Paper No. 146.

"Glossary of Highway Engineering Terms."*

By

THE SPECIFICATIONS AND STANDARDS COMMITTEE OF THE INDIAN ROADS CONGRESS.

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[Following precedent, the recommendations of the Specifications and Standards Committee on "Glossary of Highway Engineering Terms" are published in the Journal for discussion and comments of Members before finalization as an approved standard.]

1. Highway Engineering like every other branch of Engineering is a science as well as an art. Both in science and in art, the terms used must have exact meanings which are understood by all concerned. A dictionary gives several meanings for each word applicable to the context in which it is to be used; a glossary gives the particular meaning to each word or phrase which is applicable to the science or art for which the glossary has been prepared. Some examples are Glossary of Acoustical Terms, Glossary of Electrical Engineering Terms, Glossary of Welding Terms etc.

2. Further it may be conceded by every highway engineer that, in the absence of specific limitations to the use of a word in relation to technical literature concerning his subject, there has often been a confusion in understanding. Similar confusion may often arise in the interpretation of orders, instructions, or similar communication from one engineer to another, if there is no common basis for understanding. The Glossary of Highway Engineering terms is intended to give philological exactitude and to serve as the common basis of understanding.

3. SOURCES AND REFERENCES.

3.1. In the compilation of this Glossary, the Committee have examined the glossaries published in the English language and listed in Appendix I.

3.2. The Committee has also been influenced by the meanings of words as commonly understood in India as they did not wish to suggest any violent departures from common usage. They aimed at the same time in establishing a base for the understanding of technical literature published in U.S.A. and U.K. and have therefore, on occasion, added explanatory notes.

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4. THE LANGUAGE.

The Glossary has been compiled in the English language. If at any time in the future it is proposed to use the National Language, Hindi, in engineering also, this Glossary will be a help in compiling one in the National Language.

5. THE SECTIONS.

For the purpose of easy reference the terms have been grouped in eight sections, and sub-sections as given below:

Section 1. Highways — general, classification.

Section 2. Preliminary operations.
21. Location.
22. Surveying.
23. Setting out.

Section 3. Preparatory works.
31. Earth works.
32. Soils.
33. Drainage.
34. Structures.

Section 4. Surface construction.
41. Surfacing types.
42. Construction details.

Section 5. Materials.
51. Classes.
52. Properties and tests.

Section 6. Plant and Machinery.

Section 7. Traffic.
71. General terms.
72. Signs and directions.

Section 8. Miscellaneous.

6. In this Paper, Sections 1, 2, and sub-section 31. are dealt with. After receipt of comments and discussion at the coming General Session the finalised Glossary will be published as a separate publication of the I.R.C. To facilitate reference to published literature as classified and arranged in libraries, the Universal Decimal Classification number has been given against each term as far as possible.

7. The use of term appearing within brackets is deprecated. e.g. (Vertex under term No. 23·01).

GLOSSARY
OF
HIGHWAY ENGINEERING TERMS.
SECTION 1.
HIGHWAYS, GENERAL, CLASSIFICATION

TERM NO.	U. D. C. NO.	TERM	DEFINITION
11.01	625.712.27	**BLIND ALLEY.**	A way or road open at one end only. (*See 11.25*)
11.02	625.712.7	**BRIDLE PATH.** BRIDLEWAY.	A way limited to the use of led, driven, or ridden animals.
11.03	625.711.3	**BY-PASS ROAD**	A road to enable through traffic to avoid congested areas or other obstructions to passage.
11.04		**CARRIAGE-WAY.**	That portion of the roadway designed and constructed for vehicular traffic. (*See 11.12 and 11.28*)
11.05	625.711.8	**CART TRACK.**	A way for use by carts and over which a right-of-way exists.
11.06	625.711.4	**CYCLE TRACK.**	A way or a part of a roadway designed and formed for use by pedal bi-cycles and over which a right-of-way exists.
11.07	625.711.1	**DISTRICT ROAD. MAJOR**	A road classified as such by a competent Authority.
11.08	625.711.1	**DISTRICT ROAD. OTHER**	A road classified as such by a competent Authority.
11.09		**DRIVEWAY.**	A way to secure access from a road to private property, and constructed with the permission of and to the standards fixed by the highway Authority, & further subject to certain conditions imposed by that Authority for the portion within the limit of the road land. (*See 1126.*)

TERM NO.	U. D. C. NO.	TERM	DEFINITION
11.10	625.711.2	FIELD-PATH.	A foot-path providing means of passage across a field or similar enclosed lands and over which right-of-way exists. (*See 11.11*)
11.11	625.711.6	FOOTPATH.	A way or means of passage for use by pedestrians only and over which there is a right-of-way.
11.12		FORMATION WIDTH.	The finished width of earthwork in fill or cut for receiving the road structure. (*See 11.26, 11.27 and 11.04*).
11.13	625.71	HIGHWAY.	An important road in a road system. (*See 11.25, 11.20 and 11.22*)
11.14		INTER-SECTION.	The area common to two or more roads which meet at an angle, whether or not one such road crosses another.
11.15		INTER-SECTION FLARED	An intersection on which the number of traffic lanes or carriageway widths exceeds the normal number of lanes or normal width of carriageways.
11.16	625.712.23	LANE.	A narrow way or passage between hedges, walls, or buildings, over which a right-of-way exists.
11.17		LIMITED ACCESS HIGHWAY.	A public highway, designed for through traffic, to which owners or occupants of abutting property or the travelling public have no right of ingress or egress from or across such highway except as may be provided by the highway Authority. Such highways may be parkways with or without landscaped road sides, from which trucks, buses,

TERM NO.	U. D. C. NO.	TERM	DEFINITION
			or other commercial vehicles are excluded; or they may be motorways open to use by all common forms of highway traffic.
11.18	625.8.696	LOOP ROAD.	A route formed by a road or a series of roads to avoid an obstruction or provide an alternative way for traffic. (*See 11.03*)
11.19		MOTORWAY.	A special purpose highway reserved for high speed vehicles.
11.20	625.711.1	NATIONAL HIGHWAY.	A highway classified as such by a competent Authority.
11.21		PARKING PLACE.	An area, on or off the road, other than a garage, set apart for temporarily accommodating stationary vehicles.
11.22	625.711.1	PROVINCIAL HIGHWAY.	A highway classified as such by a competent Authority.
11.23	625.711.3	RING ROAD.	A road roughly circumferential to the centre of an urban area and enabling traffic to avoid the centre of such an area. (*See 11.03 & 11.18*)
11.24		RIGHT-OF-WAY.	The privilege of use of a way acquired by the public by law, ownership, custom, or usage.
11.25	625.7	ROAD.	A way over which both vehicles and other types of traffic may lawfully pass. It includes the whole area upto the defined boundary and all structures and appurtenances pertaining to the road.
11.26		ROAD LAND. RIGHT-OF-WAY.	The land secured and reserved to the public for road purposes.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
11.27		**ROAD SIDE. ROAD MARGIN.**	The portions of the road land not reserved for traffic.
11.28		**ROADWAY.**	That portion of a road improved, designed, or ordinarily used for traffic. It includes carriageways & shoulders. (*See 11.04 & 11.12*)
11.29	625.712.25	**SERVICE ROAD.**	(i) A subsidiary road constructed between a road and buildings or properties facing thereon and connected only at selected points with the principal road. (ii) A way at the back of buildings for "servicing" and providing other means of access.
11.30	625.712	**STREET.**	A road within a town or other centre of habitation which has become partly, or wholly, defined by buildings established along one or both frontages.
11.31		**TRAFFIC LANE.**	A longitudinal strip of the carriageway of a road, regarded as of unit width (usually taken as 10 feet) to accommodate safely the forward movement of a single line of traffic.
11.32	625.711.6 626.32	**TOW PATH.**	A road or way along the bank of a canal or waterway to give access to the latter and used for towing or other services in relation to a navigable waterway.
11.33	625.711.2	**VILLAGE ROAD.**	A road classified as such by a competent Authority.

SECTION 2.

PRELIMINARY OPERATIONS

SUB-SECTION 21. LOCATION

TERM NO.	U. D. C. NO.	TERM	DEFINITION
21.01	625.72	**ALIGNMENT.**	The course along which the centre line of a roadway is located in plan. (*See 21.03*)
21.02	625.722	**ALIGNMENT POSTS, PEGS, AND STONES.**	Marks to define on the ground the centre line of the proposed roadway. (*See 21.03*)
21.03	625.722	**CENTRE-LINE.**	The median axis of a road, bridge, culvert, sewer, or drain, in the direction of its length. The centre line may be straight or curved. (*See 21.01*)
21.04	258.096	**DETOUR.**	An alternate circuitous road for traffic.
21.05		**DEVIATION.**	An alteration of an approved proposal, relating to the geometric or structural design, or the specifications, or the estimated provisions.
21.06	625.721	**DIVERSION.**	An alteration in the course of road, river, or stream, as a temporary expediency during construction, improvement, or repairs.
21.07	625.721/2	**LOCATION.**	The act of selecting and defining in the field or on a plan the route of a proposed highway or the site of a work. (b) The actual route or site so determined.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
21.08	526.31 625.72	**RECONNAISSANCE.**	A preliminary, and usually rapid, examination or survey of a region in reference to its natural features, or other local conditions to determine the location of a proposed highway or other work.
21.09	526.32	**REFERENCE MARK.**	A mark, signal, or object, distant from observation station. Also the angular direction of a mark from the obseravtion station from which the relative directions of other marks, signals, or objects may be measured.
21.10	625.724	**TURNING POINT.**	The intersection of any two consecutive straight survey lines forming part of a closed or open traverse.

SECTION 2.

PRELIMINARY OPERATIONS

SUB-SECTION 22. SURVEYING

TERM NO.	U. D. C. NO.	TERM	DEFINITION
22.01	526.911.2	**BASE LINE.**	A straight line in the field the horizontal length of which is accurately obtained and from which, by traingulation, the position of other points may be determined or from which a survey may be expanded.
22.02	526.911.3	**BEARING.**	The angular deviation of a survey line at any point in the line from a known direction through that point. *(See 22.14)* Generally, the known direction is taken as the true north and south line through the point. N. B. For definition in relation to structures refer to Sub-section 34.
22.03	526.95	**BENCH-MARK.**	A well defined permanent mark or point of known or assumed elevation used for ascertaining the levels of other points. *(See 22.10)*
22.04	526.95	**CHANGE POINT.**	A peg or a point on which the staff is held when levelling and which permits the transfer of the instrument after a foresight reading. *(See 22.12)*
22.05	526.95	**CHECK LEVELS.**	Supplementary levels taken for the purpose of verifying a series of levels of points previously measured.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
22.06	526.952	**CONTOUR LINE.**	An imaginary line connecting a series of points on the surface of the ground which are at the same height above a prescribed datum; also the line representing this on the map or plan. *(See 22.08)*
22.07	625.732	**CROSS SECTION.**	A vertical section at right angles to the centre lines. *(See 20.21)*
22.08	526.95	**DATUM.**	A defined plane of elevation with the level of which the level of other points may be compared or related. This level may be an assumed level of a known or fixed point or the mean sea level. *(See 22.15)*
22.09	526.95 625.8	**FORMATION LEVEL.**	(a) The reduced level to which the earthworks, excavation or embankment, are to be or have been executed. (b) The new surface level obtained on completion of earth works on which material and construction are superimposed. *(See 22.16)*
22.10		**G. T. S. BENCH MARK.**	A bench mark fixed by the "great Trigonometrical Survey of India," with reference to the mean sea level at Karachi. (These G. T. S. Bench Marks are indicated in all Survey of India maps with their levels and a complete record of these is maintained by the Survey of India and all revenue departments.) *(See 22.03)*

TERM NO.	U. D. C. NO.	TERM	DEFINITION
22.11		**GROUND LEVEL.**	The reduced level of any particular point on the surface of the ground. *(See 22.16)*
22.12		**LEVELLING.**	The operation of ascertaining the relative elevations of different points with reference to the assumed level of a known or fixed point. The mean sea level is often assumed as the datum level if this is not otherwise specified.
22.13	625.723	**LONGITUDINAL SECTION.**	The outline of a vertical section usually along the centre line.
22.14	526.915	**MAGNETIC BEARING.**	The angular direction of a survey line from a point with reference to the magnetic north-and-south line through that point at the date of observation.
22.15		**MEAN SEA LEVEL.**	The mean level of the sea at a fixed point on the coast assumed as the datum. This is the mean elevation of the tidal curve at any agreed station. (This is fixed for each country.)
22.16	526.95	**REDUCED LEVEL.**	The level of a point or mark as computed with reference to a prescribed datum.
22.17	526.95 625.8	**ROAD SURFACE LEVEL.**	The surface level of the centre of the normal carriageway in cross section. (In a super elevated section with extra widening, the road surface level is the level at the centre line of the carriageway without taking into account the extra width.)

TERM NO.	U. D. C. NO.	TERM	DEFINITION
22.18	526.952	**SPOT LEVEL.**	The reduced level of a defined isolated point on the ground. (*See 22.16*)
22.19	526.95	**TEMPORARY BENCH MARK.**	A well defined object or mark, whose elevation has been determined, preferably in relation to a known datum, available temporarily for the construction of a particular work. (*See 22.08*)
22.20	526.918	**TRAVERSE.**	A survey frame work consisting of a series of consecutive straight lines, the length, and the angular direction of which are measured. (When the lines form a circuit which ends at the starting point, it is termed a closed traverse, otherwise it is termed an open traverse.)
22.21	625.732	**TYPICAL CROSS SECTION.**	A cross section of the road showing standard dimensioned details and features of the design. (*See 22.07*)

SECTION 2

PRELIMINARY OPERATIONS

SUB-SECTION 23. SETTING OUT

TERM NO.	U. D. C. NO.	TERM	DEFINITION
23.01	625.732	**APEX OF A CURVE.** (VERTEX).	The point of intersection of two straights (main tangents) connected by the curve. In a reverse curve, the apex is the point of intersection of the extreme tangents for each of the two individual components. (*See 23.13 & 23.14*)
23.02	625.732	**APEX DISTANCE OF A CURVE.**	The shortest distance from the apex to the curve.
23.03	625.736/7	**BATTER.**	The inclination of a surface to the vertical, as of a wall, expressed as a ratio of one horizontal linear unit to the number of vertical linear units. (*See 23.37*) (Used generally in the case of masonry structures.)
23.04	526.951	**BONING.**	The process of locating and driving in pegs so that they are in line and have their tops also in line, carried out by sighting between a near and a far peg previously set to the gradient desired. (*See 23.05 & 23.36*)
23.05	526.951	**BONING RODS.**	Tee-shaped rods of equal height used in sets of three to facilitate the process of boning; two of the rods are held on the near and far pegs to establish a line of sight between them in the desired gradient while the third is used to fix intermediate pegs in line. (*See 23.04 & 23.36*)

TERM NO.	U.D.C. NO.	TERM	DEFINITION
23.06	625.732	**CAMBER.**	The convexity applied for some specific purpose. **Road Usage**: The convexity given to the cross section of the surface of carriageway. Camber is expressed- (i) in the case of a curved profile, as the slope of the chord joining the crown and the edge of the carriage way. *(See 23.08)* (ii) in the case of a straight line profile, as the slope of actual surface. A camber of 1 in 60 in a carriageway 30 feet wide means a difference of 3 inches in level between the crown and the edges. **Structural**: A convexity applied to structural members to allow for deflection. The rise of the centre of a bridge or a culvert above a straight line through its ends.
23.07	625.722	**CENTRE PEGS.**	Pegs placed to mark the centre line of a carriageway or other work.
23.08	625.732	**CROSSFALL.**	The fall at right angles to an alignment given to the surface of any part of a roadway. It may be expressed as a total, but preferably as a rate. *(See 23.06)*
23.09	625.732 624.023.671	**CROWN.**	The highest point of a curved surface such as a carriageway in cross section or an arch. The crown lies commonly at or near the centre of the curved surface.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
23.10	513.73	**CURVE. DEGREE OF**	The angle in degrees subtended at the centre of a circular arc by a chord of a given length, usually one hundred feet.
23.11	625.724	**CURVE. HORIZONTAL**	A curve in plan to provide change in direction of the center line of a road.
23.12	625.724	**CURVE. TRANSITIONAL OR EASEMENT**	A curve whose radius gradually changes from infinity to a selected minimum. or the converse. for the purpose of giving easy changes of direction of a road.
23.13		**CURVE. COMPOUND**	A curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent at the point or points of junction.
23.14	625.724	**CURVE. REVERSE**	A curve consisting of two arcs of the same or different radii curving in opposite directions and having a common tangent at the point of junction. *(See 23.24)*
23.15	625.723 625.725	**CURVE. VERTICAL**	A curve in the longitudinal section of a roadway to provide for easy change of gradient.
23.16	625.723 625.725	**CURVE. SUMMIT**	The vertical *convex* curve connecting two intersecting grades.
23.17	625.723 625.725	**CURVE. VALLEY** (Curve Sag)	The vertical *concave* curve connecting two intersecting grades.
23.18	625.772	**DAGBEL.**	*(See 23.25)*

TERM NO.	U.D.C. NO.	TERM	DEFINITION
23.19	625.724	**DEVIATION ANGLE. TOTAL.**	The external angle of intersection between two straights (main tangents) at the two ends of a curve. This is the supplement of the intersection angle. (*See 23.24*)
23.20	625.725	**GRADIENT.** INCLINE. GRADE.	(a) The rate of rise or fall with respect to the horizontal along the length of a road (or other work) expressed as a ratio or as a percentage. (b) The length of a road or other work which is not level.
23.21	625.725	**GRADIENT. AVERAGE**	The net rise or fall of the road surface level in a longitudinal direction in any section divided by the longitudinal length of that section measured in the same units and expressed either as a fraction or a percentage.
23.22	625.725	**GRADIENT. LIMITING** (GRADIENT. MAXIMUM).	A gradient which must never be exceeded in any part of a road.
23.23	625.725	**GRADIENT. RULING**	The desirable upper limit of a gradient. Where keeping within the ruling gradient is not feasible, the maximum gradient may not exceed the limiting gradient. (*See 23.22*)
23.24	625.724	**INTER-SECTION ANGLE.**	The internal angle of intersection between two straights (main tangents) at the two ends of a curve. This is the supplement of the deviation angle. (*See 23.19*)

TERM NO.	U.D.C. NO.	TERM	DEFINITION
23.25	625.722	**LOCKSPIT.** DAGBEL.	A narrow continuous cut made in the ground surface along a defined line of demarcation.
23.26	526.97	**OFFSET.**	A linear measurement made from a survey line to an object situated to one side of that line, at right angles to that line.
23.27		**OSCULA-TING CIRCLE.**	A circle having a common tangent with a curve, and having the same radius as the curve at the point of contact.
23.28	625.723	**PROFILE.**	(a) An outline of a vertical section of ground usually along or at right angles to the centre line of a work. (b) The actual surface of such a vertical section.
23.29	625.724	**RADIUS OF A CURVE.**	(*In curve setting*) The radius at the point of maximum curvature in a continuous curve of varying radii (This is also the smallest radius.)
23.30	625.724	**RADIUS OF A CURVE. ABSOLUTE MINIMUM**	(*In curve setting*) The minimum radius of curvature of the centre line of a curve necessary to provide safe and comfortable travel, without skidding of vehicles at a particular design speed under wet conditions of the road surface.
23.31	625.724	**RADIUS RULING.**	The desirable minimum radius of the centre line of a curve for a particular design speed of vehicular travel. (*See 23.30*)

TERM NO.	U.D.C. NO.	TERM	DEFINITION
23.32	625.712.82	**RAMP.**	A short steeply inclined way connecting surfaces at different levels.
23.33	625.722	**REFERENCE OBJECTS.** REFERENCE PEGS.	Objects or fixed pegs with a measured relation as to level, direction, and distance, to other pegs in a survey set out to enable the latter pegs to be established, if disturbed.
23.34	625.724	**SHIFT.**	The displacement of a circular curve from the straight to provide room to introduce a transition curve between it and the straight.
23.35		**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.
23.36	526.95.6	**SIGHT RAIL.**	An above-ground horizontal rail fixed to two upright posts, one on each side of a trench excavated for a sewer, drain etc., used with other rails to establish a reference line from which the sewer, drain, etc., may be laid at the required gradient. *(See 23.04 & 23.05)*
23.37	625.725	**SLOPE.**	The inclination of a surface to the horizontal expressed as one vertical linear unit to the number of horizontal linear units. *(See 23.03)* e.g. slope of 1 *in* 50 means a rise of 1 foot in a length of 50 feet.

TERM NO.	U.D.C. NO.	TERM	DEFINITION
23.38	625.732.3	**SUPERELEVATION.** CANT. BANKING.	The inward tilt or transverse inclination given to the cross section of a carriageway on a horizontal curve to reduce the effects of centrifugal force on a moving vehicle. Superelevation is generally expressed as a slope.
23.39	625.724	**TANGENT DISTANCE.**	The length on the straight between the tangent point of a curve and its apex. *(See 23.01 & 23.40)*
23.40	625.724	**TANGENT POINT.**	The point where a straight alignment ceases and curvature begins; also a point of reversal of curvature.
23.41	625.724	**TRANSITION LENGTH.**	The length of the transition curve connecting a straight length of road with another main curve which may be circular or transitional.
23.42	625.724	**TURNING RADIUS. MINIMUM**	Radius of the path of the outer front wheel of a vehicle making its sharpest possible turn.

SECTION 3.

PREPARATORY WORKS

SUB-SECTION 31 EARTHWORKS

TERM NO.	U. D. C. NO.	TERM	DEFINITION
31.01	624.135	BACK-FILLING.	(a) Earth or other material used to replace material removed during construction, such as in culvert and pipe line trenches and behind bridge abutment, retaining walls, etc. The material removed during construction may be used as back-fill. (b) Material placed between an old structure and a new lining.
31.02	625.726	BALANCED EARTH-WORKS.	Earthworks in a length of a project in which the quantity of "Excavated material" is nearly equal to the quantity of filling and can be economically utilised for filling.
31.03	626.35 627.41	BANK.	**In Roads :** **See Embankment (31.15)** **In canals, rivers etc.** A ridge of earth, stones, etc. naturally existing or specially constructed to guide the flow or prevent overflow in floods.
31.04		BENCH.	A level ledge on the side of an embankment or cutting. (i) to intercept earth rolling down the slopes ; (ii) to improve the stability of the construction ; or (iii) to improve visibility.
31.05	624.136.13	BENCHING. STEPPING.	The formation of a series of leve platforms or ledges upon an incline.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
31.06		BORROWPIT.	An excavation (generally regular shaped) for obtaining the material for a fill or an embankment.
31.07	641.133.22 631.435.4	CLAY.	Fine grained hygroscopic silicate of alumina (usually occurring mixed with impurities) which is plastic when moist.
31.08	624.051	CLEARING. STRIPPING.	The operation of removing from the site of works, grass, weed, brushwood, and other objectionable material.
31.09	624.131.37	CONSOLIDATION.	The process of reduction in the volume of a soil, with a corresponding increase in density, such as can be produced by the expulsion of water or air from the pores of the soil under application of external force. **For "Compaction" see Sub-section 32**
31.10	624.134.1	CUT.	The material excavated to make a cutting.
31.11	624.135.5 and 625.732.2	CUT AND FILL.	A term used to describe any section of earthwork which is partly in cutting and partly in embankment.
31.12	625.732.2	CUTTING.	That portion of the site of a road where the formation is attained by excavation below ground level.
31.13	625.731.6 and 625.8.086	DRAGGING.	The operation of smoothing out and reshaping irregularities in surface earthworks by means of a drag. **(For Drag see Section 6)**
31.14		EARTH-WORK.	Any excavation in or filling with soil.

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TERM NO.	U. D. C. NO.	TERM	DEFINITION
31.15	625.731.4 or 624.136	EMBANKMENT. BANK. FILL.	An earthwork raised above the natural ground by the deposition of material to support construction at a higher level.
31.16		FILL.	Also see 31.03 for Bank See Embankment 31.15
31.17	624.135	FILLING.	Material used for raising the earth-work to a desired level.
31.18	625.725	GRADING.	See Trimming 31.40.
31.19		GRUBBING.	Removing the stumps and roots of trees and plants from an area.
31.20	551.244.2 and 624.131.537	LAND-SLIDE	Earth slips on a large scale. (*See 31. 32*)
31.21		LEDGE.	A shelf-like level projection on side of rock or mountain.
31.22	624.131.222 and 551.311. 234.4	LOAM.	A loam is a soil having a relatively even mixture of the different grades of sand and of silt and clay. It is mellow with a some-what gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by sqeezing the moist soil can be handled freely without breaking. Some loamy soils contain a considerable proportion of organic matter.
31.23	624.131.228 and 552.542	MARL.	An earthy mixture of minerals consisting of quartz, clay, calcite, and sometimes glauconitic sands. Quite often found in swamps and lakes.

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TERM NO.	U. D. C. NO.	TERM	DEFINITION
31 24	624.131.276 and 552.577	PEAT.	Dark fibrous spongy soil showing evidence of vegetableo rigin.
31.25	624.131.216	QUICKSAND.	See Running sand 31.26.
31 26	624.131.213	RUNNING SAND. QUICKSAND.	Any sand which upon saturation behaves almost like a liquid. (state) Any sand which behaves like a thick viscous fluid. (material)
31 27	624.131.212 and 551.311 234.2	SAND.	Granular, gritty, loose grains of silicious origin of grain size not exceeding 2.00 m. m. and free from appreciable amounts of clay and silt and hence non-plastic and cohesionless. (*For purposes of mortar etc., See section 51*)
31 28	624.159.2 and 624.131.526	SETTLEMENT.	Downward movement of the soil or of the structure which it supports due to shrinkage by consolidation or subsidence caused by the movement of the subsoil. (*See 31.37.*)
31.29	552.522	SHALE.	A compressed and laminated clay not so hard as slate, with or without associated organic matter.
31.30	625.736	SIDE CUT.	An excavation in a transverse slope to form a bench or shelf wholly within the profile of the ground before excavation. (*See 31.05.*)
31.31	532.584	SILT.	Mud consisting of fine, barely visible grains, with grains of specified size, with little or no plasticity and no cohesion, usually deposited as a sediment in water.

TERM NO.	U. D. C. NO.	TERM	DEFINITION
31.32	624.131.543	**SLIP.**	Local soil movements produced by a mass of soil sliding over a slope.
31.33	631.4 624.131.2 and 551.311.234	**SOIL.**	A mixture of earthy materials with particles differing physically in size, shape, and cellular structure, and varying in chemical composition. (Soil is of secondary origin and is produced by the decomposition of various kinds of rocks inter-mingled more or less with organic matter resulting from the growth and decomposition of animal matter or vegetation.)
31.34		**SPOIL.**	Surplus excavated material.
31.35		***SPOIL BANK.***	*An earthwork bank formed by* depositing spoil.
31.36	624.136.13	**STEPPING.**	See Benching 31.05.
31.37	624.131.526 and 624.159.2	**SUBSIDENCE.**	Downward movement of the soil produced by removal or displacement of the underlying strata.
31.38	625.731.1	**SUB-SOIL.**	The undisturbed strata lying below the natural top soil.
31.39	624.131. 531.1	**SURCHARGE.**	Earth supported by a retaining wall above the top level of the wall.
31.40	624.136.1	**TRIMMING.** GRADING.	The operation of excavating and shaping the surface of earthworks.

APPENDIX I

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Paper No. 147.

"An Adaptable Steel Centring for Reinforced Concrete Bridges"

By A. Nageswara Ayyar

1. Much of the cost of long span reinforced concrete bridge structures is due to the necessity for providing an efficient centring for retaining the concrete until it set and became strong enough to sustain its own weight and the extraneous load coming on it. Before the second World War, timber fit for use in centrings was fairly cheap and was being extensively used for the purpose but the price of timber has now increased considerably, up to four to five times the pre-war level, whereas other structural materials like cement and steel have risen only about two and a half times.

2. Hence the cost of centrings which are, after all, only temporary structures erected to retain the concrete until it sets and no part of the finished structure, often bears an undue relation to the cost of the bridge itself. Structures like bowstring girders of large span, which in suitable conditions make for considerable economy in the use of steel and cement, possess considerable reserve strength, and reduce the cost of approaches by giving the maximum clearance over floods, often prove uneconomical on account of the high cost of centring.

3. In shallow rivers which dry up in the hot season, it is not difficult to support the centring from the dry bed, but this implies cessation of work in the flood seasons and entails long delays and mounting overhead charges in the case of bridges having a series of spans.

4. Where the rivers are deep, or when there is deep water during all seasons, the provision of supports from the bed is very costly and often impracticable. In such cases, R. C. bridges of large spans become exceedingly costly as specially designed centrings, often spanning large gaps, have to be provided.

5. A heavy programme of bridge construction is now in hand throughout the country. Some convenient form of steel centring so designed that it

(i) can be adapted to varied structures,

(ii) can be repeatedly used any number of times during its life, and

(iii) will not require stoppage of work in the flood season,

is necessary for the economical construction of bridges. A design has been worked out for a centring satisfying the above conditions and is described below. [Plates I. & II].

6. In designing this centring, the following objectives have been kept in view:—

(i) The structure should consist of a minimum number of interchangeable parts;

(ii) The component parts should be of such dimensions and weight as to be capable of being easily transported to the bridge site readily assembled there and, after completion of the work, readily dismantled and brought back to stores;

(iii) The parts should be capable of being fitted for use as a centring for any span in multiples of 10 feet up to a maximum of 150 ft and for any kind of reinforced concrete bridge structure commonly met with;

(iv) Consistent with interchangeability of parts and capacity for sustaining the maximum loads coming on the centring, its weight should be the minimum so as to secure economy;

(v) In long series of spans the trusses forming the centring should be capable of being moved from one span to another without being dismantled;

(vi) Parts of the centring should be so designed that they can be used as centrings for other reinforced concrete structures.

CENTRINGS FOR BOWSTRING GIRDER BRIDGES, 150 FT. SPAN

7. Except in rare cases, spans of more than 150 feet will not be used. The usual width of roadway is that required for two-lane traffic, generally 22 feet, with or without foot-paths 5 to 6 feet wide on each side. The centring described in this Paper has been designed initially for use on a bowstring girder span of 150 feet with 22 feet roadway and wheel guards one foot wide on each side but it can be adopted for use on other types of bridges and other spans.

8. The trusses for the 150 ft span bowstring bridge will have a bearing of 3 feet on each pier and can be fitted with suitable packing pieces on the bed blocks outside the bowstring arch. The main trusses will be in three tiers, fitted one over the other, making a total height of 37 ft. 6 in. This height was adopted so as to support an arch with a rise of one fifth of the span or 30 ft and depth at the crown of about 4 ft. 6 in.

9. By a series of trials it was found that a length of 11 ft. 3 in. gave full interchangeability of parts without fouling adjoining members and provided the necessary height for the truss. The diagonals should have an inclination of 65° to the horizontal. Utilizing the above data, a complete design has been worked out and is shown in the plans attached.

10. The whole centring is to be carried by two main trusses. The total load to be carried by each truss as shown in the calculations attached is 450 tons. The trusses have been designed for this loading. As the designed truss comes under the category of an indeterminate structure, the stresses on whose members cannot be directly determined, the stresses have been calculated by two approximate and indirect, but recognized, methods and for any member the higher of the stresses obtained by either method has been adopted.

11. The stresses on every member have been shown in Plate No. III. The stresses that will be taken up by the middle horizontals are not easily calculable and their existence has been neglected in calculating the stresses on other members. This error will be on the side of safety as it will reduce the stresses on other members such as the top and bottom booms etc. The middle horizontals are, however, necessary to give lateral stiffness to the compression members and to give rigidity to the structure.

12. As the stresses in the top and bottom booms come to nearly 250 tons, the net area required in the tension member, after making allowance for bolt holes and limiting the stress to about 8 tons per sq. inch, is 32 sq. inches. The members being interchangeable, they will have to bear either tension or compression according to their position in the truss. With these considerations in mind, and taking into account the facilities for jointing, a channel section 15 in. × 4 in. with an area of 12.5 sq. inches and weighing 42.5 lbs. per Rft. has been adopted. Making allowance for two bolt holes in flanges to pass 1 in. diameter bolts, the net area of each channel will be slightly over 11 sq. in. Three channels jointed together as shown give sufficient material for the tension boom.

13. As regards the compression boom, the minimum dimension of the built up member with the channels fitted as shown in drawings is 15 ins., and the panel length is 11 ft. 3 ins. There is a strong wind brace connecting the two trusses at each panel point.

The length of the compression member for stress calculation has, therefore, been taken as 11 ft. 3 ins. With these assumptions, the maximum compressive stress on the boom comes to about 7 tons per sq. inch which is quite safe. The other portions of the booms do not require any discussion as the material allowed in the different panels is more than is required to take the stresses coming on them.

14. Regarding diagonals, except in the case of the first three bays, the stresses are less than what the members can take up. Where they are not sufficiently strong, two channels 6″ × 3″ are added on each flange of the main channel, as shown in plans, and these make them quite strong.

15. The cross beams are to be of built up channels firmly bolted to the main trusses. They will be made in two pieces of 24 ft. and 16 ft. length so that, when jointed, they will form beams 40 feet long, and will enable centrings for footpaths to be supported. Individually, these can be used for centrings for slab bridges as the webs have a smooth surface. With this object in view, the flange angles of the channels should be welded to the web plate and not rivetted. For each panel point, two cross-girders have been provided so that the centring of deck slab in each bay can be separately removed without disturbing the adjoining bays.

16. The wind braces which, under the wind pressure, will be in compression, will consist of 4 angles $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by 3/8 in. properly braced so as to form a column 1 ft. 6 in. square. For the unsupported length of 32 feet, they will be able to sustain a load of about 25 tons whereas the actual load coming on them will be less than 5 tons. They will be made in 16 ft. lengths with facilities to combine two to make up a length of 32 feet. They can also be used as derrick posts for hoisting purposes.

17. The form-work for arches will be supported from the trusses and the wind braces. In addition to the top wind braces, additional timber spars will be tied at the intermediate panels, partly to support the arch work forms and partly to stiffen the whole centring. Some wood work as shown in the plans is also required to complete the centring.

18. As some of the bolts in the middle of the booms and in some of the diagonals will be heavily stressed, the bolts should all be of 1 in. clear diameter and made of high tensile steel. Newall bolts are recommended for the purpose or bolts made from special steel.

19. The varieties of standard parts are only eleven as under:

1. Main channel bars 15 in. by 5 in. by 11 ft. 3 in. with holes drilled so as to suit every position;

2. Additional channels 6 in. by 3 in. for strengthening diagonals;
3. Intermediate gusset plates.
4. Gusset plates for top and bottom booms.
5. Gusset plates for end sloping booms.
6. Bolts 1 in. diameter, $2\frac{1}{2}$ in. to 3 in. long.
7. Cross girders 24 ft. long.
8. Cross girders 16 ft. long.
9. Wind braces 16 ft. long.
10. Brackets for holding arch form work.
11. Channel connecting pieces for connection at panel joints.

20. Centrings sufficient for at least three spans should be held in stock. It is only then that they can be combined to form a continuous truss over three spans and be capable of being moved from the one span to another without dismantling or providing supports from bed when moving. As each truss will weigh only 65 tons and has been designed for a load of 450 tons, there is no danger in allowing one full truss to overhang and hence, when centrings for three spans are provided, they can be moved from one set of three spans after concreting to the next set of three spans.

CENTRING FOR OTHER SPANS AND OTHER TYPES

21. For bowstring girder bridges of say 100 feet span, the trusses may be made of two tiers. This will give a height of 25 feet and, as the rise will be only 20 feet, there will be ample margin for the arch form support. For T-beam bridges of 60 to 70 feet span, a single tier truss can be built up to support the form work.

22. Thus, if centrings for three bowstring arch spans of 150 feet be held in stock, the centring for any type of bridge of a single span or a series of spans can be built up with the available materials.

23. Plans and estimates, with calculations for the strength of the various parts, are attached.

24. The Author wishes to express his thanks to Shri Brij Narayan, who encouarged him to work out the design and gave him valuable advice on important aspects of the design and indicated a rough outline. He wishes also to express his thanks to Messrs. P. S. Subramaniam, Designs Engineer of Messrs. Gannon Dunkerley and Co., Madras, and Srirangachari, Divisional Engineer, Highways, Madras, for independently calculating the stresses in the various parts of the indeterminate trusses and for their general check of the design.

APPENDIX I

AN ADAPTABLE STEEL CENTRING FOR A BOWSTRING GIRDER OF 150 FT. SPAN.

Given below are detailed calculations of weights, bending moments, sections adopted, quantities of structural steel work required, and approximate cost for a steel centring for a bowstring girder bridge of 150 feet clear span.

CALCULATIONS

Assumptions made for determining weights :—

Arch section at crown 2 ft. 3 in. × 5 ft.
Arch section at haunches 2 ft. 3 in. × 7 ft.
Tie-beams 2 ft. 3 in. × 5 ft. with a recess of 3 ft. 6 in. by 1 ft. 3 in.
Cross beams at 11 ft. 3 in. centres.
Roadway 22 feet.
Wheel-guards 1 ft. by 1 ft.
Width between girders 24 ft.
Slab 9 in. thick.

Structural Steel

Safe tensile stress 8 tons per sq. in.
Safe compressive stress $7\frac{1}{2}$ tons per sq. in.
Safe stress in bolts with high tensile steel 8 tons per sq. inch.

Weight

Arches on both sides, 2 by 165 ft. by 2 ft. 3 in. by 5 ft. 6 in. (average)	=	4084 cft.
Tie beams (sectional area $6\frac{3}{4}$ sq. ft.) 2 × 156 ft. × $6\frac{3}{4}$ (sq. ft.)	=	2106 cft.
Cross beams, 15 × 24 ft. × 2 ft. 6 in. × 1 ft.	=	900 cft.
Slab 156 ft. × 24 ft. × 9 in.	=	2808 cft.
Total :		9898 cft.

Allowing 15 cft. per ton, weight	=	660 tons
Girders and centring	=	212 tons
Add for timber work in centring	=	12 tons
Work people and additional loads	=	11 tons
Total		895 tons

On each truss — 448 tons or 32 tons per panel.

N.B. (Weight due to foot-paths, hangers, wind braces and wearing coat have not been taken into account as these will be done only after the arch-itself is partly set and is able to take the loads.)

Total height of the bridge = 37 ft. 6 inches.

Effective depth from centre to centre of boom 36 ft. or 432 inches.

Incidentally the weight of finished superstructure for a 150 ft. span bow-string girder is estimated below for reference only.

WEIGHT OF ONE SPAN OF CONCRETE FINISHED

Concrete as above	=	9898 cft.
Foot-paths 2 × 156 ft. × 6 ft. × 3 in.	=	468 cft.
Cross-beams for foot-paths 2 × 15 × 6 ft. × 1 ft. 3 in. × 6 in.	=	113 cft.
Wind braces 4 × 24 × 1 ft. 6 in. × 2	=	288 cft.
Wearing coat 1 × 156 ft. × 22 × 3 in.	=	858 cft.
Handrails 2 × 156 ft. × 1 ft.	=	312 cft.
		11937 cft.

Total weight of one span as finished (dead load only) 800 tons.

Main Girder

Three tiers of triangular trusses are proposed as per plan (Plate I.)

Aggregate height = 37 ft. 6 in.

Net depth of beam between centres of booms = 36 ft. or = 432 inches.

Top boom consisting of 3 channels 15 in. × 4 in. weighing 42.5 lbs. per foot and area 12.5 sq. inches.

Allowing for bolt holes of 1 in. dia the net deduction in any section will be (2 × 1 × 0.4) + (2 × 0.6) = 2 sq. inches in the extreme case when 4 holes are in one section. Hence net area for each channel is equal to (12.5—2) or 10.5 sq. inches.

For three channels 10.5 × 3 = 31.5 sq. inches.

Maximum stress in middle bay is 245 tons.

Area required, 30 sq. inches at 8 tons per sq. inch.

Three channels as provided give 31.5 sq. inches which is more than ample.

In Compression

Least dimension = 15 inches.

Panel length = 135 in. Therefore $\frac{1}{d} = 9$ and hence the column will be treated as a short column.

Total sectional area = 37.5 sq. inches.

Maximum stress in end posts is 249 tons.

Stress in compression member $\frac{249}{37.5} = 6.6$ tons per sq. inch.

Hence the section adopted is sufficient.

Actually the middle horizontals also take up some load, reducing the stresses in the booms. Hence the section consisting of 3 channels 15 inches × 4 inches weighing 42.5 lbs. per foot, fitted as shown in plans, is sufficient.

Although we can reduce 3 channels to 2 for the last three bays near the supports of bottom boom, it is better to continue the same section as in the centre because when the girders are moved forward over the next set of spans these will become compression members.

Diagonals-Minimum dimension of a 15 in. × 4 in. channel is 4 inches.

Unsupported length effective = 120 inches.

Least radius of gyration is 1.15.

$$\text{Therefore } \frac{l}{v} = \frac{120}{1.15} = 105.$$

$$\text{Capacity of column} = \frac{12.5 \times 7\frac{1}{2}}{1 + \frac{1}{30000} \times 105 \times 105} = \frac{93.7}{1.37}$$

= 68 tons.

In tension the net area = 12.5 — 2 × .6 or = 11.3 sq. inches
Strength = 90 tons.

The compression members whose stresses are more than 62 tons are nil.

The tension members which exceed 90 tons are $L_2 A_2 \times K_2 Y_2$, $L_1 A_3 \times K_1 X_1$ (vide Plate III.)

The compression members $A_2 B_2$ and $H_2 K_2$ may be strengthened.

For strengthening 2 channels 6 in. × 3 in. weighing 12.4 lbs. per foot are to be added on each side.

The net area added is 2 × 3.6 − 2 × .65
= 7.2 − 1.30 = 5.9 sq. inches.

The additional strength in tension is 47 tons giving a total of 90 + 47 or 137 tons.

In compression, the strength of the column will be 120 tons.

The number of 6 in. × 3 in. channels required for strengthening are

L_2A_2, K_2Y_2	= 2 × 2 =	4
L_1A_3, K_1X_1	= 2 × 4 =	8
L_2B_2, H_2K_2	= 2 × 6 =	12
	=	24 Nos.

All other diagonals are stressed less than their strength.

Cross Girders

Weight coming on the cross-girders.

Tie-beams wt. 2 × 11 ft. 3 in. × $6\frac{2}{4}$ sq. ft. = 10 tons 5 tons acting 3 ft. from end on each side uniformly distributed load

Cross-beams	1 × 24 × 2 ft. 6 in.	= 60 cft.
Slab	1 × 24 × 11 ft. 3 in. × 9 in.	= 203 cft.
Wheel guards	2 × 11 ft. 3 in. × 1 ft. × 1 ft	= 23 cft.
		286 cft. or 19 tons
Add for wt. of cross-beams and centring.		3 „
Add for workmen		2 „
		24 tons

Unsupported length of girder is 32 feet.

$$\text{B.Moment} = \frac{24 \times 32 \times 12}{8} + 5 \times 3 \times 12 \text{ in tons.}$$

$$= 1152 + 180 = 1232 \text{ in tons}$$

Section proposed to be adopted is shown in sketch.

This section is proposed so that it can be useful for centring for T-beams, etc. The angle is proposed to be welded.

Area of angle 4 in. × 4 in. × $\frac{1}{2}$ in. section = 3.75 sq. inches.
Add for that portion of the plate which adjoins the angle 4 × $\frac{1}{4}$ inch. = 1 sq. inch.
Total 4.75 sq. inches.

Resisting Moment = 21 × 4.75 × 7 (only 7 tons allowed being welded steel) = 698 inch tons.

Two of these will give 1396 inch tons, which is more than the bending moment.

Load on cross beams

Concrete in beams	24×2 ft. 6 in. $\times 1$ ft.	= 60 cft. (provision made for 6 inches more)
Slab	24×11 ft. 3 in. $\times$ 9 in.	= 203 cft.
Wheel guards	2×11 ft. 3 in. $\times 1$ ft. $\times 1$ ft.	= 23 cft.
		286 cft. or 19 tons
Add for weight of cross-beams and centring		3 ,,
Add for workmen		3 ,,
		25 tons

$$B.M. = \frac{25 \times 24 \times 12}{8} \text{ in tons} = 900 \text{ inch tons.}$$

Resisting moment $= 4.75 \times 7 \times 21 = 698$ inch tons as above.

As there are 2 girders, this is more than sufficient.

Details of weight of cross-girders

For 24-ft. length

Angles $4'' \times 4'' \times \frac{1}{2}''$ weighing 12.75 lbs. per foot	2 Nos. $\times$ 24 ft. $\times$ 12.75 lbs.	= 612 bls.
Web $\frac{1}{4}''$ thick weighing 10 lbs. per sq. foot.	1×24 ft. $\times 2$ ft. $\times 10$ lbs.	= 480 lbs.
End angles for connecting with adjoining length $3'' \times 3'' \times \frac{3}{8}''$ weighing 7.2 lbs. per ft.	2×2 ft. $\times$ 7.2. lbs.	= 29 lbs.
Angle stiffners $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ weighing 4 lbs. per foot.	11×2 ft. $\times 4$ lbs.	= 88 lbs.
		1209 lbs.

For 16 ft. Length

Angles $4'' \times 4'' \times \frac{1}{2}''$ as above.	2×16 ft. $\times$ 12.75 lbs.	= 408 lbs.
Web plate —do—	1×16 ft. $\times 2$ ft. $\times 10$ lbs.	= 320 lbs.
End angles $3'' \times 3'' \times \frac{3}{8}''$	2×2 ft. $\times$ 7.2 lbs.	= 29 lbs.
Stiffeners $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$	7×2 ft. $\times 4$ lbs.	= 56 lbs.
	Total:	813 lbs.

To connect the two 24 ft. and 16 ft. lengths, we require two 4 in. $\times \frac{3}{8}$ in. plates 2 ft. 6 in. long weighing 10 lbs. per foot for each.

i.e. 4 $\times$ 2 ft. 6 in. $\times$ 10 lbs = 100 lbs.

Total for 1 beam 40 feet long—(1209+813+100) lbs.	= 2122 lbs.
Add for bolts for connecting	78 ,,
Total weight for 40 ft. length	= 2200 lbs.
Weight per foot	= 55 lbs.

Weight for 24 ft. beams = 1209 lbs.

Add for bolts 15 ,,

Total for 24 ft. length = 1224 lbs. or weight per foot = 51 lbs.

Brackets for holding arch plates.

Channels 4 in. $\times$ 2 in. section weighing 7.91 lbs. and area 1.4 sq. ins.

Each bracket = 18 ft. $\times$ 7.91 lbs,	= 142 lbs.
Add for cross bar plate	12 lbs,
	154 lbs.
Add for fixing bolts 1 in. dia. and plate washers for fixing.	26 lbs.
	180 lbs.

Bolts

Tension boom maximum stress 245 tons.

No. of bolts provided = 40 Nos. of which 20 are in double shear and the rest in single shear.

The resistance $= 2 \times 20 \times .78 \times 8$ $(+20 \times .78 \times 8)$ = 375 tons.

Even if they be in single shear $40 \times .785 \times 8$ tons = 251 tons.

Hence the bolts are sufficient.

Diagonals maximum is 116 tons.

These have 10 bolts, where strengthened by additional channels, they are in double shear.

The resistance $2 \times 10 \times .785 \times 8$ = 125 tons.

In other cases, stresses are less than 62 tons.

10 bolts will take up $10 \times .785 \times 8$ = 63 tons.

These bolts will, therefore, suffice.

Top Ties

Wind ties at every apex point: built up struts as shown in plan.
Length 32 feet in two pieces of 16 feet each.

Angle iron $2\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. weighing 5.90 lbs. per R. ft. 4×32 ft. $\times$ 5.90 lbs.	755 lbs.
Plates at ends $\frac{1}{4}$ in. thick for a length of 2 ft. } $2 \times 4 \times 1$ ft. 6 in. $\times 2$ ft. $\times$ 5 lbs.	120 lbs.
Plates at centre connecting the angles 4×3 ft. $\times$ 1 ft. 6 in. $\times$ 5 lbs.	90 lbs.
Braces 2 in. $\times$ $\frac{3}{8}$ in. weighing 2.6 lbs. per foot. $2 \times 2 \times 6 \times 4 \times 2$ ft. $\times$ 2.6 lbs.	499 lbs.
Add for bolts etc. to connect the two pieces and the main trusses	20 lbs.
Total	1484 lbs.
or Say	1500 lbs.

Weight for 32 ft. = **1500 lbs.**
Per foot = **47 lbs.**

DETAILED QUANTITIES OF STRUCTURAL STEEL-WORK

Channels 15 in. $\times$ 4 in. weighing 42.5 lbs. per foot, each 11 ft. 3 in. long :—

For top and bottom booms for two trusses $2 \times 25 \times 3$	...	150 Nos.
and sloping booms $2 \times 6 \times 3$	...	36 ,,
horizontals 2×25	...	50 ,,
inclined members 2×72	...	144 ,,
	Total	380 ,,

II. 15 in. $\times$ 4 in. channel section connection pieces for top and bottom booms 4 ft. 2 in. long 2×27 ... 54 Nos.
channels for sides 6 ft. long ... 8 ,,

III. Cross girders suspended from main girders weighing 55 lbs. per foot. 2×13 Nos. $\times$ 40 ft. ... 26 Nos.

IV. Cross beams as supports for decks weighing 51 lbs. per foot 2×15 Nos. $\times$ 24 ft. ... 30 Nos.

V. Top built-up wind braces weighing 47 lbs. per foot. 12 Nos. $\times$ 32 ft. ... 12 Nos.

VI. Intermediate ties and stiffeners to be of timber 12 in. $\times$ 6 in. in section or rounds 9 in. dia. (not included in steel work.)

VII. Gusset Plates.

1. Top and bottom gusset plates of size 4 ft. 2 in. $\times$ 3 ft. 9 in. $\times$ $\frac{1}{2}$ in. each weighing 315 lbs.

   10 Nos. in top and 13 Nos. in bottom. Total No. required 2×23 Nos. $\times$ 2 ... **92 Nos.**

2. Middle gusset plates of size 5 ft. 4 in. $\times$ 3 ft. $\times$ 6 ft. $\frac{1}{2}$ in. weighing 375 lbs. each

   Upper $2 \times 11 \times 2$ = 44 }
   Lower $2 \times 12 \times 2$ = 48 } 92 Nos.

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3.	End gusset lpates 4 ft. 6 in. × 4 ft. 6 in. × ½ in. weighing 405 lbs. each.	16 Nos.
	Middle gusset at end booms 4 ft. 6 in. × 6 ft. × ½ in. weighing 540 lbs. each. 2×2×4 ...	16 Nos.

VIII. Bolts to be cut of higher tensile steel so as to give a safe stress of not less than 10 tons per sq. inch in tension and 8 tons in shear approx. weight of bolts including nuts and washers etc. 3 per cent of total weight.

IX. Plates ⅛ in. thick weighing 5 lbs. per sq. ft.

1.	Connecting cross beams 15 × 24 ft. × 1 ft. 6 in.		=	540 sq. ft.
2.	Plates under tie beams	2×150×3 ft.	=	900 sq. ft.
3.	Side plates	2×150×6 ft.	=	1800 sq. ft.
4.	Inner side plate	2×136×2 ft. 6 in.	=	680 sq. ft.
5.	For wheel guards	2× 150×1 ft.	=	300 sq. ft.
6.	Plates for decking	14×10 ft. 6 in × 24 ft.	=	3528 sq. ft.
7.	For arch sides	2×2×165×6 ft.	=	3960 sq. ft.
8.	For bottom arch	2×165×3 ft.	=	990 sq. ft.
				12698 sq. ft.

X.	Strengthening bars for braces, channels 6 in. × 3 in. weighing 12.4 lbs. per running foot.	24 Nos.
XI.	Channel bracket for arch work each weighing 180 lbs. 2×15	30 Nos.
XII.	Flat bars 4 in. × ½ in. and 3 ft. long 7½ lbs. each for connecting bottom of cross beams 5×15	75 Nos.

Weight of the Steel Work.

1.	380 Nos. channels 15 in. × 4 in. × 42.5 lbs. per running foot 380×11 ft. 3 in. × 42.5 lbs.	=	1,81,688
2.	26 Nos. bottom cross girders 26×40 ft. × 55 lbs.	=	57,200
3.	30 Nos. cross beams 30×24 ft. × 51 lbs.	=	36,720
4.	75 flat bars 3 ft. × 4 in. × ½ in. connecting top booms of cross girders at 7.5 lbs each.	=	563

14

5.	Wind braces at 47 lbs. per foot 12×32×47	= 18,048	lbs.
6.	92 Nos. gusset plates 4 ft. 2 in. × 4 ft. 2 in. weighing 315 lbs. each.	= 28,980	,,
7.	92 Nos. gusset plates 5 ft. 4 in. × 3 ft. 6 in. weighing 375 lbs. each.	= 34,500	,,
8.	16 Nos. End gusset plates 4 ft. 6 in. × 4 ft. 6 in. weighing 405 lbs each.	= 6,480	,,
	16 Nos. middle gussets at end boom 6 ft. × 4 ft. 6 in. × ½ in. weighing 540 lbs.	= 8,640	,,
9.	12698 sq. ft. plates for decking for arches weighing 51 lbs. per sq. ft.	63,490	,,
10.	24 Nos. strengthening channel bars 11 ft. 3 in. long 6 in. × 3 in. weighing 12.5 lbs. per foot. 24×11 ft. 3 in. × 12.5	3,375	,,
11.	30 Nos. channels for brackets for arch shuttering at 180 lbs. each	5,400	,,
12.	54 Nos. connecting pieces 4 ft. 2 in. 54×4 ft. 2 in. × 42.54	9,562	,,
	8 pieces 6 ft. long.	2,040	,,
	Total:	4,56,686	lbs.
	Add 3% for weight of bolts, nuts, etc.	13,700	
	Sundries.	3,000	
	Total:	4,73,386	lbs.

Or 212 tons, allowing for some wastage.

Parts excluding side girders.

Bottom cross girders	=	57,200	lbs.
Top wind braces	=	18,048	,,
Cross beams	=	36,720	,,
Flat bars	=	563	,,
Total		1,12,531	lbs.
For bolts etc. at 3 percent.		3,375	lbs.
Total		1,15,906	lbs. or 52 tons.

Plates 63490 lbs. or 28.4 tons.

Brackets for arch shuttering = 5400 lbs. or 2.4 tons.

Main girders 212 − 83	=	129; each girder is 65 tons.
A. Main side Girders	=	129 tons.
B. Cross Girders and wind ties	=	52 tons.
C. Plates	=	28.4 tons.
D. Brackets for arch formwork	=	2.4 tons.
	Total	211.6 tons.
	or	212 tons.

For 1 span 212 tons steel work at Rs. 800 per ton.	Rs. 169,600
Contingencies.	10,400
	Rs. 180,000

Cost for 3 spans:—

Add extra for connecting the three trusses so that they can be moved from one set of spans to the next.

Channels top boom $2 \times 2 \times 3 \times 3$	...	36 Nos.
Middle $2 \times 2 \times 2$	...	8 Nos.
Bottom 2×2	..	4 Nos.
	Total	48

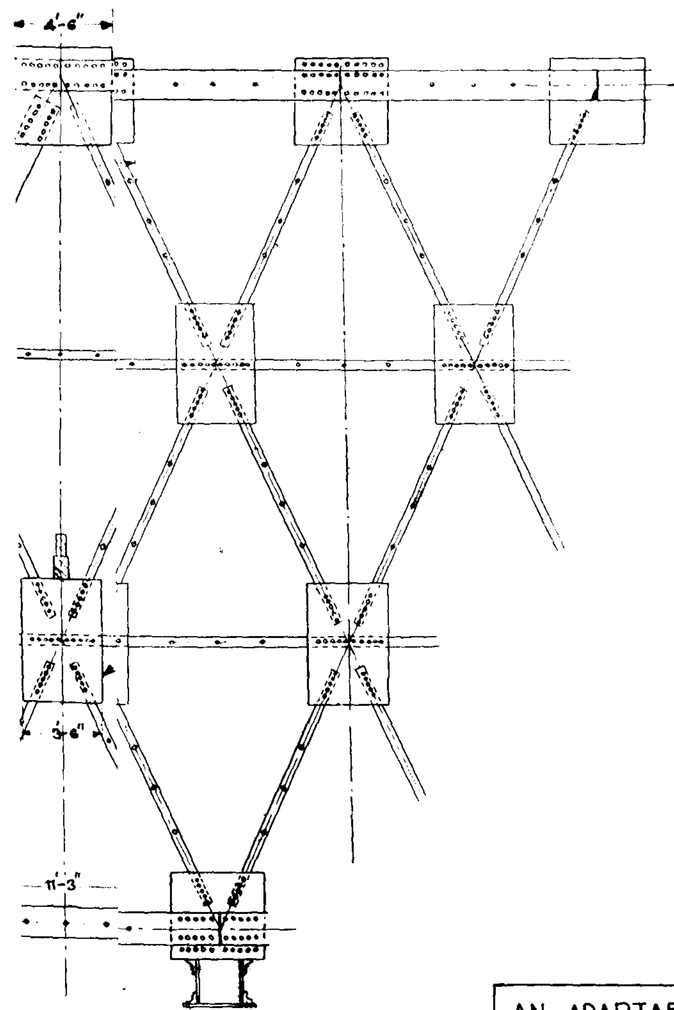
48 Nos. channels 11 ft. 3 in. @ 425 lbs. per foot.	22950
Add 3 per cent for bolts.	690
	23,640
	or 11 tons.

Steel work for 3 spans @ 212 tons per span.		636 tons
Extra bars for connecting the three trusses so as to form a continuous girder.	...	11 tons
	Total	647 tons

COST

647 tons @ Rs. 800 per ton	...	Rs. 5,17,600
Contingencies	...	32,400
	Total	Rs. 5,50,000

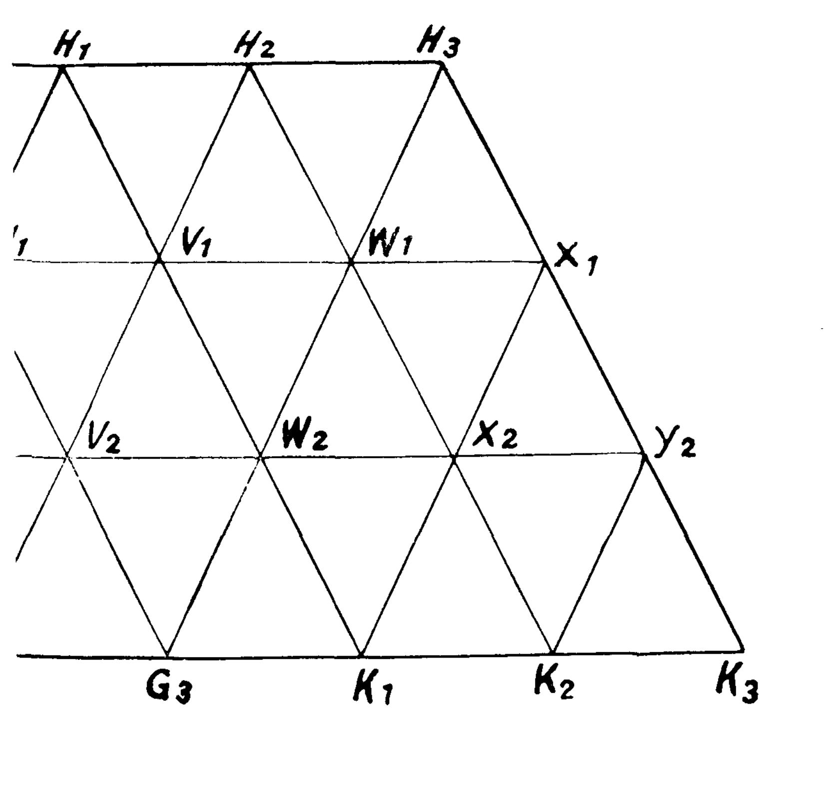
PLATE I



AN ADAPTABLE STEEL CENTERING FOR REINFORCED CONCRETE BRIDGES

SCALE:— 0 1 2 3 4 8 FT

PLATE No. III.



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RESEARCH PUBLICATIONS

1. USE OF STABILISED SOIL IN ENGINEERING CONSTRUCTION

Effect of moisture of compaction on the structural stability of soils.

By

S. R. Mehra & H. L. Uppal

1. INTRODUCTION — THE PROBLEM

1.1. Construction of mud houses is an ancient practice. From time immemorial, man has constructed shelters for himself out of the local soil. The method of construction has varied from place to place and various improvements have been made from time to time as a result of experience.

1.2. Owing to the fact that sufficiently weather-resistant types of construction have not so far been generally evolved in northern India, the technique of building in mud has not been recognised as standard practice even in limited urban areas. No recorded information is, therefore, easily available about the actual behaviour of mud construction in changing weather conditions or about its cost of maintenance. The general belief based on current practice, however, is that the outside plaster has not only to be frequently renewed but it has also to be constantly watched and carefully maintained during wet weather to avoid serious damage.

1.3. The only type of mud construction which has received recognition in the engineering profession in this country, is masonry consisting of sun dried mud bricks laid in mud mortar. But even that type has the following inherent limitations and is, therefore, fit only for inferior temporary structures.

a. No plaster will adhere properly to it for any length of time.

b. It has no resistance to water and this, together with the fact mentioned above, involves risk of serious damage during the rains.

c. It has a low and uncertain compressive strength of about four tons per square foot.

1.4. There are reports from other countries of the world of rammed earth churches and other buildings having stood up to the weather very well indeed. This happened in particular areas, probably because of the suitability of the local soil as it existed. But, so far as is known, no scientific investigations have ever been made on the good behaviour of these structures, nor have failures been explained.

1.5. This is in great part responsible for the fact that construction in mud has never had official backing. In recent years, however, the young science of soil mechanics has been so well developed that it is now possible, by a proper scientific study of a soil, to predict with reasonable accuracy its behaviour in engineering structures. There is, consequently, a rapidly increasing tendency now to consider soil as an alternative material of construction.

1.6. Use was made of this so-called soil-consciousness recently when the East Punjab was faced with the problem of rapidly constructing several thousand permanent houses for refugees from the West Punjab, as a result of the partition of the country. Through lack of transport and other reasons, sufficient coal was not available for burning bricks and it was decided to resort to the scientific use of local soil for replacing burnt brick masonry in permanent house construction.

1.7. To achieve this end, it was necessary to so improve the local soil that it should attain the following properties in the resulting structure :

a. High density.

b. High resistance to softening under water.

c. High compressive strength.

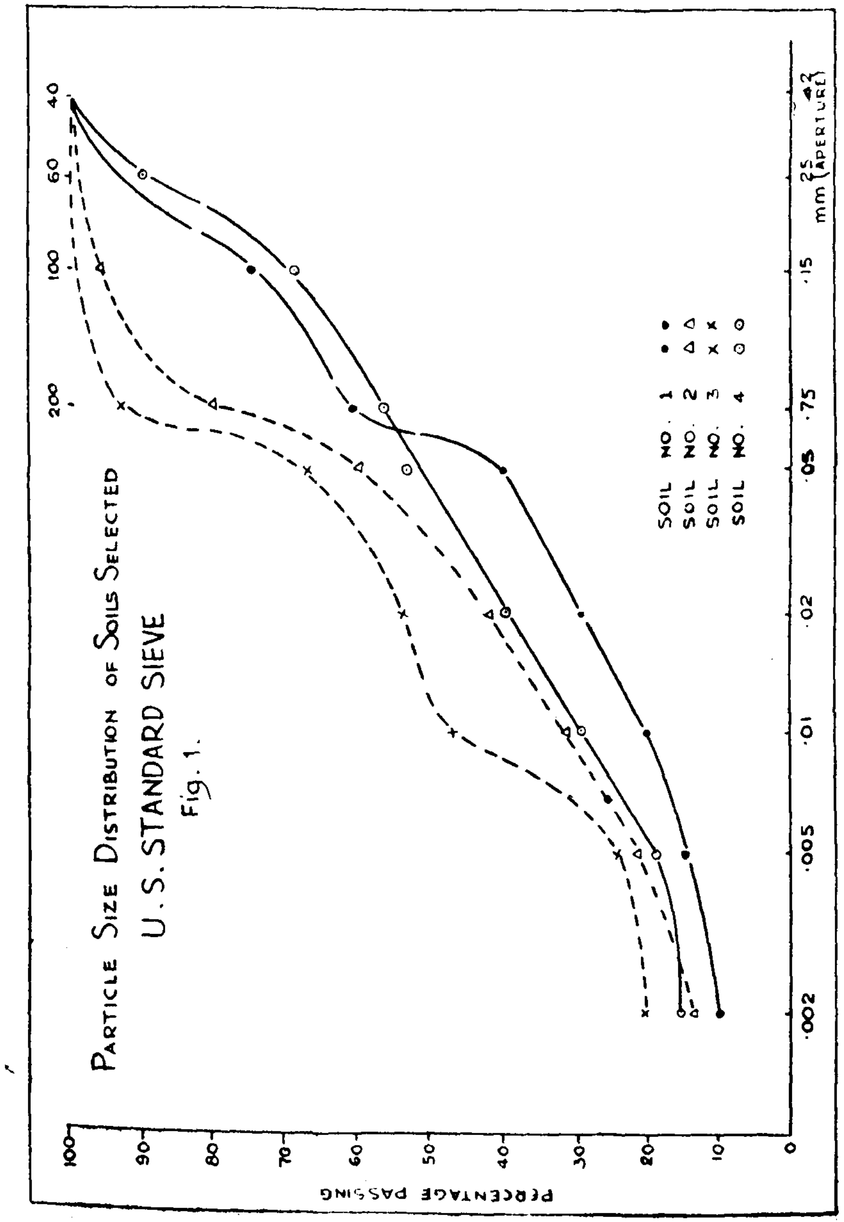
d. Low shrinkage on drying.

e. Low thermal expansion and contraction.

f. High adhesion to plaster, under changing climatic conditions.

2. SCIENTIFIC USE OF SOIL PROVIDES SOLUTION

2.1. Each one of the above problems was studied at the Soil Research Laboratory at Karnal in continuation of previous work done at the Soil Research Laboratory at Lahore in so far as this work related to soils found generally in the East Punjab. Four typical soils were selected for this study and the physical and chemical characteristics of these are given in Table 1 and Fig. 1.



PARTICLE SIZE DISTRIBUTION OF SOILS SELECTED
U. S. STANDARD SIEVE
Fig. 1.

TABLE I

Analysis of soils selected for the study.

Soil No.	Descrip-tion.	Liquid Limit.	Plasticity Index.	Sand content.	Optimum moisture.	Exchangeable Ca m.e.*/100 gm.	Exchangeable Na m.e.*/100 gm.	Total solids
1.	Silty Loam	27.2	8.0	38.0	13.0	6.4	1.30	Negligible
2.	Silty loam	27.5	8.7	18.9	12.0	7.0	1.60	,,
3.	Silty clay loam	37.00	17.3	8.4	12.0	14.8	1.10	,,
4.	Loam	24.7	9.5	43.9	11.0	8.7	1.14	,,

* m.e. stands for mili-equivalents.

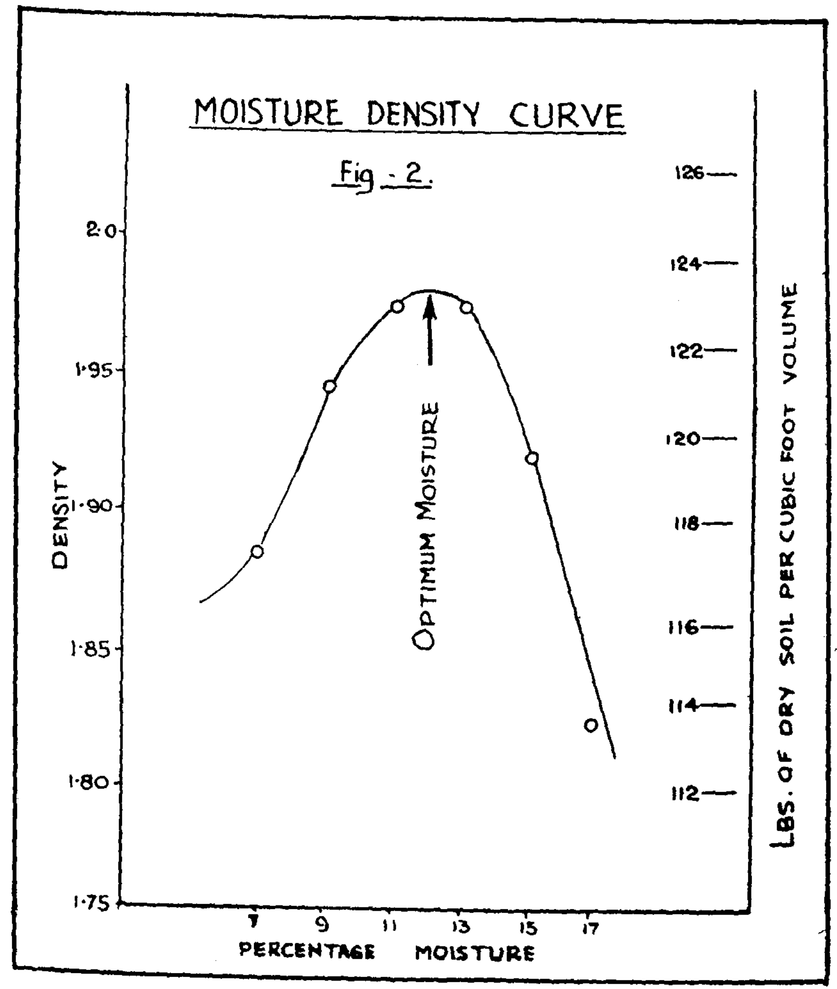
2.2. The object of the present study, which is the first of a proposed series, is to investigate the effect of compaction of a soil at different moisture contents on the stability of engineering structures in which it is used.

2.3. Soil compaction is a process in which the soil particles are forced to get packed together. This is brought about through the help of moisture which plays an important part during the process. The degree of compaction is generally described through the density attained as a result of the compaction and expressed as the weight of dry soil per cubic foot volume, or in metric units as grams of dry soil per cubic centimeter. Immediately after compaction, the weight of the wet soil and the volume occupied by it are measured to find out the wet density. The moisture content of the wet soil is then determined to calculate the dry density according to the following formula :

$$\text{Dry density} = \frac{\text{Wet density}}{100 + \text{moisture}} \times 100.$$

When a soil is compacted at different moisture contents, maximum density is attained at what is termed the optimum moisture content for that mode of compaction. This is an important factor in soil mechanics. The optimum moisture varies from soil to soil.

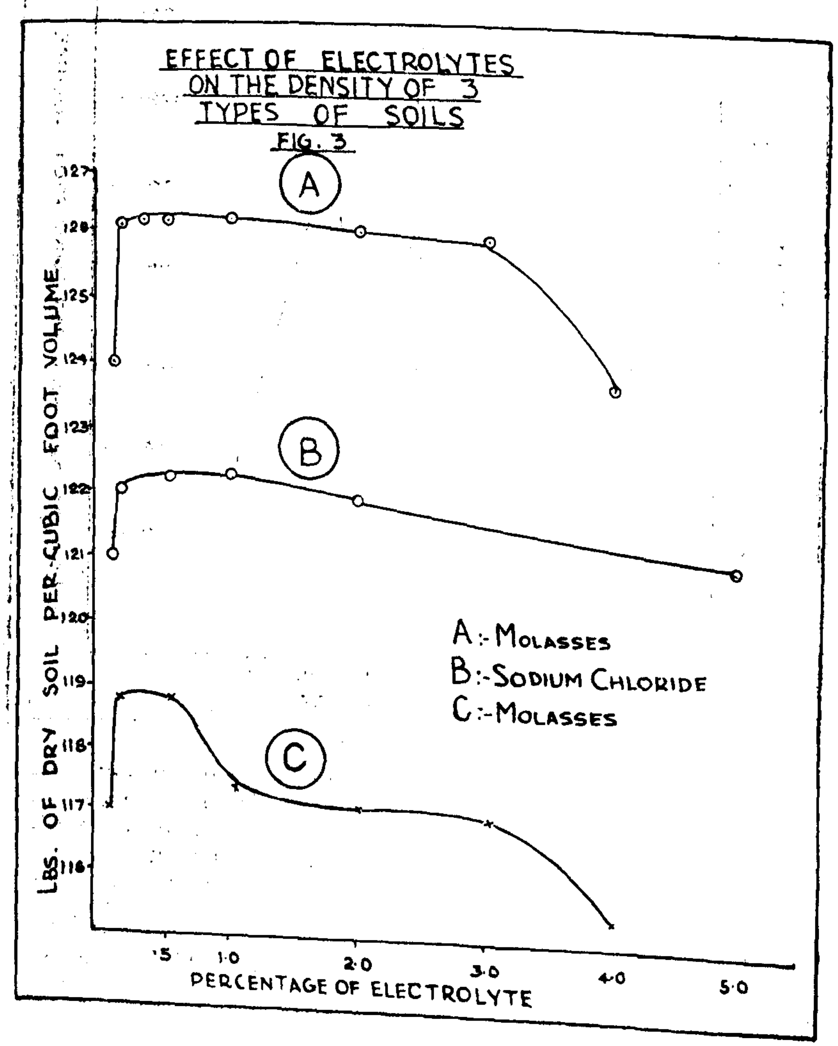
2.4. A typical moisture density curve is given in Fig. 2.



The reason for different densities at different moistures of compaction is that at low moisture content there is not enough moisture to lubricate all the particles to enable them to slip into position and drive out the air in the voids. As the moisture is increased, the particles are lubricated more and more and get packed further, resulting in higher density and lower percentage of air voids. As the quantity of water is still further increased, the excess water, after lubricating all the particles, combines with the residual air in the voids and tends to push the soil particles apart.

The voids thus continue to increase and the density continues to fall correspondingly as indicated on the right side of the peak of the curve.

2.5. It is possible to increase the density still further by adding a very small quantity of an electrolyte to the moisture before compaction. This is due to the fact that, in the presence of an electrolyte, water is able to exist in much thinner films between soil particles, than without it.



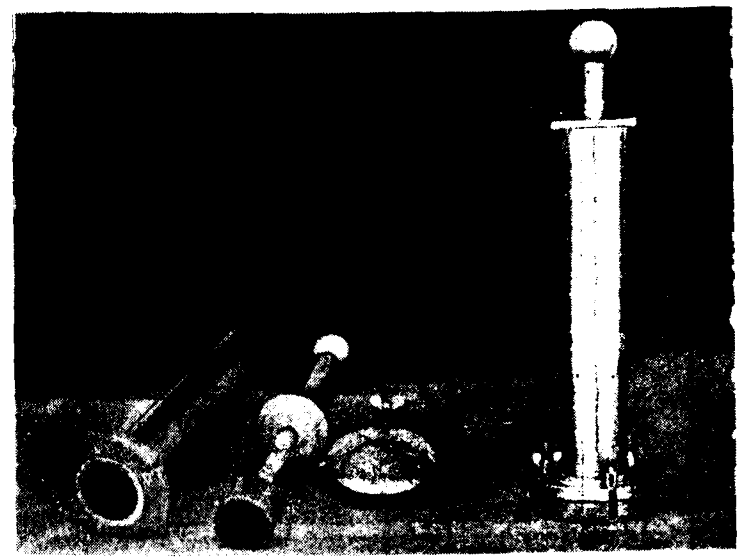
2.6. A few typical curves showing the change in density with a change in the percentage of the electrolyte are given in Figure 3.

A small increase in density at those higher limits means a colossal increase in the engineering properties of soil such as compressive strength and abrasive resistance etc.

3. THE APPARATUS

3.1. An apparatus for determining optimum moisture is shown in the photograph.

It consists of a $5\frac{1}{2}$ lb. rammer dropping freely through a height



The Compacting Apparatus.

of 15 inches, within a 2.5 inch diameter copper pipe standing on a detachable base. The number of blows of the rammer represents the degree of compactive effort spent on the soil. For determining the optimum moisture for use in field compaction, the number of blows is correlated with the mode of compaction in the field.

3.2. The higher the compactive effort the higher is the maximum density attained and correspondingly the lower is the optimum moisture requirement for the same soil. This is illustrated by moisture-density curves of a soil compacted with increasing blows of the compaction apparatus *Vide* Fig. 4 and Table 2. It is also obvious from these curves that whereas compactive effort has a considerable effect upon the resulting density on the dry side of the optimum moisture, it has comparatively little effect on the wet side.

TABLE 2

Effect of Increased Compaction on the Density of Soil at various Moisture Contents.

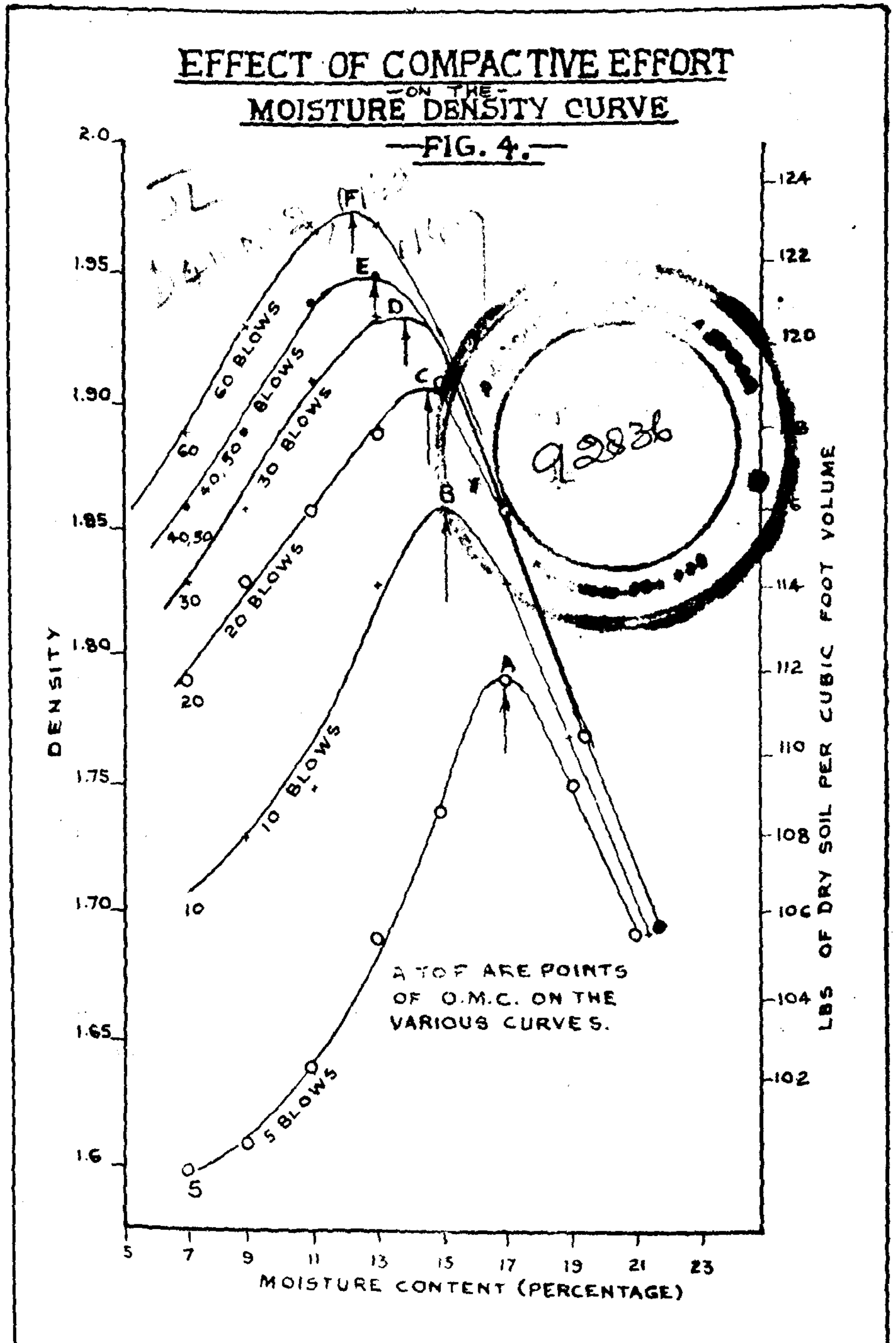
(See Figure 4)

Soil used	Moisture per cent.	Number of strokes of rammer.						
		5	10	20	30	40	50	60
		Dry Bulk Density						
No. 4	7	1.60	1.71	1.79	1.83	1.86	1.86	1.89
	9	1.61	1.73	1.83	1.86	1.89	1.89	1.93
	11	1.64	1.75	1.86	1.91	1.94	1.94	1.97
	13	1.69	1.83	1.89	1.94	1.95	1.95	1.97
	15	1.74	1.86	1.91	1.91	1.91	1.91	1.93
	17	1.79	1.83	1.86	1.86	1.86	1.86	1.85
	19	1.75	1.77	1.77	1.79	1.79	1.79	1.79
	21	1.69	1.69	1.71	1.73	1.73	1.73	1.73

Note: The horizontal steps indicate the O.M.C. position.

4. FIELD APPLICATION

4.1. It is obvious from the above that, for the determination of optimum moisture for field construction, it is necessary to correlate the laboratory compactive effort (number of blows) with the mode of compaction available in the field. This is done as described hereafter.



4.2. With the compaction equipment available for the work concerned, four or five small lengths are compacted, using the same soil, but varying percentages of moisture. The exact percentage of moisture at the time of compaction of each length, and the resulting density are carefully determined and a moisture-density curve is plotted. In the laboratory, a series of moisture-density curves are obtained by using the same soil as in the field, but changing the number of blows in the compaction apparatus. The moisture-density curve obtained in the field, is then compared with the series of similar curves obtained in the laboratory, and a suitable curve is selected from these, keeping in mind that the field density should not be less than 95 per cent of the laboratory density. The number of blows for the curve thus selected, gives the laboratory compactive effort about equal to the field compactive effort and on which is based the determination of optimum moisture for the field construction concerned.

5. SCOPE OF THE STUDY

5.1. The effect of the compaction of soil on its structural stability has been studied in the following two aspects.

(a) Effect of compaction of soil at different moistures on the compressive strength.

(b) Effect of compaction of soils on the water resisting quality of the resultant mass.

6. COMPRESSIVE STRENGTH

6.1. Two hundred grams of the oven- dried soil was compacted into a block in the compaction apparatus (described in para. 3.1) with an effort of forty strokes. The resultant blocks had a diameter of 2.5 inches and a height of about 1.3 inch.

6.2. Blocks were compacted, as mentioned above, at different moisture contents, including the optimum for the soils selected for the study. These blocks were allowed to dry in the shade and then, finally, oven-dried to a constant weight at 50°C to 60°C. The blocks compacted at different moisture contents were subjected to the compressive strength test and the results are given in Table 3 and reproduced in figure 5.

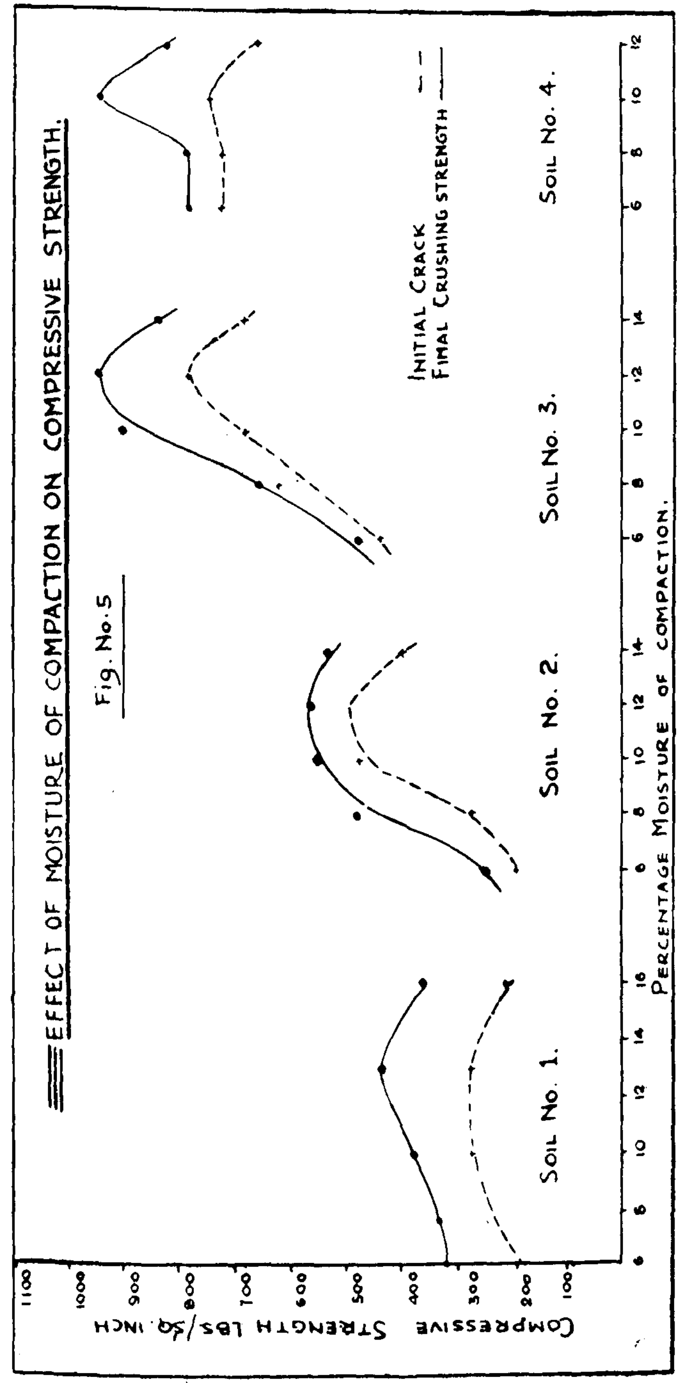


TABLE 3

Compressive Strength of Soil Blocks Compacted at various Moisture Contents.

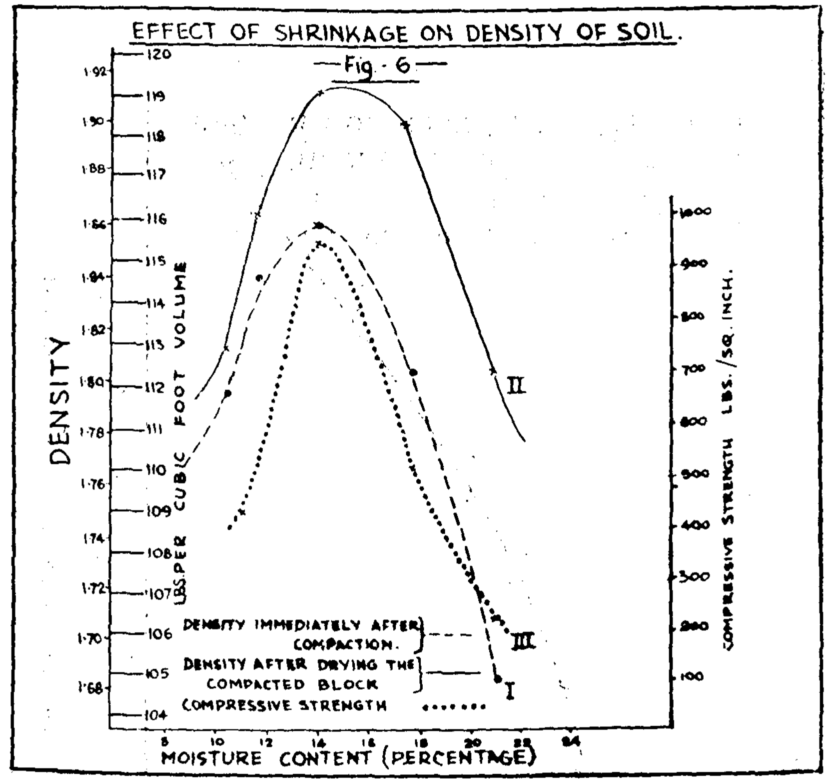
Soil Used	Moisture content per cent	Compressive strength lb. per sq. in. Initial crack	Final crack	Dry bulk density	Weight of dry soil per cubic foot volume-lbs
1	6	186.9	318.5	1.75	109.25
	8	250.4	328.6	1.77	110.5
	10	278.0	378.4	1.81	113.0
	13	**282.7**	**433.2**	**1.84**	**114.9**
	16	228.0	373.0	1.81	113.0
2	6	210.0	250.0	1.72	106.0
	8	288.6	482.8	1.75	109.2
	10	490.2	547.0	1.81	113.0
	12	–	**551.7**	**1.82**	**113.6**
	14	401.2	538.0	1.80	112.4
3	6	437.7	471.9	1.75	109.2
	8	620.1	642.9	1.82	113.6
	10	693.1	912.0	1.88	117.4
	12	**784.3**	**1048.0**	**1.90**	**118.6**
	14	688.5	828.0	1.82	113.6
4	7	736.4	784.3	1.82	113.6
	9	718.2	779.7	1.89	118.0
	11	**731.8**	**943.0**	**1.96**	**122.4**
	13	654.3	813.9	1.89	118.0

6.3. A comparison of the results shows that, for the same soil, the compressive strength is maximum when compaction is carried out at optimum moisture, and falls when compaction is done either above or below optimum moisture.

7. INCREASE IN DENSITY, ON ACCOUNT OF SHRINKAGE, AS A RESULT OF DRYING

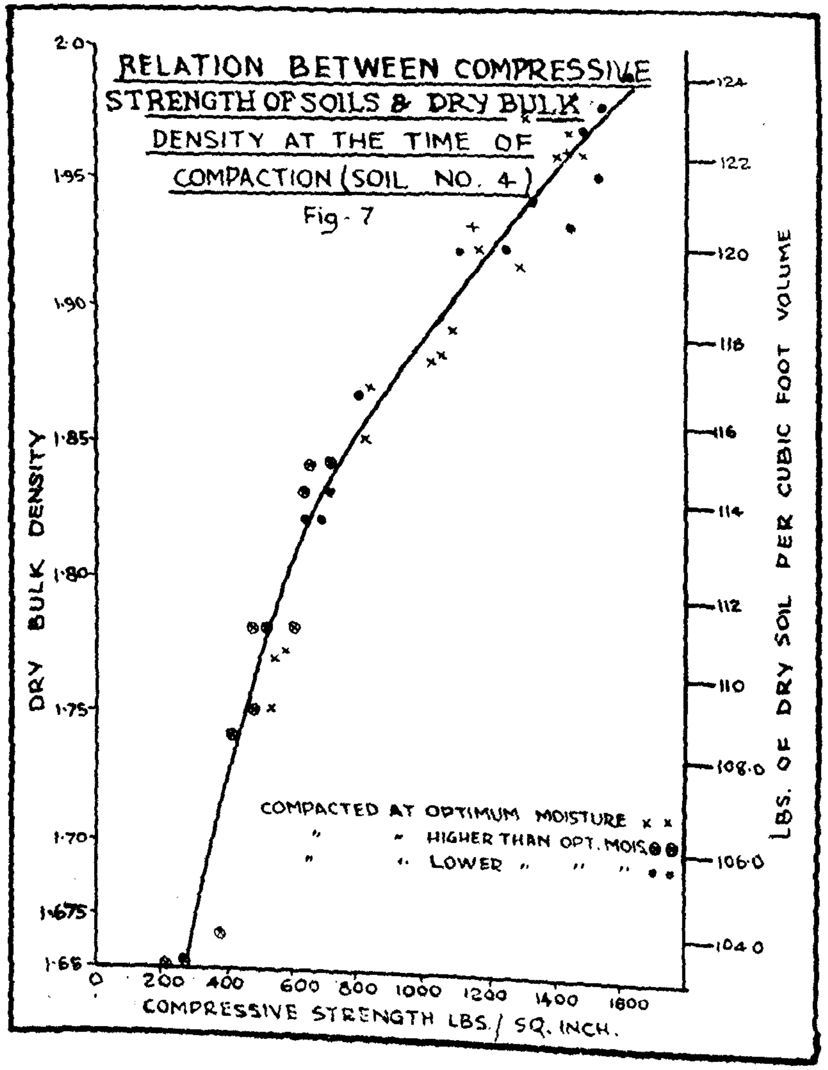
7.1. When a soil, compacted at a certain moisture content is allowed to dry, it shrinks and decreases in volume. As a result of the decrease in volume the dry density increases. The fact is brought out clearly in Fig. 6. Curve No. I is a common moisture-density curve, the density being the dry density at the time of compaction.

Curve No. II shows the densities of the same soil blocks after they have been allowed to dry out, the moisture content at compaction being the same. Curve No. III gives the compressive strength (final crack) corresponding to the same moisture content at compaction as in curves No. I and II.



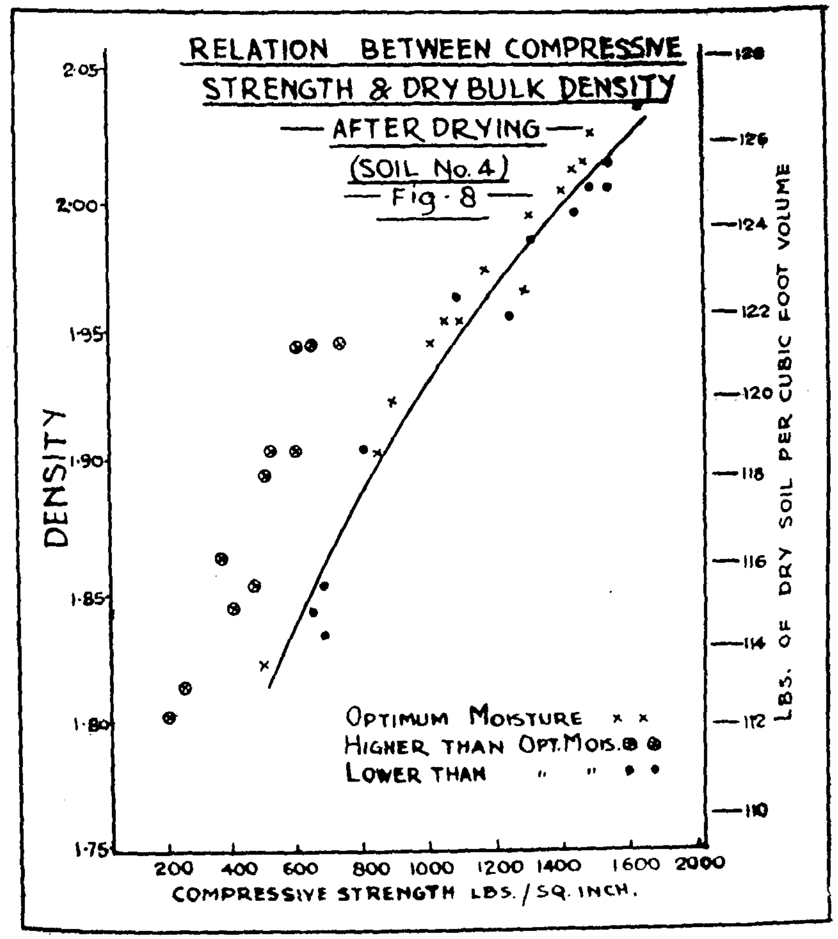
7.2. It can be concluded from these curves that the compressive strength of compacted soil is related much more closely to the dry bulk density at the time of compaction than to the dry bulk density attained after the compacted soil has dried out and consequently has attained a higher density due to **shrinkage.**

7.3. The fact was further verified by determining the compressive strength (final crack) of a large number of blocks, of the same soil compacted at optimum moisture, on the dry side of optimum moisture, and on the wet side of optimum moisture, with different number of blows, to attain various densities. In Fig. 7 the compressive strength is plotted against dry bulk density determined at the time of compaction. In Fig. 8 the compressive strength is plotted against dry bulk density attained when the compacted soil has dried out.



RELATION BETWEEN COMPRESSIVE STRENGTH OF SOILS & DRY BULK DENSITY AT THE TIME OF COMPACTION (SOIL NO. 4)

Fig - 7



RELATION BETWEEN COMPRESSIVE STRENGTH & DRY BULK DENSITY — AFTER DRYING — (SOIL No. 4)

Fig - 8

7.4. Comparing the two curves it appears that the compressive strength bears a definite relation to the dry bulk density determined soon after compaction. From Fig. 8 it is further clear that the dry bulk density determined after complete drying out bears a definite relation to the compressive strength, only when the soil has been compacted either at optimum moisture or on the dry side of it. But when the soil is compacted with moisture content higher than the optimum, no such relationship holds.

7.5. These results have a practical bearing on the field control of compaction in as much as they indicate that, for control purposes, the density in the field should be determined immediately after compaction and not when the compacted soil has dried out.

If under certain conditions it becomes impossible to determine the dry bulk density immediately after compaction then, for control purposes, it becomes very essential that, in no circumstances, should the compaction be carried out at moistures higher than optimum moisture. In that case the dry bulk densities of the dried out soils can be used as an index of the compressive strength of soils.

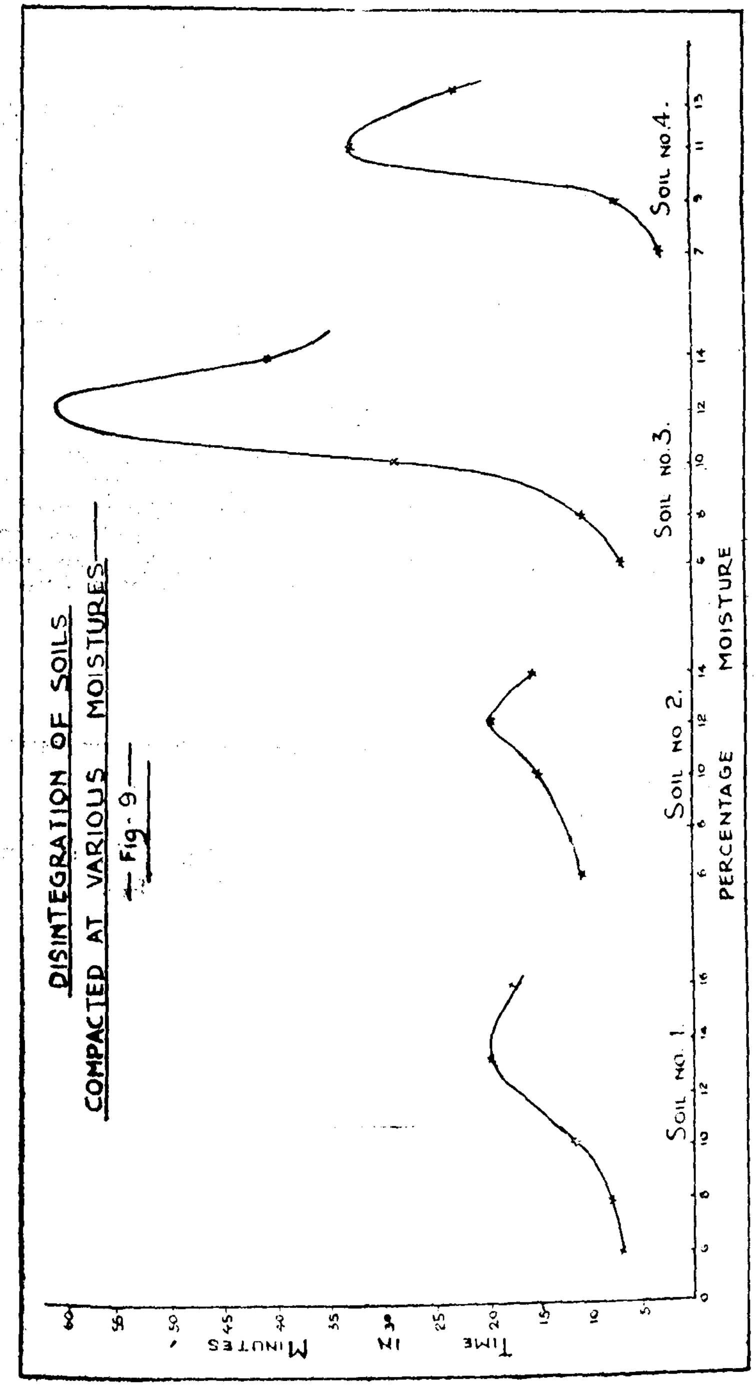
8. DISINTEGRATION OF COMPACTED SOILS

8.1. Soil blocks, as used for tests of compressive strength, were made. They were dried out in an oven at 50 deg. C. to 60 deg. C. to a constant weight. These were then placed under water at 20-25 deg. C. and the time taken for complete disintegration was noted. The tests were carried out with the four typical soils, and the results obtained are given in table 4 and reproduced in Fig. 9.

TABLE 4

Disintegration of Soil Blocks Compacted at Various Moisture Contents.

Soil used	Moisture content of compaction per cent	Disintegration time in minutes	Density	Weight of dry Soil per cu. ft. volume, lbs.
1	6	7	1.75	109.2
	8	8	1.77	110.5
	10	12	1.81	113.0
	13	**20**	**1.84**	**114.9**
	16	18	1.81	113.0
2	6	11	1.72	106.1
	8	14	1.75	109.2
	10	15	1.81	113.0
	12	**20**	**1.82**	**113.0**
	14	16	1.80	112.4
3	6	7	1.75	109.2
	8	11	1.82	113.6
	10	29	1.88	117.4
	12	**61**	**1.90**	**118.6**
	14	41	1.82	113.6
4	7	3	1.82	113.6
	9	7	1.89	118.0
	11	**33**	**1.96**	**122.4**
	13	23	1.89	118.0



8.2. It appears from the results that blocks compacted at optimum moisture are the most resistant to water.

8.3. It is further illustrated (Fig. 9) that, so far as disintegration is concerned, a soil compacted slightly on the wet side of optimum moisture content resists failure better than one compacted on the dry side of optimum moisture content with the same mode of compaction and the same interval from the optimum moisture, even when the density is the same in both the cases (table No. 4). This is probably due to the fact that free water is pushed upwards during compaction, and brings to the surface some clay which clogs the pores, thereby resisting further entry of water and consequent disintegration.

9. SUMMARY

9.1. The importance of compaction at optimum moisture is indicated. It not only increases the dry bulk density but also greatly improves the compressive strength and resistance to disintegration, which play an important role in the use of soil as a construction material. It has further been shown that the compressive strength of compacted soil increases with the dry bulk density as determined **immediately after compaction.**

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A method of Soil Stabilisation for Low Cost Roads; Paper No. 110, Indian Roads Congress Journal, Vol. X, 1946.

2. EXPERIMENTAL TRACKWAYS FOR MOTOR TRAFFIC ON THE DELHI-MEERUT ROAD*

Compiled by the Standards Section, Central Roads Ogranisation

A note dealing with the performance of cement concrete trackways for bullock cart (iron-tyred) traffic appeared in the I. R. C. Journal for January, 1949 (Vol. XIII-3). Here is a similar note dealing with brick trackways for pneumatic-tyred traffic.

SYNOPSIS

This note deals with the construction and performance of experimental trackways laid on the Delhi Meerut Road in 1941. The trackways were laid to different specifications with the object of finding an answer to the problem of building roads for pneumatic tyred traffic in localities where road building materials were not available and water was scarce, but bricks could be had within reasonable distances. Brick trackways behaved unexpectedly well, while composite trackways. consisting of bricks bonded with brick ballast cement concrete, did not fare so well, Various maintenance methods were also tried.

The experiments showed that

(i) in the conditions where there is no risk of heavy traffic coinciding with heavy rainfall brick trackways could be used in emergencies :

(ii) occasional blinding with earth is advantageous and a paint coat with chips or a light coat of premix restores evenness to the surface and develops good bond with the brick surface.

1. INTRODUCTION.

1.1. Several miles of new roads had to be constructed expeditiously to take occasional heavy motor traffic as an emergent measure in places where the usual road materials were not available for construction and water was scarce. Bricks could, however, be manufactured at some distance from the road and carted. This circumstance suggested the adoption of brick trackways as an emergent measure. Before adopting any particular specification for the brick trackways which had not been tried before on any large scale, it was considered desirable to lay experimental stretches of these to different specifications, on a road subjected only to motor traffic to see how these behave under traffic. The Delhi Meerut road between Delhi and Shahdara was specially selected as on this stretch there were two parallel carriageways, one with bituminous surface reserved for fast motor traffic, and the second with a concrete pavement reserved for slow cart and tonga traffic. Further, being near Delhi, the specifications could be rigidly enforced under proper departmental supervision and the progress of experiments carefully watched.

* Details of construction were given in I. R. C. Journal, Volume VII-2, January 1941 and are repeated here also.

1.2. Advantage was also taken to test the performance of cement concrete trackways with brick metal aggregate, of different thicknesses, with and without end reinforcements. To reduce the quantity and hence the cost of cement concrete, brick blast cement concrete bonded with ordinary bricks and special semi-elliptical bricks was also laid in some lengths.

1.3. To make the experiments conform to actual construction on earth roads, the metalling and soling were removed from the existing road and the road level brought up by earth filling, dressed, watered and consolidated in layers by sheeps-foot rammers and rollers at optimum moisture content. Trenches were then excavated to the required width of the trackways and the bottom soil consolidated again with sheeps-foot rammers. The trackways were then laid.

1.4. In the case of cement concrete trackways traffic was not allowed till the concrete was cured by ponding.

2. DETAILS OF CONSTRUCTION

2.1. The trackways consisted of two tracks, 2 ft. 9 in. wide each, and spaced 5 ft. 6 in. centre to centre.

2.2. The Specifications adopted for the different sections were as detailed below.

A. Brick Trackways.

Experiment No. I.

Brick on edge laid with $\frac{1}{4}$ in. joints, the joints sanded to within $\frac{1}{2}$ in. of the top and then grouted with as much as they would take of.

(i)	(a)	Tar No. 2.	50 ft. length	Herring-bone bond. As in Fig. 1, Plate II
	(b)	Bitumen.	50 ft. length	
(ii)	(a)	Tar No. 2	25 ft.	Header and Stretcher bond as in Fig. 1, Plate II.
	(b)	Bitumen	25 ft.	

Experiment No. II.

Brick on edge laid with bricks half dipped in

(i)	(a)	Tar No. 2.	50 ft.	Herring-bone bond.
	(b)	Bitumen	50 ft.	
(ii)	(a)	Tar No. 2.	25 ft.	Header and Stretcher bond.
	(b)	Bitumen	25 ft.	

Experiment No. III.

Dry brick-on-edge trackways without any grouting.

(a) 50 ft. Herring-bone bond.
(b) 50 ft. Header and Stretcher bond.

B. Cement Concrete Trackways

The proportions for cement concrete in all the tests was 2 cft. of sand and 4 cft. of aggregate for every 90 lbs of cement by weight. Badarpur sand and brick ballast, 1 in. gauge, were used for fine and coarse aggregates.

Experiment No. IV.

Trackways in cement concrete laid in 25 ft. strips, width of each joint $\frac{1}{4}$ in. with precast bituminous joint filler.

(i) (a) 6 in. thick with cantilever end reinforcement— Length 75 ft
(b) 6 in. thick without any reinforcement — Length 75 ft
(ii) (a) 4 in. thickwith cantilever end reinforcement— Length 75 ft
(b) 4 in. thick without any reinforcement. — Length 75 ft

The cantilever end reinforcement consisted of four mild steel rods $\frac{3}{8}$ in. diameter and 2 ft. 6 in. long.

Experiment No. V.

Brick-bonded brick ballast cement concrete (Fig. 2., Plate II) with flat bricks bonded with brick ballast cement concrete.

(a) 6 in. thick with cantilever end reinforcement — Length 50 ft
(b) 6 in thick without any reinforcement — Length 50 ft

Experiment No. VI.

Brick-bonded brick ballast cement concrete (Fig. 3, Plate II) with bricks on edge bonded with brick ballast cement concrete.

(a) $6\frac{1}{2}$ in. thick with cantilever end reinforcement — Length 50 ft
(b) $6\frac{1}{2}$ in. thick without any reinforcement. — Length 50 ft

Experiment No. VII.

Brick-bonded brick ballast cement concrete (Fig. 4, Plate II) with specially burnt semi-elliptical bricks bonded with brick ballast cement concrete.

(a) 6 in. thick with cantilever end reinfocement — Length 50 ft
(b) 6 in. thick without any reinforcement. — Length 50 ft

2.3. In experiments IV to VII, a portion of each experimental length was done with selected blue 'jhama' brick ballast and the remaining portion with assorted brick ballast, i.e., brick ballast from which only honey-combed or under-burnt material had been eliminated.

2.4. The layout of the experimental lengths is given in Plate I, and the cost per running foot is given in Appendix I.

3. TRAFFIC.

A traffic count was taken over a period of one month (January-February 1941). The intensity of traffic varied from 952 to 2530 tons per day, the average being 1561 tons per day. The distribution of traffic was as under :

Light Cars	—	20 per cent
Buses	—	50 per cent
Lorries	—	30 per cent

There was a slight reduction in the daily traffic intensity from the middle of August 1941 owing to petrol rationing.

4. PERFORMANCE OF BRICK TRACKWAYS.

Experiments I, II, & III.

4.1.1. The trackways were opened for traffic on the 14th January 1941. Whithin a few days there was heavy rain (2½ inches in a few hours) and the subgrade under these trackways became water logged.

4.1.2. The brick trackways (Experiment III) which were not treated with bitumen or tar, failed completely and some of the bricks were also crushed. The portions of Sections I and II treated with tar (both grouted, and half dipped in tar) stood well without any subsidence presumably due to the water-tightness of the joints. The portions similarly treated with bitumen failed in places due to the rain water seeping through some of the joints which were not watertight.

4.1.3. Traffic was suspended after 5½ days for relaying the tracks. The total traffic that passed over the trackways in this period was 8585 tons.

4.2.1. The portions of the trackways in experiments I and II and the entire length of experiment No. III which had shown subsidence were removed and relaid to the original specification after recompacting the subgrade and improving the drainage, where defective. In Experiment No. III where the bricks had been crushed, these were replaced by sound and hard bricks from

Shahdara rejecting the soft and unsound bricks from Okhla. The work was completed in four days and the traffic was allowed again from the morning of the 24th February 1941.

4.2.2. After traffic had used the trackways for about ten days (total traffic 14050 tons) it was noticed that the grout in the joints in Experiment No. I had gone down by half an inch to one inch. The joints were re-topped with bitumen to the surface. The performance of the trackways continued to be satisfactory till 6. 11. 41. with a total traffic count of 3,55,000 tons. Further modifications in the specifications were made in the tracks to study relative performance of different methods of maintenance. The special tests are detailed in 4.3 below.

4.3. Special tests on brick trackways

4.3.1. Special test on Section I [i- (b)- Brick-on-edge Herring-bone bond, joints grouted with bitumen].

In this section the surface of the trackways was sound after 3,55,000 tons of traffic but it was a little rough. Some of the bricks had also been crushed. Half of this section was given a paint coat with chips and the other half a light premix coat, screeded off with a straight edge. The purpose of the premix was only to fill the depressions and the joints, thus bringing the surface to the original level, with the bricks practically uncovered as before. This gave a smooth riding surface and secured good bond between the bricks and the paint coat, and the bricks and the premix. The section was dismantled in March 1942 after the purpose of the test had been accomplished.

4.3.2. Experiment No. II (Bricks half-dipped in binder)

After a total traffic of 14,050 tons it was noticed by the first week of March 1941 that the joints were wide and bricks were loosely held without sufficient contact with the adjacent bricks. Also, the bricks were acting individually under the wheels and some bricks were also getting crushed. Blinding with Jamuna sand to a thickness of half to 1 in. was done. The sand worked into the joints and the bricks got well packed. Thereafter the performance was satisfactory till the trackways were dismantled.

4.3.3. Experiment III: Dry brick trackways

As in the case of Experiment II, by March 1941, after a traffic of 14050 tons had passed over, the joints were wide and the bricks were loose and acting individually under the wheels with some bricks getting broken. Road-side earth to a thickness of ½ to 1 in. was spread over the whole section after the broken bricks had been replaced. The earth gradually worked its way into the joints and made them tight. Further crushing of the bricks was not noticed. After 51 days of traffic with a total of 79611 tons these dry brick trackways were as good as those in Experiments I and II.

A further test was made in the dry bricks trackways (Experiment III) at this stage. Half of each sub-section was cleaned. The joints were brushed out. The surface was painted with the minimum quantity of tar necessary to provide a skin of tarred brick. This was done on 22-5-41 after a total traffic of 1,35,807 tons had passed over the surface. The quantities of tar used were-

Experiment III (a) Herring-bone bond

(i) Left side —— 21.7 lbs. per 100 sq. ft.
(ii) Right side —— 17.5 lbs. per 100 sq. ft.

Note: Joints were raked and kept deep.

Experiment III (b) Header & Stretcher bond

(i) Left side —— 16 lbs. per 100 sq. ft.
(ii) Right side —— 11.6 lbs. per 100 sq. ft.

Note: Joints were brushed and not raked.

After two months (total traffic 2,34,150 tons) no appreciable difference in wear and tear of the trackways was noticeable. Tar did not penetrate into the joints and adhere to them. It had caked at the joints and was pealing off.

By 7-11-41 a total traffic of 3,55,300 tons had passed over these trackways without any noticeable defect. Further observation was discontinued.

4.3.4. General Conclusions

The experiments on brick trackways led to the following general conclusions:—

(i) The behaviour of the dry brick trackways (after the initial failure owing to heavy rain) was encouraging. It showed that in places, where there is no risk of heavy rainfall coinciding with a concentration of traffic, the brick trackways could be advantageously used in emergencies.

(ii) Herring-bone bond gave a smoother riding surface than the Header & Stretcher bond, though both gave satisfactory results.

(iii) It is advantageous to blind the tracks occasionally with sand or side-earth. This fills the joints and keeps the trackways compact.

(iv) A paint coat with chips or a light premix can be used for restoring the even surface when the trackways become uneven.

5. PERFORMANCE OF CONCRETE TRACKWAYS

Experiments IV to VII.

5.1. The behaviour of all the experimental sections of concrete trackways was very similar.

5.2. Within a month of opening to traffic (total traffic 50,000 tons) the 4-in. sections (Experiment IV—(ii)) had cracked badly as also brick-bonded brick ballast cement concrete with special elliptical bricks (Experiment VII). Other sections had been giving satisfactory performance.

5.3. After 90 days when a total traffic of 1,40,500 tons had passed over, all sections had cracked. Sections IV(ii) and VII referred to in 5.2 which had cracked within a month were specially bad. The "rail action" at the joints was also very marked when a lorry or a bus passed over them. The riding quality of the surface was, however, satisfactory.

5.4. After a period of over six months all the concrete sections had very badly cracked but the riding surface continued to be satisfactory, and this continued till a traffic of 4,19,320 tons had passed over in a total period of about 10 months. Further observations were not made and the sections were considered to have failed and fit for removal.

5.5. The general conclusion is that the brick-bonded brick ballast cement concrete or brick ballast cement concrete 4 in. thick will not be satisfactory for the trackways.

6. COST.

The cost per running foot of trackways (two lines) are given in Appendix I against each specification.

APPENDIX I

Experimental Trackways Delhi-Meerut Road (1941.)

Specifications and Costs of Experiments.

Experiment No.	Specifications	Cost per running foot (period 1940-41) Rs.	A.
I.	Brick-on-edge laid with ¼" joints; the joint sanded to within ½" of the top and then grouted with as much as they would take of		
	(i) (a) Tar No. 2 – 50 ft. length } Herring-bone-bond	1	8
	(b) Bitumen – 50 ft ,, } Herring-bone-bond	1	7
	(ii) (a) Tar No. 2 – 25 ft. ,, } Header and Stretcher bond	1	7
	(b) Bitumen – 25 ft. ,, } Header and Stretcher bond	1	6
II.	Brick-on-edge laid with bricks half dipped in		
	(i) (a) Tar No. 2 – 50 ft. length } Herring-bone bond	1	9
	(b) Bitumen – 50 ft. ,, } Herring-bone bond	1	10
	(ii) (a) Tar No. 2 – 25 ft. ,, } Header and Stretcher bond	1	7
	(b) Bitumen – 25 ft. ,, } Header and Stretcher bond	1	7
III.	Dry brick-on-edge trackways without any grouting.		
	(a) 50 ft. length, Herring bone bond.	1	0
	(b) 50 ft. length, Header and Stretcher bond.	0	15
IV.	Cement concrete trackways, with brick ballast (1" guage) Badarpur sand and cement in the proportion of 4: 2: 1; laid in 25-foot strips, width of each joint ½", with pre-cast bituminous joint filler. ...		
	(i) (a) 6 in. thick with cantilever end reinforcement, 75 ft. length.		
	50 ft. with selected blue ballast	2	10
	25 ft. with assorted ballast	2	9
	(b) 6 in. thick without any reinforcement, 75 ft. length.		
	50 ft. with selected blue ballast	2	8
	25 ft. with assorted ballast	2	7

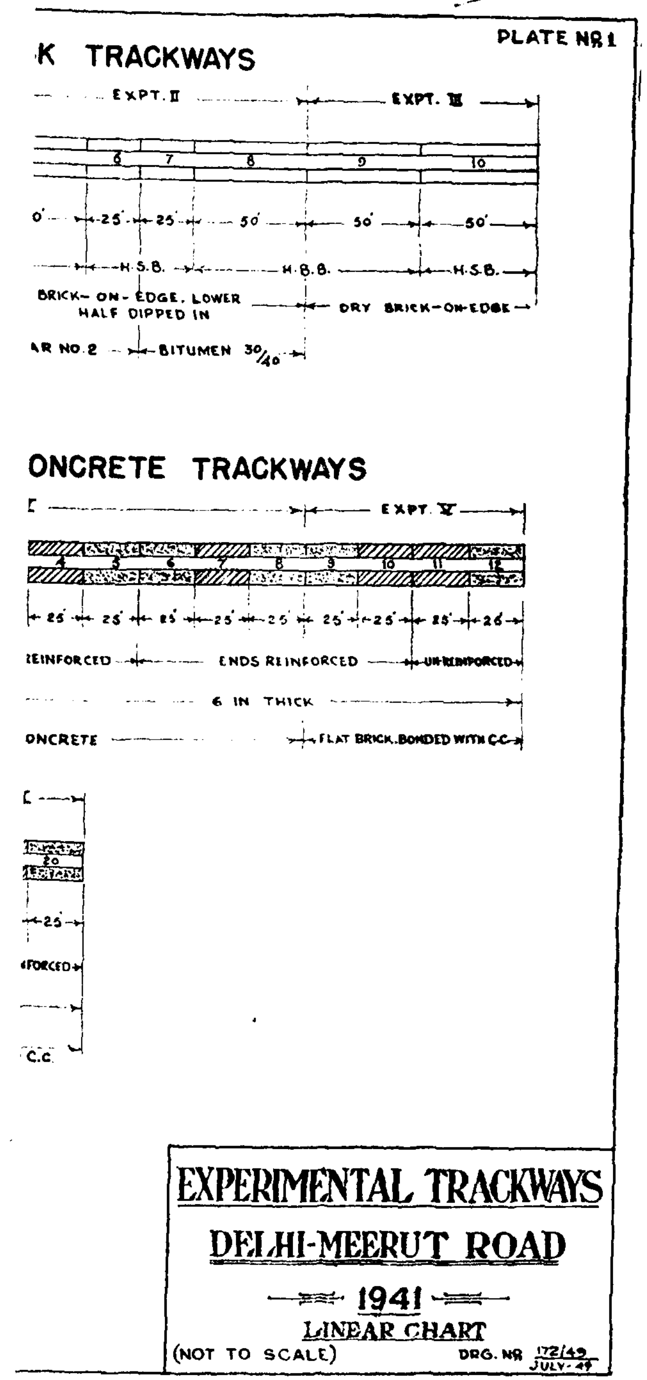
Experiment No.	Specifications	Cost per running foot (period 1940-41) Rs.	A.
	(ii) (a) 4 in. thick with cantilever end reinforcement, 75 ft. length.		
	75 ft. with selected blue ballast	2	2
	(b) 4 in. thick without any reinforcement 75ft. length.		
	75 ft. with selected blue ballast	2	0
V.	Brick-bonded brick ballast cement concrete with flat bricks bonded with brick ballast cement concrete 4: 2: 1.		
	(a) 6 in. thick with cantilever end reinforcement; 50 ft. length.		
	25 ft. with selected blue ballast	2	9
	25 ft. with assorted ballast	2	9
	(b) 6 in. thick without any reinforcement, 50 ft. length.		
	25 ft. with selected blue ballast	2	7
	25 ft. with assorted ballast	2	7
VI.	Brick-bonded brick ballast cement concrete with bricks on edge bonded with brick ballast cement conrete 4 : 2 : 1.		
	(a) 6½ in. thick with cantilever end reinforcement, 50 ft. length.		
	25 ft. with selected blue ballast	2	10
	25 ft. with assorted ballast.	2	9
	(b) 6½ in. thick without any reinforcement, 50 ft. length.		
	25 ft. with selected blue ballast	2	8
	25 ft. with assorted ballast	2	7
VII.	Brick-bonded brick ballast cement concrete with specially burnt semi-elliptical bricks with brick ballast cement concrete 4:2:1.		
	(a) 6 in. thick with cantilever end reinforcement, 50 ft. length.		
	25 ft. with selected blue ballast	2	13

(55)
(85)

Experi-ment No.	Specifications	Cost per running foot (period 1940-41)
	25 ft. with assorted ballast	2 13
	(b) 6 in. thick without any reinforcement, 50 ft. length.	
	25 ft. with selected blue ballast	2 11
	25 ft. with assorted ballast	2 11

Note. 1. In experiments Nos. IV to VII, part of each experimental length was done with selected blue 'Jhama' brick ballast and part with assorted brick ballast, i e. brick ballast from which only honey- combed or under-burnt material had been eliminated.

Note. 2. Cost per running foot includes Rs -/4/- for providing a 6″ layer of earth and consolidating it at optimum moisture content with sheeps foot rammers, sheeps foot roller drawn by a tractor and finished with a 4-ton roller, digging side trenches and dressing.



3. EXPERIMENTS ON CONCRETE TRACKWAYS ON BLACK COTTON SOIL

SYNOPSIS

This note describes the experiments on Concrete Trackways on black cotton soil. Thirteen different specifications are being tried near Nagpur since August 1947. Only specifications and construction details are given here. Performance records will be published in subsequent issues.

1. OBJECT OF EXPERIMENTS

The Nagpur Conference of Chief Engineers recommended that concrete trackways for District roads and Village roads "might be considered where maintenance was a problem or apt to be neglected". Such trackways have been tried on ordinary good soil and information on their performance on such soil is available but they have not so far been tried on Black Cotton Soil. In order to investigate the behaviour of cement concrete trackways on Black Cotton Soil experiments are being carried out in the Central Provinces near Nagpur.

2. **SITE**:—The Nagpur-Katol road was selected and experimental trackways were laid over half a mile between miles 5/5 and 6/2.

3. **SPECIFICATIONS** :—It was decided to try fourteen different specifications of varying thickness, subgrades, foundations and joint supports. The details of these specifications are given below :

Experiment No.	Sketch No.	Specification	Length in feet
1	IV-A	Trackways in moorum embankment one ft. high without sleepers. Slab 5 in. thick.	210
2	IV-A	-do- -do- but slab 6 in. thick.	210
3	IV	Trackways in moorum embankment 1 ft. 6 in. high with cement concrete sleepers under joints. Slab 5 in. thick.	210
4	IV	-do- -do- but slab 6″ thick	210
5	III	Trackways on moorum subgrade 1 ft. 3 in. compacted by sheepsfoot rammers, natural soil below moorum bed treated with sand piles 4 in. dia. 3 to 4 ft. deep at 12 to 15 inches centres, slab 6 in. thick.	Not carried out.

Experiment No.	Sketch No.	Specification	Length in feet
6	III	-do-..............centres, with c. c. sleepers under joints and slab 5 in. thick.	65
7	II–A	Trackways on boulder *soling* hand-packed with c. c. sleepers under joints. Slab 5 in. thick.	210
8	II–A	-do- -do- but Slab 6" thick.	210
9	II	As in experiment 7 but without sleepers, Slab 6 in. thick.	210
10	II	-do- -do- but slab 5 in. thick.	210
11	I–A	Trackways on moorum subgrade 1 ft. 6 in. thick compacted by sheeps-foot rammers with c. c. sleepers under joints, slab 5 in. thick.	210
12	I–A	-do- -do- but slab 6 in. thick.	210
13	I	As in experiment 11 but without sleepers. Slab 5 in. thick.	210
14	I	-do- -do- but slab 6 in. thick.	210

Due to exigencies of the site experiment No. 5 could not be laid out according to specifications.

Detailed cross sections of the above experimental section as actually constructed are shown in Plates I and II.

4. SUBGRADE :—The existing road has a W. B. M. surface with a 21 ft. formation and 14 ft. metalled width. The subgrade for the trackways was laid by the side of the existing road. It was consolidated with a hand-roller in 6 in. to 9 in. layers and thoroughly watered. This job was completed before the 1946 monsoon and opened to traffic.

Under the effects of the monsoon and traffic the subgrade settled down. The formation level was brought up to required grade and camber by filling low places with moorum and consolidating with hand rammers.

5. LAYING THE TRACKWAYS

5.1. Two parallel trenches, each 2 ft. 6 in. wide, and spaced 4 ft. 6 in. centre to centre were excavated to a depth half inch less than the slab thickness specified for experiments 13 and 14 (420 ft. length). For subsequent lengths the centre to centre distance was reduced from 4 ft. 6 in. to 4 ft. 0 in. in order to conform to the distance (centre to centre) between wheels of carts usually plying on the road.

The trenches were watered and thoroughly compacted with sheeps-foot rammers before laying the concrete.

5.2. **Insulation Layers.**— An insulation layer of sand was laid on the compacted subgrade on experiments 12, 13, and 14. On the remaining lengths slabs were laid direct on the subgrade.

5.3. For experiments 13 and 14 the slabs were laid 4 ft. 6 in. centre to centre. Over the remaining lengths they were laid 4 ft. centre to centre.

Plates III to IX give the plans and cross sections of the trackways, date of laying each bay, quantity of cement used in each bay and the maximum and minimum temperatures prevailing during the construction period.

6. C. C. SLABS

6.1. **Materials**:

6.1.1. **Cement.** "Swastika" brand cement was used.

6.1.2. **Fine Aggregate.** River-sand from the Kanhan river (13 miles lead) was used. This sand is coarse, hard and very clean.

6.1.3. **Coarse Aggregate.** Local broken trap-stone aggregate (Boregaon Quarry, lead 2 miles) was used. Sieve tests and void tests for 1½ in. size, ¾ in. size and various mixtures of the two sizes are given (vide tables I to IV).

6.2. **Proportions.**— It has been found from experience of concrete works in Nagpur that a very dense concrete results from a mixture of 40% 1½ in. size and 60% ¾ in. size metal. This is borne out by void tests also (Table III).

The proportions specified were 1 : 2 : 4. Each batch was therefore formed by mixing one bag (1.25 c. ft.) of cement, 2½ c. ft. sand, 3 c. ft ¾ in. size aggregate and 2 c. ft. 1½ in. size aggregate.

6.3. **Water-cement Ratio.**— 5½ to 6½ gallons water was used per bag of cement.

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6.4. **Mixing.**—All materials were accurately measured by wooden boxes on to a portable platform. They were mixed thoroughly by hand, first dry and then wet after adding water.

6.5. **Concreting.**— Concrete was poured between timber forms, punned into position, sliced against the forms, tamped with a wooden tamper and finished with a wooden float. Forms were removed after 24 hours.

6.6. **Joints.**— Positions of joints are shown on plates I and II. Slab lengths of 15 ft., 20 ft., and 30 ft. were adopted.

Ordinary joints were cleaned and filled with molten bitumen and fine dry sand.

Expansion joints at 60 ft. or 65 ft. intervals were made with a pre-moulded filler

6.7. **Curing.**— Slabs in experiments 13 and 14 and some slabs in experiments 11 and 12 (vide plates VIII and IX) were cured with a patent compound ("True Cure") applied with a hand brush at 142 sq. ft. per gallon (Manufacturer's Specification 200 sq. ft. per gallon applied with a spray pump). Remaining portions were cured with water by 'ponding' for about 14 days

7. **COMPLETION.**— The work was completed in July 1947 and opened to traffic in August 1947.

8. **COSTS.**— The total cost of the experiments was Rs. 20,808/-. Cost figures and unit costs will be found in Appendix — I

9. **TRAFFIC.**— Traffic data will be found in Appendix — II.

10. **GENERAL.**— The provincial P. W. D. has been requested to maintain and supply records of actual traffic intensities, periodical maintenance charges, and the performance of the trackways. These will be published in this journal from time to time.

TABLE No. I

Sieve Analysis of aggregates of Experimental Trackways

Dated 19th May 1947.

Passed size sieve	Retained on size of sieve	Weight in tolas	Percentage	Total Percentage.	Remarks.
		1½ in. metal			
	2 in.	—	—	—	
2 in.	1½ in.	304	46.7	46.7	
1½ in.	1 in.	315	48.3		
1 in.	¾ in.	27	4.1	99.1	
¾ in.	⅜ in.	5	0.9	100.0	
				237.9	
			+	600	
				8.37	
				Fineness modulus 8.37	
		¾ in. metal.			
	1 in.	155	18.2		
1 in.	¾ in.	443	52.0	70.20	
¾ in.	⅜ in.	230	27.07	97.27	
⅜ in.	3/16 in.	23	2.73	100.00	
				267.47	
			+	500	
				7.67	
				Fineness modulus 7.67	
		Mixed aggregates 40% 1½ in. and 60% ¾ in.			
	2 in.	17	1.24	1.24	
2 in.	1½ in.	190	13.91	15.15	
1½ in.	1 in.	349	25.47		
1 in.	¾ in.	372	27.23	67.85	
¾ in.	⅜ in.	337	24.67	92.52	
⅜ in.	3/16 in. (¼")	101	7.48	100.00	
				276.76	
			+	500	
				7.76	
				Fineness modulus 7.76	

TABLE No. II

Sieve Analysis of aggregates of Experimental Trackways

Dated 22nd May 1947

Passed sieve size	Retained on sieve size	Weight in tolas	Percentage	Total percentage	Remarks
		$1\frac{1}{2}''$ metal			
	2″	–	–		
2″	$1\frac{1}{2}''$	216	21·90	21·90	
$1\frac{1}{2}''$	1″	510	51·67 }	91.30	
1″	$\frac{3}{4}''$	175	17·73 }		
$\frac{3}{4}''$	$\frac{3}{8}''$	84	8·50	99·80	
$\frac{3}{8}''$	3/16″ ($\frac{1}{4}''$)	2	0·20	100·00	
		987		313·00	
				500·00	
				8.13	
				Fineness modulus 8·14	
		$\frac{3}{4}''$ metal			
$1\frac{1}{2}''$	1″	127	12·2 }	55·40	
1″	$\frac{3}{4}''$	450	43·2 }		
$\frac{3}{4}''$	$\frac{3}{8}''$	365	35·06	90·46	
$\frac{3}{8}''$	3/16″ ($\frac{1}{4}''$)	79	7·60	98·06	
3/16″ ($\frac{1}{4}''$)	$\frac{1}{8}''$	20	1·94	100·00	
		1041		343·92	
				400·00	
				7·43	
				Fineness modulus 7·4	
		Mixed aggregates 40% $1\frac{1}{2}''$ and 60% $\frac{3}{4}''$			
–	2″	17	1·06	1·06	
2″	$1\frac{1}{2}''$	121	7·54	8·60	
$1\frac{1}{2}''$	1″	457	28·50 }	66·47	
1″	$\frac{3}{4}''$	471	28·37 }		
$\frac{3}{4}''$	$\frac{3}{8}''$	406	25·32	91·79	
$\frac{3}{8}''$	3/16″ ($\frac{1}{4}''$)	100	6·23	98·02	
3/16″ ($\frac{1}{4}''$)	1/8″	31	1·98	100·00	
		1603		365·94	
				400·00	
				7·65	
Voids 47 %				Fineness modulus 7·65	

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TABLE No. III

Voids Tests of aggregates of Experimental Trackways

Dated 1st June 1947

$1\frac{1}{2}''$ metal	...	52% voids
$\frac{3}{4}''$,,	...	48% voids
Mixed 40% $1\frac{1}{2}''$, 60% $\frac{3}{4}''$	...	50% voids

Void tests carried out on 3rd June 1947

Mixed 55% $\frac{3}{4}''$, 45% $1\frac{1}{2}''$	Voids 48.6%
Mixed 45% $\frac{3}{4}''$, 55% $1\frac{1}{2}''$	Voids 50.5%
Mixed 50% $\frac{3}{4}''$, 50% $1\frac{1}{2}''$	Voids 50.07%

Voids tests carried out on 5th June 1947

60% $\frac{3}{4}''$, 40% $1\frac{1}{2}''$	Voids 48.4%
40% $\frac{3}{4}''$, 60% $1\frac{1}{2}''$	Voids 50.6%

TABLE No. IV

Sieve Analysis of Aggregates of Experimental Trackways

Dated 28th May 1947

Passed sieve size	Retained on sieve size	Weight in tolas	Percentage	Total percentage	Remarks
			1½" metal		
—	2"	—	—	—	
2"	1½"	280	24.47	24.47	
1½"	1"	730	63.81	97.45	
1"	¾"	105	9.17		
¾"	⅜"	29	2.55	100.00	
				221.92	
				+ 600	
				8.21	
				Fineness modulus 8.21	
			¾" metal		
1½"	1"	107	8.78	49.17	
1"	¾"	492	40.39		
¾"	⅜"	538	44.17	93.34	
⅜"	3/16" (¼")	74	6.07	99.41	
3/16" (¼")	No. 7 (⅛")	7	0.59	100.00	
				341.92	
				+ 400	
				7.41	
				Fineness modulus 7.41	
			Mixed aggregates 40% 1½" and 60% ¾"		
—	2"	—	—	—	
2"	1½"	142	9.00	9.00	
1½"	1"	4585	29.04	73.74	
1"	¾"	63	35.70		
¾"	⅜"	349	22.13	95.87	
⅜"	3/16" (¼")	59	3.74	99.61	
3/16"	No. 7 (⅛")	6	0.39	100.00	
				378.22	
				+ 400	
				7.78	
		Voids 48%.		Fineness modulus 7.78	

APPENDIX I

Cost of Nagpur-Katol Road Experiments.

Exp. No.	Sketch No	Specifications	Length in feet	Cost per 100 sft. Rupees
1	IV-A	Trackways in moorum embankment one ft. high without sleepers slab 5 in thick.	210	159
2	IV A	—do— —do— but slab 6" thick	210	172
3	IV	Trackways in moorum embankment 1 ft 6 in. high with cement concrete sleepers under joints, slab 5 in. thick.	210	186
4	IV	—do— —do— but slab 6" thick.	210	199
5	III	Trackways on moorum subgrade 1ft. 3 in. compacted by sheeps-foot rammers, natural soil below moorum bed treated with sand piles 4" dia. 3 to 4 ft. deep at 12 to 15 inches centres, slab 6 in thick.	Not carried out	
6	III	—do— ... centres, with c c. sleepers under joints and slab 5 in. thick.	60	215
7	II-A	Trackways on boulder soling hand-packed with c.c. sleepers under joints, slab 5 in. thick	210	203
8	II-A	—do— —do— but slab 6" thick.	210	216
9	II	As in experiment 7 but without sleepers, slab 6 in. thick.	210	215
10	II	—do— —do but slab 5" thick.	210	201

Exp. No.	Sketch No.	Specifications	Length in feet	Cost per 100 sft.
				Rupees
11	I-A	Trackways on moorum subgrade 1 ft. 6 in. thick compacted by sheep-foot rammers with c. c. sleepers under joints, slab 5 in. thick.	210	190
12	I-A	—do— —do— but slab 6″ in. thick.	210	193
13	I	As in experiment 11, but without sleepers—slab 5 in. thick. (Curing by "True Cure")	210	184
14	I	—do— —do— but slab 6 in. thick.	210	197

APPENDIX 1

Cost of Nagpur-Katol Road Experiments

Serial No.	Items	Quantity	Rate	Per	Cost Rupees
1	Excavation in hard soil	66817 cft.	18 0 0	%	1204
2	Benching out in natural ground	15750 cft.	0 6 0	%	58
3	Earth consolidation	62740 cft	3 4 0	%	2041
4	Moorum collection	45800 cft.	7 14 0	%	3609
5	Moorum consolidation	44340 cft.	3 4 0	%	1440
6	Cement concrete 1:2:4	4907 cft.	100 0 0	%	4907
7	Form work for C.C	5115 sft	0 3 0	sft.	959
8	Preparation of subgrade	10560 sft.	0 0 6	sft.	330
9	Rubble and stone collection	4400 cft.	24 0 0	%	1056
10	-do- -do- consolidation	4400 cft.	5 0 0	%	220
11	C C. Sleepers	56 cft.	100 0 0	%	56
12	Sand piles	240 cft.	0 8 0	each	120
13	Expansion joints	—		L.S.	200
14	True cure treatment	—		L.S.	100
15	Carriage of cement	1117 cft.	16 3 0	%	181
16	Carting metal	5000 cft.	5 2 3	%	258
16 (a)	,, sand	2500 cft.	47 8 6	%	1188
17	Carriage of metal etc , during consolidation	50 carts	3 2 0	each	156
18	Carriage of water	100 carts	3 2 0	,,	313
19	Chowkidar during construction	—	—	L.S.	200
20	Sign boards for experiment giving particulars	—	—	L.S.	200
21	Uprooting trees	80 Nos.	2 0 0	each	160
22	Chowkidars for directing traffic	12 months	25 0 0	month	300
23	Huts for chowkidars	L S.		L S	100
				Rs.	19356
	Contigencies 5%			...	968
	Work establishment $2\frac{1}{2}$%			...	484
	GRAND TOTAL			Rs. ...	20808

APPENDIX II

Statement showing traffic for 24 hours on 17th, 18th and 19th June 1946 on Nagpur-Katol Road at mile 2

Day — 7 A.M. to 7 P.M.
Night — 7 P.M. to 7 A.M.

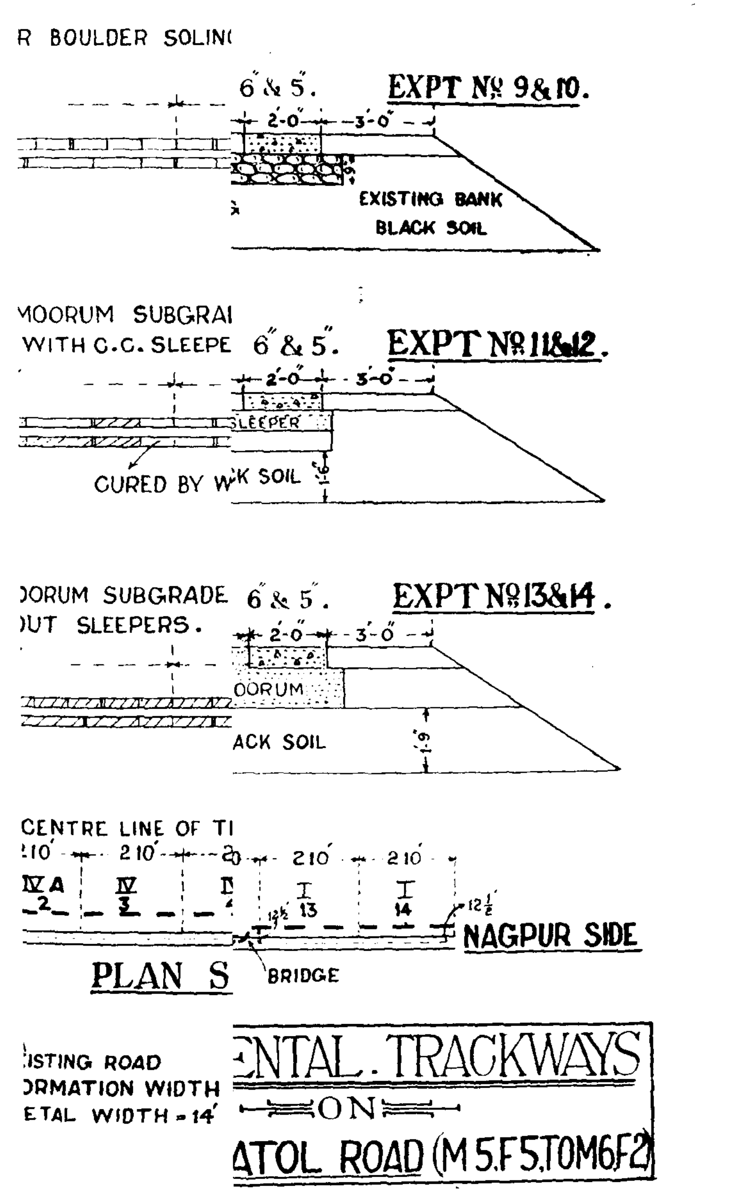
Date	Traffic in tons per day	Remarks
17-6-46	808·27 tons	It rained till 9 A.M.
18-6-46	838·63 ,,	Bazar day.
19-6-46	1058·24 ,,	
Total	2705·14 tons	

∴ Average traffic per day for 14 ft. width 901·71 tons
say 900 tons per day.

Deduct 25 per cent for quarry traffic passing the counting post but not using the track-ways ... 225 tons per day

Nett traffic on trackways ... 675 tons per day

PLATE I



Track type tractors are suitable for work up to 1,000 ft. lead but, when the lead exceeds 500 ft., they become less economical than wheel type tractors. Track type tractors can work in all sorts of soils varying from fairly wet soils to soft rock. They may, however, get bogged in very wet and soft soils.

5. Where large quantities of earth having leads longer than 500 ft. are involved, it is desirable to go in for a unit of wheel type tractors with scrapers attached in the same way as for track type tractors or motorised scrapers with the scraper and tractor forming one machine, provided the soil where they are to work is not soft or wet.

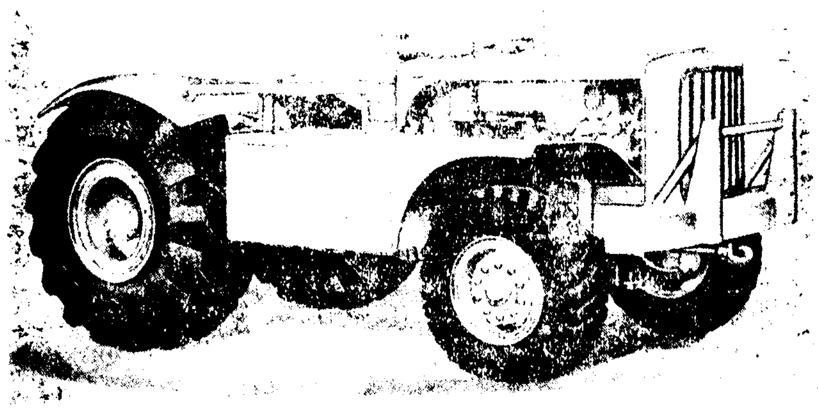


Photo. No. 2. **Wheel Type Tractor.**

TRACTOR ATTACHMENTS

6. (1) **Dozers** are economical for earth work involving lift up to about 4 ft. and lead up to about 150 ft. They are also very useful for clearing jungle and uprooting trees. For leads greater than 150 ft. and lifts higher than 4 ft., it is generally economical to use scrapers.

(2) Dozers are of two main types, straight dozers and angle dozers. Angle dozers have a general utility and are as a rule to be preferred to straight dozers but the straight dozers have an advantage over angle dozers where the nature of work is very hard, e. g. uprooting of very big trees or dislocating big boulders. For making roads on hillsides angle dozers are essential, as earth has to be moved from one side to other which straight dozers cannot do, as they can only push the earth forward.

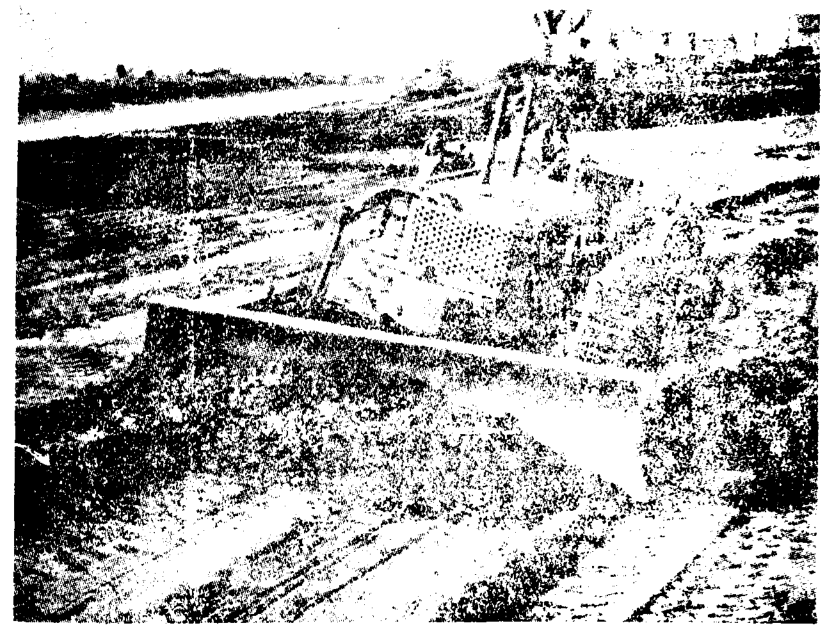


Photo. No. 3. **Dozer with Tractor.**

7. **Scrapers** are earth-moving machinery, capable of digging, loading, hauling, dumping, and spreading earth. The cutting and spreading depths can be controlled within certain limits. They are designed to make shallow cuts and spread earth in thin layers.

(2) Scrapers can be used to haul broken rock and other difficult material but they are more economical for light and medium soils relatively free from heavy roots and boulders. They can also be used for moving sand but it is difficult to fill them completely in case of loose, and dry sand. Thus, in very dry and loose sandy soils, their efficiency is reduced.

8. **Rippers**. Stiff clay, soft rock, or other hard soils, should be loosened by means of rippers before moving of earth with either dozing equipment or scrapers is attempted.

AUXILIARIES

9. **Graders**. When the ground is uneven, it is often desirable first to grade the surface with motor graders before using scrapers, as this leads to greater efficiency.

PLANT, MACHINERY AND APPARATUS SECTION

Technical Note No. 3

Some Types Of Earth-Moving Machinery for Roads

Where comparatively short leads are concerned, there are two main categories of earth-moving machinery, namely,

(1) dragline excavators and shovels, and

(2) tractors with various forms of auxiliary equipment.

2. Dragline excavators are efficient and economical where a large quantity of concentrated work is to be done and where the maximum lead is small. Ordinarily, these are not suitable for road work as the quantity of earth work required per foot length of a road is relatively small.

3. Tractors with attachments like dozers or scrapers are more versatile and are better suited for road work as they are more mobile and can economically handle work where the cross section of the earthwork is relatively small.

TRACTORS

4. Tractors themselves can be divided into two categories, namely,

(1) track type, and

(2) wheel type.

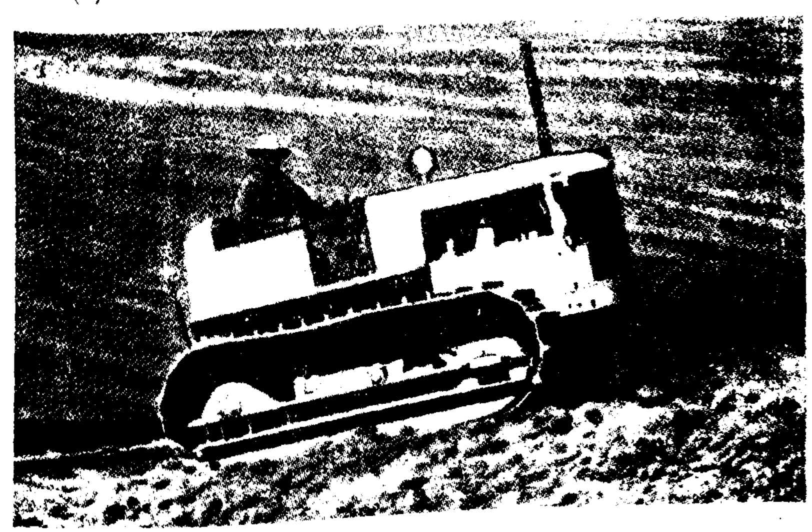


Photo. No. 1. Track Type Tractor.

Track type tractors are suitable for work up to 1,000 ft. lead but, when the lead exceeds 500 ft., they become less economical than wheel type tractors. Track type tractors can work in all sorts of soils varying from fairly wet soils to soft rock. They may, however, get bogged in very wet and soft soils.

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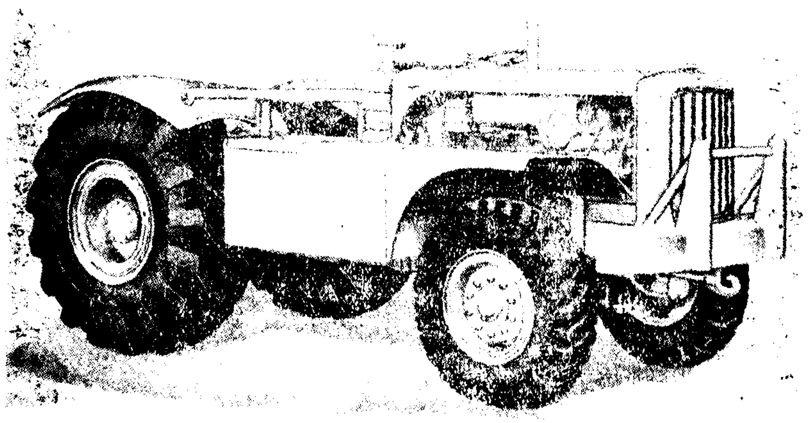

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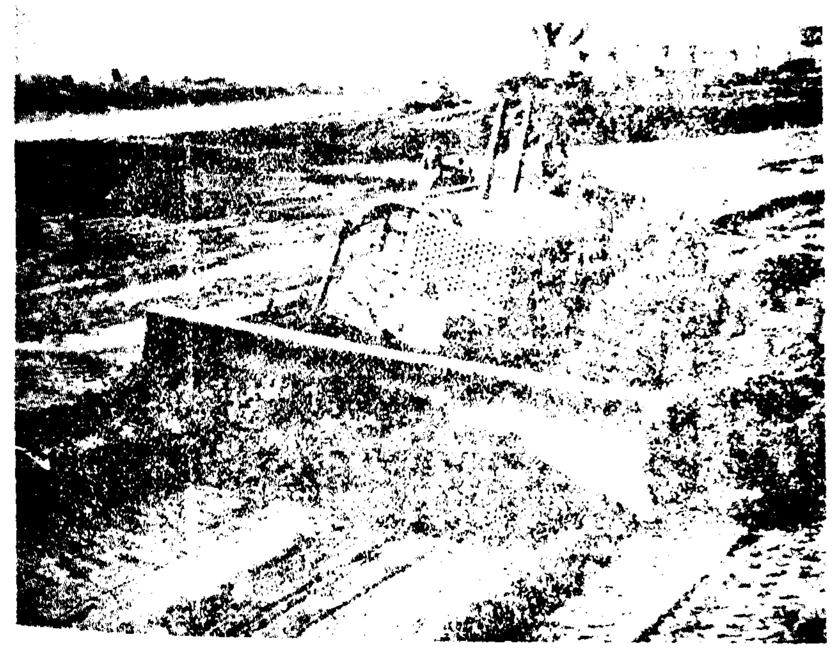

Photo. No. 3. **Dozer with Tractor.**

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8. **Rippers.** Stiff clay, soft rock, or other hard soils, should be loosened by means of rippers before moving of earth with either dozing equipment or scrapers is attempted.

AUXILIARIES

9. **Graders.** When the ground is uneven, it is often desirable first to grade the surface with motor graders before using scrapers, as this leads to greater efficiency.

OPERATION OF DOZERS AND SCRAPERS

10. Both dozers and scrapers are operated either hydraulically or by means of cables. In the case of cable operated scrapers, it is essential to have a double drum power control unit. In the case of dozers, though they require a single drum power control unit, it is best to have a double drum power control unit for these also. In this case the same unit can be used for both scraper and dozer attachments. Also a tractor with a double drum power control

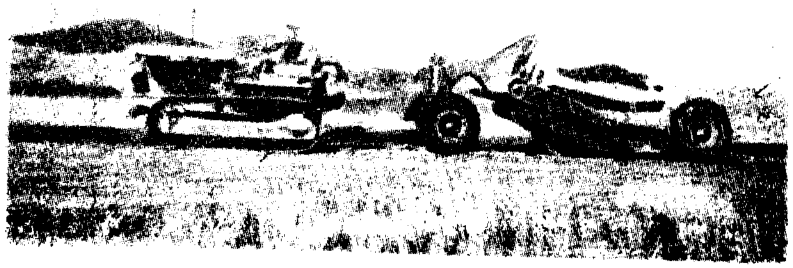

Photo. No. 4. Scraper with Track Type Tractor.

unit can have a dozer attached to it in front while it is operating a ripper or hauling another tractor at the back. In the case of hydraulically operated dozers or scrapers, the hydraulic equipment is supplied together with these items and it is not necessary to provide any separate power control unit.

11. Hydraulic operated dozers and scrapers are better for very hard material where a great deal of force is required in giving a cut but, under normal conditions, cable operated dozers and scrapers are preferable, as they are easier to maintain. Some engineers prefer to have cable operated scrapers at the back and hydraulic operated dozers at the front of all their tractors. This has certain advantages, particularly as a dozer can remain attached to a tractor while it is operating a scraper.

HORSE POWER

12. For earth work in ordinary soil, tractors having horse power as low as 50 or lower can be used but it is generally economical to provide tractors of much greater horse power except

where the quantities of earth work to be removed during the life time of the tractor are relatively small at each site and it is not considered desirable to lock up a large capital outlay in bigger machines.

Photo. No. 5. Motorised Scraper.

WORKS ORGANISATION

13. Tractors should be worked in units of from 5 to 10 tractors each, as this results in economical maintenance and supervision. It is, in addition, necessary to have a field workshop with each unit to enable running repairs to be carried out on the spot and without delay. It is also necessary to stock an adequate quantity of spares of all types of machines used.

14. Important details of some of the well-known types of tractors are given in **Appendix I** for track type tractors and **Appendix II** for wheel type tractors and motorised scrapers.

15. **Appendices III and IV** give details of units of track type and wheel type tractors considered economical. It will be seen that in the case of both these units, motor graders and field workshops are provided and that in the case of wheel type tractors, sheepsfoot rollers and pusher dozers are provided in addition.

16. Motor graders are useful for levelling and dressing both the ground to be dug and the embankment to be formed,

while pusher dozers are required to help the wheel type tractors and scrapers or motor scrapers in digging and loading as in both of them the draw-bar-pull is generally not sufficient for this purpose.

17. Details of field workshops are given in **Appendix V**.

18. **Appendices VI and VII** give average hourly working expenses under the present-day conditions, including repairs and depreciation of tractors with dozers and scrapers respectively. It will be seen from these calculations that the life of tractors has been assumed as 10,000 working hours. This is the life to be expected from tractors which are well looked after. The life may be less or more depending upon the amount of care devoted to their maintenance.

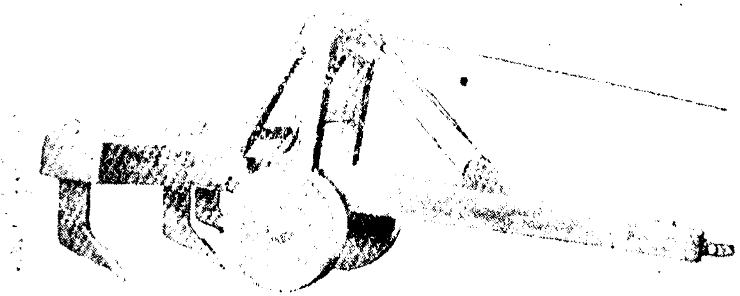

Photo. No 6. **Ripper**.

RATES

19. It is difficult to work out rates of earth work as these depend upon the nature of soil, lead, lift, efficiency of operators, and amount of care given to maintenance. It is, however, considered that under the present-day conditions, the rate for earth work in medium soils done by heavy track type tractors will work out to about Rs. 15 per 1,000 c. ft. for work up to 150 ft. lead, i. e. work suitable for dozers and about Rs. 20 per 1,000 c. ft. for work involving leads up to 500 ft. i. e. work suitable for scrapers.

20. With wheel type tractors or motor scrapers, it would probably be possible to do the work in Rs. 20 per 1,000 c. ft. up to 700 ft. lead. These rates are inclusive of repairs, interest and depreciation of the machinery used, but assume that the operators are reasonably efficient and that the machinery is well looked after.

21. These figures are very approximate and should not be taken as anything more than a very rough guide.

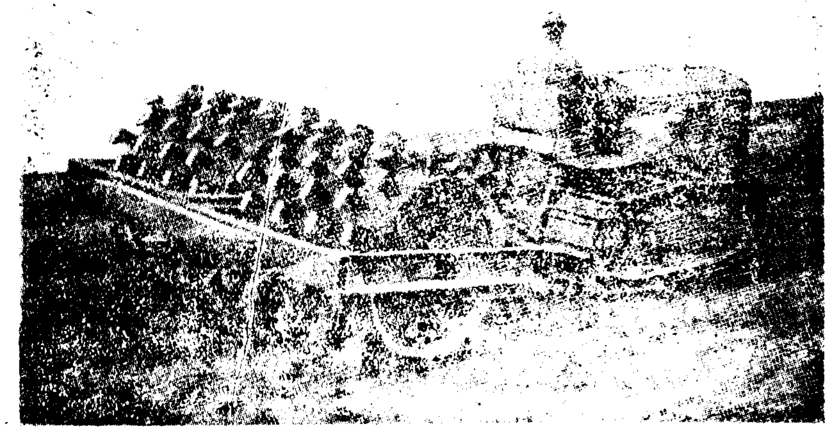

Photo. No. 7. **Double-drum Sheeps-foot Roller with Tractor.**

W BAR PULL IN LBS			Struck capacity of scraper in cu. yds. that the tractor can haul	Remarks
4th gear Speed/D.B.P.	5th gear Speed/D.B.P.	6th gear Speed D.B.P.		
3.7/12,600	4.8/9,550		13.5	Electric starting equipment is provided on extra payment.
4.6/5,994	6.0/4,550		8.7	—do—
4.4/4,730	5.8/3,130		6.0	—do—
			14.2	Exact speeds corresponding to the drawbar pulls are not known.
3.54/8,060	4.62/5,850	6.03/4,100	8.7	
5.0/3,500			5.50	
3.3/7,827	4.6/5,157	5.7/3,833	6.7	Also equipped with engine of 80.5 Drawbar Horse power.
3.4/5,683	4.8/3,824	5.8/2,925	5·50	

1.6%-14 : 10%

9).

B.H.P./Drawbar Pull in lbs ...r	3rd gear	4th gear	5th gear	Brakes	Tyres	Turning Radius for non-stop turn	Remarks
5	7.2/5,090	11.7/3,135	18.8/1,950	Air operated synchronised with tractor brakes	Two 12.0 × 20 0-14 Ply Four 21.0 × 25.0-20 Ply	Not known	Electric starting equipment is provided on extra payment
00	7.5/13,400	15.0/6,700		Multiple Disc Air Brakes	Four 24.00 × 29-24 Ply	33′	
own	8.65/not known	17.3/not known		do	Four 21.00 × 25-20 Ply	14′-6″	
t own	11.39/not known	20.05/not known		do	Four 21.00 × 25-20 Ply	14′-6″	
t own	10.17/not known	17.69/not known	25.27/not known	do	Four 14.00 × 32-12 Ply	19′	
43	8.5/5,295	14.9/3,006		Wagner Electric Hydraulic System	Four 21.00 × 24-20 Ply	30′	
344	11.59/3,672	23.19/1,836		Multiple Disc Air brake	Two 14.00 × 32-10 Ply Two 9.00 × 16-10 Ply	17′	
own	10.23/not known	18.0/not known		Special Heavy Duty Timken-Detroit air brakes.	Four 21.00 × 29-20 Ply	29′	

APPENDIX IV

A Unit of Earth-Moving Machinery (Wheel type Tractors).

1. Four Wheel type Tractors with Scrapers or motorised scrapers.
2. One Track type Tractor of 130 H. P. for pushing.
3. One Double Drum Power Control Unit for above.
4. One Straight Dozer for above.
5. One 45 H. P. track type Tractor for Sheepsfoot Roller.
6. One Double Drum Sheepsfoot Roller.
7. One Heavy duty Ripper for operating with item No. 2.
8. One Motor Grader 45 to 80 H. P.
9. One Field Workshop.

Note:—

(1) Sheepsfoot rollers are necessary as the wheel type tractors do not consolidate the earth.

(2) Number of tractors and scrapers may be increased upto ten if there is a large quantity of concentrated work. In this case the number of track type tractors and their auxiliary equipments may be suitably increased.

APPENDIX V

Equipments required for Field Workshop.

1. One 8 K.W. generating unit.
2. One Lathe, 6" × 6' bed.
3. One drilling machine, ½" spindle.
4. One Air Compressor, capacity 20 to 25 cu. ft. per min. at 100 lbs. sq. in.
5. One Portable ⅜" Electric drill.
6. One Spark Plug cleaner and testor.
7. One Oxy-Acetylene Welding and cutting plant.
8. One 3 Tons Hydraulic Press.
9. Two vices.
10. One 10 Ton lifting and traversing jack.
11. One 10" Grinder.
12. Blacksmiths' Tools-Portable folding forge plus a wel selected assortment of blacksmiths' tools.
13. Master mechanics' tool kit, machinists' precision tool kit, and complete set of hand tools.
14. Electricians' tool kit.

APPENDIX VI

Owning & operating cost of various Tractors with Dozers.

Operating cost per hour.		@		Dozer with 130 H.P. tractor. (Rs. 79,000/-)		Dozer with 80 H.P. tractor (Rs. 62,000/-)		Dozer with 65 H.P. tractor (Rs. 49,900/-)
Diesel Oil	5 glns.	1/6		6 14 0	3.25 glns.	4 7 6	2.6 glns	3 9 2
Petrol	.125 ,,	2/9		0 5 2		0 5 2		0 5 2
Lub. Oil	.09 ,,	5/-		0 7 2	0.06 ,,	0 4 10	0.04 ,,	0 3 5
Grease	.42 ,,	1/6		0 9 3	0.40 ,,	0 8 10	0.30 ,,	0 6 7
Operator & cleaner, pay				1 0 0		1 0 0		1 0 0
Operating charges per Hour.				9 3 7		6 10 4		5 8 4
Depreciation, complete write off in 10,000 hrs.				7 14 5		6 3 2		4 15 10
Running Repairs & Major Overhauls at 1½ of the cost				11 13 8		9 4 9		8 7 9
Interest @ 4% on the investment				0 5 0		0 4 0		0 3 2
Owning charges per Hour.				20 1 1		15 11 11		13 10 9
Total :				29 4 8		22 6 3		19 3 1
Say Rupees				29 5 0		22 6 0		19 3 0

APPENDIX VII

Owning and operating costs for various tractors with scrapers.

Operating cost per hour.	@		Scraper with 130 H. P. tractor. (Rs. 1,17,165/-)		Scraper with 80 H. P. tractor. (Rs. 87,675/-)		Scraper with 65 H. P. tractor. (Rs. 66,625/-)
Diesel oil	1/6	5 gls.	6-14- 0	3.25 gls.	4- 7- 6	2.6 gls.	3- 9- 2
Petrol	2/9	.125 gls.	0- 5- 2		0- 5- 2		0- 5- 2
Lub. Oil.	5/-	.09 ,,	0- 7- 2	0.06 ,,	0- 4-10	0.04 ,,	0- 3- 3
Grease	1/6	.42 ,,	0- 9- 3	0.40 ,,	0- 8-10	0.30 ,,	0- 6- 7
Operator & Cleaner, Pay			1- 0- 0		1- 0- 0		1- 0- 0
Operating charges per Hour.			9- 3- 7		6-10- 4		5- 8- 2
Depreciation : complete write off in 10,000 Hours			11-11- 6		8-12- 3		6-10- 7
Running Repairs and Major Overhauls at 1½ of the cost			17- 9- 3		13- 2- 5		9-15-11
Interest @ 4% on the investment			0- 7- 6		0- 5- 7		0- 4- 3
Owning charges per hour.			29-12- 3		22- 4- 3		16-14- 9
Total :—			38-15-10		28-14- 7		22- 6-11
Say Rupees			39- 0- 0		28-15- 0		22- 7- 0

1112

INFORMATION SERVICE

BITUMINOUS TREATMENT OF WET AGGREGATES.

The Council of the Indian Roads Congress, at their 21st meeting held at Lucknow in September 1944, decided to appoint a Subcommittee to examine the literature on the subject of the increase in the adhesive capacity of binders that could be made possible by adding water, certain oils such as turkey red oil and certain minerals such as lime, etc., to the aggregates and to correlate the results of the tests made in different places.

An interesting Paper (No. 99) on "Adhesion of bituminous binders to stone metals and the use of slaked lime for the treatment of wet aggregates" by C. J. Fielder published in Volume IX of the Journal of the Indian Roads Congress was discussed at the Ninth Session held at Madras in February, 1945.

Arising out of this Paper, and in compliance with the Council's decision referred to above, a separate technical Sub-committee was appointed to examine and investigate methods designed to render the bituminous treatment of wet aggregates both feasible and effective under Indian climatic conditions.

On the recommendation of the Subcommittee, detailed specifications (Appendices III to V) supplied by (i) Road Tar Manufacturers, (ii) Bitumen Suppliers, and (iii) Emulsion Manufacturers, along with a Memorandum (Appendix I), and a form for recording details of experiments (Appendix II), were forwarded to Chief Engineers of all Provinces, major States, Engineer-in Chief's Branch, C. P. W. D. and others, recommending full scale field trials of wet aggregates under controlled conditions, in their road building programmes for 1946 47.

The following recommendations were made in regard to the trials :—

(i) An adequate length of road should be allotted to each trial specification. One furlong was considered to be the minimum suitable length and as much as one mile would be preferred.

(ii) The binder suppliers' specifications should be adhered to and exact records of the trials should be kept.

(iii) Full details of the methods and materials used in the construction should be recorded, including the quantities, sources, and exact nature of the aggregates. A copy of the information should be sent to the Secretary,

Indian Roads Congress, as soon as possible after the completion of the work.

(iv) In order to establish the efficacy, or otherwise, of the methods proposed, the trials should include control lengths in which wet aggregate and binder should be laid *without* the use of lime or special wetting agents.

(v) The trial sections should be laid under wet weather conditions but not during heavy rain. The section should be inspected at regular intervals, and a careful record made of the condition of the surfaces and of other apparent factors. A copy of such inspections should be sent quarterly to the Secretary, Indian Roads Congress, with a view to the correlation of the results and the eventual compilation of a general report by the Subcommittee.

(vi) The suppliers of the binder materials should be given adequate notice of the trial in order they might make the services of their technical personnel available during the laying of the trial sections.

(vii) In regard to the specifications for the use of Bitumuls with wet aggregates, M/s. Bitumen Emulsions (India) Ltd., suggested that the process should be carried out with :

(a) Bitumuls Two Coat Wearing Surface, as outlined in Appendix V.

(b) cold premix, to the specification given in Appendix V and of a thickness that would be in keeping with the thickness of the premix carpets laid with tar or bitumen and carrying approximately the same amount of traffic as these carpets.

Some of the interim reports received from Provinces and States which were examined by the Subcommittee in February 1947 showed promising results and seemed to justify carrying out of more trials. Provinces, States, and other Administrations were accordingly asked to carry out full scale trials in as many localities as possible. The administrative and transport difficulties caused by the partition during 1947 generally prevented any great progress being achieved in the testing of the specifications in that year but a fair number of trials were carried out during the monsoon of 1948. The test lengths covered a total of about 157 furlongs in all.

The experiments have embraced high altitude localities near Simla, Darjeeling and Dehra Dun, down to localities near about sea-level with uniformly satisfactory results. The results are summarised in Appendix VI.

APPENDIX I

INDIAN ROADS CONGRESS

Memorandum Dated February 1946.

Bituminous Treatment Of Wet Aggregates.

The present extent of our knowledge on this subject has been summarised in Paper 99 presented to the Indian Roads Congress in January, 1945, and in a Paper read before the Institution of Civil Engineers by A. R. Lee and H. J. E. Carter in November, 1945, entitled 'The Use of Cold & Wet Aggregates in Bituminous Constructions of Roads and Aerodromes'.

The use of Slaked Lime has been proved to be very beneficial in promoting adhesion between bituminous binders and stone metals and renders possible the use of wet aggregate in surface painting and premix macadam without detrimental effect.

Furthermore it promotes and greatly improves adhesion between stone metal and binder in cases where the former has been found, even when used in the dry state, to display poor binder adhesion, e.g. quartzites and granites.

As pointed out in Paper 99 referred to above, the Slaked Lime Wet Aggregate Process appears to have special interest for Road Engineers in India as the wet monsoon season occurs during the warm period of the year when it would, in many cases, be advantageous for Road Surfacing programmes to proceed. Surface deterioration on Bituminous Treatment occurs for the most part during the rainy season and this process enables expeditious repairs to be carried out effectively and economically.

It is desirable that the possibilities of this process under Indian climatic conditions be fully explored as soon as possible and that Road Engineers should familiarise themselves with the technique and assess the value of the treatment by actual field Tests.

It is hoped, therefore, that it will be possible for Road Engineers, in all provinces where monsoon conditions are liable to prevail, to organise full scale trials of this treatment to the specifications recommended, during the 1946 monsoon season, and to submit reports on such trials in due course to the Congress for correlation and publication.

APPENDIX II

A. Bituminous Treatment of Wet Aggregate — Surface Dressing

I. Province (or State) ...
Division ...
Subdivision ...

II. **Location of treatment** ...
(i) Road ...
(ii) From Miles furlongs ...
To — — ...
(iii) Total Running Feet ...

III. Treatment commenced on ...
— completed on ...

IV. Type of Treatement ...
Surface Dressing 1st Coat
— — 2nd —
— — simultaneous two coat

V. Treated Road Width ...

VI. Condition of Road Surface prior to treatment ...

VII. Nature of Repairs (if any) ...

VIII. Quantity of Lime applied per 100 sq. ft. to the original surface (if any) ...

IX. (i) Grade of Bituminous Binder (If the Binder contains a Wetting Agent or if a Wetting Agent is added prior to application of the binder, this should be clearly stated with details of quantities)
(ii) Quantity of binders applied per 100 sq. ft. of surface. ...

X. (i) Nature of stone chippings and size gradings ...
(ii) Quantities employed per 100 sq. ft
(iii) Quantity of Lime (if any) added per cu. ft. of chippings ..

XI. (i) Weight of Roller ...
(ii) Number of Passes ...

XII. Weather conditions prevailing ...
(i) at time of laying ...
(ii) 1 day after — ...
(iii) 2 days — — ...
(iv) 3 — — — ..
(v) 7 — — — ..

XIII. Appearance of Surface (with special reference to adhesion of binder to chippings and chippings to the Road Surface in comparison with control lengths ...

(i) 7 days after laying ...
(ii) 1 month — — ...
(iii) 6 months — ...
(iv) 1 year — — ...

B. Bituminous Treatment of Wet Aggregate Premix Macadam

I. Province (or State) ...
Division ...
Subdivision ...

II. **Location of treatment** ...
(i) Road ...
(ii) From Miles furlongs ...
To — — ...
(iii) Total Running Feet ...

III. Treatment commenced on ...
— completed on ...

IV. Type of Treatment Premixed Macadam/Chipping Carpet Consolidated Thickness ...

V. Treated Road Width ...

VI. Condition of Road Surface prior to treatment ...

VII. Nature of Repairs (if any). ...

VIII. Quantity of lime (if any) applied per 100 sq. ft. to the original surface ...

IX. (i) Grade of Bituminous Binder applied as Tack Coat (if any) ...
(ii) Quantity of binder employed per 100 sq. ft. of surface ...

X. (i) Grade of Bituminous Binder employed for premixing. (If the Binder contains a Wetting Agent or if a Wetting Agent is added prior to application of the binder, this should be clearly stated with details of quantities) ...
(ii) Quantity of Binder applied per cu. ft. main course ...
(iii) — — — — top course

XI. (i) Nature of stone chippings/aggregate and size gradings ...
(ii) Quantities of stone metal employed per 100 sq. ft. ...
(iii) Quantity of Lime (if any) applied per cu. ft. of chippings or aggregate. ...

XII. (i) Weight of Roller ...
(ii) Number of Passes ...

XIII. Weather conditions prevailing ...
(i) at time of laying ...
(ii) 1 day after — ...
(iii) 2 days — — ...
(iv) 3 — — — ...
(v) 7 — — — ...

XIV. Appearance of Surface (with special reference to adhesion of binder to chipping and chippings to the Road Surface in comparison with control lengths) ...
(i) 7 days after laying ...
(ii) 1 month — — ...
(iii) 6 months — — ...
(iv) 1 year — — ...

APPENDIX III

SURFACE TREATMENT WITH SHALIMAR ROAD TAR AND WET AGGREGATES

I. Single Coat Painting Over Water Bound Macadam.

(i) The existing waterbound macadam surface must be swept free of excess binding and water, long-handled brooms being used for the purpose. Wire brushes may be used to remove caked mud but not in such way as to destroy good interlocking.

(ii) Slaked Lime in dry powdered form is then dusted over the surface by hand at the rate of 8 lbs. per 100 sq. ft. A long handled broom may be used to help distribute the lime evenly and to remove any lumps formed.

The best quality of Slaked Lime (Fat Lime) available should be selected. Hydraulic or 'Kankar' lime is definitely unsuitable. If lime is unobtainable cement may be substituted and spread at 10 lbs. per 100 sq. ft.

(iii) Road Tar No. 3 heated to 220° F. is then applied from a perforated sprinkling can or preferably sprayed over the lime-covered surface at the rate of 36 lbs. per 100 sq. ft. The Road Tar may be brushed out, if necessary, to ensure an even application.

(iv) Wet stone chippings or gravel of hard quality and to the specified size grading are coated with Slaked Lime as follows :—

The Wet chippings, or gravel, washed free of any adhering mud if necessary, are loaded into an improvised drum mixer with Slaked Lime at 1 lb. per c. ft. of chippings. One minute's mixing in the drum is sufficient to ensure a good coating of lime on the wet chippings.

The following grading of Stone Chippings, or gravel, is recommended :—

Passing ¾" & retained on ½" mesh — 2/3rds by volume.
" ½" " " " 1/10th" mesh — 1/3rd by volume.

(v) The lime-coated chips or gravel are then spread evenly over the Road Tar application at the rate of 5 c. ft. per 100 sq. ft.

(vi) Rolling is provided with a 6 to 8 ton roller & traffic may be allowed over the surface as soon as rolling is complete.

SURFACE TREATMENT WITH SHALIMAR ROAD TAR AND WET AGGREGATES

II. Renewal or 2nd Coat Surface Painting

(i) If any pot-holes exist these must be previously repaired with premix metal or by patch painting in accordance with our standard specification.

(ii) Sweep off all water lying in depressions. In places where the surface is seriously worn and the stone metal of the waterbound base is exposed a light application of Slaked Lime is given at 8 lbs. per 100 sq.ft. prior to the application of the Road Tar.

(iii) Road Tar No. 3 heated to 200°F. is sprayed or poured from a perforated can @ 28 lbs. per 100 sq. ft.

(iv) Wet stone chippings or gravel of hard quality and to the specified size grading are coated with Slaked Lime as follows :—

The wet chippings or gravel washed free of any adhering mud, if necessary, are loaded into an improvised drum mixer with Slaked Lime @ 1 lb. per c. ft. of chippings. One minute's mixing in the drum is sufficient to ensure a good coating of lime on the wet chippings.

The following grading of Stone Chippings or gravel is recommended :—

Passing ½" mesh & retained on 3/8th" mesh—2/3rds. by volume
" 3/8th" " " " 1/10th" mesh—1/3rd. by volume

(v) The lime-coted chips or gravel are then spread evenly over the Road Tar application at the rate of 3½ c. ft. per 100 sq. ft.

(vi) Rolling will be provided by a 6 to 8 ton Roller and traffic may be allowed over the finished surface as soon as rolling is complete.

SURFACE TREATMENT WITH SHALIMAR ROAD TAR AND WET AGGREGATES.

III. Simultaneous Two Coat painting Over Waterbound Macadam.

(i) The existing waterbound macadam surface must be swept free of excess blindage and water, long handled brooms being used for the purpose. Wire brushes may be used to remove caked mud but not in such way as to destroy good interlocking.

(ii) Slaked Lime in dry powdered form is then dusted over the surface by hand at the rate of 8 lbs per 100 sq. ft. A long handled broom may be used to help distribute the lime evenly and to remove any lumps formed.

> The best quality of Slaked Lime (Fat Lime) available should be selected. Hydraulic or 'Kankar' Lime is definitely unsuitable. If lime is unobtainable cement may be substituted and spread @ 10 lbs. per 100 sq. ft.

(iii) Road Tar No. 3 heated to 220° F. is then applied from a perforated sprinkling can or sprayed over the lime-covered surface at the rate of 32 lbs. per 100 sq. ft. The Road Tar may be brushed out to ensure an even application.

(iv) Wet Stone Chippings or gravel of hard quality to the specified size grading are coated with Slaked Lime as follows:-

> The wet chippings or gravel washed free of any adhering mud if necessary, are loaded into an improvised drum mixer with Slaked Lime @ 1 lb. per c. ft. of chippings. One minute's mixing in the drum is sufficient to ensure a good coating of lime on the wet chippings.
>
> The following grading of Stone Chippings or gravel is recommended :—
>
> Passing $\frac{3}{4}''$ mesh & retained on $\frac{1}{2}''$ mesh 2/3rds. by volume
> " $\frac{1}{2}''$ " " " 1/10th" mesh— 1/3rd by volume

(v) The lime-coated chips or gravel are then spread evenly over the Road Tar application at the rate of $4\frac{1}{2}$ c. ft. per 100 sq. ft.

(vi) Roll twice with 6 to 8 ton Roller.

(vii) Immediatly after rolling apply Road Tar No. 3 heated to 200° F. at the rate of 28 lbs. per 100 sq. ft.

(viii) Spread $2\frac{1}{2}$ c. ft. per 100 sq. ft. of stone chippings or gravel which have been coated with lime as described in Para (iv) above.

The following grading of stone chippings or gravel is recommended :—

Passing $\frac{1}{2}''$ mesh & retained on 3/8th" mesh -- 2/3rds.
" 3/8th" mesh & " " 1/10th" mesh -- 1/3rd.

(ix) Roll to set : 8 to 12 turns of the Roller is usually sufficient.

(x) Open to traffic after 24 hours.

SURFACE TREATMENT WITH SHALIMAR ROAD TAR AND WET AGGREGATES

IV. Tar Premix Macadam

Premix Chipping Carpet

(i) The standard specification for premix using dry stone metal aggregate chippings should be followed with these modifications :—

> After measuring the wet graded stone metal aggregate or chippings into the mixing machine or hand-mixer, add powdered Slaked Lime of good quality at the rate of 1 lb. per c. ft. of stone metal or chippings and mixing is continued for 1 minute, or in the case of a hand-mixer for 12 revolutions of the drum. This is sufficient to coat the metal with Slaked Lime and the hot Road Tar as specified for grade and quantity is then introduced and premixing completed in the usual way in $2\frac{1}{2}$ minutes to 3 minutes.
>
> With good quality Slaked Lime i.e. Fat Lime—(hydraulic or 'Kankar' lime is definitely unsuitable) excellent coating of the stone metal or chippings with Road Tar is attained.
>
> If Slaked Lime is not available cement may be substituted.

(ii) **Tack Coats** -- For Premix Chipping Carpets of less than $1\frac{1}{2}''$ consolidated thickness a tack coat of Road Tar No. 3 must first be applied. If the carpet is to be applied over a previously treated surface no change of specification is involved but if it is to be applied over a waterbound macadam surface then the latter should first be given an application of Slaked Lime in dry powdered form 8 lbs. per 100 sq. ft. and Road Tar No. 3 then applied according to the specification.

V. Patch Repairs With Shalimar Road Tar and Wet Aggregates

PREFACE. It is in wet weather that a surfaced road is most likely to develop potholes and unless these are treated at once serious deterioration of the surface follows. The following specifications are offered to enable repairs to be executed promptly in wet conditions. The specifications are similiar to those normally used in dry weather except that slaked lime is used to coat the wet stone surfaces to obtain satisfactory adhesion of the Tar.

SPECIFICATIONS

I. Shallow Depressions And Breaks in the Surface Up To ½″ Deep.

1. Cut the area square or rectangular depending on the shape of the break and clean out loose material.
2. Dust the bottom and sides with slaked lime at 8 lbs. per 100 sq. ft.
3. Paint bottom and sides with Road Tar No. 3 at 200°F at 45 lbs. per 100 sq. ft.
4. Blind with chips or gravel of suitable size pre-coated with slaked lime at 1 lb. per c. ft. of stone metal.
5. Hand-ram or roll as convenient and open to traffic.

II. Potholes And Ruts Up To 1″ Deep.

1. Cut the area square or rectangular according to the shape of the break. Remove loose material. The cut out sides should be as vertical as possible and excess water removed.
2. Dust the bottom and sides of the cut with slaked lime at 8 lb. per 100 sq. ft. and paint lightly with Tar No. 3 at 200°F.
3. Fill depression suitably proud with ¾″ chippings premixed as described under.
4. Hand-ram or roll as convenient, dust lightly with sand and open to traffic.

III. Potholes And Ruts Up To 2½″ Deep.

1. Treat damaged area as in II (1) above.
2. Treat as in II (2) above.
3. Fill depression suitably proud with premixed stone metal 1½″—1″, and ram well.
4. Spread topping course of premixed chippings or gravel ¾″ in size.
5. Hand-ram or roll. Sprinkle lightly with sand, and open to traffic.

IV. Premixing With Wet Aggregate.

1. Place the wet aggregate in a mixer, add slaked lime at 1 lb. per c. ft. of stone and give a few turns to precoat the stone with lime.
2. Add Tar No. 3A heated to 220° at the rate of 4½ lbs. per c. ft. of metal or 5 lbs. per c. ft. of ¾″ and under chippings or gravel.
3. Rotate till thoroughly coated with Tar.

APPENDIX IV

Notes On The Execution of Road Surfacing With Bitumen In Wet Weather and Suggestions For Trials

1. Introductory:

A process has been developed, initially in the U. K. and, during the War, in India also, that enables road surfacing with Bitumen to be carried out in wet weather, e. g., on a wet surface and using wet aggregate.

The process takes advantage of the ability of a combination of SLAKED LIME and certain ACIDS to form calcium compounds which impart hydrophobic properties to the aggregate. Wet aggregates coming in contact with these calcium compounds in the presence of Bitumen throw off their water film and attract the Bitumen Binder in its place.

The process enables surfacing work to be carried out in wet weather. A second advantage is sometimes claimed; this is that the process results in increased adhesion between the aggregate and the film of Bitumen Binder. The validity or otherwise of this claim has yet to be established.

2. Methods of Work:

A. The principal use of the 'Wet stone' process is in the construction of Premix Stone Carpets of any thickness. Ordinary standard methods are employed with the following modifications:—

(1) The aggregate, which is, of course, wet, is treated with slaked lime before the Bitumen Binder (hot) is added.

(2) A special (hot) Bitumen Binder, in Cut-back form in which a small percentage of fatty acid has been added, is used.

A typical specification for a 1″ consolidated carpet is as follows:—

Aggregate: shall be hard, clean, graded stone ⅝—¼″ size. (60/⅝—½, 40/⅜—¼″) 10 cubic feet stone be used for 100 sq. feet of area.

Lime: The stone will be wet: before coating with Bitumen slaked lime shall be thoroughly mixed with it in a quantity of ¾—1 per cent by weight.

Bitumen Binder: Specially treated Bitumen containing a small percentage of acid shall be used. The Binder shall be applied **hot at** a temperature of 275—300°F. at a rate of 4 lb. per cubic feet of stone.
For details of alternative binders see further Note (3) below.

Mixing: The hot binder shall be added to and mixed with the lime treated wet stone in portable, power driven mixing machines and mixing continued until the water has been driven off and all stones are properly coated with binder.

If power driven mixers are not available, hand operated drum mixers may be used.

Laying: The coated stone shall be laid to templates and true to line and level at the rate of 10 cubic feet per 100 sq. feet.

Consolidation: Shall be carried out with 6-8 ton power rollers as soon as a sufficient area of carpet has been laid to permit rolling to commence,

Opening to Traffic: The carpet may be opened to traffic after 24 hours at the discretion of the Engineer in charge.

NOTES:

(1) Tack Coat: The question of whether or not a tack coat shall be provided under the carpet depends upon :

(a) the texture of the existing surface over which the carpet is to be laid, and

(b) the thickness of the carpet.

Carpets of thickness of 1" and above are considered to have sufficient inherent stability not to require a Tack Coat. For carpets of a thickness less than 1 in. a Tack Coat is advisable, particularly if base is smooth. If a Tack Coat is required it can be applied in the same binder as used in the construction of the carpet, at a rate of 15—20 lb. per 100 sq. ft., by the method described below under "Surface Dressing."

(2) Seal Coat: A Seal Coat is not immediately necessary for light carpets composed of graded aggragate. Whether or not a Seal Coat is required later depends upon the 'working up' of the surface under traffic and can be determined by the Engineer in charge, by inspection.

(3) Binder: A specially treated Cut-back Binder, containing a percentage of added acids, is available in limited quantities from Messrs Burmah-Shell Oil Co. Ltd., and is called 'Shelmac D'.

Normal Cut-back Binders such as Shelmac S. 125 or Shelspra B-S, can be treated with Fatty Acids at site. The amounts of acid required can only be determined by test and vary with the acid used. The amount, in each case, is of the order of 3 to 6 per cent by weight of the Binder. The following fatty acids have been found satisfactory for this purpose :—

(a) Cresylic Acid: This is a particularly effective agent.

(b) Turkey Red Oil: (Sulphonated Caster Oil): It is difficult to obtain this material free from water and trouble from frothing is apt to be experienced when it is added to hot Bitumen. Supplies are available from Oil mills in the U.P.

(c) Oleic Acid: This acid is also effective in this process. Supplies can be had from Chemical manufacturers, e. g. Messrs. Smith, Stanistreet, Ltd., Calcutta.

(d) Blown Rapeseed Oil: This fatty acid is also suitable for wet stone work. Supplies are available from Oil Mills in the U. P.

B. Surface Dressing:

The wet stone process can also be applied to surface dressing as well as to the construction of Premix carpets. The differences between this work and ordinary surface painting are :—

1) The wet surface to be treated is first sprinkled with slaked lime at a rate of 5 lbs. per 100 sq. ft. This forms a slurry with the water on the wet surface and this slurry should be brushed out evenly so that the whole surface is covered,

2) A special binder containing fatty acid is required. The same binders as are recomended for the Premix carpets — vide A (3) above — will be suitable.

3) The Bitumen should be applied by pressure sprayers as owing to the underlying lime slurry it is not possible to brush it out by brooms or squeegees as can be done in normal dry weather surface dressing.

4) The chippings to be applied over the binder, which will be wet, should be pre-treated by mixing with ¾—1 per cent of slaked lime.

In all other respects normal quantities and sequences of operation are followed.

3. Additional Notes:

(a) Road Trials To-date:

The first road trial of this method carried out in India was laid in March 1942 when a length of 1"Premix chippings carpet was laid by the Central P. W. D., on the Grand Trunk Road, Delhi - Shadra section near the Jumna Bridge. This has given very satisfactory service under heavy lorry traffic for over 4 years. The binder used was Shelmac S/125 with various quantities of Cresylic Acid and Turkey Red Oil.

Other practical trials were carried by the Military in 1943-45 in Assam and Bengal.

More recently practical trial of Premix carpets and surface painting were carried out, in 1945, by the Bombay P. W. D. on the Bombay-Poona Trunk Road near Thana and near Poona. The binder used was Shelmac 'D' in the former and Shelspra B-S with Blown Rapeseed Oil in the latter.

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APPENDIX V

Bitumuls Specifications

Bitumuls Two Coat Wearing Surface

(1/2 in. fully compacted)

This specification can be laid over water bound macadam or over an already treated surface.

This is the standard specification for the surfacing of waterbound macadam roads, but it is also recommended for laying on concrete and other hard surfaces, where fast and heavy traffic is encountered. The aggregate is bonded between the lower and upper application of emulsion and an excellent surfacing of 1/2 in. thickness is obtained.

PREPARATION OF SURFACE

Clean the surface of the roadway thoroughly. Fine material should be removed from the interstices of the base metal to a depth of at least ½ in. for a waterbound macadam surface. This may be done with brushes or brooms, but in the case of caked mud, dirt, cowdung, etc., it will be necessary to use wire brushes. It is essential to have the exposed metal faces clean so as to obtain firm adhesion.

Patch holes or depressions with Bitumuls HX and chippings as already detailed under "Patch Repairs."

FIRST COAT APPLICATION

Sprinkle the road surface lightly with water as this will lay the dust and also ensure better penetration of the emulsion. On the waterbound macadam surface spray Bitumuls HX at the rate of 2.75 gallons per 100 sq. ft. (In the case of an already treated surface the first application should be modified to 2.0 gallons of Bitumuls HX.)

First Layer Chippings.

Immediately after spraying, spread chippings or bajri ¾ in. — ½ in. at the rate of 3.5. cu. ft. per 100 sq. ft. evenly over the whole surface. Level off where necessary. (A Bitumuls drag broom can be used for this with great advantage.)

Two hours after the aggregate has been levelled off, roll twice. Any low depressions or levelling up can be done by the addition of more bajri.

SPECIFICATIONS

		Per 100 sq. ft.
1.	Clean the surface of the road thoroughly.	
2.	Sprinkle the road surface lightly with water.	
3.	On the dampened surface - Spray Bitumuls HX.	2.75 gallons.
4.	Immediately after spraying - Spread ¾ in. - ½ in. chips or bajri	3.5 cu. ft.
5.	Drag-broom and roll over twice after 2 hours.	
6.	Sprinkle the surface with water.	
7.	On the dampened surface - Spray Bitumuls HX.	2.75 gallons.
8.	Immediately after spraying - Spread ¼ in. - 1/8 in. chips or bajri.	2.0 cu. ft.
9.	After two hours roll to compaction and open to traffic after 12 hours.	

This specification may also be laid over an already tarred or bitumen surface where it is desired to level up a rough surface or lay a more durable wearing surface. The first spray of Bitumuls (item No. 3) should then be modified to 2.0 gallons. THIS is the only change in the specification for such work.

TOTAL REQUIRED. 5.5. gallons Bitumuls. 5.5. cu. ft. chippings

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COLD PREMIX

Some engineers regard premix as the only scientific and practical method of road construction, the reason being that every face of every stone is covered with a thin film of Bitumen and a cold emulsion is very suited for this process. Moreover, when using emulsion for premix work all preparations are carried out cold and there is no difficulty to contend with in regard to heating the binder or cold damp aggregate.

Bitumuls HRM is a slow breaking emulsion which has been specially adapted for cold premix work with aggregate for new road construction, resurfacing and patching.

The emulsion is mixed with the cold aggregate and no heating plant is required. The aggregate must be clean and may be dampened, especially in dry dusty weather. Aggregate up to ⅜ in. may be mixed with Bitumuls HRM by hand in troughs or cut drums, but if over ¾ in. it is recommended that rotary drums or mechanical mixers are employed. If mixed in a central mixing plant, the coated aggregate should be transported to the road side and raked into position. The mixing may also be done in a concrete mixer on the road, in which case the aggregate is stored at suitable points along the roadside and the coated material dumped on the area to be surfaced and spread with shovels or rakes. Rolling should be carried out after the emulsion has broken, usually any time up to 24 hours, depending on climatic conditions.

LAYING.

Clean the surface of the roadway. Spray or brush on a tack coat; spread the premix evenly with rakes, forks or shovels to the desired thickness and contour, allowing for consolidation. Leave until the emulsion has broken and roll to compaction, keeping the roller wheels damp. Premixes of ¾ in. and 1 in. thickness are laid in one course, but anything over 1 in. should be laid in two courses, the larger graded aggregate providing the base for the finer aggregate surface course.

After the premix has been rolled and compacted, the seal coat should be sprayed on at about 1.0 to 1.5 gallons per 100 sq. ft. and blinded with coarse sand at 1.5 cu. ft. per 100 sq. ft. Open to traffic after 48 hours or when the premix has definitely set hard. Bitumuls HX or HRM can be used for the tack and seal coats.

The following table gives the materials required for premix carpets from ¾ in. — 3 in. thickness :—

BITUMULS PREMIX

(HRM and WRM Grades)

Materials required for Surfaces of Various Thicknesses

Thickness in inches	Size of metal (in inches)	Quantity of metal per 100 sq. ft. in cu. ft.	Bitumuls per cu. ft. of metal in lbs.	Tack Coat per 100 sq. ft. in Galls.	Seal Coat per 100 sq. ft. in Galls.	Coarse sand blindage per 100 sq. ft. in cu. ft.	Total Bitumuls per 100 sq. ft. in Galls.
¾	½ — ⅛	7.50	6	1.5	1.0	1.50	7.0
1	¾ — ¼ Below ¼ — ⅛	6.0 4.0	6	1.5	1.0	1.50	8.5
1¼	1 — ¾ ⅜ — ⅛	11.0 5.5	3 7	1.5	1.0	1.50	9.65
2	1½ — ¾ ½ — ⅛	15.0 7.5	2.5 7.0	1.5	1.0	1.50	11.5
2½	2 — 1 ½ — ⅛	18.0 9.5	2.5 6.5	1.5	1.0	1.50	13.17
3	2 — 1 ½ — ⅛	20.0 12.0	2.5 6.5	1.5	1.0	1.50	15.8

APPENDIX VI

EXPERIMENTAL RESULTS ON BITUMINOUS TREATMENT OF WET AGGREGATE

(1) Surface Dressing

LOCATION	DATE	NUMBER OF TESTS	BINDER	TOTAL LENGTH OF ROAD TREATED	NATURE OF REPORT ON RESULTS OBTAINED
ASSAM	1946	1	Road Tar	3/8 Mile	Favourable
BENGAL	1946/48	10	Tar	1.3/4 Mile	Favourable
BIHAR	1947/48	10	Road Tar (9) Bitumen (1)	2.1/2 Miles	Favourable
BOMBAY	1945 & 1948	2	Bitumen	1/2 Mile	Favourable
CENTRAL PROVINCES	1948	1	Bitumen	1/12 Mile	Unfavourable
PUNJAB (Simla)	1944/47	6	Tar (4) Bitumen (2)	2.1/2 Miles	Favourable
UNITED PROVINCES	1947/48	8	Tar	4.1/2 Miles	Favourable
				12.1/4 Miles	

EXPERIMENTAL RESULTS OF BITUMINOUS TREATMENT OF WET AGGREGATE

(2) Premixed Carpets

LOCATION	DATE	NUMBER OF TESTS	BINDER	TOTAL LENGTH OF ROAD TREATED	NATURE OF REPORT ON RESULTS OBTAINED
1. ASSAM	1942 & 1946	2	M. E. S. laid certain unrecorded lengths with Road Tar in 1942 on the Manipore Road.	1/2 Mile	Favourable
2. BENGAL	1946/48	13	Road Tar (11) Bitumen (2)	2.1/8 Miles	Favourable
3. BIHAR	1946/48	12	Road Tar (9) Bitumen Emulsion (2) Bitumen (1)	2.1/2 Miles	Favourable (with one exception)
4. BOMBAY	1948	4	Bitumen	2.1/2 Miles	Favourable (with one exception)
5. CENTRAL PROVINCES	1948		Bitumen	—	Favourable
6. UNITED PROVINCES	1942 & 1947	2	Bitumen (1) RoadTar (1)	1/4 Mile	Favourable
				7.3/8 Miles	

(3) LOCATION OF TRIAL SETIONS.

BIHAR

Surface Dressing.

1.	September	1946	Purulia-Ranchi Road	Mile 31	(f. 1 & 2)	Road Tar
2.	September	1946	Ranchi-Chaibassa Road	Mile 12	(f. 7 & 8)	Road Tar
3.	August	1947	Chaibassa-Jaintgarh Road	Mile 29	(f. 1 & 2)	Road Tar
4	August	1947	Ranchi Daltonganj Road	Mile 22	(f. 2 & 3)	Road Tar
5.	September	1947	Bihar-Nawadah Road	Mile 16	(f. 1 to 4)	Road Tar
6.	August	1948	Barakar Purulia Road	Mile 9	(f. 6 to 8)	Road Tar
7.	September	1948	Barhi-Hazaribagh Road	Mile 11	(f. 7 & 8)	Road Tar
8.	September	1948	Ranchi- Chaibassa Road	Mile 6	(f. 2)	Road Tar
9.	January	1949	M. E. S. Road — Ranchi			Road Tar
10.	January	1949	M. E. S. Road — Ranchi			Bitumen

Premixed Carpet

1.	September	1946	Purulia-Ranchi Road	Mile 32	(f. 5 & 6)	Road Tar
2.	September	1946	Ranchi-Chaibassa Road	Mile 12	(f. 6)	Road Tar
3.	August	1947	Patna-Buktiarpur Road	Mile 6	(f. 5 & 6)	Bitumen Emulsion
4.	August	1947	Chaibassa Jaintgarh Road	Mile 29	(f. 3 & 4)	Road Tar
5.	September	1947	Bagodar Hazaribagh Road	Mile 22	(f. 4 to 8)	Road Tar
6.	September	1947	Ranchi Daltonganj Road	Mile 22	(f. 5)	Road Tar
7.	August	1948	Chas. Gobindpur Road	Mile 31	(f. 1 & 2)	Road Tar
8.	August	1948	Chas. Gobindpur Road	Mile 5	(f. 1)	Bitumen Emulsion
9.	September	1948	Barhi Hazaribagh Road	Mile 11	(f. 7 & 8)	Road Tar
10.	October	1948	Ranchi Chaibassa Road	Mile 6	(f. 3)	Road Tar
11.	January	1949	M. E. S. Road — Ranchi			Road Tar
12.	January	1949				Bitumen

UNITED PROVINCES

Surface Dressing

1. September	1946	Lucknow-Jhansi Road	Mile 18	(f. 1 to 4	Road Tar
		&	Mile 117	(f. 7, 8)	Road Tar
2. October	1946	Delhi-Rajpur-Mussoorie Road	Miles 145 & 153		Road Tar
3. July	1947	Bareilly-Almora Road	Mile 2	(f. 1, 2)	Road Tar
4. September	1947	G. T. Road Allahabad	Mile 502	(f. 1, 2)	Road Tar
5. September	1947	Allahabad-Rewa Road	Miles 10 & 17		
6.	1948	Dehra Dun-Doiwalah Road	Mile 8	(f. 2, 3, 4 & 6)	Road Tar
			Mile 9	(f. 6, 8)	Road Tar
			Mile 10	(f. 1, 2, 3, 6 & 7)	Road Tar
7. October	1948	Dehra Dun-Chakrata Road	Mile 6	(f. 2, 3)	
			Mile 9	(f. 7, 8)	
8. October	1948	Agra-Bombay-Delhi Road	Mile 751	(f. 3, 4)	

Premix

1. March	1942	Delhi-Meerut Road (Near Sharda)			Bitumen
2. August	1947	G. T. Road Allahabad	Mile 503	(f. 1 & 2)	Road Tar

BENGAL

Surface Dressing

1. 1946	Grand Trunk Road	Mile 8	(f. 2 & 7)	Road Tar.
2. 1946	Darjeeling H. C. Road	Mile 40		Road Tar.
3.	Peshoke Road	Mile 1	(f. 4 to 8)	
4. 1947	Raniganj-Midnapore Road	Mile 39	(f. 1 to 4)	Road Tar.
5. 1947	,, ,, ,,	Mile 49	(f. 1 to 4)	Road Tar.
6. 1947	,, ,, ,,	Mile 92	(f. 3)	Road Tar.
7. 1947	Assam Access Road (Cooch Behar)			Bitumen.
8. 1948	Grand Trunk Road	Mile 4	(f. 4)	Road Tar.
9. 1948	,, ,, ,,	Mile 21	(f. 1 to 4)	Road Tar.
10. 1948	Dum Dum-Cossipore Road	Mile 1	(f. 1 & 2)	Road Tar.

Premixed Carpet

1. 1946	Grand Trunk Road	Mile 8	(f. 2 to 6)	Road Tar.
2. 1946	Darjeeling-Lebong Cart Road	Mile 3	(f. 4 to 8)	Road Tar.
3. 1947	Raniganj-Midnapore Road	Mile 39	(f. 4 to 6)	Road Tar.
4. 1947	,, ,, ,,	Mile 49	(f. 4 to 6)	Road Tar.
5. 1947	Assam Access Road (Cooch Behar)			Bitumen.
6. 1948	Calcutta Maidan (Dufferin Road)			Road Tar.
7. 1948	Grand Trunk Road	Mile 21		Road Tar.
8. 1948	Dum Dum-Cossipore Road	Mile 1	(f. 1 & 2)	Road Tar.
9. 1948	Grand Trunk Road	Mile 4	(f. 4 & 5)	Road Tar.

		BOMBAY			
		Surface Dressing			
September	1945	Bombay Agra Road	Mile 21	(f. 7 & 8)	Bitumen
August	1948	Poona Bangalore Road	Mile 216	(f. 1 & 2)	Bitumen
		Premixed Carpet			
September	1945	Bombay Agra Road	Mile 21	(f. 8)	Bitumen
August	1948	Poona Bangalore Road	Mile 216	(f. 3 & 4)	Bitumen
September	1948	Poona Sholapur Road	Mile 7	(f. 1 & 2)	Bitumen
September	1948	Bombay Poona Road	Mile 100	(f. 5 to 7)	Bitumen
		PUNJAB			
		Surface Dressing			
1. August	1944	Kalka-Simla Road	Mile 88	(f. 1 to 4)	Road Tar
2. August	1944	Circular Road to Chota Simla			Road Tar
3. June	1946	Simla, Sanjauli Circular Cart Road			Road Tar & Bitumen
4. September	1946	Kalka-Simla Road	Mile 87	(f. 6 to 8)	Road Tar
5. April	1947	Kalka-Simla Road	Mile 87	(f. 1 to 5)	Bitumen
		ASSAM			
		Surface Dressing			
1. September	1946	Assam Trunk Road (West)	Mile 25		
		Premixed Carpet			
1.	1942	Manipur Road			Road Tar
2.	1946	Dhubri-Gouripur/Bashbari Road	Mile 6		Road Tar
		CENTRAL PROVINCES			
August	1948	Palm Road, Nagpur	Mile 1	(f. 1)	Bitumen

BOOK REVIEWS

I. "HIGHWAY SPIRALS, SUPERELEVATION AND VERTICAL CURVES"

by H. CRISWELL, M.I.C.E. Second Edition (Revised and enlarged). The Carriers Publishing Co., Ltd., 65, Victoria Street, London. S. W. I. Price 42 sh. net.

The second edition of this pocket-book for Highway Engineers contains 445 pages, 125 Figures, and 75 Tables. The first edition was published in 1937. In the revised edition the scope of the book has been greatly increased and the chapters on "Vertical Curves" have been entirely rewritten.

The Tables of Transitions for horizontal curves have been increased in number by the addition of Tables for 40 and 55 m. p. h. so that the range now extends at 5 m. p. h. intervals from 20 to 60 m. p. h. and includes Tables for 75 and 100 m. p. h.

New chapters have been added on the layout of transition Curves of unequal length and for compound curves. The setting out of dual carriageways by means of concentric arcs and their transitions has received attention as well as methods of effecting concentric widening.

The theory of superelevation and its application to practice is thoroughly discussed, including the superelevation of dual carriageways treated separately or as a single unit, no less than five methods being referred to in some detail.

There is also a new chapter on the formulae used in the compilation of the "A" and "B" Tables for the eleven design speeds included, followed by a brief description and method of using the perspex transition curves, which facilitate the plotting of the transitions.

A substantial portion of the book is devoted to the subject of vertical curves which has been very thoroughly dealt with. The principles determining the vision distances and the lengths of curve required for summits or valley curves for two-way and one-way roads are discussed. Such curves are illustrated by several examples of both simple and cubic parabolas, complete with detailed working.

The book is sure to prove very useful for highway engineers. The Author whose contributions have appeared from time to time in the vaious issues of "Roads and Road Construction" deserves very high commendation for his efforts in being able to put in the hands of highway engineers such an authoritative and practical guide to aid them in their work.

II. "**ROUTE SURVEYS**" by Russel R. Skelton, published by McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 18, N. Y., first eddition, 1949. Pages X+531. Price $ 4.50.

The Author is the Professor of Civil Engineering in the University of New Hampshire, U. S. A., with 25 years of professional and teaching experience. The book is thus sure to appeal to both the practical engineer and the student. It caters for the highway as well as the railway engineer.

The three brief and pithy chapters on survey deal with reconnaissance, preliminary and location surveys. The advantages of aerial survey are stressed. In any book on route surveys curves would naturally come in for detailed analysis and the Author covers this ground over five chapters. Simple circular curves, compound and reverse curves, parabolic curves, and spiral curves are examined.

The vexed questions concerning earthwork, various methods of earthwork measurement by cross-sections or by borrrow pits, corrections for earthwork on curves, shrinkage, swell and so on are discussed. The text is accompanied by numerous worked out examples illustrating methods, theory and economy.

Extensive curve tables and trignometric and logarithmic tables make the book self-contained.

III. "**MODERN RAILROAD STRUCTURES**" by Charles P. Disney and Robert F. Legget, McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, 18, N. Y., U.S.A. (Price 5.00 dollars) 1st Edition, 1949.

The Senior Author of this excellent book is an ex-Bridge Engineer of the Canadian National Railways, while Mr. Legget is the Director of the Division of Building Research of the National Research Council of Canada. Although the book deals primarily with railroad structures there is so much common ground in highway and railroad structures that highway engineers might study the book with interest and advantage.

The book is an attempt to compile, in a handy form, accounts of new processes, new techniques and new materials, used successfully on structures like bridges, abutments, piers and tunnels etc. A chapter is devoted to stress the importance of soil mechanics in all types of transportation engineering, whether railroads, highways, or even navigation canals which have to be made safe against subsidence and land slides.

The chief interest of the book, however, centres in the chapters on methods of restoration and repair. Recent improvements in the art of grouting and repairing concrete and masonry *under water* are fully covered.

The book is printed on art paper and is profusely illustrated.

IV. "**BASIC ROAD STATISTICS OF INDIA, 1948.**"

Compiled by the Consulting Engineer (Roads) to the Government of India. Published by the Manager of Publications, Delhi. Imperial Octavo pp. 164+vii. Price Rs. 8/8 (or 13 sh. 6 d).

In India, the first obstacle which one meets with when initiating any sort of enquiry, whether of research or administrative planning, is the absence of a satisfactory statistical background. This disadvantage has in no department of enquiry been more evident than in road transport. The present publication is the outcome of a very laudable attempt on the part of the Statistical Section of the Roads Organisation to overcome this disadvantage, by providing a source of authoritative reference on statistical data of everyday utility to the Road Engineer and those interested in road transport generally. The large volume of statistical data contained in this volume is at present not easily available from any other source. The extent of the patient and exacting labour which must have been expended in the collecting and compilation of the data is easily evident on every page.

The publication gives numerical data fully classified in regard to details on every aspect of road transport for as many back years as possible. This feature by itself makes it an ideal reference book of permanent value. It will not be disputed that the preparation of this volume has made the problem of maintaining and publishing the data uptodate very much easier than what it was previously. We hope to see in future an annual publication giving the necessary figures to keep this volume uptodate.

Other useful features are the incorporation of comparative statistics of foreign countries wherever relevant, and a short history of road developement in India and of the Central Road Fund.

Incidentally, we feel that the title of the publication is more modest than its contents warrant. It would even seem justifiable to call it Basic Transport Statistics of India. In addition to six sections dealing respectively with Growth of Traffic, Current Traffic Statistics, Road Milage, Road Finance, the Central Road

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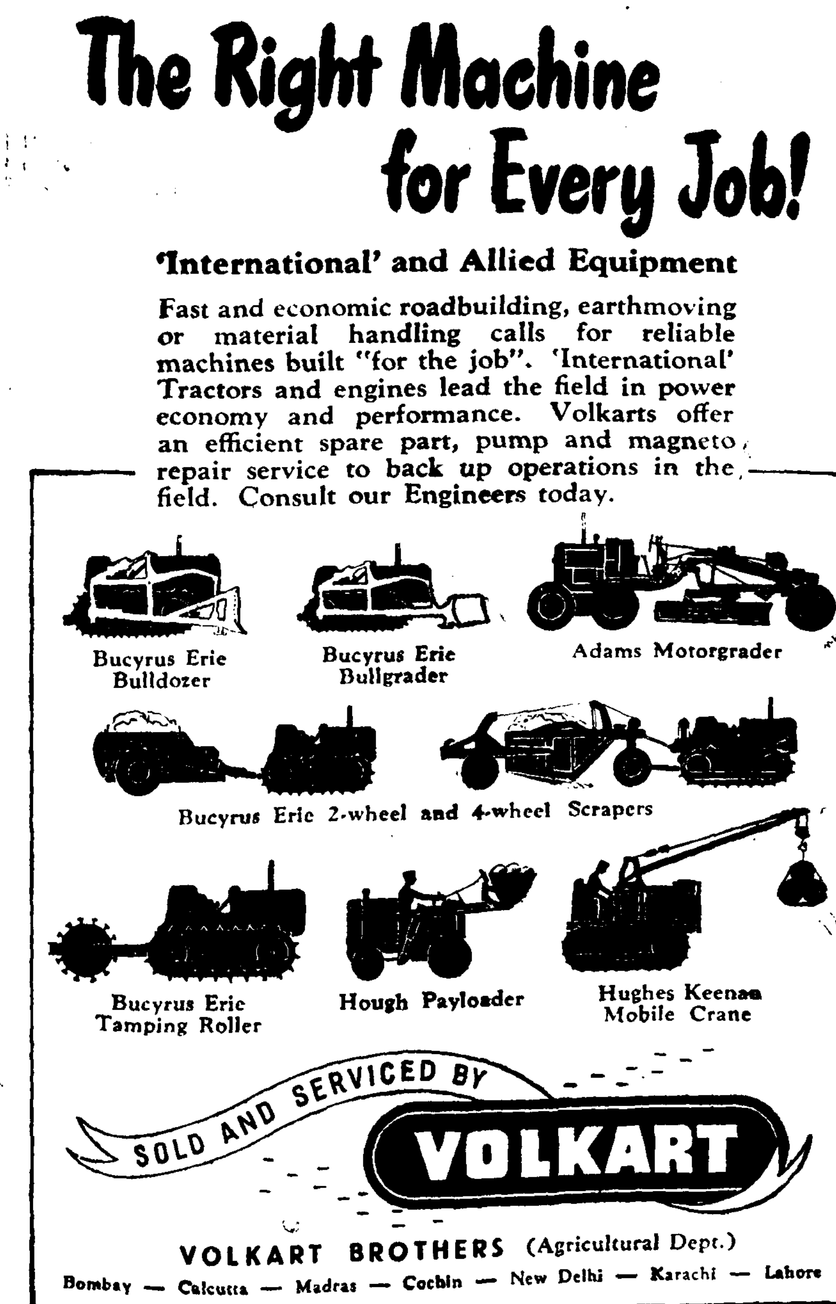
Fund, and Road Expenditure, a separate section is devoted to other forms of transport, another to the changes in estimates necessitated by the Partition of India, and a third relating to 'Miscellaneous' items.

The last mentioned is a veritable hotchpot of statistical information and contains data on such diverse subjects as area, population, agricultural production, production of cement and steel, and imports of asphalt, to give only a short random selection. Because of the inclusion of such information the book is bound to be of permanent interest, not merely to the road engineer, road transport executive, or planner, for whom it is primarily intended, but also to the administrator, the research worker, and officials connected with any of the present day forms of transport, not to mention students of economic affairs generally. We commend it to all these persons with confidence.



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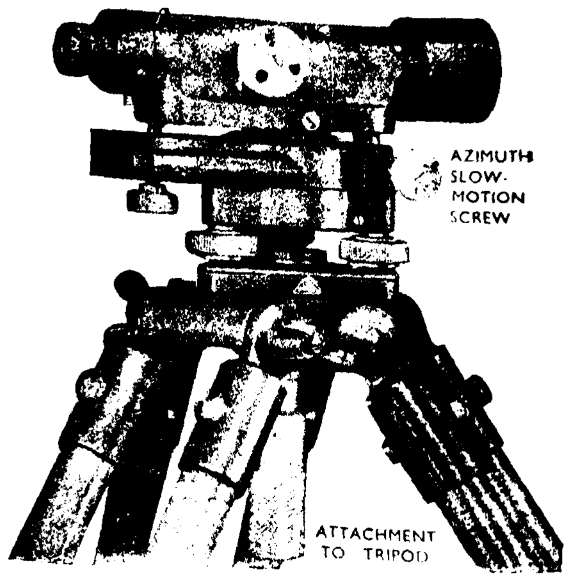

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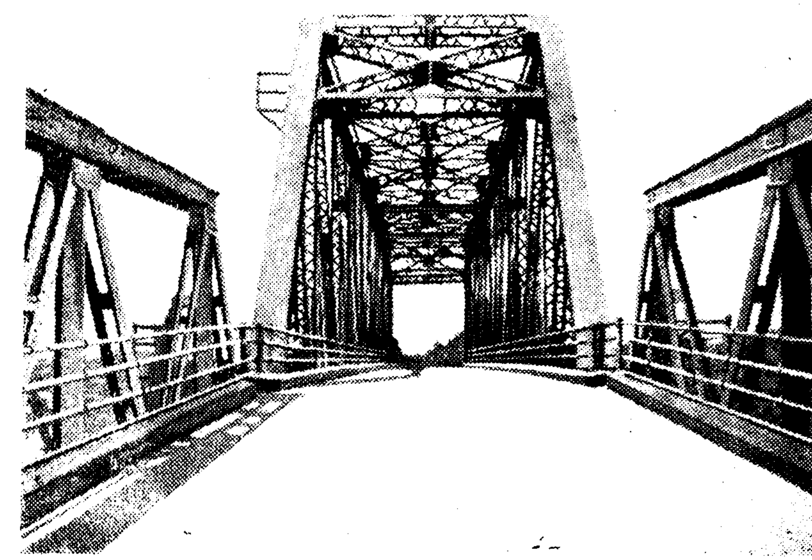

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