

INDIAN ROADS CONGRESS
NOTICES AND ANNOUNCEMENTS
NEW ADMISSIONS.

LIST OF MEMBERS OF THE INDIAN ROADS CONGRESS
ENROLLED FROM 12-9-1951 to 10-2-1952.

<i>Serial No.</i>	<i>Roll No.</i>	<i>Name</i>	<i>Address</i>
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1459	1603	S. M. Madbhavi,	Deputy Engineer, P. A. to Superintending Engineer, K. I. C. Dharwar, (Bombay State).
1460	1604	B. N. Ghosh,	Assistant Engineer, 2, Huzuri Mull Lane, Calcutta-14.
1461	1605	R. S. Rangaswamy,	Supervisor (Bridges), 11- Rajaratnam Street, Kilpauk, Madras.
1462	1606	R. C. Patro,	Assistant Engineer, National Highways Sub-Division, Keonjhar, District Keonjhar (Orissa).
1463	1607	N. N. Dogra,	Assistant Engineer, P. W. D., Ramban, (Kashmir State).
1464	1608	P. V. Divatia,	Chief Engineer, P. W. D., & Irrigation, Madhya Bharat Government, Gwalior.
1465	1609	G. P. Nagarkar,	Professor of Applied-Mechanics, L. D. College of Engineering, Ahmedabad-9.
1466	1610	A. R. Satyanarayana Rao	Assistant Engineer, Highways, Daba Gardens, Waltair R. S.

DEATH

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

Serial No.	Roll No.	Name	Address
1	740	B. R. Kagal (Life Member),	Chief Town Administration Officer, Jamshedpur. (Bihar).

Paper No. 158.

"Construction of the Shillong-Silchar Road, Assam."

By

S. C. PAL AND R. C. DAS

CONTENTS

	Page
1. History	152
2. Physical Features, Climate, etc.	153
3. Alignments Examined & Reconnaissance	156
4. Alignment Selected	159
5. Laying Out	163
6. Detailed Survey	166
7. Specifications and Standards	171
8. Construction	173
9. Drainage	180
10. Miscellaneous	186
11. Work Incomplete	191
12. Costs	193
13. Conclusion	194
Appendix I	195
Appendix II	196
Appendix III	197
Plates—Six	199

SYNOPSIS.

The Paper describes the alignment, survey, and construction in 1948-49 of a road in Assam from Shillong to Silchar (212 miles) through previously unexplored mountains, and tropical forests. The necessity for the work arose after the partition of India when long stretches of the previous road from Shillong to Silchar via Sylhet passed into Pakistan.

The estimated cost of the work with a 16 ft. formation and a 12 ft. carriage-way was about Rs 1,20,000 per mile. Notwithstanding the very arduous conditions of work, the whole length of the new construction (163 miles) was completed in 18 months—nine miles of new road per month.

1. HISTORY

1.1. In the year 1874 the province of Assam, which for the previous 40 years or so had been part of the province of East Bengal, was constituted as an independent administration under a Chief Commissioner. The tract thus united under one Government was made up of three naturally distinct portions—the Brahmaputra and Surma Valleys to the North and South and the intervening hill tracts—each of which in former times possessed a separate history.

1.2. The Brahmaputra valley alone covers about half the area of Assam and has for centuries been closely connected with the main course of Indian history though it has never formed an integral part of any of the previous Indian empires. Not much is known of the early history of the Surma valley which is largely an alluvial tract still in the process of deltaic formation and still subject to heavy floods though these are not so disastrous as they were at the end of the eighteenth century.

1.3. The hill tracts intervening between these valleys stretch east-west and comprise the Naga, the North Cachar, the Khasi, the Jaintia, and the Garo hills. Since they were first formed ages ago the Brahmaputra and Surma valleys have remained isolated from each other as the intervening hills are covered with unexplored and dense tropical forests infested with wild and dangerous animals.

1.4. A railway through the hills was commenced in 1891 but was not finally completed till 1903 because of the exceptional difficulties met with during construction. It is recorded that sections of the railway run through

“shale of the worst description...which swells when exposed and causes heavy slips or exerts immense pressure on the sides of the tunnels...Apart from the special engineering difficulties, great inconvenience was experienced owing to the absence of local labour and food supplies, and to the unhealthiness of the country traversed...At one time...food for more than 25,000 men had to be carried.....”

This description has particular relevance with respect to what is said later in this Paper on the difficulties met with in constructing the Shillong-Silchar road.

1.5. A road through the hills to Shillong appears to have been built in the last century but it was not till 1933 that an excellent motor road (60 miles) was built from Shillong via

Pynursla to Jaintiapur* in the rich, rice-growing plains of Sylhet. This road extends, via Sylhet, Karimganj, and Badarpur, to Silchar, the headquarters of the Cachar district at the extreme south-east end of the State of Assam.

1.6. Within less than 15 years of the construction of this road, road communication between the Cachar district and the main part of the State was again severed—this time by political barriers. In August 1947 when Pakistan was created, 60 miles of the Shillong-Sylhet-Silchar road, viz., the portion Jaintiapur-Sylhet-Karimganj, passed over into Pakistan. The district of Cachar and the adjoining (erstwhile “Indian”) State of Tripura were completely isolated from the main Indian territory. The only link left was the circuitous railway from Gauhati via Lumding and Badarpur—a total distance of 363 miles by a slow, metre gauge, mountain railway. (See plates I & II)

1.7. Immediately after the partition, the Government of India decided upon the construction of a road link from Shillong to Silchar and on to Agartala, the capital of Tripura.

1.8. Reconnaissance was carried out from November 1947 to March 1948. Work started in April 1948 on the basis of a preliminary rough estimate of Rs 1.92 crores, and a fair weather jeepable road was cut in October 1949.

2. PHYSICAL FEATURES, CLIMATE, ETC.

2.1. The alignment between Shillong and Silchar covers two civil districts—the Khasi-Jaintia Hills District and the Cachar, District—and traverses the civil subdivisions of Shillong, Jawai, North Cachar Hills, and Silchar. The entire country is mountainous, rugged, and broken. The hills are covered with dense jungles and thick undergrowth of evergreen bush, bamboo and kail. On the Borail Range, trees are very old and big and yield excellent timber for building wooden bridges.

2.2. The mountain ranges rise from the plains (200 to 250 ft above sea-level) to as much as 6,000 ft in places in this region. On account of the broken nature of the country only a saw-tooth alignment is possible, repeatedly rising and falling. (Plate No. III)

*The construction is described in the Indian Roads Congress Paper No. 30 “Construction of the Shillong Jaintiapur Road in the Khasi Hills, Assam” by F. P. Cormack; published in Volume II of the Journal.



Photograph No. 1.

Dense tropical forests in the Borail Range
(The newly made road is seen in the picture).

2.3. Rainfall.

Assam is a land of heavy rainfall. Cheerapoonji, the wettest place in the world, is situated here and has an average rainfall of 458 in. and the maximum recorded rainfall of 905 in. in 1861. At Haflong, a town on the finally selected route, the maximum and minimum annual rainfall over 18 years ending 1949 were 120.3 in. in 1948 and 71.7 in 1944, the average figure being 95 inches. At the same station, the maximum intensity of rainfall on record was 9 in. in 24 hours.

2.4. Climate.

On the whole the climate during the rainy season, from April to September, is very moist and malarious. Thick, low lying clouds reduce visibility, impede movement, and holdup work. Otherwise the climate is temperate and there are no violent fluctuations in temperature. The following room temperatures were recorded at Haflong in 1949:—

Minimum Temperature.

Max. ... 75 deg. F. on 18th-20th Sep. 1949
Min. ... 52 deg. F. in December 1949 (several days)

Maximum Temperature.

Max. (Summer) 86 deg. F. on 3.9.49
Max. (Winter) 64 deg. F. on 21.12.49

Maximum Range of Temperature.

3.9.49 14 deg. F. (86°-72°)
December 1949 10 deg. F. (64°-54°)

2.5. Winds.

There are high winds during the monsoon months from April to September. During April, May, and June, these winds often attain cyclonic fury.

2.6. Agriculture, Forest Produces, Population.

2.6.1. The area is thinly populated and cultivation is limited but wherever it has been undertaken the resulting deforestation has given rise to considerable soil erosion.

2.6.2. The rich forests on the Borail Range have been practically unexploited so far. The hills are infested with white ants and the timber trees here seem to have developed an immunity against this pest. They are, therefore, a source of valuable timber. With the construction of the road the export of timber for building construction, sleepers for railway tracks, light timber for plywood industry, cane, bamboo, and thatching grass, is bound to increase. The Forest Department will be one of the biggest beneficiaries of this project.

2.7. Geology.

2.7.1. The geological map of India shows that the North Cachar hills, parts of the Naga, Lushai, Tippera, and Chittagong hills are Tertiary formations and consist of alternate beds of sandstones and carbonaceous shales. The sandstones vary from hard blue and green textured stone, very good for building purposes and for road metal, to yellow, soft, and friable stone which is liable to disintegrate on exposure to the weather.

2.7.2. The availability of the better type of stones is very limited. Good stone is largely met with in the lower reaches of the hill faces,

2.7.3. The composition of the shales varies from very hard slaty stones to a soft variety, only slightly harder than the hardened blue mud. All varieties of these shales, without exception, disintegrate very quickly and easily when exposed to the atmosphere. Some of the types had to be blasted but perished readily when exposed.

2.7.4. Nearly all these shales had a great capacity for absorbing moisture. This property created endless trouble as, on absorbing water, they swelled and then shattered. This often caused enormous landslides.

2.7.5. Blue shale is the most treacherous of all as it swells very considerably. In some box cuttings in blue shale areas it was noticed that the road surface which had been cut to the proper formation rose 4 to 5 ft on absorbing water. Perhaps the weight of the adjacent slopes also helped in squeezing up the mass to some extent.

2.8. The area is also frequently rocked by earthquake tremors. The shock which occurred on the 15th August 1950 was one of the severest earthquakes experienced at Haflong in living memory. Most of the stone buildings at Haflong were damaged during this earthquake.

3. ALIGNMENTS EXAMINED AND RECONNAISSANCE

3.1. There was an existing bridle path connecting Shillong with Silchar Via Jawai, Garampani, Haflong, and Borkhola. This bridle track was divided into the following Sections:

Shillong to Jawai	40 miles
Jawai to Garampani	35 "
Garampani to Haflong	55 "
Haflong to Borkhola	70 "
Borkhola to Silchar	12 " (already a motor road)
Total	212

3.2. The portion of this bridle path from Shillong to Jawai (40 miles) was, when the work described in this Paper started, already being improved into a motorable road and the last 12 miles were already a motor road. Thus a length of 160 miles only from Jawai to Borkhola, remained to be built. It was proposed to improve this into a motor road. An estimate of Rs 1,92,47,527 for 160 miles was submitted to the Government of India.

3.3.1. It was, however, decided to explore other possible routes also before finally selecting any particular alignment.

3.3.2. One of these alternative routes demanding examination was: Jawai - Sutnga - Serpai - Harangjo - Damcherra - Chandarnathpur - Silchar. The portion of this route from Jawai to Harangjo lies through virgin country.

3.4. The two alignments were studied on the 1910 2 in. topographical maps of the Survey of India, the largest and most up-to-date available maps of the area, which showed in general outline, rivers, hill ranges, spot levels of high peaks, trigonometrical survey points, and approximate contours at 100 ft intervals. Obligatory points were decided upon from these maps along each of the alternative routes.

3.5. Detailed study on the spot then followed. The maps were found to be substantially correct but many streams and gorges were missing on them. Some villages had disappeared while others seemed to have sprung up subsequent to the preparation of the maps.

3.6. The first route followed a well-established bridle path with inspection bungalows and tribal villages all along it. Touring along it was not very difficult. Much information was obtained from the P.W.D. officers in charge of the roads.

3.7. The reconnaissance of the second route, however, needed elaborate arrangements and strenuous efforts. The



Photograph No. 2.

A "Recce" Officer in difficulties.

portion from Jawai to Harangjo (about 60 miles) passed through dense reserved forests and uninhabited country. There were no known paths in this area, and therefore no guides. Rations and all supplies had to be carried from the base. Elaborate arrangements had therefore to be made, as for a military expedition, equipped with all necessities of life. The principal requirements of the survey organization can be summed up as follows :—

Camp Equipment.—An austere supply of tents, tarpaulins, camp furniture, lamps, crockery, etc., had to be taken for the senior members in the party. Temporary improvised shelter was made at each camp site for the others. It was proposed to provide the party with blankets, jersies, socks, patties, boots, etc., but actually nothing but blankets could be obtained.

Rations.—Every item of essential rations had to be carried by the party—rice, ‘dal’, salt, oil, spices, potatoes, and for labourers ‘gur’ and ‘chira’ as emergency rations.

Essential Tools and Instruments.—Besides surveying instruments like prismatic compasses, binoculars, aneroid barometers, clinometers, tapes, scales, set-squares, and of course topographical maps, a small supply of tools for cutting jungle, making paths, and rigging up the daily camp was also carried.

Medical Aid.—A small quantity of essential medicines and first-aid equipment was carried in the charge of a compounder attached to the Recce party. The whole party was Vaccinated and inoculated against cholera before setting out.

Transport.—As there were no mule paths in the area, everything had to be carried by porters. As the area is uninhabited, the porters were all outsiders and many of them had elaborate kit of their own. Every two to three porters needed one for their own kit. This swelled the total number of men needed. The load carried by a porter was 40 lb in the initial stages of the expedition but progress from camp to camp was very slow and many porters straggled behind every day. The load was therefore reduced to 30 lb. Porters cost Rs 1-8-0 to Rs 2 per day with free rations (of a few essential items of food.)

Efforts were made to secure some elephants for transport on a hire basis. The usual daily hire is Rs 20 to Rs 25 per elephant. The elephant carries about 10 maunds (7 cwt). But no elephant owner could be persuaded to accept the job because travelling on steep hill tracks with back-loads

gives rise to sore backs and sometimes injures the animal permanently. Moreover, as the country traversed was “elephant country” the owners feared that on seeing their native land the domesticated elephants might develop “home sickness” and refuse to return to civilisation.

The whole party, workers and porters taken together, was 150 strong.

Base Camp.—A base camp was established at a rail head or a motor-road head for despatch of rations and other requirements of the survey party.

Mails.—A well organized mail runner system was maintained. This was necessary to keep up the morale of the party who might otherwise feel cut off from the world and lost in the jungles. It also helped to keep the authorities informed about the progress of the survey work.

3.8. At one stage, for 11 days, the Recce party was lost in the jungle country—it sighted no paths and no human habitation. The Recce officer reported, however, that the route presented no serious engineering obstacles, the soil encountered was generally earth and soft shale, road construction would be fairly easy but maintenance would be correspondingly difficult and costly on account of land slides.

3.9. On many occasions, the “Recce” parties or their porters came across wild animals and tigers. If left undisturbed, these animals usually leave the human being alone. In such chance encounters “ahimsa” is good, but it is better to have a few guns and some ammunition. “Ahimsa” of the strong, not of the coward!

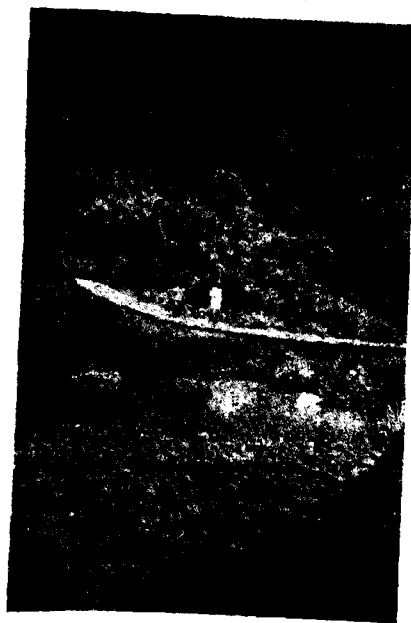
3.10. On one occasion a gang of about 20 porters were returning after they had delivered supplies at a forward camp in the Serpai area. They found a previous wayside camp trampled down and destroyed by wild elephants. The leader of the herd sighted the porters and gave chase. They saved themselves somehow but on reaching safety they refused to move until an armed guard was detailed to escort them.

4. ALIGNMENT SELECTED

4.1. At this stage the Government ruled that Garampani and Haflong must be touched by the proposed alignment. With these ruling points further search for radically different routes was dropped and the first alignment was then examined in detail.

4.2. While it was found that the construction of a motorable road from Jawai to Garampani along the existing bridle path was quite feasible, the rest of the track presented difficulties for the reasons described in the following paragraphs.

4.3. Between Garampani and Haflong the bridle track crosses the Diyung river twice—once at Derebera, almost midway between Garampani and Haflong, and again near Lower Haflong Town, some $4\frac{1}{2}$ miles from Haflong. In both these places the river passes through deep gorges. The bridle path is very steep at these locations; for instance, from Lower Haflong railway crossing (R. L. 1505) to the suspension bridge over the Diyung river (R. L. 1000) the road descends by 505 ft in $1\frac{1}{2}$ mile—an average grade of 1 in 13, but much steeper in many places. There are as many as 13 zigzags in a short length of about a mile.



Photograph No. 8.

The Pedestrian Suspension Bridge over the Diyung near Lower Haflong.

4.4. Crossing the river in these gorges would have meant complete re-alignment of long lengths of road—sometimes about five miles on either bank. Moreover, as the gorges were narrow and the streams fast in these places, bridges would be needed immediately. Otherwise no traffic would be possible as “Marboat” ferries could not ply in the rapids in the vicinity of these crossings.

4.5. Between Lower Haflong and Chotto-wapu (135 miles) the bridle path passes over a hill face liable to heavy landslides at about seven miles from Haflong. Taking the road over these slipping hills would mean leaving a perpetual defect in the road. Diversion was, therefore, decided upon and the bridle path was abandoned between Chotto-wapu and Haflong.

4.6. It was, however, found subsequently that there could not be any guarantee that such unstable areas could be completely avoided in the North Cachar hills. The composition of soil is very much the same all over these hills and such slips occur in many places after heavy and continuous rainfall.

4.7. Between Haflong and Borkhola the bridle track crosses the Jatinga river twice. This is a furious, mountain river which falls into the Barak a few miles after leaving the hills. Between Jatinga village and Borkhola the bridle track follows the Jatinga valley very close to the river bank and crosses a large number of its tributaries very near to their outfalls into the Jatinga. Some of these tributaries are as wide and as deep at their outfalls as the main river. There are also numerous deep ravines. To follow this bridle path here would mean the construction of many long, high-level bridges and viaducts. An alignment along the river valley, that is, on the lower reaches of the range, would run on unstable and difficult slopes and would be a source of perpetual trouble. The railway on the opposite bank is still experiencing such difficulties although it was built more than half a century ago.

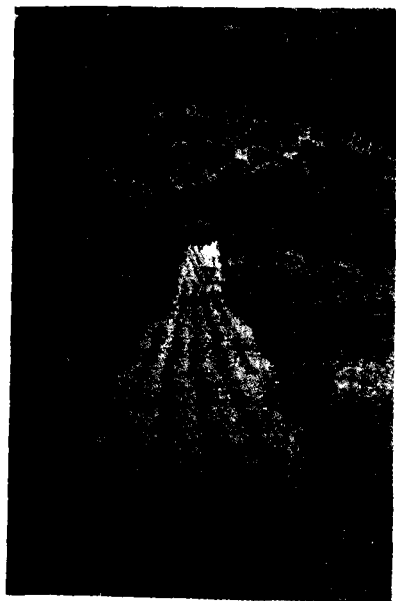
4.8. Taking these factors and local administrative requirements into consideration, the following changes in the alignment from the bridle track were finally decided upon.

4.9. Diversions From The Bridle Track

4.9.1. The Diyung crossing at Derebera, where the bridle track has a sheer drop of about 1,000 ft in about a mile, gradients like 1 in 6, and a succession of 15 hairpin bends, had to be avoided. It was decided to cross the river about 8 miles downstream of Derebera, at Dihangi Arda, where the river has rocky banks and the channel is stable and narrow. At the same time there are pools for plying a “Marboat” ferry until a bridge can be put up. The banks rise up gradually and the ascent from the river can be easily provided. This, in fact, is the only suitable crossing in the middle and lower reaches of this river. As a result of this proposed diversion the bridle track was abandoned from Bagha (mile 102) to Thana Lumbra (mile 126).

4.9.2. To avoid unstable ground and the difficult Diyung crossing at Lower Haflong, the alignment was diverted from

Chotto-wapu (136 miles) to Mahur which was now declared a ruling point, and thence to Jatinga Saddle (166 miles) along the west slope of the main Borail Range.



Photograph No. 4.

Another view of the
Pedestrian Suspension
Bridge.
(Note the woven matting
floor).

4.9.3. It was not possible to run the alignment closer to Haflong and an approach road was proposed from Jatinga saddle to Haflong.

4.9.4. From Jatinga Saddle the bridle path was again given up for reasons described in para. 4.7, and a new alignment was reconnoitred. At Dawheng Saddle (2200 ft) the new alignment crosses the main Borail Range, runs up the southern slopes of the Range to Dolia Saddle (3800 ft) and then descends to the plains of the Cachar district at Amarnagar Tea Gardens (451 ft). From Amarnagar to Silchar, motorable Tea Garden roads existed.

4.10. Taking into account the detours and re-aligned portions, the distance from Shillong to Silchar, along the finally selected route, worked out to 218 miles. The length of new road was about 163 miles from Jawai to Amarnagar, which included 72 miles along the bridle path (Jawai to Bagha 61 miles, and Thana Lumbra to Chotto Wapu 11 miles). The remaining 91 miles were altogether new. (See Plate II).

5. LAYING OUT

5.1. When the alignment had been tentatively fixed and the main obligatory points settled, the next step was to lay out the alignment on the ground.

5.2. For this purpose the permissible gradients were first decided upon. These were :—

In hills

Ruling gradient 1 in 15

Maximum gradient 1 in 12 for lengths not exceeding 330 ft

In plains and rolling country

Ruling gradient 1 in 30.

5.3. The selected route was then marked on a contoured map, from one obligatory point to the next, according to these gradients. The difference in the levels of these obligatory points was found from the maps and checked by aneroid barometer readings where possible. The distance between the obligatory points was measured as accurately as possible on the map along the alignment marked. From this data the possible average gradient between two successive obligatory points could be worked out.

5.4. A "line" was then run along the hill slopes at the pre-determined grades. Laying out such a line between the obligatory points gives the shortest length of road between these points.

5.5. The quickest and the best instrument for laying out a line on any given slope is the De Lisle clinometer. If properly and correctly used it gives very accurate results. Other instruments used on the work were :—

- (1) Ghat tracers
- (2) Tangent clinometers
- (3) Abney's level
- (4) American compass clinometers

5.6. Ghat tracers too give good results and the Abney's level is useful for obtaining *level* lines along precipices and sidelong ground.

5.7. Sometimes while running the line obstacles like broken country, deep gorges, landslides, very steep or vertical hill faces, heavy rocks, etc., are met with. These obstructions can easily be dealt with locally. In order that the tracing party, who are

at the moment "slaves" of the clinometer, may be forewarned of these obstacles, the officer-in-charge himself should move a few furlongs ahead of the party. This is particularly necessary when the vision of the tracing party is limited by thick jungle. This procedure avoids waste of energy, labour, time, and money.

5.8. When detected in time the obstacles can be avoided by varying the grade within the permissible limits and by changing the position of level stretches if any. The most difficult case is when the line is running at the ruling gradient throughout between two obligatory points. Unless the two adjacent obligatory points can be joined by reasonable grades, avoiding all real bad spots, one of the "obligatory" points may have to be bypassed or changed.

5.9. Zigzags.

5.9.1. As far as possible zigzags should not be introduced as a means of avoiding bad spots or for gaining length. All possible alternatives should be tried before adopting a zigzag.



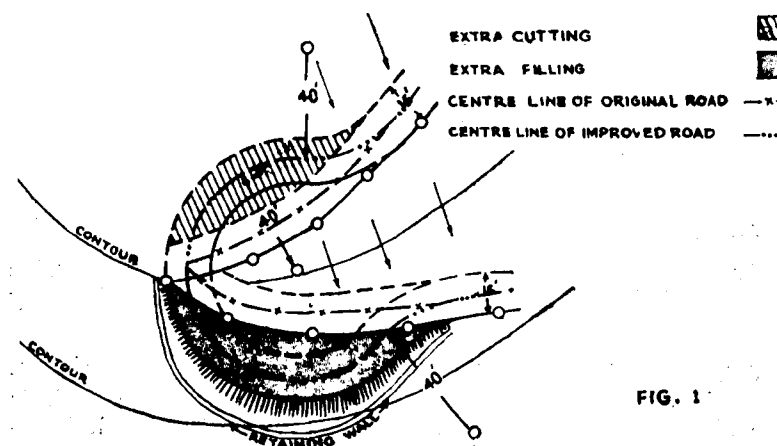
Photograph No. 5.

A zigzag in mile 198.

as what may look like bad spots at first sight may, on closer examination, turn out to be not so. It may rather be possible to make an ultimately economical and stable road at such a spot.

5.9.2. Zigzags do not advance progress towards the destination. While height is surmounted, distance is not overcome and, on the whole, an alignment with zigzags is generally longer than a straightforward line.

5.9.3. If suitable natural ledges are not found for turning places the hair pin bends of zigzags involve very heavy cutting, filling, and a toe or retaining wall. (See figure 1).



5.9.4. Travelling on zigzags is dangerous and very uncomfortable for passengers of fast moving motor vehicles. In the case of slow bullock-cart traffic, hopeless traffic jams occur when strings of bullock-carts travelling in opposite directions meet at a zigzag.

5.9.5. A slip on one arm of a zigzag generally disturbs the adjacent arms as well.

If the drainage cannot be taken clear of the road at the end of each arm, a succession of culverts has to be built for taking the same 'nalla' under the various arms.

The spoil of cutting from the upper arms falls on the lower arms and is to be removed again and again. This further adds to the expenditure.

5.9.6. If absolutely unavoidable the turning places of zigzags should be level and not at a gradient.

5.9.7. Unfortunately, on this alignment zigzags could not be avoided and had to be introduced at many places. The turning points were made easy as far as possible.

5.10. **Final Lay-Out**—After marking one trial line the officer-in-charge should again examine the hill face, both above and below the trial line and see if there is any room for further improvement, by reducing length, avoiding costly cutting, or by avoiding bad spots. Wherever possible, other trial lines should be run before accepting one of them finally.

5.11. Time devoted to careful location is well spent.

5.12. In road making, more than in anything else, "more haste means less speed," and "incalculable expense."

6. DETAILED SURVEY

6.1. **The Trace.**—As soon as the alignments has been finally selected by the officer-in-charge, a grade path or a trace, about 1½ ft to 2 ft wide, is cut all along the alignment from obligatory point to obligatory point. At the same time undergrowth is cut down to give a clearing 5 ft to 6 ft wide all along the trace. This increases visibility and the grade path makes for the easy movement of survey parties and inspecting officers.

6.2. In rocky places the trace is marked in the correct position with whitewash or red paint. In such places the path is made above the line for the use of the survey party. Such diversions are also made when the line comes up against big trees or thick bamboo clusters.

6.3. The grade path "fixes" the alignment against any intentional or unintentional shifting by the contractor or his men. Labourers are required to stand on this path and cut inwards.

6.4. This path also serves as a permanent mark if the execution is delayed by a few months.

6.5. Longitudinal Section.

6.5.1. The detailed survey is carried out along the trace. The longitudinal section is taken along the line of the probable finished road and not necessarily along the trace. Even apart from the places where the trace is unintentionally diverted on account of obstacles (e. g., rock or trees) there is almost always an appreciable difference between the trace and the location of the

probable finished road is to follow correct slopes and is to be straightened out as far as possible, avoiding sharp curves round nallas and spurs.

6.5.2. It will be evident from this that the length of the finished road will necessarily be somewhat less than that of the trace. The original trace should therefore be laid out to an easier grade than that intended for the road when complete. The allowance made varies with the nature of the ground. In general, 1 in 22 will work out to 1 in 20, and 1 in 17 to 1 in 15.

6.5.3. As the longitudinal section has to follow a pre-determined gradient, ground levels and formation levels are identical, except where "through" cuttings and fills are introduced for the sake of straightening the alignments or easing sharp curves.

6.5.4. While taking levels for the longitudinal section a continuous chainage is measured, as usual, and a new series of pegs are driven in at all necessary points. Old pegs used at the time of tracing should be removed at this stage in order to avoid confusion later on.

6.5.5. All points of change of grade are marked with special pegs.

6.5.6. All these pegs are taken up in the chain and compass survey and shown on the land plan.

6.6. Cross Sections.

6.6.1. For calculating the quantity of excavation involved, cross sections of the hill face are taken at suitable intervals, at the same time as when the longitudinal section is being run. The chainage of a cross section and the letters "CS" are noted in the field book as well as on the peg fixed at the point of the cross section.

6.6.2. These pegs also are taken up in the chain and compass survey.

6.6.3. No definite rule can be suggested for spacing these cross sections. The spacing depends on the nature of the hillside. The general principles observed on this work were to take cross sections :—

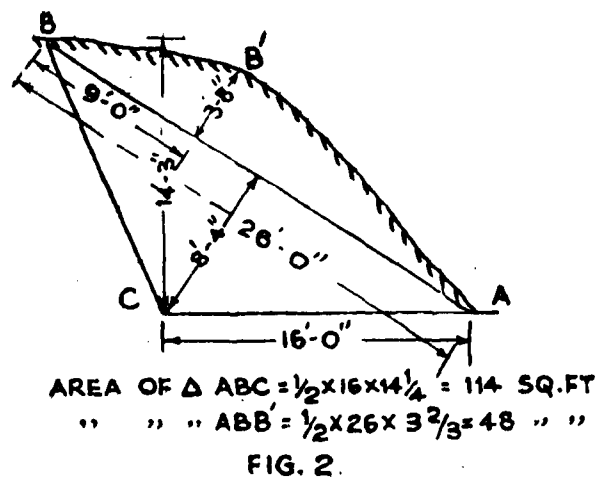
- (i) at obvious places of maximum and minimum cuttings;
- (ii) at close intervals where rock cutting was involved; and
- (iii) wherever the soil classification changed definitely.

6.6.4. Cross sections were taken by the "stepping method" using tapes and marked rods and this procedure was considered accurate enough for the purpose of estimating earthwork (See para. 6.6.9.).

6.6.5. An estimate of earthwork before actual excavation is at best an approximation, as the back slope cannot be determined correctly before the nature of the soil is known. Also, the appropriate rate cannot be applied. Very often it was found that where nothing but soil or moorum was visible at the surface, solid, continuous rock was met with below.

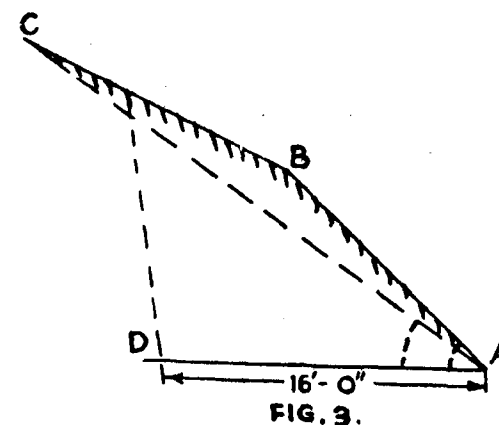
6.6.6. A cross section should extend 30 to 50 ft (measured on the slope) above the road level and about 15 to 20 ft below it.

6.6.7. When the cutting is high, the profile of the hill slope is seldom a straight line. In such cases care has to be taken in the method of measuring, otherwise rather big mistakes are likely to creep into the estimates.



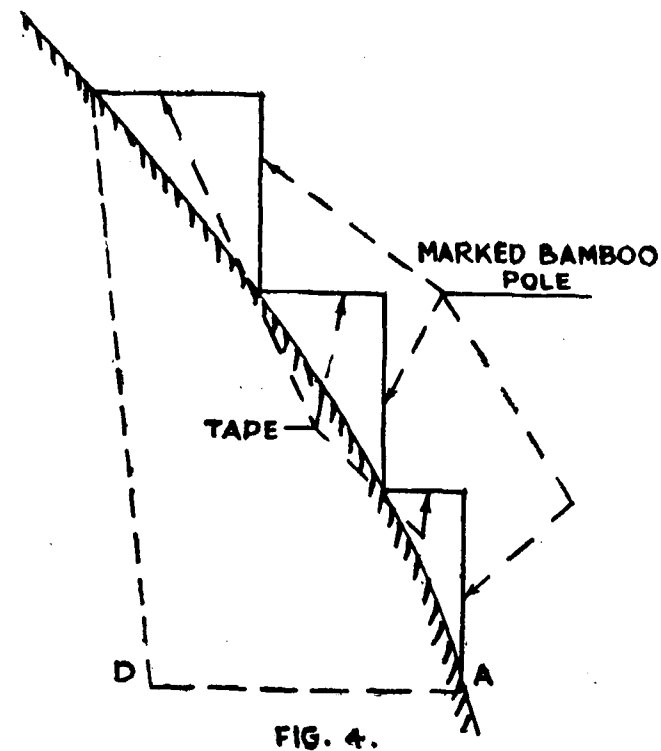
6.6.8. In figure 2, for example, an intermediate reading at B' is called for, otherwise an error of about 40 per cent would occur. The dimensions given on the figure illustrate an actual case.

One method adopted on the work for avoiding such errors is described here. (Fig 3.)



Standing at A, hold the target at B; read the vertical angle DAB, and measure AB with a tape.

Then transfer the target to C, read the angle DAC, and measure BC. The cross section can now be plotted accurately and a correct configuration of the hill face is obtained.



6.6.9. But the "stepping method" of taking the cross section with a tape and a marked bamboo pole is quick, accurate and more practical (Fig. 4) and, as stated before, this method was adopted extensively on this work (para. 6.6.4).

6.7. Making the Plan.

6.7.1. **Compass Survey.**—A compass survey was carried out after the longitudinal section had been prepared and checked up again for any unsuitable gradients. The distance between compass stations was necessarily small because long sights are generally not obtainable in hill road work. Special attention had therefore to be paid to accuracy in plotting the bearings as well as distances.

6.7.2. The plan showed all permanent features near the alignment, the trace line, the line of the finished road, the location of the cross sections, bridges, culverts, important retaining walls, mileage, camp sites, the uphill and the downhill sides of the road, the direction of flow of every stream and nalla, and the boundary for land acquisition.

6.7.3. Where land acquisition was not involved, the plan was made on a scale of 100 ft to an inch.

6.7.4. The plan and the longitudinal section were made on the same sheet of paper for ready reference from one to the other.

6.8. **Soil Surveys.**—Soil surveys, in this case, were confined to classifying soils according to the nomenclature used in the schedule of rates. The following classification was adopted and noted on the longitudinal section :—

	Rate per 100 cu. ft.
	Rs
1. Soil not requiring the use of pick axe or crowbar ;	40
2. Hard soil requiring the use of pick axe and crowbar ;	52
3. Hard soil mixed with moorum, gravel, and boulders up to 6 in. dia., requiring the use of pick axe or crowbar ;	70
4. Hard soil mixed with moorum, gravel, and boulders exceeding 6 in. dia., removeable with crowbars ;	80

	Rs
5. Hard soil mixed with shale, requiring the use of pick axe, crowbar, and wedges, but not blasting ;	85
6. Soft sandstone or laminated rock, removeable with pick axe, crowbar, and wedges, but not requiring blasting ;	95
7. Medium stone requiring blasting ;	112
8. Hard stone requiring blasting.	200

6.9. **Cost of Surveys.**—The total cost of setting out the alignment, carrying out the detailed survey, and preparing the estimate for 89 miles of road in the Haflong Division came to Rs 47,700, or Rs 535 per mile.

7. SPECIFICATIONS AND STANDARDS

7.1. The following specifications were approved for this road project :—

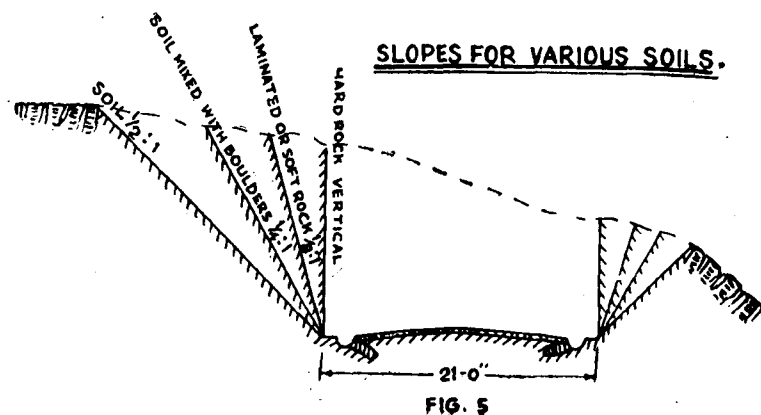
1. Formation width	16 ft, with widening at curves (Maximum widening 4 ft).
2. Carriageway	12 ft
3. Gravelling of carriageway	2 in. thick, or 10,000 cu. ft. per mile.
4. Metalling (not executed)	9 ft wide, 5 in. thick water-bound macadam over 4 in. to 6 in. thick soling coat.
5. Major Bridges	Single lane No such bridges were actually built. Ferry arrangement have been made on the Diyung river at Dihangi Arda.
6. Minor Bridges	(a) 12 ft wide carriageway (b) Timber construction (c) Class 12 loading
7. Culverts	Full formation width (Armco or timber) for 12 ton loads.
8. Gradients	(a) <i>For hilly portion :</i> Ruling 1 in 15 Maximum 1 in 12 (b) <i>For plain & rolling country</i> Ruling 1 in 30

9. Curves Minimum radius in hilly areas 40 ft
 In plain or rolling country 100 ft
 Extra widening at curves 4 ft
10. Sloping back No sloping back where the height of cutting did not exceed 5 ft. For heights from 5 ft to 10 ft the cut was sloped back only where the nature of the soil warranted it.
 For heights exceeding 10 ft the cut was necessarily sloped back to avoid slips.

Maximum limit of sloping back. (Fig. 5.)

Class of soil	Vertical dimension	Horizontal dimension
Ordinary or Hard soil	2	1
Soil mixed with gravel boulders, shale, etc.	4	1
Soft sandstone or laminated rock	8	1
Hard Rock	Vertical	

In the first instance all cuttings were to be made vertical. Sloping back at any particular place was to be ordered in writing after determining the soil classification at the point.



8. CONSTRUCTION

8.1. Construction started in April 1948 and it continued up to October 1949 when further work was postponed.

8.2. For the execution of the work three P.W.D. divisions were set up with headquarters at Shillong, Haflong, and Silchar.

8.3. The Shillong Division extended from Shillong to Khorungma (mile 90), the Haflong Division from Khorungma to Dawheng (mile 174), and the Silchar Division from Dawheng to Silchar (mile 218).

8.4. Besides 84 miles of the main road the Haflong Division was also responsible for the five mile approach road to Haflong.

8.5. The longitudinal section of the road in the Haflong Division is given in Plate III. The scale of the plate is too small for details to be shown on it, but it gives a clear idea of the rise and fall in the alignment and the overall gradients adopted.

8.6. Earthwork.

8.6.1. In general, the formation cutting in hill road work consists of sidelong excavation along the previously established traces. This was the case on this project also. Through cutting was done in some places to ease the curves while going round spurs. Embankment was very rarely necessary as flat ground was rarely met with.

8.6.2. The formation width was cut in three stages. In the first stage a 10-ft wide strip was cut. The spoil was deposited on the outer edge. The changes of the spoil staying put depended on the slope of the hill face, which varied from 30 degrees with the horizontal to nearly vertical. On the steeper slopes the spoil generally rolled away downhill and did not add to the width of the formation. On comparatively easy slopes, or on thickly wooded hill faces, the spoil was more stable, particularly where it had a fair amount of stones in it.

8.6.3. This 10 ft track was quickly cut as it made only small percentage of the total volume of earthwork. A 16 ft road cut into a hill face with a 45 deg. slope, in soil requiring a back slope of 3 in. in a foot, has a cross-sectional area of 171 sq. ft. A 10 ft track with the back vertical would have a cross-sectional area of 50 sq. ft — merely 29 per cent of the total work.



Photograph No. 6.
A 20-ft deep through cut.

8.6.4. Cutting such a track was of immense help in the execution of the work as it provided facilities of transport for inspecting officers, labourers, stores, and rations.

8.6.5. Another advantage was that in situations where the hill slopes was easy and favourable and the spoil added to the width of the formation, it was possible to reduce the width of subsequent (second stage) cutting by 2 to 4 ft. Wherever possible, advantage was taken of this in saving excavation.

8.6.6. Moreover, this procedure gave scope for rectifying defects detected at a late stage. Minor deviations of the alignment, straightening unnecessary curves, easing of sharp curves,

and such other improvements were possible besides saving on earthwork.

8.6.7. In the second stage the 10-ft track was widened to the full formation width—16 ft. The back was still kept vertical.

8.6.8. In the third stage, back slopes were cut according to the nature of the soil actually met with.

8.6.9. The nature of the soil and the extent of the back slope could not be decided upon unless the composition of the exposed soil and the dip of the strata were known. A very careful determination of the back slope had to be made as the cost involved in cutting was very heavy.

8.6.10. A table showing the percentage increase in the volume of earthwork for a few typical natural hill slopes (assumed uniform at a particular cross section) with different angles of back slope is given below:—

Percentage increase in the volume of earthwork
by back slope cutting.

Width of roadway - 16 ft.

Slope of hill face Horizontal Vertical	Percentage increase						
	1½ in. horizontal to 12 in. Vertical						
	1/8 : 1	1/6 : 1	1/4 : 1	1/3 : 1	1/2 : 1	3/4 : 1	1 : 1
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
2 : 1	7	10	15	20	32	56	102
1½ : 1	10	15	21	30	55	110	215
1 : 1	14	21	34	50	98	304	...
¾ : 1	23	33	60	84	200	...	...
½ : 1	34	54	104	200	...	...	...

8.6.11. To avoid unnecessary cutting the back slope was cut last of all after a careful examination of the soil. Generally the slope was 3 in. to 4 in. per foot (that is, 1/4 : 1 to 1/3 : 1), but in soft shales a slope of even 1 : 1 was made.



Above and below

Photographs Nos. 7 and 8.
Two views of the completed Road.



8.6.12. In the beginning excavation of the full formation width was started and back slopes were also allowed to be made, but as the number of labourers employed was very large the supervision was not as effective as it should have been. The contractors took advantage of the temporary absence of the supervisory staff and did some unnecessary cutting. Mistakes also occurred in deciding in advance the correct slope to be cut. It was, therefore, made a strict rule that, at the initial stage, the back should be made vertical and the back slope should be made subsequently on the written instructions of the officer-in-charge. In the absence of written orders, any cutting done for sloping back was not measured or paid for.

8.6.13. Where any contractor objected to undertake cutting for the back slope, because he considered the system inconvenient or for any other reason whatsoever, he was not forced to carry out the third stage of the excavation. The cutting was then left vertical for the time being.

8.6.14. The object of sloping back is the avoidance of slips, but the cost of original cutting for sloping back is much higher than that of clearing slips. For one thing, these slips did not necessarily occur everywhere and for another, the rate for slip clearance was much cheaper.

8.6.15. At a place where sloping back was proposed, the top boundary of the cutting was marked with strong pegs, their horizontal distance (from the central line) being noted down graphically on a chart signed by a responsible officer as well as by the contractor. This chart formed the basis of measurements. The upper limit of cutting was spit-locked from peg to peg.

8.6.16. Even after making suitable back slopes it was felt that some sort of further, positive, protection against slips would be necessary in the form of pitching, breast walls, or toe walls. This work has not, however, been done yet. In places where the spoil was clayey soil with (or without) an admixture of stones, temporary methods of retaining it in position were tried, when the slope of the hill face was favourable. One of the methods consisted in the use of a series of bamboo palisades at suitable intervals on the slope with the spoil filled in between. The palisades served to check the spoil from flowing down during rains. Eventually, the stuff got stabilized when vegetation took root in the spoil.

8.6.17. The total quantity of earthwork in the Haflong Division (89 miles length) amounted to about 58 million cu. ft. or on an average, about 6,50,000 cu. ft. per mile, and 123 cu. ft. per lineal foot of road. Between Mahur (153 miles) and Dawheng

(174 miles) this average works out to 168 cu. ft. per lineal foot. Earthwork accounted for about 67 per cent of the expenditure incurred in this Division (see Appendix II).

8.7. Measurement of Earthwork.

8.7.1. Great importance must be attached to recording correct measurements of earthwork as actually excavated. This is a difficult matter in hill road work, and correct methods of measurement should be discussed by all concerned and then uniformly adopted.



Photograph No. 9.

Measurement of Excavation.

8.7.2. The cross section of a road in the hills is likely to vary appreciably from point to point. It was found practically impossible to maintain "witnesses" or "deadmen" at close distances. This was particularly so in rocky portions. It is, therefore, essential to take accurate cross sections of the entire rocky area at suitable intervals before starting excavation. The cross sectional areas were recorded in advance in the measure-

ment book and were again verified when the cutting had been completed. Payment was made on the basis of these measurements.

8.7.3. When hard rock or large boulders were encountered in an otherwise softer variety of earthwork measurements of the rock or boulders were taken in advance before blasting or removing them. Unless this is done no trace of the boulder will be found afterwards.

8.7.4. Care had to be taken to record the exact location of such boulders or rocks so as to be able to deduct the quantity from the total quantity of cutting at the cross section concerned.

8.7.5. When boulders stood on the surface of the soil to be excavated and their volume was not likely to be included in the measurement of the excavation at the corresponding cross sections, advance measurement of such boulders was taken and recorded under "surface boulders."



Photograph No. 10.

"Witnesses"
(Seven "witnesses" are
seen beyond the bridge).

8.7.6. These measurements were verified by responsible controlling officers before permission to blast the boulders was given. A similar procedure of measuring in advance was followed in the case of clearing slips, cutting trees, uprooting stumps, or removing bamboo clusters.

8.7.7. Except in rocky areas, where it was not possible to do so, a sufficient number of "witnesses" were maintained until the measurements had been taken and until written orders were given for the removal of such "witnesses."

8.8. Soil Classification.

8.8.1. The classification of soil in hill road work varies from point to point. As the rates of payment varied considerably for various classes of work, it was necessary that the classification should be clearly understood and uniformly recorded by all measuring officers. An incorrect classification of the earthwork is likely to have a much more serious effect than a slightly incorrect measurement and it is, therefore, most necessary to classify the work meticulously.

8.8.2. Detailed explanatory notes on the interpretation of the various classes of excavation were issued by the controlling officers. Practical demonstration was provided by asking all measuring officers to measure up a typical length and to record the measurements according to the accepted classification. These measurements were then checked on the spot by the controlling officer and a wrong classification, if any, was brought to the notice of the measuring officers. The process was repeated until all misunderstandings were removed.

8.8.3. The surface of the back slope seldom gives an indication of the correct classification of the spoil removed at that cross section. It generally presents a much higher and costlier type of earthwork than that of the spoil removed. The sectional elevation of the "witnesses" indicates fairly accurately the composition of the soil actually cut. The measuring officers were, therefore, instructed to be guided by the soil in the "witnesses" and not by the surface appearance of the back slope.

9. DRAINAGE

9.1. Side Drains.

9.1.1. A side drain was provided on the inner side where the road was on sidelong ground and on both sides in through cuttings. The drains were V-shaped, one foot wide at the top, and 6 in. to 1 ft deep. They were unlined.

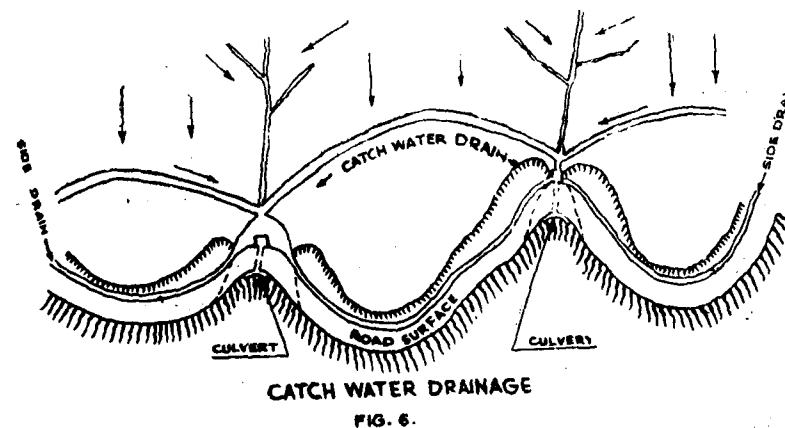
9.1.2. The drain was made at a clear distance of one foot from the toe of the hill slope so that any scour in the drain might not undermine the slope and give rise to slips.

9.1.3. Cross drains were provided at suitable intervals to carry off the water from the side drains.

9.1.4. The side drains were taken clear of the road at hair-pin bends wherever possible.

9.2. Catchwater Drains.

9.2.1. It is proposed to provide catchwater drains at 20 to 50 ft from the edge of the road. They will consist of trenches 2 ft 6 in. wide and 1 ft deep, leading the rain-water towards the nearest culverts. (See fig. 6.)



9.2.2. These drains are sometimes a potential danger, particularly in shale areas, and unless correctly sited and properly looked after, they give rise to slips instead of preventing them.

9.3. Cross Drains.

At intervals of 10 ft or so cross drains, a few inches in depth, were made in the berms to lead the surface water off the road, either into the side drains or out at the outer edge of the road, and thence down the hillside.

9.4. Culverts.

9.4.1. Properly placed and built culverts are one of the most important features of hill road construction. A culvert is required

at almost every re-entrant for the water coming down the ravine or for the water brought down to it by the roadside and catchwater drains.

9.4.2. It was found that an average of eight culverts per mile was a fairly accurate estimate of the number required on this hill road. In some sections, particularly where the road passed along the lower reaches of the mountain face, as many as 16 to 20 culverts per mile had to be provided.

9.4.3. All the culverts provided for in the designs have not, however, been built as yet. Only about $\frac{1}{3}$ th the number had been built when the work was suspended in November 1949.

9.4.4. The types of culverts adopted were :—

- (1) Slab drains
- (2) Armco culverts
- (3) Stone culverts
- (4) Timber culverts

9.4.5. Plate No. IV shows the plans of a typical stone culvert in mile 139.

9.4.6. As building stone was not available in most places and as Armco culverts were in short supply, timber culverts had to be resorted to.

The designs adopted are illustrated in Plate No. V.

9.4.7. The total cost of culverts (mostly of timber) on the completion of the work is expected to be Rs 5,000/- per mile in the Haflong Division.

9.5. Bridges.

9.5.1. Under this head are classified all structures with spans of 10 ft and above.

9.5.2. Altogether 101 bridges with spans varying from 10 ft to 22 ft were built in the Haflong Division (length 89 miles).

9.5.3. For want of time, materials for constructing permanent bridges could neither be got together locally, nor obtained from outside and transported to the site. Timber bridges were, therefore, designed and built. The best hard timber available locally was used in the construction.

9.5.4. The maximum span allowed was 22 feet.

9.5.5. As the bed of most of the waterways consisted either of rock or of big boulders at the surface or a few feet below it,



Photographs Nos. 11 and 12.

A Timber bridge under construction.

The bridge is 18 ft long, 40 ft high, has 9 spans of 20 ft each.

"Witnesses are seen in the background in photo. No. 12."

Photo No. 10 is also a view of the same bridge.

pile driving could not be adopted successfully. A trench, ft to 12 ft deep—according as the soil permitted—was dug. A wooden beam, 14 in. by 12 in. in section, was placed at the bottom of the trench. Special hard timber was selected for this purpose so as to resist the ravage of white-ants and the action of water. Wooden piles stood in recesses made in this "sill" beam.

9.5.6. Further details of a 15 ft span timber bridge are given in Plate No. VI and may be seen there.

9.5.7. The reason for putting the piles over a sill beam was that if, at the time of scour, a row of piles were struck by a floating tree or by a boulder, the piles should not be free to give way individually.

9.5.8. Except in a few cases, no signs of deep scour have been noticed yet. Some of the bridges have seen three monsoons and others two.

9.5.9. Most of the streams on which these bridges have been built are deep and narrow at the bottom. They are dry or nearly dry during the winter and carry heavy discharge during the rains and bring down floating timber and rolling boulders. In constructing the timber bridges, care was taken that no row of piles was put at the centre of a channel where scour was likely to be the deepest and flow the strongest. Thus, for a waterway of 22 ft or less, only one span was provided but if the length of the bridge was to be greater, one span was placed centrally and other spans added on the sides. The centre of the channel was thus kept unobstructed as far as possible.

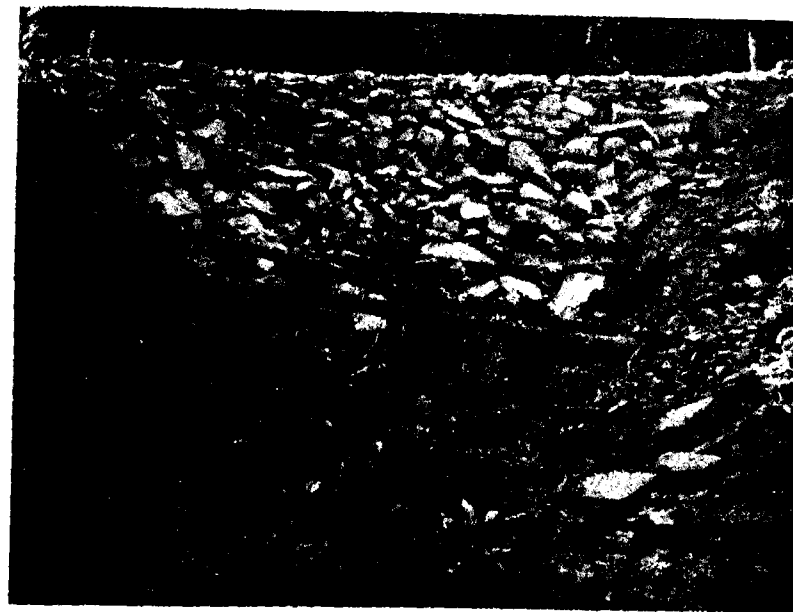
9.5.10. In no case was a two span bridge, with a row of piles in the centre of the channel, constructed.

9.6. Drainage by Percolation.

9.6.1. In many places in hill road construction sharp and narrow re-entrants are met with and the road cannot possibly follow the configuration of the hill face at such places. Very often there is little or no continuous flow of water at these re-entrants even during the rains. At such situations the road is built on spoil dumped from the excavation done within the minimum lead included in the rate. This serves to straighten the alignment and save unnecessary expense on cutting into the re-entrants.

9.6.2. The small discharge in such places is dealt with by placing big boulders to an appreciable height at the bottom of the fill. The rain-water ponded up by the fill percolates

through the boulder. If necessary, a very small culvert is provided in the fill.



Photograph No. 13.
Drainage by percolation.

9.6.3. This method was devised by Major K. E. L. Pennell, M.C., I.S.E., late Chief Engineer, Assam, and has been used successfully in many places and has saved much expensive bridgework.

9.7. Ferries.

9.7.1. There is only one river crossing on this road—the Diyung river at Dihangi Arda—where a major bridge, about 250 ft in length, will be required. The flood level here shoots up by 30 to 40 ft during rains and the river brings down large quantities of drift timber. A timber bridge will not, therefore, be suitable here.



Photograph No. 14.
A "Marboat" in midstream on the
Diyung River at Dihangi Arda.



Photograph No. 15.
A rubber boat at Dihangi Arda
(Displacement 1,000 lb; Cost
Rs 100/-; Useful on "recces".)

9.7.2. At present a ferry, with a 6-ton ferry boat, has been set up at this crossing. A smaller boat for casual pedestrian traffic has also been provided.

10. MISCELLANEOUS

10.1. Accommodation.

10.1.1. Great difficulty was experienced on this project in providing suitable accommodation for the field staff. Proper materials and labour, even for erecting temporary sheds, were not available. Improvised sheds of a very poor type, with no furniture of any sort, were built and the scale of accommodation per head was very low indeed.

10.1.2. In the Haflong Division some semi-permanent buildings with stone plinths, cement or plank flooring, split bamboo walls plastered over with 1:8 cement mortar and whitewashed, and bamboo shingle roofing, were constructed at Haflong, Mahur, Gunjaon, and Bagha.

10.1.3. Almost everywhere else the temporary shelters had bamboo "machan" floors, 1½ ft to 3 ft above the ground, bamboo and mat walls, and mat or thatch roofs. The occupants were exposed to rain during the monsoon months and to bitter cold in the winter. An adequate number of tents or tarpaulins was not available at any stage of the work.



Photograph No. 16.
Temporary hut made of bamboo
and thatch on bamboo
"machan" floor.



Photograph No. 17.
Temporary shed. Everything
made of bamboo. An elephant
head is seen in the foreground.
Local belief is that elephants
come to this place to die. Other
heads and bones available
nearby.

10.1.4. The total cost of permanent and semipermanent buildings for officers' residences, staff quarters, offices, etc., in the Haflong Division was Rs 3,57,000/-.

10.2. Rations.

10.2.1. The supply of rations to labour camps on this project was not always satisfactory. Instances were occasionally reported where some men starved, left the work, and went away.

10.2.2. When the only means of transport available were human porters and when the distances involved were ten or more stages of 10 miles each, it became a really difficult problem to keep the labour force well supplied with all their requirements. At every stage some porters were kept for the transport of rations.

only and as these porters formed a considerable force in themselves, further porters were needed to keep them supplied. The estimates of the number of porters varied very considerably. There is no wonder then that sometimes rations ran short and people had occasionally to starve. Wrong calculations of the number of porters required seemed to be the cause of shortages rather than a scarcity of rations at the base.

10.2.3. Appendix III gives a table and a formula for determining the number of porters needed to carry rations for 100 labourers working at any stage, up to ten stages from the base.

10.3. Water Supply.

10.3.1. The supply of drinking water was very scarce because the alignment ran for the most part on the upper reaches of the mountain ranges. This scarcity was particularly marked during the winter months—December to April. Except for a few perennial water springs, situated at long intervals, all springs in the hills dried up in the upper reaches although the same sources continued yielding water at lower levels. Even at such places the discharge became scanty and hardly sufficed for drinking purposes. Bathing and washing in such places was often out of question.

10.3.2. Labour camps had to be located near the springs, often a considerable distance away from the alignment.

10.3.3. Where this was not possible, special gangs of men were employed to bring water from the springs to the camps, and large containers had to be provided at the camps. Springs were protected against pollution by fencing off their precincts and appointing chowkidars.

10.4. Medical Aid and Sanitation.

10.4.1. Very satisfactory arrangements were made for medical aid and sanitation on this project. Hospitals and dispensaries were established at several convenient places along the alignment and were adequately supplied with drugs and equipment. No serious accidents occurred, nor was there any outbreak of infectious or contagious diseases. The incidence of sickness was comparatively low because proper precautions were taken in time.

10.4.2. As the climate of the locality is very moist and warm in summer, the most common ailment was malaria. Sporadic cases of malaria are found up to elevations of 4,000 ft above the sea and most of the alignment lies at much lower altitudes. Malaria oil and DDT solution were extensively sprayed round and in the camps. Though the labourers could not be educated or

persuaded to give up some of their primitive habits all at once, frequent spraying of these solutions and the use of Paludrine, as a preventive against malaria gave good results.

10.4.3. Some places, for instance Garampani and Dihangi, are infested with troublesome pests which made life at these places miserable. Leeches, sandflies, 'kutkis', rats, white-ants, and mosquitos, are but a few of these pests. The bites of sandflies and 'kutkis' gave rise to blisters which festered in a moist and warm climate.

10.4.4. The insidious leech is noticed only after it has sucked a large amount of the blood of its unfortunate victim. Repeated attacks by a leech can cause great harm to a man's vitality and capacity for work. Leeches have been known to go through shoe-eyelets and open textured socks. Vigilance is the only means of escape from this danger.

10.4.5. The smell and fumes of burning rags were found to be effective means of keeping away sandflies and 'kutkis'.

10.4.6. In the Haflong Division there were 17 deaths during 18 months, though no fewer than 4,000 labourers, contractors, and Government officers were at work at a time

10.4.7. In this Division there were two medical units with two Assistant Surgeons and five compounders, and they treated 13,249 patients.

10.4.8. The ailments, the number of patients treated, and the number of deaths, are tabulated below :—

Incidence of sickness in the Haflong Division

Disease	No. of patients treated	Deaths
1. Malaria	5,525	10*
2. Dysentery	1,770	2
3. Diarrhoea	378	—
4. Other intestinal troubles	842	—
5. Pneumonia	71	2
6. Debility	—	2
7. Accidents	—†	1
8. Other petty ailments	4,663	—
Total	13,249	17

* Due to cerebral malaria.

† Not known; probably included in item 8.

10.5. Labour.

10.5.1. As the country through which the alignment passes is mostly uninhabited, no local labourers were available except a few for jungle cutting and constructing temporary sheds.

10.5.2. The bulk of the porters were muslims who hailed from East Pakistan, particularly from the Noakhali, Tippera, and Sylhet districts. They were good at hill excavation but rather inclined to do unauthorized extra cutting.

10.5.3. Skilled labour for timber and stone work came from Manipur, Khasi Hills, Nepal, and, in a few cases, from the plains of the Cachar district.

10.5.4. Nepali and Bhutia labourers were the best on excavation work.

10.6. Transport.

10.6.1. On those sections between Shillong and Haflong which followed the old bridle path, pack animals were used for transport. All other sections of the alignment depended entirely upon porters for the transport of supplies and materials. In the early stages of the work, transport became a serious bottleneck because everything such as rations, building materials, tools and plant, camp equipment, etc., had to be carried by manpower alone.



Photograph No. 18.

Naga labourers have no kit of their own.

10.6.2. Men from the plains proved to be quite unsuitable for this job. Gurkhas from Nepal, Bhutias, Khasis, and tribal people were suitable for portage. Beside the fact that they are experienced mountaineers, their great merit is that they are

very simple in their habits and carry little or no equipment of their own. Compared to them the Bengalee porter is useless as he is a bad hill climber and is fastidious in his habits. He cannot do without his bedding, spare clothes, pillows, utensils, etc., and can carry little besides his own paraphrenalia.

10.6.3. In this connection attention is invited to Appendix III where it is shown that to keep 100 men working at the end of 10 days march adequately supplied with rations only, a chain of 158 porters is needed along the supply lines. More men would be needed for carrying stores and materials required for the work.

10.6.4. In order to overcome this difficulty of transport a 10 ft track was excavated as the first stage of the work (see para. 8.6.2). This track was used for pack-animal transport.

10.7. Protection.

10.7.1. Wild animals and tigers were often encountered during the reconnaissance surveys as well as during construction. A reconnaissance party working near Chandarnathpur was once roused at the dead of night by the roaring of tigers. A bright petromax lamp hanging from a tree, and a bonfire which had not quite died out and was quickly replenished, restored confidence in the camp. A few shots were fired and the tigers retired.

10.7.2. Tigers were often seen near water springs but fortunately, no party came across a real man-eater who is a wily, animal and seldom gives warning before attacking.

10.7.3. No special protection against wild animals was provided at camps or work sites, but some officers and contractors provided themselves with guns and these came in handy on many occasions. They were used more often to frighten than to kill, but they helped to keep up the morale of the staff and the workmen.

11. WORK INCOMPLETE

11.1. On account of financial stringency, and for other reasons, the work was suspended from the 1st November 1949. Before that, on the 25th October 1949, a jeep carrying the Chief Engineer and a small party had travelled right from Shillong to Silchar.

11.2. The sudden stoppage of the work left it incomplete in many places and in many respects.

11.3. Over stretches, totalling about 3 miles, the bridle path was hardly improved at all.

11.4. In certain miles, after execution, the gradient turned out to be steeper than was intended—though, generally, not steeper than 1 in 12. In a few places, however, it is as steep as 1 in 8. This could have been avoided if the work had not been done in great haste and if more time had been available for attending to details.

11.5. Drainage remained defective. Side drains, catchwater drains, culverts, and bridges have not all been finished according to plan.

11.6. Slips have occurred in numerous places. They can be classified as:

- (1) Ordinary slips which can be normally expected on any new hill road;
- (2) slips caused by the lack of adequate drainage;

Side drains and catchwater drains could not be made in all places before the work was suspended. A case in point was mile 188 which was subject to heavy slips but was subsequently improved completely by providing proper drainage.

- (3) Slips due to faulty strata (for example, at miles 155.5 and 157.9. An alternative alignment bypassing these bad spots was not found feasible).
- (4) Slips due to want of retaining walls, etc.

11.7. Full formation width has not been cut in many places some of which are as narrow as 8 feet. This defect, however, can be rectified easily.

11.8. Beyond Haflong, towards Silchar, a large number of zigzags have been made—sometimes even five in one mile. The hair-pin bends of these zigzags are sometime so sharp that they have an angle of as low as 20 degrees between their arms. These zigzags appear to have been introduced to avoid soft, unstable hillsides or precipices involving very high cutting. Neither of these objects was, in fact, attained. On the other hand, a permanent defect in the form of zigzags was introduced.

11.9. There are many bad corners where a vehicle has to manoeuvre and reverse two or three times before it can negotiate the corner (or zigzag bend). These corners and bends are being improved and eliminated gradually.



Photograph No. 19.

Zigzags in mile 189.

(Three arms are seen in the photo.).

11.10. Practically no retaining walls, toe walls, or revetments, were built and the road remains subject to damage and heavy slips for want of these protective measures.

12. COSTS

12.1. The amount originally sanctioned for the project (160 miles of new construction) was Rs 19.2 millions, or about Rs 1,20,000/- per mile. This does not include metalling and surface dressing.

12.2. Details of the expenditure incurred in the Haflong Division are incorporated here (Appendices I & II) and may be taken to be representative of the other two Divisions also. On completion according to the design the road is expected to cost Rs 97,000/- per mile in the Haflong Division.

13. CONCLUSION

When work was suspended in November 1949 the road was only a fair weather road, but the primary object of re-establishing communications between the two parts of Assam, cut off from each other by the Partition, had been achieved. Had the work not been suddenly suspended, most of the shortcomings mentioned in the foregoing pages would not have been there. Gradually, as some of the essential items of work like side and catchwater drains, culverts, and bridges are completed, curves improved, and narrow sections widened, the road will develop into an all-weather road. It will then bring to this backward and undeveloped area all the benefits that a good motor road alone can confer.

Detail of Excavation in the Haflong Division.

Serial No.	Item of work	Quantity & cost as estimated			Quantity & cost as executed		
		Quantity	Rate per 1000 cft.	Cost. Less contingency	Quantity	Rate per 1000 cft.	Cost
		cu. ft.			cu. ft.		
A.	Hill cutting						
1.	Soil not requiring the use of pickaxe or crowbar.	13,19,982	36/0	47,524/-	694,938	35/4	24,480
2.	Hard soil requiring the use of pickaxe or crowbar.	96,96,871	49/12	4,82,382/-	96,15,938	49/9	4,76,849
3.	Hard soil mixed with moorum, gravel, boulder upto 6" dia. requiring the use of pickaxe or crowbar.	1,29,32,226	68/14	8,90,913/-	1,12,31,075	66/2	7,42,391
4.	Hard soil mixed with boulder above 6" dia. removable by crowbar.	1,28,43,314	74/5	9,55,213/-	1,14,48,527	75/2	8,60,397
5.	Hard soil with shale not requiring blasting.	1,21,94,315	81/12	9,96,866/-	1,41,79,793	80/3	11,36,816
6.	Hard shale requiring petty blasting.	44,96,522	102/10	4,61,387/-	35,51,780	97/11	3,47,064
7.	Soft stone & laminated rock, not requiring blasting.	50,02,126	91/2	4,55,937/-	32,16,585	94/11	3,04,616
8.	Medium stone requiring blasting.	2,24,488	142/13	32,059/-	4,38,772	126/14	55,664
9.	Hard stone requiring blasting.	59,76,493	211/7	10,77,865/-	34,31,681	167/15	5,76,244
B.	Embankment						
1.	Earth work in Embankment.	75,58,245	50/-	37,869/-	68,600	50/0	3,433
		6,54,44,618		54,38,015/-	5,78,77,689		45,28,054

Appendix II

Details of Expenditure in the Halflong Division

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sl. No.	Item of works	Estimated amount WITH 5% CONTINGENCY. Rupees (,000)	Amount Spent : Rupees (,000)	Percentage of work done :	Amount that would have been spent if the work was completed. Rupees (,000)	Average cost per mile. On Completion Rupees.
1.	Earth work	57,09.9	45,28.0	95% comp- lete.	47,66.4	53,555/-
2.	Gravelling	6,92.3	98.9	15% ..	6,60.0	7,415/-
3.	Bridges	10,74.8	6,12.4	90% ..	6,80.5	7,646/-
4.	Culverts	6,97.5	1,11.4	25% ..	4,45.5	5,005/-
5.	Stone works	8,86.8	1,70.9	25% ..	6,83.6	7,681/-
6.	Maintenance during construction	2,86.5	1,11.1	100% ..	1,11.1	1,248/-
7.	Miscellaneous	5,46.2	5,33.3	90% ..	5,92.5	6,657/-
8.	Medicine	58.3	34.5	90% ..	38.3	430/-
9.	Work Establishment	1,24.4	1,03.4	80% ..	1,29.2	1,452/-
10.	Accommodation	3,83.5	3,56.8	80% ..	4,45.9	5,011/-
11.	Service Path	17.5	6.3	100% ..	6.3	71/-
12.	Level crossing	11.7	Nil	Nil	11.7	132/-
13.	Mar-boat	31.5	28.9	100% ..	28.9	325/-
14.	Compensation L.A.	66.2	64.3	100% ..	64.3	722/-
		1,05,87.0	67,67.2		86,63.4	97,351/- per mile.

Appendix III

Requirements of Transport.

The problem is to find out the total number of porters required to supply rations for 100 workmen at a distance of 10 days march from the base.

Assumptions:

- (1) A porter can carry a total load of 25 seers of rations (50 lb) including his own ration.
- (2) The ration requirements of one man are $1\frac{1}{2}$ seers per day.

Let x_1 porters be employed at the first stage.

The first day they carry 25 seers each and come back the next day, i.e., in two days they consume $2\frac{1}{2}x_1$ seers and deliver $22\frac{1}{2}x_1$ seers at the second stage.

At the second stage there are $\frac{22\frac{1}{2}}{25}x_1 = x_2$ porters. They consume $2\frac{1}{2}x_2$ seers and deliver $22\frac{1}{2}x_2$ seers at the third stage.

At the third stage there are

$$x_3 = \left(\frac{22\frac{1}{2}}{25}\right)x_2 = \left(\frac{22\frac{1}{2}}{25}\right)^2 x_1 \text{ porters and so on.}$$

At the ninth stage there are

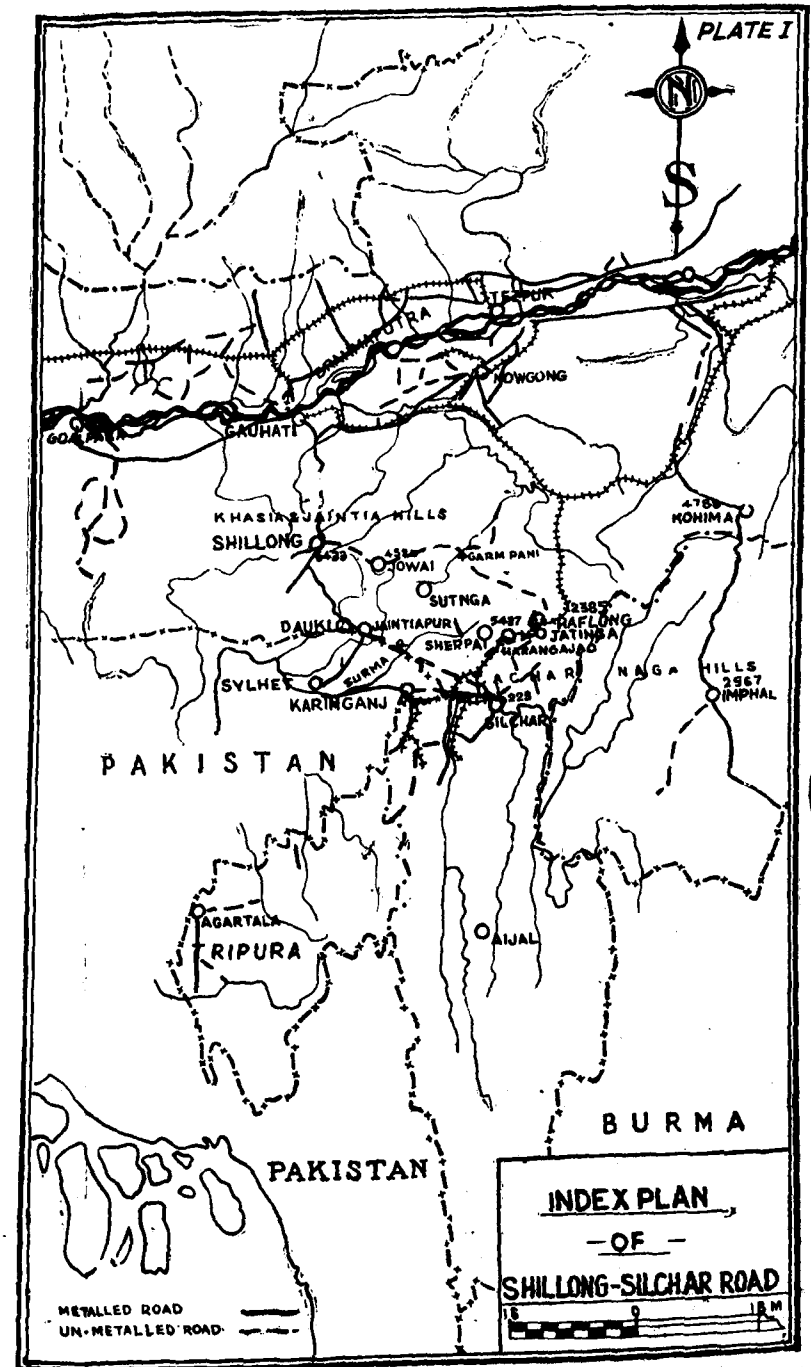
$$\left(\frac{22\frac{1}{2}}{25}\right)^8 x_1 \text{ porters} = x_9.$$

They deliver $22\frac{1}{2}x_9$ seers, which should suffice to feed x_{10} workmen at the tenth stage. At $2\frac{1}{2}$ seers per man

$$\begin{aligned} \therefore x_{10} &= \frac{22\frac{1}{2}x_9}{2\frac{1}{2}} \\ &= 9x_9. \end{aligned}$$

i.e., Total number of porters to maintain x_{10} workmen at the tenth stage (excluding the x_{10} workmen themselves)

$$\begin{aligned} &= x_1 + \left(\frac{22\frac{1}{2}}{25}\right)x_1 + \left(\frac{22\frac{1}{2}}{25}\right)^2 x_1 + \dots + \left(\frac{22\frac{1}{2}}{25}\right)^8 x_1 \\ &= X, \text{ say.} \end{aligned}$$



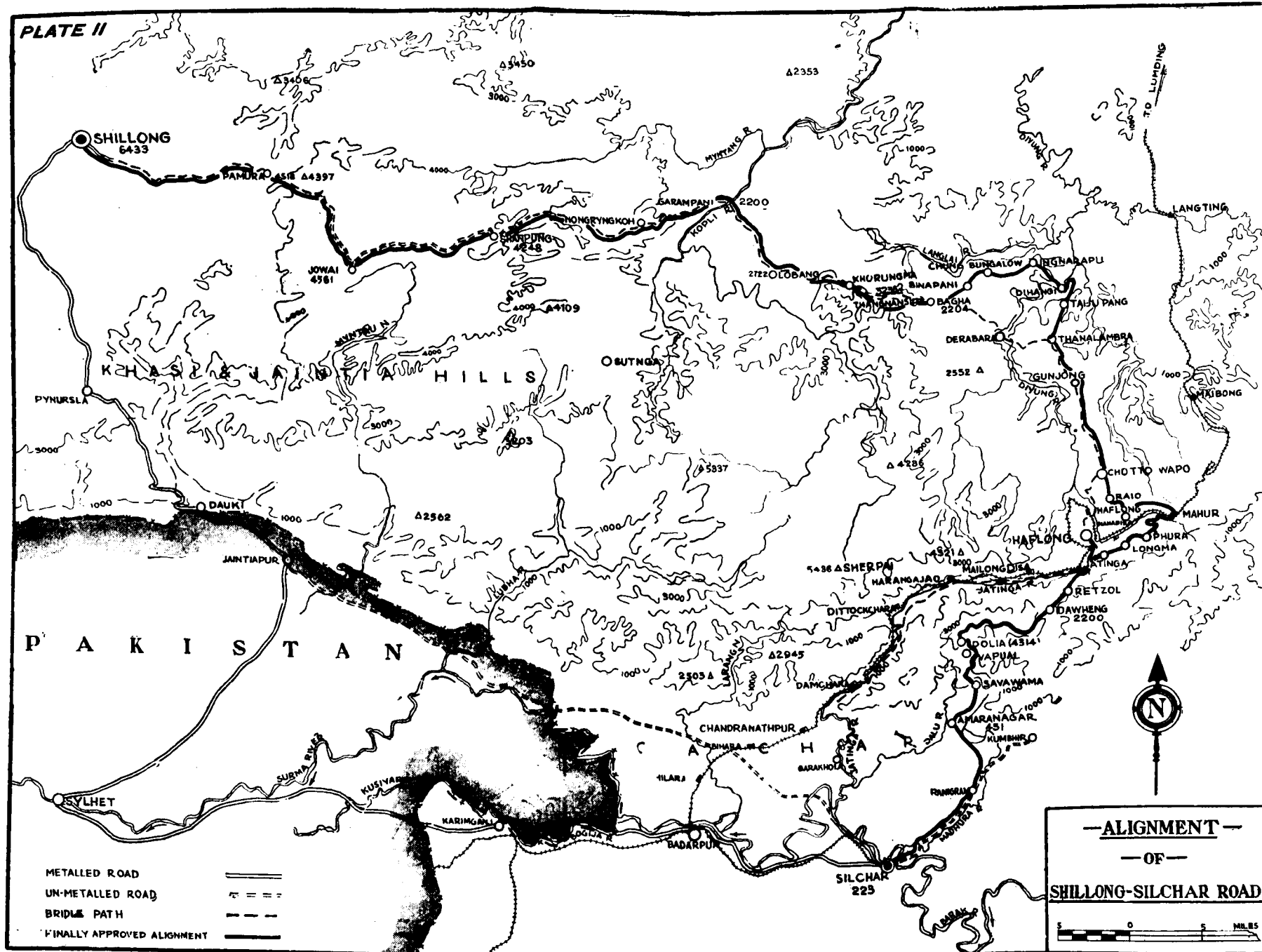
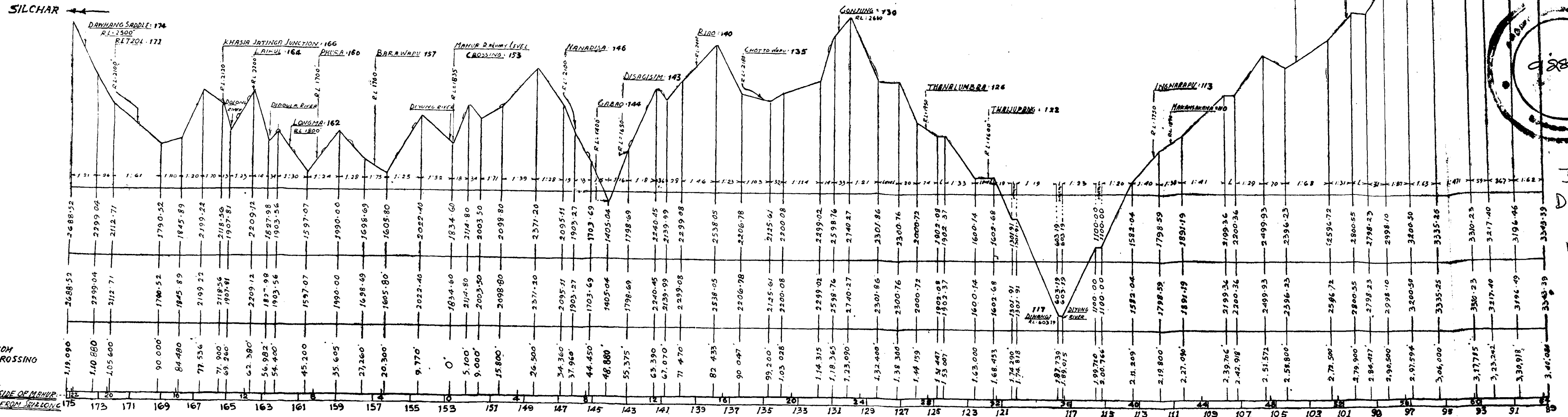
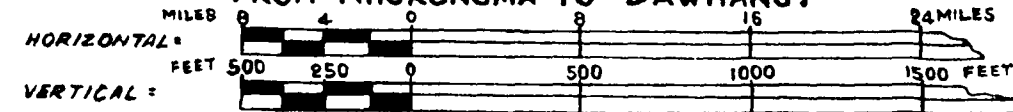


PLATE III

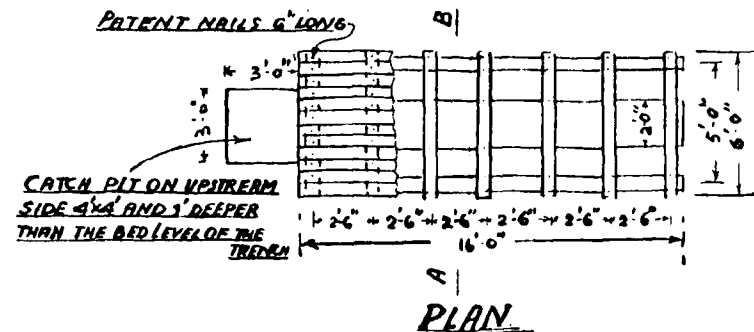
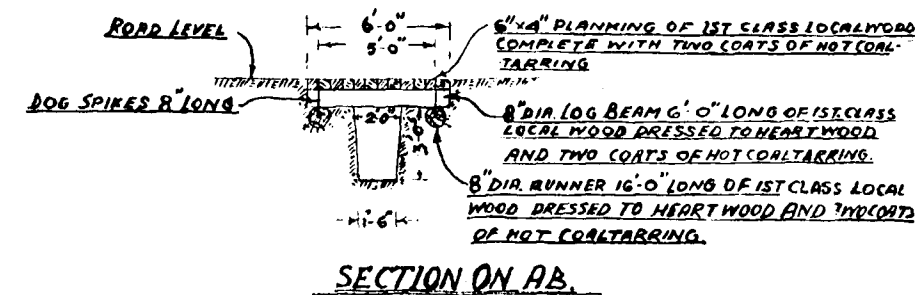
SHILLONG.

HORIZONTAL:

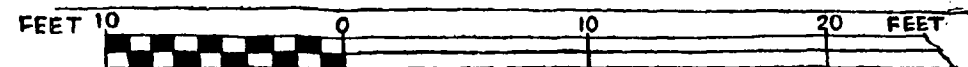
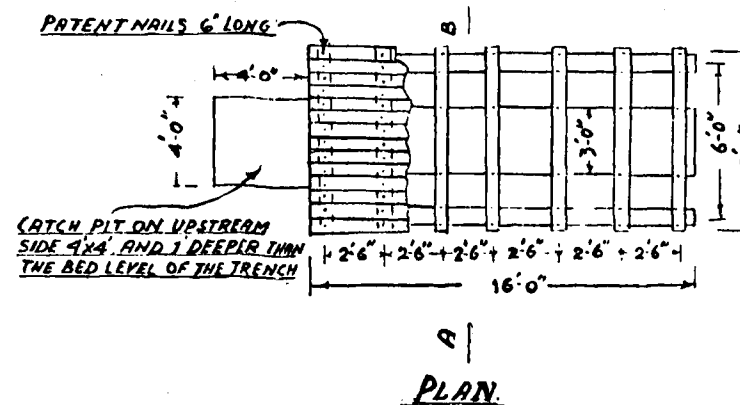
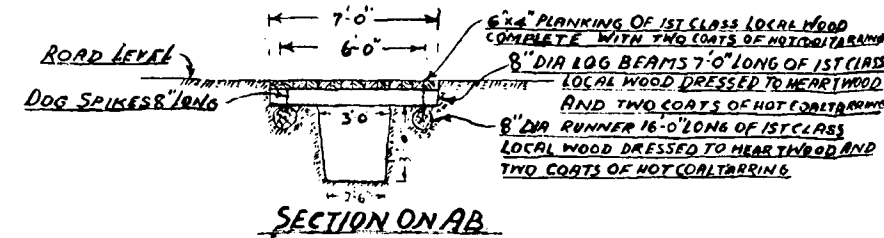


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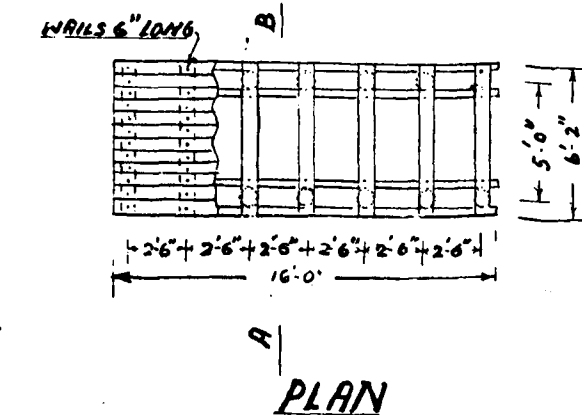
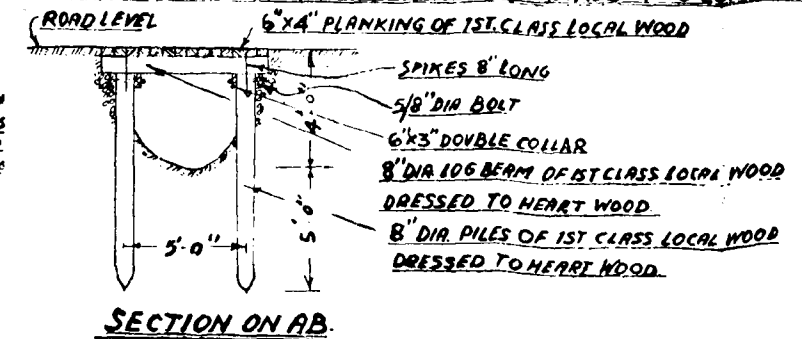
PLATE V

TIMBER CULVERT OF 2'0" WIDE TRENCH.

NOTE:—THESE CULVERTS ARE MEANT TO BE CONSTRUCTED IN PLACES WHERE CROSS DRAINS ARE NECESSARY & WHERE THERE ARE NO REGULAR DEEP CHANNELS. THE TRENCHES ARE TO BE CUT ON THE SOLID FORMATION.

TIMBER CULVERT OF 3'0" WIDE TRENCHDESIGN OF TIMBER CULVERT, 5 FT. SPAN.

(N.B.: ALL WOOD WORK TO BE COALTARRED TWO COATS (HOT) BEFORE USE)



Paper No 159.

" The Importance of Organization "

By

R. P. CHANDA

CONTENTS

	Page
1. Introduction	205
2. Establishment, Personnel, and Training	207
3. Materials, Tools and Plant, and Transport	211
4. Execution of Works	214
5. Miscellaneous	217
6. Conclusion	221

SYNOPSIS

The Paper describes the present day difficulties in the execution of works and the handicaps under which the engineering profession has to work now-a-days and suggests that foresight and proper organization on the part of engineers can overcome most of these handicaps. The Author has made various suggestions to improve the present state of affairs.

1. INTRODUCTION

1.1. The two world wars—particularly the Second World War—have made every intelligent man conscious of the importance of organization in all human activities. A very large number of men have come into contact with the army in one capacity or another and seen the army methods of work at close quarters. They feel that if some civilian institutions took a leaf out of the army's book, it would do them immense good. They are convinced that a properly organized work runs smoothly and objectives are achieved without an unnecessary strain on the energy and nerves of the workers.

1.2. It is essential to realise that men in the forefront of activity—those who bear the brunt of the battle, be the battle against an enemy or against the forces of nature—cannot give much forethought to the future. They are always too engrossed with the present. There must be some organization at their back which will forestall their probable and possible needs and make provision for fulfilling these needs when they arise.

1.3. Like the army, the railways too have a vast organization at their back. To support their major constructions they have their stores department, machinery and plant depots, workshops with highly experienced foremen and crews, field dispensaries and their doctors, their detailed instruction manuals, I.S.R. standards, and even their own police force. They have very voluminous catalogues giving detailed description of spare parts and stores. They have their own organization of communications—telephones, telegraph, etc.—and transport.

1.4. In contrast to this, the state highway departments in India may often be said to have no organization worth the name. One of the main reasons for this apathy is that the jobs connected with more organization are not spectacular. Most of these jobs are behind the scenes and, therefore, thankless. As long as all goes well, the men who execute work get all the praise, but as soon as anything goes wrong the men at the back are made the scapegoats. Odd men who are supposed to be good for nothing else are placed in the charge of those behind-the-scene works on which much of the success of the whole project often depends.

1.5. In the post-war period the highway construction programme in every State has expanded to bursting point. But the supporting organization has not been strengthened proportionately. The young engineers and subordinates who have no pre-war experience of the management of works are greatly handicapped by being suddenly confronted with unusual situations and saddled with unknown responsibilities.

1.6. It has become almost an everyday experience to find that young and immature officers are sent out to survey projects or to start constructions. They often have had no previous training and no experience of handling men or contractors, and no real acquaintance with plant and machinery. Their ideas on specifications are hazy. Their knowledge of accounts and departmental codes and procedure is often next to nothing. Some of them do not even realise the need of these things: their ignorance is colossal and pathetic.

1.7. It is, therefore, necessary to give expression to and discuss the need for a good organization in the interests of efficiency and speed of execution of works, particularly in those States where a heavy construction programme has been launched and which, even in the pre-war era, were not known to possess a sufficiently big baseline organization.

1.8. The question arises: Is the situation unavoidable? Perhaps it is so in certain places and in certain circumstances. People are suddenly becoming conscious of the importance

of roads and clamouring for more and more of them. Experienced personnel to take charge of the expanding works cannot be created overnight, and use has to be made of whatever material that comes to hand. But a more important question is: What are we doing about it so that the situation does not become chronic and the period of these teething troubles is shortened as much as possible? In the following pages the difficulties experienced by the divisional, sub-divisional, and sectional officers are discussed. If not relieved, these difficulties are likely to lead to discouragement, pessimism, and general frustration.

1.9. The problem of organization has many aspects and will be discussed here under the following heads:—

- (1) Establishment, Personnel, and Training;
- (2) Materials, Tools and Plant, and Transport;
- (3) Execution of works;
- (4) Miscellaneous.

2. ESTABLISHMENT, PERSONNEL, AND TRAINING

2.1. Establishment and Personnel.

2.1.1. In almost all the States large post-war road development programmes have been undertaken. The Public Works Departments in some of the States have had to be expanded to unprecedented scales. In such States it has become unavoidable to put a large number of inexperienced engineers and overseers in the charge of works really difficult for beginners to handle. These beginners have not been in the department long enough to have the benefit of even routine training on specifications, construction practices, maintenance routine, accounts, and so on. They have not had sufficient contacts with their more experienced superiors.

2.1.2. Not unoften it happens that as soon as a subdivision or division is created, the engineer is the first man to be appointed and sent out into the wilderness, so to speak. He does not know where he will set up his office or live. In very few cases, indeed, has he even barely adequate camp equipment. He gets strange men as his staff who, before even reporting on duty, start going on leave. There is no knowing when he will have a reasonable quota of men to assist him. When his staff do turn up in the end, they are often found to be a set of inexperienced, and raw, ignoramuses.

Nevertheless, the engineer is promptly faced with problems big or small according to the job in hand. Contractors with hundreds of labourers start reporting to him. Naturally time

is wasted and the contractors, as well as the department, suffer. Efficiency is at a low ebb and the engineers get a bad name.

2.1.3. A divisional office may require, in these days, a year or even more to settle down and equip itself with office space, some sort of furniture, stationery and forms, and personnel for accounts, technical assistance, and routine clerical work. The town or village where the headquarters might be located is, more often than not, overcrowded and the staff seldom know where to live. That is why transfer from one place to another is now-a-days looked upon by some as one of the worst forms of punishment and expression of displeasure.

Yet the department (and the public) expect these silent sufferers to produce results.

Is it too much to ask that, like the army division, a P. W. D. division should be fully equipped before it is sent out?

2.1.4. In newly set up offices even minor troubles assume serious proportions. There have been instances when it took a year (or two) before a sweeper or a night watchman was permitted to be employed, or before sanction was received to obtain stationery, typewriters, or instruments. There is seldom a central store to come to the rescue in such cases and yet the weekly and monthly reports and returns must be submitted, muster rolls and accounts must be maintained, indents must be issued, and a thousand and one other similar functions **must** be performed.

2.1.5. Even to obtain stationery for normal official use, engineers have had to resort to questionable means which, if detected, could be interpreted as dishonest conduct. Do the authorities realise that this is insidious training? Do they realise that from such little beginnings bigger abuses arise?

2.1.6. Delays in the communication of financial sanctions arise from "red tape" and from the long and tortuous course of the "proper channel" with its backwaters and whirlpools where things get stuck up or sucked down. Do those "chair-borne" officials who sit in Finance or Audit offices realize the ill effects of their slow procedures and their lack of appreciation of realities?

2.1.7. A division or subdivision generally has no standard reference books. Even the departmental codes, or works coded, have become things of the past. In some States these publications have been out of print for a long time. Thus, a new entrant, who is robbed of all opportunities of guidance from senior officers, has no opportunities of self-help even. Has Government no printing presses?

2.1.8. Some **suggestions** to improve the situation are given below :—

- (a) Central stores should be established and should have reasonable stocks of stationery, forms, important items of furniture, (cash chests, almirahs, blue-printing frames, etc.), drawing and survey instruments, first-aid kit, map cases, camp furniture, and so on.

Even a modest stock would be of great help to a new unit, and to established units in critical periods.

- (b) A central library should be set up in each State. This should supply to new units codes, section books, general data books, specifications, selected Indian Roads Congress publications, all Indian Roads Congress standards, manuals of construction and maintenance, and such other books as are required frequently for the efficient and quick execution of works.

Apart from this, the central library should afford facilities for consulting other reference books, important text books, magazines, journals, and research publications.

The keen young engineer may then be able to train himself by his own efforts. He deserves to be given a chance at least.

- (c) State and Central Government should arrange to publish their own codes, specifications, and construction and maintenance manuals. Where these were published and are now out of print, they should be re-printed, or revised and new editions brought out.
- (d) Minimum scales should be fixed for a new division or subdivision in regard to the contingent staff, stationery and forms, office equipment, instruments, and library books. Steps should be taken to equip every unit, on creation, according to these scales.
- (e) Scales of residential accommodation should be fixed and such accommodation should be invariably provided.

Specifications for this accommodation, if newly built, may be commensurate with the expected life of the division or subdivision.

- (f) For maintenance personnel, cheap but durable huts may be prescribed and provided, say one hut at every 8 to 10 miles.

When a project is in the construction stage these huts may accommodate supervisory staff.

Some arae, adjoining such huts should be fenced off as a store-yard for keeping stocks of bitumen, steam coal, tools, etc.

In sparsely populated areas, gang huts, with well equipped stores, are a fair beginning.

2.2. Training.

2.2.1. The young engineer fresh from college needs to be encouraged to study the practical side of technical processes. The Indian Roads Congress Journals have, by now, published a paper or two on most of the subjects connected with highway engineering. These Papers have been written by experienced engineers, and a careful study of the Journals would impart to the young engineer some of the 'know-how' which he needs.

2.2.2. Some of the older issues of the Indian Roads Congress Journals are now out of print. It is suggested that the more useful Papers published in these Journals should be printed again along with the discussions on them. It would be a good plan to print the various Papers on the same or allied subjects together. For example, one volume may contain Papers on bridge construction, another on bridge failures, a third one on all the standards and specifications and so on. These volumes would then be placed in all subdivisional office libraries for the guidance of young engineers.

2.2.3. In training personnel, practical courses of intensive study should be instituted. These courses should be conducted in the slack season when outdoor works are generally slowed down.

2.2.4. The courses should be held under the auspices of the specialist branches of the department—like the planning divisions, designs divisions, stores divisions, workshops, etc. Instruction should be imparted by actual demonstration and by allotting tasks to the trainees.

2.2.5. Accounts, audit, indenting on stores, use and maintenance of tools and plant, emergency bridging, labour control, all these should form part of the syllabus of these training courses.

2.2.6. During such courses current or typical engineering problems should be discussed and the trainees should be required to produce their individual solutions.

2.2.7. Tests should be held at the end of these courses and the results of individual officers should be taken into consideration at the time of promotions and confirmation.

2.2.8. Where results are below standard, the officers concerned should be required to repeat the courses at another suitable opportunity.

3. MATERIALS, TOOLS AND PLANT AND TRANSPORT

3.1. Materials.

3.1.1. It is well known that in these days a hand-to-mouth existence is led by most of the P. W. D. divisions in the matter of supplies of materials. Generally, there are no central stores or depots to fall back upon as is the case in the army or in the railways. And, there is a limit to improvising or scrounging.

3.1.2. A divisional officer considers himself lucky if he can somehow, in the course of a working season, scrape together just enough materials for his work. Progress reports are full of complaints about shortages of cement, steel, bricks, coal and timber—forming the main bottleneck responsible for the delays in completing works according to schedule.

3.1.3. Under these circumstances there is no possibility of laying by something for emergencies. In easily-flooded, low lying areas, where roads and road structures are vulnerable, it is desirable to have stocks of sleepers, rolled steel beams, some light bridging units, built-up steel cribs, derrick posts, strong flexible wire ropes, heavy duty winches, hydraulic jacks, and so on. Such a pool should be maintained at divisional headquarters or at strategic points.

3.1.4. No doubt some useful articles or pieces of equipment are available in many places, but almost nowhere are there enough of them. Some of these items, for example rolled steel beams, light steel cribs, crabs, and winches, should be looked upon as indispensable and provided generously to all divisions.

3.2. Tools and Plant.

3.2.1. Details of tools and plant needed to be acquired, specially for bridge work. The characteristics and performance data of earth-shifting machinery have appeared from time to time in the Indian Roads Congress Journals*. If funds are available acquisition is an easy matter. What is really difficult is to maintain the equipment in proper working order and to get over breakdowns when they occur.

3.2.2. In this connection it is necessary to emphasise the importance of a programme of inspections and maintenance. It is not often realised that "a stitch in time saves nine" is parti-

* Vol. I, p. 199—209; Vol. XII—2, p 278—76; Vol. XIV—3, p 345—59,

cularly true of equipment scattered along long stretches of road and working in places which are not easily accessible. By merely tightening a few loose nuts, replacing a few washers or oil-seals, considerable potential harm can be prevented. But it is only a trained eye and a trained ear which can detect such little defects. It is, therefore, all the more important that such little jobs should form a part of the daily and weekly maintenance.

3.2.3. It is surprising how the maintenance programme gradually falls into disuse, and a major breakdown comes as a rude shock to the crew as well as to the engineers on the job.

3.2.4. Most of our operators have not yet developed a real sense of responsibility. A mere motor mechanic will, with unwarranted confidence, take charge of unfamiliar machinery and, having ruined it, go back quietly and become a motor mechanic again. Only men with good references should be taken on to operate equipment and officers should be very careful that they do not recommend or give "chits" to undesirable and inefficient operators.

3.2.5. An over enthusiastic mechanic or supervisor may find particular delight in undertaking difficult repairs. This is not, however, something to be commended or recommended. There should be a clear demarcation between what can, and what may be, attempted in the field by the operating staff and what should, on no account, be undertaken by them.

3.2.6. Technical inspecting staff should go round periodically, or on receipt of an "SOS", and inspect the equipment. The upkeep of costly equipment should not be left to people who are not competent for the job.

3.2.7. Another important problem is the supply of spare parts and accessories. Indenting for these is generally left to the operators who are often obsessed with the immediate troubles and requirements of their machines. In every machine there are parts which wear out more quickly and require replacement more frequently than others. Every mechanic does not know such details, and every road engineer is not machine-minded. The indenting and stocking of spares needs to be placed on a better and sounder footing than is the case at present.

3.2.8. The selection of lubricants—oils and greases is another specialist job. A bewildering variety of lubricants, with different trade names, is available and only tends to confuse the uninitiated. There are not only different grades of lubricants for the different parts of a machine but also different grades whose use depends upon variations in the weather or in the conditions under which a machine is operated.

3.2.9. Every driver and cleaner should be trained by actual demonstration to use the correct variety and grade of lubricants in every machine and in every part of a machine.

3.2.10. And, when all is said and done, it may so turn out that on a particular job there is only one greasegun, or oil can, for administering every kind of lubricant.

3.2.11. The care of equipment, when idle, is as important as when it is working. That is the time for thorough repairs. After repairs the machinery should be properly stored and occasionally brushed off.

3.2.12. Surveying and mathematical instruments often go out of order and no quick repair facilities are available. The National Instruments Factory or the Roorkee University Depot cannot be expected to serve adequately the needs of this vast country in this respect. Every State should have some central repair establishment for such instruments.

3.3. Transport.

3.3.1. Departmental vehicles are not always well looked after. One of the reasons is that officers have a tendency to drive themselves and relegate the driver to the back seat most of the time. The driver's interest in the vehicle naturally begins to flag.

3.3.2. On the other hand, when more than one officer go out together in the same vehicle, it is an advantage that as many officers as possible should sit at the front. But the driver also should be given an opportunity to drive for a part of the day's journey.

3.4. Suggestions.

3.4.1. A few suggestions to remedy the present state of affairs are made here :

- (i) The State central stores should have a stock of materials and tools and plant for emergencies.
- (ii) The central stores should have an adequate supply of spare parts for all types of machines in use in the State. Some spares should be kept in the divisional stores also. Standard lists of items to be stocked in the central stores and in the divisions should be compiled. With such ready stocks, idle periods caused by breakdowns in the midst of a busy season will be reduced to the minimum.

A mechanical engineer should be made responsible for looking after the job for ensuring that sufficient spare parts are held in stock at the central store.

- (iii) In the central stores there should be stocks of mathematical instruments and facilities for their repairs and maintenance.
- (iv) Similar to the regular inspection of boilers there should be a periodical inspection of all equipment, at least once a month in the working season and less frequently at other times.

This should be a regular routine and the inspecting officers should have a log book for every piece of important equipment.

Such inspections should be followed immediately by effective steps to remedy the defects observed.

- (v) Indents for spare parts, accessories, working tools, and lubricants required by the divisional unit should be prepared at least once in six months by a mechanical foreman in consultation with the machine crews and the storekeeper. Such indents should be sent to the central depot.
- (vi) Every division should be encouraged to keep a stock of materials, and tools and plant, as would be required to meet an emergency within its area. These stocks should be in addition to the special requirements of sanctioned projects.
- (vii) All engineers and overseers should be made to go through a short course of training at the plant depot. Such a course will make them take some intelligent interest in the machines.

4. EXECUTION OF WORKS

4.1. Works are executed either by departmental labour or through contractors. The latter is the more usual method for new works.

4.2. Contractors.

4.2.1. There is a general impression that contracting resources of the country for road works are not adequate or up to the mark. As the work is of a scattered nature, big contracting firms do not often come into the field for this work. They prefer

to bid for concentrated forms of work like a big bridge construction. Petty contractors can be had, but they often lack financial resources. Delays in the payment of their bills or in the refund of their securities completely upsets these small contractors.

4.2.2. As competition for road work is not keen, the rates tendered are not competitive.

4.2.3. Means should be devised of making the work attractive to the better class of contractors as well as of assisting the petty contractors to tide over their own peculiar difficulties. The Indian Roads Congress may consider setting up a Subcommittee to consider the contract rules of every State, initiate discussions, and standardise the rules for adoption throughout the country.

4.3. Departmental Execution.

4.3.1. Meanwhile, every Public Works Department should take steps to train their own personnel to carry out works by departmental labour. Departmental execution of works calls for a different type of training for the engineers in charge than that which they get normally. The department's engineers may be very good at supervising contractor's works or issuing instructions and getting them carried out, but, without special training they are not likely to be good works managers.

4.3.2. They may not know the requirements of manpower, or tools or plant, needed on a job. It needs a great deal of experience, resourcefulness and foresight to collect men and materials in correct numbers and quantities for the successful and timely execution of a work. The peculiar mental outlook and the routine nature of the duties of the majority of departmental engineers are a great handicap in the direct execution of works.

4.3.3. Steps should be taken to train all engineers on carrying out fair sized works efficiently and economically entirely by their own efforts. Every Public Works Department should have a unit for carrying out works departmentally and its personnel should be changed from time to time so that the technical personnel, properly trained in the unit, may serve as a leaven in the whole department. In times of emergency this unit can be expanded quickly.

4.3.4. There is a nucleus of such a set up in the roads maintenance staff. This should be developed further.

4.3.5. An important and urgent requirement in this respect is the development of a highly trained foreman class of workers.

The erection of girders, laying cement concrete pavements, premix work with bitumen, emergency bridging, etc., need supervision which only persons with long experience can exercise.

4.3.6. As an experimental measure a road maintenance gang, led by a good foreman, and staffed by specially chosen men, each of whom should be skilled in more than one trade, should be told to carry out all works on a selected length of road. No work on that stretch should be given out on contract. Transport should be provided to carry men and materials to work. The necessary tools and plant should be supplied. The gang should function fully as a contractor's labour force would do. The technical officer in charge (generally a "supervisor") should be "a man with a mission", practical, and determined.

4.3.7. After some experience the unit should be sent out to take charge where a contractor has failed, or where no contractor offers to work.

4.3.8. In order to afford a fair comparison, full details of cost must be maintained. On this data would depend the success or failure of the scheme.

4.3.9. Mobility is an important factor in the success of such a venture. All efficient contractors realise this and provide transport for their labour, where labour camps cannot be established at or near the site of the work. At present departmental maintenance gangs lose half their time and energy in going to and returning from the work site.

4.3.10. Mobility is also important in keeping up an adequate supply of materials so that the labour and the equipment on a job do not waste time or stand idle for want of supplies.

4.3.11. In this respect, however, foresight is even more important than mobility.

4.3.12. Only as many direct labour units should be organized as can be kept busy continuously, otherwise when work is not available the tools and plant will remain idle and the men will soon be out of practice and lose their skill. It is not uncommon to find, in every division, long lists of almost useless tools and plant. These were probably purchased for some direct labour job long ago but lie forgotten except at the time of preparing periodical reports.

4.4. Engineer-Contractor Relationship.

4.4.1. As practically all works are at present done through contractors the young engineer needs some instruction and guidance as to how to deal with contractors of different types and

ability. Should he be severe and unbending? Should he be friendly and familiar? Or, should he be distant and aloof? Should he be affable or inaccessible?

4.4.2. Should he follow specifications rigidly according to the letter, or can he use some discretion and follow them according to the spirit? Can he sometimes relax the specifications in order to speed up work?

4.4.3. If he is unduly lenient he will be reprimanded for defects or deficiencies in the contractor's work. If he is severe and exacting, he may be accused of impeding the progress of the contractor, who may intentionally slow down and start marking time.

4.4.4. Imposing penalties or taking extreme steps may not always solve the problem unless an alternative agency or a departmental direct labour organization is there to fall back upon.

4.4.5. Contracting resources are sometimes so poor in some places that, instead of being driven a contractor may even have to be humoured by the engineer, if he feels that the former is willing and good-intentioned but not pushing or resourceful enough. This actually has been a very common experience in the recent years.

4.4.6. The problem is a complex one. What the young engineer really needs is a lesson in tact, which may not be easy to impart, but senior officers can, by their timely advice and encouragement, help considerably.

5. MISCELLANEOUS

5.1. Preservation of Highways.

5.1.1. Roads are built at a high cost and effective measures should be taken to ensure that they are not used except for the purpose for which they are meant. Temporary or permanent encroachments, ever-growing ribbon development, indiscriminate parking of vehicles on the road, the use of the road for "bazaars" weekly markets, local fairs, and even as store-yards and workshops, are common abuses of the highway and tend to choke it off. The public are both the offender and the sufferer.

5.1.2. "Haats" and "bazaars", that is, weekly or more frequent markets, spring up along most of the important routes. In built up areas, shops with balconies, porches, and open air sitting arrangements squeeze out the road user. Peripatetic shops on wheels compete for space with the legitimate traffic. The road

with a well-looked-after surface becomes a playground for children and an open air club for adults. To authorities (other than road authorities) these may seem to be signs of growing prosperity of the neighbourhood and "popularity" of the road. But the road becomes practically useless for traffic.

5.1.3. At the first signs of encroachment, engineers may be furious and run to the civil authorities. But there they do not get much encouragement or quick redress. The continued existence of some encroachments encourages others.

5.1.4. Damage to road property like mile and furlong stones, road signs, etc., is a common experience. Very few of the saboteurs are caught red-handed and brought to book.

5.1.5. Practical remedies have to be devised to reduce such malpractices and vandalism. There are some regulations existing almost in every State to deal with such matters, but it is pertinent to ask how far they are, or can be, enforced? Two suggestions are made here for consideration :

- (i) **Education**—Better relations should be established with the public through intensive propaganda. The public should be made to feel that the highway belongs to all of them and, therefore, should be left free for all to use. It does not belong to a few who usurp others' rights by encroaching upon it or monopolise it by making it their business headquarters.
- (ii) Highly mobile special highway police units should be set up, particularly in the vicinity of important urban areas—more as a preventive measure than as a prosecuting agency.

5.2. Highway Police.

5.2.1. The Indian Roads Congress may give special thought to the second proposal made above. Such a police force, as is suggested here, will be able to remove encroachments as soon as they begin to appear. They can educate the public to observe rules, framed for the safety of the public, and stop indiscriminate parking and other temporary misuse of the road.

5.2.2. In the discharge of their functions the police should act in close co-operation with the engineering department and should accept guidance from the latter. Highway property—land, signs, milestones and other amenities—should be the special charge of this police force. In built up areas (but outside municipal limits where land is very valuable and traffic heavy, such a

police force is likely to justify the additional expenditure by the timely detection and prevention of anti-social activities of some members of the public.

5.2.3. This police force will be the prosecuting agency where necessary, and should relieve engineers of this unpleasant task for which they are not temperamentally suited.

Pilot schemes should be started in selected areas.

5.3. Office Routine.

5.3.1. **The Statistical Awakening.**—In recent years large demands for statistical data have been coming in from all sources. Reports are demanded continuously by the higher authorities in larger and larger numbers. Lengths of roads, classification according to which authorities responsible for maintenance, classification according to surface types, bridge particulars (even about bridges which have been there since the Moghul days), all these and many other kinds of data are called for periodically. Mostly it is the sectional officer who has to bear the brunt of this statistical awakening.

5.3.2. Some people seem to think that filling in forms is easy. This may be so in certain departments where data are to be compiled from office files. But in the case of highway statistics the material lies scattered all over the country and is being constantly created or altered. Discrepancies, are therefore, bound to occur, and then it falls to the lot of the sectional officer to run about and find facts.

5.3.3. The collection of statistics should be placed on a scientific basis by devising forms in which data should be continuously maintained, which may be easy to fill, and on which information may be entered by jotting down a few figures, or by simply marks—dots, dashes, or ticks—instead of long narratives.

5.3.4. **Voluminous Clerical Work.**—It is a common experience that clerical work has increased very greatly in all offices. This increase may not be resented where that is the only work to be done. But an engineering department has to do real, tangible work. Not only have they very little time for clerical work but their working conditions are not conducive to such work which requires tables, chairs, ink stands, and typewriters. A stone under a tree may be all the furniture that an engineer on the job may be able to command writing pads, carbon papers, and copying pencils are the stationery which would suit such environments. Their use should be recognised and encouraged.

5.3.5. A sufficient number of copies of important orders or instructions meant for being passed on to subordinate offices should be issued by the office of origin where facilities generally exist for duplication. These copies would be merely endorsed and passed on without adding to unnecessary clerical work at every stage.

5.4. Periodical "Refugees".

In the interest of work the engineering staff are transferred frequently, and, very often, to out of the way places. Every such transfer inevitably means some breakages, some "left-overs", and some expense to set up afresh in a strange place. The travelling allowance rules take no account of such things. The transfer T. A. rules provide for fares for the transferee's family, as defined in the rules, and freight for luggage up to an upper limit by weight. "T. A. must not be made into a source of profit," say the rules. The net result of all this is that a transfer becomes a source of inconvenience and considerable financial loss. There is a strong case for a "rehabilitation" allowance for these periodical "refugees."

5.5. Better Public Relations.

5.5.1. In recent years some of the tortuous village streets have become highways. Where previously only a few bullock-carts plied, convoys of fast, dust-raising, and mud splashing motor vehicles pass. The villagers have been aroused from a peaceful slumber and are face to face with a nightmare. Quite a natural reaction is to curse and to pray. Such prayers and petitions for relief are received daily from the suffering inhabitants. The engineers can do a lot to mitigate the sufferings of these people in order that these new means of fast movement may be properly appreciated and better relations may prevail between the officials and the public. Roads should be properly designed within built up areas. Some suggestions are made here and recommended for adoption, particularly in such built up areas which are not big enough to have their own municipal or local organization.

- (i) Roads passing through built-up areas should be widened to 2-lanes at least.
- (ii) In such areas the whole width of the road, from kerb to kerb, should be made dust-proof.
- (iii) Intersections should be properly designed. In small localities traffic police would not be justified and traffic islands or other such simple features should be provided.

- (iv) Road signs should be put up.
- (v) Horticulture should receive special attention and groves of trees should be planted along the roads in the vicinity of towns and villages.
- (vi) Small roadside parks, with benches, should be provided. Even a few well maintained grassy plots would be appreciated.

5.5.2. Some of these amenities can be provided and maintained by the road gangs without much extra expense. This expenditure is, however, repaid manifold in the form of the goodwill earned.

6. CONCLUSION

6.1. The object of this Paper is to emphasise the need for re-organising properly the Public Works Department and its activities. This need for organisation has always been realised and since engineers by their training and profession have to be methodical, the Public Works Department in every State **should be** highly and well organized. But the times are out of joint and the organization requires a little shaking up. New ideas to suit new circumstances have to be discussed and adopted from time to time. The conditions under which men live and work have become difficult—extremely so—of late. Accommodation, food supplies, construction materials, in short everything is difficult to obtain through ordinary trade channels. Since a contractor is not handicapped by any departmental rules, he can still get things done. The department has, however, to pay a heavy price for his services.

6.2. Every State should have central stores for office equipment, and libraries of reference books, and should publish (or republish) codes, specifications, and manuals which have become things of the past, and are no longer available. Materials for use in emergencies should be stocked at strategic points. Efficient arrangements should be made for the maintenance of surveying and mathematical instruments, tools and plant, and vehicles. The engineering staff should have to go through special training courses in the maintenance of equipment.

6.3. A nucleus staff should be trained for direct labour work so that the contractor's rates may be kept within limits.

6.4. Cumbersome methods of office work should be overhauled.

RESEARCH PUBLICATION

An Examination of Black-Top Surface Dressings laid for Field Tests in 1945 on the Bombay-Delhi Road, Mile 736.*

BY

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CONTENTS

	Page
1. Introduction	... 225
2. Field Tests on the Bombay-Delhi Road, mile 736 - description and presumptions	... 227
2.1. Layout	... 227
2.2. Binders and Primers	... 229
3. Some Observations on surface dressings	... 231
4. Investigations	... 231
4.1. Samples	... 231
Photographs	... 232
4.2. Depth of Penetration	... 238
4.3. Content of Binder	... 238
5. Results	... 239
5.1. Penetration of Binder	... 239
5.2. Content of Binder	... 242
6. Evolution	... 243
6.1. Content of Binder	... 243
6.2. With or without Primer	... 244
7. Conclusion	... 245
7.1. Specifications used	... 245
7.2. Primers	... 245

SYNOPSIS

Light surface dressings for roads were tested at the Calcutta Road Test Track during 1939-41. As a result of this study modified specifications were laid out in 1945 for field tests on a main road near Agra, with the main object of investigating the need for and the utility of primers. Samples were cut out of the crust after the road had been six years under traffic. These were analysed in the Central Road Research Institute, Okhla, Delhi, for their residual bitumen content. This report discusses the specifications and the condition of the road after six years. It concludes that primers might be useful with bitumen but not with tar. As the specifications adopted were considered too high, further tests with reduced quantities of binders and primers are suggested.

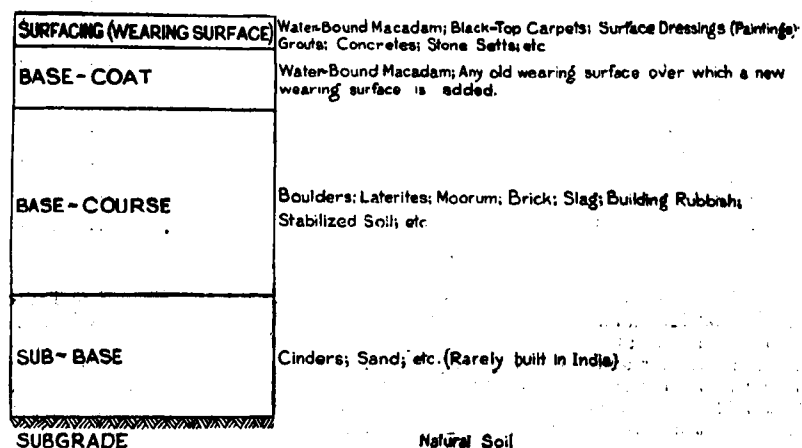
* Report to the Test Track Committee of the Indian Roads Congress.

GLOSSARY OF HIGHWAY TERMS

As defined by the

INDIAN ROADS CONGRESS

- Base-Coat** An intermediate coat between the base course and the wearing surface.
- Base Course** That part of the construction resting upon, and through which the load is transmitted to, the sub-base or, in the absence of a sub-base, to the sub-grade or supporting soil.
- Binder** A material used for the purpose of uniting mineral particles and assisting cohesion.
- Bituminous** Pertaining to, or characterized by the presence of, tar or bitumen.
- Carpets** A type of surfacing formed with a binder and an aggregate, applied as a complete thin layer and generally described after the type of binder used, such as, asphalt carpet, tar carpet, etc.
- Grouting** The act of pouring a binder in a liquid state on to a partially consolidated surface or a layer of a road metal, so that the binder penetrates the interstices, the consolidation then being completed with the addition of sand or fine stone.



THE ROAD STRUCTURE

Fig. 1 (As defined in the I. R. C. Specifications)

- Painting** (Surface Painting) (Surface Dressing) The wearing coat resulting from the application to a road surface of a film of bituminous or other binding agent on which has been spread a layer of chippings or other fine mineral aggregates.
- Primer** A liquid bituminous road material of low viscosity which, on application to a non-bituminous surface, is completely absorbed. Its purpose is to waterproof the existing surface and prepare it to serve as a base for the construction of a bituminous surface dressing or carpeting.
- Sub-Base** A layer of material placed between the foundation or base course and the formation, usually for a special purpose, such as
- (a) drainage,
 - (b) replacing undesirable soil,
 - (c) increasing the area of the soil over which the load of the pavement is distributed,
 - (d) decreasing the cracking of the pavement.
- Subgrade** The earth foundation as prepared and shaped to receive the actual construction forming the carriage-way.
- Surfacing** (Wearing Surface) A wearing surface laid upon a base-coat (*q. v.*) in the form of a continuous surface layer and without open joints.
- Surface Dressing** Same as Painting (*q. v.*).

1. INTRODUCTION

1.1. The significance of surface-dressed road surfaces on highways in India.

To improve road crusts—to make them strong enough to withstand the strain of the ever growing and varied traffic they carry, to mitigate dust, and to decrease the possibility of accidents—these crusts have to be covered with some sort of wearing surface or surfacing. This surfacing increases the cost of a road considerably. Many kinds of surfacings are possible—they vary from simple surface dressings with bituminous materials (paintings) to compact, scientifically developed surfacings to bituminous carpets or grouts, concretes, etc.

The cheapest specification, which may not necessarily be the most economical, would probably be provided by a surface dressing or painting. In the usual case in India this surfacing would be provided by spraying a bituminous product over stone chips spread over a well consolidated and even waterbound macadam road surface, the whole being finished with a layer of grit.

The terms, surface dressing, painting, wearing surface or surfacing, base coat, etc., used in this Report are illustrated in Figure 1, and definitions are given of the more common terms as prescribed in the draft Indian Highway Glossary of the Indian Roads Congress.

The decision on ~~what~~ kind of surfacing should be laid on any part of a road depends on the administrative or other classification of the road, the kind of traffic it carries, the local weather conditions, and, not least, the funds that can be made available for its improvement.

The problem facing India is to decide on what kind of surfacing should be given to the country's roads to improve their condition to the greatest possible extent at the minimum cost. Factors to be considered are, that a very great mileage of earth roads will have to be converted into all-weather roads; that, for a considerable time, traffic on the great majority of India's roads will remain average or light relative to the traffic in more developed countries; and that the funds available for road development are very limited.

The surfaced mileage in the whole of India is a small proportion of the total existing road mileage. To mitigate this kind of under-development with the very limited funds available, that is, to increase the mileage of surfaced roads or even to make the more heavily trafficked roads dust-free is a difficult problem. Experience in India has shown that under all kinds of middle and light traffic surface dressings are the cheapest. The following pages therefore examine and discuss a design for this method of construction.

All other surfacings, black-topped carpetings, grouts, concrete surfacings, etc., that are being used extensively in the Western countries are very expensive and suitable in India for only the very heavily trafficked roads. At present the funds available for road development do not even permit of extensive surface improvement of the large mileage of waterbound macadam surfaced roads. Therefore, we shall have to be content at present with limiting this improvement by providing a surface which gives a relatively efficient service with low initial costs at the expense of some additional cost of maintenance.

1.2. The Test Track Committee of the Indian Roads Congress.

Fully aware of local conditions, the Indian Roads Congress has been studying this problem for many years. The construction of a Road Test Track at Alipore, Calcutta, in 1938 gave an opportunity for accelerated testing of surfacings and the first series of tests in the three-year period 1939 to 1941 were devoted almost exclusively to testing light surface dressings, the subject discussed in this report. After studying the results of these tests, the Test Track Committee recommended in 1943 that field tests according to modified specifications should be carried out on the Delhi-Agra road and elsewhere.

Mile 736 of the road (near Agra) was selected for one of these field tests and 12 sections were laid in 1945 as described in the following paragraphs. These were inspected every year on behalf of the Committee and the Committee itself met at the site on the 9th and 10th April 1951 to discuss the results to date. The three types of binders used in the field tests represented the same types as were used in the tests on the Alipore Test Track in 1941 without any variations in the quantities of the binders used. The coarse aggregate consisted of Delhi and Jhansi (Bharatkup) stones.

The Committee found that the condition of the surface dressings was reasonably good even after six years' service. At this meeting it was decided, on the suggestion of the Director, Central Road Research Institute—a member of the Committee—to request the Central Road Research Institute to take out samples of the crust from all the sections and analyse them for their residual binder content and other characteristics in order to investigate the need for and the utility of a primer.

2. FIELD TESTS ON THE BOMBAY-DELHI ROAD, MILE 736—DESCRIPTION AND PRESUMPTIONS

2.1. Layout.

In May 1945 a length of 5 furlongs and 305 ft of the Bombay-Delhi Road from mile 735-1-330 to 735-6-635 was surface treated. The traffic which moves over this part of the Bombay-Delhi Road is from average to light in intensity, i.e., about 465 tons a day including lorries, cars, and bullock-carts.

The whole length was divided into two parts each with the same layout but the first part was given a base coat of Delhi stone (75 per cent $1\frac{1}{2}$ in. gauge and 25 per cent $\frac{3}{4}$ in. gauge) and the second part a base coat of Bharatkup stone of the same sizes. Table 1 gives construction data for each of the field-test lengths.

AGRA PROVINCIAL DIVISION.
Control Test in Mile 736 of Bombay—Delhi Road.
M. 735-6-535.

Table 1.
Mile 735-1-330.

No. of Experiment Section/Sample	1	2	3	4	5	6	7	8	9	10	11	12
Date of Completion	12-5-45	13-5-45	20-5-45	21-5-45	16-5-45	17-5-45	14-5-45	15-5-45	23-5-45	23-5-45	19-5-45	19-5-45.
Date of Start	12-5-45	13-5-45	20-5-45	21-5-45	16-5-45	17-5-45	13-5-45	15-5-45	22-5-45	23-5-45	18-5-45	19-5-45.
Cost of % cu. ft. in Rs	37/4/-	36/-	38/12/-	37/4/-	39/8/-	38/-	40/4/-	39/1/-	41/10/-	40/5/-	42/7/-	40/12/-
Quantity of Grit in cu. ft. % sq. ft.	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25
Grit Quality and Gauge	←	←	←	←	←	←	←	←	←	←	←	←
Cold Primer lb per % sq. ft.	22	—	23	—	23	—	23	—	23	—	23	—
Dressing Material lb per % sq. ft.	TARS 53	56	BITUMEN 53	BITUMEN 55	BITUMEN 53	BITUMEN 55	TARS 53	56	BITUMEN 53	55	BITUMEN 53	55
Top Coat Quality and Gauge	←	←	←	←	←	←	←	←	←	←	←	←
Length ft.	225	275	300	275	275	275	300	360	330	330	330	330

The whole experimental length was surface dressed or painted in the following manner:—

The first part was divided into six sections. The surfaces were treated with a normal surface dressing and a cold primer in sections Nos. 1, 3 and 5, and sections Nos. 2, 4, and 6 were without primer. In all the sections Delhi stone chips (two-thirds, 5/8 in. and one-third, 1/2 in.) were used as aggregate.

The second part was also divided into six sections. Cold primer and binder were applied in the same way as mentioned above. In all of these six sections Bharatkup stone chips were used in the same proportions and sizes as Delhi stone in the first part.

Sections 1, 2, 7, and 8 were treated with tar and a tar primer, and the remaining sections with two different bitumen with the same penetration and a corresponding primer.

The quantity of cold primer used in every case was 22 to 23 lb per 100 sq. ft. The quantity of the aggregate used was 5.25 cu. ft. per 100 sq. ft. throughout. The quantity of tar and bitumen varied from 53 to 56 lb per 100 sq. ft.

More binder, 2 to 3 lb per 100 sq. ft., was used in the sections which were not primed.

Particulars of sections 1 to 6 from which samples were taken are given in Table 2.

2.2. Binders and Primers.

The binder used was:—

Sections 1 and 2, Tar No. 3; Sections 3 and 4, Bitumen (Socony) penetration 80/100; Sections 5 and 6, Bitumen (Mexphalt) penetration 80/100. No particulars of the nature of the primers used were recorded in the specifications at the time the test lengths were laid in 1945, but presumably the properties were the same as those of the material used on the Calcutta Test Track during the 1939-41 period.

On the basis of information now supplied by the firms the primer used on section 3 in combination with Bitumen (Socony) was similar to the cut-back specified today as SC-1 which contained about 50 per cent bitumen 80/100 and 50 per cent kerosene and diesel oils. The primer used on section 5 in combination with Bitumen (Mexphalt) was similarly a cut-back and contained about 30 per cent bitumen 80/100 and 70 per cent furnace oil. The primer used on section 1 was tar primer. No. 2 which is a liquid tar mixture,

Sample	Date of start	Primer		Binder		Condition *	
		Quantity	Type	Quantity	Type	28-11-49	15-11-50
1	12-5-45	22 lb % sq. ft.	Tar Primer No. 2	53 lb % sq. ft.	Tar No. 3	patchy	patchy
2	13	—	—	56	Do.	Do.	Do.
3	20	23	50% Bitumen (Socony) Pen. 80/100; 50% Kerosene + Diesel-oil.	53	Bitumen (Socony) Pen. 80/100.	—	Do.
4	21	—	—	55	Do.	—	Do.
5	16	23	30% Bitumen (Mexhalt) Pen. 80/100 70% Furnace-oil	55	Bitumen (Mexphalt) Pen. 80/100.	—	Do.
6	17	—	—	53	Do.	—	Do.

* Conditions stated by the Executive Engineer, Provincial Division, Agra.

3. SOME OBSERVATIONS ON SURFACE DRESSINGS

The appearance of the test surfaces did not show any differences between themselves on observation of the sections laid with the same binder with or without primer. As a matter of fact, there was very little visual difference between the three groups of surfaces. After six years under normal road traffic it could not be said merely from appearance whether it would be advantageous to use primers or not. This could only be found out by investigating the condition of the body of the different surface dressings.

Before going into this matter, an important principle might be mentioned. A surface dressing, with and without primer, laid in one or more layers, has some peculiarities as compared with a normal compact bituminous or tar carpet. As against a uniformly and homogeneously constructed compact crust, a surface dressing is irregular and heterogeneous; that is to say, there might be great differences in the distribution of the binder and the fine mineral material in each small area of a surface dressing and no regularity and uniformity might be found anywhere.

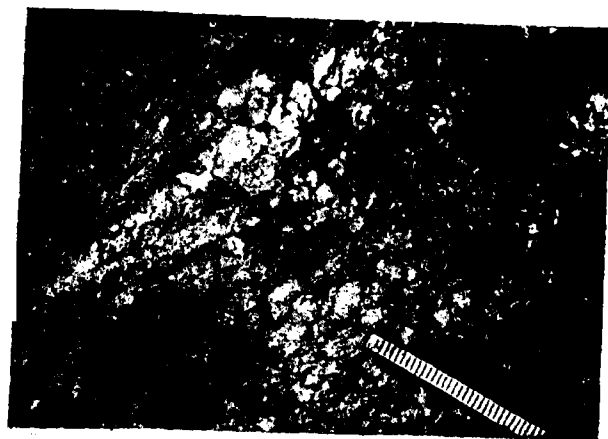
In appearance the surfacing might seem to be regular but in reality the engineer is never sure which part of the surface has received surplus binder and therefore will be liable to get soft under traffic or which part will become dry and get rigid sooner than the rest of the surface. These characteristic properties, these irregularities of the surface-dressed road, created a problem that had to be solved before the ultimate behaviour of different test sections could be estimated.

4. INVESTIGATIONS

4.1. Samples.

The test surfaces were laid in exactly the same way for the two different types of stone. As the main problem was to examine the behaviour of the binder, with or without primer, and not the behaviour of the two types of stone with different binders, only samples of the surface where Delhi stone was used were taken out. Results with the same binders when used with other stones are expected to be essentially similar.

Samples, about one square foot in size, had to be cut from the road up to a depth where no binder was present, that is to say, it was essential to excavate the road crust to an appreciable thickness. These samples had to be brought unbroken to the Central Road Research Institute for further investigation. To

**Sample 1**

Binder : Tar No. 3

Primer : Tar Primer No. 2

Photo 1 (above) — shows the depth of penetration which is 40-50 mm.

Photo 7 (centre)— showing the underside, limit of penetration of sample 1.

Photo 13 (bottom)— Surface of the road, sample 1.

**Sample 2**

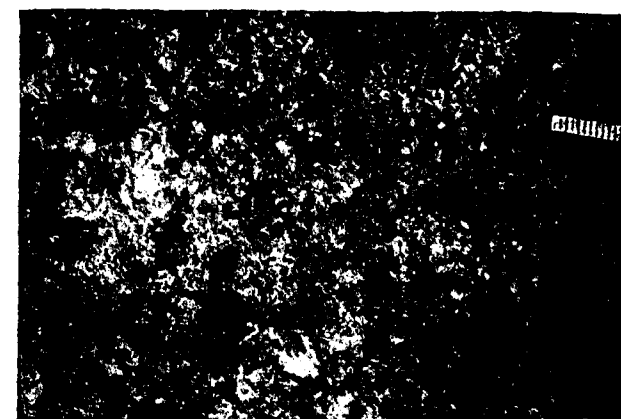
Binder : Tar No. 3

Primer : Nil

Photo 2 (above)—shows the depth of penetration which is 30-40 mm.

Photo 8 (centre)—showing the underside, limit of penetration of sample 2.

Photo 14 (bottom)—Surface of the road, sample 2.



**Sample 3**

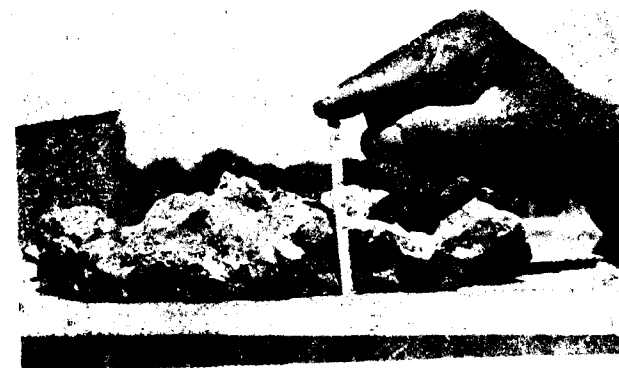
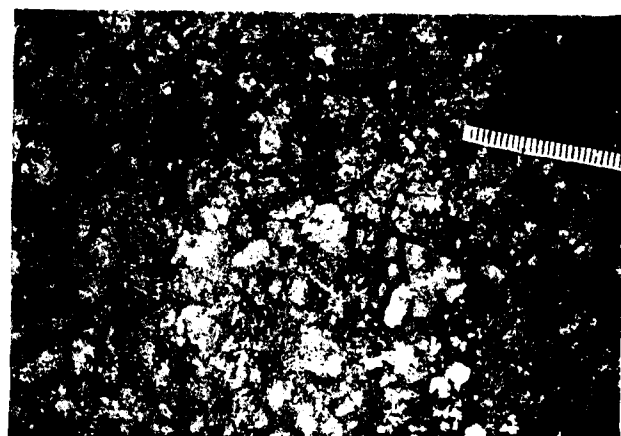
Binder: Bitumen (Socony)
(Pen. 80/100)

Primer: 50% Bitumen (Soc.)
Pen. 80/100, 50% Kerosene
+ Diesel oil.

Photo 3 (above)—shows the
depth of penetration which is
20-30 mm.

Photo 9 (centre)—showing the
underside, limit of penetra-
tion of sample 3.

Photo 15 (bottom)—Surface of
the road, sample 3.

**Sample 4**

Binder: Bitumen (Socony)
(Pen. 80/100)

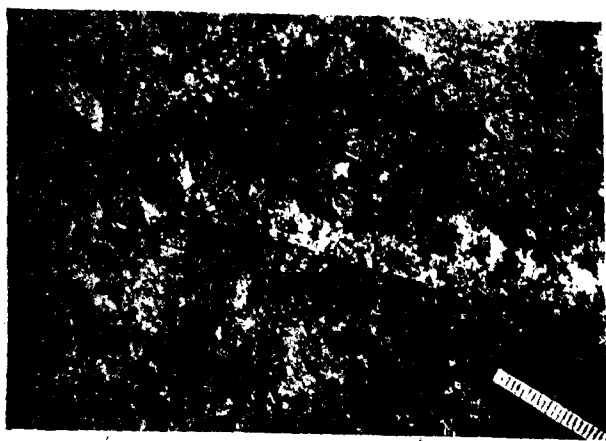
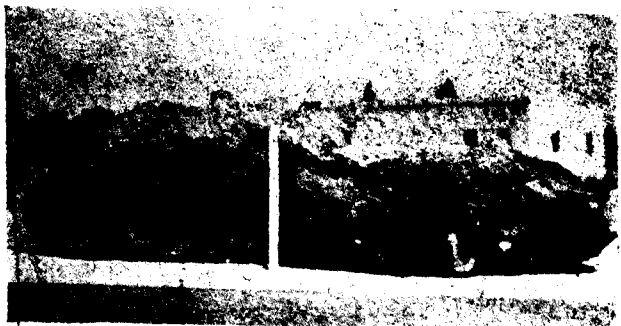
Primer: Nil

Photo 4 (above)—shows the
depth of penetration which is
10-25 mm.

Photo 10 (centre)—showing the
underside, limit of penetra-
tion of sample 4.

Photo 16 (bottom)—Surface of
the road, sample 4.



**Sample 5**

Binder: Bitumen (Mexphalt)
(Pen. 80/100)

Primer: 30% Bitumen (Mexph.)
Pen. 80 100, 70% Furnace oil.

Photo 5 (above)—shows the
depth of penetration which is
45-65 mm.

Photo 11 (centre)—showing the
underside, limit of penetra-
tion of sample 5.

Photo 17 (bottom)—Surface of
the road, sample 5.

**Sample 6**

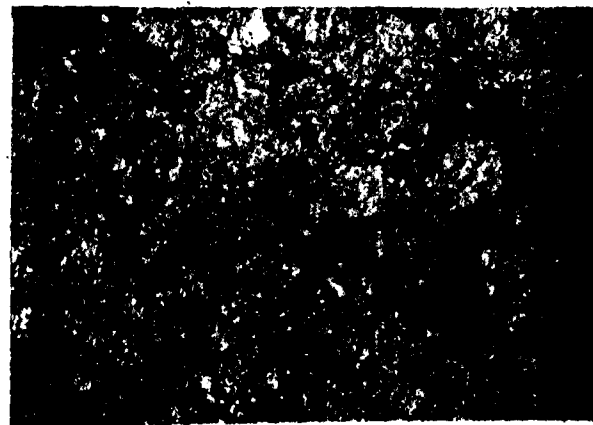
Binder: Bitumen (Mexphalt)
(Pen. 80/100).

Primer: Nil

Photo 6 (above)—shows the
depth of penetration which is
15-25 mm.

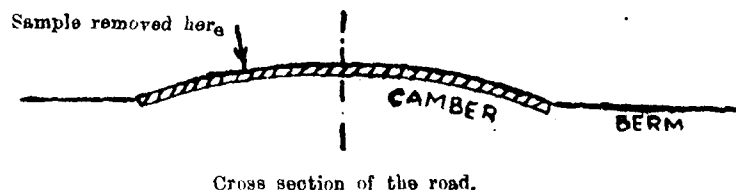
▲ Photo 12 (centre)—showing the
underside, limit of penetra-
tion of sample 6.

Photo 18 (bottom)—Surface of
the road, sample 6.



avoid having to work under an April sun and to avoid the breakage of samples if the work were done on a dark night, the excavation had to be done on a full-moon night and was carried out between the 20th and the 21st April 1951.

From the crown of a road surface some free binder could possibly flow down towards the sides on account of the camber. Near the flanks there is the possibility that the binder might flow into the berm or stagnate near the edge of the surface. A sample taken at either of these locations would probably not contain the average quantity of binder originally provided according to the specification adopted. To reduce the probable variations on this account to a minimum, the samples were taken from parts of the surface near the quarter line of the surfaced width, which appeared to have gradually worn themselves to a more or less average content of binder and in which, after the original placing, no further redistribution of binder was likely to have taken place, see Fig.



4.2. Depth of Penetration.

The effect of the use of a primer can be observed by measuring the depth of penetration of the binder in the samples.

4.3. Content of Binder.

The content of binder after six years' use in the road can be found by extracting the binder in the laboratory.

The results obtained in these extractions are to be considered carefully because the binder was not distributed in the aggregate in any specified proportion by volume or by weight as in a premix. It was distributed by spraying over the previously compacted aggregate (waterbound macadam) in a specified quantity by weight per 100 sq. ft. of surface area. As the spraying operation is not susceptible of very accurate control, many variations of the binder content as derived from samples of relatively small areas might be expected.

5. RESULTS

5.1. Penetration of Binder.

The depth of penetration of the binder into the road surface could be clearly seen in the samples because the oily particles of the binder penetrated more or less to an average depth in each sample and it was easily possible to measure the depth even after six years. Photographs 1 to 6 show the penetration in the six different samples and photographs 7 to 12 show the appearance of the material at the limits of the depth of penetration. The penetration could be easily traced by the brown colour of the road material caused by the bituminous oil which had soaked into it. The figures of penetration were found to be between 10 and 65 mm and are given for each sample in Tables 3 and 4.

5.1.1. Tar Treated Sections (Samples 1 and 2).

The depth of penetration of tar (Tar No. 3 as a binder or low Viscosity Tar as a primer) is influenced, firstly, by its higher specific gravity as compared with the average bitumen-based binder (this makes for easier and deeper sinking into the base-coat) and secondly, by its greater fluidity—or lower viscosity—at the normal temperature of use. These temperatures appear to have been relatively high for the tars found in the samples examined because of the presence of small quantities of an organic filler insoluble in carbon bisulphide, which would comply with authorised practice now-a-days.

It is, therefore, only natural that there should be relatively deep penetration (45 mm in sample 1 and 35 mm in sample 2, on the average) in these samples. Also the fact that tar and its oils become very thin and fluid in the normal summer conditions in India accounts for the small difference in penetration in the samples with and without a primer.

Because of its higher specific gravity the volume of tar is about 10 per cent less than that of bitumen. This fact should not be overlooked because tar is added normally in the same way as bitumen, i.e., by weight whether it is a premix or a surface dressing.

5.1.2. Bitumen Treated Sections (Samples 3, 4, 5 & 6).

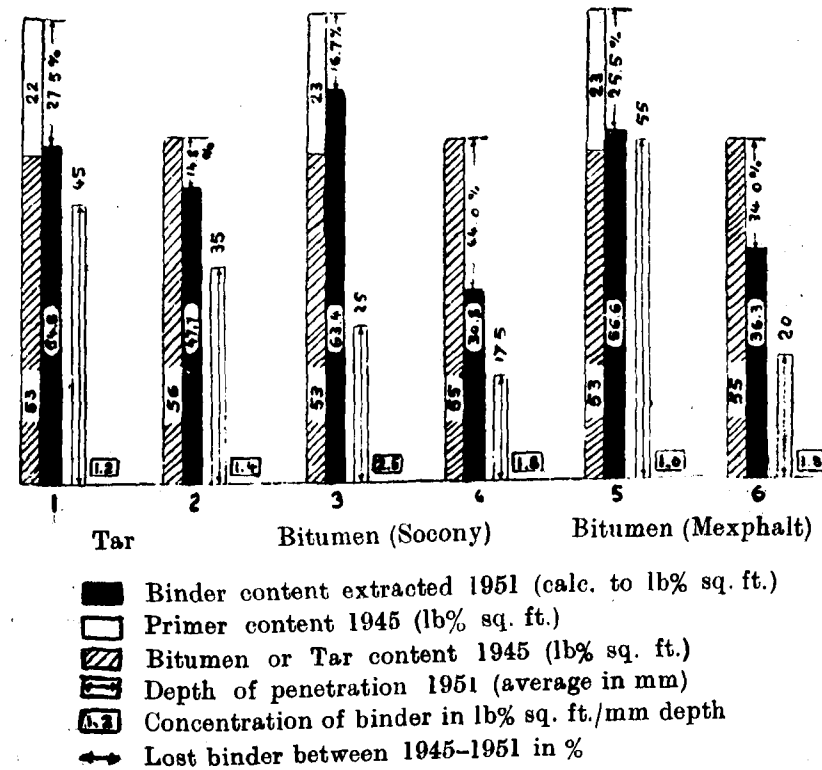
With bitumen, which has a tendency to stay near the surface or to climb to the top of the road under the influence of the sun's heat, different results are obtained. Those test surfaces that were laid without the use of a primer showed a very small depth of penetration (17.5 mm in sample 4 and 20 mm in sample 6 on the

Sample	Binder	Binder + Primer 1945	Extracted Binder content on 20- 4-51	Lost Binder 1945-1951	Penetration of Binder after six yrs.	Concentration of binder
		lb% sq. ft.	lb % sq. ft.	%	mm	lb% sq. ft. mm
1	T+Pr.	75	54.5	27.5	40 - 50	1.2
2	T	56	47.7	14.8	30 - 40	1.4
3	So+Pr. 50/50	76	63.4	16.7	20 - 30	2.5
4	So	55	30.8	44.0	10 - 25	1.8
5	Me+Pr. 30/70	76	56.6	25.5	45 - 65	1.0
6	Me	55	36.3	34.0	15 - 25	1.8

ZIPKES ON

T = Tar; So = Bitumen (Socony) ; Me = Bitumen (Mexphalt) ; Pr. 50/50 ; Pr. 30 70 = the Primers corresponding to Table 2.

Table 4



average). It seems that most of the binder remains at or just under the surface and the result is a very rich and fat surface. While such a surface, because of its density, protects the base courses against infiltration of water, it is liable to be more easily damaged on account of its thinness.

When a primer is used this tendency of the bitumen binder to remain at the top would not entirely disappear, but its effects would be less marked. In both the samples containing bituminous binder, the primer used had a high content of liquid oil (50 per cent for sample 3 and 70 per cent for sample 5) which penetrated easily into the wearing coat owing to its low viscosity (25 mm in sample 3 and 55 mm in sample 5 on the average).

The figures in Tables 3 and 4 and Photographs 1 to 6 clearly show the difference of penetration of the two types of binder used, namely, tar and bitumen, and the effect on the penetration of using a primer.

5.2. Content of Binder.

Relatively big pieces of the surface dressing were taken to extract the binder. The content of binder when obtained had then to be correlated not only with the surface area of the selected pieces but with the average area over the whole thickness of the sample. This had to be done because of the typical characteristic properties of a surface dressed road as mentioned in para. 3.

The results have been compiled in Tables 3 and 4. Apart from the present binder content, the binder lost during six years of use is noted as a percentage. Where it is not specially mentioned to the contrary, this means percentage of the total binder and primer taken together. The Tables also give the concentration of binder in pounds per 100 sq. ft. surface per mm depth of penetration.

5.2.1. Tar.

It seems that in the case of tar (samples 1 and 2) the quantity of binder lost increased with the depth of penetration and the fluidity of the black material. This might have happened because of the comparatively large amount of oil used which could not remain in the surface dressing for a long period. The presence of this additional oil appears to have helped the naturally included tar-oils to evaporate quicker than was the case when no primer was used (sample 1 against sample 2).

5.2.2. Bitumen.

Taking the same facts in the case of the two types of bitumen and primer used, the results are the reverse of those observed in the case of tar. The percentage loss of binder on the primed surfaces is much less than that on the corresponding unprimed surfaces (see Tables 3 and 4).

Considering the properties of bitumen, it seems that the climbing tendency of ordinary bitumen already referred to was offset to some extent by the penetration effects of the oil in the primer. The oil appears to have carried the bitumen down into the base coat and distribute it better. After the evaporation of the oil the bitumen stayed put and there was no further loss during the period of the field test.

5.2.3. Observations.

The results appear to indicate that the addition of a primer has a totally different effect when considering the loss of binder content of tars and bitumen respectively. The following factors, however, are relevant:—

Because of the difficulties pointed out in arriving at the exact average of the binder content, the results obtained from the

samples cannot be accepted as uniformly applicable to the whole surface of the corresponding test section. In other words, although the binder content of a sample can be found fairly accurately, the result cannot apply to the whole road surface with any degree of certainty, as the sample might not be exactly representative.

As mentioned above (para. 5.1.1 and 5.1.2) the penetration of binder in the six different treatments seems to be clear in comparison with the effects of the binder used. So, an attempt was made to correlate these results with the present binder content and the quantity of the binder lost in the course of the past six years. These correlations can be taken in a general way only on account of the particular properties of surface dressings.

6. EVOLUTION

The question now is to find what should be the normal content of binder for the kind of surface treatment considered and especially to determine when an ordinary surface dressing should be combined with the use of a primer. Furthermore, it is to be decided if the use of a primer will be of any advantage at all for a surface dressed road.

The Test Track Subcommittee found when they inspected the field tests in 1951 that, even after six years under traffic, all six surfaces were good. This seems to be due to the large amount of binder used.

6.1. Content of Binder.

6.1.1. Bitumen.

Comparing the instructions of firms like Shalimar Tar Products or Burmah-Shell who supply binder materials and who normally are interested in serving the profession in the best way, we find on page 29 of the Burmah-Shell publication* that the firm recommends a binder content of 40 lb per 100 sq. ft. with a wastage of 2½ per cent. This quantity probably corresponds to present normal practice but it might still be possible to save some percentage of binder.

On the other hand, there is no doubt that the special and typical user of most roads in India, viz., the bullock-cart whose steel-tyred wheels are especially hard on black-topped road surfaces, would require a surface where a little more binder had been provided than would otherwise be required. On this con-

* "Handbook of Bituminous Road Construction" published by M/S. Burmah-Shell.

sideration it may not be possible to reduce to any great extent the quantities recommended by the supplying firms.

6.1.2. Tar.

Similarly, when tar is used instead of bitumen, some reduction in the binder content may be feasible in spite of the smaller volume of tar. In this case, however, the percentage of reduction might be found to be less than for bitumen.

6.1.3. General Deductions.

From the discussion in the foregoing paragraphs and having regard to relatively large quantities of binder still left in the surface dressings after six years' service, it would seem that the specifications used in the tests were too high and especially so when a primer was used. The traffic on the road was admittedly light but not less than that on the average black-topped road. The general conclusion is that all six surfaces were too rich in binder content for an average road of the type tested. Moreover, the specifications were too expensive.

The road surface dressing is no doubt of a good quality and will last for some more years. On the other hand, the rich mixes employed might have led to patches on the surface (compare the statements in Table 1) which have not only disturbed the uniformity of the texture but are likely causes of dangerous slipperiness.

The correct binder content varies in very narrow limits between a too poor and a too rich specification to give a clear optimum to cover all cases. Much will depend on the special character and locality of the road, the average and extreme temperatures, the aggregates used, the kind of traffic, and the nature of the binder in question - in short, on what are called the local conditions. Photographs Nos. 13 to 18 show the texture of the surface of the six samples. There is room for further research on this question and no conclusion is therefore attempted in this report.

6.2. With or Without Primer.

The question whether a primer should be used or not is completely independent of the fact whether the surface dressing has to be done in one, two, or more layers.

6.2.1. Tar.

Due to the nature of tar it does not seem necessary to use a primer because this material is able to penetrate deeply enough by itself. The use of a primer would only increase the cost without helping very much the purpose for which a primer is used. The samples themselves prove that no appreciable advantage appears to have been gained by using a primer with tar.

6.2.2. Bitumen.

On the other hand, in the case of bitumen, it will be of advantage to ensure better penetration of the binder with the help of a primer. In the conditions prevailing under the 1945-51 field tests a remarkable reduction in the bitumen content of the binder was observed when a primer was not used. The exact specifications to be adopted in any particular case will, of course, depend on the special conditions, traffic, climate etc., prevailing at the site but the addition of a primer would appear to be indicated in most cases. Further research on this is, however, necessary.

7. CONCLUSION

7.1. Specifications Used.

The specifications used in the test surfaces built in 1945 were too high and, therefore, it was not possible to get clear results by merely looking at the surfaces.

From a study of the result of investigations into the residual binder content of the surface dressings after they had been under traffic for six years it seems probable that at least an equally good surface dressing would have remained at the end of the six year period had a smaller quantity of binder (both bitumen and tar) been used both when a primer was or was not used.

7.2. Primers.

7.2.1. Tar.

With tar a primer should not be necessary.

7.2.2. Bitumen.

The combination of a bitumen binder and a bitumen primer is obviously of advantage as compared with a bitumen without a primer. By using a primer it should be possible to save bitumen by getting a normally deeper penetration than would be obtained without a primer.

INFORMATION SERVICE

(i) CEMENT-AGGREGATE REACTION IN CONCRETE.

(A SURVEY OF RECENT LITERATURE ON THE SUBJECT).

By

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BANERJI, M.Sc.

1. INTRODUCTION

1.1. Deterioration of concrete in service is divisible into four distinct types with respect to their causes (9), viz., deterioration due to

- (a) gradual or normal weathering,
- (b) accelerated weathering,
- (c) chemical attack from outside, and lastly,
- (d) abnormal expansion, a question that has, during the last decade, aroused considerable interest among scientists in America and Australia. Chemical reaction between the aggregates and the cement in concrete is the main cause of this abnormal expansion. Many instances of failure in concrete structures brought about by such unfavourable reactions have been reported.

1.2. The purpose of this note is to give a brief review of the existing facts known about this cement-aggregate reaction and to advocate the necessity of conducting research on this problem in view of the large number of dams and other concrete structures proposed to be built in this country.

2. BRADLEY PAVEMENT FAILURE

2.1. In 1938, a series of concrete pavement failures in the form of expansion, resulting in buckling at the expansion joints and severe cracking throughout the structure were noticed in the western states of America (21). The first failure which attracted notice was a section of concrete pavement north of the town of Bradley, California. The Californian Division of Highways conducted systematic research to determine the causes of such failures and to find ways of preventing them. The results of the investigation were published in 1940 by Stanton (21). In the course of the investigation, Stanton observed that failure had

taken place predominantly in those portions where local fine aggregate, "Oro Fino", had been used. It was also observed that the same fine aggregate when used with a different brand of cement had behaved in a perfectly normal manner. At certain places Stanton came across structures which had been built with aggregates from a different source and the same brand of cement that had been used in the construction of the Bradley pavements. On a close examination of these structures no sign of any abnormal expansion was observed.

2.2. These observations led to the belief that chemical action between certain ingredients in the aggregates and the cement used were responsible for the failures. Chemical analysis of various brands of cement revealed that not all cements contain the same amount of free alkali in the form of Sodium Oxide and Potassium Oxide. The cement used on the Bradley job contained 1.14 per cent of alkali as Sodium Oxide. Experiments conducted with cement containing only 0.5 per cent of the total alkali as Sodium Oxide and "Oro Fino" sand showed no expansion at all. Alkali in the cement was thus supposed to be one of the probable cause of the excessive expansions.

2.3. However, all aggregates do not cause severe expansion with a high-alkali cement. It was observed that aggregates rich in opal, shale and chert were highly reactive in this respect. Experiments with opaline shales and cherts revealed that these minerals were readily attacked by caustic alkalis. Consequently it was suggested that a basic factor responsible for the failure of the structures was the chemical reaction between the alkalis released during the hydration of the cement used and the mineral constituents, e.g., opal, shale, phyllite, etc., of the aggregates.

2.4. The aggregates containing the above-mentioned minerals were considered as deleteriously reactive, while the reaction itself was called "Cement-Aggregate Reaction".

2.5. Research conducted by Conrow revealed, that in certain cases even low alkali, cements were capable of producing marked expansion when used with reactive aggregates (3). Similar expansion has also been observed by those who have taken up this problem in Australia (24).

2.6. Conrow, however, held the opinion that the predominant reactive ingredient in the cement-aggregate reaction was calcium-hydroxide and that sodium and potassium oxides merely acted as catalysts.

3. CRITERIA OF CEMENT-AGGREGATE REACTION

3.1. Only experienced petrographers can determine whether or not a specific instance of deterioration is mainly due to cement-aggregate reaction. The adequacy of the sample of concrete, the character of alteration products, and the extent to which the extraneous substances have developed, play an important part in the successful recognition of the cement-aggregate reaction.

3.2. **Siliceous Gels:**—Gel formation takes place between the minerals of the aggregate and the alkali in the cement and is one of the most important criteria of this reaction (12). These gels might be watery, viscous, or brittle, or all these types in close association. They fill the voids in the cement paste and are also present as exudations on the external surfaces. Some of these gels being open to the atmosphere, get carbonated. Sometimes these gels are visible to the unaided eye but mostly they are visible only under a petrographic microscope. Occasionally the slide prepared for microscopical examination does not include a portion of the concrete containing silica gels or sometimes they get destroyed while preparing thin slides. Either case may lead to a wrong conclusion. It is, therefore, safer to prepare flat surfaces of the concrete by fine grinding. They can then be examined for gel bodies with a hand lense or a microscope and the slides prepared accordingly.

3.3. The gels encountered in cement concrete consist essentially of alkali and silica. A typical chemical composition is given in Table I.

Table I. Chemical analysis of beads from "pop-outs"
(From A. S. T. M. Proc. Vol. 47, 1947, p. 988).

Constituents	%	Constituents	%
SiO ₂	50.00	Loss on ignition	11.04
R ₂ O ₃	0.50	Na ₂ O	24.67
CaO	2.75	K ₂ O	8.16
MgO	0.15	Cl	Traces
SO ₃	2.59		

3.4. Another gel from the interior of the concrete gives as much as 81.9 per cent of silica and 6.0 per cent of alkali. However, the chemical difference seems to be only quantitative and not qualitative.

3.5. The refractive index of siliceous gels is very low and varies with the water content. The average range is between 1.46 and 1.49. The gels give a cloudy appearance under a microscope probably owing to the presence of fine inclusions.

3.6. **Reaction Rims:**—Another criterion referred to by McConnell (12) is the presence of reaction rims. Quoting McConnell, "the occurrence of alteration rims on aggregate grains of certain rock types, when properly interpreted, may be diagnostic of cement-aggregate reaction". This sounds plausible but almost similar rims are also found in certain rocks owing to the weathering of ferromagnesian mineral in them, and therefore it is necessary to show, while examining these rims for the reaction, that no such rims existed in the representative sample of the un-used aggregates. However, from various considerations mentioned below, it may be possible to decide easily the origin of the rims.

- The rims may be significantly different in character which can only be decided by a very experienced petrographer.
- Only certain types of minerals in nature are deleteriously affected by cement alkalis.
- Gel deposits are usually found close to the aggregate grains showing altered rims and, thereby, establishing the reaction.

3.7. The peripheral zone of aggregate particles gets weakened by interaction with cement alkalis and the void thus caused usually gets filled with silicious gels. A thin section of such a rock, when examined under a petrographic microscope, shows a narrow rim separated from the main body and this rim usually has a higher transparency than the interior portion of the rock particles. This has been attributed to two probable causes: the removal of some rock particles by dissolution, and the increase in optical homogeneity as a result of the penetration of alkali silica gels inside the rock. These reaction rims have been noticed more prominently on glassy andesites and phyllites. It has been observed that these reaction rims and gel deposits often occur in close proximity.

3.8. There are, however, certain other phenomena which occur in concrete affected by cement-aggregate reaction. But they are not criteria for cement-aggregate reaction, in so far as they are also associated with deterioration of concrete by other causes. These phenomena are:

(a) embayment, encroachment, and penetration of aggregate grains by cement paste, (b) microfractures in the concrete, and (c) deposits of fibrous calcium sulpho-aluminate, and (d) carbonation of the cement paste.

4. PHYSICO CHEMICAL INVESTIGATIONS AND MECHANISM OF DETERIORATION

4.1. The deterioration of concrete caused by the reaction between the aggregate and the alkali of the cement is purely a physico-chemical reaction, but the mechanism by which this reaction produces forces capable of producing severe cracks in the concrete is not clear. However, Hansen's "Osmotic Pressure Hypothesis" (7) is supported by many investigators of this problem. It is believed that the silica of the reactive aggregate reacts with the alkali-hydroxide in the cement paste to form alkali-silicate, which may be represented by the equation :



4.2. The alkali-silicate is in the form of a gel, whose silica-ions associate into complex ions. These complex ions are not capable of diffusing out through the hardened cement paste.

4.3. McConnell and his co-workers have demonstrated the semi-permeable nature of this hardened paste. A hollow concrete cylinder was filled with water-glass (Na_2SiO_3) and was totally sealed except for a small-bore glass tube at the upper end. On immersing the cylinder in water, the liquid level rose from zero to 240 cm. after 195 days. The concrete thus permits the inward penetration of water, but inhibits the outward movement of water-glass. The magnitude of the osmotic-pressure, measured by these workers was about 550 lb per sq. in., a value of about the same magnitude as the tensile strength of the concrete.

4.4. Owing to this force, the cement paste immediately surrounding the reactive particle is ruptured and the gel accumulates in the fracture thus formed. The continued inhibition of water by these gels, cause the enlargement of these fractures. When the fractures are located near the surface, the gels exude in the form of beads. A reference to these beads has already been made in para. 3.3.

4.5. According to Parson and Insley (17), the silica gel permeates the cement matrix in the vicinity of the reactive particle and fills the adjacent air-voids through channels in the cement matrix of high permeability. A reaction then takes place at the walls of the pores filled with liquified gel, to form a semi-permeable membrane. Osmotic pressure finally ruptures and

forms a crack in the concrete, extending away from the active particles. As the pressure is released the liquified gel bursts out through the crack. Thus, the origin of the cracks, according to these authors, is the original air-filled pores and not the active mineral sockets.

4.6. In spite of a large amount of research work, the exact nature of the semi-permeable membrane is not yet clearly understood. It has been suggested by Parson and Insley that a reaction between the alkali-silica gel and the calcium-containing products of the cement, produces the semipermeable membrane. Kalousek suggests (10) that a soda-lime silicate gel, a reaction product of sodium oxide, calcium oxide, and water is probably the essential material constituting the semi-permeable membrane.

5. SOME RECENT INVESTIGATIONS

5.1. Research work in Australia on cement-aggregate reaction has resulted in the advancement of some unique theories, which have been summarized by Vivian (24) and are described here briefly.

(a) Changes in the tensile strength of mortar:—

It has been observed that microscopic cracks are formed in the concrete, prior to the development of abnormal expansion. In certain cases these microfractures have reduced the tensile strength of the mortar by as much as 75 per cent. The time interval between the commencement of the reduction in the tensile strength and the expansion of the concrete, depends on the alkali content of the cement.

(b) Effect on expansion of void space in the mortar:—

It is known that the amount of void space in the mortar can be increased either by decreasing the proportion of cement to aggregate or by decreasing the water-cement ratio. It was found that when the void space in the mortar exceeded 7-8 per cent by volume, the mortar did not expand abnormally, whereas when the amount of void-space was less than 7-8 per cent by volume, the expansion was very large. In both the cases the reactive aggregates were attacked by the alkali in the cement. Therefore it was concluded that void spaces in mortar are very important in combating the cement-aggregate reaction.

6. TEST PROCEDURES AND THEIR CORRELATION WITH FIELD EXPERIENCE

6.1. Intensive research has revealed a long list of minerals which are capable of reacting with the alkali of the cement to

form alkali-silica gels of the type described in section 4. Thus, apart from opal, shale, and chert, the presence of minerals like obsidian, andesite, phyll or chalcedony in the aggregate is also considered as deleterious for the concrete.

6.2. Realizing this, various investigators carried on research and developed simple test procedures for detecting deleteriously reactive aggregates, prior to their use in concrete. (13, 15, 16, 19, 25). Some of the tests are described here :

(a) **Mortar Expansion Test:—**

The mortar expansion test procedure was devised by Stanton in 1940, to trace the causes of the Bradley pavement failures mentioned earlier (para. 2). Mortar bars using the same brand of cement, and coarse and fine aggregates that had been used in the construction of the pavements were cured under various conditions for one year. It was observed that bars contained in sealed containers with a little water at the bottom has developed cracks similar to those observed in the pavements. Later, the test was further developed at the U. S. Bureau of Reclamation.

Mortar bars (1 inch $\times$ 1 inch $\times$ 11½ inches) are prepared in triplicate using a mix of one part of cement to two parts of the aggregates under test. The net water-cement ratio is maintained at 0.40 by weight. The ingredients are properly mixed and bars fabricated in the moulds in a manner similar to the fabrication of bars in the Autoclave Expansion test (20). The specimens are then cured in a moist room at 70 degrees Fahrenheit for seven days, the moulds being removed from the bars after four days. After the curing period, the lengths of the bars are measured in a comparator and the bars are then placed vertically in a container with a little water at the bottom to maintain the humidity. The containers are sealed and kept at 100 degrees Fahrenheit. The change in the length is determined at monthly intervals. If at the end of one year, the expansion of the bars is found to be more than 0.20 per cent of the original length, the aggregate is considered as deleterious.

Excellent correlation between the results of mortar expansion tests and field experience has been observed in a number of cases (21). Mortar expansion tests showed that sand and gravel from Cowlitz River, Washington, were harmful with a high-alkali cement. However, with a low-alkali cement very slight expansion of the bars took place (23). When these laboratory results, obtained by the mortar expansion test, were compared with the service records of bridges built with high-alkali and low-alkali

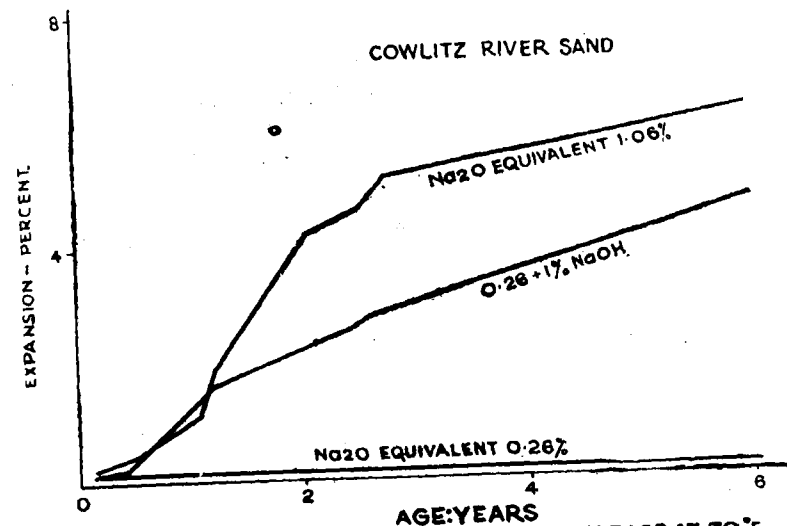


FIG. 1- EXPANSION OF MORTAR BARS IN SEALED STORAGE AT 70°F
FROM PROC. A. S. T. M. VOL. 48, 1948 P. 1088.

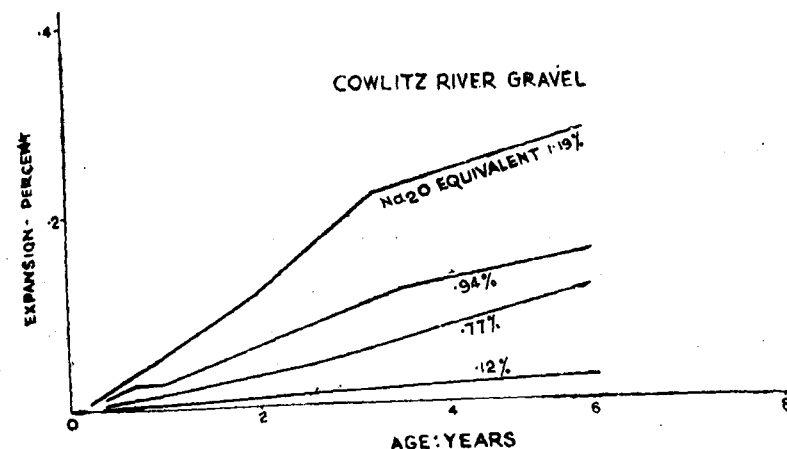


FIG. 2- EXPANSION OF MORTAR BARS IN SEALED STORAGE AT 70°F
FROM PROC. A. S. T. M. VOL. 48, 1948 P. 1088.

cements and the same aggregates, excellent correlation was found to exist. Thus the group of bridges made with a high-alkali cement had developed severe cracks, whereas the other group made with a low-alkali cement were normal (Figs. 1 and 2). The expansion in the first group was about 0.2 per cent which agreed with the laboratory results.

A serious drawback in this test procedure is the time required for the completion of the test.

(b) Chemical Test Procedure :—

A chemical test procedure for detecting the potential deleteriousness of the aggregate has been developed by R. C. Mielenz and others at the U. S. Bureau of Reclamation. These workers have made a detailed study of the effect of alkaline solutions on aggregates and also the effect of aggregates on alkaline solutions. The results of their earlier works and also of other's have been summarized by Mielenz (15). The Bureau of Reclamation ultimately established that, "The dissolution of silica from aggregates by 1 N NaOH solution and the concomitant reduction in the alkalinity of the solution are closely related to deleteriousness."

The test is performed by first crushing the aggregates to the No. 50 - No. 100 size. It is then immersed in the 1 N NaOH solution at 80 degrees Centigrade for 24 hours. At the end of this period the solution is filtered and the filtrate analysed for dissolved silica. The reduction in the alkalinity of the solution is measured by titration to the phenolphthalein end point. For deleterious aggregates, the ratio Sc/Rc is greater than unity where Sc represents millimoles of silica dissolved per liter and Rc represents reduction in the alkalinity of the solution expressed as millimoles per liter.

About 71 aggregates were tested at the Bureau of Reclamation by the chemical test procedure and these aggregates were also subjected to the mortar expansion test. These two test procedures gave excellent correlation in their results as shown in Table II. The chemical test takes three-man-days to complete.

Table II.

Dissolution of Silica from rocks and minerals by a N. NaOH solution and the concomitant reduction in alkalinity of the solution.

Aggregate Material			Results of Chemical Test with NaOH Solution No. 50 to 100			Maximum expansion at 1 year mortars containing aggregate (per cent)
No.	Designation	Source	Silica Dissolved concentration in m M/L (Sc.)	Alkalinity Reduction in m M/L (Rc.)	Sc/Rc	
26	Obsidian	Lake County, Ariz.	97	30	3.23	0.261
30	Perlite	Near Superior Ariz.	229	108	2.07	0.254
52	Flint	Crown Point, N. Y.	205	53	2.87	0.352
39	Andesites	Sand Joagin River Calif.	660	168	3.93	0.477
28	Brown Obsidian	Near George Town, Colo.	208	97	2.14	0.516
55	Chalcedony	Lead Pipe-Springs	840	203	3.29	0.940
57	Opal	Near Quincy Wash.	1040	307	3.31	1.613
66	Quartz	Near Denver. Colo.	31	31	1.00	0.033
60	Lime Stone	Bridge Canyon, Ariz.	2.4	15	0.16	0.021
61	Marble	Yule, Colo.	2.3	12	0.19	0.022
32	Rhyolite	Castle Rock, Colo.	850.0	381	2.23	0.400

(From the Journal of American Concrete Inst., November, 1947)

(c) Petrographic Examination:

Petrographic examination of aggregates by polarized light or by the immersion method is also helpful in identifying and establishing the physical properties of minerals which are likely to cause expansion of concrete (18, 13). The procedure adopted by the U.S. Bureau of Reclamation has been described by Mielenz. Some of the minerals whose presence in the aggregates are undesirable are opal, chalcedony, tridymite, cristoballite, zeolite, heulandite, rhyolite, andesites and certain phyllites. It has been observed that the immersion method is very useful in identifying minerals similar to opal or chalcedony. Mather has given (11) a valuable list of the optical properties of some of the above-mentioned minerals. The method of determining the refractive index put forward by Dodge (4) is very useful identifying quartz from chalcedony in a mixture of these two substances.

Among the various test procedures, the above three are the most important. The Bureau of Reclamation has included the above-mentioned procedures in the list of tests which have to be performed on aggregates prior to their use.

7. SUGGESTED REMEDIES FOR CEMENT-AGGREGATE REACTION

7.1. From all that has been written above, it appears that the safest course for the engineer would be to discard aggregates which are diagnosed as deleteriously active. But in many cases this may not be economical and such aggregates will have to be used. Hence from time to time remedies have been suggested, aimed at preventing an abnormal expansion of concrete, even when a deleteriously active aggregate has been used.

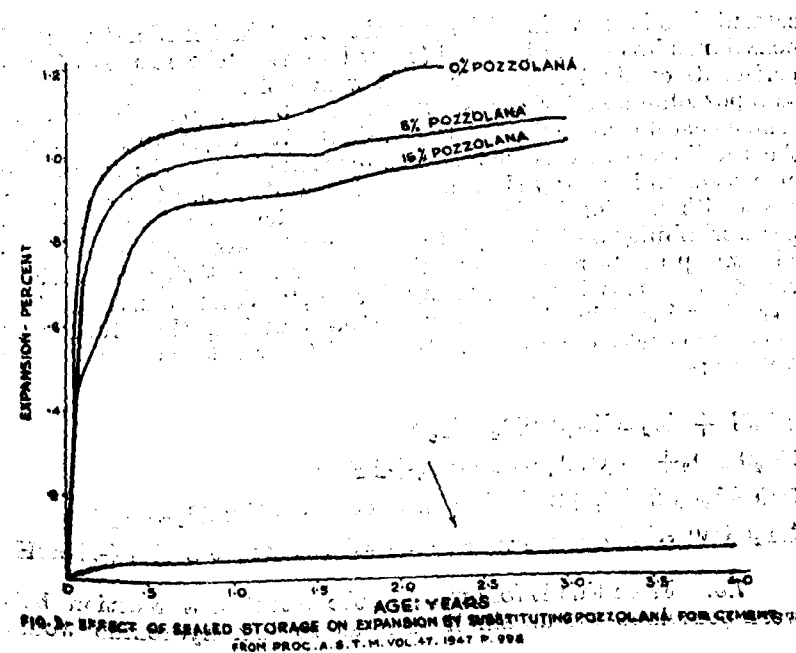
7.2. Obviously one of the safest practice would be to limit the alkali content of the cement. The conclusion that can be drawn from the works of various authorities on this problem is that 0.6 per cent of total alkali is the maximum limit that can be permitted in cement. The U. S. Bureau of Reclamation has used (2) low-alkali cement as a precautionary measure in a number of their projects, like the Davis Dam, the Hungry Horse Dam, etc. It must be pointed out that this measure is not a remedy, in so far as it does not inhibit the cement-aggregate reaction, but simply delays it. Vivian and others in Australia made a study of the "Mobility of alkalies in hardened mortar", and their conclusion, in the words of Vivian, is that "it is reasonable to assume

that, provided moisture conditions remain suitable, sufficient alkali migration and consequent expansion will eventually occur in mortars made from low-alkali cement and reactive aggregates. Thus the adoption of an arbitrary limit for the alkali content of the cement for use with reactive aggregates may be inadequate, since it may not prevent serious reaction and abnormal expansion of mortar and concrete but only delay it" (24).

7.3. Two instances have been reported by Hanna where concrete structures built with a high-alkali cement and reactive aggregates had shown no sign of any distress. Close examination of the structures revealed that both of them had received a coat of water proofing paint (5).

"PESSIMUM"

7.4. While discussing the cement-aggregate reaction Stanton has introduced a word "pessimum", suggesting thereby that for a good concrete the aggregates must contain the pessimum amount of reactive particles. Where the aggregates lack this pessimum amount, addition of small amount of ground pozzolanas rich in opal has been suggested (5). In some cases 30-40 per cent of the



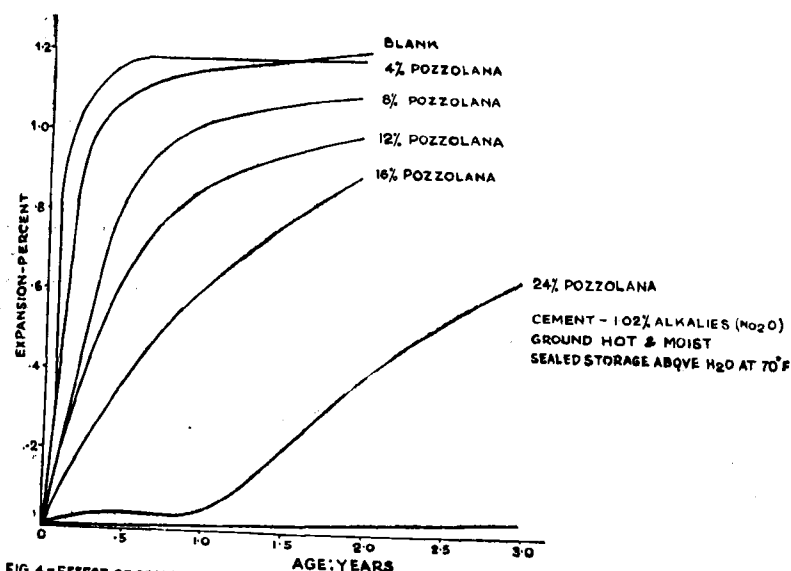
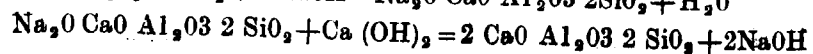
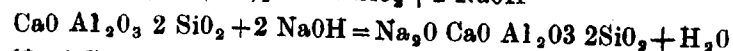
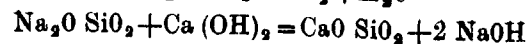
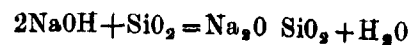


FIG. 4.-EFFECT OF SEALED STORAGE ON EXPANSION BY SUBSTITUTING POZZOLANA FOR CEMENT.
FROM PROC. A. S. T. M. VOL. 47, 1947, P. 398

cement has been replaced by pozzolanas. The beneficial effect of pozzolanas has been discussed (5) by Hanna. The results of experiments conducted for four years with calcined Phillips Shale as a pozzolanic material is shown in Figs. 3 & 4. (5). In fig. 3 the cement employed contained 1.15% alkali (as Na₂O) and in fig. 4 the alkali content was 1.02%. The marked effect of the admixture of pozzolana is clearly shown. Good pozzolana must be able to react with solution in the concrete and at the same time give proper workability and strength to the concrete. Jordan had developed a test procedure to measure the pozzolanic activity of various varieties of pozzolana. Quoting Jordan, "Various investigators have found that in Portland-pozzolana reaction, the alkalis in the cement act as catalysts. Some of the reactions may be as follows :—



7.5. From this it follows, that the extent of a reaction between pozzolana and an alkali such as sodium hydroxide would

also be a measure of its pozzolanic activity". The U.S. Bureau of Reclamation has therefore used Phillips shale and Monterey shale as additions to combat abnormal expansion in the construction of the Davis Dam (2). Besides combating expansion in the concrete, the use of pozzolana imparts other beneficial effects to the concrete which have been summarised by Blanks (2).

7.6. Rocks containing minerals like opal, chalcedony, andesites, and phyllite are by no means confined to America alone. In India too, many varieties of rocks contain some of these minerals.

8. CONCLUDING REMARKS

8.1. The works of various investigators quoted above reveal the following basic facts known about cement-aggregate reaction :

- Deterioration of the concrete takes place as a result of the interaction of the alkalis released during the hydration of the cement, and some minerals in the aggregates.
- Comparatively, deterioration is more predominant and occurs earlier with a high-alkali cement than with a low-alkali cement.
- Concretes deteriorated by the cement-aggregate reaction contain alkali-silica gels round the reactive particles, in the air voids, inside the cracks and also appear as exudations on the surface.
- Deterioration can be prevented by the use of some pozzolanic materials, in a finely divided form, containing reactive minerals like opal, shale etc.

8.2. There are, however, many problems associated with cement-aggregate reaction which have not yet been solved satisfactorily. Thus the beneficial effect obtained by the use of pozzolanic material containing the same minerals which are known to cause severe expansion, has not been explained.

It has not yet been possible to fix the maximum limit of the alkali content of cement.

Similarly the exact nature of the semipermeable membrane has not been explained clearly.

Solutions to these problems will only come through intensive research.

8.3. Since many important concrete structures and roads are likely to be built in this country in the near future, it is essential that research work on this problem of cement-aggregate reaction should be taken up as soon as possible.

8.4. The Building and Road Research Station of Uttar Pradesh, Public Works Department at Lucknow, has now been completely equipped for carrying out the mortar bar expansion test, chemical tests, and petrographic examination of aggregates as described in this note. Work on this problem has been started with a view to investigate the probable incidence of cement-aggregate reaction in concrete structures in Uttar Pradesh.

8.5. Some of the important facts known about cement-aggregate reaction have been presented briefly in the foregoing paragraphs. In such a treatment, it is not possible to devote much space to any one topic. For the benefit of readers interested in the subject a list of references is given which may be consulted for more detailed information.

8.6. This note forms a part of the work done at the Building and Roads Research Station of the Uttar Pradesh Public Works Department (B & R) at Lucknow, and is being published with the kind permission of the Chief Engineer, Uttar Pradesh.

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(ii). THE NINTH INTERNATIONAL ROAD CONGRESS, LISBON

September 24th to October 3rd, 1951

Thirteen years after the Eighth Congress held at the Hague in 1938 the International Road Congress met again at Lisbon in September-October 1951. According to its constitution the Congress is to be convened at intervals of four years and even this interval has been held by some to be too long. But a long war and the post-war difficulties prevented the Permanent Committee from convening the Ninth Congress earlier.

On account of the long interval of thirteen years numerous technical problems connected with highways were awaiting discussion and the vast experience acquired during these fateful years awaited expression.

The Lisbon Congress afforded a unique opportunity for this purpose when about 1,200 delegates representing more than 40 countries took part in the Conference. Some countries like the United Kingdom and France sent more than 100 delegates each.

India became a permanent member of the Congress in 1913 when the Third Session of the Congress was held in London. Since then most of the Congress Sessions have been attended by Indian delegates. The delegates to the Lisbon Congress were :—

Government Delegates

- | | |
|--|-----------------------------|
| 1) Shri M. L. Champekar,
Chief Engineer,
Public Works Deptt.,
Bombay. | Leader of the
Delegation |
| 2) Shri H. P. Sinha,
Deputy Consulting Engineer to the Govt. of India (Roads)
Ministry of Transport,
New Delhi. | |

Non-official Delegates

- 1) Mr. W. A. Griffiths, representing Burmah Shell (India).
- 2) Mr. H. S. Batlivala, representing the Concrete Association of India.

Mr. Batlivala could not attend the Session.

The President of the Republic of Portugal inaugurated the Session on the 24th September 1951. The business meetings were

held from the 24th upto the 29th September. The technical reports received from several countries all over the world were considered and discussed at these meetings. These reports had been summarized and compiled by the Reporters appointed for this purpose. Printed copies of these compilations were distributed to the delegates. The conclusions arrived at after the discussions were confirmed at the final meeting held on the 29th September. These conclusions formed, the most important outcome of the deliberations.

In order to acquaint the delegates with the progress made in road engineering in Portugal, the Congress arranged excursions and visits along important highways, both in the neighbourhood of Lisbon and in other parts of Portugal. The inspection of works which included several large bridges, a tunnel, auto-estrada (the expressway of Lisbon), a fly-over crossing, two airports, the national stadium, and several newly developed areas, was most illuminating and revealed how Portugal had been making a rapid advance on the engineering side, although it is a country very small in size. Its area is 35,521 square miles, which is about 3 per cent of the area of India and somewhat less than the area of Punjab (I).

The delegates were also invited to visit the Civil Engineering Laboratory of the Ministry of Public Works, Portugal, Lisbon. This laboratory is equipped with a large number of up-to-date instruments and it appears that the Portuguese Government is fully alive to the great necessity of scientific investigations on the subject of road engineering.

During the business meetings, lasting more than six days, it was possible to cover a very large field of road engineering as arrangements had been made for simultaneous translation of the speeches into three languages, viz., English, French, and Portuguese.

Two separate meetings were held simultaneously so that two questions could be discussed at one time.

In addition to the discussions carried out during business meetings and the visits to works and laboratories, it was possible for the Indian delegates to make contacts during the Congress with many eminent engineers and scientists connected with road work.

All the important countries in the world, with the exception of the United States of America, were represented. Owing to a decision by the United States Congress, no engineer from that country participated. The United States Government holds the

view that only government-appointed delegates should participate in the Congress. As the International Congress did not subscribe to this view and did not exclude all but government-appointed delegates, the United States engineers stayed away. Hope was expressed at the Session that some means will be found to enable the American engineers to be represented at the next Congress.

Almost complete unanimity was achieved on the technical conclusions which were adopted formally on the 29th September. These conclusions are reproduced here in full.

The Permanent Commission will shortly consider the date and place of the next Congress and it is hoped that it will be possible to hold it in 1955.

CONGRESS CONCLUSIONS

SECTION 1-CONSTRUCTION AND MAINTENANCE.

First Question:—Progress made since the Hague Congress in 1938 concerning the (A) Use of cement and other special materials on road pavements and aerodrome runway surfaces; (B) Preparation and use on roads and runways of plastic binders (tars, bitumens, powdered asphalt fillers etc.).

General Reporter: ENGINEER ANTONIO COMELHO, SALLES HENRIQUES, DIRECTOR OF THE ROAD BUILDING SERVICES OF THE "JUNTA AUTONOMA DE ESTRADAS".

GENERAL

No new materials: (a) The progress which has been recorded in regard to the surfacing of roads and runways since the Hague Congress, in 1938, and up to the end of 1950, is concerned almost exclusively with the improvement of the characteristics of the materials and constructional methods which were being applied at that date: there are no new materials in use at the present time, nor even any new types of surfacing in connection with which definite conclusions can be drawn at the moment.

The war prevented any further advance in this field during the course of the past 12 years.

(b) **General Use of Investigations and Tests.** It is observed that remarkable progress has been made in the general establishment of special laboratory investigations and tests and that progress is concerned not only with binders and aggregates, but also with compounds.

Apart from laboratory tests, it is essential that research on the roads and runways themselves should be carried out and that these investigations should relate both to methods of construction and to the behaviour of surfacings. It is an established rule that laboratory work should always be complemented by full-scale tests carried out on the site of the work.

(c) **Mechanisation of Operational Methods.** There has been a noticeable development in the mechanisation of methods for the preparation of materials, the manufacture of the concretes and the construction of the various types of surfacings.

(d) **Need for Firm and Well-drained Foundations.** The need for constructing firm and well-drained foundation to roads and runways has been emphasised largely as a result of the increase in the weights and numbers of motor vehicles and planes.

(A) CEMENT AND OTHER SPECIAL MATERIALS.

I. Cement.

(1) The most widely used type of cement pavement is the standard pavement of concrete slabs, with or without reinforcement.

The utilisation of cement-grouted macadam has not been developed, although it is considered that use can be made of it, especially for foundations.

(2) Although reinforced concrete is recognised generally to be advantageous, its use has been restricted for economic reasons and because unreinforced pavements have been constructed in some cases with good results.

(3) The use of pre-stressed concrete for surfacings constitutes an innovation in roadway technique, and also this system is still in the experimental stage, it would be advisable to continue investigations into its use as it would seem likely to play an important part in the future.

(4) The use of the standard type of Portland cement has become general, but it is expected that blast-furnace cement will become of considerable importance in countries which have an extensive iron and steel industry.

(5) A tendency towards the reduction of the proportion of cement is observed and this may be attributable to the improvement in the characteristics, and an increase in the power, of modern mixing and vibrating machines.

(6) Rough-textured broken stone and gravel aggregates have given similar results.

(7) In view of the results of trials which have been made, it would seem that there should be no hesitation in using discontinuously-graded aggregates.

(8) There is an apparent tendency towards the use of concrete of uniform composition, even where the application is made in two layers.

Despite the increase in thickness and the reduction in the water-cement ratio, the use of a single layer, without detriment to the compactness and the final strength, is tending to become general owing to the technical developments which have taken place in the construction of vibrators.

(9) It is observed that there is a clearly marked tendency to lay slabs of uniform thickness, that is without additional thickness at the edges or on the corners.

(10) Progress continues to be made in the development of mathematical analyses for calculating the dimensions of rigid surfacings; the question is considered to be still in the course of solution.

It is regarded as absolutely essential, however, to carry out direct tests under the conditions which the projected types of surfacing will have to withstand.

(11) Although the problem of joints has been the subject of detailed investigation with a view to obtaining improvements in methods of construction, or to a reduction of the number of joints to a minimum, or even to their complete elimination, a satisfactory solution which has been confirmed by long experience has not yet been reached, nevertheless certain joints have given promising results over a period of a few years.

Today, joints are still the weak point of these surfacings both from construction and maintenance points of view.

(12) The use of central concrete-mixing plants has become general, since they ensure a uniform product and enable the mixing to be controlled.

II. Other Materials.

(1) **Stone-sett Paving.** No technical progress is reported in respect of these surfacings, which continue to be employed in certain countries, although only on a limited scale. The problem of filling the joints does not appear to have been solved in a satisfactory manner in every case.

(2) **Rubber.** Many lengths of asphalt have been laid with rubber-bitumen mixtures during the past 15 years, but so far no definite general conclusions have been reached regarding any improvement produced by the addition of rubber in the road-performance of the asphalt. Further systematic investigations in laboratories and on roads are required and the result should be reported at the next Congress.

(3) **Cast-iron, Steel and Other Materials.** No reference is made to the use in recent years of cast-iron or steel for pavings, nor of other materials deserving mention.

(B) PLASTIC BINDERS.

(1) The most widely used plastic binders are still bitumen tar, bituminous emulsion and cut-backs.

A tendency is noted for the use of cut-backs to become general, mainly in countries where the bitumens employed are derived from the distillation of petroleum. The use of cut-backs presents no difficulty in surface dressing, but in paving mixtures it is necessary to select the type of cut-back most suitable for the grading of the aggregate.

(2) Generally speaking, it is observed that researches on tars have led to important improvements with regard to their manufacture, as a result of which certain modifications have had to be introduced into corresponding specifications. New characteristics have been established with obvious advantages in the utilisation of this material.

As far as bitumen, emulsions and cut-backs are concerned, all that there is to note are some appreciable modifications in the characteristics and specifications for cut-backs where the introduction of types with higher viscosity is reported.

(3) The problem of the adhesion between binders and aggregates has been the subject of extensive research but it does not appear that any satisfactory conclusions have yet been reached, and, on that account, it is to be hoped that these researches will be actively pursued.

(4) The addition of activators to binders, for the purpose of ensuring their adhesion in the presence of moisture, is a question of the very greatest importance, chiefly in countries with a wet climate. It is for this reason that the hope is expressed that researches which are in hand will result in establishing suitable types of activators and technical guidance for their application, so that the use of these products may be made practical and economic. Nevertheless some reports say that the problem has been solved for surface-dressing.

(5) Among the most widely used types of surfacing, based on the application of a plastic binder—types which include surface treatment, semi-penetration treatments, tar macadam and pre-mixed carpet—special emphasis must be given to the remarkable extension which has taken place in the use of the last-named type of surfacing since the Congress of 1928.

(a) Bitumen carpets and stone-filled asphalt, laid hot, continue to be regarded as very good material for wearing courses based on plastic binders, as far as strength and wearing qualities are concerned.

(b) The technique of pre-mixed surfacings, in conjunction with the general use of fixed mixing plants, and of mechanical means for spreading, etc., has developed in a remarkable manner and reached a high level of perfection. As a result of these improvements, the use of thin carpets has become general, either on the old surfacing, or directly on macadam foundations. There is a movement towards the replacement of surface dressings by low-cost pre-mixed carpets which is resulting in improved riding qualities with less risk of bleeding.

(c) It is to be hoped that the technique of the manufacture and application of cold mixes may make such progress as will enable low cost carpets, possessing the necessary properties for withstanding the action of traffic and water, to be laid with confidence.

(6) It would appear desirable to recommend that investigations into the effects of the characteristics or fillers on the various types of surfacings should be continued.

(7) It is to be hoped that steps will be taken to standardize, as far as possible, the terminology used in connection with plastic binders and the methods for testing the various materials employed in road construction. It would be advisable for the problem to be studied by a permanent committee functioning

under the aegis of the Permanent International Association of Road Congresses, as was in fact suggested in this connection at the Hague Congress in 1938.

(8) In view of the failures observed in some countries in the application of bitumen derived from petroleum, although the product complied with the standard specifications, it would seem essential that this question should be thoroughly investigated by a Commission under the Permanent International Association of Road Congresses in collaboration with the manufacturers of bituminous road materials and with the refineries, since it is possible that this may lead to the determination of additional characteristics which would enable the quality of bitumen to be controlled satisfactorily.

(9) In the reports on the 1st Question, frequent references are made to the non-skid qualities of the surfacings. It is considered that a Committee, under the aegis of the Permanent International Association of Road Congresses, should proceed at once to investigate the various types of machine designed for measuring road-skid qualities with a view to the determination of the characteristics to be adopted for these machines and to the specification of minimum values for the coefficients of friction of road surfacings. These investigations should be undertaken as soon as possible, and the results should be discussed during the periodic sessions of the Permanent Committee and during the next Congress.

(10) The IXth International Road Congress records with satisfaction the great improvements in road construction plant which have been effected by manufacturers and which have enabled the standard of workmanship and finish to be raised appreciably.

Second Question: Progress made since the Hague Congress in 1938 in the study of road sub-grades.

(A) Determination of the properties of sub-grades; testing methods, and measurement apparatus. (B) Stabilisation of the soil for use in road foundations and surfacings.

General Reporter: ENGINEER EDUARDI DE ARANTES E OLIVEIRA, DIRECTOR OF THE CIVIL ENGINEERING LABORATORY.

(A) DETERMINATION OF THE PROPERTIES OF SUBGRADES ; ETC.

(a) General Properties of the Sub-Soil.

Exploration.

(1) The methods of direct exploration by trial holes and borings are relatively slow and expensive and there is sometimes an advantage in combining them with other exploration processes of a more expeditious and cheaper nature such as penetration tests and geophysical exploration.

(2) The development of dynamic penetration methods, especially suitable for firm soils, demands that the complex phenomena affecting the penetration of the probe should be the object of more precise experimental research.

(3) It would be a great advantage to develop a light and handy probing equipment for determining quickly and cheaply the structure of the upper strata of the sub-soil.

Identification Tests.

(4) It is recommended that the search for better methods of analysing the fine component of clay soils than those at present available should be continued.

(5) The Atterberg limits give a means of identifying cohesive soils yielding more useful results than the mechanical analysis of their fine component.

Search should be made for perfecting the methods of determining these limits with the object of reducing the influence of the human factor and above all of establishing a closer relation between the test results and the mechanical properties of the soils.

(b) Water in the Sub-Soil.

(6) Previous knowledge of the moisture-content values of the sub-soil which will exist after the construction of a road is a very important factor in its design, since the principal variables which govern the strength of the sub-soil depend on the moisture content.

(7) The distribution of moisture in the soil involves complex phenomena for the explanation of which it is necessary of undertake research principally outside the field of the classic theories employed in soil mechanics,

(8) In the practical field it is recommended that investigations should be continued into methods of measuring those properties of soils which will permit the easy determination of the moisture distribution in subgrades of roads and airfields.

(9) It is recommended that investigations should continue into the correlation of the suction properties of soils and other properties capable of easier and quicker determination such as the liquid and the plastic limits.

(10) For information purposes the results of the systematic observation of water in the sub-soil of existing roads are of particular value. In this respect, it is recommended that work should be instituted with the object of perfecting the apparatus for measuring moisture content and the pore water pressures, both positive and negative.

(11) On the subjects of freezing and thawing, it is acknowledged that appreciable progress has been made in the understanding of the phenomena and also in the fixing of standards for the assessment of the frost susceptibility of soils and in the precautions to be taken to avoid harmful effects on highways.

(12) The continuance of research in the field of the problem of movements of the sub-soil due to the shrinkage or clayey soils by excessive reduction of their moisture content is considered desirable. Observation of existing roads is very helpful in this connection.

(c) Compaction of the Sub-Soil.

(13) The compaction of the sub-soil has been increasingly employed in the construction of embankments and of road and airfield foundations and structures.

It is desirable to continue the efforts for perfecting the theories, the methods of construction, and the equipment on which the efficiency and the economy of the compaction depend.

(14) The method of studying the compaction properties of soils which is most generally followed is based on the Proctor test.

Experience in the use of this test reveals, however, that certain reservations are necessary as to its reliability and significance in some soils.

The existing tendency is to make use of the Proctor test principally for the classification of soils.

(15) The modifications introduced in various countries in the compaction test routine, intended to produce either a greater homogeneity in the samples, or to obviate the disadvantage of the repetition of the compaction operation on a single specimen, or to increase the particle-size limit of the specimen, are considered worthy of attention without losing sight of the merits of a uniform standard.

(16) Site tests with compaction plant, when the nature of the work makes them practicable, can furnish very interesting information as to the most suitable kind of plant and as to the most appropriate method of use.

(17) For the continuous *in situ* checking of the compaction operations on earthworks, more rapid methods than those involving finding the dry density must be developed.

The usefulness of the penetration needle in this respect seems very limited.

Interesting results have been obtained with the manual conical penetrometer.

(d) Stability of the Sub-Soil.

(18) In the last decade there has been a very useful advance in the development of rational methods for designing roads and airfields. At the present juncture, however, the methods giving the most reliable results are still wholly or partly empirical and depend upon judgement of the stability of the sub-soil by means of laboratory or site tests.

The most general tests are the test for the determination of the California bearing ratio—for the design of flexible pavements—and the plate-bearing test, on the site—for the design of rigid pavements.

(19) The original technique of the C. B. R. test is capable of being perfected in particular as regards a more accurate reproduction in the test sample of the actual sub-soil conditions.

In particular, the original routine for the soaking of the sample gives a conservative result in many instances and there would be an economic advantage in replacing it by a test routine which would impart to the specimen moisture conditions equivalent to those existing effectively in the sub-soil after the construction of the pavement, where it is possible to forecast them with a satisfactory degree of assurance.

In the interpretation of the results of the C. B. R. test *in situ* it is necessary to bear in mind that the natural moisture

conditions of the sub-soil at the moment of the test may be more favourable than those which will be met with in the sub-soil after the construction of the pavement.

(20) The tediousness of the test, and the bulk of the equipment necessary, constitute objections to the plate-bearing test on the ground. In addition, the test is not usually performed under the most unfavourable conditions of moisture content of the sub-soil.

(21) It is agreed that there is advantage in expressing the results of the plate-bearing tests by means of parameters which, unlike the reaction modulus of the sub-soil, can represent properties of the sub-soil under test.

(22) In the application of the results of plate-bearing tests to the design of rigid pavements by Westgaard's theory it is necessary to consider in addition the stresses produced in the concrete slab by temperature variations—particularly in their vertical gradients—and also by the eventual variations in the volume of the sub-soil resulting from fluctuations in its moisture content.

(23) The method of calculating the thickness of road pavements on clayey sub-soils from the shear strength of the soil, by simple compression testing on the site, has been tried successfully in certain countries. It is recommended that the attempts to perfect it, on which its more widespread use depends, should be continued.

(24) The attempts at the development of new testing methods, applicable to the design of rigid or flexible pavements, which would supplant the defects of the present methods, are worthy of attention.

In order that the new solutions should be adopted, it is necessary to subject them to confirmation by systematic application to real problems as far as possible in conjunction with the actual current techniques.

(25) The formulation of simple and precise rules, principally for application to secondary roads, deduced from more complete studies of soils with similar properties which would permit the determination of the characteristics of the road by simple tests of the soil properties is considered very useful.

(26) The method of designing pavements, founded on the elastic theory applied to systems of several superimposed layers, has been substantiated in a satisfactory manner by experiments in the laboratory and on the ground; and at present this can be considered the most satisfactory theoretical method.

It is desirable to pursue investigations to obtain a better explanation of the real behaviour of the sub-soil and pavement under the action of traffic loads and other superimposed loads, taking into account their frequency of application, to make it possible to perfect the existing methods, or to introduce new sound theoretical methods for the designing of roads and airfields.

(e) Roads on Soft Sub-Soils.

(27) In order to limit the deformations of roads resting on peaty sub-soils, it is desirable that, before construction, a reduction, as far as is possible, should be made in the moisture content, and the carrying capacity of the sub-soil improved by drainage and consolidation. With the same object the sub-soil should be compacted by an adequate process.

As far as is possible the subsequent variations in the moisture content of the sub-soil should be prevented, in particular, by the infiltration of rain water, thereby necessitating the adoption of impermeable surfacings.

(28) When it is necessary to replace bad ground by a suitable filling material, founded on an underlying stratum of good ground, the use of explosives will, in general, constitute a satisfactory solution with a possibility of very considerable economy compared with the usual earthworks practice, at least up to depths of the order of 6 metres to a firm stratum.

(29) For greater thickness of bad ground the choice of the solution to be adopted should be made after special investigation.

The cheapest solution will in general be that of the use of a mattress of fascines.

If the ground features do not permit this solution, it is necessary to choose, with a predominating criterion of economy, between replacement of the bad ground by a suitable material and the construction of a supporting structure resting through the medium of piles on the firm ground.

(B) STABILISATION OF SOIL.

(a) General.

(1) The method of soil stabilisation applied to the construction of the foundations and of the surfacings of roads and airfields has aroused an increasing interest in all countries.

This circumstance, allied to the important progress achieved in the last decade in the technique of design and construction and to the advantages of economy and speed, leads to the prospect of an appreciable development of the application of soil stabilisation in the years to come, in places where local conditions do not especially favour traditional methods.

(b) Principles.

Classification.

(2) It is considered desirable that the classification of the different stabilisation methods and the relevant terminology should as far as possible conform with uniform standards in the different countries.

Methods of Investigation.

(3) The stabilised mixtures using clay as a binder are very sensitive to moisture. Therefore in the use of such stabilised layers the road should be designed in such a way that there is no danger of the stabilised layer being soaked and made unstable by sub-soil water. It will be essential to adopt a superficial impermeable coating in districts where the evaporation precipitation balance, over a suitable period, will be unfavourable.

(4) For the study of the composition of soil mixtures, satisfactory empirical rules are in use, depending on the mechanical analysis and the Atterberg limits of the mixture.

Continuous grading is not, however, essential to obtain good compaction.

The maximum conditions of compaction and the mechanical resistance of the stabilised soil can be advantageously investigated by combining the normal compaction tests and the C. B. R. test.

It is considered good from the practical point of view that the moisture content for optimum compaction should not be critical.

(5) The determination of the minimum admixture of cement, when this is the binder used for the stabilisation of the soil, ought to be made on the basis of the results of simple compression tests and resistance to weather (wetting-drying and frost-thaw).

There is, however, a tendency not to make weather-resisting tests—as a routine procedure—since such tests, add little information to that provided by mechanical strength tests.

(6) Bituminous binders can be used in the construction of stabilised pavements, either as soil-stabilising agents or for forming the superficial protective coating of the stabilised base.

For the good performance of a protective coating on a mechanically stabilised base, the preliminary process of priming with binders of appropriate properties is considered essential.

(7) In the trials of the behaviour of stabilised soils with bituminous binders, the North American technique has been used.

The conical penetrometer has been found very useful for checking the mechanical strength of the stabilised mixtures especially in the case of sandy soils.

The efficacy of water-proofing agents can be checked by a capillary water absorption test on a sample appropriately compacted.

(8) The results of the most recent research justify the trend towards the adoption of the combination of the normal compaction test methods and the C. B. R. for the determination of the compactness and mechanical strength of stabilised soils whatever may be the stabilisation process adopted.

(c) Methods of use.

(9) The stabilisation processes ought to be adapted in a well-considered manner to existing local conditions, not only in respect of the properties of the natural soil, the estimated traffic and the climate, but also the available resources in materials and plant.

In the interpretation of the results obtained in other countries, account must be taken of these factors.

(10) Among the most common stabilisation processes, the mechanical stabilisation of soil mixtures has the largest application in the foundations of roads of all categories and in the surfacing of roads with moderate traffic. Except in very favourable conditions of climate, an adequate seal coat is essential. The use of hygroscopic materials is common.

The use of cement as a binder is increasing in countries where there is an abundance of this material.

Stabilisation with bituminous binders tends to be confined to cases where other cheaper solutions would not be permissible.

Other chemical processes, using lime mixtures, lime pozzolane and cement-pozzolane, natural or synthetic resins, industrial residues, etc., can be used successfully in particularly favourable circumstances.

(d) Conditions Affecting use.

(11) The method adopted for mixing a stabiliser with soil is an important factor in the stabilisation process. Mixing in a central depot possesses appreciable technical advantages, but the relative output and cost of mix-in-place and central plant mix is, above all, dependent upon the actual design of individual plant.

(12) The lack of adequate equipment has sometimes been a serious obstacle to the extension of the use of soil stabilisation in road construction.

Although there has been some useful progress in the development of plant for soil stabilisation, this has lagged behind developments in the technical aspects of the processes.

For this purpose, close collaboration is desirable between the administrations, the laboratories, the contractors, and the plant manufacturers.

(e) Prices.

(13) The cost of soil stabilisation is considerably affected by factors of importance differing from one case and another—such as: the size of the programme to be undertaken, the kind of equipment available, the distances of the sources of supply of the materials, the cost of transport, etc.

It can be affirmed, however, that when they are used in the proper manner, soil stabilisation processes in many cases can lead to much lower costs than those of the traditional methods, taking into account not only the constructional costs but also those of the upkeep of the road.

This advantage will naturally tend to increase as the design and construction methods undergo progressive improvement.

SECTION 2 - CIRCULATION, EXPLOITATION AND ADMINISTRATION

Third Question : (A) Basic elements for road design. (B) Determination of traffic and of the conditions by which it is influenced; especially: Speed of the vehicles; Type of traffic; Overtaking; Design of intersections.

General Reportar: ENGINEER MANUEL MOREIRA DE AMARAL, PROFESSOR AT THE FACULTY OF ENGINEERING OF THE OPORTO UNIVERSITY.

(A) BASIC FACTORS IN ROAD DESIGN.

(1) The guiding rules for the construction of roads should be related to the purpose which the roads are intended to serve (long-distance traffic, local traffic, tourist traffic, etc.)

(2) The geometrical characteristics of the road should enable vehicles to travel in comfort and safety at the speed for which the road is designed.

(3) From the point of view of economy it is advisable to construct roads suitable for the traffic densities to be expected for a reasonable number of years.

At the same time it is essential that the plans should make provision for widening the carriageways, or if found to be necessary, the construction of dual carriageways, cycle tracks, modification of junctions and any other features required for the safety and efficiency of the traffic to be expected in the foreseeable future.

(4) It does not appear possible to specify numerical values (for general application to every country) for the geometrical characteristics of roadways such as the radii, widening and superelevation on curves, gradients, sight-distances, etc., since the determination of these values depends on the climate the principal types of vehicles employed, the individual abilities of drivers, the types of road-surfacing, the economic circumstances, etc.

These are the data on which the determination of such characteristics should be based in every country, when considering the factors which influence the driving, running, and safety of vehicles.

(5) When for a given section of road it is economically impossible to maintain at the desired standards the value of the design characteristics indicated in the preceding paragraph, the section should be provided with the necessary traffic signs.

(6) The separation of local traffic from through traffic is recommended.

(7) Railway level-crossings should be eliminated, where traffic and safety considerations justify the cost.

(8) It is advisable to exercise care in the design of junctions in order to ensure the safety of traffic and the saving of time as well as to prevent accidents which frequently occur at these points.

Crossing at different levels (fly-over junctions) should be carefully considered in view of their high cost and the space they occupy.

Roundabouts, provided they are of adequate size, have proved satisfactory for dealing with high densities of traffic.

(9) Investigations should be made into the causes of accidents attributed to road conditions, in order to eliminate them as far as possible.

(B) STUDIES OF TRAFFIC AND OF THE CONDITIONS WHICH INFLUENCE IT.

(1) In order to determine the daily and hourly traffic densities, and the nature of the traffic, observation points are set up, and observers stationed at these points to count the numbers of the various types of vehicles passing. Counts are made for a certain number of days, which are usually spread over the whole year, so that the traffic on each day of the week is counted at least twice at different seasons of the year. Separate counts of shorter duration can be of great value.

(2) In order to obtain other data, such as distance covered, speed, passenger-miles, ton-miles, etc., the methods may include: (a) a questionnaire by which a form containing simple questions is handed to drivers to be returned to the control point after completion; (b) direct interview of the drivers who are stopped at control-points and asked a few simple questions; (c) observers in a control car who record data such as traffic speeds, traffic densities, etc.

(3) Electro-mechanical apparatus and car registration plates (when the latter indicate the canton or province from which the vehicle comes) are of considerable assistance in determining the various data relating to traffic which are mentioned in conclusions (1) and (2).

(4) Roads should be constructed so as to permit traffic to circulate freely during the peak hours which normally occur, and should also allow for future increases in these peak values.

(5) No practical conclusions are reported as to the effects of speed, the nature of the traffic, overtaking, and the crossing of traffic streams, except in certain very special cases, but some indication is given of the factors which must be considered in the investigation of these important problems.

(6) Traffic statistics should be internationally comparable and to secure this the problem should be studied by a Subcommittee of the Association.

Fourth Question: Road Exploitation.

General Reporter: ENGINEER MARIO JOSE DE ABREU E SILVA
DIRECTOR OF THE CENTRAL SERVICES OF THE
GENERAL DIRECTION OF ROAD TRAFFIC.

(1) Road works are to be considered as economically sound if they are capable of producing, for the community, a total annual reduction in motor transport cost and other economic advantages which are greater than the annual charges for construction and maintenance.

(2) It is recognized that economic soundness in the sense given to it in Conclusion (1) is an important element on the evaluation of road-work schemes, since it enables a measureable economic value to be attributed to road improvements to the extent to which deficiencies in the highway are prejudicial to motor traffic since this value is an index, although not necessarily the only index, of the practicability and expediency of undertaking the proposed road work.

An element may consist in certain circumstances of the enhancement of the economic activity of certain regions and the linking up of backward areas.

(3) Economic soundness is closely connected with the state of the road-surfacing and conditions making for safety. It is recognised that it is not easy, at the present time, to estimate accurately the effect of these factors on the cost of road transport. In order that the suggested concept may lead to really useful results, it is essential to carry out research and surveys to clarify this concept.

(4) Factors which influence the economic soundness of road works include modifications in the technical characteristics of the roadway which lead to:

More rapid transport,
A reduction in operating costs,
A reduction in running costs, and
Increased safety.

However, such modifications are, in themselves, only economically sound if there is a certainty of a minimum of traffic to justify them.

(5) The standardisation of methods of road construction and repair should be investigated with a view to making such operations as cheap and rapid as possible; so that results predicted in regard to the economic soundness of road schemes should not be prejudiced. It is generally anticipated that, on heavy-trafficked roads, standardisation can only be achieved by complete mechanisation of construction and maintenance methods.

(6) The effect of the cost of road work in determining economic soundness shows how essential it is that the following rules should be applied:

- (a) The technical and economic functions of highway administration should be in the hands of a specialist organization. This organization should be free to administer the funds entrusted to it by the State, because it is found that such a system leads to efficiency and flexibility.
- (b) Such an organization should be given a definite percentage of the total taxes and dues imposed on road users in order that it may be aware, sufficiently far in advance, of the funds which will be at its disposal and thus be in a position to organise its annual work in the most effective manner.

(7) It is acknowledged that there are other conceptions of the rentability of road work based on different ideas from those which have been discussed in the preceding conclusions as, for example, in the case of rentability regarded from the angle of special taxation for the use of a particular road, or on the enhanced value of adjacent land.

(8) It is also necessary to consider, with a view to financing road work, the rentability of a road system which takes into account the relation between the annual outlay on roadways and the revenue derived from their use, or from activities related to that use.

Fifth Question: (A) General road features (B) Urban road features; Surfaces allowing easy repair of underground mains; Pipes; Tramways; Smoke (exhaust gases, etc.); Visibility; Longitudinal gradient; Restrictions on frontage with regard to future building.

General Reporter: ENGINEER MANUEL MOREIRA DUARTE DE SA E MELO, GENERAL DIRECTOR OF THE BOARD OF TOWN PLANNING.

(A) GENERAL CHARACTERISTICS OF ROADWAYS.

(1) Roadways constitute one of the most important factors in the economic life of a country and they are essential to its progress. Consequently, the maximum efficiency, must be obtained from mechanically-propelled road traffic and the layout of the road must be used to the best advantage.

The characteristics of the roads must be designed with this object in view, unless there are reasons to the contrary arising from the topographical features of the terrain, the probable traffic density, or the high cost of the road work.

(2) Roads are grouped in various classes and categories according to the purpose they serve. The technical characteristics vary with the category and class of each road.

(3) The characteristics of roadways should be determined on the basis of following factors:

Density and type of traffic
Maximum speed of the vehicles
Characteristics of the vehicles.

(7) In calculating the density and type of the traffic, economic, social, and strategic factors, which may exert an effect on the volume and development of the traffic, must be taken into account.

It is advisable to take into consideration the probable effects of the economic development of the country and of changes in population, the relation between the number of motor vehicles and the number of inhabitants, and also of the conditions under which the traffic moves on the roads.

We recommend that **traffic censuses** should be taken periodically, in order that the development of the traffic, and the conditions under which it operates, may be ascertained.

(5) The technical characteristics of roads should be determined by taking into consideration, in addition to the characteristics of the vehicles, the value at which the basic speed is fixed and the traffic density. In determining the maximum permitted speed, due consideration should be given to the increasing percentage of motor vehicles using the roads, the category to which the road belongs and the topographical features of the country.

(6) The technical characteristics of the layout in plan of the roads should be modified according to whether they are intended exclusively for motor traffic—e.g., motorways—or for mixed traffic.

On motorways, separate carriageways should be provided for traffic in each direction and crossings on the same level should be eliminated.

The **minimum value of radii** for the road bends should be modified according to the topographical characteristics of the ground. They should not, however, be less than 250 metres.

Normal speeds should be fixed at 100 to 150 km. per hour, according to the density of the traffic and the topographical features of the ground.

On roads carrying mixed traffic, the characteristics of the layout in plan should be determined on the basis of maximum speeds of 70 to 125 km. per hour, according to the relief of the terrain.

(7) The technical characteristics of the longitudinal section should be modified in accordance with the class of the road, the traffic, the speed and the topographical conditions.

On motorways **the longitudinal slope** may be as much as 6 per cent.

On roads carrying mixed traffic the maximum gradient may range from 5 to 8 per cent, and may even be 10 per cent for the less important roads or in hilly districts.

In hilly country, a minimum longitudinal slope of 1.5 to 2.0 per cent should be provided in order to ensure adequate drainage.

(8) The **width of the carriageway** on the roads should be related to the class of road and the number of traffic lanes that are required, having regard to the density and specific nature of the traffic.

Every carriageway on which there is one-way traffic should have not more than three traffic lanes, each 3.50 metres wide.

On roads having a single carriageway and traffic moving in both directions, there should not be more than two traffic lanes in each direction, which is equivalent to a maximum width of 14 metres for the carriageway.

(9) The characteristics of the vehicle running on the roads in different countries should be controlled, particularly as far as the maximum dimensions, the maximum weights per two-wheeled axle and per vehicle, and also the maximum number of trailers are concerned, by the ultimate adoption of the characteristics indicated by the Economic Commission for Europe, especially for main roads or heavily-trafficked roads.

(10) **Adequate sighting distance**, in plan and in profile, should always be provided, and the governments of every country should make the necessary legal arrangements to ensure that these requirements are met.

(11) **Cycle paths** are particularly advisable in districts where their construction is justified by the volume of this special traffic.

(12) **Road crossings** at different levels, except for motorways and trunk roads with a considerable flow of traffic, are only advisable when the traffic movement justifies it, and if local conditions permit.

The solution advocated by Holland for crossings at the same level is worthy of recommendation.

(13) **Marginal access** should be the subject of regulation and it is essential to arrange for the demarcation of zones in which building is prohibited, the width of such zones being varied according to the nature of the traffic and the class and category of the road.

In the particular case of motorways there should be no direct communication between marginal properties and the roadway.

The making of appropriate legal provisions for this purpose is a matter of urgency.

(14) The adaptation and transformation of the existing network of roads, in order to render them suitable for motor traffic, together with the characteristics which are advisable under various circumstances, are deserving of study in the form of a general plan, based on the results of the traffic censuses which have been carried out, and on the class and category of the road. The plan should be drawn up in relation to the economic and financial resources of each country.

(15) Attention should be paid to the **aesthetic appearance** of roadways which should be harmonised with the landscape without detriment to the natural beauties of the district.

(B) CHARACTERISTICS OF URBAN THOROUGHFARES.

(1) The crossing of built-up areas by main roads carrying heavy traffic is inadvisable. Such roads should skirt the town as closely as possible and without any modification of the characteristics which they have in the open country. These characteristics must be maintained and adequate legal provision should be made to prevent the future construction of marginal buildings which would prove detrimental to the flow of long-distance traffic along the road.

(2) Connection between the general traffic highways and urban centres should be effected by means of approach roads, in the form of branch roads linked to the main (State) roads, the characteristics of which allow of the movement of the heavy traffic which utilises them. The layout of these approach roads should be studied at the time the town-planning scheme is drawn up and should be in accordance with the town-planning standards which govern the organization of the urban centres, in such a manner as to avoid interference by local activities with the traffic passing on to the main roads or entering from them.

(3) The characteristics of urban thoroughfares must be subordinated to the needs of the population in their activities as citizens, whether for work, health, social relations, education,

pleasure, or the parking of their cars, etc., or whether such activities have as their object movement from certain specialised districts to others within the limits of the same urban centre.

The layout and cross-sections of urban roads must comply with the aims fixed by the organization controlling the life of the urban centre and determined by the criteria of town-planning adopted by the city authorities, and provide the traffic foreseen on such roads in the town plan.

It is essential, determining the characteristics of such **urban thoroughfares** to conform to the stipulations enumerated below :

- (a) The minimum width of the roadway should not be less than 8 metres.
- (b) The longitudinal slope should not exceed 5 to 6 per cent ; higher values up to 10 per cent are only justifiable when topographical conditions render them necessary.
- (c) Good visibility should be ensured on urban roads, especially at road crossings.
- (d) The construction of urban thoroughfares, together with their characteristics, their maintenance, and their cleansing, must satisfy the legitimate requirements of the population, but they must, nevertheless, be subordinated to the financial resources of the municipal authorities who may impose conditions prior to the solution of the many economic problems connected with local traffic.
- (e) The removal of the surfacings from urban thoroughfares and the opening of trenches in such surfacings should be reduced to an indispensable minimum, and it is of the very greatest advantage to establish plans of road work, drawn up by the municipal authorities in agreement with the undertakings holding the concessions for public services, who maintain the conduits in the sub-soil of the streets, so that advantage may be taken of a single opening up of trenches for carrying out work covering the greatest possible number of buried mains.
- (f) The expenditure involved, and the time during which traffic is suspended, owing to the removal and re-laying of the surfacings resulting from the opening of trenches in urban thoroughfares, must be kept to a strict minimum.

In these thoroughfares the foundation should be of lean concrete whenever possible and it should, preferably, be

laid in slabs of adequate size with sloping joints in the area corresponding to the width of the trenches.

- (g) The materials to be used for paving urban roads must have all the qualities considered indispensable for such a purpose (such as adhesivity, roughness, strength, suitable appearance, etc.) and lend themselves to easy, rapid and economical repair so as to reduce the period during which the traffic is stopped as a result of opening the trenches ; this work should be done in such a way that the paving retains its original characteristics.

It is also to be recommended that local conditions (such as the presence of regional materials and the cost of labour) should be taken into consideration.

- (h) Mains should, as far as possible, be installed in accessible underground galleries, particularly where streets with dense or fast-moving traffic are concerned.

In cases where they cannot be housed in accessible galleries, mains in the sub-soil should be installed, as far as possible, beneath the footways of urban thoroughfares and arranged in accordance with installation schemes in which the position of mains of each kind is always the same in relation to that of the others, and determined in accordance with the frequency and ease with which inspections are carried out.

- (i) The quality and the type of the materials used for buried mains, as well as the technique and the system governing their installation, must be as near perfect as possible, in order to minimise the frequency of inspection of the installation, whether for reasons of current operation or on account of fortuitous repairs.
- (j) The installation of mains in the sub-soil, particularly where telephone and telegraph cables are concerned, should be carried out by passing them through ducts or special tubes of suitable dimensions, which allow of their replacement and which are provided at intervals with manholes for inspection and for junctions.
- (k) The construction of sewers for domestic waste, when they do not form component parts of accessible underground galleries should be carried out in a completely and permanently water-tight manner, and it should be possible to undertake the cleansing, or freeing from obstruction, of such sewers without it being necessary to proceed to the opening of trenches in the paving.

- (l) Tram tracks in urban thoroughfares should be laid on a continuous slab of concrete, with or without reinforcement, according to the nature of the soil, which should extend over the entire width of the street in order to serve also as a foundation for the surfacing.

Ballast, preferably consisting of concrete made without sand, may be laid on the slab, and wooden sleepers then laid on the ballast.

When there are special reasons for laying the rails on a concrete foundation, an elastic pad of wood should be inserted between the lower part of the rail and the foundation.

The problem of urban tram tracks, in relation to the need for maintaining the surfacings in good repair, involves the study of the characteristics of the rolling stock, as well of the need for impervious surfacings and a well-drained soil.

This problem cannot be regarded as having been solved; it should again be the subject of discussion at the next Road Congress.

- (m) In order to protect public health, which is affected by the existence, in the atmosphere of urban centres, of too high a content of carbon monoxide, it is desirable that an official service for the control of combustion should be instituted, the function of which should be to check and correct the toxicity of the products of combustion in industrial establishments which burn coal, and in the petrol engines of motor vehicles. As a measure which is more practicable, and can be applied immediately, it is recommended that motor traffic in narrow and badly-ventilated streets in urban centres should be restricted.
- (n) In order to improve, as far as possible, the conditions of visibility in urban thoroughfares, it should be recommended that the frontages of buildings situated at the corners of main thoroughfares should be rounded off, or the corners cut off.
- (o) It is advisable, in drawing up town-planning schemes for new urban centres, or for making new roads through existing built-up areas, to arrange that in the construction of the streets the longitudinal slopes shall be maintained within the limits: 0.2 per cent and 10 per cent.

- (p) The easements with regard to future building to be imposed on the owners of properties bordering on urban thoroughfares should be determined according to the regulations for town-planning schemes approved by the Government, or in default of such regulations, according to the general legislation of the country, with the object of enabling the municipal authorities to undertake, in a suitable manner, the defence of the interests of traffic and, generally speaking, of the health, well-being and amenities of all the inhabitants.
- (q) On those sections of main roads, beyond the urban limits, which serve centres of population and are outside the belt which is regarded as urbanisable, the defence of the interests of traffic and of those of public health, as also of those of the general amenities of the population, should be the responsibility of the government department which administers these roads and which should also be competent to authorise marginal building and to fix the building line when there are no regional town-planning schemes approved by the government.

Sixth Question: Construction and maintenance of roads in thinly populated or under-developed regions, with special reference to available resources and to the traffic to be carried. Allocation of funds to the construction and maintenance of these roads.

General Reporter: ENGINEER MARIO JOSE FERREIRA MENDES, HEAD OF THE DEPARTMENT OF PUBLIC WORKS ON THE COLONIAL DEVELOPMENT SERVICES.

(1) The adaptation of countries or regions which are still underdeveloped economically to present-day needs and those which can be foreseen in the near future, necessitates the improvement and extension of their road systems.

(2) Since the financial resources of these countries are fairly limited, every endeavour should be made to reduce the cost of constructional work on new roads, as well as the outlay on maintenance, major repair and improvement of existing roads. It is essential, therefore, to solve the problem of the "low-cost road".

(3) The roadway is a progressive creation which passes in succession through a series of intermediate stages.

(4) This progressive transformation requires a minimum period for its completion and this, as a general rule, will take several years.

(5) The construction and improvement of a low-cost road are intimately connected with its maintenance.

(6) The solving of the problem of the low-cost road does not consist of working to a standard plan, which is applicable to every road, but, on the contrary, calls for the adoption of a more flexible method which may be defined as follows :

- (a) Endeavouring to provide routes which are uniform from the point of view of traffic movement ;
- (b) Making the best use of the material and financial resources available.
- (c) To seek solutions, adapted to the present state of road development, which economically and technically fulfill this condition and do not prejudice the future.

(7) Without detriment to the rules stated above, allowance must be made for the fact that, in many cases, the road replaces the railway and, consequently, it must, when necessary, be constructed in such a manner that it is fully capable of serving that purpose.

(8) The carrying out of an important plan of road construction must be adjusted to the economic and social resources of the country.

(9) It is advisable to proceed cautiously and to set limited objectives at the outset ; the rate of execution of the road work can afterwards be accelerated as and when resources permit.

(10) The introduction of equipment for undertaking the work should be preceded by the setting up of means for surveying (which are essential) and the engaging of qualified staff.

(11) For carrying out the road work, use should be made, as far as possible, of local man-power which must be trained so that it is converted into a useful labour force.

(12) The work of organization should not be confined to the road sites only, but should also be concerned with those ancillary activities which govern the progress of the work.

(13) The mechanization of road construction is becoming absolutely necessary and indispensable, more especially in the regions where labour is scarce or of poor quality.

(14) Mechanized plant must be carefully selected and be provided in sufficient quantity for the work which has to be performed.

(15) The operation of the machines and the repair of plant are factors of outstanding importance for the successful mechanization of road work.

(16) The surveying of new roads, or of improvements to existing roads and tracks, calls for particular care. It is therefore recommended :

- (a) That it should be entrusted to a highly qualified staff ;
- (b) That the work of the survey teams should be preceded by cartographical surveys, preferably carried out by means of aerial surveys.

(17) In certain circumstances, the survey teams should be entrusted with the execution of rudimentary construction work and such teams should, therefore, be provided with suitable equipment for this purpose.

(18) Except in special cases (tracks constructed in countries with an extremely dry climate and which meet, more or less satisfactorily, the needs of a small volume of traffic) it is recommended that earth roads should be so constructed that they are fit to receive a permanent surfacing when this is deemed to be necessary.

(19) There is general agreement with regard to the advantage in constructing earth roads, from the outset, to their final alignment and gradients.

(20) The same agreement is no longer obtained in regard to whether it is appropriate to give such roads a definite cross section. A few national reports having emphasized the danger there would be of adopting a too narrow carriageway (considering 8 m. as the "normal optimum") it is recommended that this question be examined at the next Congress.

(21) The technical characteristics of low-cost roads vary considerably from one country to another.

(22) The study of the characteristics of bridges, particularly as regards height, useful width and loading capacity, is of utmost importance for the solution of road problems,

It is also recommended to put on the agenda of the next Congress the question of small scale works (calculation of outlets, calculation of capacity of catchment area, standardisation of small scale works).

It is also recommended that a committee be entrusted by this Association to study these two questions and to submit a Report.

(23) The need for a permanent surfacing on low-cost roads arises when the traffic density reaches a critical figure, which varies according to local conditions, but exceeds 50 vehicles per 24 hours.

(24) Generally speaking, light types of surfacing are sufficient for current requirements.

(25) (i) Types of surfacings, together with wearing courses and methods for their construction and application are, at the present time, the subject of experiments, the results of which must be awaited.

(25) (ii) The study of laterite soils, which constitute an important fraction of the soil met with in tropical and equatorial countries, is recommended particularly in regard to the possibility of impregnating them with the appropriate cut-backs.

(26) The width of the paved carriageway is in terms of traffic intensity, of the nature of the paving, of the visibility of the shoulders and of the more or less hilly nature of the layout; there is no universally accepted formula to establish the width of a carriageway. It is recommended that this question should be put on the Agenda of the next Congress.

(27) The lower the cost of construction of a roadway, the greater the care which must be given to its maintenance.

(28) (i) The system of upkeep must be suited to the type of foundation and surfacing.

(28) (ii) No definite conclusion appears in the national reports in regard to the protection of carriageways against erosion. It is recommended that this question be put on the Agenda for the next Congress.

(29) (i) The problem of maintaining low-cost roads should be made the subject of further investigation and extended trials.

(29) (ii) The necessity for adequate and precise statistical data is generally recognized; it should be gathered and presented in an orderly manner for the information of the next Congress.

(30) Financial means for the construction and maintenance of roads are administered in a different manner in each country.

(31) It is observed that, generally speaking, the funds placed at the disposal of the highways departments are insufficient to ensure the execution of the plans for the extension and improvement of the road networks, and this is likely to prove detrimental, not only to the economy of each country, but also to world economy.

(32) The **financing of a low-cost road** should not be considered from a fiscal standpoint but exclusively from the point of improving the local and general economic conditions of the region concerned.

(iii) INTERNATIONAL CONFERENCE ON SOIL MECHANICS AND FOUNDATION ENGINEERING

The Third International Conference on Soil Mechanics and Foundation Engineering will be held in **Switzerland in 1953**. The tentative dates are the 16th to the 26th August 1953.

Participants:—The main participants of the Conference will be the members of National Societies*, but all engineers or groups of engineers interested in soil mechanics and foundation engineering will be welcome to participate in the Conference. Such engineers, whether practical engineers, research workers, or teachers, may register as guest-participants and may join in discussions by previous arrangement with the National Society.

Programme:—The first part of the Conference, from the 16th to the 20th August 1953, is to take place in Zurich and includes the opening of the Conference, eight technical sessions of about two to three hours each, lectures on general and specific (Swiss) problems, one or two short excursions, and daily visits to the soil mechanics laboratory. From August 21 to 24 the Conference will conduct an excursion through the Alps. The closing session will take place in Lausanne on the 25th August.

Papers.—Only those Papers will be printed which:—

- (a) are a real contribution to knowledge of the fundamental properties of soils, or
- (b) indicate new methods of application of soil mechanics which have proved satisfactory in practice, or
- (c) contain case records and measurements in connection with a detailed description of the soil, and include comparisons between measurements and calculations.

Technical Sessions.—The titles of the sections under which Papers will be accepted and discussed during the eight sessions are:—

Session No.	Subject
1	Theory and hypotheses of general character, soil properties classification, engineering geology.
2	Laboratory investigation (including compaction tests and improvement of soil properties).

* For India, the Indian National Society of Soil Mechanics and Foundation Engineering, Curzon Road Barracks, New Delhi,

- 3 Field investigations, compaction control, soil stabilization, technique of field observations.
- 4 Foundations of buildings and dams, bearing capacity, settlement observations, regional subsidences.
- 5 Piles and pile foundations, settlement of pile foundations.
- 6 Roads and runways, airports (flexible and rigid pavements and their foundations).
- 7 Earth pressure, retaining walls, earth tunnels, and pits.
- 8 Stability and deformation of slopes and earth dams, research on pore pressure-measurements, ground-water problems.

Submission of Papers.—All Papers from members in India must first be submitted to the Secretary of the National Society. Preliminary selection of Papers will be made by the National Committee. Final selection, however, rests with the General Reporters.

Submission Dates.—Three copies of the summary (not exceeding 300 words) of each proposed Paper should be submitted to the National Society not later than the 30th April 1952.

Detailed information about the last date for submitting complete Papers, the length of Papers, sizes of figures and photographs accompanying them, addresses of General Reporters, etc., etc., may be had from the Secretary of the National Society.

BOOK REVIEW.

"Quality Concrete" published by the Concrete Association of India, 1, Queen's Road, Bombay, 218 pages, 172 illustrations and diagrams, 42 tables, size $9\frac{3}{4} \times 7\frac{1}{2}$, price Rs 7-8-0.

The Concrete Association of India are to be congratulated on the production of a well-conceived, profusely illustrated, comprehensively written, and exceedingly well got-up treatise on concrete.

The book deals with the properties of the materials used in concreting their tests, and the methods of storing and handling them on the job.

The manufacture and Chemistry of cement are only briefly touched upon but the various types of special cements, (such as "rapid hardening", "low-heat", "air-entraining" and many others) and the conditions under which they are used, are described in detail. Results of research such as that on the expansive reaction between cement and aggregates are given. Under "aggregates" besides recounting what constitutes soundness, strength, resistance to abrasion etc., the book goes into details about their geological characteristics and there is a most useful chapter on the classification of rocks for aggregates.

A complete chapter is devoted to the proper designing of concrete mixes. All steps in the making of concrete, from mixing and transporting to placing in the forms, compacting and curing are dealt with lucidly and fully. Modern machinery such as crushers, truck mixers, batching plants, buckets, hoists, chutes, belt conveyors, concrete pumps, and tremies (for placing concrete under water) which are coming more and more into use are described and illustrated with photographs.

The book is a valuable contribution to the production of quality concrete and should be a useful guide to engineers, students and contractors.

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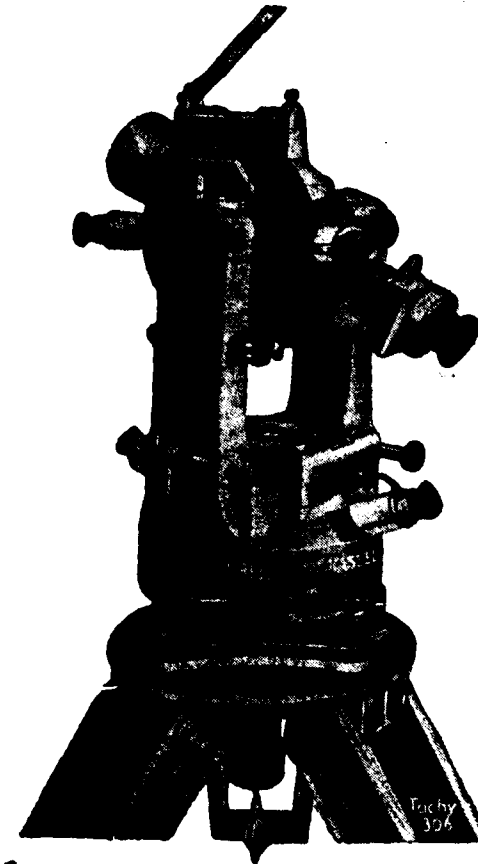
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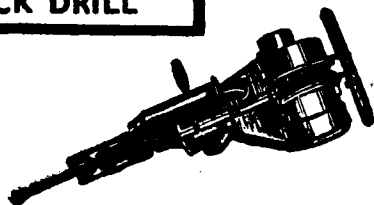
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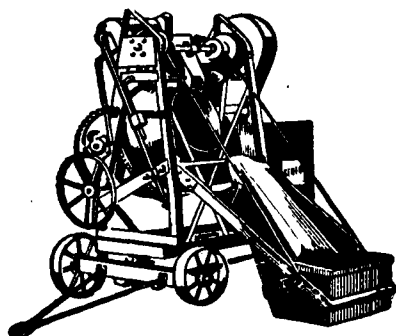
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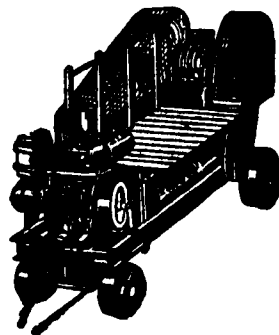
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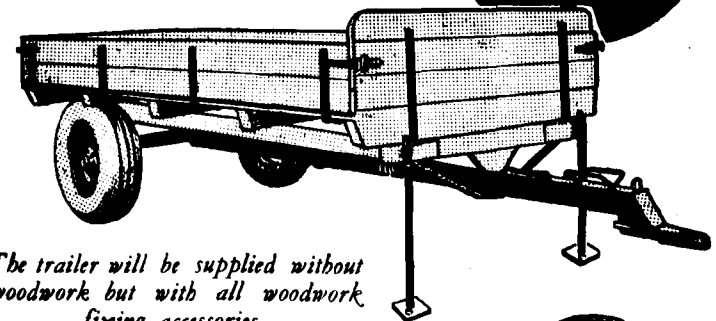
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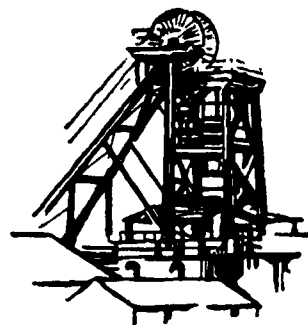
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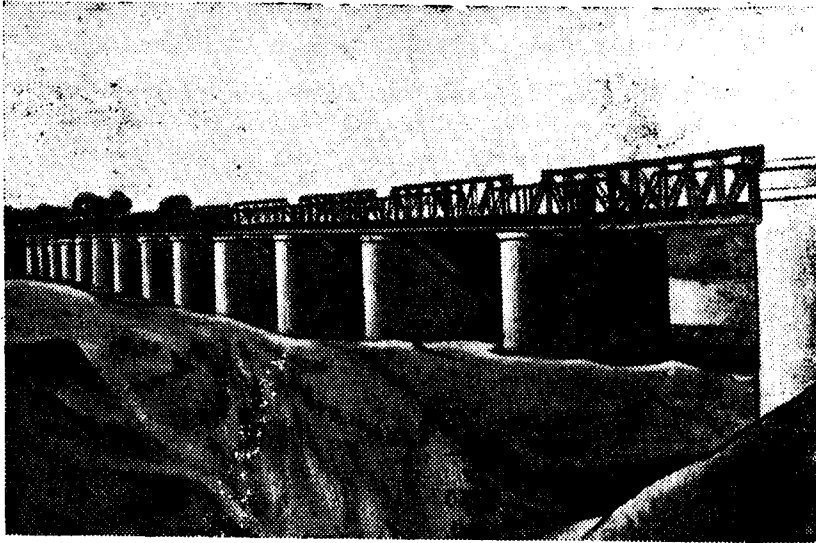


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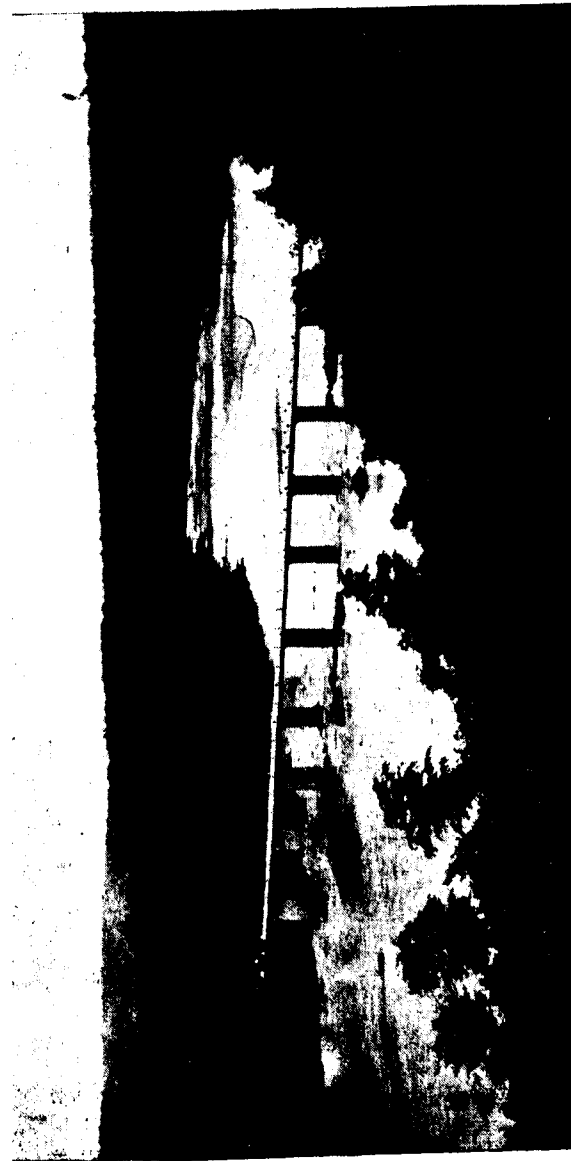


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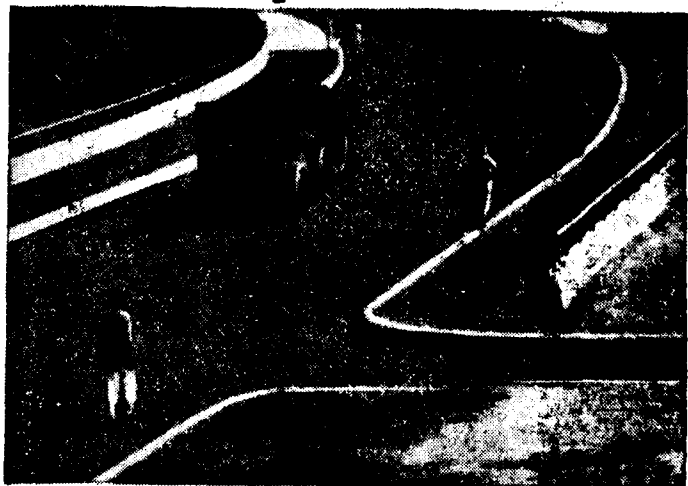
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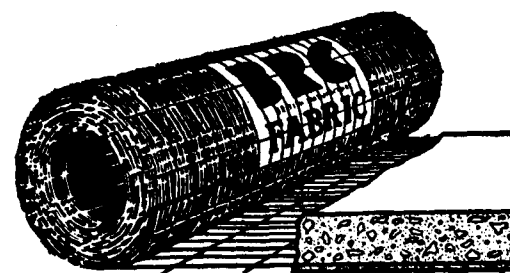
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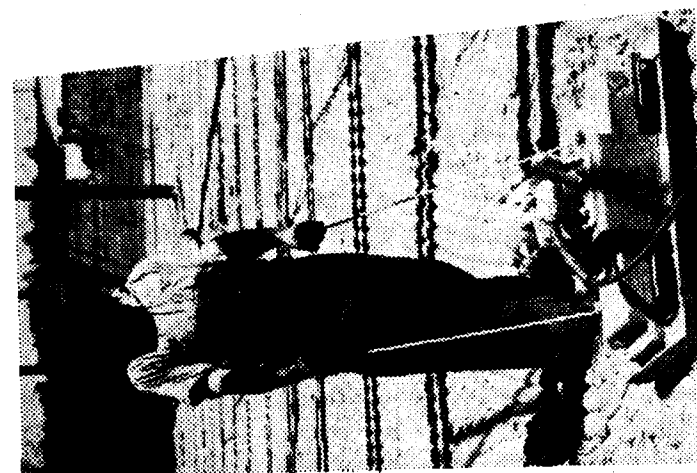
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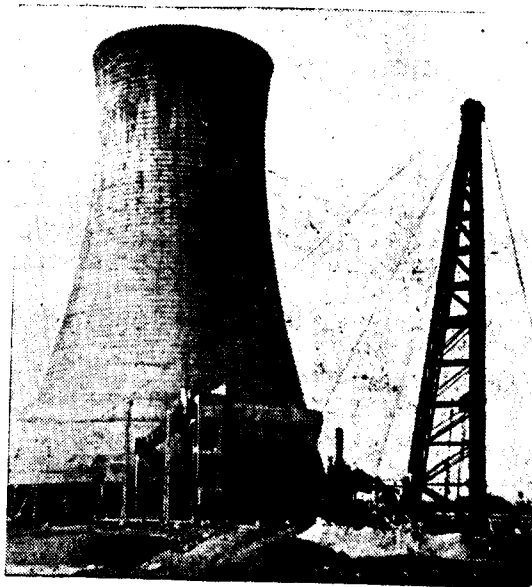


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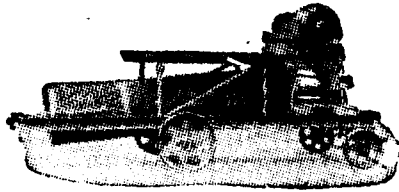
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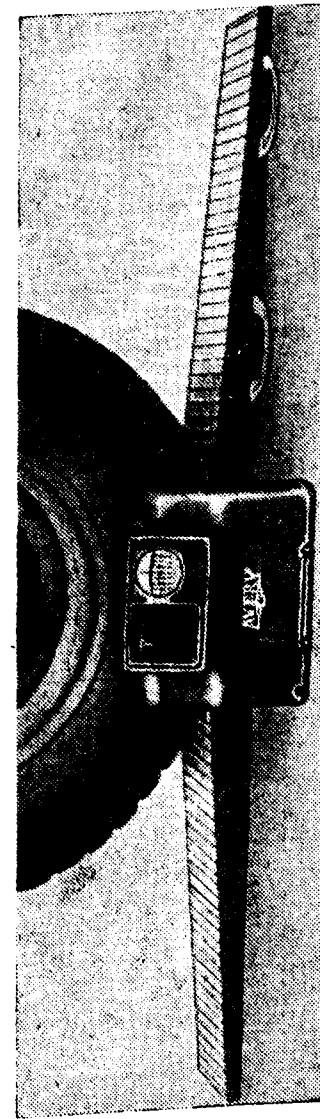
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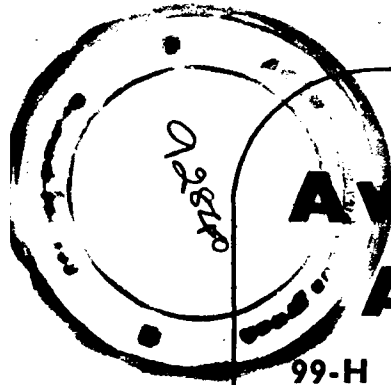
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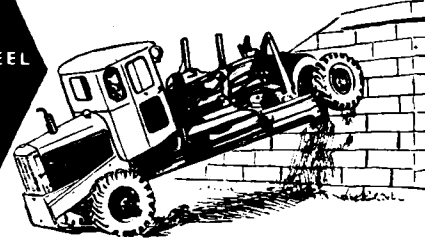


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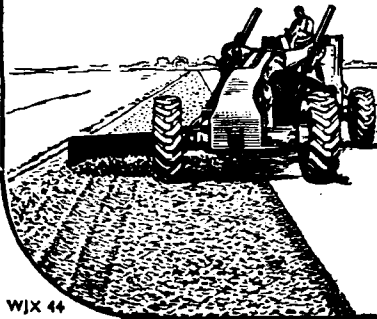
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