The Indian Roads Congress as a body does not hold itself responsible for statements made, or for opinions expressed, in the Papers or discussions in its Proceedings.

Dr. Rajendra Prasad

President of the Republic of India

is pleased to be the

Patron

of the

Indian Roads Congress, New Delhi.

By Command of the President of the Republic of India

Military Secretary's Office,
The 5th March 1951.

B. Chatterjee, Colonel,
Military Secretary to the President

INDIAN ROADS CONGRESS

ESTABLISHED: 1934 **REGISTERED: 1937**

OFFICE-BEARERS AND COUNCIL 1952-53.

President:

T. Mitra, I.S.E.,
Chief Engineer,
Works & Buildings, West Bengal,
Calcutta.

Vice-Presidents:

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C/o. M/s. Burmah Shell Oil Co., Ltd.,
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Chief Engineer,
Capital Project, Chandigarh (Punjab)

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Ministry of Transport, Roads Organization,
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J. M. Trehan,
Divisional Engineer (Consultant),
Ministry of Transport, Roads Organization,
New Delhi.

Members of Council:

1. F. P. Antia.
2. C. J. Fielder.
3. R. N. Joshi.
4. E. A. Nadirshah.
5. L. R. Patel.
6. B. N. Roy.
7. M. Meeran.
8. N. Durrani.
9. G. C. Khanna.
10. C. P. Misra.
11. R. C. Roy.
12. M. L. Bahl.
13. U. N. Mahida.
14. R. K. Batra.
15. D. P. Nayar.
16. C. M. Bennett.
17. G. N. Dutt.
18. M. S. Bisht.
19. S. N. Chakravarti.
20. D. V. Rao.
21. Raghbir Singh.
22. Kishore Lal Mathur.
23. U. J. Bhatt.
24. K. K. Kartha.
25. D. N. Gupta.
26. P. V. Divatia.
27. Brig. Partap Narain.
28. M. S. Mathur.
29. Brijmohan Lal.
30. Romesh Chandra.
31. A. C. Mukerjee.
32. G. M. McKelvie.

LIST OF COMMITTEES AND SUBCOMMITTEES

1. *SPECIFICATIONS AND STANDARDS COMMITTEE:*

G. M. McKelvie — *Convenor*
H. Sunder Rao — *Member-Secretary*

(i) *Geometric Design Division*:

T. Mitra
N. V. Modak
Brijmohan Lal
K. K. Nambiar
Goverdhan Lal
H. P. Sinha

(ii) *Structural Design Division:*

(a) *Rigid Pavements*:

A. C. Mukerjee or nominee
A representative of E-in-C.
C. V. Nazareth
H. P. Sinha
Goverdhan Lal

(b) *Flexible Pavements :*

A representative of E-in-C.
C. J. Fielder
H. P. Sinha
Goverdhan Lal
S. R. Mehra
G. Srirangachari
Sujan Singh
H. R. Dhir

(iii) *Specifications and Costing Division*:
[For items other than (i) & (ii)]
Goverdhan Lal
A representative of E-in-C. (Surveyor of Works)
H. P. Sinha
Nominee of C.P.W.D.

2. *BRIDGES COMMITTEE :*

H. P. Mathrani — *Convenor*
S. L. Bazaz — *Member-Secretary*

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

A representative of E-in-C.
H. P. Sinha
Kanwar Sain
G. R. Nangea
J. Chambers
A representative of C.B.I. & P.

(ii) *Substructure and Superstructure Division :*

K. F. Antia
D. S. Desai
K. G. Bhate
S. K. Ghosh
V. Venkataramayya
H. P. Sinha
S. B. Joshi
E. P. Nicolaides
P. S. Subramanyam
M. V. Joglekar
K. K. Nambiar

3. *TECHNICAL SUBCOMMITTEE*:

(i) *Test Track Division :*

T. Mitra (West Bengal) —*Convenor*

C. J. Fielder
S. N. Gupta
Dr. E. Zipkes
E. A. Nadirshah
G. Srirangachari
S. N. Chakravarti
G. M. McKelvie
Sujan Singh
T. C. Sahani (Co-opted)
H. Sunder Rao—*Member-Secretary.*

(ii) *Research Organisation Division*:

H. P. Sinha — *Convenor*

A representative of E-in-C (connected with research work)
Chief Engineer, Buildings & Roads, Uttar Pradesh
Chief Engineer (Highways), Madras
Chief Engineer, Buildings and Roads, Punjab
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
Dr. E. Zipkes
H. Sunder Rao
J. Subrahmanyam — *Member-Secretary*

4. *ROADS TRANSPORT SUBCOMMITTEE*:

E. A. Nadirshah — *Convenor*

K. M. Kantawala
V. N. Rangaswami
B. V. Vagh
N. D. Daftary
R. N. Dogra
N. V. Modak
M. L. Champhekar
C. S. Anantapadmanabhan *Member-Secretary*

INDIAN ROADS CONGRESS

NOTICES AND ANNOUNCEMENTS

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

The next General Session of the Indian Roads Congress is to be held in February, 1953. 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 younger engineers are particularly requested to contribute Papers which, if required, will be suitably edited by the Indian Roads Congress Office before publication.

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

(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.

5. 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.

6. Rules and Regulations for the contribution of Technical Papers and the Award of Medals are published elsewhere in this issue.

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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. RULES REGARDING 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. RULES REGARDING 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 1/16 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 standpoint 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 bridgework 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

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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.

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IV. Library.

1. Information and books on loan from the libraries of the Consulting Engineer (Roads) 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 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 (Roads)'s 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.

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

V. NEW ADMISSIONS

LIST OF MEMBERS OF THE INDIAN ROADS CONGRESS ENROLLED FROM 1—7—1952 TO 30—9—1952

Serial No.	*Roll No.*	*Name.*	*Address.*
1284	1681	Subbiah, G.	Supervisor, Highways, Nanguneri (TINNELVELLI DISTRICT) (SOUTH INDIA).
1285	1682	Baronia, L. R.	Assistant Manager & Superintendent of Works, Provincial Transport Ltd. Civil Lines, NAGPUR, (M.P.)
1286	1683	Venkoba Rao. M. S.	Junior Scientific Officer, Central Road Research Institute, P.O. Okhla, DELHI.
1287	1684	Shah. B. G.	Deputy Engineer, Designs Division, POONA-1.
1288	1685	Patel, C. M.	536, Albert Avenue, East Lansing (Mich.), U.S.A.
1289	1686	Govil, C. P.	Executive Engineer, Delhi State Division No. 1, NEW DELHI.
1290	1687	Latuckar, S. K.	Deputy Engineer, Dharwar Roads & Buildings Sub-Division, Dharwar. (BOMBAY STATE.)
1291	1688	Mehta, M. C.	Executive Engineer, Division 2, P.W.., DRATGHAH, BHOPAL.
1292	1689	Ruthnaswamy, V. V.	Dy. Chief Engineer, J and K, C/o. NEW DELHI APO 56.
1293	1690	Ojah, B.	Professor of Civil Engineering, P.O. Bihar Institute of Technology (Via Dhanbad), Dist. Manbhum (BIHAR).
1294	1691	Ojha, B.	Assistant Engineer, P.W.D., Sub-Division No. 1, Muzaffarpur,
1295	1692	Oke, B. K.	Executive Engineer, P.W.D., Tandula. Division, DRUG (M.P.)
1296	1693	Saxena, S. P.	District Engineer, P.W.D., B and R, BIJNOR.
1297	1694	Bhargava, J. P.	District Engineer, P.W.D., AZAMGARH. (U.P.)

VI. DEATHS

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

Serial No.	Roll No.	Name.	Address.
1	50	Manohar Nath.	P. A. to Chief Engineer, Himachal Pradesh P.W.D. Himachal Dham, SIMLA-4.
2	633	K. A. N. Chetty	Divisional Engineer (Highways), Saidapet. (MADRAS STATE).
3	89	Sant Ram Sahgal (L.M.)	C/o. Shri D. K. Sahgal, Executive Engineer, 430, Hide Market, AMRITSAR.

VII. ADDRESSES OF MEMBERS WANTED.

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

Serial No.	Roll No.	Name.	Address.
1	1394	Anand, R. M.	Sub Divisional Officer, Development, Sub Division 1, Model Town, Jagadhri, Ambala District.
2	58	Bishamber Dayal (L.M.)	District Engineer, ROHTAK.
3	782	Bhattacharjee, K. D.	Executive Engineer, Airfield Arrears Division No. 1, 1, Charnock Place, Central P.W.D., CALCUTTA.
4	1388	Biswas, K. K.	Assistant Engineer, 29 C, Creek Row, CALCUTTA.
5	887	Chari, T. V. R.	Assistant Engineer, Puttur Sub Division, South Kanara Division, PUTTUR (Madras State.)
6	1184	Damodar Das	District Engineer, P.W.D., B. & R, Orai, District JALAUN, (U.P).
7	1315	Gupta, Ranjit Kumar	Assistant Engineer (W. & B. Deptt.), C/o. K. K. Biswas, 29 C, Creek Row, CALCUTTA.
8	652	Guruswamy, S. (L.M).	No. 9, Appaswami Koil Street, P.O. Mylapore, MADRAS.
9	1253	Hasan, S. M. I.	Assistant Engineer, P.W.D. I/c, Ranchi No. 3, Sub Division, RANCHI (BIHAR).
10	1026	Hege, W. D.	Asphalt Sales Engineer, C/o. Caltex (India) Ltd., P.O. No. 155, Ballard Estate, BOMBAY.
11	465	Jha, B. K.	Village Banu Chopra, P. O. Bettiah, District Champaran, O & T Railway (BIHAR).
12	714	Kazi Mahboob Ilahi	C/o. Asiatic Construction Co., Anderkilla, CHITTAGONG. (EAST BENGAL).
13	984	Mathew, K. M.	Executive Engineer, P.W.D., Sinculam Division, MUNNAR. (Travancore-Cochin).
14	1256	Mazumdar, J. P.	Consulting Engineer, Architect Builder, 52-B, Kailash Bose Street, CALCUTTA-6.
15	797	Mohana Rao, T. K.	Assistant Engineer, P. W. D., Nidadavole, (NIDAVOLE). (West Godavari District).
16	90	Mohd. Abu Turab	Superintending Engineer (Retired), A/8 No. 220, Lane Opposite Raj Mahal Talkies, LINGAMPALLY, Hyderabad-Deccan.
17	9.5	Naidu, S. R. M	Garrison Engineer, Dehu Road.
18	924	Rajan, G. A. N.	Assistant Engineer, Central P.W.D., CALCUTTA Air Port, Dum Dum.
19	702	Rathod, G. D.	Executive Engineer, C/o, Palji Mistry Quarter No. 26, Mall Road, DELHI CANTT.
20	1238	Resham Singh.	C/o. The Principal, Central School of Drilling, DHANAAURI, P. O. ROORKEE Cantt.
21	726	Shafiqual Haq	Assistant Engineer, Design Division, (Irrigation), Eden Building, 17, DACCA. (East Pakistan).
22	1325	Sharan, Raghunath	Assistant Engineer, Waterways, Chaibasa, SINGHBHUM (BIHAR).
23	1117	Sundaraj, B. K.	Assistant Engineer, Now United Construction Co., Ltd., KHAPERKHEDA, via Nagpur G. P. O.

Serial No.	Roll No.	Name.	Address.
24	33	Syed Arifuddin	Retired Chief Engineer, 1246 Chaderghat High School Lane, Abid Road, HYDERABAD-DECCAN.
25	1366	Varma, K. N.	Sub Divisional Officer, P. W. D., MOKAMEH (Bihar).
26	543	Venkatachallam, K.	Executive Engineer (Irrigation), Warangal District, HANAMKONDA. Post, Via Kazipet. N. S. Rly.
27	1120	Wadia, K. C.	Officer-on-Special Duty, Finance Department, Hyderabad Government, HYDERABAD-DECCAN.
28	236	Zutshi, M. N.	Valab Hotel, Kulri, MUSSOORIE (U.P.)

ASSOCIATE MEMBER

29	20	Garewal Sapuran Singh	C/o., The Master Construction Company Ltd., Engineers and Contractors, Cosy Coto KATHIAR (BIHAR).

MEMBERSHIP OF THE INDIAN ROADS CONGRESS.

Year of Enrolment with Roll Numbers.

Calendar Year	Ordinary Members.		Associate Members.	
	From	To	From	To
1934 — 1936	1	191	1	3
1937	192	252	4	–
1938	253	294	–	–
1939	295	388	5	6
1940	389	453	7	9
1941	454	501	10	–
1942	502	548	–	–
1943	549	598	11	–
1944	599	649	12	17
1945	650	781	18	20
1946	782	997	21	23
1947	998	1169	24	30
1948	1170	1306	31	34
1949	1307	1449	35	40
1950	1450	1535	41	43
1951	1536	1605	44	46
1952	1606		47	–

ALPHABETICAL LIST OF MEMBERS.

Corrected upto 30—6—1952 and Roll No. 1680.

PATRON

Dr. Rajendra Prasad

President of Republic of India.

HONORARY MEMBER

Sir Kenneth Mitchell, C.I.E., K.C.I.E., Beechwood, Wickhambrook, near New Market, Suffolk, (England).

Ordinary and Life Members.

(L.M. denotes Life Members.)

Serial No.	Roll No.	Name.	State/Country.
		"A"	
1	1531	Abdul Ala, M.	Hyderabad.
2	487	Abdul Aziz	Pakistan.
3	1263	Abdul Rahman	Madras.
4	1591	Abraham, M.C.	West Bengal.
5	684	Acharya, D. K.	Orissa.
6	850	Acharya, P. G.	Rajasthan.
7	763	Acharya, S.	Orissa.
8	721	Acherjee, F. C.	Govt. of India.
9	826	Adaviyappa, S.	Rajasthan.
10	242	Adke, A. S.	Bombay.
11	227	Adshetti, G. K.	Bombay.
12	1655	Aga, A. K.	Bihar.
13	531	Agarwal, S. K.	Uttar Pradesh.
14	711	Agarwal, Shyam Krishna	Uttar Pradesh.
15	1389	Agarwal, K. C.	Uttar Pradesh.
16	957	Agarwala, D. R.	Uttar Pradesh.
17	781	Agarwala, R. P.	Bihar.
18	1060	Agarwala, M. G.	Uttar Pradesh.
19	684	Agarwala, R. M.	Uttar Pradesh.

Serial No.	Roll No.	Name	State/Country.
20	1592	Agarwal, Balbir Singh	Uttar Pradesh.
21	1106	Agarwala, C. S. L.	Uttar Pradesh.
22	1547	Agarwal, G. D.	Madhya Pradesh.
23	1223	Agarwala, P. S.	Uttar Pradesh.
24	1397	Ahmed Ovaise	Govt. of India.
25	1660	Ahuja, B. D.	Govt. of India
26	1001	Ahuja, P. R.	Govt. of India.
27	1055	Aiyangar, R. A. Sampat	Mysore.
28	995	Aiyar, C. S. Padmanabha	Travancore-Cochin.
29	452	Ajwani, J. M.	M. E. S.
30	1388	Akalankan, N. A.	Madras.
31	341	Akhtar, S. E.	Bihar.
32	1427	Albert Mayor.	U. S. A.
33	1687	Amanullah, N.	Bihar.
34	821	Amarinderjit Singh	Pepsu.
35	1189	Amin, M. P.	Bombay.
36	1086	Aminbhavi, L. T.	Madhya Pradesh.
37	420	Amingad, A. K.	Hyderabad.
38	1394	Anand, R. M.	Punjab.
39	675	Ananda Rao, U.	Madras.
40	1251	Andavan, G. M.	Madras.
41	562	Annaswami, V. S.	Govt. of India.
42	1285	Ansari, M. N.	Madhya Pradesh.
43	1241	Antia, K. F.	Bombay.
44	1414	Apte, K. V. (L.M.)	Bombay.
45	1522	Apte, M. P.	Bombay.
46	1382	Arjun Singh.	Bihar.
47	1308	Arjun Thakur	Bihar.
48	1284	Arnold, G. J.	Govt. of India.
49	442	Arora, K. N.	Uttar Pradesh.
50	1339	Arunachalam, S.	M. E. S.

Serial No.	Roll No.	Name.	State/Country.
51	736	Asarpota, D. M.	Bombay.
52	1509	Aserappa, R. E. (Brigadier)	"Corps of Engineers".
53	588	Athawale, V. L.	Madhya Bharat.
54	91	Ayyangar, M. R. Duraiswami	Madras.
55	76	Ayyar, A. Nagoswara (L. M.)	Madras.
56	109	Ayyar, Lakshman Venkatakrishnan (L.M.)	Madras.
57	98	Ayyar, K. Trimalaiswamy (L. M.)	Madras.
58	656	Ayyar, V. A.	Rajasthan.
59	1599	Ayyar, V. V. Gopalakrishna	Travancore-Cochin.
60	1254	Ayyaswami, G.	Madras.
		"B"	
61	213	Bagchi, C. C.	Uttar Pradesh.
62	977	Bahl, D. R.	Govt. of India.
63	399	Bahl, M. L. (L.M.)	Bihar.
64	836	Bais, Ram Singh	Rajasthan.
65	1481	Bakeri, R. D.	Bombay.
66	897	Baksi, R. D.	Bihar.
67	458	Bala Pershad, S.	Hyderabad.
68	544	Balasubrahmanyam, M.	Madras.
69	68	Balwant Singh	Punjab.
70	253	Bamji, H. F. (L.M.)	Bombay.
71	355	Bammi, D. R.	Delhi.
72	1162	Banerjee, Ajit Kumar	Bihar.
73	85	Banerjee, M. G. (L. M.)	West Bengal.
74	779	Banerjee, Shishir Kumar	Bihar.
75	1292	Banerjee, S. C.	Govt. of India.
76	1456	Banerjee, S. N.	West Bengal.
77	88	Banerjee, Tulsidas	Madhya Pradesh.
78	877	Banerjee, P. K.	Uttar Pradesh.
79	1133	Banerjee, S. K.	West Bengal.
80	962	Bannerjee, J. K.	West Bengal.
81	910	Bannerjee, S. R.	West Bengal.
82	1181	Bansal, K. L.	Uttar Pradesh.
83	929	Bansal, K. S.	Madhya Pradesh.
84	336	Bansor, H. S.	M. E. S.
85	1186	Bapat, M. S.	Uttar Pradesh.
86	1247	Barua, H.	Assam.
87	234	Barua, H. P. (L. M.)	Assam.
88	880	Barua, K.	Assam.
89	1579	Basant Lal	Rajasthan.
90	892	Basant Singh, S.	Punjab.
91	814	Bashoor Ahmed	Madras.
92	51	Bashi Ram, S. (L. M.)	Punjab.
93	1510	Basu, B. B.	M. E. S.
94	1421	Basu, K. N.	West Bengal.
95	1514	Basu, S. C.	West Bengal.
96	383	Batlivala, H. S.	Bombay.
97	1602	Batni, K. B.	Govt. of India.
98	978	Batra, R. K.	Madhya Pradesh.
99	981	Battiwala, K. P.	Bombay.
100	1359	Baul, Raghudas.	West Bengal.
101	322	Bazaz, Shamlal.	Govt. of India.
102	57	Bedekar, V. P.	Bombay.
103	328	Behera, S. S.	Orissa.
104	1399	Benjamin, George	M. E. S.
105	204	Bennett, C. M.	Orissa.
106	1593	Berry, R. K.	Punjab.
107	266	Bhagat, D. G.	Government of India.
108	1207	Bhagat, N. S.	Delhi.
109	1463	Bhagwagar, K. D.	Bombay.
110	149	Bhalla, Prem Nath	Madhya Bharat.
111	1446	Bhalla, R. S.	Government of India.

Serial No.	Roll No.	Name.	State/Country.
112	1050	Bhambhani, B. I.	Bombay.
113	1619	Bhandari, V. D	Government of India.
114	14	Bhandarkar, G. P. (L. M.)	Bombay.
115	827	Bhargava, I. D.	Rajasthan.
116	251	Bhargava, K. N.	Rajasthan.
117	1114	Bhargava, M. C.	Uttar Pradesh.
118	1644	Bhargava, N. C.	Uttar Pradesh.
119	1175	Bhargava, M. G.	Uttar Pradesh.
120	783	Bhargava, T. N.	Government of India.
121	169	Bharucha, M. D.	Bombay.
122	1402	Bhasin, P. C.	Punjab.
123	329	Bhate, K. G.	Bombay.
124	1122	Bhatia, H. T.	M. E. S.
125	658	Bhatia, M. S.	Government of India.
126	62	Bhatnagar, Jagmohan Lal (L. M).	Rajasthan.
127	860	Bhatnagar, P. S.	Uttar Pradesh.
128	1304	Bhatnagar, S. S. L.	Uttar Pradesh.
129	1661	Bhatnagar, V. R.	Rajasthan.
130	214	Bhatt, U. J.	Saurashtra.
131	1213	Bhatta, H. C. K.	Mysore.
132	782	Bhattacharjee, K. D.	Government of India.
133	245	Bhattacharya, N. G. (L. M.)	Rajasthan.
134	549	Bhattacharya, S. K.	Bihar.
135	1413	Bhattacharya, S. P.	West Bengal.
136	1508	Bhatti, K. S.	M. E. S.
137	815	Bhojani, M. D.	Saurashtra.
138	455	Bhonsale, N. K.	Madhya Bharat.
139	484	Bhupendra Nath	Government of India.
140	1301	Bhuvaragha Moorthy, R.	Madras.
141	272	Bhuyan, M. N.	Orissa.
142	1370	Bibhuty, L. N. S.	Bihar.

Serial No.	Roll No	Name.	State/Country.
143	831	Bijawat, M. C. (L.M.)	Uttar Pradesh.
144	462	Bikramjit	Punjab.
145	58	Bishambar Dayal (L. M.)	Punjab.
146	1524	Bishnoi, Anand Singh	Uttar Pradesh.
147	205	Bisht, M. S.	Uttar Pradesh.
148	1383	Biswas, K. K.	West Bengal.
149	1617	Bolakani, T. C.	Government of India.
150	1244	Bora, K. C.	Assam.
151	1395	Borwankar, S. G.	Madhya Pradesh.
152	1628	Bose, A. K.	West Bengal.
153	589	Bose, K. N.	West Bengal.
154	1443	Bose, M. M.	Government of India.
155	1201	Bose, R. C.	West Bengal.
156	1648	Bose, S. K.	Himachal Pradesh.
157	42	Brijmohan Lal (L.M.)	Punjab.
158	616	Brij Narayan	Delhi.
159	1149	Brinda Roy	Bihar.
160	1502	Bulsara, N. C.	Bombay.
161	352	Bushby, W. E.	Delhi.
		"C"	
162	1182	Cantlay, L. F.	England.
163	796	Caprihan, S. P.	Madhya Pradesh.
164	1196	Chablani, M. B.	Mysore.
165	519	Chacko, I. C. (L.M.)	Travancore-Cochin.
166	599	Chadda, S. R.	Uttar Pradesh.
167	201	Chaddha, Ulfatrai	Delhi.
168	1155	Chakraburty, N. B.	West Bengal.
169	1559	Chakravarthi, K. S.	Mysore.
170	789	Chakravarti, B. M.	Assam.
171	712	Chakravarti, J. C.	Govt. of India.
172	1649	Chakravarti, S. C.	West Bengal.

Serial No.	Roll No.	Name.	State/Country.
173	17	Chakravarti, S. N. (L.M.)	West Bengal.
174	1634	Chakravarti, A. C.	Bihar.
175	323	Chambers, J. (L.M.)	West Bengal.
176	275	Champa Lal	Delhi.
177	1527	Champhekar, M. L.	Bombay.
178	1324	Chanda, R. P.	West Bengal.
179	1680	Chandel, I. S.	Tripura.
180	994	Chandrasekharan, E. C.	Madras.
181	1004	Chandratreya, S. V.	Bombay.
182	1357	Channiab, H.	Mysore.
183	372	Chaphalkar, V. P.	Hyderabad.
184	896	Charan, S. K.	Uttar Pradesh.
185	887	Chari, T. V. R.	Madras.
186	565	Chatterjee, Dinabandhu	Govt. of India.
187	1348	Chatterjee, M. K.	West Bengal.
188	1426	Chatterjee, P. C.	West Bengal.
189	918	Chatterjee, P. K.	Govt. of India.
190	934	Chatterjee, P. L.	Govt. of India.
191	1347	Chatterjee, P. N.	West Bengal.
192	529	Chatterjee, R.	West Bengal.
193	624	Chatterjee, S. N.	West Bengal.
194	1411	Chattopadhya, B. N.	West Bengal.
195	1496	Chattopadhya, K. P.	West Bengal.
196	1589	Chattopadhya, S. N.	West Bengal.
197	1526	Chaturvedi, D. C.	Uttar Pradesh.
198	1264	Chaudhury, T. K. Roy	West Bengal.
199	691	Chauhan, P. M.	Bihar.
200	1203	Chavan, D. N.	Bombay.
201	906	Chawla, S. S.	M. E. S.
202	263	Chenoy, Faridoon, S. (L.M.)	Hyderabad.
203	898	Chetan Das	M. E. S.

Serial No	Roll No.	Name.	State/Country.
204	633	Chetty, K. A. Nanjundeswara	Madras.
205	1436	Chetty, Subramania, K.	Government of India.
206	281	Chinchakar, K. B.	Bombay.
207	313	Choksi, B. K. (L.M.)	Bombay.
208	145	Chopra, A. N. (L. M.)	Delhi.
209	991	Chopra, I. S.	Government of India
210	1455	Chopra, P. C.	Madhya Pradesh.
211	1092	Chopra, Y. P.	Punjab.
212	1541	Choudhry, D. C.	Bihar.
213	704	Chougule, Y. K.	Bombay.
214	215	Chowdhury, Abid Raza	Pakistan.
215	749	Chowdhury, A. N. Dutta	West Bengal.
216	941	Chowdhury, B. (L.M.)	Assam.
217	709	Chowdhury, B.	Bihar.
218	1294	Chowdhury, D. P. Roy	West Bengal.
219	346	Chowdhury, Imam-uz-Zaman	Pakistan.
220	963	Chowdhury, P. R.	Assam.
221	321	Chowdhury, Ram Narain	Rajasthan.
222	202	Chowdhury, S. P.	Assam.
223	419	Chowla, P. D.	Govt. of India.
224	289	Cochrane, G.A.D. (L. M.)	England.
225	905	Cocksedge, H. G.	Assam.
226	28	Colabawala, J. R. (L. M.)	Pakistan.
227	1623	Collins, A. E. L.	Delhi.
		"D"	
228	261	Daftary, G. D. (L. M.)	Bombay.
229	1336	Daftary, N. D.	Bombay.
230	1477	Dalal, M. N. (L. M.)	Bombay.
231	140	Dam, S. C. (L. M.)	West Bengal.
232	1184	Damodar Das	Uttar Pradesh.
233	1371	Damodaran, A. M.	Madras.

Serial No.	Roll No.	Name.	State/Country.
234	1487	Daruwala, P. K.	Bombay.
235	552	Daryanani, C. S.	Bombay.
236	1137	Das, A. C.	Orissa.
237	919	Das, A. L.	West Bengal.
238	161	Das, B. C.	Assam.
239	1664	Das, C. J. Venkatesa	Mysore.
240	1556	Das Gupta, A. K.	West Bengal.
241	1202	Das Gupta, B. B.	West Bengal.
242	203	Das Gupta, J. N. (L.M.)	West Bengal.
243	319	Das Gupta, J. N.	West Bengal.
244	560	Das, K. C.	Orissa.
245	774	Das, P. B. (L.M.)	Madhya Pradesh.
246	285	Das, P. C.	Orissa.
247	518	Das, S.	Assam.
248	1197	Das, S. M. Mohan	Madras.
249	1505	Das, T. M.	West Bengal.
250	659	Datt, J.	Bihar.
251	15	Datta, A. K. (L.M.)	West Bengal.
252	412	Datta, A. K.	Bihar.
253	157	Datta, D. C. (L.M.)	Assam.
254	1849	Datta, D. C.	West Bengal.
255	1156	Datta, P. L.	Government of India.
256	1618	Datta, Suram Singh	Rajasthan.
257	1422	Datta, S. M.	Assam.
258	158	Datta, S. K.	Assam.
259	71	Davo, D. P.	Madhya Pradesh.
260	1043	Daver, F. K.	Hyderabad.
261	758	D'Costa, A. J.	Government of India.
262	1144	De, Anil Chandra	Orissa.
263	532	De, S. N.	West Bengal.
264	1161	De Sousa, P.	Government of India.

Serial No.	Roll No.	Name.	State/Country.
265	199	Dean, A. W. H. (L.M.)	England.
266	1483	Doodhar, M. D.	Bombay.
267	1582	Deo, T. S.	Madhya Bharat.
268	776	Des Raj (L.M.)	Government of India.
269	940	Desai, C. B.	Rajasthan.
270	1322	Desai, C. N.	Bombay.
271	165	Desai, D. S.	West Bengal.
272	1629	Desai, G. S.	Bombay.
273	1485	Desai, M. M.	Bombay.
274	1466	Desai, N. K.	Bombay.
275	778	Desai, R. V.	Bombay.
276	1497	Deshpande, D. V.	Bombay.
277	1484	Deshpande, K. S.	Bombay.
278	1651	Deuskar, V. R.	Bombay.
279	358	Devarajan, A.	Hyderabad.
280	694	Devarajan, K. S.	Madras.
281	1667	Deviah, N. S.	Madras.
282	182	Devi Dayal	Delhi.
283	787	Dewan, N. G.	Government of India
284	1663	Dhamdhere, H. V.	Bombay.
285	813	Dhanarajan, S. H.	Mysore.
286	1468	Dhanokar, T. H.	Bombay.
287	1538	Dhar, A. N.	M. E. S.
288	899	Dhara, B. B.	West Bengal.
289	925	Dhar, B. K.	West Bengal.
290	1578	Dhar, Dina Nath	Kashmir.
291	1045	Dharma Rajan, N.	Government of India
292	617	Dhaul, K. K.	Government of India
293	1838	Dhillon, Arjan Singh	Pepsu.
294	614	Dhingra, A. D.	Bombay.
295	1243	Dhir, H. R.	Punjab.

Serial No.	Roll No.	Name.	State/Country.
296	1145	Dhruva, R. C.	Bombay.
297	567	Dhumal, R. J.	Madhya Bharat.
298	250	Dildar Hussain	Hyderabad.
299	1170	Dinesh Mohan	Uttar Pradesh.
300	1608	Divatia, P. V.	Madhya Bharat.
301	357	Divatia, S. S.	Bombay.
302	1549	Doctor, P. K.	Pakistan.
303	457	Dogra, R. N.	Punjab.
304	1607	Dogra, N. N.	Kashmir.
305	494	Domingo, T. B.	Bihar.
306	210	Doshi, M. M.	Bombay.
307	1279	Dubash, M. D.	Bombay.
308	1546	Dube, S. B.	Madhya Pradesh.
309	602	Dubey, B. P.	Bihar.
310	623	Dubey, Jagdish Prasad	Bihar.
311	730	Durairaj, T.	Madras.
312	1412	Durga Prasad	Rajasthan.
313	246	Durrani, N.	Madras.
314	1393	Dutt, A. C.	West Bengal.
315	1620	Dutta, D. N.	Assam.
316	1140	Dutt, G. N.	Assam.
317	948	Dutt, N. N.	Government of India.
318	530	Dutt, Priya Ranjan	West Bengal.
319	688	Dutta, S. C.	Assam.
		"E"	
320	801	Eapen, K. E.	Travancore-Cochin.
321	168	Eccleston, W. T. (L. M.)	England.
322	184	Edibam, N. R.	Uttar Pradesh.
323	94	Edwin, J. W. (L. M.)	Mysore.
324	86	Endlaw, D. N.	Government of India.

Serial No.	Roll No.	Name.	State/Country.
		"F"	
325	222	Fateh Chand (L.M.)	Uttar Pradesh.
326	594	Fergusson, F. F.	Bombay.
327	231	Fielder, C. J.	West Bengal.
328	911	Fonsoka, C. E.	Ceylon.
		"G"	
329	1480	Gadhoko, S. R.	Rajasthan.
330	829	Gadre, N. B. (L.M.)	Bombay.
331	1543	Gahlowt, R. S.	Uttar Pradesh.
332	1641	Ganapathy, G. S.	Madras.
333	858	Gandhi, J. H.	Bombay.
334	98	Gandhi, K. J. (L. M.)	Bombay.
335	467	Gandhi, M. M. (L. M.)	Bombay.
336	1597	Gandhi, N. K.	Bombay.
337	1457	Gandotra, H. K.	Kashmir.
338	179	Gangadhara, K. S.	Mysore.
339	1652	Ganguli, A. C.	West Bengal.
340	1094	Ganguli, A. N.	West Bengal.
341	1369	Ganguli, D. N.	West Bengal.
342	1508	Ganguli, H. D.	West Bengal.
343	942	Garg, S. K.	Uttar Pradesh.
344	501	Garr, B. L.	Punjab.
345	1268	Gauri Nath	Punjab.
346	1267	Gautam Narayan, Raj Kumar	West Bengal.
347	1029	George, K. T.	Travancore-Cochin
348	68	Ghanekar, Y. K.	Madhya Pradesh.
349	208	Gharpure, A. V.	Bombay.
350	1575	Ghatpande, G. S.	Madhya Bharat.
351	1550	Ghosh, M. B.	West Bengal.
352	56	Ghosh, S. K.	Bihar.
353	1080	Ghosh, A. K.	West Bengal.
354	1604	Ghosh, B. N.	West Bengal.

Serial No.	Roll No.	Name.	State/Country.
355	1462	Ghosh, D. N.	West Bengal.
356	510	Ghosh, K. P.	M. E. S.
357	1277	Ghosh, Sripada	West Bengal.
358	641	Ghosh, S. B.	Bihar.
359	651	Ghosh, Pasupati	West Bengal.
360	486	Ghosh, Sushil Kumar	Bihar.
361	1286	Ghosh, Taradas	Bihar.
362	808	Ghosh, S. K.	West Bengal.
363	1424	Ghoshal, P. K.	West Bengal.
364	708	Gidwani, M. M.	Govt. of India.
365	1638	Gill, A. S.	Punjab.
366	1058	Gill, Jagmal Singh	PEPSU.
367	1520	Gill, S. S.	PEPSU.
368	946	Goel, R. R.	Uttar Pradesh.
369	1091	Goel, Harish Chandra	Govt. of India.
370	1136	Goel, Harbans Lal	PEPSU.
371	468	Goghari, N. W.	Bombay.
372	1284	Golikere, P. R.	Madras.
373	1625	Gonsalves, G. F. D.	Govt. of India.
374	1187	Goyal, J. P.	Uttar Pradesh.
375	1218	Goyal, S. C.	Uttar Pradesh.
376	1192	Goyal, Sohan Lal	Uttar Pradesh.
377	47	Gopalacharya, G. (L.M.	Madras.
378	1044	Gopalan, S.	Hyderabad.
379	1143	Gore, R. R.	Madhya Pradesh.
380	700	Goswami, S. M.	West Bengal.
381	879	Goverdhan Lal	Govt. of India.
382	1428	Govindarajulu, K.	Madras.
383	1248	Govindarajulu, S. P.	Bombay.
384	1581	Govindaswami, V.	Madras.
385	1616	Grewal, B. S.	Punjab.

Serial No.	Roll No.	Name.	State/Country.
386	1580	Grewal, R. S.	Kashmir.
387	938	Growall, R. S.	M. E. S.
388	80	Griffiths, W. A.	Madras.
389	1387	Grover, D. T.	Govt. of India.
390	102	Guo, K. C. (L.M.)	West Bengal.
391	119	Guo, T. C.	Vindhya Pradesh.
392	1293	Guha, Asutosh	West Bengal.
393	151	Guha, J. C. (L.M.)	West Bengal.
394	1230	Guha, M. K.	West Bengal.
395	1498	Guha, M. N.	West Bengal.
396	611	Guha, P. R.	Bihar.
397	1618	Gulabani, B. G.	Punjab.
398	1225	Gulzar Singh, S.	Punjab.
399	663	Gupchup, N. S.	Bombay.
400	440	Gupta, B. B. (L.M.)	West Bengal.
401	1154	Gupta, B. N.	Indian Railways.
402	547	Gupta, D. N.	Rajasthan.
403	1624	Gupta, D. N.	Kashmir.
404	509	Gupta, Indu Bhushan Das	West Bengal.
405	886	Gupta, Govinda	Govt. of India.
406	1028	Gupta, H. K.	Govt. of India.
407	511	Gupta, Harbans Lal	Uttar Pradesh.
408	816	Gupta, Hari Dutta	Rajasthan.
409	1643	Gupta, H. R.	Madhya Pradesh.
410	1227	Gupta, Ishwar Chandra	Punjab.
411	1239	Gupta, J. P.	Uttar Pradesh.
412	830	Gupta, Kanchandu.	Punjab.
413	597	Gupta, K.	Bihar.
414	1588	Gupta, L. N.	Uttar Pradesh.
415	125	Gupta, N. Das	Delhi.
416	1815	Gupta, Ranjit Kumar	West Bengal.

Serial No.	Roll No.	Name.	State/Country.
417	1051	Gupta, R. L.	Madhya Pradesh.
418	471	Gupta, S.	Bihar.
419	587	Gupta, S. C.	Madhya Bharat.
420	936	Gupta, Sachindra Nath	West Bengal.
421	1283	Gupta, Sudhindra Nath	Govt. of India
422	1379	Gurbaxani, T. C.	Madhya Pradesh.
423	1242	Gurcharan Singh	Punjab.
424	655	Gurjar, N. P.	Bombay.
425	1078	Gursahani, R. L.	Govt. of India.
426	1573	Guru Dayal	Uttar Pradesh.
427	652	Guruswamy, S. (L. M.)	Madras.
428	1003	Gwyn, E. H.	British West Indies.
		"H"	
429	1252	Hajeley, S. P.	Uttar Pradesh.
430	930	Haldor, S. D.	Govt. of India.
431	571	Handa, K. L.	Madhya Bharat.
432	894	Hanly, P. J.	Pakistan.
433	74	Hardikar, J. C.	Hyderabad.
434	41	Hardit Singh	Delhi.
435	785	Har Dayal (L. M.)	Govt. of India.
436	248	Harris, J. (L. M.)	Uttar Pradesh.
437	1253	Hasan, S. M. I.	Bihar.
438	38	Haval, Anant Balwant	Bombay.
439	1026	Hage, W. D.	Bombay.
440	840	Hem Raj	Bhopal.
441	640	Hemnani, M. Rup Chand	Punjab.
442	1320	Hirenath, S. A.	Madhya Pradesh.
443	1159	Hoda, S. A.	Bihar.
444	1489	Huchveeriah, T.	Mysore.
445	424	Huda, N.	Bihar.
446	104	Hughes, H. (L. M.)	England.

Serial No	Roll No.	Name of Members.	State/Country.
447	1615	Hukam Singh	Punjab.
		"I"	
448	1378	Iengar, B. Krishna	Bombay.
449	1568	Idiculla, K. S.	Travancore-Cochin.
450	1283	Inamdar, H. M.	Madhya Pradesh.
451	900	Inamdar, S. G.	Madhya Pradesh.
452	563	Inamdar, S. R.	Madhya Bharat.
453	562	Indramanikar	Orissa.
454	521	Iqbal Singh	Punjab.
455	1057	Iyengar, M.V.Krishnaswami (L.M.)	Mysore.
456	1087	Iyar, B. S. Raju	M.E.S..
457	395	Iyengar, C. L.	Hyderabad.
458	1129	Iyengar, C. L. N.	Bombay.
459	364	Iyengar, M. A. R.	Hyderabad.
460	1438	Iyengar, M. S. Thirumalo	Madras.
461	722	Iyengar, N. Narasimham	Govt. of India.
462	883	Iyengar, R. K. N.	Govt. of India.
463	1068	Iyer, A. R. Krishna	Travancore-Cochin.
464	292	Iyer, E. V. S.	Orissa.
465	1011	Iyer, R. Ganapathy	Travancore-Cochin.
466	997	Iyer, T. S. Narayanaswami	Madras.
		"J"	
467	1076	Jabbar, M. A.	Pakistan.
468	1659	Jacob Thomas, A.	Travancore-Cochin.
469	1194	Jagdish Bahadur	Uttar Pradesh.
470	1391	Jagdish Kumar	Uttar Pradesh.
471	52	Jagdish Prasad	Uttar Pradesh.
472	287	Jagmohan	Uttar Pradesh.
473	1474	Jagus, P. J.	Bombay.
474	1536	Jain, C. B.	Govt. of India.
475	1188	Jain, D. C.	Uttar Pradesh

Serial No.	Roll No.	Name.	State/Country.
476	1441	Jain, G. C.	Uttar Pradesh.
477	1425	Jain, K. C.	Govt. of India.
478	707	Jali, F. C.	Assam.
479	697	Jambunathan, S.	Govt. of India.
480	670	Janardan Rao, C.	Madras.
481	1275	Jaswant Singh	Govt. of India.
482	1180	Jategaonkar, V. L.	Bombay.
483	787	Jathal, M. N.	Bombay.
484	1656	Javali, S. C.	Bombay.
485	1568	Jayaraj, A. C.	Madras.
486	1429	Jayaraman, B.	Madras.
487	271	Jayaswal, U. S.	Bihar.
488	1070	Jaywant, L. K.	Madhya Bharat.
489	1418	Jeya Singh, H.	Madras.
490	1142	Jha, B. D.	Madhya Bharat.
491	465	Jha, B. K.	Bihar.
492	1587	Jha, C. N.	Bihar.
493	1177	Jha, U. N.	Bihar.
494	496	Joglekar, G. D.	Bombay.
495	1450	Joglekar, K. V.	Bombay
496	1169	Joglekar, M. V.	Bombay.
497	1646	John, A. Pouptis	Bombay.
498	1101	John, K. P.	Travancore-Cochin.
499	761	John Mukand.	Govt. of India.
500	1337	John, P. V.	Travancore-Cochin.
501	1398	Johorey, M. C.	Uttar Pradesh.
502	1036	Jones, Glyn	Pakistan.
503	134	Jones, R. Trevor (L.M.)	England.
504	304	Jootla, Baboo Singh	Orissa.
505	1235	Joshi, J. S. (L.M.)	Bombay.
506	1282	Joshi, N. P.	Bombay.

Serial No.	Roll No.	Name.	State/Country.
507	122	Joshi, N. S. (L.M.)	Bombay.
508	1430	Joshi, R. N.	Bombay.
509	815	Joshi, S. B. (L.M.)	Bombay.
510	31	Jussawala, J. R. (L.M.)	Hyderabad.
511	1226	Jyoti Prakash.	Uttar Pradesh.
		"K"	
512	1408	Kabiraj Lakshmi Narayan	Bihar.
513	1228	Kakar, J. N.	Punjab.
514	621	Kale, C. G.	Bombay.
515	1670	Kale, L. W.	Bombay.
516	1657	Kale, M. D.	Bombay.
517	823	Kallukaran, J. V.	Travancore-Cochin.
518	1097	Kamath, M. N.	Madras.
519	852	Kandaswamy, V.	Govt. of India.
520	874	Kanga, F. J. (L.M.)	Bombay.
521	107	Kanhore, V. P. (L.M.)	Bombay.
522	1504	Kankanwadi, D. B.	Bombay.
523	1016	Kantawala, K. M.	Bombay.
524	1874	Kanwar Sain (L.M.)	Govt. of India.
525	1577	Kapadia, R. I.	Hyderabad.
526	1407	Kapoor, S. P.	Punjab.
527	695	Kapur, C. D.	Govt. of India.
528	1198	Kar, S. M.	Uttar Pradesh.
529	1453	Karandikar, S. K.	Bombay.
530	1493	Kar Kare, M. P.	Bombay.
531	1102	Karra, J. R.	Hyderabad.
532	1654	Kartha, K. K.	Travancore-Cochin.
533	750	Kartik Pershad	Uttar Pradesh.
534	1335	Kartik Oraon	Bihar.
535	1115	Kashyap, M. G.	Orissa.
536	249	Katrak, M. M.	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
537	1574	Kaushika, K. R.	Bombay.
538	252	Kerr, J. Oldfield	Pakistan.
539	720	Kewal Krishan	Punjab.
540	1081	Khabade, J. G.	Bombay.
541	297	Khan Abdul Jabbar	Uttar Pradesh.
542	387	Khan, J. H.	Kashmir.
543	689	Khan, M. A.	Bihar.
544	306	Khan, M. I.	Pakistan.
545	255	Khan, Mohammed Abdul Kayyum	Hyderabad.
546	1015	Khan, Mohammed Azam (L.M.)	Pakistan.
547	446	Khanna, G. C.	Punjab.
548	72	Khanna, Indra Narain	Govt. of India.
549	698	Khanna, N. N.	Govt. of India.
550	97	Khanna, Prem Nath	Uttar Pradesh.
551	1134	Khanna, P. N.	PEPSU.
552	1589	Khathuria, B. L. (L.M.)	Rajasthan.
553	78	Khatri, K. C.	Govt. of India.
554	1403	Khosla, B. R.	M.E.S.
555	591	Khot, N. A. (L.M.)	Madhya Bharat.
556	1561	Khurana, D. N.	Madhya Pradesh.
557	187	Kikkeri, S. A.	Punjab.
558	1182	Kochhar, B. K.	Uttar Pradesh.
559	1439	Koenigsberger, O. H.	England.
560	1270	Kohli, J. S.	M.E.S.
561	979	Kothari, V. C.	Saurashtra.
562	1487	Koya, K. V. Ahmed	Madras.
563	1152	Krishna Moorthy, T.	Madras.
564	681	Krishnamurti, B.	Madras.
565	888	Krishnamurti, M. R.	Madras.
566	1545	Krishnamurti, P.	Madras.
567	1448	Krishnan, E.	Madras,

Serial No.	Roll No.	Name.	State/Country.
568	605	Krishnan, K. S.	Madras.
569	719	Krishnan, M. P. Sivarama	Madras.
570	1298	Krishnan, N.	Govt. of India.
571	217	Krishnan, O. C. K.	Bombay.
572	976	Krishnan, R.	Madras.
573	1856	Krishnaswamy, C. R. Mudaliar	Mysore.
574	448	Krishnaswamy. P. A. (L. M.)	Madras.
575	867	Krishnayya, Y.	Madras.
576	1330	Kujur, L. K.	Bihar.
577	775	Kumar, A.	Mysore.
578	782	Kumar, G. L.	Madhya Pradesh.
579	1669	Kumaran, M.	Madras.
580	947	Kumar, Y. D. (L. M.)	Uttar Pradesh.
581	845	Kumawat, B. P.	Rajasthan.
582	1048	Kurup, P. K.	Travancore-Cochin.
583	1062	Kuruvila, P.K.	Travancore-Cochin
584	1529	Kuttalanathan, L.	Madras.
585	18	Kynnersley, T. B. S. (L.M.)	Bombay.
		"L"	
586	778	Laha, Kashi Pati	West Bengal.
587	1566	Laha, S. K.	West Bengal.
588	725	Lahiri M. C.	Govt. of India.
589	1632	Lahkar, K. D.	Assam.
590	374	Lakadawala, Rustum M.	Hyderabad.
591	284	Lakshman Swarup	Uttar Pradesh.
592	932	Lakshmi Chand (L. M.)	Uttar Pradesh.
593	1361	Lakshmi Narayan	Bihar.
594	1469	Lakshmi Narayan, V.	Mysore.
595	26	Lakshminarayana Rao, A. (L. M.)	Madras.
596	1364	Lal, A. K.	Bihar.
597	747	Lal, M. B.	Govt. of India

Serial No.	Roll No.	Name.	State/Country.
598	627	Lall, B.	Bihar.
599	1259	Lall, Y. K.	Bihar.
600	1513	Lalvani, M. N.	West Bengal.
601	1199	Laroia, D. K.	Uttar Pradesh.
602	678	Lawrence, M. S.	Madras.
603	196	Lawson, A. Burns	Bombay.
604	1246	Logavinayagam, K. S.	Madras.
605	1431	Lokagariwar, P. L.	M.E.S.
606	921	Lokanathan, P.	Madras.
		"M"	
607	686	Macha, T. K.	Bombay.
608	1608	Madbhavi, S. M.	Bombay.
609	869	Maddimsetty, R. S.	Madras.
610	449	Madhav, T. K.	Delhi.
611	646	Madhava, K. B. (L. M.)	Madras.
612	181	Madhava Rao, Ch.	Madras.
613	148	Mahabir Prasad (L. M.)	Uttar Pradash.
614	1176	Mahabir Prasad	Uttar Prsdesh.
615	1375	Mahadevan, C. R.	Madras.
616	1380	Mahal, R. S.	Govt. of India.
617	689	Mahalanobis, P. C. (L. M.)	West Bengal.
618	803	Mahapatara, M.	Orissa.
619	714	Mahboob Ilahi Kazi	Pakistan.
620	561	Maheshwar Prasad	Bihar.
621	553	Mahida, U. N.	Bombay.
622	1633	Mainthia, D. P.	Kutch.
623	1653	Maitra, M. S.	West Bengal.
624	1650	Majumdar, B. N.	West Bengal.
625	1809	Majumdar, S. N.	West Bengal.
626	952	Makhanwahla, R. B.	Bombay.
627	298	Malhotra, Ajit Chand	Punjab.

Serial No.	Roll No.	Name.	State/Country.
628	96	Malhotra, B. R. (L. M.)	Govt. of India.
629	972	Malhotra, C. L.	Madhya Pradesh.
630	974	Malhotra, D. P.	Kashmir.
631	1678	Malhotra, O. P.	Punjab.
632	470	Malik, Abdul Mannan	Pakistan.
633	67	Malik, Teja Singh (L. M.)	Delhi.
634	620	Malik, C. P.	Govt. of India.
635	533	Mallick, D. N.	West Bengal.
636	1668	Manohigiah, M. H.	Mysore.
637	1401	Mane, P. M.	Bombay.
638	568	Mane, Y. G. (L.M.)	Madhya Bharat.
639	1601	Manerikar, V. B.	Bombay.
640	423	Mani, M. W. G.	Madras.
641	50	Manohar Nath	Himachal Pradesh.
642	1551	Manzoor Ali	Bihar.
643	512	Marik, T. P.	West Bengal.
644	1053	Marya, Jugdev Singh	PEPSU.
645	1590	Massarik, P.	West Bengal.
646	1473	Masarwala, V. J.	Bombay.
647	1071	Mason Jerry	West Bengal.
648	1472	Mastoor, A. R.	Bombay.
649	984	Mathew, K. M.	Travancore-Cochin.
650	1288	Mathrani, H. P.	Govt. of India.
651	1204	Mathur, A. C.	Uttar Pradesh.
652	834	Mathur, B. D.	Rajasthan.
653	992	Mathur, B. G. (L.M.)	Rajasthan.
654	1518	Mathur, B. S.	Punjab.
655	864	Mathur, C. B. L.	Rajasthan.
656	842	Mathur, J. L.	Rajasthan.
657	1222	Mathur, K. C.	Uttar Pradesh.
658	331	Mathur, Kishore Lal	Rajasthan.

Serial No.	Roll No.	Name.	State/Country.
659	1203	Mathur, G. D.	Uttar Pradesh.
660	828	Mathur, M. M.	Rajasthan.
661	418	Mathur, M. S.	Govt. of India.
662	759	Mathur, S. B.	Uttar Pradesh.
663	1676	Mathur, S. B.	Rajasthan.
664	117	Matthew, P. G. (L.M.)	Travancoro-Cochin.
665	618	Mawani, K. H.	Saurashtra.
666	1256	Mazumdar, J. P.	West Bengal.
667	54	McKelvie, G. M. (L.M.)	Govt. of India.
668	671	Meeran, M.	Madras.
669	542	Mehandru, B. L.	Bombay.
670	506	Mehar Singh	Govt. of India.
671	1302	Mehndiratta, M. R.	Punjab.
672	277	Mehra, S. R.	Punjab.
673	810	Mehta, D. J.	Bombay.
674	370	Mehta, Des Raj	Bihar.
675	114	Mehta, Iqbal Narain	Punjab.
676	34	Mehta, J. T.	Saurashtra.
677	1392	Mehta, J. V.	Madhya Pradesh.
678	1002	Mehta, M. A.	Pakistan.
679	237	Mehta, N. N.	Govt. of India.
680	1220	Mehta, V. C.	Saurashtra.
681	1621	Mehta, Y. K.	Bombay.
682	1358	Menon, K. B.	Travancore-Cochin.
683	1146	Menon, M. D.	Govt. of India.
684	988	Menon, T. Balakrishna	Travancore-Cochin.
685	396	Mengi, B. N.	Kashmir.
686	212	Meswani, V. M.	Bombay.
687	1464	Mewada, M. N.	Bombay.
688	1636	Mirchandani, I. D.	Punjab.
689	705	Mirchandani. N. D. (L.M.)	Govt. of India.

Serial No.	Roll No.	Name.	State/Country.
690	444	Mirza, Fahim Beg	Bhopal.
691	302	Mirza, M. A.	Uttar Pradesh.
692	557	Mirza, Mohammed Ahmed	Hyderabad.
693	1111	Mirza, R. E.	Pakistan.
694	1272	Mishra, U. N.	Orissa.
695	728	Misra, B.	Orissa.
696	1278	Misra, B.	Orissa.
697	975	Misra, B. B.	Govt. of India.
698	434	Misra, Chandi Prasad	Bihar.
699	1306	Misra, D. S.	Orissa.
700	999	Misra, K. N.	Uttar Pradesh.
701	837	Misra, Lakshmi Pati (L.M.)	West Bengal.
702	1217	Misra, P. N.	Uttar Pradesh.
703	901	Mistry, C. Mani Lal	Bombay.
704	1409	Mital, G. L.	Uttar Pradesh.
705	1569	Mitra, A. C.	West Bengal.
706	459	Mitra, C. D.	Bihar.
707	1310	Mitra, N. B.	Govt. of India.
708	1459*	Mitra, S. K.	West Bengal.
709	316	Mitra, T.	West Bengal.
710	1158	Mital, O. P.	Uttar Pradesh.
711	915	Mittal, Om Prakash	Govt. of India.
712	10	Modak, N. V. (L. M).	Bombay.
713	1482	Modi, I. K.	Bombay.
714	520	Mody, M. T.	Bombay.
715	580	Moghe, L. V.	Madhya Bharat.
716	1131	Mohammad	Bihar.
717	1548	Mohd. Abdul Khadir	Hyderabad.
718	90	Mohammad, Abu Tarab	Hyderabad.
719	256	Mohammed, Asadullah	Hyderabad.
720	408	Mohammed, Farhatullah	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
721	1165	Mohd. Hasnain	Bihar.
722	259	Mohammed Ibrahim	Hyderabad.
723	394	Mohammed Ibrahim (L. M.)	Hyderabad.
724	673	Mohammed Share Ali	Madras.
725	326	Mohammed Usman	Hyderabad.
726	625	Mohanty, A.	Orissa.
727	696	Mohile, N. H.	Madras.
728	1009	Mohindra, O. P.	Govt. of India.
729	739	Mohindra, S. K.	Bihar.
730	742	Mohiuddin, B. S.	Madras.
731	891	Mohury, B. D.	West Bengal.
732	1237	Momin, G. C.	Assam.
733	983	Mone, V. T.	Bombay.
734	244	Mookerjee, R. N.	West Bengal.
735	177	Morgan, I. (L. M.)	West Bengal.
736	1051	Motalib, A.	Pakistan.
737	664	Mudaliar, T. S. K.	Madras.
738	693	Mudaliar, K. M. Rajaratnam	Madras.
739	46	Mukerjee, A. C.	Uttar Pradesh.
740	1410	Mukherjee, Asim	West Bengal.
741	1317	Mukerjee, P. K.	Bihar.
742	608	Mukherjee, P. R.	West Bengal.
743	450	Mukherjee, S. N.	West Bengal.
744	139	Murari Lal	Punjab.
745	309	Murti, N. V. S.	Hyderabad.
746	755	Murty, N. G. K.	Bombay.
747	267	Murty, B. Narayana	Madras
748	1396	Murty, P. L. N.	Madhya Pradesh.
749	762	Muthukumara Swamy, A.	Madras.
		"N"	
750	1012	Nadgauda, P. M.	Bombay.

Serial No.	Roll No.	Name.	State/Country.
751	23	Nadirshah, E. A.	Bombay.
752	1377	Nadkarni, D. S.	Bombay.
753	1100	Naegamvala, J. P.	Bombay.
754	1014	Naga Bushanam, P. R.	Madras.
755	488	Nagarkar, D. B.	West Bengal.
756	1609	Nagarkar, G. P.	Bombay.
757	950	Nagarsheth, M. P.	Govt. of India.
758	594	Naidu, A. N. Damodaram	Madras.
759	583	Naidu, C. N.	Madhya Bharat.
760	820	Naidu, P. Ethirajulu	Madras.
761	654	Naidu, S. R.	Madras.
762	935	Naidu, S. R. M.	M. E. S.
763	581	Naik, B. G.	Madhya Bharat.
764	949	Naik, Ishwar Lal Kasanji	Bombay.
765	1420	Naik, K. Sundar	Madras.
766	982	Nair, E. Sivaraman	Travancore-Cochin.
767	1037	Nair, K. R. Madhavan	Travancore-Cochin.
768	1025	Nair, N. Krishnan	Travancore-Cochin.
769	178	Nair, P. T. Narayanan	Madras.
770	1066	Nair, V. P. Narayanan	Travancore-Cochin.
771	268	Nambiar, K. K.	Madras.
772	1116	Nambiar, K. K. Narayanan	Madras.
773	1296	Nanawatty, B. K.	Bombay.
774	60	Nanda B. D. (L. M.)	Kashmir.
775	661	Nanda, G.	Orissa.
776	1640	Nanda Gopal, G.	Madras.
777	1445	Nanda, J. B.	Kashmir.
778	888	Nanda, M. L.	Govt. of India.
779	1151	Nandi, S. C.	Bihar.
78	838	Nangea, G. R.	Himachal Pradesh.

Serial No.	Roll No.	Name.	State/Country.
781	29	Narasimham, J. S	Hyderabad.
782	927	Narasimham, R. K.	West Bengal.
783	1460	Narasimha Rao, K.	Madras.
784	1274	Narasimhamurthi, B. S.	Govt. of India.
785	916	Narasu, P. Lakshmi	Madras.
786	428	Narayana, A.	Uttar Pradesh.
787	1355	Narayanaswamy, S.	Mysore.
788	1212	Narayanasetty, H. S.	Mysore.
789	657	Narayanan, P.	Madras.
790	1552	Narboo, S.	Kashmir.
791	1479	Narke, S. P.	Bombay.
792	1645	Natarajan, M.	Madras.
793	679	Natesan, L. N.	Madras.
794	166	Nath, R. M.	Assam.
795	183	Nawab, Ashan Yar Jung. Bahadur (L. M.)	Pakistan.
796	660	Nayak, S. C.	Madras.
797	154	Nayar, D. P.	Punjab.
798	1517	Nayar, K. Krishnan	Madras.
799	1024	Nayar, K. Madhavan	Travancore-Cochin.
800	1211	Nayaz Ahmed	Bhopal.
801	688	Naydu, Dharma Rao, N.	Madras.
802	427	Nayyar, Sohan Lal	Punjab.
803	1183	Nazareth, C. V.	Delhi.
804	390	Nehra, V.	M. E. S.
805	1565	Nerurkar, M. S.	Bombay.
806	1611	Neurgaorkar, S. K.	Bombay.
807	342	Nicolaides, E. P.	Bombay.
808	1483	Nigam, S. P.	Uttar Pradesh.
809	1680	Niranjan Paul	West Bengal.
810	550	Nivas, H. K.	Bihar.
811	182	Nougerede, C. E. Dela	Assam.

Serial No.	Roll No.	Name.	State/Country
		"O"	
812	105	Oram, A.	Ireland.
813	1245	Ormerod, H. E. (L. M.)	England.
814	795	Otia, J. C.	Bombay.
815	790	Oza, M. G.	Govt. of India.
816	767	Oza, N. M.	Bombay.
		"P"	
817	690	Padhi, R. N.	Orissa.
818	564	Padhi, Sita Ram	Orissa.
819	1125	Padmanabhan, C. V.	Madras.
820	1082	Padmanabham, Y.	Madras.
821	1512	Pagay, R. M. (L. M.)	Uttar Pradesh.
822	959	Pai, M. V.	Bombay.
823	945	Pal, S. C.	Assam.
824	912	Panchanathan, S.	Madras.
825	1198	Pancharatnam, G. M.	Madras.
826	197	Pancholi, D. B.	Saurashtra.
827	383	Pancholy, H. M.	Bombay.
828	1442	Pandya, K. C.	Bombay.
829	1224	Panjwani, S. N.	Uttar Pradesh.
830	417	Parang, Hari Ram (L. M.)	Pakistan.
831	1571	Paranjpye, V. K.	Madhya Pradesh.
832	1209	Parekh, J. H.	Bombay.
833	513	Parija, K. C.	Orissa.
834	128	Parikh, H. B. (L.M.)	Bombay.
835	1519	Parikh, R. M.	Bombay.
836	264	Parmara, D. S.	Uttar Pradesh.
837	1582	Parmanand T. Sehra	Govt. of India.
838	1631	Parmar, P. K.	Saurashtra.
839	743	Partap Singh	Uttar Pradesh.
840	1063	Patel, Ahmed Ibrahim	Pakistan.

Serial No.	Roll No.	Name.	State Country.
841	859	Patel, A. T.	Uttar Pradesh.
842	188	Patel, B. D. (L.M.)	Bombay.
843	890	Patel, B. P.	Govt. of India.
844	717	Patel, C. B.	Govt. of India.
845	1276	Patel, C. I.	Bombay.
846	968	Patel, D. C.	Bombay.
847	967	Patel, J. C.	Bombay.
848	1415	Patel, M. D.	Bombay.
849	735	Patel, M. M.	Govt. of India.
850	1206	Patel, M. M.	Bombay.
851	1492	Patel, Manibhai M.	Bombay.
852	44	Patel, M. R. (L.M.)	Bombay.
853	653	Patel, N. B.	Bombay.
854	1313	Patel, N. C.	Saurashtra.
855	1011	Patel, N. K.	Bombay.
856	1491	Patel, O. H.	Bombay.
857	793	Patel, Y. G.	Bombay.
858	577	Patil, B. D.	Madhya Bharat.
859	359	Patil, G. K.	Bombay.
860	584	Patil, Y. K.	Madhya Bharat.
861	1528	Patkar, B. B. (L.M.)	Bombay.
862	1606	Patro, R. C.	Orissa.
863	672	Patrulu, P. S.	Madras.
864	769	Pederson, S.	Denmark.
865	648	Perry, R. G.	West Bengal.
866	477	Porshad, B.	Bihar.
867	895	Pessi, B. P. Mana	Pakistan.
868	339	Pessumal, N Dhamani, L.M.)	Delhi.
869	392	Phadke, P. G.	Madhya Bharat.
870	1596	Phansalkar, R. L.	Bombay.
871	1021	Philipose, E. U.	Travancore-Cochin.

Serial No.	Roll No.	Name.	State/Country.
872	1109	Philipose, P.	Travancore-Cochin.
873	1658	Pillai, A. Sivarama	Travancore-Cochin.
874	1061	Pillai, K. Gopala	Travancore-Cochin.
875	1018	Pillai, K. J.	Travancore-Cochin.
876	1047	Pillai, K. N. Govinda	Travancore-Cochin.
877	1476	Pinto, C. J.	Bombay.
878	885	Poonen, P. C.	Govt. of India.
879	813	Prabhala, R.	Madras.
880	1384	Prakash, Anand	Uttar Pradesh.
881	733	Prasad, B.	Bihar.
882	1200	Prasad, D. N.	Bihar.
883	1635	Prasad, G.	Bihar.
884	1124	Prasad, G. S.	Bihar.
885	1384	Prasad, Jai Kishore	Bihar.
886	1679	Prasad, K.	Bihar.
887	1360	Prasad, Krishto	Bihar.
888	1642	Prasad, M.	Bihar.
889	1250	Prasad, Nandkishore	Bihar.
890	1348	Prasad, Nilkanth	Bihar.
891	1318	Prasad, Rajdeo	Bihar.
892	898	Prasad, Ram Swarup	M.E.S.
893	436	Prasad, Rashdhari	Bihar.
894	1368	Prasad, Sarju	Bihar.
895	1344	Prasad, Singheswar	Bihar.
896	1295	Prasad, S.	Bihar.
897	1626	Prasad, Sheo Nandan	Bihar.
898	1185	Pratap, B.	Govt. of India.
899	907	Prem Chand	Uttar Pradesh.
900	1416	Prem Manohar	Uttar Pradesh.
901	1157	Prem Mohan	Uttar Pradesh.
902	1537	Prem Sagar, T.	Madras.

Serial No.	Roll No.	Name.	State/Country.
903	1297	Prosad, L. U.	Bihar.
904	402	Pujari, Achyutanand	Orissa.
905	1126	Punnaiah, P. B.	Madras.
906	482	Puranik, R. G.	Bombay.
907	327	Puri, A. N.	Bombay.
908	310	Puri, B. S.	Govt. of India.
909	1108	Puri, P. R.	Govt. of India
910	1215	Puttaswamy, H.	Mysore.
		"Q"	
911	1672	Qazi Mohd. Afzal	Kashmir.
912	384	Qureshi, A. H.	Pakistan.
913	882	Qureshi, A. H.	Pakistan.
914	884	Qureshi, A. R.	Pakistan.
		"R"	
915	500	Radha Krishna	Punjab.
916	1511	Radhey Shiam	M.E.S.
917	1107	Rafi Ahmed, S. M.	Pakistan.
918	87	Raghavachary, K. S. (L. M.)	Thailand.
919	849	Raghavan, N. C. S.	Madras.
920	1008	Raghavan, P.	West Bengal.
921	771	Raghaviah, M.	Madras.
922	1677	Raghbir Singh, S.	PEPSU
923	1172	Raheja, M. L.	M.E.S.
924	628	Raj, P. V.	Madras.
925	880	Rajagopalan, D.	Madras.
926	965	Rajagopalan, K. G.	Govt. of India.
927	1486	Rajagopalan, K.	Travancore-Cochin
928	724	Rajagopalan, S. K.	Govt. of India.
929	190	Rajam, M. K. (L. M.)	Mysore.
930	924	Rajan, G.A.N.	Govt. of India.
931	756	Rajaraman, S.	Travancore-Cochin.
932	868	Raju, D. Narayana	Madras.

Serial No.	Roll No.	Name.	State/Country.
933	162	Raju, P. V.	Madras.
934	746	Raju, R. L.	Mysore.
935	751	Raju, S. P. (L. M.)	Hyderabad.
936	1454	Rajwade, M. V.	Madhya Pradesh.
937	1121	Ram Bilas	Punjab.
938	492	Ram, G. S.	Bihar.
939	1534	Rama Brahmam, M.	Kutch.
940	1214	Rama Nand, A. B.	Mysore.
941	1249	Rama Rao, N.	Govt. of India.
942	496	Rama Rao, T. (L. M.)	Mysore.
943	1262	Rama Rao, V.	Orissa.
944	535	Rama Sundaram, U. S.	Madras.
945	230	Ramamurty, K.	Madras.
946	1179	Ramanathan, G. S.	Madras.
947	1104	Ramaswami, P.	Govt. of India.
948	407	Ramaswamy, K.	Hyderabad.
949	752	Ramaswamy, N. S.	Govt. of India.
950	1269	Ramaswamy, S.	Mysore.
951	421	Ramchandani, N. R.	Assam.
952	1470	Ramiah, V.	Mysore.
953	1588	Ranade, J. Y.	Bombay.
954	438	Rangarajan, P.	Madras.
955	152	Rangaswami, M. A.	Bihar.
956	1605	Rangaswami, R. S.	Madras.
957	669	Rangaswami, T. V.	Madras.
958	82	Rangaswami, V. N.	Madras.
959	108	Rangaswami, V. S.	Madras.
960	1678	Rao, K. Amritha.	Madras.
961	1221	Rao, A. Lakshmikant	Govt. of India.
962	1827	Rao, A. Rajeswara.	Orissa.
963	1610	Rao, A. R. Satyanarayana	Madras.

Serial No.	Roll No.	Name.	State/Country.
964	1013	Rao, B. K. V.	Madras.
965	589	Rao, B. M.	Madhya Bharat
966	1067	Rao, C. B. Madhu Sudana.	Travancore-Cochin.
967	1639	Rao, D. V.	Hyderabad.
968	1023	Rao, E. Gopala Krishna	Govt. of India.
969	389	Rao, H. Sunder (L. M.)	Govt. of India.
970	1564	Rao, K. Bapa	Madras.
971	800	Rao, K. Gopinatha	Rajasthan.
972	1554	Rao, K. Narayana	Madras.
973	1265	Rao, K. Ramamohan	Madras.
974	649	Rao, K. Subba	Madras.
975	1465	Rao, K. Subba	Mysore.
976	1540	Rao, K. V.	M. E. S.
977	835	Rao, M. A.	Madhya Pradesh.
978	1647	Rao, M. Subba	Madras.
979	1077	Rao, M. Seshumadhava	Madras.
980	103	Rao, N. Subba (L. M.)	Mysore.
981	1164	Rao, N. S. Lakshmana	Govt. of India.
982	524	Rao, M. S. Sitaram	Hyderabad.
983	1095	Rao, P. V. S. Prasada	Madras.
984	983	Rao, N. Venkata	Govt. of India.
985	757	Rao, R. Rama Mohan	Madras.
986	873	Rao, R. R. Thimmaji	Madras.
987	545	Rao, S. Ramachandra	Madhya Pradesh.
988	1562	Rao, S. Subba	West Bengal.
989	1405	Rao, S. Subba.	Kutch.
990	1526	Rao, T. Satchidananda	Madras.
991	797	Rao, T. K. Mohana	Madras.
992	1444	Rao, U. B. Sreepada	Madras.
993	1435	Rao, V. Subba	Madras.
994	643	Rastogi, D. P.	Rajasthan.

Serial No.	Roll No.	Name.	State/Country.
995	454	Rastogi, K. S.	Delhi.
996	451	Rath Nilkanth	Orissa.
997	702	Rathod, G. D.	Delhi.
998	498	Rathod, M. P.	Bombay.
999	973	Rathod, N. G.	Saurashtra.
1000	73	Ratnagar, R. D. (L. M.)	West Bengal.
1001	909	Ray, K. B. (L. M.)	West Bengal.
1002	944	Ray, K. C.	Wset Bengal.
1003	987	Ray, K. C.	Madhya Pradesh
1004	1341	Ray, S. N.	Bihar.
1005	1544	Ray, S. N.	West Bengal.
1006	748	Reddy, A. Narasimha	Madras.
1007	1419	Reddy, B. V.	Madras.
1008	876	Reddy, C. Krishna	Madras.
1009	1555	Reddy, C. N.	Hyderabad.
1010	847	Reddy, K. Ramaswamy	Madras.
1011	1052	Reddy, L. C. Muniswamy	Mysore.
1012	1112	Reddy, P. R. G.	Madras.
1013	1113	Reddy, T. A. Ramanatha	Madras.
1014	163	Rege, D. Y.	Bombay.
1015	1288	Resham Singh.	Uttar Pradesh.
1016	559	Rijhwani, J. M.	Govt. of India.
1017	156	Romesh Chandra	Uttar Pradesh.
1018	1299	Roy, B. N.	Bihar.
1019	112	Roy, G. P. (L. M.)	Orissa.
1020	1447	Roy, J. K. (L. M.)	West Bengal.
1021	1271	Roy, K. P.	West Bengal.
1022	1266	Roy, P. K.	Bihar.
1023	766	Roy, R. C.	West Bengal.
1024	435	Roy, T. K.	Pakistan.

Serial No.	Roll No.	Name.	State/Country.
		"S"	
1025	365	Saberi Yousaf, M. L.	Hyderabad.
1026	1130	Sabharwal, G. C.	M.E.S.
1027	1280	Sadarangani, T.	Govt. of India.
1028	969	Sadasivaswami, P. S.	Madras.
1029	1417	Saha, N.	West Bengal.
1030	1099	Saha, R. K.	Govt. of India.
1031	335	Saha, S. L.	Govt. of India.
1032	536	Sahu, B. N.	Orissa.
1033	1321	Sahay, T. K.	Bihar.
1384	61	Sahney, J. C.	Uttar Pradesh.
1035	1255	Sahni, K. S.	Uttar Pradesh.
1036	89	Sahgal, Sant Ram (L.M.)	Punjab.
1037	439	Saigal, Balbir Singh	Govt. of India.
1038	1168	Sajjan Basettappa.	Govt. of India.
1039	120	Saksena, C. P.	Vindhya Pradesh.
1040	1232	Samad, M. A.	Madras.
1041	1553	Samaddar, S. K.	West Bengal.
1042	1328	Samanta, N. K.	Bihar.
1043	861	Samitha, M. U.	Madras.
1044	376	Sandhawalia, N. S.	Bombay.
1045	1314	Sani, G. H.	Delhi.
1046	66	Sanjana, N. P.	Bombay.
1047	194	Sankaram, G. B.	Madras.
1048	1390	Sanyal, P. K.	Burma.
1049	1340	Sarkar, B. N.	West Bengal.
1050	387	Sarkar, Phani Bhushan	West Bengal.
1051	1072	Sarma, S. V.	Travancore-Cochin.
1052	1195	Sarna, V. C.	Govt. of India.
1053	932	Sastri, K. V. Subramanya (L.M.)	Mysore.
1054	1034	Sastri, S. S.	Travancore-Cochin.
1055	928	Sathaye, H. S.	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
1056	990	Satya Nand	Bihar.
1057	1404	Satya Narayana, D.	Corps. of Engineers.
1058	1160	Satya Prakash	Uttar Pradesh.
1059	1598	Satyanarain Singh	Rajasthan.
1060	186	Satyanarayana, B. (L.M.)	Madras.
1061	1627	Satya Narayana, B.	Madras.
1062	1662	Satyanarayan, K.	Madras.
1063	993	Sawai, D. B.	Bombay.
1064	1229	Sawhney, R. P.	Punjab.
1065	233	Sayoji Rao, H. R.	Madras.
1066	1359	Seetharamiah, H.	Mysore.
1067	307	Sen, A. K.	Tripura.
1068	727	Sen, B. R.	Uttar Pradesh.
1069	1032	Sen, D. M.	West Bengal.
1070	1010	Sen Gupta, K. C.	West Bengal.
1071	1515	Sen, N.	Govt. of India.
1072	863	Sen Gupta, P. N.	West Bengal.
1073	1500	Sen, R. B.	West Bengal.
1074	1331	Sen, S. K.	Bihar.
1075	1557	Seshappa, A.	Mysore.
1076	472	Seshagiri Rao, N.	Madras.
1077	1570	Sethana, H. K.	West Bengal.
1078	1090	Sethi, G. R.	Govt. of India.
1079	1329	Sethi, V. P.	Madhya Pradesh
1080	726	Shafiqul Haq	Pakistan.
1081	551	Shah, M. J.	Rajasthan.
1082	1506	Shah, S. G.	Bombay.
1083	1585	Shah, S. R.	Kashmir.
1084	35	Shah, V. J.	Bombay.
1085	175	Shahani, C. M.	West Bengal
1086	1507	Shaikh, A. A. K.	Pakistan.

Serial No.	Roll No.	Name	State/Country.
1087	83	Shannon, I. A. T.	Bombay.
1088	1059	Sharangapani, P.S. (L.M.)	Bombay.
1089	1825	Sharan, Raghunath	Bihar.
1090	96	Shareef, S. A.	Pakistan.
1091	579	Sharma, Baij Nath	Ceylon.
1092	504	Sharma, D. C.	Punjab.
1093	115	Sharma, Hari Shankar	Uttar Pradesh.
1094	1118	Sharma, K. N.	Rajasthan.
1095	870	Sharma, M. R.	Punjab.
1096	516	Sharma, Purnanand	Bihar.
1097	1452	Sharma, P.	Assam.
1098	1467	Sharma, S. A.	Madhya Pradesh.
1099	164	Sharma, S. S.	Uttar Pradesh.
1100	1084	Shastri, M. Balagangadhara.	Madras.
1101	1091	Shaukat Rai	Delhi.
1102	1675	Shaw, J.	Orissa.
1103	720	Shaw, M. (L. M.)	Govt. of India.
1104	619	Sheikh, Mohd. Kasim G.	Pakistan.
1105	39	Shenoy, B. N.	Govt. of India.
1106	786	Sheo Dip Narayan	Bihar
1107	489	Sheth, K. L.	Bombay.
1108	382	Shinde, P. K. (L. M.)	Bombay.
1109	1595	Shinde, Y. A.	Bombay.
1110	388	Shiva Raj, A.	Hyderabad.
1111	127	Shivdasani, K. J.	Bombay.
1112	1148	Shivdasani, P. D.	Bombay.
1113	490	Shobha Ram.	Uttar Pradesh.
1114	953	Shri Krishna	Govt. of India.
1115	152	Shukla, C. N.	Uttar Pradesh
1116	792	Shukla, G. D.	Bombay.
1117	1560	Siddabasaviah, K. V.	Mysore.

Serial No.	Roll No.	Name.	State/Country.
1118	1287	Sil, Krishna Shankar	West Bengal.
1119	1852	Singh, J. N.	Bihar.
1120	1449	Singh, J. P.	PEPSU.
1121	1135	Singh, R. C.	Punjab.
1122	1351	Singh, R. P.	Bihar.
1123	1372	Singh, S. M. P.	Bihar.
1124	1367	Singh, S. N.	Bihar.
1125	1614	Singhal, Mangat Rai	Bombay.
1126	1286	Sinha, A. C.	West Bengal.
1127	340	Sinha, B.	Bihar.
1128	971	Sinha, B. P.	Bihar.
1129	734	Sinha, B. P.	Bihar.
1130	1261	Sinha, D. P.	Bihar.
1131	804	Sinha, Debi Saran	Madhya Pradesh.
1132	191	Sinha, H. P.	Govt. of India.
1133	960	Sinha, K.	Uttar Pradesh.
1134	1342	Sinha, L. U. C.	Bihar.
1135	425	Sinha, M. K. P.	Bihar.
1136	1237	Sinha, N. K.	Bihar.
1137	1291	Sinha, Nilkanth	Bihar.
1138	706	Sinha, P. P.	Bihar.
1139	1278	Sinha, P. S.	Uttar Pradesh.
1140	1319	Sinha, R. P.	Bihar
1141	754	Sinha, S. K.	Bihar.
1142	1260	Sinha, Shyam Lal	Bihar.
1143	871	Sinha, S. N.	Bihar.
1144	1103	Sinha, Shyam Narain	Bihar.
1145	1127	Sinha, S. N.	Orissa.
1146	219	Sirajuddin, P.	Madras.
1147	875	Sircar, S. C.	Bihar.
1148	856	Sircar, S. K.	Bihar

Serial No.	Roll No.	Name.	State/Country.
1149	680	Sivaprakasam, P. S.	Madras.
1150	626	Sivasankaran, O.	Madras.
1151	715	Sivasubramanian, M. K.	Govt. of India.
1152	692	Sivaswamy, A. R.	Madras.
1153	20	Smith, H. C. (L. M.)	Bombay.
1154	283	Sohan Lal	Bihar.
1155	1316	Som, A. K.	West Bengal.
1156	1488	Sompura, G. B.	Saurashtra.
1157	12	Sowani, D. G. (L. M.)	Bombay.
1158	1584	Spencer, S. S.	Bombay.
1159	682	Sreekantiah, C. K.	Madras.
1160	240	Srinivasan, K.	Madras.
1161	1098	Srinivasan, K. S.	Madras.
1162	1423	Srivastava, A. K.	Uttar Pradesh.
1163	1665	Srivastava, C. P.	Vindhya Pradesh.
1164	1354	Srivastava, G. N.	Bihar.
1165	1205	Srinivasan, T. K.	Madhya Pradesh.
1166	618	Srirangachary, G.	Madras.
1167	570	Srivastava, Hari Shankar	Madhya Bharat.
1168	45	Srivastava, Madho Prasad	Uttar Pradesh.
1169	958	Srivastava, P. N.	Uttar Pradesh.
1170	514	Srooty, M. S.	Madras.
1171	1210	Subbiah, C. P.	Govt. of India.
1172	1311	Subbaraju, Bh.	Madras.
1173	723	Subrahmanyam, J.	Govt. of India.
1174	866	Subrahmanyam, P. L.	Madras.
1175	1312	Subramaniam, P. S.	Madras.
1176	1451	Subramaniam, S. K.	Madras.
1177	1674	Subramaniam, V.	Madras.
1178	1105	Sud, A. N.	Punjab.
1179	1231	Sudhamoy Pal	West Bengal.

Serial No.	Roll No.	Name.	State/Country.
1180	65	Sujan, S. B.	Uttar Pradesh.
1181	1432	Sujan Singh	Delhi.
1182	1171	Sukhrani, R. R.	Govt. of India.
1183	872	Sultan Mohd. Naim	Pakistan.
1184	1117	Sundaraj, B. K.	Madhya Pradesh
1185	1406	Sundaram, Shunmuga R.	Madras.
1186	791	Sundaram, S.	Madras.
1187	141	Sundaresan, T. V.	Bombay.
1188	1385	Sur, A. K.	Uttar Pradesh.
1189	926	Sur, S. K.	West Bengal.
1190	25	Surati, H. M.	Hyderabad.
1191	637	Surya, N. S.	Govt. of India.
1192	1345	Swaminathan, C. G.	Madras.
1193	1440	Swaminathan, S. S.	Madhya Pradesh.
1194	1671	Syed Abdul Latheef	Madras.
1195	1499	Syed A. B. Inamul Haque	Assam.
1196	83	Syed Arifuddin	Hyderabad.
1197	1333	Syed Mustafa Jamal	Bihar.
		"T"	
1198	825	Talat Baig	Madras.
1199	1434	Tamizuddin, A. G.	Madras.
1200	1400	Tandon, G. S.	Punjab.
1201	1168	Tandon, S. N.	M. E. S.
1202	794	Tank, D. M.	Saurashtra.
1203	1150	Taraporevala, J. A.	Bombay.
1204	1323	Tawadey, V. B.	M. E. S.
1205	1516	Tayal, K. C.	Uttar Pradesh.
1206	1501	Taylor, Norman Henry	Bombay.
1207	630	Thadaney, K. V.	Madras.
1208	1586	Thaker, H. J.	Madhya Pradesh
1209	1096	Thapliyal, K. N.	Uttar Pradesh.
1210	1572	Thillainayagam, R.	Madras.

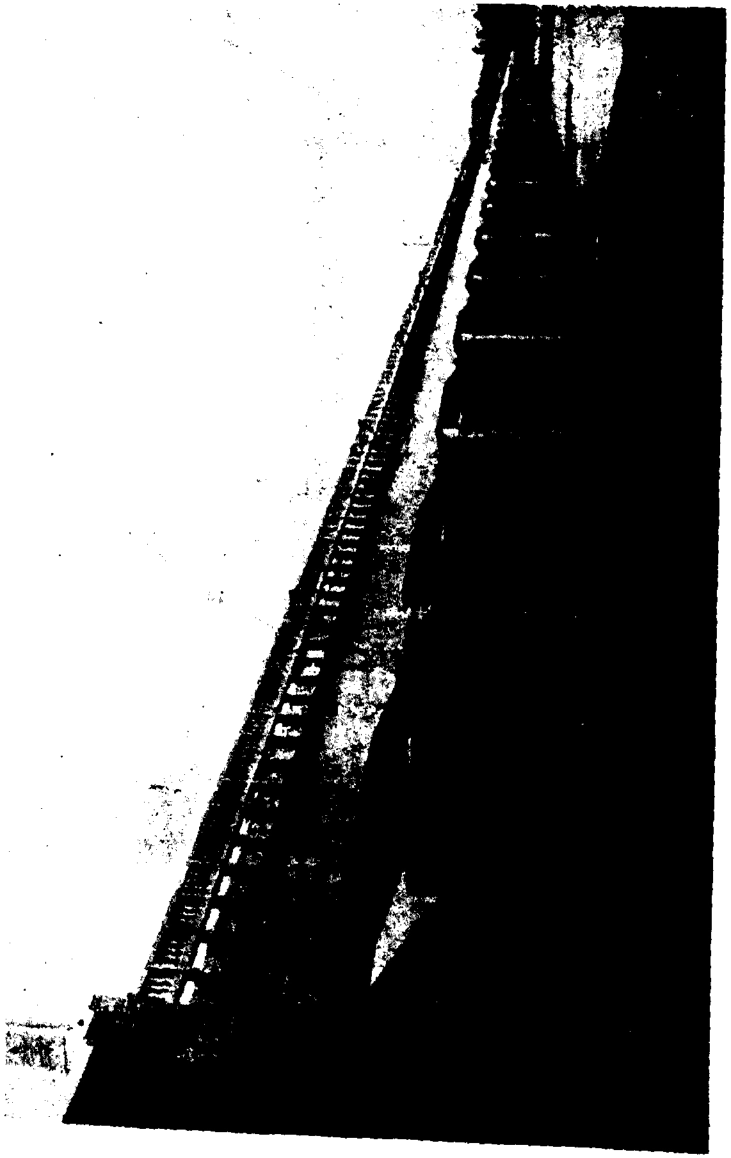
Serial No.	Roll No.	Name.	State/Country.
1211	685	Thirupuvanam, C. N.	Madras.
1212	1478	Thosar, G. S.	Bombay.
1213	1386	Thusu, A. N.	Kashmir.
1214	130	Todd, J. M.	Scotland.
1215	1666	Toki, G. S.	Punjab.
1216	1088	Toubro, S. K.	Bombay.
1217	918	Trehan, J. M. (L. M.)	Govt. of India.
1218	150	Tripathi, S. N.	Madhya Pradesh.
1219	1190	Tripathy, J.	Orissa.
1220	788	Turner, W. H.	England.
1221	6	Tweed, J. C. Rathlin	West Bengal.
1222	476	Tyabji, S. B. (L. M.)	Bombay.
		"U"	
1223	961	Udham Singh	Himachal Pradesh.
1224	1166	Uma Kant	Uttar Pradesh.
1225	847	Uppal, H. L.	Govt. of India.
1226	1612	Uppal, M. G.	PEPSU.
1227	1475	Unwalla, B. T.	Bombay.
1228	1089	Uttam Singh (L. M.)	Uttar Pradesh.
		"V"	
1 29	84	Vagh, B. V. (L. M.)	Bombay.
1230	416	Vahidy, Zahir Ahmed	Pakistan.
1231	574	Vaidya, Anant Ganesh	Madhya Bharat.
1232	351	Vaidya, G. D.	Hyderabad.
1233	846	Vaidyanathan, V. I.	Govt. of India.
12 34	738	Vaish, Vidya Ram	Govt. of India.
1235	176	Vakil, N. H.	Bihar.
1236	631	Varma, D. C.	Madhya Pradesh
1237	1300	Varma, D. N.	Bihar.
123 8	1873	Varma, D. N.	Bihar.
1239	505	Varma, Hari Gopal	Uttar Pradesh.
1240	881	Varma, J. N.	Bihar.

Serial No.	Roll No.	Name.	State/Country.
1241	1362	Varma, K. K.	Bihar.
1242	1366	Varma, K. N.	Bihar
1243	635	Varman, K. R.	Govt. of India.
1244	935	Varma, K. Raja Raja.	Travancore-Cochin.
1245	491	Varma, P. L.	Punjab.
1246	362	Vartak, G. R.	Bombay.
1247	400	Vasay, K. M.	Hyderabad.
1248	466	Vaze, D. L.	Bombay.
1249	1258	Ved Prakash	Uttar Pradesh.
1250	1178	Veera Raghavan, T. M.	Madras.
1251	862	Veeriah, P.	Madras.
1252	1523	Venkatachalam, B.	Madras.
1253	543	Venkatachalam, K.	Hyderabad.
1254	1147	Venkataraman, P.	Madras.
1255	772	Venkataramanan, T. S.	Madras.
1256	1173	Venugopal, C.	Madras.
1257	922	Vepa Krishnamurthy	Madras.
1258	1363	Verma, R. P.	Bihar.
1259	1326	Verma, S. N.	Bihar.
1260	126	Vesugar, J. B. (L. M.)	Bombay.
1261	1600	Vibhakar, P. K.	Saurashtra.
1262	1576	Vidyarthi, S. D.	Uttar Pradesh.
1263	1622	Vijh, G. C.	Punjab.
1264	1542	Vijh, H. C.	M. E. S.
1265	1471	Vora, P. K.	Kutch.
1266	1305	Vyavaharkar, D. A.	Bombay.
		"W"	
1267	1085	Wadhwani, G. B.	Uttar Pradesh.
1268	1120	Wadia, K. C.	Bombay.
1269	235	Wale, N. D.	Bombay.
1270	75	Walker, W. F. (L. M.)	England.

Serial No.	Roll No.	Name.	State/Country.
1271	1583	Wanchoo, P. N.	Kashmir.
1272	3	Warren, P. F. S.	West Bengal.
1273	822	Williams, L. C.	Ceylon.
		"Y"	
1274	1289	Yadav, Brij Lal	Uttar Pradesh.
1275	578	Yadav, H. J.	Madhya Bharat.
1276	1567	Yadva, S. G.	Bombay.
1277	1530	Yegna Narayana, K.	Madras.
1278	1006	Yogi, M. V.	M.E.S.
1279	541	Younus, S. M.	Hyderabad.
		"Z"	
1280	1303	Zaki, A.	Bihar.
1281	1535	Zipkes, E.	Govt. of India.
1282	236	Zutshi, M. N.	Uttar Pradesh.
1283	954	Zutshi, Y. N.	Uttar Pradesh.

Associate Members

Serial No.	Roll No.	Name.	State.
1	31	Antia, F. P.	Bombay.
2	39	Basil Gray	Delhi.
3	35	Caltex (India) Ltd.	Bombay.
4	43	Central Standard Office for Railways.	Govt. of India.
5	45	Chatterjee, D.	West Bengal.
6	41	Do, K. C.	West Bengal.
7	30	Engineer, M. B.	Bombay.
8	16	Engineer-in-Chief's Branch	Govt. of India.
9	48	Faujdar Thakur	Bihar.
10	20	Garewal, Saparan Singh	Bihar.
11	27	Gupta, L. K.	West Bengal.
12	15	Heatly & Gresham Ltd.	West Bengal.
13	36	Indian Malleable Castings Ltd.	West Bengal.
14	31	Khanna, K. N.	Delhi.
15	38	H. D. Mayes	West Bengal.
16	44	Laurie, F. J. K.	West Bengal.
17	6	Madden, W. J.	West Bengal.
18	22	Moss, G. L. M.	West Bengal.
19	29	Society of Motor Manufacturers & Traders Ltd.	Delhi.
20	14	Patell, J. K.	Bombay.
21	46	Patel, K. R.	West Bengal.
22	21	Patel, L. R.	West Bengal.
23	47	Principal, M. B. M. College Engineering, Jodhpur.	Rajasthan.
24	34	Ramsay, A. R. P.	West Bengal.
25	40	Shahani, T. C.	Delhi.
26	42	Weatherall, H. M.	Bihar.
27	28	Willcox, E. W.	Delhi.
28	37	William Harrison	Bihar.



Photograph No. 1. A view of the completed bridge.

Paper No. 161

"THE INVESTIGATION, DESIGN, AND CONSTRUCTION OF THE CAUVERY BRIDGE AT PUGALUR"

By

K. K. NAMBIAR, B.E.

AND

K. NAMASIVAYAM, B.E.

CONTENTS

SYNOPSIS

The Paper describes the investigations, design and construction of a bridge over the Cauvery on National Highway No. 7. The project was approved in 1940 and executed in 1949—50, with considerable modifications arising from consideration of the flood-controlling effects of the Mettur dam which had become apparent during this interval. The total length of the bridge is 2,634 ft with 40 equal spans of 66 feet. Both open foundations and well foundations consisting of three 8 ft x 9 ft rectangular wells under a pier, were adopted. The superstructure is of R.C. T-beams continuous over units of three spans. The details of construction, the difficulties encountered during execution, the methods adopted to overcome these difficulties, and the results of tests on concrete and reinforcement welds, are described. Design calculations are not given.

1. INTRODUCTORY

1.1. The Cauvery bridge at Pugalur on National Highway No. 7 (Banaras—Cape Comorin Road) was the first major bridge work to be taken up and completed by the Madras State under the National Highways Programme. The bridge is situated at the border of the Salem and Trichinopoly districts—about 16 miles from the town of NAMAKKAL in the Salem district, and about 12 miles from the town of KARUR in the Trichinopoly district. The site is shown in the Key Map (Plate I). The bridge work was formally inaugurated on 9—5—49 by the Hon'ble Minister for Public Works, Madras, the construction proper was actually commenced in June 1949, and the work was completed and the bridge opened for traffic on 23—12—51. (Photo 1).

1.2. The object of this Paper is to place before Members an account of the events from the original proposal of 1938 to construct a bridge under the Road Development Fund up to the time of the completion of the bridge under the National Highways programme. The methods of construction employed and the difficulties encountered during construction are also described.

2. THE CAUVERY RIVER

2.1. Course

2.1.1. The Cauvery, the largest river in South Madras, rises near Mercara in the Coorg State and drains a considerable area of the eastern slopes of the Western Ghats. This area is subject to heavy rainfall during the south-west monsoon, from June to September and it is during these months that the Cauvery carries the greater part of its annual discharge.

2.1.2. Early in its course, the Cauvery enters the Mysore State where it is joined by its tributaries, the Hemavathi and the Lakshmanathirtha. Here the river is intercepted by the Krishnarajasagara Dam constructed by the Mysore Government. Lower down, the river is joined by the Kabbini and other less important tributaries. The river then takes a sharp turn towards the south at the Hogainakal falls which form the northern limit of the Mettur reservoir constructed by the Madras State Government. Leaving Mettur, the Cauvery takes a southerly course as far as Bhavani town, where it is joined by an important tributary of that name which drains the mountainous Nilgiris district and the north-west part of the Coimbatore district. This place of confluence is 9 miles from Erode. Here the Cauvery and the Bhavani each has a separate highway bridge.

2.1.3. Near Bhavani the Cauvery enters the plains and has a railway bridge at Erode. Lower down, it is joined by the Noyyal river, about five miles above the site of the Pugalur bridge which is the subject of this Paper.

2.2. Catchment

2.2.1. Above the site of the Pugalur bridge, the catchment area of the Cauvery and its tributaries is about 22,100 sq. miles.

2.2.2. A map showing the course of the river, its catchment area, etc., is appended. (Plate II).

2.3. Maximum discharge at the bridge site

2.3.1. The site where the bridge has been constructed is about 40 miles downstream of the Erode railway bridge and about 75 miles below the Mettur Dam. The worst known flood in the Cauvery occurred in 1924 when the maximum discharge recorded at the Erode bridge was 485,500 cusecs. The maximum flood in the Bhavani occurred in the year 1930 when the discharge was of the order of 122,100 cusecs. The Mettur Dam was built in 1934 and it is very improbable that, with the flood-moderating effect of the Mettur reservoir, the discharge in the river at the bridge site could be anywhere near the maximum discharge recorded in 1924 in the pre-Mettur period.

2.4. Flood-moderating effect of Mettur Reservoir

2.4.1. In this connection it is pertinent to place on record the discharges that were let down the Cauvery from Mettur from 1934 onwards :

Maximum discharge from Mettur (Stanley) Reservoir.

Year	Discharge in cusecs	Year	Discharge in cusecs
1934	30,000	1942	57,000
1935	32,000	1943	1,39,000
1936	50,000	1944	27,000
1937	67,000	1945	27,000
1938	54,000	1946	1,10,000
1939	30,000	1947	88,000
1940	91,000	1948	1,06,000
1941	1,64,000		

2.4.2. It will be observed that over fifteen years after the completion of the Mettur Dam the maximum discharge below the dam was only 164,000 cusecs against a designed outflow at the dam of 387,600 cusecs which could be expected under the worst possible condition, i.e., if a high flood of the 1924 intensity occurred with the reservoir already full.

2.4.3. From the actual discharge figures given above, the conclusion could safely be drawn that the Mettur reservoir does have a very appreciable moderating effect on floods in the Cauvery and that this could be counted upon in the design of bridges further downstream (see also para 6.1.6.)

3. 1938—INVESTIGATION AND ESTIMATES.

3.1. Existing Bridges

3.1.1. Till the construction of the Pugalur bridge, the Cauvery had highway bridges only at Bhavani and Tiruchirapalli. These places are about 100 miles apart, and the absence of a road bridge across the river at an intermediate point caused much inconvenience to traffic between the districts of Salem and Tiruchirapalli. There is a good deal of traffic across the Cauvery between these districts, carried by means of ferry boats and coracles, practically at intervals of every 4 miles throughout the length of the river.

3.2. Necessity for a bridge at Pugalur

3.2.1. The necessity for a bridge at an intermediate point connecting Namakkal Taluk of Salem district and Karur taluk of Tiruchirapalli district had been keenly felt for a very long time. It was also recognised that a bridge across the Cauvery in this area would be useful not only with reference to the needs of the two districts referred to above, but also from the point of view of the general road-traffic requirements of the whole of South India. Such a bridge would open up an entirely new traffic route from Salem on the north to Dindigul and Madura p the south and would be of great value to trade and commerce

3.3. First proposal

3.3.1. The proposal to construct a bridge across the Cauvery in this area first took shape in the "Vipan Scheme"* of Road Development for the Madras Presidency which was tentatively drawn up in 1936.

* "Scheme of Road Development for the Madras Presidency" by A. Vipan, M.I.C.E.. Special Engineer, Road Development, Madras (1935); p. 32

There were the usual conflicting claims regarding the site to be adopted. In deciding on the Pugalur site, the merits and demerits of five alternative sites were gone into in great detail. After a thorough examination of the technical, economic, and trade needs, and the opinion of the various authorities concerned, it was decided to construct the bridge at the Pugalur site. The preliminary survey was completed in 1938 and an approximate estimate for Rs 10 lakhs was framed.

The scheme was sanctioned for execution in 1940, but on account of the conditions created by World War II the work was postponed.

3.4. First Estimate

3.4.1. The estimate as finalised in 1940 provided for constructing a bridge of 48 spans of 60 feet each to cover the width of the river from bank to bank and the design provided for the peak discharge of 485,500 cusecs observed at the Erode railway bridge during the 1924 floods. The flood-moderating effect of the Mettur Reservoir was not taken into account in that design as the dam had been functioning for a few years only and the knowledge of the extent of this effect was incomplete. The bridge was designed for the Madras B-Class loading, then in vogue in the State, with a roadway of 18 feet clear width.

4. SANCTION OF ESTIMATE UNDER THE NATIONAL HIGHWAYS SCHEME

4.1. After the introduction of the National Highways Scheme this bridgework was included in the Five Year Programme of Post-war Road Development. The approved alignment for National Highway No. 7 (Banaras-Cape Comorin Road) through the three districts of Madura, Tiruchirapalli and Salem is from Madura to Salem via Dindigul, Karur and Namakkal. There has been considerable controversy as to what alignment this National Highway should take between Karur and Namakkal—both being obligatory points. A bridge was a necessity in this section of the route for the continuity of this National Highway and the question of a suitable site for the bridge once again figured in the discussions.

4.2. It is evident from the Key Map (Plate I) that the direct line between Karur and Namakkal passes through Mohanur and this line was provisionally accepted by the Government of India as the alignment for the National Highway. But the Mohanur site was not insisted upon on the ground that a bridge here would be very expensive as the foundations would have to be taken down very deep. The Government of India, therefore, suggested that the route should take approximately the next shortest suitable line from Karur to Manmangalam, crossing the Cauvery at Nanniyur (where site conditions were very good), and thence to Vallipuram and on to Namakkal.

4.3. The State authorities, however, felt that the Highway should be diverted so as to pass through Pugalur and Velur with a bridge at the site that had been decided upon in 1938 as the most suitable in all respects—the route being Karur-Manmangalam-Pugalur-Velur-Vallipuram-Namakkal. Both the routes are common south of Manmangalam and north of Vallipuram but the route through Pugalur would be seven miles longer than that through Nanniyur.

The Government of India agreed to the longer route via Pugalur, subject to certain financial adjustments.

5. A BRIEF DESCRIPTION OF THE BRIDGE

5.1. General

5.1.1. The Pugalur bridge is a reinforced concrete structure of continuous Tee-Beam and Slab design supported on piers and abutments. The continuous beam type was selected in this case as the foundation conditions were ideal for that type.

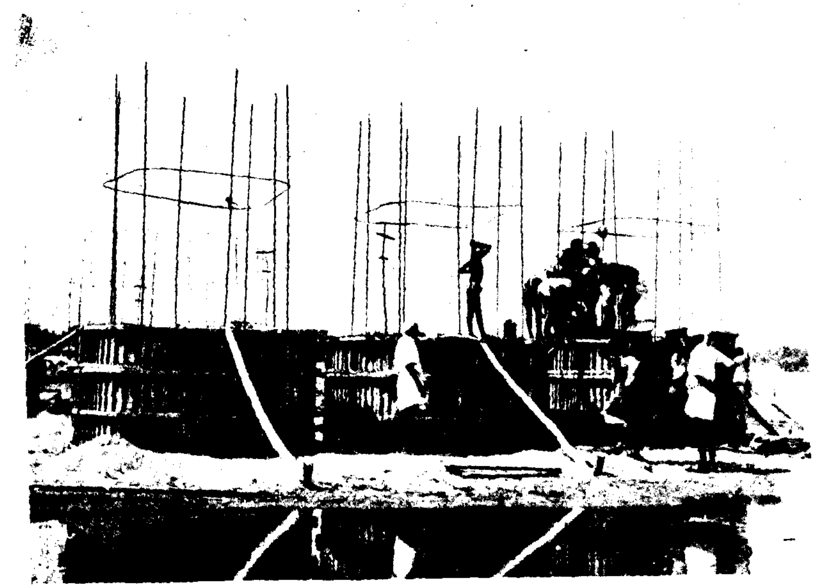
The total length of the bridge, comprising 40 equal spans of 60 feet clear, is 2,634 feet between faces of the abutments or 527 feet shorter than the bridge designed in 1940. The bridge carries a 22-foot wide clear roadway.

5.2. Foundations

5.2.1. For the abutments and wings on the left (Velur) side and piers Nos. 1 to 8 and No. 10, open foundations were provided. For the remaining piers and the abutment-pier on the right (Pugalur) side, well foundations were adopted. These consisted of three separate rectangular cement concrete wells with rounded corners under each pier. The outer size of each well was 8 feet by 9 feet with a 2-ft thick steining. The wells for the abutment-pier were of a slightly larger size, i.e., 8 ft by 9 ft 6 inches. The wells under each pier were capped with reinforced concrete slabs, 32 ft 6 in. by 8 ft 6 in. by 1 ft 6 in. thick.

5.3. Piers and Abutments

5.3.1. The piers were built of coursed rubble masonry in 1 : 4 cement mortar below low water level and in 1 : 5 mortar



Photograph No. 2.

Rectangular wells with rounded corners–Concreting in progress for steining.

above that level. For piers Nos. 4 to 8 and 10, the substructure was of mass cement concrete 1 : 3 : 6 mix. The mass concrete and the masonry below the bed level were stepped above the bed level, a uniform batter of 1 in 24 was given in the piers. The abutments were built with a front batter of 1 in 12 and a back batter of 1 in 5. The piers had a thickness of 6 ft at the top. Semi-circular cutwaters were provided both at the upstream and downstream ends of the piers. At the top, each pier was provided with a bed block of reinforced concrete, 1 ft 6 in. thick, for the bed plates of roller and rocker bearings. These bed blocks projected 3 inches beyond the pier face to produce a cornice effect.

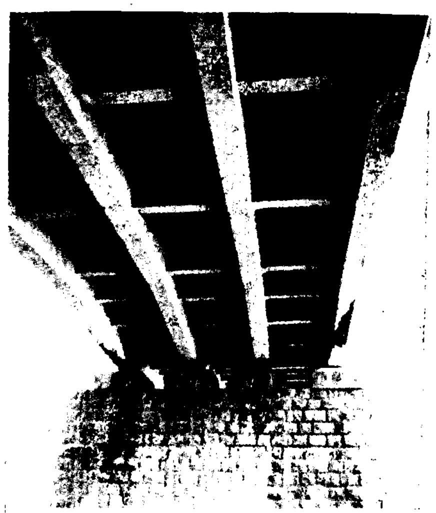
5.3.2. The Velur side (left) abutment had straight return walls, founded on rock. The Pugalur side (right) abutment was constructed as an abutment-pier to allow for future extension of the bridge if this were ever required.

5.4. Bearings

5.4.1. Cast steel bearings of rocker and roller type have been adopted. In each unit of three spans, the expansion bearings at the end support consist of a two-roller assembly while the expansion bearing at one of the intermediate supports has a four-roller assembly. The other intermediate support has a fixed rocker bearing with a 3-in. diameter pin. The rollers used were of three sizes viz., 6¼ in., 7¾ in. and 7 in. diameters. The first two sizes were received as billets from the Railway Department and the difference in the sizes was utilized for raising the level of the two intermediate beams to give the camber required on the deck.

5.5. Superstructure

5.5.1. The superstructure consists of a reinforced concrete continuous Tee-Beams and Slab-decking. Twelve units of three spans each and one unit of four spans have been provided. The depth of the rib of the Tee-beam at mid-span is 5 feet and over the supports 6 feet 6 inches. A straight (horizontal) haunch for a distance of 15 feet from the face of the pier has been provided at either end of each beam. This gives a very pleasing effect on the finished structure. To give stiffness to the ribs of the Tee-beams, ten cross beams have been provided in each span.



Photograph No. 8.

A view from below showing the T-beams and cross beams.

5.5.2. Provision for expansion has been made at the end of every unit of three spans.

5.5.3. The wearing surface consists of three inches of 1 : 1½ : 3 cement concrete laid over the deck slab, the top having a parabolic shape sloping towards the kerbs. The clear width of the carriageway is 22 ft with 9 in. by 12 in. R. C. kerbs (see Plate III).

5.5.4. There are no footpaths. Reinforced concrete hand-rails have been provided.

6. DESIGN

6.1. Discharge and Waterway

6.1.1. As already mentioned in para 3.4.1, the peak discharge of the river assumed for the design finalized in 1940 was 485,500 cusecs. The postponement of the work in 1940, however, provided an opportunity for a *de novo* examination of the question of discharge and waterway to be provided through the bridge in the light of the known flood-moderating effect of the Mettur reservoir.

6.1.2. At the site of the bridge the current of the river is set towards the left margin and the active channel has remained close to the left (Velur) bank for years. On the right (Pugalur) bank the bed is heavily silted and is now above normal water level over a length of about three miles and a width of about 700 feet. The width of the river, bank to bank, is 3,120 feet. The set of the river to the left appears to be permanent, because of a well-established bend a mile and a half upstream which makes the river flow along the left margin in the region where the left abutment of the bridge has been built. The construction of the bridge does not alter these hydraulic conditions. The deep channel of the river, after passing the bridge site, hugs the left margin for some distance and then gradually swings to the right margin about three-quarters of a mile downstream (see Fig. 1).

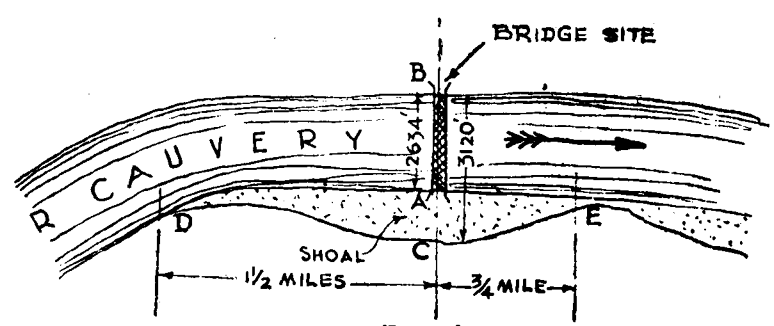


FIG. 1

6.1.3. The right abutment-pier located at A (Fig. 1) is nearly on the line joining D and E. When a high flood comes down the river, there will be water on the shoal. But the flow over the width A C would be extremely sluggish and practically stagnant as one approaches C.

For the highest flood on record since the construction of the Mettur Dam, the maximum depth of water near about A was reported to be only about 5 to 6 feet. Local enquiry indicated that even on that occasion there was practically no flow at all adjacent to C and for a considerable distance along C A. It would, therefore, appear that generally there was no scouring velocity in the flow over the shoal and that DAE would remain the boundary of the shoal, with or without the bridge.

6.1.4. The facts described above indicated the possibility of designing a shorter bridge and omitting a few of the originally designed 48 spans (vide para 3.4.1) on the right bank over the silted portion, and substituting a stop-bank with adequate protection. With the stop-bank, the utmost that can happen is some parallel flow towards the last vent along the toe of the revetted upstream slope of the stop-bank. The parallel flow may gain some velocity as it approaches the vent and a scouring velocity is likely to develop in the region of abutment-pier. Protection in that region had to be designed so as to prevent the collapse of the bank.

6.1.5. From the details given in para 2.4.1, it will be seen that the maximum surplus from the Mettur Reservoir in the last 18 years has been only 164,000 cusecs. Similarly the Bhavanisagar Dam (under construction) will have a moderating effect on the floods in the Bhavani river. The maximum recorded discharge in the Bhavani was 122,100 cusecs in 1930. As the Bhavani Reservoir is still incomplete and the bridge was expected to be completed before the Bhavanisagar reservoir began to function, it was assumed for purposes of design that the reservoir did not exist and that a figure of 122,100 might be assumed as the maximum flood discharge from the Bhavani river.

6.1.6. Further, assuming the worst condition that the Cauvery and Bhavani floods would be simultaneous, one could expect only a maximum discharge of 164,100 plus 122,100 = 286,100 cusecs at the bridge site.

6.1.7. The flood level for this discharge passing through the bridge with only 40 spans of 60 ft each (as against 48 spans of 60 ft each proposed in 1940) is expected to be about 396.00. This will make hardly any mark on the right side stop-bank, even in the region of the abutment-pier.

6.1.8. If the sand bed is scoured away down to shingle, a waterway of 40,874 sq. ft will be available for passing the flood discharge of 286,100 cusecs. The maximum average velocity will then be only in the region of 7 per sec. Thus it was concluded that there would be no danger in restricting the waterway by cutting out right spans on the Pugalur side. Accordingly the bridge was designed and constructed with 40 spans of 60 feet.

6.1.9. As already indicated (para 6.1.4) it was necessary to take adequate measures to protect the approach bank from the effects of parallel flow and scour. These measures are described later under the heading "Protective Works" (Para 6.4).

6.1.10. To allow for any future extension of the bridge over the shoaled portion, should that become necessary, the abutment on the Pugalur side was built as an abutment-pier.

6.2. Foundations

6.2.1. The design of foundations was very simple. The boring results indicated a bed of coarse sand with rock below a moderate depth of sand on the left bank. Approaching the right half of the width, the rock bed dipped down. The depth of the rock surface below the average bed level varied from 4 ft at the site of the left abutment to 40 ft at the right abutment-pier—vide boring chart (Plate IV). Well foundations taken down to rock were the obvious choice in this case except for the left abutment and a few piers on the left side where rock was available at fairly shallow depths. At the time of estimating it was thought that the left abutment and piers 1 to 12 on this side, where the depth of rock below the bed was within 12 ft, could be executed in the open. In actual execution, however, open foundations were adopted for the left abutment and wings and piers 1 to 8 and 10 and well foundations were adopted for the remaining piers including piers 9, 11, and 12.

6.3. Substructure

6.3.1. Good building stone was available locally for the construction of piers and abutments, for which a minimum width of 6 ft at the top was considered necessary to accommodate the bearings of the Tee-beams. The usual side batter of 1 in 24 was provided for the piers which gave a base width of 7 ft 6 in. on the well caps. The section adopted was found to be adequate to take safely the direct as well as the lateral forces acting on the pier.

6.3.2. The abutment on the left bank and the abutment-pier on the right bank were designed as straight retaining walls to withstand safely the earth pressure as well as the effect of live load on the back fill.

6.4. Protective Works

6.4.1. The precise nature of the protective works required to prevent the possible collapse of the stop-bank at the right flank was determined by model experiments conducted at the Irrigation Research Station, Poondi. The problem posed was to study the flow pattern resulting after the construction of the bridge and to examine the security of the right approach embankment against scour along its sides caused by lateral flow and around the right abutment-pier. The scour round the bridge piers themselves was not of great importance since the piers were all proposed to be taken down to rock. The model study was made on the basis of a discharge of 286,100 cusecs (see para 6.1.6) and a flood level of +396·00 at the site of the bridge The model study indicated that although the construction of the bridge and the approach bank on the right flank would not materially alter the normal flow pattern, some concentration of flow might be expected round the right abutment-pier, thereby indicating the need for some protective works on the right flank.

6.4.2. Two types of devices were tried on the model, viz., (i) Bell's bund and (ii) Hanging groynes along the approach embankment. With a Bell's bund it was observed that although there was no noteworthy change in the flow pattern, the scour got shifted from around the right abutment-pier to the nose of the Bell's bund. This was a desirable feature since thereby the security of the approach embankment was ensured and the scour at the nose of the Bell's bund itself could be controlled by falling aprons. The hanging groynes helped to mitigate the concentration of flow round the abutment-pier but objectionable scour persisted at the nose of the approach embankment. For these reasons a Bell's bund was finally adopted.

6.4.3. The Bell's bund was of 150 ft straight length (100 ft upstream and 50 ft downstream), protected by suitable pitching and an apron. A plan and section of the Bell's bund is shown in Plate V.

6.5. Superstructure

6.5.1. The complete design calculation is too voluminous for reproduction in this Paper. The salient features and the main principles of design only will be mentioned briefly.

(a) **Design Data** : The Tee-beams are carried over masonry piers 6 ft thick at the top.

Clear width of roadway	22 feet.
Kerbs	9 in. x 1 ft.
Wearing coat of cement concrete ($1:1\frac{1}{2}:3$)	3 in. uniform thickness

(b) **Loading** : I. R. C. Class A (two-lane) or I. R. C. Class AA (single lane) whichever produced more severe conditions on the member under consideration.

(c) **Impact** : According to Clause 209 of the I. R. C. (draft) Bridge Code.

(d) **Working Stresses** : Ordinary grade cement concrete of 1 : 2 : 4 mix was adopted for all members of the superstructure. The following safe working stresses were allowed in the design :—

(1) **Concrete.**

fc = (Compressive stress—bending)
= 750 lb per sq. in.

v = (Shear stress)
= 75 lb per sq. in.

u = (Bond stress)
= 10 lb per sq. in.

(2) n = (Modular ratio) = 15

(3) **Steel** : Tested mild steel rods were used throughout.

fs = (Safe tensile and shear stress in steel) = 18,000 lb per sq. in.

(e) **Decking** :

The deck consists of a uniform 3-in. thick cement concrete wearing coat laid separately over an 8-in. thick reinforced cement concrete slab. The reinforced cement concrete girders are four in number spaced at 6 ft centres, the rib width being 15 in. uniform. This gives a clear span of 4 ft 9 in. between the ribs of the Tee-beams and the slab was designed for this clear span. The maximum intensity of stresses on this portion of the slab are induced when one of the tracks of the 70-ton tracked vehicle (of Class AA I. R. C. loading) is located at the middle of the slab span. But the design of the cantilever portion of the slab was governed by the maximum wheel load (12,500 lb) of the Class A load train.

The deck slab was designed according to Pigeaud's method with the dispersion of the wheel load suggested by W. L. Scott. Here the Poisson's ratio assumed for concrete was 0.15. The longitudinal reinforcement provided in the slab was not less than

$\frac{1}{\sqrt{L}}$ times the transverse steel. The main deck reinforcement consisted of 5/8 in. diameter rods at $6\frac{1}{2}$ in. centres in the transverse direction and $\frac{1}{2}$ in. diameter rods at 9 in. centres in the longitudinal direction.

As the slab is cast monolithic with the T-beam with fillets provided at the junctions there is a certain amount of rigidity at the supports. Yet in view of the large ratio between the dead load and the live load there is a possibility of a slight negative bending moment occurring in the middle of any span when the other spans are loaded. Suitable reinforcement has been provided to take up this negative bending moment also.

(f) **T-beams**:

The 70-ton tracked vehicle controlled the design of the T-beams. As the spacing of the beams was only 6 ft against the spacing of 6 ft 9 in. between the centres of the tracks, only one track could come over each beam. In designing the beams no distribution of load was assumed as between beams, and the whole load due to one track was taken as borne fully by one beam.

The beams are continuous over three spans and have variable moments of inertia. The depth of the Tee-ribs below the slab is 5 ft in the central 30 ft length with symmetrical straight haunches on both sides. The haunch depth at the support is 18 inches.

The beams are supported on cast steel roller or rocker bearings.

Influence lines were drawn for 10 sections in each span for bending moments and shears. The influence lines for bending moments were obtained graphically by plotting "Fixed Points" obtained by the usual formulae. Necessary correction due to haunching was made for calculating the shear stresses.

The moment and shear influence lines are shown in Plates VI and VII and the reinforcement details in Plates VIII and IX.

7. CONSTRUCTION AND PROBLEMS ENCOUNTERED

7.1. Foundations

7.1.1. As already stated, the results of trial borings indicated hard rock at shallow depths on the left bank of the river, the rock dipping down to a depth of more than 40 ft below bed leve

as one approached the right margin. Where rock was met at shallow depths i.e., up to 12 feet, open foundations were provided and, for the rest well foundations.

7.2. Well Foundations:

7.2.1. The work on the bridge was commenced in June 1949 when the kerbs for the wells were laid. The work was started in the "closure" period but the Mettur was expected to release water within a few days so only Pier No. 32 and those beyond on the right margin were tackled as they were all located on the shoal. As the summer water level was low and the river bed was high in these reaches, sand had to be excavated almost down to the low water level before the cutting edges were laid.

Photograph No. 4.

A general view of the work in its early stages.

7.2.2. The cutting edge in this case consisted of 6 in. by 4 in. by $\frac{1}{2}$ in. unequal angles with the 6-in. leg vertical pointing downwards. The horizontal leg was anchored to the reinforced concrete kerb by means of nuts provided at the ends of the vertical bond rods. For some wells the cutting edge was bent to the required shape by heating it but it was very difficult to get the top surface plane. Subsequently Vee-shaped cuts were made in the horizontal leg of the cutting edge at the bends. This facilitated bending the angle-iron to the correct shape by means of jim-

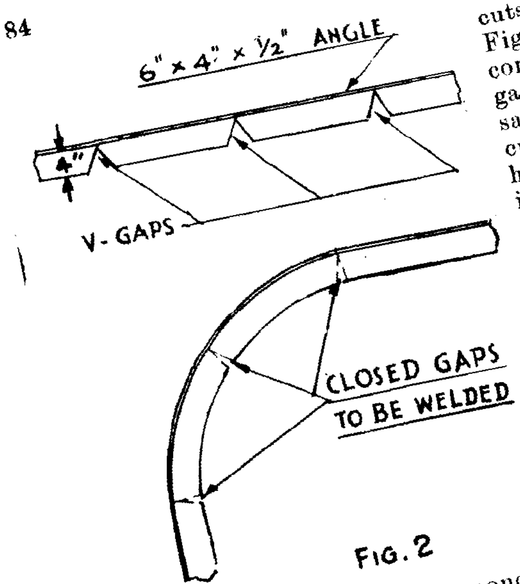


FIG. 2

crows. After bending, the cuts were welded up (see Fig. 2). This process was comparatively easy and gave a neat finish. At the same time it saved the cutting edge from being heated and hammered into a less well-finished shape.

7.2.3. When a few wells which were seated on rock were examined before plugging, it was found that the angle iron forming the cutting edge had buckled under the weight of the steining because of uneven seating on the hard rock and had been wrenched away from the bond rods. As a result the edge of the concrete kerb had spalled off. These defects could perhaps have been avoided if the vertical leg of the cutting edge had pointed upwards instead of downwards..

7.2.4. From the experience gained on this work it was found that the vertical leg pointing downwards does not help appreciably in sinking a well. For sinking through sand the steel cutting edge did not seem to be required at all. For sinking in clay, the sinkers always managed to scoop a few inches beyond and behind the cutting edge to reduce the sinking effort. This made the steel cutting edge practically functionless.

7.2.5. All the wells were provided with reinforced concrete kerbs (1 : 2 : 4 mix).

7.2.6. For the steining, cement concrete of 1 : 3 : 6 mix was used with river shingle for coarse aggregate as this was available in large quantities in the shoaled-up portion of the river. The size of the shingle was 1½ inches. Even though the proportion adopted was 1 : 3 : 6 with practically no slump, this gave a very good concrete. Cubes were tested and it was found that the first crack occurred at a stressof 1,011 lb per sq. in. on an average. The average crushing strength was 1735.5 lb per sq. in. Test results are given in Appendix I.

7.2.7. The well steining, which was 2 ft thick, had eight bond rods located along the centre line of the steining at suitable

intervals. These bond rods were tied together by bond plates of 3 in. by ¼ in. flat iron spaced at 3 ft 6 in. vertical intervals. The bond rods were extended by means of bottle nuts.

7.2.8. Concrete for the steining was laid in stages of 5 ft height. The moulds for the steining and the kerb were of timber with G. I. sheet linings. With only two major repairs, the steining moulds were able to stand more than 100 repetitions. After the kerb had been laid and sunk it was observed that it began to sink further while concrete for the first stage of the steining was being poured. To avoid this, pieces of planks were introduced under the cutting edge and the whole of the kerb space was refilled with sand.

7.3. Well Sinking

7.3.1. The kerb portion and the first ten feet of the steining were sunk by divers without using helmets. Beyond this depth of 13 feet, well sinkers used helmets, supplied with compressed air. In the initial stages the rate of sinking through sand was observed to be about 5 feet in a working day. Sinking the wells through sand and shingle was an easy job but the real trouble came when the wells had to be sunk through a soil of exceptionally hard variety, viz., well compacted loam with nodules of kankar. In some cases the nodules of kankar formed the major part. There was practically no water in this stratum but under-cutting was difficult and the progress of sinking was practically nil for days on end at the beginning. Crow-bars, jumpers, and crowbars all proved failures until pneumatic jack-hammers and clay diggers came to the rescue. Even with this equipment the rate of sinking was about a foot per week on an average. As days advanced and the well sinkers got more and more experienced in the manipulation of pneumatic tools under water there was a definite improvement in the rate of sinking.

7.3.2. Even though this stratum was not water-bearing the wells could not be effectively de-watered because of the cataract-like flow of water that occurred close to the outside of the steining whenever an attempt was made to empty the wells. This phenomenon was due to the habit of the divers always digging a few inches outside the cutting edge when excavating in the wells. In a few cases, however, the gap between the steining and the clay stratum outside it got sealed up to such an extent that the wells could be dewatered with the help of pumps, and men were able to work in about a foot depth of water.

7.3.3. The sinking effort through this type of soil was found to be very heavy.

7.3.4. In one particular case, out of the three wells under a pier, the two side wells were sunk and seated on rock but the middle well remained 5 ft higher. Even though the clay below it was removed up to rock level and sinkers could even touch the steinings of the side wells, the middle well would not go down. Even kentledge to the tune of 40 tons had no effect. Blasting was also attempted, using a maximum of 4 ounces of gelignite at a time, but with no result. One foot beyond the outer periphery of the well, casing pipes were driven to various depths in clay. They were withdrawn for about 9 inches and gelignite charges were put inside the casing pipes. Even this method was unsuccessful. Finally attempts to sink the middle well were abandoned and the space below the cutting edge down to the rock bed was excavated and plugged with concrete.

7.3.5. In the region of piers 9 to 20 it was observed that, after the wells had been sunk through the top bed of sand, a layer of soft rock was met with although the original borings indicated hard rock below the sand. As this rock was not hard enough to provide an unyielding base for the continuous girder type superstructure adopted on this bridge, the wells had to be sunk further till soil of a sufficiently hard nature was met with. In such cases when no further sinking could be done, the soil inside the wells and under their steinings was scooped out with chisels and pneumatic tools and the resultant pits filled with concrete.

7.3.6. In the case of pier No. 24, just above the hard clay level, a tree trunk was found lying right across the upstream and the middle wells. As the trunk had not decayed it had to be chipped bit by bit.

7.3.7. A very large sized boulder was met with right in the middle of another well and it was cleared out with great difficulty.

7.4. **Shifting and Tilting of Wells**

7.4.1. While sinking through sand a tendency for the two outer wells to draw closer to the central well was noticed. This was prevented by introducing timber distance pieces between the steinings.

7.4.2. There was no other great difficulty experienced by way of shifting or tilting of the wells while sinking through sand, any slight tilt occurring being easily rectified by inserting planks under the tilted (lower) side below the cutting edge and dredging on the other side.

7.4.3. The wells, however, tended to tilt when they had passed through sandy strata and were about to enter hard, loamy strata. The tilt was pronounced when the surface of the hard, loamy stratum was found sloping.

7.4.4. Many methods were attempted to rectify such tilts, a few of which are described below :

(i) The well was strutted on the leaning side and sinking continued (Strut A in Fig. 3);

(ii) Struts were put in at the bottom, inside the well on the lower side, and excavation continued on the opposite side (Strut B in Fig. 3). The wells were then given a slight run and the cant was noticed to rectify itself ;

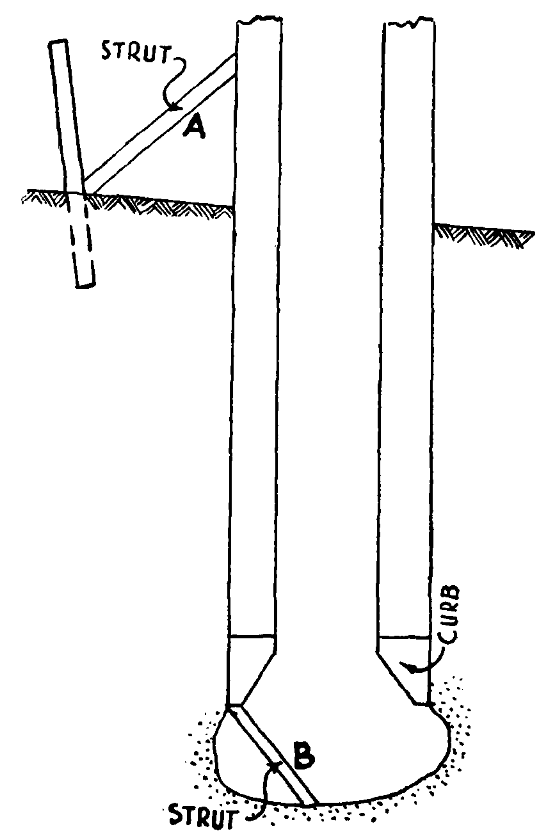


FIG. 3

(iii) Loading on the higher side, including cantilever loading, was also attempted but did not give good results;

(iv) In one case the tilted (lower) side of a well was held up by a chain taken round the cutting edge from inside to the outside and made fast to a fixed girder above the ground. When the well was sunk further an appreciable rectification of the cant was noticed;

(v) In two or three cases the top of the tilted well was tied by wire ropes to a well in the next pier. The wire ropes were tightened with strainers and the tilted well was sunk further. This method also yielded good results.

There was no case of a bodily shift of considerable dimensions in any of the wells.

7.4.5. During the first working season after the commencement of the work the contractors were lucky in that a big sand bank formed right along the centre line of the bridge. The dry weather flow of about 4,500 cusecs (hydro-electric discharge from the Mettur Dam) restricted itself to a width of about 350 feet on the left flank. There was therefore no need to form individual islands for laying the cutting edges.

7.5. Provision of Anchor Rods for Well Foundations

7.5.1. The design stipulated that in the cases where the rock at the bottom was sloping and could not be benched to give an even seating for the wells, steel dowels should be used to anchor the wells to the foundation rock. These dowels were one inch diameter steel bars going at least 3 ft 6 in. into the bed rock and projecting upwards by at least 3 ft 6 in. into the bottom plug of the well. One rod was provided for every two square feet of dredge hole area, or ten rods for each well. Drilling holes in rock for these bars was a difficult process. In the initial stages, hand boring sets were used and holes were made with boring chisels. This was found very costly, each hole costing about Rs 50. Next a Calyx drill was used and gave good progress, two holes being drilled per day. At later stages when work had to be rushed, drilling holes with heavy pneumatic drills under water was attempted and was found to be a success, ten holes being drilled in a day.

7.6. Plugging the Wells

7.6.1. Bottom Plugging:—The estimate provided for plugging the wells at the bottom with 1 : 2 : 4 cement concrete with

$1\frac{1}{2}$ in. granite coarse aggregate. Three wells were plugged with this concrete for the bottom 4-foot depth i.e. to one foot above the top of the kerb. On dewatering it was found that the plugs were not water-tight. After trial cement concrete of 1 : $1\frac{1}{2}$: 3 mix, with $1\frac{1}{2}$ in. granite metal, was found to give the best results.

The concrete was placed under water by means of dumping buckets (Plate X).

7.6.2. Sand Filling.—The sand filling inside the wells was done as follows:

The wells were filled with water and sand was dumped in from above, and this gave the best compaction.

In the later stages, when the bottom plugs had been found to be perfectly water-tight, it was not considered necessary to wait till the bottom plug had set. In laying the concrete for the bottom plug some cement got dispersed and was suspended in the water in the well. To utilize this suspended cement, sand was poured in immediately after laying the bottom plug. In this way the cement-mixed water in the well and sand formed a lean cement mortar.

7.6.3. Top Plugging.—The top plugging was done for a depth of 2 feet with cement concrete of 1 : 3 : 6 mix using $1\frac{1}{2}$-in. size river shingle.

7.7. Capping Slab

7.7.1. The three wells of a pier were connected together at the top with a reinforced concrete capping slab, 1 ft 6 in. thick, with about 4 lb of steel reinforcement per cubic foot of concrete. The capping slab was designed to span the gaps between the wells as also the holes of the wells. The vertical bond rods of the steining were taken into the capping slab and anchored there.

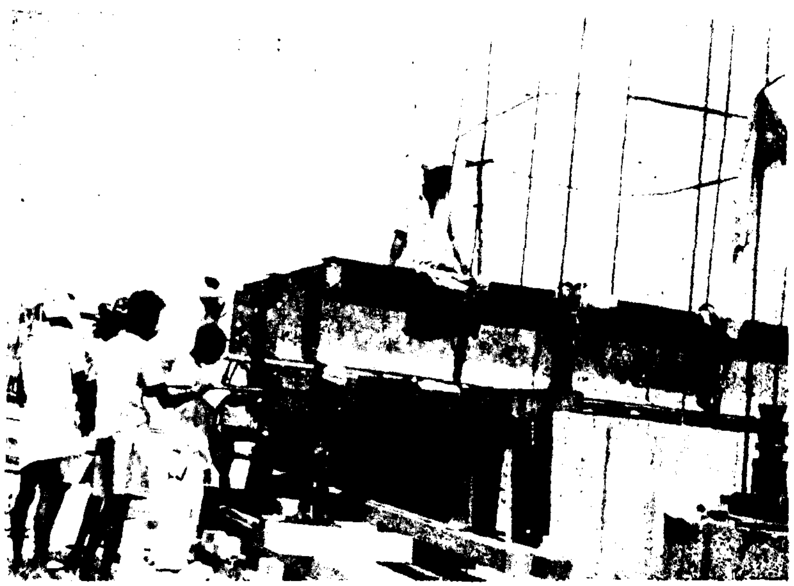
7.7.2. The formwork for the bottom of the capping slab outside the well areas was made of very weak shingle concrete, rendered with cement mortar.

7.7.3. The capping slabs were built entirely above the water level, so as to avoid heavy shoring and pumping.

7.8. Transplantation of Wells

7.8.1. The approved estimate provided for open foundations for pier No. 10 (vide paras 5.2.1 and 6.2.1.) But the contractors preferred to adopt well foundations for this pier on account of the difficulty of dewatering for open work. They were permitted to do so on a "no extra cost" basis. After the wells had been sunk to a depth of about 6 feet only it was found that they rested on a hard rock ledge only about 3 feet wide. With the experience of a somewhat similar situation met with in the case of pier No. 39 (see para 7.9), it was decided to abandon the proposal of providing well foundations for this pier (No. 10), and adopt open foundation as originally designed. By then work on the adjacent pier (No. 11) had not commenced and so the idea of bodily shifting the partly sunk wells from the site of pier No. 10 to that of pier No. 11 suggested itself.

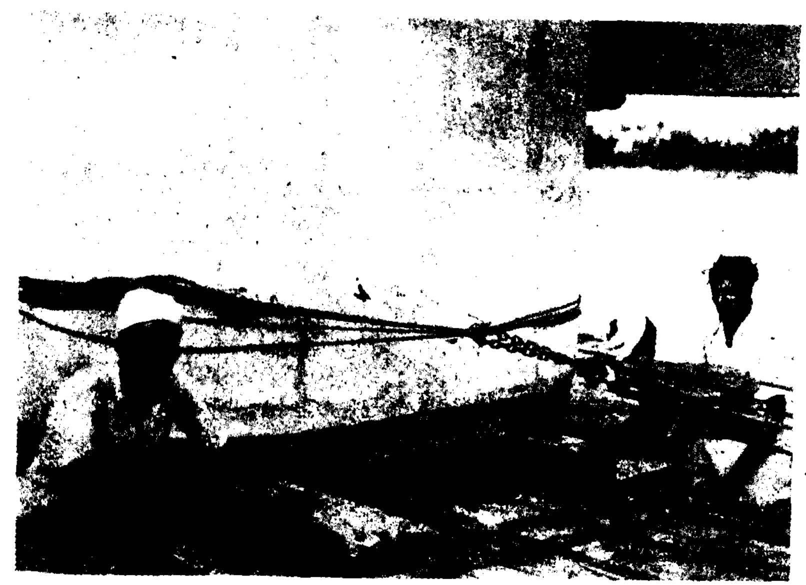
7.8.2. Wire ropes were passed round the steining from outside to inside and their ends were tied to two rolled steel joists placed over each well. These joists (and well with them) were then lifted up with the aid of four 10-ton jacks placed on a timber staging erected by the side of the well (Photo 5). To prevent the timber staging bearing the jacks collapsing in as the well came out, the inside of each well was filled with sand beforehand. As the wells rose, the sand inside these subsided and filled up the cavity below.



Photograph No. 5.
A well of pier No. 10 being jacked up.

7.8.3. The wells came out without any difficulty. After the wells had been lifted up to the ground level they were dragged to the site of the adjacent pier (No. 11) over a distance of 66 feet.

7.8.4. To prevent damage to the cutting edge while the well was being dragged, two rolled steel joists were inserted below it. Sheet piles were then spread over the sandy river bed and the well was dragged with the help of winches, using $1\frac{1}{2}$ in. diameter rods as rollers between the rolled steel joists and the sheet piles (Photo 6).



Photograph No. 6.
A well of pier No. 10 being dragged to the site of pier No. 11 (Note the wire ropes tied around the steining and the rollers at the bottom to facilitate movement.)

7.8.5. Although each well weighed about 24 tons, no difficulty was experienced in placing them in the required positions. It cost the contractors only Rs 750 for transplanting the three wells from the site of pier No. 10 to that of pier No. 11.

7.9. The Peculiar Case of Pier No. 39.

7.9.1. When the wells for pier No. 39 were sunk, it was found that they could not attain an even seating at the bottom because of a sudden dip in the rock surface. The wells sat on a ledge of rock, so to speak, with each well partly resting on the rock and partly overhanging. The height of the ledge varied from 3 to 5 feet. The rock under the overhanging portion could not be exposed as sand was continuously flowing in and filling up the space (Fig. 4-a). The depth of the wells was 35 feet.

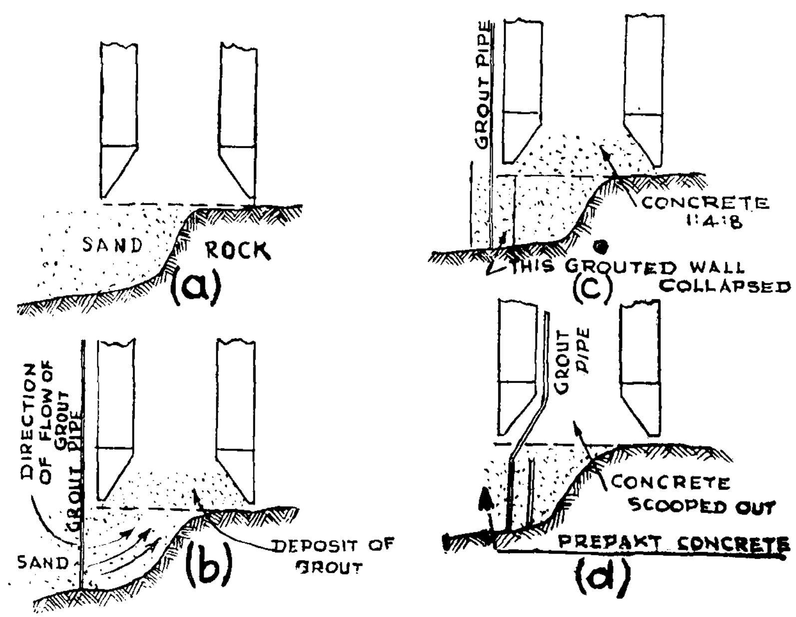


FIG 4.

7.9 2 To prevent sand from flowing in, it was proposed to stabilise it around the outside periphery of the steining by cement grouting (Fig. 4-b). This process was carried out but after completion it was found that all the grout had flown into the well without effectively consolidating the sand.

7.9.3. To prevent this flow of grout it was decided to plug the well for a depth of one foot with a weak cement concrete (1 : 4 : 8) and grout the sand outside as before (Fig. 4-c). After grouting, when the concrete plug was removed and the sand was being excavated, it was found again that the grouting had not been much of a success. Sand began to flow in through spaces in the "grouted sand wall" and when it was removed to a depth of a little more than two feet, the cement grouted sand wall collapsed. The pit was again filled completely with sand.

7.9.4. A third process was now tried. Grout pipes were inserted from inside the well and suitably bent so that they went under the steining of the overhanging portion of the well (Fig. 4-d). Metal of $\frac{3}{4}$ to 1 inch size was dumped from inside around the grout pipe. At the same time, water under pressure was pumped down the grout pipes. The sand floated up and the metal went down and settled at the bottom over the rock. When sand was completely replaced with metal, cement grout was pumped in. This formed practically a 'prepakt' concrete. After this concrete had set, it was excavated down to the rock bed within the steining (i.e., over an area equal to the 5 ft x 4 ft bore of the well). Struts of iron rods were put in to prevent the collapse of the grouted concrete round the excavation.

7.9.5. Thus it was possible to expose the rock surface only inside the well but the portion below the steining could not be cleared. As the grouted concrete below the steining was unreliable, the steining could not be depended upon to effectively transmit load to the rock below. It was therefore necessary to devise an alternative arrangement by which the load from the superstructure could be transmitted to the foundations otherwise than through the steining. The best solution that offered itself in the circumstances was to cast a column in each of the three wells, using the steining as a casing for the columns. The load coming on each column was found to be about 200 tons. For a column of section 5 ft by 4 ft and with the steining case already in place plain cement concrete filling would have been sufficient, but as an additional measure of safety, a nominal reinforcement consisting of 10 rods of 1 in. diameter was provided along the inner periphery of the well.

7.9.6. To keep these rods in position, $\frac{1}{2}$ in. diameter binders at one foot intervals were provided. Before placing this grill inside the well, anchor rods were placed in position as described in para 7.5, $1\frac{1}{2}$ in. square bars being used in this case. The grill for the column was then placed inside and the bottom of the wells for a depth of 6 to 8 ft was plugged with cement concrete (1 : $1\frac{1}{2}$: 3) under water. The wells were then dewatered and cement concrete (1 : 2 : 4) was laid up to the top of the well. The well cap, which was redesigned as a slab supported on the three columns, was then laid, and the masonry pier constructed.

7.10. Open Foundations

7.10.1. For all the piers in the region of deep water (vide para 6.2.1 and Plate No. IV) open foundations were adopted and so cofferdams had to be built. The depth of soft rock below the bed varied from 1 foot to 12 feet. For the shallower foundations, coffer dams of sand bags were built and, by providing a sufficient width of bagging, percolation through the sand bags was brought down to such an extent that the foundation pit of 50 ft by 20 ft, with a normal water depth of 5 feet, could be controlled with pumps of about 30 to 40 horse power.

7.10.2. For greater depths concrete caissons, 12 ft by 12 ft by 8 ft with a shell thickness of 9 inches (reinforced with wire mesh), were cast in situ and sunk (Photo 7). They had to be loaded heavily in the last stages of sinking. The proposal was to

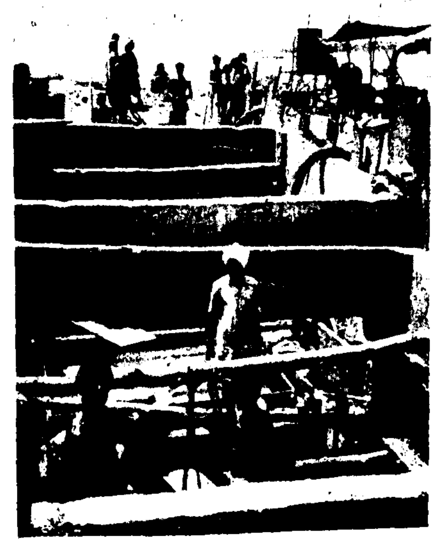
Photograph No. 7.

Open foundations for pier No. 7-Shuttering for concrete caisson ready to receive the concrete.

sink three such caissons *side by side* at the site of each pier (Photo 8) till they touched the rocky strata, close the bottom all round the periphery inside with concrete laid under water, dewater the caissons and then carry on further excavation under practically dry conditions. After completing the excavation to the required level and dewatering, the interior walls of the composite caisson so formed were to be broken up and the concrete and masonry in foundations laid (Photo 9).

Photograph No. 8.

Three concrete caissons for pier No. 7 cast in situ side by side being sunk.

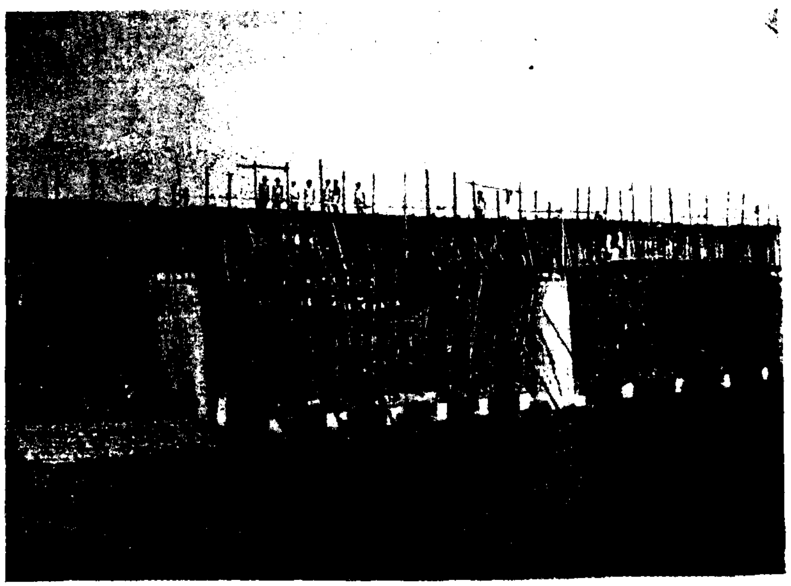


Photograph No. 9.

The caissons sunk to the required levels and the partition walls broken before concreting.

7.10.3. This system was adopted for two piers and, as ill luck would have it, the caissons struck boulders of a big size and all attempts to remove the boulders proved unsuccessful. Timber-plank piling had to be provided below the level of the concrete caissons and concreting done separately in each compartment.

7.10.4. In the original proposals only two feet thick concrete had been specified at the bottom for piers built in open foundations. The piers themselves were to be of coursed rubble masonry in 1 : 4 cement mortar up to six inches above low water level. During construction, however, it was found that, on account of the occasional failure of the pumps, water rose up above the level at which masonry work happened to be in progress. When the pumps began to function again, the water in going down washed out a considerable quantity of the green mortar also, leaving at times no option but to do the whole work all over again. Further, the masonry work was very slow, and held up the pumps which were urgently required to tackle other open foundations. On account of these difficulties it was decided to carry out the foundations up to low-water-level in mass cement concrete (1 : 3 : 6) with granite coarse aggregate. To make the piers strong enough to withstand the impact of rolling debris their upstream faces and 5-ft lengths on either side of the upstream faces, were made of 1 : 2 : 4 concrete to a depth of one foot.



Photograph No. 10.
Timber centring for superstructure. Obstructs the channel and cannot be used during the flood seasons

7.10.5. Providing coffer dam and baling out water from them were found to be very slow and costly. So the contractors preferred to build piers 9, 11, and 12 on well foundations on a "no-extra-cost" basis. This was permitted.

7.11. **Centring for the Superstructure** (Photo 10)

7.11.1. The centring to support the formwork for the tee-beam and the slab consisted of *casuarina* posts 25 feet long with an average diameter of 5 inches. Horizontal bracing, in both directions, was provided at 4-ft vertical intervals. Similarly diagonal bracing was also provided in both directions. The bracing was bolted on to the verticals with 5/8-in. diameter bolts.

7.11.2. Whether the bed was naturally dry or whether sand islands were artificially formed, ground sills of country wood planks (8 in. by 2 in. and about 14 ft long) were placed on well rammed and levelled ground and the posts were erected over these sills.

7.11.3. In the case of the first unit on the left bank, where water had to be allowed to flow, R. C. pipes, 3 ft in diameter and 6 ft long, were sunk, filled with rubble, and plugged with concrete at the top. Over these pipes concrete pedestals, 2 ft by 2 ft by $1\frac{1}{2}$ ft high, were built. Four rows of such pillars were built in the direction of the span and 6 rows across in each span. R. S. girders. 24 in. by 7 in. and 18 in. by 6 in., (parts of a war-surplus Callendar-Hamilton Bridge of 120 ft span) were used to span the pillars and over this a matting of 8 in. by 8 in. angle iron was spread to act as sills for the *casuarina* posts.

7.11.4. The runners for supporting the formwork were 6 in. by 4 in. country wood scantlings bolted on to the vertical posts.

7.11.5. The spacing of the posts did not exceed 5 feet in any direction. This gave a loading of $2\frac{1}{4}$ tons for each post.

7.11.6. In one case the process of forming an island with sand, protected with sand bags, and erecting posts on sills laid on the sand failed completely. An unexpected flood overtopped the island. This scoured away the sand and the whole staging collapsed. To meet such a contingency in subsequent cases, *casuarina* piles were driven under each post and their heads sawn off at the same level. Over these piles, 6 in. by 4 in. timber sills were fixed and the posts were erected on these sills. Each post had a pile under it. The usual sand bag protection to the island was given. When flood water overflowed, it caused some scour but as the piles had been driven 6 to 7 feet into the sand, the staging remained undisturbed. After the water had subsided the island was again formed and protected. This method was effective and also proved cheaper ultimately.

7.12. Suspended Centring for Superstructure

7.12.1. **Working Season.**—Owing to the existence of the Mettur Dam the flow in the river is practically regulated except when the river is in flood and the dam is overflowing. Water is closed down for irrigation works by the first week of February and opened by the first week of June, giving four months to work. During this period there is a discharge of only about 4,500 cusecs —the issues from the hydro-electric pipes at Mettur. But this discharge is occasionally increased due to rains in the Moyar, Bhavani and Noyyal basins. For the rest of the eight months there is a minimum flow of 26,000 cusecs (being the requirements for the Tanjore irrigation), the river flowing to a depth of 5 feet.

7.12.2. When the working season in 1951 came to an end in June, water from the Mettur reservoir was let into the river for irrigation purposes. The superstructure for ten spans, two units of three spans and one unit of four spans, still remained to be built. The completion of this work under normal circumstances would have meant postponement of this work until the next working season commencing in February 1952. It was thought inadvisable to waste practically eight months on this score. As all the piers had been constructed up to the bearing level, it was decided to suspend the centring from temporary steel trusses erected over the completed piers.

7.12.3. Parts of a 120 foot span Callendar-Hamilton bridge were available and these were utilized to manufacture temporary trusses of the 'N' type, 5 ft 9 in. high. Two such trusses were used to support the formwork for each R. C. beam. The trusses were designed to function as simply supported beams when loaded, but were connected to each other over the piers to facilitate launching. They were fabricated in independent units of 20 ft 6 in. and 26 feet, each 66-ft span having two 20-ft 6 in. units and one 26-ft unit. The purpose of this arrangement was to utilise these trusses for smaller spans also in other places. The temporary trusses for each span were assembled in the yard and brought on rails to the water's edge.

7.12.4. It will be obvious that eight trusses, continuous over three spans, were needed, simultaneously, two for each tee-beam.

7.12.5. The launching of the trusses consisted of two different types of operations, viz., one for hoisting and launching the two outer trusses and the other for assembling and launching the six intermediate trusses. The two outer trusses were hoisted on to the noses of the piers of a completed unit of three spans and rolled out into position. The other six trusses were erected on the deck of the completed unit and rolled out. The process is described, in detail below.

7.13. Hoisting and Launching Outer Trusses

7.13.1. In Plate No. XI & XII the figures 28, 27, 26 and 25 represent piers over which a reinforced concrete superstructure had already been built by means of centring and staging erected from the bed. Similar staging could not be erected from the bed for spans 23, 24 and 25. It was therefore decided to suspend the centring from steel trusses erected over the completed piers 25, 24, 23 and 22. The following *modus operandi* was adopted.

7.13.2. Hoists were erected over the completed decking of spans 26, 27, and 28. The assembled trusses were brought close to the end of the cut waters, hoisted up, and placed on 5-in. diameter steel rollers working in angle iron frames fixed on the cut water caps of piers 25, 26, 27, and 28. The trusses were then connected together with gusset plates. Both the outer trusses were hoisted and connected in this manner.

7.13.3. The next operation was to launch them. To do this, runner tackles with double pulley blocks for each truss were used with 5/8 in. diameter wire ropes. One double pulley block was attached to the bottom boom of the truss at the place marked A (Plate No. XI & XII). The other double pulley block was attached to pier No. 25 by means of wire ropes tied round the top of this pier at point B. The end of the wire rope was attached to the winch C which in turn was anchored to the bottom of pier No. 26. By working the winch the truss was launched forward as shown dotted in Plate XI. Rollers were placed over the cut-water tops of piers 24, 23. and 22 to receive these girders.

7.13.4. Just before resting on the next pier (No. 24) the truss had an overhang of about 60 feet. This caused its forward end to sag considerably, and consequently it was very difficult to lift it and put it on the roller on pier No. 24. To get over this difficulty a device known as the "**launching nose**" was attached to the leading end of the truss. This launching nose was made out of 6 in. by 6 in. by ½ in. angle and attached to the end of the truss in such a way that when the truss approached the rollers on pier No. 24 the bottom of the launching nose was just above the level of the roller. When the truss was rolled out further, the launching nose sat on the roller and the girder followed easily.

7.13.5. During launching some more difficulties were met with. The top of the trusses had a tendency to fall inwards or outwards. The bottom boom also had a tendency to shift. The top boom was prevented from falling outwards by means of L shaped rails placed over the wheelguard of the completed unit (see Fig. 5). To prevent the top boom from falling inwards towards the tee-beam, struts with rollers at their ends were attached at about 20-ft intervals to the top boom (see Fig. 5).

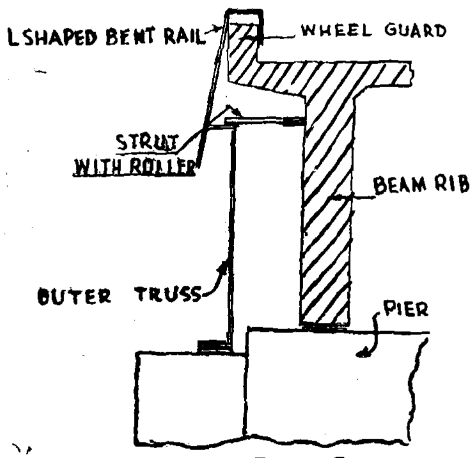
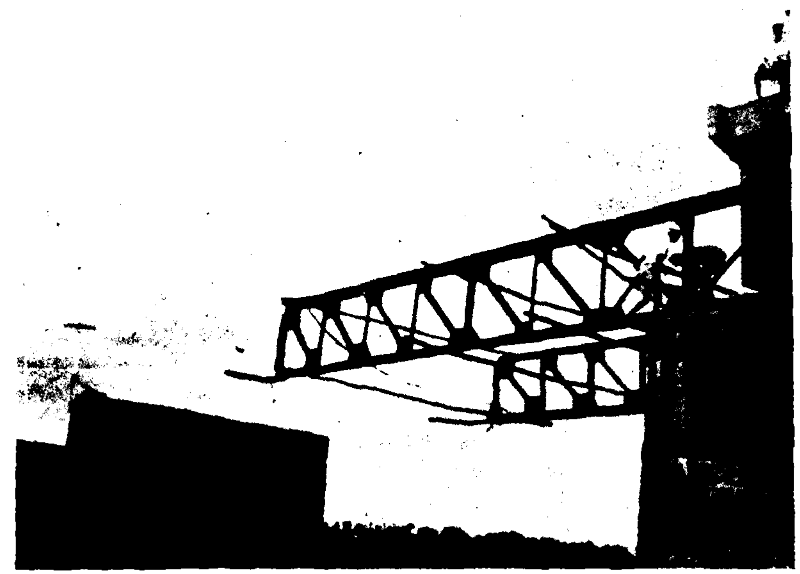


FIG. 5

7.13.6. To prevent the bottom booms from shifting, those of the two outer trusses were connected by *casuarina* bullies which kept them at a constant distance apart. Timber blocks placed against the tee-beam ribs prevented the two trusses shifting enblock.

7.13.7. The expedients described above served only on the portions of the trusses moving along the R. C. tee-beams. They were of no avail on the portions which had been launched forth. As the trusses were pushed forward, the side sway in the launched portions was found to be terrific. To prevent this, to keep the trusses vertical, and to make the two trusses act in unison during launching, horizontal diagonal bracing of *casuarina* bullies was provided (Photo 11).

7.13.8. In this manner the two outer trusses were launched over spans 25, 24, and 23 and rested in their new positions over the cut waters of piers 25, 24, 23 and 22.



Photograph No. 11.

Suspended centring for superstructure. The two end girders being launched. (Note the launching nose fixed to the end of the girders and the bracings of casuarina bullies connecting the two girders to make the latter act in unison while being launched.)

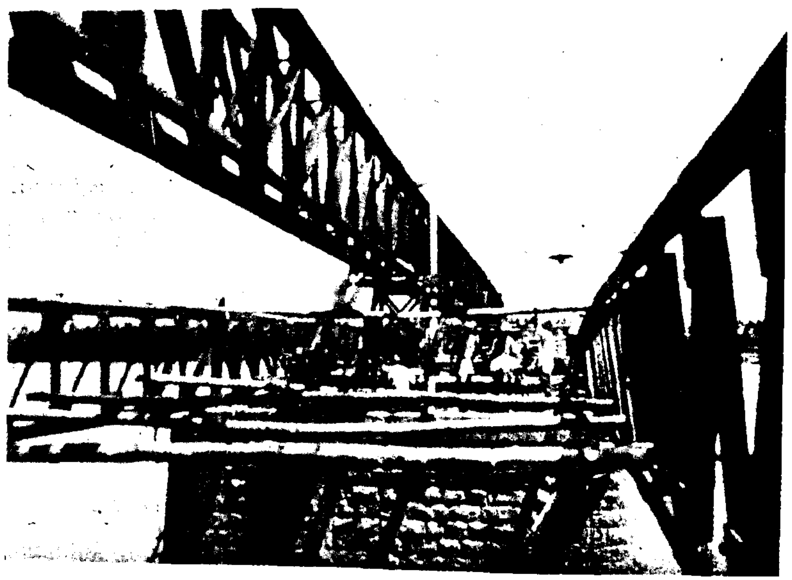
7.13.9. These outer trusses initially served as temporary bridges and were useful for conveying materials etc. for laying bed blocks over piers 24, 23, and 22.

7.14. Assembling and Launching of Intermediate Trusses

7.14.1. The intermediate trusses were assembled on the decking of the completed spans 28, 27 and 26. They were connected in pairs and bolted together for the whole length of 201 feet. To launch them, a derrick was erected over pier No. 22 and fixed in position by stays attached to piers 21 and 23, as illustrated in Plate No. XIII. A derrick was also erected over the R. C. decking over pier No. 25. The twin truss (Photo 12) was then placed over pipe rollers. The launching was done in this case also with runner tackles using double pulley blocks and 5/8 in.

diameter steel wire ropes. A sling was attached to the twin truss in the middle of its height and a double pulley block 'A' was hooked to the sling. The other double pulley block was attached to the derrick over pier No. 22 at point B. The wire rope passing through these pulley blocks was taken over to a winch located at the end of the decking over span 26. The winch was anchored to the decking with wire ropes taken through the drain pipe holes in the decking

7.14.2. 'Horses' made out of angle iron with rollers on the top were fixed over piers 24 and 23 (Photo 12). The top level of the rollers was so kept as to have a down gradient from the level of the deck slab over pier 25. Timber staging was erected over piers 25 and 22 to receive the ends of the girders. As the winch was worked, the twin truss slid forward and as it came near the 'horse' over pier 24, it was cajoled on to the rollers.



Photograph No. 12.

Suspended centring for superstructure. A pair of intermediate girders launched to the full length but yet to be lowered to the final position. Note the 'horse' temporarily erected on top of the pier to support the girders during launching. The two outer girders are already in position.

Thus it was dragged over spans 25, 24 and 23 and its ends were made to rest on the timber staging. Timber staging was also erected over the piers 23 and 24 round the 'horses' and the truss made to rest on this staging with the help of jacks. The 'horses' were then dismantled and removed and the whole twin truss was jacked down to the required level. This operation was found to be very slow and laborious.

7.14.3. These trusses were made to rest on greased rails placed over the piers and were finally slid out to the required position.

7.14.4. A sag in the middle of these trusses was anticipated, so their centres were raised by 1½ inch. During actual execution the sag was found to be only one inch

7.14.5. This type of suspended centring was adopted for 10 spans. When the unit with four spans was tackled, an additional set of eight trusses was assembled for the fourth span. These were hoisted up one by one and placed on the piers.

7.15. Form work for Superstructure

7.15.1. The form work for the bottom of the tee-beams and slabs consisted of timber frames 15 feet long with 3-ft iron plates nailed over them. The form work was raised or lowered with the help of timber wedges.

7.15.2. The form work for the sides of the tee-beams, wheel guards, etc., consisted of timber frames with planks nailed on. These side shutters were also provided with galvanized iron sheet lining. For fillets, initially wooden planks were used but as they warped even with one repetition, steel plates were afterwards used instead.

7.16. Main Reinforcement in Tee-beams

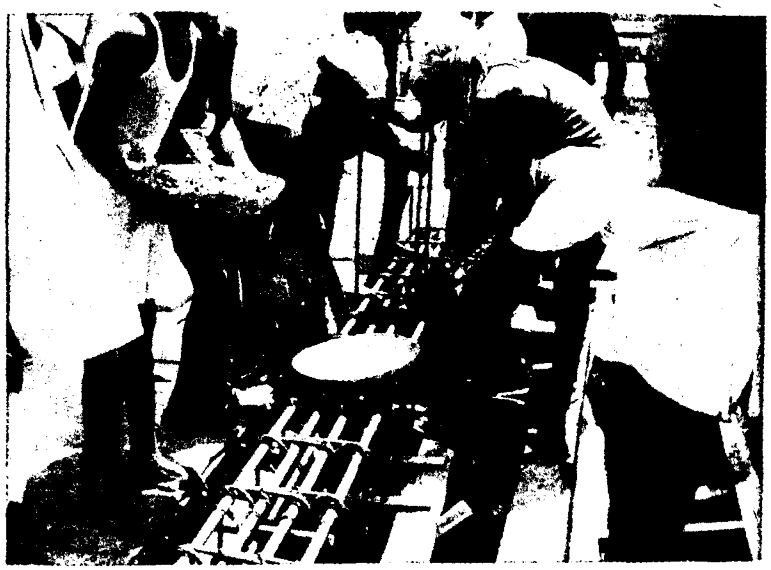
7.16.1. In each unit of three spans, at the middle of the outer spans, and over the two intermediate supports, there were three rows of tension steel with 1 in. spaces between rows. The maximum size of rods used was 1½ inch diameter. As there was not sufficient space for turn buckles or overlapping, welding was resorted to. The ends of the rods were cut into V shape and butt welding was carried out with No. 8 size electrodes. The welded joints were tested and it was found that the failure always took place outside the limits of the weld. Test results are appended (Appendix II).

7.16.2. In arranging the disposition of the welded jointal care was taken to see that no two welds came in the same vertics, plane and the welds were staggered by about 2 feet and more. To facilitate handling and fixing in position and tying, the whole length of a bar over three spans was not welded but lap joints were provided on alternate piers in such a way that not more than two such joints per beam occurred at a particular cross-section. The maximum length of welded rods handled was only 120 feet.

7.16.3. Most of the steel used came from Belgium and was all in 40-foot lengths. It was tested in the laboratory at Madras and found to satisfy the B.S.S.

7.17. Concreting the Superstructure

7.17.1. The ribs of the tee-beams were concreted first (Photo 13). The cross beams were also concreted at the same time so as to get a good connection between the ribs and the cross beams. The concrete was vibrated with pin vibrators (both pneumatic and petrol driven). For the concrete used in the ribs and the cross beams the slump was kept between 1 inch and ½ inch, the greater slump being used till the reinforcement at the bottom of the beam was covered. Field test blocks were made and the tests gave very good results (See Appendix III).



Photograph No. 13.
Concreting the rib of the Tee-beam.

7.17.2. The time lag between laying the rib and the deck was, in extreme cases, only five days. Special care was taken to see that the joint between the rib and the slab was perfect. The rib concreting was always stopped 3 inches below the haunch levels to facilitate fixing and tying of haunch bars. Electric form vibrators were used in concreting the slab.

7.17.3. Sand for the concrete could not always be had dry and due allowance was made for the bulking of sand in proportioning the ingredients for concrete. A contrivance with proper scales marked on it readily gave the bulkage of the sand.

7.17.4. To take advantage of the slab formwork, the wheel-guards were also concreted immediately after the deck slab, but construction joints were left over each pier to avoid unsightly cracks.

7.18. Wearing Coat

7.18.1. The wearing coat was of cement concrete 1 : 1½ : 3 mix. It was laid to a uniform thickness of three inches, the top having a parabolic curve in the transverse direction. The cross-fall was maintained with a uniform thickness of wearing coat, as this fall had been introduced in the structure itself. To achieve this the middle two beams were raised by 1½ inches. This could be done easily because of the different sizes of rollers obtained from the Railway Department. Where these different-sized rollers were not available, the depth of the intermediate beam at the supports was increased to get the required height.

7.18.2. Six drain pipes with gratings were provided in each span to drain away the rainwater—three on each side of the roadway.

7.18.3. Longitudinal construction joints were provided throughout in the middle.

7.18.4. As the length of each unit, was 198 feet, even though expansion joints were provided at the ends of each unit, contraction joints were provided at every 66 feet for the wearing coat alone. For the expansion joints at the ends of the units, grooved copper sheets were provided to support the joint filler.

7.19. Hand Rails

7.19.1. The hand railing consists of R.C. posts, 8 in. by 8 in., spaced at 4 ft 1 in. centre to centre, and two R.C. rails with precast panels in between. The dimensions of the rails conform to the I.R.C. specification. The height of the top rail above the kerb (2 feet 2 inches) as proposed in the I.R.C. Code was however considered to be too low from the point of view of safety and was therefore increased to three feet above the wheel guard which gave a total height of 3 feet 9 inches above the wearing coat.

7.20. **Appendices IV and V** give brief details of the time taken to build one unit of the superstructure and the tools and plant used on the work.

8. CONCLUSION

8.1. From the details of analysed costs (see Appendix VI) it will be seen that the cost of construction of the bridge was about Rs 965 per running foot, which is not at all high having regard to the conditions prevailing during construction. It is, however, felt that the economy of continuous spans was not fully realised in this case on account of the following factors:—

(i) The cost of cast steel rocker and roller bearings used was very high. This type of bearings had necessarily to be provided in this case in view of the length of a unit. With simply supported spans, mild steel plate bearings would have been quite sufficient in which case the cost of bearings would have been considerably less.

(ii) With the adoption of continuous spans, the foundations had to be taken down to rest on hard soil (practically rock) to avoid even a minute settlement. This meant that wells had always to be sunk a few feet through soft rock till they reached practically hard rock. With simply supported spans, the wells could have been stopped at the soft rock level and sinking through soft rock, involving additional expenditure could have been avoided.

Otherwise the design was found to be quite satisfactory.

Appendix I
(Para 7.2.6.)

Compression Tests on some Concrete Cubes for the Pugalur Bridge
Carried out at the Strength of Materials Laboratory,
College of Engineering, Guindy.
Size: 6 in. x 6 in. x 6 in.

College Number	Mix	Area of Cross section sq. ft	Weight of cube lb	First Crack		Crushing		Remarks
				Load lb	Stress lb per sq. in.	Load lb	Stress lb per sq. in.	
1	1 : 3 : 6	¼	19¼	37206.4	1033.51	63660.8	1768.35	
2	1 : 3 : 6	¼	19½	34899.2	998.08	62496.0	1736.00	

Appendix II
(Para 7.16.1)

RESULTS OF TENSILE TESTS OF WELDED RODS

Mark on specimen	Initial diameter of rod welded (inches)	Breaking load in lb	Breaking strength in lb per sq. inch	Remarks
A A	$1\frac{1}{4}$	86,000	70,000	Specimen failed outside the weld
A A	$1\frac{1}{4}$	88,600	71,700	-do-
B B	$1\frac{1}{4}$	77,500	63,200	-do-
B B	$1\frac{1}{4}$	83,000	67,600	-do-
C C	$1\frac{1}{2}$	1,07,500	61,900	-do-

Appendix III
(Para 7.17.1)

COMPRESSION TESTS OF CONCRETE CUBES

Carried out at the Concrete Research

Laboratory, Chepauk, Madras

Size of test cube : 6 in. × 6 in. × 6 in.

Area under compression = 36 sq. in.

Mix : 1 : 2 : 4

Sl. No.	Mark on specimen	Water-cement ratio	Load at first crack		Crushing load	
			Total (lb)	lb per sq. in.	Total lb	lb per sq.in.
1.	16-12-51 Slab Concreting	·50	160,000	4,450	215,000	5,990
2.	13-12-51 Beam Concreting	·58	120,000	3,340	147,500	4,100
3.	12-12-51 Beam Concreting	·56	60,000	1,670	117,500	3,270
4.	17-11-51 Beam Concreting	·58	110,000	3,060	127,500	3,550
5.	16-11-51 Beam Concreting	·60	80,000	2,222	115,000	3,200
6.	16-11-51 Beam Concreting	·56	90,000	2,500	142,500	3,970

Appendix IV
(Para 7.20)

TIME TAKEN TO BUILD A UNIT OF SUPERSTRUCTURE (3 SPANS)

Erection of staging ...	8	days.
Fixing the forms for the bottom for all the four beams ...	6	,,
Placing and tying the reinforcement for beams	8	,,
Fixing the Tee-beam side-shuttering and formwork for the slab ...	6	,,
Concreting of the beams ...	3	,,
Placing and tying reinforcement for slab ...	5	,,
Concreting slab ...	3	,,

Note: *These timings could be practically halved if the carpenters and fitters worked in two shifts.*

Appendix V
(Para 7.20)

TOOLS AND PLANT USED ON THE WORK

1. PUMPS			
2. COMPRESSORS	I. R.	3 (150, 100 and 90 cu. ft.)	
	C. P. Compressor	1 (60 cu. ft.)	
	Curtis	1 (20 cu. ft.)	
	Worthington	1 (30 cu. ft.)	
3. MIXERS	...	4	
4. PNEUMATIC TOOLS			
5. PRIME MOVERS:	Detroit Engine	38 H. P.	1
	Detroit Engine	45 H. P.	1
	John Fowler	20 H. P.	2
	Crossley	10 H. P.	1
	Electric Motor	15 H. P.	1
	-do-	10 H. P.	2
	-do-	5 H. P.	4
6. PETTER ENGINE		10 H. P.	4
LISTER ENGINE		10 H. P.	2
CUB DIESEL ENGINE			1
7. LORRIES			4

Appendix VI
(Para 8.1)

PARTICULARS AND ANALYSED COSTS OF THE CAUVERY (PUGALUR) BRIDGE.

(Note :- All levels are based on the G. T. S. Datum)

I. LOCATION:

(1) State	MADRAS
(2) Name of River Crossing Site	CAUVERY
(3) National Highways No.	7 (Banaras-Cape Comorin Road)
(4) Latitude and Longitude: (taken from Maps)	LAT. 11°6′ N; LON. 78°-1′E.
(5) Year of Construction.	1949—1951

II. TOPOGRAPHICAL FEATURES OF THE CROSSING:

(1) Nature of Bridge site (hilly, rocky, flattish, etc.) In case of flat alluvial sites, state whether it is at a node.	FLATTISH (Not alluvial)
(2) Nature of river at site (snowfed, rain-fed, perennial, seasonal, alluvial, deltaic, navigable, tidal etc.)	Rain-fed ; perennial.
(3) Nature of banks (well-defined or not, of hard rock, soft rock, gravel, clay, sandy-clay, silt, sand etc.)	Well defined, clay.
(4) Nature of bed (hard rock, soft rock, gravel, clay, sand, sand overlying rock etc. Results of Borings).	Sand overlying rock.
(5) Analysis of sand or silt forming bed as regards diameter of particles, silt factor, etc.	Coarse sand.

(6) Whether the bridge is on a reasonably straight reach of the river or on a definite bend.	Reasonably straight reach.
(7) Length-bank to bank of river.	3240 ft
(8) Approximate bank levels.	Left Bank (400.00) ; Right Bank (404.00);
(9) Lowest bed level in the dry weather.	381.00
(10) Approximate average bed level in the dry weather.	383.00

III. HYDRAULIC DATA :

(1) Catchment area in square miles.	22,100 sq. miles (roughly)
(2) Nature of catchment (approximate shape triangular, rectangular etc. hilly, plain, wooded, bare, grassy, cultivated etc. for mixed areas approximate area of each).	Hilly in the higher reaches and plain in lower reaches. Rectangular.
(3) Particulars of storage reservoirs which control discharge.	(i) Krishnarajasagara Dam across the Cauvery in the Mysore State. (ii) Mettur Dam across the Cauvery in the Madras State-about 75 miles up-stream of the bridge site. (iii) Pykara Dam which controls the discharge in the Bhavani river which is a tributary of the Cauvery joining the latter about 50 miles above the bridge site. (iv) Moyar Dam (under construction) over the Moyar river, a tributary of the Bhavani river.

and	(v) Bhavanisagar dam (under construction) over the Bhavani river.
(4) Rainfall particulars of the catchment :	—
(i) Average annual rainfall.	—
(ii) Average rainfall during the rainy season.	—
(iii) Maximum recorded intensity of rainfall per hour.	—
(iv) If catchment gets specially heavy rainfall due to being directly in a line with path of storms, brief particulars of the same	—
(5) Maximum H. F. L. (or full supply level in case of canals) in the natural channel with corresponding values of wetted perimeter, area, slope, discharge and average velocity :	400.30 (observed in 1924) *485,500 (cusecs).
(a) Actually observed.	Figures given were actually observed.
(b) Anticipated.	—
(6) Maximum range of tides, and H. F. L. in the natural channel when floods and high tides synchronize (in case of tidal rivers only).	Not tidal.
(7) O. H. F. L. in the natural channel. Give also corresponding values of wetted perimeter, area, slope, discharge and average velocity.	—

* Maximum discharge recorded at the Erode bridge (40 miles upstream of the bridge site) during the high floods of 1924 - i.e., before the Mettur Dam was built. The design is not based on this figure

(8) Low water level in the natural channel during dry weather. Give also the corresponding values of :—	382.50.
(i) wetted perimeter area.	—
(ii) slope discharge.	—
(iii) average velocity.	—
(9) Back water effects on H.F.L. due to storage or flooding downstream, if any.	Nil.
(10) Maximum depth of scour in the natural channel under H. F. L. (particularising the point where taken) :—	
(a) expected	Upto soft rock i.e., 371.00 (average).
(b) observed	Not observed.
(11) Approximate volume of discharge per year in feet per acre.	
(a) during flood season.	—
(b) during the rest of the year.	—
(12) Hydraulics of the bridge site after construction of the bridge :	
(i) H.F.L. including afflux tidal and backwaters effects if any.	396.00
(ii) average velocity under the bridges.	7 ft per sec.
(iii) discharge through the bridge.	286, 100 cusecs*
(iv) discharge assumed or observed to pass through spillways or breaching sections if any.	No spillway or breaching section.

* See para 6.1.6.

(v) Maximum depth of scour under H. F. L. (particularise the point where observed. The worst scour generally occurs round piers or at upstream head of guide banks).	Not observed.
(vi) approximate number and duration of traffic interruptions per year in case of submersible bridges.	Not a submersible bridge

IV. DESIGN OF BRIDGE :

(1) Type of Bridge (high level, submersible, arch, girder, cantilever, suspension, steel, R. C., masonry, combined road-rail etc.)	High level R. C. T-beam and Slab highway bridge.
(2) Details of design :	
(i) No. and length of spans.	40 spans of 60 ft clear each, or 66 ft from centre to centre of piers.
(ii) Length of bridge including abutments.	2680 ft.
(iii) Design, details of foundations and nature of strata on which it rests.	Foundations taken down to rest on fairly hard or hard rock. Open foundations for the left abutment and piers 1 to 8 and 10 and well foundations for the remaining piers including the abutment-pier on the right side.
(iv) Design, type and shape of piers, abutments and wings and material used.	Of coursed rubble masonry first sort in cement mortar 1 : 4 below LWL, and 1 : 5 above. Top width of piers 6 ft; side batter 1 in 24. Semi-circular cut waters. For piers 4, 5, 6, 7, 8 and

	10 substructure below LWL is of mass cement concrete (1 : 3 : 6).
(v) Design of superstructure and handrails and material used.	4 Reinforced Concrete T-Beams (continuous over 3 spans) and slab decking. Handrails of reinforced concrete with vertical posts at 4 ft centres and two horizontal rails with an ornamental precast panel between the rails.
(vi) Clear width of roadway between kerbs.	22 feet.
(vii) Clear width of footpaths, if any.	No footpaths.
(viii) Type and thickness of deck and wearing surface.	Thickness of R. C. deck 8 in. Wearing surface 3 in. cement concrete (1 : $1\frac{1}{2}$: 3).
(ix) Design and type of bearings.	Cast steel roller bearings for the free ends and cast steel rocker bearing for the fixed ends. (For further details see V (4) page 118.
(x) If the bridge is on a skew, the angle of skew.	Not on a skew.
(3) Training works	Bell's bund at the right abutment-pier, of 150 ft. straight length (100 ft. upstream and 50 ft. downstream) with suitably designed noses. Front apron of Bell's bund 15 ft wide with thickness varying from 2 to 3 ft.
(i) General description.	
(ii) Type and length of bunds ; aprons : spurs ; etc.	
(4) Levels & heights on the bridge :	
(i) R. L. of foundations of piers and abutments.	Varying from 380.00 at the left abutment to 346.80 at the right abutment-pier.

(ii) R. L. of bases of bearings on piers and abutments	403.00
(iii) R. L. of the lowest part of the superstructure at the centre of the span	405.37
(iv) R. L. of the crown of the road over the bridge	411.29
(v) R. L. of footpaths, if any	No footpaths.
(vi) Height of kerb above adjacent roadway	9 in.
(vii) Height of railing above adjacent kerbs of footpaths	3 feet above top of curb.
(viii) Clearance prescribed for navigation, if any	No navigation.
(ix) Clearance above railway or roads in case of over bridges.	Not an overbridge.
(x) R. L. of tops of guide banks and training works if any	Top of guide bank 402.00
(5) Live loading which the bridge will safely take	I. R. C. Heavy loading (Class AA).
(6) Wind pressure allowed for in the design.	20 lb per sq. ft.
(7) Temperature variation allowed for in the design.	± 30° F.
(8) Maximum pressure intensity	
(i) on bearings.	600 lb per sq. in.
(ii) on foundations on the different kinds of soil met with.	5 tons per sq. ft. (Foundations resting on rock).
(9) Particulars of loading test, if carried out.	Not yet carried out.

V. QUANTITIES OF VARIOUS TYPES OF WORK INVOLVED IN THE BRIDGE

Leading quantities in (1) foundations:	Earthwork	1,05,000	Cft.
	Plain cement concrete	1,36,000	Cft.
	Well sinking	2,330	Rft.
	Reinforced cement concrete	21,100	Cft.
	Coursed rubble masonry	4,600	Cft.
	Sand filling inside wells	31,200	Cft.
(2) Piers.	Coursed rubble masonry.	1,37,300	Cft.
	Plain cement concrete.	3,100	,,
(3) Super-structure.	Reinforced cement concrete	1,32,500	,,
	Plain cement concrete.	14,550	,,
(4) Bearings	Cast steel rocker bearings.	52	Nos.
	Cast steel roller bearings (4-Roller assembly).	56	Nos.
	Cast steel roller bearings (2-roller assembly).	104	Nos.
	Reinforced cement concrete for bed stones.	8,600	Cft.
(5) Approaches.	Not furnished as it is not included in the costs vide VI below.		
(6) Training works	Earthwork	2,00,000	,,
	Apron and pitching.	85,300	,,

VI. COSTS:

(Rounded off to the nearest thousand rupees).

		Rupees.
(1)	Foundations	8,09,000
(2)	Piers	2,81,000
(3)	Abutments	42,000
(4)	Bearings	*2,32,000
(5)	Superstructure	11,40,000
(6)	Training works, if any	83,000
(7)	Total Cost	25,87,000

*including bed stones.

VII. ANALYSED COSTS:

(Length of bridge includes abutments)

(i) Per rft. of bridge	Rs 965
(ii) Per Sft. of carriageway excluding footpaths	Rs 44.54
(iii) Per Sft. of roadway including footpaths	No footpaths.
(iv) Per sft. of entire elevation area. This area is calculated as enclosed between the line connecting the lowest part of the foundations and the line connecting the uppermost points of superstructure. In the case of through bridges, railings will be included in this area but in case of deck bridges, exclude the railings from the area of elevation	Rs 19.92
(v) Per Cft of bridge from bottom of foundation to top of roadway.	Rs 0-13-9

VIII. Contractors:

Messrs. Gannon Dunkerley & Co., (Madras), Ltd.

IX. GENERAL REMARKS:

For example:

(1) If cost is abnormally high explain why.	The cost is not abnormally high.
(2) If the design has proved specially satisfactory or unsatisfactory in any respect, explain this briefly.	—
(3) Give brief particulars of any special difficulties which had to be overcome.	—

—o—

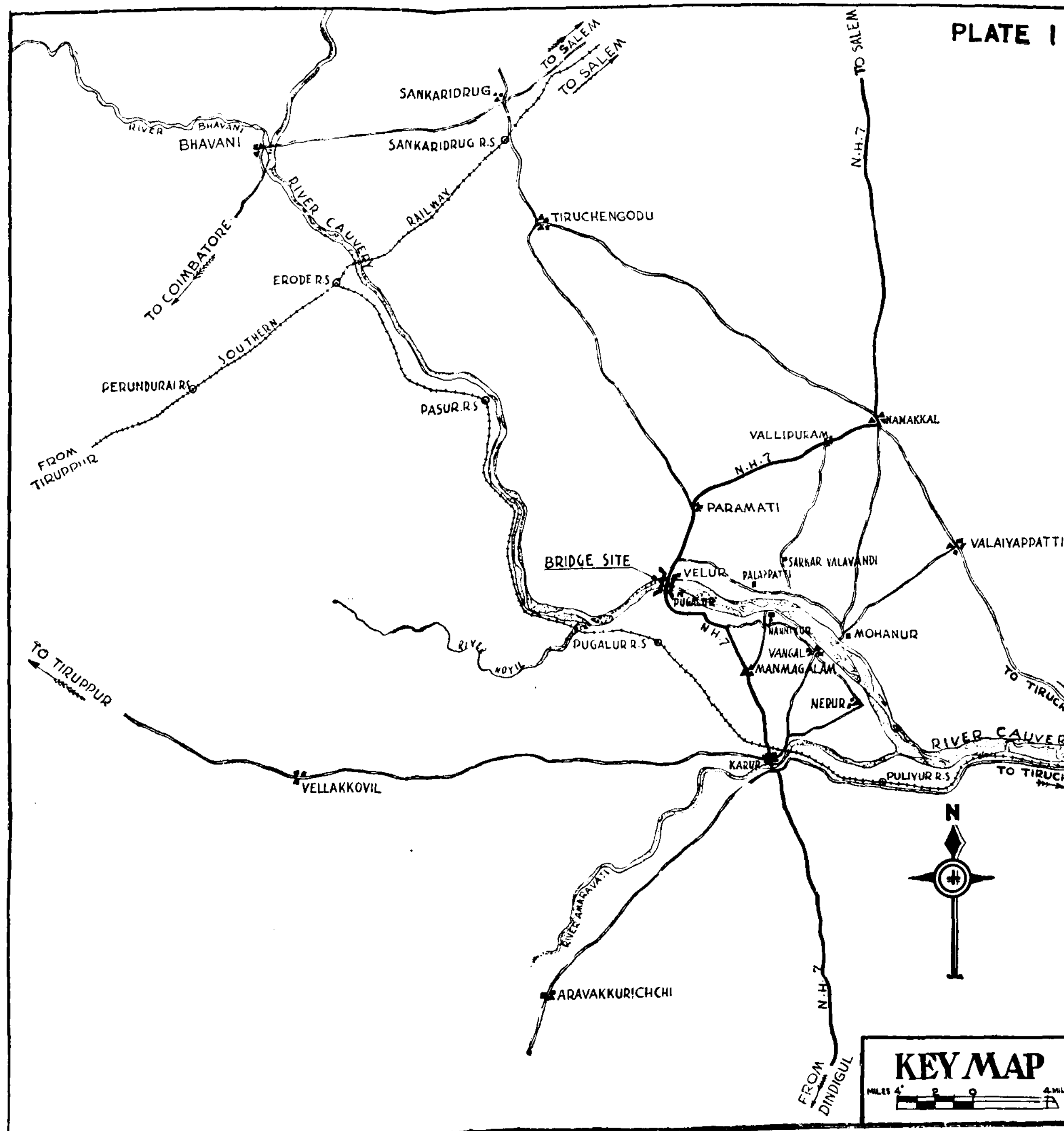


PLATE I
TO SALEM
TO SALEM
TO SALEM
SANKARIDRUG
SANKARIDRUG R.S
BHAVANI
RIVER BHAVANI
RIVER CAUVERY
RAILWAY
TIRUCHENGODU
N.H.7
TO COIMBATORE
ERODE R.S
SOUTHERN
PERUNDURAI R.S
PASUR R.S
FROM TIRUPPUR
NAMAKKAL
VALLIPURAM
PARAMATI
VALAIYAPPATTI
BRIDGE SITE
VELUR
PUGALUR
SARKAR VALAVANDI
MOHANUR
VANGAL
MANMAGALAM
NERUR
PUGALUR R.S
RIVER NOYIL
TO TIRUPPUR
TO TIRUCHY
RIVER CAUVERY
KARUR
PULIYUR R.S
TO TIRUCHY
VELLAKKOVIL
N
RIVER AMARAVATI
ARAVAKKURICHCHI
FROM DINDIGUL
KEY MAP

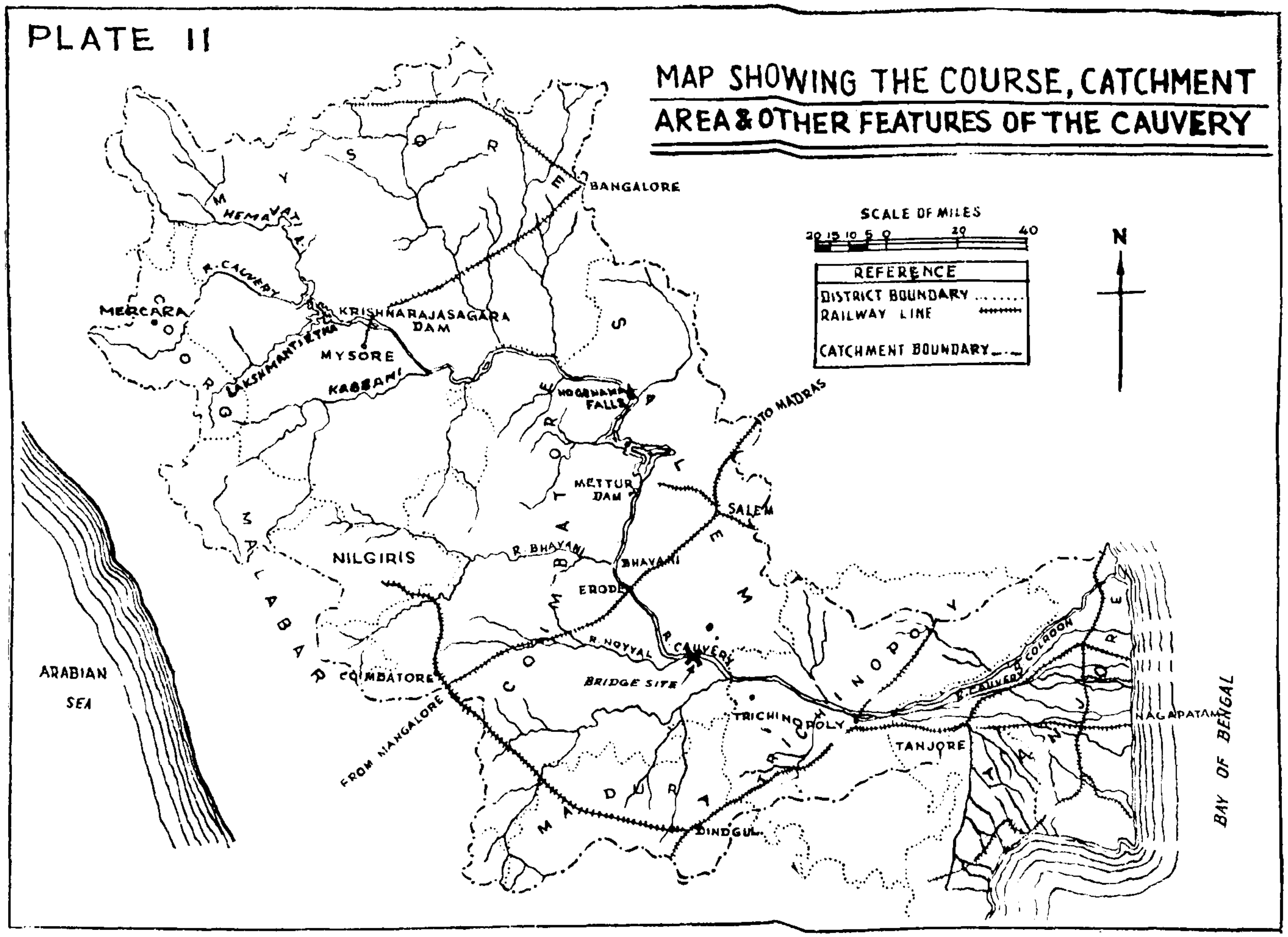
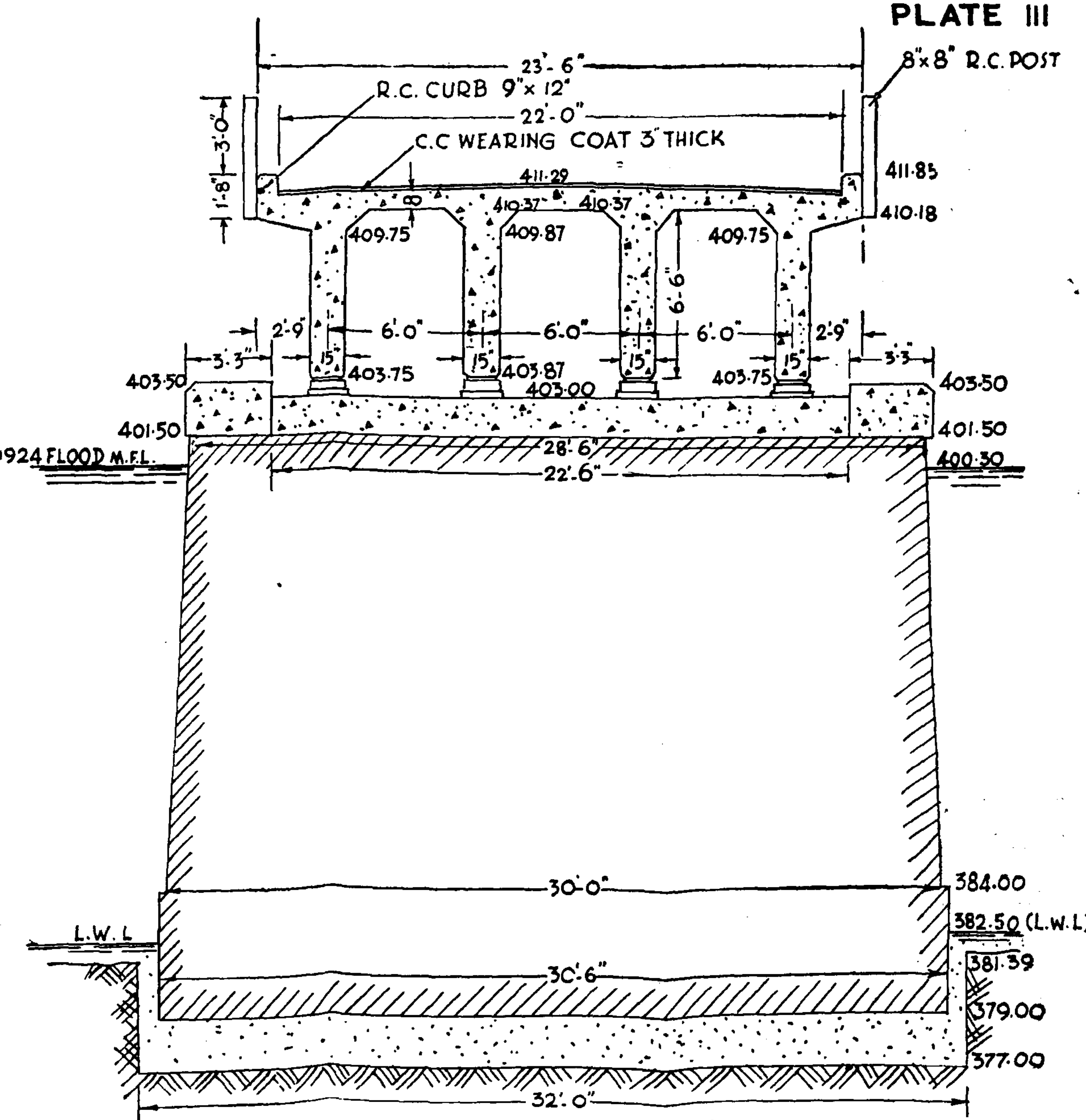


PLATE II
MAP SHOWING THE COURSE, CATCHMENT AREA & OTHER FEATURES OF THE CAUVERY
SCALE OF MILES
REFERENCE
DISTRICT BOUNDARY
RAILWAY LINE
CATCHMENT BOUNDARY
N
BANGALORE
MYSORE
MERCARA
KRISHNARAJASAGARA DAM
R. CAUVERY
HEMAVATI
KABBANI
LAKSHMANTIRTHA
NILGIRIS
METTUR DAM
SALEM
TO MADRAS
R. BHAVANI
BHAVANI
ERODE
R. NOYYAL
R. CAUVERY
BRIDGE SITE
COIMBATORE
FROM MANGALORE
TRICHINOPOLY
TANJORE
NAGAPATAM
DINDIGUL
COLEROON
ARABIAN SEA
BAY OF BENGAL

PLATE III



C. S. AT PIER No. 2

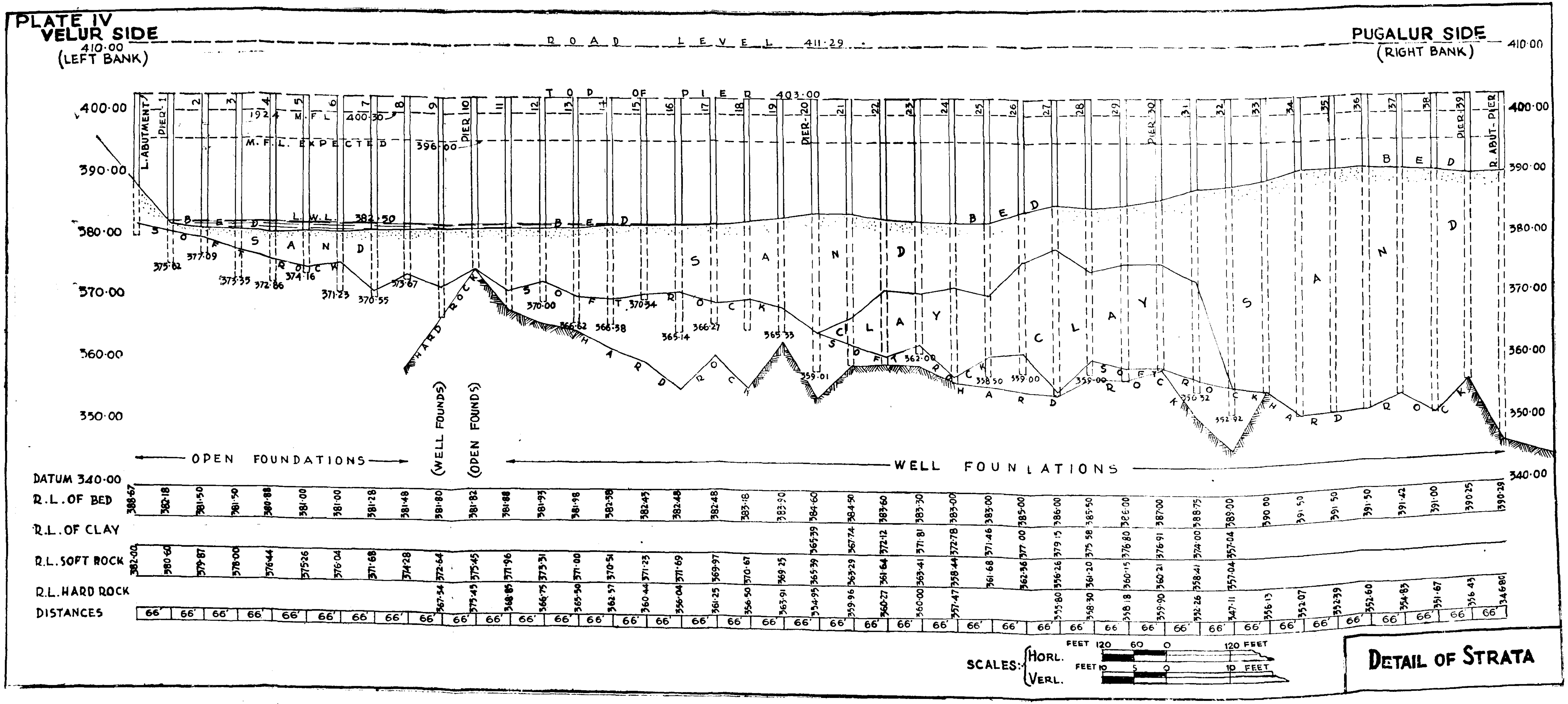


PLATE IV
VELUR SIDE
(LEFT BANK)
PUGALUR SIDE
(RIGHT BANK)
ROAD LEVEL 411·29
TOP OF PIER 403·00
1924 M.F.L 400·30
M.F.L. EXPECTED 396·00
L.W.L. 382·50
BED
SAND
SOFT ROCK
HARD ROCK
CLAY
OPEN FOUNDATIONS
(WELL FOUNDS)
(OPEN FOUNDS)
WELL FOUNDATIONS
DATUM 340·00
R.L. OF BED
R.L. OF CLAY
R.L. SOFT ROCK
R.L. HARD ROCK
DISTANCES
SCALES: HORL. VERL.
DETAIL OF STRATA

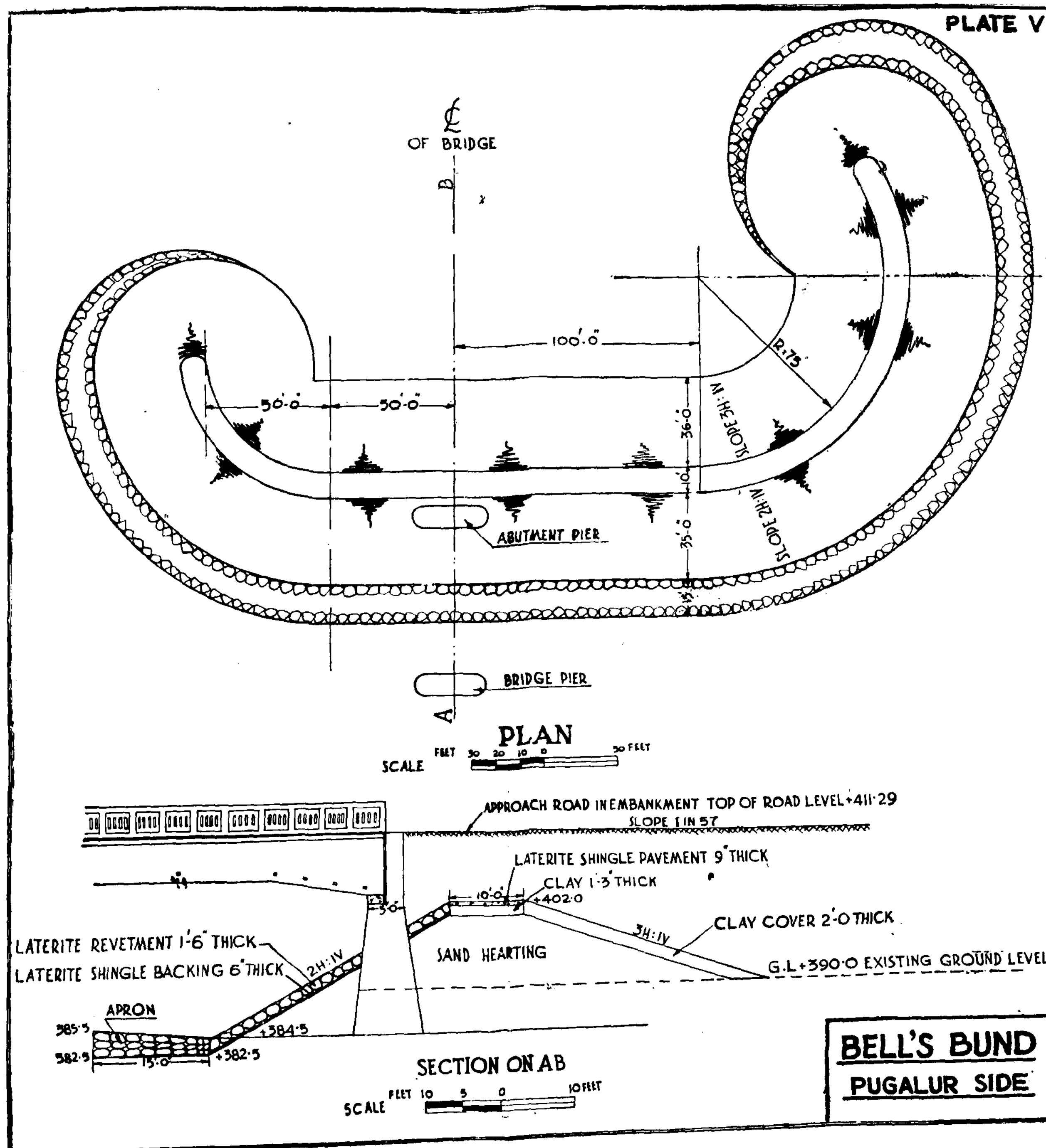


PLATE V
℄ OF BRIDGE
B
100'.0"
R:75
50'.0"
50'.0"
36'.0"
10'
35'.0"
15'
SLOPE 3H:1V
SLOPE 2H:1V
ABUTMENT PIER
BRIDGE PIER
A
PLAN
SCALE FEET 30 20 10 0 30 FEET
APPROACH ROAD IN EMBANKMENT TOP OF ROAD LEVEL +411·29
SLOPE 1 IN 57
LATERITE SHINGLE PAVEMENT 9" THICK
CLAY 1'·3" THICK
+402·0
10'.0"
3'.0"
CLAY COVER 2'-0 THICK
3H:1V
SAND HEARTING
G.L+390·0 EXISTING GROUND LEVEL
LATERITE REVETMENT 1'-6" THICK
LATERITE SHINGLE BACKING 6" THICK
2H:1V
APRON
385·5
582·5
+384·5
+382·5
15'.0"
SECTION ON AB
SCALE FEET 10 5 0 10 FEET
BELL'S BUND
PUGALUR SIDE

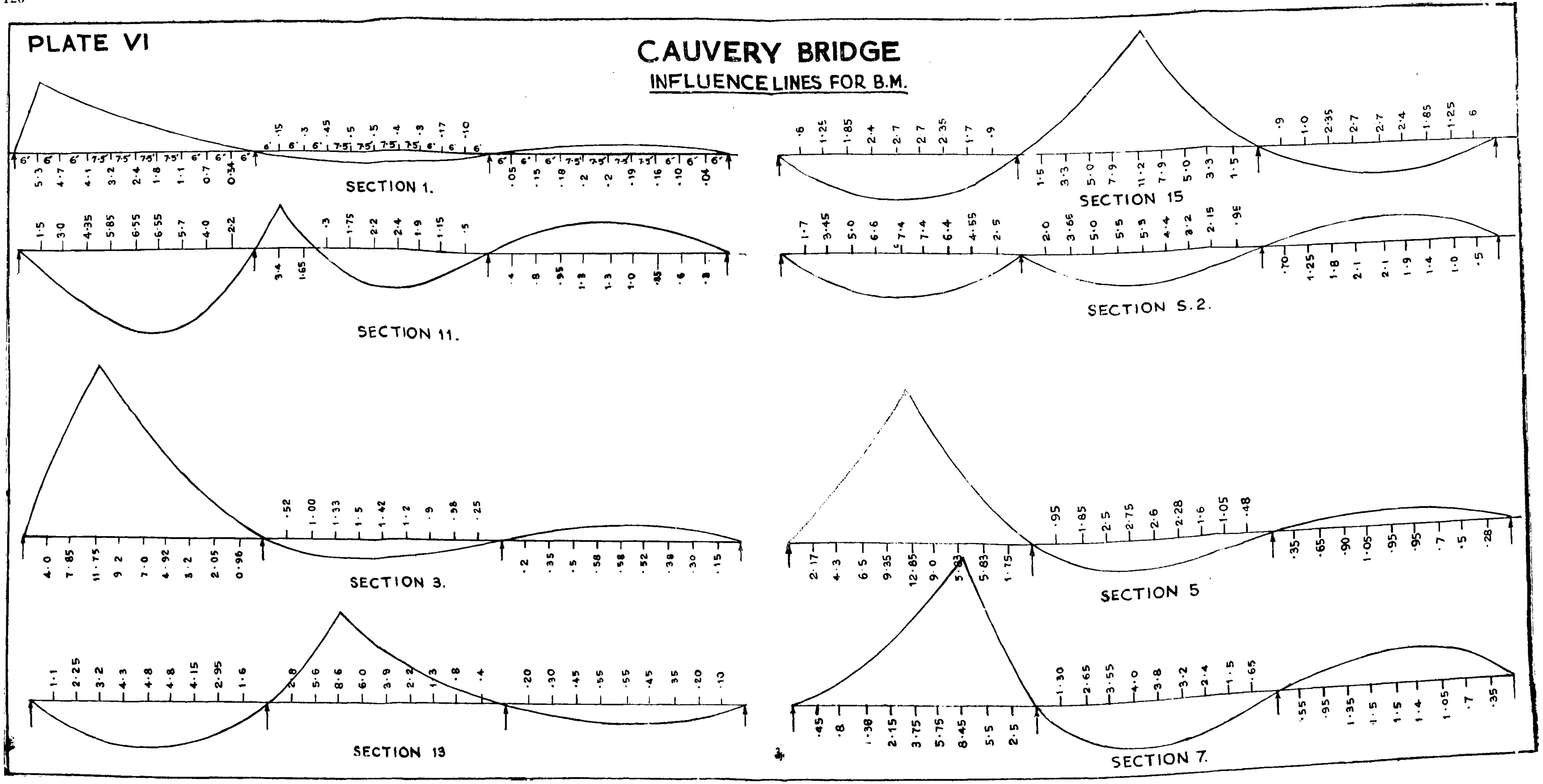
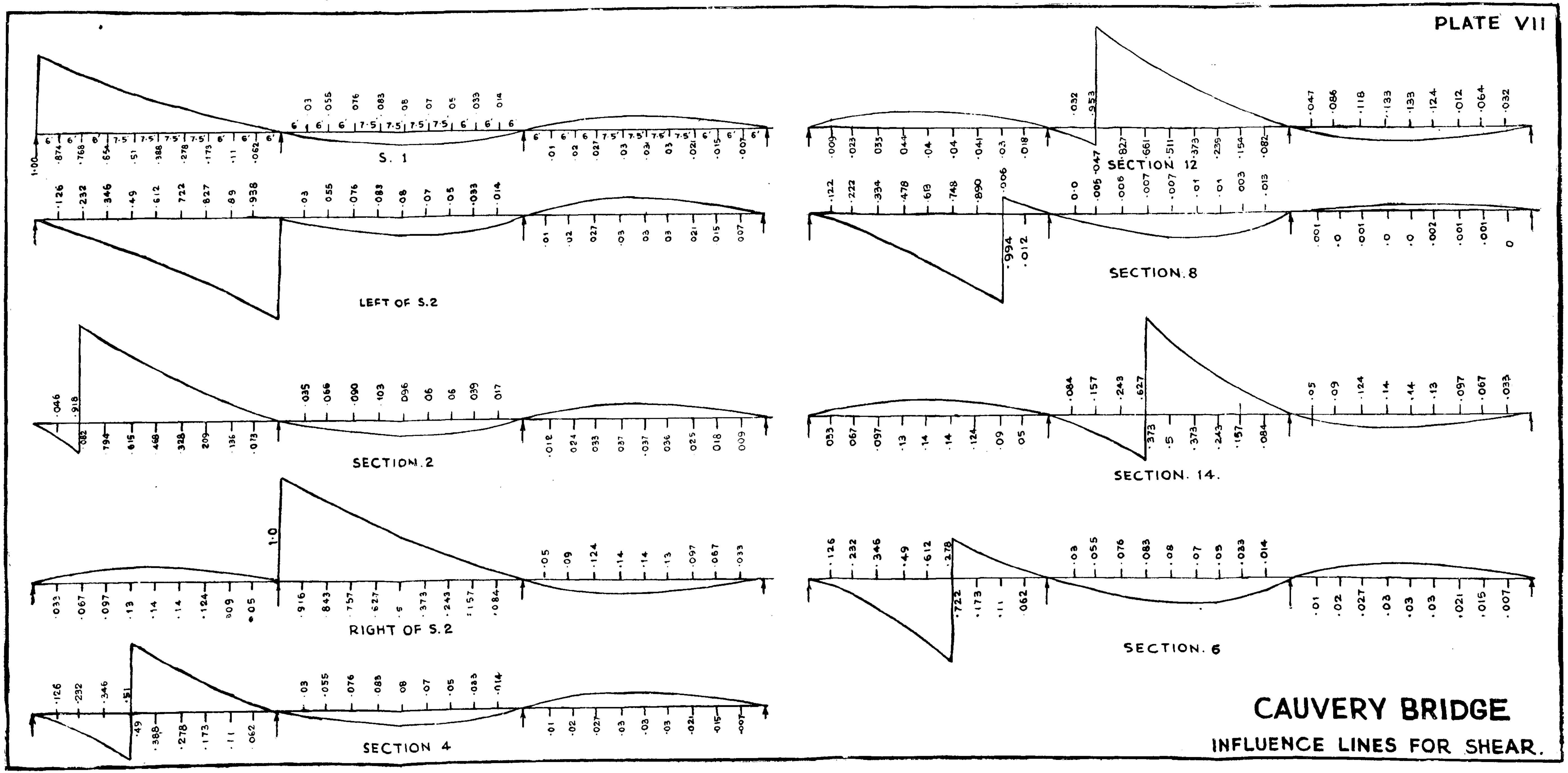


PLATE VI
CAUVERY BRIDGE
INFLUENCE LINES FOR B.M.
SECTION 1.
SECTION 15
SECTION 11.
SECTION S.2.
SECTION 3.
SECTION 5
SECTION 13
SECTION 7.

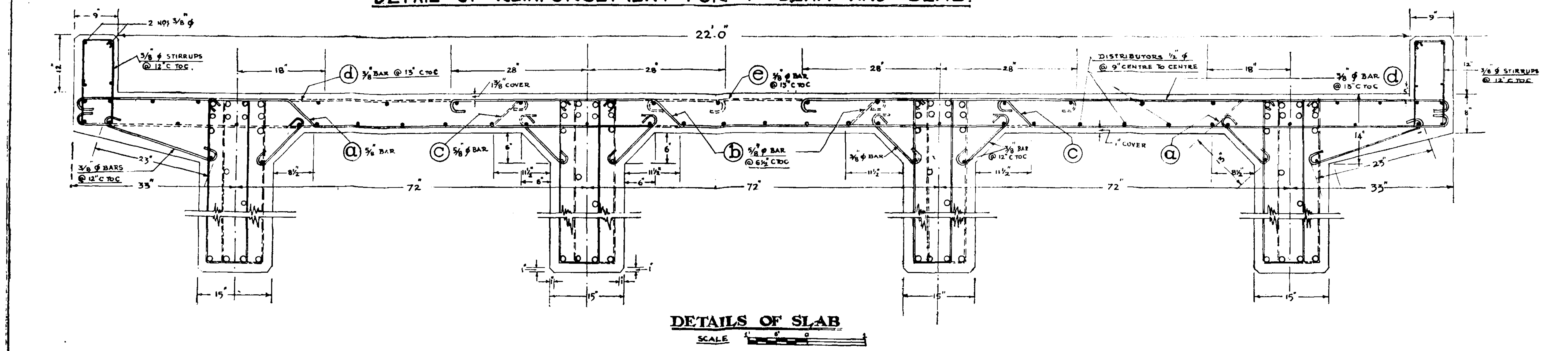
PLATE VII



CAUVERY BRIDGE
INFLUENCE LINES FOR SHEAR.

PLATE VIII

DETAIL OF REINFORCEMENT FOR "T" BEAM AND SLAB.

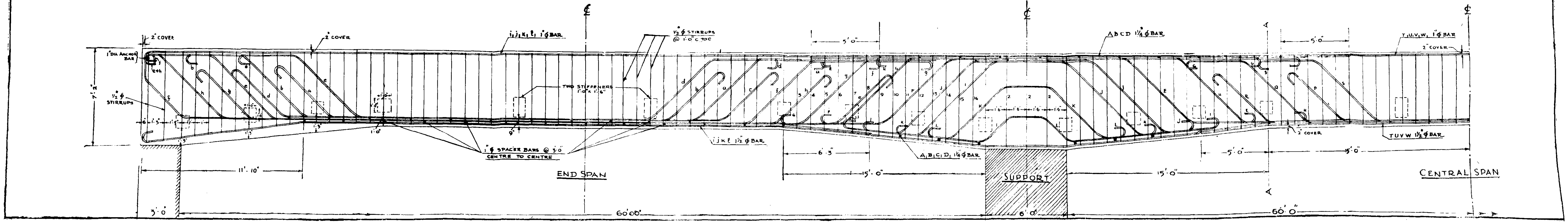


DETAILS OF SLAB

SCALE

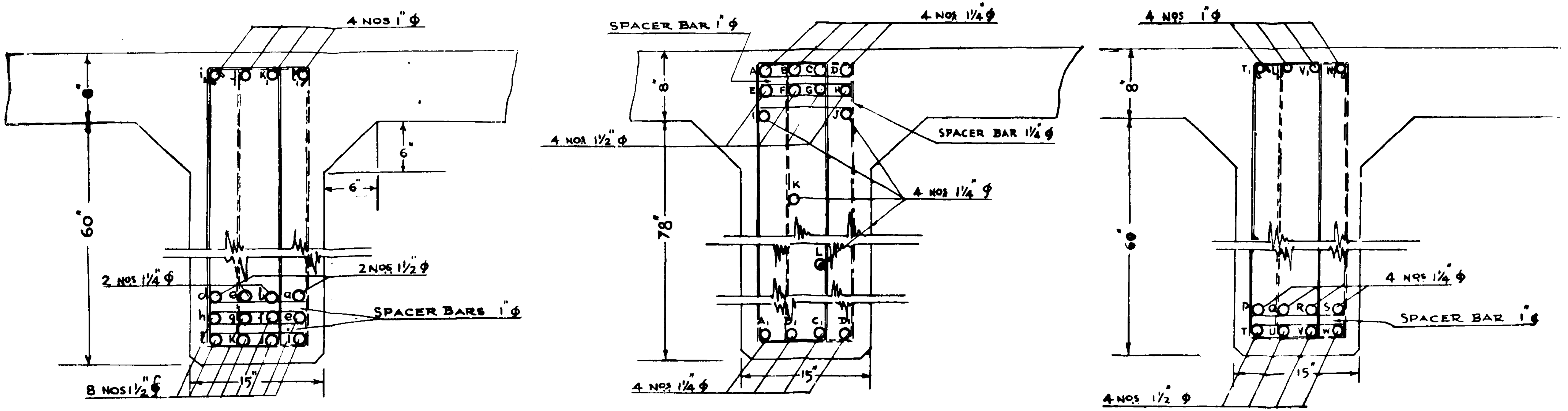
SCHEDULE OF REINFORCEMENT FOR SLAB

ITEM No	TYPE DETAILS OF BAR	NAME OF BAR	DIA OF BAR	No OF BAR OF SAME SIZE AND SHAPE	LENGTH OF EACH BAR	TOTAL LENGTH OF SIMILAR BAR	TOTAL LENGTH OF BARS OF SAME DIA.	WEIGHT	TOTAL WEIGHT OF STEEL	TOTAL QUANTITY OF CONCRETE	TOTAL WEIGHT OF STEEL PER C.FT.	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13
1	3'-7" 5'-7"	a	5/8"	366	10'-9"	3935	5/8" ITEMS 1+2+3	12874×1.043 = 13434 = 6 TONS	T CWT LBS 10 . 7 . 3 0 . 1 . 95 10 . 8 . 98	TOTAL 3399 C.FT.	23394 / 3399 = 6.9 LBS.	
2	3'-6" 5'-5"	b	5/8"	366	10'-6"	3843	= 3935+3843 +4483 =12261 & 5% WASTAGE = 12261+613					
3	3'-6" 7'-1"	c	5/8"	366	12'-3"	4483	= 12874					
4	7'-8"	d	3/8"	366	8'-3"	3019	3/8" ITEMS 4+5+7+8	7780 × .376 = 29,25 LBS. = 1 TON-6 CWT - 13 LBS.	($^T 6$)+($^T 1$-6 CWT 13 lbs)+($^T 3$ + 0 CWT + 102 LBS) = ADD BINDING WIRE 1 CWT = TOTAL	SLAB = 23'-6" × 198 × 2/3 = 3102 } KERB = 2 × 198 × 3/4 × 1 = 297 }	T CWT LBS 10 8 98 / 3399	
5	DISTRIBUTOR 3'-11"	e	3/8"	183	4'-6"	823	3019+1588+1980 +825 & 5% WASTAGE = 7410 7410+370 =7780					
6	197'-9"		1/2"	49	198'-6"	9727						
7	KERB 197'-9"		3/8"	8	198'-6"	1588	1/2" 9727+5% WASTAGE 9727+486 =10213	10213 × .668 = 6544 LBS = 3 T - 0 CWT - 102 LBS				
8	7" 17 1/2"		3/8"	2×198	5'-0"	1980						



DETAILS OF 'T' BEAM

SCALE 3 2 1 0 3 FEET



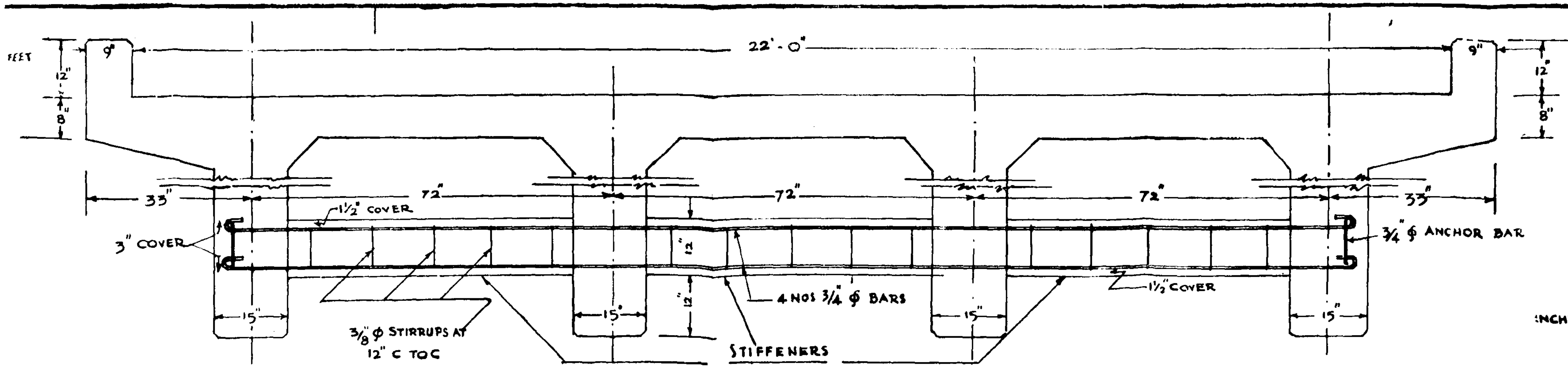
SECTION AT END SPAN

SECTION AT SUPPORT

SCALE FOOT 1 6" 0 1 FOOT

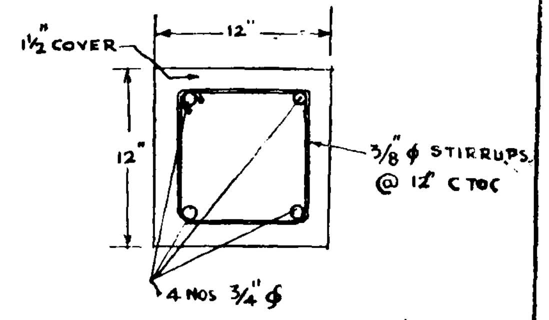
SECTION AT CENTRAL SPAN

PLATE IX



SECTION ON AA SHOWING DETAILS OF STIFFENER

FEET 2 1 0 2 FT. SCALE



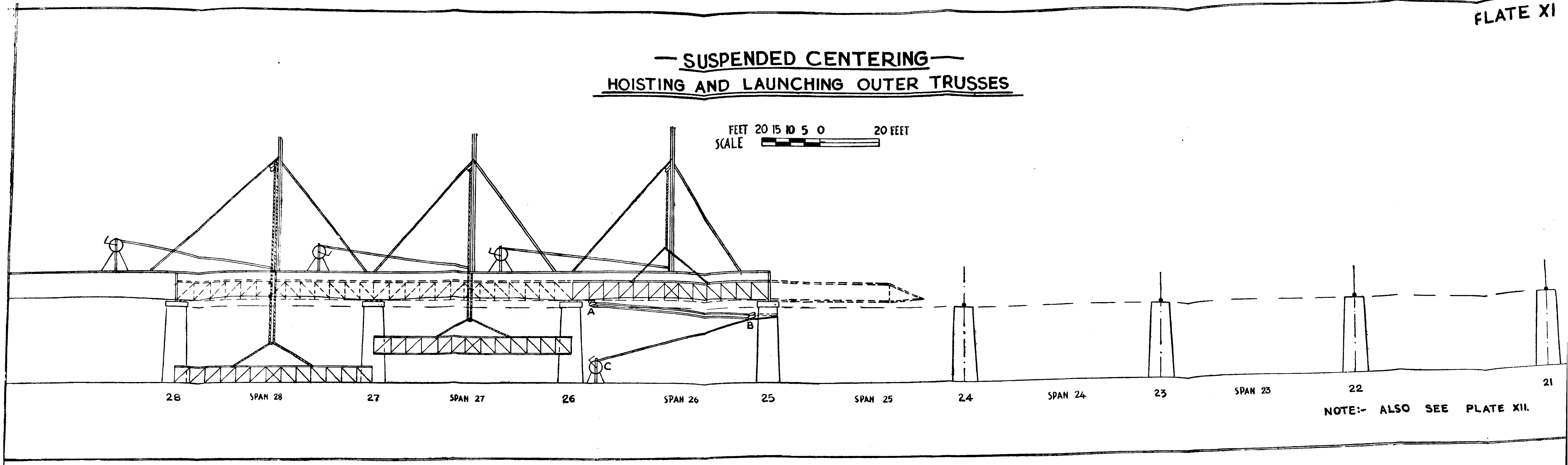
SECTION OF STIFFENER

INCHES 12 9 6 3 0 1 FEET

SCHEDULE OF REINFORCEMENT FOR STIFFENERS 24 NOS OF 12" x 12" SIZE & 6 NOS OF 18" x 12" SIZE											
ITEM NO	TYPE DETAILS OF BAR	DIA. OF BAR	NO OF BARS OF SAME SIZE AND SHAPE	TOTAL NO.	LENGTH OF EACH BAR.	TOTAL LENGTH OF SIMILAR BAR	TOTAL LENGTH OF BARS OF SAME DIAMETER.	WEIGHT	TOTAL WEIGHT OF STEEL	TOTAL QUTY. OF CONCRETE	TOTAL WEIGHT OF STEEL PER CFT.
1	18'-9"	3/4"	30x4	120	20	2400	1" ITEMS 1+2+3 2400+96+36 =2532+128 =2660	2660 x 1.502 = 3995	3995 + 702 = 4697 LBS. ADD BINDING WIRE 1 LBS/CWT - 42 LBS TOTAL WEIGHT OF STEEL 4697+42 LBS = 4739 LBS.	14.25 (24x1x1 + 6 x 3/2 = 14.25 (24+9) = 470.25 cft.	.4739 / 470.25 = 10 LBS
2	1½" 9" 1½"	3/4"	24x4	96	1'-0"	96					
3	1½" 1'-3" 1½"	3/4"	6x4	24	1'-6"	36					
4	9" 9"	3/8"	24x15	360	3'-9"	1350	3/8" ITEMS 4+5 =1778+5% =1778+89 =1867	1867 x .376 = 702			
5	9" 1'-3"	3/8"	6x15	90	4'-9"	428					

DETAILS OF REINFORCEMENT FOR "T" BEAM AND SLAB

FLATE XI



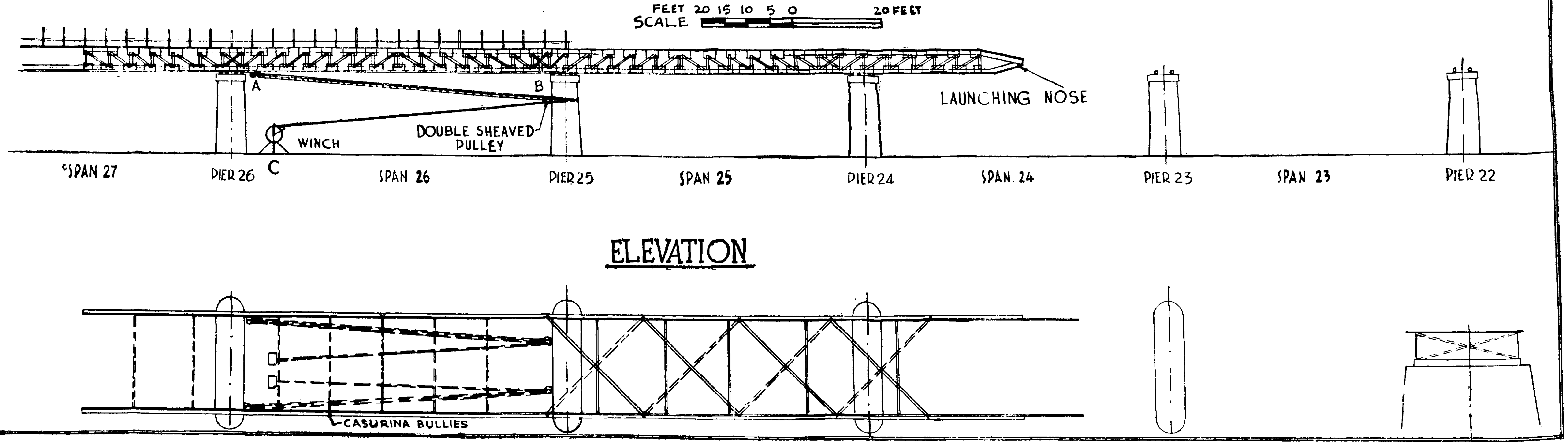
— SUSPENDED CENTERING —
HOISTING AND LAUNCHING OUTER TRUSSES
FEET 20 15 10 5 0 20 FEET
SCALE
A
B
C
28
SPAN 28
27
SPAN 27
26
SPAN 26
25
SPAN 25
24
SPAN 24
23
SPAN 23
22
21
NOTE:- ALSO SEE PLATE XII.

PLATE XII

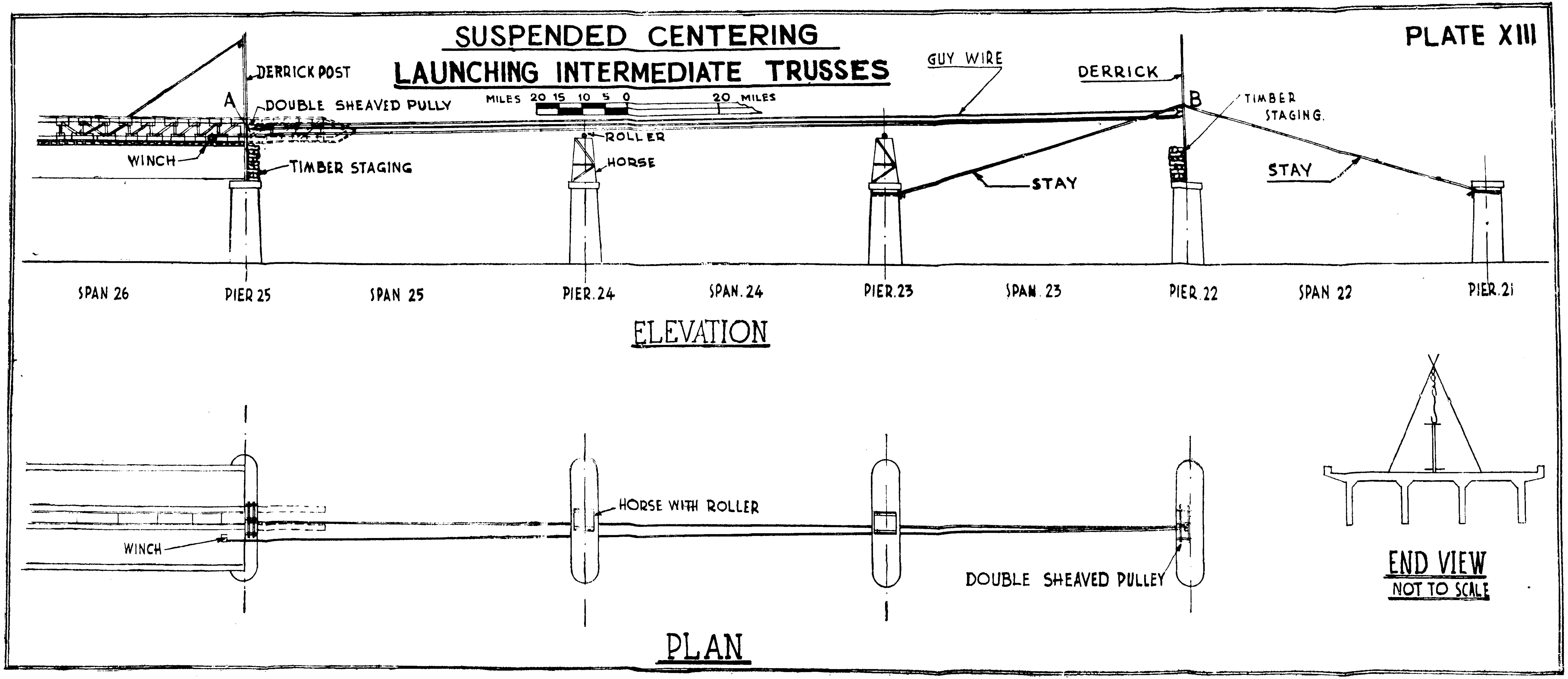
—SUSPENDED CENTERING—

HOISTING AND LAUNCHING OUTER TRUSSES

NOTE:- ALSO SEE PLATE XI



ELEVATION


SUSPENDED CENTERING
LAUNCHING INTERMEDIATE TRUSSES
PLATE XIII
DERRICK POST
A
DOUBLE SHEAVED PULLY
MILES 20 15 10 5 0 20 MILES
GUY WIRE
DERRICK
B
TIMBER STAGING.
ROLLER
HORSE
WINCH
TIMBER STAGING
STAY
STAY
SPAN 26
PIER 25
SPAN 25
PIER.24
SPAN.24
PIER.23
SPAN. 23
PIER.22
SPAN 22
PIER.21
ELEVATION
HORSE WITH ROLLER
WINCH
DOUBLE SHEAVED PULLEY
END VIEW
NOT TO SCALE
PLAN

INFORMATION SERVICE

(i) TYPE DESIGNS FOR FURLONG AND BOUNDARY STONES

In supersession of the type designs for furlong and boundary stones, published at pages 137–140 of Volume XIV-1 of the Journal, revised type designs as finalized by the Specifications and Standards Committee of the Indian Roads Congress are given here.

1. **USE.**— These type designs are intended for adoption only when new furlong and boundary stones are installed or when broken ones are replaced.

2. **MATERIAL.**—Furlong and boundary stones may be made out of dressed hard stone, if locally available, or of lightly reinforced cement concrete.

3. FURLONG STONES.

3.1. **Location and Fixing of the Stone**. Furlong stones like milestones, are to be located on the left-hand side of the road as one travels from the terminal station from which the milage count starts. The stones should be fixed in position with mud concrete all round. They should be fixed at the edge of the formation, the inscribed face being placed parallel to the centre line of the road and facing the road or with faces at right angles to the centre line of the road, in which case both faces will bear the (same) inscription.

3.2. **Designation of Furlongs.**—Two methods of designating furlongs are now in use.

In the first method, the 5th furlong stone of the first mile, for example, is designated as 0/5. Similarly, 4/6 represents the end of the 6th furlong in 5th mile. In other words, the furlong stone is situated 4 miles and 6 furlongs from the starting point of the road.

In the second method the furlong stones mentioned above are designated as 1/5 and 5/6 respectively or the fifth furlong of mile one and the sixth furlong of mile five respectively.

In most of the States, the first method is in use and this practice should be adopted : that is, **the inscription on a furlong stone should denote its distance from the starting point of the road**.

3.3. **Inscription**.—The number indicating the mile should be inscribed above the number indicating the furlong (see Plate I).

It is recommended that, for ease of replacement, the furlong numeral should be engraved and the milage numeral painted.

The use of quarter-mile stones with fractions as $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, to indicate fractions of miles is not recommended.

4. BOUNDARY STONES

4.1. **Spacing**.—The boundary stones shall be fixed on each side of the road land,

(1) at intervals of one furlong or less where the boundary is in a curve or the land is costly and likely to be encroached upon ; and

(2) at all angular points of the road boundary.

4.2. **Mode of Fixing**.—Where the soil is good, the boundary stones may be fixed in compacted natural soil. Lime-surkhi concrete, or lean cement concrete shall be used in the foundations :

(1) where wet cultivation abuts the road-land and boundary stones are apt to be displaced during agricultural operations ;

(2) where the road runs in built-up areas ; and

(3) where the boundary stones are intended to serve as permanent land marks.

The portion above the ground shall be 12 inches high and the lower 2 ft shall be let into the foundation and encased on all sides by at least 6 in. of foundation material.

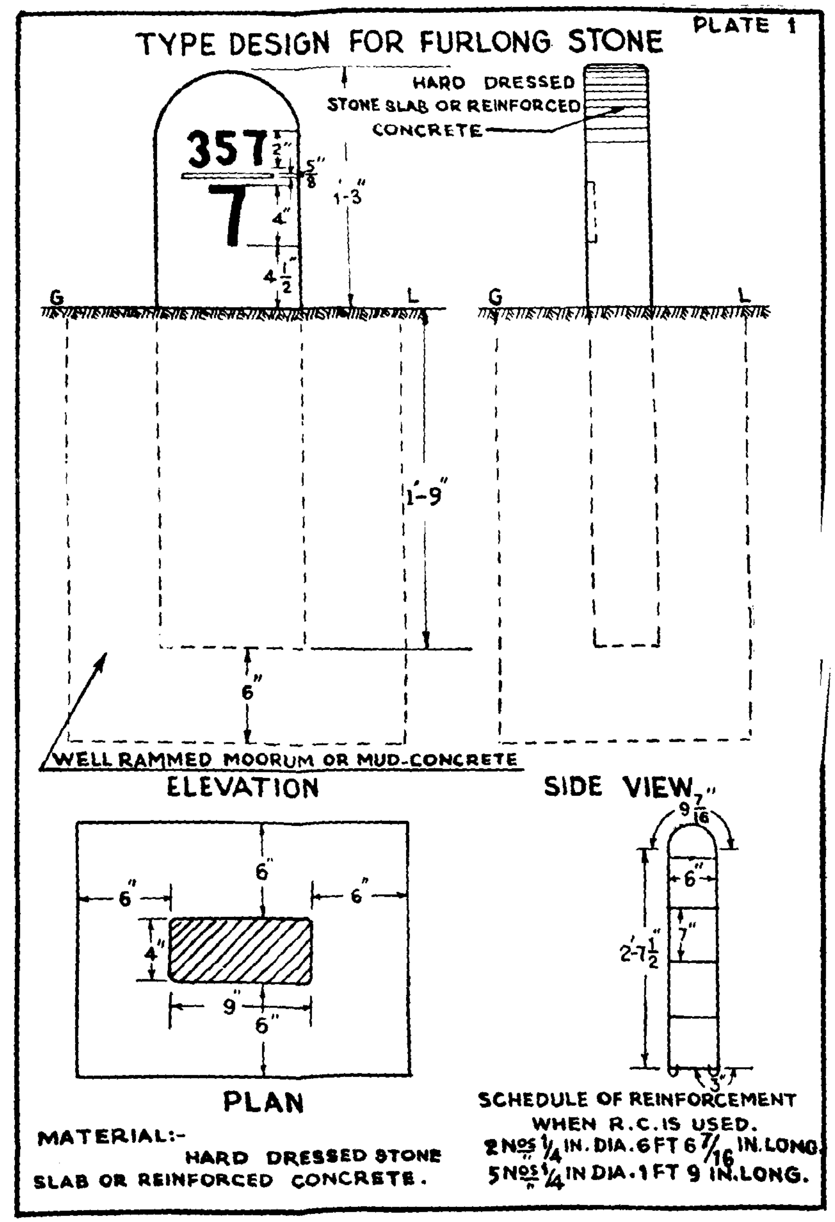


PLATE 1
TYPE DESIGN FOR FURLONG STONE
HARD DRESSED STONE SLAB OR REINFORCED CONCRETE
357
7
G
L
1'-3"
1'-9"
6"
WELL RAMMED MOORUM OR MUD-CONCRETE
ELEVATION
SIDE VIEW
PLAN
MATERIAL:- HARD DRESSED STONE SLAB OR REINFORCED CONCRETE.
SCHEDULE OF REINFORCEMENT WHEN R.C. IS USED.
2 Nos 1/4 IN. DIA. 6 FT 6 7/16 IN. LONG.
5 Nos 1/4 IN DIA. 1 FT 9 IN. LONG.

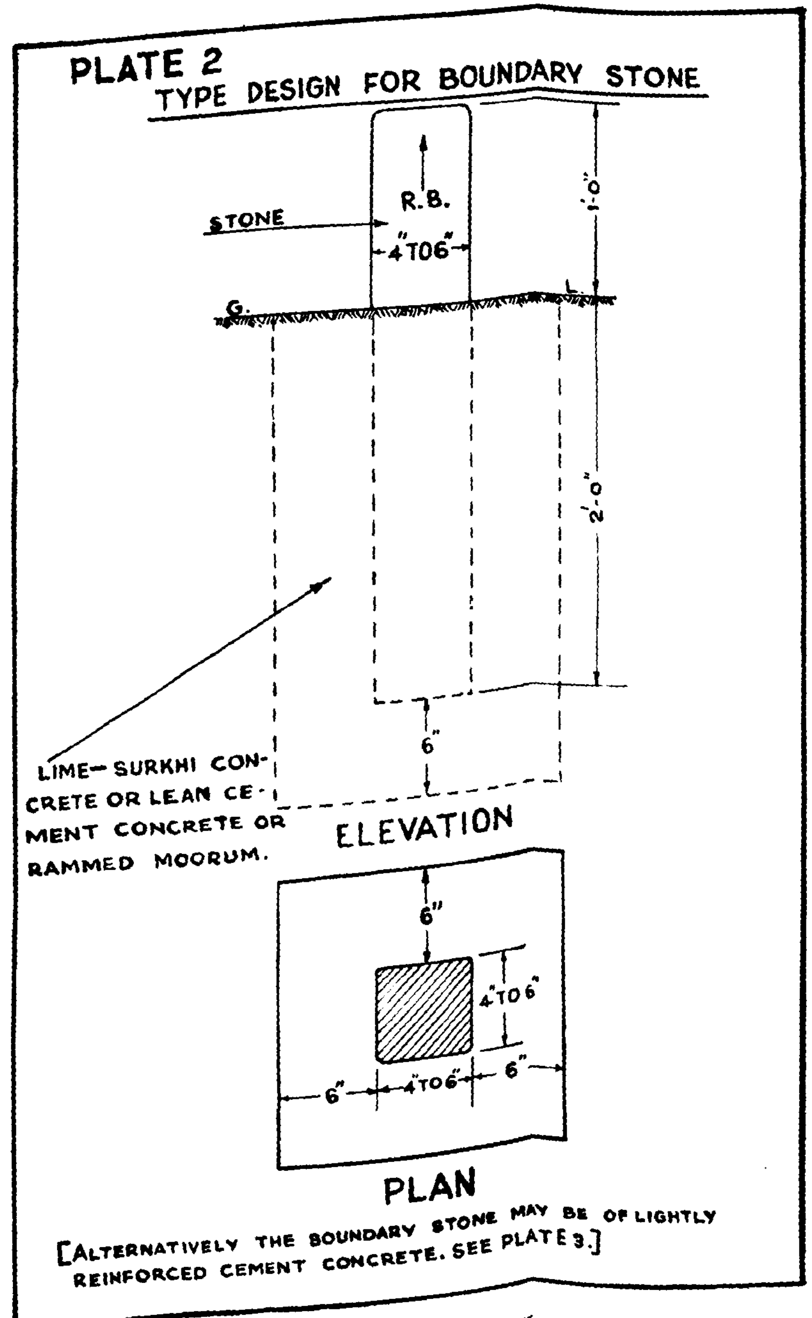
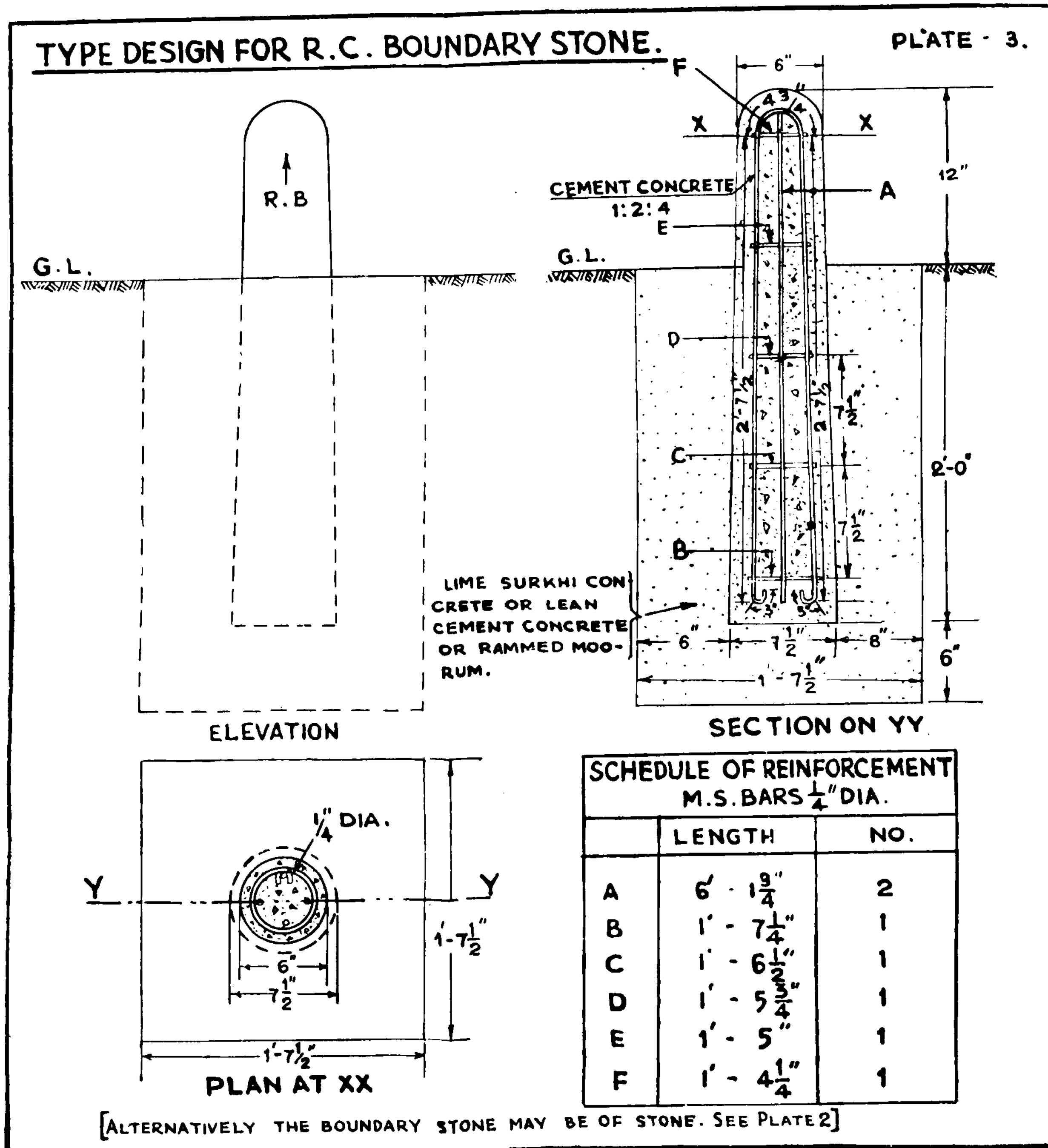


PLATE 2
TYPE DESIGN FOR BOUNDARY STONE
R.B.
STONE
4" TO 6"
1'-0"
G.L.
2'-0"
6"
LIME-SURKHI CON-CRETE OR LEAN CE-MENT CONCRETE OR RAMMED MOORUM.
ELEVATION
6"
4" TO 6"
6"
4" TO 6"
6"
PLAN
[ALTERNATIVELY THE BOUNDARY STONE MAY BE OF LIGHTLY REINFORCED CEMENT CONCRETE. SEE PLATE 3.]



SCHEDULE OF REINFORCEMENT M.S. BARS 1/4" DIA.

	LENGTH	NO.
A	6' - 1 9/4"	2
B	1' - 7 1/4"	1
C	1' - 6 1/2"	1
D	1' - 5 3/4"	1
E	1' - 5"	1
F	1' - 4 1/4"	1

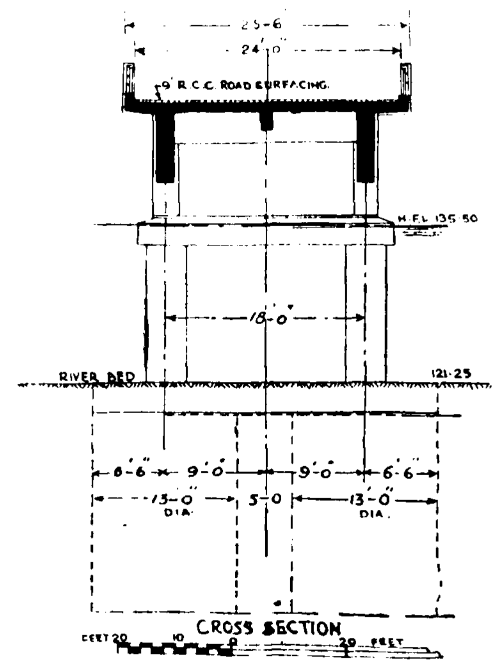
LOAD-TEST OF THE KUAKHAI BRIDGE SUPERSTRUCTURE

By

S. N. GUPTA.

1. INTRODUCTION

1.1. A highway bridge on National Highway No. 5 was built during 1948–50 across the Kuakhai, a deltaic branch of the Mahanadi in Orissa. The total length of the bridge is 1696 ft with 15 equal spans of 106 feet and a 53-foot cantilever span at each end. The bridge carries a 24-ft carriageway and two six-foot foot-paths. The foundations are two circular wells, 13½ ft dia-



meter, under each pier. The superstructure is of the reinforced concrete balanced cantilever and suspended span type, and consists of three R.C. girders spaced 11 ft centre to centre, connected with a 9-in thick R.C. deck slab. The main reinforcement in the girders was welded. The foundation wells were tested before they were plugged.

1.2. The work is described in Paper No. 155 in Indian Roads Congress Journal Volume XV. This note describes the load-test carried out on the superstructure.

1.3. The test lasted from the 21st November 1950 to the 1st week of January 1951. All the spans were tested one by one. This note gives the details of test of one end unit of the bridge, consisting of a main span, the cantilever arms, and a suspended span.

2. PRELIMINARY ARRANGEMENTS.

2.1. The bridge was designed for two lanes of I. R. C. class A or one lane of I. R. C. class AA load, whichever produced higher stresses on individual members. Since on calculation it was found that, in the spans under review, I. R. C. class A loading produced severer stresses than I. R. C. class AA, the test was conducted under the former loading. For purposes of the test, the loading was converted into an equivalent uniformly distributed loading plus a knife edge load.

2.2. The test-load consisted of sand—loose and in bags. A bag contained about 1.25 cu. ft. of sand. The weight of sand was assumed to be 90 lb per cu. ft. against its actual weight of 88·94 lb per cu.ft.

2.3. Wooden platforms (Fig. 1) were used to transmit knife-edge loads.

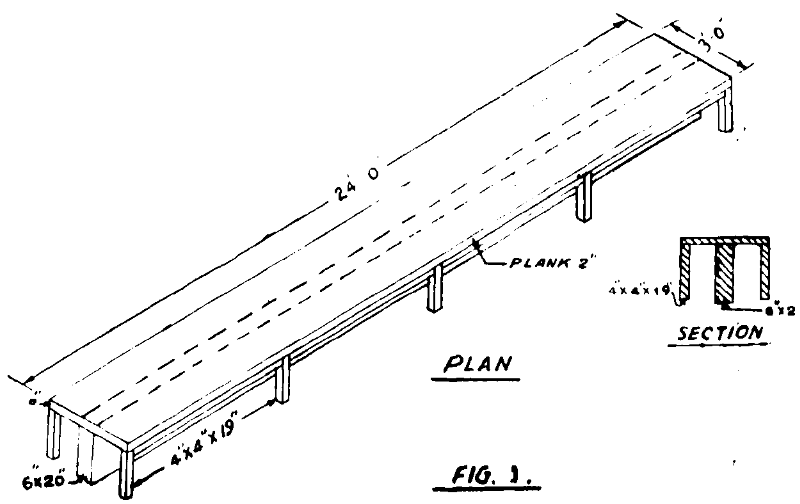


FIG. 1.

2.4. As no better instruments for recording deflections were available three levelling instruments were used for this purpose.

2.5. One levelling instrument was placed at point A (see Fig. 2) over a concrete platform on the embankment near the abutment. The other two instruments were placed on the deck-slab over the third pier which was assumed to be unaffected by loads placed between piers 1 and 2.

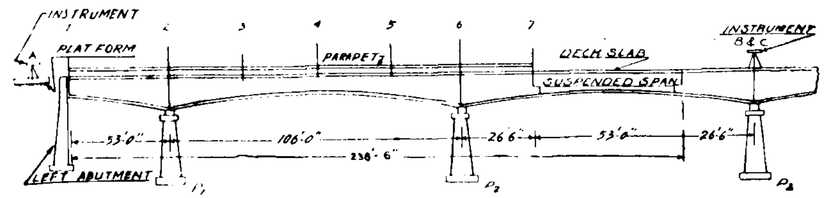


FIG. 2

2.6. The following seven points (see Fig. 2) were selected for the observation of deflections in each of three girders:

(1) Free end of the cantilever (abutment side)

(2) Pier No 1

(3) First quarter-point

(4) Centre of span

(5) Third quarter-point

(6) Pier No. 2

(7) Free end of the cantilever (adjacent to pier No .2)

2.7. To mark the positions of the points during the test, and to prevent sand getting on to them, vertical cylinders of tin with open ends were placed over these twenty-one points.

3. TEST PROCEDURE.

3.1. Before loading the span, readings on all the 21 points (7 points × 3 girders) as well as on two bench marks—one on the abutment near instrument "A" and the other on the kerb of the footpath beyond pier No. 3—were recorded with the three instruments.

3.2. In order to develop the maximum positive moment in the main span, the platform for the knife-edge load was first placed at the centre of the span with its longitudinal axis across the direction of traffic. Starting from the centre of the span towards the piers, the carriageway and the foot-paths of the main span were filled, simultaneously in both directions, with sand to a depth of 1.322 ft on the carriageway and 0.633 ft on the foot-paths. At the same time the platform for the knife-edge load was loaded with 536 bags. The cantilevers were left unloaded. After the span had thus been fully loaded between the piers, readings were again taken on all the 21 points and deflection calculated.

Photo No. 1 shows the main span loaded with the knife-edge load at its centre.

Photograph 1

3.3. To obtain the maximum positive moment in the suspended span, it was loaded with a knife-edge load of 580 sand bags at its centre and a distributed load of 1.477 ft of sand on the carriageway and 0.667 ft on the footpath. The distributed load on the main span remained as before, but its knife-edge load was removed. Readings were taken, before and after loading, over eadh girder at three points (viz., the centre and the ends), and ceflections calculated.

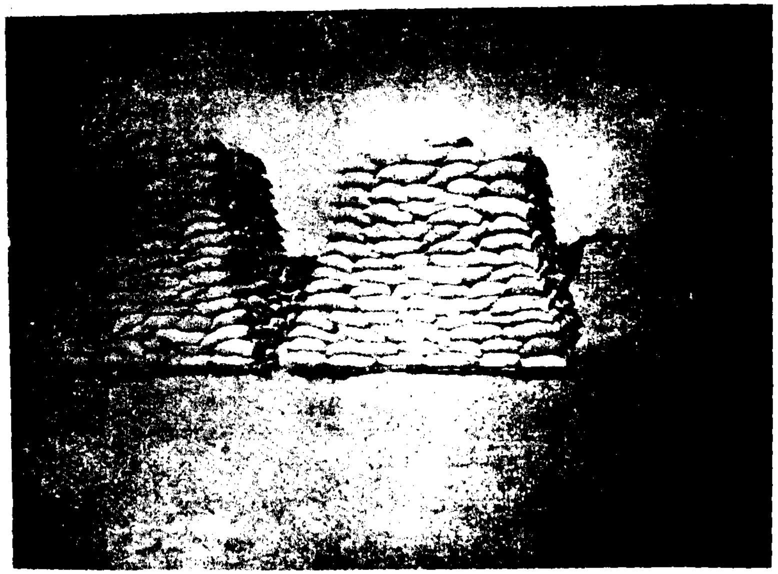
Photo No. 2 shows the suspended span with the distributed and knife-edge loads.

Photograph 2

3.4. For the maximum moment in the cantilever the carriageway over the cantilever was loaded with sand to a depth of 1.644 ft and the foot-path to a depth of 0.667 ft. The knife-edge load was removed from the suspended span and two knife-edge loads were placed at the ends of cantilevers. Distributed load on the main and the suspended spans remained as before. Readings were then taken at the points mentioned in paras 2.6 and 2.7 and deflections calculated.

Photo No. 3 shows the loaded cantilevers with two knife-edge loads.

3.5. For the maximum negative moment in the main span, the load on the main span (between Piers 1 and 2) was completely removed. The suspended span had only distributed load on it whereas the cantilevers had both distributed and knife-edge loads. Readings were again taken on all the 21 points on the main span and the cantilevers, and deflections calculated.



Photograph 3

3.6. Figs. 3, 4 & 5 show the deflections of the girders at different points, under the various loading arrangements.

4. SHEAR TEST.

4.1. The main span was again loaded uniformly. The knife-edge loads were shifted from the ends of the cantilever and placed just by the side of the pier, first towards the cantilever side and then towards the supported span side. The number of sand bags required for the knife-edge load was 790 on the cantilever side and 670 on the other side. The slab and the girders stood the load all right, and no cracks were observed.

5. BEHAVIOUR.

5.1. Before putting on the load, some of the existing temperature cracks were fitted with tell-tales to observe if the cracks widened under the test loads. At the end of the test, none of the cracks was found to have widened or extended.

5.2. The movement of the roller bearing was also observed.

5.3. The superstructure regained its original position about 24 hours after the removal of all loads.

6. COST.

6.1. The cost of the test per running foot worked out to about Rs 12. The test took almost seven weeks to complete. Had it been carried out by means of moving loads, as assumed for the design the time required would not have been more than two or three days. In that case the cost, too, might have been much less. The test was more elaborate than would usually be required but it was considered necessary in this case to carry out a rather elaborate test as this was the first time the I. R. C. loadings had been tested on a balanced cantilever bridge.

The statement of cost is attached (pages 148—150.)

STATEMENT OF COST

Length Tested 238 ft 6 in. (see Fig. 2)

Serial No.	Description.	Quantity.	Rate Unit	Rate Rs A	Amount Rs	Total Amount.
I.	**Supported Unit between Piers 1 and 2 (106 ft.)**					
1.	Collecting sand from the river bed and stacking on road embankment.	4240 cu.ft	%	10-0	424/-	
2.	Loading sand on the deck.	4240 cu.ft	%	2-0	85/-	
3.	Cost of empty cement bags (including 13 bags for wastage.	549 Nos.	%	30-0	165/-	
4.	Filling and stitching bags.	536 Nos.	%	12-8	67/-	
5.	Loading, unloading and carriage of bags.	536 Nos.	%	9-6	50/-	
6.	Fitting and placing platform for the knife-edge load.	1 No.	each	10-0	10/-	801/-
II.	**Cantilevers (53 ft 0 in. and 26 ft 6 in.)**					
1.	Collecting sand from the river bed and stacking on road embankment.	3864 cu.ft	%	10-0	386/-	
2.	Loading sand on the deck.	3864 cu.ft	%	2-0	77/-	
3.	Cost of empty bags (including 20 bags for wastage.)	840 bags	%	30-0	252/-	

Serial No.	Description.	Quantity.	Rate Unit	Rate Rs A	Amount Rs	Total Amount.
4.	Filling and stitching bags.	820 bags	%	12-8	105/-	
5.	Loading, unloading and carriage of bags.	820 bags	%	9-6	77/-	
6.	Fitting and placing platform for the knife-edge load.	2 Nos.	each	10-0	20/-	917/-
III.	**Suspended span between Cantilevers (53 ft)**					
*1.	Collecting and stacking sand from the river bed.	2378 cu.ft	%	10-0	238/-	
2.	Loading sand on the deck.	2378 cu.ft	%	2-0	47/-	
3.	Filling and stitching the bags.	576 Nos.	%	12-8	72/-	
4.	Loading, unloading, and carriage of bags.	576 Nos.	%	9-6	54/-	
5.	Fitting and placing platform for the knife-edge load.	1 No.	each	10-0	10/-	421/-
IV.	**Shear test**					
	Fitting and placing platforms for the knife-edge load.	4 Nos.	each	10-0	40/-	
	Loading, unloading and carriage of bags 790 × 4 =	3160 bags	%	9-6	296/-	336/-

* Same sand as in item I was used for remaining spans adding only the wastage in every operation.

Serial No.	Description.	Quantity.	Rate Unit Rate Rs A	Amount Rs	Total Amount.
Cost of making five platforms :					
					B/F 2475/-
1.	Timber.	240 cu.ft	at Rs 9/- per cu. ft	160/-	
2.	Labour charges		(Lump sum)	600/-	
3.	Cost of fittings (Bolts, nuts, angles, cleats, etc.)		(Lump sum)	250/-	
4.	Cylinders	36	at Rs 5/- each	180/-	

Total cost of platforms 3,190/-
No. of Units tested = 8

Proportionate cost of platforms per unit $= \frac{3190}{8} = 399/-$

Total Cost 2874/-

Cost of test per running foot $= \frac{2874}{238.5}$

= Say Rs 12/-.

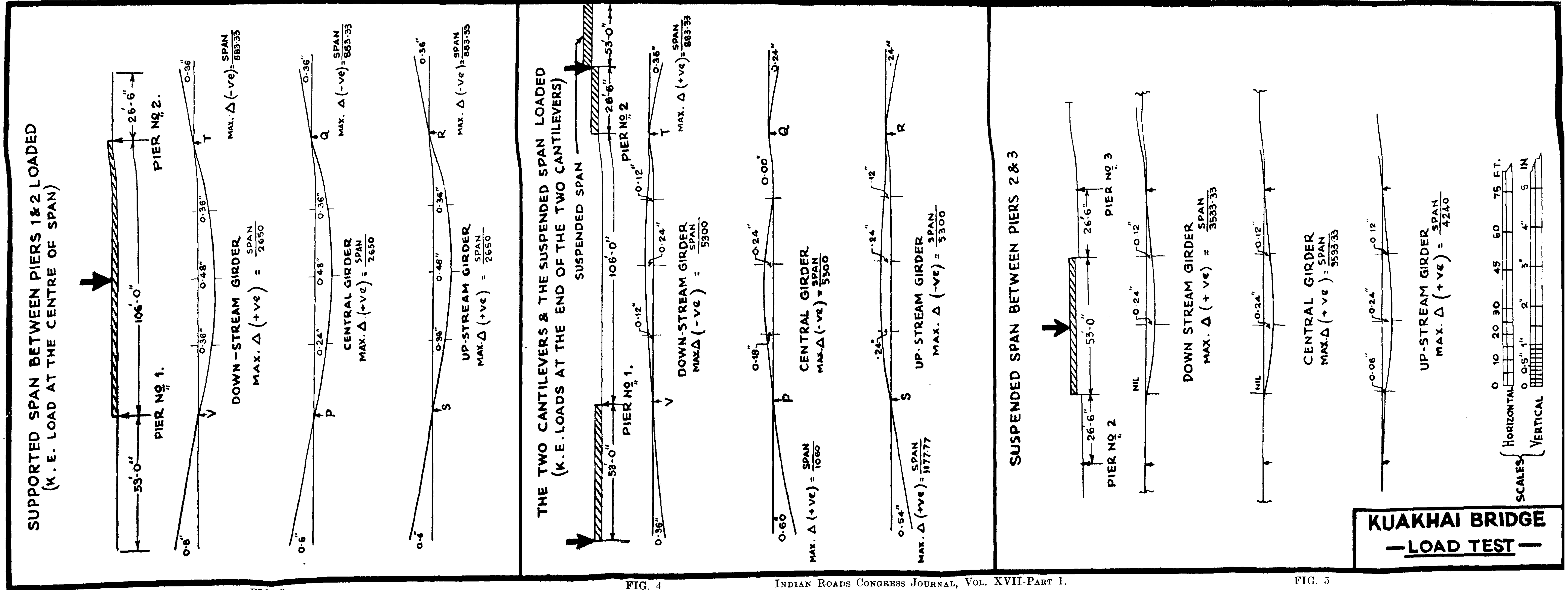


FIG. 3

FIG. 4

FIG. 5

SOME OBSERVATIONS ON AIRFIELD RUNWAY SURFACES

A Bituminous Surfaced Runway
A Concrete Surfaced Runway

CENTRAL ROAD RESEARCH INSTITUTE
Okhla, Delhi.
Director, Dr. E. Zipkes.

CONTENTS

SYNOPSIS

The Note describes the results of the examination of the runway pavements of two aerodromes in India. In one case, the bitumen carpet had become dry and rough and caused excessive wear of aircraft tyres. Investigations revealed a very coarse-graded quartzite aggregate and a binder content in excess of the requirements of that type and grading of aggregate. The note discusses the specifications and suggests remedies.

In the other case, the coarse aggregate of a cement concrete runway showed signs of staining, burning, and pitting ascribed to corrosive liquids dropping from aircraft or to the hot exhaust from jet aeroplanes. Investigations showed that neither of these surmises was correct and the reason for the damage was the use of a particular kind of aggregate.

INTRODUCTION

This study deals with two cases of runway surfaces, one bituminous and one concrete. Both cases show how modifications in design or construction might have resulted in prolonging the life of the surfaces somewhat.

The discussion and conclusions arrived at, although applicable in the case of the first study to runway surfaces only, have some bearing on analogous road design and construction problems.

The fundamental requirements for runway as for road surfaces are essentially identical. But in runways the conditions are more or less uniform while the design of road surfaces varies according to the type, weight, and speed of the traffic to be provided for on each particular road and the application of the fundamental principles, therefore, varies accordingly.

These studies were conducted as a part of the research programme of the Central Road Research Institute.

The Director acknowledges the help given by their work in the laboratory by Messrs R. B. Seth, S. R. Bindra and K. P. Bannerjee of the Institute staff.

INVESTIGATION OF THE SURFACE OF THE BITUMINOUS CARPET OF A RUNWAY USED BY NORMAL AIR TRAFFIC

1.1. The Problem

1.1.1. Exposition

The problem for examination was put to the Central Road Research Institute in the form of a statement :—

> "Whether the surface of the carpet on the main runway, had dried up too much and whether there was still sufficient binder left to keep the bituminous premix in a workable condition."

This question arose when the experience of the aircraft maintenance crews showed very high wear on the rubber tyres of the aircraft using the runway. The heavy wear indicated a very rough surface of the runway which was not usually found with bituminous premix carpets.

It appeared from an examination of the specifications received from the authority responsible for the construction that a 2½-in. premix carpet with 25 lb of Shellmac for every 4 cu. ft. of grit, ½ inch downward, had been laid on the runway in 1945-46. A tack coat covered by a seal coat using 15 lb of Shellmac B. S. and 2½ cu. ft. of grit, ¼ inch downward, per 100 sq. ft. already existed under the premix carpet. These two preliminary coats were given in order to fill up the depressions in the older carpet constructed in 1942, and to get an even surface on which the 2½-in. premix carpet could be laid.

1.1.2. Appearance

The surface looks level in spite of the very coarse grit which shows, on account of its coarse size, partial depressions and stoney projections. The peculiarity is that the coarse pieces of grit, up to about ½ inch in diameter, show a strong interlocking even without being covered and coated with binder. The quartzite grit shows its crystalline texture clearly which indicates once again the difficulties created by the poor adhesive capacity of crystalline grit (compare Photos 3 to 6).

1.2. Investigations

1.2.1. Binder Content and Grading

After having excavated two samples (vide Photos 1 and 2), each 1 sq. ft. in area, of the surface up to a depth where binder was no longer found, pieces of the top 2½ inches of the surface were cut off from these samples and from these pieces the binder content extracted.

The results of extraction from these two relatively large pieces of the top carpet gave an average binder content of about 6.2 per cent. The sieve analysis of the mineral residue is given in Table 1 and presented graphically in Figure 1.

The resulting summation curve of the mineral fractions of the runway surface is compared with a grading obtained from the normal grit, of a size ½ inch downward, from an ordinary quartzite quarry. Table 1 and Figure 1 show clearly that the mineral residue in the runway, in spite of a content of about 10 per cent fine materials [less than 0.85 mm dia. (B. S. S. 18)], consists of almost 65 per cent of grit bigger than ¼ inch and therefore is, all in all, of a considerably coarser grading than the ½ inch grit from the quarry.

Table 1

Grain Size Distribution and Summation Curves

British Standard Sieves	Fractions ½ inch normal	Fractions Surface examined	Summation ½ inch normal	Summation Surface examined
½ inch	2.03	—	100.00	—
3/8 do.	13.53	43.23	97.97	100.00
¼ do.	25.22	19.86	84.44	56.77
5 mesh	23.46	14.90	59.22	36.91
8 do.	18.74	7.77	35.76	22.01
18 do.	11.96	4.95	17.02	14.24
36 do.	1.42	1.80	5.06	9.29
60 do.	1.71	2.19	3.64	7.49
100 do.	0.90	1.21	1.93	5.30
200 do.	0.67	1.77	1.03	4.09
Passed 200 mesh	0.36	2.32	0.36	2.32
	100.00	100.00		

Photo 1.

A sample of the runway surface. It lies upside down and shows, in a depth of 5 inches, a well preserved accumulation of pure binder.

Scale in inches.

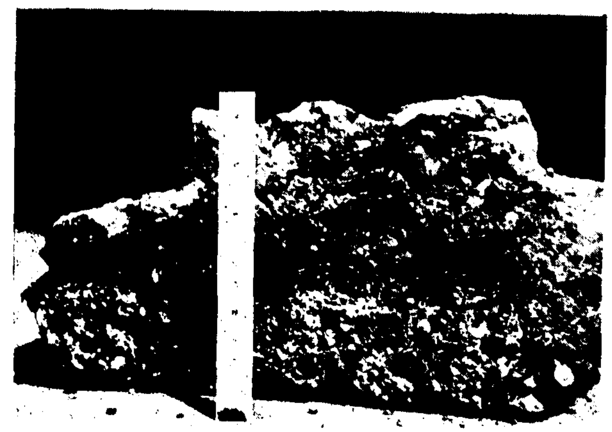


Photo 2.

Another sample out of the same runway put upside down. The top carpet constructed in 1945-1946 of 2½ in. thickness is clearly seen below the older surface of 1½ in. thickness constructed in 1942.

Scale in inches.

Note :—Photo 1 of a sample lying upside down, i. e., with the wearing surface downwards, shows that below the older surface constructed in 1942, in the sub-base, occasional nests of pure binder are formed. This does not, however, necessarily indicate that this binder has flowed from the present surface (carpet) into the sub-base. It could have come from the coat (1942) in the same way and might probably be attributed to that period.

Photo 3.

These Photos show the average surface of the runway. Some stones are noticed to be coated with binder and others show hardly any bituminous material. The sharp edges are clearly to be seen.

Scale in mm. About 78% natural size.

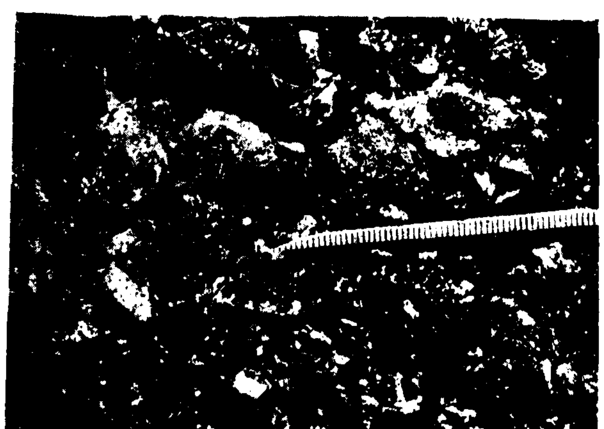


Photo 4.

Photo 5.

These Photos show portions from parts of the surface where extreme conditions are met. Almost all binder has disappeared. The chips themselves are well interlocked but all edges are very much exposed.

Scale in mm. About 78% natural size.

Photo 6.

1.2.2. Deliberations

The original specification provided a binder content of 25 lb for every 4 cu. ft. of grit, ½ inch downward. This gives a binder content of about 7 per cent. The content extracted from the 2½ inch thick surface layer after 6-7 years of use is found to be about 6·2 per cent. This diminution can be considered as normal, taking into account the weather effects of seven summers.

Today it seems that the originally applied content of 7 per cent was a little too much for a premixed carpet containing the coarse grit found in the samples. The result was that the coating layer of binder round the grit became relatively thick and then, on exposure to the hot sun, it flowed down into the lower portion of the top carpet, where it remained relatively immune to the effects of the weather. Otherwise, the whole layer could not have retained till now 6·2 per cent binder out of the 7 per cent applied.

With a binder of a lower penetration this effect might have been diminished to a certain extent, but this property of the binder should probably not be considered as one of the main reasons of the defects observed.

1.3. Evaluation

The investigation shows that as the grading of the 2½ in. premixed carpet constructed in 1945-46 (vide Table 1 and Figure 1), was extremely coarse, the applied binder covered the grit with a very thick coat. This coat could not adhere well to the grit, owing to the crystalline texture of the quartzite, and was exposed to the normally hot sun rays during seven summers.

These reasons resulted in a flow of the binder from the surface into the lower portions of the top carpet so that the stones at the surface, in spite of being well interlocked, presented an extremely rough surface—almost uncoated and with sharp edges—which resulted in a very high and abnormal wear of the rubber tyres of aircraft (compare Photos 3 to 6). The wear-effect will occur and is easily noticed during landings, when the quartzite edges come into contact with tyres moving at a high speed and partially skidding on the runway.

1.4. Conclusion

The high wear of rubber arose out of the too coarse grading used, which made the originally specified binder content surplus and resulted in a thick coat of binder on the pieces of grit. Due to the sun's rays this thick coat of binder flowed downwards and the surface became very dry. Actually almost clean quartzite grit came into contact with the rubber tyers. The overall content of binder in the top carpet built in 1945-46 was reduced during seven years of use from 7.00 per cent to an average of 6.2 per cent which can be considered as a normal loss.

It cannot be said that the carpet as a whole has dried up or the bituminous mixture is no longer effective. But the bitumen having sunk down, the surface is left almost free of binder and this has resulted in a sharper-edged surface texture than is desirable in a runway.

1.5. Remedies

1.5.1. Strength and Requirements

The samples excavated from the runway show that the original base-course and the underlying premix which serves today as a base-coat, are (in addition to the surfacing carpet of 2½ in.) quite capable of taking the load of the present flying traffic. Therefore, when it is asked what would be a suitable method of repairing this surface, it is obvious that the present sub-base, sub-coat and surface can, and should, be retained.

The new surface then has only to fulfil, besides the well known general requirements, the special requirements of runway surfaces, i.e. the surface layer ought to be well compacted and dense, it should provide friction enough to help slow down the landing speed of the incoming aeroplanes, and it should be smooth enough to keep the wear on the rubber tyres within reasonable limits.

1.5.2. Road and Runway Traffic Compared

The fundamental difference between the traffic on a normal runway and that on roads is that, after construction, the traffic load on a runway does not count as a factor for post-compaction while this is an important factor on roads. Hence, on a runway full compaction has to be done during construction and, at the same time, the exposure of the compacted surface to the rays of the sun has to be taken into consideration.

1.5.3. Proposal

Taking into account these two conditions on the runway in question, the whole surface should be covered with a relatively thin (½ in. to 1 in.) premix carpet with a relatively fine and well, graded aggregate. The binder used should have a low penetration and should contain only a small percentage of special cut-back oil required during the period of construction. The oil ought to evaporate soon after the runway is in use.

1.5.4. Gradings

In Figure 1 is given the grading of a normal aggregate of a size ½ in. downward (obtained from a local quarry). Similarly the grading of an aggregate of a size ¼ in. downward from the same place is plotted.

The ¼ in. graph shows definitely a greater fineness but it is still too poor in fine fractions and too rich on the coarse side for a well graded aggregate of the type required. A suitable grading for the proposed repair work should lie in the space shown in the chart (Figure 1) which gives, for instance, American Standards for Runways (1944) for bituminous mortar-carpets in a slightly modified form.

GRAIN-SIZE DISTRIBUTION CURVE

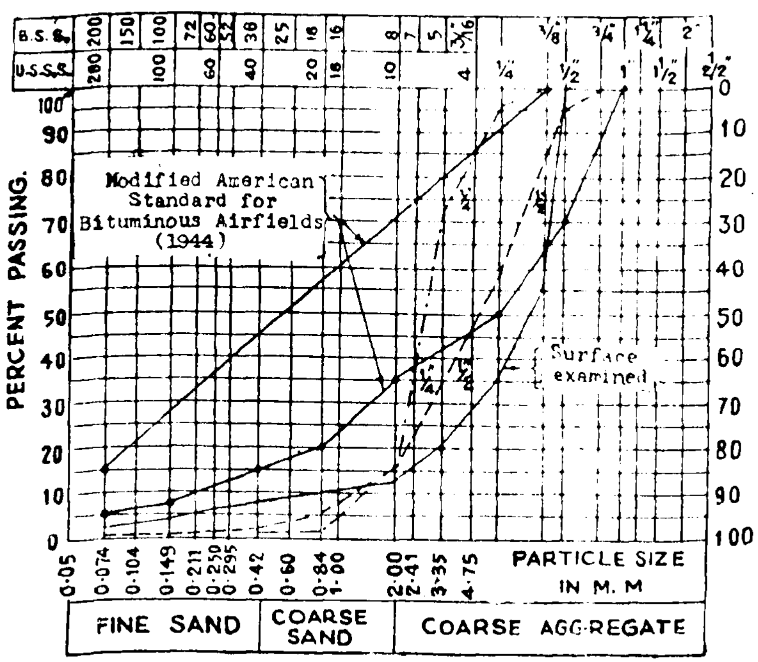


Figure 1.

This means that the local ½ in. aggregate mentioned above will have to be improved by the addition of one or more other aggregates containing more fines to better the grading.

The reason why so much weight has to be given to grading in this particular case, is to ensure that, on the one hand, the surface is coarse enough to provide the required frictional resistance and, on the other, fine enough to seal the surface and to ensure an optimum compaction.

In this special case, because the base course and base-coat together seem to be strong enough, it is not necessary to recoat the surface with two layers in different thicknesses and different aggregate sizes. The new coat is not required to provide additional strength but merely a suitable surface.

1.5.5. General Remarks

In general, to prevent deterioration after some years of service of the kind noticed on this runway, it is necessary that the design should take into consideration both the grading of the aggregate employed and the type of binder to be used.

The binder coat should not be made too thick and the binder used should be hard enough to resist flow within the mix after it is laid. If either of these conditions is not complied with failure may result. Only if both conditions are properly provided for, will good results be obtained.

INVESTIGATION OF THE COARSE AGGREGATE USED IN THE CONCRETE-SLABS OF A RUNWAY UNDER NORMAL AIR TRAFFIC.

2.1. The Problem

2.1.1. Exposition

The problem for examination was put to the Central Road Research Institute in the form of a statement :—

"It has been reported that a portion of the concrete pavement has badly stained or burnt due to the take-off of a jet-aeroplane. This happened at the time of the take-off, and the diameter of the cavities is $1\frac{1}{2}$ inch dia. and $1\frac{1}{2}$ inch deep".

2.1.2. Report

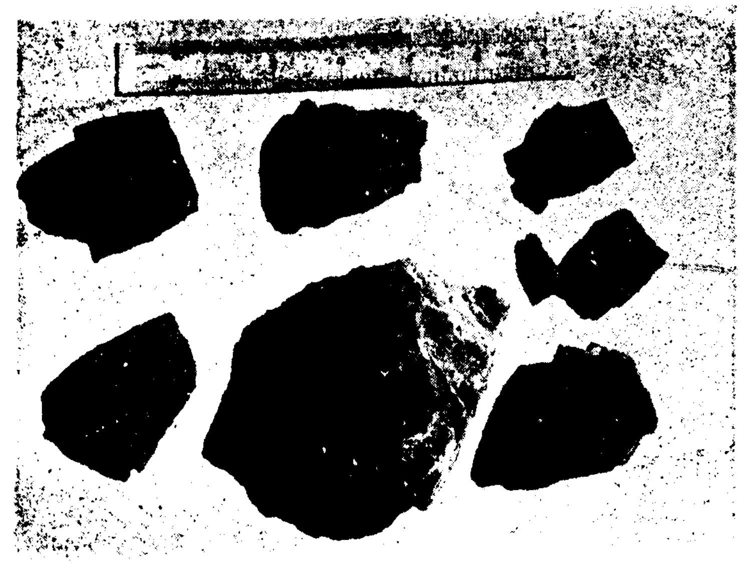
This was based on the following part of a report of the local supervising engineer to the authority concerned.

"It is seen that the concrete has been completely burnt out to ashes in two places. The size of the cavities so formed is not more than $1\frac{1}{2}$ inch deep and about $1\frac{1}{2}$ inch in diameter on the surface. The cavities exhibit a charred appearance and are surrounded by discoloration ranging from darkish brown to light brown as we recede from the cavity. At other places there are stains only and the sizes of these stains vary from $\frac{1}{4}$ inch dia. to 1 inch dia. These stains are darkish brown in the centre and light brown at the periphery. I can ascribe this kind of burning away or staining of the concrete to some kind of corrosive liquid which has a chemical compound affecting the silion in the concrete.

"This liquid appears to have dripped from the aircraft on to the parking apron. Some such stains are also to be seen at the end of the runway from where the aircrafts have taken off. This question was also discussed by me with the Controller of Aerodromes. He was of the opinion that the burns have been caused by the exhaust gases of the aircraft. I, however, cannot subscribe to his views in the face of the facts that the staining in some places is only about $\frac{1}{4}$ inch in diameter and the exhaust from the aircraft could not have been limited to such a minute area".

The runway in question was constructed in 1942.

A$_1$



A$_2$ B$_2$ B$_3$ A$_3$ B$_1$ Samples

B$_1$ Samples

Photo 1. Compare Table 1.
Scale in inches. Excavated : A_1; B_1; B_3.
Collected : B_2; A_3.

Photo 2. A corner of one of the concrete-slabs.

Photo 3.

A piece of metal out of Photo 2 (left).

Scale in cm.

Photo 4.

A piece of metal out of Photo 2 (centre). Scale in cm.
The biggest sample in Photo 1 is the same piece of metal after the excavation.

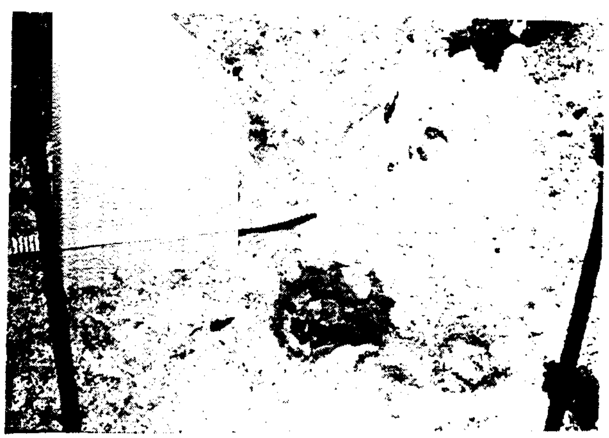


Photo 5.

'Coal-metal' in the concrete surface with some signs of discoloration.
Scale in mm.
About 75% natural size.

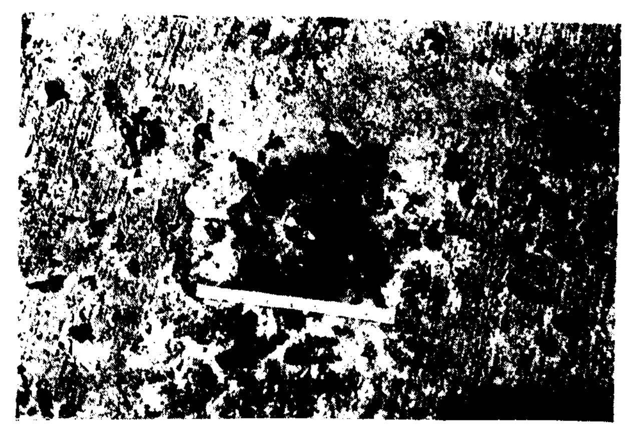
Photo 6.

'Coal-metal' in the concrete surface. The process of shrinkage is very visible.
Scale in mm.
About 75% natural size.

Photo 7.

Hole and discoloration. Dust and powder are still in the hole.
Scale in cm.

Photo 8.



The same place as Photo 7. Dust and powder are removed and the black 'coal-metal' piece is visible deep in the hole.
Scale in cm.

2.2. Preliminary Examinations

2.2.1. Samples

The observed damage of both types, destruction and discoloration, was investigated by examining samples of metal chiselled out of the concrete apron or collected near at hand as shown below.

Stones excavated or collected and tested

No.	Colour	Excavated or collected	Location.
A_1	Dark-grey	Excavated	Apron.
A_2	Dark grey	Collected	Near the runway.
A_3	Reddish-brown	Collected	Near the runway.
B_1	Greyish-blue	Excavated	Apron.
B_2	Black	Excavated	Apron.

Photo 1 shows the different samples collected. Photos 2, 3, and 4, show how the samples B were lying in the surface of the concrete slab. Photo 2 shows a corner of the concrete slab with many big and small samples of the B kind. Photos 3 and 4 show the bigger pieces of metal on a larger scale than that of Photo 2. The biggest sample in Photo 1 is also to be seen in Photo 4 before excavation.

The results of the investigations—physical and chemical—are given in Table 1.

2.2.2. Deliberation

First of all, from the distribution of the damage and its continued occurance even after the first report it seems to be obvious that it was not caused by jet aircraft because no jets, except once for one landing, used this airfield up to the time the samples were collected.

Secondly, many spots of damage showed no trace of any liquid which might have dropped on the concrete-surface. Therefore, the damage could not have arisen solely from dropped hot liquid.

Table 1.

No.	Colour	Excavated or collected	Specific gravity (Average)	Organic matter %	Mineral matter or Ashes %	Iron %	CaO %	SiO_2 %
A_1	Dark-grey	Excavated	2.861	1.297	98.703	5.266	7.539	47.66
A_2	Dark-grey	Collected near the ends of the runway	2.924	—	—	—	—	—
A_3	Reddish-brown	Collected near the ends of the runway	2.555	—	—	2.987	0.389	86.98
B_1	Greyish-blue	Excavated	1.450	77.27	22.73	1.108	0.236	13.37
B_2	Black	Excavated	1.507	62.85	37.15	0.635	0.581	22.65

Furthermore, where discoloration of the surface was noticed, it was always found in close contact with a piece of a certain kind of aggregate. But all areas where that type of aggregate existed were not found to be necessarily discoloured.

2.3. Investigations

2.3.1. Results

Examination showed that two kinds of aggregate had been used, one with a normal specific gravity between 2.5 and 2.9 (Samples A_1, A_2, A_3) and the other with about half of that value, i.e., between 1.4 and 1.5 (Samples B_1, B_2). Samples B_1 and B_2 gave a mineral residue (23 per cent and 37 per cent) and a corresponding high percentage of organic matter (77 per cent and 63 per cent), while the other samples (A) contained nominal percentages of organic matter. The aggregate represented by samples B_1 and B_2 is not any stone usually used for concrete work, but is very similar to coal and will be referred to as 'coal-metal' in the following paragraphs.

2.3.2. Evaluation

Because no samples from the quarry could be obtained, it could not be traced if this 'coal-metal' was a part of the material existing in the quarry or if it had come from other sources. The mixture of the ordinary aggregate (Sample A) with this 'coal-metal' seems to have taken place towards the end of the construction work because it is found only near the ends of the air strip and the apron that was subsequently constructed.

It may, however, be possible that in the quarry itself 'coal-metal' exists as a small mineral deposit, and that this had wrongly been collected and used towards the end of the work. Alternatively the 'coal-metal' may have been mixed with the main aggregate by mistake during the collection, loading, transport, or mixing process.

It is obvious that an unusual quantity of the light-weight 'coal-metal' would be found near the surface of the concrete slab (compare Photos 2 to 8) as it would tend to float in the concrete mix. During construction, however, a sand-cement slurry was swept over the surface of the runway and apron and it took some time for this to wear off under use.

The process which had been taking place during these last 10 years since the work was completed might have been as follows: The 'coal-metal' is very sensitive to heat and, as it

was exposed for many summers to the hot rays of the sun, a slow process of oxidation took place, resulting in a decrease in the volume of the 'coal-metal' pieces.

The effect of this decrease in volume can easily be noticed in Photos 3, 5 and 6. The result was a gradual loosening of the contacts of the 'coal-metal' pieces with the cement mortar. Photo No. 6 shows the relatively big channels that can develop between such pieces and the concrete.

It does not need much external force — even such a small force as may be caused by passing wheels or pedestrians, or any moving contact with any hard material would be sufficient — to dislodge these shrunken, brittle, and soft pieces with a high percentage of voids. Then the bits of the 'coal-metal' are either blown away by wind or settle inside the cavity thus created.

Apart from this process there has taken place another process of oxidation. The results of chemical analysis (Table 1) show that the normal aggregate used in the slab (sample A_1) has a relatively high percentage of Fe-content. This might also be true in the case of the sand used. These minerals must necessarily have been exposed for a long time to the process of oxidation taking place in the 'coal-metal' mentioned above and be affected by this oxidation.

It seems therefore that the first process of oxidation was followed by another less destructive, which involved the iron content of the mortar and the surrounding aggregate, thus changing their colour. This would explain the colour patches as found in places on the surface.

As mentioned above, the coloured patches are always found in contact with a piece of 'coal-metal' which, in every case, was located near the top of the slab or actually at the surface.

Photos 7 and 8 show such a coloured spot, in the middle of which a relatively deep hole existed filled with dust and blue-grey powder overlying a piece of 'coal-metal'. Photo 7 shows the untouched spot. Photo 8 shows the hole after the dust had been removed and a piece of soft 'coal-metal' revealed.

2.4. Conclusion

This investigation and the properties found to exist in the different kinds of aggregates used, lead to the assumption that the defects in the runway and apron had nothing at all to do with any special lubricant that may have been used by the aircraft. The defects seem to arise entirely from the disintegration of the 'coal-metal' during a long period of exposure to the tropical sun. This accounts for both the defects reported — destruction and discoloration of very small areas — in particular parts of the runway and the apron of the airfield.

2.5. Remedies

What will be the consequences of the observed damage to the runway?

It seems obvious that the damage will not affect any normal air traffic operations of the usual present day service. However, if under changed conditions, the single wheel loads of the aeroplanes in use increase, some precautions may have to be adopted.

The runway and apron were constructed without reinforcement and, being only 5 inches thick, might show in small areas a certain accumulation of the observed damage. Obviously, this will reduce the constructional thickness and to that extent the strength of the concrete pavement will be lowered.

If a heavier air service is to be introduced and the wheel loads begin to approach the limits of the reduced bearing capacity of the concrete-slabs, their strengthening might be necessary.

This can perhaps best be done by covering the surface where the defects have been noticed by a black-top-paving of sufficient structural strength to restore the loss of strength arising from the reduced thickness of the concrete. From then onwards, oxidation will take place only at a very diminished rate. Any "dips" subsequently appearing can easily be filled with a black-top mixture.

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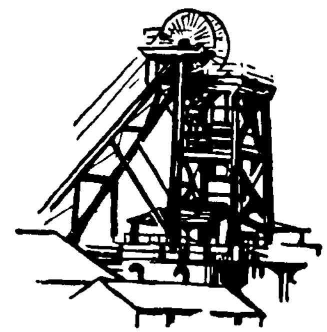

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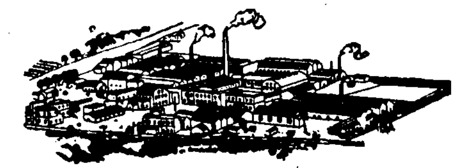

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