Two " " "
H.A.44	" " " ...	Two " " "
	Assorted Nuts ...	One lot " "
	Split pins spring washers ...	One lot " "
	Asbestos string ...	½ lb Ball " "
	Elements for Volco Air Filter ...	Two for each roller
GDQ.4026	Pawls for Hydraulic coupling	Two " " "
GDT.4025	Pawls pivot Pins "	Four " " "
GDT.4028	Spring Pins " "	Two " " "
GDT.40213	Springs for " "	Two " " "

7. **Cooling System.** The engine cooling system shall be of an efficient radiator type. It shall be of ample cooling capacity and suitable for the climatic conditions specified in para. 6 of this specification.

8. **Governor.** The engine shall be provided with a sensitive governor for controlling the speed.

9. **Filters.** Ample air and lubricating oil filters shall be provided. These shall be suitable for "desert" conditions.

10. **Fuel Tank.** The fuel tank shall have a capacity sufficient for at least 30 hours' running under normal working conditions.

11. **Clutches.** The clutches shall be suitably protected and be of the fabric lined or other approved type. The clutches shall have renewable linings easily accessible for inspection and service.

12. **Gear Box & Gearing.** The gears shall be totally enclosed in a robust gear box having an oil bath or in which is incorporated a suitable oil pump providing ample lubrication to all wearing surfaces; input and output shafts shall be efficiently isolated. The gear ratios as provided shall be such that the roller is capable of operating in either direction within a range of 7/8 m. p. h. to 4 m. p. h. All gear box shafts, except the output shafts, shall be of suitable alloy steel and all heavily loaded fast running shafts shall be mounted in adequate ball or roller bearings.

13. **Differential.** The differential gear shall be efficiently guarded and lubricated. If inside the main gear box, it shall comply with B. S. specification No. 436 as far as applicable; and if incorporated outside the gear box, the pinions and bevel wheels shall be so constructed and fitted that when assembled the load is evenly distributed between all the bevel pinions. A locking device shall be provided so as to put the differential gear out of action when required.

14. All gear cases shall have covers of ample size and readily removable for examination.

15. **Final Drive.** The final drive shall be through spur gears direct to the rear rolls and be effectively guarded and lubricated.

16. **Lubrication.** Lubrication of the diesel engine shall be by an efficient forced feed system operated by an oil pump of ample size and with an efficient strainer. The remainder of the

lubrication throughout the roller shall be of an effective type suitable for operation in tropical and desert conditions and by semi-skilled labour. The lubrication fittings shall include weather- and dust—excluding reservoirs of large capacity. Details of the method of lubrication shall be shown in the Technical Schedule—Annexure I.

17. **Front and Rear Rolls.** The rolls shall be constructed of cast iron of a high quality equal to that of the best imported makes or alternatively of mild steel. All wheels including the front roller shall have detachable centres. The holes for securing these centres to the outer portion of the wheels shall be big drilled in order to ensure absolute interchangeability. The front wheel or roller shall be in two parts each revolving independently of the axle and its path shall overlap the paths of the rear wheels by not less than 2" on each side. Good quality bronze bushes shall be provided in the wheel bearings. The front rolls shall be not less than 3′ 3″ dia. × 2′ 10″ wide (in halves) and the rear rolls not less than 4′ 6″ dia. × 1′ 4″ wide. The thickness of the front rolls shall be not less than 1″ if of cast iron or 3/4" if of mild steel; the thickness of the rear rolls shall be not less than $1\frac{1}{4}$" if of cast iron and $1\frac{3}{8}$" if of mild steel. The hubs shall have renewable gun-metal bushes and shall be lubricated by "Stauffer" type lubricators or by pressure type lubrication.

18. **Scrapers.** Adjustable spring scrapers shall be provided at the front and rear of the rear wheels and adjustable scrapers at the front and back of the front roller.

19. **Variation in Rolling Pressures.** Tenderers shall put forward their proposals for providing ballasting or other device to give road pressures on the rear rolls ranging from 350 lb to 470 lb per inch width of rim. Water ballasting will not be accepted for this purpose.

20. **Brakes.** Two independent brakes shall be provided, one operated by foot, the other by hand. These brakes shall act on large diameter brake drums. One brake may act on the transmission but at least one brake must act direct on the rear wheels. The brake bands shall be lined with approved friction material giving adequate holding power under all climatic conditions. Either brake shall be capable of holding the roller stationary on an incline of 1 in 5 in either direction.

21. **Forecarriage and Fork.** The fork shall be of cast steel or mild steel. The forecarriage and forecarriage bracket shall be of ample strength for rough usage.

22. **Steering Gear.** The steering gear shall be controlled by a hand wheel acting through a worm gear and spirally grooved chain barrel and chains on the front roll fork, or through other approved type of mechanism.

23. **Shafts.** All shafts including axles shall be of good quality mild steel suitably finished and working in well lubricated bronze bushed bearings, or in adequate ball or roller bearings.

24. **Exhaust Pipe.** The exhaust pipe or pipes shall be lagged where necessary and shall be carried clear to one side of the roller or to above the awning.

25. **Centre of Gravity.** The centre of gravity of the roller shall be as low as possible consistent with the provision of suitable road clearance.

26. **Awning.** An awning extending the full length of the roller shall be provided. This shall be of sheet metal lined with timber or of other approved design.

27. **Curtains.** Side and end "roll-up" curtains of heavy waterproof material shall be supplied together with straps and buckles for securing these when not in use.

28. **Draw Bar.** A strong cast steel or mild steel draw bar attachment shall be fitted at the rear of the roller. A forged steel draw bar pin shall be provided, attached to the roller by a chain.

29. **Controls.** All operating levers, controls, brake pedals, levers, and steering wheel shall be so situated that the driver will have an unobstructed view of all operations. A suitable and comfortable seat shall be provided for the driver.

30. **Accessibility.** All machinery shall be so designed and arranged as to afford easy access for cleaning, lubrication repairs and adjustment.

31. **Operating Characteristics.** The tenderer shall submit with the tender full details of the operating characteristics and capacity of the roller in the form shown in the accompanying Technical Schedule—Annexure I.

32. **Equipment.** The tenderer's standard set of accessories shall be provided. A full detailed list of these shall be included in the Technical Schedule—Annexure II.

Note :—Water sprayers, water filters, winding drums and lamps are not required, but lamp brackets must be provided so that the purchaser may fit his own lamps for night driving if desired.

33. **Extracts.** The tenderer may quote as an extra for any or all of the following :

(a) Provision of a hydraulic coupling "Fluidrive" incorporated in the main drive from the engine.

(b) Provision of power steering.

(c) Any item which he recommends, not included as standard equipment or not mentioned in this specification.

34. **Instructional Literature.** An Instruction Book or books dealing with maintenance of the power unit, transmission, steering gear and all moving parts of the roller together with a lubrication chart shall be supplied with each roller. Spare copies of these books and charts totalling twice the number of rollers ordered shall be supplied in addition.

35. **Tools.** The tenderer shall supply with each road roller such tools as are required for the efficient maintenance and operation of the roller at site. Particulars of tools proposed shall be included in the Technical Schedule (Annexure II). The tools shall include one 10-ton lifting and traversing jack of approved make. A fitting shall be cast on or securely attached to the front fork or other convenient place, to hold the jack on the roller while it is travelling.

36. **Tool Box.** A spacious and well fitted lock-up sheet steel tool box to accommodate all tools shall be supplied. The box shall be "built in" or welded on the roller.

37. **Spares.** The tenderer shall show in the Technical Schedule (Annexure II) a full list of spare parts he recommends to cover a period of 2 years working and two copies of a comprehensive illustrated spare parts list shall be supplied with each roller.

38. **Finish.** The roller shall be painted with a high quality weather resisting paint.

Inspection and test.

39. Every engine shall be tested under load on the test bench prior to fitting in the roller.

40. The first engine of a type (selected at random by the Inspecting Officer from the batch) shall be tested under brake at engine builders' works and under such test must give the output at its normal speed over a period of 6 hours of the H. P.

at which it is rated, as given by the maker in the attached Technical Schedule Annexure I. After satisfactory test all bearings and wearing surfaces shall be opened up for inspection. The finished roller after completion and painting shall be weighed in the presence of the Inspecting Officer on a suitable weigh-bridge. The roller shall then be loaded to full working weight and tested on the road under all normal conditions of service. It will be required to climb an incline of not less than one in five. The brake shall be tested on this incline and shall hold the roller securely in either direction. The roller shall steer and manoeuvre, with the engine working at all speeds forward and reverse, to the entire satisfaction of the Inspecting Officer. After satisfactory road test the bearing and wearing surfaces shall be opened up for inspection. Subsequent rollers of that batch shall be given a road test at the discretion of the Inspector.

41. **Cost of Testing**. The contractor shall provide all labour, facilities, tools and apparatus necessary for all tests. The cost shall be included in the tender price.

42. **Acceptance**. Approval in writing from the Inspector shall be the only acceptance.

43. Each roller shall bear a maker's nameplate bearing the the following identification particulars:

Maker's name .....

Type and size of roller .....

Serial Number .....

Contract No. .....

Indent No. .....

Govt. Mark (as given on the schedule) .....

44. **Government Marking**. The marking given in the schedule shall be cast on the maker's nameplate.

45. **Packing**. After approval, the roller shall be securely and suitably prepared for rail or sea transport. All easily detachable fittings shall be removed and separately packed; jointing materials where necessary must be included for refitting. Bright parts shall be efficiently protected from corrosion where necessary and shall not be packed in straw. All packages shall have stencilled upon them in good oil paint the consignee's address as given in the schedule. Cases shall have stencilled

upon them in addition net and gross weights and description of contents. Stencil plates shall be provided by the contractor. A packing notes, detailing the stores, indent number and item numbers is to be enclosed in each package. A duplicate copy of this packing note shall be sent separately to the consignee by registered post and a triplicate copy shall be provided for the Inspector.

46. **Drawings**. The contractor shall supply without charge one general arrangement print of each roller to a scale of not less than $\frac{3}{4}$" per foot. He shall also supply in duplicate with each roller such arrangement drawings as are necessary to enable the purchaser adequately to maintain and repair the engine and other parts of the rollers. Such drawings may at the contractor's discretion be incorporated in the instruction book referred to in para. 34 hereof. All drawings shall show the I.S.D. No, the Contract No. and the date, the Indent No. and date, the Item No. and the name of the contractor. The drawings shall be handed to the Inspecting Officer at the time of final inspection and will be initialled by him as correctly representing the roller as made and finished.

TECHNICAL SCHEDULE—Annexure I

Technical data to be given at the time of tendering:—

(1) (a) Weight in working order.....tons.....cwts.

(b) Net weight of empty roller.....tons.....cwts.

(2) Ground pressure per inch of width

Front roller maximum.....

,, ,, minimum.....

Hind Wheels maximum.....

,, ,, minimum.....

(3) Method by which rolling pressure is varied.....

(4) Number of gears and speed in each gear on level.....

(5) Maximum grade roller will climb.....

(6) Minimum turning circle (outside radius).....

(7) (a) Steering rollers.....dia.....width.....thickness

(b) Driving wheels.....dia.....width.....thickness

(8) Design and material of frame.....

(9) Design and material of forecarriage and fork.....

(10) Lubrication, method of.....
(a) Engine.....
(b) Transmission.....
(c) Chassis.....
(11) Road clearance.....

DIESEL ENGINE

(12) Makers
(13) Type
Maker's type or size (code) description.
(14) Cylinders, number.
(15) Cylinders bore and stroke
.....in. × stroke.....in.
(16) R.P.M. normal.
.....revs. per minute.
(17) Rated output at 30 in. mercury 62° F.as defined in B.S.S. No. 649 B.H.P.....
(18) B.H.P. required to drive the Road Roller on the level when fully loaded and ballasted.
(19) Reserve of Engine Power available after allowing for working with the roller ballasted and fully loaded at a temperature of 125° F humidity 90 per cent altitude 2,000 ft. and on a Gradient of 1 in 5.
(20) Guaranteed consumption of fuel oil in lb per hour under normal working conditions at site.
(21) Consumption of lubricating oil lb per hour in the engine under normal working conditions at site (no credit to be taken for recovered oil):
.....lb. per hour
(22) Specification of lubricating oils recommended.
(23) Engine Cooling System:
(a) Type
(b) Radiator
(c) Water Circulation.
(d) Maximum temperature of cooling water, leaving the cylinder jackets when the engine is working at the rated output given under Item 17.

TECHNICAL SCHEDULE - Annexure II

(a) **Standard Accessories & Tools.**

To be specified in detail by Contractor, but shall in general consist of the following:

Tool Box, steel, with galvanised padlock and two keys.

Hammer, fitters' 1½ lb.

12 inch second cut file with handle.

Cold Chisel.

Two shifting spanners, 0 in. to ¾ in., and ¾ in. to 1 in

Full set double ended spanners.

½ gallon can filled with lubricating oil.

Grease in tin ..... 7 lb.

One pint oil feeder.

Water funnel.

Petrol funnel.

2 gallon galvanised bucket.

Assorted split pins.

Pinch bar.

Clutch adjusting tools.

2 lb cotton waste.

Frost cogs, or suitable non-slip fittings in lieu shall be provided if called for in the contract schedule.

(b) **Spares.**

The Contractor shall give a list, with prices, of the spare parts recommended for 2 years' normal working.

Appendix III.

LIST OF PARTS No. 1

HEAD, BRIDGE, FORECARRIAGE and FRONT ROLLS

(Vide Plate IV)

Spec. No.	Name of Part.	No. in set.	Manufacturers' Part No.
1.	Steering Spindle.	1	G.D.F. 0007
2.	Head with 3 Bushes fitted.	1	G.D.F. 2368
3.	Front Rolls & Axle.	2	G.D.F. 2380
4.	Hub for front Rolls.	2	G.D.F. 23825
5.	Steering Worm case.	1	G.D.F. 24235
6.	Registration Number Plate.	1	G.D.H. 1344
7.	Horse-Trade mark.	1	G.D.H. 1346
8.	"INVICTA" Scroll.	1	G.D.H. 1347
9.	Scraper for front Rolls.	2	G.D.H. 1376
10.	Bridge and pivot Pin assembly.	1	G.D.H. 2360/2
11.	Bridge.	1	G.D.H. 2365
12.	Black Plate for "INVICTA" Trade mark.	1	G.D.H. 1345
13.	Forecarriage casting.	2	G.D.H. 23620
14.	Inner Bearing seal.	1	G.D.H. 23815
15.	Front Axle.	1	G.D.H. 23823
16.	Rim for front Rolls.	2	G.D.H. 23824
17.	Bush for front Rolls.	4	G.D.H. 23826
18.	Disc for front Rolls.	4	G.D.H. 23827
19.	Steering Segment.	1	G.D.H. 24211
20.	Steering Pinion & Shaft.	1	G.D.H. 24212
21.	Steering Worm Wheel.	1	G.D.H. 24220
22.	Washer plate for front Scrapers.	4	G.D.T. 1377
23.	Bush in head for Steering Pinion.	1	G.D.T. 2364

Spec. No.	Name of Part.	No. in set	Manufacturers' Part No.
24.	Fixing Pin.	1	G.D.T. 2367
25.	Wearing Plate.	1	G.D.T. 2369
26.	Bracket for Transfer Weights.	2	G.D.T. 13217
27.	Warning Plate.	1	G.D.T. 13439
28.	Dowel for Wearing Plate.	2	G.D.T. 21520
29.	Locking Screw for front Axle.	2	G.D.T. 23624
30.	Trunnion Pin for Forecarriage.	2	G.D.T. 23634
31.	Locking Plate for Trunnion.	2	G.D.T. 23635
32.	Cap for Wearing Plate Head.	1	G.D.T. 23636
33.	Nut for Wearing Plate Head.	1	G.D.T. 23637
34.	Setscrew for Retaining Disc.	6	G.D.T. 23644
35.	Retaining Screw for Bearing Seal.	1	G.D.T. 23816
36.	Felt Washer for Bearing Seal and Forecarriage Casting.	4	G.D.T. 23817
37.	Adapter for Axle Grease Nipples.	4	G.D.T. 23818
38.	Forecarriage Side Frame complete with Axle Bearings.	2	G.D.T. 23632
39.	Washer for Worm Wheel.	1	G.D.T. 24236
40.	Collar for front Drawlug.	1	G.D.T. 30513
41.	Spring for front Drawlug.	1	G.D.T. 30514
42.	Locating Screw for front Drawlug Collar.	1	G.D.T. 30515
43	R. H. Bracket for front Lamp and Transfer Weights.	1	G.D.Q. 1394
44.	L. H. Bracket for front Lamp and Transfer Weights.	1	G.D.Q. 1395
45.	Bush for head—Top, with Setscrew.	1	G.D.Q. 2362
46.	Bush for head—Bottom, with Grubscrew.	1	G.D.Q. 2363

Spec. No.	Name of Part.	No. in set.	Manufacturers's Part No.
47.	Transfer Weights.	28	G.D.Q. 13216
48.	Manufacturers Plate.	1	G.D.Q. 13430
49.	Reference Plate.	1	G.D.Q. 13431
50.	¼" Dia. holes with Threads.	4	G.D.Q. 13432
51.	Back Plate for Forecarriage Casting.	2	G.D.Q. 23621
52.	Felt-Ring for Dust Excluder.	1	G.D.Q. 23625
53.	Wearing Plate Head.	1	G.D.Q. 23638
54.	Cover for Head.	1	G.D.Q. 23639
55.	Retaining Disc for Pivot Pin.	1	G.D.Q. 23640
56.	Clamp for Wearing Plate Head.	1	G.D.Q. 23641
57.	Pivot Pin.	1	G.D.Q. 23642
58.	Cover plate for Worm Case.	1	G.D.Q. 24229
59.	Front Drawing.	1	G.D.Q. 30512
60.	¾" B.S.F. × 2" fitting bolts.	56	3W8
61.	¾" B.S.F. Nuts.	92	22P8
62.	¾" dia. Spring Washers.	88	27P8
63.	¾" B.S.F. × 2¼" long fitting Bolts.	24	3W8
64.	¾" B.S.F. × 3¼" long.	4	16P8
65.	¾" B.S.F. × 6" long Bolts.	4	16P8
66.	⅝" B.S.F. × 1½" long Setscrew.	4	18P7
67.	⅝" dia. Spring Washer.	9	27P7
68.	⅜" B.S.F. × 1" long Setscrews.	2	18P3
69.	¾" B.S.F. × 5" long Setscrew.	4	18P8
70.	⅜" dia. Spring Washer.	13	27P3
71.	¼" Grub Screw.	1	108PS
72.	Setscrew.	1	18PS
73.	Armoured hose ⅝" dia. bore 2 ft long.	1	Stand
74.	¾" Elbow.	1	B.S.F.

Spec. No.	Name of Part.	No. in set.	Manufacturer's Part No.
75.	⅜" back Nut.	1	B.S.F.
76.	⅝" B.S.F. × 2" long Stud.	4	17P7
77.	1½" dia. Setscrew.	1	18PS
78.	⅝" B.S.F. × 2½" long Bolt.	8	16P7
79.	¼" B.S.F. × ¾" long Bolt.	1	16P10
80.	⅝" B.S.F. × 3¾" long Bolt.	1	16P7
81.	Tecalemit Grease Nipple for Axle.	2	H29
82.	0.120" dia. Holes.	4	No. 31 drill
83.	Spring Washer.	1	27P10
84.	1 5/16" Key.	1	38P
85.	⅜" B.S.F. × ¾" long Setscrew.	11	18P3
86.	6" dia. locking Wire.	1	
87.	1¼" dia. Spring Washer.	2	27P5
88.	⅝" Nut.	12	22P7
89.	Spring Washer.	8	28P7

LIST OF PARTS No. 2

HIND AXLE ARRANGEMENT

(Vide Plate V)

Spec. No.	Name of Part.	No. in set.	Manufacturer's Part No.
1.	Driving Ring.	1	G.D.F. 12532
2.	Locking Bracket for Hind Axle.	2	G.D.H. 2306
3.	Dust Guard.	2	G.D.H. 12535
4.	Hind Axle.	1	G.D.H. 23039
5.	Hind Roll Rim.	1	G.D.H. 24025
6.	Hind Roll Outer Disc.	1	G.D.H. 24027
7.	Hind Axle Cap.	2	G.D.Q. 23033
8.	Locking pin for Hind Axle.	2	G.D.T. 2307
9.	Felt Washer.	4	G.D.T. 2308
10.	Bracket for lubricator.	4	G.D.T. 12533
11.	Clip for GDT 23059 (on Gear box)	2	G.D.T. 12534
12.	Distance Piece for Guard-Short.	6	G.D.T. 12537
13.	Distance Piece for Guard-Long.	2	G.D.T. 12538
14.	Connecting Strip for Guard.	2	G.D.T. 12539
15.	Pin for Hind Axle cap.	2	G.D.T. 23035
16.	Lubricating Pipe, Final Drive Pinion.	2	G.D.T. 23058
17.	Lubricating Pipe, Differential Shaft Bearing.	2	G.D.T. 23059
18.	Horizontal Grease pipe.	1	G.D.T. 24030
19.	Clip for GDT 23058	2	S.A.T. 10810
20.	Rotherham $\frac{1}{4}$" B.S.P. union body	1	Standard.
21.	Rotherham T4 Brass Tap, with Nut & Nipple.	1	Standard.

Spec. No.	Name of Part	No. in set.	Manufactures' Part No.
22.	$\frac{5}{16}$" B.S.F. × $\frac{3}{4}$" long Bolt.	6	16P2
23.	$\frac{3}{8}$" B.S.F. × $1\frac{1}{4}$" long Bolt.	4	16P3
24.	$\frac{1}{2}$" B.S.F. × $2\frac{1}{2}$" long Stud.	6	17P5
25.	$\frac{5}{8}$" B.S.F. × $4\frac{3}{4}$" long Stud.	2	17P7
26.	$\frac{5}{8}$" B.S.F. × $\frac{3}{4}$" long Setscrew	12	18P3
27.	$\frac{1}{2}$" B.S.F. × $\frac{3}{4}$" long Setscrew	2	18P5
28.	$\frac{5}{16}$" B.S.F. Nut	6	22P2
29.	$\frac{3}{8}$" B.S.F. Nut.	4	22P3
30.	$\frac{1}{2}$" B.S.F. Nut.	6	22P5
31.	$\frac{1}{2}$" B.S.F. Lock-nut.	2	23P5
32.	$\frac{5}{16}$" B.S.F. Spring-Washer.	6	27P2
33.	$\frac{3}{8}$" B.S.F. Spring-Washer.	16	27P3
34.	$\frac{1}{2}$" B.S.F. Spring-Washer.	8	27P5
35.	2" × $\frac{1}{4}$" × 2" long split Pin.	2	29P8
36.	$2\frac{1}{4}$" long Key for Hind Axle.	2	38P13
37.	2" Kingfisher Blued steel oil lubricator $\frac{1}{4}$" B.S.P.	4	95P6
38.	$\frac{1}{4}$" B.S.P. Socket.	4	Standard.

BOOK REVIEW

Traffic Surveys Under Indian Conditions by C. S. Anantapadmanabhan, Roads Organisation, Ministry of Transport. Published by the Manager of Publications, Delhi; 1950, pp. iii + 75; paper bound; Price Rs 2-6-0 or 6s.

This handy volume discusses fairly exhaustively various methods of traffic survey employed in India and such of the methods adopted in foreign countries as are specially applicable to Indian conditions and comments on the merits and demerits of each method.

While primarily intended for traffic surveys on roads, the volume is sure to interest others—railway officials concerned with surveys in connection with proposed railway lines, port trust officials designing yards and clearing routes, economists studying economic aspects of transport, statisticians interested in applying statistical technique to transport problems, in fact all those interested in the study of traffic problems and locomotion in all its aspects.

The book treats of volumetric surveys of traffic, both urban and rural, and origin and destination surveys. It describes the analysis and presentation of data in tabular, and graphical or map form, and tells clearly of the various practical uses to which traffic survey data can be put. It gives the method of forecasting traffic while, at the same time, warning the reader of the dangers involved in drawing hasty conclusions.

Till now there has been, in this country, no readily available compendium of the various possible methods of carrying out traffic surveys under Indian conditions. This compilation will supply this want and form a useful book of reference.