1068

Indian Roads congrees.

Vol. XIX – I

1954 – 55

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

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,	B. Chatterjee, *Colonel,*
The 5th March 1951.	*Military Secretary to the President*

INDIAN ROADS CONGRESS

ESTABLISHED : 1934 REGISTERED : 1937

OFFICE-BEARERS AND COUNCIL 1954-55.

President :

H. P. Mathrani, I.S.E.,
Consulting Engineer to the Government of India,
(Road Development), and Joint Secretary to the
Government of India, Ministry of Transport, (Roads Wing),
NEW DELHI.

Vice-Presidents :

C. M. Bennett, I.S.E.,
Chief Engineer, P.W.D., B. & R.,
BHUBANESWAR (Orissa).

U. N. Mahida, I.S.E.,
Chief Engineer, P.W.D., R. & B.,
BOMBAY.

F. P. Antia,
Joint General Manager,
M/s. Cement Marketing Co. of India,
1, Queen's Road, Fort,
BOMBAY.

Honorary Treasurer :

H. P. Mathrani, I.S.E.,
Consulting Engineer to the Government of India,
(Road Development), and Joint Secretary to the
Government of India, Ministry of Transport, (Roads Wing),
NEW DELHI.

Honorary Deputy Treasurer :

Goverdhan Lal,
Deputy Consulting Engineer to the Government of
India (Roads), Ministry of Transport, (Roads Wing),
NEW DELHI.

Honorary Secretary :

J. Subrahmanyam,
Divisional Engineer (Consultant),
Ministry of Transport, (Roads Wing),
NEW DELHI.

Members of the Council :

1. C. J. Fielder
2. R. N. Joshi
3. O. C. K. Krishnan
4. E. A. Nadirshah
5. L. R. Patel
6. S. N. Sinha
7. M. Meeran
8. S. N. Gupta
9. C. P. Misra
10. E. V. S. Iyer
11. S. C. Nayak
12. J. M. Frederick
13. B. Chaudhury
14. M. L. Bahl
15. R. K. Batra
16. K. K. Nambiar
17. D. P. Nayar
18. M. S. Bisht
19. T. Mitra
20. H. R. Gupta
21. D. V. Rao
22. D. N. Gupta
23. P. V. Divatia
24. Raghbir Singh
25. Kishore Lal
26. U. J. Bhatt
27. K. K. Kartha
28. Brig. K. N. Dubey
29. M. S. Mathur
30. G. M. McKelvie

PERSONNEL OF THE TECHNICAL COMMITTEES AND SUBCOMMITTEES

1. *SPECIFICATIONS AND STANDARDS COMMITTEE* :

Goverdhan Lal ... *Convenor*
H. Sunder Rao ... *Member-Secretary*

(i) *Geometric Design Division* :

T. Mitra
J. M. Trehan
K. K. Nambiar
U. N. Mahida
H. P. Sinha
J. Subrahmanyam
N. V. Modak
P. L. Varma

(ii) *Pavement Design Division* :

M. S. Bisht
J. Subrahmanyam
U. J. Bhatt
H. P. Sinha
S. R. Mehra
J. M. Trehan
C. J. Fielder
Sujan Singh
K. F. Antia
O. C. K. Krishnan

(iii) *Specifications & Costing Division* :

H. P. Sinha
S. E., Planning Circle, C. P. W. D.
J. M. Trehan
J. Subrahmanyam
Chief Surveyor of Works, E-in-C's Branch
U. N. Mahida

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
G. R. Nangea
Balwant Singh Nag
J. Chambers
A representative of Central Board of Irrigation & Power

(ii) *Substructure and Superstructure Division* :

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

3. *TECHNICAL SUBCOMMITTEE* :

(i) *Test Track Division* :

T. Mitra ... *Convenor*

C. J. Fielder
S. N. Gupta
Director, C. R. R. I.
E. A. Nadirshah
S. N. Chakravarti
H. P. Mathrani
Sujan Singh
T. C. Sahani
G. Srirangachari

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 & 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
Director, C. R. R. I.
A representative of Soil Laboratory, West Bengal
K. F. Antia
H. Sunder Rao ... *Member-Secretary*

4. *ROAD TRANSPORT SUBCOMMITTEE* :

U. N. Mahida ... *Convenor*

K. M. Kantawala
V. N. Rangaswami
B. V. Vagh
R. N. Dogra
N. V. Modak
E. A. Nadirshah
N. D. Daftary

C. S. Anantapadmanabhan ... *Member-Secretary*

5. *SOIL RESEARCH SUBCOMMITTEE* :

Director, C. R. R. I. ... *Convenor*

U. J. Bhatt
Director, Hyderabad Research Station
E. C. Chandrasekharan
S. R. Mehra
D. C. Chaturvedi
A. K. Deb
S. N. Gupta
J. M. Trehan
G. Srirangachari

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

6. *EDUCATION SUBCOMMITTEE* :

E. A. Nadirshah ... *Convenor*

N. V. Modak
K. F. Antia
S. R. Mehra
Goverdhan Lal
P. L. Varma
K. K. Nambiar
H. Sunder Rao

D. G. Bhagat ... *Member-Secretary*

7. *PROVINCIALIZATION OF LOCAL BODIES ENGINEERING SERVICES SUBCOMMITTEE* :

B. N. Roy ... *Convenor*

Y. K. Chaugule
H. S. Sharma
T. K. Macha
M. P. Srivastava
B. N. Shenoy
S. Gupta
U. N. Mahida

S. K. Rajagopalan *Member-Secretary*

8. *PAPERS SUBCOMMITTEE* :

H. P. Mathrani ... *Convenor*

U. N. Mahida
K. F. Antia
Goverdhan Lal

Secretary, I. R. C. ... *Member-Secretary*

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

R. S. Bhalla ... *Convenor*

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

10. *ORGANIZATION COMMITTEE* :

H. P. Mathrani ... *Convenor*

H. P. Sinha
K. K. Nambiar
U. N. Mahida
U. J. Bhatt
Kishore Lal

Secretary, I. R. C. ... *Member-Secretary*

11. *ROAD OPERATION COST COMMITTEE* :

H. P. Mathrani ... *Convenor*

K. K. Nambiar
Jagadish Prasad
N. D. Daftary
U. N. Mahida
E. A. Nadirshah
H. Sunder Rao

C. S. Anantapadmanabhan ... *Member-Secretary*

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

INDIAN ROADS CONGRESS

NOTICES AND ANNOUNCEMENTS

CONTRIBUTION OF PAPERS FOR THE SESSIONS OF THE INDIAN ROADS CONGRESS

The Nineteenth General Session of the Indian Roads Congress be held from 18th to 25th at Srinagar (Kashmir) in June 1955. The detailed programme of the Session will be communicated to Members in due course.

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

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

3. **The complete Paper, if intended to be read at the 20th Session, should preferably be submitted within next six months.**

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

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

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

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

(i) **The Mitchell Medal**:

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

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

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

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

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

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

1. The following Medals are available for award:

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

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

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

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

2. PROCEDURE FOR CONTRIBUTION OF TECHNICAL PAPERS

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

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

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

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

3. RULES FOR THE CONTRIBUTION OF TECHNICAL PAPERS

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

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

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

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

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

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

4. SCRIPT

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

a. All contributions should be drafted in the third person.

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

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

5. ILLUSTRATIONS

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

a. Line drawings.

b. Half-tones.

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

Line drawings are generally classified into two categories:

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

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

5.3. *Diagrams*:—The matter for the Journal is printed in 10 pt. size type (nearly 1/16 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 at least be $\frac{1}{8}$ 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. In drawing diagrams or graphs, the following points deserve the consideration of Authors.

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

The appearance and effectiveness of a graph depend in a large measure on the relative width of lines used in its component parts. The thickest line should be used for the principal curve if several curves are presented on the same graph, the line width used for curves should be less than that used when a single curve is presented. Co-ordinate rulings should be the narrowest in thickness. Principal reference lines such as the axes should be wider than other rulings but narrower than curves. For the size of reduction that is usually adopted, for the I. R. C. Journals, it is considered that the thickest line *when finally reduced* should not be more than $2\frac{1}{2}$ points, *i.e.* 0.035 inch in width.

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

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

6. BRIDGE DETAILS

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

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

b. A dimensioned cross-section of the roadway;

c. The loading on which the design is based;

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

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

7. UNITS

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

STANDARD UNITS OF WEIGHT AND MEASURE

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

8. FORMULAE

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

9. ABBREVIATIONS

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

10. ITALICS AND EMPHASIS

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

11. PARAGRAPHING

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

I.
II.
    1.
    2.
        a.
        b.
            (i)
            (ii)

12. ACKNOWLEDGMENTS

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

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

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

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

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

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

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

6. Members who do not want to speak but want clarification of any issues arising out of the discussion or the introductory remarks of the Author should write out their queries on

"Comment Slips" which will be provided for the purpose while the discussions are in progress. Volunteers will be deputed to distribute and collect these slips at frequent intervals. The slips will be sorted out by the Secretary and at the end of the talk by the Speaker or Speakers, the Chairman will read out the queries and the Speaker or the Author will give a reply.

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

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

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

IV. LIBRARY

1. Information and books on loan from the libraries of the Consulting Engineer (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.**

Applications 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.

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

(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 deprive 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 (Road Development)'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.

V. NEW ADMISSIONS

LIST OF MEMBERS OF THE INDIAN ROADS CONGRES! ENROLLED FROM 1—10—1954 TO 15—2—1955

Serial No.	*Roll No.*	*Name*	*Address*
1	1851	K. K. Sarda	Executive Engineer, Roads Construction Division, Sirsa, Distric Hissar.
2	1852	V. M. Bawishi	Superintending Engineer, P.W.D. B/R, Saurashtra, Rajkot.
3	1853	K. B. Mathur	Assistant Engineer, P.W.D., B/R Rajasthan, South Sub-Division Alwar.
4	1854	I. D. Vyas	Deputy Engineer, P.W.D., Dilaram Race Course Road, Baroda.
5	1855	B. N. Sahay	Sub-Divisional Officer, P.W.D. Road No. 9, Qr. No. 3, 'R' Block Patna. (Bihar).
6	1856	Alam Singh	Assistant Professor, M. B. M. Engineering College, Jodhpur.
7	1857	T. S. Khanna	Senior Scientific Officer, The Centra Road Research Institute, C.R. R.] Post, Okhla, New Delhi.
8	1858	R. T. Ghia	Executive Engineer, P.W.D., Sorat Division, Junagadh.
9	1859	S. Balbir Singh	Assistant Engineer, Central Work Sub-Division, No. I, Centre P.W.D., Dhanbad.
10	1860	T. M. Sidhwa	Assistant Engineer, U.P., P.W.D B & R, Meerut.
11	1861	J. G. Bodhe	Consulting Civil Engineer an Architect, 24-26, Dalal Street Fort, Bombay.
12	1862	P. C. Varghese	Lecturer, Civil Engineering Department, Indian Insitute of Technology, Kharagpur. (West Bengal).
13	1863	Bhawanath Prasad	Assistant Engineer, P.W.D., Saharsa District Saharsa. (Bihar).
14	1864	J. M. Frederick	Chief Engineer (Highways), Andhı State, 11/12, First Line Beacl Madras-1.

ASSOCIATE MEMBERS

1	53	Messrs Shah Construction Co. Ltd.	198, Churchgate Reclamation, Jamshedji Tata Road, Bombay-1.
2	54	Messrs Burn & Co. Ltd.	12, Mission Row, Post Box No. 191, Calcutta-1.

VI. DEATHS

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

Serial No.	*Roll No.*	*Name*	*Address*
1	196	A. Burns Lawson	The Hindustan Construction Co., Ltd., Ballard Estate, Bombay.
2	1798	M. N. Patni	Executive Engineer, City Division, Bikaner.
3	272	M. N. Bhuyan	Executive Engineer, New Capital, Bhubaneswar (Orissa).

VII. ADDRESSES WANTED

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

Serial No.	*Roll No.*	*Name*	*Address as last known*
1	452	Ajwani, J. M.	C/o. Shri Moti G. Ajwani, 56, Bhagwandas Chawl, Bhavani Peth, Poona.
2	1771	Krishnappa, S.	Surveyor Assistant (M. E. S.), C/o. Shri M. K. Subba Rao, B-7/125, Lodhi Colony, New Delhi.

VIII. FIFTH MEETING OF THE INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING, LISBON.

The subjects for the 5th Congress of the I A B S E, which will be held from 18th to 23rd June 1956 at Lisbon, are as follows:

GENERAL QUESTIONS

I. Loading and Strength of bridges and structures.

a. Behaviour of materials and structures under statical long time loading.

b. Behaviour of materials and structures under dynamical loading. (Vibrations, fatigue, impact.)

II. Slabs and various curved structures in reinforced concrete.

a. General calculations (in elastic and plastic fields); experimental methods.

b. Application of the methods of calculation to steel structures.

c. Application of the methods of calculation to reinforced concrete structures.

STRUCTURES IN STEEL AND LIGHT METAL

III. Welded steel structures.

a. Systematic investigation of constructional details (theory and experiment).

b. Structural steels for welded structures.

c. Various welding methods for the execution of welded steel construction.

IV. Structures in steel and light alloys.

a. Light construction in steel.

b. Construction in light alloy.

c. Various structures (Power transmission poles etc.)

d. Maintenance of metal structures.

STRUCTURES IN REINFORCED AND PRESTRESSED CONCRETE

V. **Special problems of reinforced and prestressed concrete.**

a. Crack formation (Use of high tensile steels and steels with high bond strength, and anchorages, distribution of reinforcement, shear strength).

b. Influence of atmospheric actions and of temperature changes on the behaviour of structures.

c. Safety (calculation against cracking, rupture etc.)

VI. **Practice of reinforced and prestressed concrete.**

a. Execution of the structures (formwork, shuttering, placing and control of concrete, transport of concrete, jointing of pre-fabricated elements, observation, control and maintanence of structures).

b. New developments.

Paper No. 171

A NEW APPROACH TO THE ANALYSIS OF STABILITY OF SLOPES

By

P. C. VARGHESE, B.Sc., B.Sc. (Eng.), M.Sc., M. Eng. (Harvard).

CONTENTS

SYNOPSIS

A procedure for analysing homogeneous clay slopes by "Resistance Envelopes" is described. It is claimed that "Resistance Envelope" which is evolved by assuming a number of "Circles of failure" for a given slope, can be used as a design curve for that slope.

The results show agreement with those obtained by the "Friction Circle" method. Worked out examples are given.

1. INTRODUCTION

1.1. Soil slopes are usually analysed by the Swedish method. This method was originated by Petterson who first applied it to the analysis of the failure of a quay wall in Sweden in 1916. The following assumptions are made :

(a) The material is homogeneous.

(b) The shear strength characteristics of the material are known.

(c) The slope fails by sliding along an arc of a circle.

1.2. Different procedures have been recommended for the analysis of slopes by this method but all of them require a knowledge of the actual values of cohesion c and the angle of internal friction ϕ before the analysis can be made. Generally the value of ϕ is assumed and the factor of safety of the slopes with respect to c

is calculated by trial and error. However, the whole operation of trial and error has to be repeated if the value of ϕ is changed. This entails as many operations of trial and error as the number of values of ϕ assumed. Hence it is very desirable to develop a procedure by which the trial and error work is done only once and solutions for any combinations of c and ϕ can be readily found without recourse to additional trial and error. This Paper describes such a general procedure.

2. THEORY OF THE SUGGESTED GENERAL PROCEDURE

2.1. Consider a unit length of plane slope of homogeneous material represented by ac in Fig. 1. Let arc ab represent the assumed sliding surface. The mass above ab is in equilibrium

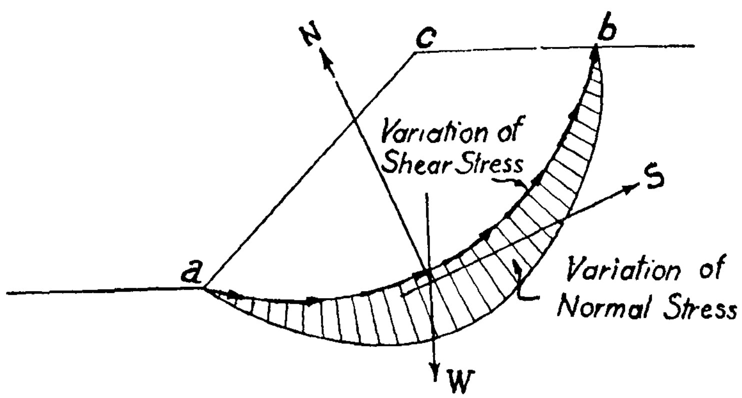


Fig. 1. **Equilibrium of a Sliding Mass of Soil.**

under the action of three forces :

(a) The weight of the mass (W).

(b) The shearing resistance (S) of the soil along arc ab.

(c) The normal pressure (N) along the arc ab.

2.2. The normal pressure and shear resistance developed vary along the arc ab as indicated in Fig. 1, the actual distribution being unknown. The problem is therefore statically indeterminate unless some simplifying assumptions concerning the distribution of normal pressure or the distribution of shear resistance are made. So, in the analysis of clay slopes, the assumption that the shear stress is uniformly distributed along the arc of sliding is made. In the Friction circle* method the assumption is made that the resultant of the normal and shearing stresses is tangential to the friction circle due to friction on the surface of sliding. Once the direction of S or N is determined, their values can be easily found by drawing a triangle of forces.

2.3. Let S and N be the magnitude of the resultant shear resistance and resultant normal force determined by incorporation of suitable assumptions. The average shear stress along the arc of failure is then designated as $\frac{S}{L}$ and the average normal stress as $\frac{N}{L}$ where L is the length of chord ab. To represent these quantities for any circle of failure by dimensionless quantities the following terms must be introduced.

$$\overline{S}=\frac{S}{L\gamma_m H}$$

$$\overline{N}=\frac{N}{L\gamma_m H}$$

where γ_m = Unit weight of earth fill,

H = Height of the slope, and

L = Length of chord ab.

2.4. For any one slope, each assumed circle of failure will yield a set of values of $\overline{S}$ and $\overline{N}$ which can be plotted on a $\overline{S}-\overline{N}$ diagram as shown in Fig. 2. The envelope obtained by plotting

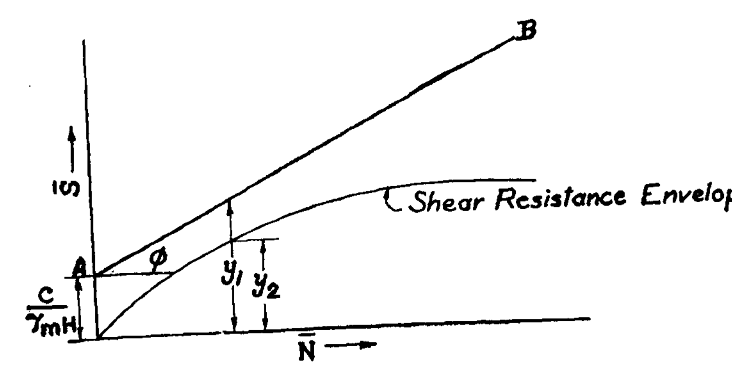


Fig. 2. **$\overline{S}-\overline{N}$ Curve and determination of Factor of Safety.**

*See Fundamentals of Soil Mechanics by D. W. Taylor, John Wiley and Sons, New York, 1948, (p. 441).

all possible values on the $\bar{S}-\bar{N}$ diagram may be termed "Shear Resistance Envelope" (Fig. 2) for the particular slope. As this shear resistance envelope (a plot between dimensionless quantities) is independent of the shear strength characteristics of the soil it represents a general relation between the normal pressure and the minimum value of shear strength that should be developed by the material for stability of the slope.

2.5. The factor of safety of a slope against failure (Gs) may be defined as

$$Gs = \frac{\text{Shear strength available}}{\text{Shear strength required for equilibrium}}$$

For determining Gs for a given slope, the shear strength—normal pressure curve for the soil composing the slope ($s-p$ curve) obtained by shear tests should be reduced to one which can be plotted on the $\bar{S}-\bar{N}$ diagram. Then the smallest value of the ratio

$$\frac{\text{Value of } \bar{S} \text{ on the strength curve}}{\text{Corresponding value of } \bar{S} \text{ on resistance envelope}}$$

gives the factor of safety of the slope against failure.

2.6. For example, to find the factor of safety of a slope of height H in a material whose shear strength is assumed to follow the relationship $s=c+p \tan \phi$ the procedure is as follows. Plot on the $\bar{S}$ axis (Fig. 2) a point A having an ordinate equal to $\frac{c}{\gamma_m \times H}$ and draw a line AB at an angle ϕ to the $\bar{N}$ axis. Then AB represents the strength line on the $\bar{S}-\bar{N}$ diagram. The factor of safety of the slope in question is given by the smallest ratio of $\frac{y_1}{y_2}$. The true factor of safety is calculated for a given problem as shown in examples at the end of the Paper.

2.7. The advantage of the suggested procedure lies in the fact that once the resistance envelope is developed for a particular slope the factor of safety of the slope can be found out for any strength curve, either straight or curved from the resistance envelope. In contrast, when using the existing procedure it is customary to make a separate analysis for each assumed strength curve. Thus the new procedure of analysis may be called the general procedure for analysis of slopes. Different procedures to suit individual taste can be used to evaluate the values of $\bar{S}$ and $\bar{N}$. These different methods are not dealt with in this Paper as they are well known.

3. APPLICATION OF THE PROCEDURE

3.1. On the basis of the above procedure plane slopes of 15°, 30°, 45°, 60°, 75°, and 90°, were analysed by the Author and the results of analysis are given in Table 1. These values are plotted on the $\bar{S}-\bar{N}$ diagram in Plate I. The value of S was determined on the assumption that the shear resistance is uniform along arc ab. Investigation with other types of distribution showed that the above simple assumption gave good results for all practical purposes and that the differences in the values obtained by the various assumptions regarding the distribution of the shear resistance were practically negligible. The curves in Plate I represent the resistance envelope diagram for the various slopes and can be used for design of slopes by plotting the strength curves for the given soils alongside the $\bar{S}-\bar{N}$ diagram as explained in para. 2.4. Examples at the end of the Paper illustrate this.

3.2. In general, all the resistance envelope diagrams pass through the origin at an angle equal to the angle of the slope. The value of $\bar{S}$ then gradually increases with $\bar{N}$ until it reaches a maximum value. The position of the centres of the critical circles (i.e., circles which are represented on the $\bar{S}-\bar{N}$ diagram) lie on a curve as shown in Plate II. In general they lie on a curve which begins at the point corresponding to the failure circle for $\phi=0°$ and asymptotically approach the perpendicular bisector of the slope.

3.3. The above can be explained by the fact that the tangent at the origin of the resistance envelope represent the value of ϕ when $c=0$ and as the cohesion of the soil increases the value of ϕ required for equilibrium decreases until for a certain value of c the value of ϕ required is zero. With this gradual change the centre of the critical circle shifts along a smooth curve from infinity to the centre of the circle for the case $\phi=0$.

TABLE 1

Values of $\overline{N}$ and $\overline{S}$ for Points on Resistance Envelopes for Toe-Circle Failure in Plane Slopes

Slope Angle in degrees	$\overline{N} = \frac{N}{\gamma_m HL}$	$\overline{S} = \frac{S}{\gamma_m HL}$	Slope Angle in degrees	$\overline{N} = \frac{N}{\gamma_m HL}$	$\overline{S} = \frac{S}{\gamma_m HL}$
15	1.260	0.145	60 (*Contd.*)	0.279	0.186
	0.762	0.133		0.251	0.181
	0.434	0.099		0.221	0.175
				0.190	0.168
30	0.653	0.156		0.167	0.157
	0.544	0.154		0.138	0.145
	0.486	0.150		0.117	0.132
	0.403	0.142		0.083	0.107
	0.378	0.140			
	0.315	0.131	75	0.301	0.218
	0.260	0.118		0.258	0.217
	0.208	0.099		0.202	0.209
	0.151	0.075		0.145	0.188
				0.104	0.162
45	0.446	0.171		0.061	0.127
	0.401	0.170		0.030	0.081
	0.324	0.164			
	0.271	0.158	90	0.270	0.261
	0.204	0.138		0.240	0.261
	0.161	0.120		0.193	0.251
	0.116	0.096		0.146	0.237
				0.103	0.213
60	0.357	0.191		0.070	0.183
	0.311	0.189		0.044	0.148
				0.020	0.105

4. COMPARISON OF RESULTS

4.1. A comparison of the results obtained by the procedure described was made with the results obtained by the "Friction circle" procedure originated by Prof. Taylor, Table 2. The results show a fair agreement of values.

TABLE 2

Comparison of Results obtained by the New Procedure with Results Obtained by the Friction Circle Procedure

Slope Angle	ϕ Degrees	$\frac{c}{\gamma_m H}$ by ϕ circle procedure	$\frac{c}{\gamma_m H}$ by new procedure	Slope Angle	ϕ Degrees	$\frac{c}{\gamma_m H}$ by ϕ circle procedure	$\frac{c}{\gamma_m H}$ by new procedure
15°	0	0.144	0.145	60°	0	0.191	0.191
	5	0.072	0.073		5	0.163	0.161
	10	0.024	0.025		10	0.139	0.137
					15	0.118	0.117
					20	0.098	0.097
					25	0.081	0.080
30°	0	0.156	0.156	75°	0	0.219	0.218
	5	0.112	0.110		5	0.195	0.195
	10	0.078	0.075		10	0.173	0.174
	15	0.049	0.047		15	0.153	0.155
	20	0.027	0.023		20	0.135	0.137
	25	0.010	0.007		25	0.118	0.122
45°	0	0.170	0.171	90°	0	0.261	0.261
	5	0.138	0.136		5	0.239	0.240
	10	0.110	0.110		10	0.218	0.217
	15	0.086	0.087		15	0.199	0.200
	20	0.065	0.065		20	0.182	0.185
	25	0.046	0.046		25	0.166	0.168

5. CONCLUSIONS

5.1. The general procedure described in this Paper can be applied also to the analysis of irregular slopes. An example of such a slope with its resistance envelope is shown in Plate IV. The factor of safety of the slope for any soil having any values for c and ϕ can be obtained using the resistance envelopes described in para. 2.4.

5.2. The same type of analysis can be applied for base failure of slopes. Results of an investigation for a 30° slope for various depth factors are shown in Plate III.

5.3. The general procedure of analysis can be used with suitable modification for the analysis of slopes under submerged and sudden draw down conditions. The effect of submergence can be easily taken into account by considering the unit weight of the material of the slope to be equal to its submerged unit weight. The effect of sudden draw down can be taken by either reducing the effective frictional angle ϕ or by actual determination of the neutral pressure. This is illustrated in the first worked out example.

5.4. The general procedure of analysis of stability of slopes is thus a practical tool for analysis of slopes. For regular slopes the curves developed by the Author can be used for design purposes and the factor of safety of the slope for any soil can be easily determined very quickly. For irregular slopes the general procedure can be used to develop the resistance envelope, Plate IV. The advantage of this procedure over others is that the trial and error work has to be done only once and the resistance envelope forms the design curve that can be used for any shear strength characteristics, including the variations of shear strength with time.

6. EXAMPLES

Example I

A 45° cut 20 feet deep is to be made across flat land where the water table is just at ground surface. The soil has a specific gravity of 2.80 and a void ratio of 0.75. It is specified that the true factor of safety is to be 1.5. The effective angle of internal friction may be assumed to be constant and equal to 15°. What values of unit cohesion are required for stability when

a. the cut is submerged,

b. the cut is unwatered and there is a steady state of seepage, and

c. there is a drop in the water table and no seepage

Let c = Apparent cohesion of soil.

F_c = Factor of safety with respect to cohesion.

γ_m = Weight per unit volume of soil.

H = Height of slope.

ϕ = Angle of shearing resistance of soil.

F_f = Factor of safety with respect to friction.

F_t = True factor of safety as defined by Prof. Taylor, i.e., factor of safety with respect to both friction and cohesion.

(a) The Cut Submerged

Effective weight of soil $= \frac{s-1}{1+e} w_o$ = 64.3 lb per cu. ft.

e = Void ratio.

s = Specific gravity of the soil.

w_o = Weight of one cu. ft. of water = 62.5 lb.

If we choose to use a factor of safety F_t with respect to both friction and cohesion we have

$$F_c = F_f = F_t = 1.5$$

$$\phi_D = \frac{\phi}{F_t} = \frac{15}{1.5} = 10^\circ$$

Draw a line LM at 10° to the horizontal and tangential to the $\bar{S} - \bar{N}$ diagram for 45° as in Plate V.

Intercept on $\bar{S}$ axis $= 0.110 = \frac{c}{\gamma_m H}$

Value of c required for a factor of safety of 1.5 with respect to cohesion. $\Big\}$ $= 0.110 \times 64.3 \times 20 \times 1.5$ = 212 lb per sq. ft.

(b) Cut Unwatered and in a Steady State of Seepage.

The weighted friction angle $\phi_w = \frac{s-1}{s+e} \times \phi$

$$= \frac{1.8}{3.55} \times 15 = 7.6$$

$$\phi_D = \frac{\phi_w}{F_t} = \frac{7.6}{1.5} = 5.1^\circ$$

Effective weight of soil = 64.3 + 62.5 = 126.8 lb per cu. ft.
Intercept of Line YZ on $\bar{S}$ axis for a 45° slope with $\phi_D = 5.1°$

$$= 0.136 = \frac{c}{\gamma_m H} \text{ (See Plate V).}$$

Value of c required with a factor of safety of 1.5

$$= 0.136 \times 126.8 \times 20 \times 1.5 = 520 \text{ lb per sq. ft.}$$

(c) Complete Consolidation

$$\phi_D = \frac{\phi}{1.5} = \frac{15}{1.5} = 10^\circ \text{ as in case (a)}$$

Effective weight of soil = 126.8 lb per cu. ft.

Intercept on S axis with $\phi_D = 10° = 0.110 = \frac{c}{\gamma_m \bar{H}}$ and slope angle 45° (Plate V).

Using a factor safety of 1.5 value of c required

$$= 0.110 \times 1.5 \times 126.8 \times 20$$
$$= 418 \text{ lb per sq. ft.}$$

Example 2

A certain soil on testing gave the following results. $c = 300$ lb per sq. ft. $\phi = 15°$. Assuming depth of cut 20 ft and unit weight of material as 100 lb per cu. ft., design a suitable slope to give factor of safety of 1.5 with respect to cohesion and friction.

$$\phi_D = \frac{\phi}{F_t} = 10^\circ = \text{absolute value of } \frac{c}{\gamma_m H}$$

$$= \frac{300}{100 \times 20} = 0.150$$

With factor of safety of 1.5, the required value of $\frac{c}{\gamma_m H}$ for

$$\text{equilibrium} = \frac{0.150}{1.5} = 0.100$$

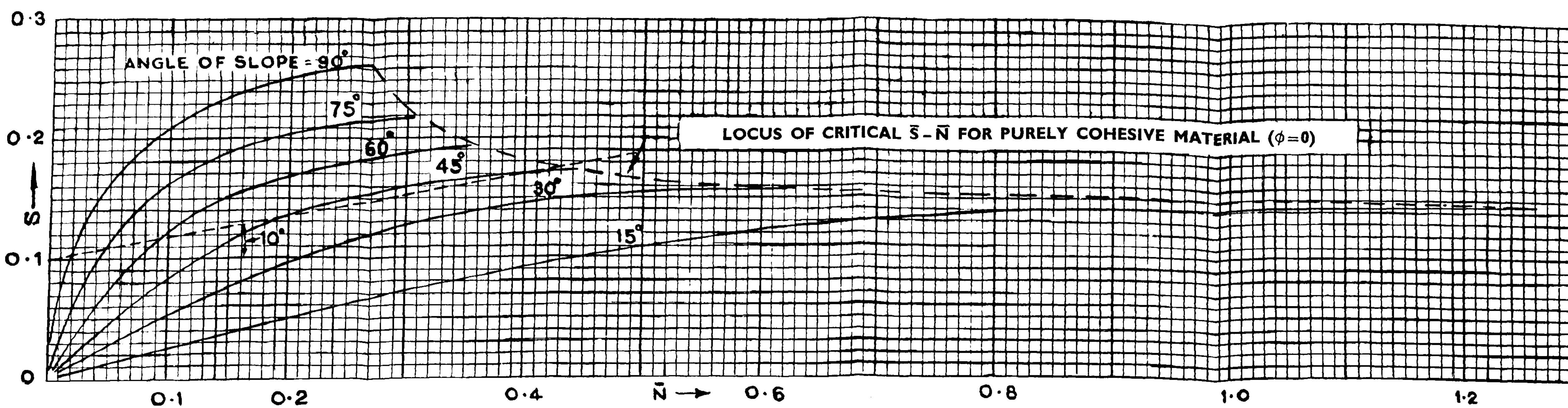
Drawing the strength line with $\frac{c}{\gamma_m H} = 0.10$ and $\phi_D = 10°$ on the $\bar{S}-\bar{N}$ diagram (Plate I). By interpolation between curves of 30° and 45° it is found that the curve corresponding to a slope angle of 40° will be tangential to the strength line.

Hence the value of angle of slope for the given condition is equal to 40 degrees.

ACKNOWLEDGMENT

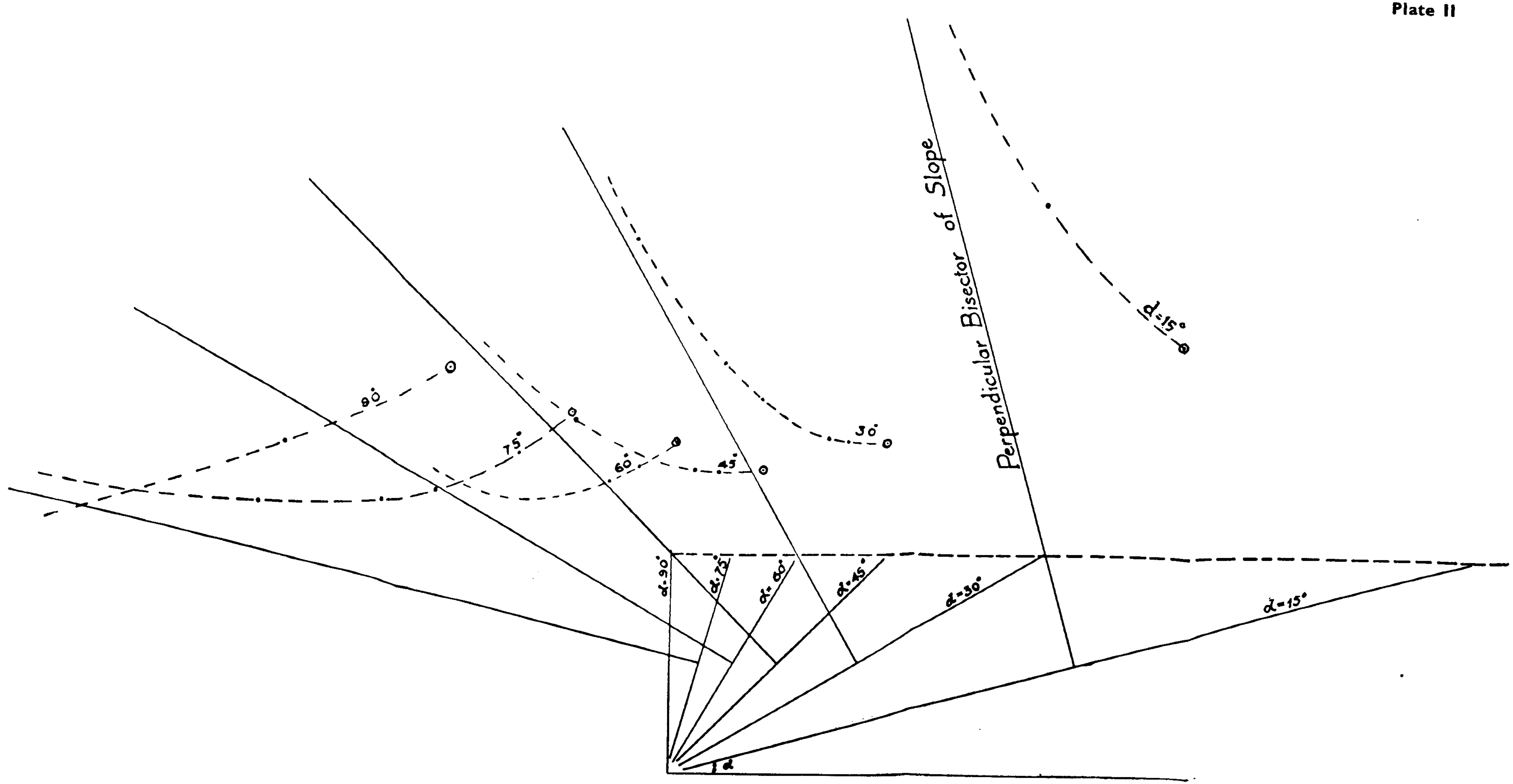
The possibility of the representation of the solution of the stability of slope as given in this Paper had been first suggested to the Author by Prof. Casagrande while the former was a student under the latter in Harvard University.

Plate I



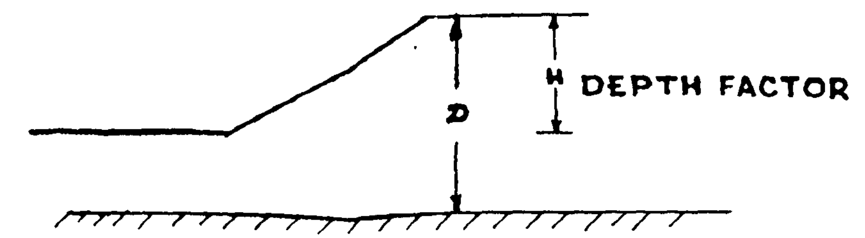
RESISTANCE ENVELOPE FOR TOE-CIRCLE FAILURE IN PLANE SLOPES

Plate II

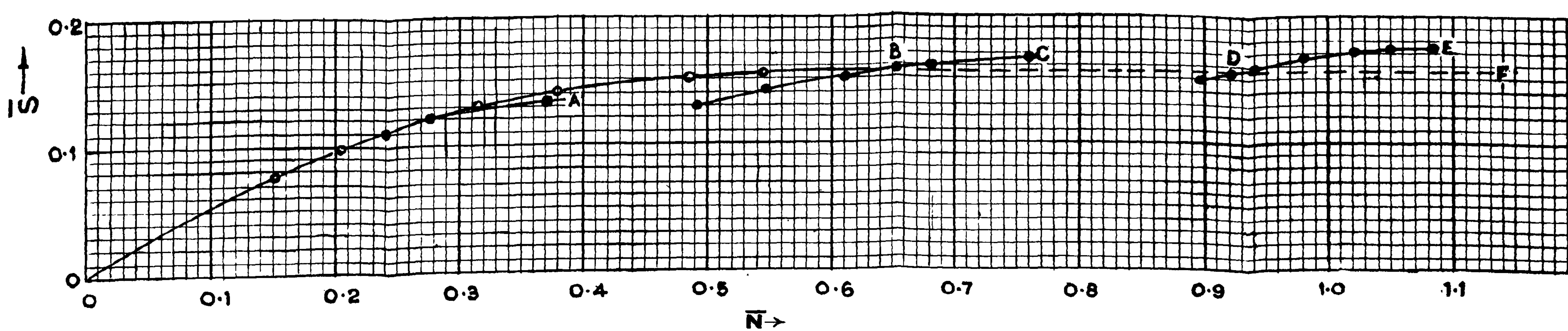


POSITION OF CENTRES OF CRITICAL CIRCLES FOR TOE-CIRCLE FAILURE IN PLANE SLOPES

Plate III

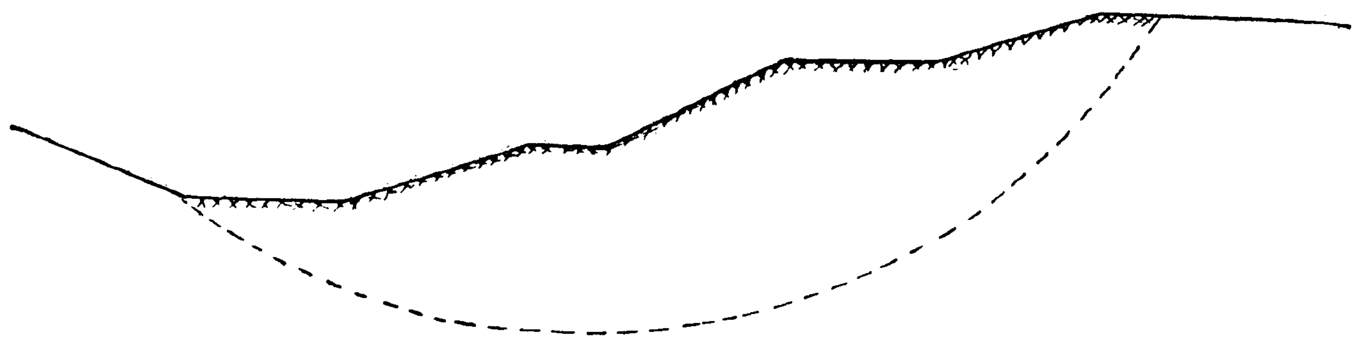


OA - FAILURE OF SLOPE—DEPTH FACTOR = 1
OBC - BASE FAILURE—DEPTH FACTOR = 1.5
ODE - „ „ „ = 20
OBDF - FAILURE OF SLOPE BY TOE CIRCLE FAILURE

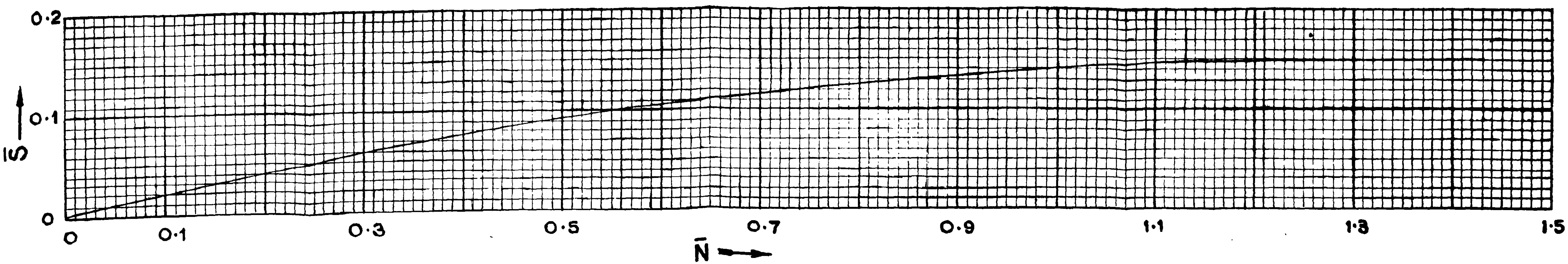


RESISTANCE ENVELOPE FOR
BASE FAILURE IN PLANE SLOPES
ANGLE OF SLOPE 30°

Plate IV

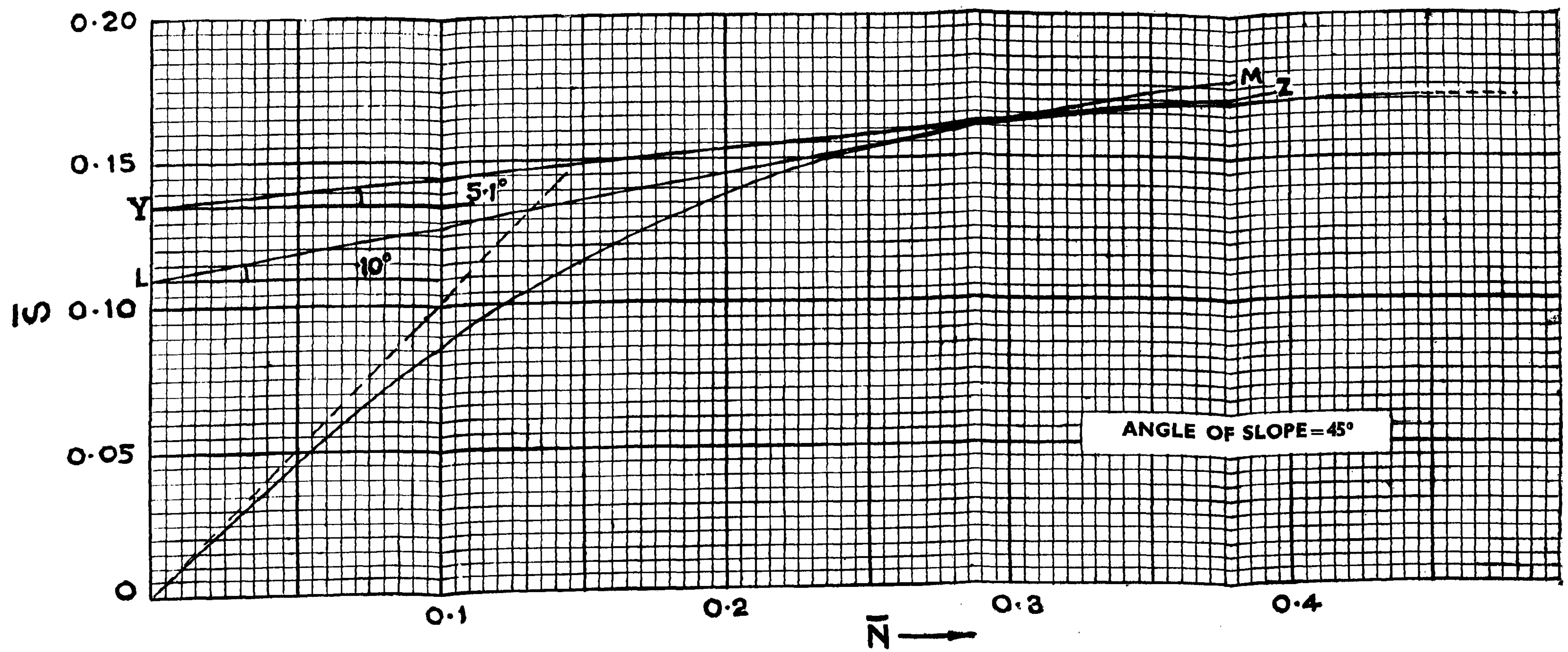


PROFILE OF AN IRREGULAR SLOPE



RESISTANCE ENVELOPE FOR AN IRREGULAR SLOPE

Plate V



RESISTANCE ENVELOPE FOR TOE-CIRCLE FAILURE IN PLANE SLOPE OF 45°

Paper No. 172

BITUMINOUS TREATMENT OF BRICK METAL WATER-BOUND MACADAM SURFACES IN U. P.

By

D. C. CHATURVEDI, C.E. (Hons.), D.I.C. (London).

CONTENTS

SYNOPSIS

The Paper describes the behaviour of surface dressing over brick ballast water-bound macadam road surfaces in Uttar Pradesh. The chips used for the surface dressing were of hard stone.

Many miles of the surfacings laid during the last 20 years have been observed to function satisfactorily under traffic ranging from 300 to 1,000 tons per day. There was no difference either in service efficiency or life in comparison to surfaces where hard stone metal was used. The specifications followed and the special precautions necessary to obtain satisfactory results are described.

The economics of the treatment is discussed.

This treatment is recommended for roads bearing traffic up to 800 tons per day in areas where stone metal is scarce or is available at high cost, and specially for providing dustless surfaces through built-up areas.

1. INTRODUCTION

1.1. Uttar Pradesh has an abundance of road building materials required for modernising roads. Unfortunately, these occur near the foothills of the Himalayas in the north and in the Vindhya ranges in the south of the State. Nothing but kankar can be found in the alluvial plain in the centre of the State. Transport of stone metal from the sources to the alluvial plain is expensive and difficult as long distances have to be covered.

1.2. If cheaper local material with short leads could be used for water-bound macadam in place of stone metal, the milage of hard surfaced and dustless roads in the State could be increased at a faster pace. Therefore, the State P. W. D. have been trying various substitutes. Of these, over burnt brick ballast has been found to be a suitable alternative, provided the surface is protected by two coats of surface dressing with bitumen or tar using hard stone chips.

1.3. The process, in brief, consists of (i) consolidating a $4\frac{1}{2}$ in. thick coat of brick ballast on existing kankar or other surface with a light roller, and (ii) applying two coats of surface dressing according to usual specifications using stone chips.

1.4. Plate I shows the areas of the State where experimental lengths with brick ballast have been laid. It will be seen that in areas where stone quarries exist nearby, brick ballast has not been tried.

1.5. First trials were made in 1931 but large-scale experiments were started from 1936-37. Since then many miles of different roads have been treated under different conditions prevailing in the State. These portions have been under traffic for a number of years now and have behaved very satisfactorily.

2. PROPERTIES OF BRICK BALLAST

2.1. Attrition

The results of attrition tests* on ten kinds of bricks carried out in 1938 are given in Appendix I. The tests showed that 'over burnt' brick ballast compared favourably with good quality road stone but indicated incidentally the enormous difference in quality between road metal from properly over burnt bricks and that from bricks which were just 'well-burnt'.

* By Doval Attrition Machine B. S. S. 812 : 1951.

2.2. Abrasion

Results of tests† on representative samples of over burnt, well burnt and under burnt bricks for the abrasion value by Los Angeles Abrasion Testing Machine[1] are given in Table 1. Also included in the Table are test results of 14 samples of bricks from various places in the State. This test is regarded as a combined test for hardness and toughness.

TABLE 1

Los Angeles Abrasion Values of Some Brick Ballast Samples

Sl. No.	Source	Quality and Colour	Abrasion Value Per cent	Remarks
1.	Gonda Division	Over burnt	38.9	Satisfactory
2.	,, ,,	Well burnt	41.5	Not Satisfactory
3.	,, ,,	Under burnt	46.4	-do-
4.	Agra Division (Etah)	Over burnt	38.9	
5.	Lucknow Division (Unnao)	,, ,,	39.4	
6.	Bareilly Division	,, ,,	36.2	
7.	,, ,,	,, ,,	35.9	
8.	Lucknow Division (Rae Bareilly)	Over burnt Deep blue*	31.6	
9.	,, ,,	Over burnt Blue*	29.8	
10.	,, ,,	Over burnt Dark Brown*	32.9	
11.	,, ,,	Over burnt Brown*	28.7	
12.	Gonda Division	Over burnt	35.5	
13.	Lucknow Division	,, ,,	31.8	
14.	,, ,,	,, ,,	29.7	
15.	,, ,,	,, ,,	29.8	
16.	,, ,, (Rae Bareilly)	,, ,,	31.3	
17.	,, ,,	,, ,,	35.2	

†The grading used for the tests was: $\frac{1}{2}$-1 in. 1250 gm; 1-$\frac{3}{4}$ in. 1250 gm; $\frac{3}{4}$-$\frac{1}{2}$ in. 1250 gm; and $\frac{1}{2}$-$\frac{3}{8}$ in. 1250 gm. Total = 5,000 gm.

*The four samples were sorted out in four groups, according to colour of the brick ballast from a heap of the sample obtained from the source.

In the A. S. T. M.* standard specifications for crushed stone, crushed slag and gravel for water-bound macadam base and surface courses of pavements[2], the following requirements are specified for the aggregate :

	Aggregate for use in Base courses	Aggregate for use in Surface courses
Wear in Los Angeles Abrasion Machine Maximum Per cent	60	40

For bituminous macadam base and surface courses the maximum values of abrasion specified are 50 and 40 per cent respectively[3]. The value of 38.9 for overburnt brick ballast is just below the maximum permissible limit of 40 for surface courses.

The over burnt brick ballast does not come into direct contact with vehicular traffic and is not, therefore, subject to direct wear and tear when a wearing course consisting of two coats of surface dressing is laid over it. This material can therefore be safely used.

2.3. Affinity of Brick Metal for Bitumen and Tar

Tests carried out by the State P. W. D. showed that the Khanjar brick ballast (black colour and well-burnt) had better affinity to asphalt than to tar, and its affinity to the binders was comparable with that to other good stones.

The following tests were carried out in State P. W. D. Research Institute, Lucknow, in connection with the comparative study of the quality of aggregates in respect of adhesion to bituminous binders :

1. Reidel-Weber Test (which is generally used for determining affinity of aggregates with binder).
2. Water-Immersion Test.
3. Immersion Compression Test.

The results of these tests are given in Table 2.

*American Society of Testing Materials.

TABLE 2

Results of Adhesion Tests on Over Burnt Brick Ballast

Sl.No.	Name of Test	Reference of Test	Results with Tar	Results with Bitumen	Rating in respect of Tar	Rating in respect of Bitumen
1.	Reidel-Weber Test	German U.37 Test*	*Adhesion No.* 0	5	Poor	Just good
2.	Water Immersion Test	Modification of of Test of Mallison and Schmidt and Lee & Carter†	*Percentage Unstripped* 70.0	50.0	Just good	Fair
3.	Immersion Compression Test	A. S. T. M. Test to determine effect of water on cohesion of compacted bituminous mixtures[4]	*Percentage Compressive Strength Retained* 56.0	83.0	Fair	Good

The results of test 1 show that the affinity of over burnt brick ballast to tar is poor and that to bitumen is fair ; but tests 2 and 3 show that the affinity is either fair or good. However, judged by these tests it can be said that brick ballast has better affinity to bitumen than to tar.

Reports of field trials indicate that the adhesion of binder to brick ballast is satisfactory in most of the cases. But few reports indicate that the affinity to bitumen is greater than that to tar.

3. DETAILS OF WORK DONE

3.1. Details of work done so far are given in Appendix 3. Details about consolidation of brick metal, surface dressing, traffic intensity, and remarks about the behaviour of the surfaces as reported by Executive Engineers have been included. A total length of nearly 130 miles has been laid using different kinds of binders.

* See page 19 of the Journal of the Indian Roads Congress, Vol. IX-1, December 1944.

† See Appendix 2.

3.2. For easy reference, the traffic intensity obtaining on portions of some important roads on which this treatment has been used and the behaviour of the surfaces are given in Table 3.

TABLE 3

Traffic Intensity on Some Roads and their Behaviour

Sl. No.	Road	Traffic intensity per day in tons *Maximum*	*Average*	Behaviour of surface
1.	Lucknow - Gorakhpur Road N. H.		350-400	Smooth s[illegible]es.
2.	Lucknow-Banaras Road (Banaras Distt.)		500	Smooth [illegible]ace, good adh[illegible]on.
3.	do. (Lucknow Distt.)	949	616	Satisfactory.
4.	Lucknow-Jhansi Road N. H.	835	486	Portions standing well.
5.	Lucknow-Bareilly-Meerut Road N. H.	834	272	Nothing unusual was report[illegible]
6.	do. do.	2131	776	do. [illegible]
7.	Unnao-Hardoi Road	[illegible]	687	Portions standing well.
8.	Grand Trunk Road N. H. (Agra Dn.)	732	430	Satisfactory.
9.	do. (Farrukhabad Dn.)	719	423	Surface smooth & standing well.
10.	Agra-Aligarh Road		700	Satisfactory.
11.	Barabanki-Gonda Road	676.5	390	Surface is standing well.
12.	Agra - Etawah - Fatehpur Road N. H.	*Approximate*	1000	Fairly smooth.
13.	Sitapur-Lakhimpur Road		858	Fairly smooth.

4. BEHAVIOUR OF THE SURFACES

4.1. Behaviour of the surfaces Appendix 3, so far indicates that this treatment is quite suitable for fairly heavy traffic. The surfaces compare well with black-top surfaces over stone ballast macadam. See Photos 1 and 2. This is evident from the behaviour of the portions on Lucknow-Jhansi Road (N. H.) which

Photo 1

Photo 2

Photos 1 & 2

Surface dressing w[illegible]tar over brick ballast in m[illegible]e 119 of Lucknow-Bareilly Road.

Photo 3

Surface in mile 12 of Lucknow-Jhansi Road (N. H.)

were modernized about 18 years ago and where brick ballast has been found to be unimpared (See Photo 3).

On the whole, it can be said that surfaces obtained in most of the cases have been quite satisfactory and adhesion of binders with brick metal has been satisfactory.

4.2. K. C. De, in his Paper [5] " Behaviour of Brick Metal in Tar Carpets ", says that " as a result of painting the surface of a brick metal water-bound macadam road with Road Tar, the attrition and crushing of the metal under steel-tyred traffic is considerably reduced. It is assumed, therefore, that the absorption of road tar by brick metal has toughened it."

4.3. Where, however, traffic is extremely heavy and where superior type of surface like cement concrete is necessary, this treatment may not be successful. In such cases, surface dressing over stone ballast macadam also may not be very successful.

5. FAILURES

5.1. There have been some failures. These are due mainly to the following :

(i) Use of inferior materials, i. e., under burnt brick ballast or brick ballast from first-class bricks.

(ii) Large amount of bullock cart traffic for which normally cement concrete is suitable.

5.2. It was noticed that in some places where the thickness of wearing coat was small, patches were easily formed. It was also observed that adhesion of binder to moist brick ballast was not satisfactory; in areas where moist ballast was used patches were formed quickly and the surface became uneven.

6. QUANTITIES OF BINDER AND GRIT

6.1. It has been observed that surface dressing over brick ballast requires somewhat more grit and binder than those required for use over the stone ballast surface. Brick ballast has a tendency to absorb some binder and, hence, if usual quantities of binder and grit are applied, the grit is not absorbed fully. On an average, it was noted that quantities of binder and grit required for brick ballast surfaces was 10 per cent in excess of the quantities required for painting a stone ballast surface.

6.2. Table 4 gives the quantities of binder and grit which may be taken as the average figures required for two coat surface dressing over brick and stone ballast surfaces.

TABLE 4

Average Quantities of Binder and Grit required for Surface Dressing

<table>
<tr><th rowspan="3"></th><th colspan="4">Surface dressing over stone ballast</th><th colspan="4">Surface dressing over brick ballast</th></tr>
<tr><th colspan="2">Binder</th><th colspan="2">Stone grit in cu. ft.</th><th colspan="2">Binder</th><th colspan="2">Stone grit in cu. ft.</th></tr>
<tr><th>1st coat</th><th>2nd coat</th><th>1st coat</th><th>2nd coat</th><th>1st coat</th><th>2nd coat</th><th>1st coat</th><th>2nd coat</th></tr>
<tr><td>Quantity per 100 sq. ft.</td><td>42 lb</td><td>23 lb</td><td>4.4</td><td>2.2</td><td>46.5 lb</td><td>25.5 lb</td><td>4.8</td><td>2.4</td></tr>
<tr><td>Quantity per mile including wastage.</td><td>12.6 tons</td><td>7 tons</td><td>2780</td><td>1390</td><td>14 tons</td><td>7.7 tons</td><td>3070</td><td>1530</td></tr>
</table>

7. COMPOSITE COAT

7.1. Composite coat of stone and brick ballast is also being tried on $5\frac{1}{2}$ furlong-length of Moradabad-Amroha-Bijnor Road. This consists of $1\frac{1}{2}$ in. thick coat of stone ballast over $4\frac{1}{2}$ in. thick coat of brick ballast to give hard surface on top. Usual specifications for surface dressing will be followed.

8. GENERAL SPECIFICATIONS

8.1. In general, P. W. D. detailed specifications for brick ballast collection, consolidation and surface dressing have been followed. These are given in detail in Appendix 4.

9. PRODUCTION OF GOOD QUALITY BRICK METAL

9.1. Great care has to be exercised for producing good quality of brick metal. Precautions are also necessary while using this material in road construction.

9.2. Soil

It is necessary to have the soil tested in the laboratory to determine its suitability for high quality bricks. If necessary, possibilities of using suitable admixtures like alkaline sodium salt (Soda Ash) should be examined in order to obtain over burnt bricks.

The Central Building Research Institute, Roorkee, has carried out experiments and has come to the conclusion that by suitably modifying the mechanical composition of the soil, good quality bricks possessing high crushing strength can be produced. It is possible that over burnt bricks suitable for road work may also be produced cheap by some such process.

9.3. Burning of Bricks

Pajawa kiln must not be used for burning bricks. The brick ballast produced from this type of kiln is of poor quality. Proper 'Bull' type kilns must be set up to produce the right type of material. Excessive over burning produces spongy material which is useless while under burning results in bad material. So, vitrified and under-burnt bricks should be rejected and bricks with bluish veins should be selected.

Possibilities of burning bricks for producing brick ballast for road construction were examined in the past. 2 in. thick bricks were tried in Allahabad and the resulting material was good. But it was considered that more fuel than that necessary for the usual size of bricks would be necessary, resulting in higher costs.

On the Grand Trunk Road in Mainpuri District burning of 3 in. cubes in roadside kilns was tried. The material produced was not of a good quality. In 1946, on Saharanpur-Muzaffarnagar Road, round balls of earth were made, dried and burnt in roadside kilns. The material produced was also not satisfactory. It consumed more coal than the usual type of bricks.

It is, however, considered that further experiments and research is necessary for producing good quality brick metal suitable for road work at cheaper cost near the site of the work.

10. PRECAUTIONS AND SUGGESTIONS FOR IMPROVEMENT OF SURFACE

10.1. A coat of brick metal $4\frac{1}{2}$-in. thick is the minimum necessary to receive the paint coat and no reduction in thickness should be made.

The size of brick ballast should be $1\frac{1}{2}$ to 2 in. and the grading should be according to specifications.

10.2. Consolidation should be done with a light roller not exceeding 8 tons. After consolidation, the brick ballast surface should be kept constantly blinded with earth or sand till it dries up and the first coat of painting is done.

Consolidation of brick ballast must not be taken up until the grit and binder for painting have also been collected and are ready at hand as delay in painting extending to more than a month or two after consolidation may cause the surface to become corrugated or break up under traffic.

10.3. It is very essential that the first coat of paint be given soon after consolidation. Since it is not always possible to arrange that the consolidation of brick ballast shall be deferred to the end of the rainy season, there will be many cases where the first coat of paint will have to be given while the road is still damp. Tar cannot be used while there is dampness and the first coat may, in that case, have to be of bitumen emulsion. A cutback would do equally well provided the road is nearly dry. Besides, the surface treatment under wet conditions will have to be according to the 'wet aggregate' process using lime or any other agent.

10.4. Research has shown that the most important factor affecting the performance of a surface dressing is the rate of spread of binder; the appropriate rate depends on the type and size of chippings used and the condition of the old road and the intensity of traffic.

To ensure uniform application of binder at the required rate of spread, the use of tank sprayers is recommended. This is, however, economical only when large stretches of a road are to be modernized.

10.5. Viscosity of binder is also important and should be chosen according to the season in which work is being done, the higher viscosities being used in warmer weather.

The application temperature of asphalt should be controlled within limits, depending upon its viscosity. Asphalt should not be applied at a temperature greater than necessary, because the spraying asphalt at excessive temperature reduces its penetration and ductility and frequently results in gravity flow of the applied asphalt on inclined surfaces.

10.6. Grit to be used should be of hard variety and should have high abrasion value. There should be closer control over grading of aggregates.

An aggregate of approximately uniform size, with a maximum of voids is most desirable for penetration asphalt surface treatments in order that a maximum amount of asphalt binder may be used without the aggregates becoming sufficiently embedded to result in a slick, bleeding surface. Also, uniform size aggregates usually develop better interlocking and provide lateral support to adjacent particles thereby preventing displacement.

10.7. Where traffic is very heavy, the first coat should be made thicker. Sufficient grit should be used for this purpose.

10.8. To avoid formation of waviness amounting to roughness in the surface, two precautions are necessary:

a. Several coats of paint at comparatively short intervals or repaint before there had been any appreciable reduction in the thickness of the existing coat or coats by the action of traffic, should be avoided.

b. Excess of bitumen or tar and too little grit result in a soft pliable coating which will be pushed by the action of traffic and are to be avoided.

10.9. Certain suggestions which have been put forward by some engineers of the department from the experience gained in this type of work, are given below:

a. Brick ballast should not be dry rolled. Sufficient hoggin should be left over the sub-grade to enable it to work up and fill the interstices of brick ballast for some depth.

b. The consolidated surface should be blinded with sand instead of earth. Sand can be cleaned easily and will also help the brick ballast to give out its moisture before painting is started.

c. The grit for each coat should be spread in two layers and each layer should be rolled separately.

d. In the selection of grit for dressing, the process by which stones are broken should be considered. The crusher gives a well graded material having cubica shape, while hand breaking gives angular pieces. It is recommended that 60 per cent hand broken and 40 per cent crusher broken material should be used where possible.

These, however, need further experimentation before definite conclusions can be arrived at.

11. ECONOMICS OF THE TREATMENT

11.1. Total costs for the following three types of surfaces have been worked out for various periods, Table 5, for purposes of comparison :

a. Kankar macadam surface.

b. Surface dressing over brick ballast water-bound macadam.

c. Surface dressing over stone ballast water-bound macadam.

TABLE 5

Total Cost at different Periods

Sl. No.	Years	5	10	15	20	25	30
1.	Kankar macadam surface	29,095	58,650	92,350	121,450	165,950	205,600
2.	Blacktop over brick ballast	48,980	78,440	130,077	166,000	213,900	262,300
3.	Blacktop over stone ballast	63,140	93,240	154,860	192,800	243,350	295,100

Assumptions

a. A kankar macadam surface requires renewal after every 3 years.

b. Black top surface over brick ballast as well as over stone ballast requires repainting every 3 years and renewal every 15 years.

c. Kankar macadam (i) Initial thickness, 6 in.
(ii) Renewal thickness, 4½ in. (consolidated to about 3 in.)

d. Black-top over brick ballast and stone ballast :

1. *Initial construction*

(i) 4½ in. thick metal.

(ii) 2 coats surface dressing.

2. *Repainting* — one coat

3. *Renewal*

(i) 3 in. metal.

(ii) 2 coats surface dressing.

Period of comparison — 30 years.

Rate of interest, compound — 3 per cent per annum.

The costs assumed in the calculation are given in Appendix 5.

11.2. **Ultimate cost with different rates of road metal**

Table 6 shows the 30 year costs of the three kinds of surfaces mentioned in para. 11.1 for different rates of metal. These are plotted in Plate II. Rates for items other than metal are the same as in Appendix 5.

TABLE 6

30 Years Costs for different Rates of Metal

Kankar Water-Bound Macadam					
Rate	20	25	30	35	40
Total cost	167,000	191,250	215,500	239,750	264,000
Surface Dressing over Brick Ballast Water-Bound Macadam					
Rate	35	40	45	50	55	60
Total cost	253,700	258,050	262,400	266,800	271,200	275,550
Surface Dressing over Stone Ballast Water-Bound Macadam					
Rate	60	70	80	90	100	110
Total cost	241,100	254,400	268,100	281,400	295,100	308,500

The graphs in Plate II show the following :

(i) Where kankar and brick ballast cost Rs 40 per 100 cu. ft., each surface dressing over brick ballast is cheaper than kankar macadam surface.

(ii) Total cost of kankar macadam is equal to that of surface dressing over brick ballast when kankar and brick ballast cost about Rs 38/8/- each.

(iii) Total cost of painted surface over stone ballast is higher than that of painted surface over brick ballast if cost of stone ballast is above Rs 85 and maximum cost of brick ballast is Rs 60.

11.3. Comparative costs for different rates of material can easily be found out from the graph to see which surface works out cheaper in long run. There are many factors other than the rate of metal which affect the total cost, and they should be taken into consideration in particular cases.

12. CONCLUSIONS

12.1. Experience gained so far has shown that surface dressing applied over brick ballast macadam behaves satisfactorily even under fairly heavy traffic. The treatment compares well with that applied over stone ballast macadam.

12.2. The quantities of binder and chips required for surface dressing over brick ballast are about 10 per cent more than those required for use over stone ballast macadam.

12.3. The total cost of black top over brick ballast is less than that over stone ballast unless stone ballast is available cheap.

12.4. The treatment should be suitable on roads which require modernization but where funds are limited or good road metal is costly, and where traffic does not exceed 800 tons per day.

12.5. The production of brick metal and its use, however require close supervision and care.

13. ACKNOWLEDGMENTS

The Author is indebted to Shri M. S. Bisht, Chief Engineer, U. P., P. W. D., for his encouragement in writing this Paper and for permission to take extracts from the circulars issued by the U. P., P. W. D.

The Author also expresses his grateful thanks to Shri P. N. Srivastava, Superintending Engineer (Planning), U. P., P. W. D., for his advice and to all Executive Engineers of the department for their help and co-operation in supplying the required information.

BIBLIOGRAPHY

1. Abrasion of Coarse Aggregate by use of Los Angeles Machine: C 131-47-ASTM Standards 1949 (Part 3)-Published by American Society of Testing Materials.

2. Standard for crushed stone, crushed slag or gravel for water-bound macadam base and surface courses of pavement: D 694-49-ASTM Standard 1949 (Part 3) published by American Society of Testing Materials.

3. Standard for crushed stone and crushed slag for bituminous macadam base and surface courses of pavements: D 693-49-ASTM Standard 1949 (Part 3) published by American Society of Testing Materials.

4. Effect of Water on Cohesion of Compacted Bituminous Mixtures: D 1075-49 T ASTM Standard 1949 (Part 3) published by American Society of Testing Materials.

5. Behaviour of Brick Metal in Tar Carpets-K.C.D-*Indian Roads Congress Journal*, Vol. XV-3, January, 1951.

6. Detailed Specification Part I - Section (B) -Roads. U.P., P.W.D., Buildings & Roads Branch, Supdt., Printing & Stationery, Allahabad.

7. Types of Road Surfacing and maintenance using Tar or Asphalted Bitumen—*Road Research-Road Note No. 5*—Her Majesty's Stationery Office (U.K.)

8. Thoughts & Theories on Bituminous Surface Treatments by Jerome P. Kearby—"*World Construction*" —May-June, 1953.

9. Economics of Highway Types—K. S. Raghavachary, *Indian Roads Congress Journal*, Vol. X-I, 1945-46.

10. Standard specifications for bituminous filled brick surface—State Highway Commission, Indiana, U.S.A.

APPENDIX 1

Results of Attrition Test on Brick Ballast

Sl. No.	Name of Division or Distt.	Description of the sample of burnt brick	Percentage loss of weight in Deval type Attrition Tester: Dry test on 11 lb	Percentage loss of weight in Deval type Attrition Tester: Wet test on 11 lb of brick ballast with 1.1 gallon of water	Specific gravity	Remarks
1	2	3	4	5	6	7
1.	Meerut Division	Red in colour	23.6	27.7	2.31	The wearing qualities compare very unfavourably with those of good quality road stone and good quality brick ballast.
2.	do.	Darker than Sample 1 in colour	7.6	11.1	2.28	do.
3.	Lucknow Division	Burnt at road-side in mile 16 of Lucknow-Jhansi Road	11.6	22.6	2.25	Wearing quality is reasonably good for its class but compares unfavourably with that of good quality stone metal.
4.	Agra Division	Sample from red bricks	10.5	11.1	2.25	Wearing qualities compare very unfavourably with those of good quality road stones.
5.	do.	Black in colour and over burnt	3.7	4.5	1.96	The wearing qualities are not much lower than those of good quality road stone but are normal for this class of brick ballast.

(*Contd.*)

APPENDIX 1 – (*Contd.*)

Sl. No.	Name of Division or Distt.	Description of the sample of burnt brick	Percentage loss of weight in Deval type Attrition Tester: Dry test on 11 lb	Percentage loss of weight in Deval type Attrition Tester: Wet test on 11 lb of brick ballast with 1.1 gallon of water	Specific gravity	Remarks
1	2	3	4	5	6	7
6.	Banaras Division	Overburnt (Jaunpur-Mirzapur Road).	3.1	5.0	2.2	The sample is considered to be good for its class and compares favourably with stone ballast having fairly good wearing qualities.
7.	Bareilly Division	Red in colour	8.8	11.5	2.29	The wearing qualities compare very unfavourably with those of good quality road stone and good quality brick ballast.
8.	do.	Black and over-burnt	6.3	7.4	2.17	The wearing qualities compare unfavourably with those of good quality road stones and good quality brick ballast.
9.	Faizabad Division	From Lucknow-Gorakhpur Road	3.0	4.8	2.23	The wearing qualities are slightly inferior to those of good quality road stones but are normal for this class of brick ballast.
10.	do.	From Allahabad-Faizabad Road	3.6	4.2	2.29	do.

APPENDIX 2

WATER IMMERSION TEST

A modified form of test based on the two original tests of Mallison and Schmidt* and Lee and Carter† was developed at P. W. D. Research Institute. Size of Aggregate was kept as passing 1/2 in. and retained on 3/8 in. sieve. 8 per cent Tar and 6 per cent bitumen by weight were mixed at a temperature of 100°C and 150°C respectively. Previous to mixing the materials were kept in an oven at the specified temperature for 15-20 minutes. The mixture was then cured in air for 36 hours. Twenty well painted pieces were picked up and put into two small bottles. The pieces were covered with distilled water and then kept in an oven at 50°C for one hour. The bottles remained in an unsealed condition. The condition of stripping was then studied and percentage of unstripped pieces in both the bottles decided by visual examination and an average taken. For purpose of counting, all pieces which showed more than 50 per cent stripping were considered as fully stripped.

The following classifications for adhesion quality was adopted:

(1) Good aggregates: Those containing 60-100 per cent unstripped pieces after test.

(2) Ordinary aggregates: Those containing 30-60 per cent unstripped pieces after test.

(3) Bad aggregates: Those containing less than 30 per cent unstripped pieces after test.

---

* Tar chippings and water affinity 4. Teer, 1939, 39 (4) 51-4; (5), 59-62; (6) 75-9; (7), 91-5 - Mallison & Schmidt.

† The Use of Cold and Wet Aggregates in Bituminous Construction for Roads and Aerodromes by Alfrid Robert Lee & Henry James Edward Carter - Institution of Civil Engineers (Road Engineering Division), Road Paper No. 12—1944.

APPENDIX 3

Details of work done on Bituminous Treatment of Brick ballast water-bound macadam in U.P.

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day Tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
1.	**Muzaffarnagar - Saharanpur Road:**											
	Mile 15	8	4½ in. (2 in. gauge).	2/50	Tar No. 3 14 tons per mile.	Mohand grit (1/4 in.–3/4 in. size) 4000 cu. ft. per mile.	5/50	Bitumen 80/100 7 tons.	Mohand grit 1/8 in.–3/8 in. size, 2000 cu.ft. per mile	6/51	—	Adhesion satisfactory. Surface uneven. Patches are formed rapidly, probably on account of the fact that brick ballast used was not over burnt.
	,, ,, Mile 21	3	,,	9/49	,,	,,	11/49	,,	,,	4/50	—	,, ,, ,,
	Mile 27	8	,,	3/51	,,	,,	6/51	,,	,,	5/52	—	Surface not very uneven and no patches have been found as yet.
	,, ,, Mile 28	8	,,	1/50	,,	,,	4/50	,,	,,	5/51	—	Surface not much uneven. Adhesion of binder good.
2.	**Saharanpur - Nakur-Gangoh Road:**											
	Mile 13	8	,,	9/50	Tar No. 3 10 tons. per mile.	Grit 3000 cu. ft. per mile.	11/50	Bitumen 80/100 5.5 tons.	Grit 1500 cu. ft. per mile	5/51	—	Width treated is 9 ft. Surface not much uneven. Adhesion of binder good.
	,, ,, Mile 15	8	,,	11/50	,,	,,	,,	,,	,,	,,	—	,, ,, ,,
3.	**Grand Trunk Road: Etah District.**											
	Mile 747	8	4½ in. consolidated to 3 in.	6/52	Cut back 44 lb per 100 sq. ft.	Haldwani 1/2 in. grit 4.5 cu. ft. per 100 sq. ft.	6/52	Not	done yet		Max. 624 tons. Ave. 345 tons.	The behaviour of the surface is satisfactory. The surface is smooth and there are no signs of paint not adhering to the brick ballast.
	,, ,, Mile 748	8	,,	3/52	,,	,,	5/52	,,	,, ,,		—	,, ,, ,,
	,, ,, Mile 749	8	,,	,,	,,	,,	,,	,,	,, ,,		Max. 548 tons. Ave. 306 tons.	,, ,, ,,
	,, ,, Mile 754	8	,,	6/52	,, 48 lb	1/2 in. Delhi grit 4.5 cu. ft. per 100 sq. ft.	7/52	,,	,, ,,		—	,, ,, ,,
	,, ,, Mile 755	8	,,	6/52	,,	,,	6/52	,,	,, ,,		—	,, ,, ,,
	,, ,, Mile 756	8	,,	10/51	,, 46 lb	1/2 in. Haldwani grit 4.5 cu. ft. per 100 sq. ft.	11/51	Cut back 24 lb per 100 sq. ft.	3/8 in. Delhi grit 2.5 cu. ft. per 100 sq. ft.	5/52	—	,, ,, ,,
	,, ,, Mile 757	8	,,	10/50	Cut back 45 lb per 100 sq. ft.	,,	10/50	Cut back 20 lb per 100 sq. ft.	,,	5/51	Max. 693 tons. Ave. 400 tons.	,, ,, ,,
	,, ,, Mile 759	8	,,	,,	,,	,,	,,	,,	2.7 cu. ft. per 100 sq. ft.	6/51	—	,, ,, ,,

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Grit and rate of application.	Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Grit and rate of application.	Time of application.	Traffic intensity per day Tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
	Grand Trunk Road : (Etawah District) Mile 760	8	4½ in. consoli dated to 3 in.	10/50	Cut back 45 lb per 100 sq. ft.	1/2 in. Haldwani grit 4.5 cu.ft.	11/50	Cut back 20 lb per 100 sq. ft.	3/8 in. Delhi grit 2.5 cu. ft. per 100 sq. ft.	5/51	—	The behaviour of the surface is satisfactory. The surface is smooth and there are no signs of paint not adhering to the brick ballast.
	,, ,, Mile 761	8	,,	3/51	Cut back 48 lb per 100 sq. ft.	,,	4/51	Cut back 24 lb	,,	11/51	—	,, ,, ,,
	,, ,, Mile 762	8	,,	4/51	,, 46 lb	,,	5/51	,,	,,	,,	—	,, ,, ,,
	,, ,, Mile 763	8	,,	,,	,, 47 ,,	,,	5/51	,,	,,	10/51	—	,, ,, ,,
	,, ,, Mile 764	8	,,	5/51	,, 48 ,,	,,	6/51	,,	,,	,,	—	,, ,, ,,
	,, ,, Mile 765	8	,,	10/51	,, 46 ,,	,,	10/51	Cut back 20 lb	,,	3/52	—	,, ,, ,,
	,, ,, Mile 766	8	,,	3/51	,, 49 ,,	,,	4/51	,, 24 lb	,,	4/52	—	,, ,, ,,
	,, ,, Mile 767	8	,,	10/51	,, 46 ,,	,,	10/51	,, ,,	,,	,,	Max. 732 tons Ave. 430 ,,	,, ,, ,,
	Mile 776	2	,,	10/51	Bitumen 80/100 4.5 lb per sq. yd.	1/2 in. Delhi grit 0.4 cu. ft. per sq. yd.	11/51	Bitumen 80/100 2.5 lb per sq. yd.	1/4 in. Delhi grit 0.25 cu. ft. per sq. yd.	10/52	,, Approx. 800 tons	Smoothness fair ; adhesion fair.
	,, ,, Mile 777	2	,,	5/51	,,	,,	6/51	,,	,,	,,	—	Rough surface ; adhesion fair.
4.	**Agra-Aligarh Road:** ,, ,, Mile 38	8	,,	6/51	Asphalt 180/200 4.5 lb per sq. yd.	,,	,,	——————being done——————			700 tons approx.	The treatment was for 4 ft on either side of 9 ft cement concrete. Surface is quite smooth; adhesion good. The brick ballast was not dry rolled. The consolidated surface was not blinded, nor any traffic allowed before painting.
5.	**Aligarh-Kasimpur Road :** Mile 2	8	,,	10/50	Bitumen 80/100 @ 3.5 lb per sq. yd.	1/2 in. Najibad grit at 0.4 cu. ft. per sq. yd.	11/50	Bitumen 80/100 @ 3 lb per sq. yd.	1/4 in. Delhi grit @ 0.35 cu.ft.per sq.yd.	6/51	600 tons	Surface is fairly smooth; adhesion unsatisfactory.
6.	**Agra-Etawah-Fatehpur Road :** Mile 120	8	,,	4/52	Tar No. 3 13 tons per mile	Jhansi granite ¼ in. to ¾ in. 4.4 cu.ft. per 100 sq. ft.	5/52	2nd coat is being given now.			1000 tons	Surface fairly smooth. Some undulations have however, occurred. The binder has struck well to the brick ballast. The treatment fails under heavy traffic. The hard grit penetrates the brick ballast and the brick ballast is exposed at places. The carpets of 1st coat should therefore, be thicker i.e., more grit should be used. Width of treatment 12 ft unless otherwise stated.

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day Tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
	Agra-Etawah-Fatehpur Mile 121 (1–2 fgs.)	2	$4\frac{1}{2}$ in. consolidated to 3 in.	4/52	Tar No. 3 13 tons per mile.	Jhansi granite $\frac{1}{4}$ in. to $\frac{3}{4}$ in. 4.4 cu. ft. per 100 sq. ft.	5/52	2nd coat is being given now			1000 tons approx.	Surface fairly smooth. Some undulations have, however, occurred. The binder has struck well to the brick ballast. The treatment failed under heavy traffic. The hard grit penetrates the brick ballast and the brick ballast is exposed at places. The carpet of 1st coat should, therefore, be thicker i. e., more grit should be used.
	,, ,, Mile 121 (3–8 fgs.)	6	,,	2/52	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 122	8	,,	5/52	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 123	8	,,	12/52	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 124	3	,,	11/52	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 137	8	,,	11/51	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 138	8	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 139	8	,,	12/51	,,	,,	,,	,,	,,	,,	,,	,, ,,
	,, ,, Mile 140	8	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,,
7.	**Kalyanpur-Bithoor Road:** Whole length 7 miles 4050 ft	8	$4\frac{1}{2}$ in. ($1\frac{1}{2}$ in. gauge)	1950	Tar No. 3 44 lb per 100 sq. ft.	Stone grit $\frac{3}{8}$ in. size 4.1 cu. ft. per 100 sq. ft.	10/50 to 11/50	,,	,,	,,	100 tons approx.	Width treated is 9 ft. The surface is smooth but adhesion of binder to brick ballast is ordinarily poor.
8.	**Grand-Trunk Road: Provl. Divn. Farrukhabad:** Mile 720	8	,,	9/51	Cut back 45 lb per 100 sq. ft.	Delhi grit ($\frac{3}{4}$ in. -$\frac{1}{4}$ in.) 4.4 cu. ft. per 100 sq. ft.	11/51	Cut back 24 lb per 100 sq. ft.	Delhi grit (3/8 in.–1/8 in.) 2.5 cu. ft. per 100 sq. ft.	6/52	Ave. 423 tons. Max. 719 tons.	Portion became rough after 3 months of 1st coat painting and there were signs of wear. After 2nd coat surface has become smooth and is behaving well.
	,, ,, Mile 732	5	,,	11/51	,,	,,	11/51	,,	,,	11/52	,,	,, ,,
	,, ,, Mile 728	8	,,	9/51	Tar No. 3 50 lb per 100 sq. ft.	,,	,,	,,	,,	6/52	,,	,, ,,
	,, ,, Mile 729	8	,,	,,	Bitumen 45 lb per 100 sq. ft.	,,	,,	,,	,,	6/52	,,	,, ,,

APPENDIX 3—(*Contd.*

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
	Grand-Trunk Road: Provi. Divn. Farrukhabad: ,, ,, Mile 719	2	4½ in. (1½ in. gauge)	9/51	Cut back 45 lb per 100 sq. ft.	Delhi grit (¾ in. -¼ in.) 4.4 cu.ft. per 100 sq. ft.	10/52	—	—	—	—	Portions now need repainting.
	,, ,, Mile 724	8	,,	11/52	,,	,,	12/52	—	—	—	—	,, ,,
	,, ,, Mile 725	8	,,	11/52	Tar No. 3 50 lb per sq. ft.	,,	11/52	Bitumen 80/100, 24 lb per 100 sq. ft.	Delhi grit 2.5 cu. ft. per 100 sq. ft.	6/53	—	Portions became rough after 6 months of 1st coat painting. After 2nd coat, the surface is smooth and is behaving well.
8.	**Grand-Trunk Road:** Mile 730	8	4½ in. (1½ in. gauge)	10/52	Asphalt 50 lb per 100 sq. ft.	Delhi grit (¾ in.-¼ in.) 4.4 cu. ft. per 100 sq. ft.	11/52	Bitumen 24 lb per 100 sq. ft.	Delhi grit 2.5 cu. ft. per 100 sq. ft.	6/53	—	Portions became rough after six months of 1st coat painting. After 2nd coat, the surface is smooth and is behaving well.
	,, ,, Mile 732	3	,,	,,	,,	,,	,,	—	—	—	—	Portion needs repainting.
	,, ,, Mile 733	8	,,	11/52	Cut back 45 lb per 100 sq. ft.	,,	12/52	Asphalt 25 lb 100 sq. ft. (5 fgs.)	Delhi grit 2.5 cu. ft. per 100 sq. ft.	6/53	—	The portion where 2nd coat has not been given needs repainting. Other portions are behaving well.
	,, ,, Mile 734	8	,,	10/52	,,	,,	10/52	—	—	—	—	Need repainting now.
	,, ,, Mile 735	8	,,	,,	,,	,,	11/52	—	—	—	—	,, ,, ,,
	,, ,, Mile 736	8	,,	,,	,,	,,	12/52	—	—	—	—	,, ,, ,,
	,, ,, Mile 740	8	,,	11/52	,,	,,	12/52	Asphalt 25 lb per sq. ft. (5 fgs.)	Delhi grit 2.5 cu. ft. per 100 sq. ft.	6/53	—	The portion where 2nd coat has not been given needs repainting. Other portions are behaving well.
	,, ,, Mile 722	8	,,	4/52	,,	,,	5/53	—	—	—	—	Portions now need repainting Greater quantity of grit was used than in other portions. Wear was noticed after a longer period than in other miles.
	,, ,, Mile 731	8	,,	,,	,,	,,	,,	—	—	—	—	,, ,, ,,
9.	**Meerut-Bareilly Road N. H. No. 24 Bareilly District.** Mile 118	8	(4½ in.- 1½ in.- 2 in. size)	9/51	Tar No. 3 51 lb per 100 sq. ft.	Najibabad stone grit (1¼ in. to ¾ in. size) 5.0 cu. ft. per 100 sq. ft.	11/51	Bitumen 80/100 28.3 lb per 100 sq. ft.	Najibabad grit (⅜ in. to ⅝ in.) 3 cu. ft. per 100 sq. ft.	6/52	Max. 834.5 tons Ave. 272.75 tons	Nothing unusal has been observed so far.

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day Tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
	Meerut-Bareilly Road : N. H. No. 24 Bareilly District.											
	,, ,, Mile 117	8	$4\frac{1}{2}$ in. ($1\frac{1}{2}$ in.-2 in. size)	9/51	Tar No. 3 51 lb per 100 sq. ft.	Najibabad stone grit ($\frac{1}{4}$ in. to $\frac{3}{4}$ in. size) 5.0 cu. ft. per 100 sq. ft.	11/51	Bitumen 80/100, 28.3 lb per 100 sq. ft.	Najibabad grit ($\frac{3}{8}$ in. to $\frac{5}{8}$ in.) 3 cu. ft. per 100 sq. ft.	6/52	Max. 834.5 tons Ave. 272.75 tons	Nothing unusal has been observed so far.
	,, ,, Mile 116 (fg. 5 to 8)	4	,,	10/51	,,	,,	,,	,,	,, 2.6 cu. ft.	6/52	—	,, ,,
	,, ,, Mile 113 (fg. 1, 2, 7, 8)	4	,,	9/51	,,	,,	10/51	,, 31 lb	,, 2.8 cu. ft.	5/52	Max. 351.0 tons per day Ave. 120.5 tons per day	,, ,,
	,, ,, Mile 112	8	,,	8/51	,,	,,	,,	,, 27 lb	,, 3.1 cu. ft.	,,	—	,, ,,
10.	**Lucknow-Bareilly Road : Route No. 24 N. H. Bareilly District.**											
	Mile 137	8	,,	9/51	Tar No. 3 46.8 lb per 100 sq. ft.	Haldwani grit ($\frac{3}{8}$ in.–$\frac{5}{8}$ in. size) 4.75 cu. ft. per 100 sq. ft.	12/51	Bitumen 80/100, 29 lb per 100 sq. ft.	Najibabad grit ($\frac{1}{8}$ in. to $\frac{3}{8}$ in. size) 2.75 cu. ft. per 100 sq. ft.	3/52	Max. 2131.25 tons Ave. 776.5 tons	,, ,,
	Mile 138	8	,,	,,	,,	,,	11/51	,,	,,	,,	—	,, ,,
11.	**Unnao-Hardoi Road :** Mile 72 (fg. 3-4)	$1\frac{1}{3}$	$4\frac{1}{2}$ in. consolidated ($1\frac{1}{2}$ in. -2 in. size)	11/51	Tar No. 3 45 lb per 100 sq. ft.	Najibabad grit ($\frac{3}{4}$ in. to $\frac{1}{4}$ in.) 2.5 cu.ft. per 100 sq. ft.	3/52	—	—	—	300 tons	Width treated 20 ft. The surface has not yet become smooth. Adhesion satisfactory.
12.	**Lucknow-Bareilly Road: (N. H. No. 24) Shahjahanpur Distt.**											
	Mile 106	8	,,	1950	Tar No. 3 12 tons per mile	River bajri $\frac{1}{4}$ in.–$\frac{3}{4}$ in. (2800–3000) cu.ft. per mile	1950	Asphalt 80/100 5–7 tons per mile	River bajri $\frac{1}{8}$ in.–$\frac{1}{2}$ in. (1400–1600) cu.ft. per mile)	1952	Max. 552.25 tons Ave. 304.7 tons	Behaviour satisfactory.
	,, ,, Mile 107 to 110	32	,,	1951	,,	,,	1951	,,	,,	,,	—	,, ,,
	,, ,, Mile 111	8	,,	1950	,,	,,	1950	,,	,,	,,	—	,, ,,

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolida-tion.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of applica-tion.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day Tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	9	9
	Lucknow-Bareilly Road : N. H. No. 24 Shahjahanpur Distt.											
	,, ,, Mile 117 (1-5 fg.)	5	4½ in. consolidated (1½ in.–2 in. size)	1950	Tar No. 3 12 tons per mile	River bajri ¼ in.–¾ in. (2800–3000 cu. ft. per mile)	1951	Asphalt 80/100 5–7 tons per mile	River bajri ⅛ in.–½ in. (1400–1600 cu. ft. per mile)	1951	Max. 552.25 tons Ave. 304.7 tons	Behaviour satisfactory.
	,, ,, Mile 117 (6–8 fgs.)	3	,,	1952	,,	,,	1952	—	—	—	—	,, ,,
	,, ,, Mile 118	8	,,	1952	,,	,,	1952	—	—	—	—	,, ,,
	,, ,, Mile 119	8	,,	1952	,,	,,	1952	—	—	—	—	,, ,,
	,, ,, Mile 112	8	,,	1949	,,	,,	1950	Asphalt 80/100 5–7 tons per mile	River bajri ⅛ in.–½ in. (1400–1600 cu. ft. per mile)	1950	—	,, ,,
	Sitapur Distt. ,, ,, Mile 31 (N. H. Mile 275)	8	,,	10/50	Tar No. 3 15 tons per mile	Haldwani grit ⅜ in.–¾ in. (3000 cu.ft. per mile)	11/50	Bitumen 80/100 8 tons per mile	Haldwani grit ⅛ in.–½ in. (1500 cu.ft. per mile)	6/51	Ave. 321.5 tons Max. 599.25 tons (1947–48) in Mile 31	Adhesion of binder to brick ballast is good. Surface is sufficiently smooth except at some places due to hand spreading of Tar.
	,, ,, Mile 32 (N. H. Mile 274)	8	,,	10/49	Cut back	,,	11/49	,,	,,	5/50	,,	Adhesion to brick ballastt was not found satisfactory and heavy patches were formed soon after. The surface was good after 2nd coat.
	,, ,, Mile 33 (fg. 1–4) (N. H. Mile 273)	4	,,	,,	Tar	,,	,,	,,	,,	,,	,,	Adhesion of tar was found good. Surface is sufficiently smooth.
	,, ,, Mile 33 (N. H. Mile 273) (fg. 5–8)	4	,,	2/50	,,	,,	4/50	,,	,,	11/50	,,	Adhesion of tar was found good. Surface is sufficiently smooth.
	,, ,, Mile 34 (N. H. Mile 272)	8	,,	3/50	Tar No. 3	,,	4/50	,,	,,	12/50	,,	Adhesion of binder to brick ballast found good.
	,, ,, Mile 35 (N. H. Mile 271)	8	,,	5/51	,,	,,	6/51	,,	,,	10/51	,,	Adhesion good. Surface is also satisfactory.
	,, ,, Mile 36 (N. H. Mile 270)	8	,,	9/51	,,	,,	10/51	,,	,,	3/52	,,	,, ,,
13.	**Sitapur-Bahraich Road :** Mile 6	8	,,	10/51	,,	,,	11/51	—	—	—	Max. 430 tons Ave. 265 (1947–48).	,, ,,

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day Tons.	Remarks.
1		3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
14.	**Sitapur - Lakhimpur Road :** (Kheri District)											
	Mile 28	8	4½ in. consolidated (1½-2 in. gauge).	3/51	Tar No. 3	Haldwani grit ¾ in.	5/51	—	—	—	Ave. 858 tons per day (Novr., 1952).	The surface is smooth and adhesion of binder is satisfactory.
15.	**Unnao - Hardoi - Road :** Lucknow Division											
	,, Mile 1	6	,,	4/49	Tar No. 3 72.2 lb per 100 sq. ft.	Jhansi grit ¾ in. 6 cu. ft. per 100 sq. ft.	5/49	Tar No. 3 37.8 lb per 100 sq. ft.	Jhansi grit ¾ in. 3.9 cu. ft. per 100 sq. ft.	11/49	687 tons	Width treated 20 ft. The surface wore out under traffic.
	,, Mile 1	1 fg. 646 ft	,,	8/49	Tar No. 3 60 lb per 100 sq. ft.	Jhansi ¾ in. 4.9 cu. ft. per 100 sq. ft.	11/49	Bitumen 80/100 26.7 lb	Jhansi ½ in. 2.9 cu. ft. per 100 sq. ft.	5/50	,,	,, ,,
	,, Mile 2	8	,,	9/49	Tar No. 3 57.3 lb per 100 sq. ft.	Jhansi ¾ in. 4.57 cu. ft. per 100 sq. ft.	11/49	Bitumen80/100 24.7 lb per 100 sq. ft.	Jhansi ½ in. 2.47 cu. ft. per 100 sq. ft.	6/50	—	,, ,,
	,, Mile 3	8	,,	10/49	Tar No. 3 62.8 lb per 100 sq. ft.	Jhansi ¾ in. 4.42 cu. ft. per 100 sq. ft.	12.49	,,	Jhansi ½ in. 2.68 cu. ft. per 100 sq. ft.	,,	—	Standing well.
	,, Mile 4	3	,,	,,	,,	,,	,,	Bitumen80/100 29.2 lb per 100 sq. ft.	Jhansi ½ in. 3.0 cu. ft. per 100 sq. ft.	,,	—	,, ,,
	,, Mile 4	5	,,	1/50	,,	,,	4/50	—	—	—	—	,, ,,
	,, Mile 5	8	,,	3/50	58.8	4.61 cu. ft.	,,	—	—	—	—	,, ,,
	,, Mile 8	8	,,	,,	,,	4.61 cu. ft.	5/50	—	—	—		,, ,,
	,, Mile 9	8	,,	2/50	,,	,,	,,	—	—	—		,, ,,
	,, Mile 10	8	,,	3/50	,,	,,	,,	—	—	—	—	,, ,,
16.	**Lucknow-Banaras Rd :** State Highlway.											
	,, Mile 9	8	,,	1939	Tar No. 2.	Details not available.	May, '39	Asphalt	Details not available.	Novr., 1939	Max. 946 tons. Ave. 616 tons.	Repainting with Bitumen 180/200 in May 1944 and with Bitumen 80/100 in June 1950. Thesurface now requires repainting.
	,, Mile 10	8	,,	,,	,,	,,	June, '39	,,	,,	Dec., 1939		Repainting with Bitumen 180/200 in June 1942, June 1945 ; with Bitumen 80/100 in March 1949 and with Tar No. 3 in May 1953

APPENDIX 3–(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat.			Wearing surface 2nd coat.			Traffic intensity per day Tons.	Remarks.
					Binder and rate of application.	Grit and rate of application.	Time of application.	Binder and rate of application.	Grit and rate of application.	Time of application.		
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
	Lucknow-Banaras Road: State Higlway Mile 11	8	4½ in. consolidated (1½-2 in. gauge)	1939	Tar No. 2	Details not available	July, '39	Asphalt	Details not available	April 1940		Repainting with Bitumen 180/200 in June 1942 and with Bitumen 80/100 in March 1949. The Surface now requires repainting.
	,, Mile 15	8	,,	,,	,,	,,	Novr., 1939	,,	,,	,,	Max. 423 tons Ave. 302 tons	Repainting with Bitumen 180/200 in June 1942 and with Bitumen 80/100 in June 1950. The surface now requires repainting.
	,, Mile 41	8	,,	7/50	Bitumen.	Jhansi 1 in. grit.	11/50	Bitumen	Jhansi ½ in.–¾ in.	—	Max. 779 tons Ave. 292 tons in mile 40.	The surface is behaving very well and is quite smooth. Adhesion of top coat to brick ballast is perfect.
	,, Mile 42	3	,,	,,	,,	,,	,,	,,	,,	—		,, ,,
	,, Mile 42	5	,,	1/50	,,	,,	5/50	,,	,,	11/50		,, ,,
	,, Mile 43	3	,,	,,	,,	,,	,,	,,	,,	,,		,, ,,
	,, ,,	5	,,	,,	Tar No. 3.	,,	,,	,,	,,	,,		,, ,,
	,, Mile 44	8	4½ in.	10/49	,,	,,	11/49	Bitumen	Jhansi ½ in.–¾ in.	5/50	—	These portions have been repainted in 5/53. The surface is smooth and is behaving well.
	,, Mile 45	8	,,	9/49	Bitumen.	,,	,,	,,	,,	,,	—	,, ,,
	,, Mile 46	8	,,	,,	,,	,,	,,	,,	,,	4/50		The surface is behaving well.
	,, Mile 47	8	,,	8/49	,,	,,	10/49	,,	,,	,,	Max. 531 tons Ave. 336 tons in Mile 49.	,, ,,
17.	**Lucknow-Jhansi Road: N. H.** Mile 7 (fg. 4–8)	5	←			No details available.		———————	→	1933	—	
	,, Mile 8	8				,,	,,	,,	,,	1931	—	The portions are standing well.
	,, Mile 9 (fg. 1–4)	4				,,	,,	,,	,,	1936	—	,, ,,
	,, Mile 9 (fg. 5–8)	4				,,	,,	,,	,,	1937	—	,, ,,
	,, Mile 10	8				,,	,,	,,	,,	1937	—	,, ,,
	,, ,, 11	8				,,	,,	,,	,,	1937	Max. 835 tons. Ave. 486 tons.	,, ,,
	,, 12	8				,,	,,	,,	,,	1936		,, ,,
	,, 13	8				,,	,,	,,	,,	1937		,, ,,
	,, ,, 14	8				,,	,,	,,	,,	1936		,, ,,
	,, ,, 15	8				,,	,,	,,	,,	1936		,, ,,
	,, ,, 16	8				,,	,,	,,	,,	1937		,, ,,
	,, ,, 17	8				,,	,,	,,	,,	1936	Max. 806 tons. Ave. 408 tons.	,, ,,

APPENDIX 3—(*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day tons.	Remaeks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
18.	**Cantonment Branch Road : Lucknow** State Highway	1 fg. 165 ft 1 fg. 358 ft	←			No details available →				1939 1941		
19.	**Lucknow-Gorakhpur Road : N. H.** Mile 161	5 8 8	$4\frac{1}{2}$ in. ($\frac{3}{4}$in.-2 in. size).	9/50	Bitumen 14 tons per mile	Katerniaghat stone grit 3500 cu. ft. per mile.	11/50	Not yet painted			350 tons to 400 tons (1948)	Good in all respects i.e., smooth surface and good adhesion with binder.
			,,	,, 10/50	,, Tar No. 3 14 tons per mile	,, ,,	,, 4/51	,, 8 tons per mile	2000 cu. ft. per mile		,, 350 tons to 400 tons (1948)	,, ,, Smoothness is fair and adhesion good.
	,, Mile 160	8	,,									
	,, Mile 159		,,									
				,,	,,	,,	5/51	,,	,,		,,	,, ,,
	,, Mile 158	8										
			,,	10/51	,,	,,	11/51	Not yet painted			,,	,, ,,
			,,	11/51	Bitumen 14 tons per mile	,,	5/52				,,	
	,, Mile 154	8										
	,, Mile 153	8										
20.	**Behraich-Balrampur Road :** Mile 3 (fg. 4-8)	5	$4\frac{1}{2}$ in. ($1\frac{1}{2}$ in. size)	8/51	Tar No. 3	Katerniaghat grit $\frac{3}{4}$ in.-$\frac{1}{4}$ in.	1952	2nd. coat not yet given			—	Width treated 9 ft. Deep patches have developed and smoothness is poor. Adhesion of binder was poor. Over-burnt brick ballast mixed with deep red first class brick ballast was used.
	,, Mile 4 (fg. 1-6)	6	,,	9/51 (fg 1-4) and 2/52	,,	,,	,,	,,			—	Adhesion of binder is poor.
21.	**Faizabad-Bahraich Road :** ,, Mile 19	8	,,	10/52	Tar No. 3 50 lb per 100 sq. ft.	Haldwani grit $\frac{3}{8}$ in.-$\frac{1}{8}$ in. 4.5 cu. ft. 4.5 cu. ft. per 100 sq. ft.	—	,,			Ave. 200 tons Max. 350 tons	No report available as surface has been under traffic for a short time.
	Mile 20	8	,,	11/52		,,	—	,,			—	,, ,,
	Mile 69	8	,,	2/52	,, Tar No. 3 60 lb per 100 sq. ft.	Grit 5 cu. ft. per 100 sq. ft.	6/52	,,			Ave. 300 tons Max. 500 tons	Adhesion of the binder with brick ballast is good. The surface is not smooth.

APPENDIX—3 (*Contd.*)

Serial No.	Name of Road and milage.	Length treated in Furlongs.	Thickness of brick metal and its size.	Time of consolidation.	Wearing surface 1st coat. Binder and rate of application.	Wearing surface 1st coat. Grit and rate of application.	Wearing surface 1st coat. Time of application.	Wearing surface 2nd coat. Binder and rate of application.	Wearing surface 2nd coat. Grit and rate of application.	Wearing surface 2nd coat. Time of application.	Traffic intensity per day tons.	Remarks.
1	2	3	4	5	6 (i)	6 (ii)	6 (iii)	7 (i)	7 (ii)	7 (iii)	8	9
22.	**Lucknow-Banaras Road: (Distt. Partapgarh).**											
	M. 82 Fg. 6 to 7	2	4½ in. thick (2½ in. size)	Not known	—	Not known	Not known	Tar No. 2	Not known	Not known	—	The portions are less smooth than stone ballast painted length. Patches are easily formed where the wearing coat is less in thickness. Can withstand for 4 to 5 years if regularly painted after that period.
	89 1 to 4	4	,,	,,	—	,,	1941	,,	,,		Max. 495 tons Ave. 189 tons	
	93 1½ to 5	3½	,,	,,	,,	,,	1941	,,	,,		—	
	100 2¼ to 4½	2	,,	,,	Not known	,,	Not known	,,	,,	6/50		
	102 4½ to 7	2½	,,	,,	,,	,,	,,	,,	,,		Max. 513 tons Ave. 328 tons	
	109 7½ to 8	½	,,	,,	,,	,,	,,	,,	,,			
	110 0 to 1½	1½	,,	,,	,,	,,	,,	,,	,,			
	114 5 to 7½	2	,,	,,	,,	,,	,,	,,	,,			
	158 6 to 8	2	4½ in. thick (2½ in. size)	5/51	,,	,,	6/51	,,	,,	6/51	Max. 948 tons Ave. 413 tons in mile 160 fg. 4	The surface is quite satisfactory. Life is about 2 years.
	159 1 to 4	7	,,	,,	,,	,,	,,	,,	,,	,,	—	
23.	**Barabanki-Gonda Road:** Mile 11	8	,,	10/51	Bitumen 80/100, 16 tons per mile	¼ in. to ¾ in. Katerniaghat grit 4.7 cu. ft. per 100 sq. ft.	12/51	—	—	—	Max. 768.5 tons Ave. 390.25 tons	Behaviour satisfactory. The surface is standing well.
,,	Mile 12	8	,,	,,	,,	,,	,,	—	—	—	—	,, ,, ,,
24.	**Allahabad-Faizabad Road:** Mile 61	8	,,	1949	Bitumen 80/100, 16 tons per mile	Bharatkup metal (1¼ in.-¾ in.) 4.7 cu. ft. per 100 sq. ft.	1949	—	—	—	Max. 213.75 tons Ave. 139.75 tons	Surface is smooth and binding seems satisfactory.
25.	**Lucknow Banaras Road:**											
,,	Mile 184	8	4½ in. consolidated to 3 in. (1½ in. to 2 in. gauge)	9/49	Bitumen 13 tons per mile	Gaya grit (1¼ in. to ¾ in. size) 4.4 to 5 cu. ft. per 100 sq. ft.	11/49	Bitumen	Gaya grit	6/51	500 tons approx.	Surface smooth and adhesion of binder to brick ballast is good.
,,	Mile 186	8	,,	3/50	,,	,,	5/50	,,	,,	6/52	,,	,, ,, ,,
,,	Mile 181	8	,,	2/51	,,	,,	6/51	,,	Being painted		,,	,, ,, ,,

Note:—In addition to above further work is in progress on Rampur-Ghat Road, Lucknow-Gorakhpur Road and Mirzapur-Jaunpur Road in Banaras Division and on

Detailed P. W. D. Specifications for Brick Ballast Collection ; Brick Ballast Consolidation and Surface Dressing

Brick Ballast Collection

General

The bricks from which the ballast is to be broken shall be overburnt and not merely well burnt.

Bricks which are not overburnt shall not in any circumstances be used.

Size and Test

The ballast shall be broken to the gauge specified in the contract and the Engineer-in-Charge or his assistant may, if he deems it necessary, test the size according to the following procedure.

An average sample of ballast weighing 100 lb shall be tested with gauge screen and shall conform to the following conditions :

(a) the whole shall pass through a screen having square meshes ½ inch greater than the specified gauge.

(b) not more than 20 per cent, shall pass through a screen having square meshes ½ inch less than the specified gauge.

(c) no portion shall pass through a screen having square meshes 1½ inches less than the specified gauge.

The quality of brick ballast shall not be inferior to the sample supplied by the contractor and sealed with the seals of the department and the contractor and kept in the custody of the Engineer-in-Charge.

Stacking

The metal shall not be thrown down on the travelling surface or patries of the road under any circumstances, but shall be shot on the lower berm, where the stack is to be formed as directed by the subordinate-in-charge. Before stacking, the site shall be cleaned and levelled by the contractor and approved by the subordinate-in-charge. The collection and stacking of metal shall commence at one end of the portion to be renewed in each mile and be continued to the other end of that portion. The stack shall be 12 in. high and shall be free from all rubbish and dry leaves, etc.

Brick ballast consolidation

General

As a brick ballast road cannot stand traffic unless painted, it is essential that brick ballast should be consolidated either before or after the rains so that first coat of paint can be given within one month.

Preparation of surface

The surface of the old metalling shall be thoroughly cleaned of all dirt and all deep holes in the old metalled surface shall then be roughly repaired. The whole of the old surface shall then be scarified or wholly picked upto a depth of 1½ in. and the whole of the roughened surface raked true to template. If the old surface is badly rutted the higher portion shall be wholly excavated to such a depth as will ensure, when the broken up surface, has been trued to template, that the depth of the loosened surface is uniform.

Two parallel mud walls 8 in. wide by 6 in. high made of well primed clay shall be formed along the outer edges of the metalling to confine the new metal and prevent it from spreading under the action of the roller. These mud walls shall be aligned with flags under the direction of the subordinate-in-charge and the clear width between them shall be the exact width of the new metalling.

Spreading of metal

The brick ballast shall then be spread evenly over the surface true to the template. The metal shall be carefully handpacked, the bigger pieces of metal being placed below and the smaller pieces in the interstices of the bigger pieces. The templates shall be placed at distances apart not exceeding 50 feet and shall be fixed truly horizontally so as to ensure that both sides of the road are dead level. The bottom member of the template shall be of a depth equal to the unrolled thickness of the coat of metal being applied. The metal when spread shall also be to the level of the top of the bottom member of the template.

The camber of the template shall be 1 in 60.

No earth or organic material shall be mixed with or spread over the metal before, during or after consolidation.

Consolidation

The brick ballast shall then be rolled with a light road roller, not exceeding 10 tons, commencing at the edges and working

towards the centre. The metal shall be dry rolled until no lines of the roller are left on the surface, i.e., until the metal has been thoroughly compacted. The surface shall then be saturated with water and rerolled until thoroughly compacted and no marks are left on the surface by the roller or by any cart which may pass over it. After the metalling has been rolled as specified above, the blinding material shall if so directed by the Engineer-in-Charge be spread evenly over the whole surface and be of such a thickness as will when watered and rolled, only just fill all interstices. The blinding material shall not contain clay or organic material. After the spreading of the blinding material the surface shall be well rolled and watered to such an extent that the blinding material is formed into a slurry. The slurry shall be brushed slightly with brushes backwards and forwards in front of the roller and the rolling and brushing shall continue until the surface is passed by the Executive Engineer or his assistant.

Not more than one furlong of road shall be under operation in any one mile at one and the same time.

Patries

The earthen sides (patries) shall be made up to a uniform width of 10 feet from the edge of the metal as soon as the adjacent metalled portion has been opened to traffic. The surface shall be flush with the surface of the metal at the inner edge and shall be given an outward slope of 1 inch in 3 feet. All holes, channels and other irregularities in the slopes of the embankment shall be filled up. The earth shall be obtained from the boundary ditch or such other place as the Executive Engineer or his assistant may direct and shall be dug evenly and neatly, deep and unsightly holes being avoided. The boundary locks-pit and the outer slope of the boundary ditch shall not be disturbed and no earth shall be dug within 3 feet of a tree, milestone, furlong post or boundary pillar. The earth thrown on the patries and slopes shall be beaten down, all clods being broken in the borrow-pits and the surface shall be smoothly dressed. In places where earth is obtainable only with difficulty during the rains a strip of patrie 3 feet wide adjoining the edges of the metal shall be made up as soon as the adjacent portion of metal is opened to traffic and the remainder shall be completed later. Borrowpits should not be dug in town or village but if unavoidable shall not be more than 12 in. deep and shall be drained properly.

Surfacing dressing

General

Except with the express permission of the Superintending Engineer surface dressing shall not be applied to a water-bound kankar or a soft stone surface. Old stone or brick surface shall only be painted if in good condition and free from pot holes and ruts.

Newly consolidated surfaces

When consolidation is done with the intention of painting the surface no material shall be used for binding or for blinding which is of such a nature that it cakes hard and is therefore difficult to remove. Moorums must be avoided for this reason. The use of roadside earth provided it is not clayey, is permissible only for blinding the surface after consolidation but must not be used as a binding agent during the work. Fine stuff resulting from scarifying if left on the surface of the road before spreading the metal partially fills the voids and obviates the necessity for any additional binding material, though surface blinding will still be necessary.

In all cases the consolidation must be complete and must not cease until the roller fails to make any mark on the surface. The ballast should be well graded and, if necessary, more than one size should be purchased though it is preferable to have metal which has not been screened.

Type of painting. Unless otherwise ordered by the Superintending Engineer all painting of surfaces not previously painted shall be done in two coats. The binding material for the first coat shall be one which has penetrative properties for example tar, bitumen emulsions and bitumen cutbacks. The material for the second coat shall normally be a bitumen applied hot, but for experiments other materials may be used as ordered by the Superintending Engineer.

Grit. The grit shall either be broken stone or coarse river bajri. The hardest material available at a reasonable price shall be used and it is immaterial whether the shape of individual pieces is angular, as in broken stone, or round as in the case of bajri. For the first coat on a newly consolidated roadthe grit shall be screened so that 100 per cent passes through a 3/4 inch screen and retained on a 1/4 inch screen. The grit for the second coat, or for repainting a surface previously painted, shall bescreened so that 100 per cent passes a 1/2 inch screen. Where very thin

coats of binder are applied it may be necessary to use still finer grit or even coarse sand.

Time for painting

The period which must elapse between completion of consolidation and the commencement of painting depends on the material to be used, the time of year and to some extent on the traffic. No painting shall be done during December and January. No hot painting shall be done during the rainy season or painting with emulsion or cutback while it is raining or rain is imminent.

First coat with tar. The road must be bone dry before painting is commenced and this dry condition must extend right down to the earth subgrade. To secure this condition the surface of the road must be kept continuously protected by blinding with a material which does not cake hard if required.

In no case should painting be delayed more than three months from the date of completion of consolidation and if the time of year is such that it is anticipated that more than this period will elapse before the road is fit for hot paint, an emulsion should be applied as soon as possible after consolidation as described below. If this has not been done, and it is found that the surface will not be dry within 3 months an emulsion should be applied within three months.

First coat with emulsion. When the first coat is to be with emulsion, either from choice or for the reasons given above, it should be applied within ten days of completion of consolidation during which time the surface should be protected with blinding as above.

First coat with cutback. The road must be reasonably dry but need not be bone dry right through. Two days dry weather, even during the monsoon, will usually suffice.

Preparation of the surface

Before the application of paint, the surface of the road shall be thoroughly cleaned of all caked mud and cow dung with stiff brooms or, if necessary, with wire brushes. These latter should only be used if the foreign matter is caked so hard that the brooms fail to remove it. The road shall then be swept with bass brooms followed by housemaid's brushes of medium softness. Finally, and immediately prior to painting, it shall be blown free of all dust by means of gunny bags or, if available hand or mechanical blowers. The dirt and dust removed from the surface shall be removed and deposited at a distance from the road. Only that amount of surface shall be broomed and brushed as can be painted the same day and the final cleaning by blowing shall not precede the application of paint by more than half an hour.

During the cleaning the berms and patries shall be kept thoroughly watered. When an emulsion is used for the first coat the surface of the road shall be well soaked with water before the application of the paint but at the time painting is commenced there must be no free water on the surface and the road must be in a "thoroughly damp condition".

Quantity of paint

When the paint is applied by pouring attempts should be made to restrict of the quantities to those given below :

1st coat with tar
from 41 to 45 lb per 100 sq. ft.

1st coat with emulsion
from 33 to 39 lb per 100 sq. ft.

1st coat with cutback
about 30 lb per 100 sq. ft.

2nd coat with hot bitumen
from 23 to 29 lb per 100 sq. ft.

2nd coat with Tar
from 22 to 28 lb per 100 sq. ft.

Application of paint

The binder shall be heated to a temperature not higher than that specified by the makers in boilers each of which is provided with a suitable thermometer. The material should not be poured on to the heated surface of the boiler as it is liable to be cured. Heating must be gradual and the paint shall not be heated to a higher temperature than necessary and in no case shall the maximum temperature given by the makers be exceeded. As the boiler becomes empty the fire shall be gradually withdrawn or damped so as to avoid any noticeable increase in temperature in

the smaller quantity that remains. Boilers must be carefully cleaned every month.

The paint shall be applied to the road surface with specially constructed pouring cans with wide mouths and of known capacity. To obtain correct and even distribution of paint the road surface may be divided into rectangles of known area each suitable for the contents of one pouring can and the paint then poured longitudinally and brushed evenly over the surface with bass brooms. Brushing shall always be done from the sides towards the crown. Brooms must be cleaned at the end of the day's work.

Gritting

As soon as the paint has been spread, in the case of hot paint, or as soon as the paint commences to break in the case of an emulsion, the grit shall be broadcast on to the surface. Before doing so, the grit should be screened into two portions one containing the larger pieces and the other the smaller. The larger grit shall be spread first, made into an even layer by hand, and the smaller grit then spread over it. The whole shall be made as even as possible before rolling.

The quantity of grit to be used shall be not less than the following :

1st coat with tar, emulsion or cutback.
4.4 cubic feet per 100 sq. feet.

2nd coat with hot bitumen or tar
2.2 cubic feet per 100 sq. feet.

After the grit has been spread evenly over the surface it shall be rolled with the lightest roller available. Rolling shall be done sufficiently to press the grit into the painting material and to fill the interstices of the metal in the case of the first coat. Excessive rolling crushes the grit and must be avoided. During the rolling workmen should follow the roller and, with extra grit, fill in all lean places and with country whisks, brush all surplus grit from those places which have excess grit. Close and even packing of the grit is essential for a good result. The roller must be driven at the slowest speed possible and care must be taken not to start, or stop, with a jerk. The roller shall never be permitted to stop on a part of the surface which has not been finished and should never stop at the same spot twice.

Some weeks after painting, the period depending on the volume of traffic, surplus grit may be removed and stacked by the road side. During and after this period all spots which show signs of "bleeding" shall be covered with fine sand and, a roller is available, rolled; the use of grit for this purpose produces high spots.

Edging

As a general rule, the edges of the painted road shall be protected by brick on edge and/or by strips of water-bound macadam at least 12 in. wide and 4½ in. thick. Stone, brick ballast, kankar or other suitable material may be used.

Second coat

The second coat of paint shall be applied as soon as the first coat has reached its "optimum" condition, that is when the surface has become smooth, exhibits a mosaic and all loose grit has been absorbed. The period which will elapse between the first and second coats of paint will depend on the volume of traffic and on the material used for painting. It is essential that tar should be allowed to harden before being repainted with bitumen as otherwise it remains as a soft layer under the relatively hard bitumen and the road surface soon becomes uneven.

In the majority of cases the period between the two coats will not be less than three months and may extend to as much as six or more if traffic is light and the season of the year unfavourable for painting.

Repainting

Unless the Superintending Engineer orders otherwise, the material used for repainting shall be the same as was used for the original paint coat or, in two coat work, the second coat.

Repainting should not be carried out merely because a certain period has elapsed since the last paint coat was given and normally, a mosaic or larger stone should appear before repainting is required thus indicating that the previous coat has been worn out.

If, in spite of patch repair having been properly done without delay, the surface continues to break up rapidly and there

are indications that the paint has ceased to adhere to the surface in a great part of the mile, the existing paint should be entirely removed, the surface thoroughly cleaned in the usual way and the road treated exactly as if original painting were being carried out; i.e., the first coat shall be given with a material with penetrative properties followed by a second coat later on. If the existing surface has not worn in patches but its condition is so wavy and uneven amounting to roughness, the surface shall be scraped and the road treated exactly as described above.

If the condition is not such as to necessitable scraping, all patches shall be carefully repaired and it is preferable that this is done at least a month before repainting. The quantities of paint and grit, as well as the size of the grit, shall be the same as for the second coat of a two coat work.

APPENDIX 5

Rates of Materials and Labour Assumed for Calculation of Ultimate Cost of Kankar Macadam Surface

Kankar Metal Surface

Cost of kankar metal—Rs 28 per 100 cu. ft.
Consolidation of kankar metal—Rs 8 per 100 cu. ft.
4½ in. thick renewal every 3 years—Rs 9,490 per mile.
Annual maintenance cost—Rs 850 a year per mile.

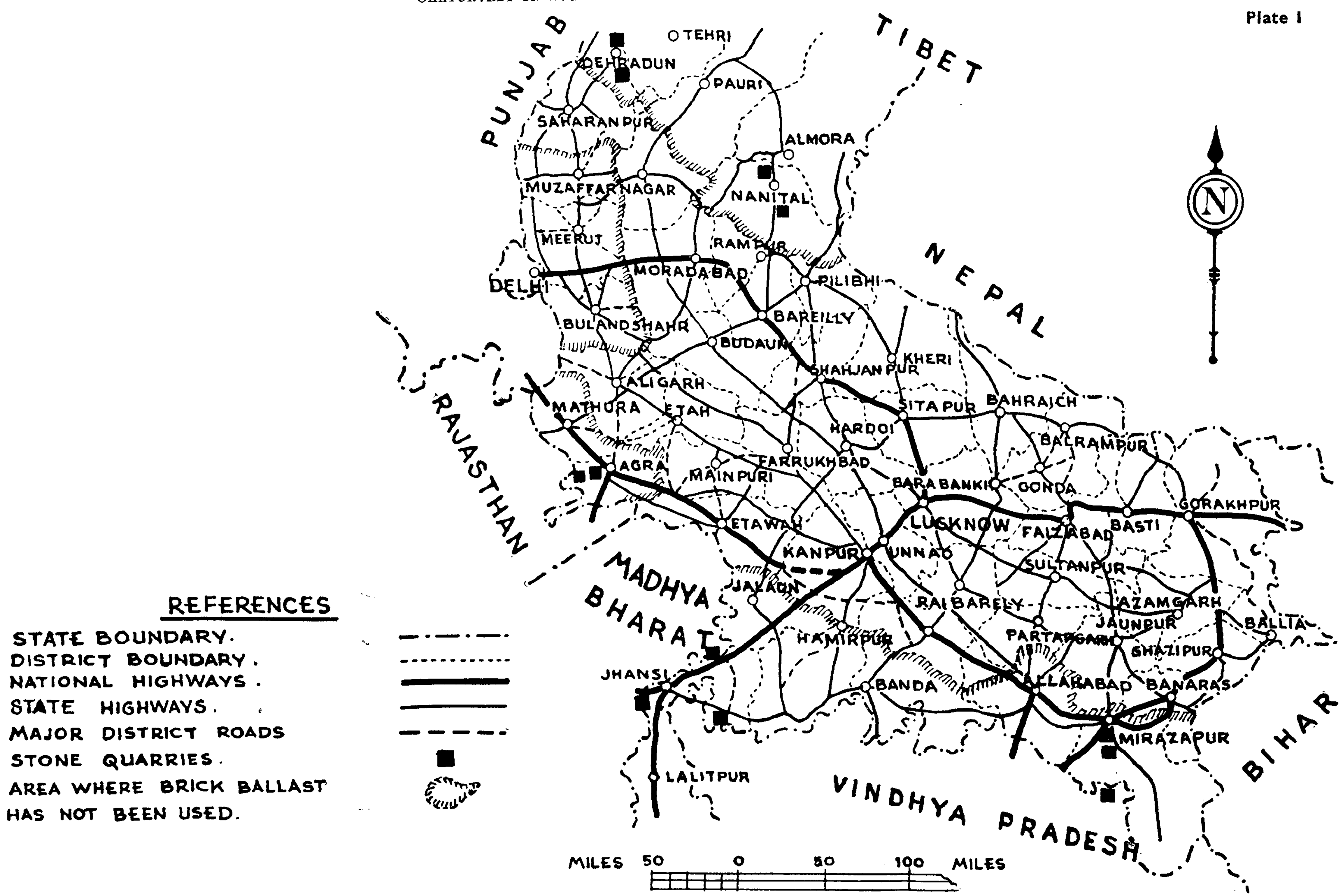
Surface Dressing over 4½ in. thick Brick Ballast Water-Bound Macadam

Cost of brick metal—Rs 45 per 100 cu. ft.
Consolidation of brick metal—Rs 9/8/- per 100 cu. ft.
Tar for 1st coat surface dressing—14 tons at Rs 250 per ton.
Bitumen for 2nd coat—Rs 450 per ton.
Stone chips—Rs 135 per 100 cu. ft.
Labour for surface dressing—Rs 2/12/- per 100 sq. ft.
Annual maintenance—Rs 1,330 per mile.
Repainting every 3 years—Rs 6,700 per mile.
Renewal, 3 in. metal every 15 years—Rs 18,870 per mile.

Surface Dressing over 4½ in. Stone Metal Water Bound Macadam

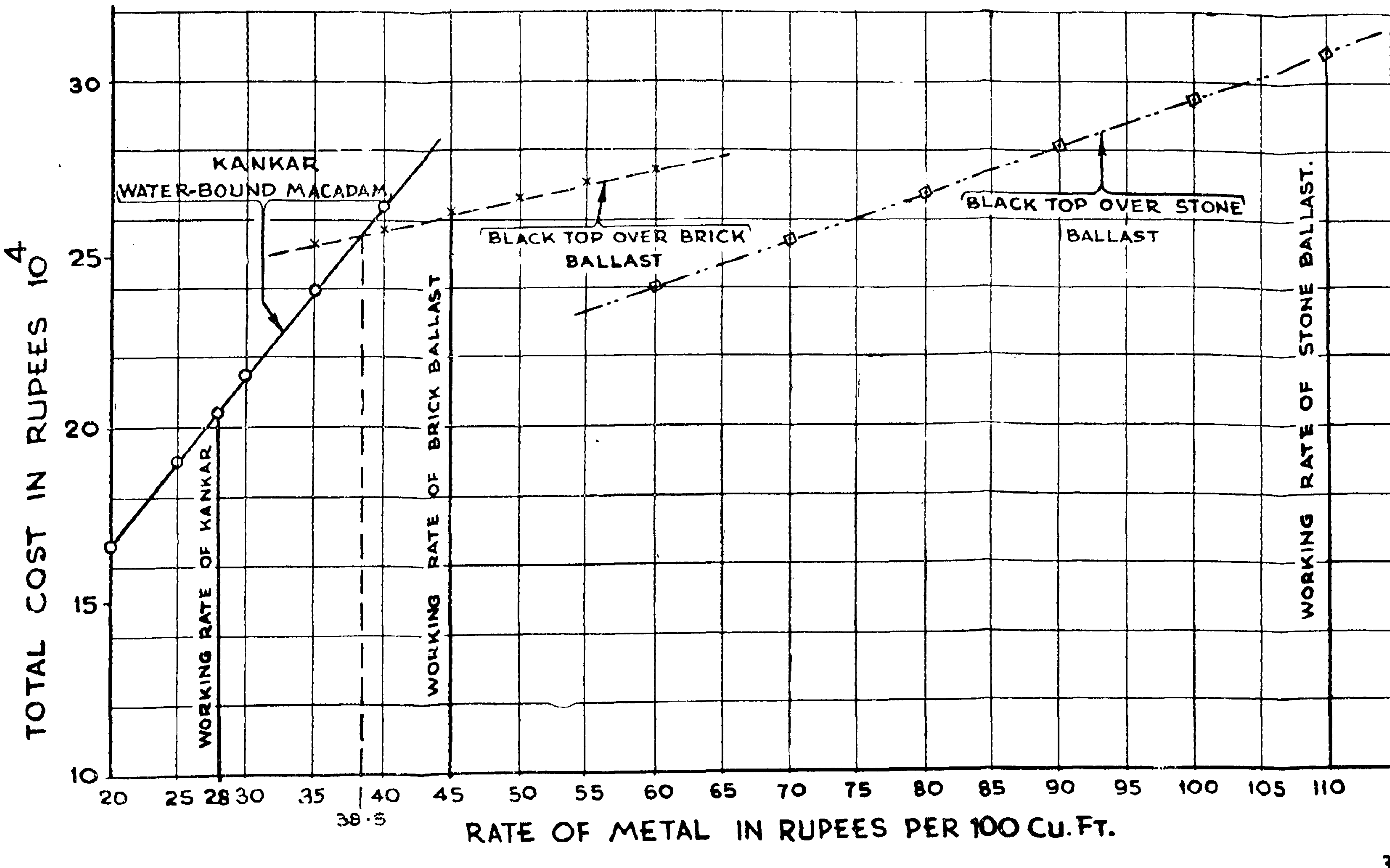
Cost of stone metal—Rs 100 per 100 cu. ft.
Consolidation of metal—Rs 12 per 100 cu. ft.
Tar for 1st coat surface dressing–12.6 tons at Rs 250 per ton.
Bitumen for 2nd coat surface dressing—7 tons at Rs 450 per ton.
Stone chips—Rs 135 per 100 cu. ft.
Labour for surface dressing—Rs 2/12/- per 100 sq. ft.
Annual maintenance—Rs 1,250 per mile.
Repainting every 3 years—Rs 6,100 per mile.
3 in. renewal every 15 years—Rs 27,660 per mile.

Plate I



MAP OF UTTAR PRADESH

Plate II



30 YEAR COSTS

Paper No. 173

CONSTRUCTION OF A SUBMERSIBLE BRIDGE ACROSS RIVER MAHANADI NEAR BHANJANAGAR (GANJAM) IN ORISSA

By

E. V. S. IYER, B.E., A.M.I.E. (Ind.), A.M.SOC.E.

AND

D. C. PANDA, B.SC. (Eng.)

(*Published in an abstract form*)

SYNOPSIS

This Paper deals with the details of design and construction of a submersible bridge over raft foundation. The work was executed departmentally; some pertinent details of organization and costs of certain items of work have been given to show that under favourable conditions, departmental execution is worth undertaking as it is the best way of training young engineers.

1. THE SITE

1.1. The bed of the river Mahanadi, a tributary to the Rishikulya, is sandy at the site of its crossing the Bhanjanagar-Asoka road. Three alternative sites for a bridge were investigated. Borings revealed that the coarse sand strata extends up to a depth of 10 to 15 ft and overlies stiff clay or sand mixed with clay. The subsoils at all the sites were more or less the same. Therefore, the cost of land acquisition for the approaches was the deciding factor in the final selection and the siting of the bridge along the old road crossing has resulted in a saving of Rs 14,000. The right side abutment was kept a little inward the river to help shifting the course of the deep channel towards the centre.

1.2. From considerations of scour depth and nature of substrata, it would have been obligatory to take the foundation of each pier down to stiff clay i.e., beyond the range of scour necessitating costly well or open foundations with attendant difficulties and delays in execution. The river remains dry for half the year and the difference between the ordinary and high flood levels is (100.47 — 97.22) only 3.25 ft. Under these conditions a submersible bridge over raft foundation was favoured. In the opinion of the Authors, the conditions favourable for the adoption of a submersible bridge with raft foundation are:

(i) Duration of interruption to traffic on account of overtopping during floods is not more than 3 days at a time or more than 6 times in a year.*

(ii) Bed of the river is sandy for considerable depth.

(iii) The flood of the river spills over its banks.

(iv) The river remains dry for a considerable period.

(v) The scour depth is low under ordinary flood conditions.

1.3. In the present case, the Mahanadi river has several sharp bends for about 5 miles upstream of the bridge site and the banks are being continuously scoured. The flood water overtops a discontinuous flood bank constructed late in the 19th century and which is not maintained. The discharge of the river at the bridge site is therefore not its entire discharge. If a high level bridge were contemplated, double banking for about 6 miles would have been necessary for passing the entire flood discharge under the bridge resulting in high initial cost and recurring maintenance expenditure for the double banking.

2. DESIGN

2.1. There is perhaps no difference between a weir and a submersible bridge except that of function**. Therefore the design principles of a river weir with sluices and a submersible bridge may be assumed to be more or less the same. A sound design must satisfy the following criteria:

(i) The structure should be safe against over turning or uplift under the critical condition i.e., when the flood water is just about to overtop.

(ii) It should be safe against undermining, piping or retrogression of levels on the downstream side.

* I. R. C. Code of Practice 1950. Clause 103.

** "Causeways on Sandy Beds" by Y. K. Lall. Journal of the Indian Roads Congress, Volume XIII-3.

The design of the raft with its cut-offs must ensure the incompressibility and prevent movement of the particles of the sandy strata enclosed. Under such conditions the raft design is the simplest and permits execution without the difficulties and troubles generally experienced in deep open or well foundations.

The design calculations are given in Appendix 1.

3. FOUNDATIONS

3.1. A cement concrete raft is provided which runs continuously over the entire length (406 ft) of the bridge. The raft is 29 ft wide with sloped aprons extending 5 ft upstream and 14 ft downstream. The raft is 3 ft 3 in. thick at the pier base and 2 ft 3 in. at mid-span giving the shape of an inverted arch which has two functions:

(i) The barrel shaped vents are expected to function comparatively more efficiently.

(ii) The uplift pressure is relieved partially due to arch action and due to its shape, the raft can take more tension at the mid-span.

The top of the raft is kept at the average bed level of the river.

Details of the cut-off walls and pitching are given in Plate I.

4. SUPERSTRUCTURE

4.1. Span

In a submersible bridge, the area of obstruction has to be minimum possible. This necessitates (i) lowering of the road level; (ii) greater span length i.e., less number of piers; and (iii) minimum thickness of decking. All these again depend upon (a) frequency and levels of low and high floods, (b) tension at the mid-span of raft, and (c) possibility of vents getting blocked due to floating timber, brush wood, etc. Taking all these factors into consideration it was decided to adopt 15 ft clear spans. Details are given in Plate I.

4.2. Decking

R. C. C. slab 17 in. thick designed as freely supported has been adopted. If a continuous slab over three vents had been laid, it would have reduced the slab thickness to $15\frac{1}{2}$ in. and the cost by Rs 4,900; but the submerged weight of the structure would have been reduced, a risk on the stability of the bridge. Also, due to non-uniform reaction at the supports, even a slight unequal settlement would have damaged the structure.

4.3. Guard Stones

In a submersible bridge floating logs invariably damage the railings and the slabs to which they are anchored. Therefore, provision of railings is considered to be hazardous, unless they are of the collapsible type. Collapsible railings again require prompt and careful attention which may not be always possible in out of the way places. In this bridge, cement concrete guard stones 15 in. in height, 12 in. in diameter at base and 9 in. at top have been provided at 5 ft centres.

4.4. Wearing Coat

3 in. cement concrete wearing coat is provided with a camber of 1 : 120 with " Tel-tale " hoops.

4.5. Expansion Joints

Between the deck slabs, expansion joints one inch thick have been provided which are filled with road tar with a little admixture of sand. To allow for free expansion, the top of the pier caps were finished smooth, greased and glossy paper put on top.

5. ORGANIZATION

5.1. As the bridge work was in the Community Project area the work was undertaken departmentally in order to utilize local resources to the maximum extent.

This involved the following objectives :

(i) Tuning of the departmental organisation, which was only familiar with the contract system of execution to tackle the job efficiently.

(ii) Selection of suitable persons for handling the job in all its aspects and fixing of responsibilities and duties.

(iii) Co-operation of the community project officials and the villagers in the Community Project area.

(iv) Control of rates on the bridge construction without adversely affecting the Community Project works in the neighbourhood.

5.2. The collection of materials like stone, metal and chips was entrusted to job and piece workers. A sub-divisional officer assisted by an overseer was made responsible for this and payment of 95 per cent of the value of the materials collected was made once in 3 days.

The excavation of foundations for the cut-off walls and the raft and driving of piles below the downstream apron were done by daily labour. The laying of concrete and the masonry work in superstructure, the R. C. slab decking, revetment work, etc. were entrusted to job workers on labour contracts.

5.3. The staff employed on the bridge work was :

Sub-divisional Officer	1
Overseers	3
Clerk	1
Peons attached to the above officers	4
Work sirkar	1
Night watchers	2
Drivers for stone crushers and pumps.......	2

The total expenditure on the above establishment was nearly Rs 11,000 about 5 per cent of the total cost of the bridge.

The following plant and machinery were used on the job.

1.	Stone crusher	1
2.	Granulator	1
3.	Winget concrete mixer	1
4.	Water pumps (Power driven)	2
5.	Monkey with guide rod	1
6.	Winch crab and derrick for pile driving	1 (set)

6. EXECUTION

6.1. The work was started in February 1953 and completed in March 1954. From May 1953 to October 1953 there was no progress due to shortage of cement. But for this the work would have been completed in June 1953.

At first, timber centring was erected for 2 vents and it was found that if the slabs had to be cast rapidly, a large quantity of centring materials would be necessary. The barrel shaped vents created some difficulties. To avoid the extra cost, labour and time involved in the erection, striking and re-erection of timber, the vents were filled with sand taken from the bed of the river and consolidated in layers. The sides of the vents were closed with wooden planks which were laterally supported by bracings and struts. Over the filled up sand, a layer of stone jelly 3 inches thick was laid and was grouted with wet sand, plastered over with weak cement mortar 1 : 12 and finished with neat cement to get a smooth surface. After oiling the top of centring, concrete for the deck slabs of alternate spans was poured. After 21 days of curing, the sand filled centring was removed and the stone used on top was taken out and reused on road work.

7. COSTS

The rates at which the different items of work were executed are given in Appendix 2. A saving of Rs 30,000 from the sanctioned estimate amount is expected. The cost works out to very nearly Rs 500 per foot run.

8. ACKNOWLEDGMENT

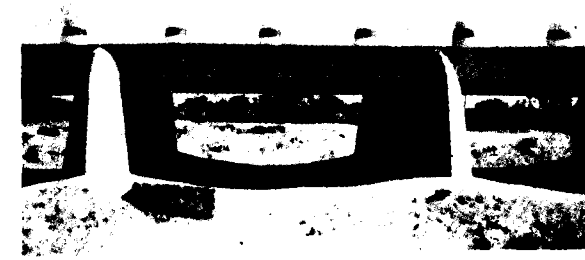
The Authors wish to convey their thanks to Mr. C. M. Bennett, O.B.E., I.S.E., Chief Engineer, Public Works Department, Orissa, for his kind interest and encouragement in writing this Paper.

Photo 1

The completed Bridge

Photo 2

The Barrel-shaped Vent



APPENDIX 1

DESIGN CALCULATIONS

Discharge

Area of catchment – 350 sq. miles

Discharge by Ryve's formula, $C = 563$ – 27,960 cusecs

A portion of this discharge spills over the low banks in the upper reaches of the river.

Ordinary flood level – 97.22

Area of cross section at the ordinary flood level viz., 97.22 – 2,322 sq. ft

Wetted perimeter – 520.46 ft

Hydraulic mean depth, r – 4.46 ft

Slope as observed, S – 0.00138 ft per foot

Rugosity of bed, n 0.03

Velocity in ft per sec. $V = \dfrac{1.486}{n} \times r^{\frac{2}{3}} \times S^{\frac{1}{2}}$

$= 4.928$ or 4.93 ft per second

Discharge in cusecs Q – $4.928 \times 2322 = 11{,}442$ cusecs

Contracted area of flow – 1407 sq. ft.

Velocity in the vents – $\dfrac{1.1 \times 2322 \times 4.93}{1407}$

$= 8.94$ ft per sec. or 9 ft per sec.

PRESSURE CALCULATIONS

The worst effects will occur when the water is just over topping the bridge. Water will be backed up on the upstream side in front of the slab and on the downstream side there will be a trough of standing water owing to the high velocity of the stream.

Forces to be considered are those due to :

1. the static head,
2. the impact of the water and debris,
3. the eddy motion,
4. the friction of water against the pier and the bottom of slab, and
5. the uplift.

The sum total of all the horizontal forces will be taken to test the stability of the pier against over-turning.

1. Pressure due to Static head

Where W = weight of one cu. ft. of water = 62.4 lb

h = Afflux + depth of slab and wearing coat + depth of tail water below the bottom of slab.

Afflux = 0.81 or say 1.0 ft	1.0
Depth of slab & wearing coat = 17 in. +3 in. = 20 in.	1.67
Depth of the water below the bottom of slab say..................................	0.83
	3.50 ft

$Wh = 62.4 \times 3.5 = 218.4$ say 218 lb.

Pressure due to the depth of water $= \dfrac{WH^2}{2}$

Where H = 7.25′ including head due to velocity of approach.

$$\frac{WH^2}{2} = \frac{62.4 \times (7.25)^2}{2} = 1640 \text{ lb}$$

This acts on an area of the face of the cut water $\Big\} = 2 \times 2.9 \times 6.25$

$$\therefore \text{ Pressure per sq. ft.} = \frac{1640}{2 \times 2.9 \times 6.25}$$

$= 45.2$ or say 45 lb......(1)

2. Pressure due to Impact of Water and Debris

$$\text{Impact pressure} = \frac{WV^2}{2g} \left(\frac{a}{A-a}\right)^2$$

Where W = Weight of one cu. ft. of water = 62.4 lb.

V = Velocity of the stream = 4.93 or say 5 ft per sec.

g = acceleration due to gravity = 32.2 ft per sec.^{2}

A = area of flow just upstream of site = 2322 sq. ft.

a = area of obstruction.

$= 2322 - 1407 = 915 = 915$ sq. ft.

$$\therefore \text{ Impact pressure} = \frac{62.4 \times 5^2}{2 \times 32.2} \times \left(\frac{915}{2322-915}\right)^2$$

$$= \frac{62.4 \times 25}{64.4} \times \left(\frac{915}{1407}\right)^2$$

$= 24.2 \times 0.42 = 10.16$ or say 10 lb......(2)

3. Pressure due to Eddies $= W \dfrac{(Vv - V)^2}{2g}$

Where Vv = Velocity through the openings = 8.94 or say 9 ft per sec.

V = Velocity of approach say 5 ft per sec. approx.

$$\therefore W\frac{(Vv-V)^2}{2g} = \frac{62.4 \times (9-5)^2}{2 \times 32.2}$$

$= \dfrac{62.4 \times 16}{64.4} = 16$ lb approx.........(3)

4. **Friction on the causeway** $= fp\left(\frac{V}{10}\right)^2$

Where f = friction coefficient = 1

p = area of the surface of the causeway in contact with water = as below $(15'-6''-3'') \times 2$.

V = Velocity through the openings = 9 ft per sec.

Friction per sq. ft of obstruction works to 9.5 lb......(4)

5. **Uplift head under the slab**

This is equal to the thickness of slab and wearing coat and afflux less the head lost due to increase in velocity through the vents.

Thickness of slab and wearing coat	=1.67
Afflux (assumed)	=1.00
	=2.67

h = Uplift head $= 2.67 - \frac{(V_1^2 - V_2^2)}{2g}$ loss or head due to increase in velocity.

Where V_1 = Velocity under the vents = 9 ft per sec.

V_2 = Original velocity before approaching the bridge = 5 ft per sec.

$\therefore \quad h = 2.67 - \left(\frac{9^2-5^2}{2\times 32.2}\right)$

Uplift pressure $= W \times h$

$= 62.4\left\{2.67 - \frac{(9^2-5^2)}{2\times 32.2}\right\}$

$= 62.4 \times (2.67 - 0.87)$

$= 62.4 \times 1.80 = 112$ lb............(5).

But the dead wt. of R. C. slab alone is 150 lb per cu. ft.

Hence it is safe.

Total of horizontal forces to be considered for the stability of the pier are the total of 1 to 5 = 45+10+16+9.5+112 = 193 or 200 lb

Taking a pier face area $= 2 \times 2.9 \times 6.25$.

Total horizontal pressure acting on the pier face at 1/3 height $= 200 \times 2 \times 2.9 \times 6.25$ = 7250 lb or say 7500 lb

Weight of pier $= 23'\text{-}6'' \times 2'\text{-}6'' \times 6'\text{-}3'' \times 140$

Loss of weight due to floatation $= 23'\text{-}6'' \times 2'\text{-}6'' \times 6'\text{-}3'' \times 62.4$.

Net weight of the pier $= 23'\text{-}6'' \times 2'\text{-}6' \times 6'\text{-}3'' \times (140 - 62.4)$

28,500

Net weight of cut water say = 1,500

30,000 lb

Net weight of R. C. slab and wearing coat 54,332 lb

84,332 or 84,000 lb.

Net weight of pier and slab = 84,000 lb against the total horizontal pressure of 7,500 lb.

Hence the design is safe.

Critical Velocity

Critical Velocity $= Vo = 1.01\ d^{0.64}$

Where Vo = Critical velocity which would cause neither scour nor silting. Each river will have its own characteristics as regards the nature of silt brought down by floods and their capacity to retain it notwithstanding any obstruction. It has to be seen that the causeway does not reduce the velocity on the upstream side to below the critical velocity to prevent the vents from choking up.

d = the depth of water in the channel = 4.46

$$\therefore \quad Vo = 1.01 \times 4.46^{0.64}$$

$$= 1.01 \times 2.81 = 2.84 \text{ ft per sec.}$$

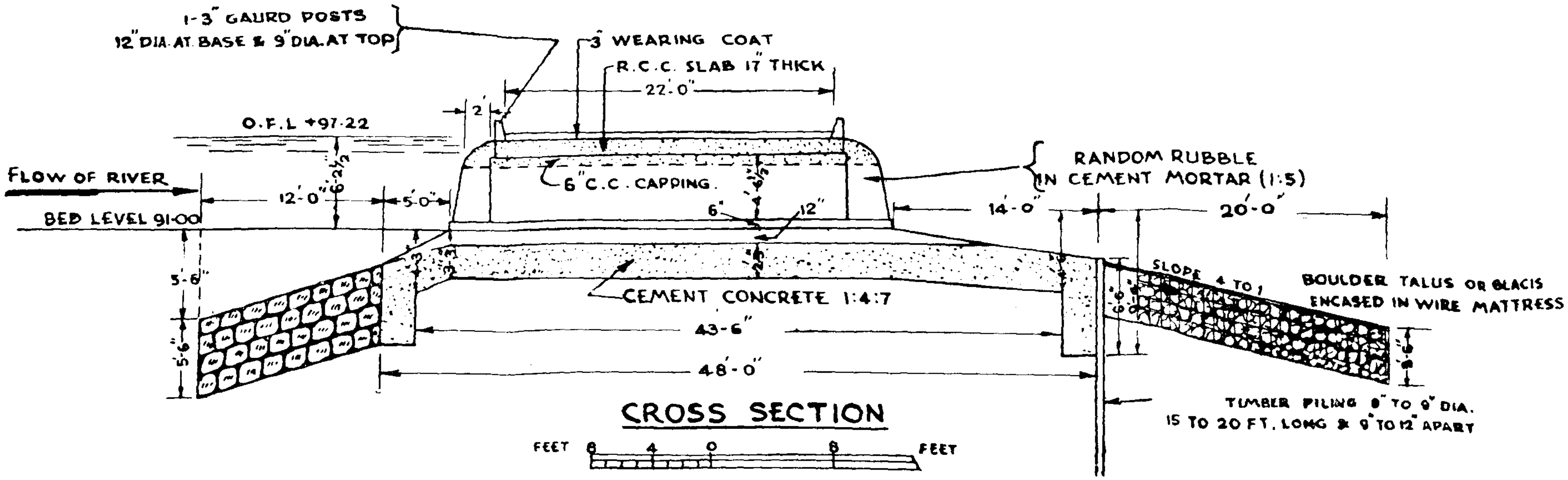
The velocity is more than the critical velocity.

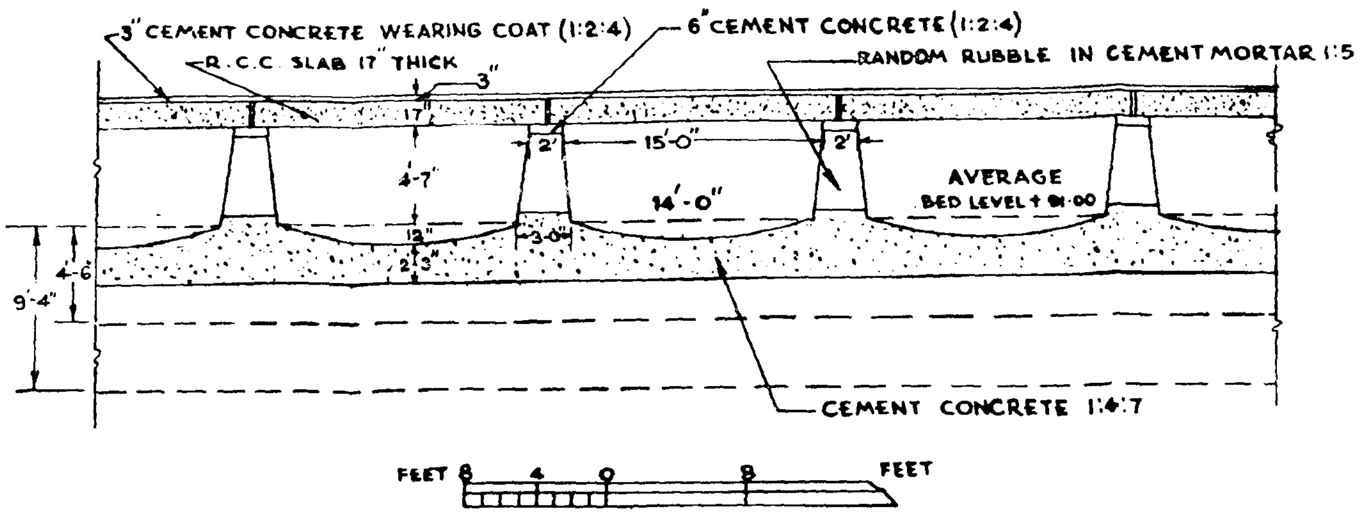
APPENDIX 2

Actual Costs and Schedule of Rates for some Important Items of Work

Item	*Actuals*			*Schedule*
	Cost of labour	*Cost of materials*	*Total*	
Earthwork in trenches for cut-off walls ...	15/3/-	—	15/2/-	16/
Random rubble granite masonry in cement mortar (1:5) including conveyance of rubble stone 3½ miles per 100 cu. ft. ...	13/3/4	62/6/8	76/4/-	84//4-
Cement concrete 1 : 4 : 7 per 100 cu. ft.	7/2/0	102/7/-	109/9/-	116/5/-
Preparing wire mesh 12 in. × 12 in. with 8 B.W.G. per 100 sq. ft. ...	3/3/1	10/3/2	13/6/8	No schedule
Boulder talus work with wire nets on the down-stream side per 100 sq.ft.	0/6/7	33/11/8	34/2/3	Do.
Pile driving, per ft run.	0/3/9	0/3/7	0/7/4	Do.

PLATE I





SUBMERSIBLE BRIDGE ACROSS MAHANADI NEAR BHANJANAGAR (ORISSA)

INFORMATION SECTION

EXPERIMENTAL GROUTED CEMENT CONCRETE ROADS IN TRAVANCORE-COCHIN

By

E. U. PHILIPOSE

CONTENTS

SYNOPSIS

Details of construction of two experiments on grouted concrete roads in Travancore-Cochin State and their performance under traffic are described. The first experiment was with a 1 : 3 grout on a $3\frac{1}{2}$ - 4 in. thick pavement. The second was with 1 : 2 grout on a $4\frac{1}{2}$ - 5 in. thick pavement.

Suggestions for further study are offered.

1. INTRODUCTION

1.1. The pattern of road traffic in Travancore-Cochin State, which consisted mostly of bullock carts with a small percentage of motor vehicles before World War II, has now undergone a change. The increase in motor vehicle traffic combined with the destructive effect of bullock cart has rendered the water-bound macadam surfacing uneconomical.

In the search for a surfacing suited to the present traffic, the State P. W. D. have, as an experimental measure, tried, among others, a surface grouted with cement mortar on a road carrying comparatively heavy traffic.

2. GENERAL DESCRIPTION

2.1. The grouted process consists in placing large sized stones 1 to 3 in. size to the specified thickness and pouring the grout of cement, sand and water. The grout will penetrate the voids in the stone and will set hard, making the whole into a stable and durable mass.

2.2. The grout is made with the help of a special mixer which is essentially a colloidal mill. In the colloidal mill the wetting of cement results from the rubbing and shearing action which takes place. Each solid particle is caused to mix with the liquid by rolling in such a way that any film of air or other gas is removed and the surface of the solid is made to come into contact with the liquid, thus ensuring a perfect mix.

2.3. The grout is prepared in the mixer by mixing cement, sand and water. The mixer has two compartments in one of which cement and water are added to form a colloidal mix while in the other sand is added. The sand mixes with the colloidal liquid and forms a stable grout. The mixer contains a paddle activated by diesel or electrical power. Whereas the ordinary grout composed of cement, sand and water will separate out before the initial set, the grout prepared in the special mixer remains stable until it sets.

2.4. The strength of concrete depends upon the strength of the matrix and it is not reduced by grading the aggregate with a view to reducing the quantity of matrix required. This property is made use of and the stones are packed as closely as possible to give the minimum of voids. The grout fills the voids between the stones to form a solid mass. Since the quantity of grout required depends on voids, the closer the stones are packed the less the quantity of grout required. Conversely, the greater the quantity of stone in the concrete, the greater will be its density, strength and resistance to temperature changes. Also, since volume for volume the stone is cheaper than grout, the pavement will cost less.

3. THE ADVANTAGES CLAIMED FOR THE GROUTED METHOD OF CONSTRUCTION

3.1. The advantages over ordinary cement slurry manufacture or concrete mixing claimed from the process are given below :

(a) The grout is thoroughly mixed. It is stable and fluent. Once mixed it does not separate.

(b) The grout is of uniform quality and since it is directly applied to the aggregate and tamped or rolled, the mixing of the aggregate as in ordinary cement concrete is not required.

(c) Only about one-fourth of the materials which go through an ordinary concrete mixer have to be mixed. The rest is dumped where it is wanted. This permits the maximum size of aggregates to be used.

(d) Construction can be done at greater speed. Laying of the coarse aggregate in place and grouting can be done independently.

(e) Since the mixer is required to mix only the grout, it can be small and easily portable.

(f) Since the process uses only as much grout as is required to fill the voids in the stone kept in place, there is saving in labour, sand and cement.

4. THE FIRST EXPERIMENT

4.1. Mile 93.4 to 94.3 of M. C. road (State Highway) in Central Travancore, with a traffic of 1,755 tons per day of which 155 tons are iron-tyred bullock carts was selected for the experiment.

4.2. The traffic in this section of the road justified a 20-ft width of surfacing, but the existing water-bound macadam crust was only 14 ft and widening was not possible without improvements to the road at considerable cost. Since the experiment was more concerned with the quality of road surfacing and cost, it was decided to have a 14-ft width over a water-bound macadam renewal coat 15 ft wide on the existing crust which was 12 in. deep.

4.3. The road surface was picked up and metalled for 15 ft width with a 4 in. thick coat using 1½ in. size metal for 2½ in. thickness and the picked up metal for 1½ inches. A camber of 1½ in. was given for the surface and the usual specification for water-bound macadam was followed. The grouting was done in two strips of 7 ft width. The formwork consisted of 4 in. × 4 in. jungle wood sleepers placed 7 ft apart and fixed by iron spikes. Two in. size metal was spread to a thickness of 4½ in. and the grout (1 : 3) poured on the metal to fill up voids to a depth of 3 inches. The stone was lightly rolled with a 6-ton roller to squeeze the mortar up and final screeding done at every 33 ft. The surface was cured for 21 days. The central longitudinal joints were only construction joints without any bitumen filling. Transverse contraction joints in the two halves were staggered and the distance between the joints varied from 1 to 4 feet. A typical section is given in Fig. 1. No insulation layer was provided between the pavement and the base course.

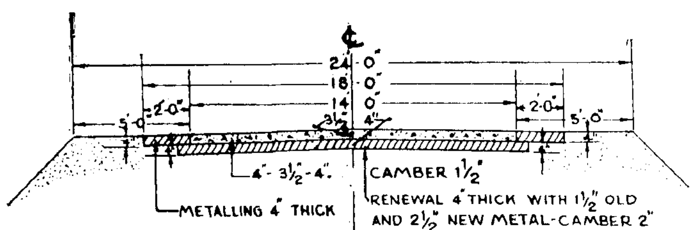


Fig. 1. **Typical Section—Experiment in 93/4 to 94/3.**

4.4. Costs

The cost of the grouted pavement worked to Rs 60 per 100 sq. ft. For the same thickness, a concrete road would have cost Rs 95 per 100 sq. ft. Thus the saving per 100 sq. ft. of grouted road surfacing over pre-mixed concrete was Rs 35.

5. BEHAVIOUR OF THE PAVEMENT

5.1. The road was opened for traffic on 21-11-1949 and the surface of the slabs was examined on 10-1-1950 hardly two months after the opening. It was found that there were hair cracks on several of the slabs. The positions of these cracks are shown in Fig. 2. The smooth surface formed by the excess grout was slowly wearing out. The cracks were not very serious and since almost all of them occurred at the position of contraction joints, they were explained as sympathetic cracks. The reasons why most of the cracks occurred on the left side slabs are obscure. Bitumen was applied on the hair cracks.

5.2. The surface was again examined on 13-2-1950. More hair cracks were noted on more slabs as shown in Fig. 2. The cracks observed originally had also slightly increased

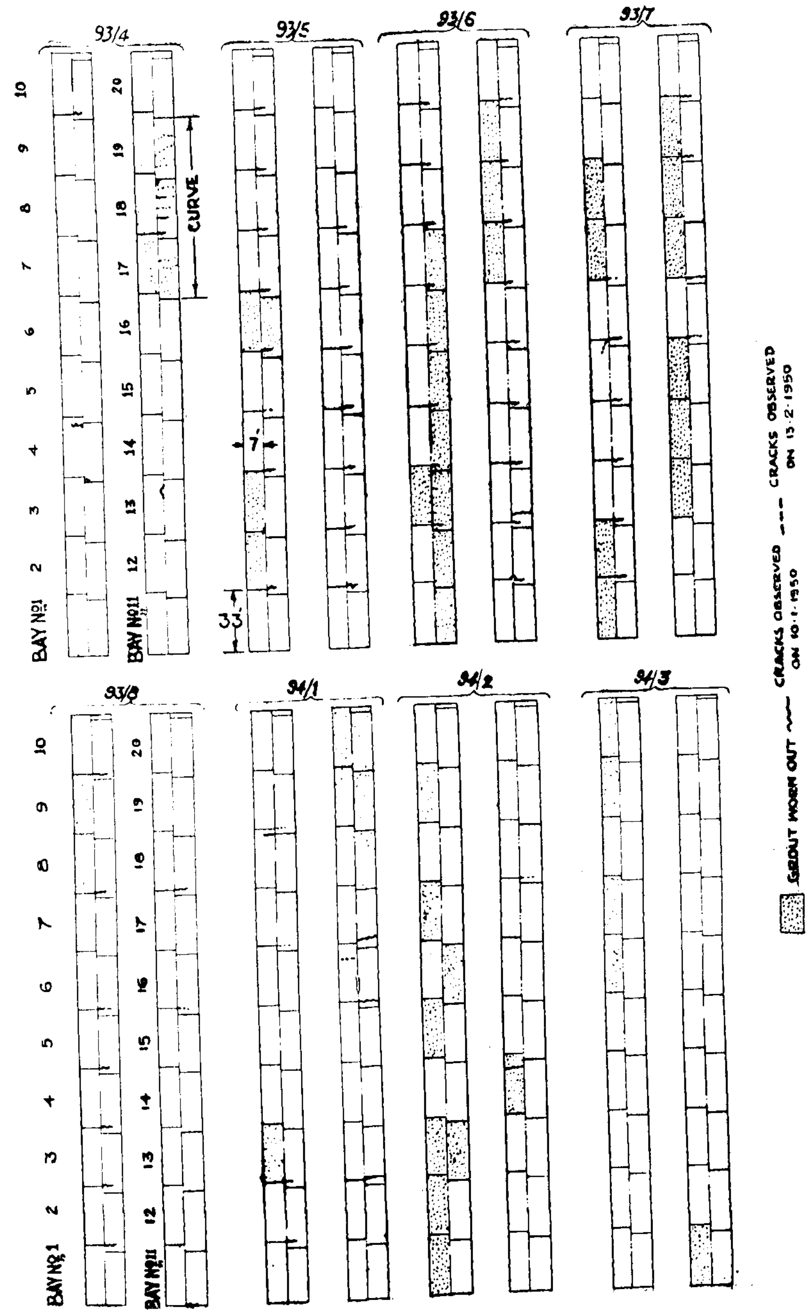


Fig. 2. **Condition of the Grouted Road, 93/4 to 94/3 of M. C. Road.**

in length. The smooth finished surface had worn off and the metal surface was exposed. The metal in some slabs was seen projecting up with the cement grout slightly below the surface. The inner slabs at curves had crumbled at several places with cracks in a few of them. In certain slabs, especially at the beginning, the surface had disintegrated slightly.

6. CAUSES FOR THE FAILURE

6.1. The possible causes for the failure are given below:

(1) The 4-in. thickness which is considered by some as inadequate even for the conventional type of concrete road surfaces, was insufficient.

(2) The proportion of cement and sand for the grout, which was 1 : 3, was insufficient since weight for weight the proportion approximated only to 1 : 3 : 8 concrete.

In view of the fact that the smooth finished surface formed by the grout had worn off by the abrasive action of traffic, it was felt that measures should be taken to expose only as little of the surface with the grout covering as possible. For this the use of smaller sized metal not less than $\frac{3}{4}$ in. size on the top layers of the bigger aggregate was considered desirable.

7. THE SECOND EXPERIMENT

7.1. A revised specification was, therefore, drawn up for grouting the portion from mile 97/5 to 98/8 of the M. C. road. A richer grout, i. e., 1 : 2 instead of 1 : 3, increased thickness of

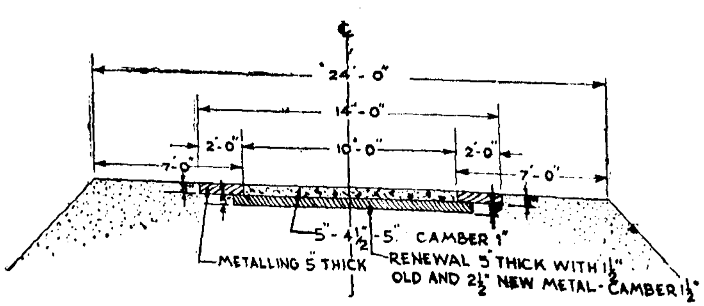


Fig. 3. Typical Section—Experiment in 97/5 to 98/8.

the slabs from 4 in. to 5 in. and provision of $\frac{3}{4}$ in. metal at top to fill the interstices of the 2 in. metal, were the main alterations in the specification. It was hoped that the above improvements in the specification would ensure the prevention of the defects noticed in the earlier experiment.

The traffic per day in this section of the road is 1,700 tons, of which 150 tons was bullock-cart traffic. The cost per 100 sq. ft. of pavement as per the revised specifiation worked out to Rs 74-8-0. A typical section is shown in Fig. 3.

8. BEHAVIOUR OF THE TWO EXPERIMENTAL LENGTHS

8.1. The experimental lengths have been subjected to traffic since 1950 and their condition was examined in the beginning of 1954 to study their behaviour under traffic.

8.2. **First Experimental Length between 93/4 to 94/3 M. C. Road**

The initial finish on the entire surface had worn out leaving a mosaic appearance. The wearing of the grout was quicker than that of the aggregate over the entire surface, but was noticeable more in places where abrasion due to traffic was greater such as along wheel tracks and in curves where superelevation was not adequate.

The cracks mentioned in para. 5.2 had not developed but some new cracks at a few other places, sometimes right across the half-bay and in one or two cases parallel to the longitudinal joints had occurred. These were only hair cracks which did not cause any discomfort to motor traffic.

Almost all transverse joints had proved unsatisfactory. During construction, rolling was done by the power roller only beyond 2 ft of a transverse joint. Hand tamping and screeding were done for 2 ft on either side of the joint. Uniformity in levels of contiguous slabs near transverse joints had been made up mainly in the final finish with the grout. Therefore, when the grout had worn out, irregularity between adjacent slabs had become manifest. Where this was very pronounced, the impact of wheels of fast moving vehicles jumping from one slab to another had caused pot holes very near the transverse joints in a few of the slabs. These pot holes were $\frac{1}{2}$ to 1 in. deep and were due to the removal of grout and small stones from the top layer. In the holes formed, the stones were left exposed projecting upwards with their bottoms held together by the grout. They could not be dislodged by hand but were liable to be removed by wheels of fast moving vehicles. The pot holes had been filled with a mixture of tar and sand laid hot and did not show any signs of further development. Apart from the pot holes formed adjacent to the transverse joints, a few were formed at other places also. The possible causes for this were poor workmanship, sufficient grout not having entered the area and the wearing out of the grout which had been used to make up surface irregularities of $\frac{1}{2}$ to 1 in.

The crumbling and disintegration noticed and mentioned in para. 5.2 had not increased but at a few places the stones had been dislodged forming pot holes.

Due to the various defects mentioned above, the riding comfort was very much below that of a premixed concrete surface while the maintenance cost was also high.

8.3. **Second Experimental Length between 97/5 to 98/8 M. C. Road**

As in the case of the first length, the grout had worn out uniformly leaving a mosaic finish. Due to the richer mix of the grout used and the smaller exposed area of grout attributable to the smaller sized aggregates near the top surface, the wearing was very much less than in the first length. Cracks were very much less in evidence, but a few were seen. The unsatisfactory transverse joints were seen in this portion also but there were pot holes at two places only. However, the entire surface present da better appearance than in the first experiment.

9. CONCLUSIONS

From a study of the above two experimental lengths the following aspects of grouted road construction are noted.

The richer the grout mix used the better the wearing quality of the surface, and stronger the slab to resist cracks.

Use of smaller sized aggregates for the top layer of the slab reduces the area of grout exposed to the wearing action of traffic and is helpful in keeping down the wear on the road surface.

Other things conforming to the specifications, the quality of cement concrete depends on the water-cement ratio. In the method of construction adopted the amount of water is not controlled, and this factor is likely to affect the quality and strength of the road slab. The rapid wearing of the grout observed is attributable to this.

In the grouted method of construction, a light roller was used for consolidation. The use of power rollers does not give a surface comparable in evenness to that obtained on premixed concrete road by hand tamping or vibrating tampers.

In the portions of the slabs where consolidation was done by hand tamping, due to the difficulty of taking the power roller very near the transverse joints the consolidation obtained was not to the same standard as that obtained by power rollers. An even surface was often secured by finishing with the grout and this wears off rapidly under traffic, leaving the adjacent slabs at different levels, with the result that the traffic feels less comfortable on the grouted road than on a premixed concrete road.

Due to the impact from the wheels of fast moving vehicles jumping from one slab to another, pot holes are formed adjacent to transverse joints.

In spite of the provision of contraction joints hair cracks are found in the slabs.

During construction, when the grout is poured on the hand packed metal and rolled with a power roller, grout escapes to the sides. There is no possibility to prevent this loss of grout.

Under special circumstances the grout-process may be suitable for roads to serve for short periods and where rapid execution is desirable.

10. SUGGESTION FOR FUTURE WORK

10.1. The difference in levels between adjacent slabs separated by transverse joints has caused some pot holes.

Hand tamping may avoid this difference level and give an even surface.

10.2 The possibility of adopting a flexible layer of 1 in.

thick asphaltic concrete over the grouted road formed of weak grout, that will have a compressive strength of 3,000 lb per sq. in. at 28 days, to get over the disadvantages caused by directly exposing the surfacing to traffic, is also worthy of study.

RESEARCH SECTION

A METHOD FOR ESTIMATING THE BEARING CAPACITY OF ROAD CRUSTS WITH SOFT MATERIALS

CENTRAL ROAD RESEARCH INSTITUTE,
OKHLA, DELHI.

FOREWORD

It is the fundamental task of a road engineer to make the most possible use of the material occurring at or near the place of a road construction. There are, however, vast areas where the commonly used constituents for road construction like hard rock are not found and the engineer has to face soils, bricks, or other weaker materials.

But when there is no choice for getting suitable minerals, a utilisation of the available means has to be devised. This study describes one of such cases. The only available materials were laterites, bricks, and soils with no possibility of their replacement with harder and more suitable rocks. Specifications as suggested were investigated together with several surfacings developed by the Central Road Research Institute, using exclusively local materials.

The tests applied are well known, but the method developed is new and may have a possible application in testing the bearing capacity of road construction. The purpose of this investigation is to furnish the field engineers with data disclosing what can be expected from the proposed specifications under the given conditions without having to do full scale tests which are usually time consuming, relatively uncontrollable, and fairly costly.

The studies were conducted as a part of the research programme of the Central Road Research Institute. In conducting the various tests help was given by Messrs. G. F. D. Gonsalves and R. Nagarajan in assisting in the analysis of the test results, by Messrs. Y. C. Gokhale and R. Krishnamachari in connection with the design of the bituminous surfacings and conduction of the physical tests, and by Dr. H. L. Uppal where tests on stabilised soils were concerned. The Director also wishes to acknowledge the help given by Mr. J. M. Trehan of the Roads Wing, Ministry of Transport in editing this note.

Central Road Research Institute,
Okhla, Delhi.

E. ZIPKES,
Director.

CONTENTS

A METHOD FOR ESTIMATING THE BEARING CAPACITY OF ROAD CRUSTS WITH SOFT MATERIALS

1. INTRODUCTION

1.1. General

The efficiency of a road lies in its alignment and its kind of construction. Its strength depends on the kind of construction, which varies with the bearing capacity of the sub-grade, the way how the crust is constructed, and the properties of the material used.

In the case under investigation, the road under construction provides the first and, for the time, the only land communication between the main city of a State to other towns in the neighbouring States. The length of the road in question is about 130 miles.

The road had to be constructed through difficult country and in a relatively short time. Several chains of low hills rising upto a height of about 2000 ft above sea level and of very torn and soily structure had to be crossed with long plain stretches between the hills. Thus the road runs in partly plain country and partly typical hilly country, without being actually a hill road.

1.2. Traffic

The traffic expected on this road can be considered as light in the early stage, but it is likely to increase steadily. Possibly during the first stage the number of vehicles will not reach the estimated frequency, but as this road is the only means of communication in the area, the traffic is bound to increase.

2. CONSTRUCTION

2.1. Width

The carriageway is a single lane one with hardly any provision of a second lane. In general, it is about 10 ft wide.

Width of a lane and a half would have had some advantages (even considering the higher cost) not only in easing the traffic flow but also in providing for the effect of the moving wheels on the road crust, viz., the additional compaction after construction and the ironing effect of traffic on the surface which are essential for roads under similar conditions. The effect of the narrow width can be seen in the different behaviour of the wheel tracks under the high load and of the strips outside and between the wheel tracks where practically no load comes on the crust. This effect has an adverse influence because both the crust and the sub-base are exposed to extreme load differences over the width. Therefore the road crust is subjected to differential settlement; also some movement will occur in horizontal direction, at least in the top layers of the crust. Photos 1 and 2 show the beginning of this effect on a part of the road where flat laid bricks are used for soling. The settlement in those parts of the cross section where the wheels move, against the higher level of the middle portion of the lane and of the side borders, can be noted in the photos.

2.2. Camber

The camber was designed as an arc of a flat circle. Photos 3 and 4 give views of the road before and after the base course and the base coat were applied.

Under the prevailing conditions, a flat camber of about $1\frac{1}{2}$ per cent transverse slope would have suited better. A flat horizontal surface with no camber at all would have served the purpose as long as no settlement occurred. The small width of the road and the longitudinal slope would at any rate guarantee the flow off of any surface water. Moreover, a circular camber is disadvantageous for the animal and motorised traction.

2.3. Road crust

Although the sub-grade of this particular road gives no reason for not being allowed to assume a normal bearing capacity for a road under normal conditions, the construction of the crust has to be considered under some different aspects. Ordinarily the hardest mineral should be used for soling as well as for metalling. Materials of medium strength should be avoided, and certainly materials known to be weak. For this road there was only one kind of stone available at the site, viz., laterite, which is a relatively weak material for use in road construction. The properties of laterite* from different quarries of the area are described in detail and the conclusion was drawn that these laterites could be used in cases where a weak material had to be used for road

* 'An Investigation on some Laterites', Journal of the Indian Roads Congress, Vol. XVIII-1, 1953. Reprinted as Road Research Notes No. 4, 1953 of the Central Road Research Institute, Delhi.

construction comparable to bricks (first class) with an average compression strength of about 1500 lb per sq. in. in flat position.

Following the current specifications, parts of the road have been provided with the base course of 4-inch laterite boulders (4 in. dia.) and a 6 in. base coat of laterite metal of $1\frac{1}{2}$-2-in. size (Photos 5 and 6). This study therefore follows this general specification.* To cover, strengthen and protect these layers a wearing coat has to be provided with the available materials which are described later, and different specifications were considered. A surfacing coat, about one inch thick was proposed as being sufficient for the purpose.

2.4. Materials available

Materials available in the areas in question are :

Soil,
River sand,
Laterite,
Bricks (locally burnt), and
Sandstone.

In the course of the investigation, samples of the following materials were received :

	No. of samples received.
Different soils	9 samples
River sand	5 samples
Laterite	12 samples
Bricks	4 samples
Sandstone	5 samples
Bitumen	of varying penetration.

Table 1 gives some particulars of these materials. It was understood that such of these materials were to be utilised which serve the purpose best, due consideration being given to their properties and the quantities available.

3. OBJECT OF THE INVESTIGATION

3.1. Problems

The object of the investigation was **to estimate the strength of the proposed crust built with laterite** and to **evolve a specification for the surface** using laterite, or a combination of materials

* It would have been preferable to have followed the general experience, and to have provided 6 inches for soling and on top of this 4 inches of metal course.

available with or without laterite, so as to give the best kind of protective and strengthening surface treatment for traffic intensities heavier than merely local traffic.

Therefore, under the pravailing conditions, the best suitable kind of surface dressings were studied and specifications of bituminous carpets and surface dressing using mainly laterite, sandstone, and sand were tried. These and the base course and base coat described in para. 2.3, were tried with some variations in a series of tests which are given below. One test, using entirely Delhi quartzite, and one test using a stabilised soil layer in place of the laterite base coat were added to draw comparisons. The combinations of crust constructions tested are given below:

Layer	Test I	Test II	Test III	Test IV	Test V
Surface 1 in.	Carpet using sand-stone and sand	Surface dressing using laterite	Carpet using laterite and sand	Carpet using quartzite and sand	Surface dressing using laterite
Base coat 6 in.	Laterite metal	Laterite metal	Laterite metal	Quartzite metal	Soil stabilised with Laterite metal
Base course 4 in.	Laterite boulder	Laterite boulder	Laterite boulder	Quartzite boulder	Laterite boulder

For the detailed specification see para. 5.

3.2. Use of laterite for road construction

The use of laterite for road construction is not new. Particularly in areas where no other suitable stone material is available, its use is as common as that of bricks. But being a weak, or in general unsuitable, material for this kind of construction, it was adopted only for local roads where very little traffic was expected, and even then the quick wear of the laterite and consequent high costs of maintenance were well known.

Many local roads of the area are built using laterites for the base course (the soling) and the base coat (the metalling). Usually, due to the weak nature of the laterite, the metal was soon crushed, building a fine layer between and also upon the boulders of the base course. Under the weathering process in a sub-tropical climate the crushed and pulverised laterite sometimes formed a more or less compact layer, but due to its heterogeneous character the laterite still wore out quicker than the usual stone metal. Local road experts recommend a new general laterite construction (both soling and metalling) every two years, and remetalling every six months. How the surface of such roads looks after sometime under traffic is shown in Photos 7, 8 and 9. Photos 7 and 8 show the wear of the surface due to traffic and photo 9 shows the wear almost exclusively due to the influence of the climate. As the position of the rough laterite boulders is on the outside of a turn of the road, where usually no vehicles drive, the weathering effect can be easily seen.

Photo 10 shows the view of a laterite quarry. The material occurs in layers of different thicknesses, and lies below a few feet of soil. The laterite strata is shown in Photo 11. A view of the typical texture of the laterite is shown in Photo 12.

4. TESTING OF THE MATERIALS

4.1. Laterites

The results of the chemical and physical tests of six laterites, Nos. 1 to 6 were published previously. The remaining laterites showed great similarity to those already investigated (vide para. 2.3). Therefore only the aggregate crushing values of lateritics Nos. 10 and 11 were determined and are given in Table 2 together with that of laterites 1—6. The sample of laterite No. 12 was so brittle that no aggregate crushing value could be determined.

4.2. Sandstone

The aggregate crushing values of the five sandstones are given in Table 2.

4.3. Bricks

Four different kinds of bricks were received. Out of these samples Nos. 1 and 4 were burnt, No. 3 was sun-dried, whereas No. 2 was a mixture of burnt and unburnt pieces of bricks. Therefore sample Nos. 1 and 4 were tested for their compression strength under dry and saturated conditions, their absorption capacity, as well as their aggregate crushing value. Sample No. 2 could only be tested for its compression strength in a dry condition. Immersed in water, the bricks of sample No. 3 disintegrated after two hours. For sample No. 2 the aggregate crushing value was determined from the burnt pieces only. Results are given in Tables 2 and 3.

Due attention should be paid to the great variation in the compressive strength. It shows the unreliable influence of hand moulding and burning—which depends on the position of the brick in the kiln—as well as the difficulty in selecting burnt bricks with similar strength.

4.4. Soils

The nine samples of soil were analysed chemically and physically and their sieve analysis were determined. Results are given in Table 4 and the grain size distribution curves shown in Figure 1.

4.5. Sands

The mechanical analysis of the five sands is given in Table 4 and graphically in Figure 1.

4.6. Bitumen

The bitumen was not tested, the given penetration being found reliable. Two grades of bitumen with different penetrations were used.

5. DESIGN OF DIFFERENT CRUSTS

Five different types of construction were investigated (vide para. 3.1). Where laterite is mentioned, a mixture of all kinds of laterites is meant because the available sample of any one kind was not large enough for all the tests.

Several types of surface pavings were studied utilising the materials available. Studies conducted in varying compositions with laterite, sandstone, bricks, sand and bitumen resulted in the types ultimately selected for the Tests Nos. I, II, III and V.

5.1. First test

Base course : Laterite boulders 4 in. size (no weight was taken)

Base coat : Laterite metal 2—3 in. size (no weight was taken)

Surfacing : Compact carpet of crushed sandstone.

Sandstone No. 3 and sand No. 4 were used in the following specifications (vide grain size distribution curve B in Figure 2).

	Per cent by weight
Sandstone crushed 3/4 - 1/4 in.	46.5
Sandstone crushed finer than 1/4 in.	28.0
Sand	18.5
Bitumen—60-70 penetration	7.0
	100.0

The mixture was prepared at 150° C., the carpet was rolled and finished at 90° C. with a small roller, giving similar specific pressures as a full size 8 ton smooth wheel roller. Photo 13 gives a sectional cut through the surface after the execution of the test.

The use of sandstone was based on the normal quantity and grading needed for a 1-inch thick carpet providing about 3.5 per cent voids in compacted state. As it was expected that sandstone was available in quantities sufficient for use in an appreciable milage of road surface, no attempt was made to replace more sandstone with river sand. The same specification was adopted in the case of Test IV, where quartzite was used. A more generous use of river sand would have needed a higher percentage of binder and would have resulted in correspondingly higher costs.

5.2. Second test

Base course : Laterite boulders 4 in. size, 16 lb 10 oz and 5 lb of smaller size, to even the surface.

Base coat : Laterite metal 2—3 in. size, 28 lb 4 oz and 3 lb of smaller size, to even the surface.

Surfacing : Surface dressing in 3 coats crushed laterite of ½—¼ in. was used in all 3 layers, 5¾ lb per sq. ft. in all.

Bitumen 30-40 Penetration cut-back with 5 per cent white petrol at 80° C. was used for all 3 layers at 1⅓ lb per sq. ft in all.

The laterite was almost equally distributed in all the three layers and some compaction was given after the first and the second dressings. After the third layer, full compaction was given with the roller used for Test I.

The use of laterites as a surfacing material in general was specified according to the conclusion of the publication on the investigation of laterites vide para. 2.3 where it was said that laterites had to be crushed to a size where no shells were left intact, and that the finer material had to be removed by sieving. Therefore the crushed laterite used did not exceed the size of ½ in. and could not have contained a greater amount of fines than chippings usually have.

A further possible destruction of laterite shells had to be avoided. This would give rise to an increase in the voids and a decrease in the volume, necessarily followed by an undesirable settlement irrespective of whether laterite was used for surface dressings or in carpets.

Preference was given to surface treatment in three coats of binder and grit. One coat only could hardly be considered as an equivalent of even a sealing coat for a rough surface texture resulting from the use of laterite as metal. Furthermore, though the comparatively cheaper process of a surface dressing was used, it had to serve for providing as a somewhat strengthening effect for the laterite metal. It had therefore to be applied in a thickness, which could be treated as a layer and not merely as a seal coat, by rolling in three applications to a thickness of about 3/4 of an inch. This thickness has to be taken as a minimum considering the general objectives of designing the crust.

5.3. Third test

Base course : Laterite boulder 4 in. size, 14 lb 14 oz and 5 lb of smaller size, to even the surface.

Base coat : Laterite metal 2--3 in. size, 26 lb 6 oz and 3 lb 4 oz of smaller size, to even the surface.

Surfacing : Compact carpet using crushed and sieved laterite in the following composition :

Grading of crushed laterite	Per cent by weight
½ to ⅜ in.	30
⅜ to ¼ in.	35
¼ to $\frac{2}{16}$ in.	15
$\frac{3}{16}$ to sieve No. 8 (2 mm)	20
	100

The surfacing was made of crushed laterite (graded as above),

sand and bitumen in the following proportions, vide grain size distribution curve A in Figure 2:

	Per cent by weight
Graded crushed laterite	45.75
Sand (No. 4)	45.75
Bitumen 60-70 penetration	8.50

The mixture was prepared at 140° C. and the carpet was rolled and finished at 90° C. with the same small roller used for Test I. Photo 14 gives a sectional cut through the surface after the test.

The use of crushed laterite in a carpet has to follow principles different from those when good stone material is used.

The explanation under para. 5.2 about the size of laterite, which should be smaller than that of sandstone after crushing, holds good for a carpet also. Normally the maximum size of the stone used in a carpet will be chosen according to its thickness which was the case when sandstone was used. Further due to the relative weakness of the laterite, it was preferred to base the strength of the surface more on a bitumen-sand mixture than on the laterite. Therefore, the laterite was considered as being more of a filling material than a structural one, although an exact distinction in this aspect cannot be carried through. Because of the finer composition of the laterite carpet the binder content had to be raised to 8.5 per cent of weight.

In order to make sure that the carpet does not change its grading on being compacted, a paving was mixed and rolled according to the specification before the main test was conducted. Then when the compaction was finalised the mineral (laterite plus the percentage of sand) was extracted and its sieve analysis determined. It was seen that some additional crushing had occurred during the compaction but did not exceed the normal amount to be expected under a roller of 8 tons and therefore the necessity of the condition to crush the laterite upto a certain size was established.

Passing BS-sieves	½ in.	⅜ in.	¼ in.	$\frac{3}{16}$ in.	No.8	18	36	60	100	200
Composed grading for the carpet	100	85	68	60	50	50	50	42	21	5
Extracted minimum after compaction with the roller.	100	88.8	74.94	64.12	52.8	50.65	50.50	44.72	20.92	4.85

Compare the grain size distribution curves A (before compaction) and C after compaction) in Figure 2.

5.4. Fourth test

Base course : Quartzite (Delhi) boulder 4 in. size, 20 lb 10 oz, and 6 lb 8 oz of smaller size, to even the surface.

Base coat : Quartzite 2—3 in. size, 33 lb 4 oz, and 5 lb 4 oz of smaller size, to even the surface.

Surfacing : Compact quartzite carpet.

This carpet was based on the same specification as that of Test I with the difference that Delhi quartzite was used instead of sandstone.

The mixture was prepared at 140° C., as used in Test I the carpet was rolled and finished at 90° C. with the same roller. Photo 15 gives a sectional cut through the surface after the execution of the test.

5.5. Fifth test

Base course : Laterite boulder 4 in. size, 30 lb 6 oz and 6 lb 4 oz of smaller size, to even the surface.

Base coat : Soil stabilised with laterite metal.

Surfacing : Surface dressing in 3 coats to the same specification as in Test II.

For the stabilised soil layer the soil No. 7 from mile 14/2 was stabilised with sand No. 3 from mile 14/2 in the proportion of 85 per cent to 15 per cent by weight. This stabilised soil showed a Plasticity Index of 9.2, its fineness, the percentage passing through sieve No. 200 (particles smaller than 0.075) was 52 per cent and had an optimum moisture content of 13 per cent. The metal mixed with the stabilised soil consisted of laterite crushed and graded in the following proportion :

Crushed laterite	2 - 1 in.	50 per cent
	1 - ½ in.	30 per cent
	½ - ¼ in.	20 per cent

The proportion in which the laterite and the stabilised soil were mixed was one part of the former and two parts of the latter.

A moisture content of 16.5 per cent was added providing a 3.5 per cent excess over the optimum, to meet the expected evaporation during the mixing and laying process, and on account of the textural nature of the laterite. A layer of 8.5 in. of loose soil-laterite mixture was compacted to 6 in. with a 10 lb rammer. This resulted in a density of the compacted layer of 132 lb per cu. ft. To cure it, it was kept in shade for one day before its top was covered with surface dressing. The specification of the surface dressing with laterite chipping was the same as for Test II.

5.6. General remarks

The surfacings of Tests I, II & III cover possible cases which could be designed by using laterites and sandstone to strengthen the laterite construction as well as protect it against traffic wear and weather influence. The variation in the surface providing a surface dressing was made in order to investigate the use of a cheaper wearing coat. Brick metal could not be utilised in the carpet owing to its porosity and poor adhesive properties.

Test IV was conducted as a comparative construction as quartzite is commonly used in Delhi. The strength of the quartzite mineral expressed in its aggregate crushing value is also given as a test result in Table 2.

Test V was added to find out whether the provision of a stabilised soil layer showed any advantage in strengthening a road crust. As this form of construction has some differences in its test conditions which will be discussed later, its results have to be interpreted by considering these differences. The layer of stabilised soil was combined with a surfacing of three coats of surface dressing, in order to evolve a system of construction with material most easily available locally. The use of laterite was reduced to a minimum in order to make the design economic.

6. TESTS AND GENERAL CONDITIONS

6.1. Arrangement

These five different designs of crust construction were filled into a cylindrical steel mould of one foot inside diameter and 11 inches height. The height of 11 inches was according to the thickness of the crust designed, 4 in. for base course, 6 in. for base coat and about one in. for surfacing.

The two bottom layers were laid by hand and the surfacing was done under conditions similar to those usually obtaining on the road. Assembled in this way the content of the cylinder represented a part of the crust as being taken out of a newly constructed road and of the specification proposed to be tested without reduction in scale i.e., with 100 per cent natural size.

On the surface a circular plate of one ft diameter and 1½ in. thickness was put, which fitted exactly into the test cylinder. Photos 16, 17 and 18 show the 3 layers of Test V in the test mould.

6.2. Test procedure

The form completely filled according to the specification and covered with the plunger was then put under the compression machine (Photo 19) and the settlement was taken in relation to the load applied. The load was given in steps of 1 ton (at greater loads in steps of 2 tons) and the next increment was applied when the rate in settlement was less than 0.005 in. per minute. Normally the test was stopped when a total settlement of about one in. had been reached. In the case of Tests IV and V no more load was applied after settlement of about ¾ in. because in the case of Test IV, this load was very high, and in case of Test V, the plunger was protruding only about ¾ in. above the form at the beginning of the test and could go in only to that extent.

6.3. Conditions of the load settlement test

The general mechanical condition under which these tests were conducted was that they were completely confined on all sides. A confinement like this does not allow of conclusions applicable directly to cases under natural conditions. Natural conditions always have limited confinement which can hardly be reproduced. But a complete confinement allows comparisons of different specifications when conducted under exactly the same conditions, and conclusions as to the behaviour of the basic specification as well as to the materials used can be drawn.

6.4. C. B. R. test

The whole arrangement might be considered as being similar to the C. B. R. determination. In a certain way it is, and some of the differences in principle between the two tests are briefly discussed here.

The C. B. R. test provides an additional surcharge which represents the weight of the surfacing material, when a sub-base is tested. Therefore a given way of the tested material is possible. Then, usually materials of one kind are tested and the test is not meant for complete road-crusts. The C. B. R. gives freedom of movement in one direction for the material to be tested whereas the test procedure adopted here confines the material in all directions. Therefore the enforced settlement can only result from the crushing of the weakest material used.

As it was one of the purposes of this investigation to find how far the bearing strength of the material used in the construction could go, all variables except a vertical settlement were eliminated. This led to the arrangement of complete confinement. The results show that under these conditions, conclusions of comparative values of the bearing capacity of the different specifications could be drawn.

7. RESULTS

7.1. Settlement under load

The settlement under a certain load in the case of each specification is given in the load settlement curve of the 5 specifications in Figure 3. The final settlement under the maximum load applied for the 5 different tests is also given below:

Test	I	II	III	IV	V
Final settlement in inches	1.33	1.05	1.34	0.78	0.77
Final load applied in tons	12	11	11	62	26

7.2. Crushed material

After the test the layers of laterite were taken out from the bottom of the form and mechanically analysed. The results are shown in Table 5 and in Figure 4. Some material could not be collected because a certain quantity remained sticking to the binder at the bottom of the surface layer. This is also given in Table 5 as a difference of the collected material and the material originally filled into the form. For Test I, initial weight was not taken (vide para. 5.1).

These figures can only give a rough check and were used for a confirmative calculation to the results of the load settlement lines.

8. EVALUATION

8.1. Load-settlement factor

The relation of the settlement to the load is shown in Figure 3. It can be noted that the load settlement curve can be assumed as being a straight line for a wide range of load for Test IV and for almost the complete range for Tests I, II, III and V. The proportion which can be arrived from a straight line is used for calculating the comparative factor against unity in Test IV which was the control test.

The ratio of the tangent of each of the load settlement curves to tangent of the load settlement curve of Test IV is given below :

Test	I	II	III	IV	V
tan / tan Test IV	1/9.35	1/8	1/10	1/1	1/2.67
or	0.107	0.125	0.1	1.0	0.375

This would mean that the load bearing capacity of the laterite construction according to specifications of Tests I, II and III is only about 1/8 - 1/10 of that of the quartzite construction whereas specification No. V seems to have a load bearing capacity of about 1/3 of quartzite construction (Test IV).

8.2. Crushed material/settlement/load factor

Using another approximate calculation of a factor: crushed material (per cent)/settlement (inches)/load (tons), an attempt was made to obtain some confirmation of the above. To do this, some assumptions had to be made. For this a figure for the amount of laterite subjected to load or crushed under the load had to be allocated. The mass of material which was subjected to the load can be estimated only very vaguely by sieving the laterite material after the test, taking into account the percentage of the material finer than the sizes used for filling the form for the base course and base coat, the fractions passing $1\frac{1}{2}$ inches size.

The results of the sieve analysis of the crushed laterite in all the five tests are given in Table 6 and in Figure 4. A correction had to be allowed in case of Test II due to the fact that under the surface dressing some quantity of the binder penetrated from the surfacing into the base coat. The amount involved was about 10 per cent of all the material under consideration.

A further correction was made for Test V because the original laterite layer was about half the thickness of those in Tests I, II and III. As the laterite used in this test was somewhat coarser than in the others, the crushed percentage based on the calculation for Test V was taken roughly 50 per cent from the fraction passing 2 inches. Including these corrections, the factor of crushed laterite/settlement/load in the dimensions per cent/inches/tons arrived at is given below:

Test	I	II	III	IV	V
Per cent of crushed laterite/inch settlement/ton load.	7.24	7.48	7.19	1.0	3.52

Photo 1

Brick soling in the plain part of the road. Wheel tracks can be recognised as well as the deformation of the original camber.

Photo 2

Brick soling in the plain part of the road. Wheel tracks can be recognised as well as the deformation of the original camber,

Photo 3

Part of the road in mile 80 in cutting, the soling is not yet put.

Photo 5

Laying of the soling of 4 in. size laterite boulders.

Photo 4

The soling and metal is laid and is under use. Two tracks of the wheels can be recognised.

Photo 6

Laying of the metal and the soling.

Photo 7

Road with low traffic built out of laterite. Surface worn out through traffic. The harder and bigger pieces of the laterite of the soling wear out slowly and can be seen.

Photo 10

Laterite quarry.

Photo 8

The same road showing the worn laterite crust.

Photo 11

Laterite in rocky form in layers of approximately 6 ft.

Photo 9

A part of the same road where the outside portion in a bend is worn out through weathering effect.

Photo 12

Laterite in rocky form, close up view of Photo 11.

Surface→

Photo 13

Sectional cut through the Sandstone carpet (Test I) in about 85 per cent natural size.

←Surface

Photo 14

Sectional cut through the laterite carpet (Test III) in about 85 per cent natural size.

Surface→

Photo 15

Sectional cut through the quartzite carpet (Test IV) in about 85 per cent natural size.

Photo 16

Steel mould for settlement tests. Content shows the base course layer, laterite boulders of 4 in. size.

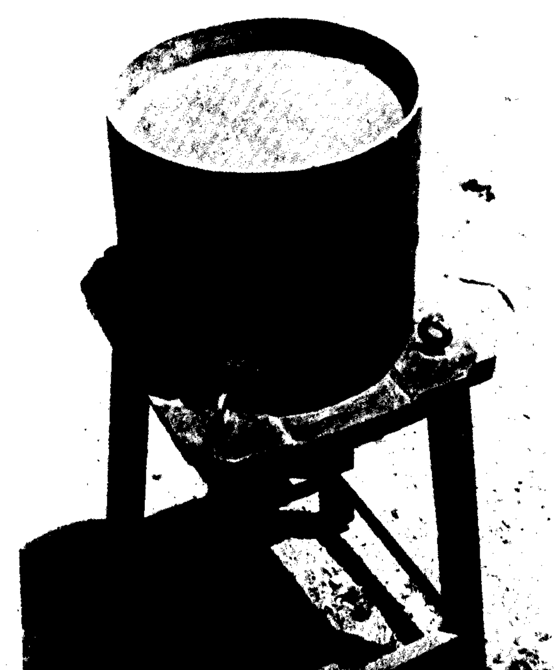


Photo 17

Steel mould for settlement tests. Conten shows the complete base coat layer stabi lised soil-laterite mix o Test V.

Photo 18

Steel mould for settlement tests. Content shows the finished surface dressing of Test V.

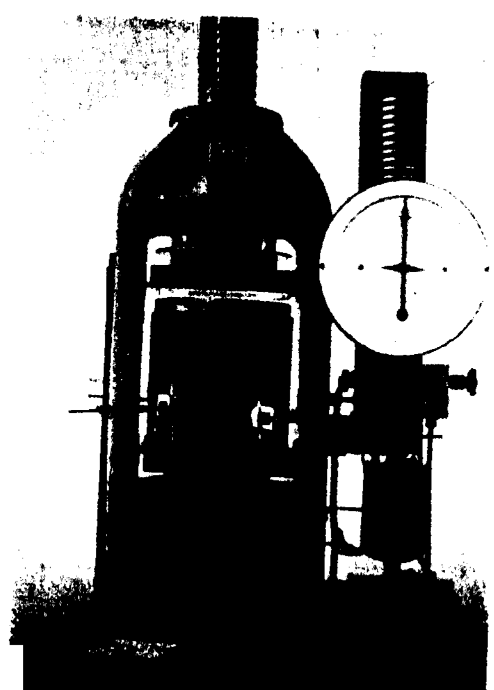


Photo 19

The prepared road crust in the steel mould covered with the plunger, placed in the compression machine before the test.

This would explain that the specific crushed amount of laterite material is practically the same in the Tests I to III, half of that in Test V, being approximately 7 and $3\frac{1}{2}$ times higher than in Test IV, the comparative quartzite test.

8.3. Character of surfacing

Some additional remarks may be given about the three Tests I, II & III which follow the same principle of construction of the base course and the base coat differing only in the kind of surface.

Because of the very little difference in the result there seems to be not much which could be ascribed to the influence of the different kinds of surfacing used. Against the presumptions that, from its results, Test II where the surface dressing was used seems to be more favourable than the other two using carpets although the difference is very small, stands the knowledge of the higher strength of a carpet as a wearing coat. It would be misleading to believe that a carpet gives less strength than surface dressing. The weak character of the laterite is bound to give rise to crushing much earlier than the strengthening effect of any method of construction comes into appearence. A carpet, while distributing the load due to its construction, has also the task of protecting the layers below, against being disturbed or decomposed. The surface dressing being only a pressed mass of crushed stones without grading, mixed under doubtful control with a certain amount of binder, does not even assure everywhere a uniform mixture of the two materials. Therefore, its ability to distribute the load is less reliable. Its function lies more in building up a protective layer for the laterite material below, which seems to be the prominent one in this particular problem than in distributing the load.

The fact that the load-settlement curve of Test II with no more destruction (vide Table in para. 8.2) than in the other tests, shows less settlement under the same load than Test I or III could be traced to some accidental facts i.e., the well packed three layers and that the use of liquid binder creating more stickiness to the steel form than when premixes were used.

8.4. Stabilised soil layer

The figure of crushed laterite/settlement/load of Test V is about half of that of the Tests I to III with the same mixture of laterite in the base course. For this figure the load arrived at seems to be mostly responsible. On the other hand the application of a layer of stabilized soil in Test V has to be taken as the reason for the higher load bearing capacity, and because test results could be interpreted in different ways some remarks may be given in this connection.

In order to explain retrospectively how the load of 26 tons was being absorbed by the different courses created with the provision of the relatively thick compact layer of stabilised soil, some assumptions have to be made to complete those data arrived at by experiment. The load absorbing functions can be described as:

1. Friction on the inside of the test cylinder between soil and steel due to the compaction of the soil during the preparation of the crust sample and by the full load during the test.

2. Vertical force which passed through the soil layer and to which the sub-base was subjected.

3. Transverse force in the soil layer under total load taken by the confinement (steel cylinder).

to 1. The force due to friction was found by experiment to be about 2.6 tons by measuring the force needed to push the undisturbed soil layer out of the steel cylinder after the sub-base was removed.

to 2. The vertical force to which the laterite layer was subjected can be assumed to be not more than about 11 tons as being similar to the total load of the Tests I, II & III due to the comparable similar crushing effect on the laterite layers.

to 3. The transverse force, the part of the lateral pressure transmitted to the sides of the cylinder can roughly be calculated to an amount of 12.6 tons under the assumption of the friction coefficient of soil on steel of 0.5 and the Poisson ratio* with 0.4 which brings the factor of $\frac{\text{lateral stress}}{\text{normal stress}}$ to 0.54.

* The average Poisson ratio for clay and sand can be assumed as 0.4 and 0.3 respectively. As the Poisson ratio of 0.5 applies to incompressible material, the value of 0.4 may be considered as adequate for the highly compacted soil layer. The factor of lateral stress/normal stress was found by Terzaghi with 0.4 - 0.45 for dry sand and 0.70 - 0.75 for clay. Under the chosen assumption the factor works out to 0.54.

References : Terzaghi : Principles of Soil Mechanics, Engineering News Record, Vol. 95, 1925.

Krynine : Soil Mechanics, 1947 (p. 127).

Tschebotarioff : Soil Mechanics, Foundation and Earth Pressures, 1951 (p. 248).

Under load the forces mentioned with (1) and (3) do occur together. As it was explained under: to (1) the determination of the force due to friction alone (2.6 tons) was done under conditions other than those in the load settlement test i.e., only force just sufficient to push out the soil layer was applied. Therefore the results arrived at by experiment and calculations based on assumptions may be taken as an indication explaining the heavy load the specification was able to take by means of inserting a compact layer in between the base course and the surfacing.

They also explain the influence of the complete confinement in a form of 12 in. diameter when compact layers are applied. These conditions will never occur in this uniform and extreme way in a road crust in the field.

Considering now the chosen assumptions and results arrived at and tracing back the assumed values on which they are based we find that they are quite reasonable. The results further show that with a layer of soil or stabilised soil respective results could be achieved depending on the confinement which can be attained. The results then depend on the degree of confinement But in case the confinement is weak and uncertain to be relied the risk of disintegration from the sides or at the bottom through giving way of the base course, as it might be the case under consideration, is very great.

9. DELIBERATION

The load bearing capacity of a structure depends on the weakest material used. In this case, it is the laterite. A confirmation of the ability and behaviour of one material in a certain position excludes uncertainties about a possible internal collaboration (or composite action) of different materials within the same crust. We get, therefore, an undisturbed comparison as far as the material used is concerned.

The results of the Tests I, II and III show that the load bearing capacity to be expected is somewhat between 1/8th to 1/10th of that of a similar construction using quartzite. It is natural that the carpet would add a little to that strength whereas a surface dressing would not do so, although the test results could be interpreted otherwise. The main purpose, however, in this case is to be seen not so much in a strengthening effect of the surfacing construction on the crust—because the strength of the base course and base coat is any way weaker than that of such carpets—as in the protection which a stronger kind of wearing coat gives to the load taking layers in so much as it helps to stiffen the construction in cases the layers below are inclined to show little movements. This could happen due to the slow destruction through crushing. In addition, in general, surface layers, being constructed more or less in a stiff way like premix carpets, should be kept confined at the side to avoid the breaking out, which follows by a change in the position as well as a deterioration on the flanks. This effect is all the more seen in cases where the road is of a narrow width.

To the extent that the structure in situ of the different designs of road crust under investigation is known, relative comparisons can be made. The tests conducted show the behaviour of the different crusts, under increasing load, and describe distinctly the limitations of the materials used in respect of strength and in respect of the possible composite action of the various materials used in a specification. Such an arrangement as that used evolving the presented results is suitable to be adopted when similar clarification is needed.

10. CONCLUSIONS

The investigations conducted show that specifications as designed and tested will be able to carry a load of 1/8th to 1/10th of the same specification when quartzite is used. The tendency of the laterite to be crushed in the structure as specified (when used in a base course and base coat) can be estimated to be not less than 7 times the destruction which will take place when quartzite is used under the same or similar conditions.

Construction and labour difficulties may arise when layers of stabilised soil for the base coat as well as bituminous pavings for surfacing in sensitive specifications are applied, although some of them may prove advantageous under certain conditions. Therefore the utilisation of relatively unskilled labour as well as the need for using only the simplest machinery point to the necessity at present of adopting simple specifications in such areas.

Considering the prevailing conditions the construction as per Test II (base course and base coat with laterite boulders, multi-surface dressing using laterite chippings) can be recommended for application. A multiple surface dressing, for instance a three-coat surface dressing, is desirable due to the unevenness and quick wear of the laterite. A crust construction like this is economical in respect of labour and machinery, although it has to be realised that a specification like this presents a weak construction of a crust. Costlier and more complicated paving specifications do not show a correspondingly higher load bearing capacity, when laterite is used.

In areas where bricks are available, only well burnt bricks are recommended for the base course and the base coat. Layers of full size bricks should not be treated with a surface dressing directly. A layer of brick ballast of sufficient thickness, evened with an adequate quantity of laterite chippings, smaller than 3/8 in. size, can be provided as a layer between the brick layer and multi-surface dressings.

Wherever sandstone is available, it should be utilized as chippings in the surface and, when available, also for the base course and base coat.

At the present stage, a width of 1½ lane is recommended. This will not only increase the traffic capacity but also reduce the wear, and consequently the costs of maintenance.

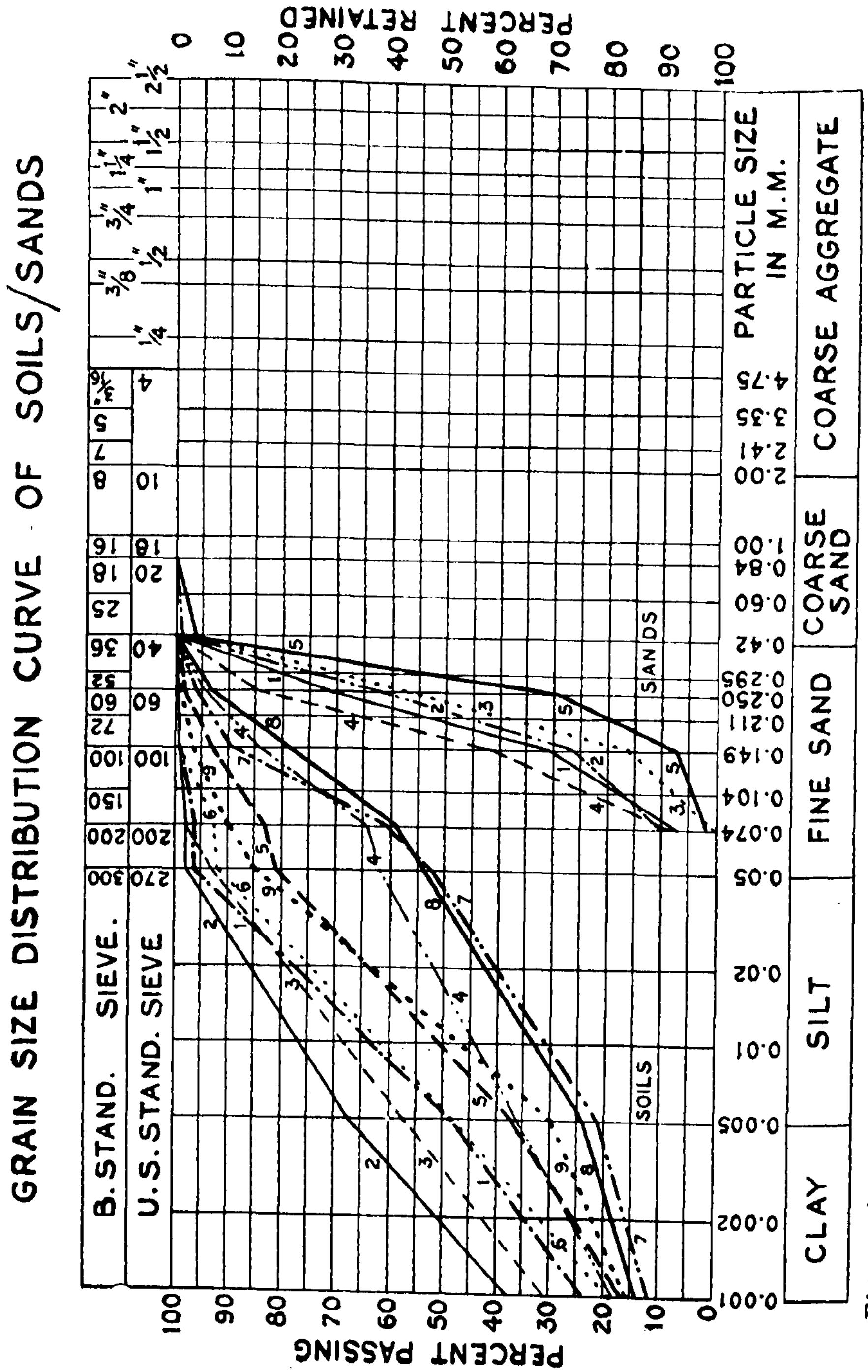


Figure 1

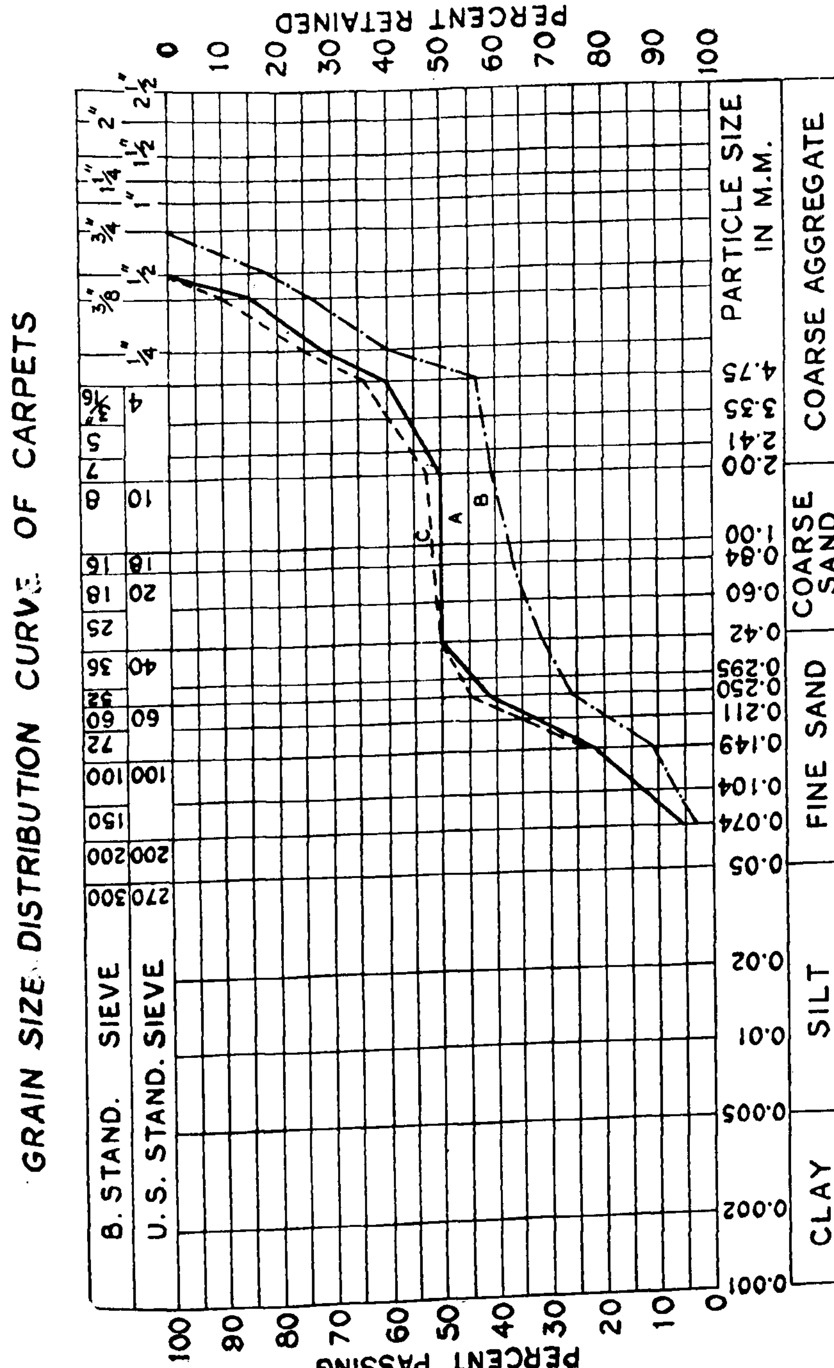


Figure 2

A = Carpet with Laterite and Sand (Test III)
B = Carpet with Sandstone/Quartzite and Sand (Tests I and IV)
C = Carpet with Laterite and Sand after Compaction with Roller

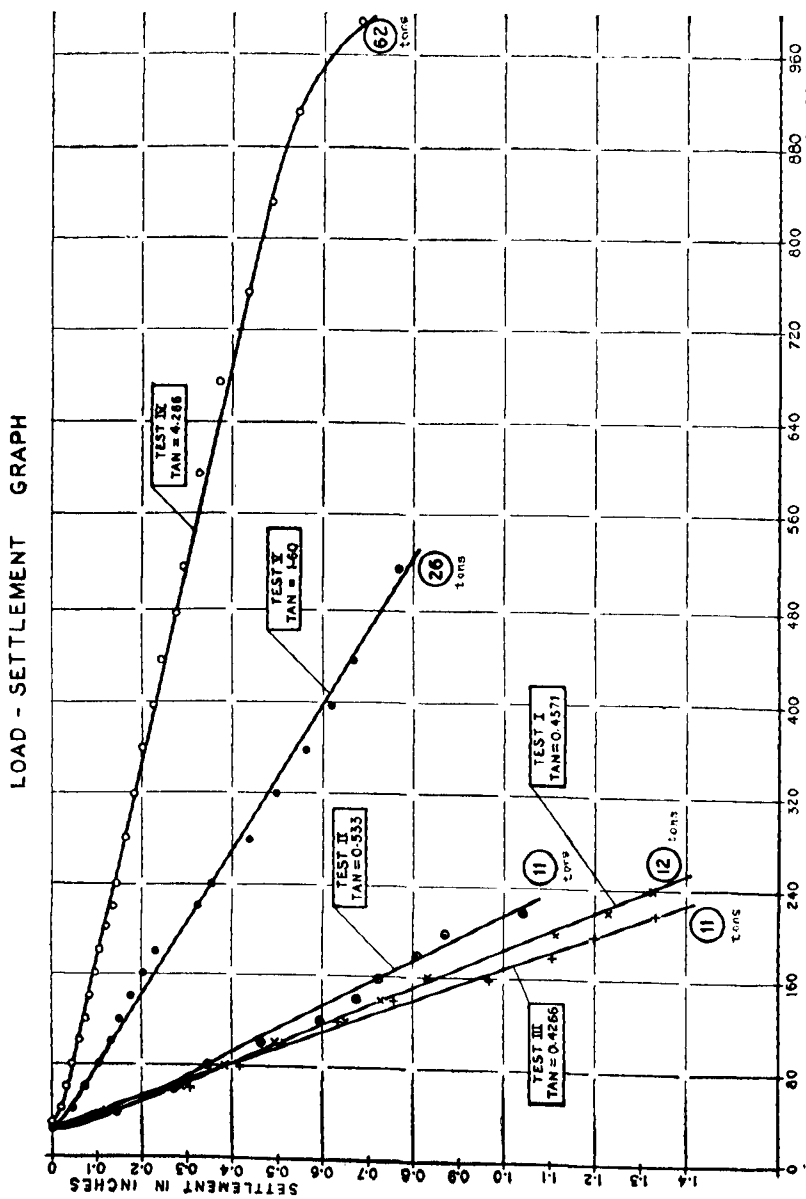
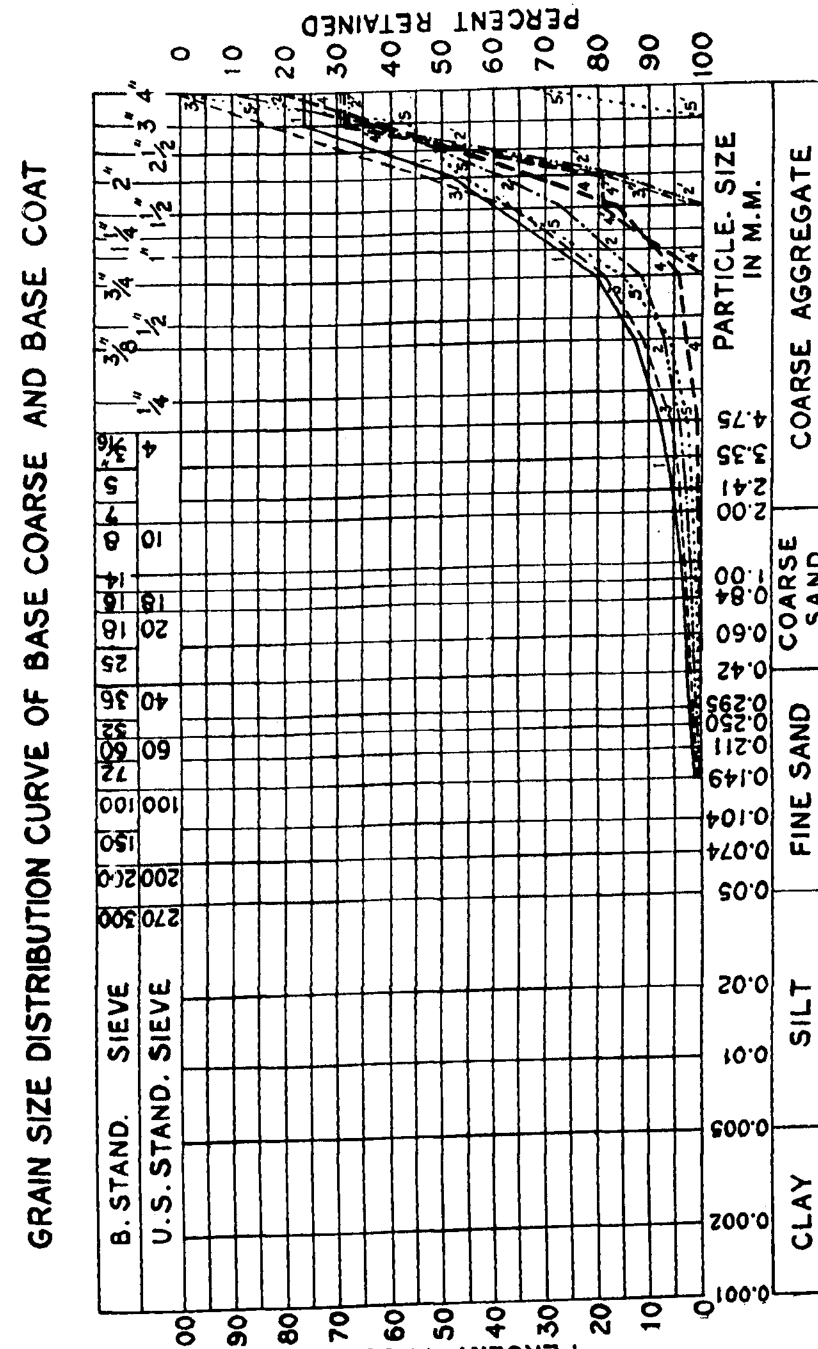


Figure 3



1 to 5 = After Test
2′ to 5′ = Before Test

Figure 4

Table 1.—**Availability and Source of the local Material**

Material	Availability	Mile Furlong
Laterite Nos. 1 to 6	Limited	73, 95, 102, 106 125 & 130
Laterite Nos. 7 to 9	do.	63, 53, 37
Laterite Nos. 10 to 12	do.	18, 23
Sandstone No. 1	do.	—
Sandstone Nos. 2 to 4	do.	66, 45, 20
Sandstone No. 5	do.	20
Brick Nos. 1, 2	To be manufactured and bound to the No. of kiln.	15
Brick No. 3		28
Brick No. 4		Unknown
Soil Nos. 1 to 8		2/3, 3/6, 5/6, 9/2, 10/4, 12/1, 14/2, 15/2
Soil No. 9	Unlimited	Unknown
Sand Nos. 1 to 4	do.	5/8, 12/1, 14/2, 15/1
Sand No. 5	do.	—
Bitumen	Penetration 60/70 and 30/40	Manufactured in the area

Table 2.—**Test Results of Laterites, Sandstones and Other Materials**

	Sample No.	Aggr. Crushing value. Average of 2 tests. Per cent	Compression strength		Absorption per cent
			Dry lb per sq. in.	Wet lb per sq. in.	
Laterite	1*	40.42	1454.0	533.5	9.38
	2*	50.40	896.2	1228.0	8.31
	3*	47.95	882.4	698.2	13.62
	4*	34.80	852.9	871.0	11.26
	5*	41.70	1965.0	1112.0	12.93
	6*	42.32	1014.0	1626.0	8.02
	7	—			
	8	—			
	9	—			
	10	49.52			
	11	30.14			
	12	—			
Sandstone	1	21.20			
	2	29.39			
	3	19.88			
	4	31.00			
	5	21.06			
Brick burnt	1	66.25	Compare Table 3		
,, unburnt	2	—			
,, ,,	3	—			
,, ,,	4	37.99			
Delhi quartzite*		19.65	—	—	—
Delhi brick I*		50.31	1495.0	—	—

* From Journal of the Indian Roads Congress Vol. XVIII—1 and Road Research Notes No. 4.

Table 3.—Test Results on Bricks

Brick sample No.	Absorption in cold water per cent	Absorption in boiling water per cent	Saturation Co-efficient	Aggregate Crushing Value per cent	Compression strength of brick in flat position						Remarks
					Tons per sq. ft.		Lb per sq. in.		Kgm. per sq. cm.		
					Dry	Wet	Dry	Wet	Dry	Wet	
1	14.66	20.07	0.7302		63.48	62.27	986.8	968.5	69.37	68.10	Burnt bricks
	15.61	21.76	0.7173		150.1	96.87	2334.0	1507.0	164.2	105.90	
	19.54	25.09	0.7789		122.7	73.94	1909.0	1150.0	134.3	80.85	
Average	16.6	22.31	0.7421	66.25	112.1	77.69	1743.0	1209.0	122.6	84.95	
Difference from Max. to Min.					86.62	34.60	1347.2	538.5	94.83	37.0	
Difference from Max. to Min. as per cent of minimum value							137.0	55.70			
2	15.04	19.41	0.7749	not done	150.3	180.2	2337.0	2803.0	164.3	197.1	only one burnt brick
3	not possible				33.49	not possible	520.8	not possible	36.62	not possible	Unburnt, only sun-dried bricks. No resistence when in water
					22.58		351.3		24.69		
					17.03		265.0		18.62		
					24.86		386.8		27.19		
					23.57		366.5		25.77		
Average	—	—	—	not done	24.31		378.1		26.58		
Difference from Max. to Min.					16.46		255.8		18.00		
Difference from Max. to Min. as per cent of minimum value					—		96.5				
4	16.11	20.24	0.7958		260.2	210.6	4047.0	3275.0	284.5	230.3	Burnt bricks
	12.94	18.79	0.6887		155.0	151.6	2411.0	2358.0	169.4	165.8	
	14.44	20.08	0.7190		101.2	155.7	1574.0	2422.0	110.7	170.3	
Average	14.5	19.7	0.7345	37.99	172.1	172.6	2677.0	2685.0	188.3	188.8	
Difference from Max. to Min.					159.0	59.0	2473.0	917.0	273.8	64.5	
Difference from Max. to Min. as per cent of minimum value							157.0	39.0			

Each full size brick was cut into two halves. One half was tested for compression strength in dry state, the other was used for ie determination of the absorption and then the compression strength in wet state. The aggregate crushing value was deterined with bits of the same kind of bricks.

Table 4.—Test Results on Soils and Sands

	Mechanical Analysis									Specific Gravity	pH	Total Solids in per cent	LL	PL	PI
	By Sieving Passing Sieve BSS/ASTM						By Sedimentation Millimeter								
	8	18	36/40	60	100	200	0.05	0.005	0.001						
	Coarse sand			Fine sand				Silt	Clay						
Soil 1	—	—	100.0	99.65	98.95	95.95	95.95	48.46	23.69	2.702	7.6	0.03	45.67	25.2	20.47
2	—	—	—	100.0	99.60	98.00	98.00	66.88	37.48	2.684	8.0	0.043	57.58	36.88	20.70
3	—	—	100.0	99.85	99.48	97.30	93.00	56.99	30.58	2.702	7.5	0.026	54.19	27.27	26.92
4	—	—	100.0	94.70	84.10	64.25	61.87	35.28	18.55	2.677	8.0	0.016	36.81	20.00	16.81
5	—	—	100.0	98.25	93.45	83.30	81.16	35.64	17.06	2.654	7.8	0.012	46.44	22.94	23.50
6	—	—	100.0	99.90	99.40	94.55	93.21	48.45	19.02	2.706	7.7	0.020	46.35	24.48	21.87
7	—	—	100.0	96.60	89.05	60.45	52.46	20.94	11.38	2.676	7.8	0.020	27.54	16.67	10.87
8	—	—	100.0	94.10	78.45	59.55	53.53	23.90	13.60	2.672	7.7	0.032	25.71	14.00	11.71
9	—	100.00	99.85	98.85	96.85	89.40	84.03	29.53	16.18	2.680	7.4	0.0093	39.30	18.70	20.60
Sand 1	—	100.00	99.86	70.74	30.00	7.07	—	—	—						
2	100.0	99.91	99.51	62.28	27.29	8.27	—	—	—						
3	100.0	99.70	99.16	57.12	15.34	1.09	—	—	—						
4	100.0	99.99	99.96	84.21	40.76	6.96	—	—	—						
5	—	100.00	96.80	28.31	6.39	2.28	—	—	—						

Table 5.—Sieve Analysis of the Laterite Layers (Base Course and Base Coat) before and after the Test

BSS-Sieve	Test I Premix Sand stone		Test II Surface Dressing Laterite		Test III Premix Laterite		Test IV Premix Quartzite		Test V Surface Dressing/Soil	
	Before	After	Before	After	Before	After	Before	After	Before	After
Retained on 4 in.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4 ,,	69.0	76.27	68.55	87.07	69.72	100.0	68.69	78.82	31.84	100.0
3 ,,	69.0	76.27	68.55	63.56	69.72	82.65	68.69	66.59	31.84	56.52
2 ,,	16.0	48.48	15.13	37.42	16.79	52.23	18.21	32.37	—	47.83
1½ ,,	—	39.314	—	26.85	—	36.28	18.21	16.49	Only 4/10 mat. against tests I - IV.	36.29
3/4 ,,		20.884		11.06		19.26	—	4.90		15.20
3/8 ,,		12.756		6.78		11.74		2.115		6.574
3/16,,		7.837		4.085		6.80		0.839		3.188
Passing No. 7		5.212		2.634		4.48		0.55		2.058
No. 14		3.694		1.89		2.72		0.29		1.335
No. 25		2.617		1.349		1.71		0.17		0.82
No. 56		1.623		0.85		0.65		0.08		0.38
No. 100		0.0088		—		—		—		—

Table 6.—Crushed Material/Settlement/Load Factor

	Test I Premix Sandstone	Test II Surface Dressing Laterite	Test III Premix Laterite	Test IV Premix Quartzite	Test V Surface Dressing Soil
1. Crushed Mat. (Laterite) smallest size put in (1½ in.) per cent (2 in.)	39.31	26.85	36.28	16.49	47.8 × ½
2. Crushed mat. (Laterite) gr. before	not taken	23976.9	22283.1	29876.9	8901.9
after	22930	19302.0	20260.8	27830.9	7825.4
Diff.		4674.9	2022.3	2046.0	1076.5
3. Laterite thickness after test in inches.	8¾	7	8¼	9¼	4
4. Maximum load reached for settlement of 1 in. in tons (approximate)	12	11	11	62	26
5. Factor tan/tan IV settlement/load taken from Fig. 3.	$0.107 = \frac{1}{9.35}$	$0.125 = \frac{1}{8}$	$0.1 = \frac{1}{10}$	$1.0 = \frac{1}{1}$	$0.375 = \frac{1}{2.67}$
6. Final settlement in inches when (4) was applied.	1.33	1.05	1.34	0.78	0.77
7. Crushed Laterite per settlement in per cent per inch.	29.6	28.2	27.1	21.2	31.2
8. Crushed Laterite per settlement per load in per cent per inch per ton.	2.47	2.56	2.46	0.342	1.20
9. Item for test 8/8 (IV)	7.24	7.48	7.19	1.0	3.52

BOOK REVIEW

THE INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING— FOURTEENTH VOLUME (1954)

(Published by Verlag Leeman, Zurich)

This 14th volume of "Publications" contains 14 Papers—7 in English, 3 in French and 4 in German, of which the following are of interest to Highway Engineers :

(1) The calculation of concrete girders, prestressed unsymmetrically above and below, taking more precise account of creep and shrinkage. (in German).

(2) Statistical calculation of strength of reinforced concrete beams. (in English).

The strength of reinforced concrete structures has hitherto been based on the assumption that the strength of concrete and the strength of reinforcement have definite values. This assumption is incorrect since the observed values of these quantities normally exhibit a certain dispersion (scatter, spread). The Paper derives equations for strength of reinforced concrete beams taking into account this dispersion.

(3) An experimental investigation of slabs subjected to concentrated loads. (in English).

To obtain information about the stress distribution in reinforced concrete slabs subjected to concentrated loads, experiments have been conducted for investigating the influence of the size of loaded surface (the concentration of the load) on the bending moments in the slab, and investigating the stress distribution in the slab as a function of the boundary conditions and the location of the load. The results are compared with the results obtained by theoretical calculation.

(4) Measurement of the stress and deflection of Kanzaki Bridge. (in English).

The live load stress and deflection measurements on the Kanzaki Bridge, which is a composite bridge built up of five main beams, are reported.

The object of this test is to assess the extent of load borne by the parallel beams when one beam is loaded. The stress ratio $\frac{\text{measured stress}}{\text{calculated stress}}$ and deflection ratio $\frac{\text{measured deflection}}{\text{calculated deflection}}$ were 66 and 80 per cent respectively. On the other hand, the experiment with a single beam structure showed that the above ratios were 89 and 84 per cent, from which it is clear that the stress ratio is smaller in parallel beam structure. This is due to the cooperation of the slab and all the beams connected by the slab.

(5) Suspension bridges. The aerodynamic problem and its solution. (in English).

Some bridge failures like that of the Tacoma Bridge have led to the creation of a new science, viz. Bridge Aerodynamics. With regard to the action of wind, its vertical component is more dangerous than the horizontal component. The stability or instability of a section depends on the "velocity ratio" V/Nb, where V signifies the wind velocity, N the natural frequency of the oscillating structure, and b the width of the section. By increasing depth, rigidity, and bracing; by adding center stays, longitudinal diagonal stays, transverse diagonal stays, or other stays; and by introducing artificial damping devices, resistance to aerodynamic instability may be built up to any desired amount.

—