Indian Roads congre

~~1950 + 51~~

Aug 1950

JL
D411m5,1:49
N50;2
92838

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

INDIAN ROADS CONGRESS

ESTABLISHED : 1934 REGISTERED : 1937

OFFICE-BEARERS AND COUNCIL, 1950-51.

President :

Romesh Chandra, I. S. E.,
Chief Engineer, Assam (On leave).

Vice-Presidents :

A. C. Mukerjee, I. S. E.,
Chief Engineer,
P. W. D., B. & R.,
Lucknow (U. P.).

N. P. Gurjar, I. S. E.,
Additional Chief Engineer,
P. W. D., Secretariat,
Bombay Castle,
Bombay-1.

S. B. Joshi,
Engineer & Contractor,
Examiner Press Building,
35, Dalal Street, Fort, Bombay.

Honorary Treasurer :

G. M. McKelvie, O. B. E., C. I. E., I. S. E.,
Consulting Engineer to the
Government of India (Roads),
Ministry of Transport,
Roads Organization,
New Delhi.

Honorary Secretary :

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

Members of Council :

(Some nominations are still awaited.)

1. R. K. Batra.
2. Brig. Partap Narain.
3. B. S. Puri.
4. C. G. Kale.
5. S. N. Chakravarti.
6. Brijmohan Lal.

7. F. P. Antia.
8. E. A. Nadirshah.
9. C. J. Fielder.
10. L. R. Patel.
11. V. N. Rangaswami.
12. Hari Shankar Sharma.
13. K. Narasimha Rao.
14. K. G. Bhate.
15. C. P. Misra
16. D. B. Nagarkar.
17. K. K. Nambiar.
18. M. L. Bahl.
19. C. M. Bennett.
20. M. S. Thirumale Iyengar
21. P. L. Varma.

92858

LIST OF COMMITTEES AND SUBCOMMITTEES

213

1. *SPECIFICATIONS AND STANDARDS COMMITTEE:*

G. M. McKelvie — *Convenor*
K. S. Raghavachary — *Member-Secretary*

(i) *Geometric Design Division*

T. Mitra
N. V. Modak
Brijmohan Lal
K. K. Nambiar

(ii) *Structural Design Division*

(a) *Rigid Pavements:*

A. C. Mukerjee or nominee
M. S. Thirumale Iyengar or nominee
One representative of E-in-C.
C. V. Nazareth

(b) *Flexible Pavements:*

Brig. Partap Narain
C. J. Fielder
S. R. Mehra
G. Srirangachary
V. N. Rangaswami

(iii) *Specifications and Costing Division:*

[For items other than (i) & (ii)]

H. Sunder Rao
One representative of E-in-C (Surveyor of works)
N. V. S. Murti
H. P. Sinha or nominee of C. P. W. D

2. *BRIDGES COMMITTEE:*

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

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

Brig. Partap Narain
A. Nageswara Ayyar
Kanwar Sain
G. R. Nangea
J. Chambers
A representative of C.B.I.

(ii) *Substructure and Superstructure Division:*

K. F. Antia
D. S. Desai
K. G. Bhate
S. K. Ghosh
S. B. Joshi
E. P. Nicolaides
P. S. Subramaniam
M. V. Joglekar
V. Venkataramiayya

3. *TECHNICAL SUBCOMMITTEE:*

(i) *Test Track Division:*

Chief Engineer (W. Bengal) —*Convenor*

C. J. Fielder
K. S. Raghavachary
S. N. Gupta
Satya Nand
G. Srirangachary
S. N. Chakravarti

(ii) *Research Organization Division:*

K. S. Raghavachary — *Convenor*

A representative of Engineer-in-Chief's Branch
Chief Engineer, Works & Buildings, West Bengal
Chief Engineer, Buildings & Roads, Uttar Pradesh
Chief Engineer (Highways), Madras
Chief Engineer, Buildings & Roads, Punjab.

4. *ROAD TRANSPORT SUBCOMMITEE:*

F. P. Antia — *Convenor*

K. M. Kantawala
V. N. Rangaswami
E. A. Nadirshah
R. N. Dogra

5. *BULLOCK-CART SUBCOMMITTEE:*

B. V. Vagh — *Convenor*

S. B. Joshi
J. A. Taraporevala
E. A. Nadirshah

6. *SOIL RESEARCH SUBCOMMITTEE:*

S. R. Mehra — *Convenor*

{One representative of E-in-C.
U. J. Bhatt
C. J. Fielder
V. N. Rangaswami
{One representative from Central Board of Irrigation
K. S. Raghavachary
G. Srirangachary
H. L. Uppal

7. *EDUCATION SUBCOMMITTEE:*

V. N. Rangaswami— *Convenor*

N. V. Modak
E. A. Nadirshah
K. S. Raghavachary
J. A. Taraporevala

8. *BITUMINOUS TREATMENT OF WET AGGREGATES SUBCOMMITTEE:*

W. A. Griffiths — *Convenor*

M. L. Bahl
R. N. Dogra
D. C. Dutta
Lakshman Sarup
T. Mitra

9. *HIGHWAY LAYOUT SUBCOMMITTEE:*

H. S. Batliwala — *Convenor*

T. Mitra
R. N. Dogra
M. Meeran
N. V. Modak
V. N. Rangaswami

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

S. K. Sinha — *Convenor**

11. *PAPERS SUBCOMMITTEE:*

G. M. McKelvie — *Convenor*

Brig. Partap Narain
B. S. Puri
A. C. Mukerjee

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

H. P. Mathrani — *Convenor*

R. S. Bhalla — *Member-Secretary*

F. P. Antia
Brig. Partap Narain
M. L. Bahl
L. R. Patel
B. S. Puri

13. *ORGANIZATION COMMITTEE:*

G. M. McKelvie — *Convenor**

The Consulting Engineer to the Government of India (Roads) is an ex-officio member of all Committees and Subcommittees

INDIAN ROADS CONGRESS

NOTICES AND ANNOUNCEMENTS

1. Contribution of Papers for the Fifteenth Session of the Indian Roads Congress.

The next General Session of the Indian Roads Congress is likely to be held sometime in January–February 1951. The exact date, place and programme of the Session will be communicated to Members in due course.

2. 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. **The complete Paper, if intended to be read at the next Session, should preferably be submitted within the next three months, but not later than September 1950.**

3. 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 in their contributions within the next **four months.** 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 before publication.

5. 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.

7. **ESSAYS:** Members are informed that the Council of the Indian Roads Congress, at their 34th meeting held at Bombay on the occasion of the 14th Session, have decided to discontinue the Prize Essay Competition.

8. Rules and Regulations for the Contribution of Technical Papers and the Award of Medals are published on pages 9 to 14 of Volume XIV-1 of the Journal of the Indian Roads Congress–September 1949.

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 ON 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 Sessions.

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

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

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

3. RULES FOR THE CONTRIBUTION OF TECHNICAL PAPERS.

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

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

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

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

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

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

4. RULES REGARDING SCRIPT.

4.1. The following instructions are for the guidance of Author's of Papers :

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

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

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

5. RULES REGARDING ILLUSTRATIONS.

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

a. Line drawings.

b. Half-tones.

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

Line drawings are generally classified into two categories:

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

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

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

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

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

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

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

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

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

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

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

6. BRIDGE DETAILS.

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

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

b. A dimensioned cross-section of the roadway;

c. The loading on which the design is based;

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

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

7. UNITS.

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

STANDARD UNITS OF WEIGHT AND MEASURE

Description of work	Units to be adopted.
1. Road materials 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. Similary 225° C should be written as 225 degrees centigrade, and so on.

10. ITALICS AND EMPHASIS.

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

11. PARAGRAPHING.

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

I.

II.

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

12. ACKNOWLEDGMENTS.

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

—

III. Procedure regarding the discussion of Papers at the Annual Sessions of the Indian Roads Congress

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

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

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

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

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

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

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

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

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

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

IV. Library.

1. Information and books on loan from the libraries of the Consulting Engineer (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 continous use.** The library cannot be expected to relieve officers of the necessity of purchasing books required constantly or for long periods of time.

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

5. The following rules will be strictly enforced:

(a) Books are issued for one month in the first instance. If a book is required for a longer period, an intimation should be sent to the Secretary, Indian Roads Congress for renewal before the due date of return. The book may then be re-issued for another month at a time at the discretion of the Secretary, but in no case will any book be issued for a total period exceeding three months.

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

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

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

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

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

6. **Instructions**:—

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

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

7. **General**:

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

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

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

V. New Admissions.

LIST OF THE MEMBERS OF THE INDIAN ROADS CONGRESS ENROLLED FROM 1-3-1950 TO 20-6-1950.

Serial No.	Roll No.	Name.	Address.
1361	1505	T. M. Das.	Assistant Engineer, (W & B), P.O. Balurghat, Dist. West Dinajpur.
1362	1506	S. G. Shah.	Deputy Engineer, Desai Polo, Rander (Surat).
1363	1507	A. A. K. Shaikh.	Superintendent, (City Survey and Land Records, Warden Road, Cumballa Hill, Bombay-26.
1364	1508	K. S. Bhatti.	Assistant Garrison Engineer, M. E. S. Jubbulpore.
1365	1509	R. E. Asorappa.	Chief Engineer, Eastern Command, Ranchi.
1366	1510	B. B. Basu.	S. O. R. I. E. II (Works), Chief Engineer's Office, Eastern Command, Ranchi.
1367	1511	Radhey Shiam.	Assistant Garrison Engineer, Garrison Engineer's Office, M. E. S. Ishapore. (24 Parganas).
1368	1512	R. M. Pagay (L.M.)	Lecturer in Civil Engineering, Hewett Engineering School, Kakkar Park, Choupatiyan, Lucknow.
1369	1513	M. N. Lalvani.	Assistant Engineer, Central P. W. D., 9/4, Chowranghee Lane, Calcutta-16.
1370	1514	S. C. Basu.	Executive Engineer, Hoogly Construction Division, W & B Department, Government of West Bengal, Chinsurah.
1371	1515	Niranjan Sen.	Assistant Engineer (Consultant), Ministry of Transport, Roads Organization, Jamnagar House, New Delhi.
1372	1516	K. C. Tayal.	District Engineer, P. W. D., Bara Banki, (Uttar Pradesh).
1373	1517	K. Krishnan Nayar.	Assistant Engineer, Highways, Tellicherry, North Malabar.
1374	1518	B. S. Mathur	Assistant Town Planner, Jullundur (Punjab).

Associate Member.

1	42	H. M. Weatherall.	C/o Arthur Butler & Co. (Muz) Ltd., Muzaffarpur, Bihar.

VI. Deaths.

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

Serial No.	Roll No.	Name.	Address.
1	585	S. N. Datta.	Superintendent, Water Works, Gwalior.
2	666	K. Bala Krishna-Menon.	Divisional Engineer, (B), Coimbatore North Division, Coimbatore.
3	276	H. Bhattacharya.	Assistant Engineer, Works-Buildings, P. O. Barajaguly, District Nabadwip, (West Bengal).

VII. Addresses of Members Wanted.

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

Serial No.	Roll No.	Name of Member.	Last known address.
1	227	Adshetti, G. K.	Chartered Engineer, Saraswati Niwas, Pratap Ganj, Baroda.
2	271	Jayaswal, U. S.	District Engineer, Muzaffarpur (Bihar).
3	178	Kidar Nath.	32, Kaonli Road, Dehra-Dun (Uttar Pradesh).
4	24	Korni, M. A.	114, Regent Estate, Tolly Ganj, Calcutta.
5	572	Malik, N. M. Khan.	C/o Said Ahmed Esquire, Director, Land Records, Bhopal.
6	1219	Mehta, Vasant, V.	Assistant Engineer, Amarnath Vishwanath Building, near Gutaiya Market-Tower, 113/109 Swarup Nagar, Kanpur (Uttar Pradesh.)
7	188	Nawab Ahsan Yar Jung Bahadur (L.M)	Afsar Manzil, Jubilee Hill, Hyderabad-Deccan.
8	417	Parang, Hari Ram (L.M.)	Retired Executive Engineer, Lal Chowk Qila Gujar-Singh, Lahore.
9	720	Shaw, M. (L.M.)	Executive Engineer, C. P. W. D., Indore.

ALPHABETICAL LIST OF MEMBERS.

Corrected upto 20—6—1950 and Roll No. 1518.

Honorary Members

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

Ordinary and Life Member.

(L. M. denotes Life Member).

Serial No.	Roll No.	Name.	State/Country
		"A"	
1	487	Abdul Aziz.	Pakistan.
2	262	Abdul Hai.	Hyderabad.
3	923	Abdul Jabbar.	Bihar.
4	1263	Abdul Rahman.	Madras.
5	629	Abraham, J. G.	Madras.
6	684	Acharya, D. K.	Orissa.
7	850	Acharya, P. G.	Rajasthan.
8	768	Acharya, S.	Orissa.
9	721	Acherjee, F. C.	Government of India.
10	826	Adaviyappa, S.	Rajasthan.
11	242	Adke, A. S.	Bombay.
12	227	Adshetti, G. K.	Bombay.
13	917	Agarwal, C. P.	Uttar Pradesh.
14	531	Agarwal, S. K.	Uttar Pradesh.
15	1389	Agarwal, K. C.	Uttar Pradesh.
16	957	Agarwala, D. R.	Uttar Pradesh.
17	781	Agarwala, R. P.	Bihar.
18	1060	Agarwala, M. G.	Uttar Pradesh.
19	634	Agrawala, R. M.	Uttar Pradesh.
20	1106	Agrawala, C. S. L.	Vindhya Pradesh.
21	1223	Agrawala, P. S.	Uttar Pradesh.
22	1397	Ahmed Ovaise.	Uttar Pradesh.
23	1001	Ahuja, P. R.	Government of India.
24	1055	Aiyangar, R. A. Sampat	Mysore.

Serial No.	Roll No.	Name.	State/Country.
25	995	Aiyar, C. S. Padmanabha	Travancore-Cochin.
26	452	Ajwani, J. M.	M. E. S.
27	1388	Akalankan, N. A.	Madras.
28	341	Akhtar, S. E.	Bihar.
29	1427	Albert Mayor.	U. S. A.
30	821	Amarinderjit Singh.	PEPSU.
31	1189	Amin, M. P.	Bombay.
32	1086	Aminbhavi, L. T.	Madhya Pradesh.
33	420	Amingad, A. K.	Hyderabad.
34	317	Amir, S. A.	Pakistan.
35	1394	Anand, R. M.	Punjab.
36	675	Ananda Rao, U.	Madras.
37	677	Ananthanarayanan, A. S.	Madras.
38	1251	Andavan, G. M.	Madras.
39	642	Angadi, R. B.	Bombay.
40	562	Annaswami, V. S.	Government of India.
41	1285	Ansari, M. N.	Madhya Bharat.
42	1241	Antia, K. F.	Bombay.
43	650	Anwarullah, M.	Hyderabad.
44	1414	Apte, K. V. (L.M.)	Bombay.
45	1332	Arjun Singh.	Bihar.
46	1308	Arjun Thakur.	Bihar.
47	1234	Arnold, G. J.	Government of India.
48	442	Arora, K. N.	Uttar Pradesh.
49	1239	Arunachalam, S.	M. E. S.
50	736	Asarpota, D. M.	Bombay.
51	1017	Asbeck, Ir. W. F. Baron Van.	England.
52	1503	Aserappa, R. E.	M. E. S.
53	588	Athawale, V. L.	Madhya Bharat.
54	91	Ayyangar, M. R. Duraiswami.	Madras.
55	76	Ayyar, A. Nageshwara (L.M.)	Government of India,

Serial No.	Roll No.	Name.	State/Country.
56	109	Ayyar, Lakshman Venkata Krishnan (L.M.)	Madras.
57	98	Ayyar, K. Trimalaiswamy (L.M.)	Madras.
58	656	Ayyar, V. A.	Rajasthan.
59	1073	Ayyar, V.V. Gopala Krishna	Travancore-Cochin.
60	1254	Ayyaswami, G.	Madras.
		"B"	
61	213	Bagchi, C. C.	Uttar Pradesh.
62	977	Bahl, D. R.	Government of India.
63	399	Bahl, M. L.	Bihar.
64	836	Bais, Ram Singh	Rajasthan.
65	1481	Bakori, R. D.	Bombay.
66	897	Baksi, R. D.	Bihar.
67	458	Bala Porshad, S.	Hyderabad.
68	544	Balasubrahmanyam, M.	Madras.
69	741	Balasubramaniam, M. R.	Madras.
70	253	Bamji, H. F. (L. M)	Bombay.
71	355	Bammi, D. R.	Punjab.
72	1152	Banerjee, Ajit Kumar	Bihar.
73	85	Banerjee, M. G. (L.M)	West Bengal.
74	779	Banerjee, Shishir Kumar	Bihar.
75	1290	Banerjee, S. C.	Government of India.
76	1456	Banerjee, S. N.	West Bengal.
77	88	Banerjee, Tulsidas	Madhya Pradesh.
78	877	Banerji, P. K.	Uttar Pradesh.
79	1133	Banerji, S. K.	West Bengal.
80	962	Bannerjee, J. K.	West Bengal.
81	910	Bannerjee, S. R.	West Bengal.
82	1181	Bansal, K. L.	Uttar Pradesh.
83	929	Bansal, K. S.	Madhya Pradesh.
84	336	Bansor, B. S.	M. E. S.
85	1186	Bapat, M. S.	Uttar Pradesh.

Serial No.	Roll No.	Name.	State/Country.
86	1247	Barua, H.	Assam.
87	234	Barua, H. P. (L. M.)	Assam.
88	889	Barua, K.	Assam.
89	892	Basant Singh, S.	Punjab.
90	814	Basheer Ahmed.	Madras.
91	51	Bashi Ram, S. (L. M.)	Punjab.
92	745	Bashir Ahmed.	Pakistan.
93	1510	Basu, B. B.	M. E. S.
94	1421	Basu, K. N.	West Bengal.
95	453	Basu, N.	M. E. S.
96	1514	Basu, S. C.	West Bengal.
97	383	Batlivala, H. S.	Bombay.
98	978	Batra, R. K.	Madhya Pradesh.
99	981	Battiwala, K. P.	Bombay.
100	1350	Baul, Raghudas.	West Bengal.
101	322	Bazaz, Shamlal	Government of India
102	57	Bedekar, V. P.	Bombay.
103	1495	Bedeker, V. V.	Hyderabad.
104	328	Behera, S. S.	Orissa.
105	1399	Benjamin, George	M. E. S.
106	204	Bennett, C. M.	Orissa.
107	266	Bhagat, D. G.	Government of India.
108	1207	Bhagat, N. S.	Uttar Pradesh.
109	1463	Bhagwagar, K. D.	Bombay.
110	149	Bhalla, Prem Nath	Madhya Bharat.
111	1446	Bhalla, R. S.	Government of India.
112	1050	Bhambhani, B. I.	Bombay.
113	14	Bhandarkar, G. P. (L. M.)	Bombay.
114	827	Bhargava, I. D.	Rajasthan.
115	251	Bhargava, K. N.	Rajasthan.
116	1114	Bhargava, M. C.	Uttar Pradesh.
117	1175	Bhargava, M. G.	Uttar Pradesh.

Serial No.	Roll No.	Name.	State/Country.
118	783	Bhargava, T. N.	Government of India.
119	169	Bharucha, M. D.	Bombay.
120	1402	Bhasin, P. C.	Punjab.
121	329	Bhate, K. G.	Bombay.
122	1122	Bhatia, H. T.	M. E. S.
123	460	Bhatia, K. M.	Government of India.
124	658	Bhatia, M. S.	Government of India.
125	716	Bhatnagar, Chanderlal	Hyderabad.
126	62	Bhatnagar, Jagmohan Lal (L.M.)	Rajasthan.
127	860	Bhatnagar, P. S.	Uttar Pradesh.
128	1304	Bhatnagar, S. S. L.	Uttar Pradesh.
129	214	Bhatt, U. J.	Saurashtra.
130	1213	Bhatta, H. C. K.	Mysore.
131	732	Bhattacharjee, K. D.	Government of India.
132	245	Bhattacharya, N. G. (L.M.)	Rajasthan.
133	549	Bhattacharya, S. K.	Bihar.
134	1413	Bhattacharya, S. P.	West Bengal.
135	1508	Bhatti, K. S.	M. E. S.
136	815	Bhojani, M.D.	Saurashtra.
137	455	Bhonsale, N. K.	Madhya Bharat.
138	484	Bhupendra Nath.	Government of India.
139	1301	Bhuvaragha Moorthy, R.	Madras.
140	272	Bhuyan, M. N.	Orissa.
141	1370	Bibhuty, L. N. S.	Bihar.
142	831	Bijawat, M. C. (L.M.)	Uttar Pradesh.
143	462	Bikramjit.	Punjab.
144	53	Bishamber Dayal (L.M.)	Punjab.
145	943	Bishan Saran.	Uttar Pradesh.
146	205	Bisht, M. S.	Uttar Pradesh.
147	1383	Biswas, K. K.	West Bengal.
148	1461	Bomanji, P.	M. E. S.

Serial No.	Roll No.	Name.	State/Country.
149	1244	Bora, K. C.	Assam.
150	1395	Borwankar, S. G.	Madhya Pradesh.
151	278	Bose, K. M.	Orissa.
152	539	Bose, K. N.	West Bengal.
153	1443	Bose, M. M.	Government of India.
154	1201	Bose, R. C.	West Bengal.
155	522	Bose, R. K.	West Bengal.
156	731	Bose, T. K.	Bihar.
157	42	Brijmohan Lal (L.M.)	Punjab.
158	616	Brij Narayan.	Delhi.
159	1149	Brinda Roy.	Bihar.
160	147	Brown, G. A. M.	Pakistan.
161	135	Browne, C. A.	Bihar.
162	68	Budhiraja, Balwant Singh	Punjab.
163	1502	Bulsara, N. C.	Bombay.
164	852	Bushby, W. E.	Delhi.
		"C"	
165	615	Calder, W. B.	Scotland.
166	16	Campbell Gray, T.	England.
167	1182	Cantlay, L. F.	England.
168	796	Capriban, S. P.	Madhya Pradesh.
169	1196	Chablani, M. B.	Government of India.
170	519	Chacko, I. C. (L.M.)	Travancore-Cochin.
171	599	Chadda, S. R.	West Bengal.
172	201	Chaddha, Ulfatrai.	M. E. S.
173	1155	Chakraburty, N. B.	West Bengal.
174	789	Chakravarti, B. M.	Assam.
175	712	Chakravarti, J. C.	Government of India.
176	17	Chakravarti, S. N. (L.M.)	West Bengal.
177	323	Chambers, J. (L.M.)	West Bengal.
178	275	Champa Lal.	Punjab.

Serial No.	Roll No.	Name.	State/Country.
179	1324	Chanda, R. P.	West Bengal.
180	994	Chandrasekharan, E. C	U. S. A.
181	1004	Chandratreya, S. V.	Bombay.
182	1357	Channiah, H.	Mysore.
183	372	Chapdalkar, V. P.	Hyderabad.
184	896	Charan, S. K.	Uttar Pradesh.
185	887	Chari, T. V. R.	Madras.
186	565	Chatterjee, Dina Bandhu	Government of India.
187	483	Chatterjee, G. C.	West Bengal.
188	1348	Chatterjee, M. K.	West Bengal.
189	1426	Chatterjee ,P. C.	West Bengal.
190	913	Chatterjee, P. K.	West Bengal.
191	934	Chatterjee, P. L.	Government of India.
192	1347	Chatterjee, P. N.	West Bengal.
193	529	Chatterjee, R.	West Bengal.
194	624	Chatterjee, S. N.	West Bengal.
195	1411	Chattopadhya, B. N.	West Bengal.
196	1496	Chattopadhyay, K. P.	West Bengal.
197	1264	Chaudhury, T. K. Roy	West Bengal.
198	691	Chauhan, P. M.	Bihar.
199	1208	Chavan, D. N.	Bombay.
200	906	Chawla, S. S.	M. E. S.
201	263	Chenoy, Faridoon, S. (L.M.)	Hyderabad.
202	893	Chetan Das.	M. E. S.
203	633	Chetty K. A. Nanjundeswara	Madras.
204	1436	Chetty, Subramania, K.	Government of India.
205	281	Chinchakar, K. B.	Bombay.
206	348	Choksi, B. K.	Bombay.
207	145	Chopra, A. N. (L.M.)	Government of India.
208	991	Chopra, I. S.	Government of India.
209	1455	Chopra, P. C.	Vindhya Pradesh.
210	1092	Chopra, Y. P.	Punjab.

Serial No.	Roll No.	Name.	State/Country.
211	704	Chougule, Y. K.	Bombay.
212	215	Chowdhury, Abid Raza	Pakistan.
213	749	Chowdhury, A. N. Dutta	U. S. A.
214	941	Chowdhury, B.	Assam.
215	709	Chowdhury, B.	Bihar.
216	1294	Chowdhury, D. P. Roy	West Bengal.
217	474	Chowdhury, K. V.	Madras.
218	346	Chowdhury, Imam-Uz-Zaman	Pakistan.
219	963	Chowdhury, P. R.	Assam.
220	821	Chowdhury, Ram Narain	Rajasthan.
221	765	Chowdhury, S. Gurbachan Singh	Government of India.
222	202	Chowdhury, S. P.	Assam.
223	419	Chowla, P. D.	Government of India.
224	289	Cochrane, G. A. D. (L.M.)	England.
225	905	Cocksedge, H. G.	Assam.
226	28	Colabawala, J. R. (L.M.)	Pakistan.

"D"

Serial No.	Roll No.	Name.	State/Country.
227	261	Daftary, G. D. (L.M.)	Bombay.
228	1336	Daftary, N. D.	Bombay.
229	1477	Dalal, M. N. (L.M.)	Bombay.
230	140	Dam, S. C.	West Bengal.
231	1184	Damodar Das.	Uttar Pradesh.
232	1371	Damodaran, A. M.	Madras.
233	1487	Daruwala, P. K.	Bombay.
234	552	Daryanani, C. S.	Bombay.
235	1137	Das, A. C.	Orissa.
236	919	Das, A. L.	West Bengal
237	161	Das, B. C.	Assam.
238	780	Das Gupta, A. K.	Bihar.
239	1202	Das Gupta, B. B.	West Bengal
240	203	Das Gupta, J. N.	Delhi.

Serial No.	Roll No.	Name.	State/Country.
241	319	Das Gupta, J. N.	West Bengal.
242	1046	Das, J. C.	Assam.
243	560	Das, K. C.	Orissa.
244	774	Das, P. B.	Madhya Pradesh.
245	285	Das, P. C.	Orissa.
246	518	Das, S.	Assam.
247	1197	Das, S. M. Mohan	Madras.
248	1505	Das, T. M.	West Bengal.
249	659	Datt, J.	Bihar.
250	15	Datta, A. K. (L. M.)	West Bengal.
251	412	Datta, A. K.	Bihar.
252	157	Datta, D. C.	Assam.
253	1349	Datta, D. C.	West Bengal.
254	1156	Datta, P. L.	Government of India
255	1422	Datta, S. M.	Assam.
256	158	Datta, S. K.	Assam.
257	71	Dave, D. P.	Madhya Bharat.
258	1043	Daver, F. K.	Hyderabad.
259	433	Dayal, B.	Bihar.
260	758	D'Costa, A. J.	Government of India.
261	1144	De, Anil Chandra	Orissa.
262	532	De, S. N.	West Bengal.
263	1161	DeSousa, P.	Government of India.
264	199	Dean, A. W. H. (L. M.)	England.
265	1483	Deodhar, M. D.	Bombay.
266	776	Des Raj.	Government of India.
267	940	Desai, C. B.	Rajasthan.
268	1322	Desai, C. N.	Bombay.
269	165	Desai, D. S.	West Bengal.
270	904	Desai, I. C.	Bombay.
271	1485	Desai, M. M.	Bombay.
272	1466	Desai N. K.	Bombay.

Serial No.	Roll No.	Name.	State/Country.
273	773	Desai, R. V.	Bombay.
274	1497	Deshpande, D. V.	Bombay.
275	1484	Deshpande, K. S.	Bombay.
276	937	Devapriam, A.	Madras.
277	353	Devarajan, A.	Hyderabad.
278	694	Devarajan, K. S.	Madras.
279	118	Devasthala, K. B.	Madhya Pradesh.
280	182	Devi Dayal.	Himachal Pradesh.
281	737	Dewan, N. G.	Delhi.
282	313	Dhanarajan, S. H.	Mysore.
283	1468	Dhanokar, T. H.	Bombay.
284	899	Dhara, B. B.	West Bengal.
285	925	Dhar, B. K.	West Bengal.
286	1045	Dharma Rajan, N.	Delhi.
287	617	Dhaul, K. K.	Government of India.
288	1338	Dhillon, Arjan Singh	PEPSU.
289	614	Dhingra, A. D.	Bombay.
290	1243	Dhir, H. R.	Punjab.
291	590	Dhodi, S. D.	Madhya Bharat.
292	1145	Dhruva, R. C.	Bombay.
293	567	Dhumal, R. J.	Madhya Bharat.
294	250	Dildar Hussain	Hyderabad.
295	1170	Dinesh Mohan	Uttar Pradesh.
296	573	Divatia, P. V.	Madhya Bharat.
297	357	Divatia, S. S.	Bombay.
298	575	Dixit, M. K.	Madhya Bharat.
299	701	Dogra, H. R.	Madras.
300	457	Dogra, R. N.	Punjab.
301	494	Domingo, T. B.	Bihar.
302	210	Doshi, M. M.	Bombay.
303	1279	Dubash, M. D.	Bombay.
304	602	Duboy, B. P.	Bihar.

Serial No.	Roll No.	Name.	State/Country.
305	623	Duboy, Jagdish Prasad	Bihar.
306	730	Durairaj, T.	Madras.
307	1412	Durga Prasad	Rajasthan.
308	246	Durrani, N.	Madras.
309	1393	Dutt, A. C.	West Bengal
310	1140	Dutt. G. N.	Assam.
311	908	Dutt, K.	West Bengal.
312	948	Dutt, N. N.	Government of India.
313	530	Dutt, P.	West Bengal.
314	688	Dutta, S. C.	Assam.
		"E"	
315	801	Eapen, K. E.	Travancore-Cochin.
316	168	Eccleston, W. T. (L.M.)	England.
317	184	Edibam, N. R.	Uttar Pradesh.
318	94	Edwin, J. W. (L.M.)	Mysore.
319	86	Endlaw, D. N.	Government of India.
		"F"	
320	222	Fateh Chand, (L.M.)	Uttar Pradesh.
321	594	Fergusson, F. F.	Bihar.
322	231	Fielder, C. J.	West Bengal.
323	288	Fleury, W. R.	Bihar.
324	911	Fonseka, C. E.	Ceylon.
		"G"	
325	1480	Gadhoke, S. R.	Rajasthan.
326	829	Gadre, N. B. (L.M.)	Bombay.
327	274	Gnana Prakasam, N. T.	Madras.
328	409	Ganapathy, G. S.	Madras.
329	858	Gandhi, J. H.	Bombay.
330	93	Gandhi, K. J. (L.M.)	Bombay.
331	467	Gandhi, M. M. (L.M.)	Bombay.
332	1457	Gandotra, H. K.	Kashmir.

Serial No.	Roll No.	Name.	State/Country.
333	179	Gangadhara, K. S.	Mysore.
334	1094	Ganguli, A. N.	West Bengal.
335	1369	Ganguli, D. N.	West Bengal.
336	1503	Ganguli, H. D.	West Bengal.
337	942	Garg, S. K.	Uttar Pradesh.
338	501	Garr, B. L.	West Bengal.
339	1268	Gauri Nath.	Punjab.
340	1267	Gautam Narayan, Raj Kumar	West Bengal.
341	1029	George, K. T.	Travancore-Cochin.
342	63	Ghanekar, Y. K.	Madhya Pradesh.
343	208	Gharpure, A. V.	Bombay.
344	598	Ghatge, Krishna Rao Raghoji	Bombay.
345	1292	Ghose, A. C.	West Bengal.
346	56	Ghose, S. K.	Bihar.
347	1030	Ghosh, A. K.	West Bengal.
348	1462	Ghosh, D. N.	West Bengal.
349	510	Ghosh, K. P.	Madras.
350	1277	Ghosh, Sripada	West Bengal.
351	641	Ghosh, S. B.	Bihar.
352	651	Ghosh, Pasupati	West Bengal.
353	486	Ghosh, Sushil Kumar	Bihar.
354	1286	Ghosh, Taradas	Bihar.
355	808	Ghosh, S. K.	West Bengal.
356	1424	Ghoshal, P. K.	West Bengal.
357	708	Gidwani, M. M.	Government of India
358	1058	Gill, Jagmal Singh	PEPSU.
359	946	Goel, R. R.	Uttar Pradesh.
360	1091	Goel, Harish Chandra	Government of India.
361	1136	Goel, Harbans Lal	PEPSU.
362	468	Goghari, N. W.	Bombay.
363	1284	Golikere, P. R.	Madras.

Serial No.	Roll No.	Name.	State/Country.
364	1187	Goyal, J. P.	Uttar Pradesh.
365	1218	Goyal, S. C.	Uttar Pradesh.
366	1192	Goyal, Sohan Lal	Uttar Pradesh.
367	47	Gopalacharya, G. (L.M.)	Madras.
368	1044	Gopalan, S.	Hyderabad.
369	1143	Gore, R. R.	Madhya Pradesh.
370	700	Goswami, S. M.	West Bengal.
371	408	Govel, K. C.	Delhi.
372	879	Goverdhan Lal.	Government of India
373	1428	Govindarajulu, K.	Madras.
374	1248	Govindarajulu, S. P.	Bombay.
375	938	Grewall, R. S.	M. E. S.
376	80	Griffiths, W. A.	Madras.
377	1387	Grover, D. T.	Government of India
378	102	Guo, K. C. (L.M.)	West Bengal.
379	119	Guo, T. C.	Vindhya Pradesh.
380	1293	Guha, Asutosh	West Bengal.
381	151	Guha, J. C. (L. M.)	West Bengal.
382	1230	Guha, M. K.	West Bengal.
383	1498	Guha, M. N.	West Bengal.
384	611	Guha, P. R.	Government of India
385	1225	Gulzar Singh, S.	Punjab.
386	663	Gupchup, N. S.	Bombay.
387	440	Gupta, B. B.	Bihar.
388	1154	Gupta, B. N.	West Bengal.
389	547	Gupta, D. N.	England.
390	509	Gupta, Indu Bhushan Das	West Bengal.
391	886	Gupta, Govinda	Orissa.
392	1028	Gupta, H. K.	Government of India.
393	511	Gupta, Harbans Lal	Uttar Pradesh
394	816	Gupta, Hari Dutta	Rajasthan.

Serial No.	Roll No.	Name.	State/Country.
395	1227	Gupta, Ishwar Chandra	Punjab.
396	1239	Gupta, J. P.	Uttar Pradesh.
397	330	Gupta, Kanchandu	Bihar.
398	595	Gupta, K. M.	Madhya Bharat.
399	597	Gupta, K.	Bihar.
400	125	Gupta, N. Das	Delhi.
401	1315	Gupta, Ranjit Kumar	West Bengal.
402	1051	Gupta, R. L.	Madhya Pradesh.
403	471	Gupta, S.	Bihar.
404	587	Gupta, S. C.	Madhya Pradesh.
405	936	Gupta, Sachindra Nath	West Bengal.
406	1233	Gupta, Sudhindra Nath	Government of India.
407	1379	Gurbaxani, T. C.	Madhya Pradesh.
408	1242	Gurcharan Singh.	Punjab.
409	655	Gurjar, N. P.	Bombay.
410	1078	Gursahani, R. L.	Government of India.
411	652	Guruswamy, S. (L.M.)	Madras.
412	1003	Gwyn, E. H.	British West Indies.
		"H"	
413	5	Hain H. W. T.	West Bengal.
414	1252	Hajeley, S. P.	Uttar Pradesh.
415	930	Halder, S. D.	Government of India.
416	1382	Hambly, D. M.	West Bengal.
417	571	Handa, K. L.	Madhya Bharat.
418	1307	Handa, R. R.	Orissa.
419	894	Hanly, P. J.	West Bengal.
420	74	Hardikar, J. C.	Hyderabad.
421	41	Hardit Singh.	Delhi.
422	785	Har Dayal. (L.M.)	Government of India.
423	11	Hari Chand	Delhi.
424	248	Harris, J. (L.M.)	Uttar Pradesh.
425	1253	Hasan, S. M. I.	Bihar.

Serial No.	Roll No.	Name.	State/Country.
426	784	Hashmi, K. B. R.	Pakistan.
427	38	Haval, Anant Balwant	Bombay.
428	1026	Hege, W. D.	Bombay.
429	840	Hem Raj.	Bhopal.
430	640	Hemnani, M. Rup Chand	Punjab.
431	1320	Hiremath, S. A.	Madhya Pradesh.
432	1159	Hoda, S. A.	Bihar.
433	229	Hodgson, E. S.	England.
434	1489	Huchveeriah, T.	Mysore.
435	424	Huda, N.	Bihar.
436	104	Hughes, H. (L.M.)	England.
		"I"	
437	1378	Iengar, B. Krishna	Bombay.
438	1283	Inamdar, H. M.	Madhya Pradesh.
439	900	Inamdar, S. G.	Madhya Pradesh.
440	563	Inamdar, S. R.	Madhya Bharat.
441	632	Indramonikar.	Orissa.
442	521	Iqbal Singh.	Punjab.
443	1057	Iyengar, M. V. Krishna-swamy (L.M.)	Mysore.
444	1087	Iyar, B. S. Raju	M. E. S.
445	395	Iyengar, C. L.	Hyderabad.
446	1129	Iyengar, C. L. N.	Bombay.
447	364	Iyengar, M. A. R.	Hyderabad.
448	1438	Iyengar, M. S. Thirumalo	Madras.
449	722	Iyengar, N. Narasimham	Government of India.
450	833	Iyengar, R. K. N.	Delhi.
451	1068	Iyer, A. R. Krishna	Travancore-Cochin.
452	292	Iyer, E. V. S.	Orissa.
453	1041	Iyer, R. Ganapathy	Travancore-Cochin.
454	997	Iyer, T. S. Narayanaswami	Madras.

Serial No.	Roll No.	Name.	State/Country.
		"J"	
455	1076	Jabbar, M. A.	Pakistan.
456	1042	Jacob, A. T.	Travancore-Cochin.
457	566	Jadhav, M. K.	Bombay.
458	1194	Jagdish Bahadur.	Uttar Pradesh.
459	52	Jagdish Prasad.	Uttar Pradesh.
460	287	Jagmohan.	Uttar Pradesh.
461	1474	Jagus, P. J.	Bombay.
462	1138	Jain, D. C.	Uttar Pradesh.
463	1441	Jain, G. C.	Uttar Pradesh.
464	1425	Jain, K. C.	Government of India.
465	707	Jali, F. C.	Assam.
466	697	Jambunathan, S.	Government of India.
467	670	Janardan Rao, C.	Madras.
468	857	Jasjit Singh.	Punjab.
469	1275	Jaswant Singh.	Government of India.
470	1180	Jatogaonkar, V. L.	Bombay.
471	787	Jathal, M. N.	Bombay.
472	1429	Jayaraman, B.	Madras.
473	271	Jayaswal, U. S.	Bihar.
474	1070	Jaywant, L. K.	Madhya Bharat.
475	1418	Jeya Singh, H.	Madras.
476	1142	Jha, B. D.	Madhya Bharat.
477	465	Jha, B. K.	Bihar.
478	1177	Jha, U. N.	Bihar.
479	819	Joginder Singh, S.	PEPSU.
480	596	Joglekar, G. D.	Bombay.
481	1450	Joglekar, K. V.	Bombay.
482	1169	Joglekar, M. V.	Bombay.
483	1101	John, K. P.	Travancore-Cochin.
484	761	John Mukand.	Government of India.
485	1337	John, P. V.	Travancore-Cochin.

Serial No.	Roll No.	Name.	State/Country.
486	569	Johri, Brij Mohan	PEPSU.
487	1398	Johorey, M. C.	Uttar Pradesh.
488	1036	Jones, Glyn.	Bombay.
489	134	Jones, R. Trevor (L.M.)	England.
490	304	Jootla, Baboo Singh.	Orissa.
491	1235	Joshi, J. S. (L.M.)	Bombay.
492	1282	Joshi, N. P.	Bombay.
493	122	Joshi, N. S. (L.M.)	Bombay.
494	1430	Joshi, R. N.	Bombay.
495	315	Joshi, S. B. (L.M.)	Bombay.
496	31	Jussawalla, J. R. (L.M.)	Hyderabad.
497	1226	Jyoti Prakash.	Uttar Pradesh.
		"K"	
498	1408	Kabiraj Lakshmi Narayan.	Bihar.
499	740	Kagal, B. R. (L. M.)	Bihar.
500	1228	Kakar, J. N.	Punjab.
501	621	Kale, C. G.	Bombay.
502	823	Kallukaran, J. V.	Travancore-Cochin.
503	1097	Kamath, M. N.	Madras.
504	852	Kandaswamy, V.	Government of India.
505	874	Kanga, F. J. (L. M.)	Bombay.
506	107	Kanhere, V. P. (L. M.)	Bombay.
507	1504	Kankanwadi, D. B.	Bombay.
508	1016	Kantawala, K. M.	Bombay.
509	1374	Kanwar Sain. (L. M.)	Government of India.
510	1407	Kapoor, S. P.	Punjab.
511	695	Kapur, C. D.	Government of India.
512	1193	Kar, S. M.	Uttar Pradesh.
513	1453	Karandikar, S. K.	Bombay.
514	1493	Karkare, M. P.	Bombay.
515	1102	Karra, J. R.	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
516	996	Kartha, K. K.	Travancore-Cochin.
517	750	Kartik Porshad.	Uttar Pradesh.
518	1335	Kartik, Oraon	Bihar.
519	1115	Kashyap, M. G.	Orissa.
520	249	Katrak, M. M.	Hyderabad.
521	124	Keatings, H. A.	West Bengal.
522	252	Kerr, J. Oldfield	Pakistan.
523	729	Kewal Krishan.	Punjab.
524	1081	Khabade, J. G.	Bombay.
525	931	Khalique, M. V.	Pakistan.
526	297	Khan, Abdul Jabbar	Uttar Pradesh.
527	337	Khan, G. H.	Kashmir.
528	676	Khan, G. M.	Pakistan.
529	798	Khan, Ikram Ullah	Pakistan.
530	799	Khan, Inayat Ullah	Pakistan.
531	689	Khan, M. A.	Bihar.
532	306	Khan, M. I.	Pakistan.
533	255	Khan, Mohammed Abdul Kayyum	Hyderabad.
534	345	Khan, M. A. Subhan	Hyderabad.
535	572	Khan, N. M. Malik	Bhopal.
536	1015	Khan, Mohammed Azam (L.M.)	Pakistan.
537	446	Khanna, G. C.	Punjab.
538	72	Khanna, Indra Narain	Government of India.
539	698	Khanna, N. N.	Government of India.
540	97	Khanna, Prem Nath	Uttar Pradesh.
541	1134	Khanna, P. N.	Punjab.
542	78	Khatri, K. C.	Government of India.
543	556	Khattak, A. K.	Pakistan.
544	1403	Khosla, B. R.	M. E. S.
545	591	Khot, N. A. (L. M.)	Madhya Bharat.
546	1141	Khursale, N. R.	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
547	173	Kidar Nath.	Uttar Pradesh.
548	187	Kikkeri, S. A.	Punjab.
549	1182	Kochhar, R. K.	Uttar Pradesh.
550	1439	Koenigsberger, O. H.	Government of India.
			M. E. S.
551	1270	Kohli, J. S.	West Bengal.
552	24	Korni, M. A.	Hyderabad.
553	363	Kosanam, S. S.	Saurashtra.
554	432	Kothari H. J.	Madhya Pradesh.
555	979	Kothari, V. C.	Madras.
556	1437	Koya, K. V. Ahmad	Madras.
557	1152	Krishna Moorthy, T.	Madras.
558	681	Krishnamurti, B.	Government of India.
559	770	Krishnamurti, M.	Madras.
560	888	Krishnamurti, M. R.	Madras.
561	1448	Krishnan, E.	Madras.
562	605	Krishnan, K. S.	Government of India.
563	719	Krishnan, M. P. Sivarama	Government of India.
564	1298	Krishnan, N.	Bombay.
565	217	Krishnan, O. C. K.	Madras.
566	976	Krishnan, R.	Mysore.
567	1356	Krishnaswamy, C. R. Madaliyar	Mysore.
568	1049	Krishnaswamy, M.	Bombay.
569	1019	Krishnaswamy, M. K.	Madras.
570	448	Krishnaswami, P. A.	
571	867	Krishnayya, Y.	Madras.
572	1330	Kujur, L. K.	Bihar.
573	775	Kumar, A.	Mysore.
574	782	Kumar, G. L.	Madhya Pradesh.
575	947	Kumar, Y. D. (L.M.)	Uttar Pradesh.
576	845	Kumawat, B. P.	Rajasthan.
577	1048	Kurup, P. K.	Travancore-Cochin.

Serial No.	Roll No.	Name.	State/Country.
578	1062	Kuruvila, P. K.	Travancore-Cochin.
579	18	Kynnersley, T. R. S. (L.M.)	Bombay.
		"L"	
580	778	Laha, Kashi Pat	Bihar.
581	725	Lahiri, M. C.	Government of India.
582	374	Lakadawala, Rustum, M.	Hyderabad.
583	1458	Lakhani, S. G.	Bombay.
584	284	Lakshman Swarup.	Uttar Pradesh.
585	932	Lakshmi Chand.	Uttar Pradesh.
586	1361	Lakshmi Narayan.	Bihar.
587	1469	Lakshmi Narayan, V.	Mysore.
588	26	Lakshminarayana Rao, A. (L.M.)	Madras.
589	1364	Lal, A. K.	Bihar.
590	747	Lal, M. B.	Government of India.
591	627	Lall, B.	Bihar.
592	1259	Lall, Y. K.	Bihar.
593	1513	Lalvani, M. N.	West Bengal.
594	1199	Laroia, D. K.	Uttar Pradesh.
595	171	Lawley, W.	Pakistan.
596	678	Lawrence, M. S.	Madras.
597	196	Lawson, A. Burns	Bombay.
598	207	Lewis, A. Sturat	West Bengal.
599	218	Lloyd, M. .E	Ceylon.
600	1246	Logavinayagam, K. S.	Madras.
601	1431	Lokagariwar, P. L.	M. E. S.
602	921	Lokanathan, P.	Madras.
		"M"	
603	636	Macha, T. K.	Bombay.
604	869	Maddimsetty, R. S.	Madras.
605	449	Madhav, T. K.	Delhi.

Serial No.	Roll No.	Name.	State/Country.
606	646	Madhava, K. B. (L.M.)	Madras.
607	181	Madhava Rao, Ch.	Madras.
608	148	Mahabir Prasad, (L.M.)	Uttar Pradesh.
609	1176	Mahabir Prasad.	Uttar Pradesh.
610	1375	Mahadevan, C. R.	Madras.
611	1380	Mahal, P. S.	Government of India.
612	639	Mahalanobis, P. C. (L.M.)	West Bengal.
613	303	Mahapatara, M.	Orissa.
614	714	Mahboob Ilahi Kazi.	Pakistan.
615	561	Maheshwar Prasad.	Bihar.
616	553	Mahida, U. N.	Bombay.
617	1309	Majumdar. S. N.	West Bengal.
618	952	Makhanwahla, R. B.	Bombay.
619	298	Malhotra, Ajit Chand.	Punjab.
620	36	Malhotra, B. R. (L.M.)	Government of India.
621	972	Malhotra, C.L.)	Madhya Pradesh.
622	974	Malhotra, D. P.	Kashmir.
623	470	Malik, Abdul Mannan	Pakistan.
624	67	Malik, Teja Singh (L.M.)	PEPSU.
625	620	Mallik, C. P.	Government of India.
626	533	Mallick, D. N.	West Bengal.
627	1401	Mane, P. M.	Bombay.
628	568	Mane, Y. G.	Madhya Pradesh.
629	423	Mani, M. W. G.	Madras.
630	1376	Mankokar, S. R.	Bombay.
631	50	Manohar Nath.	Delhi.
632	512	Marik, T. P.	West Bengal.
633	1053	Marya, Jugdev Singh	PEPSU.
634	1473	Masarwala, V. J.	Bombay.
635	1071	Mason Jerry.	West Bengal.
636	1472	Mastoor, A. R.	Bombay.

Serial No.	Roll No.	Name.	State/Country.
637	984	Mathew, K. M.	Travancore-Cochin.
638	998	Mathew, K. George	Travancore-Cochin.
639	1288	Mathrani, H. P.	Government of India.
640	534	Mathrani, N. P.	Bombay.
641	1204	Mathur, A. C.	Uttar Pradesh.
642	834	Mathur, B. D.	Rajasthan.
643	992	Mathur, B. G. (L. M.)	Rajasthan.
644	1518	Mathur, B. S.	Punjab.
645	864	Mathur, C. B. L.	Rajasthan.
646	842	Mathur, J. L.	Rajasthan.
647	1222	Mathur, K. C.	Uttar Pradesh.
648	331	Mathur, Kishore Lal	Rajasthan.
649	830	Mathur, J. K. P.	Rajasthan.
650	1203	Mathur, G. D.	Uttar Pradesh.
651	828	Mathur, M. M.	Rajasthan.
652	418	Mathur, M. S.	Government of India.
653	759	Mathur, S. B.	Uttar Pradesh.
654	117	Matthew, P. G. (L. M.)	Travancore-Cochin.
655	464	Maujamdar, A. B.	West Bengal.
656	607	Maujamdar, Santosh Kumar	West Bengal.
657	613	Mawani, K. H.	Saurashtra.
658	1256	Mazumdar, J. P.	West Bengal.
659	54	McKelvie, G. M. (L. M.)	Government of India.
660	671	Meeran, M.	Madras.
661	542	Mehandru, B. L.	Bombay.
662	506	Mehar Singh.	Punjab.
663	1302	Mehndiratta, M. R.	Punjab.
664	277	Mehra, S. R.	Punjab.
665	810	Mehta, D. J.	Bombay.
666	370	Mehta, Des Raj	Bihar.
667	114	Mehta, Iqbal Narain	Punjab.

Serial No.	Roll No.	Name.	State/Country.
668	610	Mehta, Javer Chand	West Bengal.
669	34	Mehta, J. T.	Saurashtra.
670	1392	Mehta, J. V.	Madhya Pradesh.
671	1002	Mehta, M. A.	Bombay.
672	237	Mehta, N. N.	Government of India.
673	1220	Mehta, V. C.	Saurashtra.
674	1219	Mehta, Vasant, V.	Uttar Pradesh.
675	1353	Menon, K. B.	Travancore-Cochin.
676	1146	Menon, M. D.	Government of India.
677	988	Menon, T. Bala Krishna	Travancore-Cochin.
678	396	Mengi, B. N.	Kashmir.
679	212	Moswani, V. M.	Bombay.
680	1464	Mewada, M. N.	Bombay.
681	705	Mirchandani, N. D. (L. M.)	Government of India.
682	1153	Mirza, Ahmed Baig Ghazi	Hyderabad.
683	444	Mirza, Fahim Beg	Bhopal.
684	302	Mirza, M. A.	Uttar Pradesh.
685	260	Mirza, Mehdi Ali	Hyderabad.
686	567	Mirza, Mohammed Ahmed	Hyderabad.
687	1111	Mirza, R. E.	Pakistan.
688	1272	Misra, U. N.	Orissa.
689	687	Misra, Aswami Kumar	West Bengal.
690	728	Misra, B.	Orissa.
691	1278	Misra, B.	Orissa.
692	975	Misra, B. B.	Government of India.
693	434	Misra, Chandi Prasad	Bihar.
694	1306	Misra, D.	Orissa.
695	999	Misra, K. N.	Uttar Pradesh.
696	837	Misra, Lakshmi Pati (L. M.)	West Bengal.
697	1217	Misra, P. N.	Uttar Pradesh.
698	901	Mistry, C. Mani Lal	Bombay.

Serial No.	Roll No.	Name.	State/Country.
699	1409	Mital, G. L.	Uttar Pradesh.
700	459	Mitra, C. D.	Bihar.
701	1310	Mitra, N. B.	Government of India.
702	1459	Mitra, S. K.	West Bengal.
703	316	Mitra, T.	West Bengal.
704	1158	Mital, O. P.	Uttar Pradesh.
705	915	Mittal, Om Prakash	Government of India.
706	10	Modak, N. V. (L. M.)	Bombay.
707	1482	Modi, I. K.	Bombay.
708	520	Mody, M. T.	Bombay.
709	580	Moghe, L. V.	Madhya Bharat.
710	1131	Mohammad.	Bihar.
711	90	Mohammed, Abu Tarab	Hyderabad.
712	441	Mohammed, Ashraf	Hyderabad.
713	256	Mohammed, Asadullah	Hyderabad.
714	403	Mohammed, Farhatullah	Hyderabad.
715	1165	Mohd. Hasnain	Bihar.
716	253	Mohammed Ibrahim	Hyderabad.
717	394	Mohammed Ibrahim (L. M.)	Hyderabad.
718	673	Mohammed Share Ali.	Madras.
719	326	Mohammed Usman.	Hyderabad.
720	380	Mohammed Vajahat Ali.	Hyderabad.
721	625	Mohanty, A.	U. S. A.
722	696	Mohile, N. H.	Bombay.
723	1009	Mohendra, O. P.	Government of India.
724	739	Mohindra, S. K.	Bihar.
725	742	Mohiuddin, B. S.	Madras.
726	891	Mohury, B. D.	Government of India.
727	1237	Momin, G. C.	Assam.
728	363	Mone, V. T.	Madhya Pradesh.
729	244	Mookerjee, R. N.	West Bengal.
730	177	Morgan, I. (L. M.)	West Bengal.

Serial No.	Roll No.	Name.	State/Country
731	1031	Motalib, A.	Pakistan.
732	664	Mudaliar, T. S. K.	Madras.
733	693	Mudaliar, K. M. Rajaratnam	Madras.
734	92	Mudaliyar, T. Lokanatha	Madras.
735	206	Mufti, M. I. D.	M. E. S.
736	865	Muhammad, Akram, M.	Pakistan.
737	46	Mukerjee, A. C.	Uttar Pradesh.
738	1410	Mukherjee, Asim	West Bengal.
739	753	Mukherjee, B. B.	West Bengal.
740	102	Mukherjee, P. K.	West Bengal.
741	1317	Mukerjee, P. K.	Bihar.
742	608	Mukherjee, P. B.	West Bengal.
743	450	Mukherjee, S. N.	West Bengal.
744	139	Murari Lal.	Punjab.
745	878	Murtaza, S. G.	Pakistan.
746	309	Murti, N. V. S.	Bombay.
747	755	Murty, N. G. K.	Bombay.
748	267	Murty, B. Narayana	Madras.
749	1396	Murty, P. L. N.	Madhya Pradesh.
750	479	Muthian, T.	Madras.
751	762	Muthukumara Swamy, A.	Madras.
		"N"	
752	1012	Nadgauda, P. M.	Bombay.
753	23	Nadirshah, E. A.	Bombay.
754	1377	Nadkarni, D. S.	Bombay.
755	1100	Naegamvala, J. P.	Bombay.
756	1014	Naga Bushanam, P. R.	Madras.
757	468	Nagarkar, B. B.	West Bengal.
758	960	Nagarsheth, M. P.	Government of India.
759	583	Naidu, C. N.	Madhya Bharat.
760	683	Naidu, Dharma Rao, N.	Madras.

Serial No.	Roll No.	Name.	State/Country.
761	820	Naidu, P. Ethirajulu	Madras.
762	654	Naidu, S. R.	Madras.
763	935	Naidu, S. R. M.	M. E. S.
764	581	Naik, B. G.	Madhya Bharat.
765	949	Naik, Ishwar Lal Kasanji	Bombay.
766	1420	Naik, K. Sundar	Madras.
767	982	Nair, E. Sivaraman	Travancore-Cochin.
768	1037	Nair, K. R. Madhavan	Travancore-Cochin.
769	1025	Nair, N. Krishnan	Travancore-Cochin.
770	178	Nair, P. T. Narayanan	Madras.
771	1079	Nair, R. Velayudhan	Travancore-Cochin.
772	1066	Nair, V. P. Narayanan	Canada.
773	379	Najabat Ali.	Hyderabad.
774	268	Nambiar, K. K.	Madras.
775	1116	Nambiar, K. K. Narayanan	Madras.
776	824	Nambiar, P. G.	Madras.
777	1296	Nanawatty, B. K.	Bombay.
778	60	Nanda, B. D. (L.M.)	Uttar Pradesh.
779	661	Nanda, G.	Orissa.
780	1445	Nanda, J. B.	Kashmir.
781	883	Nanda, M. L.	Government of India.
782	1151	Nandi, S. C.	Bihar.
783	338	Nangea, G. R.	Punjab.
784	1358	Nanjappa, D.	Mysore.
785	1064	Naqvi, S. M. H.	Hyderabad.
786	29	Narasimham, J. S.	Hyderabad.
787	927	Narasimham, R. K.	U. S. A.
788	1460	Narasimham Rao, K.	Madras.
789	1274	Narasimhamurthi, B. S.	Government of India.
790	916	Narasu, P. Lakshmi	Madras.
791	428	Narayana, A.	Uttar Pradesh.

Serial No.	Roll No.	Name.	State/Country.
792	1054	Narayanaswami, B. S.	Mysore.
793	1355	Narayanaswami, S.	Mysore.
794	665	Narayana Rao, C. R.	Madras.
795	1212	Narayanasetty, H. S.	Mysore.
796	657	Narayanan, P.	Madras.
797	1479	Narko, S. P.	Bombay.
798	679	Natesan, L. N.	Madras.
799	166	Nath, R. M.	Assam.
800	183	Nawab Ahsan Yar Jung Bahadur (L.M.)	Pakistan.
801	660	Nayak, S. C.	Madras.
802	154	Nayar, D. P.	Punjab.
803	1517	Nayar, K. Krishnan	Madras.
804	1024	Nayar, K. Madhavan	Travancore-Cochin.
805	1211	Nayaz Ahmed.	Bhopal.
806	427	Nayyar, Sohan Lal	Punjab.
807	1183	Nazareth, C. V.	Bombay.
808	390	Nehra, V.	M. E. S.
809	342	Nicolaides, E. P.	Bombay.
810	1433	Nigam, S. P.	Uttar Pradesh.
811	550	Nivas, H. K.	Bihar.
812	132	Nongerede, C. E. Dela	Assam.
		"O"	
813	105	Oram, A.	Ireland.
814	1245	Ormerod, H. E. (L.M.)	England.
815	795	Otia, J. C.	Bombay.
816	790	Oza, M. G.	Government of India.
817	767	Oza, N. M.	Bombay.
		"P"	
818	690	Padhi, R. N.	Orissa.
819	564	Padhi, Sita Ram	Orissa.
820	1126	Padmanabhan, C. V.	Madras.

Serial No.	Roll No.	Name.	State/Country.
821	1082	Padmanabhan, Y.	Madras.
822	1512	Pagay, R. M. (L.M.)	Uttar Pradesh.
823	959	Pai, M. V.	Bombay.
824	945	Pal, S. C.	Assam.
825	441	Palit, S. K.	Orissa.
826	912	Panchanathan, S.	Madras.
827	1198	Pancharatnam, G. M.	Madras.
828	197	Pancholi, D. B.	Saurashtra.
829	333	Pancholy, H. M.	Madhya Pradesh.
830	818	Pandharkar, G. R.	Bombay.
831	1442	Pandya, K. C.	Bombay.
832	1033	Pani, M. C.	Orissa.
833	1224	Panjwani, S. N.	Uttar Pradesh.
834	417	Parang, Hari Ram (L. M.)	Pakistan.
835	1281	Parekh, Chaganlal Jivanlal	Saurashtra.
336	1209	Parekh, J. H.	Bombay.
837	513	Parija, K. C.	Orissa.
838	128	Parikh, H. B. (L. M.)	Bombay.
839	264	Parmara, D. S.	Uttar Pradesh.
840	955	Parmeshri Das.	Uttar Pradesh.
841	743	Partap Singh.	Uttar Pradesh.
842	1063	Patel, Ahmed Ibrahim	Pakistan.
843	859	Patel, A. T.	Uttar Pradesh.
844	188	Patel, B. D. (L. M.)	Bombay.
845	890	Patel, B. P.	Government of India
846	717	Patel, C. B.	Government of India.
847	1276	Patel, C. I.	Bombay.
848	968	Patel, D. C.	Bombay.
849	967	Patel, J. C.	Bombay.
850	1415	Patel, M. D.	Bombay.
851	735	Patel, M. M.	Government of India.

Serial No.	Roll No.	Name.	State/Country.
852	1206	Patel, M. M.	Bombay.
853	1492	Patel, M. M.	Bombay.
854	44	Patel, M. R. (L. M.)	Bombay.
855	653	Patel, N. B.	Bombay.
856	1313	Patel, N. C.	Bombay.
857	1011	Patel, N. K.	Bombay.
858	1491	Patel, O. H.	Bombay.
859	793	Patel, Y. G.	Bombay.
860	577	Patil, B. D.	Madhya Bharat.
861	359	Patil, G. K.	Bombay.
862	584	Patil, Y. K.	Madhya Bharat.
863	672	Patrulu, P. S.	Madras.
864	1128	Paul, J. D. Bayliss	Madhya Bharat.
865	769	Pederson, S.	Bombay.
896	648	Perry, R. G.	West Bengal.
867	477	Pershad, B.	Bihar.
868	895	Pessi, B. P. Mana	Pakistan.
869	339	Pessumal, N. Dhamani (L. M.)	Delhi.
870	392	Phadke, P. G.	Madhya Bharat.
871	1021	Philipose, E. P.	Travancore-Cochin.
872	1109	Philipose, P.	Travancore-Cochin.
873	986	Pillai, A. Sivarama	Travancore-Cochin.
874	1061	Pillai, K. Gopala	Travancore-Cochin.
875	1018	Pillai, K. J.	Travancore-Cochin.
876	1047	Pillai, K. N. Govinda	Travancore-Cochin.
877	744	Pillai, T. K. A.	Madras.
878	1476	Pinto, C. J.	Bombay.
879	885	Poonen, P. C.	Government of India.
880	813	Prabhala, R.	Madras.
881	1384	Prakash, Anand	Uttar Pradesh.
882	733	Prasad, B.	Bihar.

Serial No.	Roll No.	Name.	State/Country.
883	1200	Prasad, D. N.	Bihar.
884	1124	Prasad, G. S.	Bihar.
885	1334	Prasad, Jai Kishore	Bihar.
886	1360	Prasad, Krishto!	Bihar.
887	1250	Prasad, Nandkishore	Bihar.
888	1343	Prasad, Nilkanth	Bihar.
889	1318	Prasad, Rajdeo	Bihar.
890	898	Prasad, Ram Swarup	M. E. S.
891	436	Prasad, Rashdhari	Bihar.
892	1368	Prasad, Sarju	Bihar.
893	1344	Prasad, Singheswar	Bihar.
894	1295	Prasad, S.	Bihar.
895	1185	Pratap, B.	Government of India.
896	907	Prem Chand.	Uttar Pradesh.
897	1416	Prem Manohar	Uttar Pradesh.
898	1157	Prem Mohan	Uttar Pradesh.
899	1297	Prosad, L. U.	Bihar.
900	402	Pujari, Achyutanand	Orissa.
901	1126	Punnaiah, P. B.	Madras.
902	482	Puranik, R. G.	Bombay.
903	327	Puri, A. N.	Bombay.
904	310	Puri, B. S.	Government of India.
905	1108	Puri, P. R.	Government of India.
906	1215	Puttaswamy, H.	Mysore.
		"Q"	
907	384	Qureshi, A. H.	Pakistan.
908	882	Qureshi, A. H.	Pakistan
909	884	Qureshi, A. R.	Pakistan.
910	841	Qureshi, Azeezullah	Pakistan.
911	825	Qureshi, Mohd. Ayub	Pakistan.
		"R"	
912	500	Radha Krishnan	Punjab.

Serial No.	Roll No.	Name.	State/Country.
913	1511	Radhey Shiam	Bihar.
914	1107	Rafi Ahmed, S. M.	Pakistan.
915	87	Raghavachary, K. S. (L.M.)	Government of India.
916	849	Raghavan, N. C. S.	Madras.
917	1008	Raghavan, P.	West Bengal.
918	771	Raghaviah, M.	Madras.
919	1172	Raheja, M. L.	M. E. S.
920	839	Rahman, A.	Pakistan.
921	843	Rahman, M. A.	Madras.
922	989	Rahman, S.	Pakistan.
923	713	Rahmatullah, S.	Government of India.
924	628	Raj, P. V.	Madras.
925	1490	Raja Rathnam, K. V.	Mysore
926	880	Rajagopalan, D.	Madras.
927	965	Rajagopalan, K. G.	Government of India.
928	1486	Rajagopalan, K.	Travancore-Cochin.
929	724	Rajagopalan, S. K.	Government of India.
930	190	Rajam, M. K. (L.M.)	Mysore.
931	924	Rajan, G. A. N.	Government of India.
932	756	Rajaraman, S.	Travancore-Cochin.
933	868	Raju, D. Narayana	Madras.
934	162	Raju, P. V.	Madras.
935	746	Raju, R. L.	Mysore'
936	751	Raju, S. P. (L.M.)	Hyderabad.
937	1454	Rajwade, M. V.	Madhya Pradesh.
938	1121	Ram Bilas	Punjab.
939	492	Ram G. S.	Bihar.
940	1214	Rama Nand, A. B.	Mysore.
941	1249	Rama Rao, N.	Government of India.
942	496	Rama Rao, T. (L.M.)	Mysore.
943	1262	Rama Rao, V.	Orissa.

Serial No.	Roll No.	Name.	State/Country.
944	535	Rama Sundaram, U. S.	Madras.
945	230	Ramamurty, K.	Madras.
946	1179	Ramanathan, G. S.	Madras.
947	1104	Ramaswami, P.	Government of India.
948	407	Ramaswamy, K.	Hyderabad.
949	752	Ramaswamy, N. S.	Government of India.
950	1269	Ramaswamy, S.	Mysore.
951	421	Ramchandani, N. R.	Kutch.
952	1470	Ramiah, V.	Mysore.
953	1065	Ranganathan, V.	Travancore-Cochin.
954	438	Rangarajan, P.	Madras.
955	152	Rangaswami, M. A.	Bihar.
956	669	Rangaswami, T. V.	Madras.
957	82	Rangaswami, V. N.	Delhi.
958	108	Rangaswami, V. S.	Madras.
959	1221	Rao, A. Lakshmikant	Government of India.
960	1327	Rao, A. Rajeswara	Orissa.
961	1013	Rao, B. K. V.	Madras.
962	589	Rao, B. M.	Madhya Bharat.
963	1067	Rao, C. B. Madhu Sudana	Travancore-Cochin.
964	1023	Rao, E. Gopala Krishna	Delhi.
965	389	Rao, H. Sunder	Government of India.
966	1265	Rao, K. Ramamohan	Madras.
967	800	Rao, K. Gopinatha	Rajasthan.
968	172	Rao, K. Subba	Madras.
969	649	Rao, K. Subba	Madras.
970	1465	Rao, K. Subba	Mysore.
971	835	Rao, M. A.	Madhya Pradesh.
972	1110	Rao, M. Brahmananda	Madras.
973	812	Rao, M. R. Krishnamurti	Mysore.
974	1077	Rao, M. Seshumadhava	Madras.

Serial No.	Roll No.	Name.	State/Country.
975	1240	Rao, M. N. Lakshmana	Mysore.
976	103	Rao, N. Subba (L.M.)	Mysore.
977	1164	Rao, N. S. Lakshmana	Madras.
978	524	Rao, M. S. Sitaram	Hyderabad.
979	1095	Rao, P. V. S. Prasada	Madras.
980	933	Rao, N. Venkata	Government of India.
981	757	Rao, R. Rama Mohan	Madras.
982	873	Rao, R. R. Thimmaji	Madras.
983	545	Rao, S. Ramchandra	Madhya Pradesh.
984	1188	Rao, S. Ramchandra	Bihar.
985	1405	Rao, S. Subba	Orissa.
986	398	Rao, T. K.	Hyderabad.
987	797	Rao, T. K. Mohana	Madras.
988	1444	Rao, U. B. Sreepada	Madras.
989	1435	Rao, V. Subba	Madras.
990	643	Rastogi, D. P.	Rajasthan.
991	454	Rastogi, K. S.	Delhi.
992	451	Rath, Nilkanth	Orissa.
993	702	Rathod, G. D.	Delhi.
994	498	Rathod, M. P.	Bombay.
995	973	Rathod, N. G	Saurashtra
996	73	Ratnagar, R. D. (L.M.)	West Bengal.
997	909	Ray, K. B. (L.M.)	West Bengal.
998	944	Ray, K. C.	West Bengal.
999	987	Ray, K. C.	Madhya Pradesh.
1000	1341	Ray, S. N.	Bihar.
1001	748	Reddy, A. Narasimha	Madras.
1002	1419	Reddy, B. V.	Madras.
1003	876	Reddy, C. Krishna	Madras.
1004	347	Reddy, K. Ramaswamy	Madras.
1005	1052	Reddy, L. C. Muniswami	Mysore.

Serial No.	Roll No.	Name.	State/Country.
1006	1112	Reddy, P. R. G.	Madras.
1007	1113	Reddy, T. A. Ramanatha	Madras.
1008	163	Rego, D. Y.	Bombay.
1009	123	Rego, S. B.	Bombay.
1010	1238	Resham Singh.	Uttar Pradesh.
1011	559	Rijhwani, J. M.	Assam.
1012	956	Rizvi, S. H.	Uttar Pradesh.
1013	156	Romesh Chandra.	Assam.
1014	1299	Roy, B. N.	Bihar.
1015	257	Roy, C. B.	Madhya Pradesh.
1016	112	Roy, G. P. (L.M.)	Orissa.
1017	1447	Roy, J. K. (L.M.)	West Bengal.
1018	1271	Roy, K. P.	West Bengal.
1019	1266	Roy, P. K.	Bihar.
1020	766	Roy, R. C.	West Bengal.
1021	415	Roy, S. K.	Bihar.
1022	435	Roy, T. K.	Pakistan.
		"S"	
1023	365	Saberi, Yousaf, M. L.	Hyderabad.
1024	1130	Sabharwal, G. C.	M. E. S.
1025	1280	Sadarangani, T.	Government of India.
1026	32	Sadarangani, V. H.	Madras.
1027	1038	Sadasivan, V.	Travancore-Cochin.
1028	969	Sadasivaswami, P. S.	Madras.
1029	1417	Saha, N.	West Bengal.
1030	1099	Saha, R. K.	Government of India.
1031	335	Saha, S. L.	Government of India.
1032	536	Sahu, B. N.	Orissa.
1033	1321	Sahay, T. K.	Bihar.
1034	61	Sahney, J. C.	Uttar Pradesh
1035	1255	Sahni, K. S.	Uttar Pradesh.

Serial No.	Roll No.	Name.	State/Country.
1036	89	Sahgal, Sant Ram (L.M.)	Punjab.
1037	439	Saigal, Balbir Singh	Government of India.
1038	1163	Sajjan Basettappa	Government of India.
1039	120	Saksena, C. P.	Vindhya Pradesh.
1040	844	Salukhe, V. B.	Madhya Bharat.
1041	1232	Samad, M. A.	Madras.
1042	848	Samanta, Brindaban	Bombay.
1043	1328	Samanta, N. K.	Bihar.
1144	861	Samitha, M. U.	Madras.
1045	876	Sandhawalia, N. S.	Bombay.
1046	1314	Sani, G. H.	Delhi.
1047	66	Sanjana, N. P.	Bombay.
1048	194	Sankaram, G. B.	Madras.
1049	1390	Sanyal, P. K.	Burma.
1050	1340	Sarkar, B. N.	West Bengal.
1051	387	Sarkar, Phani Bhushan	West Bengal.
1052	606	Sarma, P. V. N.	Madras.
1053	1072	Sarma, S. V.	Travancore-Cochin.
1054	1195	Sarna, V. C.	Government of India.
1055	832	Sastri, K. V. Subrahmanya (L.M.)	Mysore.
1056	1034	Sastri, S. .	Travancore-Cochin.
1057	1039	Sastrigal, H. Nataraja	Madras.
1058	928	Sathaye, H. S.	Hyderabad.
1059	990	Satya Nand	West Bengal.
1060	1404	Satya Narayana, D.	Bombay.
1061	1160	Satya Prakash	Uttar Pradesh.
1062	186	Satyanarayana, B. (L.M.)	Madras.
1063	993	Sawai, D. B.	Bombay.
1064	1229	Sawhney, R. P.	Punjab.
1065	1391	Saxena, J. K.	Uttar Pradesh.
1066	233	Sayoji Rao, H. R.	Madras.
1067	1859	Seetharamaiah, H.	Mysore.

Serial No.	Roll No.	Name.	State/Country.
1068	305	Sekharan, T.	Madras.
1069	307	Sen, A. K.	Tripura.
1070	727	Sen, B. R.	Uttar Pradesh.
1071	1032	Sen, D. M.	West Bengal.
1072	1010	Sen Gupta, K. C.	West Bengal.
1073	1515	Sen, N.	Government of India.
1074	863	Sen Gupta, P. N.	West Bengal.
1075	1500	Sen, R. B.	West Bengal.
1076	1331	Sen, S. K.	Bihar.
1077	314	Senapathy, G. N.	Orissa.
1078	1035	Seshadri, C. R.	Travancore-Cochin
1079	472	Seshagiri Rao, N.	Madras.
1080	1090	Sethi, G. R.	Government of India.
1081	1329	Sethi, V. P.	Madhya Pradesh.
1082	726	Shafiqul Haq.	Pakistan.
1083	551	Shah, M. J.	Rajasthan.
1084	1506	Shah, S. G.	Bombay
1085	35	Shah, V. J.	Madhya Pradesh.
1086	175	Shahani, C. M.	West Bengal.
1087	1507	Shaikh, A. A. K.	Bombay.
1088	1005	Shamanna, A.	Madhya Pradesh.
1089	83	Shannon, I. A. T.	England.
1090	1059	Sharangpani, P. S. (L.M.)	Bombay.
1091	1325	Sharan, Raghunath	Bihar.
1092	96	Shareef, S. A.	Pakistan.
1093	579	Sharma, Baij Nath	Ceylon.
1094	504	Sharma, D. C.	Punjab.
1095	115	Sharma, Hari Shankar	Uttar Pradesh.
1096	1118	Sharma, K. N.	Rajasthan.
1097	870	Sharma, M. R.	Punjab.
1098	516	Sharma, Purnanand	Bihar.
1099	1452	Sharma, P.	Assam.

Serial No.	Roll No.	Name.	State/Country.
1100	1467	Sharma, S. A.	Madhya Pradesh.
1101	164	Sharma, S. S.	Uttar Pradesh.
1102	1084	Shastri, M. Balagangadhara	Madras.
1103	1091	Shaukat Rai	Delhi.
1104	720	Shaw, M. (L.M.)	Government of India.
1105	463	Sheikh, Abdul Hakim	Pakistan.
1106	503	Sheikh, Mohd. Akram Mohd. Ebrahim	Pakistan.
1107	619	Sheikh, Mohd. Kasim, G.	Pakistan.
1108	39	Shenoy, B. N.	Government of India.
1109	951	Shenoy, R. C.	Government of India.
1110	786	Sheo Dip Narayan	Bihar.
1111	489	Sheth, K. L.	Delhi.
1112	382	Shinde, P. K. (L.M.)	Bombay.
1113	388	Shiva Raj, A.	Hyderabad.
1114	127	Shivdasani, K. J.	Bombay.
1115	1148	Shivdasani, P. D.	Bombay.
1116	490	Shobha Ram	Uttar Pradesh.
1117	953	Shri Krishan.	Government of India.
1118	792	Shukla, G. D.	Bombay.
1119	711	Shyam Krishna.	Uttar Pradesh.
1120	1287	Sil, Krishna Shankar	West Bengal.
1121	228	Simhaiya N. Lakshminara	Rajasthan.
1122	1346	Singh, B. L.	Bihar.
1123	1352	Singh, J. N.	Bihar
1124	1449	Singh, J. P.	PEPSU.
1125	1135	Singh, R. C.	Punjab.
1126	1851	Singh, R. P.	Bihar.
1127	1872	Singh, S. M. P.	Bihar.
1128	1367	Singh, S. N.	Bihar.
1129	1236	Sinha, A. C.	West Bengal.
1130	340	Sinha, B.	Bihar.

Serial No.	Roll No.	Name.	State/Country
1131	971	Sinha, B. P.	Bihar.
1132	734	Sinha, B. P.	Bihar.
1133	1261	Sinha, D. P.	Bihar.
1134	804	Sinha, Debi Saran	Madhya Pradesh.
1135	191	Sinha, H. P.	Government of India.
1136	960	Sinha, K.	Uttar Pradesh.
1137	1342	Sinha, L. U. C.	Bihar.
1138	425	Sinha, M. K. P.	Bihar.
1139	1257	Sinha, N. K.	Bihar.
1140	1291	Sinha, Nilkanth	Bihar.
1141	706	Sinha, P. P.	Bihar.
1142	1273	Sinha, P. S.	Uttar Pradesh.
1143	1319	Sinha, R. P.	Bihar.
1144	754	Sinha, S. K.	Bihar.
1145	1260	Sinha, Shyam Lal	Bihar.
1146	871	Sinha, S. N.	Bihar.
1147	1103	Sinha, Shyam Narain	Bihar.
1148	1127	Sinha, S. N.	Orissa.
1149	219	Sirajuddin, P.	Madras.
1150	875	Sircar, S. C.	Bihar.
1151	856	Sircar, S. K.	Bihar.
1152	680	Sivapraksaam, P. S.	Madras.
1153	626	Sivasankaran, O.	Madras.
1154	715	Sivasubramanian, M. K.	Government of India.
1155	692	Sivaswamy, A. R.	Madras.
1156	20	Smith, H. C. (L. M.)	Bombay.
1157	283	Sohan Lal.	Bihar.
1158	1316	Som, A. K.	Bihar.
1159	1488	Sompura, G. B.	Saurashtra.
1160	2	Sondhi, R. L.	Punjab.
1161	12	Sowani, D. G. (L. M.)	Bombay.
1162	682	Sreekantiah, C. K.	Madras.

Serial No.	Roll No.	Name.	State/Country.
1163	116	Srinivasa Murthi, K. V.	Madras.
1164	537	Srinivasa Rao, K. V.	Hyderabad.
1165	240	Srinivasan, K.	Madras.
1166	1098	Srinivasan, K. S.	Madras.
1167	1423	Srivastava, A. K.	Uttar Pradesh.
1168	1354	Srivastava, G. N.	Bihar.
1169	1205	Srinivasan, T. K.	Madhya Pradesh.
1170	618	Srirangachary, G.	Madras.
1171	570	Srivastava, Hari Shankar	Madhya Bharat.
1172	45	Srivastava, Madho Prasad	Uttar Pradesh.
1173	958	Srivastava, P. N.	Uttar Pradesh.
1174	514	Srouty, M. S.	Madras.
1175	1210	Subbiah, C. P.	Government of India.
1176	1311	Subbaraju, Bh.	Madras.
1177	723	Subrahmanyam, J.	Government of India.
1178	866	Subrahmanyam, P. L.	Madras.
1179	1312	Subramaniam, P. S.	Madras.
1180	1451	Subramaniam, S. K.	Madras.
1181	1105	Sud, A. N.	Punjab.
1182	1231	Sudhamoy, Pal	West Bengal.
1183	65	Sujan, S. B.	Punjab.
1184	1432	Sujan Singh.	Delhi.
1185	1171	Sukhrani, R. R.	Government of India.
1186	872	Sultan Mohd. Naim.	Pakistan.
1187	939	Sundara Raman, C. K.	Travancore-Cochin.
1188	1117	Sundaraj, B. K.	Madhya Pradesh.
1189	1406	Sundaram, Shunmuga R.	Madras.
1190	791	Sundaram, S.	Madras.
1191	141	Sundaresan, T. V.	Bombay.
1192	1385	Sur, A. K.	Uttar Pradesh.
1193	926	Sur, S. K.	West Bengal.
1194	25	Surati, H. M.	Hyderabad.

Serial No.	Roll No.	Name.	State/Country.
1195	637	Surya, N. S.	Government of India.
1196	1345	Swaminathan, C. G.	Madras
1197	1440	Swaminathan, S. S.	Madhya Pradesh.
1198	393	Syed Ali Raza.	Hyderabad.
1199	1499	Syed A. B. Inamul Hoque	Assam.
1200	33	Syed Arifuddin	Hyderabad.
1201	1333	Syed Mustafa Jamal.	Bihar.
		"T"	
1202	825	Talat Baig.	Madras.
1203	1365	Tambe, R. V.	Madhya Pradesh.
1204	1434	Tamizuddin, A. G.	Madras.
1205	1020	Tampi, N. Kesavan	Travancore-Cochin.
1206	1400	Tandon, G. S.	Punjab.
1207	1168	Tandon, S. N.	M. E. S.
1208	794	Tank, D. M.	Saurashtra.
1209	1150	Taraporevala, J. A.	Bombay.
1210	1323	Tawadey, V. B.	M. E. S.
1211	1516	Tayal, K. C.	Uttar Pradesh.
1212	1501	Taylor, Norman Henry	Bombay.
1213	1381	Tellis, C. S. J.	M. E. S.
1214	630	Thadaney, K. V.	Madras.
1215	1096	Thapliyal, K. N.	Uttar Pradesh.
1216	685	Thirupuvanam, C. N.	Madras.
1217	1074	Thomas, P. J.	Travancore-Cochin.
1218	1478	Thosar, G. S.	Bombay.
1219	1386	Thusu, A. N.	Kashmir.
1220	853	Thirumala, C. S.	Bihar.
1221	130	Todd, J. M.	Scotland.
1222	1088	Toubro, S. K.	Bombay.
1223	918	Trehan, J. M. (L.M.)	Government of India.
1224	150	Tripathi, S. N.	Madhya Pradesh.
1225	1190	Tripathy, J.	Orissa.

Serial No.	Roll No.	Name.	State/Country.
1226	788	Turner, W. H.	Madras.
1227	6	Twood, J. C. Rathlin	West Bengal.
1228	476	Tyabji, S. B. (L.M.)	Bombay.
		"U"	
1229	961	Udham Singh.	Himachal Pradesh.
1230	1166	Uma Kant.	Uttar Pradesh.
1231	1494	Umrigar, E. J.	Bombay.
1232	847	Uppal, H. L.	Punjab.
1233	1475	Unwalla, B. T.	Bombay.
1234	1089	Uttam Singh. (L.M.)	Rajasthan.
		"V"	
1235	84	Vagh, B. V. (L.M.)	Bombay.
1236	416	Vahidy, Zahir Ahmed	Pakistan.
1237	574	Vaidya, Anant Ganesh	Madhya Bharat.
1238	351	Vaidya, G. D.	Hyderabad.
1239	846	Vaidyanathan, V. I.	Government of India.
1240	738	Vaish, Vidya Ram	Government of India.
1241	176	Vakil, N. H.	Bihar.
1242	631	Varma, D. C.	Madhya Pradesh.
1243	1300	Varma, D. N.	Bihar.
1244	1373	Varma, D. N.	Bihar.
1245	505	Varma, Hari Gopal	Uttar Pradesh.
1246	881	Varma, J. N.	Bihar.
1247	1362	Varma, K. K.	Bihar.
1248	1366	Varma, K. N.	Bihar.
1249	635	Varman, K. R.	Government of India.
1250	935	Varma, K. Raja Raja	Travancore-Cochin.
1251	491	Varma, P. L.	Punjab.
1252	110	Varma, R. L.	Assam.
1253	362	Vartak, G. R.	Bombay.
1254	400	Vasay, K. M.	Hyderabad.
1255	466	Vaze, D. L.	Bombay.
1256	1258	Ved Prakash	Uttar Pradesh.

Serial No.	Roll No.	Name.	State/Country
1257	1178	Veera Raghavan, T. M.	Madras.
1258	862	Veeriah, P.	Madras.
1259	543	Venkatachalam, K.	Hyderabad.
1260	173	Venkatakrishniah, D.	M. E. S.
1261	1147	Venkataraman, P.	Madras.
1262	772	Venkataramanan, T. S.	Madras.
1263	1173	Venugopal, C.	Madras.
1264	922	Vepa Krishnamurthy	Hyderabad.
1265	1363	Verma, R. P.	Bihar.
1266	1326	Verma, S. N.	Bihar.
1267	126	Vesugar, J. B. (L. M.)	Argentina.
1268	1471	Vora, P. K.	Kutch.
1269	1305	Vyavaharkar, D. A.	Bombay.
1270	802	Vydianathan, P. H.	Travancore-Cochin.
		"W"	
1271	1085	Wadhwani, G. B.	Uttar Pradesh.
1272	1120	Wadia, K. C.	Bombay.
1273	49	Wadley, K. L. H.	England.
1274	461	Waheed, M. A.	Pakistan.
1275	235	Wale, N. D.	Bombay.
1276	75	Walker, W. F. (L.M.)	England.
1277	3	Warren, P. F. S.	West Bengal.
1278	1083	Warrier, K. Ramchandra	Travancore-Cochin
1279	822	Williams, L. C.	Ceylon.
1280	764	Winckler, L. A. H.	Mysore.
		"Y"	
1281	1289	Yadav, Brij Lal	Uttar Pradesh.
1282	578	Yadav, H. J.	Madhya Bharat.
1283	1006	Yogi, M. V.	M. E. S.
1284	641	Younus, S. M.	Hyderabad.
		"Z"	
1285	1303	Zaki, A.	Bihar.
1286	236	Zutshi, M. N.	Uttar Pradesh.
1287	954	Zutshi, Y. N.	Uttar Pradesh.

Associate Members.

Serial No.	Roll No.	Name.	State/Country.
1	33	Allan deSa.	Bombay.
2	32	Antia, F. P.	Bombay.
3	10	Bakewell, W. B.	West Bengal.
4	39	Basil Gray.	Delhi.
5	26	Claydon, E. W.	Ceylon.
6	36	Das Gupta, A.	West Bengal.
7	41	De, K. C.	West Bengal.
8	30	Engineer, M. H.	Bombay.
9	16	Engineer-in-Chief's Branch.	Government of India.
10	20	Grewal, Sapuran Singh	Uttar Pradesh.
11	27	Gupta, L. K.	West Bengal.
12	35	Hughes, H. G.	West Bengal.
13	31	Khanna, K. N.	Delhi.
14	38	Kraty, F. C.	West Bengal.
15	6	Madden, W. J.	West Bengal.
16	15	Manager, Heatly & Gresham Ltd.	Delhi.
17	22	Moss, G. L. W.	West Bengal.
18	29	Munday, E. T.	Delhi.
19	21	Patel, L. R.	West Bengal.
20	14	Patell, J. K.	Bombay.
21	34	Ramsay, A. R. P.	West Bengal.
22	25	Ranade, J. Y.	Bombay.
23	40	Shahani, T. C.	Delhi.
24	17	Subrahmanyam, R. V.	Madras.
25	42	Weatherall, H. M.	Bihar.
26	23	Willcox, E. W.	Delhi.
27	37	William Harrison	Bihar.

MEMBERSHIP OF THE INDIAN ROADS CONGRESS.

Year of enrolment with Roll Numbers.

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

Paper No. 148.

A Design for Bullock Cart Wheels

Part IV.

Report on Tests

By

B.V. Vagh, B.E. (Civil), M.I.E. (Ind.)

INTRODUCTORY.

1. The programme of work set for this investigation, with which the Author has been associated since April 1944 under the auspices of the Council of the I. R. C. and its Bullock-cart Sub-committee, was as given in Annexure I. All this programme has now been completed excepting items III (2) (c) and III (3) of that Annexure.

2. The arrangement in regard to these unfinished items, agreed to with the States of India, is that four pairs of wheels will be manufactured in each of the major States for field tests under normal conditions of loading for twelve months if possible, or one wet and one dry season, to ascertain the design which each State considers the most suitable for local conditions. (See Para 28). The States will also be requested to suggest improvements, if any, in the light of their local experience.

3. In the light of the tests already completed, the States will be requested to manufacture and test side by side with their selected wheels, the following pairs of wheels:—

(i) **One pair of wheels** made in all respects like the wheels in use at present at the station to be selected for these tests.

(ii) **One pair of wheels**, with a $3\frac{1}{2}$ **in. by** $\frac{3}{8}$ **in.** tyre, made in all respects like No. (i) but with a wheel-diameter which with the proposed tyre will produce a wheel of as nearly as possible the same weight and, therefore, cost as No. (i).

(iii) **One pair of wheels with the same tyre and same wheel diameter** as No. (ii) but employing a lathe-turned axle and cast iron bearings (in place of hand-made axle and mild steel bearings) with rubber fixtures for self-alignment and flexibility.

(iv) **One pair of wheels** made to Shri Nageswara Ayyar's design but **with the same tyre width and same wheel-diameter as No. (iii).**

In the case of Arm-type wheels which employ at present a tyre wider than 3½ in., the same width of tyre as is in use at present, but ⅜ in. thick, should be employed with a wheel-diameter which, with the new tyre, will produce a wheel of the same weight and cost as the present wheel for No. (ii) above, the new wheel being of the spoke-type. Nos. (iii), (iv), and (v) will have the same tyre and same wheel diameter as No. (ii). Designs for Nos. (ii), (iii), and (iv) will be supplied to the States.

These field tests will complete the investigation in all respects.

DESCRIPTIVE.

4. This Paper relates to the final set of experiments completed in 1949 and is made up of the following parts:—

I. Optimum diameters and widths of tyre for bullock-cart wheels.

II. The tractive effort required for the optimum wheel as compared to that of the wheel in use at present.

III. Provision for self-alignment in the optimum wheel.

IV. Provision for flexibility in the optimum wheel.

V. Mr. Raju's Roller Wheels.

VI. Summary of conclusions from tests.

VII. Field Tests and Check Tests.

VIII. Record of Tests.

IX. Acknowledgment.

5. The Paper was circulated for comments to the Members of the Bullock-cart Subcommittee. The comments which some Members were kind enough to offer are discussed in Annexure VIII

I. OPTIMUM WHEEL DIAMETERS & WIDTHS OF TYRE.

(a) Based on tests for tractive effort.

6. Tests projected to ascertain the optimum wheel diameters and widths of tyre, reasons for them, and the test procedure employed were discussed in the last Paper of the series (Paper No. 137, I. R. C. Journal Vol. XIII-2). Of the two test series projected, that on tractive effort was completed last year. The conclusions were as follows:—

(a) The tractive effort of wheels employing lathe-turned axles and cast iron cylindrical bearings, with a tyre-width of from 3½ in. to 5 in., which can be employed in place of wheels in use at present without exceeding their cost (Table on page 203, I. R. C. Paper No. 137) is less than that of the latter. (Para. ix p. 204, I.R.C. Paper No. 137).

(b) It is likely that their tractive effort will be less, even if hand-made axles and mild steel bearings in use at present are employed in them in place of lathe-turned axles and cast iron bearings. (Para. xiv p. 205, I.R.C. Paper No. 137).

(c) If further tests establish the correctness of the presumption made in (b) above, it would indicate that the scheme of improved wheels made to the design in use at present but with optimum diameters and tyres could be introduced in two stages:—

(i) Employing hand-made axles and mild steel bearings as in use at present, till lathe-turned axles, etc., are available on a large scale.

(ii) Fitting, in the same wheels, new fixtures as and when they are ready. (p. 187. I.R.C. Paper No. 137 para. 19).

(d) According to the tractive effort tests the following two types of wheels seemed suitable:—

(i) 3½ in. tyre with a minimum wheel diameter of 36 inches for rural carts.

(ii) 4 in. tyre with a minimum wheel diameter of 48 inches for urban carts.

In both cases, the wheel-diameter to be employed at any station should be increased to the extent to which it can be fitted in the cost of wheels in use at present at that station (Para. 12, sub-paras. i, ii and iii, p. 184 and 185 I. R. C. Paper No. 137), and the body of the cart raised to the level of bullocks' necks.

(b) Based on tests on the wear and tear of road surfaces.

7. The other series of tests, *viz.*, that on the wear and tear of road surfaces caused by wheels of various wheel-diameters and widths of tyre was partly carried out last year and has since been completed (Annexure II). It has been possible to derive a relationship between the width of the tyre of a wheel and its diameter to produce the same wear and tear of a road surface as that caused by the present wheels (para. 9, Annexure II). From this relationship it is possible to ascertain the extent of wear to road surfaces caused by wheels having a tyre-width of $3\frac{1}{2}$ in. to 5 inches and varying diameters, which can be employed within the range of costs and the tractive efforts of the present wheels (based on tests on tractive effort) and arrive at the optimum wheel diameter and tyre-width to produce the maximum saving in the wear and tear of road surfaces (para. 11, Annexure II).

(c) Alternatives.

8. One of the comments on the last Paper of this series related to conclusion (d) in para. 6 above regarding wheel-diameters and a suggestion was made that as far as practicable wheel-diameters should not be drastically reduced as carters were likely to object to wheels of smaller diameter than those in use at present. That carters will object is quite true, but what is equally true is the fact that **it is not practicable to employ a broad tyre without reducing the present wheel-diameters if the cost of the present wheels is not to be exceeded.** Therefore, the only alternative is to choose a wheel which, without exceeding the present cost and requiring greater tractive effort, will produce the maximum saving in the wear and tear of road surfaces. This would safeguard the interests of the carter on the one hand by not adversely affecting either his pocket or his bullocks and of the community on the other by saving roads. In the ultimate analysis the point at issue is the **carter's sentiment** against any reduction in wheel diameters and the **community's interest in roads and bullocks.**

The community is entitled to claim a maximum saving in damage to roads from a class of road-users who do not contribute anything towards the upkeep of the roads, so long

as it is possible to produce a wheel of the same cost and tractive effort as at present. However, it is best to leave the decision to the States, who should choose between a certain wheel-diameter and a certain saving in the wear and tear of road surfaces in the light of local conditions. With this end in view, alternatives have been worked out (paras. 11 and 12, Annexure II) from which it should be possible to choose a design best suited to local conditions.

(d) Merits and Demerits of the Alternatives.

9. A 3 in. tyre entails the least reduction in wheel-diameters (about 5 to 10 per cent) and produces, with the proposed wheel-diameters, a saving of about 20 to 25 per cent in the wear of the road surfaces. A 4 in., $4\frac{1}{2}$ in. or 5 in. tyre entails the greatest reduction in wheel-diameters (about 30 to 35 per cent) and produces, with the proposed wheel-diameters, a saving of about 40 to 45 per cent in the wear of road surfaces. A $3\frac{1}{2}$ in. tyre is intermediate between the two and entails a reduction of about 14 to 17 per cent in the wheel-diameters and produces, with the proposed wheel-diameters, a saving of about 35 per cent in the wear of road surfaces. This would seem to be the best combination to employ. It is important to note here that **these conclusions relate to wheels of the same cost** as that of wheels in use at present, excluding provision for:—

(a) Lathe-turned axles and smooth bearings.

(b) Self-alignment.

(c) Flexibility.

To arrive at this conclusion the same method, materials of construction, and weight as those of the present wheels have been assumed in the proposed wheels. This does not mean that the conclusions relate to wheels manufactured to the present wheel design only. They apply to all wheels of the same diameter and same tyre width manufactured to any design, e.g., the Cumming wheel, the A. Nageswara Ayyar wheel, or the Morgan wheel and so on. If, without exceeding the present cost, wheels made to any of these designs can be obtained with a larger diameter or a wider tyre, that will be an advantage, if their performance is satisfactory. If, within the cost of the present wheels, they require a smaller diameter or a narrower tyre, that will be a disadvantage unless their performance counterbalances this defect. If it is possible to produce the same diameter and the same tyre-width in the same costs as that of wheels made with present materials, etc., then their selection will depend on their respective performances. All these points will be decided by the field tests proposed to be carried out in the States.

II. THE TRACTIVE EFFORT OF THE OPTIMUM WHEELS

10. It has been mentioned in para. 6(a) above that, according to the tests on tractive effort carried out in 1948, it was found that wheels with 3½ in. to 5 in. tyres, with diameters which can be fitted in the cost of the present wheels, will require a lower tractive effort than the wheels in use at present. To ascertain the extent of this, a fresh series of tests on tractive effort was carried out on one specific case, viz., a 3½ in. tyre and various diameters employing lathe-turned axles and cast iron bearings which, in the light of the wear and tear tests (Annexure II), seemed to be a happy medium. The tests were extended to see whether the use of hand-made axles and mild steel bearings would increase the tractive effort of the proposed wheels to more than that of wheels in use at present employing the same fixtures:

(a) When the bearings were new, and

(b) When they developed a slack by use.

Particulars of these tests will be found in Annexure III. It will be seen from them that with lathe-turned axles and cast iron bearings the proposed wheels of 3-1/2 in. tyre require from about 10 to 19 per cent less tractive effort than the present wheels corresponding to them. Their tractive effort is about 1 to 10 per cent less if hand-made axles and mild steel bearings are employed and that there is no increase in their tractive effort when mild steel bearings develop a slack by use [Annexure III para. 10 (iii) and (iv)]

11. This means that in the case of wheels built to the design in use at present but with the diameter and tyre proposed in Annexure II, even the present axle equipment can be employed without increasing the tractive effort of the wheels in use at present. This is a point in favour of the present design if in the light of field tests it is found satisfactory since it means that in its case the scheme of the proposed wheels can be introduced immediately as all materials required in their construction are those in use at present; workmanship, the technique of building and therefore the cost, will all be the same as at present. Improved axle equipment, which is meant to produce better performance and is, therefore, extra to the present requirements can be introduced in them as and when it is ready.

III. PROVISION FOR SELF-ALIGNMENT.

(i) The extent to which it is required.

12. The object of providing self-alignment in a wheel with a rigid tyre like a bullock-cart wheel is to enable it to tilt in such a way that its tyre will contact a road surface fully and distribute the load evenly. The theory of this was discussed in I. R. C. Paper No. 128, pp. 45 to 48. It was mentioned there that, provided the profile of a road surface was true to the camber, self-alignment was not required for travel on the slopes of a road.

13. In the first series of tests carried out under this head (Annexure IV, para. 6) it was found that the profile of a road was very rarely true to the road camber and it varied from point to point especially in the case of water-bound macadam surfaces, because of difficulties in rolling, uneven spreading of metal, or subsequent patching for repairs. Hence, if the objective be a full tyre contact in any wheel position, the **self-slignment to be provided in a wheel will have to be sufficient to meet conditions of travel not only when a cart is astride the crown of a road but also over the normal unevenness of a road surface causing variations in the camber in any part of its profile.** In the light of tests discussed in Annexure IV. para. 9 (vi), a provision for tilting to an angle of about 1 in 15 seems sufficient for both purposes.

(ii) Self-aligning wheels.

14. So far the following three types of self-alignment have come to the Author's notice:

1. Mr. Morgan's design.
2. Shri Nageswara Ayyar's design.
3. The Author's suggestion in the second Paper in these series (Paper No. 128, IRC Journal Vol. XII-4) to employ rubber fixtures in a wheel made as at present but with provision for two rubber sleeves in its hub and two rubber paddings outside the hub.

15. Morgan's wheel was not received for testing although Messrs. Morvi Chemical and Metallurgical Works Ltd., Morvi, Saurashtra, who claimed to have bought the patent, had agreed to send it. Hence, Nos. 2 and 3 were tested. Mr. Morgan has promised to have his wheels sent up for testing later. As soon as they are received and tests on them are completed, a separate note on them will be issued.

(iii) The tilt of self-aligning wheels.

16. Shri Nageswara Ayyar's design and the Author's design both induce a tilt in the wheel (Annexure IV, para. 9). The extent of this tilt varied but this is a matter for adjustment in the final design. The tilt in Nageswara Ayyar's wheel is about

1 in 30, that in Vagh's (Author's) wheel is about 1 in 15. If, in the field tests which will be carried out in the States, it is found that a greater or smaller tilt than this is required in practice it can be obtained by varying the size of the aperture of the bearing in No. 2 and the compressibility of rubber in No. 3. Therefore, both the designs can be employed in field tests.

17. As No. 3 requires two rubber fixtures, one on the bearings and the other by the side of the hub, six series of tests had to be carried out on it to ascertain whether in practice only one or both fixtures were necessary and in the latter case whether there should be one or two paddings and with one padding only whether on the inside or outside. Results indicate that both a sleeve and a padding are necessary for a full tilt [Annexure IV, para. 9 (iv)]. It is not clear from the tests whether one or two paddings may be used but for practical considerations and for ease of travel on curves two paddings may probably be more useful.

(iv) The effect of self-alignment on tractive effort.

18. The natural tendency of a self-aligning wheel is to incline and not remain true vertically like other wheels e.g., a tonga wheel or the Dunlop bullock-cart wheel. Therefore, to the extent to which it is designed to tilt it acts as a drag and requires a greater tractive effort during normal travel than a non-self-aligning wheel.

19. Both the self-aligning designs tested established this point. In the case of wheels employing rubber fixtures, wheels of various diameters were available for testing. Hence full information regarding them in all ranges of wheel diameters (for a $3\frac{1}{2}$ in. tyre) could be had. According to this information provision for self-alignment increases the tractive effort of a wheel by 11 to 14 per cent or 12.5 per cent on an average. [Col. 8, Table in para. 10 (a) (i) Annexure IV].

20. In the Nageswara Ayyar design only a 60 in. by 4 in. wheel was available for testing. It registered a tractive effort of about 86 lb. against about 52 lb. required by a non-self-aligning wheel of the same diameter and tyre but employing a lathe-turned axle and smooth cast iron bearings [items 10, 13 and 14, Appendix E (5), Annexure IV], an increase of about 65 per cent. This big increase cannot be due solely to self-alignment but to other causes also suggested in para. 10 (b) (iii) of Annexure IV. To what extent these causes operate in this design can be ascertained after correcting them. Also tests on Mr. Morgan's wheels will show

to what extent his method of self-alignment increases the tractive effort.

21. On the basis of an increase of 11 to 14 per cent in the tractive effort of self-aligning wheels employing rubber fixtures (para. 19 above), the most important point for consideration is whether the employment of self-alignment in wheels of $3\frac{1}{2}$ in. tyre proposed in Annexure II will entail a greater tractive effort than the corresponding wheels in use at present. Columns 2 and 6 of Table in para. 10 (a) (i), Annexure IV, show that this will not be the case so long as smooth bearing surfaces, e. g., lathe-turned axles and smooth cast iron bearings, are employed. Similar information about the Nageswara Ayyar and Morgan wheels will be available when such wheels undergo field tests.

(v) The tractive effort of self-aligning wheels on curves.

22. Tests indicate that, with a clearance of about 1/2 inch on the axle, self-aligning wheels should be easier to pull on curves than normal wheels (Annexure IV, para. 14).

IV. PROVISION FOR FLEXIBILITY.

23. A wheel requires a greater tractive effort during travel over pot-holes. [Annexure V, para. 13 (i)]. With a provision for flexibility this increase in the tractive effort is reduced not only during travel over pot-holes but also on normal road surfaces having surface irregularities [Annexure V para. 13 (iii) & and (iv)]. It was not possible to ascertain the extent of this reduction in tractive effort for the various designs for reasons mentioned in para. 14 of Annexure V.

24. When a provision for flexibility in a bullock cart wheel was first suggested by the Author in his second Paper in this series (Paper No. 128, I.R.C. Journal Vol. XII-4) the idea was as follows :—

(a) Flexbility might absorb impacts caused by travel on bad and worn out road surfaces and might reduce injuries caused to bullocks' necks and damage to road surfaces by such impacts.

(b) In the structure of the bullock-cart wheel there was no space for providing springs and, in any case, springs would be expensive. Hence the simplest plan might be to provide short rubber sleeves over the bearings.

(c) If a rubber sleeve on these lines proves useful for absorbing impacts caused by pot-holes its composition may be so designed as to provide tilting also, so that one fixture may be employed for two purposes.

25. The tests now carried out seem to indicate that a rubber sleeve designed on the above lines may not only provide tilting and absorb impacts during travel on pot-holes but also reduce the tractive effort of tilting wheels during normal travel on uneven road surfaces. This indication is so significant from the point of view of wheel design that, side by side with field tests, it may be useful to carry out more detailed investigation on flexibility by obtaining for testing as many self-aligning wheels as possible.

V. RAJU'S ROLLER WHEELS.

26. These were subjected to the same tests as other wheels (see particulars in Annexure VI). These tests do not seem to bring out any point in favour of roller wheels but see comments in Annexure VI.

VI. SUMMARY OF CONCLUSIONS FROM TESTS.

27. (i) Wheels of $3\frac{1}{2}$ in. to 5 in. tyre which can be manufactured within the cost of the spoke type wheels, in use at present in India by employing the same materials and methods of construction and the same axle equipment as are in use at present will not entail a greater tractive effort than the corresponding present wheels in spite of a reduction in their wheel-diameters [Para. 6(a), (b) and para. 10].

(ii) A 3 in. tyre entails the least reduction, (viz., 5 to 10 per cent) in wheel-diameters in use at present and produces a saving of about 20 to 25 per cent in damage to road surfaces. A 4 in. to 5 in. tyre entails the greatest reduction in wheel-diameters in use at present (of 30 to 35 per cent) and produces a saving of about 40 to 45 per cent in damage to road surfaces. A $3\frac{1}{2}$ in. tyre is intermediate between the two as it entails a reduction of 14 to 17 per cent in wheel-diameters in use at present and produces a saving of about 35 per cent in damage to road surfaces. Hence a $3\frac{1}{2}$ in. tyre seems most suitable for employment in place of the present 2 in. tyre at stations in India employing at present a wheel-diameter of up-to 54 inches in spoke-type wheels (para. 12 Annex. II).

(iii) At stations where spoke type wheels of diameters between 54 inches and 66 inches are in use a 4 in. to 5 in. tyre may be employed if the stations concerned have no objection to the reduced wheel-diameters they entail. Otherwise they also may employ a $3\frac{1}{2}$ in. tyre (para. 12, Annexure II).

(iv) At stations where Arm-type wheels are in use at present employing a tyre wider than $3\frac{1}{2}$ in., the same width of tyre as is in use at present but $\frac{3}{8}$ in. thick should be employed with a wheel-diameter, which with the new tyre will produce a wheel of the same weight as the present wheel, the new wheel being of the spoke type (para. 3).

(v) The tractive effort of these proposed wheels will be less than that of corresponding wheels in use at present if their hand-made axles and mild steel bearings are replaced with lathe-turned axles and smooth cast iron bearings as in tonga wheels [Table para. 10(ii), Annexure III]. The latter will also eliminate wheel wobble and provide better lubrication.

(vi) Self-alignment to ensure a full tyre-contact in all wheel positions and flexibility to absorb shocks during travel on uneven road surfaces and pot-holes can be provided in these wheels with rubber fixtures, consisting of two short sleeves one inch thick on the bearings and two paddings also one inch thick, one on either side of the wheel (I.R.C. Paper No. 128 para. 44).

(vii) During normal travel the tractive effort of these wheels with a provision for self-alignment and flexibility as described above will be greater than that in No. (v) but less than that of wheels in use at present corresponding to them on account of their broad tyres and smooth bearing surfaces (para. 21).

(viii) In all cases the new wheels may be employed either with new axle equipment including a provision for self-alignment and flexibility, if it is available immediately, or with the present axle equipment till such time as the new equipment is available (para. 11).

(ix) All the above conclusions relate to wheels built in all respects like **the wheel in use at present which** for comparison in respect of essential requirements, viz., cost, performance, the extent to which they provide work to the village wheelwright industry and the carters' reaction, **have to be taken as the standard wheels.**

(x) Any other wheel not built in all respects like the wheels in use at present can be compared to the above in respect of the essential requirements enumerated above **by making it to the same wheel-diameter and the same width of tyre and testing it side by side with the wheel in No.** (ix) (para. 9).

(xi) Of the three wheel designs in the above category which have so far come to the Author's knowledge, viz., the Nageswara Ayyar wheel, the Morgan wheel and the Raju wheel, the first produces self-alignment up to an angle of about 1 in 30 but can be designed for a greater self-alignment if required (para. 16). The Morgan wheel has not yet been tested. The Raju wheel also produces self-alignment (Annexure VI, para. 5). The tractive effort of the Nageswara Ayyar wheel and the Raju wheel is greater than that of the corresponding wheels in use at present and also wheels described in No. (ix) above employing rubber fixtures [Annexure IV, para. 10 (b) and Annexure VI] but can probably be reduced by suitable changes in the designs. None of these designs has a provision **for flexibility in them and should be expected to require a greater tractive effort during travel over pot-holes and possibly also during normal travel on uneven road surfaces** (Annexure V)

VII. FIELD TESTS AND CHECK TESTS.

28. These conclusions have been based on tests carried out so far, whose primary object was to evolve a basic wheel, incorporating essential requirements, which can be compared to the wheels in use at present on the one hand and wheels made to various designs to replace the present wheels on the other. Tests of this nature are exploratory and have to be carried out on short distances and over short periods and will not, therefore, furnish data on cost, maintenance and sustained performance. Hence to arrive at final conclusions it is essential to carry out field tests if possible in all States to ascertain this data and also the views of the States on the various types available. To provide comparable data all wheels to be tested will be manufactured to the same wheel diameter and the same width of tyre so that their relative merits and demerits can be judged in respect of the following points :

(1) Cost, both initial and recurring :

(2) Performance :

(3) The extent to which they provide work to the village wheel-wright industry :

(4) Cartmen's reaction to them.

As will be seen from para. 3 the programme of field tests has been comprehensive and includes all wheel-designs known at present. It may be useful to make this programme known to the public and to invite ideas, designs, etc., if any, to meet our requirements.

29. The Author has also suggested to the Consulting Engineer to the Government of India (Roads), to have a similar set of wheels manufactured for field tests at the Pusa Agricultural Institute, New Delhi, and to repeat on them all the tests which have been carried out so far employing the same test procedure and introducing such variations as may be suggested by Members. Tests on points not investigated so far which may be suggested by Members can also be carried out on these wheels. Lastly, the same wheels may be tested to destruction at the Alipore Test Track, if it be feasible to do so, to test their relative structural stability.

VIII. RECORD OF TESTS.

30. A summary of tests carried out so far is appended in Annexure VII for the purpose of a record. There were 12 series of tests which took about 22 months for field work. Out of this period about 12 months were taken up by tests at the Alipore Test Track and about ten months by tests at the College of Engineering, Poona. Sundry tests taken from time to time at the laboratory of the College of Engineering, Poona, have not been shown separately.

31. All sheets on tractive effort ascertained from the dynamometer have been numbered and filed to facilitate reference at any time. Test sheets in the various annexures of this Paper show the number of dynamometer record sheet against each wheel. The tractive effort in every single case recorded in this Paper was calculated with a planimeter.

IX. ACKNOWLEDGMENT.

32. All tests except the wear and tear tests at Alipore were carried out by Mr. S.V. Chandratreya, the Engineer-Liaison Officer of the Bullock-cart Sub-committee (who also collaborated with the staff of the Test Track in tests on tractive effort carried out there) under the direction of Mr. J. A. Taraporevala, and the Author. He was also responsible for making all calculations, compilations, charts, and drawings and also a survey of bullock-cart wheels in use at present in India. The tests at the Test Track were carried out by the Test House staff under the direction of Mr. Sinha. The Author is grateful to all those who assisted him in this work. His special thanks are due to Mr. Taraporevala who designed a self-recording dynamometer for these tests and made it possible to evolve a reliable method of recording and who also made himself available freely for discussion on numerous points which cropped up from time to time. Excepting the first series of tests from September 23, 1947 to December 10, 1947 carried out at Poona, which was left entirely to Mr. Taraporevala, the programme of all other tests was circulated to the members of the Bullock-cart Subcommittee well in advance with a request to offer suggestions and to see the tests. The programme of tests at the Test Track was arrived at a joint meeting of the Test Track and Bullock-cart Subcommittees held in January 1948. Draft copies of this Paper were also circulated to the members of the Bullock-cart Subcommittee as and when its parts were ready for their comments. The Author is grateful to those members who commented on the programme and the Paper. It has not been possible either for any member of the Bullock-cart Subcommittee, except Mr. Taraporevala, or for the Author to be present at any of these tests nor was it necessary as a self-recording dynamometer was employed.

ANNEXURES.

- I. Bullock-cart Subcommittee's Chart of work.
- II. Tests on Relative Wear & Tear of Road Surfaces caused by Bullock-cart Wheels.
- III. Tests on Relative Tractive Effort of the Present and Proposed wheels.
- IV. Tests on Self-alignment.
- V. Tests on Flexibility.
- VI. Tests on Mr. Raju's Roller Wheels.
- VII. Summary of Tests.
- VIII. Comments received from Subcommittee Members.

Annexure I.

THE BULLOCK-CART SUBCOMMITTEE

Chart of work on an improved bullock cart wheel.

I. BROADENING OF TYRE.	1. Collect information by random survey on: (a) Main types of wheels in India; (b) Their methods of construction, cost, life and performance; (c) Present widths of tyres; (d) Their effect on road surfaces.
	2. Obtain and investigate suggestions to broaden the present tyres: (a) As far as possible without changing the present design of wheels; (b) To suit the main types of wheels in India; (c) With as small extra cost as possible in both initial cost and maintenance of a wheel.
	3. Initial testing on suggestions which are considered feasible and which satisfy requirements under (2) as regards: (a) Constructional feasibility; (b) Performance under normal loading conditions; (c) Cost; (d) Possible improvements.
II. IMPROVED BEARINGS.	1. Collect information by random survey on: (a) Main types of bearings employed at present in cart wheels, their cost, and performance; (b) Collect similar information about other vehicles; (c) Ascertain requirements of bearings to obtain maximum advantage of a broad tyre in distributing the load in all conditions of travel.
	2. Obtain and investigate suggestions to improve the present bearings: (a) To meet requirements under I (c); (b) To compare favourably with the bearings in other vehicles; (c) As far as possible to fit in a hub built as at present; (d) With as small extra cost as possible both in initial cost and maintenance.

3. Initial testing on suggestions which are considered feasible and which satisfy requirements under (2) as regards: (a) Constructional feasibility: (b) Performance under normal loading conditions: (c) Cost; (d) Possible improvements.

III. STANDARDISATION OF DESIGN.

1. Obtain test data on: (a) The effect of variations in wheel diameters and width of tyre on tractive effort; (b) Relative wear of road surfaces under wheels of different widths of tyres but carrying the same load; (c) Performance of different bearings *in regard* to the flexibility and self-alignment of a wheel: (d) Comparative behaviour of a normal wheel, a wheel produced in the light of tests under (a), (b), and (c) and a pneumatic-tyred wheel.

2. (a) Collect information district by district in various States regarding the present design; (b) Ascertain the *number* of improved types which can be employed in place of (a) without exceeding their tractive effort and as far as possible cost. (c) **Test them under normal conditions of loading for 12 months, if possible, or one wet and one dry season to ascertain:** (i) their suitability to local materials and climatic conditions; (ii) *reaction* of wheel-wrights and carters; (iii) preference, if any, for *any of the types employed*: (iv) *suggestions* for improvements in them in the light of local experience.

3. ***Correlation of results in (1) and (2)*** **to evolve a basic design suitable for all India with as few types as possible; (b) Standardisation of the types so required and of the materials and methods of manufacturing them.**

Annexure II.

TESTS ON THE RELATIVE WEAR AND TEAR OF ROAD SURFACES CAUSED BY BULLOCK-CART WHEELS

1. These were carried out at the Majherhat Test Track between 22.8.48 to 22.12.48.

2. They relate to series No. 2 mentioned on p. 228 of Paper No. 137, I.R.C. Journal Volume XIII-part 2. The test procedure was the same as that employed in series No. 1 described in Annexure IV of that Paper, except that a new road surface was not prepared in between the three sub-series. Instead the existing road was scarified and re-laid.

3. **Test results,** as received from the Test Track, are enclosed in Appendix A to this Annexure. They are summarised below:—

Sub-series.	Wheels dia. (in.) by tyre (in.)	Wear (ins.)	Ratio of wear.	Inverse ratio of wheel-diameters.	Per cent Cols. 4 to 5.	Remarks.
1.	2.	3.	4.	5.	6.	7.
(i) 1.	36 × 5	0.19	1.06	1.50	70	Difference between (i) & (ii) in col. 6 is apparently due to the difference in the consolidation of the road.
2.	54 × 5	0.18				
(ii) 1.	54 × 5	0.12	1.20*	1.22	98	
2.	66 × 4	0.11				
(iii) 1.	54 × 5	0.12	1.5	—	—	
.	Pneumatic-tyres	0.08				

* Arrived at as follows:—

Wear of 66 **in. by 4 in.** $= 0.11$ in.

$\therefore$ Wear of 66 in. by 5 in. $= \frac{4}{0.9 \times 5} \times 0.11$ in. (para. 7 below)

$= 0.10$ in.

Wear of 54 in. by 5 in. $= 0.12$ in.

$\therefore$ Ratio $= 1.2$

Correlation of these results and those of Series No. 1 is discussed hereafter.

4. An iron-tyred wheel causes the wear and tear of a road surface in three ways :—

(i) By its tendency to deform a road surface by load concentration at the point of contact ;

(ii) By the abrasion of its tyre ;

(iii) By speed.

5. In the case of wheels of the same diameter but with varying tyre-widths and travelling at the same speed, No. (i) above will vary inversely and No. (ii) will vary directly as the tyre-width under the same load, for the same reason in both cases, viz., an increase in the contact area of the tyre with a road surface.

6. In the case of wheels of the same tyre-widths but with varying wheel-diameters and travelling at the same speed both Nos. (i) and (ii) in para. 4 may be assumed to vary inversely as the wheel diameter under the same load as shown in Appendix B. All the wheels employed in both the series of the wear and tear tests were electrically controlled and travelled at the same speed. Hence the speed factor does not enter in this discussion.

7. Results in series No. 1, Wear and Tear tests, have indicated that, as the combined effect of factors (i) and (ii) para. 4 above, the effective tyre-width in the case of wheels of the same diameter but with varying tyre-widths, is about 100 per cent up to a tyre-width of $3\frac{1}{2}$ in. and between 90 to 93 per cent in the case of tyre-widths of 4 in. to 5 in. (p. 232 I.R.C. Paper No. 137). This perhaps indicates that above a tyre-width of $3\frac{1}{2}$ in. the effects of abrasion become noticeable but for practical purposes the effective tyre-width may be taken as 90 per cent for all tyre-widths tested, i.e., from $3\frac{1}{2}$ in. to 5 in. That is, if a tyre is widened from T_1 inches to T_2 inches for the same wheel diameter the wear and tear caused by T_2 under the same load may be assumed as being reduced to $\frac{T_1}{0.9\,T_2}$ times the wear caused by T_1.

8. Results in Series No. 2, Wear and Tear Tests (para. 3 above), have indicated that the ratio of the wear and tear of a road surface is about 70 to 98 per cent of the inverse ratio of the wheel diameters for the same tyre-width according to the degree of consolidation of the road surface. As shown in Appendix B, for practical purposes, the ratio of wear may be taken at 100 per cent of the inverse ratio of wheel diameters. That is if a wheel diameter is reduced from D_1 to D_2 the wear caused by it for the same tyre width may be assumed as being increased in the ratio $\frac{D_1}{D_2}$ times the wear caused by D_1 under the same load.

9. Thus the wear X caused by a wheel of diameter D_1 and tyre T_1 will be $\frac{T_1}{0.9\,T_2} \times X$ if the tyre is widened to T_2 for diameter D_1 (para. 7) and this wear of $\frac{T_1}{0.9\,T_2} \times X$ for D_1 will be $\frac{T_1}{0.9\,T_2} \times X \times \frac{D_1}{D_2}$ if the diameter is reduced to D_2 with tyre T_2 (para. 8).

When the wear in both cases i.e. diameter D_1 and tyre T_1 and diameter D_2 and tyre T_2 is the same :

$$X = \frac{T_1}{0.9T_2} \times X \times \frac{D_1}{D_2}$$

$$\therefore \quad T_2 = \frac{D_1}{D_2} \times \frac{T_1}{0.9}$$

That is, if the diameter of any wheel in use at present with tyre T_1 is altered from D_1 to D_2 the tyre-width T_2 required to produce with the altered diameter the same wear and tear as at present can be obtained from the above formula.

10. On page 203, para. (vii) I.R.C. Paper No. 137, three groups of spoke type wheels with a tyre-width of $3\frac{1}{2}$ in. to 5 in. have been mentioned as suitable for employment in place of spoke type wheels in use at present, without exceeding either their cost of manufacture or their tractive effort. The tyre-widths required in each wheel in these groups to produce with the proposed wheel diameters the same wear and tear as the corresponding wheels in use at present are given in Appendix C (obtained by the formula in para 9 above). The tyre-width which can be employed in each case without exceeding the cost of the present wheels and their tractive effort and the per cent saving in the wear and tear of road surfaces has also been mentioned.

11. From it the following points may be noticed :

(i) Up to a wheel diameter of 54 inches in the present construction tyre-widths of $3\frac{1}{2}$ in., 4 in., and $4\frac{1}{2}$ in. produce the same saving in the wear and tear of road surfaces with the proposed wheel diameters.

(ii) At a wheel-diameter of 60 inches in the present construction there is no difference in the wear and tear of a road surface caused by a $3\frac{1}{2}$ in. and 4 in. tyre with the proposed wheel diameters. A $4\frac{1}{2}$ in. or 5 in. tyre produces more saving in the wear and tear.

(iii) At a wheel diameter of 66 inches in the present construction, 4 in., $4\frac{1}{2}$ in. and 5 in. tyres produce more saving in the wear and tear of road surfaces than a $3\frac{1}{2}$ in. tyre for their proposed respective wheel diameters.

12. A majority of States in India employ in the present construction wheel-diameters ranging from 42 inches to 54 inches. They can employ a $3\frac{1}{2}$ in. tyre which requires a minimum reduction of about 14 to 17 per cent in the present wheel-diameters to obtain a saving of about 35 per cent in the wear and tear of their roads. Mysore, Madras, and portions of Orissa and Hyderabad bordering on Madras employ, in the present construction, wheel diameters of from 60 inches to 66 inches. They have before them the following two alternatives;

(i) Employ the same tyre-width i.e. $3\frac{1}{2}$ in. with the same reduction in the present wheel diameters i.e. about 14 to 17 per cent to obtain the same saving in the wear and tear of road surfaces, i.e. about 35 per cent, as the other States.

OR

(ii) Employ tyre-widths of from 4 in. to 5 in. with the wheel diameters shown in the table to obtain a greater saving in the wear and tear of road surfaces.

13. It is interesting to note here that, if a 3 in. tyre is employed instead of $3\frac{1}{2}$ in. to 5 in., so as to fit as large a wheel-diameter as possible within the cost of the present wheels, the saving in the wear and tear of road surfaces is only about 20 to 25 per cent (Appendix D) against 35 per cent of a $3\frac{1}{2}$ in. tyre and 40 per cent of a 4 in., $4\frac{1}{2}$ in. and 5 in. tyre. **Hence from the point of view of wear and tear a tyre should not be less than $3\frac{1}{2}$ in. wide.**

14. According to the results in para. 3 item (iii) above, the wear and tear caused by a normal pneumatic tyre employed in bullock-cart wheels is about 0.67 times that caused by a **54 in. by 5 in.** wheel. The wear and tear caused by the latter is about $\frac{2}{0.9 \times 5} = 0.44$ times that caused by a **54 in. by 2 in.** wheel (para. 7). Hence the wear and tear caused by a pneumatic tyre is about 0.67 by 0.44 = 0.295, say 0.3 times that caused by a 54 in. by 2 in. wheel. That is, the per cent reduction in the wear and tear of a road surface by employing a pneumatic tyre in place of **54 in. by 2 in.** wheel in use at present will be about 70 per cent against 35 per cent of a $3\frac{1}{2}$ in. wide steel tyre with the proposed wheel diameters (A 54 in. diameter wheel has been taken here for comparison as it represents the mean of diameters in use at present ranging from about 42 inches to 66 inches). On the assumption

that these figures are correct the choice between the two will be governed by the saving in road maintenance on the one hand and the cost of wheels and their maintenance on the other.

APPENDICES TO ANNEXURE II.

A : Wear and Tear of road surfaces under

(i) 54 in. by 5 in. & 36 in. by 5 in. wheels.

(ii) 66 in. by 4 in. & 54 in. by 5 in. wheels.

(iii) 54 in. by 5 in. & pneumatic-tyred wheels.

B : Effect of wheel diameter on wear and tear.

C : Table (para. 10).

D : Table (para. 13).

Annexure II.
Appendix A.

TESTS AT THE CALCUTTA TEST TRACK ON THE WEAR & TEAR OF ROAD SURFACES CAUSED BY BULLOCK CART WHEELS
SERIES No. 2

(i) 54″ × 5″ & 36″ × 5″ wheels

Description of test surface	Details of Bullock-cart wheels	Particulars of rut	Depth of rut or wear in inches at distance 0′	30′	60′	90′	120′	150′	Average of six readings	Average wear in inches of trackway A & B or C & D	Average wear in inches of both in straight portions	Remarks
Southern straight portion of the track	Test cart with wheels 54″ diameter × 5″ width of tyre	Trackway 'A'	0.2	0.2	0.4	0.3	0.2	0.1	0.23	0.22		Wet surface
		,, 'B'	0.3	0.2	0.1	0.3	0.2	0.1	0.20			
Northern straight portion of the track	–do–	,, 'A'	0.0	0.1	0.1	0.1	0.2	0.2	0.12	0.14	0.18	
		,, 'B'	0.2	0.1	0.1	0.1	0.1	0.3	0.15			
Southern straight portion of the track	Test cart with wheels 36″ diameter × 5″ width of tyre	,, 'C'	0.3	0	0	0.4	0.2	0.2	0.19	0.20		
		,, 'D'	0.3	0.2	0	0.5	0.1	0.1	0.20			
Northern straight portion of the track	–do–	,, 'C'	0.2	0	0.3	0.3	0	0.3	0.18	0.18	0.19	
		,, 'D'	0.4	0	0.1	0.1	0.2	0.3	0.18			

Note: A: Wheel mark close to the outer-rail
B: ,, ,, ,, ,, ,, inner-rail.

Annexure II.
Appendix A. (*Contd.*)

(ii) 66″ × 4″ & 54″ × 5″ wheel

Description of test surface	Details of Bullock-cart wheels	Particulars of rut	Depth of rut or wear in inches at distance 0′	30′	60′	90′	120′	150′	Average of six readings	Average wear in inches of trackway A&B or C&D	Average wear in inches of trackway A&B or C&D	Remarks
Southern straight portion of the track	Test cart with wheels 54″ diameter × 5″ width of tyre	Trackway 'A'	0.1	0.2	0.2	0.2	0.1	0	0.15	0.16	0.12	
		,, 'B'	0.2	0.2	0	0.3	0.3	0	0.17			
Northern straight portion of the track	–do–	,, 'A'	0.1	0	0	0.2	0.1	0.2	0.10	0.075		
		,, 'B'	0.2	0	0	0.1	0	0	0.05			
Southern straight portion of the track	Test cart with wheels 66″ diameter × 4″ width of tyre	,, 'C'	0.1	0.2	0	0.2	0.1	0	0.10	0.13	0.11	
		,, 'D'	0.2	0.1	0.1	0.2	0.2	0.1	0.15			
Northern straight portion of the track	–do–	,, 'C'	0.1	0.2	0.1	0.2	0.1	0	0.12	0.09		
		,, 'D'	0.1	0.1	0	0.1	0	0	0.05			

Note:—A: Wheel-mark close to the outer-rail
B: ,, ,, ,, ,, ,, inner-rail

Annexure II.
Appendix A. *(Contd.)*

(iii) 54″ × 5″ & Pneumatic tyred wheels (36″ × 3½″)

Description of test surface	Details of Bullock-cart wheels	Particulars of rut	Depth of rut or wear in inches at distance 0′	30′	60′	90′	1	150′	Average of six readings	Average wear in inches of trackway A&B or C&D	Average wear in inches of both the straight portions	Remarks
Southern straight portion of the track	Test cart with steel tyred wheels 54″ diameter × 5″ width of tyre	Trackway 'A'	0.1	0.2	0.1	0.1	0.1	0.1	0.12	0.11		
		,, 'B'	0.2	0.1	0	0.1	0.1	0.1	0.10		0.12	
Northern straight portion of the track	–do–	,, 'A'	0.1	0.1	0.2	0.1	0.1	0.2	0.13	0.13		
		,, 'B'	0.1	0.2	0.1	0.2	0	0.1	0.12			
Southern straight portion of the track	Test cart with pneumatic tyred wheels 36″ diameter × 3½″ width of tyre	,, 'C'	0.1	0	0	0.1	0.2	0.1	0.08	0.05		
		,, 'D'	0	0	0.1	0	0	0.1	0.03		0.8	
Northern straight portion of the track	–do–	,, 'C'	0.1	0.1	0.1	0.1	0.2	0.1	0.12	0.10		
		,, 'D'	0	0.1	0.1	0.1	0.1	0.1	0.08			

Note :- A : Wheel-mark close to the outer-rail
B ,, ,, ,, ,, ,, inner-rail.

Annexure II.
Appendix B.

EFFECT OF WHEEL DIAMETERS ON THE WEAR AND TEAR OF ROADS

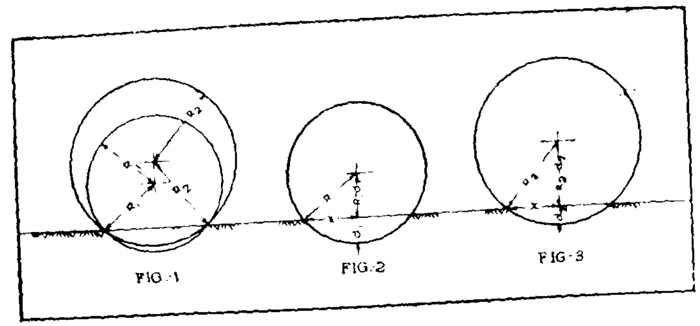


FIG. 1 FIG. 2 FIG. 3

1. Fig. 1 shows how two wheels of different diameters but of the same tyre-widths and carrying equal loads will tend to deform a road surface by load concentration which, in the case of the smaller wheel, is proportionate to d_1 (Fig. 2) and in the case of the larger wheel is proportionate to d_2 (Fig. 3).

2. The chord representing the projected contact area being the same for the same load in both cases, the values of d_1 and d_2 will be :—

$$x^2 = R^2_1 - (R_1 - d_1)^2$$
$$= 2d_1R_1 - d_1^2$$
$$= d_1 \times 2R_1 - d_1^2 \text{ in Fig. 2}$$
$$= d_2 \times 2R_2 - d_2^2 \text{ in Fig. 3}$$

d_1^2 and d_2^2 can be neglected as the deformation of a normal road surface built to carry wheel-loads should not be more than a small fraction of an inch.

$$\therefore \text{ Equating } \frac{d_1}{d_2} = \frac{2R_2}{2R_1}$$

That is, the load concentration and, therefore, the deformation and tyre abrasion caused by it are inversely proportional to the wheel diameters. In practice they will be less than this in the case of the smaller wheel since deformation is resisted by the upward pressure exerted by a road surface due to consolidation and the deeper the wheel goes the greater is this pressure.

3. If a road surface is so compact that a wheel load makes no deformation in it at all, the surface becomes tangential to the wheel. In that case the wheel diameter does not come into the picture. If a road surface is soft then the extent to which it can be consolidated under a particular load will determine the deformation caused by a wheel. In this case the smaller wheel will sink less than shown in para. 2 on account of the upward pressure of the consolidated surface in the rut. Here also the deformation will be less. Hence generally speaking, the conclusions in para. 2 will be safe.

Annexure II.
Appendix C.

Table (See para. 10)

Present wheels (D1 × T1)	PROPOSED WHEELS: Group 1 (Tyre width proposed A = 3½ inches): Proposed wheels (D2 × A)	Group 1: Tyre width (T2) required with dia. D2 for the same wear as of wheel D1 × T1	Group 1: Percentage reduction in wear over the existing wheels	Group 2 (Tyre width proposed A = 4 inches): Proposed wheels (D2 × A)	Group 2: Tyre width (T2) required with dia. D2 for the same wear as of wheel D1 × T1	Group 2: Percentage reduction in wear over the existing wheels	Group 3 (Tyre width proposed = A): Proposed wheels (D2 × A)	Group 3: Tyre width (T2) required with dia. D2 for the same wear as of wheel D1 × T1	Group 3: Percentage reduction in wear over existing wheels
(inches)	(inches)	(inches)		(inches)	(inches)		(inches)	(inches)	
1. 42 × 2	36 × 3½	2.6	35	......Same as in Group 1......			......Same as in Group 1......		
2. 48 × 2	39 × 3½	2.75	27						
3. 54 × 2	45 × 3½	2.66	32	39 × 4	3.06	33	36 × 4½	3.34	34
4. 60 × 2	51 × 3½	2.62	35	45 × 4	2.96	33	42 × 4½	3.18	40
							or 37½ × 5	3.56	40
5. 66 × 2	57 × 3½	2.58	35	51 × 4	2.86	40	45 × 4½ or	3.26	38
							42 × 5	3.5	43

Note: (1) If the diameters of Nos. 2 and 3 in Group 1 and Nos. 3 and 4 in Group 2 are increased by 2 in. and 1 in. respectively the per cent reduction in the wear and tear caused by them will be 35 per cent against 27 per cent, 32 per cent and 33 per cent respectively.

(2) Groups showing the same saving have been underlined.

Annexure II.
Appendix D.

TABLE (See para. 13): Tyre width proposed, A = 3 inches

Present wheels ($D1 \times T1$) (inches)	Proposed wheels ($D2 \times A$) (inches)	Tyre-width (T2) required for dia. D2 for the same wear as of wheel $D1 \times T1$ (inches)	Percentage reduction in wear over the existing wheels
1. 42×2	39×3	2.40	25
2. 48×2	42×3	2.54	18
3. 54×2	48×3	2.52	19
4. 60×2	57×3	2.34	28
5. 66×2	63×3	2.34	28

Annexure III.

TESTS ON THE RELATIVE TRACTIVE EFFORT (T.E.) OF THE PRESENT AND PROPOSED WHEELS

NOTE: L.T.A. and C.I.B stand for Lathe-Turned Axles and Cast Iron Bearings.

H.M.A. and M.S.B. stand for Hand-Made Axles and Mild Steel Bearings.

The Object of these tests was to ascertain the relative tractive effort of the present wheels and those which can be employed in their place with a tyre-width of 3-1/2 in. according to the conclusions arrived at in Annexure II by employing in the latter:

(i) Lathe-turned axles and cast iron bearings.

(ii) Hand-made axles and mild steel bearings (new).

(iii) When the latter get worn in use, producing a slack in the bearings and a play on the axle.

2. The tests were carried out in the same manner as before (Annexure II, I.R.C. Paper No. 137) except that:

(a) They were carried out on one road surface only, viz., water-bound macadam:

(b) The position of the wheels was astride the crown of the road:

(c) Averages from test sheets were ascertained with a planimeter.

3. Previous tests on tractive effort were carried out as follows:—

(a) Different road surfaces;

(b) Travel on the side of a road surface, instead of being astride the crown;

(c) Manual labour for pulling the wheels;

(d) Averages from test sheets were ascertained by inspection.

4. The object of the previous tests being to fix up the gradation of various wheels in respect of their tractive effort (a) above was necessary to obtain three or more points for plotting a chart. The object of the present tests being relative tractive effort of two sets of wheels only one type of road surface was sufficient for that purpose.

5. Travel with wheels astride the crown was employed in the present tests to obtain data for comparison with self-aligning fixtures, thus saving one operation which would have been necessary had the wheels been tested on the side of a road surface as in the previous tests.

6. A preliminary series of tractive effort tests was carried out by employing bullocks in place of manual labour. It was found that bullocks introduced too many variables, such as turning their necks sideways and up and down, starting with varying jerks and not keeping the same speed in the short distances used in the tests. Again it was difficult to keep the driver from twisting the bullocks' tails for no reason and it was impossible to keep off flies from the bullocks. Both these factors influenced the bullocks' movements. After several expedients it was found impossible to minimise these variables. Hence manual labour was employed after consulting Mr. Taraporevala who confirmed that his dynamometer was not designed for these variables.

7. The method of ascertaining averages by inspection was found to be fairly accurate in previous tests but was open to the objection that it may not produce the same degree of accuracy in all cases. Hence in the present tests a planimeter was employed to ascertain averages.

8. The following wheels were tested for tractive effort per ton:

(i) 39 in. by 2 in.
(ii) 53 in. by 2 in.
(iii) 67 in. by 2 in.
} As in use at present employing hand-made axles and mild steel bearings (new) with no slack in the bearing and no play on the axle.

(iv) 36 in. by $3\frac{1}{2}$ in.
(v) 54 in. by $3\frac{1}{2}$ in.
(vi) 66 in. by $3\frac{1}{2}$ in.
} (a) Lathe-turned axles and cast iron bearings with no slack in the bearing and no play on the axle.

(b) Hand-made axles and mild steel bearings with no slack in the bearing and no play on the axle.

(vii) 53 in. by 2 in.
(viii) 54 in. by $3\frac{1}{2}$ in.
(ix) 66 in. by $3\frac{1}{2}$ in.
} Hand-made axles and mild steel bearings (old) with a slack of $\frac{1}{8}$ in. in the bearings and a play of $\frac{3}{8}$ in. on the axle for comparison with:

(a) Lathe-turned axles and cast iron bearings;

(b) Hand-made axles and mild steel bearings (new)

9. Charts for the tractive effort per ton of these wheels and the test sheet from which they have been plotted will be found in Appendix A (Nos. 1 to 5) to this Annexure. Curves of relative tractive effort obtained from them will be found in Appendix B.

10. The following points may be seen from the latter:

(i) The tractive effort curves of wheels of $3\frac{1}{2}$ in. tyre whether they employ lathe-turned axles and cast iron bearings or hand-made axles and mild steel bearings are below the tractive effort curve of wheels of 2 in. tyre employing hand-made axles and mild steel bearings (Appendix B, Chart I).

(ii) The relative tractive effort of the wheels in use at present (H.M.A. and M.S.B.) and of the $3\frac{1}{2}$ in. tyre wheels which can be employed in their place according to Annexure II is as follows (Appendix B, Chart I).

Present wheels diam. (in.) × Tyre width (in.)	Tractiv Effort lb/ ton.	Proposed wheels Diam. (in.) × Tyre width (in.)	L.T. axles & C.I bearings		H. M. axles and M. S. bearings	
			T.E. lb/ ton	Difference over col. 2	T.E. lb ton	Difference over col. 2
1	2	3	4	5	6	7
42×2	95.0	**36 × $3\frac{1}{2}$**	82.0	– 13.7%	89.0	–6 3%
48×2	84.5	**39 × $3\frac{1}{2}$**	76.5	– 9.5%	84.0	– 0.6%
54×2	76.5	**45 × $3\frac{1}{2}$**	69.0	– 9.8%	75.5	– 1.3%
60×2	72.0	**51 × $3\frac{1}{2}$**	62.5	– 13.2%	68 5	– 4.8%
66×2	70.0	**57 × $3\frac{1}{2}$**	57.0	– 18.5%	63.0	– 10.0%

(iii) This means that the tractive effort of the proposed wheels is from about 10 to 19 per cent less (col. 5 in above table) with L.T.A. and C.I.B. and from about 1 to 10 per cent less (col. 7 in above table) with H.M.A. and M.S.B. than that of the corresponding wheels in use at present.

(iv) The tractive effort of a wheel of the same diameter and tyre is not increased when its M.S. bearings develop a slack and the wheel develops a play on the axle by wear (Appendix B, Chart II). This is probably because the surface of a new M.S.B. is uneven and it becomes smooth by wear as it grows old.

APPENDICES TO ANNEXURE III:

A: (1) Tractive effort per ton, present wheels.

(2) Tractive effort per ton, proposed wheels (L.T.A. & C.I.B.).

(3) Tractive effort per ton, proposed wheels (H.M.A. & M.S.B.).

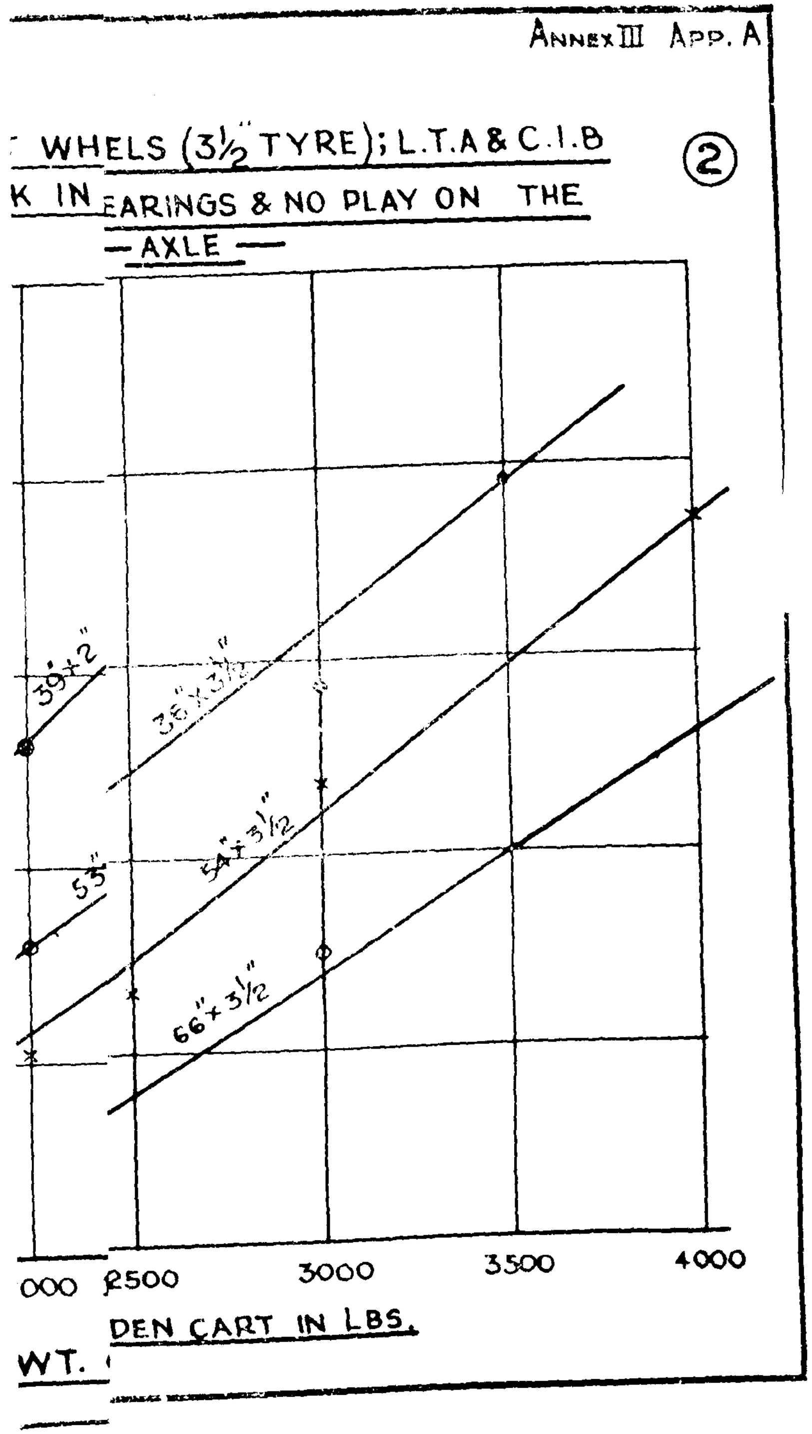
(4) Tractive effort per ton, (H.M.A. & M.S.B., Old): 2 in. & 3½ in. tyres.

(5) Tractive effort per ton, Test Sheet.

B: Relative tractive effort.

I. Present and proposed wheels.

II. Same wheels with new and old M.S.B.



TRACTIVE EFFORT PER TON — **Annexure III.**

Test Sheet — **Appendix A5.**

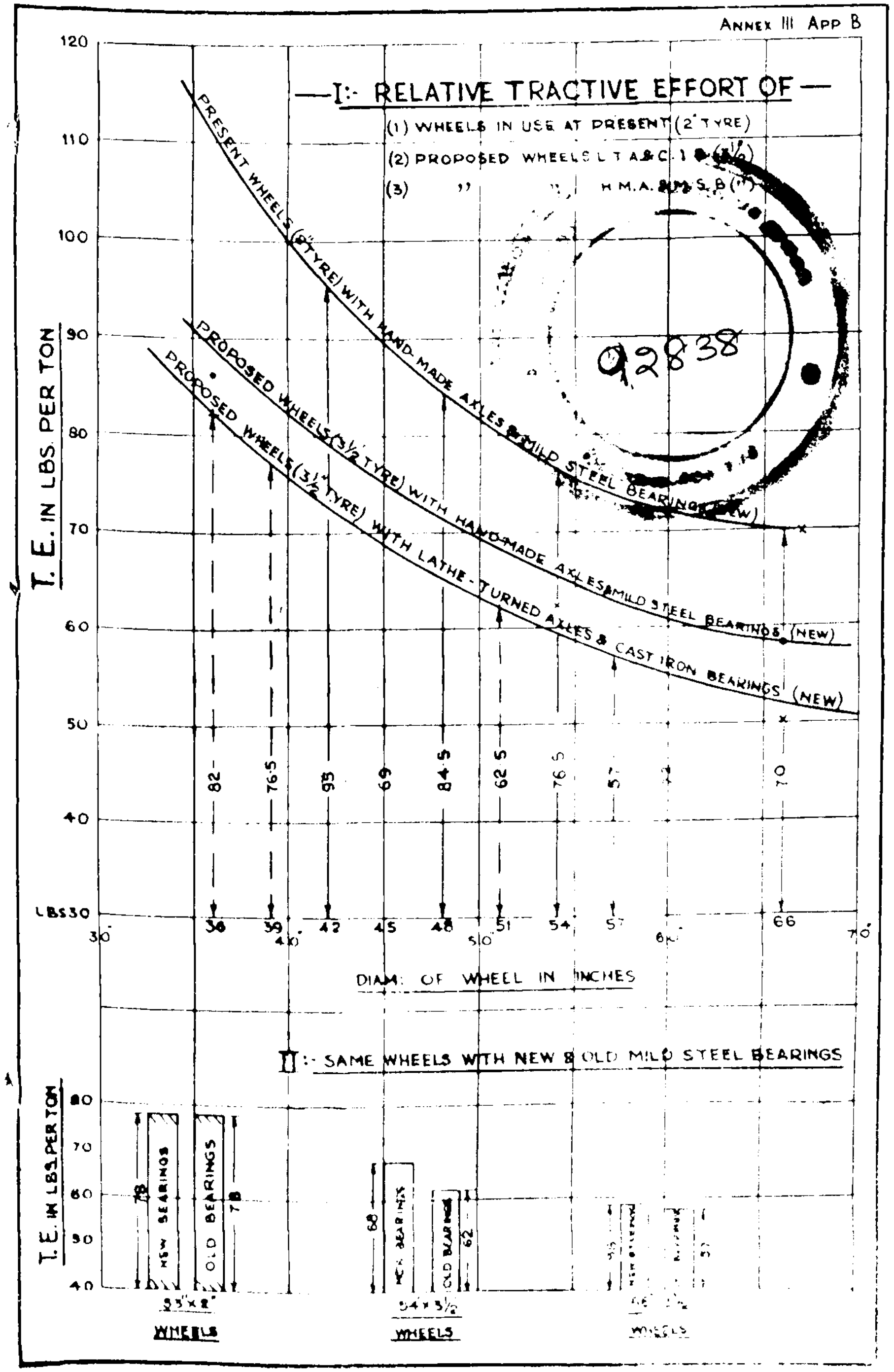
Date of test	Sheet No.	Wheel Diameter & Tyre	Tractive effort (lb) on the crown of a W. B. Macadam Road for various loads: 1500 lb Rolling T. E.	2000 lb Rolling T. E.	2500 lb Rolling T. E.	3000 lb Rolling T. E.	3500 lb Rolling T. E.	4000 lb Rolling T. E.	1 ton Rolling T. E.
		I :	**Present wheels : H. M. A. & M. S. B. (new) : No play on the axle**						
29 4 49	28 to 30	39″ × 2″	74·13	92.5	112.0	130.12	—	—	102.0
14 4 49	31 to 33	53″ × 2″	—	72.6	83.7	97.7	—	—	78.0
7 4 49	34 to 36	67″ × 2″	49·4	60.67	76.5	93.0	—	—	70.0
		II :	**Proposed wheels : L. T. A. & C. I. B.: No play on the axle**						
28 4 49	1 to 3	36″ × 3½″	—	82.0	—	97.0	117.5	—	82.0
1 4 49	4 to 6	54″ × 3½″	—	—	67.27	87.37	—	113.7	62.0
25 4 49	7 to 9	66″ × 3½″	—	51.2	—	69.5	—	83.0	50.0
		III :	**Proposed wheels : H. M. A. & M. S. B. (new) : No play on the axle**						
28 4 49	10 to 12	36″ × 3½″	—	83.0	—	103.6	123.5	—	86.0
2 4 49	13 to 15	54″ × 3½″	—	66.5	—	103.0	—	116.5	68.0
26 4 49	16 to 18	66″ × 3½″	—	2300 lb 56.0	—	78.66	—	95.0	58.0

Test Sheet (*Continued*)

Tractive Effort on the crown of a W. B. Macadam Road for various loads

IV : Same wheels H. M. A. & M. S. B. (new & old)

Date of test	Sheet No.	Wheel Diameter & Tyre	1500 lb Rolling T. E.	2000 lb Rolling T. E.	2500 lb Rolling T. E.	3000 lb Rolling T. E.	3500 lb Rolling T. E.	4000 lb Rolling T. E.	1 ton Rolling T. E.
14 4 49	31 to 33	53″ × 2″ (new bearings)	—	72.6	83.7	97.7	—	—	78.0
14 4 49	19 to 21	53″ × 2″ (old bearings)	—	69.5	86.67	98.5	—	—	78.0
2 4 49	13 to 15	54″ × 3½″ (new bearings)	—	66.5 / 2300 lb	—	103.0	—	116.5	68.0
4 4 49	22 to 24	54″ × 3½″ (old bearings)	—	—	66.9	—	103.0	117.25	62.0
25 4 49	16 to 18	66″ × 3½″ (new bearings)	—	56.0	—	78.66	—	95.0	57.0
18 5 49	25 to 27	66″ × 3½″ (old bearings)	—	—	55.15 / 2120 lb	67.8	—	110.0	58.0



Annexure IV.

TESTS ON SELF ALIGNMENT.

The Object.

1. The object of these tests was to ascertain the following points:

I. The extent to which self-aligning wheels made to different designs tilt on the axle to produce in practice as nearly as possible a full tyre contact with a road surface:

(a) when the cart is astride the crown of a road;

(b) during travel on uneven road surfaces.

II. The effect of self-alignment on the tractive effort of a wheel.

III. The tractive effort of self-aligning wheels on superelevated curves.

Test Wheels.

2. The following wheels were tested:

I. Extent of Tilt.

(i) **39 in. × 2 in.**, **53 in. × 2 in.**, **67 in. × 2 in.** Representing wheels in use at present with a slack in the bearing and a play on the axle for comparison with self-aligning wheels.

(ii) **36 in. × 3½ in.**, **54 in. × 4 in.**, **66 in. × 4 in.** With lathe-turned axles and cast iron bearings, employing rubber fixtures variously as shown below:

(a) No sleeve on the bearing and no padding on the sides; **54 in. by 4 in.** wheel;

(b) Sleeve on the bearing but no padding on the sides; **54 in. by 4 in.** wheel;

(c) Sleeve on the bearing and padding on the inside; **54 in. by 4 in.** wheel;

(d) Sleeve on the bearing and padding on the outside; **54 in. by 4 in. and 36 in. by 3½ in.** wheels;

(e) Sleeve on the bearing and padding on both sides; **54 in. by 4 in., 36 in. by 3½ in.** and **66 in. by 4 in.** heels;

(f) No sleeve on the bearing but paddings on both sides; **54 in. by 4 in.** wheel.

(iii) **60 in. × 4 in.** Two pairs of self aligning wheels to Shri Nageswara Ayyar's design.

54 in. × 4 in., **66 in. × 4 in.** Self aligning wheels with rubber fixtures to obtain a mean for a **60 in. by 4 in.** wheel with similar fixtures for comparison with the above.

All these wheels were tested on the crown of a water-bound macadam road.

Results of tests on wheels in

(i) are in Appendix A;

(ii) are in Appendix B. (a) to (f);

(iii) are in Appendix C, (a) and (b).

A longitudinal section of the road on which these tests were carried out is in Appendix D.

II. The effect of self-alignment on tractive effort.

(i) **36 in. × 3½ in.**, **54 in. × 3½ in.**, **66 in. × 3½ in.** Wheels with lathe-turned axles and cast iron bearings with rubber fixtures tested on a water bound macadam surface for comparison with the same wheels without rubber fixtures tested previously on a similar surface.

The chart for the tractive effort per ton of these wheels is in App. E. No. 1 and that for their comparative tractive effort with and without self-alignment and with different bearings in App. E. No. 2.

(ii) **60 in. × 4 in.** Two pairs of wheels to Shri Nageswara Ayyar's design.

54 in. × 4 in., **66 in. × 4 in.** Lathe-turned axles and cast iron bearings, with rubber fixtures to obtain a mean for a **60 in. by 4 in.** wheel with similar fixtures for comparison with the above.

These wheels were tested on two surfaces, viz., a water bound macadam straight portion [See Appendix E (3)] and a cement concrete road on a curve, [See App. E (4)], for comparison during normal travel and travel on superelevations.

The test sheets from which charts for wheels described in II (i) and (ii) have been plotted are in App. E (5). The longitudinal section of the road on which these tests were taken is in App. F.

3. Tests on the above wheels, except Shri Nageswara Ayyar's wheels were completed by the end of May 1949. By the time the Nageswara Ayyar wheels could be got ready after repairs for tests in the first week of June 1949 the monsoon broke out and there were a few showers. Hence to obtain relative data for the two types of wheels they were re-tested for a 1-ton loading in the first week of July on the same road and in all respects under the same conditions there being no showers during the testing period. Further, the 66 in. by 4 in. wheel used in the previous tests was converted to 60 in. by 4 in. Figures of these tests [App. E (5) III : Check tests] will be used for comparison which will be found in App. G.

4. Side by side with these check tests a few more tests were also carried out at the suggestion of Shri Nageswara Ayyar introducing two variations in the test procedure to see whether and to what extent they affected the results. These variations were as follows :

(i) Use two stout tension springs in the Taraporevala Dynamometer instead of two compression and one tension springs used at present.

(ii) Re-plot the test graph obtained by using three springs to one scale instead of two as at present.

Variation on account of (i) was found to be from (minus) 3 per cent to (plus) 3 6 per cent [items 12 and 15, App. E (5)] ; that on account of (ii) was 0.03 per cent [item 14 (a) same Appendix].

Test Procedure to ascertain tilt.

5. The object of providing self-alignment in a wheel being primarily to ensure a full tyre-contact with a road surface when the wheel is astride the crown of a road one series of tests was run to measure actual tyre contact by two methods :

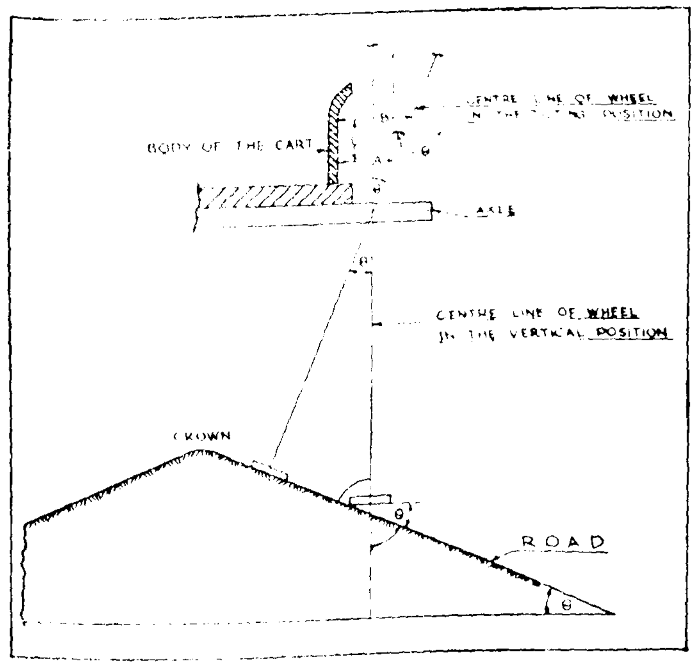
(a) by painting the tyre, and

(b) by spreading a layer of fine earth on a road surface to obtain an impression of the tyre-contact.

6. Painting did not prove effective as the paint, even when renewed often, got rubbed out leaving an imperfect impression of the tyre. In this respect a layer of earth proved more effective but produced incorrect results on account of the practical difficulty

of spreading it uniformly throughout the track on an uneven surface. The result was that where the road surface was extremely uneven a full tyre-contact could be obtained in the case of some wheels even without a provision for self-alignment in them. After inspecting a number of road surfaces, from water-bound macadam to cement concrete, it was found that a perfectly true surface was impossible to obtain and, therefore, so long as this contingency was present, the method of measuring a tyre-contact was bound to be inaccurate. Hence, it was decided to measure the actual incline of the wheel and to compare it with **the actual road camber at the wheel position, not the overall camber of the road.** When the wheel-incline is nearly equal to the road camber at the wheel position the tyre will naturally contact the road surface whatever its condition.

7. The method was to measure A, B and C shown in the following sketch and the road camber at each wheel position.



Then $\frac{B-A}{C}$ = Tan θ = Angle of the tilt.

Test Procedure to ascertain tractive effort

8. The same test procedure was employed as in the case of tests discussed in Annexure III.

CONCLUSIONS

9. From the results given in the Appendices the following conclusions are suggested :—

I. Self-alignment.

(i) Wheels in use at present in all ranges of diameters in use produce a slight tilt when their mild steel bearings develop a slack and the wheel develops a play on the axle by wear and tear but such tilt is not sufficient for a full tyre contact [App. A (a), (b), and (c)].

(ii) The tilt will be less if hand-made axles and mild steel bearings in use at present are replaced with lathe-turned axles and cast iron bearings as the latter do not develop a slack [App. B (a)].

(iii) The provision of rubber sleeves on the cast iron bearings improves the tilt but the maximum tilt is less than the road camber and, therefore, insufficient for a full tyre-contact. [App. B (b)].

(iv) The use of a rubber padding either on the inside or outside or both sides of a wheel in addition to rubber sleeves on the bearings, improves the tilt which is very nearly equal to the road camber. [App. B (c), (d), (i), (e), (i)]. This is true whatever the wheel-diameter and the tyre-width [App. B (d) (ii), (e) (ii) and (e) (iii)].

(v) The use of two paddings without a sleeve on the bearings does not produce a full tilt [App. B (f)] and the tilt produced is less than that in (iii) above.

(vi) Both the pairs of wheels made to Shri Nageswara Ayyar's design can tilt to a limited extent, i.e., up to an angle of about 1 in 30, [App. C (a) and (b)], and, therefore, do not produce a full tyre-contact on uneven surfaces. Since a road surface built to a camber has been found in practice to vary a great deal from one position to another in the same profile it is desirable to redesign these wheels for a camber of about 1 in 15 to meet all conditions of travel as in the case of 54 in. by 4 in., 36 in. by 3-1/2 in., and 66 in. by 4 in. wheels with rubber fixtures [App. B (e) (i), (ii) and (iii)].

10. **II. The effect of self-alignment on tractive effort.**

(a) Wheels employing rubber fixtures :

(i) From the tractive effort curves in chart No. 2, App. E the relative tractive effort of the present wheels (2 in. tyre) and those (3-1/2 in. tyre) which can be employed in their place (see Annexure II) with different bearings and with and without provision for self-alignment is as follows :—

Annexure IV

Present wheels	Tractive effort lb/ton	Proposed wheels	L.T.A. & C.I.B. without self-alignment		L.T.A. & C.I.B. with self-alignment		Percentage increase in tractive effort of the same wheel's A/c of self-alignment : Difference cols. 6 & 4 on col. 4	H.M.A. and M.S.B.		
Dia. & Tyre (inches)		Dia. & Tyre inches	Tractive effort	Difference on col. 2 (Per cent)	Tractive effort	Difference on col. 2 (Per cent)		Without self-alignment	With self-alignment with the addition of the difference in tractive effort A/c of self-alignment as per col. 8	Percentage difference over col. 2
1	2	3	4	5	6	7	8	9	10	11
42 × 2	95.0	**36 × 3-1/2**	82.0	−13.7	91.0	−4.2	+11.0	89.0	99.0	+ 4
48 × 2	84.5	**39 × 3-1/2**	76.5	− 9.5	86.0	+1.7	+12.4	84.0	94.5	+12
54 × 2	76.5	**45 × 3-1/2**	69.0	− 9.8	77.5	+1.3	+12.3	75.5	84.7	+10.7
60 × 2	72.0	**51 × 3-1/2**	62.5	−13.2	70.5	−2	+12.8	68.5	77.0	+ 7.0
66 × 2	70.0	**57 × 3-1/2**	57.0	−18.5	65.0	−7	+14.0	63.0	72.0	+ 3.0

Note : L.T.A. means Lathe-Turned Axle.
C.I.B. means Cast-Iron Bearings.
H.M.A. means Hand-Made Axle.
M.S.B. means Mild Steel Bearings.

(ii) The tractive effort of the proposed wheels which, with L. T. A. and C. I. B. and without self-alignment, is from about 9 to 19 per cent less (col. 5) than that of the present wheels becomes from 2 to 7 per cent less in three cases and about 2 per cent more in two (col. 7) when a provision for self-alignment is made in them as the latter increases the tractive effort by about 12·5 per cent on an average (col. 8).

(iii) **Therefore it will be feasible to provide self-alignment in the proposed wheels without increasing their tractive effort only if lathe-turned axles and smooth bearings are employed in them.**

(iv) If hand-made axles and M. S. B. are employed in them the tractive effort of the proposed wheels will be from 3 to 12 per cent greater than that of the corresponding wheels in use at present.

(b) **Shri Nageswara Ayyar's Wheels :**

(i) Both the pairs of wheels received for testing being of the same diameter and tyre, viz., **60 in. by 4 in.** they were compared with a **60 in. by 4 in.** wheel, employing a lathe-turned axle and cast iron bearings, with and without rubber fixtures on the one hand and a normal Madras wheel **67 in. by 2 in.** on the other, the latter because it was used by the designer in similar tests before.

(ii) This comparison was confined, at the designer's suggestion, to design No. 1 which was in use in Madras for some time and whose bearings were likely to be smoother by use than those of design No. 2 which was a new pair. It may be seen (App. G) that **on a water-bound macadam road Shri Nageswara Ayyar's Wheels registered a greater tractive effort than a 60 in. by 4 in. wheel (L. T. A. and C. I. B.) with or without rubber fixtures and also a normal Madras wheel.**

(iii) The reasons for this would seem to be :—

(a) The internal finish of the bearings of Shri Nageswara Ayyar's wheels, even after they were in use for some time, is much inferior to that of the **60 in. by 4 in.** wheel which had a lathe-turned axle and cast iron bearings of smooth internal finish. The chart in Annexure III, App. B, indicates that for the same size of the bearings the difference between the tractive effort of the same wheel employing smooth and uneven bearing surfaces is about 10 per cent on account of friction.

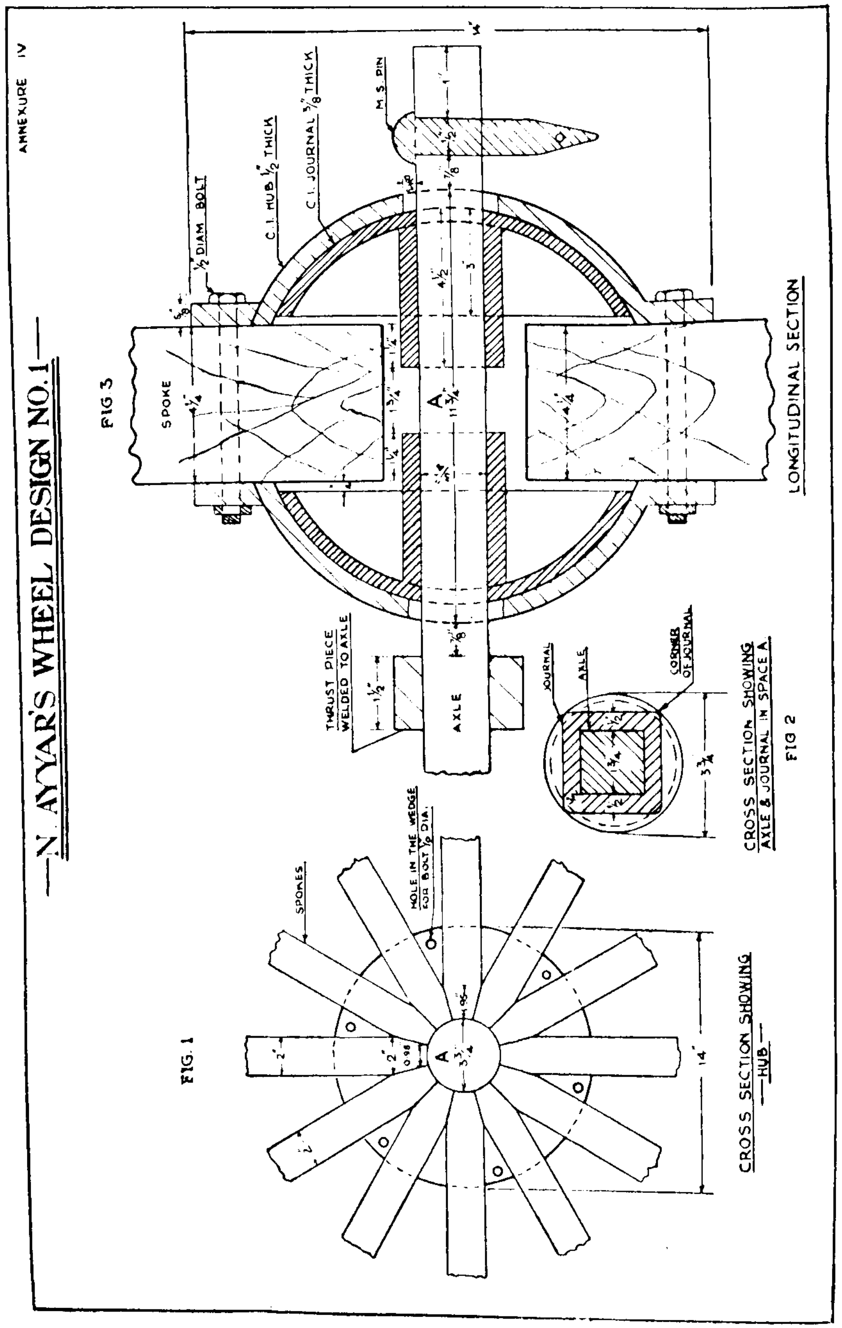
(b) The frictional surface of the bearings in Shri Nageswara Ayyar's wheels is roughly about twice that in the other wheel. This may also account for an increase in friction. This is suggested by the fact that in spite of its broad tyre, Shri Ayyar's wheel registered a greater tractive effort than a normal Madras wheel which had a smaller frictional surface of the bearings.

(c) In this wheel the space A in the hub (Fig 1, next page) around the two journals which project into it to a distance of $1\frac{1}{4}$ in. each (Fig 3, next page) is circular while the journals are square (Fig. 2, next page). When the cart is loaded the axle with its journals touches the underside of A and since the axle and the journals are stationary while the wheel moves the corners of the journals interfere with the wheel's movement. Here the action is similar to rotating a square peg in a circular hole. The space A is all serrated on the inside showing what actually happens. The resistance to movement caused by the corners of the journals may increase the tractive effort of this wheel. This might have happened had the journals been circular as shown by dotted lines in Fig. 2. In that case the effect would have been the same as in a normal wheel with a small slack in the bearing.

(d) As indicated by tests on flexibility (Annexure : V) a lack of flexibility also might have been a contributary cause.

11. On Jan. 24, 1947 Shri Nageswara Ayyar carried out tests on tractive effort employing an ordinary spring balance registering up to 100 lb for the purpose. Tests were carried out in Madras city on five types of road surfaces, viz., earth, W.B. Macadam, new W.B. Macadam, old bituminous surface and "bad" bituminous surface. The following results were obtained:

	Type I (Gross weight 3426 lb).	Madras cart (Gross weight 3367 lb)
Earth :	90 lb	—
W.B.Macadam.	80 to 88 lb	—
New W.B.Macadam.	84 to 88 lb	76 to 100 or more
Old bituminous road.	80 to 92 lb	60 to 100 or more
Bad bituminous road.	84 to 88 lb	76 to 100 or more
Average :	56 lb/ton	60 lb/ton
According to the present tests :	85.87 lb	74.5 lb



These results illustrate fully the Author's objections (para. 9 of Indian Roads Congress Paper 137) to the use of a spring balance for work of this type as it shows :

(1) Practically the same tractive effort on any type of road surface and,

(2) practically the same tractive effort for any type of wheel. This is because with a spring balance it is impossible to note the correct readings on account of continuous fluctuations. The dynamometer gives an automatic record of fluctuations on a graph so that an average can be worked out with a planimeter and checked at any time. The dynamometer also makes it possible to take tractive effort tests for three or more different loadings, so that the tractive effort line can be averaged to eliminate experimental errors.

III. The tractive effort of self-aligning wheels on curves.

12. Two pairs of normal wheels and two pairs of self-aligning wheels were tested for tractive effort, (a) during normal travel and (b) during travel on a superelevated curve to see whether a provision for self-alignment in a wheel increases its tractive effort on curves.

13. The following results were obtained :

	Normal travel	Travel on curves.	Difference per cent	Clearance on axle.
	per ton lb	per ton lb		
Normalwheels : 39″ × 2″ Nagpur (Annexure : VI, App. C)	102	124	+ 22	⅜ in.
67″ × 2″ Madras (Annexure : IV, App. E.5 item 9)	74.5	96	+ 29	⅛ in.
Self-aligning wheels : 60″ x 4″ Nageswara Ayyar's No.1:(Annexure: IV, App. E.5 item 13).	85.87	74.74	- 13	1¾ in.
60″ x 4″ Rubber fixtures (- Do - item 11)	54.03	57.17	+ 5.8	½ in.

14. These figures seem to indicate that the clearance on the axle influences the tractive effort of a wheel on curves. This is borne out by tests on Mr. Raju's wheels also (see Annexure: VI, para 6). The disadvantage is that the greater the clearance the greater is the wastage of the lubricant. Hence initially it may be restricted to about $\frac{1}{2}$ inch as, with this clearance the increase in tractive effort of self-aligning wheels on curves seems to be less than that of normal wheels.

APPENDICES:—

A: (a), (b) & (c): Tests on tilting: normal wheels.

B: (a) to (f) ,, ,, wheels with rubber fixtures.

C: (a) & (b) ,, ,, Nageswara Ayyar's wheels.

D: L.S. of a W. B. M. road on which tests on tilting were carried out.

E: (1) Tractive effort per ton of $36 \times 3\frac{1}{2}$ inch, $54 \times 3\frac{1}{2}$ inch & $66 \times 3\frac{1}{2}$ inch wheels rubber fixtures.

,, (2) Comparative T. E. of—do—with L.T.A. & C.I.B., & H.M.A. & M.S.B.

,, (3) Tractive effort per ton of 60×4 inch self-aligning wheels on a W.B. Macadam road.

,, (4) —Do —on a Cement Concrete Curve.

,, (5) Test sheet for wheels in (1) to (4).

F: L.S. of W. B. M. road on which the above tractive effort tests were carried out.

G: Comparative tractive effort of various wheels.

Annexure IV.
Appendix A.

Legend: H.M.A: Hand-Made Axle.
M.S.B: Mild Steel Bearing.

TESTS ON SELF-ALIGNMENT.
Existing Wheels.

Name and size of wheel	Fixtures	Position of wheel	Laden weight 1500 lb				Laden weight 3000 lb				Remarks
			Left wheel		Right wheel		Left wheel		Right Wheel		
			Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	
(a) Nagpur wheel 39″ × 2″ 30-4-49	H. M. A. and M. S. B: slack in bearing 1/8″, play on axle 3/8″.	1	—	Level	—	Level	—	Level	—	Level	Tilt insufficient for full tyre contact.
		2	1 in 64	1 in 24	1 in 64	1 in 20	1 in 64	1 in 20	1 in 64	1 in 24	
		3	1 in 64	1 in 18	1 in 64	1 in 20	1 in 64	1 in 18	1 in 64	1 in 18	
		4	1 in 72	1 in 20	1 in 64	1 in 24	1 in 72	1 in 24	1 in 72	1 in 20	
(b) Average Deccan wheel 53″ × 2″ 13-2-49	Do.	1	—	Level	—	Level	—	Level	—	Level	Do.
		2	1 in 52	1 in 20	1 in 104	1 in 30	1 in 52	1 in 24	1 in 52	1 in 22	
		3	1 in 52	1 in 20	1 in 52	1 in 24	1 in 52	1 in 22	1 in 52	1 in 20	
		4	1 in 52	1 in 18	1 in 52	1 in 20	1 in104	1 in 30	1 in 52	1 in 18	
(c) Madras wheel 67″ × 2″ 8-4-49	H. M. A. and M.S.B.; slack in bearing 1/32″, play on axle 1/8″.		Laden	Weight	2000	lb	Laden	Weight	3000	lb	Do.
		1	—	Level	—	Level	—	Level	—	Level	
		2	1 in 64	1 in 30	1 in 64	1 in 25	1 in 80	1 in 18	1 in 80	1 in 20	
		3	1 in 40	1 in 18	1 in 80	1 in 24	1 in 80	1 in 24	1 in 80	1 in 24	
		4	1 in 80	1 in 24	1 in 80	1 in 20	1 in 55	1 in 22	1 in 55	1 in 18	

Annexure IV.
Appendix B.

TESTS ON SELF-ALIGNMENT.

Wheels with rubber fixtures on Lathe-Turned Axles and Cast-Iron Bearings.

Size of wheel	Fixtures	Position of wheel	Laden Weight 2000 lb: Left wheel: Tilt of wheel	Laden Weight 2000 lb: Left wheel: Road camber	Laden Weight 2000 lb: Right wheel: Tilt o wheel	Laden Weight 2000 lb: Right wheel: Road camber	Laden Weight 3000 lb: Left wheel: Tilt of wheel	Laden Weight 3000 lb: Left wheel: Road camber	Laden Weight 3000 lb: Right wheel: Tilt of wheel	Laden Weight 3000 lb: Right wheel: Road camber	Remarks
(a) $53\frac{3}{8}'' \times 4\frac{1}{16}''$ 23-4-49	No sleeve and no padding; slack in bearing 1 32", play on axle 1 32".	1	—	Level	—	Level	—	Level	—	Level	Tilt is less than wheel of the same diameter used at present, App. A(b), owing to smaller slack.
		2	1 in 60	1 in 24	—	1 in 24	1 in 60	1 in 20	1 in 64	1 in 18	
		3	—	1 in 20	1 in 68	1 in 18	1 in 64	1 in 24	1 in 64	1 in 20	
		4	1 in 60	1 in 18	1 in 60	1 in 20	1 in 80	1 in 22	—	1 in 24	
(b) $53\frac{3}{8}'' \times 4\frac{1}{16}''$ 22-4-49	Rubber sleeves on the bearings, but no padding; slack 1/32", play 1/20" to 1/32".	1	—	Level	—	Level	—	Level	—	Level	Tilt is insufficient for full tyre contact.
		2	1 in 15	1 in 25	1 in 64	1 in 24	1 in 30	1 in 18	1 in 60	1 in 22	
		3	1 in 30	1 in 20	1 in 30	1 in 20	1 in 60	1 in 22	1 in 64	1 in 24	
		4	1 in 60	1 in 22	1 in 60	1 in 20	1 in 64	1 in 24	1 in 30	1 in 20	
(f) $53\frac{3}{8}'' \times 4\frac{1}{16}''$ (for c, d, e, see next page)	No rubber sleeves on the bearings, but 1" thick paddings on both sides.	1	—	Level	—	Level	—	Level	—	Level	Tilt insufficient for full tyre contact.
		2	1 in 60	1 in 20	1 in 48	1 in 24	1 in 48	1 in 24	1 in 60	1 in 18	
		3	1 in 52	1 in 18	1 in 60	1 in 20	1 in 60	1 in 20	1 in 80	1 in 24	
		4	1 in 80	1 in 24	1 in 80	1 in 18	1 in 52	1 in 24	1 in 48	1 in 20	

Legend:—L.T.A: Lathe-Turned Axle.
C.I.B: Cast-Iron Bearing.

Annexure IV.
Appendix B. (*Contd.*)

TESTS ON SELF-ALIGNMENT.

Wheels with rubber fixtures.

Size of wheel	Type wheel	Position of wheel	Laden weight 2000 lb: Left wheel: Tilt of wheel	Laden weight 2000 lb: Left wheel: Road camber	Laden weight 2000 lb: Right wheel: Tilt of wheel	Laden weight 2000 lb: Right wheel: Road camber	Laden weight 3000 lb: Left wheel: Tilt of wheel	Laden weight 3000 lb: Left wheel: Road camber	Laden weight 3000 lb: Right wheel: Tilt of wheel	Laden weight 3000 lb: Right wheel: Road camber	Remarks
(c) $53\frac{3}{8}'' \times 4\frac{1}{16}''$ 21-4-49	Rubber sleeves on the bearings, and paddings on inside.	1	—	Level	—	Level	—	Level	—	Level	Tilt is almost equal to road camber in majority of cases.
		2	1 in 21	1 in 22	1 in 30	1 in 30	1 in 21	1 in 20	1 in 21	1 in 22	
		3	1 in 20	1 in 20	1 in 21	1 in 22	1 in 14	1 in 18	1 in 14	1 in 18	
		4	1 in 30	1 in 30	1 in 60	1 in 24	1 in 13	1 in 24	1 in 21	1 in 20	
(d) i. $53\frac{3}{8}'' \times 4\frac{1}{16}''$ 20&21-4-49	Rubber sleeves on the bearings, and paddings on the outside.	1	—	Level	—	Level	—	Level	—	Level	Same result as with padding inside.
		2	1 in 16	1 in 18	1 in 32	1 in 30	1 in 20	1 in 30	1 in 21	1 in 22	
		3	1 in 20	1 in 20	1 in 20	1 in 20	1 in 24	1 in 25	1 in 24	1 in 24	
		4	1 in 40	1 in 30	1 in 40	1 in 25	1 in 21	1 in 22	1 in 20	1 in 20	
			Laden weight 1500 lb				Laden weight 3000 lb				
(d) ii. $36'' \times 3\frac{1}{2}''$ 13-4-49	Do.	1	—	Level	—	Level	—	Level	—	Level	Do.
		2	1 in 20	1 in 20	—	1 in 30	1 in 18	1 in 18	1 in 24	1 in 24	
		3	1 in 18	1 in 18	1 in 24	1 in 24	1 in 24	1 in 24	1 in 18	1 in 20	
		4	1 in 24	1 in 24	1 in 20	1 in 20	1 in 18	1 in 20	1 in 18	1 in 20	

TESTS ON SELF-ALIGNMENT.
Wheels with Rubber Fixtures.

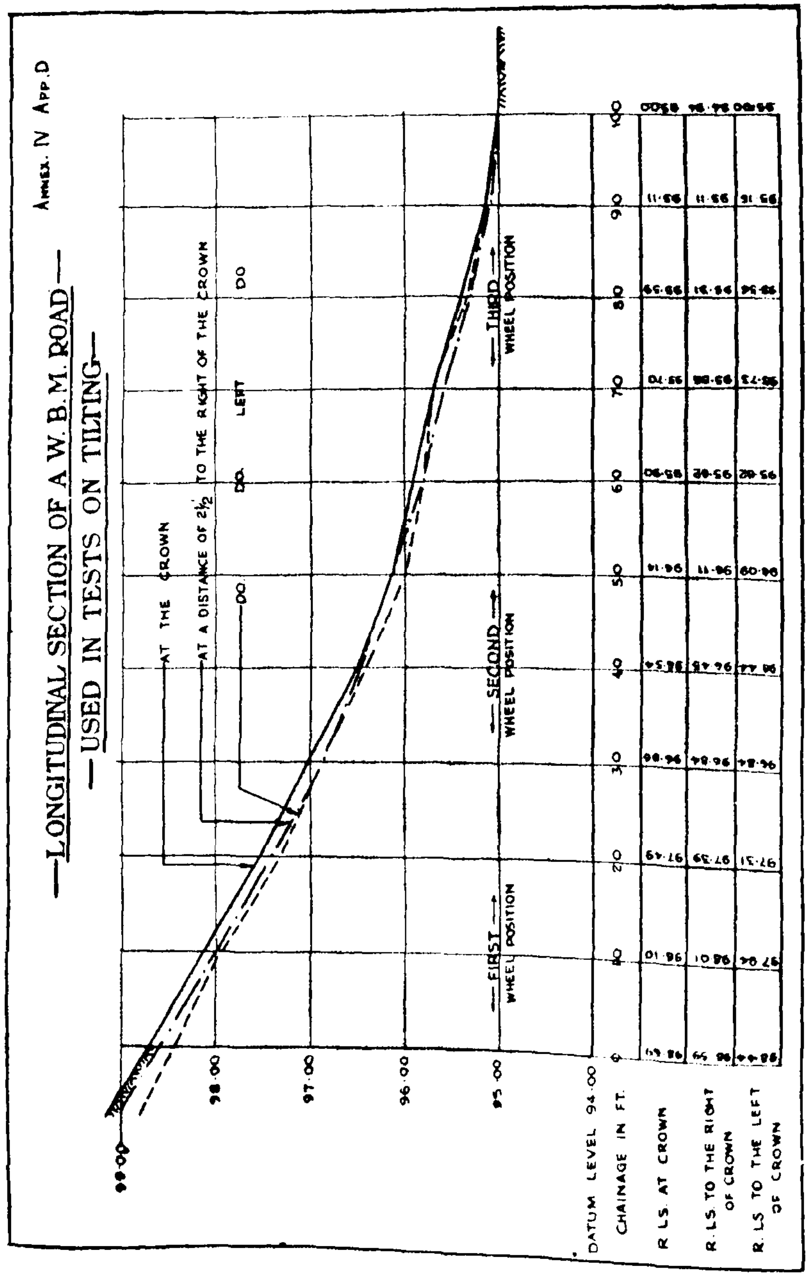
Annexure IV.
Appendix B. (*Contd.*)

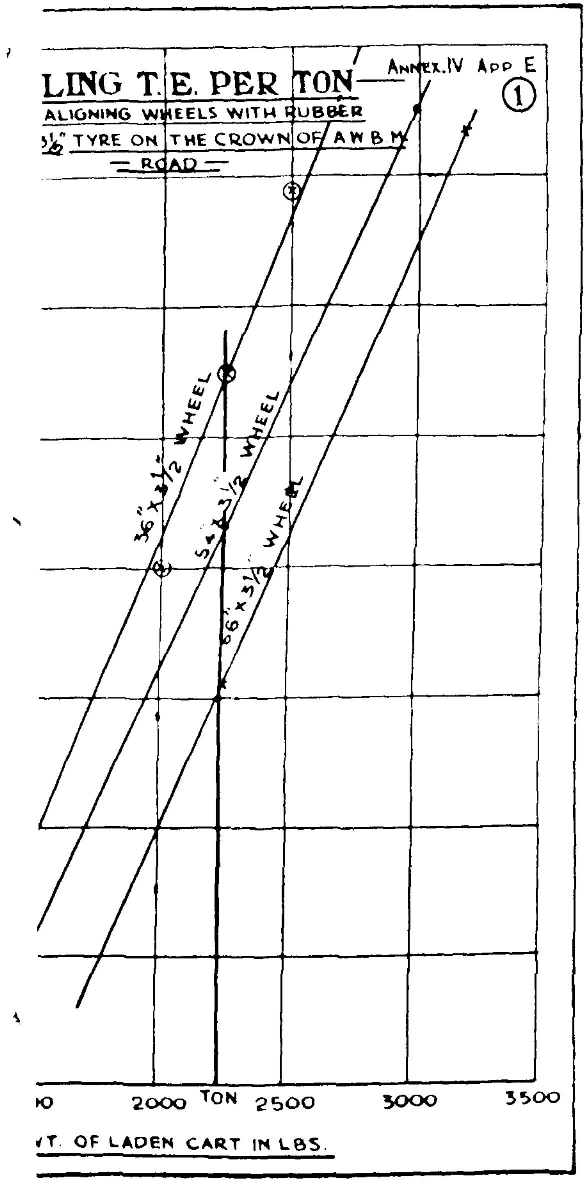
Size of wheel	Fixtures	Position of wheel	Laden weight 2000 lb				Laden weight 3000 lb				Remarks
			Left wheel		Right wheel		Left wheel		Right wheel		
			Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	
(e) i. $53\frac{3}{8}'' \times 4\frac{1}{16}''$	Rubber sleeves on bearings, and paddings on both sides.	1	—	Level	—	Level	—	Level	—	Level	Tilt is almost equal to road camber.
		2	1 in 20	1 in 20	1 in 28	1 in 30	1 in 24	1 in 24	1 in 24	1 in 24	
		3	1 in 24	1 in 24	1 in 20	1 in 18	1 in 16	1 in 18	1 in 20	1 in 20	
20-4-49		4	1 in 20	1 in 18	1 in 24	1 in 22	1 in 20	1 in 20	1 in 13	1 in 18	
			Laden	weight	1500 lb		Laden	weight	3000 lb		
(e) ii. $36'' \times 3\frac{1}{2}''$	Do.	1	—	Level	—	Level	—	Level	—	Level	Do.
		2	1 in 16	1 in 17	1 in 16	1 in 18	1 in 21	1 in 25	1 in 16	1 in 18	
		3	1 in 21	1 in 20	1 in 21	1 in 24	1 in 21	1 in 22	1 in 21	1 in 22	
12-4-49		4	1 in 21	1 in 20	1 in 21	1 in 20	1 in 16	1 in 18	1 in 21	1 in 24	
			Laden	weight	2000 lb		Laden	weight	3000 lb	Level	
(e) iii. $66'' \times 4''$	Do.	1	—	Level	—	Level	—	Level	—	1 in 20	Do.
		2	1 in 24	1 in 24	1 in 24	1 in 24	1 in 18	1 in 18	1 in 20	1 in 22	
		3	1 in 18	1 in 18	1 in 18	1 in 28	1 in 24	1 in 24	1 in 24	1 in 24	
5-4-49		4	1 in 20	1 in 20	1 in 24	1 in 22	1 in 20	1 in 22	1 in 24		

TEST ON SELF-ALIGNMENT.
Nageswara Ayyar's wheels (60 in. x 4 in).

Annexure IV.
Appendix C.

Details of wheels	Position of wheel	Laden weight 2000 lb				Laden weight 3000 lb				Remarks
		Left wheel		Right wheel		Left wheel		Right wheel		
		Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	Tilt of wheel	Road camber	
(a) Design No. 1:— C. I. Journal and spherical bearings. 1-6-49	1	—	Level	—	Level	—	Level	—	Level	Tilt insufficient for a full tyre contact.
	2	1 in 36	1 in 24	1 in 36	1 in 25	1 in 32	1 in 20	1 in 36	1 in 18	
	3	1 in 38	1 in 30	1 in 34	1 in 22	1 in 32	1 in 24	1 in 60	1 in 30	
	4	1 in 32	1 in 18	1 in 32	1 in 18	1 in 40	1 in 18	1 in 34	1 in 24	
(b) Design No. 2:— C. I. Journal and segmental casings. 7-6-49	1	—	Level	—	Level	—	Level	—	Level	Do.
	2	1 in 36	1 in 22	1 in 64	1 in 25	1 in 32	1 in 20	1 in 60	1 in 30	
	3	1 in 32	1 in 24	1 in 34	1 in 20	1 in 48	1 in 22	1 in 36	1 in 24	
	4	1 in 48	1 in 20	1 in 32	1 in 18	1 in 36	1 in 24	1 in 32	1 in 22	


LONGITUDINAL SECTION OF A W. B. M. ROAD
USED IN TESTS ON TILTING
ANNEX. IV APP. D
AT THE CROWN
AT A DISTANCE OF 2½" TO THE RIGHT OF THE CROWN
DO LEFT
DO
FIRST WHEEL POSITION
SECOND WHEEL POSITION
THIRD WHEEL POSITION
DATUM LEVEL 94·00
CHAINAGE IN FT.
R. LS. AT CROWN
R. LS. TO THE RIGHT OF CROWN
R. LS. TO THE LEFT OF CROWN
98·00
97·00
96·00
95·00
0
10
20
30
40
50
60
70
80
90
100


LING T.E. PER TON
ANNEX. IV APP E
①
ALIGNING WHEELS WITH RUBBER
3½" TYRE ON THE CROWN OF A W B M
ROAD
36"×3½" WHEEL
54"×3½" WHEEL
66"×3½" WHEEL
2000
TON
2500
3000
3500
WT. OF LADEN CART IN LBS.

Annexure V.

TESTS ON FLEXIBILITY.

1. The object of these tests was to ascertain whether a provision for flexibility in a wheel, self-aligning or non-self aligning, does or does not affect its tractive effort during travel over old worn-out road surfaces containing pot-holes and high spots.

2. Information regarding the extent to which the tractive effort is affected, if at all, may have been useful but this will depend upon a number of factors such as the number of pot-holes and high spots, their individual size and their location, i.e., whether they are under one or two wheels during travel. These factors will always vary from road to road and time to time and will be indeterminate. Hence no attempt was made to ascertain this point.

3. To ascertain the effect on tractive effort of travel over pot-holes a known number of pot-holes of a known size and known location were dug into a W.B.M. road (sketch in App. A) and iron *ghamellas* were buried into them to ensure that the sides of the pot-holes were not damaged by successive trips of a cart during tests and that the pot-holes were exactly the same throughout.

4. A pair of $54 \times 3\frac{1}{2}$ inch wheels was first tested, with and without provision for flexibility, on a W.B.M. road with no pot-holes. Then the same wheels were tested on the same road after making pot-holes in it. **The data thus relates to the same wheel, with and without provision for flexibility in it, on the same road, with and without pot-holes.**

5. The results are enclosed in App. B. & C. It will be seen from Appendix B that, on a road without pot-holes the tractive effort per ton of the flexible wheel was 67·75 lb against 59 lb of the same wheel without provision for flexibility. This is borne out by tests on similar wheels in the other series [Annexure IV, para. 10 (a) (i)] **where flexible wheels registered a greater tractive effort on the same road than a non-flexible wheel of the same diameter and tyre.**

6. This increase is understandable since the flexible wheel employed in these tests was also self-aligning and the latter has by its design a natural tendency to tilt and not to remain truely vertical. To the extent to which it is designed to tilt the wheel acts like a drag and requires a greater tractive effort. This is borne out by tests on non-flexible but self-aligning wheels which also register a greater tractive effort than non-self-aligning wheels during normal travel [Annexure IV, para. 10 (b) (ii)].

7. The same tendency and, therefore, the same relative difference in the tractive effort of a self-aligning and a non-self-aligning wheel should be expected during travel over the same road when pot-holes were dug into it. **But in the test the self-aligning wheel registered practically the same tractive effort as the non-self-aligning wheel (App. B), i.e., the results were just the opposite.** It is interesting to note there that the distance covered in these tests was 300 ft per test. Out of it the distance covered by the three pot-holes in the line of travel of each wheel in the 2nd test was 3 ft. 9 inch, i.e., 1·25 per cent of the total distance. That is, for 98·75 per cent of the distance the road was exactly the same as in the first test. Therefore, the relative tractive effort of the two wheels should have been the same as before on that distance.

8. The reason why this did not happen was that the non-self-aligning wheel required about 11 lb more tractive effort for travel over the pot-holes against only about 1 lb more required by the self-aligning wheel (Appendix C), thus indicating that **most of the increase in the tractive effort which the self-aligning wheel should have normally required during travel over pot-holes like the other wheel was absorbed by the flexibility of the self-aligning device in it.**

9. The dynamometer graphs of these wheels registered the following average tractive effort on sections of the road in between two consecutive pot-holes under a load of 3000 lb.

Wheel (1)	Distance (2)		Road without Pot-holes (3)	Road with Pot-holes (4)
Non-flexible :—(Sheets No. 3 & 9).				
Start to 1st Pot-hole	75′		80.2 lb	76.6 lb
1st ,, 2nd ,,	50′		78.8 ,,	94.0 ,, + 19.3%
2nd ,, 3rd ,,	50′		72.5 ,,	81.2 ,, + 12%
3rd ,, 4th ,,	50′		70.0 ,,	87.5 ,, + 25%
4th ,, Finish.	75′		78.0 ,,	103.0 ,, + 32%
Flexible :— (Sheets No. 6 & 12).				
Start to 1st Pot-hole	75′		92.5 ,,	93.5 ,,
1st ,, 2nd ,,	50′		82.0 ,,	97.8 ,, + 19.3%
		125′		
2nd ,, 3rd ,,	50′		84.0 ,,	81.3 ,, — 3%
3rd ,, 4th ,,	50′		93.5 ,,	91.6 ,, — 2%
4th ,, Finish.	75′		95.5 ,,	97.5 ,, + 2%
		175′		

These figures seem to suggest that **while each pot-hole affected the tractive effort of the non-flexible wheel only the first pot-hole affected the tractive effort of the flexible wheel, the remaining pot-holes in a distance of 175 ft. having no effect on it.** It is interesting that the percentage increase in the tractive effort of the two wheels after passing the **first** pot-hole and before reaching the second was almost the same.

10. If the above results can be taken to suggest that flexibility in a wheel does absorb impacts caused by successive pot-holes and, therefore, reduces the tractive effort of a wheel then the same results have naturally to be expected during travel on uneven road surfaces, especially like a W.B.M. road, since unevenness is made up of a series of successive miniature pot-holes. Therefore, the tractive effort of a flexible self-aligning wheel should be less than that of a non-flexible self-aligning wheel on a W.B.M. surface. (It is interesting to mention that under the same load on the same W.B.M. road the men employed to pull the test carts during these and other tests found the flexible wheels easier to pull).

11. To ascertain this a **60 × 4 inch** wheel was tested for a 1-ton loading on a **W.B.M.** road for tractive effort **first** with no provision for self-alignment and flexibility in it, **then** with provision for self-alignment only and **lastly** with provision for both. The following results were obtained :—

(1) **No self-alignment and no flexibility**: 60 × 4 inch wheel with a lathe-turned axle and C.I. bearing :	51.56 lb/ton	Items 10, 13, 14 & 11. App. E. (5), Annexure IV.
(2) **Self-alignment but no flexibility**: 60 × 4 inch Shri Nageswara Ayyar's wheel No. 1.	85.87 ,, ,,	
(3) **Both self-alignment and flexibility**: 60 × 4 inch wheel L.T.A. & C.I.B. with rubber fixtures :	54.03 ,, ,,	

The increase in the tractive effort of No. 3 over that of No. 1 is appreciably less than the increase in the tractive effort of No. 2 over that of No. 1.

12. Nos. 2 and 3 were also tested under a load of 3000 lb on an old bituminous road full of pot-holes of various sizes and location to see whether No. 3 registered a lower or higher tractive effort than No. 2 on successive pot-holes. At the time this test was

carried out, a **60 × 4 inch** wheel of No. 3 type not being available, a **54 × 4 inch** and a **66 × 4 inch** wheels were tested to obtain a mean of their tractive effort which naturally would represent the tractive effort of a **60 × 4 inch** wheel. The following results were obtained :—

1. **Self-alignment but no flexibility 60 × 4 inch Shri Nageswara Ayyar's wheel :** 143.5 lb for 3000 lb (Sheet **No. 13)**

2. **Both self-alignment and flexibility L.T.A. & C.I.B. with rubber fixtures**

(1) **54 × 4 inch wheel :**	84.50 ,, ,,	(Sheet No. 14)
(2) **66 × 4 inch wheel :**	**51.75** ,, ,,	(,, No. 15)
Mean for 60 × 4 inch wheel :	68.12 lb for 3000 lb	

Here also No. 2 registers a lower tractive effort than No. 1. It is interesting to note that the difference between the tractive effort of Nos. 2 and 3 on a W.B.M. road is (85.87 against 54.03 lb para. 11) about 58 per cent while the difference between the tractive effort of the same wheels on a pot-holed surface (143.5 against 68.12 lb para. 12) is about 115 per cent. **This confirms that on successive pot-holes a flexible self-aligning wheel requires a lower tractive effort than a non-flexible self-aligning wheel.**

13. The results discussed above suggest the following conclusions :—

(i) A wheel like a normal bullock cart wheel in use at present having no provision in it either for self-alignment or flexibility requires a greater tractive effort during travel on pot-holes on account of impacts caused by them (Cols. 3 and 4 of Table in **para. 9)**.

(ii) A self-aligning wheel with no provision for flexibility in it requires a greater tractive effort than a non-self-aligning wheel, on account of its natural tendency to tilt (1 & 2 para. 11).

(iii) With a provision for flexibility in it the increase in the tractive effort of a self-aligning wheel is reduced during travel over pot-holes (1 & 2 para. 12).

(iv) Flexibility also reduces the tractive effort of a self-aligning wheel during travel on a normal road surface like a W.B.M. having surface irregularities in it **(2 & 3 para. 11)**.

14. No conclusions regarding the extent of (ii), (iii) & (iv) above have been suggested for the following reasons:—

(i) Only one type of a non-flexible self-aligning wheel i.e. Shri Nageswara Ayyar's design was available for comparison with a wheel with rubber fixtures. More definite information on this point could have been had if Mr. Morgan's wheels also were available for testing.

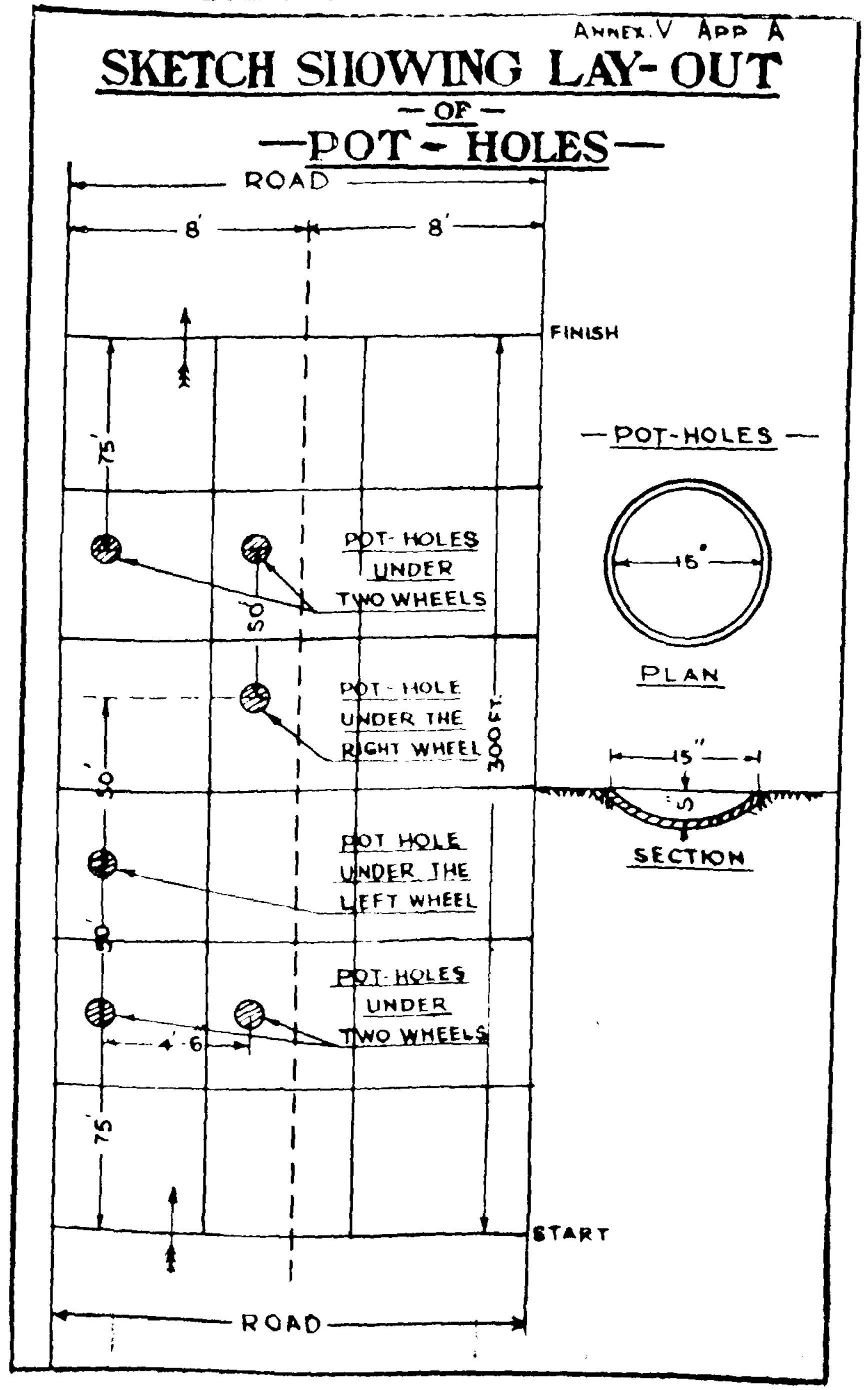
(ii) The increased tractive effort registered by the Nageswara Ayyar wheel is not due solely to self-alignment but to other causes also. Unless these causes are either eliminated or their effect on tractive effort ascertained it will not be possible to arrive at a figure for self-alignment only.

Appendices:—

A : Sketch showing lay-out of pot-holes.

B : Test sheet.

C : Tractive effort per ton.

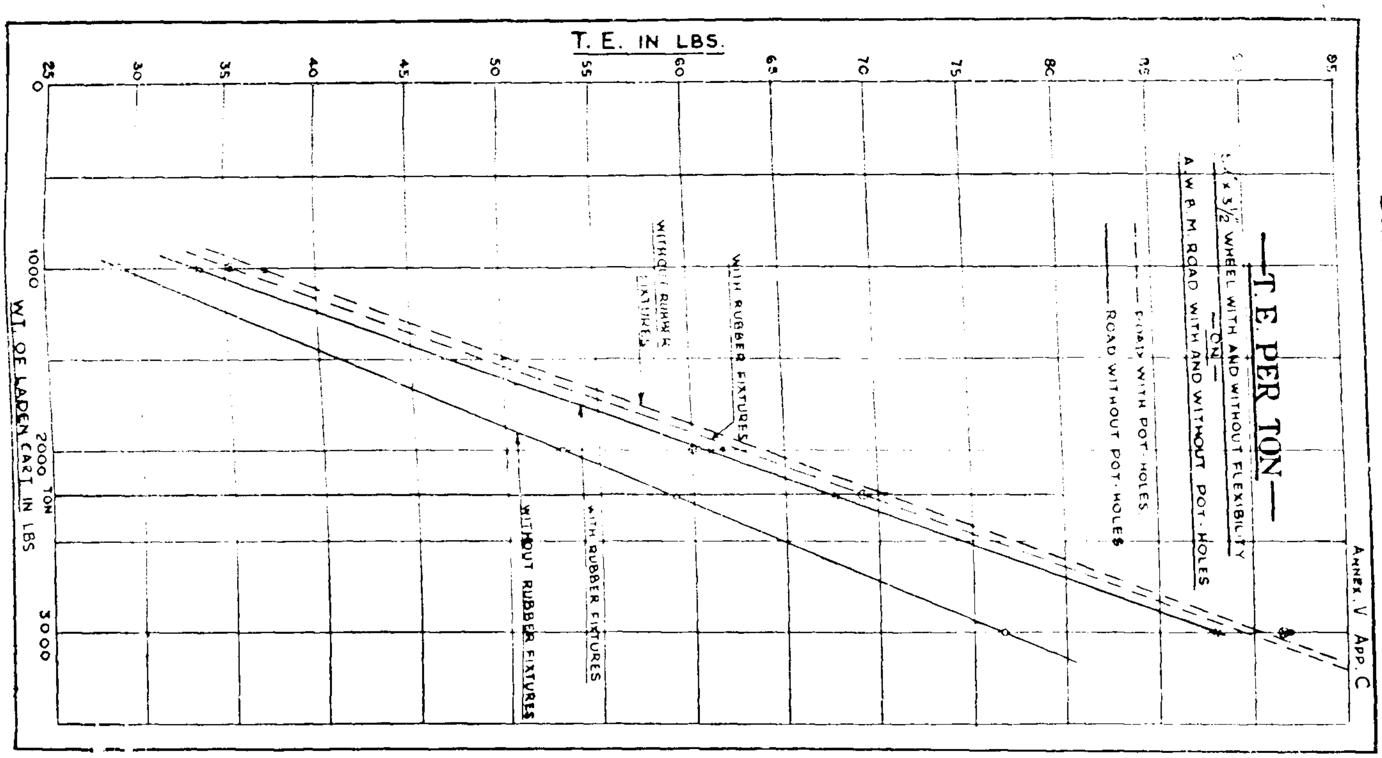


Annexure V.
Appendix B.

TEST-SHEET.

T. E. OF 54″×3½″ Wheel with & without Flexibility on a W. B. M. Road with & without Pot-holes.

Test sheet	Wheel dia. meter & tyre	Fixtures	Rolling T.E. under various loadings 1000 lb	2000 lb	3000 lb	per ton	Remarks
		I. On a road without pot-holes:					
1, 2, 3	54″×3½″	Without R. F.	29.32	53.38	76.74	59.00	R. F. means
4, 5, 6	Do.	With R. F.	33.28	61.00	88.00	67.75	rubber fixtures
		II. On a road with pot-holes:					
7, 8, 9	54″×3½″	Without R. F.	36.75	61.50	91.75	70.25	
10, 11, 12	Do.	With R. F.	34.90	60.00	91.60	69.00	



Annexure VI.

MR. RAJU'S ROLLER WHEELS

1. This is a patented design for a roller wheel (particulars in App. A) 1 ft in diameter and 2 ft long, to be employed in place of the two wheels in use at present in bullock-carts. Two guide rollers are fixed to the same axle to ensure that when the cart is astride the crown of a road and the full length of the roller wheel is not in contact with a road surface the cart may tilt on either the right or the left side and one of the guide rollers may come in contact with the road and increase the contact line. There is provision in the design for two roller bearings, one on each end of the main roller. The roller is mounted on a one inch diameter axle.

2. The basic idea of the design is as follows :—

(i) A maximum contact line to ensure a minimum load concentration on a road and, therefore, least damage to it.

(ii) As nearly as possible the same contact line when the cart is astride the crown of a road.

(iii) No increase in the tractive effort for the following reasoning :—

(a) From the cost point of view a roller wheel has necessarily to be of as small a diameter as possible.

(b) A small diameter is believed to increase the tractive effort of a wheel but a large tyre is believed to reduce it. Therefore, so long as the tyre of a wheel is sufficiently large it should counter-balance the effects on tractive effort of a small wheel diameter.

(c) As a further precaution roller bearings have been provided.

(d) Mr. Raju thinks that tractive effort has nothing to do with the tyre and the wheel diameter and it is solely a function of mass and velocity according to the following formula :—

$$P = \mu + 3\ 4\ mv^2$$

where μ = coefficient of friction

m = mass

v velocity

(points b, c, d are from a letter from Mr. Raju to the Bullock cart subcommittee).

These points will be considered below.

Damage to road surfaces.

3. Based on the wear and tear tests the following formula has been arrived at (para. 9 Annexure : II) between the tyre of a wheel and its diameter to obtain the same wear and tear of a road surface :—

$$T_2 = \frac{T_1}{0.9} \times \frac{D_1}{D_2}$$

According to it T'_2 of a roller wheel should be 20 inches with a diameter of one foot to produce the same wear and tear of a road surface as two wheels of an average diameter of 4 ft 6 in. and a tyre of 2 inches. (As the present range of wheel diameters in India is 3 ft 6 in. to 5 ft 6 in., 4 ft 6 in. has been taken to represent an average wheel diameter). Against it T'_2 is 2.4 inches in this design, i. e., 20 per cent more. Therefore, the saving in the wear and tear of roads with this roller wheel will be only about 20 per cent against 20 to 25 per cent of a 3 inch tyre, 35 per cent of a 3½ inch tyre and 40 per cent of a 4 inch to 5 inch tyre (para. 13 Annexure : II). **The design, therefore, defeats the very object for which it has been produced.**

4. It may be remembered here that 0.9 in the above formula is based on the results of tyres of 4 inch to 5 inch widths. There is no data on tyres wider than 5 inches and, in all probability, the figure will be appreciably less in the case of very wide tyres which will bridge over depressions in road surfaces and, therefore, will have a proportionately less line of contact than narrower tyres. In that case the saving in damage to road surfaces will be still less.

Contact line during Tilt.

5. Results of tests on tilting (App. B) show that the combined line of contact of the main roller and one or the other of the guide rollers when the cart was astride the crown of a W. B. M. road varied from 18 inches to 22 inches against the full width of 24 inches. On a superelevated curve a full contact could be had. As the length of guide rollers in the wheels tested was 4½ in. against 9 in. shown in the drawing it is reasonable to assume that with 8 in. guide rollers the contact line during a tilt may be nearly about the same as when the cart is on a level surface.

Tractive Effort.

6. The tractive effort of this wheel as compared to that of the smallest wheel in use at present (App. C) was as follows :—

	W. B. M.	C. C. Curve.	
Raju wheels	170 lb/ton	157 lb ton	Same level of the cart in both cases
Nagpur wheels 39 in. × 2 inch.	102 ,, ,,	124 ,, ,,	

The difference in the case of W. B. M. is about 70 per cent which is more than can be offset by roller bearings of the type employed in Dunlop bullock cart wheels which are believed to reduce the tractive effort by about 35 to 40 per cent per pair. On curves the roller wheel requires less tractive effort than on a straight portion on account of a clearance of one inch provided in the design. This enables the wheel to slide on curves more easily than a normal wheel. The wheel was not tested on pot-holes as it was feared that the axle and chassis would not stand the strain.

7. **Thus in respect of damage to road surfaces and tractive effort a roller type wheel does not seem to come up to expectations.** Besides there are other points.

Other points.

8. They are as follows :—

(i) A wooden roller wheel made of unseasoned wood is bound to crack and will have to be repaired or renewed frequently. In the wheels sent for testing all the rollers showed big cracks.

(ii) It will not be easy to fix a 1/4 inch steel plate to a wooden roller. It cannot be shrunk and will have to be fixed with screws which procedure is unsound. In the wheels sent for testing a G. I. sheet was nailed to the roller.

(iii) A 1/4 inch plate will not retain its shape for a long time. This will cause uneven wear. From the design point of view a 1/2 inch to 5/8 inch steel plate without a wooden roller inside should be a better proposition.

(iv) A one inch axle is not sufficient. In the tests on tractive effort it buckled at 2000 lb. It should not be less than $1\frac{3}{4}$ inch for urban carts and $1\frac{1}{2}$ inch for rural carts.

(v) The chassis also is weak. It buckled under a load of 2000 lb.

(vi) The width of the cart shown in the drawing is about 2 ft 2 in. against a normal width of about 3 ft 6 in. of existing carts. This means that with the latter the roller will have to be about 3 ft 4 in. long, instead of 2 ft shown in the drawing.

(vii) A vehicle must be capable of negotiating the worst conditions of travel, e.g., a road with deep-ruts or obstructions. For this purpose it is customary in a wheel-design to provide a clearance of about 18 inches between the body of a vehicle and the road. By placing a roller in this clearance you accentuate difficulties in travel. On the assumption that a roller wheel becomes universal there may be no ruts in a road surface after a number of years but there will be obstructions.

(viii) Including roller bearings the three rollers and the frame would cost more than the wheels in use at present. They will also be more expensive to maintain.

(ix) Wheel-rights will take some time learning to manufacture true cylindrical rollers.

(x) The lubrication of the wheels is defective.

APPENDICES :

A : Drawing of wheel & a note on it.

B : Tests on tilting.

C : Tractive effort per ton.

Annexure VI.

Appendix A.

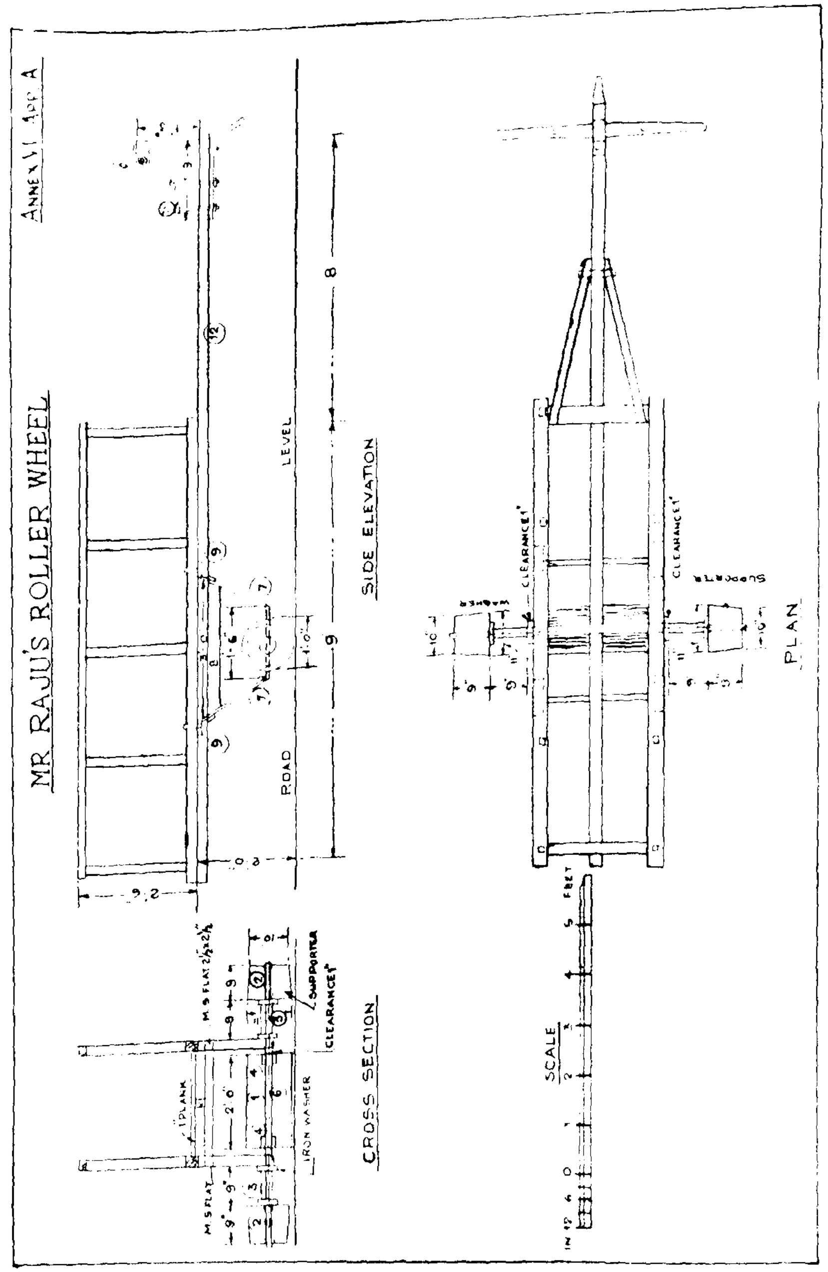
MR. RAJU'S ROLLER WHEELS.

(*Descriptive note by Mr. Raju*).

"According to this invention, the cart is fitted (see drawing opposite) with a roller (1) of 2 ft length and 1 ft diameter, made of *babool* wood and encased with a mild steel plate of $\frac{1}{4}$ inch thickness, and two free wheels, (2), one on either side, each of 9 in. length and 11 in. diameter at one end and 10 in. at the other made up of *babool* wood encased with mild steel plate of $\frac{1}{4}$ in. thickness. A hard tool steel rod of one inch diameter passes through the centres of the roller and the two free wheels and acts as an axle. (6) The roller and wheels are connected to the body of the cart by a frame (7) of flat steel of 2 in. $\times \frac{1}{2}$ in. section. The frame is fixed to the steel axle by means of clamps and bolts and nuts. Only the roller and wheels rotate freely on the axle. Two roller bearings (4) one at either end of the roller are provided for free movement. Mild steel bushes are provided, one at each end of the wheels for easy movement. The side wheels are placed 6 inches away from the frame by providing steel collars (3) and they act as supports when the body of cart tilts. For keeping the frame stiff and for supporting the body of the cart and transmitting the load of the cart to the roller two mild steel ties (8) of 2 in. $\times \frac{1}{2}$ in. section are fixed to the frame one on each side of the roller.

The steel frame is connected to the body of cart by bolts and nuts (9) so that, whenever necessary, it may be disconnected. To suit to the height of bullocks, the yoke (10) is raised by providing a wooden piece (11) on the main wooden shaft (12) of the cart.

On account of a roller of two feet length introduced in place of two wooden wheels of 2 in. to 3 in. width, the intensity of load on the road surface is largely reduced, and consequently the damage to the road surface. Instead of cutting action of bullock cart wheels due to narrow width, rolling action is introduced and consequently the strengthening of the road surface. While a pneumatic tyred wheel of a fast moving vehicle loosens the road structure due to suction action of tyres and causes formation of pits, the roller hardens the road structure due to rolling action".



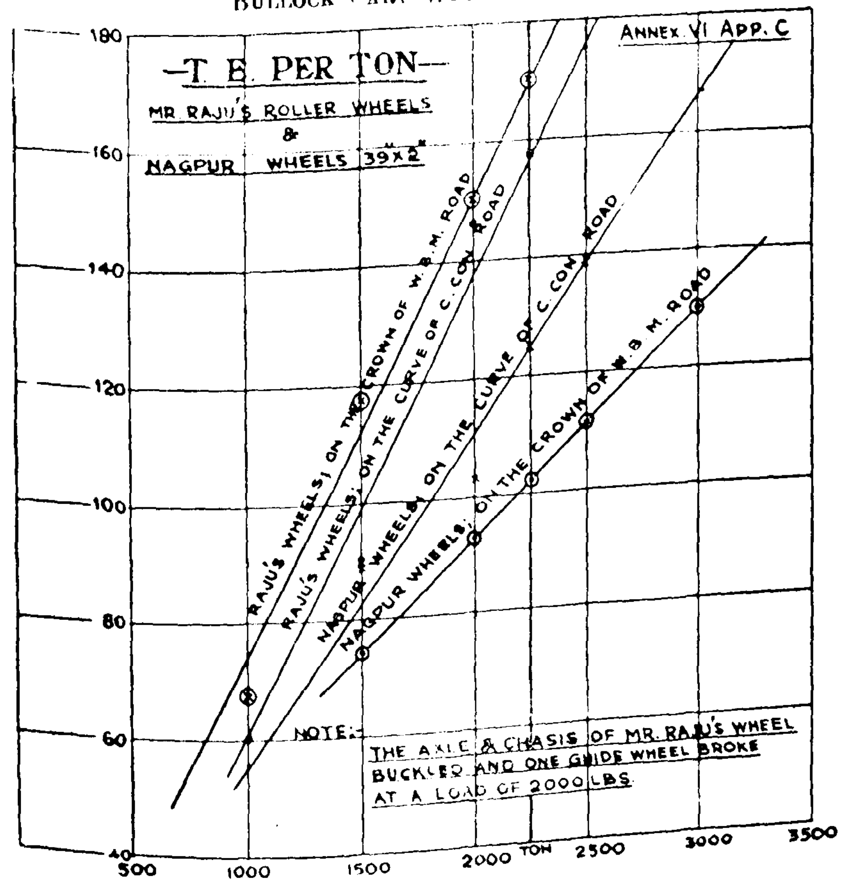
Annexure VI.

Appendix B.

TESTS ON TILTING ON MR. RAJU'S WHEELS.

Left guide wheel	Central roller wheel	Right guide wheel	Total line of contact
(1) The crown of a W. B. M. road; camber 1 in 18 to 24			
3″	18″	—	21″
—	18″	—	18″
2″	18″	—	20″
—	20″	2″	22″
—	18″	—	18″
—	18″	2″	20″
—	16″	3″	19″
3″	18″	—	21″
—	18″	—	18″
2″	16″	—	18″
—	18″	2″	20″
(2) Superelevation of a cement concrete curve			
1″	21″	1″	23″
½″	23″	½″	24″
—	24″	—	24″
¼″	23″	¾″	24″

With regard to (1) it may be noted that when a cart is astride the crown of a road only 12 in. of the central roller should contact a road surface assuming that the cart is dead on the crown. In the tests on tilting the test cart deviated from the crown on both sides by about 6 in. and it had to be stopped and started every few feet to take measurements. This deviation was particularly noticeable in these wheels on account of their natural tendency to tilt on the crown of a road.



TEST SHEET

WHEEL	ROLLING T. E. UNDER VARIOUS LOADS.					
	1000 LBS	1500 LBS.	2000 LBS	2500 LBS	3000 LBS	PER TON
			(a) ON THE CROWN OF W. B. M ROAD			
(1) RAJU'S WHEEL 12″x 2 FT.	67·38	117·25	150·00	-	-	170·00
(2) NAGPUR WHEEL 39″x 2″		74·13	92 50	112·00	130·12	102 00
			(b) ON THE CURVE OF C. CON. ROAD			
(1) RAJU'S WHEEL 12″x 2 FT	59 86	88·95	145 75	-	-	157·00
(2) NAGPUR WHEEL 39″x 2″		88 75	103 01	138·60	-	124·00

Annexure VII.

SUMMARY OF TESTS

Test Serial No.	Description	Location	Number of Dynamometer sheets	Period
1	Tests on tractive effort with Dynamometer No. 1 (para 5 Encl: II, I.R.C. Paper No. 137).	College of Engineering, Poona.	492	September to December 1947
2	Tests on tractive effort with Dynamometer No.2 (Encl: II, I.R.C. Paper No. 137).	Do.	55	
3	Tests on tractive effort with Dynamometer No.2 (Encl: III, I.R.C. Paper No. 137).	Test track Majherhat.	72	January 1948
4	Tests on wear & tear of roads (Encl: IV, I.R.C. Paper No. 137 & Encl: II, the present Paper).	Do.	six series of about 200 miles each	February to December 1948
5	Tests on tractive effort with Dynamometer No.2 on 2″ & 3½″ tyres with various bearings (Annexure: III, the present Paper).	College of Engineering, Poona	36	April to July 1949
6	Tests on tractive effort with Dynamometer No. 2—self-aligning wheels (Annexure: IV, the present Paper).	Do.	50	
7	Tests on tractive effort with Dynamometer No. 2—Tests on flexibility (Annexure: V, the present Paper).	Do.	15	

Summary of Tests *(Contd.)*

Test Serial No.	Description	Location	Number of Dynamometer sheets	Period
8	Tests on Mr. Raju's wheel (Annexure: VI, the present Paper)	College of Engineering, Poona.	9	April to July 1949
9	Tests on pot-holes; various wheels (Annex: V, the present Paper).	Do.	18	
10	Tests on tractive effort with Dynamometer No. 2 various wheels employing bullocks (para. 6, Annex: III, the present Paper).	Do.	130	December 1948
11	Tests on Tilting by measuring tyre contact (para 6 Annex: IV, the present Paper).	Do	Field book	November 1948 & January 1949
12	Tests on tilting by measuring wheel incline (App. A, B & C Annex: IV, the present Paper).	Do.		March to May 1949

Annexure VIII.

COMMENTS RECEIVED FROM BULLOCK-CART SUBCOMMITTEE MEMBERS.

Comments received from the members of the Bullock-Cart Sub-Committee to whom advance copies of the Paper were sent, are discussed below :

1. **Comment**: It does not seem to have been generally accepted that wheel-diameters should be chosen solely on considerations of cost since the tractive effort will depend not only on the diameter as such but also on the angle of pull on the axle as transmitted from the yoke on bullocks' necks. For example, if the axle is 18 inch high (a wheel of 36 inch diameter) and the yoke is 28 inch high (tall bullocks) the tractive effort will be sensibly increased by the resolved vertical component of the pull at the yoke transmitted by the sloping shaft.

   Reply :—This is true if a cart is inclined but it is not necessary at all for it to be inclined whatever the height of bullocks and the wheel-diameter. The normal practice is to jack up the cart by adjusting the depth of the cross beam supporting it to suit the height of the bullocks. As all tests on tractive effort were carried out in this position of the cart and the proposed wheel-diameters are based on them there need be no variation in the tractive effort so long as a cart is kept parallel to the road surface.

   It has been found in our survey of wheels in use all over India that wheel diameters bear no relation to the height of the bullocks.

   This point will be discussed in detail in Part V of this series of Papers.

2. **Comment** :—Minor variations in wheel-diameters may not be a serious factor in determining the cost of manufacture since the cost of any extra unshaped wood required for the bigger wheels will probably be small. Variations in the weight of wheels by themselves also may not be an important factor since the wheels themselves will be only small element in the weight of the loaded cart.

Reply :—Based on the practice of wheel wrights in Bombay, the dimensions of unshaped logs of wood required for the felloe, spokes and hub work out as follows :

Felloe :—Length of log $= R + 2''$ } See drawing below

Diameter : $= \sqrt{(D - d + 1'')^2 + 9(B + \frac{3}{4}'')^2}$

where : R = Radius of wheel excluding tyre

D = Depth of felloe (larger dimension)

d = Depth of curvature $= 0.134\ (R - D)$

B = Breadth of felloe (smaller dimension)

Spokes :—Length = Full length of spoke + 2 inches.

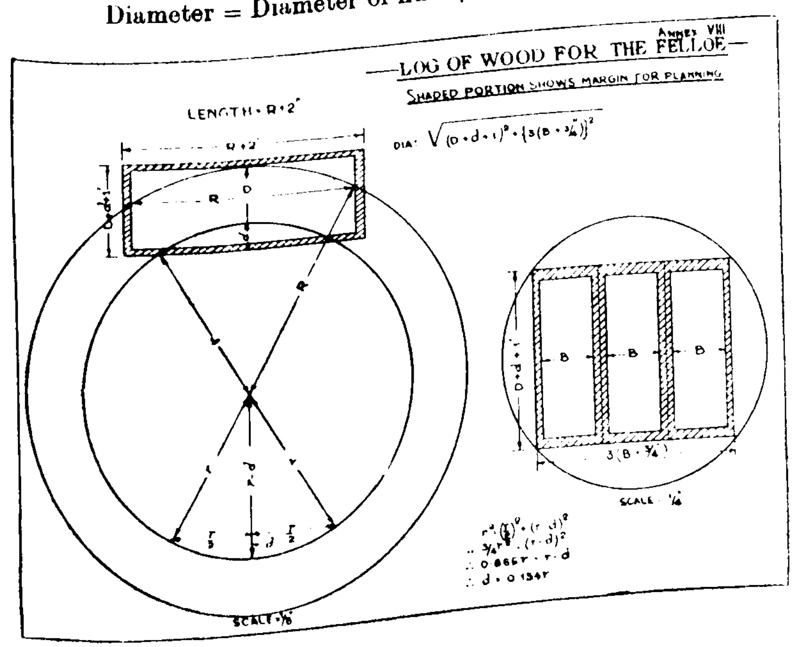
Diameter $= \sqrt{(W + 1'')^2 + 9(B + \frac{3}{4}'')^2}$

where W = width of spokes (larger dimension)

B = Breadth of spoke (smaller dimension)

Hub : Length = Length of hub + 2 inches.

Diameter = Diameter of hub + 2 inches.



Note :—A greater margin for planing is allowed here as logs are not truly circular while a hub has to be truly circular. According to the above, the quantity of unshaped wood in a wheel of an average diameter of 4 ft 6 in. works out to 504 lb against the actual weight of the felloe, spokes, and hub of 137 lb only. Therefore, the quantity of unshaped wood required in the construction of a wheel is considerable.

Out of this wood weighing 504 lb 60 per cent goes into the felloe, the quantity of wood required for which varies as the radius of the wheel Hence, an increase in the wheel-diameter will influence the cost of a wheel appreciably.

Finally, the weight of the steel tyre, which is very nearly the same as that of the felloe, and which is not a small factor in the cost of a wheel, varies as πD. Here also the wheel diameter affects costs. The weight of a loaded cart comes into the picture with regard to the tractive effort and not the cost of wheels. The cost must be influenced by the weight of a wheel since the greater the weight the greater is the quantity of unshaped wood as shown above.

3. **Comment**:—Wide tyres may not be suitable for all rural areas since it may be difficult to pull a cart with wide tyres through sticky clay soils. Carts in rural areas, where the soil is sticky clay, all have narrow tyres, which cut through the clay and reduce the tractive effort.

Reply:—(a) This assumption would be correct had narrow tyres been confined in actual practice to tracts of sticky clay only. A survey of bullock cart wheels has revealed that narrow tyred wheels exist over the greater part of India, extending from Gwalior to Trivandrum in the North-South direction and Okha to Sambalpur in Bihar and most of Assam in the West-East direction and covering a wide range of soils. This fact shows that the sole consideration in evolving the present narrow tyre is to protect the wooden felloe at a minimum cost. The wheel-wrights and carters' anxiety to reduce cost is noticed in every single item of his wheels including the wheel-diameter and its tyre.

(b) It is not clear why it should be difficult to pull a cart with wide tyres through sticky clay soils. The sinking of a cart is caused by the concentration of load on its tyres. If they are narrow they will sink more; if they are wide they will sink less. Now the greater the sinking the greater is the tractive force. Hence, the pulling of carts with wide tyres through soft soils should be easier.

4. **Comment** :—The results of the wear and tear tests have been arrived at by taking the average wear on all four tracks. If the wear on different tracks is analysed separately (as seems reasonable as the rate of wear on each track is self-consistent) the conclusion forced on one is that there is no relationship between an increase in the width of a tyre and a reduction in the diameter of a wheel.

Reply:—(a) In support of the above point the member concerned has given the following figures from the Author's Papers :—

	Wheel size	South Outer	South Inner	North Inner	North Outer	Remarks
Results published in App. B, C, D in Vol. XIII-2.	54″ × 2″	·43	·37	.43	.38	
	,,	.47	.37 ?	·37 ?	.22 ?	
	,,	.48 ?	.55 ?	.55	.45 ?	
	54″ × 3½″	.28 ?	.25	.22	.17 ?	
	54″ × 4″	.27	.23 ?	.15 ?	.20 ?	
	54″ × 5″	.20	.25	.18	.27	
			(2)			
Results now given in App. A to Annexure II.	54″ × 5″	.23 wet surface	.20	.12	.15	Wet surface; results disregarded.
	36″ × 5″	.19	.20	.18	.18	
	54″ × 5″	.15	.17	.10	.05	
	66″ × 4″	.10	.15	.12	.05	
	54″ × 5″	.12	.10	.13	.12	

(b) These figures have been wrongly compiled for the following reasons :—

(i) The wear on all tests for the 45 in. × 2 in. wheel in (1) has been lumped up together. This is not correct as each test had a fresh road surface (para. 5 p 228, I. R. C. Paper No. 137). Hence, **figures for each test have to be considered separately.**

(ii) Figures for "North Inner" are for "North Outer" and those for "North Outer" are for "North Inner".

(iii) The averages in ten (shown thus ?) out of 24 cases in series (1) have been wrongly worked out.

(c) Correct figures are as follows :—

(1)

Wheel	South Outer	South Inner	North Outer	North Inner	Average	Maximum variation.
			(i)			
54″ × 2″	0.43	0.37	0.43	0.38	0.403	0.06
54″ × 3½″	0.25	0.25	0.22	0.18	0.225	0.07
			(ii)			
54″ × 2″	0.47	0.40	0.45	0.28	0.400	0.19
54″ × 4″	0·27	0.27	0.13	0-22	0.223	0.14
			(iii)			
54″ × 2″	0·52	0.55	0.55	0.48	0.525	0.07
54″ × 5″	0.20	0.25	0.18	0.27	0.225	0·09
			2. (i)			
54″ × 5″	0.23	0.20	0.12	0.15	0.175	0.11
36″ × 5″	0.19	0.20	0.18	0.18	0.188	0.01
			(ii)			
54″ × 5″	0.15	0.17	0.10	0.05	0.118	0.12
66″ × 4″	0.10	0.15	0.12	0.05	0.105	0.10
			(iii)			
54″ × 5″	0.12	0.10	0.13	0.12	0.118	0.03
36″ × 5″ (Pneumatic tyres)	0.08	0.03	0.12	0.08	0.078	0.09

Note :—Although the above averages have been worked out to two places of decimals it is important to note that the track measurements were taken to only one place of decimal.

(d) Now let us consider this member's conclusions based on the wrong data in (a) with the correct data in (c).

Conclusion.

The above table [that in (a)] shows from an analysis on each track that :

(i) For the same wheel-diameter a 2-in. tyre does far more damage than wider tyres.

(ii) The wear does not seem to decrease when the width of tyres is made more than 4 in.

(iii) The following further results may be considered.

Wheel	Wear			
66″ × 4″ :	0·10	0.15	0·12	0·05
36″ × 5″ :	0·19	0·20	0·18	0·18
54″ × 5″ :	0·12	0·10	0·13	0·12

These figures would seem to show that more wear is caused by the smaller wheel and this is perhaps what one would expect because the relative speed between the tyre and the road in a small wheel is greater than in a big wheel. Wear must, it is presumed, be largely a function of speed.

Reply.

(i) The correct table in (c) bears this out. Nor was this point ever in doubt.

(ii) According to (c) the relative wears work out as follows :—

		3½″	4″	5″
I.	% wear :	0.56	0.56	0.43
II.	% Tyre width ;	0.57	0.50	0.40
III.	% II to I :	100%	90%	93%

That is, up to 3½ in. the full width is effective. Between 3½ in. & 5 in. only 90 per cent is effective. It will be seen that these figures have been taken in the Author's calculations.

(iii) As the 54 in. × 5 in. wheel was re-tested with the other two wheels the correct procedure is to compare its figures with those of the other wheels separately as in (2) (i) & (ii) in para. (c) above & not together. The average wear of 36 in. × 5 in. is 0·188 against 0·175 of a 54 in. × 5 in. The wear of the smaller wheel is undoubtedly more but that is not on account of speed which was the same for both wheels it being electrically controlled. The reason is that for the same tyre the wear is inversely proportionate to the wheel diameter. The test shows that it is 7 per cent of the inverse ratio of wheel-diameters in the case of these two wheels.

For the same speed in these tests a smaller wheel will make more revolutions per minute but it will cover the same length of the track in the same time as the bigger wheel.

(iv) It is rather surprising that there should be such wide variations in the wear shown in the four tracks. Perhaps the tracks showing heavy wear were lower and therefore moister than others. The results of all four tracks are, however, self-consistent and cannot be ignored.

(iv) According to figures of correct wear in para. (c) the maximum variation is from 0·03 in. to 0·12 in. (*and not wide variations*) in all cases but two. In the latter it is 0·14 in. & 0·19 in. The road had no camber so that all tracks were at the same level. The gross loading, speed and fixtures were also the same. The climatic conditions **during each sub-series** (not all sub-series) were also the same. The only variable was the condition of the W. B. Macadam, which, by the nature of its construction, **cannot** have the same profile, same consolidation, same amount of water and same blindage everywhere. Finally soft stones were used in this construction to obtain accelerated wear and some of them broke during rolling. In these conditions a variation of upto 1/5th inch on any one track in one sub-series does not seem unrepresentative of normal variation in the profile of such a surface.

(v) These conclusions are the very opposite of those arrived at in the draft Paper.

(v) In the **first place** these conclusions (in the comments) are based on wrongly compiled data in para. (a).

In the **2nd place** conclusions (i), (ii) & (iii) are identically those recorded in the Paper and not "the very opposite".

(vi) It does not yet seem to be fully established in view of what is said above that a smaller wheel produces less wear as mentioned in para. 8 of the Paper.

(vi) Para. 8 does **not say that a** smaller wheel produces less wear. The latter being a function of both the tyre and the wheel-diameter the term "small wheel" without a reference to the tyre employed does not convey an exact meaning.

(e) The basic point in this discussion is: "**What is the objective?**" Is it to ascertain the wear on a road surface or variations in its levels? If it is the former, one **must** average the wear on all four tracks since a cart creates four tracks in a road, two outgoing and two incoming and the average wear of the road **must** be the average of these four tracks. On the other hand if the objective is to ascertain the variations in the levels of a road surface then one must compare the average wear in each track, since everything other than variations in road levels was the same. **Tests were carried out to ascertain the wear.**

5. **Comment**:—It has been suggested that the Arm-type wheel should be replaced with a Spoke-type wheel. This will not be easy to do as this type has just as firmly been established as the other and, therefore, whatever improvements are considered necessary should aim not at replacing the Arm-type but retaining it like the other.

Reply:—The sole justification for an Arm-type wheel is its wide tyre. This disappears with the employment of wide tyres on Spoke-type wheels. Hence, it was suggested that for the purpose of standardisation only one type of wheel should be employed throughout India, it being the one which is used by a larger number of carters, viz: the Spoke-type. However, a census completed lately has disclosed that the number of Arm-type wheels in India spread over five States is considerable and it will obviously be impossible to replace this large number. Hence, the Arm-type wheel is now proposed to be retained like the Spoke-type with such changes in its wheel-diameter, tyre, hub and axle-equimpment as are found necessary in the light of this investigation.

6. **Comment**:—In the Table in Annexure: II App. C., the saving in the wear of road surfaces has been shown directly proportional to the width of tyres. As wear varies inversely as the width of a tyre the saving should

be worked out inversely. Para. 7 of the same Annexure mentions that upto $3\frac{1}{2}$ inches the full width of a tyre is effective yet in the formula only 90 per cent of it has been assumed as effective. It would be more correct to apply the 90 per cent allowance to tyres of 4 in. to 5 in. only. It would be interesting to see how the Table in App. C works out with the two amendments mentioned above.

Reply :—(a) This Table and also that in App. D work out as shown opposite on the basis mentioned above with which the Author agrees. It will be seen that this table confirms the comparison arrived at previously which is the main point and the $3\frac{1}{2}$ in. tyre with wheel-diameters which can be employed with it within the cost of the present wheels produces the greatest saving which is about 33 per cent. It may be pointed out that this must be considered the minimum saving since it has been based on the assumption that road wear varies inversely as wheel diameters to the extent of 100 per cent. This is not correct since a small wheel sinks less than it should in proportion (inverse) to its wheel-diameter than a large wheel on account of the upward pressure of the consolidated surface below it. Hence, the ratio of the wear will not be $\frac{D_1}{D_2}$ but $C.\frac{D_1}{D_2}$, C being less than unity. Therefore, the value of T_2 in Col 3 in this Table will be less than shown, the wear in Col. 6 also will be less than shown and therefore the saving in Col. 7 will be more than that shown.

(b) C will depend on the type of road surface employed. We have no data on this point since the wear and tear tests were carried out on one type of surface only. However it is possible to know the maximum saving. This in any road surface will arise when a tyre is widened for the same wheel-diameter. In the case of a widening of 2 in. to 3.5 in. this will be $1 - \frac{2}{3.5} = 43$ per cent.

Hence the minimum saving is 33 per cent and the maximum 43 per cent with an average of about 38 per cent which should prove as nearly accurate as possible for all practical purposes.

Annexure VIII (*Contd*)

	4	5	6	7
	$3\frac{1}{2}$" TYRE			
D2 for Wear as ×T1)	Proposed T2 i.e. A	Effective T2 : 100% upto $3\frac{1}{2}$" & 90% above	Wear with A inversely to col. 3	% Saving
= 2.34"	$3\frac{1}{2}$"	$3\frac{1}{2}$"	$\frac{2.34}{3.50} = 67\%$	33%
= 2.46"	,,	,,	$\frac{2.46}{3.50} = 70\%$	30%
= 2.40"	,,	,,	$\frac{2.40}{3.50} = 68\%$	32%
= 2.35"	,,	,,	$\frac{2.35}{3.50} = 67\%$	33%
= 2.31"	,,	,,	$\frac{2.31}{3.5} = 66\%$	34%
	$4\frac{1}{2}$" & 5" TYRE			
	Same as in Group 1			
= 3"	$4\frac{1}{2}$"	4.05"	$\frac{3}{4.05} = 74\%$	26%
= 2.86"	$4\frac{1}{2}$"	4.05"	$\frac{2.86}{4.05} = 70.6\%$	29.2%
or			or	or
= 3.22"	5"	4.50"	$\frac{3.22}{4.50} = 71.5\%$	28.5%
= 2.93	$4\frac{1}{2}$"	4.05	$\frac{2.93}{4.05} = 72.3\%$	27.7%
or				
= 3.14	5"	4.50	$\frac{3.14}{4.50} = 70\%$	30%

Paper No. 149.

"Standards for Sight Distances for Highways."

By the Specifications & Standards
Committee of the Indian Roads Congress.

[Following precedent, the recommendations of the Specifications and Standards Committee on "Sight Distances for Highways", are published in the Journal for discussion and comments of Members before finalization as approved Standards of the I.R.C.]

TABLE OF CONTENTS.

SYNOPSIS.

Pointing out the need for providing adequate sight distances on highways, the Paper discusses the various factors as perception time, brake reaction time, brake efficiency, and coefficient of friction between the tyre and road surface, that go to determine the sight distance required for the safe operation of vehicles. The various factors that influence the minimum sight distances necessary for overtaking slower vehicles are also discussed.

Standards for sight distances are worked out and prescribed for various categories of roads to suit different design speeds.

A summary of recommended practice is included.

1. INTRODUCTION

1.1. The safe and efficient operation of a road vehicle is dependent, among many other factors, on the length of road at which obstructions become visible to the driver from any point in his line of travel. So long as traffic was confined to bullock carts and similar slow speed animal-drawn vehicles, low visibility did not greatly matter. After the introduction of the motor vehicles, hazards to traffic caused by low visibility have become apparent and, in recent years, attempts have been made throughout the country to straighten out blind corners and ease summits of vertical curves and otherwise improve "sight distances". This has not, however, always been done systematically and so as to satisfy prescribed standard requirements.

1.2. While laying down standards* for horizontal curves, the Indian Roads Congress specified also the "design speeds" of different classes of roads. To make roads safe for travel at those speeds, it is necessary to consider what length of road should be visible to the driver of a motor vehicle. The traffic capacity of a road is reduced if sufficient sight distance is not provided as the design speed will not be attained and vehicles will tend to bunch together.

1.3. The standards for sight distances must satisfy two main conditions.

(i) They must ensure that the driver of a vehicle, travelling at the "design speed", has a long enough view ahead to enable him, on sighting an object on the road, so to control his vehicle as to avoid striking the object, and

(ii) They must enable the driver at reasonable intervals during his journey to overtake slower vehicles without causing an obstruction or hazard to other traffic.

1.4. Standards are suggested in this Paper which, if provided in the geometrical design of a road, will fulfil these two conditions and permit of safe travel at the design speed of the road.

* Paper No. 119 printed at pages 329-392 of the Journal of the Indian Roads Congress, Vol. XI-3.

DEFINITIONS

Term	Definition
Perception time.	The time taken by the driver of a vehicle in motion to comprehend a danger before trying to take avoiding action.
Brake reaction time.	The time lag or the brief interval between the perception of danger and the effective application of brakes.
Brake efficiency.	The ratio of the effective braking force to the mass of the vehicle expressed as a percentage. A 100 per cent efficiency would give a deceleration rate of 32.2 ft per sec per sec.
Braking distance.	The distance traversed by a vehicle between the point at which brakes are applied and the point at which the vehicle comes to rest.
Skidding.	The motion of a vehicle with its wheels locked on a road surface. It may be either longitudinal in the direction of motion of the vehicle or transverse, and is brought about by the application of a braking force on the wheels greater than the product of the mass of the vehicle multiplied by the coefficient of friction between the tyres and the road surface.
Lag distance.	The distance covered by a vehicle moving at uniform speed during Perception and Brake reaction time.
Stopping distance.	The distance travelled by a vehicle from the time a danger is comprehended by the driver, to the actual stop i.e. the distance travelled during Perception time and the Brake reaction time plus the Braking distance.
Sight distance.	The distance along the road surface at which a driver has visibility of objects stationary or moving at a specified height, above a carriageway.

Term	Definition
Minimum sight distance.	The minimum distance necessary for the safe movement of traffic within which a vehicle travelling at the design speed can be stopped.
Minimum overtaking sight distance.	The minimum distance open to the view of the driver of a vehicle intending to overtake another travelling below the design speed, so as not to obstruct traffic in the opposite direction.
Meeting of vehicles.	The act of two vehicles travelling on the same traffic lane approaching each other to end eventually in a collision if avoiding action is not taken.
Overtaking of vehicles.	The act by which a vehicle travelling at speed overtakes another vehicle moving in the same direction.
Passing of vehicles.	The act of two vehicles passing each other in opposite directions.

2. GENERAL CONSIDERATIONS

2.1. The provision of adequate sight distances in the alignment of a road to ensure the safety of traffic is a function of engineering. Adequacy of sight distance is to a great extent dependent on the mechanical perfection of the vehicle considered, the frictional force that can be brought to bear to bring it to a stop, and the many qualities that go to make an alert and efficient driver. The subject has in recent years been approached scientifically in advanced countries. In the absence of similar research in India, and until more data is available, it is suggested that the American method of analysis and the results of experiments conducted in that country be adapted to suit Indian conditions.

3. ANALYSIS OF STOPPING DISTANCE

3.1. The distance within which a motor vehicle can be stopped depends on many factors, the more obvious of them being :—

(i) the Perception Time and Brake Reaction Time of the driver ;

(ii) the efficiency of the brakes of the motor vehicle ; and

(iii) the grip of the tyres on the road surface. (Frictional resistance between the road and tyre).

Each of these is discussed below.

3.2. The Perception Time and Brake Reaction Time

3.2.1. It would appear that, even in America, only a few tests have been made to determine **Perception Time**, which means the time required for the average motor vehicle driver to come to a realization of danger ahead and decide to apply his brakes or take avoiding action. In this brief time, the driver has to realise that the object that lies in his path ahead will remain in his path and that it is likely to cause danger. The object will be such that its presence would not normally be expected on the road. Perception is limited by the strength of vision, and the angle subtended at the eye by the object, which is influenced by the size of the object. Colour contrasts and shape are also factors influencing perception.

3.2.2. The danger ahead may be from a stationary vehicle, which may be identified by the presence of persons or articles round it or by some object lying in the road. Stationary objects can be recognized as such in their positional relation with other known stationary objects as walls, fences, etc. Another factor which brings cognizance of unusual articles lying on a roadway is the recognition of colour difference as in the case of a white object lying on a black top surface All such processes of mental cognition take time.

3.2.3. As explained above, perception time may vary considerably depending upon the distance to and the size of the object, the natural rapidity with which the driver reacts, otherwise termed the alertness of the driver, his optical ability, atmospheric visibility, the type and condition of the roadway, the type, colour, and condition of the hazard etc. At high speeds, perception time may be less than at lower speeds owing to the fact that the average driver is generally more alert.

3.2.4. After the perception of danger, the driver may proceed to apply his brakes. The time interval between this perception of a danger and the commencement of the action of the braking force is called the **Brake Reaction Time.** However, since the two processes of perception and brake reaction are almost simultaneous and intimately interlinked, it is usual to consider these two together.

3.2.5. There is no one figure which can be used for the average reaction time since this depends upon the conditions under which it is measured. Laboratory tests seem to indicate that when the driver is all set and ready to act, it takes him a little over 0·4 of a second to move his foot from the accelerator to the brake pedal after the appearance of a red light. In actual practice, the reaction time is far in excess of this simple foot reaction, since the driver is not usually all set to react and he does not know the type of reaction to make as he may, instead of having to apply his brakes, have to step on the accelerator or turn the steering wheel to avoid an accident.

3.2.6. The age of the driver influences his reaction time. It is estimated that after the age of 40 the reaction time starts to increase, but the driver's experience and judgement may also increase, more than offsetting the handicap of increased reaction time. Because of the wide variety of such situations, three quarters of a second is generally used as a reasonable figure for the average reaction time in designing traffic facilities. In unusual situations, the total time required to make the correct response may be several seconds.

3.2.7. Improvements in vehicle design and construction will lessen the time required to move the foot from the accelerator to the brake pedal. Devices have already been developed by means of which the driver can keep his right foot on a single pedal to control both acceleration and deceleration.

3.2.8. Owing to the efficiency of modern braking systems, the perception time, which depends on the discrimination of the driver and on many unpredictable conditions, is probably greater than brake reaction time. In America actual perception time has been found to vary from 2 secs. for a speed of 30 m.p.h. to one sec. at 70 m.p.h and this is believed to be more than is required by most drivers. Interesting experiments have been conducted, inattention having been eliminated, to measure brake reaction time under laboratory conditions. The average reaction time was found to be 0·64 secs. Further experiments, however, showed that reaction times under road conditions may be five to seven times those obtained under laboratory conditions

3.2.9. Making allowances for all variable conditions, the American road engineers assume that a perception and reaction time varying from 3 secs at speeds upto 30 m.p.h. to 2 secs. at 70 m.p h. will cover the case of most drivers. A lower speed than 30 miles will be due to the poor condition of the road surface or lower standards of geometric design such as width of pavement, alignment etc. In such conditions the vehicle driver is generally more cautious. To be on the safe side, the perception and reaction time is kept at 3 seconds for speeds upto 30 miles per hour.

3.2.10. Since the alertness of the driver affects largely the perception and brake reaction times and this alertness is in proportion to the speed, it is suggested that under modern conditions, these times may be as shown in the Table below:—

Table 1

Perception and Brake Reaction Time

Speed, miles per hour, up to	30	40	50
Perception & Brake Reaction Time (in seconds)	3·0	2·75	2·5

3.3. Brake Efficiency and Braking Distances

3.3.1. When the driver applies his brakes, the motion of the vehicle is retarded and, after covering some distance, it comes to rest. Modern vehicle design incorporates very efficient brakes which, if maintained in efficient condition and thrust hard, can lock the wheels and prevent them from turning. Such locking, however, is apt to be dangerous as the momentum of the vehicle will carry it forward, the tyres rubbing along the road surface during the process, and produce what is called a skid. It is not generally possible to control the direction of motion of a vehicle in a skid as this direction is governed by the resultant of forces pertaining to the previous motion of the vehicle and the resistance to that motion arising from the friction between the tyres and the road surface. A braking force exceeding the total frictional resistance produces a skid. Therefore, what in effect determines the maximum effective braking effort is the frictional resistance between the tyre and the road surface.

3.4. Frictional Resistance between the Road and Tyre

3.4.1. The co-efficient of friction between the road surface and the tyres of a vehicle is dependent on :

(1) The type and condition of road surface.

(2) The presence of moisture, mud, snow, and similar soft skins covering a hard underlayer.

(3) The condition of tread and air-pressure of tyres.

3.4.2. Table 2 (page 163) gives the values of the coefficient of friction for different road surfaces under wet condition for three different speeds and for the two types of skid, that is for the straight skid and for the sideway skid. What is generally more dangerous is the sideway skid. The value of this sideway skid friction factor enters into the design of horizontal curves and of superelevation. Adequate safety has been built into design by the adoption of a fairly low friction co-efficient of 0·15 after allowing a factor of safety of 1⅓ over the tabulated figure of 0·2 for wet mud on pavements.

3.4.3. The condition governing the present case is that of straight skidding. It is observed that generally a low frictional coefficient is not consistent with high speeds as the wheels will slip without transmitting enough power to force the vehicle onwards. In American practice the friction factors for skidding are assumed to vary from 0·62 at 30 m. p. h. to 0·5 at 70 m. p. h. and with a factor of safety of 1·25 to allow for the many variations in vehicles, surface conditions, and drivers, the safe coefficient of friction is taken as varying from 0·5 at 30 m. p. h. to 0·4 at 70 m. p. h.

3.4.4. In the Australian Road Design Standards for urban roads (1939), the co-efficient of friction between tyres and the road surface is taken as 0·4 for a speed of 30 m. p. h.

Table 2

AVERAGE COEFFICIENTS OF FRICTION OF WET ROAD SURFACES
(According to Measurements made at Iowa State College)

Type of Surface	Skidding Straight Ahead — Speed of Vehicle and Condition of Tyres						Skidding Sideways — Speed of Vehicle and Condition of Tyres					
	10 m.p.h.		30 m.p.h.		50 m.p.h.		10 m.p.h.		30 m.p.h.		50 m.p.h.	
	New	Worn Smooth	New	Worn Smooth	New	Worn Smooth	New	Worn Smooth	New	Worn Smooth	New	Worn Smooth
Asphaltic Concrete ...	0.80	0.80	0.60	0.65	0.50	0.55	1.00	0.90	0.92	0.84	0.80	0.75
Asphalt Sheet ...	0.80	0.86	0.65	0.50	0.45	0.40	0.93	0.83	0.91	0.72	0.84	0.63
Asphalt, Rock, Sandstone, Sand ...	0.90	0.86	0.75	0.55	0.45	0.30	0.93	0.89	0.88	0.70	0.76	0.52
Asphaltic Macadam Retread ...	0.75	0.55	0.55	0.40	0.40	0.32	0.71	0.73	0.62	0.61	0.58	0.58
Concrete-Portland Cement ...	0.65	0.60	0.50	0.40	0.40	0.35	0.75	0.68	0.62	0.50	0.52	0.40
Gravel, Ordinary Untreated ...	0.70	0.65	0.70	0.65	0.70	0.60	0.60	0.58	0.68	0.59	—	—
Macadam, Penetration, Soft Seal Coat	0.52	0.45	0.30	0.25	0.30	0.18	0.76	0.63	0.62	0.37	0.58	0.30
Mud on Pavement Surface ...	0.25	0.20	0.25	0.20	—	—	0.28	0.25	0.23	0.20	—	—
Medium Tar Surface Treatment ...	0.65	0.70	0.47	0.42	0.40	0.25	0.90	0.80	0.72	0.67	0.58	0.50

3.4.5. In India, the Rules framed under the Motor Vehicles Act (1939) provide as follows :—

"The braking system operated by one of the means of operation shall according to whether the vehicle is laden or unladen, be capable of bringing it to rest, when travelling at the speed specified in the table below, within the distance therein specified when, at the time of the application of the brakes, the vehicle is travelling over a hard dry, level ground in good condition, with top gear and clutch engaged, or when, in the same conditions, the efficiency by the brakes as determined by a brake testing meter approved by the Provincial Government is not less than 30 percent when the vehicle is laden and not less than 40 percent when the vehicle is unladen."

Speed MPH	Distance in feet to stop from application of brakes. Vehicles laden.	Vehicles unladen.
20	45	33·5
15	25	19

3.4.6. These rules would in other words mean that the coefficient of friction is assumed to lie between 0·3 and 0·4 depending on whether the vehicle is laden or unladen. The condition of the test ground is described as "hard, dry, and level". The rules quoted, however, were framed in 1939 in relation to "the construction, equipment and maintenance of motor vehicles". These regulations were intended to have rigid control of the operating mechanism of public transport vehicles, as any mechanical defect would be detrimental to the safety of the passengers. It is also to be observed that brake design has now progressed so far that it is possible to lock the wheels if desired. Therefore the coefficients derived from the Motor Vehicles Act are no criterion of those that should be taken when calculating braking reactions under Indian conditions.

3.4.7. The type of road surface is an important factor in the determination of the coefficient of friction. (See Table 2). An analysis of the road milage in the Indian Union by surface types is as below :—

Cement concrete	...	723	miles
Bituminous	...	10,213	,,
Macadam	...	78,690	,,
Unmetalled	...	156,401	,,

3.4.8. The last category (unmetalled roads) are generally not motorable except in fair weather and may be excluded from the purview of this Paper which mainly confines itself to the design standards for motorable roads of the first three types.

3.4.9. Taking all these factors into consideration it is thought that the assumption of a friction coefficient of 0·4 would meet all contingencies and be in the interests of safety of the largest number of vehicles. The adoption of this factor will permit a deceleration rate of about 12·88 ft per second per second which may be considered to be within the rate considered comfortable for most passengers. The adoption of a lower value of 0·4 for the friction coefficient against the values ranging from 0·5 at 30 miles to 0·4 at 70 miles in American practice will have another advantage that, when the maximum design speed of 50 miles has to be raised on account of an improvement in road and vehicle standards, (and consequent improvement in surfaces) there will not be any need to realign the roads.

MOTOR VEHICLE CHARACTERISTICS

4. CALCULATION OF THE BRAKING DISTANCE

4.1. The braking distance within which a vehicle in motion can be brought to rest is derived as below by equating the work done by friction to the kinetic energy absorbed.

Let f = effective coefficient of friction operating the braking force.

w = weight of the vehicle in lb.

d = distance in feet covered during deceleration.

v = speed in ft per sec at the moment of application of brakes.

V = speed in miles per hour..... do......and

g = acceleration due to gravitational force

= 32 ft per sec per sec.

Then, assuming that the frictional force acts at a uniform rate throughout the period of deceleration.

$$f.\ w.\ d. = \tfrac{1}{2}\ w.\frac{v^2}{g}$$

or $d = \dfrac{V^2}{64f}$ ft $= \dfrac{V^2}{29{\cdot}94f} = \dfrac{V^2}{30f}$ rounding off the denominator. This formula gives the braking distance on level ground.

4.2. Braking distance on grades.

4.2.1. When the road surface has a longitudinal grade, the formula for braking distance is modified slightly because the component of gravitational force along the incline either aids frictional resistance or neutralises a part of the resistance according as the vehicle travels upgrade or downgrade.

The resulting formula is

$$d = \frac{V^2}{30\left(f \pm \frac{n}{100}\right)} \quad \text{where } n = \text{per cent grade}$$

4.2.2. The increase in the braking or stopping distance on a downgrade of 1 in 11, that is on a 9 per cent grade, for a speed of 50 miles per hour may, by calculation be seen to be 60 ft. Since in practice, this high speed will not be used on such steep grades and since, in the case of flatter grades the increased distance over the level conditions will be still less, it is considered that the effect of grades may be ignored in the standardisation of the stopping distances.

5. SAFE STOPPING DISTANCES FOR VARIOUS SPEEDS

5.1. The **Safe Distance** in which a moving vehicle can be stopped, also called the **Stopping Distance**, is made up of the distance travelled by the vehicle during the Perception and Brake Reaction time (Table 1) which may be termed the **Lag Distance** plus the **Braking Distance**. These distances for various speeds are given in the table below :—

Table 3

Safe Stopping Distance for various Speeds.

Speed	**Miles per hour** V	15	20	25	30	35	40	50
Speed	Feet per second v	22	29·33	36·67	44	51·33	58·67	**73·33**
Perception and reaction time t (secs)		3·0	3·0	3·0	**3·0**	2·87	2·75	2·5
Lag distance ($1·47\ Vt.$) ft.		66	88	110	132	148	161	183
Braking distance $\frac{v^2}{64f}$ ft. $f=0·4$		18	33	52	76	103	134	209
Stopping Distance $D = \left(1·47\ Vt + \frac{V^2}{64f}\right)$ ft.		84	121	162	208	251	295	392
Stopping Distance in round figures. ft.		**90**	**120**	**160**	**200**	**250**	**300**	**400**

6. SAFE OVERTAKING DISTANCE

6.1. Another important and frequently occuring operation is that of one vehicle overtaking another. During the overtaking operation, the overtaking vehicle may have, under certain conditions, to use that portion of the road meant for traffic coming in the opposite direction. Now, a road is used at its maximum efficiency when all the vehicles using it are kept moving at the design speed of the road. Under these conditions the road will be capable of carrying its maximum traffic. If a vehicle is moving at a much slower speed than the design speed, it should be made possible for other vehicles to overtake it safely so as to increase the capacity of the road. The distance within which an overtaking manouvre can be undertaken is thus an importont factor in road design.

6.2. The overtaking manoeuvre can be split up into three distinct operations as indicated in sketch below.

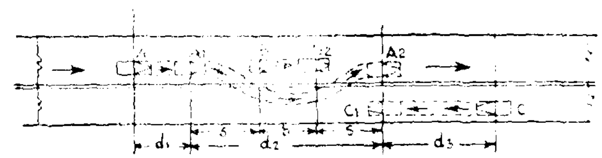


FIG. 1

6.3. In Fig. 1, A is the overtaking driver and B_1 is the overtaken driver moving at less than the design speed. A has been travelling at the design speed V_a miles per hour till he reached the position A_1 where he is compelled to slow down to the speed of B_1 say V_b equal to $(V_a - m)$ where m is the speed difference, and keeps behind B_1 at a distance S from it. It takes some time for A to size up the situation and in this interval he will have travelled to position A_1. This time interval is assumed as 2 seconds and the distance covered may be termed d_1.

6.4. At A_1 the overtaking driver turns his vehicle out of its own path, accelerates, overtakes B_1 return to his own path at A_2, and then proceeds again at the design speed. Thus, from the relative position of A_1B_1 the vehicles have taken the position B_2A_2 after the manoeuvre and therefore the vehicle A has gained a distance of $2S$ relative to the overtaken vehicle B_1 by accelerating its speed.

In the meanwhile, B_1 will have travelled the distance "b" from B_1 to B_2. Thus, the total distance d_2 involved in the actual manoeuvre is made up of $2S$ plus b.

6.5. During the operation of the overtaking of the vehicle B_1 by the vehicle A_1 it is possible that a vehicle C travelling in the opposite direction at the design speed of the road, will approach the vehicles A_1 and B_1. This opposing traffic may come into view as soon as the passing manoeuvre is begun by A_1 and hence the overtaking minimum sight distance should include, in the case of undivided highways, the distance traversed by the opposing traffic during the period of passing manoeuvre. This distance is designated d_3 in Figure 1.

The determination of these distances is dealt with below.

7. SPACING OF MOVING VEHICLES

7.1. When vehicles move at the same speed in the same direction in a traffic lane, the spacing of vehicles should be such that if one vehicle driver applies his brakes, the driver of the vehicle behind will have sufficient time to do likewise and avoid a collision. The average brake reaction time may be taken as half a second in this case because the average driver following closely on the rear of another vehicle will naturally be alert. Assuming in this case a perception time also of half a second, the total perception and brake reaction time will be one second. Assuming equal brake efficiency in both the vehicles, the theoretical safe spacing for vehicles should be the distance covered in one second plus the length of a vehicle. The length of a vehicle may be assumed to be 20 ft as this covers the case of most passenger vehicles. The theoretical spacing of vehicles thus arrived at is given in the table 4 below.

7.2. However, actual observations made through an aerial traffic survey and by means of a photographic method of studying traffic behaviour have shown that the actual spacing followed in practice is much less than the theoretical spacing and that this actual spacing closely follows a general simple formula expressed as

$S = V + 20$ where S is the spacing in feet,

and V is the speed in miles per hour.

The values for different speeds are given in Table 4 below.

Table 4

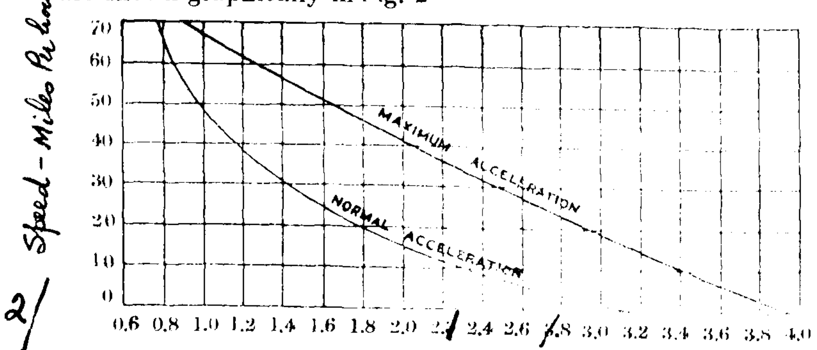
Spacing of Moving Vehicles.

Speed of Vehicle		Spacing	
V mph.	ft per sec	Theoretical feet.	Observed and adopted in the design $V+20$ Ft.
15	22	42	35
20	29	49	40
25	37	57	45
30	44	64	50
35	51	71	55
40	59	79	60
45	66	86	65
50	73	93	70

7.3. Before the operation of overtaking is begun, the two vehicles move at the beginning of the operation at the speed of the slower vehicle i. e. V_b, and the spacing between the two vehicles A_1 and B_1 will be $V_b + 20$

8. TIME REQUIRED TO COVER THE DISTANCE 2S BY ACCELERATION

8.1. The rate of acceleration of a vehicle varies considerably depending on the driving ability and habits of the driver, the horse-power-load ratio of the vehicle, and its mechanical condition Tests made in the U. S. A. in 1947 on six passenger vehicles in good condition driven by several operators indicate that normal acceleration is 60 per cent of the maximum possible. The results are shown graphically in Fig. 2



Speed-change rate-Miles per hour per second.

ACCELERATION CHART

Fig. 2

8.2. In the use of the graphs given in Fig. 2, it is to be assumed that the vehicles will be accelerated at the maximum rate as usually happens in heavy traffic. "It is assumed that the manoeuvre of passing is begun at the speed of the overtaken vehicle and completed at a much higher speed. The rate of acceleration is therefore higher at the beginning of the manoeuvre than at the end". Also it is to be assumed that passing, once begun, is done in the face of opposing traffic and most drivers accelerate as rapidly as possible to get back to their lane well before the opposing traffic can meet their vehicles. The values for maximum acceleration are therefore used in the design. These values derived from Fig 2 are given in Table 5.

Table 5

Overtaking acceleration for different speeds *

(Maximum

Speed V m.p.h.	15	20	25	30	40	50
Acceleration a ft per sec per sec	4.7	4.3	4.07	3.67	3.01	2.35
Acceleration a_2 in m.p.h. per sec.	3.2	2.95	2.78	2.5	2.05	1.6

8.3 From first principles of dynamics, distance covered = $\frac{1}{2}$ × acceleration × time ^{2}

* With acknowledgements to A.A.S.H.O.'S "A Policy on Sight distances".

i.e. $2S = \frac{1}{2} at^2$

or $t = \sqrt{\frac{4S}{a}}$ where a is the acceleration in ft per sec per sec.

or $t = \sqrt{\frac{2.73\,S}{a_2}}$ where a_2 is the acceleration in miles per hour per sec.

8.4. The above formulae and the two Tables 4 and 5 given above supply all the elements for the calculation of the time "t" taken by the overtaking vehicle to cover the distance $2S$. Assuming that the overtaken vehicle has been moving at the same uniform speed as before, it would have covered the distance "b" (See para. 8·2.) which is therefore given by the equation :

$$b = 1{\cdot}47\ V_b \times t.$$

8.5. Calculations show that distance "b" is the largest factor that enters into the total distance so that in effect, the speed of the slow moving vehicle is the greatest influencing factor. If the slow moving vehicle was not moving at much less than the design speed, the total overtaking distance would be too large for economical design of road alignment. Table 6 gives the overtaking distance for design speeds of 25 to 50 m p h. and speed difference of 10 m.p.h. between the two vehicles.

8.6. Lower speeds than 25 m.p.h. have not been included in the table as conditions for overtaking may not generally arise, or the road with such low design speeds is not important enough to warrant high standards of construction necessary to permit such overtaking.

8.7. The Table 6 has been worked out for a speed difference of 10 miles per hour. There is no hard and fast rule as to why this figure should be adopted, but at design speeds of 30 miles and over, the driver of the overtaking vehicle will, as previously explained, try to complete the operation in the shortest time possible, often with a difference in speed of over 10 miles per hour. Also it is to be conceded that ± 5 m.p h lies within the range of instrumental error or the reaction lag of the transmission operating the speedometer. It would be desirable to concede that a vehicle travelling at 10 m p.h. less than design speed of the road deserves to be overtaken by one travelling at the design speed. On this consideration, and on considerations of economy, in the prescription of the standards a speed difference of 10 m.p h. has been assumed.

Table 6

Minimum Overtaking Sight Distances.

V.	25	30	35	40	50
$V-m$.	15	20	25	30	40
$S=V-M+20$	35	40	45	50	60
a_2	2.78	2.5	2.2	2.05	1.6
$t=\sqrt{\frac{2.73S}{a_2}}$	5.8	6.6	7.4	8.0	10.1
$d_1=2.94\ (V-m)$	44	59	74	88	118
$d_2=2S+1.47\ (V-m)t$.	198	274	358	457	594
$d_3=1.47\ Vt$.	213	291	376	476	742
$d=d_1+d_2+d_3$	455	624	808	1021	1454
Overtaking sight distance.	450	600	800	1000	1450

m = Speed difference in miles per hour between the overtaken and overtaking vehicle.

d_1 = Distance travelled during perception time of 2 sec.

d_2 = Distance required for overtaking manoeuvre.

d_3 = Distance covered by vehicle travelling in the opposite lane during the overtaking manoeuvre.

SIGHT DISTANCES.

9. MINIMUM SIGHT DISTANCES ON HIGHWAYS

9.1. Having considered the elements pertaining to the operation of a motor vehicle on a road, it is to be examined how safety is to be built into roads so that each of the operations can be effected without hazard to traffic. The width of road available to carry out these operations is a preliminary consideration, because the longitudinal clear visible distance necessary depends upon whether the road is designed to accommodate one lane of traffic or two or more lanes and how such use can be regulated in practice.

10. CLASSIFICATION OF ROADS BY TRAFFIC LANES

10.1. Most of the road milage in India in non-urban areas has a pavement for one lane of traffic only but the total formation width especially in important roads carrying much motor traffic varies from 24 to 40 feet, and the berms on eitheir side of the pavement are generally provided, or are being provided, with moorum or soil stabilised surfaces to permit of occasional passing of traffic in the opposite direction or of overtaking slow vehicles in the same direction. The width of single lane pavements has been increased in many stretches from the old standard 8 to 10 feet to the I. R. C. Standard minimum width of 12 ft.

10.2. In the I. R. C. Paper No. 113 on "Widths of Pavements" the minimum standards required for road pavements, both in the number of lanes and in their width have been laid down. As a measure of expediency, a single lane pavement with a minimum width of 12 feet had been recommended with the provision of moorum or other stabilized berms 5 feet wide on either side, making a total trafficable width of 22 feet for occassional passing of vehicles in opposite direction or occasional overtaking of slower vehicles.

10.3. When traffic is not accommodated in two single lanes, attempts are sometimes made to construct three lane pavements. As has been remaked in the standards on widths of highway pavements, such construction is hazardous and should be avoided It is significant that the Protocol on International Signs, recently accepted and ratified by India among other nations, lays down that three-lane carriageways should be separated when passing outside urban areas by marking a median line. Such marking would restrict the use of the central lane width to occasional uses only as for overtaking etc.

10.4. Whenever there are four lanes or more provided for traffic, it is necessary and desirable to divide the carriageway by a median strip as the efficiency of a four lane divided highway is estimated to be quite four times that of the same four-lane pavement undivided. In the case of divided highways, there is unidirectional movement of traffic, and there is no chance of opposing vehicles meeting. Overtaking has, however, to be catered for and can be effected through the use of the adjacent lane as opportunity occurs.

10.5. Recommendations made in this Paper are therefore for two lane and three lane carriageways, in which traffic is in both directions, and divided highway, where traffic in any one carriageway is unidirectional.

11. CRITERIA FOR ADOPTION OF STOPPING DISTANCE AND OVERTAKING DISTANCE

11.1. "It is desirable that a sufficient length of road be visible at every point to permit (overtaking) with safety, but in practice this rarely is economically possible". The American policy is to provide overtaking sight distances at as frequent places as possible and to signpost sections as "Passing" or "No-Passing" zones. *Under the present conditions prevailing* in India and considering the fact that the bullock cart will continue to clutter the roads for a number of years to come, it would be uneconomical and may even be considered a waste of effort and money to try to design roads to provide for overtaking sight distances at many places throughout their length. If, as seems possible in the greater part of the plains, the natural terrain permits of the provision of overtaking sight distances throughout, these standards prescribe what that provision should be, but if the *conditions are such that overtaking places can be provided only at* intervals, the standards prescribe what the overtaking lengths should be.

11.2. It is, however, essential that at every part of the road, the alignment and surface should be such that a vehicle travelling at speed can be brought safely to rest within a reasonable distance. Thus, the design must necessarily provide at every point a sufficiently long **Sight Distance** corresponding to the required *minimum* stopping distance. Where, owing to terrain conditions or other causes, the minimum stopping distance cannot be provided for, the design speeds should be reduced in such stretches to those considered safe for the possible sight distance and conspicuous caution boards provided to warn drivers.

11.3. The different conditions may be summarised as follows :—

11.3.1. **Undivided Carriageways** may be divided into the following categories :

(a) **one lane—uni directional**—Those designed for uni-directional traffic. These are very rare at present in India. The traffic conditions on such roads do not anticipate a meeting of vehicles and provision need only be made for overtaking. The absolute minimum provision at each *overtaking section* should be a sight distance equal to ($d_1 + d_2$) *vide* paras. 6.2 and Table 6 [See also (b) below].

(b) **One Lane—two directional**—Although designed as single lane carriageways are in practice used for two-way traffic. *On these* roads which form the majority in India at the present time the overtaking manoeuvre is carried out by the temporary use of the road side berms in the face of possible opposing traffic. The minimum sight distance provision at each overtaking section should be equal to ($d_1 + d_2 + d_3$) *vide* para. 6.2 and Table 6. As this is the most common case in India at present, it is discussed further in 12.3 below.

Two-lane High ways.

The minimum sight distance provision should be,

(a) throughout the road, the minimum stopping distance as shown in Table 3, and

(b) at *overtaking sections the minimum* overtaking distance, $d_1 + d_2 + d_3$, as shown in Table 6.

Three-lane Highways.

Such highways are deprecated as the traffic hazards are greatly increased without any considerable increase in traffic capacity. Early attempts should be made to convert these to four-lane pavements, divided preferably, or undivided as an expediency, with a definite division of the pavement for traffic in either direction.

Where the existing highway consists of a three-lane pavement only, the total carriageway should be divided into two lanes by a conspicuous median line thus making it clear that the increased width of each lane is only to facilitate overtaking. Sight distance should be provided as for a two-lane highway.

11.3.2. **Divided Carriageways.**

In the case of highways whose carriageways are divided by median strip the traffic is uni-directional, and it may be sufficient to provide for the minimum stopping distance equal to $d_1 + d_2$ (Table 6) at all points.

11.3.2.1. Four-lane Highways.

It is recommended that four-lane and higer multiple-lane carriageways should always be separated by a median strip to separate the traffic moving in opposite directions. It is clear, therefore, that there is no chance for vehicles to meet and as such a sight distance equal at least to the minimum overtaking distance equal to $(d_1 + d_2)$ (Table 6) must be provided.

12. POSITIONING OF OVERTAKING ZONES

12. Overtaking zones are described in para 11.1 as lengths of a highway where it would be safe for one vehicle travelling 10 miles an hour faster than another vehicle going in the same direction to pass the second vehicle. The sight distance at every point in each of these zones must be at least equal to the minimum overtaking distance which is $d_1 + d_2$ (Table 6) if there is no opposing traffic and $d_1 + d_2 + d_3$ (Table 6) if there is opposing traffic. The zone itself must be longer (and preferably considerably longer) than these overtaking distances so as to allow more than one vehicle to overtake a slow moving vehicle and at every point in the zone. The driver must have a clear view of the road unobstructed by "blind" corners or bends or blind summit curves.

12.2. It follows that the whole of a length where vision is unrestricted and where the road (with berms) is wide enough to permit of vehicles passing, cannot be marked as a safe passing zone because the sight distance near the ends of this zone will not be sufficient. The zone must therefore be restricted to the total length where there is sufficient room to pass *minus* a length equal to the sight distance on either side i.e. *minus* $(d_1 + d_2)$ where there is no opposing traffic and *minus* $(d_1 + d_2 + d_3)$ where there is oppositing traffic. It should be noted that the marking signpost will be $(d_1 + d_2)$ or $(d_1 + d_2 + d_3)$ away from the end of the wide length at other end (vide fig. 3)

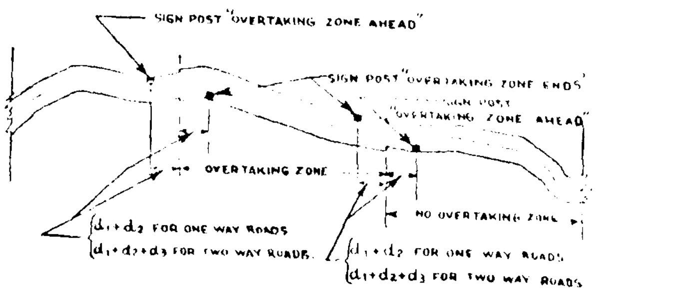


FIG 3

12.3. In single-lane highways (which as has been said, form by far the majority in India at the present time) the berms have to be used for passing. In dry weather or under favourable conditions, the sight distance may be taken as the same as for two-lane highways but these roads are unsafe for overtaking at design speed in wet weather or under unfavourable conditions. If the highway is to be safe for the design speed of its class, overtaking zones fully surfaced must be provided. The minimum length of each of such zones would be, theoretically $2(d_1 + d_2)$ when there is no opposing traffic and $2(d_1 + d_2 + d_3)$ when there is opposing traffic *vide* 12.2. In practice the length of the zone should be $3(d_1 + d_2)$ or $3(d_1 + d_2 + d_3)$ (the factor 2 being changed to 3) to allow for comfortable overtaking of one vehicle by another travelling 10 miles faster but where possible the factor should be increased to 4 or even 5 in a busy road.

12.4. Taking a factor of 3, the length of the surfaced overtaking zone on a National Highway (design speed 50 miles per hour) should be, 3 x 1450 or 4350 ft i.e. more than three quarters of a mile. It will be seen from this that no single-lane road can be considered as upto National Highway Standard in wet weather or unfavourable conditions unless it is provided with overtaking zones over a mile long at frequent intervals. In practice vehicles using these roads cannot safely travel in all weathers at what have been fixed as the ultimate design speeds.

12.5. Overtaking zones also cannot be fixed in the office merely by looking at plans as the sight distances can only be determined on the spot after taking a note of such obstructions as trees, mounds, huts etc. which interfere with sight as effectively as blind corners, sharp summits, and similar design features. In marking overtaking zones on a road, therefore, common sense must be the first consideration, calculations and formulae being regarded very much as of secondary importance.

13. DESIGN SPEEDS

13.1. As stated earlier in this Paper, the purpose of designing roads for sight distances is to achieve a safe sustained speed of travel. It is necessary, therefore, to know this substainable speed demanded by traffic for each class of roads consistent with the geometric and structural standards. Design speeds to be aimed at for the different classes of roads have been laid down* by the Indian Roads Congress Standards in Paper No. 119 on Horizontal Curves and are reproduced in Table 7.

* I.R.C. Journal Vol. XI-3.

Table 7. **Design speed for Roads.**

Classification	Design speed in miles per hour.	
	Flat or Rolling Country	Hilly or Mountainous Country.
National Highways and Provincial Highways	50	30
Major District Roads.	40	25
Other District Roads.	30	20
Village Roads.	20	15

13.2. With possible improvement in vehicle design and of the road surface in future, vehicle speeds will tend to increase. As it is difficult and costly to realign roads to suit increased speeds it is desirable, wherever possible, to design the geometric layout for the greatest possible sight distance and not merely the minimum admissible. Table 8 gives the Minimum Sight Distances both for plains or rolling terrain and for hilly country.

13.3. For new construction, even though the initial estimated provision is for a low type of pavement suited to immediate traffic demands only, the geometric standards should be for the maximum speed that future traffic will warrant.

14. MEASUREMENT OF SIGHT DISTANCES

14.1. For the purpose of measurement of a sight distance, it becomes necessary to define the height of the observing eye and that of the object observed for it is the distance between the two that determines the adequacy or inadequacy of the sight distance.

14.2. Height of driver's eye above road level.

Height of driver's eye above the road surface, is assumed in various c ntries, as under:

England	...	3.75 ft.
Australia	...	4.00 ft.
America	...	4.50 ft.
France	...	4.10 ft.

14.3. The height of the eyes of the average driver seated a in private passenger automobile varies with different makes of cars, the model of the car in each make, and the height of what may be called the average driver. Measurements taken on some of the popular models with a driver of height 5 ft 8½ in. at the wheel show that the height of the eye ranges from 4 ft to 4 ft 6 in. The

Table 8

Table of Minimum Sight Distances.

Class of High-way.	Type of Traffic.	Flat or Rolling Country. Design speed M. P. H.	Flat or Rolling Country. Minimum over-taking sight distance. Feet	Flat or Rolling Country. Stopping distance. Feet.	Hilly or Mountainous Country. Design speed M. P. H.	Hilly or Mountainous Country. Minimum over-taking sight distance. Feet.	Hilly or Mountainous Country. Stopping distance. Feet.
1	2	3	4	5	6	7	8
N. H. or P. H.	Two lanes divided	50	700	400	30	350	200
	undivided		1,450			600	
	Three lanes undivided		1,450			600	
	Four lanes divided		700			350	
	undivided		1,450			600	
M. D. R.	Two lanes divided	40	550	300	25	250	160
	undivided		1,600			450	
	Three lanes undivided		1,000			450	
O. D. R.	Two lanes divided	30	350	200	20	200	120
	,, undivided		600			300	

Note:—In practice overtaking zones of length not less than 3 times the distances given in cols. 4 and 7 should be provided at frequent intervals (vide paras. 12.2 and 12.3).

eyes of the drivers in some low-hung sports cars may be lower but these, being comparatively few, may be neglected. The drivers of buses and trucks are seated at a much higher level. The average height of an Indian is 5 ft 5 in. to 5 ft 6 in. only. It is suggested, taking all these factors into consideration, that the height of the driver's eye for Indian conditions may be assumed at 4.00 feet.

14.4. The minimum sight distance on a road is based upon the safe stopping distance or the distance required to stop from the instant a stationary object in the same lane becomes visible. The stationary object may be a small object such as merchandise dropped from a truck or a piece of boulder, or similar object. It is obvious that the dimension should be such that it would constitute a danger to the vehicle, and therefore should exceed the clearance under the car. The following table gives the ground clearance for some of the popular makes of cars of 1949.

Table 9

Ground Clearances of Popular Makes of Cars. (1949)

English Make	Clearance inches	American Make	Clearance inches	French. Make	Clearance inches
Alfa Romeo.	7	Buick	$6\frac{1}{2}$	Citroen	7
Alvis	$6\frac{1}{2}$	Cadillac	$7\frac{15}{16}$	Renault	7
Armstrong Siddley	$7\frac{1}{2}$	Chrysler	9		
Austin	$6\frac{1}{2}$ to $6\frac{3}{4}$	Chevrolet	$7\frac{7}{8}$		
Bentley	$7\frac{1}{4}$	De Soto	8		
Daimler	6 to 7	Dodge	8		
Ford	8.67to8.87	Ford	8		
Humber	$6\frac{11}{16}$to$7\frac{1}{2}$	Frazer Nash	7		
M. G.	6	Hillman	7		
Morris	$6\frac{3}{4}$ to 7	Hudson	8		
Riley	7 to $7\frac{1}{2}$	Mercury	$7\frac{3}{4}$		
Rolls Royce	$8\frac{1}{8}$	Nash	10		
Rover	$7\frac{1}{8}$	Oldsmobile	$8\frac{1}{8}$ to $8\frac{3}{8}$		
Singer	$5\frac{3}{4}$ to 7	Plymouth	8		
Standard	8	Pontiac	$7\frac{1}{2}$		
Sunbeam Talbot	6				
Vauxhall	$6\frac{7}{8}$				
Wolsley	7				

14.5. Although American cars have a ground clearance of 7 to 8 inches the American policy on sight distances assumes the height of the perceived object as 4 inches. In English practice there is no reference to such objects. It is but logical that what might be a source of danger should have a definite dimension and can also be recognized as such from the distance which is adopted as the safe distance, and *vice versa*. It would be illogical to provide a sight distance greater than the one from which the driver is not able to see the danger. The greatest stopping sight distance which corresponds to a speed of 50 m. p. h. specified in the standards is 400 ft and this is within such maximum distance from which an average driver with normal vision is able to perceive a dangerous object.

15. SUMMARY

15.1. The sight distance at every point of a highway should be as long as possible and shall not be less than the following :—

Absolute Minimum Sight Distances (Stopping distance)

Design Speed in miles per hour.	Sight distance equal to the stopping distance in feet. (Minimum) Flat Country	Hilly Country
15	—	90
20	120	120
25	—	160
30	200	200
40	300	—
50	400	—

The minimum sight distance shall be the distance along the road in which a driver whose eye is assumed to be 4 ft above the road surface can see an object 4 in. high on the Road.

15.2. On two-lane roadways, sections safe for overtaking shall be provided at frequent intervals if the terrain does not permit of providing the minimum overtaking sight distance at every point at reasonable cost. The minimum overtaking sight distance for two-lane roads shall be as follows :—

Design speed in miles per hour.	Overtaking sight distance in feet. (Minimum)
25	450
30	600
35	800
40	1,000
50	1,450

The length of the overtaking section or zone shall not be less than three times the sight distance corresponding to the design speed of the road.

15.3. As has been explained already the construction of three-lane highways is deprecated. Where the existing width of the carriageway is such as to equal three traffic lanes in width the carriageway shall be marked with a median line and sight distances provided as for two-lane highways.

15.4. Roads with four or more traffic lanes should be constructed with dual-carriageways with a median strip separating the traffic in opposing directions. Minimum overtaking distances as in the following table should be provided.

Design speed in miles per hour.	Overtaking distances on dual carriageways. (Minimum)
	Feet
25	250
30	350
35	450
40	550
50	700

15.5. Roads with carriageway suitable for a single traffic lane i.e. 12 feet and less, as in the case of village roads or roads on canal banks should have safe overtaking places provided at intervals and the lengths of such sections shall not be less than 200 feet.

15.6. The overtaking sight distance shall be the distance along the road in which a driver whose eye is assumed to be four feet above the road surface can see the top of an object 4 ft 0 in. above the road surface.

BIBLIOGRAPHY

1. American Association of State Highway Officials. "A Policy on Sight Distance for Highways", 1940.
2. Ministry of Transport, U. K. "Memorandum No. 575—on Layout and Construction of Roads", 1943.
3. Criswell, H. "Sight Distance for Highways". *Roads and Road Construction, London, October. November, December,* 1943. *January and February* 1944.
4. Specifications and Standards Committee of the Indian Roads Congress, Horizontal and Transition Curves for Highways". *Journal of the Indian Roads Congress, Vol. XI-3. Paper No.* 119, *January* 1947.
5. E. W. W. Richards. "Vertical Curves". *Roads and Road Construction, London. April to September* 1939.
6. A. Mitchell. "Design of Acceleration and Deceleration Lanes." **Transactions of the American Society of Civil Engineers. Vol. 107. 1942.**
7. "The Motor Vehicles Act, 1939". Manager of Publications, Delhi.
8. "Road Design Standards 1937. Instructions for the Design of Two-lane Rural Highways". *Main Roads, Australia, November* 1937.
9. G. Muenier. "Study of Visibility on Convex Vertical Curves in the longitudinal alignment of roads and application of this study to the reconstruction of such Curves". *Annales, Ponts et Chaussées* 1946, *Vol.* 116, *No.* 4 *Roads and Road Construction, September* 1948.
10. O. K. Norman. "Fitting Highways to the Driver". *Engineering News Record, September 1st*, 1949.
11. F. G. Royal-Dawson. "Vertical Curves for Roads". E. & F. N. Spon Ltd., London, 1946.
12. F. C. Cook, "Road Design and Road Safety". *Journal of the Institution of Civil Engineers, December* 1956.
13. Specifications and Standards Committee of the Indian Roads Congress. "Widths of Highway Pavements". *Journal of the Indian Roads Congress, Vol. XI-1, November* 1946.
14. E. C. Pike. "Coefficients of Friction", *Journal of the Royal Aeronautical Society, December* 1949.
15. Earl Allgaier. "Some Road-user characteristics in the Traffic Problem," *Traffic Quarterly, January* 1950.

RESEARCH PUBLICATIONS

USE OF STABILIZED SOIL IN ENGINEERING CONSTRUCTION

Section II-Resistance of Cement-Soil Mixture to Action of Water.*

BY

S. R. MEHRA & H. L. UPPAL.

[SOIL RESEARCH LABORATORY, KARNAL]

A soil compacted at optimum moisture content is more resistant to action of water. than when compacted at moisture contents above or below the optimum The resistance obtained through compaction at optimum moisture content is quite sufficient in ordinary weather and ground conditions but where the soil is subjected to the continuous action of water as in the case of road bases in water-logged areas, or where it is necessary to prevent surface softening as in the case of stabilized soil buildings, some further treatment is necessary to create increased water resistance. The addition of certain cheap chemicals is one form of such a treatment.

For cheapness of treatment it would obviously be advisable to use a waste product or by-product from an industry. Soluble binders like molasses which is a waste product from sugar manufacture, *lignin* which is a waste product in cardboard manufacture and "*jharua*" which is waste product in "katha" manufacture were tried. *Lignin* and *jharua* are available only in very limited quantities in India. As they are also supplied as dilute emulsions, the cost of transport limits their use round the areas where they are produced.

Molasses showed very promising results.† But by the time research on this material reached a stage where practical field work could be undertaken, other industries such as the manufacture of alcohol found a more profitable use for this product and its cost rose up sharply so that the material was no longer cheap enough for use in soil work.

Among the standardized materials, cement was considered to be the most convenient for this purpose and it was decided to try its effect on the waterproofing quality of the local soil. Ordinary slow-setting Portland cement, an analysis of which is given in Table 1, was used all along in this study.

* Section I of this series was published in Vol. XIV-Part 3 of Dec. 1949.

† The results obtained will be published separately.

Table 1

Analysis of slow setting Portland cement.

	Result obtained	Requirement of B. S. Specification No. 12-1949
1. Fineness of Grinding. Residue on B. S. Mesh No. 170	5.95 per cent	Not more than 10.0 per cent
2. Chemical Composition	Per cent	
Lime	62.80	
Soluble Silica	23.54	
Alumina	4.77	
Iron Oxide	1.98	
Magnesia	1.24	Not more than 4 per cent.
Sulphur calculated as SO_3	1.98	" 2.75 per cent.
Loss on ignition	2.89	" 4 per cent. (in hot climates)
Insoluble residue	0.46	Not more than 1.0 per cent.
	99.66	
Net proportion of lime to Silica, Alumina and Iron oxide calculated by formula in clause 4 of B.S.S. 12-49	0.84	Between 1.2 and 0.66
Net proportion of Alumina to Iron oxide	2.41	Not less than 0.66
3. Tensile Strength (Cement and Standard Sand Mortar)		
3 days (average of 6 briquettes) lb per sq. inch.	410 lb	Not less than 300 lb per sq. inch.
28 days (average of 6 briquetts) lb per sq. inch.	528 lb	Not less than 375 lb per sq. inch.
5. Setting time.		
Initial.........	130 min	Not less than 30 min.
Final...........	3 hrs 35 min	Not more than 10 hours.
6. Soundness.		
Expansion after boiling 3 hours in Le Chatelier Mould		
(a) Unaerated cement	1.0 mm.	Not more than 10 mm.

Four types of soil generally prevalent in the alluvial plains of the Punjab were selected for the study. The physical characteristics of the soils experimented on are given in Table 2.

Table 2

Showing analysis of soils used for the study.

S. No.	Descrip-tion	Liquid limit	Plasticity index	Sand content	Optimum moisture	pH	Exchangeable Ca m.e/100 grms.	Exchangeable Na+k m.e 100 gms.	Total solid
1	Silty loam	27.2	8.0	38.0	13.0	8.30	6.4	1.30	Negligible
2	Do	27.5	8.7	18.8	12.0	8.40	7.0	1.60	
3	Silty clay	37.0	17.3	8.4	12.0	8.85	14.8	1.10	
4	Loam	24.7	9.5	43.39	11.0	8.10	8.7	1.14	

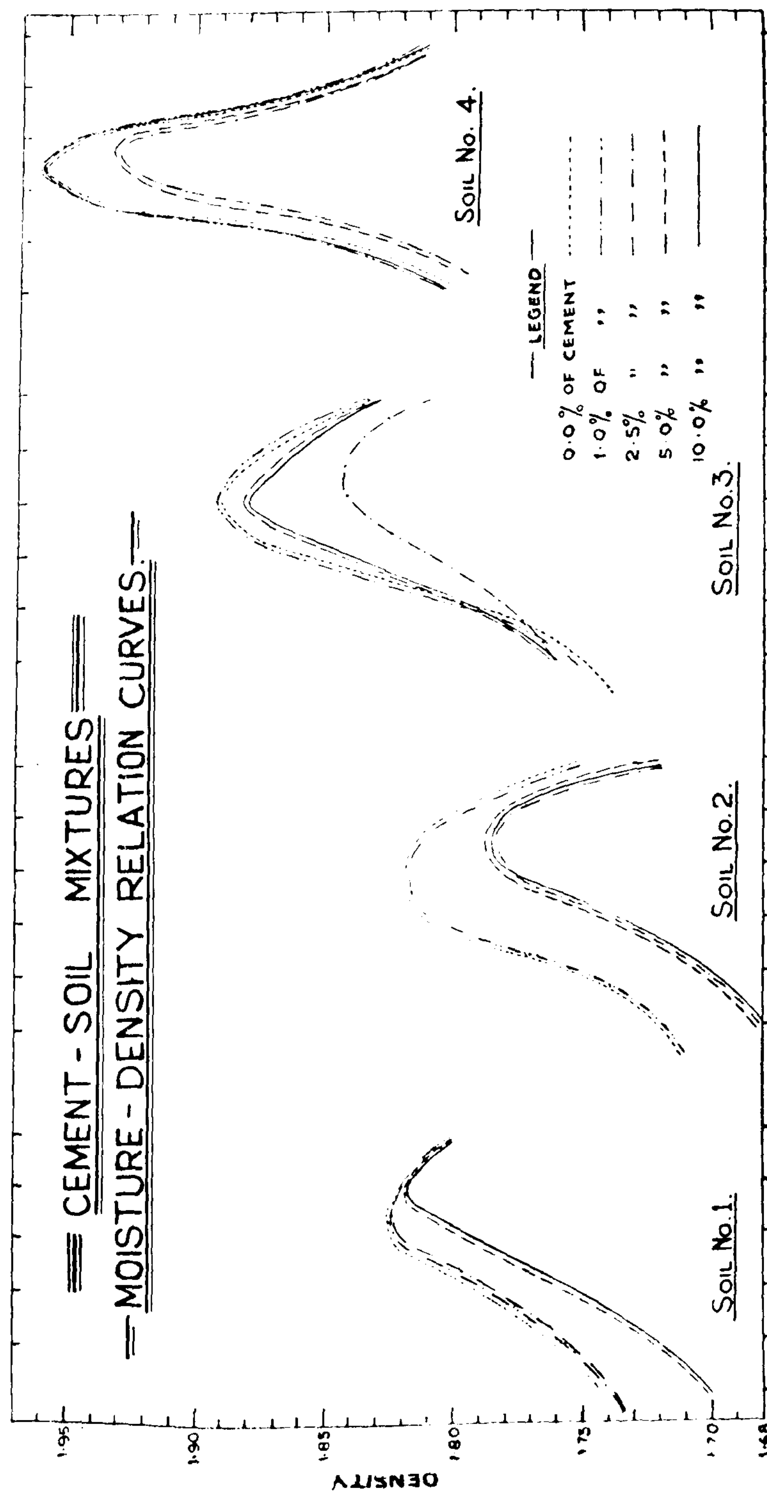
OPTIMUM MOISTURE OF CEMENT-SOIL MIXTURES.

The optimum moisture of a soil changes by the addition of cement to the soil. Moisture-density curves were therefore determined for the four types of soils, using increasing percentage of cement to find the optimum moisture corresponding to each percentage of cement. The results obtained are plotted in the Fig. on the next page.

It appears from the figure that in the case of soil No. 1, which is a silty loam soil, there is practically no change in optimum moisture and density values when cement is added up to 2·5 per cent by weight of the dry soil. When the cement added is 5 and 10 per cent of the soil the density is lowered slightly and the optimum moisture value increased by 1 per cent.

In the case of soil No. 2 which contains more silt than soil No. 1, there is no change in optimum moisture for an addition of cement up to 1 per cent. A further addition of cement of 2·5, 5, and 10 percent increases the optimum moisture by 1 per cent and lowers the density considerably. In the case of soil No. 3, which is a silty clay soil there is no change in the optimum moisture value and density with addition of 1 per cent cement but with 2·5 and 5 per cent cement although there is no appreciable change in the optimum moisture value the density falls slightly. With cement 10 per cent the optimum moisture value increases by 1 per cent and density falls considerably.

In the case of soil No. 4 which is a loam soil there is no change in the optimum moisture value and density with an addition of



cement up to 2·5 per cent. With cement 5 and 10 per cent the density falls only slightly and the optimum moisture increases by 1 per cent.

RESISTANCE OF CEMENT-SOIL MIXTURES TO ACTION OF WATER.

To study the resistance of cement soil mixtures to action of water, specimens were made with all the four types of soils by compacting 200 grams of dry soil at optimum moisture. In compacting the specimens with the different percentages of cement, the corresponding optimum moisture value as determined in Fig. on prepage was used. Blocks were compacted with compaction apparatus described in Part I of this Series (page 299, XIV-3) at 40 strokes of 5½ lb sliding weight. The resultant blocks had a diameter of of 2·5 inch and a height of about 1·3 inch. Other blocks were also compacted at moistures a little above and below optimum value to find the range in optimum moisture values which could be permitted during field construction without seriously impairing the desired stability.

The compacted cement soil blocks were cured under wet sand for a week. These were then allowed to dry slowly in the shade and finally dried in the oven at 50-60 C. to constant weight. The blocks were then immersed under w ter at a temperature of 20–25°C. and the time for complete disintegration was recorded. The results are given in Table 3, for all the four types of soils.

It was noticed that disintegration started almost immediately in the case of 1 per cent cement-soil blocks, the edges being the first affected The disintegration in the case of silty clay and loam soils (No. 3 & 4) was slower than in the case of silty loam soils (No. 1 & 2).

When 2·5 percent cement was used, the blocks remained almost intact for about a month, and the disintegration on the whole was so slow that observations were given up after 12–15 months and the dry weight of the block left behind was recorded for each soil (vide Table 3).

Similar tests were made with soil blocks prepared with 5, 7.5 and 10 per cent cement. It was observed that blocks of all the four types of soils remained intact even after they were under water for 20 months. These were very hard and it was not possible to find visually how far blocks of one soil were better than anothe. To simulate the effect of rain, the blocks were subjected to a jet of water with a velocity of 20 ft per second for six hours. It was observed that the blocks were not affected at all.

Table 3

Effect of the addition of cement to soils on their water resistance.

Soil No.	Per cent cement.	Per cent moisture of compaction	Dry Bulk density.	Disintegration time.				Weight after 15 months.
				Months	Days	Hrs.	Mins.	
1	0	10	1·8				12	
	0	13	1·81				20	
	0	16	1·75				18	
	1	10	1·77				55	
	1	13	1·80			6	11	
	1	16	1·80			2	31	
	2·5	10	1·75	12	10	—	—	
	2·5	13	1·80	14	7	—	—	23·13 grms.
	2·5	16	1·75	13	—	—	—	39·13 ,,
2	0	10	1·82				15	
	0	12	1·82				20	
	0	14	1·80				16	
	1	10	1·81				41	
	1	12	1·82			1	52	
	1	14	1·82				51	
	2·5	10	1·82	9	7	—	—	59·21 grms.
	2·5	12·7	1·82	9	20	—	—	52·48 ,,
	2·5	14	1·80					
3	0	10	1·91				21	
	0	12	1·91				61	
	0	14	1·82				16	
	1	10	1·91		4	—	—	
	1	12	1·94		33	—	—	
	1	14	1·82		34	—	—	
	2·5	10	1·91	Over 15				
	2·5	12·3	1·97	months				63·69
	2·5	14	1·82	,,				
4	0	9	1·91				7	
	0	11	1·97				33	
	0	13	1·91				23	
	1	9	1·91				75	
	1	11	1·94		43	23	—	
	1	13	1·91		42	—	—	
	2·5	9	1·88	Over 15			—	72·02
	2·5	11	1·91	months			—	75·36
	2·5	13	1·91					

Since there was a significant difference in resistance to water between blocks with 1 and 2.5 per cent cement, it was considered desirable to try intermediate percentages of cement. Similar tests were conducted using loam soil only but with 1½ and 2 per cent cement. The results are given in Table 4.

Table 4

Block No	Cement	Density	Complete time of disintegration.
1	1.5	1.92	27 days
2	1.5	1.92	36 days
3	1.5	1.93	50 days—average 37 days
4	2.0	1.91	81 days
5	2.0	1.92	116 days—average 93 days

It appears from Table 4 that the addition of less cement than 2.5 per cent can also make soil resistant to water for a short time but it is not possible to mix properly such small quantities and, secondly, such high densities are also seldom attained in the field. In any case a liberal allowance has to be made for deficient mixing in the field owing to the fact that machine mixing is not yet common in India and resort has to be made to hand mixing.

Doubts were expressed by some workers that cement formed a protective layer on the finished surface and once it was removed the blocks could disintegrate quickly. To examine the correctness or otherwise of this belief, blocks were prepared with loam soil (No. 4) mixed with 1 per cent and 2.5 per cent cement. The compacted blocks were cut into two and then immersed in water to expose the inner material also to the action of water. It was observed that the blocks took almost the same time to disintegrate as the uncut blocks in Table 3.

This shows that the resistance to water of cement soil mixtures is not due to the formation of a protective coating on the surface.

From Table 3 it will also appear that with a given percentage of cement varying from 1 to 2.5, silty clay and loam soils (No. 3 & 4) present much more resistance to the action of standing water than silty loam soils (1 & 2).

This may be explained by the fact that in the case of silty clay soil, a certain amount of active clay is left over after cement action and, when this clay comes in contact with water, it swells and clogs the surface pores thus preventing entry of water deeper down. In the case of loam soil the resistance is due to the proper grading and packing or soil particles.

But this relative resistance to water is explained by the fact that silty loam soils (1 & 2) when mixed with cement produce lower densities than silty clay and loam soils (3 & 4). These latter are clayey and well graded, and therefore require more cement to granulate loosely packed particles of clay. But as the quantity of cement is gradually increased to such an extent that there is enough cement to granulate all the clay particles, inspite of their loose packing, the behaviour of all the four cement-soil blocks is almost identical. This means that the quantity of cement required is closely related to the ultimate density.

The fact was further verified by compacting blocks of loam soil with 2.5 per cent cement, at increasing moisture content. The blocks were cured as usual and then tested for disintegration under water. The results are given in Table 5.

Table 5

Soil	Liquid limit	Plasticity index	Sand	cement content	Moisture of compaction	Density of block	Time of disintegration
			Per cent				
Loam	24.2	9.0	56.0	2.5	12	1.83	68 days
					14	1.86	Over 12 months
					16	1.83	91 days
					18	1.79	7 days
					20	1.75	5 days 6 hours

It appears from Table 5 that an addition of 2.5 per cent cement which can make a soil resistant to water for about 12 months, when compacted at an optimum moisture of 14 per cent, almost is raised when the moisture of compaction is raised to 20 per cent, that is the moisture content at which density falls and surface areas increase considerably. Therefore whenever a percentage of cement is prescribed for a certain cement-soil work, the minimum density to be attained should be specified, and also the permissible grading of soil in the field.

If for any reasons it is not practicable to control the moisture of compaction and therefore the resultant density, then the quantity of cement has to be so adjusted that it makes the compacted soil resistant to water at all practicable moistures of compaction. Apart from resistance to water the compressive strength of the resultant compacted mass has also to be considered in construction.

CEMENT CONTENT FOR LIGHT COMPACTION.

It was experimentally determined that for a very light mode of compaction giving a low density, a moisture content of 18-20 per cent is required except for a very clayey soil. With this moisture content all the four types of soil, mentioned in Table 2 can be compacted with a small force. The conditions approximate to brick moulding practised in this country. Experiments were therefore carried out to find out the resistance of cement soil mass to water, when a light mode of compaction was used. Sandy loam soil was used for the study and the results are given in Table 6.

Table 6

Liquid limit 24.2 Plasticity index 9

Sand content 56.4 Optimum moisture 14.0

Moisture of compaction	Density	Quantity of cement.	Time of disintegration
		per cent.	
20 per cent	1.72	3	5 days
	1.72	4	7 days
	1.72	5.0	Unaffected by water for 12 months.
	1.72	7.5	
	1.73	10.0	

It will appear from Table 6 that at least 5 per cent cement is required for the above type of soil to create some resistance to water. A liberal allowance has, however, to be made for field conditions.

EFFECT OF WETTING AND DRYING.

The study carried out so far gives an idea of disintegration of cement-soil blocks to continuous action of standing water. This by itself is not a complete study and should give only a rough idea of the stability of cement-soil structures. The deductions

from this study cannot be confidently applied to permanent structures exposed to weathering action. In studying weathering action the effect of cycles of wetting, heating, cooling and drying has also to be taken into consideration. Experiments were, therefore, carried out by subjecting cement-soil blocks, of all the four types of soils previously used, to the action of wetting and drying. The detail procedure consisted of immersing the blocks under water for five hours at room temperature, and then heating the wet block in an oven at 71°C for 42 hours. The block was then allowed to cool for an hour. The loose material was brushed off, and the loss in weight of the block determined. This 48 hours operation formed one cycle of wetting and drying, and conforms to the standard test used to determine the stability of cement-soil mixtures against weathering. Each block was subjected to 12 cycles, and the loss in weight determined at the end of each cycle. A mixture which lost more than 3 per cent was considered unsuitable.

The results obtained with the four soils with different percentages of cement are given in Table 7. The volume changes were insignificant and have not been included in the Table.

It will appear from the data in Table 7 that one per cent cement when used with any of the four soils, and compacted at optimum moisture cannot create resistance to wetting and drying beyond the second cycle even when the density of the compacted mixture is fairly high.

When a concentration of 2.5 per cent was used and compacted at optimum moisture content the compacted block was fully resistant to the action of wetting and drying only in the case of silty loam and loam soils (1, 2, 4).

The reason for failure with silty clay soil and this percentage of cement was that a little excess clay which was left over after cementing action, got soft when wetted and peeled off on drying. The same excess clay however retarded disintegration when such blocks were continuously exposed to standing water. The phenomenon mentioned above was true only for the corresponding densities.

When higher concentrations like 5 to 10 per cent cement were used, and compacted to the densities mentioned against each in Table 7 all the four types of soils were fully resistant to the action of weathering. The loss at the end of each cycle being insignificant has not been mentioned. The loss at the end of 12 cycles is given. It may be observed that the blocks prepared with 5 to 10 per cent cement increased in weight at the end of 12 cycles of wetting and drying. This may be explained by the fact that cement, while setting, combines with a few molecules of water, and this fixed moisture cannot be driven out at 100°C.

SUMMARY.

The effect of addition of cement to soils on their resistance to water has been studied. The results show that the addition of a small quantity of cement can make a properly selected soil completely resistant to the action of weathering, when compacted to a certain density.

Bibliography.

1. Investigation of unconfined compressive strength of soil-cement mixtures.

   U. S. Waterways Experimental Station. 1942.

—

Showing the loss in weight of

	Density	1	2	
Soil No. 3				
1% cement.	1.92	1.61	3.30	
	1.90	1.25	3.49	
	1.91	1.36	1.40	
2.5% cement.	1.91	0.80	0.35	
	1.89	+0.3	+0.45	
	1.91	0.3	0.45	
5% cement.	1.90	0.79	0.79	
	1.91	0.80	0.50	
	1.91	0.27	0.0	+
7.5% cement.	1.76			
	1.78			
10% cement.	1.77			
	1.77			
Soil No. 4				
1% cement.	1.92	0.0	0.0	
	1.92	+0.3	+0.2	
	1.92	0.0	0.50	
2.5% cement.	1.91	+0.1	+0.20	+
	1.92	0.0	0.05	+
	1.91	+0.35	+0.40	+
5% cement.	1 87			
	1.87			
7.5% cement.	1.85			
	1.86			
10% cement.	1.83			
	1.81			

USE OF STABILIZED SOIL IN ENGINEERING CONSTRUCTION

Section III—Compressive Strength of Cement-soil Mixtures.

By

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

[Soil Research Laboratory, Karnal.]

One of the essential properties of a building material is a fairly high compressive strength. Burnt brick has for a long time been used in the majority of constructions of the ordinary type because its compressive strength was known generally to lie within certain limits.

The object of the study referred to in these notes was to investigate the possibilities of so improving a soil that it attained a compressive strength well comparable to that of burnt brick. The soils selected for the study have been described already in Sections I & II of these notes.

COMPRESSIVE STRENGTH.

Blocks were compacted with all the four types of soils with 1, 2.5, 5, 7.5 and 10 per cent cement at the corresponding optimum moistures. Compaction was carried out with a sliding weight of 5½ lb falling through a height of 15 inches, and 40 such strokes were adopted as the standard. Blocks were also compacted using more and less than the optimum moisture to find out the effect of small variations in the moisture content.

Blocks were made using 200 gm dry soil mixed with increasing percentage of cement. The resultant compacted blocks had a diameter of 2.5 in. and a height of about 1.3 in. These were cured under wet sand for a week, then allowed to dry in the shade and finally dried in an oven at 50 deg. C.

The dried blocks were tested for compressive strength and the results are given in Table I.

Table 1

Showing compressive strength of cement-soil mixtures.

Soil No.	Per cent cement	Compressive strength in lb per sq. in.					
		10 per cent moisture		13 per cent (Opt. moist.)		16 per cent moisture	
		Initial crack	Final failure	Initial crack	Final failure	Initial crack	Final failure
1	2	3	4	5	6	7	8
1	0	322.50	347.2	300	433	355	295
	1	208	300	376	407	237	237
	2.5	338.0	500	494	600	300	400.0
	5.0	422.0	527	525	664	394	406.0
	7.5	614.0	694	727	837	604	604
	10.0	800.0	827	921	1050	509	703
		moisture 10 per cent		moisture 12 per cent (Opt.)		moisture 14 per cent	
2	0	490.2	547.2	412.6	551.76	401.28	538.0
	1	376.0	490	300.96	532.28	344.2	517.5
	2.5	440	597	533.5	655.7	442.3	647.5
	5.0	579.12	729.6	554.0	830.4	586	676
	7.5	642.9	848.11	647.5	969.9	743.3	834.5
	10.0	921.1	1026	760	1109	726	808.0
		moisture 10 per cent		moisture 12 per cent (OM)		moisture 14 per cent	
3	0	718	960	916	1094	688	820
	1	831	831	831	980	678	792
	2.5	742	900	860	1026	714	845
	5.0	874	909	1109	1253	837	1128
	7.5	1142	1381	1012	1378	540	1030
	10.0	1507	1637	1650	1650	955	1244
		moisture 9 per cent		moisture 11 per cent (OM)		moisture 13 per cent	
4	0	718.2	779.7	731.8	930	654.3	813.9
	1	490.2	761.0	642.9	760.4	579.1	729.9
	2.5	738.7	1030.5	759.0	959.0	950.0	1066.1
	5.0	808.4	1276	966.7	1322.4	939.3	1208.4
	7.5	991.8	1367.4	1156.8	1396	1212.5	1482.0
	10.0	969.0	1380.0	1208.4	1608	1214.0	1500

	Initial crack	Final failure.
Burnt brick No. I	663	2921
No. II	874	2213

It should, however, be mentioned that the size of block for determination of compressive strength should ordinarily be such that the height is two times the diameter, because the shear plane ordinarily develops on an angle with the horizontal of more than 60 deg. But it was not possible to make blocks of standard 1 2 ratios with the apparatus available. For comparison with well burnt brick, cores of the same size as the compacted soil blocks were cut out of bricks and tested for compressive strength. The values have been included at the foot of Table 1.

In order to find out maximum compressive strength that can be achieved by the addition of cement, blocks of all the four soils were made with increasing percentage of cement up to 50 per cent. To have a wider range of soils, soil No. 1 was replaced by sandy loam soil of higher sand content, the detailed analysis of which is given below. Soils No. 2, 3 and 4 were the same as mentioned in Section II Table 1.

Soil No. 1	Liquid limit	Plasticity Index	Sand content	Optimum moisture	Exchangeable pH Ca m.e/100	Na+k gm soil	Total solids
Sandy loam	21.8	4.9	65	13.0	8.65	.9	Negligible

The results of the tests are given in Table 2 and show that for low compressive strength of the order of about 800 lb per square inch, silty clay-loam and loam soils may also be used but, when a very high compressive strength is desired from a cement-soil mixture, the selection shall have to be made out of sandy soils.

Table 2

Showing maximum Compressive Strength of soil with increasing percentage of cement when compacted at optimum moisture.

Soil used	Cement per cent	Compressive strength in lb/sq. in. at	
		Initial crack	Final failure
1. Sandy Loam	7.5	1545	2005
	10.0	1975	2393
	20.0	2775	3047
	30	3465	3848
	40	4250	4353
	50	4490	4620
2. Silty Loam	7.5	648	969
	10.0	760	1109
	20.0	1604	1806
	30.0	1947	2110
3. Silty clay-loam	7.5	1012	1378
	10.0	1650	1650
	20.0	2123	2895
	30.0	2348	3023
4. Loam	7.5	1157	1396
	10.0	1208	1608
	20.0	2257	2504
	30.0	2273	2508

BEHAVIOUR OF SOILS WHEN SATURATED.

When designing soil cement houses for areas of heavy rainfall it is essential to know what compressive strength a cement-soil mixture will have when fully saturated with water. Work carried out elsewhere in India* reveals that the compressive strength of completely wet blocks is about 60–70 per cent of dried blocks.

For structural stability it is also important to know the effect of repeated cycles of wetting and drying on the compressive strength of compacted cement soil. Work carried out on the subject in other countries shows that the compressive strength of cement-soil blocks increases by 50 per cent after 4 cycles and 100 per cent after 12 cycles of wetting and drying.

The effect of an increasing number of cycles of wetting and drying on the compressive strength of all the four soils mentioned in Table 2, mixed with different percentages of cement was tested and the results obtained are given in Table 3.

It will appear from Table 3 that when the soils mentioned above were compacted with 2.5 per cent cement and subjected to an increasing number of cycles of wetting and drying there was no appreciable rise in compressive strength at the end of six cycles but, at the end of 12 cycles, there was an increase by about 10 per cent except in the case of silty loam soil (No. 3) which showed a slight fall.

When the concentration of cement was increased to 5, 7.5 or 10 per cent there was an increase of about 20 to 25 per cent in compressive strength at the end of six cycles, and at the end of twelve cycles there was a further appreciable increase in the case of silty loam (No. 2) and silty clay loam (No. 3) soils, but in the case of sandy loam and loam soils there was no further increase after six cycles. This showed that cement-soil mixtures gained in strength with weathering effect, and the increase in compressive strength varied with the soil and the concentration of cement used.

EFFECT OF CEMENT ON PHYSICAL PROPERTIES OF SOILS.

It will be interesting to find out the changes in physical properties that are brought about by the addition of cement. The results obtained with all the four types of soils for change in liquid limit and plastic limit are given in Table 4.

* Hyderabad Engineering Research Station, Annual Report, 1948.

Table 3

Showing effect of weathering on the Compressive Strength of Cement-Soil Mixtures.

Soil No	Description	Percent cement	Compressive Strength, lb per square inch					
			Control blocks not weathered		Six Cycle Weathering		Twelve Cycle Weathering	
			Initial crack	Final failure	Initial crack	Final failure	Initial crack	Final failure
1	Sandy loam	2.5	655.2	943.32	795.0	912.66	852.6	1692.0
		5.0	1399.86	1722.0	1609.8	2016.0	1663.2	2099.0
		7.5	2001.72	2316.7	2239.8	2757.7	2238.6	2549.8
		10.0	2058.0	2499.0	2688.0	3121.8	2814.0	3234.0
2	Silty loam	2.5	537.6	772.8	609.0	852.6	558.6	758.0
		5.0	882.0	1016.4	995.4	1398.6	1230.6	1558.2
		7.5	1197.0	1394 4	1212.0	1860.6	2016.0	2461.0
		10.0	1512.0	1747.2	1974.0	2150.4	2171.4	2377.2
3	Silty clay loam	*2.5						
		5.0	974.4	1953.0	1596.0	2049.6	1818.6	2671.0
		7.5	1707.2	2113.8	1982.0	2415.0	2591.4	3343.2
		10.0	1833.72	2234.4	2071.86	2835.0	3498.6	3910.2
4	Loam	2.5	1171.8	1539.72	1105.8	1556.5	1285.2	1701.0
		5.0	1974.0	2217.6	1927.8	2688.0	2636.0	2927.0
		7.5	2253.0	2799.0	2333.0	3433.5	2877.0	3234.0
		10.0	2491.86	3135.7	2988.72	3807.72	3704.6	3717.0

* Compressive strength was not determined because the loss in weight after 12 cycles of wetting and drying was more than 3 per cent.
The values of compressive strength on the whole are slightly higher than those attained previously with the same soils.
This is on account of the fact that heavier mode of compaction was used.

Table 4

Showing change in plasticity index of soils mixed with increasing percentage of cement.

Soil No.	Per cent Cement	Liquid limit	Plastic limit	Plasticity index
1.	**Sandy Loam**			
	0	28·3	19·5	8·8
	1	27·85	19·7	8·15
	2·5	28·9	21·7	7·2
	5·0	29·2	21·9	7·3
	7·5	29·14	22·4	6·7
	10·0	29·5	23·6	5·9
2.	**Silty loam**			
	0	28·2	20·0	8·2
	1	28·3	20·3	8·0
	2·5	28·7	21·4	7·3
	5·0	29·1	22·8	6·3
	7·5	29·1	23·4	5·7
	10·0	30·0	24·7	5·3
3.	**Silty clay loam**			
	0	35·4	19·4	16·0
	1	35·3	20·6	14·7
	2·5	35·2	21·5	13·7
	5·0	35·2	22·2	13·0
	7·5	35·0	22·3	11·7
	10·0	34·8	24·2	10·6
4.	**Loam**			
	0	25·0	16·2	9·8
	1	25·4	16·3	9·1
	2·5	26·5	17·9	8·6
	5·0	26·5	18·9	7·6
	7·5	27·6	20·7	6·9
	10·0	27·0	21·4	5·6

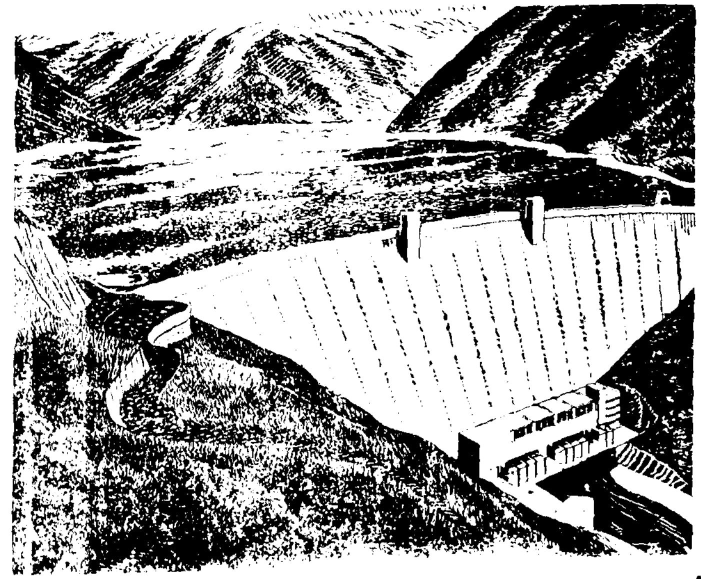
It will appear from Table 4 that the plasticity index falls as the quantity of cement increases. This fall in plasticity index is entirely due to rise in the plastic limit because up to 10 per cent addition of cement the liquid limit almost remains unaffected

SUMMARY.

Tests show that compressive strength of certain Punjab soils can be so increased by an addition of a small quantity of cement as to compare favourably with that of locally burnt brick for use in building construction. The quantity of cement required to attain the same compressive strength as that of brick varies considerably from soil to soil.

—

A.C.C. FIRST IN INDIA WITH LOW-HEAT PORTLAND CEMENT



Low heat of hydration reduces shrinkage stresses in dams and massive concrete construction

A.C.C. have pleasure in announcing that they are now in a position to offer low-heat cement from some of their works. This special cement is intended for use in massive concrete structures such as dams, heavy retaining walls, and bridge abutments, where a low heat of hydration is essential to control the temperature-rise in concrete during placing and prevent shrinkage stresses and cracking during the subsequent cooling.

This product fully complies with British Standard Specification No. 1370 : 1947 for low-heat Portland cement. Copies of test certificates are available upon request.

In view of the numerous dam projects under construction or survey in this country the development of this special cement is of the utmost importance and marks another step in A.C.C's history of continued progress.

For full details, please write to :

THE CEMENT MARKETING COMPANY OF INDIA LTD.
Sales Managers of
THE ASSOCIATED CEMENT COMPANIES LIMITED.
1 Queen's Road, Bombay

Telegrams :
" KAYMOBILE "
NEW DELHI.

Office Phone No. 8790
,, ,, 43853
,, ,, 44978
,, ,, 6392

B. K. KHANNA & CO., LTD.

CONNAUGHT CIRCUS
NEW DELHI-1

DISTRIBUTORS IN THE REPUBLIC OF INDIA

U. K.

1. BROWETT LINDLEY LTD.
Steam Engines, Air and Gas Compressors, Condensing Plant.
2. FODENS LIMITED
Dump Trucks, Passenger Trucks.
3. HUGH WOOD & CO., LTD.
Belt, Chain, Scraper and Shaker Conveyors, Pneumatic Picks, Compressed Air & Electric Drilling Equipment.
4. JAS GRUNDY & CO., LTD.
Kelvin Forms of all types, Kelvin Steel Climbing, Shuttering, Kelvin Steel Interlocking, Trench Sheeting.
5. JOHN M. HENDERSON & CO., LTD.
Aerial Cableways, Ropeways, Aerial Cableway Dragline, Excavators, Cable Drag Scrapers, Cranes of all types, Derricks Coal and Ash Handling Plant, Haulage Gears, Slipways, Suspension Bridges, Telphers, Transporters, Winches etc.
6. JOHNSTON BROTHERS (CONTRACTORS) LTD.
Road Building Machines.
7. K. & L. STEEL FOUNDERS & ENGINEERS LTD.
Various Types of Mobile Cranes.
8. ROBERT BROADBENTS & SONS LTD.
Jaw Crushers, Stone and Ore Breaking Machinery.
9. SHEEPBRIDGE ENGINEERING LIMITED.
Gyratory Crushers, Cement Plants etc.
10. STOTHERT & PITT LTD.
Concrete Mixers, Crank Level Luffing Cargo Handling Cranes, Overhead Travelling Cranes, Grabbing Cranes, Low Truck Cranes.
11. WALLIS & STEEVENS LTD.
Road Rollers from 2 tons to 10 tons.
12. WOODFIELD HOIST & ASSOCIATED INDUSTRIES LIMITED.
Piling Equipment, General purpose Winches, Derrick Cranes, Drilling rigs, Pipe line fittings, including rigid and misaligning couplings.
13. WILLIAM GRIFFIN & SONS LTD.
Chains and Attachments of various types and sizes.
14. FAIRFIELD SHIPBUILDING & ENGINEERING COMPANY LIMITED.
All Steel Welded Structor Wagons.

Telegrams :
" KAYMOBILE "
NEW DELHI.

Office Phone No. 8790
,, ,, 43853
,, ,, 44978
,, ,, 6392

B. K. KHANNA & CO., LTD.

CONNAUGHT CIRCUS
NEW DELHI-1

DISTRIBUTORS IN THE REPUBLIC OF INDIA

U. S. A.

1. AMERICAN CHAIN & CABLE CO. INC:
Wire Ropes and Cables.
2. AMERICAN ROAD EQUIPMENT COMPANY
Road Graders—Petrol and Diesel.
3. BUTLER BIN COMPANY
Hoppers, Bins, Batch Weighing Equipment All Sizes and Types.
4. BUFFALO-SPRINGFIELD ROLLER CO:
Road Rollers-Diesel 1-1/2 ton to 21 tons, 3 Wheel, Tandem and 3 Axle.
5. CLARK BROS CO. INC:
Compressors 700—60,000 c.f.m. Diesels, Industrial and Marine Alternator Sets.
6. GAR WOOD INDUSTRIES INC:
Road Wideners, Ditch Diggers, Aggregate Spreaders etc.
7. GRUENDIER CRUSHER & PULVERISER CO:
Rock Crushing and Sand Producing Plants up to 600 Tons hour.
8. KOEHRING COMPANY
Dumptors, Moto-Bugs, Pavers, Mud Jacks Finishers, Concrete Buckets, Etc. Etc.
9. LAPLANT CHOATE MANUFACTURING CO:
Self Propelled & Tractor Drawn Scrapers, Hydraulic Controls Etc.
10. LE ROI COMPANY
Mobile Compressors—Wagon Drills, Rock Drills, Paving Breakers, etc.
11. LIMA SHOVEL & CRANE DIVISION:
Cranes 60 Tons and above. Shovels 3 to 6 Cu. Yd. Capacities with Dragline etc.
12. LITTLEFORD BROS. INC:
Black Top Equipment Road Making & Maintenance.
13. LONDON CONCRETE MACHINERY CO., LTD.
Constructional Self Priming Pumps, Hoists, Concrete and Plaster Mixers.
14. PENNSYLVANIA PUMP & COMPRESSOR CO:
Compressors and Vacuum Pumps.
15. T. L. SMITH COMPANY
Concrete Mixers 1 to 6 Cu. Yd. Capacities, Mobile Truck Mixers 2 to 5-1/2 Cu. Yd. Capacities.
16. ROME GRADER DIVISION
Heavy Duty Motor Graders.

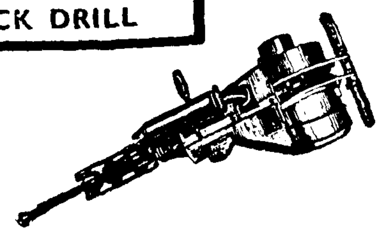
WEATHER-PROOF !

OOTACAMUND-METTUPALAYAM GHAT ROAD. MEXPHALTE SURFACE DRESSING OVER WATER-BOUND MACADAM

Burmah-Shell will be glad to give you free technical advice on the use of Bitumen for your road development programme.

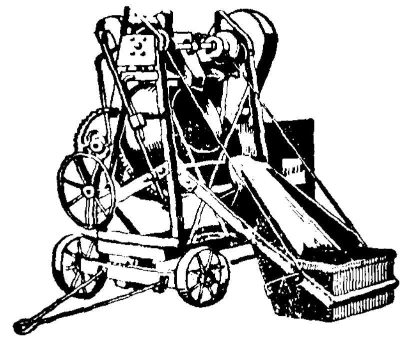
BURMAH-SHELL OIL STORAGE & DISTRIBUTING COMPANY OF INDIA LIMITED
(INCORPORATED IN ENGLAND)
AGENTS

WARSOP
ROCK DRILL



The most modern self-contained One Man power-tool for

1. Stone Quarrying
2. Surface Mining
3. Prospecting
4. Trenching for power, water & sewage lines
5. Breaking concrete & general demolition



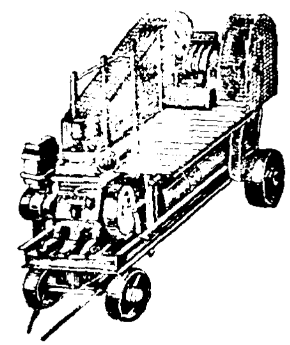
BENFORD
CONCRETE MIXERS

Mixers from 5 c.ft. max. input and 3½ c.ft. max. output to 10 c.ft. input and 7 c.ft. output—with Diesel, Kerosene, Petrol or Electric drives—available from stock.

PEGSON
ROAD & QUARRY PLANTS

The full range of Pegson machines includes:

1. Jaw Crushers & Granulators
2. Gyratory Crushers
3. Vibrating & Rotary Screens
4. Complete Crushing & Screening plants, capacity from 3 to 400 tons per hour.



Apply for details to:-

Garlick & Co. Ltd.
ENGINEERS
JACOB CIRCLE, BOMBAY 11.

Coimbatore, Madras, and New Delhi.

MILLARS'

MACHINERY

Concrete Mixers—Tilting and non-Tilting Types.
Asphalt Mixers—for Hot and Cold Mix.
Roller Pan Mixers—for Mortar.
Diaphragm Suction Pumps for effective lift up to 25 ft.
Self-Priming Pumps for handling Seepage at lowest possible cost.
Tower Hoists for speedy construction.
Complete Wellpoint Pumping Equipment for dewatering—the only successful method of combating running sand.

TIMBER

HARDWOODS - SOFTWOODS - PLYWOODS

MILLARS' TIMBER & TRADING CO., LTD.

(INCORPORATED IN ENGLAND)

Victoria House, Victoria Road, BOMBAY 27.

Telephone: **41077** *Telegrams*: **JERRAH**

Branches and Agents throughout the World.

FRANKI

COMPRESSED CONCRETE FOUNDATION PILING

AND

REINFORCED CONCRETE SHEET PILING

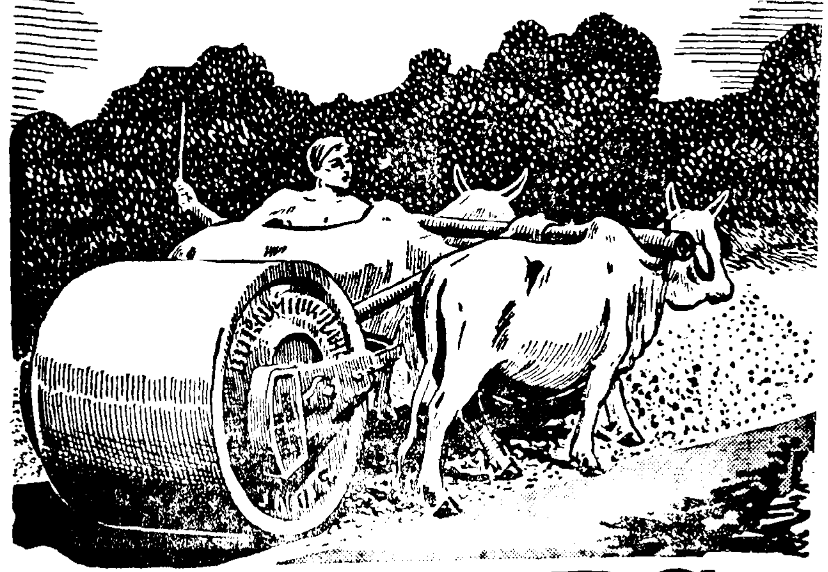
(All-India Products)

Sole Licensees in India

THE BRAITHWAITE BURN AND JESSOP CONSTRUCTION COMPANY, LIMITED

P-13, MISSION ROW EXTENSION,
CALCUTTA.

Variable Ballast



ROLLERS

Variable Ballast means, for example, that a 3 ton Roller weighs 46 cwt. empty, nearly 63 cwt. filled with water and over 70 cwt. when filled with sand.

PARTICULARS ON REQUEST

BURN & CO., LTD.

AGENCIES DEPARTMENT

12, MISSION ROW, CALCUTTA.

BRANCHES AT - NEW DELHI - BOMBAY - KANPUR

GANNON DUNKERLEY & CO., (MADRAS) LTD.

CIVIL, SANITARY AND CONSTRUCTIONAL ENGINEERS.

★

SPECIALISTS IN DESIGN AND CONSTRUCTION
OF R. C. C. STRUCTURES, BRIDGES, BUILDINGS,
WATER SUPPLY AND DRAINAGE SCHEMES,
SANITARY INSTALLATIONS, ETC.

★

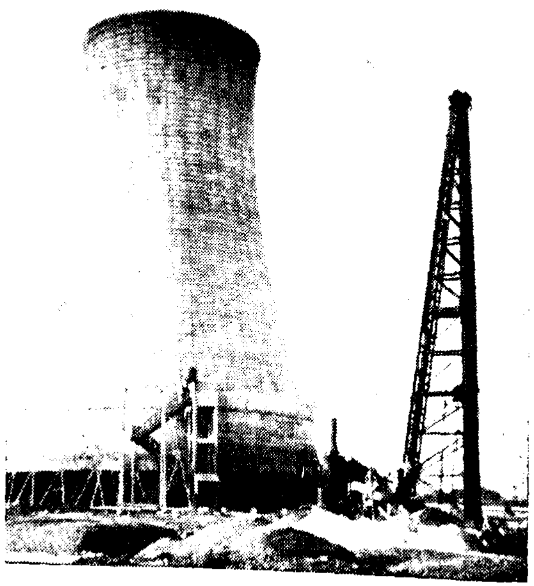
Registered Office:

14, BOAG ROAD, MADRAS - 17.

Telephone: 88316 Telegrams: "VITOPUS", Madras

For

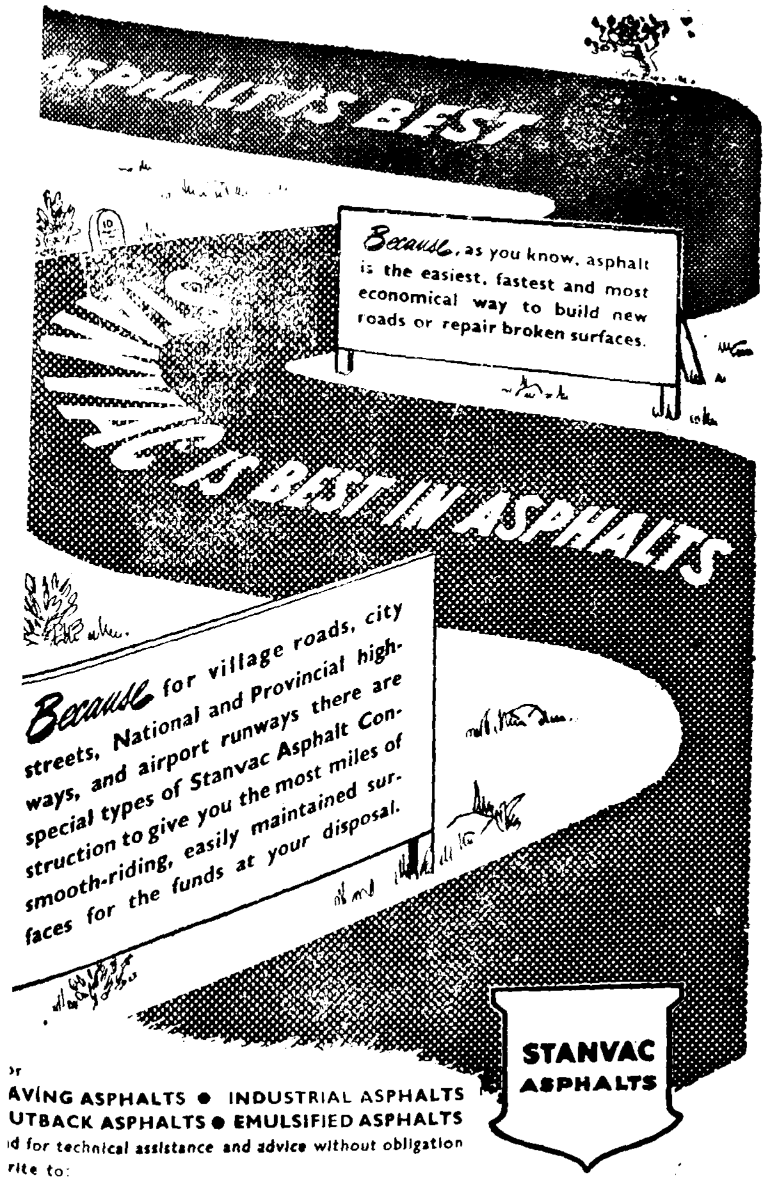
PILING AND FOUNDATIONS



Consult :

SIMPLEX CONCRETE PILES (INDIA) LTD.

CALCUTTA MADRAS

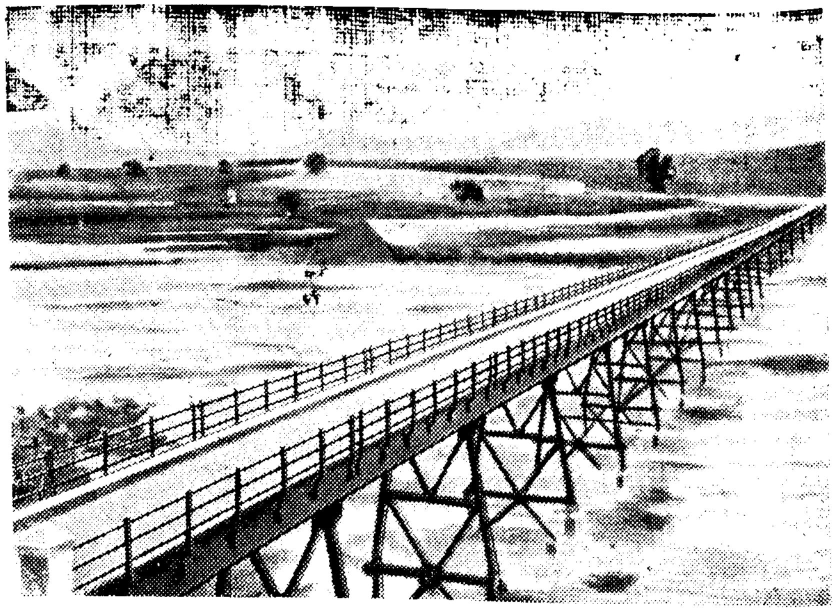


or
AVING ASPHALTS ● INDUSTRIAL ASPHALTS
UTBACK ASPHALTS ● EMULSIFIED ASPHALTS
id for technical assistance and advice without obligation
rite to:

TANDARD-VACUUM OIL CO.

(The Liability of the Members of the Company is Limited)

Bombay - Calcutta - Colombo - New Delhi - Karachi - Madras - Rangoon



Jandola Road Bridge, North West Frontier Province, 38 R.S. Joist Spans, 36-feet, on Screw Pile Piers.

BRAITHWAITE & CO.,

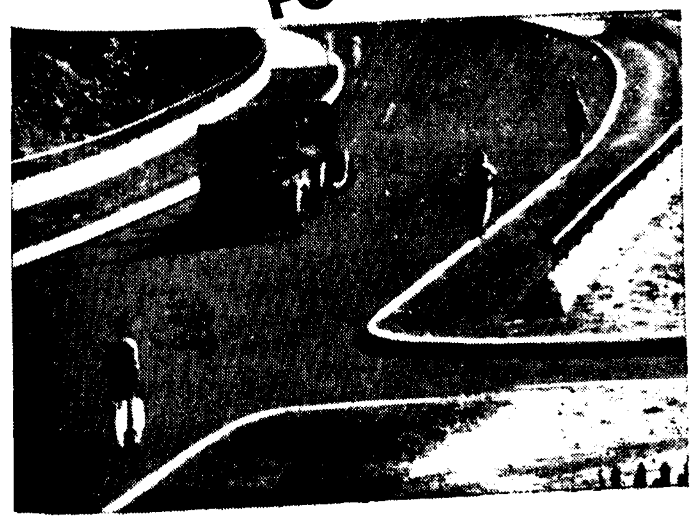
(INDIA) LIMITED

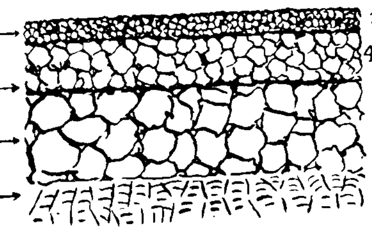
CALCUTTA

BT - 20

Specification

FOR A GOOD ROAD



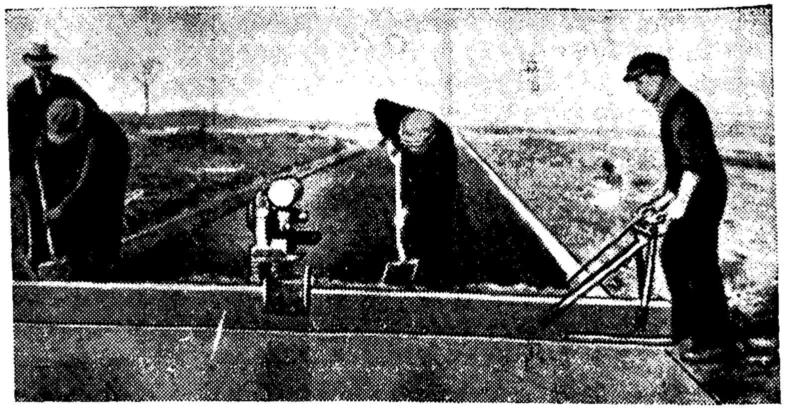


Shalimar

TAR PRODUCTS (1935) LIMITED

Managing Agents:
TURNER MORRISON & CO. LTD.
6, Lyons Range, Calcutta, 1.

TMK 7



FOR *Modern Roads...*

JOHNSONS' VIBRATING SCREED

Concrete Vibration needs no introduction to civil engineers, and the experienced engineer knows that Johnsons' Vibrating Machines make his work efficient, simple and economical.

Apart from the Vibrating Screed, illustrated here, Johnsons' make other machines for contractors engaged in road making.

C. H. JOHNSON (Machinery) LTD.

Sole Agents for India and Pakistan:

KILLICK, NIXON & CO., LTD.

(ENGINEERING DEPARTMENT)

Killick Building, Home Street,

Fort, Bombay 1.

Telegrams: "KILLICK" **Telephone: 30901**

HAER ARE SOME ADDED ADVANTAGES

- Neat, clean and dustless packing
- Absence of seepage and no waste
- Thorough protection from moisture
- Easy to handle—paper bags count 24 to the ton
- Convenient in proportioning concrete—paper bags contain 1 cubic foot of cement each

ACC Cement in jute bags marketed under brand names heretofore will continue in decreasing supply. These v contain 112 lbs.,—making 20 bags to the ton.

THE CEMENT MARKETING COMPANY OF INDIA LTD

Sales Managers of

THE ASSOCIATED CEMENT COMPANIES LIMITED

1, QUEEN'S ROAD, BOMBAY.

C.M.I. 3939

As in natural design, so in human accomplishment the perfect solution to a problem of construction is developed by trial and error from the prototype.

The development of Wheeled Locomotion has produced the perfect form of road transport and the perfect type of road to suit its purpose — a highway that is built on foundations of concrete reinforced with

BRC

Welded Fabric

No other method of road construction will carry any wheel load, however great, over any ground, however soft, and give such serviceable strength and resistance to wear at such negligible maintenance costs.

Sole Agents :

HEATLY & GRESHAM LIMITED

ESTABLISHED 1892 — INCORPORATED IN ENGLAND

P. O. Box 190
CALCUTTA

P. O. Box 225
BOMBAY

P. O. Box 228
MADRAS

P. O. Box 45
LAHORE

L-13, Connaught Circus
NEW DELHI

MARSHALLS

FOR

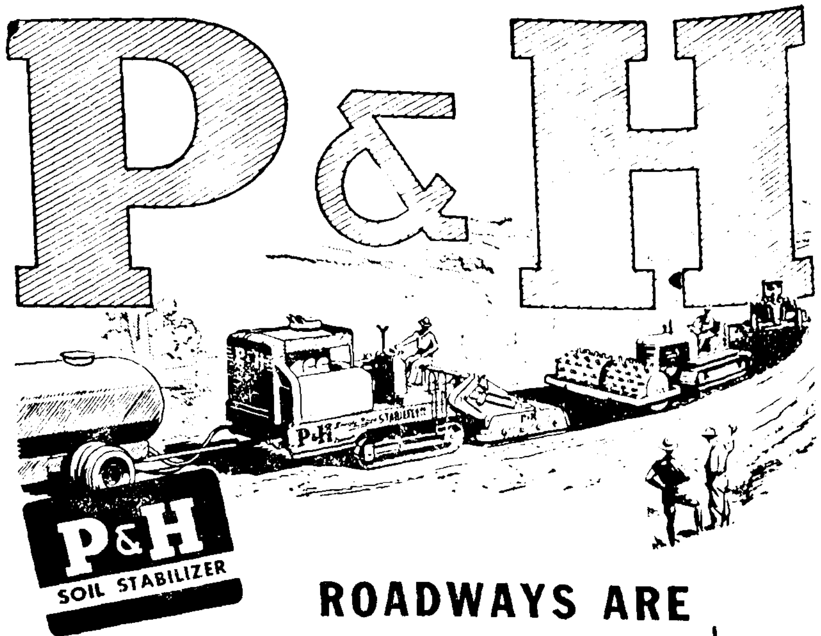
- ★ ROAD ROLLERS.
- ★ STONE BREAKERS.
- ★ GRANULATORS.
- ★ DIESEL TRACTORS.
- ★ CONCRETE MIXERS.
- ★ CONCRETE BATCHING PLANT.
- ★ CONCRETE SPREADERS AND FINISHERS.
- ★ EARTHMOVING MACHINERY

ETC., ETC.

CONSULT :—

MARSHALL SONS & Co. (India) Ltd.

CALCUTTA, BOMBAY, MADRAS, NEW DELHI.



ROADWAYS ARE FOODWAYS . . .

Leading roadway authorities are making the most of the P&H Stabilizer. It is the proved method for building stabilized roads of controlled quality—at important cost savings.

The P&H Soil Stabilizer makes it possible to produce a finished road that will measure up to requirements in strength and uniformity, mile after mile. And because it does it so quickly—at a single pass—costs are far lower than before.

The P&H Soil Stabilizer is the only single pass machine ever successfully designed for all types of stabilization work. Full information about it may be obtained from your P&H Distributor.

P&H SINGLE PASS STABILIZERS
Main Offices and Plant Milwaukee 14, Wis., U.S.A.

HARNISCHFEGER CORPORATION

Established in 1884

BETTER LIVING through BETTER ROADS

P&H DISTRIBUTOR

PASHABHAI PATEL & CO., LTD.

Construction House - Ballard Estate - Bombay

BCY 5A/22-48

BITUMULS

COLD BITUMEN EMULSIONS REQUIRE NO HEATING

"Direct From Drum To Road"

For construction of :

ROADS
FOOTPATHS
ASSEMBLY AREAS
RAILWAY PLATFORMS
AERODROME RUNWAYS

Spray pumps and ex-service supervisors provided free for all major works

Full Particulars and Technical Advice from :—

BITUMEN EMULSIONS (INDIA) LTD.

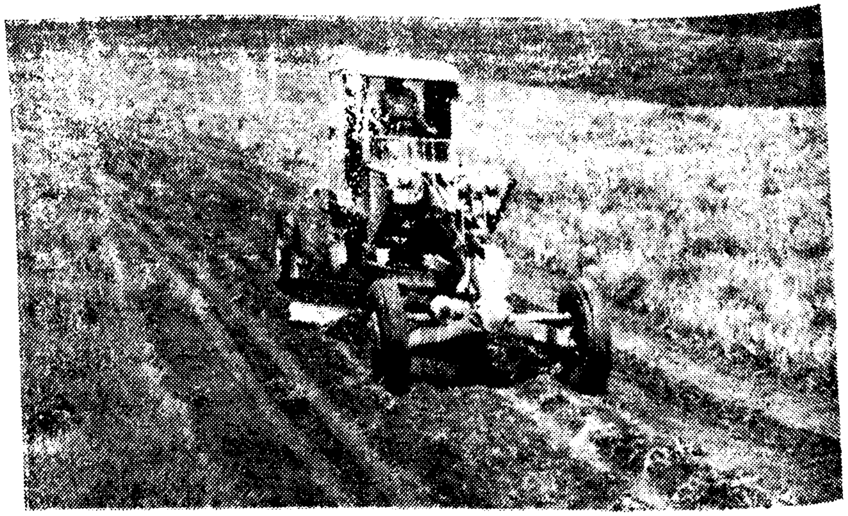
Head Office, Factory & Laboratory:

71 HIDE ROAD, KIDDERPORE, CALCUTTA.

PAKISTAN FACTORY

LAHORE CANTONMENT.

Telegrams :— BITUMULS.



Get Ahead— with the ADAMS *Motor Grader*

The Adams Motorgrader is the ideal machine for fast and accurate service on <u>your</u> road-work under even the most difficult conditions. Look at these advantages!

- ★ Rugged construction
- ★ Low fuel consumption
- ★ High front-axle clearance
- ★ High blade clearance
- ★ Long blade reach
- ★ Innumerable working positions

And spare parts are always ready for you!

Save costs of time and labour! Send to Volkart Brothers for full details of the Adams Motorgrader <u>now!</u>

VOLKART

VOLKART BROTHERS
(Agricultural Dept.)

Bombay - Calcutta - Madras - Cochin - New Delhi
Karachi - Lahore

We can supply
Ex stock
Any Quantity

"COLFIX" EMULSION
"HOTFIX" ASPHALT

TO MEET
YOUR REQUIREMENTS

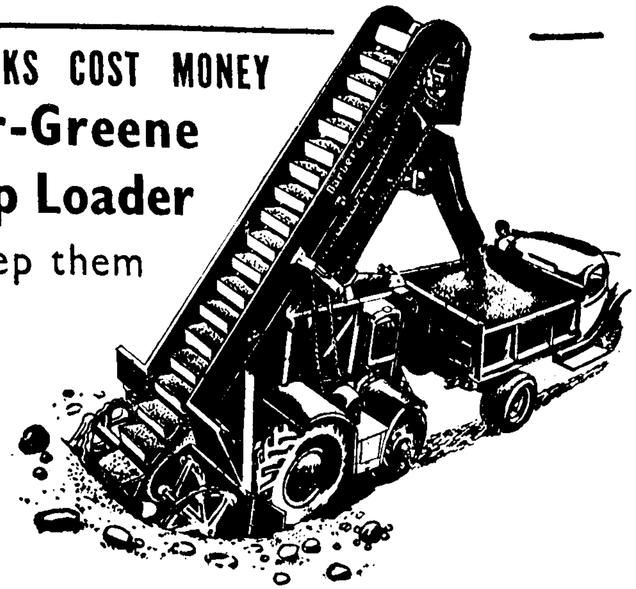
Please Apply :—

McLEOD & CO. LTD.
3, Netaji Subhas Road,
CALCUTTA.

IDLE TRUCKS COST MONEY

Barber-Greene Pick-up Loader

Will Keep them moving



USE IT IN GRAVEL - PITS, COLLIERIES, SAND AND GRAVEL STORAGE & DISTRIBUTING DEPOTS

IT IS DIESEL-DRIVEN AND MOST SIMPLE TO OPERATE

'ask jacks'
ABOUT IT

William Jacks & Co., Ltd.

CALCUTTA BOMBAY MADRAS