The Indian Roads Congress as a body does not hold itself responsible for statements made, or for opinions expresed, in the Papers, Research Notes, Information Service or discussions in its Proceedings etc.

INDIAN ROADS CONGRESS

ESTABLISHED 1934 REGISTERED : 1937

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Indian Roads congress

1953-54

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24. S. C. Nayak
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27. D. V. Rao
28. Romesh Chandra
29. Sujan Singh
30. K. V. Thadani

PERSONNEL OF THE TECHNICAL COMMITTEES AND SUBCOMMITTEES

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H. Sunder Rao ... *Member-Secretary*

(i) *Geometric Design Division :*

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K. K. Nambiar
U. N. Mahida
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J. Subrahmanyam
N. V. Modak
P. L. Varma

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Chief Surveyor of Works, E-in-C's Branch
U. N. Mahida

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(i) *Location, Layout and Hydraulics Division :*

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G. R. Nangea
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A representative of Central Standards Office for Railways
A representative of the Poona Irrigation Research Station
A representative each from Lucknow, Madras, Karnal & Hyderabad Research Stations
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A representative of Soil Laboratory, West Bengal
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K. K. Nambiar
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M. S. Mathur
S. N. Chakravarti
Goverdhan Lal
Secretary, I.R.C., ... *Member-Secretary*

9. *MANUFACTURE OF ROAD MAKING MACHINERY AND MECHANIZATION SUBCOMMITTEE:*

R. S. Bhalla ... *Convenor*
S. N. Chakravarti
U. N. Mahida
L. R. Patel
Sujan Singh
A representative of Engineer-in-Chief
H. P. Sinha

10. *ORGANIZATION COMMITTEE:*

H. P. Mathrani ... *Convenor*
S. N. Chakravarti
H. P. Sinha
K. K. Nambiar
U. N. Mahida
U. J. Bhatt
Kishore Lal
Secretary, I.R.C. ... *Member-Secretary*

The Consulting Engineer (Road Development) to the Government of India is an ex-officio Member of all Committees and Subcommittees)

INDIAN ROADS CONGRESS

NOTICES AND ANNOUNCEMENTS

CONTRIBUTION OF PAPERS FOR THE NINETEENTH SESSION OF THE INDIAN ROADS CONGRESS

The next General Session of the Indian Roads Congress is likely to be held sometime in January—February 1955. The exact date, place, and programme of the Session will be communicated to Members in due course.

2. **Procedure**: Members who intend to contribute Papers on any subject connected with Highway Engineering are requested to intimate the fact to the Secretary, Indian Roads Congress, and to send a short synopsis of their proposed Papers as early as possible.

On receipt of acceptance of the subject matter of the Paper, the Member concerned should send his contribution to the Secretary, Indian Roads Congress, complete in all respects and with original drawings, photographs, etc., **as and when ready**. At least **three** copies of the typescript matter should be sent, typed (double space) on one side of good stout paper of foolscap size.

3. The complete Paper, if intended to be read at the nineteenth Session, should preferably be submitted within the next six months.

From past experience it is observed that most of the Members send in their contributions at the last moment, when the Congress office is busy on work connected with the Session. As it takes a long time to get Papers printed in the Journal and as it is desirable that Members should have time to study Papers well in advance of the date of the Session, it is hoped, that Members will make an effort to send their contributions as and when ready.

Members may please note that Papers received late in the year are likely to be carried over to the next year.

4. The younger engineers are particularly requested to contribute Papers which, if required, will be suitably edited by the Indian Roads Congress office before publication.

5. **MEDALS**: The following Medals are available for award:

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(*i*) **The Mitchell Medal**:

For exceptionally good Papers contributed to the Indian Roads Congress in any year. This has been instituted to perpetuate Sir Kenneth Mitchell's connection with the Congress.

(*ii*) **The Indian Roads Congress Medal**:

For Papers considered by the Council of the Indian Roads Congress to be of a decidedly more than average merit.

6. The Council have reserved the right to award more than one Medal in any year or to withhold the award of a Medal in any year without assigning any reason. All Members are eligible for the award of the Medals.

7. Rules and Regulations for the contribution of Technical Papers and the Award of Medals are published on pages 8-13.

II. RULES AND REGULATIONS FOR THE CONTRIBUTION OF TECHNICAL PAPERS AND THE AWARD OF MEDALS

1. The following Medals are available for award:

(*i*) **The Mitchell Medal**:

This is a bronze medal to be awarded annually for exceptionally good Papers contributed to the Indian Roads Congress in any year. This has been instituted to perpetuate Sir Kenneth Mitchell's connection with the Indian Roads Congress.

(*ii*) **The Indian Roads Congress Medal**:

This is also a bronze medal to be awarded annually for Papers considered by the Council of the Indian Roads Congress to be of a decidedly more than average merit.

2. PROCEDURE FOR CONTRIBUTION OF TECHNICAL PAPERS

2.1. Our procedure in the past had been to invite Members to contribute Papers a few months before the holding of the General Sessions of the Indian Roads Congress. On receipt, the accepted Papers were circulated in advance to Members for prior study a month or so before the date fixed for discussion. This procedure resulted in the receipt of a large number of Papers all at one time and editing and printing had often to be done very hurriedly. Also Members often found that one month did not give them sufficient time to study all the Papers before the discussion at the Congress Session.

2.2. It has, therefore, been decided by the Council that Members should be invited, to contribute technical Papers throughout the year, as and when they are ready, and that the accepted Papers should be published in the Journals of the Society which, it is hoped, will be issued quarterly in future.

2.3. The Council considers that this will give Members more time to study the Papers and will also facilitate editing and printing. A record of the discussion and the comments received by correspondence will be published with the Author's replies in the Journal issued after the General Session.

2.4. It will be realized that it will only be possible to give effect to this new scheme if Members co-operate. The Council makes this special appeal to members to contribute Papers for discussion throughout the year at their convenience.

3. RULES FOR THE CONTRIBUTION OF TECHNICAL PAPERS

3.1. The Standing Rules for guidance when contributing Papers, as now slightly amended, are reprinted below. It is requested that Members read these rules and observe them when submitting Papers to the Congress.

3.2. Members intending to contribute Papers to the Indian Roads Congress on any subject connected with Highway Engineering are requested to send their contributions to the Secretary as and when these are ready without waiting for a special invitation.

3.3. Final acceptance of the Papers rests with the Council. In order, however, to avoid disappointment through the Council having to reject Papers owing to an excessive number being written on any one subject or for any other reason, it is requested that any Member intending to write a Paper should intimate to the Secretary the subject on which he wishes to write and enclose a short synopsis of the proposed Paper. He will then be informed whether his offer can be accepted.

3.4. The Council reserve the right to publish any Paper in the form of an abstract. When a Paper is published in abstract form the manuscript copy of the Paper as sent by the Author will be added to the Indian Roads Congress Library and made available for inspection by interested Members.

3.5. The Council have decided that Papers from non-Members who are experts or who have specialized knowledge will be welcome and acceptance of the Paper will carry honorary membership for the Author for the year provided there are good reasons that the contributor cannot join the Congress as an ordinary member.

3.6. The Council have expressed the opinion that Members, when choosing subjects for contributing Papers, should bear in mind the fact that there is often a good deal more to be learnt from failures than from success.

4. SCRIPT

4.1. The following instructions are for the guidance of Authors of Papers:

a. **ALL CONTRIBUTIONS SHOULD BE DRAFTED IN THE THIRD PERSON.**

b. Papers should be typed on one side of good stout paper of foolscap size, double spacing being used and an ample margin (not less than 2 inches) should be left on the left hand side. **At least three copies of the typescript matter should be sent.**

c. The Author's full name, designation, academic qualifications and correct postal address should be given below the title of the Paper.

5. ILLUSTRATIONS

5.1. Illustrations fall into two classes, *viz.*,

a. Line drawings.

b. Half-tones.

5.2. *Line drawings* should be made in black Indian ink on superior white drawing paper or tracing cloth. Blue prints are of no use for reproduction and black line prints are also unsatisfactory.

Line drawings are generally classified into two categories :

a. Diagrams which go into the body of the Paper.

b. Plates which are generally on separate large size sheets.

5.3. *Diagrams* :—The matter for the Journal is printed in 10 pt. size type (nearly 1.1 in. height); therefore, the written matter in diagrams should be so made that the size of the letter when reduced for reproduction should be about 1/16 in. The printed area of a page measures $6\frac{3}{4}$ in. deep by $4\frac{1}{4}$ in. wide. Therefore, the ultimate size of such drawings will not generally be more than 5 in. × 4 in. Thus, if a diagram is to be reduced to one quarter of the size submitted by the Author, the lettering on it should not be less than $\frac{1}{4}$ inch in height.

5.4. *Plates* :—Plates should preferably be prepared in widths that are multiples of $7\frac{1}{2}$ in. The size of letters used in the plate should be so chosen that after reduction no letter would be less than 1/16 in. in size. Thus if the width is 15 in. the minimum size of the letter should be $\frac{1}{8}$ in. The thickness of the letter should also stand corresponding reduction. The title should be in the right hand bottom corner in letters of such size that when reduced the size will be at least $\frac{1}{8}$ in. The name of the Author may be printed, if desired, at the bottom right hand side.

5.5. Scale should be drawn in the plate below the title to admit of reduction of drawings without altering the correct relation of the scale to the drawing. Mere mention of the scale thus "Scale 10 ft=1 inch" should be avoided as this would be incorrect when the size of the plate was reduced photographically.

5.6. Coloured inks should *not* be used. When it is desired to distinguish lines, dotted or chain dotted lines should be used instead of colours.

5.7.1. In drawing diagrams or graphs, the following points deserve the consideration of Authors.

5.7.2. From the stand point of pleasing appearance, a rectangular graph or drawing with proportions between 3 by 5 and 3 by 4 is to be preferred to a square one.

5.7.3. The appearance and effectiveness of a graph depend in a large measure on the relative width of lines used in its component parts. The thickest line should be used for the principal curve. If several curves are presented on the same graph, the line width used for curves should be less than that used when a single curve is presented. Co-ordinate rulings should be the narrowest in thickness. Principal reference lines such as the axes should be wider than other rulings but narrower than curves. For the size of reduction that is usually adopted, for the I. R. C. Journals, it is considered that the thickest line *when finally reduced* should not be more than $2\frac{1}{2}$ points, *i.e.*, 0·035 inch in width.

5.8. Finished illustrations should not be folded for purposes of despatch. When mailed flat, they should be stiffened by using card boards or rolled with the drawing outside to prevent cracking of the Indian ink lines and securely packed.

5.9. "*Half-tones*" are ordinary photographs and it is necessary to see that prints are clear, slightly over printed and preferably glazed. Photographs which are dim or out of focus do not come out distinctly in reproduction and make a bad "half-tone". Negatives should accompany the photographs whenever possible, and will if desired be returned when done with. Captions should be written on the back of prints in soft pencil.

6. BRIDGE DETAILS

6.1. Members contributing Papers on any bridge work actually carried out are requested to give *inter alia* the following details.

a. A site plan showing the road and river for two miles on either side of the bridge site ;

b. A dimensioned cross-section of the roadway ;

c. The loading on which the design is based ;

d. The cost per square foot of the elevation area comprised by the formation level and the bottom of the foundations ; and

e. The ratio of the total cost of the substructure to the cost of those parts of the superstructure as are subject to variation with variation of span.

7. UNITS

7.1. Members are particularly requested to use the standard units of weight, measure, and cost given below :

STANDARD UNITS OF WEIGHT AND MEASURE

	Description of work	Units to be adopted.
1.	Road material such as metal gravel or moorum, sand	100 cu. ft.
2.	Binder in surface dressing and grout	lb per 100 sq. ft.
3.	Binder in premix, carpets, etc.	lb per cu. ft. of aggregate.
4.	Cement	By weight and not by volume.
5.	Water Cement ratio	...gallons of water per cu. ft. of cement (assumed as 90 lb)
6.	Cost and Rates	In Indian Standard currency (Rupees, etc.)

8. FORMULAE

8.1. Mathematical formulae should be drawn carefully by hand and not set out with the typewriter.

9. ABBREVIATIONS

9.1. The use of abbreviations should be avoided. For 6'-2" × 3'-3" should be written 6 feet 2 inches by 3 feet 3 inches. Similarly 225° C. should be written as 225 degrees centigrade, and so on.

10. ITALICS AND EMPHASIS

10.1. Only those words and phrases which are to be printed in italics should be underlined.

11. PARAGRAPHING

11.1. When divisions and sub-divisions are designated by numbers and letters, the following symbols may be used in the arrangements indicated.

I.

II.

1.

2.

a.

b.

(i)

(ii)

12. ACKNOWLEDGMENTS

12.1. Sources of quotations appearing in the Papers should be stated and acknowledgment should be made for all information culled from books, periodicals, and proceedings of sister societies, etc.

III. PROCEDURE REGARDING THE DISCUSSION OF PAPERS AT THE ANNUAL SESSIONS OF THE INDIAN ROADS CONGRESS

1. The order in which Papers will be taken up for discussion will be decided by the Council and intimated to members attending the Session.

2. Every Chairman presiding at the discussion of a Paper will be introduced to the audience in appropriate terms. Similarly, the Chairman will introduce the Author and will call upon him to present his Paper for discussion. (The Paper will be taken as read.) Introductory remarks shall not ordinarily take more than 10 minutes and, unless the Author had something new to say which came to his notice since the submission of his Paper, the introduction should be limited to 250 words. After the introduction, the Paper will be open to discussion.

3. To facilitate the conduct of business and the fixation of time for various sittings and individual Papers, those desirous of raising questions or offering comments at the meeting should inform the Secretary well in advance (*at least* **24** *hours before the meeting*) about the Papers on which they would like to speak and the time they would take. Those who have not given the required intimation to the Secretary may, at the discretion of the Chairman be allowed to take part in the discussion if time permits and after those who have intimated their intention to speak in advance have spoken.

4. A copy of or the nature of the comments which a member intends to make should be sent in advance to the Author of the Paper and a copy endorsed to the Secretary.

5. If the comments are likely to take more than ten minutes or if they involve lengthy mathematical matter or diagrams, it would be desirable to send a copy of these to the Secretary at least 2 weeks before the date of the meeting so as to enable him to have them printed and circulated to all members attending the meeting before the discussion on the Paper takes place. These comments may, at the discretion of the Chairman, be taken as read and the members making them will thus only be required to explain generally the nature of his comments. The Author will, if possible, reply at the meeting as if the comments had been made orally.

6. Members who do not want to speak but want clarification of any issues arising out of the discussion or the introductory remarks of the Author should write out their queries on "Comment Slips" which will be provided for the purpose while the discussions are in progress. Volunteers will be deputed to distribute and collect these slips at frequent intervals. The slips will be sorted out by the Secretary and at the end of the talk by the Speaker or Speakers, the Chairman will read out the queries and the Speaker or the Author will give a reply.

7. Members who are unable to attend the Session and who desire to comment on any Paper should send one copy of a note of their comments to the Author of the Paper and two typescript copies to the Secretary. A gist of the comments together with the Author's reply thereto will appear in the Proceedings.

8. After all members wishing to do so have spoken on a Paper, or when the Chairman considers that because of lack of time the discussion must be brought to a close, the Author will be called upon to reply.

9. If the author of a Paper is unable to be present, he should depute another member to introduce his Paper and to reply to the discussion and should inform the Secretary accordingly.

IV. LIBRARY

1. Information and books on loan from the libraries of the Consulting Engineer (Road Development) and the Indian Roads Congress are available to **Members** of the Indian Roads Congress and can, on application, be had of the Secretary, Indian Roads Congress, New Delhi under the following arrangements :

(a) **For Members of the Indian Roads Congress who are in the service of the Central or State Governments.**

Specifically named books or literature in response to enquiries on technical subjects will be sent to officers of the rank of Executive Engineer and above. Others should apply through their Executive Engineers or officers of equivalent rank.

(b) **For members of the Indian Roads Congress who are not in the service of the Central or State Governments.**

Application for specifically named books as well as enquiries for literature on technical subjects should clearly state the Member's roll number, his correct postal address, and the title and author of the book.

2. The library is intended primarily for reference. It is the source of information from which the Secretary, Indian Roads Congress, is enabled to answer enquiries addressed to him.

3. **Books are loaned for reference only and not for continuous use.** The library cannot be expected to relieve officers of the necessity of purchasing books required constantly or for long periods of time.

4. Ordinarily not more than two books will be issued at a time, but in special cases a larger number may be issued at the discretion of the Secretary.

5. The following rules will be strictly enforced ;

(a) Books are issued for one month in the first instance. If a book is required for a longer period, an intimation should be sent to the Secretary, Indian Roads Congress for renewal before the due date of return. The book may then be re-issued for another month

NOTE: All Members of the Indian Roads Congress, not in arrears of subscription for more than 90 days, are entitled to borrow books.

at a time at the discretion of the Secretary, but in no case will any book be issued for a total period exceeding three months.

(b) If a member does not return library books when the period of loan has expired or in any case within three months of the date of issue and thus deprives other members of their use, he will be liable for a fine at the rate of one anna a day for every day of retention up to three months and two annas a day thereafter up to six months. The Secretary will also have no power to issue any more books to the member until all the books already issued are returned. If all books are not returned within six months, twice the cost of the books will be debited to the borrower in addition to the fine referred to above.

(c) Current issues of Journals cannot be issued to members outside the Consulting Engineer's (Road Development) Office, but back issues of certain Journals may be sent on loan for a limited period.

(d) Books are issued strictly subject to the condition, in all cases, that they will be returned promptly if actually required and called for by the Secretary, Indian Roads Congress. Retention of a book after it had been recalled will render the member liable to the same penalties as if he had retained a book beyond the period of original loan.

(e) Borrowers are requested to take every care of books while in their possession, and particularly not to mark, underline, or note on the pages.

(f) If, during the period of issue to a borrower, any book is lost or so damaged as to be unserviceable for future use, the Secretary shall recover from the borrower a sum equal to the cost of obtaining another copy of the book.

6. **Instructions :**

(a) No acknowledgment is required other than the postal acknowledgment card.

(b) While returning books, care should be taken to get them adequately packed to prevent damage in transit. They should be sent "**registered and acknowledgment due.**"

7. **General** :

(a) Rare or specially valuable books and certain books of reference will not be sent out of the library.

(b) Any book may, however, be consulted in the library during office hours.

(c) Members who retain books for longer than a month after they have been called back or for longer than six months from the date of original issue and thus selfishly deprive other members of the use of the books, will be fined and/or charged subject to the penalties stated in these rules and deprived of all the privileges of membership until the dues are paid.

V. NEW ADMISSIONS

LIST OF MEMBERS OF THE INDIAN ROADS CONGRESS ENROLLED FROM 28—3—1953 TO 3—11—1953

Serial No.	*Roll No.*	*Name*	*Address*
1358	1755	T. C. Agarwal	Assistant Engineer, Central P.W.D., 87-A, Colaba Road, BOMBAY.
1359	1756	Prem Chand Jain	Assistant Engineer, P.W.D., Nahan Sub-Division, NAHAN. (Himachal Pradesh).
1360	1757	S. Rajendran	Junior Engineer, Highways, KOVILPATTI, Tirunelveli District (Madras State).
1361	1758	C. S. Jain	District Engineer, P. W. D., B & R, RAMPUR. (U. P.)
1362	1759	A. C. Padhi	Assistant Engineer, C.W. & P. C., VI/15, New Capital BHUBANESWAR (Orissa).
1363	1760	M. T. Narasimhan	Junior Engineer, P. W. D., S/61, T. B. P. Damsite, P. O. HOSPET Taluq. (Madras State).
1364	1761	G. C. Pant	Assistant Engineer, P.W.D., Long View, NAINITAL. (U.P.)
1365	1762	D. N. Mishra	Sub Divisional Officer, P. W. D., (B & R), P. O. BERHAIT, Santhal Parganas District. (Bihar.)
1366	1763	K. R. Nagaraja Rao	Assistant Engineer, P. W. D., Panna Sub-Division, PANNA, (Vindhya Pradesh).
1367	1764	Jagmohan Malhotra	D-34 "C" Scheme, JAIPUR (Rajasthan).
1368	1765	A. Rangaswamy Iyer	Assistant Engineer, Highways, NAGAPATTHINAM, Tanjore District (Madras State).
1369	1766	M. K. Prabhu	Assistant Engineer, Highways, CALICUT. (MALABAR-Madras).
1370	1767	N. I. Rana	Deputy Engineer, P. W. D., Chandra Bhavan, Takhteshwar Plot, BHAVNAGAR. (Saurashtra).
1371	1768	G. Chalapati Rao	Special Junior Engineer, Highways Divisional Office (Highways), Chilakalapudi. MASULIPATAM, Krishna District.

Serial No.	Roll No.	Name	Address
1372	1769	Hotchand Hiranand Mamtani	Executive Engineer, C. D. O., Central Water & Power Commission, NEW DELHI.
1373	1770	M. C. Turkhia	Assistant Engineer, Municipal Engineer's Office, Crater, ADEN, Arabia.
1374	1771	S. Krishnappa	Surveyor Assistant (M.E.S.), C/o. Shri M. K. Subba Rao, B-7/125 Lodi Colony, NEW DELHI-3.
1375	1772	R. M. Gupta	Assistant Engineer, C/o. Sri Basant Lal, Mithapore, PATNA, (Bihar).
1376	1773	K. U. Abdul Azeez	Assistant Engineer, (Highways), P. O. TIRUPATTUR, North Arcot District. (Madras-State).
1377	1774	H. P. Sinha	District Engineer, C/o. Special Officer & Inspector of Local Works, PATNA, Bihar.
1378	1775	T. T. Selvam	Roads Engineer, C/o. Messrs. Standard Vacuum Oil Company, United Indian Building, Post Box No. 115, Esplanade, MADRAS-1.
1379	1776	K. C. Prinja	Regional Engineer, The Concrete Association of India, Exhibition Road, PATNA.

VI. DEATHS

The Council have received with regret intimations of the following deaths :

Serial No.	Roll No.	Name	Address
1	775	Anand Kumar	Regional Engineer, The Concrete Association of India, BANGALORE.
2	535	U. S. Ramasundaram	Superintending Engineer, P. W. D. TANJORE. (South India).
3	1094	A. N. Ganguli	Chartered Engineer, 7, Netajee Subhas Road, UTTARPARA P. O., HOOGHLY. (West Bengal).

Serial No.	Roll No.	Name	Address
4	533	D. N. Mallick	Executive Engineer, Mallick Villa, Grand Trunk Road, BURDWAN. (West Bengal).
5	1569	A. C. Mitra	Assistant Engineer, W & B Deptt., Bengal, 6, Sura First Lane, CALCUTTA-10.
6	329	K. G. Bhate	Deputy Secretary to the Government of Bombay, P. W. D., BOMBAY-1.

VII. 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 them are requested to forward particulars to Secretary, Indian Roads Congress.

Serial No.	Roll No.	Name	Address
1	1133	Banerji, S. K.	Assistant Executive Engineer, Assam Rail Link Project, SEVOKE, D. H. Railway.
2	887	Chari, T. V. R.	Assistant Engineer, Puttur Sub-Division, South Canara Division, PUTTUR. (Madras State).
3	652	Guruswamy, S. (L.M.)	No. 9, Appaswami Koil Street, P. O. Mylapore, MADRAS.
4	1253	Hasan, S. M. I.	Assistant Engineer, P. W. D. I/c Ranchi No. 3 Sub-Division, RANCHI, Bihar.
5	1026	Hege, W. D.	Asphalt Sales Engineer, C/o. Caltex (India) Ltd., P. O. No. 155, Ballard Estate, BOMBAY.
6	984	Mathew, K. M.	Executive Engineer, P. W. D. Sinculam Division, MUNNAR. (Travancore-Cochin).
7	90	Mohd. Aub Turab	Superintending Engineer (Retired), A/8 No. 220 Lane, Opposite Raj Mahal Talkies, LINGAMPALLY, Hyderabad-Deccan.

ADDRESSES WANTED

Serial No.	Roll No.	Name	Address
8	1185	Pratap, B.	Assistant Engineer, Planning Circle, C. P. W. D., A-20/67, Lodi Colony, NEW DELHI.
9	1390	Sanyal, P. K.	Executive Engineer (B & R). SHWEBO (Upper Burma).
10	1325	Sharan, Raghunath	Assistant Engineer, Waterways. CHAIBASA, Singhbhum, (Bihar).
11	682	Sreekantiah, C. K.	Assistant Engineer, TIRUVANNAMALAI, North Arcot District.
12	1354	Srivastava, G. N.	Executive Engineer, P. W. D., SAHARSA, O. T. Railway.
13	33	Syed Arifuddin	Retired Chief Engineer, 1246, Chadesghat High School Lane, Abid Road, HYDERABAD-DECCAN.

Paper No. 165

" A NEW METHOD OF APPLYING KENTLEDGE BY HYDRAULIC JACKS FOR SINKING FOUNDATION WELLS "

By

PROF. G. P. NAGARKAR & M. P. APTE

CONTENTS

SYNOPSIS

The Paper describes a new method of sinking foundation wells for bridges by the use of hydraulic jacks which has been successfully employed at the Sabarmati Bridge near Dholka. The merits and demerits of the older method of applying kentledge by sand bags are also given.

1. INTRODUCTION

In the course of construction of the R.C.C. bridge across the River Sabarmati on Nadiad Kaira-Dholka Road, the Authors were faced with the problem of sinking wells economically and quickly. So the technique af applying kentledge by hydraulic jacks was developed and successfully used.

2. SABARMATI BRIDGE

2.1. General.—The bridge is situated on the major district road connecting Nadiad to Dholka in the district of Ahmedabad and is an important link between Gujarat and Saurashtra. The road crosses the Sabarmati river about eleven miles from Kaira and six miles from Dholka.

2.2. Superstructure.—The bridge is a high level bridge of seven spans of 70 ft and two end spans of 56 ft each measured centre to centre of piers. The superstructure is a balanced cantilever. The deck slab is carried on a series of cross girders which are supported on two main beams. The main beams, suppported on piers, have two cantilevers of **14 ft**, one on either side, with suspended spans of 42 ft in length resting on the cantilevers.

2.3. Substructure.—The beams rest on sliding and rocker bearings fixed on the piers. Each pier consists of two R.C.C. columns, connected by a brace at the top, and erected on a cylindrical well of 9 ft internal diameter with 11 in. thick reinforced concrete steining founded on firm soil about 40 ft below the river bed. Plate I shows the details of wells and piers. The well steining has a 2 ft 6 in. high R.C.C. curb at the bottom. The wells were sunk 38 to 56 ft below the bed of the river. After sinking, they were sealed at the bottom with 5 ft deep concrete plug, filled with sand and finally sealed with 2 ft thick concrete at the top. R. C. C. well caps, were provided on which the columns rest.

2.4. In designing the wells, skin friction was neglected on account of the possible scouring effect. The top 15 ft of the soil consisted of layers of sand and below that the soil was alluvial. Plate II gives the cross section of the different strata under the river bed. A bearing capacity of five tons per sq. ft was assumed to be safe for the type of soil on which the foundation rested,

giving a safe total load of 520 tons for each well. The actual load on the foundations was 385 tons without any allowance for buoyancy of the wells.

3. SINKING OF THE WELLS

3.1. Plant and General.—The following equipment was used in sinking wells.

Two boilers, two steam winches, three dredgers, a concrete mixer, a concrete vibrator, six pairs of 50 ft long derricks for grabbing, six pairs of 40 ft long derricks for discharging the grab, pumps, chisels and other sundry equipment. Six wells used to be taken in hand for sinking at a time. Out of these, grabs were actually used only on two wells while the other four wells were being prepared for further grabbing or undergoing operations such as dewatering, loading and unloading of the kentledge, chiselling, concreting of the next portion of the steining, curing, etc.

3.2. Adopting 4 ft 6 in. Height of Steining.—It is not intended to discuss here at length the various difficulties met with during the sinking of the wells and the means used to overcome them. Only the part of the sinking, connected with the application of kentledge in the usual manner before the new method was evolved, is given.

It was found convenient to build up steining for a height of 4 ft 6 in. at a time. After this height of the steining was sunk down to the ground or island level, another 4 ft 6 in. height was concreted. Thus a well of 54 ft height was concreted and sunk in twelve stages. Indeed, it would have been convenient to have a larger height of the steining concreted at a time but in practice with the tools and the plant available it was not found possible to do so. The available derrick poles were only 50 ft long. The bigger grab had a chain length of about 32 feet. Allowing for the chain, grab, well steining above the ground, and a sufficient working space for free movement of the grab, it was not possible to increase the height of the steining to be concreted at a time. Moreover, a small height of steining above the ground level was desirable particularly because the wells had a tendency to tilt during the earlier stages of the sinking.

3.3. Frictional Resistance.—The need for applying kentledge arose specially because the design provided for a comparatively small thickness of the steining which meant very much reduced weight. The lead for metal and sand in the area was of the order of a hundred miles and therefore economy in the use of these materials was necessary. Moreover, it was feared that a large thickness of steining might prevent effective operation of the rail cutters if the well got stuck up in stiff clay. The dead weight of 132 lb per sq. ft. of the 11 in. thick steining was but a poor contribution to the sinking effort against the skin friction of the order of about 4 cwt per sq. ft. of the area of contact expected to come into operation during sinking. The dead weight of the steining would be reduced further due to buoyancy when the well was sunk below the water level.

3.4. Usual Method of Kentledge and Its Disadvantages.—In the beginning, when the new technique of applying the kentledge by hydraulic jacks had not been developed, the usual methods of loading the wells by dead load were adopted. A maximum kentledge of 180 tons was required for some wells. Pig iron or other heavy material was not available for loading. Therefore the wells had to be loaded with sand bags and boxes. To make up 180 tons, about 4,300 cubic feet of sand had to be put on the well (see photo 1). This method had the following disadvantages.

(a) The arrangement was cumbersome, there being two wells for each pier, with only three feet eight inches clear distance

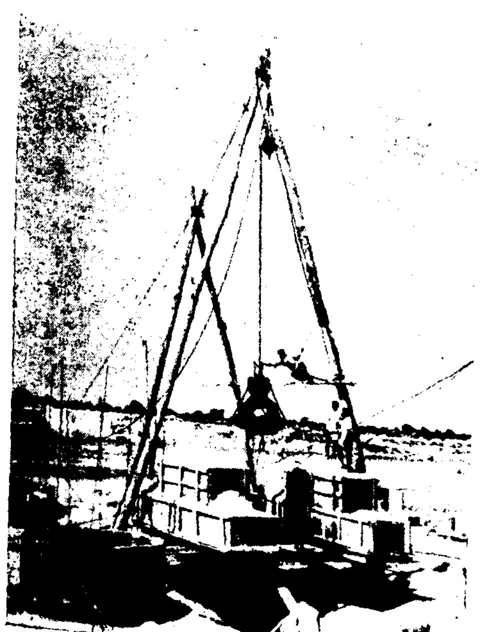


Photo 1: Kentledge by Sand Boxes.

between them. The grab had to work on the well with the dead load on and therefore it was very inconvenient to put a voluminous load which reduced the working space for the grab.

(b) To accommodate 4,300 cu. ft. of sand in a limited space meant piling up sand bags to a height of about 12 ft and so there was danger of a sudden collapse of the load from sudden sinking of the well steining.

A heap of sand bags about 12 ft high raised the position of the centre of gravity of the whole system considerably. This was very dangerous in view of the possibility of the well tilting either due to blowing in or uneven grabbing or meeting an obstacle. It was, therefore, found necessary to shift the load from side to side each time there was a little tilting.

(c) The most serious disadvantage of this method of applying kentledge was the time factor. As no mechanical devices were available, loading a well with 4,300 cu.ft. of sand in a limited space each time took about two days. When the 4 ft 6 in. height of the well steining was sunk down to the ground level, at least one day was required to unload the 4,300 cu. ft. of sand from the well before further concreting of the steining could be done. Thus three days were wasted during the sinking of every 4 ft 6 in. height of the steining. As mentioned earlier, the 54 ft well was built in twelve stages. Even assuming that no appreciable kentledge was required for the first three and that half the kentledge was used for the next four stages, the total working time wasted on each such well would be about 21 days. As the grabs and other machinery could not be kept idle, these had to be shifted from well to well several times during that period, causing waste of energy and money.

4. HYDRAULIC JACK ARRANGEMENT

4.1. Description.—Being confronted with the above mentioned difficulties in the application of the kentledge, the Authors devised and developed a method of applying kentledge by hydraulic jacks. Plate III shows the arrangement for applying kentledge up to a maximum of 200 tons. Four R. S. joists, each 24 in. by 7½ in. and 30 ft long, were laid horizontally in pairs across the well, thus forming two main beams. The clear distance between the beams, viz., 7 ft was just sufficient for the free working of the grab. The beams were in no way connected to the well, being independently supported at their ends by four columns each made of two R. S. joists, 4 in. by 1¾ in. and 6 ft long. The columns rested on cross R. S. joists of the same section laid horizontally on the ground. Each of the two main beams supported six suspenders, three on either side of the well as shown in Plate III. Each suspender was made in three pieces. The outer two pieces were made of $1\frac{1}{8}$ in. diameter bars bent to U-shape. The central piece was a screw coupling connecting the two U-shaped pieces. At their lower ends the suspenders were connected to the cross R. S. joists placed in pits. Over the cross R. S. joists were placed bullies and the whole space was then filled up with earth or sand. The buried R. S. joists served as good anchorages for the lower ends of the suspenders. It would be observed from the above description that the height of the columns being six feet, the lower flanges of the main beams were also at a height of six feet above ground level, while the height of the steining of the well was four feet and six inches. Thus there was a clear gap of 18 in. between the top of the steining and the bottom of the main beams. This gap accommodated the four hydraulic jacks placed at points A, B, C and D (see Plate III). The capacity of each jack being 50 tons, the total kentledge that could be applied was 200 tons. To distribute the load applied by each jack on a wide area of the top of the well steining a base plate was put under each jack. An angle iron guide frame was attached to the main girder above each jack to accommodate the several packing pieces that were added, one after the other, as the well sank. The guide frames could be lifted or lowered and kept at any desired level, depending upon the number of packing pieces, by inserting rods through the holes in the frame that were specially kept for the purpose. A list of materials required for applying a kentledge of 200 tons by Hydraulic Jack Method is given in *Appendix I*.

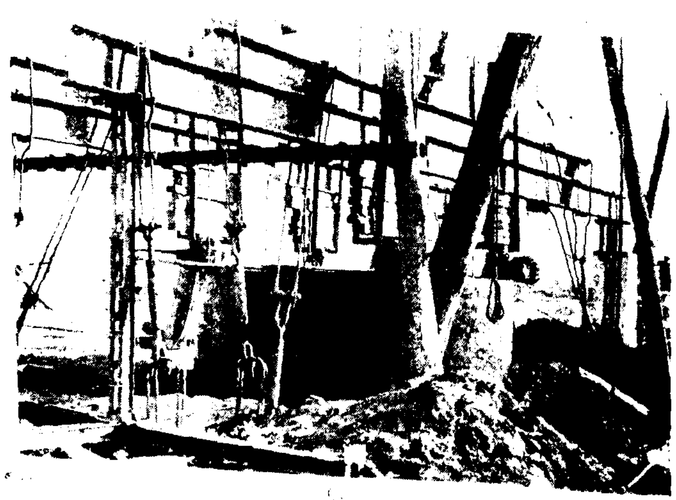


Photo 2: **View of the wells being pressed by Jacks.**

4.2. Working of the Arrangement.—After ensuring that a sufficiently deep *kundi* had been formed at the bottom of the well and that it was ready for being pressed down, four persons standing near the jacks, started operating the jacks. As the pressure of the jacks increased, the main girders tended to lift upwards but being securely anchored to the buried R. S. joists they did not move up. The reaction conveyed to the well made it sink. The lift of the ram of the jacks being only 6 in., the well

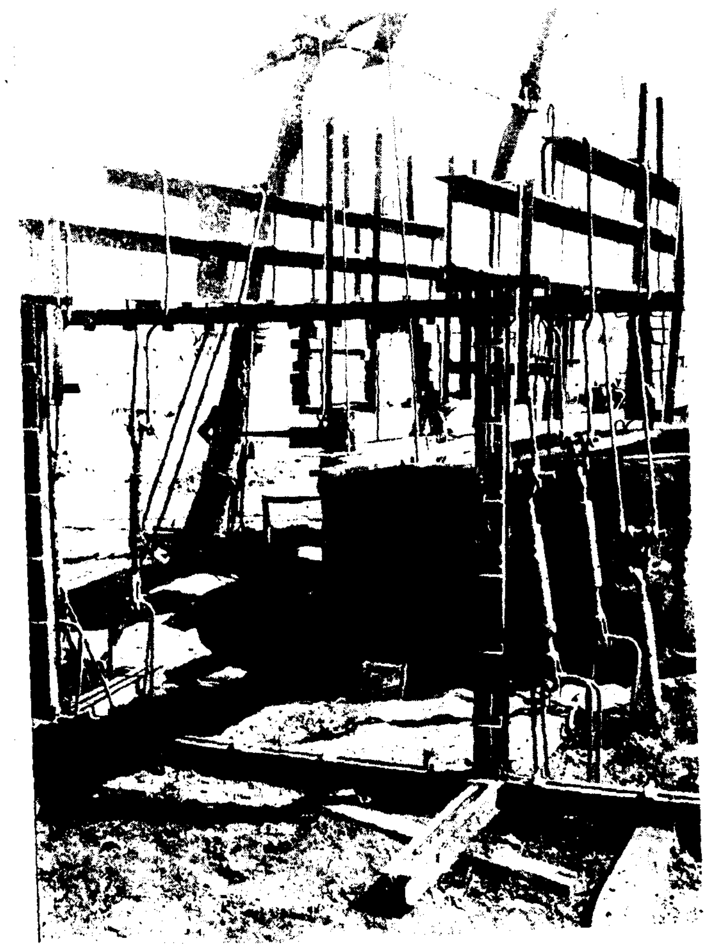


Photo 3: **Another view of the wells being pressed by Jacks.**

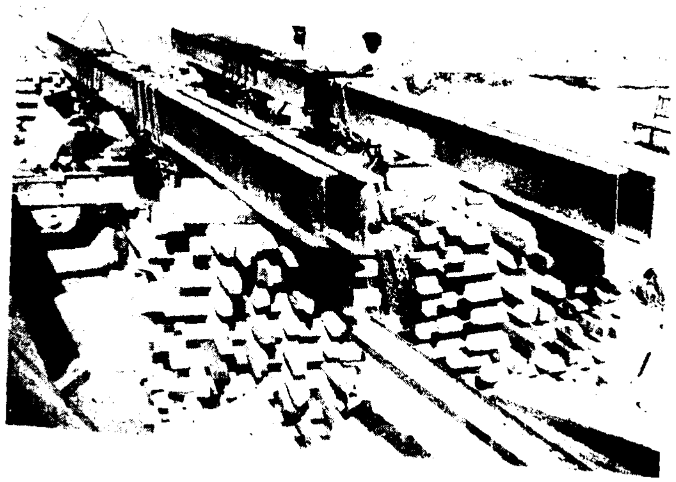


Photo 4: One more view of the wells being pressed by Jacks.

Photo 5: Dr. Jivraj Mehta—Minister for P.W.D. Bombay inspecting the Jack arrangement.

could be pressed only by about 5 in. at a time. For further pressing, the rams of all the four jacks were lowered by releasing pressure and then packing pieces were put one on each ram at a time. Pumping operation was again started and the well was sunk through a further depth of 5 inches. The process was repeated till the 4 ft 6 in. height of the well went down. When the packing pieces and the jacks were removed, the well was ready for concreting for the next stage. Photos 2 to 5 show the actual working of the method. Photo 2 shows kentledge arrangement for 120 tons where 24 in. by 7½ in. R. S. joists were substituted by smaller girders welded one over the other.

4.3. Advantages of the Method.—The following are the principal advantages of this method of applying kentledge.

(a) Once the buried anchorage, the main girders and the suspenders are ready in position, the steining can be loaded fully in half an hour. Unloading for the erection of the centering for the next stage requires removing the four jacks and the packings only. The main girders are not required to be removed. Thus there is a saving of time and labour.

(b) The kentledge does not suffer from the disadvantages of a high centre of gravity.

(c) Any tendency of the well to tilt can be easily corrected immediately it is observed by suitably varying jack pressures.

(d) There can be no accidents due to kentledge collapsing from a height.

(e) Only four persons are required for pressing the well. If uniform pressure in all the jacks is desired, they can be interconnected by means of a high pressure tubing and then only one man can operate the jacks.

(f) The load applied through the jacks is never more than necessary for sinking. If the pressures in the cylinders of the jacks are measured with the help of pressure gauges, the exact loads required for sinking can be calculated for the purposes of experiments and investigation.

(g) The new method is much cheaper than the orthodox method. A comparative statement giving the costs of the two methods is given in *Appendix II.*

4.4. Possible Developments.—The arrangement described above provides for a kentledge of 200 tons. The maximum limit to which the load can be increased with jacks is the safe compressive stress in the well steining itself. To load the wells to capacity, bigger hydraulic jacks or alternatively a larger number of them, can be used. The R. S. joists used over the jacks and the anchoring would have to be designed for higher loads to suit the circumstances.

4.4.1. The packings used by the Authors were hard timber pieces, 3 to 6 in. in thickness. They had to be put over the jacks one by one as the well sank by about 5 in. every time. Better results can be obtained if jacks with extending rams are used.

4.4.2. The anchoring R. S. joists were buried in pits by the sides of the well. But there is no objection to anchoring the hangers to the R. S. joists which could be kept on the ground itself and not in excavated pits. In the latter case a load which is a little more than the actual kentledge required for the wells must be kept on the joists so that the anchoring would be strong enough. This load would have to be left in position throughout the sinking operation. The arrangement would be more convenient where the load required is likely to occupy a large space and there is a possibility of blowing in. The anchoring actually used by excavating the pits had the advantage that the actual pull in the hangers could be much more than the dead weight of the soil excavated. This was due to the cohesion of the soil which was watered and rammed. Moreover, more working space was available round the well during the sinking operation.

4.4.3. According to the terms of contract, ten per cent wells of the Sabarmati bridge had to be loaded with 200 tons to ascertain whether they were set firm in position. The method of applying kentledge by hydraulic jacks described in this Paper is very convenient for testing wells. The load can be applied by means of jacks without any change in the method described above. Actually, one well was tested by the hydraulic jack arrangement described above.

5. DESIGN

5.1. General.—The design of the whole arrangement is quite simple. The sizes of only three members, viz., main girders, the suspenders, and the lower cross beams need to be calculated. Actually the arrangement has got to be assembled out of sections that may be available in the stores. As the arrangement is purely of a temporary nature, there is no harm in reducing the factor of safety specially as the failure of any part of the structure is not likely to cause catastrophe.

5.2. Bed Plate.—It is often found impracticable to wait even for a week to allow the well concrete to set before starting the sinking operation. In such cases it is absolutely necessary to distribute the jack reaction on a wider area of the well steining by the use of bed plates.

5.3. Deflection of the Main Beams.—It will be observed that though the total lift of the jacks is 6 in., it is not possible to sink the well by more than 5 in. at a time. The loss of about an inch is due to the deflection of the main beams and the elongation of the suspenders. By increasing the rigidity of these members the loss of one inch can be reduced.

5.4. Resistance Offered by Buried Anchorages.—The anchorages actually used on the Sabarmati bridge site consisted of R. S. joists buried in two pits, 22 ft by 10 ft by 7 ft each. Taking the density of compact sandy soil as 100 lb per cu. ft. the weight of the soil in these pits worked out to about 138 tons. Adding to this the weight of the steelwork, the total dead load came to 150 tons. Due to the cohesion of soil surrounding the pit, it was observed that the resistance offered by the anchorage proved to be greater than 200 tons. It was not possible to determine the ultimate resistance because of the limited capacity of the jacks.

6. CONCLUSION

Four wells out of the total number of twenty were sunk in the working seasons of 1951 and 1952 by the method described above. One well was also tested for full load. The new method was found to be very successful and economical and the ease with which the whole arrangement could be worked was really very encouraging to the Authors.

ACKNOWLEDGMENTS

Thanks are due to the Executive Engineer, Shri M. D. Kale, to the Superintending Engineers, Khan Bahadur Bulsara, and Shri G. K. Patil, and to the Chief Engineers, Shri M. L. Champheker and Shri U. N. Mahida for the encouragement given in using the new method. The bridge was designed and constructed by Messrs. S. B. Joshi and Co., Engineers and Contractors of Bombay.

APPENDIX I.

List of material required for applying kentledge of 200 tons by Hydraulic Jack method.

(1) Four hydraulic jacks, each of 50 ton capacity.

(2) R. S. Joists, four nos 24 in. × $7\frac{1}{2}$ in. × 30 in.

(3) R. S. Joists, 12 nos 10 in. × 5 in. and 22 feet long.

(4) Twelve nos. of U-shaped hangers for the top beams, prepared out of $1\frac{1}{8}$ inch diam. mild steel bars.

(5) Twelve nos. of inverted hangers connecting the anchorage joists and the couplings prepared out of $1\frac{1}{8}$ in. diam. mild steel bars.

(6) Couplings 12 nos. each strong enough to take a load of 17 tons.

(7) 24 rft. 3 in. × 3 in. angle iron for cleats on the main beams.

(8) 3 in. × 3 in. Angle iron, about 60 rft. for preparing guides for packings.

(9) Mild steel Bed plates for jacks 4 nos. 10 in. × 18 in. × $\frac{1}{2}$ in.

(10) Packing pieces of timber three to five inch thick.

(11) Bullies.

(12) Pressure tubing about 30 feet long if all the four jacks are to be inter-connected.

APPENDIX II.

Cost analysis for 200 ton kentledge by sand bags and Hydraulic Jacks.

Kentledge by Sand Bags

(1) Carrying, lifting and stacking sand bags quantity 4,500 cu. ft. i.e. 200 tons at Rs 2/- per 100 cu. ft. — Rs 90

(2) Unloading 4500 cu. ft. of sand at Rs 1/- per — Rs 45

Total Rs 135

100 cu. ft. on an average for each well loading and unloading operations are required to be performed seven times.

These would cost Rs 7 × 135	Rs 945
Add depreciation charges for sand bags or wooden boxes for stacking sand	Rs 120
Total kentledge charges for each well	Rs 1065

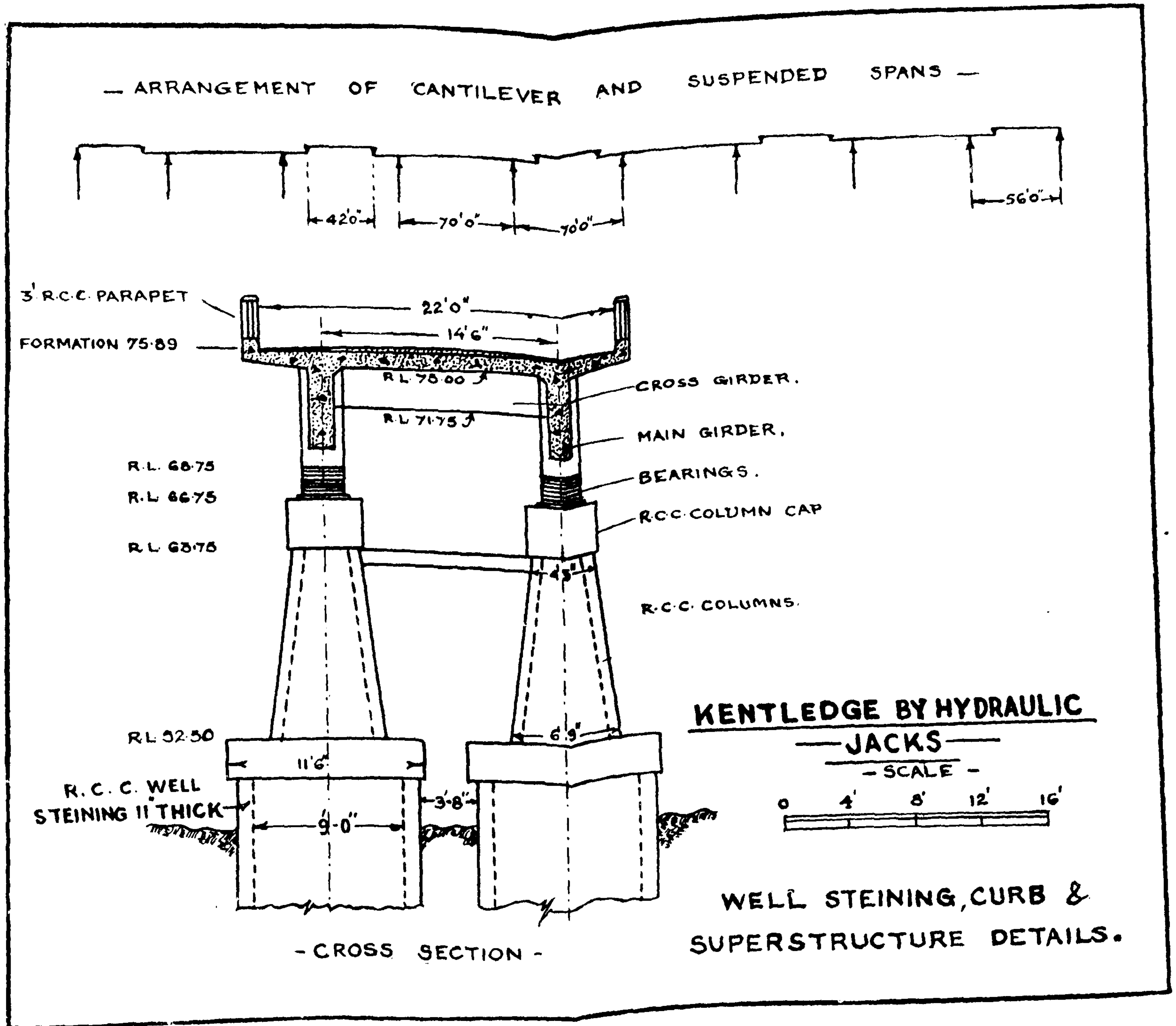
Note:—The depreciation or hire charges for R. S. Joists have not been taken into account as these are common items for both the methods of applying kentledge.

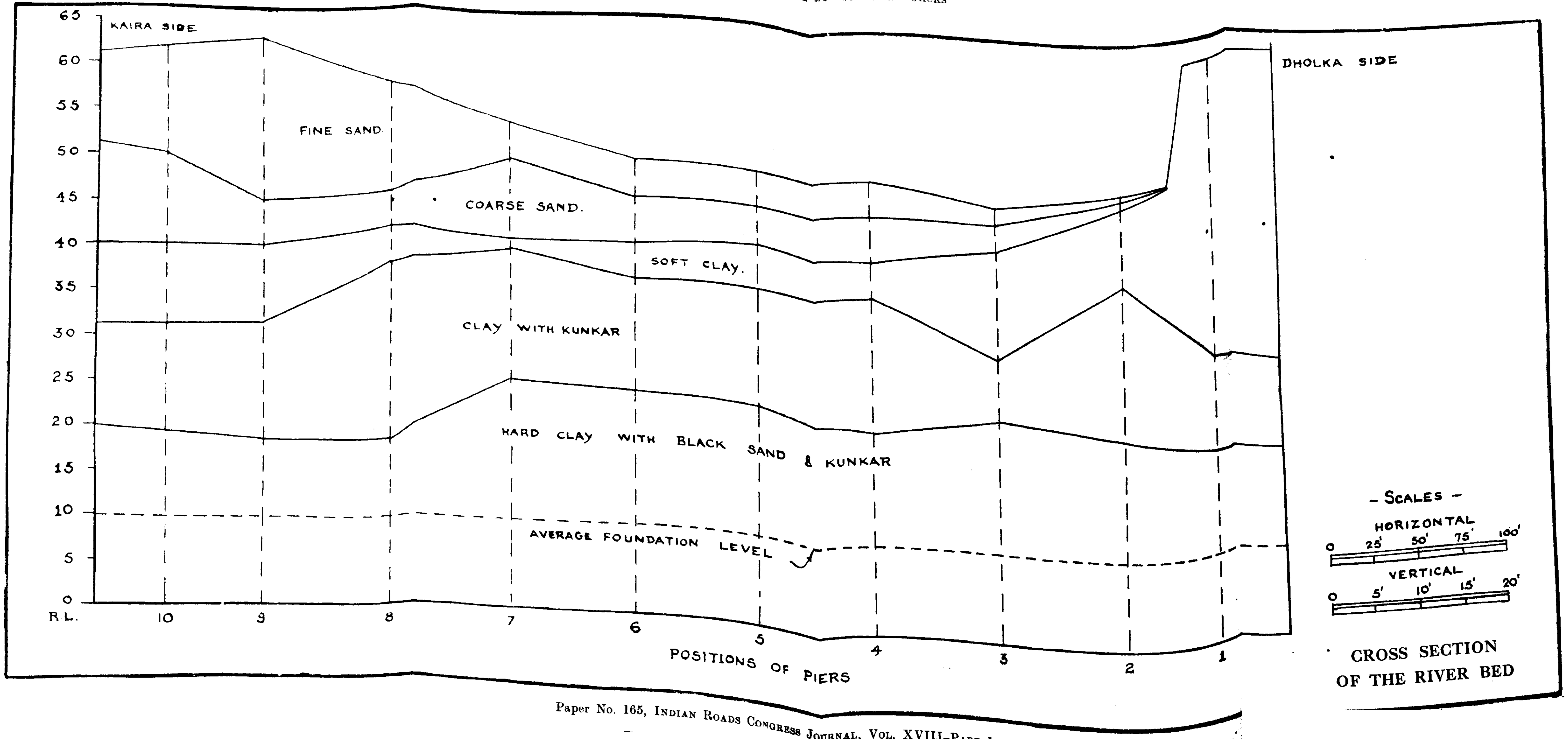
Kentledge by Hydraulic Jacks

Initial Expenses for each well:

(1) Labour charges for excavating the anchorage pits, 3200 cu. ft. @ Rs 2/-per 100 cu. ft.	Rs 64
(2) Labour for fixing the anchorages etc. 30 coolies at Rs 1/8/-	Rs 45
(3) Hire charges for jacks, say at the rate of 4 per cent cost of the jacks for each well	Rs 100
(4) Depreciation charges for hangers, timber planks, bullies etc., say	Rs 250
Running Expenses (Four coolies for loading and unloading the jacks during and after each stage of sinking the well for seven operations. 28 coolies at Rs 1/8/- per day.)	Rs 42
Total kentledge charges for each well	Rs 501

Note:—The cost of loading by sand bags increases directly as the load. But the cost when the hydraulic jack method is used is not materially affected if the load is increased. Therefore for higher loads the jack method is more economical.


— ARRANGEMENT OF CANTILEVER AND SUSPENDED SPANS —
42'0"
70'0"
70'0"
56'0"
3' R.C.C. PARAPET
FORMATION 75·89
22'0"
14'6"
R.L. 75·00
R.L. 71·75
CROSS GIRDER.
MAIN GIRDER.
BEARINGS.
R.C.C. COLUMN CAP
R.C.C. COLUMNS.
R.L. 68·75
R.L. 66·75
R.L. 63·75
4'3"
R.L. 52·50
6'9"
11'6"
R.C.C. WELL STEINING 11" THICK
3'8"
9'-0"
- CROSS SECTION -
KENTLEDGE BY HYDRAULIC JACKS
- SCALE -
0 4' 8' 12' 16'
WELL STEINING, CURB & SUPERSTRUCTURE DETAILS.



CROSS SECTION OF THE RIVER BED

Paper No. 166

"LOCATION OF ROADS IN HILLY AND MOUNTAINOUS COUNTRY"

By

B. Chaudhury, B.E., M.I.E. (Ind.)

CONTENTS

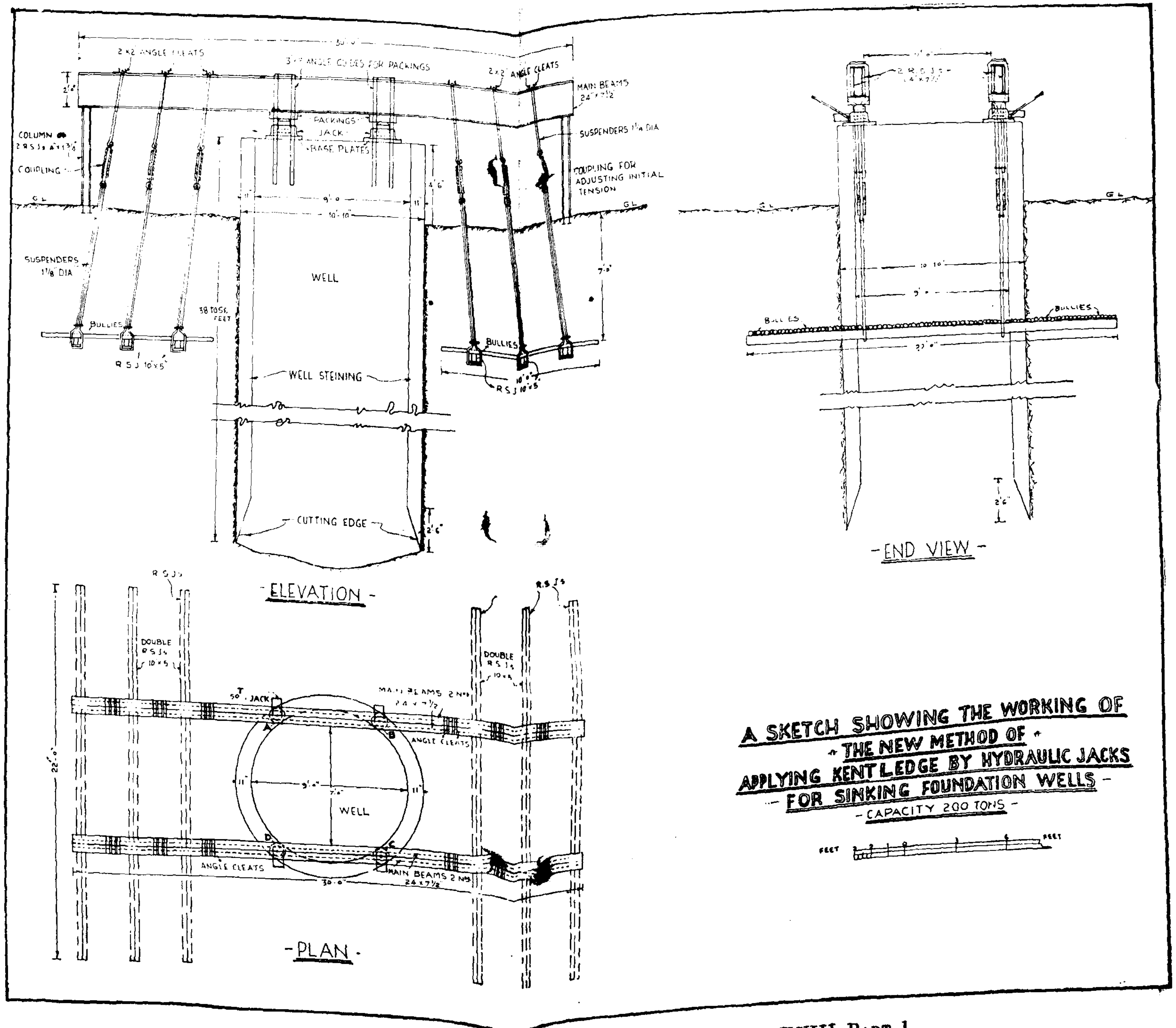
SYNOPSIS

The Paper describes the procedure to be followed in aligning a motorable road in hilly or mountainous country. The various field operations from the initiation of a proposal upto the completion of the detailed survey are described. Details of the personnel and equipment necessary for each of the operations, the information and data to be collected for the preparation of the project estimates and reports, and of the 'marks' to be left in the field, are given. The progress of field work that can be expected and costs under conditions in Assam are included.

1. INTRODUCTION

1.1. This Paper describes the details of the practice followed in Assam in regard to the location of hill roads and is placed before the Indian Roads Congress in the hope that during the discussion the special merits of this and other practices in various parts of the country will be brought out and placed on record for reference by the profession.

Plate III


A SKETCH SHOWING THE WORKING OF
THE NEW METHOD OF
APPLYING KENTLEDGE BY HYDRAULIC JACKS
FOR SINKING FOUNDATION WELLS
CAPACITY 200 TONS
ELEVATION
END VIEW
PLAN
WELL
WELL STEINING
CUTTING EDGE
BULLIES
SUSPENDERS 1⅛ DIA
COUPLING
PACKINGS
JACK
BASE PLATES
MAIN BEAMS 24"×7½
COUPLING FOR ADJUSTING INITIAL TENSION
DOUBLE R.S.J's 10×5
ANGLE CLEATS
MAIN BEAMS 2 Nos 24×7½
G.L.

1.2. The location (as also construction) of roads in hilly and mountainous country presents problems and difficulties which call for special care, attention and engineering skill.

1.3. The aim should be to establish the easiest, shortest and the most economical line of communication between the obligatory points, in consideration of the physical features of the country and traffic needs of the area served.

1.4. The principle which the Engineer should bear in mind is to so align the road that the vehicles could travel with ease and in safety, and that the expenditure of motive power and the wear and tear of the vehicle will be reduced to the minimum. Also the cost of construction and maintenance of the road should be as low as possible.

1.5. The economy of motive power (i.e. running costs and maintenance) is achieved by having easy grades, and avoiding infructuous rises and falls, and by following a direct line as far as possible between obligatory points enroute. Although directness, i.e. shortest distance is an important factor, it has to be sacrificed where it is essential to do so in order to obtain easy curvature and gradients and to avoid prohibitive cuts or fills. The gradient governs the speed and load capacity of vehicles more than curvature does. Any additional length allowed in attaining easier gradients or avoiding unnecessary climbs is amply justified. Power expended in a climb, which could be avoided, is a loss which reckoned over time can be enormous. It is, therefore, generally a sound policy to avoid steep gradients by increasing the length of the route within reasonable and economical limits.

2. TERMINAL AND OBLIGATORY POINTS AND THE SELECTION OF ROUTE

2.1. Decisions regarding the construction of a road and the selection of obligatory points enroute are usually made by the administrative and financial authorities having regard to the administrative and economic needs of the region or the necessity of developing it.

2.2. The Engineer's part mainly lies in finding out and locating a suitable route to meet the specified requirement. The route selected ultimately should ordinarily be the best from the view point of economy and technical feasibility, but sometimes deviations from technical perfection are forced when a number of conflicting interests have to be reconciled. The engineer in

charge should freely and boldly state and record his views bringing out the comparative merits and limitations of various alternatives and make his own recommendation to guide the administrative and financial authorities in taking decisions.

3. STANDARDS

3.1. The standards to be applied in the project depend on the service required, i.e., on the nature and volume of traffic that the road will have to carry, as also on the funds which can be made available for the project.

3.2. Gradients

	Ruling	Limiting	Exceptional
Important Hill Roads			
	1 in 20	1 in 15	1 in 12†
Minor Hill Roads			
Class II (Motor Roads)	1 in 17	1 in 15	1 in 12†
Class III (Jeep Roads)	1 in 15	1 in 12	1 in 10†

† For short lengths not exceeding 300 ft per mile.

3.3. Long stretches of gradients should be separated by comparatively easier grades or level lengths. Also the total rise or fall should not exceed 250 ft per mile in case of important roads and 300 ft per mile for other roads in hills.

3.4. Width of Formation. In the first phase of the work, the width of formation may be kept as 10 to 12 ft with temporary bridges and culverts constructed out of cheap local materials. The surface may be kept kutcha if the rainfall is less than 50 inches per year, and stabilized with the locally available stone or gravel if the rainfall is higher. In the second phase, the formation may be widened to 16 ft which is suitable for one lane traffic, or 24 ft if two lanes of traffic are to be allowed. Metalling and bridging with timber or steel or R. C. should be done to suit the need of traffic.

3.5. Radii of Horizontal Curves

Design speed in miles per hour	V	10	12	15	20	30
Radius of curve in feet	R	30	45	70	120	280

The minimum radius of horizontal curves adopted on hill roads in Assam is 60 feet. This is reduced to 40 ft in exceptional cases.

4. INCREASE IN LENGTH OVER "AIR DISTANCE"

4.1. The increase in length, also called "development", is required mainly for the purpose of obtaining satisfactory gradients. For example, in miles 54 to 57 of the Gauhati-Shillong Road (National Highway 40) a 3 mile length of road has been aligned to obtain the necessary gradient in climbing up to the top of a ridge whereas the shortest distance between the two end points does not exceed one furlong.

4.2. On some of the old and recently constructed hill roads in Assam, Tripura and Manipur, this increase in length is indicated in the Table below:

Road	Distance by air line in miles (approx.)	Length of road or alignment in miles	Increase in length over air distance	Approx. maximum & minimum elevation	
				Min.	Max.
			Per cent		
1. Gauhati-Shillong Road	40	63	60	180	4800
2. Shillong-Dawki Road	28	51	80	200	5900
3. Phulbari-Tura Road	28	48	70	50	2200
4. Dimapur-Kohima Road	30	46	55	300	4700
5. Mawphlong-Balat Road	32	48	50	200	4500
6. Jowai-Badarpur Road	46	82	80	100	4000
7. Shillong-Jowai Road	21	41	95	3000	5600
8. Bhagabazar-Kolasi Road	26	38	44	200	1500
9. Agartala-Assam Road	75	130	75	40	1100

4.3. This increase depends mainly on the character of the hills and the nature of the terrain to be negotiated. As a rough guide, a 70 per cent increase may be assumed in the preparation of estimates of the cost of survey, as also in framing rough estimates of the cost of construction. If, however, a bridle path or footpath exists and its length is known, 35 to 40 per cent increase over its length should do.

4.4. Estimate of the cost of surveying may preferably be prepared after the preliminary survey when the length of the proposed road can be estimated more accurately.

5. REPORTS

5.1. The report should give copious information to help the designer who may not be personally familiar with the ground. It should be written as the survey progresses and not left to the end of the work. It should be brief but full of useful data. The main faults of reports and notes are that they are not sufficiently clear and comprehensive on facts, and are couched in general terms which are not understood unless the writer is available to explain them.

5.2. A well arranged report should begin with a summary of the conclusions and then proceed to explain the details. An index should be included to facilitate reference.

5.3. Reports should be prepared on the lines given in the Ministry of Transport, Roads Wing Publication—"Highway Project Schemes, Recommended Practice for Preparation and Presentation".

6. STEPS IN ALIGNMENT

The various steps necessary in aligning a hill road are:

(a) Map Study

(b) Reconnaissance

(c) Initial location or Preliminary Survey

(d) The Detailed Survey.

7. MAP STUDY

7.1. Marking the Route on Survey Maps. One or more alignments of the proposed route should be marked on the Survey of India maps (one inch to one mile) of the area showing contours at 50 or 100 feet intervals. These alignments should touch the obligatory points. This forms the basis on which the first general examination or reconnaissance of the region will be carried out.

7.2. Fig. 1 represents the plan of a hill with contours at 100 ft intervals.

It is required to align a road from the village "A" at level 100 to the town "G" at level 600, at a uniform gradient of 1 in 16 say. The interval between the contours being 100, the plan of the road between any two contours will be the base of a right

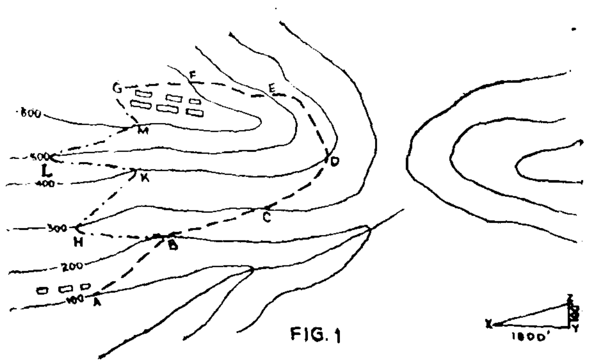


FIG. 1

angled triangle XYZ in which =1600 ft and YZ = 100 ft. Laying this distance (with the help of a compass) on the same scale as that of the map between the successive contours (see ABCDEFG) the required alignment is obtained. It may be possible to mark the route along the zigzag ABHKLMG*. But such a road is difficult and costly both in construction and maintenance and should be resorted to only when it is unavoidable.

From the route ABCDEFG marked on the map, its approximate length may be measured.

7.3. At this stage, it will be advisable generally to discuss the route marked with the administrative authorities and others possessing knowledge of the locality and to note their views and suggestions.

*Refers to serial number 8 in the bibliography.

8. RECONNAISSANCE

8.1. Reconnaissance means inspection at site of the principal physical characteristics of the area for assessing the feasibility of the alignments marked on the map and for selecting one or two routes to be investigated subsequently in detail. As visual impressions from a distance are often deceptive and cannot be depended upon in judging the physical character of an undulating or hilly region, it is advisable to check the hill slopes in places by means of simple instruments such as an Aneroid, an Abney's level, or a suitable clinometer.

Distances may be estimated roughly by pacing or the time taken in covering the distance.

8.2. The Party. This should consist of one experienced locating engineer, an assistant engineer, a guide (a local headman, forester or some one with the knowledge of the area), and a small party of khalasis (not more than four) who should also be local men. Additional men for the transport of camping kit, rations, etc., are also required.

8.3. Equipment. Two Aneroids, a clinometer or Abney's level, a pocket prismatic compass, one 100 ft tape, a foot rule with spirit level attached, a geologist's hammer and magnifying glass, note books, etc., are required.

8.4. Information to be Collected. The engineer in charge should carry out the reconnaissance himself, as this preliminary work is of the utmost importance. Copious notes should be taken so that a comprehensive report can be made to cover the following:

(i) Nature of the country, its physical features, including population, marketing centres, farms, economic potential, existing means of communications;

(ii) Lengths of alternative routes;

(iii) Possible grades:

(iv) Nature of hill slopes:

(v) Character of rivers to be crossed with important particulars:

(vi) Availability of construction materials, labour, foodstuffs, transport, camping sites, drinking water, etc.;

(vii) Quantities of earthwork involved, nature of soils encountered in various reaches;

(viii) Special features such as geology of rock formations, incidence of difficult and steep hill faces, gorges, slipping and subsiding sections, loose rock, hard rocks to be blasted, marshes to be crossed, etc. ; and

(ix) Comparative account of the merits of the various alternative alignments and recommendations as to which of them are suitable for detailed surveying.

8.5. General examination by walking or riding along the probable routes and marking the direction of the routes, on trees or with jhandis. This general examination enables the engineer to select one or two promising routes which have to be investigated in detail. It is not sufficient merely to walk along the line or lines marked in the map; one has to examine a wide belt on either side of the general direction of the route, thus covering all possible lines or combinations of lines.

It is essential to keep an open mind and try to improve on the alignments initially considered.

8.6 **Progress and Cost.** Two to four miles can be covered per day depending on the nature of the country.

The cost of reconnaissance varies between Rs 50/- and Rs 100/- per mile.

9. PRELIMINARY SURVEY

9.1. The routes selected as a result of reconnaissance become the subject of preliminary survey during which the selected lines are laid on the ground, at the proper gradients. The selection of the most suitable location is a sequence of the preliminary survey.

9.2. **Instruments Required.** A clinometer, Abney's level, or ghat tracer, a tape, some strings, a pole marked in feet, a prismatic compass, a geologist's hammer, a magnifying glass, some spades and jumpers, field books and note books, camping equipment, rations, etc. are required.

9.3. **The Party.** This should comprise:

(a) One experienced Assistant Engineer for direction along with some khalasis for clearing jungle.

(b) One Surveyor with one or two khalasis to assist in laying out the line and taking cross sections 500 to 1000 ft apart with the clinometer, Abney's level or ghat tracer. The Surveyor directs the muharrir who holds the staff for his instrument.

(c) One Muharrir, with three or four khalasis, to hold the staff for the surveyor, measure distances, cut and drive the grade and chainage pegs. One khalasi for holding one end of tape, one or two for cutting and supplying pegs, and one for driving pegs are usually required.

9.4. **Some Rules.** The line should always be traced in the field at somewhat easier grade than the one specified as ruling. Thus when the road is required to be aligned at a gradient of 1 in 15, it should be traced to a gradient of 1 in 17. This gives the designer latitude for some deviation from the field grade if required for making the design economical without exceeding the specified ruling gradient.

Similarly when negotiating a spur or a small valley, the grade should be kept flatter than that required for the finished work; viz., 1 in 17 for 1 in 15 and 1 in 22 for 1 in 20.

In locating the line during the initial layout or when carrying out the detailed survey, no attempt should be made to run in curves but the alignment should be a series of tangents along the hill faces. Short tangents should be used in going round any natural feature that will require a sharp curve in the finished road. The designer will adjust and shift his centre line as necessary for the design of the road to the standards required.

9.5. **Operation.** The Assistant Engineer should walk along the route about 200 to 300 ft ahead of the surveyor and direct the khalasis to clear the jungle. He may, with advantage, carry an Abney's level for preliminary and rough work. The width of jungle to be cleared should be 4 to 6 ft normally.

When the country is not densely wooded the clearing of jungle may follow the work of the surveyor; removal of one or two saplings, a few twigs or branches which came in the way or the line of sight of the surveyor might be sufficient to enable the surveyor to proceed forward in the initial work. It is, however, preferable (in the opinion of the Author) to have jungle cleared ahead of the surveyor, as it affords him a better view of the line and the country in general and, in addition, there is less chance of the survey pegs being disturbed than if the clearance is done subsequently.

The surveyor then lays out the line along the hill face with his instrument set at the required grade, directs the muharrir who holds the staff for him on the ground. The line is so laid that the formation is generally in side-long cutting, through cutting being permitted only where a narrow ridge or projection in the hill face has to be negotiated.

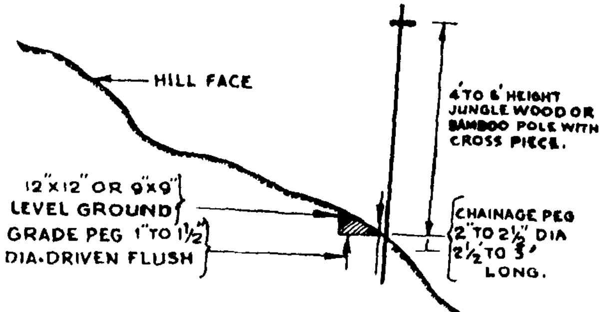


FIG. 2

When the staff is placed in the correct position on the ground, the surveyor beckons to the muharrir to drive in the grade peg (1½ in. diameter and 9 in. long) with its top flush with the ground at the proper place. The surveyor then checks the grade again and adjusts the top level of the peg if necessary.

Before this grade peg is driven, the hill face should be levelled with a spade, about 12 in. square, as shown in Fig. 2 and then a bamboo pole about 6 ft high and with a jhandi tied to it is fixed to indicate the position of the peg.

The muharrir then measures the distance of this grade peg from the preceding one with the tape, calls it out to the surveyor who records this in the field book. Then, he (the muharrir) drives the chainage peg about 2 in. dia. and about 3 ft long, 2 ft into the ground, writes on it with blue or red pencil (to be painted later) the serial number of the peg, the chainage and gradient (rise or fall) and proceeds ahead.

Whenever a high hill range has to be crossed, it is essential to select a suitable pass or saddle (which becomes an obligatory point) and to work from the top downwards. This is more convenient than working from bottom upwards, as in the latter case there is a possibility of missing the pass or saddle especially when the country is densely wooded.

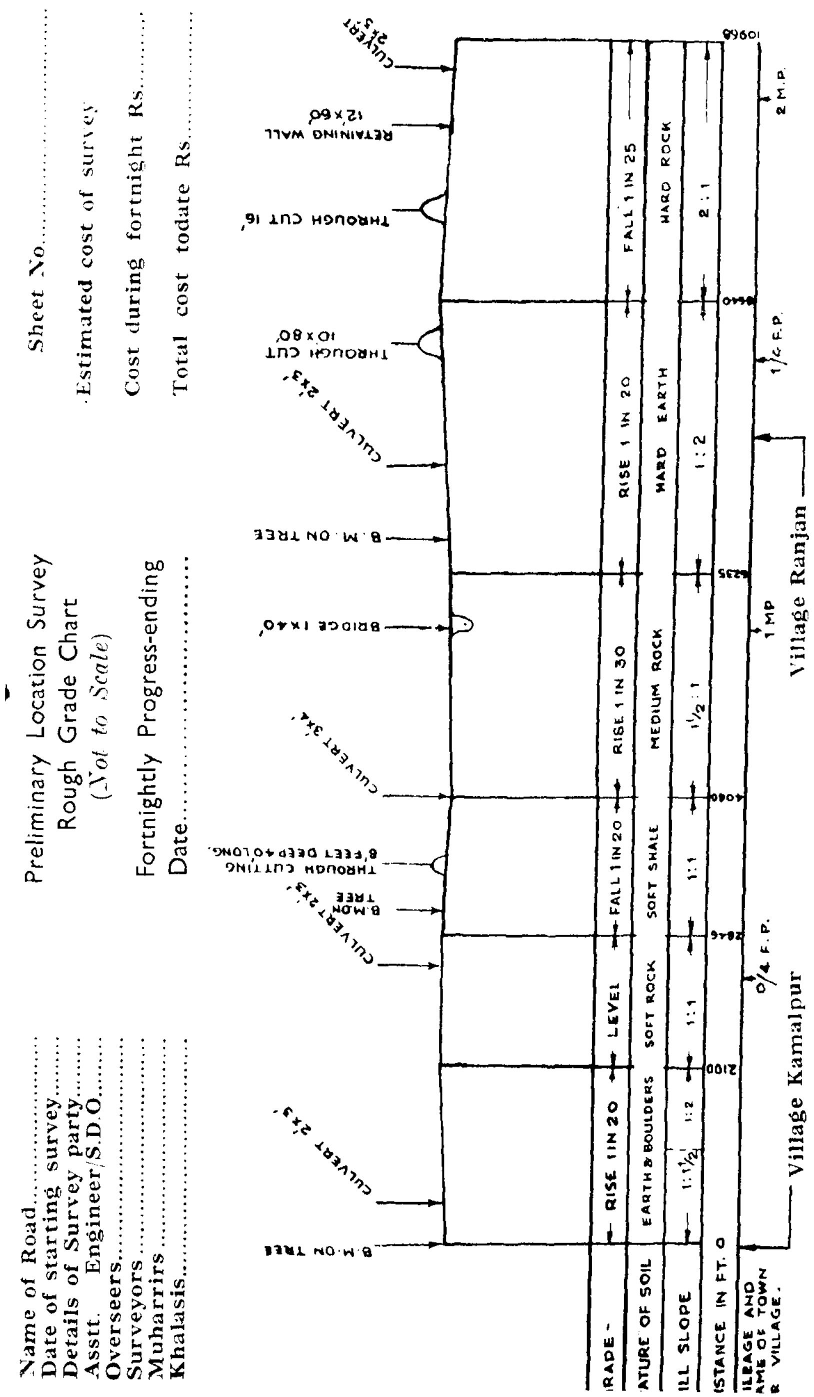


Fig. 3

The surveyor also takes cross sections about 500 ft to 1000 ft apart, makes notes in his field book on :

(i) the nature and classification of soil (including rocky outcrops, if any) ;

(ii) the character of waterways and streams ;

(iii) length and nature of bridging to be provided ;

(iv) availability of building stones or other materials such as timber, stone for road metal, gravel, sand, etc.;

(v) location of quarries :

(vi) position of rail or steamer heads, etc.

Immediately following the initial layout, a footpath 1½ ft wide has to be cut to enable the survey staff and the inspecting officers to move freely. Labour required for this work is 1 to 1¼ coolie-day per 100 running foot on the average in ordinary soil, costing Rs 100 to Rs 150 per mile. For steep hill faces and rocky soils the cost may go up to Rs 250 per mile or even more. This path should be later widened to 3 feet to facilitate detailed survey being carried out.

The Officer-in-charge of the survey party should prepare a fortnightly progress chart as illustrated in Fig 3 and submit it to the Engineer-in-charge. The chart should be diagramatic and need not be to scale. It should contain succinct but sufficient information to enable the Engineer-in-charge to get a good idea of the progress of laying out the alignment on the ground.

Longitudinal and cross sections should be plotted from the levels taken with the clinometer and a rough estimate of the cost of the project prepared.

Progress and Cost. The progress of laying out the alignments depends on the nature of the country. On the average a party can cover about 10 miles per month.

The initial laying out costs from Rs 400 to Rs 500 per mile include the cutting of 3 ft wide path and the pay of the technical staff.

Inspection of Alignment. The alignment as laid out should, on completion of the preliminary survey, be inspected by a senior officer, i.e., the Superintending Engineer in charge or the Chief Engineer and approved before the detailed survey is taken up.

10. THE DETAILED SURVEY

10.1. The Party.

On Assistant Engineer for levelling

One Surveyor for the prismatic compass survey

One Muharrir

Ten Khalasis as under :

With jhandis	2
With levelling staves	2
For the levelling instrument	1
For cutting and driving pegs	3
Chainmen for Muharrir	2

10.2. Prismatic compass or plain table survey for the preparation of ground plans has to be carried out.

10.3. Levels have to be taken for the longitudinal section along the line at every 100 feet and closer where necessary.

The chainage on longitudinal sections should be the same as shown on the alignment marked on the ground plans prepared from the prismatic compass survey.

10.4. Fixing Bench and Peg Marks. Stout pegs should be driven firmly into the ground. Marks should also be cut on trees or placed on other permanent objects, about half a mile apart. These should be connected to G. T. S. bench marks wherever possible. Where G. T. S. bench marks are not available, a suitable datum should be assumed

The grade pegs for detailed survey should preferably be of 2 in. diameter and a foot long and should be driven with their tops flush with the ground. They should be covered with 6 in. of earth to prevent their being disturbed. An indicator peg 2 to 3 in. diameter and about 3 ft long should be driven about 1½ ft into the ground near the grade peg as shown in Fig. 4. On this peg the chainage, the peg number, and the gradient should be written in red or blue pencil initially and later painted. Suitable abbreviations viz., R for rise, F for fall, L for level, etc., may be used in placing these marks. A cut about 2 ft long, one foot wide, and 9 in. deep should be made on the hill face, where the indicator peg is placed. This will help locating the grade peg should the indicator peg be removed by some one.

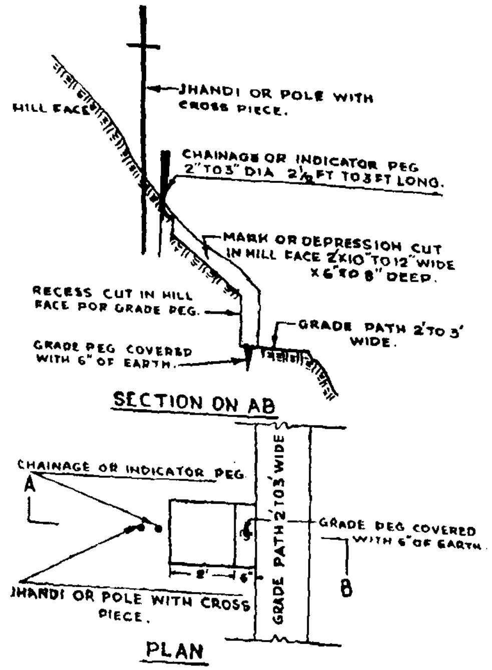


FIG. 4

The grade pegs should be looked after and kept in place till the construction of the road has been completed. When construction is in progress the contractor should be instructed to keep the tell-tales or "witnesses" at the places where grade pegs have been placed. These grade pegs are usually 50 to 100 ft apart as fixed in the course of the detailed survey. But for the purposes of construction intermediate pegs should be provided and levels given with the help of a clinometer or a road tracer.

Pegs at every 100 ft and at the end of each mile should be stout, 3 to 4 in. diameter. They should be 5 ft long and should be driven 2 ft into the ground. The chainage and the milage should be marked in bold figures on them.

10.5. Cross sections should be taken at right angles to the centre line of the alignment and at intervals of 100 ft or closer where necessary. The cross sections should extend 60 ft in the uphill side and 40 ft on the downhill from the centre line. A pole 12 to 15 ft long and marked in feet with white and black paint, a string, a tape, a spirit level, and a clinometer are required.

10.6. **Trial Pits.** An idea of the nature and classification of soils likely to be met with during construction can be had from trial pits. They should be about 2 ft wide and 5 ft long and should be spaced about half a furlong apart. The nature of outcrops of rock, if any, in the vicinity should also be noted. It is advisable to include a somewhat liberal and higher classification in the detailed estimate than that actually found in the trial pits, as it often happens that harder types of soils and rocks are met with deeper down from the surface, especially in through cutting. There is always a chance of excess over estimates unless the engineer is cautious in this respect.

Fig. 5 shows the size and position of trial pits.

10.7. Collection of Hydraulic Data

Cross sections. Cross sections of streams requiring minor bridges (less than 100 ft long) should be taken in each case at the proposed bridge site and at 300 ft to 500 ft upstream and the same distance downstream of the site.

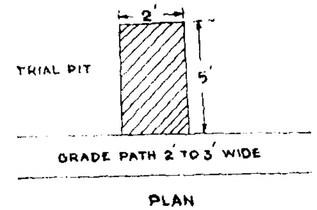


FIG. 5

In case of major crossings (waterways of 100 ft and over) cross-sections should be taken at the bridge site and at points half a mile to one mile upstream and the same distance downstream.

Longitudinal Sections. These should be taken in the reach connecting the extreme cross sections as given above. The bed level, the normal and high flood levels, low water level, and the bank levels, should be shown. Dates of the occurrence of floods should be given.

Borings. One at the centre of the channel and one at or near each bank should be taken at the selected bridge sites of all crossings of over 40 ft waterway. These borings should be taken down up to a depth of at least 50 ft below the lowest prevailing bed level at the site. A chart showing the strata met with should be prepared for the design of the type and depth of foundations.

Velocity of Current. This should be observed in normal and high floods, wherever possible.

INFORMATION SERVICE

I. "A Note on Experiments With Aerated Concrete"

By

H. Sunder Rao,

Ministry of Transport, (Roads Wing)

INTRODUCTORY

Cement concrete as usually known is a heavy dense material having considerable compressive strength. These properties have made cement concrete a widely used material in building and bridge construction.

But for certain purposes a material which is lighter and is a poor conductor of heat and which has some of the properties of concrete has been found desirable even at the sacrifice of some compressive strength. For such purposes engineers in the West have developed aerated concretes and at the present time Sweden seems to be leading in the field of production and use of light-weight and aerated concretes. In all aerated concretes the aggregate used is very fine and to this extent, the term concrete seems to be a misnomer. But following general practice, the term concrete will be used in this note to mean the product made out of a mixture of cement and fine aggregate only.

2. Experience and information about actual production of such material in India has been lacking. The following note, it is hoped, will arouse sufficient interest to experiment further on the possibilities of this material and its probable uses in India. I am glad to acknowledge the kind help, advice and co-operation received from the Government Housing Factory, the Director, Central Road Research Institute, and the Director, National Physical Laboratory, in conducting the experiments.

3. The problem that confronted the Roads Wing and which led to a rough investigation arose as follows. In the case of a railway bridge over the river Beas, which had its rails supported on a decking of trough plates about 12 in. deep and which was proposed to be provided with road decking, it was suggested that the trough plates could be made to carry the road surfacing too if the 12 in. deep troughs could be filled with a light-weight concrete of sufficient strength to carry the usual road traffic wheel loads and at the same time keep the dead weight to a minimum. The design contemplated the use of a fill material which had a weight of about 60 lb per cu. ft. (against 144 lb for

Depth of deepest scour holes in the vicinity should be observed.

Catchment area should be worked out by an inspection of the site in case of small catchments and from survey maps in case of large ones.

Field Notes. Detailed and specific notes should be taken in regard to:

(i) the nature and character of the stream;

(ii) frequency and duration of high floods;

(iii) nature of banks and bed, viz., resistibility to erosion of the soil composing the bed and banks;

(iv) the incidence of floating trees or debris; and

(v) the sizes of boats, rafts, etc., used if any.

Tentative recommendations should be included in regard to

(i) the linear waterway to be provided;

(ii) the type of structure that will suit;

(iii) the type and depth of foundations; and

(iv) the length of spans.

Copious notes on the availability of local materials should be recorded. These notes should be written by the principal officer of the survey party for the use of the designer.

10.8. **Progress and Cost.** In a day 3/8 to half mile can be covered.

Detailed survey costs from Rs 300 to Rs 400 per mile, inclusive of the cost of the preparation of project estimates with drawings.

10.9. **Scales of Drawings.** The following scales are recommended:

(a) Plan	220 ft = 1 in.
(b) L-section	220 ft = 1 in. horizontal and 20 ft = 1 in. vertical
(c) Cross sections of hill face	20 ft = 1 in. natural
(d) Cross sections of Streams	10 ft = 1 in. natural for waterways up to 300 ft, and 20 ft = 1 in. natural for longer crossings.

11. OVERALL COSTS

The total cost of reconnaissance, initial layout, and detailed survey varies from Rs 800 to Rs 1,000 per mile depending on the nature of the country. This includes the pay of the technical staff and labour and is based on the rates given below:

Pay:	Executive Engineer	Rs 800 p.m.	plus allowances at 25 to 40 per cent of pay
	Assistant Engineer or S.D.O.	Rs 400 p.m.	
	Overseer	Rs 200 p.m.	
	Surveyor	Rs 150 p.m.	
	Muharir	Rs 80 p.m.	
	Khalasis	Rs 75 p.m.	
	Daily Labour	Rs 2 per diem plus 50 per cent extra as allowance to cover arduous nature of work, unhealthy climate, etc.	

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ordinary concrete) and a compressive strength of about 200—300 lb per sq. in. on which a flexible pavement could be laid.

4. A further condition imposed was that any process suggested should be capable of being adopted in an out-of-the-way place with unskilled labour and should not require costly plant.

5. An analysis of literature on aerated concrete showed that various methods have been used for producing aeration of the concrete mix and that these processes could be classified into two main types as follows :

(1) Processes in which gas is produced by a chemical reaction within the mix before it sets ; and

(2) Processes in which a foam-producing substance is added to the mix to introduce and stabilise air bubbles.

6. The Government Housing Factory at Delhi used aerated concrete produced by a process of type (2), using "Pyrene" as the foaming agent. The foam was formed by special plant and the concrete units were cured by autoclaving, i.e., using steam at high pressure. Obviously this process was not reproducible in the field. The experiments were confined to one process of type (1) by using aluminium powder as the chemical reagent, and one process of the type (2) using "Aphrosol F. C." as the foaming agent.

PROCESS USING ALUMINIUM POWDER

7. When fine grained aluminium powder is added to cement gauged with water, the free lime in the cement and the aluminium react chemically and liberate hydrogen. Under favourable conditions the hydrogen bubbles so formed cause the mortar to puff up and a light-weight mortar results.

The objects of the experiments were:

(1) To determine the relative economical proportions of aluminium powder, cement, sand, and water to produce a light-weight concrete weighing between 60 and 70 lb per cu. ft;

(2) To see if such a light-weight concrete had the necessary compressive strength to sustain the wheel loads of road vehicles ; and

(3) To draft a detailed specification for the procedure to be followed in the field.

Materials Used in the Experiment

Cement Ordinary Portland cement manufactured at Lakheri factory. It had the following composition

	Per cent
Loss on ignition	1.7
Sulphuric anhydride	1.65
Magnesia Mgo	1.35
Iron Oxide Fe_2O_3	1.54
Aluminium Oxide	5.56
Silica	22.00
Lime	63.75

Sand—Sand quarried from banks of the rivers Yamuna and the Beas were used in the experiments. Plate I shows the mechanical analysis of the sands used.

Aluminium Powder—Fine aluminium powder that is generally used for paints and locally available in the market at about Rs 4/4/- per lb was used. It had a grading of passing through 100 mesh sieve and retained on 170 mesh sieve (B.S.).

Preliminary Experiments

8. To observe the actual behaviour of the mixed materials, a few trial mixes were prepared with two parts of sand with one part of cement to which had been added 0.1 to 0.3 per cent by weight of the aluminium powder. Water was added and the sloppy paste thoroughly trovelled was poured to a depth of about 2 in. into wooden moulds 3 in. by 3 in. by 3 in. high. After an interval of about 20 minutes, minute bubbles were seen to rise to the surface and the mortar also slowly bulked up to about the top of the mould.

9. These trials gave a rough indication of the nature of the reaction and observations were proposed to be made in respect of the following using varying proportions of the aerating agent :

(1) Time when action started and stopped after initial gauging with water ; and

(2) the percentage of rise or bulking of mortar as a rough index of the decrease in density.

10. To determine the most suitable proportions, various mixes were tried with different proportions of cement to sand, namely 1 : 2; 1 : 3; 1 : 4, and 1 : 6, and different percentages of aluminium powder. The percentage of bulking of the mix and

the time at which chemical action started and stopped were observed. The observations are given in Table I—Preliminary Tests.

11. The tests tabulated showed that the stiffer mixes yielded less bulking and to produce any appreciable bulking much more water than would be used ordinarily for mixing concrete had to be used. Also it was observed that mixes leaner than 1 : 3 produced segregation of sand at bottom. Therefore further tests were confined to mix proportions of 1 : 2 and 1 : 3.

12. The experiments with 1 : 2 and 1 : 3 proportions are tabulated in Table 2. From these observations it could be found that a mix of 1 : 3 with .004 aluminium powder by weight of cement could give the desired density and a crushing strength of 279 lb per sq. in. for autoclaved samples (steam-cured for 6 hours at a pressure of 140 lb per sq.in.). The sample cubes were autoclaved to quicken setting and subsequent testing for compressive strength. Earlier experiments with cement-sand mortars had showed that the strength of autoclaved test cubes was about $2\frac{1}{2}$ times that of water-cured samples at 28 days test.

13. Assuming a strength for water-cured samples of 0.4 times the strength of autoclaved ones, the aerated concrete would have a strength of $\cdot 279 \times \cdot 4 = 111 \cdot 6$ or 112 per sq. inch. This strength was considered sufficient to take the distributed wheel loads. Moreover, wheel loads or caterpillar track loads will be dispersed through the depth of the wearing coat.

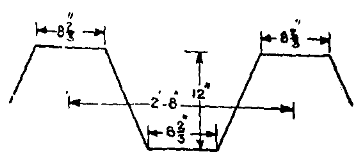


FIG. 1

14. In order to fix a procedure for the laying of the aerated concrete under actual field conditions, a piece of wooden trough, 12 in. deep, of a section as indicated in Fig. 1 to correspond to the trough plating of the bridge deck was made and aerated concrete laid in three layers, each not exceeding 4 inches. After the first layer was laid and hardened sufficiently, the second layer was laid and then the third. On laying the final layer a screed was used to remove the mortar which had risen above the deck level. Cut sections showed that the average density attained was about 63 lb per cu. ft.

15. Conclusions and Incidental Observations

(1) Aerated concrete made with 1 : 4 water-cement ratio, 1 : 3 cement-sand ratio, and aluminium powder of .004 of cement by weight, had an average density of about 63 lb per cu. ft.

(2) Proportions leaner than 1 cement : 3 sand segregate with unground Beas or Yamuna sand.

(3) The chemical action starts in about 20 minutes after gauging with water.

(4) The top layers of the aerated concrete were lighter than the bottom ones, i.e., the density in the body of the aerated concrete was not uniform in depth.

(5) The concrete has to be laid in layers not exceeding 4 in. in height.

It has to be remembered that aerated concrete as prepared above is not impermeable. There is the chance of water seeping through if water logging conditions or exposure to rain or moisture occur. Precautions have to be taken to protect the metal troughs by 2 or 3 coats of bituminous paint when aerated concrete is used to fill trough plating of bridge decks.

PROCESS USING A FOAMING AGENT

The use of "Aphrosol F.C." a foaming agent which is to be added to the mixing water for production of cement mortar has been recommended. The recommended proportion is one pint of 'Aphrosol' to 4 gallons of water. If the mixing is done in ordinary concrete mixers it was claimed that a concrete or rather a mortar weighing 100 lb to 75 lb per cu. ft. when wet could be produced. It was claimed that a concrete weighing up to 30 lb could be produced if special plant to produce the foam is used.

As the method to be adopted was one that could be followed in the field where no special pre-foaming plant is easily available, an ordinary $3\frac{1}{2}/5$ cu. ft. concrete mixer was used in the experiment.

Control Mix.—For purposes of comparison a regular or ordinary mix was made with 1 cement to 3 sand using the same quantity of water that would be used in the Aphrosol mix, 3 Nos. of 6 in. cubes were moulded with this control mix.

Actual quantities used: Sand 2 cu. ft. plus cement 60 lb plus water $3\frac{3}{4}$ gallons.

Foamed Concrete Mix.—One lb of 'Aphrosol' measuring 400 cc. was used. The quantities of sand, cement, and water were adjusted for this volume of 'Aphrosol'. The actual quantities used were: Sand $1\frac{1}{2}$ cu. ft. + cement 45 lb + water $2\frac{3}{4}$ gals. + Aphrosol 400 c.c. or 1 lb in weight.

Procedure: $\frac{3}{4}$ cu. ft. of sand and all the cement were loaded into the mixer and mixing done for about one minute. Then the water previously mixed with the 'Aphrosol' was charged into the mixer. When mixing was in progress for about a minute, foam was seen produced. Then the rest of the sand was added and the speed of rotating the drum increased.

Although instructions said that further water may be added, if necessary, it was actually found that water could even have been reduced initially. After mixing for about 3 more minutes the resulting mortar was poured out.

Observations.—It was observed that the mixed mortar was semi-fluid and contained a number of small bubbles.

3 Nos. 6 in. cube moulds were filled in and all the cubes covered with wet gunny bags.

After 24 hours the moulds were struck and the cubes weighed in wet candition:

Weight of mortar (6 in. cube) without 'Aphrosol'		132 lb per cu. ft.
do	with 'Aphrosol'	104 lb ,, ,,

The cubes were tested for compressive strength (28 days) and dry density at the National Physical Laboratory and the following are the test results:

Test Report on 6 in. Concrete Cubes

Sample number	Compressive (ultimate) stress in lb/sq. in. (28 days)	Dry Density	
		grams/cc	lb per cu. ft
With 'Aphrosol'			
AF1	278	1.31	81.7
AF2	421	1.32	82.4
AF3	278	1.31	81.7
Without 'Aphrosol'			
A1	946	1.71	106.6
A2	875	1.66	103.6
A3	980	1.66	103.6

CONCLUSIONS

'Aphrosol' F.C. could be used as a foaming agent for the production of aerated concrete, and with ordinary cement concrete mixers can give a concrete weighing about 90 to 100 lb per cu. ft. with unground Yamuna river sand. Further research may possibly indicate the means of securing reduction in weight.

CAUTION

Experiments conducted in the West have shown that all light-weight concretes have relatively high volume changes which occur on drying and subsequent wetting and with changes in atmospheric humidity. This important factor has to be borne in mind in the use of aerated concrete for any particular purpose. When used for a fill over which a wearing coat will be laid, the latter should be of the flexible type; also it should be as waterproof as possible. Two to three inch deep campact asphalt carpet would probably be the best wearing coat over the light-weight concrete.

SPECIFICATION FOR LAYING AERATED LIGHT-WEIGHT CONCRETE FILL FOR TROUGH DECKING OF BRIDGES

Materials

Sand.—The finest sand available at the locality free from excessive organic and inorganic deleterious substances (not exceeding 5 per cent) is to be used. If it is feasible to eliminate economically the coarser grains by sieving it should be done through mesh corresponding to British standard sieve size No 14.

Cement of approved brand should be used.

Aluminium powder free from oil and of the finest form procurable should be used and should in no case be coarser than the fineness of cement. The aluminium powder used for paint is quite suitable.

Preparation of the Troughing to receive the Mortar

The inside of the troughing should be painted with two coats of non-corrosive paint preferably a bituminous base paint.

Mixing

The proportion of sand to cement shall be not leaner than 3:1. After determining the cement content for each mix, the quantity of aluminium powder calculated at 4.0 per thousand by weight of cement shall be **thoroughly mixed dry** with the cement by hand. In order to have a thorough mix it is desirable to have as small a mix as economical.

The required quantities of the sand and the cement mixed with aluminium powder are put into a mortar mill and mixed in the usual manner with water added at 15 gallons per bag of 112 lb of cement. The water should be added in two doses. The first addition may not be larger than 7 gallons. The second dose may be added after mixing has continued for about 3 minutes. It will be seen that the quantity of water used is about twice the normal requirements for mortar. This is essential for proper aeration and rise of the mortar. Chemical action starts in about 20 minutes after mixing water. The mixed mortar should be laid in site within 15 minutes of the adding of water. When the mortar is dumped into the troughs, care should be taken that the depth of the added layer is not more than 3 inches at a time. The mortar is then allowed to remain undisturbed. After about 20 minutes the mortar would begin to rise slowly with a dome, like a loaf of bread, and the rising would continue for about 3 hours, the height increasing from 3 in. to about 4½ inches. The second layer of 3 in. can be laid 24 hours after the first layer. The surface of the concrete of the first layer should be roughened with a trowel to allow a good bond for the next layer of concrete.

The last layer should be laid to a depth of about 2/3rd the remaining depth so that the light-weight concrete may fill up to the top of trough after aeration. Any surplus mortar rising above the trough can be scrapped away by a trowel 4 hours after mixing, i.e., when the mortar is still green.

Curing shall be done for at least 14 days in the same way as for a cement concrete structure and the light - weight concrete thoroughly dried before laying the wearing coat on top.

Approximate Quantities required for 100 cu. ft aerated concrete.

Amount of bulking due to chemical reaction	...	2 times original volume
Amount of mortar required	...	50 cu. ft.
Sand	...	48 cu. ft.
Cement	...	16 cu. ft.
Al. Powder. 16 × 90 × ·004	...	57·6 lbs or 5·8 lbs.

The cost of Al. Powder in small quantities is Rs 4-8-0 to 5/-. It should be cheaper if purchased in bulk.

Table 1—Preliminary Tests

S. No.	Sand used	Sand Cement Ratio	Aluminium powder cement ratio	Water cement Ratio	Percentage Rise	After gauging Time at which action starts	After gauging Time at which action stopped	Remarks
						Minutes.	Minutes.	
A 1.		2 : 1	.001	0.9	40	25	90	
,, 2.		2 : 1	.002	0.65	20	25	120	
,, 3.		2 : 1	.003	1.05	60	15	120	
,, 4.		2 : 1	.004	1.05	75	15	120	
,, 5.		3 : 1	.001	1.20	40	30	60	
,, 6.		3 : 1	.002	0.88	20	36	120	
,, 7.		3 : 1	.003	1.30	45	20	120	
,, 8.	Yamuna Sand.	3 : 1	.004	1.30	45	20	90	
,, 9.		4 : 1	.001	1.30	35	40	not observed	
,, 10.		4 : 1	.002	1.10	5	45	do	
,, 11.		4 : 1	.003	1.62	20	25	120	
,, 12.		4 : 1	.004	1.62	25	25	120	
,, 13.		6 : 1	.001	1.80	negligible	60	not observed	
,, 14.		6 : 1	.002	1.80	negligible	75	do	
,, 15.		6 : 1	.003	2.29	10	40	60	
,, 16.		6 : 1	.004	2.28	20	40	60	

II. TYPE DESIGNS FOR HIGHWAY MILESTONES

1. **Scope**. Type designs, prepared by the Specifications and Standards Committee of the Indian Roads Congress, are given in Plates I to IV. These may be adopted on all roads for replacing missing or damaged milestones or for erecting new ones. The type which is the most economical and enables the use of local materials may be adopted.

2. **Size and Edge Clearances** shall be as given below :

Class of Road		N.H., P.H. & M.D.R.	O. D. R & V. R.
Design speed of road	M.P.H.	above 30	below 30
Height of numerals	in. ...	5	4
Height of lettering	in. ...	4	3
Edge clearances :			
Top	in. ...	2	4
Bottom	in. ...	6	6
Sides	in. ...	2	2
Spacing between lines	in. ...	3	3

3. **The Shape and Spacing of Letters**. The shape and spacing of letters in English shall conform to those shown in the appended Plates, viz.,

(1) Letters, 4 in. height, Plate V.

(2) Letters, 3 in. height, Plate VI.

(3) Numerals, 5 in. height, Plate VII.

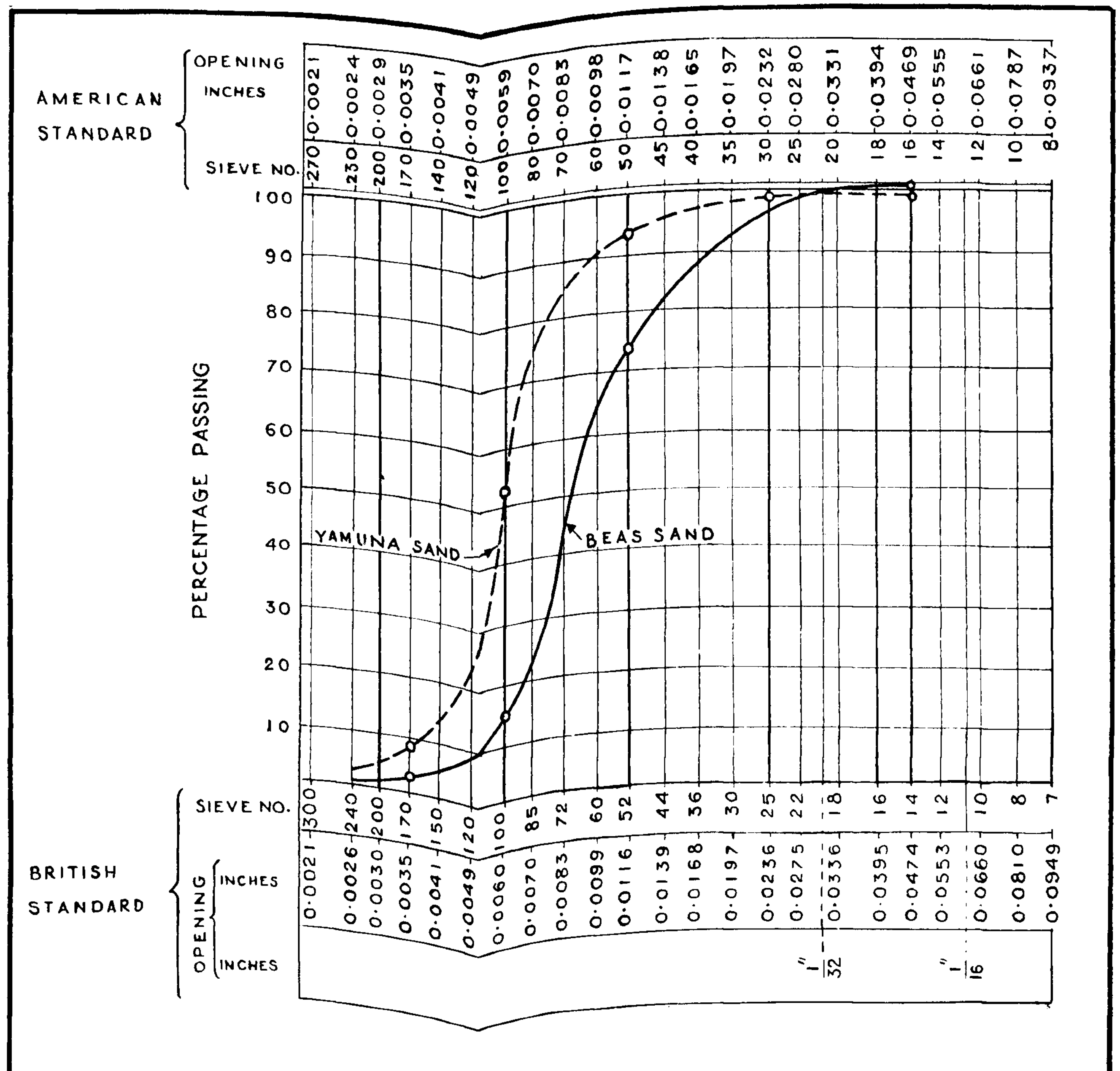
(4) Numerals, 4 in. height, Plate VIII.

(5) Numerals, 3 in. height, Plate IX.

On milestones, which are inscribed in a script other than that of English, the style of lettering shall be the one in general use. The spacing between single or compound letters shall be at least equal to the thickness of vertical strokes or to the thickness of strokes of letters in the scripts having no vertical strokes, such as in Oriya, Telugu, and Kannada.

4. **Colour of the Background and the Lettering**. The background shall be light *yellow* and the letters shall be *black*.

PLATE I



MECHANICAL ANALYSIS OF YAMUNA & BEAS SANDS

5. Script of the Inscription. The inscription may be in different scripts in the following order, only one script being used on any one milestone.

Mile No.	Inscribed script
0	English
1	Hindi (Devanagari script)
2	Local language
3	Hindi (Devanagari script)
4	Local language
5	English
	and so on (repeated in the same order).

The above order and weightage to a script may be modified at the discretion of the Road Authority.

5.2. The numerals shall in every case be in the international form of Indian numerals as detailed in Plates, VII, VIII and IX. Local or Devanagari numerals are not to be used, vide Art. 243 (1) of the Constitution.

5.3. On milestones fixed on village roads the inscription may be either in the official language of the Union, i.e., Hindi in Devanagari Script, or the script of the recognised regional language, at the discretion of the local Road Authority. Inscription in English is not necessary unless the village road leads to a place of tourist or archaeological interest.

6. Orientation. The faces of the milestone on N. H., P. H., and M.D.R. shall make an angle of 60 deg. with the centre line of the road (see Plate X).

7. Location. Milestones shall be located on the left-hand side of the road as one proceeds from the terminal station from which the milage count starts.

7.1. On embankments the stones shall be fixed outside the edge of the formation on specially erected platforms, protected by revetment, if necessary. In cuttings they shall be fixed clear of the shoulder and the side drain (see Plate X).

Plate II

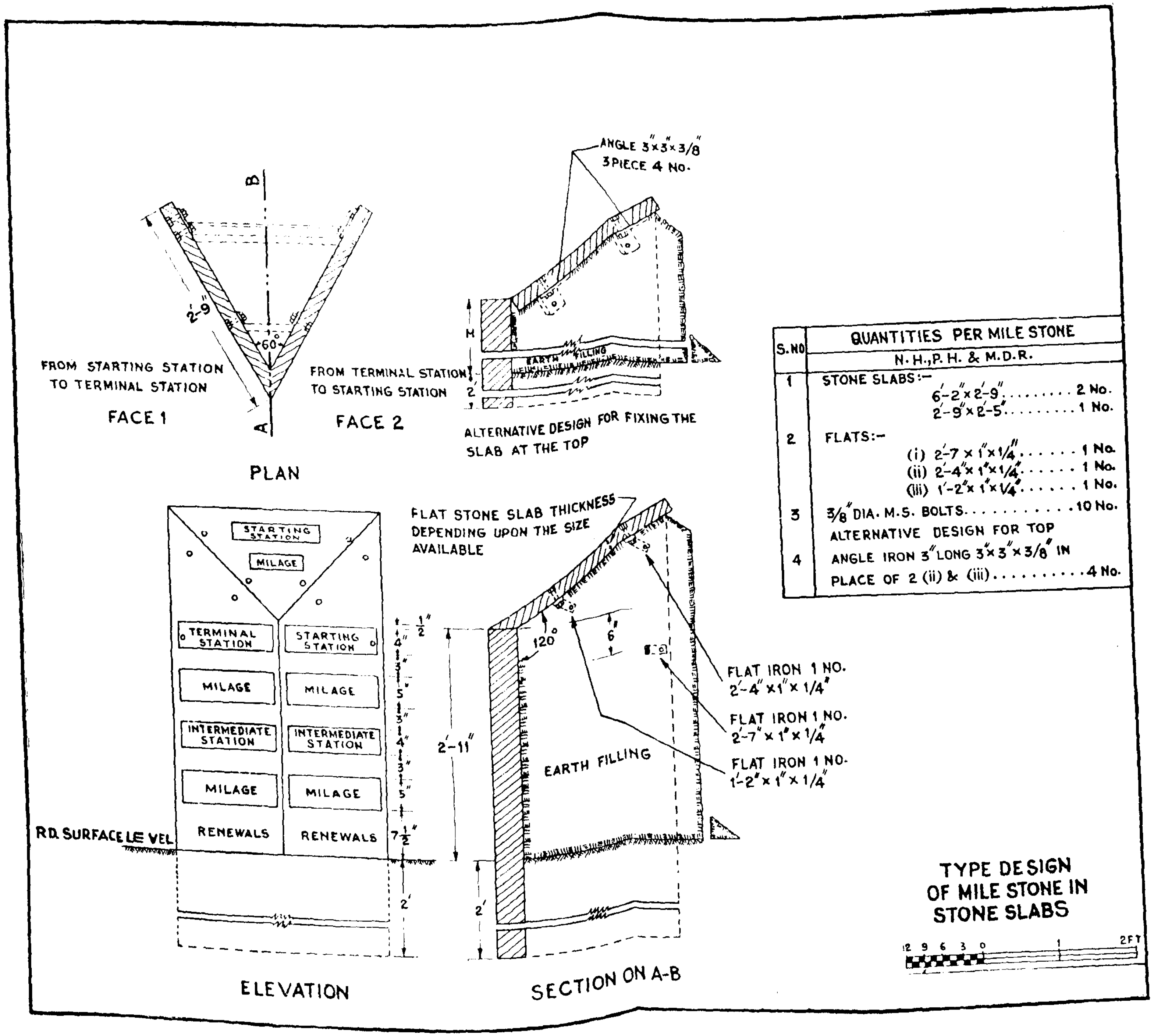
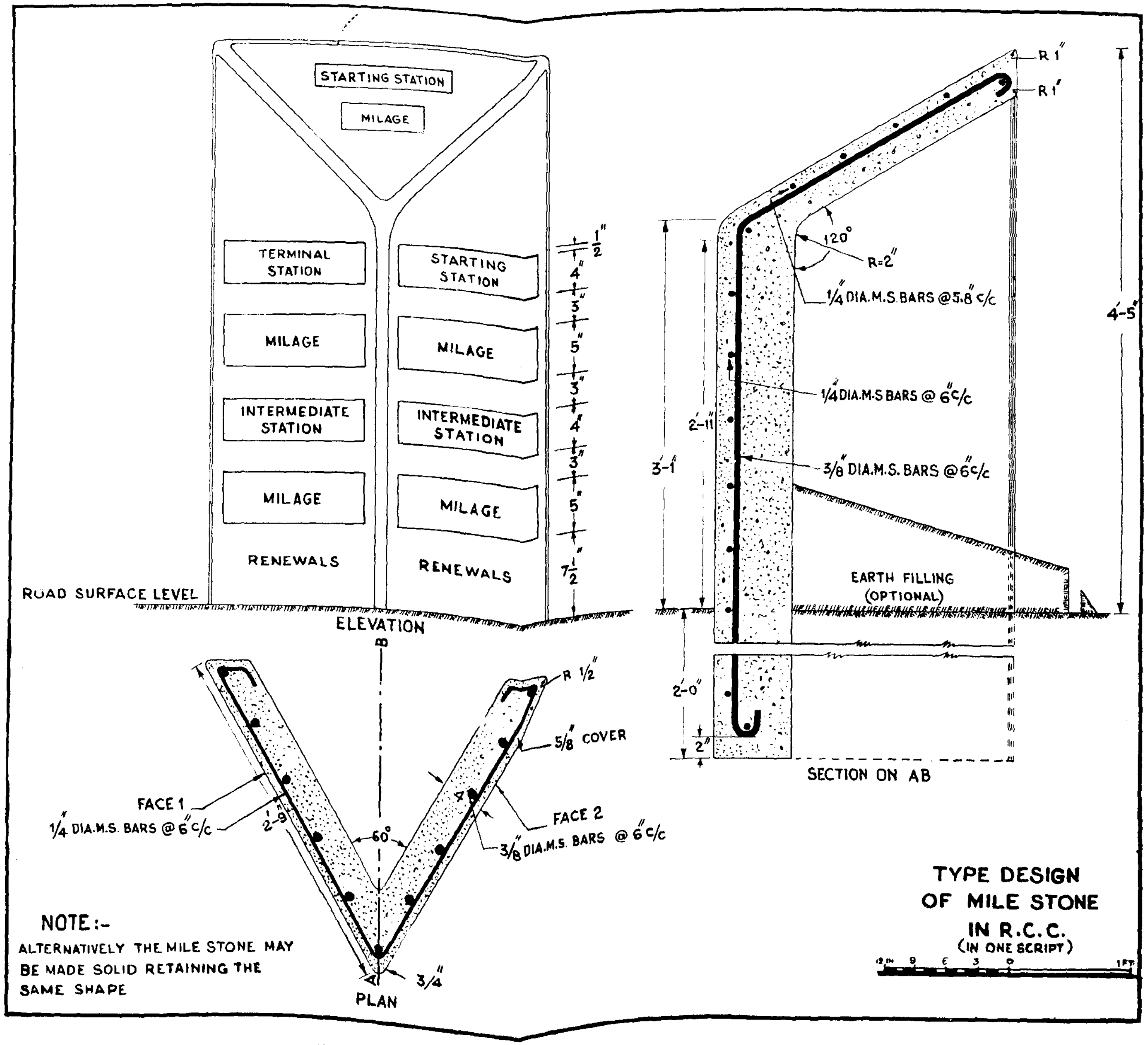
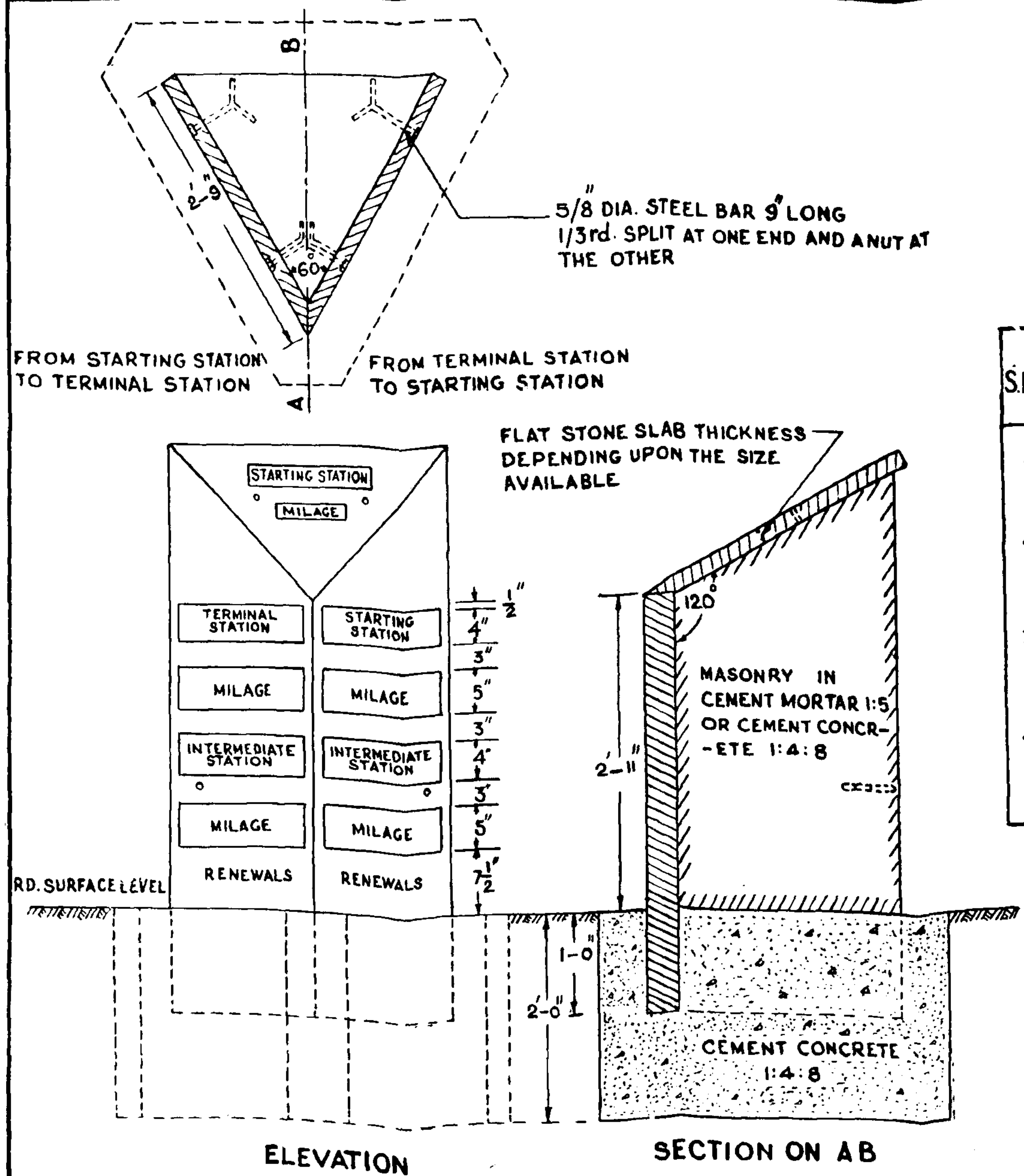

ANGLE 3"x3"x3/8"
3 PIECE 4 No.
B
A
2'-9"
60°
FROM STARTING STATION
TO TERMINAL STATION
FACE 1
FROM TERMINAL STATION
TO STARTING STATION
FACE 2
PLAN
H
2'
EARTH FILLING
ALTERNATIVE DESIGN FOR FIXING THE
SLAB AT THE TOP
S. NO
QUANTITIES PER MILE STONE
N. H., P. H. & M.D.R.
1 STONE SLABS:—
6'-2"x2'-9"........ 2 No.
2'-9"x2'-5"........ 1 No.
2 FLATS:—
(i) 2'-7 x 1"x1/4"...... 1 No.
(ii) 2'-4"x 1"x1/4"...... 1 No.
(iii) 1'-2"x 1"x1/4"...... 1 No.
3 3/8" DIA. M.S. BOLTS.......... 10 No.
ALTERNATIVE DESIGN FOR TOP
4 ANGLE IRON 3" LONG 3"x3"x3/8" IN
PLACE OF 2 (ii) & (iii).......... 4 No.
FLAT STONE SLAB THICKNESS
DEPENDING UPON THE SIZE
AVAILABLE
STARTING STATION
MILAGE
TERMINAL STATION
STARTING STATION
MILAGE
MILAGE
INTERMEDIATE STATION
INTERMEDIATE STATION
MILAGE
MILAGE
RENEWALS
RENEWALS
RD. SURFACE LEVEL
1/2"
4"
3"
5"
3"
4"
3"
5"
7 1/2"
2'-11"
2'
2'
120°
6"
EARTH FILLING
FLAT IRON 1 NO.
2'-4" x 1" x 1/4"
FLAT IRON 1 NO.
2'-7" x 1" x 1/4"
FLAT IRON 1 NO.
1'-2" x 1" x 1/4"
TYPE DESIGN
OF MILE STONE IN
STONE SLABS
12 9 6 3 0 1 2 FT
ELEVATION
SECTION ON A-B

Plate I


STARTING STATION
MILAGE
TERMINAL STATION
STARTING STATION
MILAGE
MILAGE
INTERMEDIATE STATION
INTERMEDIATE STATION
MILAGE
MILAGE
RENEWALS
RENEWALS
ROAD SURFACE LEVEL
ELEVATION
B
R 1"
R 1"
120°
R=2"
1/4" DIA.M.S.BARS @5.8" c/c
4'-5"
1/4" DIA.M.S BARS @ 6" c/c
2'-11"
3'-1"
3/8" DIA.M.S. BARS @6" c/c
EARTH FILLING (OPTIONAL)
2'-0"
2"
SECTION ON AB
R 1/2"
5/8" COVER
FACE 1
1/4" DIA.M.S. BARS @ 6" c/c
2'-9"
60°
FACE 2
3/8" DIA.M.S. BARS @ 6" c/c
3/4"
PLAN
NOTE:-
ALTERNATIVELY THE MILE STONE MAY BE MADE SOLID RETAINING THE SAME SHAPE
TYPE DESIGN OF MILE STONE IN R.C.C.
(IN ONE SCRIPT)
1 FT



SCHEDULE OF QUANTITIES

S.NO	ITEM	QUANTITIES PER MILE STONE FOR N.H. P.H. AND M.D.R.
1.	CEMENT CONCRETE 1:4:8 FOR FOUNDATION	16·4 C.F.T.
2.	MASONARY IN CEMENT-MORTAR 1:5 OR CEMENT-CONCRETE 1:4:8......	9·5 C.F.T.
3.	STONE SLABS :— 2 NOS. ..... 1 NO.	5'-2"X2'-9", 2'-9"X2'-5"
4.	5/8" DIA. STEEL BAR 9" LONG 1/3rd. SPLIT AT ONE END AND A NUT AT THE OTHER	6 NOS.

TYPE DESIGN OF MILE STONE IN STONE SLABS (2ND ALTERNATIVE)

12 IN. 9 6 3 0 1 2 FT

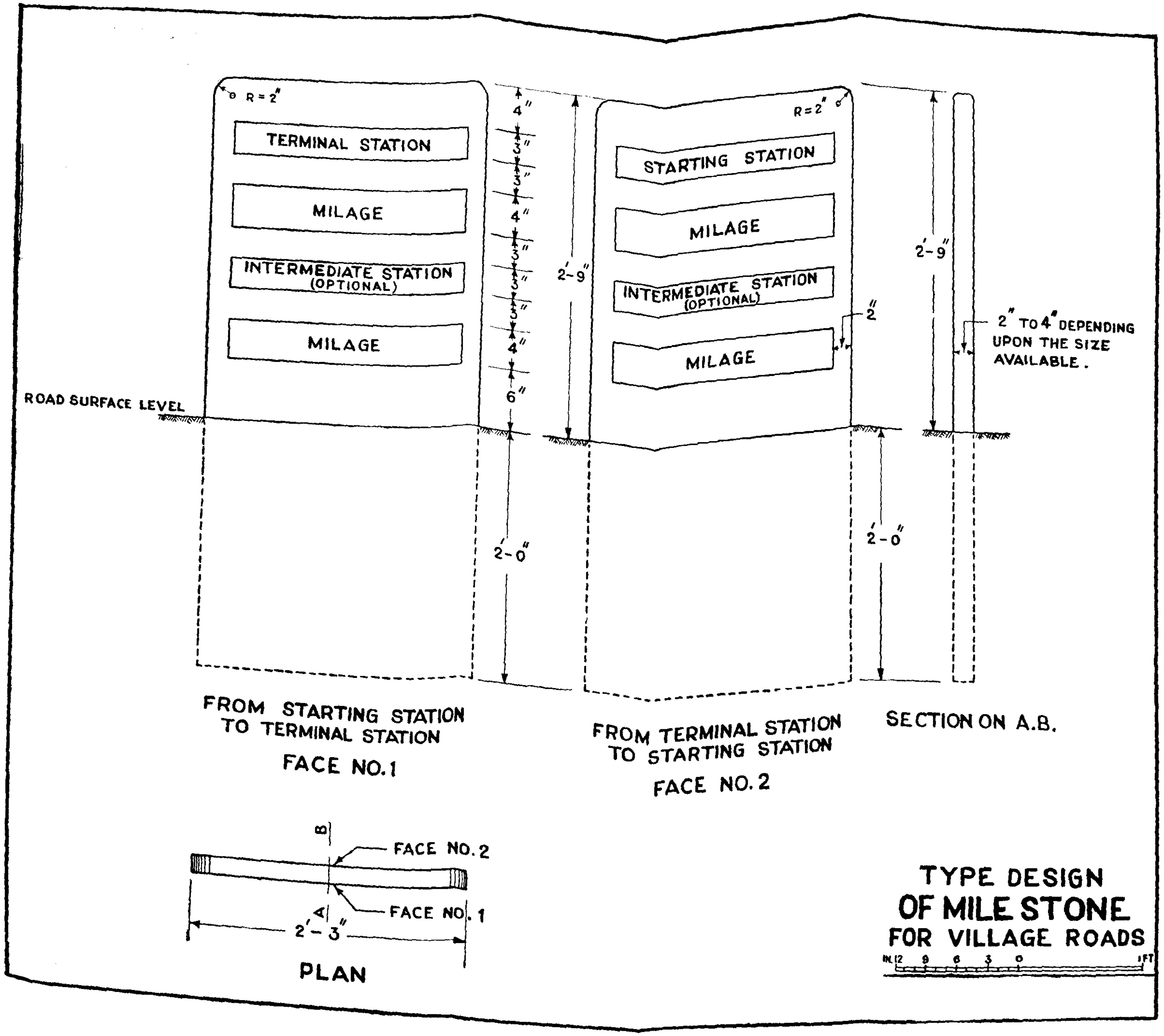
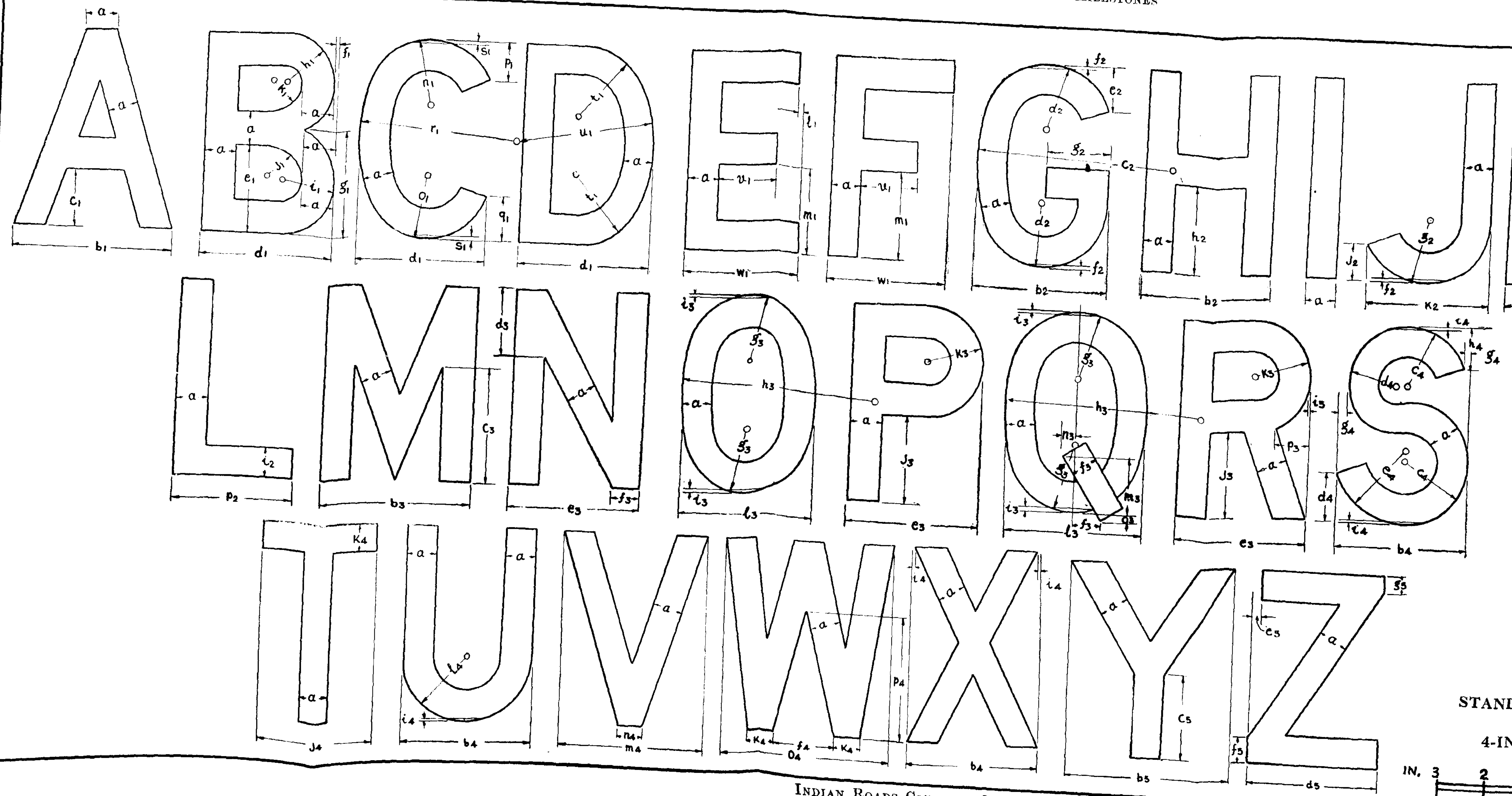

R=2"
TERMINAL STATION
MILAGE
INTERMEDIATE STATION (OPTIONAL)
MILAGE
STARTING STATION
MILAGE
INTERMEDIATE STATION (OPTIONAL)
MILAGE
ROAD SURFACE LEVEL
4"
3"
3"
4"
3"
3"
3"
4"
6"
2'-9"
2'-0"
2"
2" TO 4" DEPENDING UPON THE SIZE AVAILABLE.
FROM STARTING STATION TO TERMINAL STATION
FACE NO.1
FROM TERMINAL STATION TO STARTING STATION
FACE NO.2
SECTION ON A.B.
FACE NO.2
FACE NO.1
2'-3"
PLAN
TYPE DESIGN
OF MILE STONE
FOR VILLAGE ROADS
IN.12 9 6 3 0 1FT

Plate V



KEY SPACING FOR LETTERS					
LETTER	LEFT	RIGHT	LETTER	LEFT	RIGHT
A	III	III	N	I	I
B	I	II	O	II	II
C	II	IV	P	I	II
D	I	II	Q	II	II
E	I	IV	R	I	II
F	I	IV	S	II	II
G	II	II	T	IV	IV
H	I	I	U	I	I
I	I	I	V	III	III
J	IV	I	W	III	III
K	I	IV	X	IV	IV
L	I	IV	Y	IV	IV
M	I	I	Z	IV	IV

RIGHT ←→ LEFT	SPACING BETWEEN LETTERS
I ←→ I I ←→ II II ←→ I	0.74
I, II ←→ III, IV III, IV ←→ I, II II ←→ II	0.56
III, IV ←→ III, IV OPPOSITE	0.38
III, IV ←→ III, IV PARALLEL	0

SPACINGS BETWEEN LETTERS USE OF "KEY"

Example :—

DETERMINE THE SPACINGS BETWEEN 4-IN. LETTERS FORMING THE WORD DELHI

Solution :

D IS TO THE LEFT OF E UNDER THE COLUMN 'LEFT' IN THE KEY AGAINST D READ GROUP I. E IS TO THE 'RIGHT' OF D, AND AGAINST E, UNDER COLUMN 'RIGHT' READ GROUP IV. SO THE SPACE BETWEEN D AND E IS GIVEN AS 0.56 IN. AGAINST COLUMN

RIGHT←→LEFT

I←→IV

SIMILARLY SPACING BETWEEN E AND L WILL BE 0.56 IN. BETWEEN L AND H = 0.74 IN. AND BETWEEN H AND I = 0.74 IN.

EXAMPLES

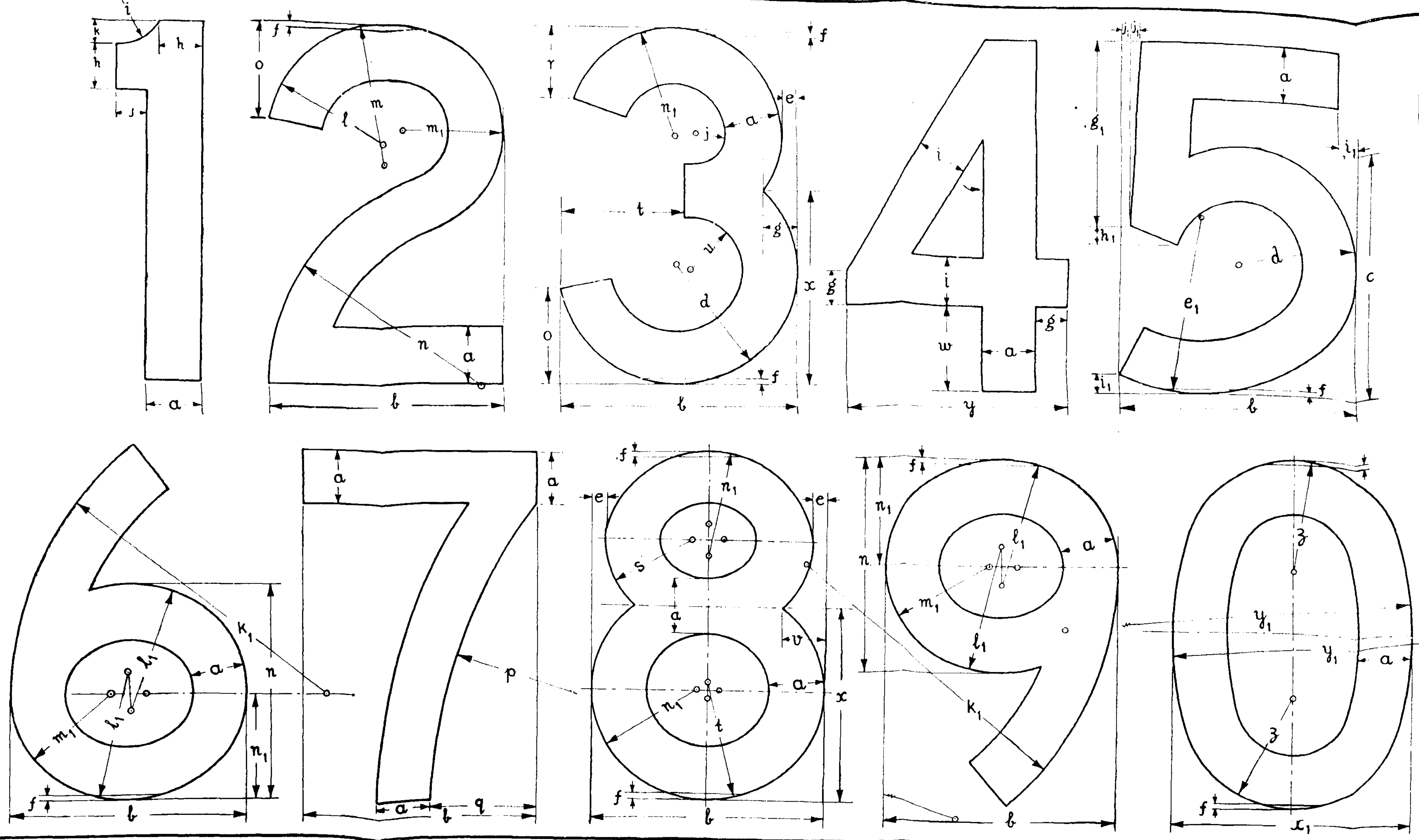
RIGHT ←→ LEFT	LETTERS	NUMERALS
I ←→ I I ←→ II II ←→ I	NI - UP - OH	11-22-21
I, II ←→ III, IV III, IV ←→ I, II II ←→ II	IA-HT-OV-GX WR-KD-TB-YS SR-OQ	14-24-57-54 41-34-66-93
III, IV ←→ III, IV OPPOSITE	WV-YV-EA-CT	96
III, IV ←→ III, IV PARALLEL	WAY-LY-AT	69-67-76

DIMENSIONS (INCHES) FOR 4 INCH HEIGHT OF LETTERS

a	b_1	b_2	b_3	b_4	b_5	c_1	c_2	c_3	c_4	c_5	d_1	d_2	d_3	d_4	d_5	e_1	e_2
$\frac{5}{8}$	$3\frac{11}{32}$	$2\frac{11}{16}$	$3\frac{3}{32}$	$2\frac{11}{16}$	$3\frac{3}{8}$	$1\frac{1}{8}$	4	$2\frac{5}{16}$	$1\frac{7}{32}$	$1\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{9}{32}$	$1\frac{11}{32}$	1	$2\frac{11}{16}$	$1\frac{3}{4}$	$\frac{7}{8}$
e_3	e_4	e_5	f_1	f_2	f_3	f_4	f_5	g_1	g_2	g_3	g_4	g_5	h_1	h_2	h_3	h_4	i_1
$2\frac{11}{16}$	$1\frac{9}{16}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{9}{16}$	$1\frac{1}{4}$	$\frac{17}{32}$	$2\frac{3}{32}$	$1\frac{5}{16}$	$1\frac{9}{32}$	$\frac{5}{32}$	$\frac{3}{8}$	1	$1\frac{3}{4}$	4	$\frac{13}{16}$	$1\frac{3}{32}$
i_2	i_3	i_4	j_1	j_2	j_3	j_4	k_1	k_2	k_3	k_4	l_1	l_2	l_3	l_4	m_1	m_2	m_3
$\frac{19}{32}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{21}{32}$	$\frac{23}{32}$	$1\frac{3}{4}$	$2\frac{7}{16}$	$\frac{5}{8}$	$2\frac{1}{2}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{1}{8}$	$1\frac{3}{8}$	$2\frac{13}{16}$	$1\frac{11}{32}$	$1\frac{3}{4}$	$1\frac{9}{16}$	$1\frac{1}{8}$
m_4	n_1	n_2	n_3	n_4	o_1	o_2	o_3	o_4	p_1	p_2	p_3	p_4	q_1	r_1	s_1	t_1	u_1
3	$1\frac{5}{16}$	$\frac{3}{32}$	$\frac{5}{16}$	$\frac{1}{2}$	$1\frac{9}{32}$	$2\frac{3}{4}$	$\frac{3}{16}$	$3\frac{1}{2}$	$\frac{13}{16}$	$2\frac{7}{16}$	$\frac{11}{16}$	$2\frac{9}{16}$	$\frac{7}{8}$	$3\frac{5}{32}$	$\frac{1}{16}$	$1\frac{7}{16}$	$2\frac{13}{16}$
									v_1	w_1							
									$1\frac{5}{32}$	$2\frac{7}{16}$							

STANDARD LETTERS OF 4-INCH HEIGHT

IN. 3 2 1 ½ 0 1 IN.



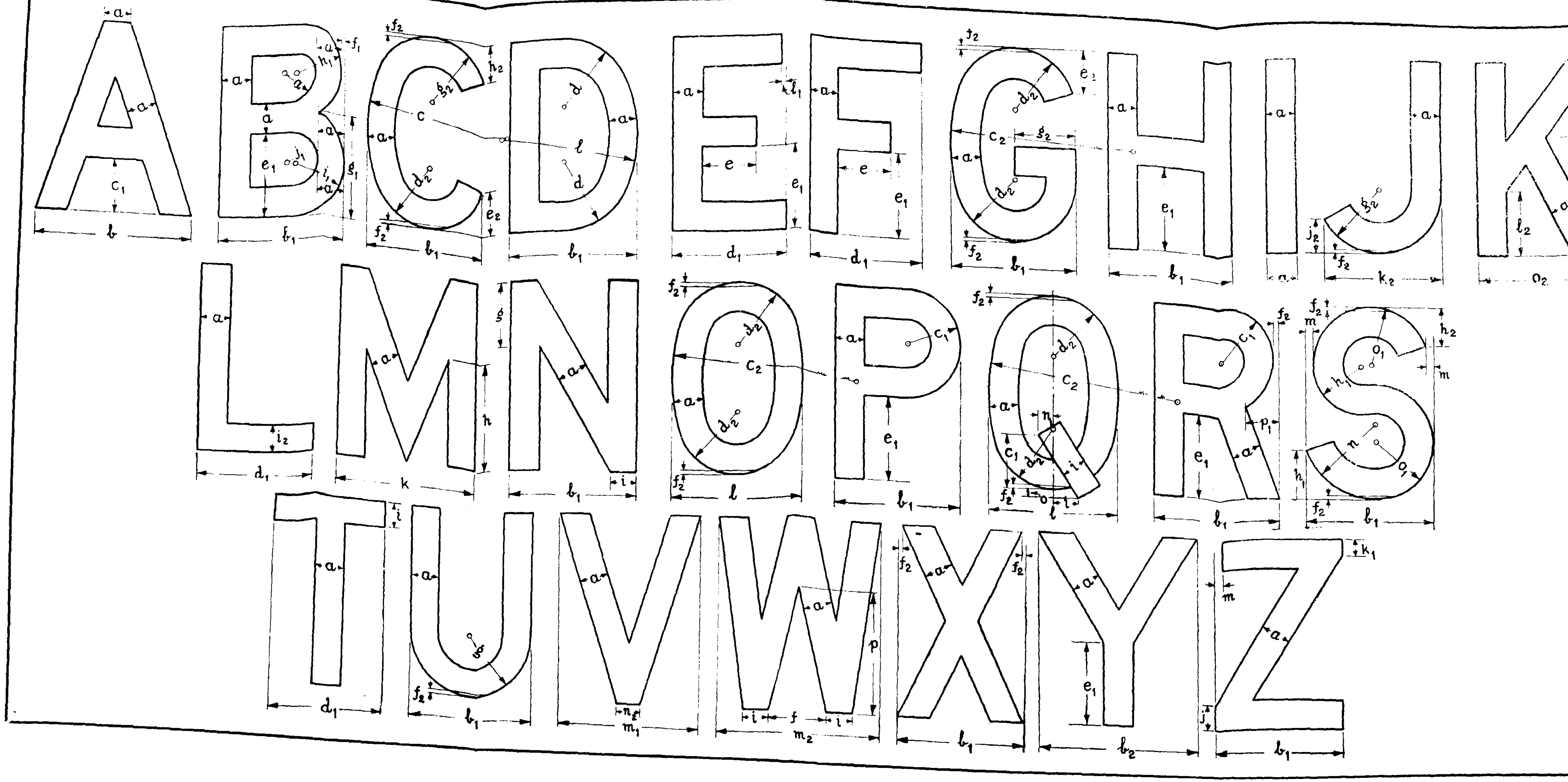
DIMENSIONS (INCHES) FOR 5 INCH HEIGHT OF NUMERALS										
a	b	c	d	e	e_1	f	g	g_1	h	h_1
$\frac{25}{32}$	$3\frac{23}{64}$	$3\frac{19}{32}$	$1\frac{43}{64}$	$\frac{3}{16}$	$2\frac{17}{32}$	$\frac{5}{64}$	$\frac{15}{32}$	$2\frac{37}{64}$	$\frac{5}{8}$	$\frac{15}{64}$
i	i_1	j	j_1	k	k_1	l	l_1	m	m_1	n
$\frac{45}{64}$	$\frac{17}{64}$	$\frac{27}{64}$	$\frac{7}{64}$	$\frac{5}{16}$	$4\frac{29}{64}$	$1\frac{41}{64}$	$1\frac{51}{64}$	$1\frac{61}{64}$	$1\frac{7}{16}$	$3\frac{3}{64}$
n_1	o	p	q	r	s	t	u	v	w	x
$1\frac{33}{64}$	$1\frac{21}{64}$	$7\frac{1}{2}$	$1\frac{31}{64}$	$1\frac{1}{64}$	$1\frac{9}{32}$	$1\frac{23}{32}$	$\frac{47}{64}$	$\frac{37}{64}$	$1\frac{1}{4}$	$2\frac{13}{16}$
			x_1	y	y_1	z				
			$3\frac{1}{2}$	$3\frac{13}{64}$	5	$1\frac{19}{32}$				

KEY SPACING FOR NUMERALS				
NUMERALS	LEFT	RIGHT	RIGHT ↔ LEFT	SPACING BETWEEN NUMERALS
1	I	I	I ↔ I	0·93
2	II	II	I ↔ II	
3	IV	III	II ↔ I	
4	IV	IV	I II ↔ III IV	0·70
5	I	II	III IV ↔ III	
6	II	II	II ↔ II	
7	IV	III	III IV ↔ III IV OPPOSITE	0·47
8	II	II		
9	II	II	III IV ↔ III IV PARALLEL	0·00
0	II	II		

STANDARD NUMERALS OF 5 INCH HEIGHT

SCALE:– 1 IN. 3/4 1/2 1/4 0 1 IN.

Plate VI



KEY

SPACING FOR LETTERS

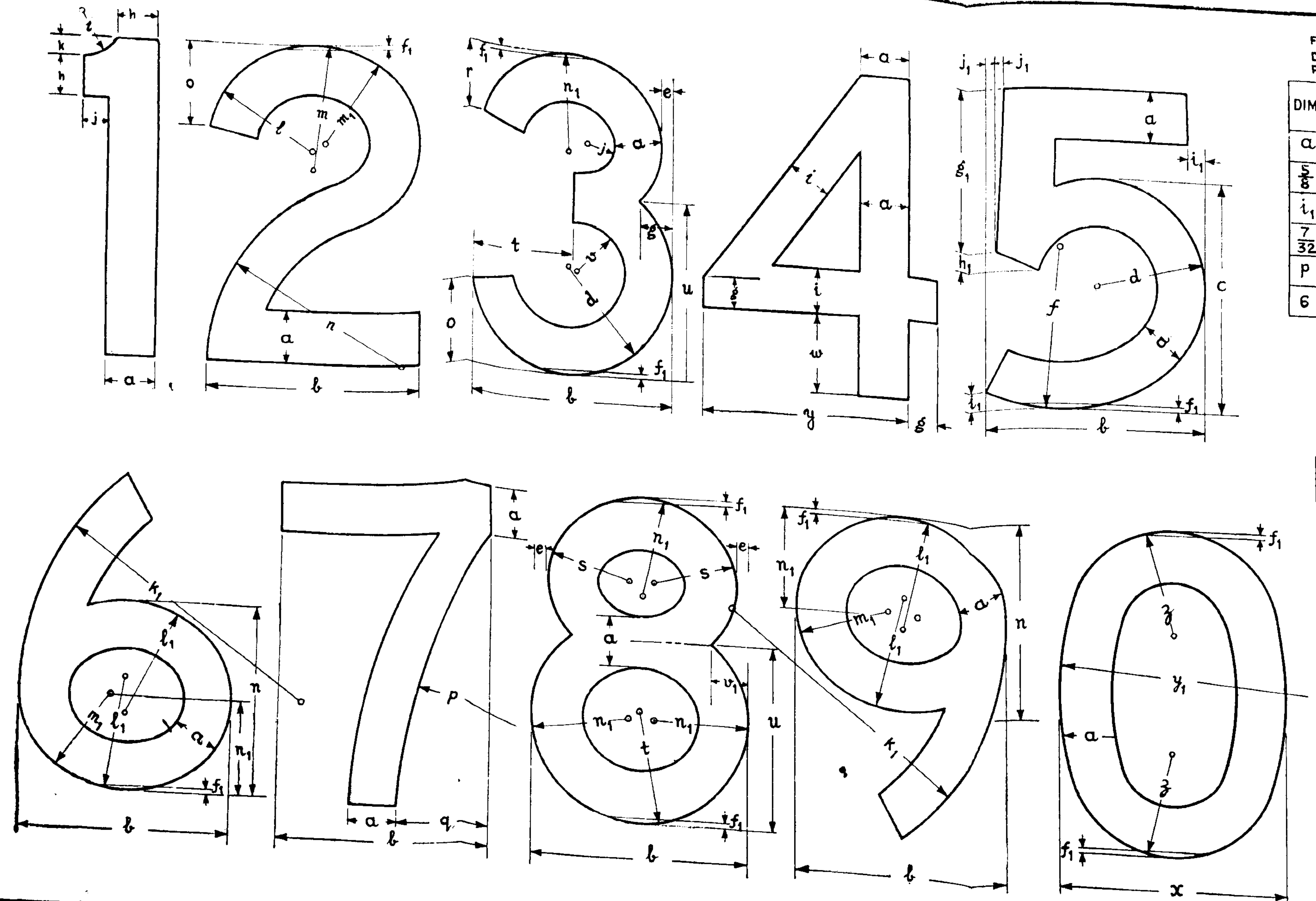
LETTER	LEFT	RIGHT	LETTERS	LEFT	RIGHT
A	III	III	N	I	I
B	I	II	O	II	II
C	II	IV	P	I	II
D	I	II	Q	II	II
E	I	IV	R	I	II
F	I	IV	S	II	II
G	II	II	T	IV	IV
H	I	I	U	I	I
I	I	I	V	III	III
J	IV	I	W	III	III
K	I	IV	X	IV	IV
L	I	IV	Y	IV	IV
M	I	I	Z	IV	IV

RIGHT ←→ LEFT	SPACING BETWEEN LETTERS
I ←→ I I ←→ II II ←→ I	0·56
I II ←→ III IV III IV ←→ I II II ←→ II	0·42
III IV ←→ III IV OPPOSITE	0·28
III IV ←→ III IV PARALLEL	0·00

DIMENSIONS (INCHES) FOR 3 INCH HEIGHT OF LETTERS

a	b	b_1	b_2	c	c_1	c_2	d	d_1	d_2	e	e_1	e_2	f	f_1
$\frac{15}{32}$	$2\frac{1}{2}$	$2\frac{1}{64}$	$2\frac{17}{32}$	$2\frac{3}{8}$	$\frac{27}{32}$	3	$1\frac{5}{64}$	$1\frac{53}{64}$	$\frac{61}{64}$	$\frac{55}{64}$	$1\frac{5}{16}$	$\frac{21}{32}$	$\frac{15}{16}$	$\frac{1}{16}$
f_2	g	g_1	g_2	h	h_1	h_2	i	i_1	i_2	j	j_1	j_2	k	k_1
$\frac{3}{64}$	1	$1\frac{9}{16}$	$\frac{63}{64}$	$1\frac{47}{64}$	$\frac{3}{4}$	$\frac{39}{64}$	$\frac{27}{64}$	$\frac{13}{16}$	$\frac{7}{16}$	$\frac{25}{64}$	$\frac{31}{64}$	$\frac{17}{32}$	$2\frac{5}{16}$	$\frac{9}{32}$
k_2	l	l	l_2	m	m_1	m_2	n	n_1	n_2	o	o_1	o_2	p	p_1
$1\frac{7}{8}$	$2\frac{7}{64}$	$\frac{3}{32}$	$1\frac{1}{32}$	$\frac{7}{64}$	$2\frac{1}{4}$	$2\frac{5}{8}$	$1\frac{11}{64}$	$\frac{15}{64}$	$\frac{3}{8}$	$\frac{9}{64}$	$\frac{29}{32}$	$2\frac{1}{16}$	$1\frac{59}{64}$	$\frac{33}{64}$

STANDARD LETTERS
OF
3 INCH HEIGHT



FOR HEIGHTS OF NUMERALS OTHER THAN 4 IN. THE DIMENSIONS GIVEN IN THE TABLE ARE TO BE PROPORTIONATELY INCREASED AND DECREASED.

DIMENSIONS (INCHES) FOR 4 INCH HEIGHT OF NUMERALS

a	b	c	d	e	f	f_1	g	g_1	h	h_1	i
$\frac{5}{8}$	$2\frac{11}{16}$	$2\frac{7}{8}$	$1\frac{11}{32}$	$\frac{5}{32}$	$2\frac{1}{32}$	$\frac{1}{16}$	$\frac{3}{8}$	$2\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{9}{16}$
i_1	j	j_1	k	k_1	l	l_1	m	m_1	n	n_1	o
$\frac{7}{32}$	$\frac{11}{32}$	$\frac{3}{32}$	$\frac{1}{4}$	$3\frac{9}{16}$	$1\frac{5}{16}$	$1\frac{7}{16}$	$1\frac{9}{16}$	$1\frac{5}{32}$	$2\frac{7}{16}$	$1\frac{7}{32}$	$1\frac{1}{16}$
p	q	r	s	t	u	v	v_1	w	x	y	y_1
6	$1\frac{3}{16}$	$\frac{13}{16}$	$1\frac{1}{32}$	$1\frac{3}{8}$	$2\frac{1}{4}$	$\frac{19}{32}$	$\frac{15}{32}$	1	$2\frac{13}{16}$	$2\frac{9}{16}$	4
					z						
					$1\frac{9}{32}$						

KEY
SPACING FOR NUMERALS

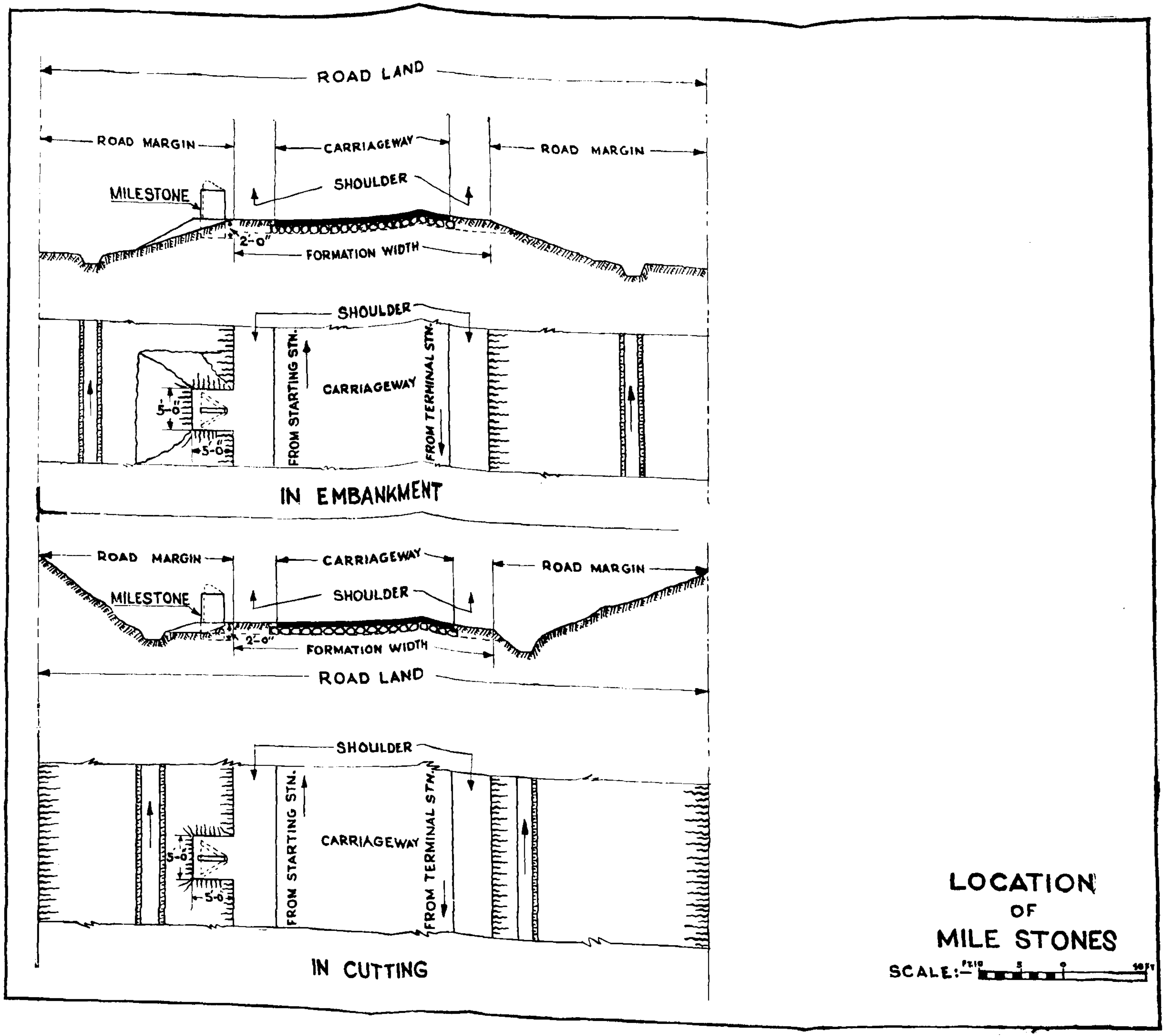
NUMBER	LEFT	RIGHT
1	I	I
2	II	II
3	IV	II
4	IV	IV
5	I	II
6	II	II
7	IV	III
8	II	II
9	II	II
0	II	II

RIGHT ↔ LEFT	SPACING BETWEEN NUMERALS
I ↔ I I ↔ II II ↔ I	0·74
I II ↔ III IV III IV ↔ I II II ↔ II	0·56
III IV ↔ III IV OPPOSITE	0·38
III IV ↔ III IV PARALLEL	0·00

STANDARD NUMERALS OF 4 INCH HEIGHT

SCALE :— 1 3/4 1/2 1/4 0 1 IN.

Plate X


ROAD LAND
ROAD MARGIN
CARRIAGEWAY
ROAD MARGIN
MILESTONE
SHOULDER
2'-0"
FORMATION WIDTH
SHOULDER
5'-0"
5'-0"
FROM STARTING STN.
CARRIAGEWAY
FROM TERMINAL STN.
IN EMBANKMENT
ROAD MARGIN
CARRIAGEWAY
ROAD MARGIN
MILESTONE
SHOULDER
2'-0"
FORMATION WIDTH
ROAD LAND
SHOULDER
5'-0"
5'-0"
FROM STARTING STN.
CARRIAGEWAY
FROM TERMINAL STN.
IN CUTTING
LOCATION
OF
MILE STONES
SCALE:-

III. PREVENTION OF WET WEATHER DAMAGE TO SURFACE DRESSINGS

(Extracted from Road Note No. 14 issued by Road Research Laboratory, Harmondsworth).

INTRODUCTION

Serious failures of newly laid surface dressings may be caused by rain displacing the binder from the chippings, which are then whipped off by traffic. To avoid these failures, surface dressing is usually confined to periods of fine weather. The unsettled weather during most British summers results in expensive delays.

Damage due to wet weather can be prevented by the adoption of a simple process which renders the dressings immune to the action of water and thus makes it possible to continue surface dressing operations with confidence throughout periods of unsettled weather. In the process a solution of an adhesion agent in creosote oil is applied to the interface between the binder and the stone chippings. Two methods of doing this are described below :

Method 1.

PRE-TREATMENT OF THE STONE CHIPPINGS

The chippings used for the surface dressing are treated before use with the solution of D. S. 2274* in a suitable mixer. Probably the cheapest method of mixing is in the double paddle mixer of a coated-macadam or asphalt plant. Chippings less liable to produce dust may also be treated by mixing in a concrete mixer. The use of the largest available mixer is recommended as it is more economical in labour and time. The mixer should be cold, clean and free from dust, tar, bitumen or cement before use. There is no need to dry the aggregate.

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*In India this preparation is marketed under the trade name of "Adhevia T." D. S. 2274 is obtainable from any of the offices of Imperial Chemical Industries Ltd. It is used as an 8 per cent solution in light creosote oil and can be used with both Tar and Bituminous binders.

The stone chippings are mixed with the D. S. 2274 solution at a rate of 0.5 to 2 gallons of solution per ton of chippings, depending on the type, size and cleanness of the stone. Large, smooth, clean stones will require less solution for adequate coating than small, rough, dusty chippings. Mixing is continued for about two minutes until the chippings are coated with the solution. When this occurs, it will be found that the chippings are waterproof: when water is poured on them, it will collect in droplets instead of wetting the stone surface. This is a convenient quick test for determining the mixing-time and quantity of solution required.

A simple reliable test to show whether the stone is efficaciously coated can be made by pressing the treated stone into a layer of binder about 3 mm. thick beneath the surface of water contained in a suitable vessel. After five minutes, the treated stone should adhere firmly to the binder.

The chippings can be mixed while dry or wet; a slight adjustment of the quantity of D. S. 2274 solution to be added may be required if the conditions change.

The coated chippings can be stocked in piles until required. Cases are known where chippings were still effectively coated after 4 months' storage by the roadside. In other cases the treatment has become less effective after a week's storage in the open. This point is still under investigation and until more is known it is recommended that chippings be used within one month of treatment.

The pre-treated stone technique is most effective with aggregates that do not produce much dust, although success can be obtained with aggregates of all types. Dusty aggregates should receive the minimum amount of handling before mixing.

The pretreatment of the stone with D. S. 2274 solution was estimated to cost not more than three half pence per sq. yard even when carried out in small batches in a concrete mixer. On a large scale, the cost should be appreciably less.

Method 2.

SPRINKLING THE SOLUTION ON THE BINDER FILM

The solution of D. S. 2274 in creosote is spread over the fresh binder film, before the chippings are applied, by means of an attachment to the back of the binder distributor.

The rate of flow of the D. S. 2274 solution to the sprinklers is adjusted to ensure that, at the specified speed of the binder distributor, the solution is applied at a rate not heavier than 140-180 sq. yard per gallon. Although the rate of application of the solution is not critical, when excess quantities are applied the creosote will soften the binder unduly.

Gritting is carried out in the normal way, immediately after the binder film has been sprinkled with the solution.

General Comments

It must be emphasised that the use of an adhesion agent will not improve an otherwise poor dressing. Most of the premature failures of surface dressings arise from the unsuitable rate of spreading binder or from an uneven distribution of binder, and failures resulting from these and similar faults cannot be prevented by the use of adhesion agents.

SPECIFICATION FOR THE SOLUTION OF D. S. 2274* IN LIGHT CREOSOTE OIL FOR USE IN SURFACE DRESSING WORK

The solution shall consist of a mixture of light creosote oil, of which the properties are defined below, and of D. S. 2274 in the proportions of 92 parts by weight of the light creosote oil and 8 parts of the D. S. 2274. The solution shall be made by mixing the creosote in a suitable vessel with the appropriate quantity of D. S. 2274 and stirring mechanically. The solution is then placed in suitable containers such as metal drums.

Specification for light creosote oil

The creosote oil shall be wholly derived from the distillation of gas works vertical—or horizontal—retort tars or of coke-oven tars.

Specific gravity

The specific gravity of the creosote oil shall lie between 0.950 and 1.000.

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*Other methods of treating wet aggregates, involving the use of turkey red oil and lime, are discussed in the I. R. C. Journal Vol. XIV—3. It has been roughly estimated that costs of applying the adhesive agent per 100 sq. ft of surface dressing are: Turkey red oil Rs 1/5/-; Lime -/8/-, and Adhevia T -/11/-.

Distillation Properties

The percentage of the oil which distils in the following ranges shall be as indicated :

Temperature range	Percentage distilled
Up to 200° C	0 — 10
Up to 250° C	not less than 60
Up to 270° C	not less than 80

Fluidity

It is most important that the creosote oil shall be fluid, that is, free from deposits of crystals at 0° C (32° F).

RESEARCH SECTION

AN INVESTIGATION ON SOME LATERITES

CENTRAL ROAD RESEARCH INSTITUTE

OKHLA, DELHI.

FOREWORD

In some parts of India laterites are the only natural road building material available. The alternatives are to import harder stone from long distances at great cost or to burn bricks locally and use them for soling and metalling.

The term 'laterite' covers a type of material which can be as soft as hard clay conglomerate or as hard as or somewhat harder than good, well-burnt bricks. Moreover, the material is not homogeneous. In a small piece some parts may be soft and others quite hard.

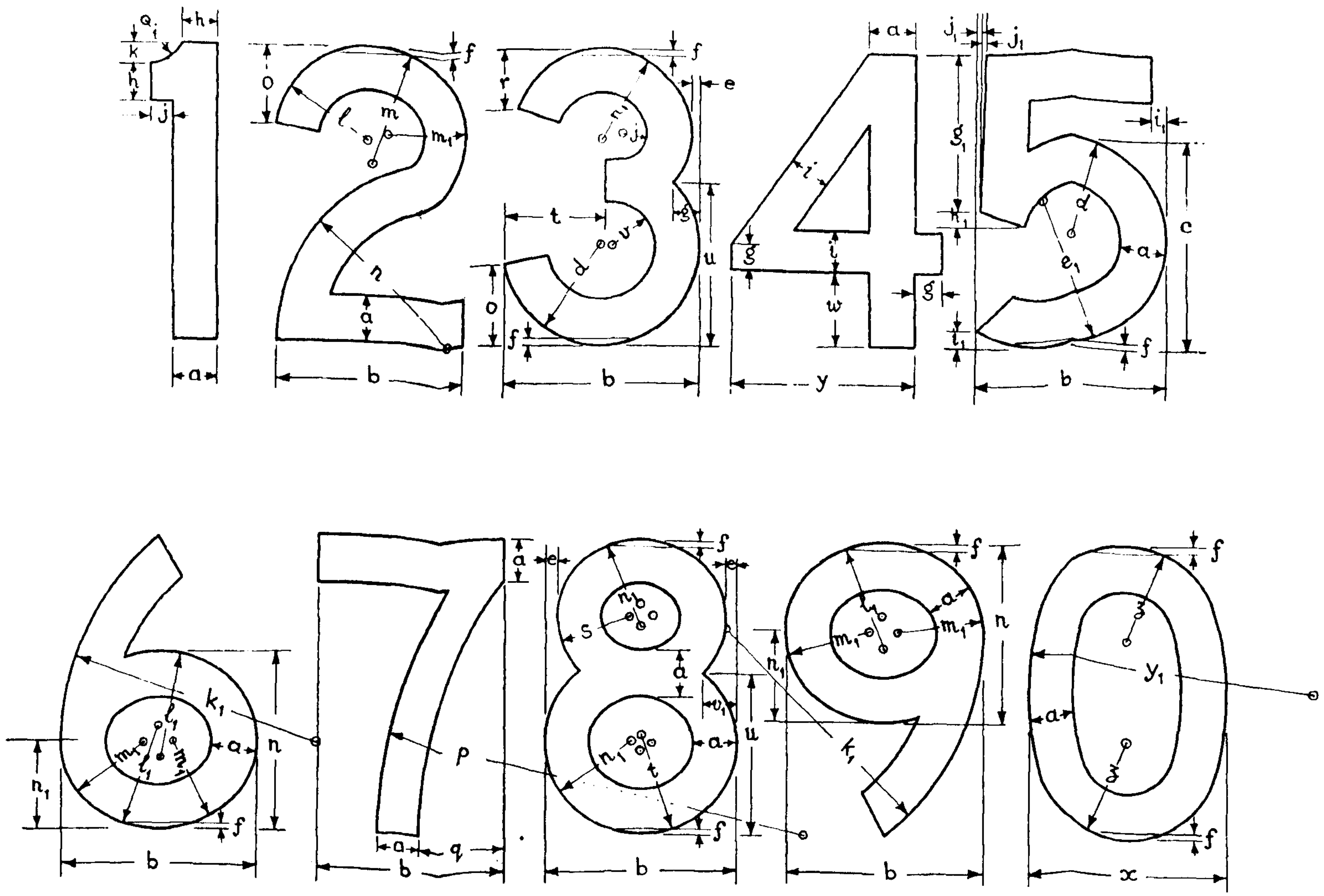
Six samples of fairly good laterite were tested in the Central Road Research Institute for their usefulness as a road making material. The results of the laboratory tests are published to give the engineers an idea of the nature of this material and its suitability for road construction. It is necessary, however, to emphasise that the results given in this Note are applicable to good laterites and not to *anything* passing under that name. In any particular case it would be desirable to test the material *actually to be used* before using it on a large scale.

This investigation was conducted as a part of the research programme of the Central Road Research Institute. The Director wishes to acknowledge the work done in conducting the chemical and physical tests in the Rigid Pavements Section by Messrs G. F. D. Gonsalves, R. Nagarajan and R. Krishnamachari, and in the Soils Section by Dr. H. L. Uppal and Messrs K. L. Nayyar and A. L. Chatwal.

Central Road Research Institute,
Okhla, Delhi.

E. ZIPKES,
Director.

Plate IX



DIMENSIONS (INCHES) FOR 3 INCH HEIGHT OF NUMERALS

a	b	c	d	e	e_1	f	g	g_1	h	h_1
$\frac{15}{32}$	$2\frac{1}{64}$	$2\frac{5}{32}$	1	$\frac{7}{64}$	$1\frac{33}{64}$	$\frac{3}{64}$	$\frac{9}{32}$	$1\frac{35}{64}$	$\frac{3}{8}$	$\frac{9}{64}$
i	i_1	j	j_1	k	k_1	l	l_1	m	m_1	n
$\frac{27}{64}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{1}{16}$	$\frac{3}{16}$	$2\frac{43}{64}$	$\frac{63}{64}$	$1\frac{5}{64}$	$1\frac{11}{64}$	$\frac{55}{64}$	$1\frac{53}{64}$
n_1	o	p	q	r	s	t	u	v	v_1	w
$\frac{29}{32}$	$\frac{51}{64}$	$4\frac{1}{2}$	$\frac{57}{64}$	$\frac{39}{64}$	$\frac{49}{64}$	$1\frac{1}{32}$	$1\frac{11}{16}$	$\frac{7}{16}$	$\frac{11}{32}$	$\frac{3}{4}$
				x	y	y_1	z			
				$2\frac{7}{64}$	$1\frac{59}{64}$	3	$\frac{61}{64}$			

KEY
SPACING FOR NUMERALS

NUMERALS	LEFT	RIGHT
1	I	I
2	II	II
3	IV	II
4	IV	IV
5	I	II
6	II	II
7	IV	III
8	II	II
9	II	II
0	II	II

RIGHT ↔ LEFT	SPACING BETWEEN NUMERALS
I ↔ I I ↔ II II ↔ I	0.56
I II ↔ III IV III IV ↔ I II II ↔ II	0.42
III IV ↔ III IV OPPOSITE	0.28
III IV ↔ III IV PARALLEL	0.00

STANDARD NUMERALS OF 3 INCH HEIGHT

SCALE :- IN. 1 3/4 1/2 1/4 0 1 IN.

CONTENTS

TABLES

All photos taken by the Central Road Research Institute, Delhi.
Colour plates printed at the Times of India Press, Bombay.

AN INVESTIGATION ON SOME LATERITES

The Suitability of Laterites for the Construction of Water-Bound Macadam Roads

1. PROBLEM

1.1. Exposition

The problem put to the Central Road Research Institute was to advise whether the laterite boulders furnished as samples were suitable for road construction.

This general problem arises in areas where no suitable mineral material is available except laterite boulders. The mineral material usually employed in road construction can be used as boulders for soling or as metal layers on top of the boulders, or as surface chippings for water-bound macadam or, when mixed with binders—bituminous or others—for surface dressings or carpets. The request put to the Institute was to investigate the suitability of these laterites for water-bound macadam. So the first problem was to ascertain the suitability of the materials for soling and metal, and only secondly for surface dressings.

1.2. The Material

Grenville A. J. Cole describes in his "Outlines of Mineralogy" published in 1913, on page 216, the possible formation of laterites as follows:

> "DIASPORE, $AlO(OH)$ (= $Al_2O_3 . H_2O$), is a colourless or palely tinted rhombic mineral, in elongated prismatic crystals, which is found with corundum in many localities. GIBBSITE (HYDRARGILLETE), $Al(OH)_3$ (= $Al_2O_3, 3H_2O$), is similarly white or palely coloured. Occurs as monoclinic six-sided platy crystals, also associated with corundum. The geological interest of these minerals lies in the probability that as a mixture they form the rock known as Bauxite, to which a composition of $(Al,Fe)_2O_3.2H_2O$ has sometimes been assigned. Bauxite may be pale blue or grey, or strongly coloured by haematite or limonite. The ferruginous varieties are known as "laterite", and occur as products of decomposition, under tropical conditions of weathering, of all manner of rocks containing aluminium silicates, such as granites, basalts, shales, etc. Moisture as well as heat seems required for the formation of laterite and bauxite; the process involves the almost complete removal of the silica from the

original silicates, but the retention of the alumina as a hydrate. Kaolinisation and laterisation thus present themselves as opposed processes.

T. H. Holland[1] points out, from his wide experience in India that dehydration proceeds in the lateritic mass. Gibbsite thus passes into diaspore, while gothite and even haematite develop.

This may explain the extremely heterogeneous character of the material. Earlier to Grenville, Newbold described in his papers (1844, 1846) very exactly how these laterites appear to a merely visual inspection. Prescott and Pendleton[2] (1952) give in a very brief manner valuable information about all sources where laterites are found. The cited description of Newbold about laterite is also found on page 5 of Prescott and Pendleton's publication.

"The laterite of Beder, generally speaking, is a purplish or brick-red, porous rock, passing into liver brown perforated by numerous sinuous and tortuous tubular cavities either empty, filled, or partially filled with a greyish-white clay passing into an ochreous, reddish and yellowish brown dust; or with a lilac-tinted lithcoargic earth.

The sides of the cavities are usually ferruginous and often of a deep brown or chocolate colour; though generally not more than a line or two in thickness, their laminar structure may frequently be distinguished by the naked eye. Before the blow-pipe it melts into a black clay attracted by the magnet, but is rarely so ferruginous as to entitle it to the character of an ore of iron: though some of the nodules are picked out, and smelted by the natives. The interior of the cavities has usually a smooth polished superficie, but sometimes mammillary, and stalactiform on a minute scale. The hardest varieties of the rock are the darkest coloured, and most ferruginous. The surface masses of the softer kinds present a variegated appearance. The clay and lithomarge exhibit lively coloured patches of yellow, lilac, and white, intersected by a network of red, purple, or brown. The softness of this rock is such that it may be cut witha spade;

1. "On the Constitution, Origin, and Dehydration of Laterite," Geol. Mag. (1903), 59, See also discussion and references in Clarke, "Data of Geochemistry", U. S. Geol. Surv., Bull. 491 (1911), 469, and in "The Interbasaltic Rocks of N. E. Ireland", Geol. Surv. Ireland (1912), 6.

2. "Laterite and Lateritic Soils" by J. A. Prescott and R. L. Pendleton, Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England (1952).

hardening by exposure to the sun and air, like the laterite of Malabar. The surface of the harder or more ferruginous varieties is usually barren, flat like a pavement and often presents a glazed or semi-vitrified appearance".

Therefore the investigation went a little more into detail about the properties of the laterites than usually done, when minerals are investigated on their suitability for road construction.

1.2.1. Location

All the six laterites originate from a State in Eastern India and represent samples from six different quarries of one district.

1.2.2. Appearance

Visual examination of the six samples of laterites show that the heterogeneous character of this material originates from a skeleton of relatively great hardness with soft materials consisting of mixtures of differently graded soils which is deposited in the cavities of the skeleton and always surround it on the outside.

Photos 1 to 6 give sectional cuts through the laterites and give an impression of the material. The structure, the skeleton and cavities, and the soft material can easily be seen. The cavities were sometimes found empty. But when full or only partly filled, the inclusions were of a silty to clayey composition while the sandy portions usually occupied the outside.

The colour of the soft material in the cavities varies between bright yellow to strong red and of the skeleton from brown to dark-violet. The mainly sandy portions between the skeletons, but not in their inside, have no typical colour-shade. Photos 7 and 8 reproduce the respective view from photos 1 and 3 in natural colours, which facilitate comparison to the colours of the four other laterite samples and also *vide* Newbold's description.

2. INVESTIGATION

2.1. Preparation of the Material

Owing to the heterogeneous character of the samples, some of the investigations, *vide* 2.2.1 to 2.2.3, were conducted separately on the component materials as well as on part of the original sample taken as a unit. The material filling the voids in the skeleton and the soft material outside displayed properties and effects entirely different from the harder material of the skeleton.

For use of the laterites in road construction it is important to know the behaviour of both the materials. Therefore, the samples were crushed, following the natural fissures and joints, after being soaked in water, and the fine material was separated from the skeleton as far as possible. The use of great force in crushing was avoided so as not to get powdered fractions from one kind of material mixed with the other. The material passing after this crushing process through ASTM Standard Sieve No. 40 was declared as the "fine," and the rest as the "coarse" fraction. These two different groups were investigated separately, both chemically and physically.

2.2. Tests Conducted and Discussion

2.2.1. Distribution of fine and coarse material and mechanical analysis of the fine fraction (Table 1).

The distribution of fine and coarse material and the mechanical analysis of the fine fraction is shown in Table 1. The percentage of the finer materials varies between 7 to 20 per cent.

The fine material has been subjected to mechanical analysis by sieving and by sedimentation. The results as well as the contents of sand : silt : clay : colloidal matters are also given in Table 1. The determination shows that the clay content of the fine fraction varies between 9 to 14 per cent and its percentage of colloidal matter between 4 and 14 per cent.

2.2.2. Physical Characteristics (Table 2)

Some physical characteristics of the six laterites, as natural mixed samples and as fine and coarse fraction, are given in **Table 2**. From the fine fraction alone, the liquid limit and the plasticity index as well as the specific gravity have been determined. The specific gravity is also shown from the coarse fraction as well as from the natural mixed samples of the laterites, from which also the void ratio and the percentage porosity have been indicated.

The results show that the plasticity index of the fine fraction varies between 12 to 23. Further, the percentage of the porosity given in percentages to the whole volume varies between 21 to 35 per cent. This shows the great influence of the cavities, which can be seen in the six photographs covering in average almost a third of the total volume.

2.2.3. Chemical Analysis (Table 3)

The results of the chemical analysis, by HCl extraction, of the six laterites are given in **Table 3.**

The laterites have been analysed for insoluble residue, sesquioxide (content of the $Fe_2O_3 + Al_2O_3$), the total basis, the loss on ignition, and the pH-value. Except the loss of ignition and pH-value, all the four analyses have been conducted on three different samples, the natural mixture, the coarse fraction, and the fine fraction. In the analysis given for insoluble residue, and sesquioxide the top line gives the values for the natural mixture following the conduction of the analysis itself and in the lower line its value as a result of a calculation out of the results of the analyses of the two fractions. The more the calculated and the determined data coincide as given in the upper and the lower lines the better was the accuracy in the fractionation and in the conduction of the three analyses for each laterite. The analyses show further whether the tested samples do really represent the natural average sample.

2.2.4. Swelling Effect (Table 4)

To find out whether the influence of the fine fraction present may have a swelling effect on the laterites, when saturated with water, all the six laterites, in the form of cubes of the size of approximately 3 to $3\frac{1}{2}$ inches, were immersed for 24 hours in water. The results of these tests are given in **Table 4**, and they show that a swelling effect is present. But its value in all the six cases is very low and of no great importance, especially because the determined swelling effect diminishes after some time of immersion, after having reached a maximum. In average, it is not more than a few hundredths of one per cent of expansion and this small expansion can be safely neglected.

The fine material will therefore have little influence on the behaviour of the material when used for purposes of road construction. There may be a possibility of "frost–effect" arising from the presence of the fine fraction deposited in the natural fissures and joints of the laterite. These deposits did not show swelling after saturation with water alone but they may attain a swelling property when subjected to frost. Tests under frost conditions were not conducted as it is not expected that there will be frost action on the roads in the particular district where the laterites could be used.

The specimens submitted to the swelling test were the same as those used for the absorption test (*vide* 2.2.5) as well as for the compression test under wet conditions (*vide* 2.2.6).

2.2.5. Capacity of Water-absorption (Table 5)

The same cubes of the six laterites used in test *vide* 2.2.4 were used for investigating their capacity for water-absorption. These tests were conducted with the samples after they had been immersed in water for 22 hours. Then for one hour they were kept in air in order to let surface water trickle off and one more hour was reserved for taking their weights. This procedure was done 3 times in continuity. The results are given in **Table 5**.

The results show that almost the whole absorption took place during the first period, in the first 22 hours. Only a very negligible quantity of water or nothing at all was absorbed during the second and third stage of immersion, which can easily be noted from **Table 5**. The results give the absorption-capacity as 8 to 13 per cent which means an approximate additional absorption of about 7 to 12 per cent to the initial moisture content.

Taking into consideration a porosity of from 21 to 35 per cent, it is obvious that not all shells and voids are filled with water, even after three immersions of 22 hours each. This proves that most of the cavities behave as if practically water-tight and do not come in touch with the liquid.

2.2.6. Compression Strength (Table 6)

The set of cubes used for the tests to determine the swelling effect and the capacity of water-absorption and one more set of similar cubes but dry were tested for their compression strength. **Table 6** gives the results of the compression tests on dry and saturated cubes.

Compression strength tests on three first class bricks, locally burnt, were also conducted. This was done to get comparable results for the planned use of laterites in road construction. The bricks were subjected "flat" to the tests because they are usually put in that position as soling material. The depression on one side of the brick was filled up with neat cement paste. The samples were then kept in air for 24 hours and both the flat sides of the bricks were capped with plaster of paris. The procedure for conducting the compression strength tests was the usual one and the results are given also in **Table 6**.

Unlike the laterites, the 3 bricks gave comparably uniform compressive-strength results with an average of 1,495 lb per sq. inch. Both the uniformity as well as high value may be influenced by the particular form of bricks in flat position. Any comparison of these values is, therefore, not to be made directly without making any allowance for this. The average values approximate to those obtained from tests on the laterites in the dry condition (laterites 1, 5, and 6) and in the saturated condition (laterites 2, 5, and 6).

Unfortunately it was not possible to subject more than one cube of laterite of each kind to the compression test and the results are therefore based on a single test instead of a larger number out of which an average could have been taken.

With materials like laterite, a very large deviation is to be expected, as indeed is clearly shown even from the few tests carried out. These results can, therefore, only be taken as symptomatic and not as suitable for arriving at firm conclusions. The reasons why more tests could not be carried out were the inadequate number of samples supplied and the peculiar structure of the material which prevented the making of smaller samples for the tests. The photographs of the six laterites also illustrate the big deviation in the composition of laterites taken from different quarries of the same district.

In spite of the inconclusiveness of the results, a comparison with bricks in general may be made. Bricks usually display an immense scattering in the values of compression strengths even when they are taken from the same kiln. The Journal of the Indian Roads Congress, Vol. XV-3, page 398, contains data collected by K.C. De on the compression strengths of first class bricks of higher values than obtained at Delhi. Possibly some of this variation arises from the difference in the sizes of the bricks tested, but it also indicates the variation in quality of bricks manufactured in different localities.

The results of the compression strength tests of the six dry and six wet sample cubes of laterite vary between 550-1960 lb per sq. inch. From this it appears that the laterite samples 5 and 6 have the highest strength. Samples 1 and 2 show lower values with high variations. Samples 3 and 4 show relatively more uniform results than the 4 other samples but their values are much lower. The different sizes of the cavities as can be seen from the Photographs 1 to 6 have certainly an influence also on the compression strength and that may explain for instance the low values of laterite 3.

2.2.7. Aggregate Crushing Value (Table 7)

As compared with the uncertainty of the results obtained from the compression strength tests, the crushing tests give a more accurate picture of the properties of the laterites. Moreover, the crushing test is more nearly comparable with the actual wear to which a road construction material is put under the action of traffic. On these considerations due weight can approximately be given to the series of tests determining the aggregate crushing value, the results of which are given in Table 7.

The tests complied with the British Standard Specification No. 812 (1951) under which the load is applied at a rate of 4 tons per minute over a period of 10 minutes. When a total load of 40 tons is reached the loading is released. Gravel of size from $\frac{1}{4}$ to $\frac{3}{4}$ inch, and approximately 1/8th cu. ft in volume is placed in this test in a circular container of 6 in. diameter to a height of four inches. The crushing value is determined by ascertaining the percentage weight of crushed material passing B. S. Sieve 1/8 in. against the original weight. The arrangement used combined with the compression testing machine is shown in Photo 9.

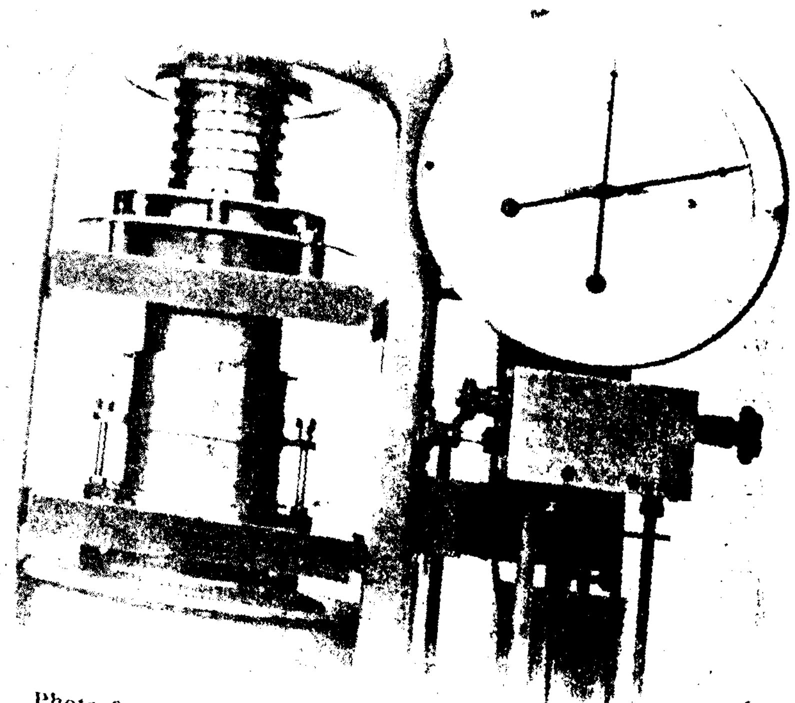


Photo 9. Arrangement for determining crushing value.

The British Standard Specification does not indicate the limits up to which crushing is permissible, but it was seen from the publication of the Cement Concrete Association of India, "Quality Concrete", Page 96, that the crushing value should not exceed 30 per cent for aggregates used in surfaces such as heavy duty floors, roads, etc., and 45 per cent in all cases.

In order to be able to compare the results of the crushing value of the six laterites, the crushing values of Delhi quartzite and first class local bricks were determined also. The quartzite, the material usually used for soling and metalling in Delhi area, is relatively hard. The first class bricks, usually used for soling and metalling, even on national highways, could be taken as a

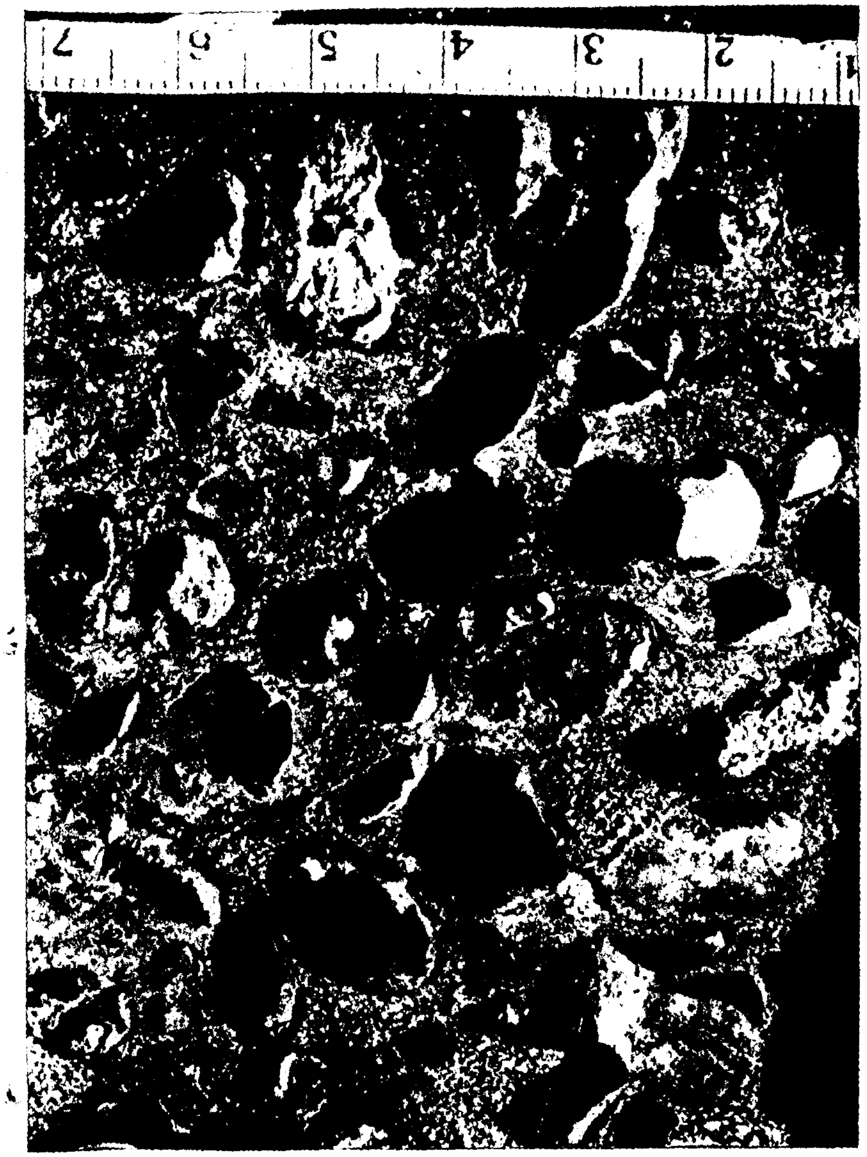


Photo: 2. Sectional cut through laterite No. 2. 160 per cent natural size (mm).

Photo: 4. Sectional cut through laterite No. 4. 160 per cent natural size (mm).

Photo: 5. Sectional cut through laterite No. 5. 160 per cent natural size (mm).

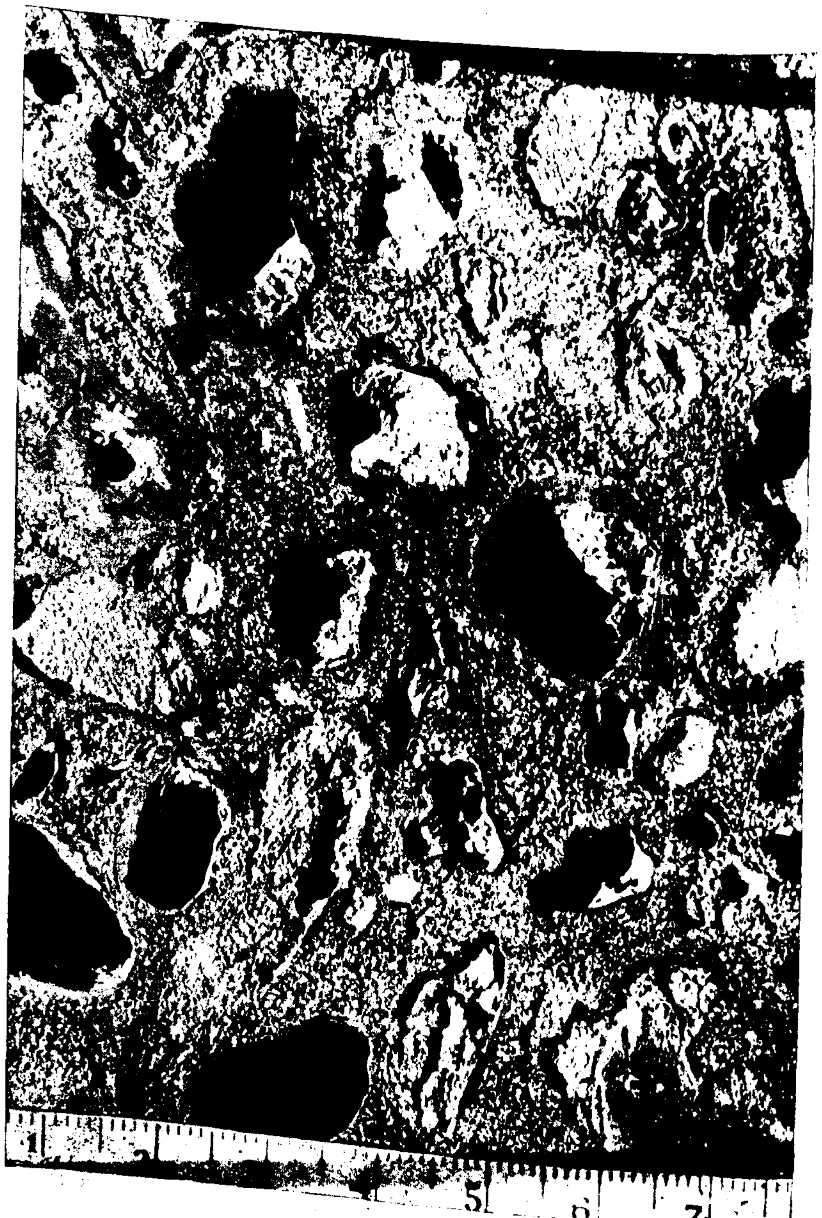


Photo : 1. Sectional cut through laterite No. 1. 160 per cent natural size (mm).

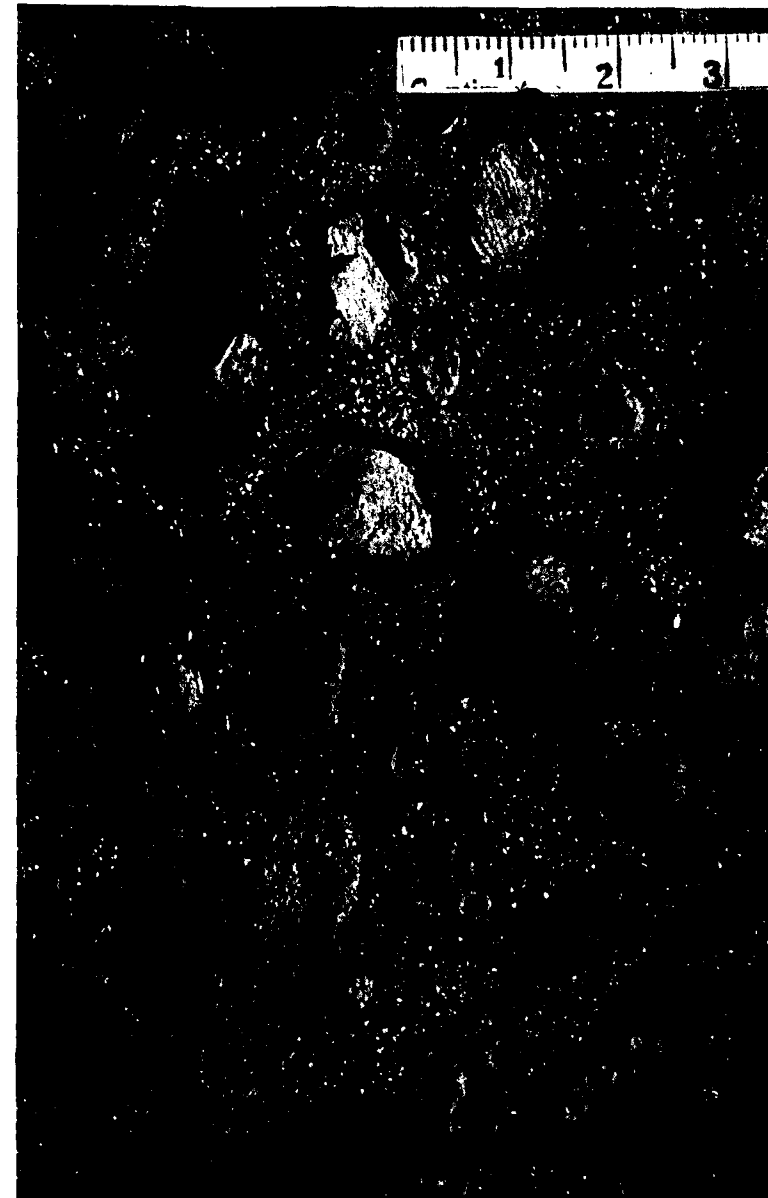


Photo : 8. Sectional cut through laterite No. 1. 160 per cent natural size (mm.).

Photo: 5. Sectional cut through laterite No. 5. 160 per cent natural size (mm).

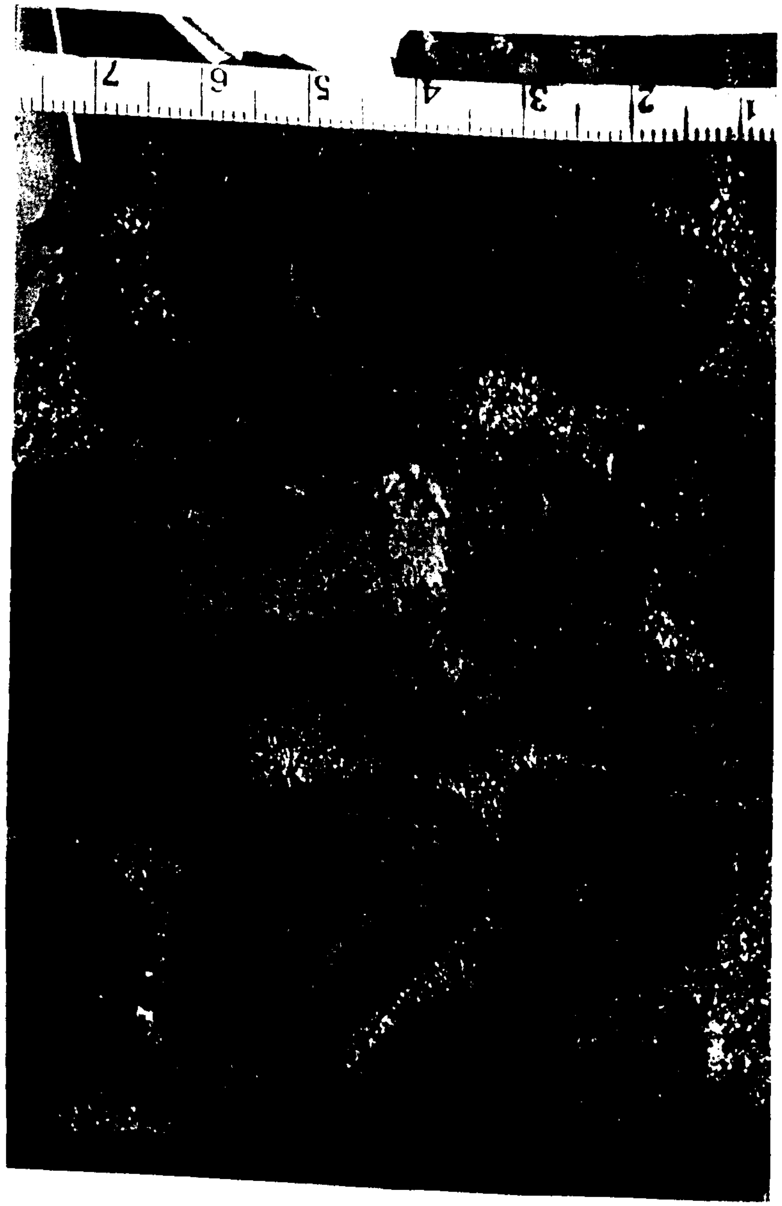


Photo : 7. Sectional cut through laterite No. 3. 160 per cent natural size (mm.).

Photo : 3. Sectional cut through laterite No. 3. 160 per cent natural size soft to medium-strong material. The results conducted on two samples of each material independently show very little deviation and therefore are reasonably conclusive.

These comparisons are valuable in the evaluation of the usefulness and suitability of broken laterite boulders as soling material and metal in road construction.

The results in Table 7 give for the quartzite, as expected, a relatively low value which corresponds to its hardness. The crushing value of the bricks is as high as about the highest value of the laterites, the laterite sample No. 2. The values given by the six laterites varied between 34 per cent and 50 per cent. Laterite of the types tested can therefore be considered for purposes of soling and metalling as a material with less wearing properties for road construction than first class bricks.

3. EVOLUTION

The investigation shows that the six laterites can safely be used for road construction when the conditions are such that would permit the use of soft materials like bricks. Such laterite can readily serve as a soling and may also be used as an inferior road metal. Before it can be used as " chippings " for the top layer in water-bound macadam roads, careful sieving should be adopted in order to remove the fine and soft fractions released by crushing the material to obtain chips.

The friction between water-bound macadam surfaces and the types of vehicles using the roads of this type will be considerable and there will be correspondingly considerable wear of both the tyres and the surfaces. It would be of advantage to consider the possibility of using the laterite surface with some kind of carpet built up of local materials and binders. A relatively thin carpet of about 1 to 1½ in. in thickness should be sufficient.

4. CONCLUSION

The material under investigation can be used for soling in the form of boulders in the usual size as well as for road metal of 2½ in. gauge, in such cases where bricks or brick metal is used for the same purpose. Before being used as surface chippings, the crushed laterite material ought to be separated from its fine and soft components. It would be of advantage also to remove fines and soft materials before using laterite as road metal and sieving should be adopted compulsorily when conditions allow of this. Further investigations are indicated with a view to devising a more suitable and less wear-producing and, therefore, a longer lasting surface.

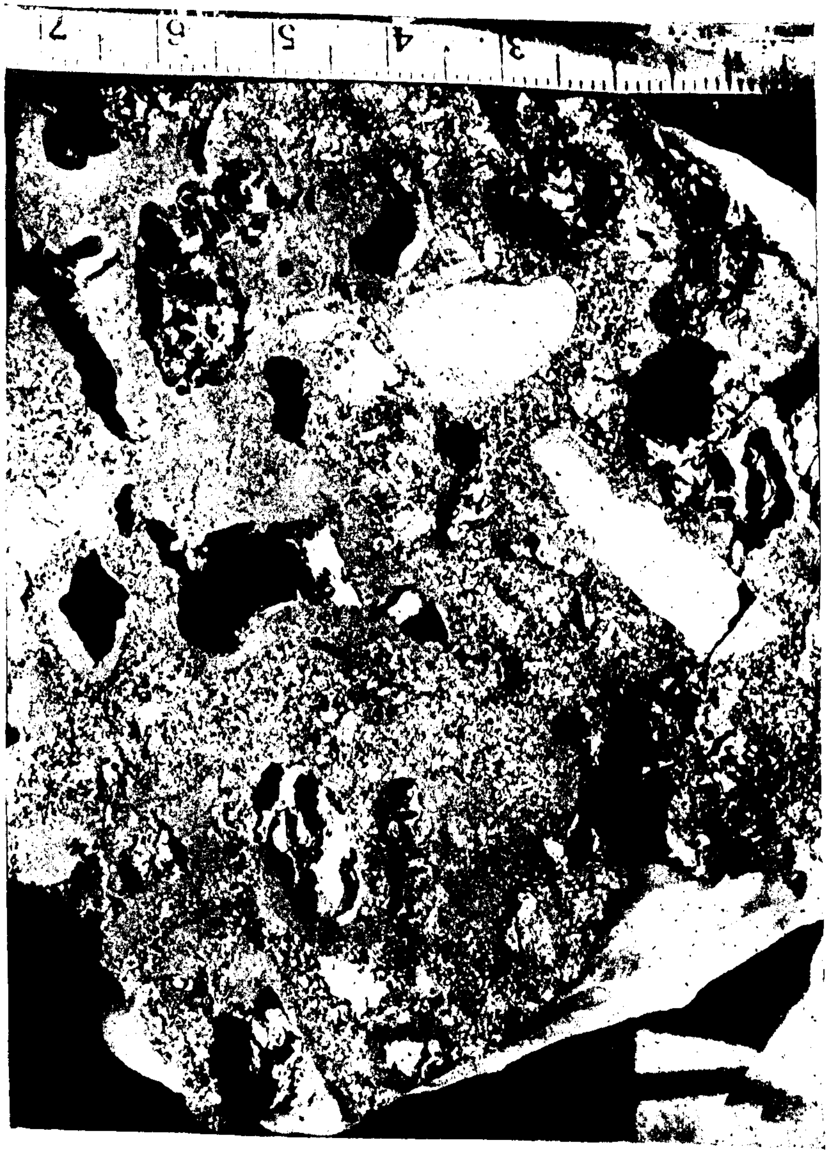


Photo : 6. Sectional cut through laterite No. 6. 160 per cent natural size (mm).

Table 1.

Distribution of fine and coarse material and mechanical analysis of the fine fraction.

Laterite. Specimen No.	Distribution of fine and coarse material percent			Mechanical analysis of the fine fraction in percent								
				Passing ASTM Sieves				by sedimentation in mm				
	Coarse*	Fine**	Error	40	60 Sand	100	200	0.05 — Silt	0.02	0.005 — Clay	0.002	0.001 Colloids
1	85.4	13.5	1.1	100	72.5	71.7	58.1	46.54	33.38	15.56	8.18	4.66
					53.46			30.98		10.90		
2	91.8	7.4	0.8	100	70.0	68.8	55.1	46.24	34.30	20.36	13.98	10.44
					53.76			25.88		9.92		
3	78.3	20.0	1.7	100	79.4	78.1	64.2	51.94	37.78	21.92	14.46	10.12
					48.06			30.02		11.80		
4	80.8	15.9	3.3	100	69.4	68.8	57.1	49.98	38.92	22.76	15.96	11.12
					50.02			27.22		11.64		
5	84.6	15.4	0.0	100	83.8	83.0	72.0	58.10	42.86	23.10	14.24	9.00
					41.90			35.00		14.10		
6	88.8	10.4	0.8	100	75.6	74.4	62.0	52.36	41.74	27.22	19.74	14.46
					47.64			25.14		12.76		

* Retention on ASTM Sieve 40. ** Passing through ASTM Sieve 40.

Table 2.

Physical characteristics of the six laterites and their fine fraction.

Laterite Specimen No.	Fine fraction			Coarse fraction	Laterite (natural)		
	Liquid Limit	Plasticity* Index	Specific gravity	Specific gravity	Specific gravity.	Void Ratio $\frac{\text{Vol. Voids}}{\text{Vol. Solids}}$	Porosity percentage
1	37.66	12.10	2.828	3.298	3.205	0.394	28.3
2	35.83	12.46	2.780	3.122	3.029	0.272	21.4
3	45.90	12.90	3.169	3.437	3.388	0.559	35.8
4	49.55	17.79	2.895	3.540	3.210	0.524	34.4
5	51.72	17.79	4.309	3.262	3.161	0.502	33.4
6	41.54	22.74	2.917	3.222	3.144	0.332	24.9

* Liquid Limit — Plastic Limit = Plasticity Index.

Table 3.

Chemical analysis of the six laterites by HCl extraction per cent.

Laterite Specimen No.	1			2			3		
Fraction.	Av.*	Coarse.	Fine.	Av.	Coarse.	Fine.	Av.	Coarse.	Fine.
Insoluble Silica.	47.10	43.08	70.40	40.73	39.71	71.29	36.90	35.98	53.62
Calculated from fine and coarse fraction.	46.36	—	—	41.73	—	—	38.03	—	—
$Fe_2O_3+Al_2O_3$ etc. (sesquioxide)	46.96	51.80	24.04	51.70	53.20	23.74	53.47	54.33	39.51
Calculated from fine and coarse fraction.	47.46	—	—	50.61	—	—	51.44	—	—
Loss on ignition.	← 6 to 7 per cent →								
pH value.	← 5.8 to 6.7 →								

* Average sample.

Tabe 3—(*contd.*)

Chemical analysis of the six laterites by HCl extraction per cent.

Laterite Specimen No.	4			5			6		
Fraction.	Av.*	Coarse.	Fine.	Av.	Coarse.	Fine.	Av.	Coarse.	Fine.
Insoluble Silica.	40.14	34.32	56.87	43.69	41.25	45.17	47.67	46.91	54.97
Calculated from fine and coarse fraction	35.77	—	—	41.85	—	—	47.37	—	—
$Fe_2O_3+Al_2O_3$ etc. (sesquioxide)	51.48	61.56	29.40	49.32	54.42	47.84	46.64	47.64	37.46
Calculated from fine and coarse fraction.	54.41	—	—	50.02	—	—	45.20	—	—
Loss on ignition.	← 6 to 7 per cent →								
pH value.	← 5.8 to 6.7 →								

* Average sample.

Table 4.

Swell test results of laterite cubes.

Specimen No.	Height of the specimen inches	Initial	Final	Max	Total Expansion inches	Expansion in per cent	Remarks
		Dial readings.					
1	$3\frac{1}{8}$	138.5	140.0	140.0	0.0015	0.048	
2	$2\frac{15}{16}$	399.0	403.0	403.0	0.004	0.1361	
3	$3\frac{3}{4}$	136.0	139.5	139.5	0.0035	0.0937	
4	$3\frac{5}{8}$	94.5	94.5	96.5	0.002	0.0552	
5	$3\frac{1}{4}$	71.5	72.0	72.0	0.0005	0.0154	
6	$3\frac{1}{2}$	35.5	36.5	38.0	0.0005	0.0143	Final expansion
					0.00125	0.0357	Max. expansion

Table 5.

Absorption of water in laterite soils.

Laterite Specimen No.	Weight of material taken Gr.	Weight after immersion in water for 22 Hrs. Gr.	44 Hrs. Gr.	66 Hrs. Gr.	Weight of material after drying to constant weight Gr.	Weight of wet residue Gr.	Weight of dry residue Gr.	Weight of total wet material Gr.	Weight of total dry material Gr.	Absorption of water based on total dry material Gr.	per cent	Initial moisture in the material per cent	Approximate addition of moisture per cent
	a	b	c	d	e	f	g	h	i	k	l	m	n
								(d+f)	(e+g)	(h−i)	$\frac{k}{i}.100$	$\frac{a-i}{i}.100$	(l − m)
1	799	856	852.25	852.0	780	11	9	863	789	74.0	9.38	1.27	8.11
2	897	955	954.0	951.5	880	7	5	958.5	885	73.5	8.31	1.36	6.95
3	679	755	754	754	665	5	3	759	668	91.0	13.62	1.65	11.97
4	990	1076	1072	1069	965	18	12	1087	977	110.0	11.26	1.33	9.93
5	1065	1185	1177.5	1179	1046	9	6	1188	1052	136.0	12.93	1.24	11.69
6	1369	1451	1448.5	14	1346.5	14	6	1461	1352.5	108.5	8.02	1.22	6.80

Table 6.

Tests on the compression strength on six dry and saturated laterite cubes and on three first class bricks.

Material	Average area out of top, centre and bottom.		Crushing load		Stress at failure.					
	Dry.	Saturated.	Dry.	Saturated.	Dry.	Saturated.	Dry.	Saturated.	Dry.	Saturated.
	sq. in	sq. in	Tons	Tons	Tons per sq. ft.		Lbs. per sq. ft.		Kg. per sq. cm.	
Lat. 1	10.55	9.61	6.85	2.375	93.53	35.58	1454.0	553.5	102.4	39.0
Lat. 2	10.47	8.93	4.19	4.90	51.62	79.02	896.2	1228.0	63.16	86.6
Lat. 3	11.7	11.55	4.01	3.60	56.74	44.89	882.4	698.2	62.19	49.2
Lat. 4	9.06	10.03	3.45	3.90	54.84	56.01	852.9	871.0	60.1	61.38
Lat. 5	10.95	10.78	9.61	5.35	126.4	71.48	1965.0	1112.0	138.5	78.36
Lat. 6	11.54	12.26	5.22	8.9	65.15	104.6	1014.0	1626.0	71.39	114.6
Brick I Cl.	39.05	—	27.0	—	99.59	—	1549.0	—	108.9	—
Brick I Cl.	38.35	—	23.0	—	86.36	—	1343.0	—	94.43	—
Brick I Cl.	41.05	—	29.2	—	102.4	—	1593.0	—	112.0	—

Table 7.

Aggregate crushing value (percent).

Material	1. Test	2. Test	Average
Lat. 1	40.98	39.87	40.42
Lat. 2	51.53	49.26	50.40
Lat. 3	47.90	48.00	47.95
Lat. 4	35.20	34.40	34.80
Lat. 5	42.81	40.59	41.70
Lat. 6	42.36	42.27	42.32
Quartzite	19.29	20.00	19.65
I Cl. Brick	50.0	50.02	50.31

B.S. Spec. No. 812 (1951) page. 48