TRANSPORT-COMMUNICATIONS

MONTHLY REVIEW (TCMR)

SEPTEMBER 1961—No. 173

26

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TRANSPORT-COMMUNICATIONS

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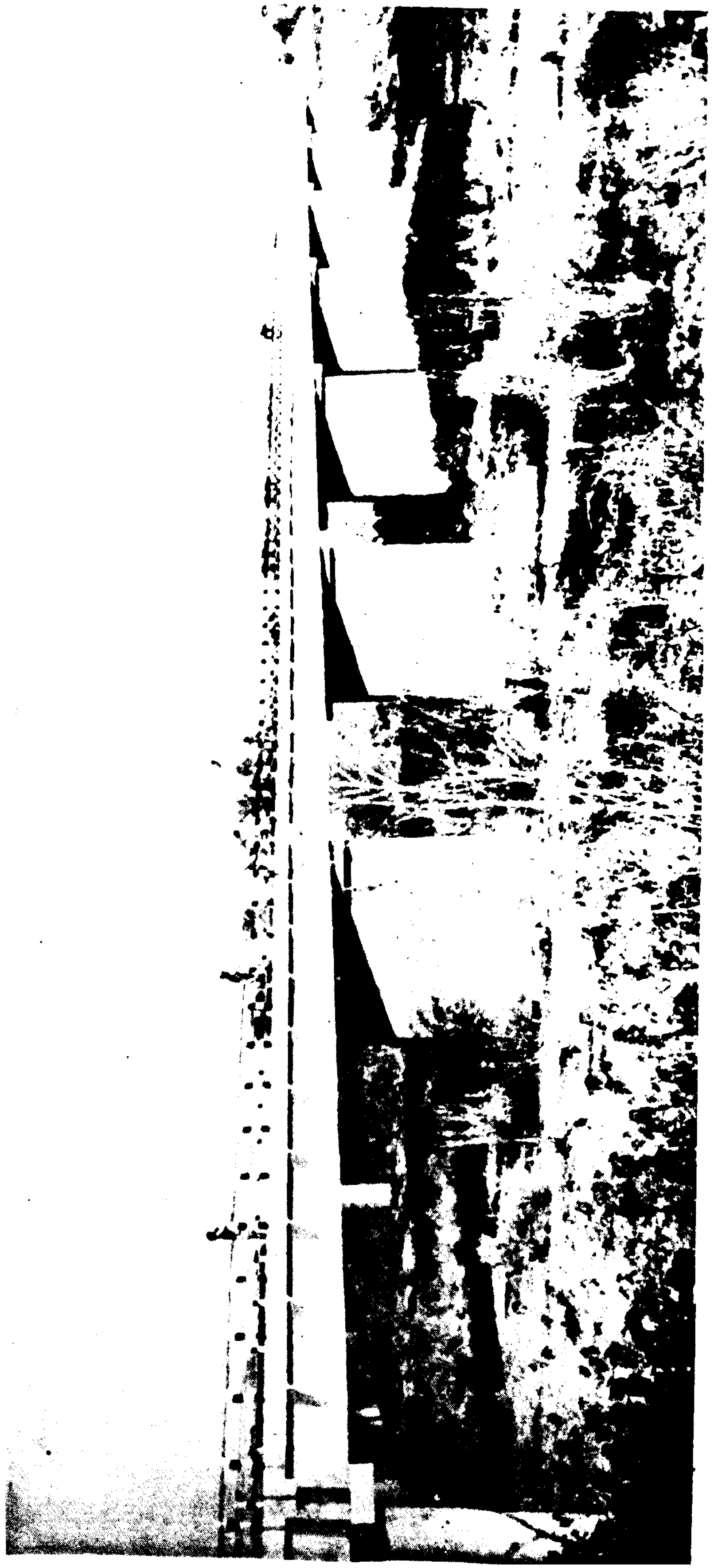


BEIN BRIDGE in Mile 218 1-2 of G. T. Road near Jullundur in Punjab. 8 spans 90 ft. 3 in. each. 7 numbers prestressed concrete beams in each span

TRANSPORT-COMMUNICATIONS MONTHLY REVIEW

A REVIEW OF
ROAD ENGINEERING, DEVELOPMENT & TRANSPORT

SEPTEMBER 1961 26

THE CENTRAL ASSESSMENT COMMITTEE

THE question of utilising new techniques of road construction evolved as a result of research and thereby effecting economy in the cost of road construction and also increasing the durability of roads has been under the consideration of the Government of India for some time. A Committee of the Panel of Scientists appointed by the Planning Commission recommended in December, 1956, that in order to bridge the gap between research and the application thereof, Assessment Committees should be set up preferably under the auspices of All-India Technical Bodies, to evaluate the results of research, to decide on large scale trials and constructional work and to make allocations for these works from the funds to be provided for the purpose. As far as road research goes, this suggestion has been examined by the Government of India in consultation with the State Governments and it resolved that a Central Assessment Committee should be constituted under the aegis of the Indian Roads Congress.

The composition of the Committee as suggested by the Indian Roads Congress and approved by the Government of India shall be as follows :—

(i) The Consulting Engineer (Road Development), Department of Transport (Roads Wing);

(ii) The President, Indian Roads Congress;

(iii) The Director, Central Road Research Institute;

(iv) & (v) Two Chief Engineers of States :

(1) The Chief Engineer, Public Works Department, Government of West Bengal.

(2) The Chief Engineer, Buildings and Communications Department, Government of Gujerat;

(vi) & (vii) Two Directors of State Road Research Laboratories:

(1) The Director, Highway Research Station, Madras;

(2) The Director, Public Works Department, Buildings and Roads, Research Laboratory, Chandigarh.

(viii) One member from a non-Governmental organisation :

Shri B. V. Vagh, Vice-President, Indian Roads and Transport Development Association, Bombay.

The Consulting Engineer (Road Development) shall be the Convenor of the Committee and an officer of the Central Road Research Institute, nominated by the Director of that Institute will act as the Secretary to the Committee.

In addition, while examining the road projects of a particular State, and while recommending suitable new techniques for replacing conventional ones, the Committee shall co-opt the Chief Engineer and the head of the Research Institute of that State, or their representatives, if they are not already on the Committee. The Committee will also have the power to co-opt three experts who have special knowledge of the subject under consideration.

The terms of reference of the Committee will be as follows :—

(i) To select new techniques of road construction for trial. In selecting new techniques, the Committee will confine itself to those which have been tried on pilot experiments and have reasonable chances of succeeding. The techniques should compare favourably with the existing methods of road construction as regards cost in the region ;

(ii) To examine the road projects of each State and determine the site, length, etc., of roads where the normal methods of construction can be replaced by a suitable new technique in furtherance of research. For each State, the Committee will recommend such replacements to the extent of one per cent of the allocation for road development schemes in the State ;

(iii) To collect such progress and performance reports as the Committee may prescribe for the work, expenditure and behaviour, and assess the results of trials of the new techniques ;

(iv) In the event of any loss of money occurring as a result of the failure of the road constructed according to the new technique or the total cost of the new technique exceeding that of the conventional method, to assess the loss or the extra expenditure, as the case may be, to be met from the "Risk Fund" set up for the purpose.

The members of the Committee, other than the Consulting Engineer (Road Development), the President of the Indian Roads Congress and the Director, Central Road Research Institute, will hold office for three years and will be eligible for re-appointment.

The first meeting of the Central Assessment Committee was held under the chairmanship of Shri H. P. Sinha, Consulting Engineer (Road Development) and Joint Secretary to the Government of India, Ministry of Transport and Communications, at New Delhi on 13th September, 1961.

INDIAN NATIONAL GROUP OF THE INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING

A meeting of the Executive Committee of the IABSE (ING) was held under the chairmanship of Shri S. L. Bazaz, Additional Consulting Engineer (Bridges) on 30th August, 1961.

The Executive Committee along with the other agenda approved the revised Constitution of the Group. The amended Constitution will now be circulated to the members of the Managing Committee.

GEOMETRIC DESIGN STANDARDS FOR THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS IN U. S. A.*

General

THE National System of Interstate and Defense Highways is the most important in the United States. It carries more traffic per mile than any other comparable national system and includes the roads of greatest significance to the economic welfare and defense of the Nation. The highways of this system must be designed in keeping with their importance as the back-bone of the Nation's highway systems. To this end they must be designed with control of access to insure their safety, permanence and utility and with flexibility to provide for possible future expansion. Two-lane highways should be designed so that passing of slower moving vehicles can be accomplished with ease and safety at practically all times. Divided highways should be designed as two separate one-way roads to take advantage of terrain and other conditions for safe and relaxed driving, economy, and pleasing appearance. All known features of safety and utility should be incorporated in each design to result in a National System of Interstate and Defense Highways which will be a credit to the Nation.

These objectives can be realized by conscious attention in design to their attainment. All Interstate highways shall meet the following minimum standards. Higher values which represent desirable minimum values, a device used in previous Interstate standards, are not shown because it is expected that designs will generally be made to values as high as are commensurate with conditions, and values near the minimums herein will be used in design only where the use of higher values will result in excessive cost. In determination of all geometric features, including right-of-way, a generous factor of safety should be employed and unquestioned adequacy should be the criterion. All design features required to accommodate the traffic of the year 1975 shall be provided in the initial design; however, where justifiable, the construction may be accomplished in stages.

The American Association of State Highway Officials' *Policy on Geometric Design of Rural Highways*,[1] the *Policy on Arterial Highways in Urban Areas*, when adopted, and the *Standard Specifications for Highway Bridges*[2] shall be used as design guides where they do not conflict with these Standards.

Traffic Basis

Interstate highways shall be designed to serve safely and efficiently the volumes of passenger vehicles, buses, and trucks, including tractor trailer and semitrailer combinations and corresponding military equipment, estimated to be that which will exist in 1975, including attracted, generated, and

* Adopted July 12, 1956, by the American Association of State Highway Officials. Approved July 17, 1956, by the U. S. Department of Commerce, Bureau of Public Roads, Washington 25, D. C.

[1] Published by the American Association of State Highway Officials, 917 National Press Building, Washington 4, D. C., at $4.50 a copy.

[2] Published by the AASHO at $4.50 a copy.

development traffic on the basis that the entire system is completed.

The peak-hour traffic used as a basis for design shall be as high as the 30th highest hourly volume of the year 1975, hereafter referred to as the design hourly volume, "DHV (1975)." Unless otherwise specified, DHV is the total, two-direction volume of mixed traffic.

Control of Access

On all sections of the Interstate System, access shall be controlled by acquiring access rights outright prior to construction or by the construction of frontage roads, or both. Control of access is required for all sections of the Interstate System. Under all of the following conditions, intersections at grade may be permitted in sparsely settled rural areas which are a sufficient distance from municipalities or other traffic-generating areas to be outside their influence, and where no appreciable hazard is created thereby.

(a) The Interstate highway is a 2-lane highway having a DHV (1975) of less than 500.

(b) Each intersection at grade is with a public road or private driveway with little potential for traffic increase and on which the current average daily traffic does not exceed 50 vehicles.

(c) Such intersections do not exceed two per side of the Interstate highway per mile.

(d) Sufficient additional corner right-of-way at each intersection at grade is acquired to insure that access connections on the cross-road are sufficiently removed to minimize interference with the Interstate highway.

(e) The right to eliminate, terminate, or reroute each such public road or private driveway is vested in the appropriate public authority at the time of initial construction.

Where a grade separation is called for under these standards and extraordinary conditions exist under which a grade separation would not be in the public interest, an intersection at grade may be permitted through agreement between the State highway department and the Secretary of Commerce.

Railroad Crossings

Railroad grade crossings shall be eliminated for all through-traffic lanes.

Intersections

All at-grade intersections of public highways and private driveways shall be eliminated, or the connecting road terminated, rerouted or intercepted by frontage roads, except as otherwise provided under Control of Access.

Design Speed

The design speed of all highways on the system shall be least 70, 60, and 50 miles per hour for flat, rolling, and mountainous topography, respectively, and depending upon the nature of terrain and development. The design speed in urban areas should be at least 50 miles per hour.

Curvature, Superelevation, and Sight Distance

These elements and allied features, such as transition curves, should be correlated with the design speed in accordance with the *Policy on Geometric Design of Rural Highways* of the American Association of State Highway Officials.

On 2-lane highways, sections with sufficient sight distance for safe passing should be frequent enough and the total length of such sections be a sufficient percentage of the highway length to accommodate the DHV. Where it is not feasible to provide enough passing opportunities, a divided highway should be provided instead.

Gradients

For design speeds of 70, 60, and 50 miles per hour, gradients generally shall be not

steeper than 3, 4, and 5 per cent, respectively. Gradients 2 per cent steeper may be provided in rugged terrain.

Width and Number of Lanes

Traffic lanes shall not be less than 12 feet wide.

Where the DHV (1975) exceeds 700 or exceeds a lower 2-lane design capacity applicable for the conditions on a particular section, the highway shall be a divided highway. For lower volumes, the highway shall be a 2-lane highway so designed and located on the right-of-way that an additional 2-lane pavement can be added in the future to form a divided highway.

Efficiency and capacity of 2-lane highways may be increased by providing added climbing lanes on upgrades where critical lengths of grade are exceeded or by providing more frequent and longer sections safe for passing.

Medians

Medians in rural areas in flat and rolling topography shall be at least 36 feet wide. Medians in urban and mountainous areas shall be at least 16 ft wide. Narrower medians may be provided in urbon areas of high right-of-way cost, on long and costly bridges, and in rugged mountainous terrain, but no median shall be less than 4 feet wide.

Curbs or other devices may be used where necessary to prevent traffic from crossing the median.

Where continuous barrier curbs are used on narrow medians, such curbs shall be offset at least 1 foot from the edge of the through-traffic lane. Where vertical elements more than 12 inches high, other than abutments, piers, or walls, are located in a median, there shall be a lateral clearance of at least $3\frac{1}{2}$ feet from the edge of the through-traffic lane to the face of such element.

Shoulders

Shoulders usable by all classes of vehicles in all weather shall be provided on the right of traffic. The usable width of shoulder shall be not less than 10 feet. In mountanious terrain involving high cost for additional width, the usable width of shoulder may be less but at least 6 feet. Usable width of shoulder is measured from edge of through-traffic lane to intersection of shoulder and fill or ditch slope except where such slope is steeper than 4 : 1 where it is measured to beginning of rounding.

Slopes

Side slopes should be 4 : 1 or flatter where feasible and not steeper than 2 : 1 except in rock excavation or other special conditions.

Right-of-Way

Fixed minimum widths of right-of-way are not given because wide widths are desirable, conditions may make narrow widths necessary, and right-of-way need not be of constant width. The following minimum widths are given as guides.

In rural areas right-of-way widths should be not less than the following, plus additional widths needed for heavy cuts and fills:

	Minimum width in feet	
Type of highway	*Without frontage roads*	*With frontage roads*
2-lane	150	250
4-lane divided	150	250
6-lane divided	175	275
8-lane divided	200	300

In urban areas right-of-way width shall be not less than that required for the necessary cross-section elements, including median, pavements, shoulders, outer separations, ramps, frontage roads, slopes, walls, border areas, and other requisite appurtenances.

Culverts

All culverts shall be of sufficient length to accommodate the pavements, median, and shoulders.

Bridges and Other Structures

The following standards apply to Interstate highway bridges, overpasses, and underpasses. Standards for crossroad overpasses and underpasses, are to be those for the crossroad.

Bridges and overpasses, preferably of deck construction, should be located to fit the overall alinement and profile of the highway.

The clear height of structures shall be not less than 14 feet over the entire roadway width, including the usable width of shoulders. Allowance should be made for any contemplated resurfacing.

The width of all bridges, including grade-separation structures, of a length of 150 feet or less between abutments or end supporting piers shall equal the full roadway width on the approaches, including the usable width of shoulders.

Barrier curbs on bridges longer than 150 feet between abutments or end supporting piers, and curbs on approach highways, if used, shall be offset at least 2 feet. Offsets to face of parapet or rail shall be at least 3½ feet measured from the edge of through-traffic lane, and apply on right and left.

The lateral clearance from the edge of through-traffic lanes to the face of walls or abutments and piers at underpasses shall be the usable shoulder width but not less than 8 feet on the right and 4½ feet on the left.

A safety walk shall be provided in tunnels and on long-span structures on which the full approach roadway width, including shoulders, is not continued.

THE SEVENTH CONGRESS ON THEORETICAL & APPLIED MECHANICS

The Seventh Congress on Theoretical and Applied Mechanics will be held under the Presidentship of Dr. D. S. Kothari, Chairman, University Grants Commission, Government of India, from December 23 to 26, 1961, at the Indian Institute of Technology, Powai, Bombay-76.

2. Papers to be contributed for the Congress should reach the officiating Secretary, with three copies of their abstract by the 15th October, 1961. The papers may be on any of the subject.

1. Elasticity, Plasticity, and Rheology,
2. Fluid Mechanics (Aerodynamics, and Hydrodynamics),
3. Mechanics of Solids (Ballistics, Vibration, Friction and Lubrication)
4. Statistical Mechanics, Thermodynamics and Heat Transfer,
5. Mathematics, Physics, and Statistics,
6. Experimental Techniques,
7. Computation methods.

For any further information on the subject, Dr. B. R. Seth, DSC (London), Secretary, Treasure, Indian Institute of Technology, Kharagpur, may be contacted.

THE MD ENGINEERING SEISMOGRAPH AND ITS APPLICATION TO HIGHWAY ENGINEERING

Dr. Harold M. Mooney

Vice-President, Geophysical Specialities Company, Hopkins Minnesota

As you may know, there has been considerable interest during the last year or two in the application of the MD Engineering Seismograph to Highway Engineering problems. Many dozens of these instruments are now in use by contractors and highway departments, and numerous papers have appeared in trade journals such as Engineering News Record and Contractors and Engineers. In view of its widespread application, it was felt that a talk describing the MD Seismograph in more detail might be of general interest. I would like to (a) describe to you the types of subsurface problems which can be solved, (b) explain the principle of operation, and (c) give you some examples of highway engineering applications.

The subsurface problems which can be solved by the MD Seismograph can be classified as follows :—

(1) Determination of thickness of a surface layer, or depth to a layer boundary.

(2) Determination of depths to two layer boundaries, for example, the thickness of soil overlying gravel together with depth to an underlying bedrock.

(3) Dip of the rock surface, if it is not horizontal.

(4) Identification of materials in each of the layers, as for example, gravel, clay, solid rock, weathered rock.

(5) Engineering classification of the material properties, such as bearing capacity, rippability.

The operating principle of the MD Seismograph can be illustrated by Fig. 1. Sound waves from a sledgehammer blow (or explosive) will travel through the subsurface along the various paths. Some of the waves travel a "Direct" path to the receiver, which is located on the surface a few tens of feet away. Other waves travel down to the high-speed rock layer (which we assume here to be present) and back to the receiver. It is the function of the MD Seismograph to measure the time of travel for the fastest wave, whatever may be its path. As can be seen in Fig. 2, the "Direct" wave will be the fastest at short distances, but for longer distances, the "Refracted" wave may arrive sooner.

An analogy which we find helpful is that of an auto race between two cities which are separated by a mountain. One auto travels the winding road over the mountain, while the other auto travels along a high-speed highway around the mountain. If the total distance is short enough, the auto on the "Direct" path over the mountain will win, but for larger distances, the higher speed along the "Refracted" path around the mountain may overcome the distance handicap.

Figure 3 shows a typical set of readings, taken along a line of 5 hammer stations. When graphed, the data appear as in Fig. 4. Three quantities can be read directly from this graph : the distance at which the intersection occurs, the slope of the first line segment (which equals the speed of sound in soil), and the slope of the second line segment (which equals the speed of sound in rock). The interpretation is shown in Fig. 5 ; the materials are identified by their characteristic velocities, and the depth is found to be 12 feet to rock.

Figures 6 and 7 show how the MD Seismograph performs its function of measuring travel time. As shown at the bottom of Fig. 7, the time reading is obtained instantaneously by means of lights on the instrument. Figure 8 pictures the unit with accessory equipment.

One of the important applications to highway engineering has been in the prediction of rock rippability. Rock velo-

OPERATION OF MD SEISMOGRAPH

MEASURES TIME INTERVAL BETWEEN

HAMMER BLOW

AND

FIRST WAVE ARRIVAL

AT RECEIVER

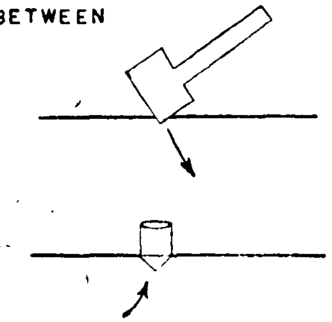


Fig. 1

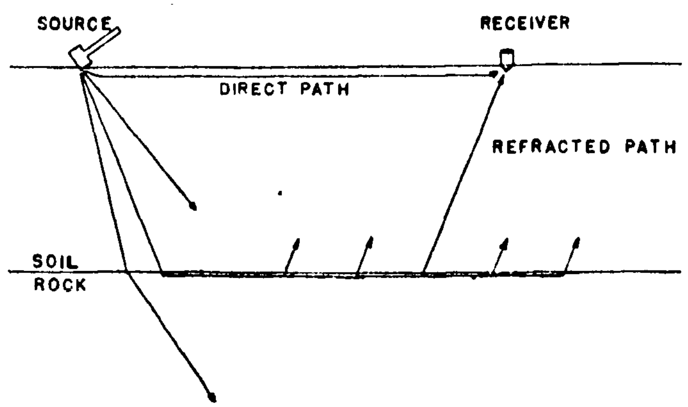


Fig. 2

FIELD DATA

DISTANCE	TIME
10 FEET	10 MILLISECONDS (= 010 SECONDS)
20	20
30	30
40	32
50	34

Fig. 3

city, as measured by the MD Seismograph, can be correlated with degree of consolidation and with rippability. Figure 9 shows how this correlation is made. By predicting rippability in advance of bidding, cost estimates can be greatly improved. This offers a tremendous competitive advantage.

The next few slides show case histories taken by the Michigan State Highway Department with the MD Seismograph over

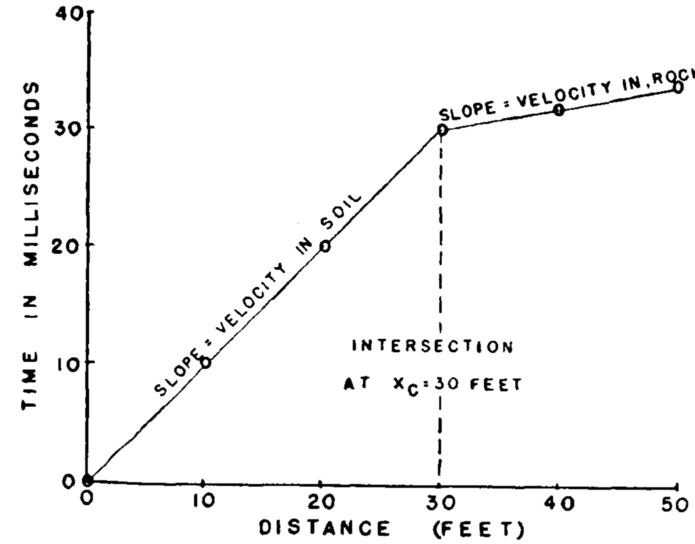
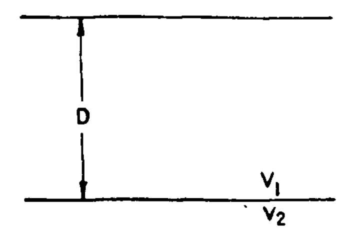


Fig. 4

INTERPRETATION



1. V_1=1000 FEET/SECOND

(CHARACTERISTIC OF SOIL)

2. V_2=5000 FEET/SECOND

(CHARACTERISTIC OF ROCK)

3. DEPTH $D = \frac{X_C}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$

$$D = \frac{30}{2}\sqrt{\frac{5000 - 1000}{5000 + 1000}}$$

D = 12 FEET

Fig. 5

FASTEST PATHS

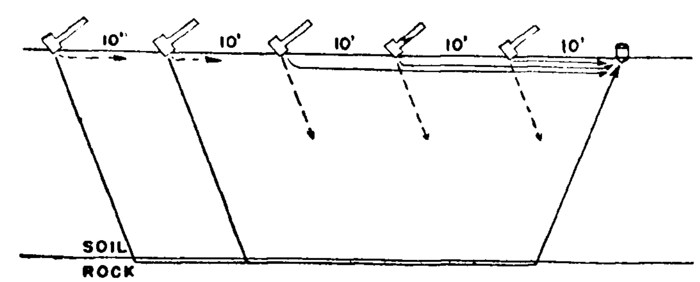
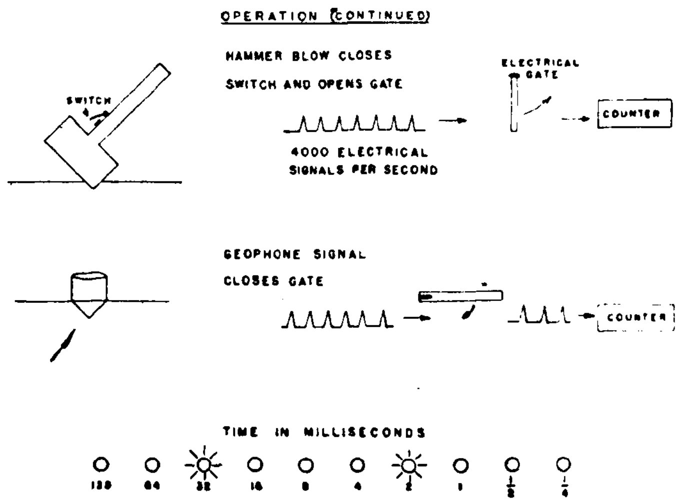


Fig. 6

the past year. They have used the unit on a great variety of problems, of which the most frequent has been determination of subsurface information on difficult cut sections.

The first example shown here, a relocation of U.S. Highway 127, is typical of the most frequent type of request for subsurface informat ion made to the Michigan Stat Highway Test Laboratory in Ann Arbor Bedrock was suspected to be within the depth of the proposed cut. Seismic soundings taken by the Soils Section showed the bedrock to exist at one end only, and there it was well below the grade line. The seismic investigation located a body of



TIME = 32 + 2 = 34 MILLISECONDS

Fig. 7

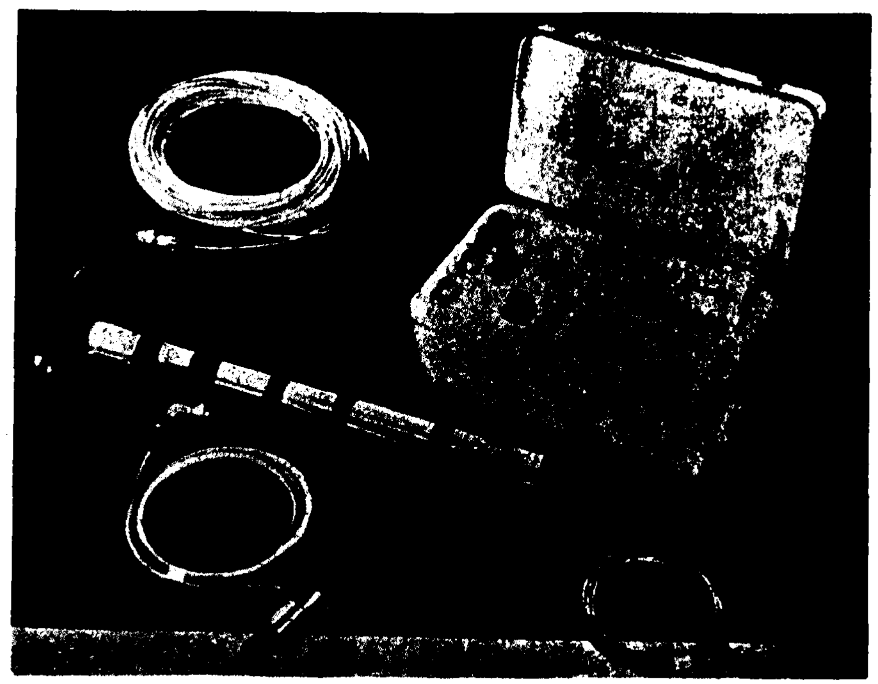


Fig. 8

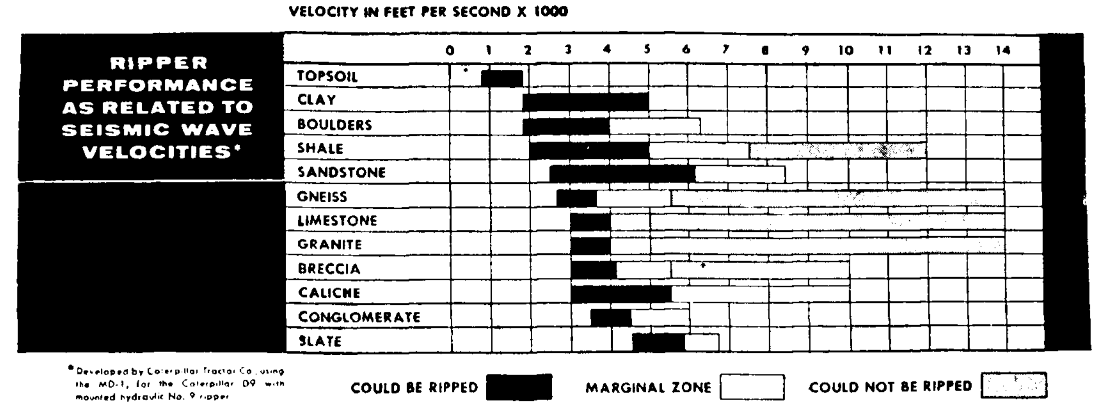


Fig. 9

compacted clay and loam, which was shown to be slightly above grade at the centre of the cut. From this information, a profile was constructed (as shown in Fig. 10) and given to the design engineers for their use in designing the sub-base and for finalizing the grade line. The information was also made available to contractors bidding on the job. The over-all result was lower bids, with substantial savings for the State of Michigan.

As can be seen from this slide, borings were made to correlate the seismic findings. They proved to be useless in establishing bedrock depth because they met refusal at points well above the bedrock, due to scattered boulders in the area.

Figure 11 shows another highway relocation job. The information made available from the seismic survey permitted the Soils Section to classify materials to be excavated; this resulted in lower bids. In this case, they determined which materials could be moved by scraper alone, which would have to be ripped out by a heavy tractor-ripper combination and then moved with scrapers and which would have to be drilled and shot.

Figure 12 shows an application in locating a borrow pit. Using the MD, Michigan State Highway Personnel proved its effectiveness in establishing depth of overburden and quantity of deposit of suitable aggregate materials. Figure 12 shows the seismic profile for this Michigan State Highway Department borrow pit. It was lying on a slope and covered with thick underbrush. It was difficult for any other exploration method to be used because of access.

Seismic Cross Sections US-127 Relocations

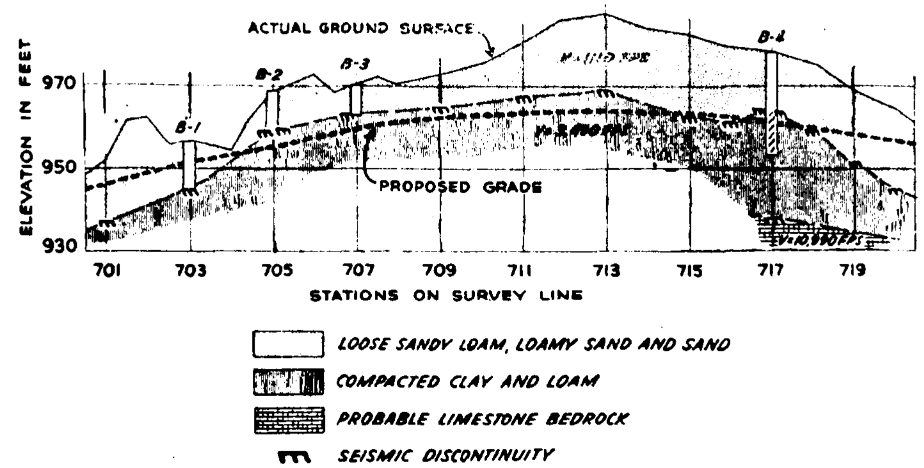


Fig. 10

Through the use of the MD Seismograph, the existence of suitable borrow was established and delineated.

Electrical resistivity equipment proved helpful in providing more exact information about the nature of the materials in this glacial drift deposit, but proved useless

different seismic properties as was demonstrated by seismic analysis.

These are just a few of the wide variety of problems which can be handled by the MD Engineering Seismograph. The unit has been field proven for over three years in climates as varied as Greenland, Alaska,

Seismic Cross Section M-78 Relocation

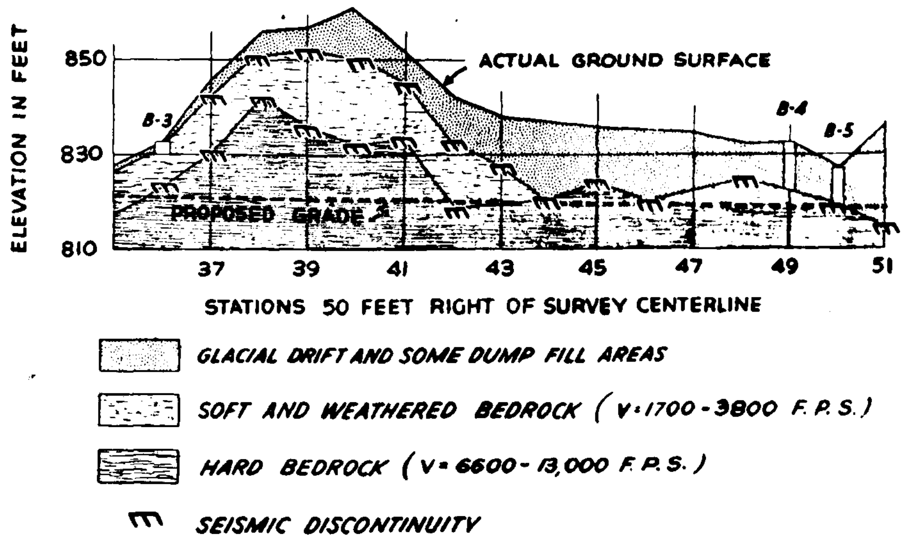


Fig. 11

Cross Sections from Profile-Contours and Seismic Discontinuitis Pit 7

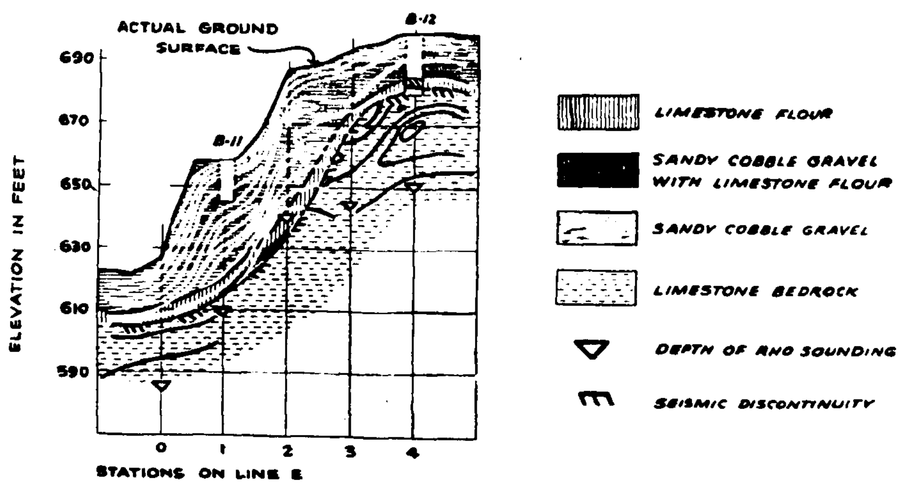


Fig. 12

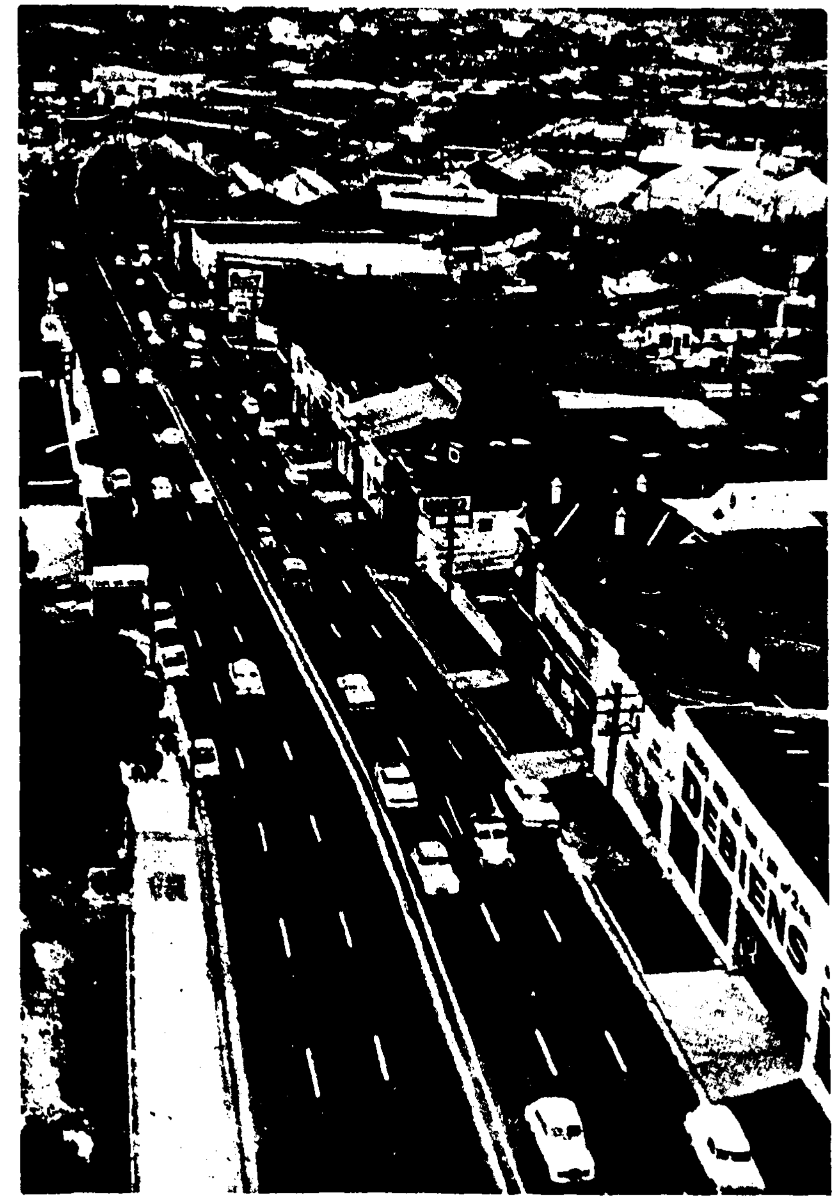
for providing depth information because as is shown here, the lines of electrical resistance did not follow the layers of soil materials. Bedrock and overlying drift had similar electrical properties but vastly

Guam, Pakistan. It is now in use in 23 countries of the world.

(From "Journal of the Tennessee Highway Conference Bulletin No. 22," December, 1960.)

CONSTRUCTION OF NARROW MEDIANS IN URBAN ROADS

DURING recent years, the Department of Main Roads has had in progress an active programme of construction of medians in six-lane arterial roads in the Sydney metropolitan area. In earlier years most of the metropolitan Main Roads had carriageways only 42 feet wide, some less. At an early stage in the history of the



Narrow median on Parramatta Road (Great Western Highway) at Taverners Hills, Lewisham

Department, it was decided to widen many of these to 60 feet, i.e., by increasing the original road reserve width from 66 feet to 84 feet. In the first place the roads were "realigned" to this width, which meant that no new building could be built subsequently on the strip required for widening. It was intended that, at a later date, as traffic increased, the property would be acquired and the carriageway then widened.

Since the war, such property acquisition and widening have been put in hand on a number of arterial roads, and increasingly these are being converted in this way from four lanes (42 feet) to six lanes (60 feet).

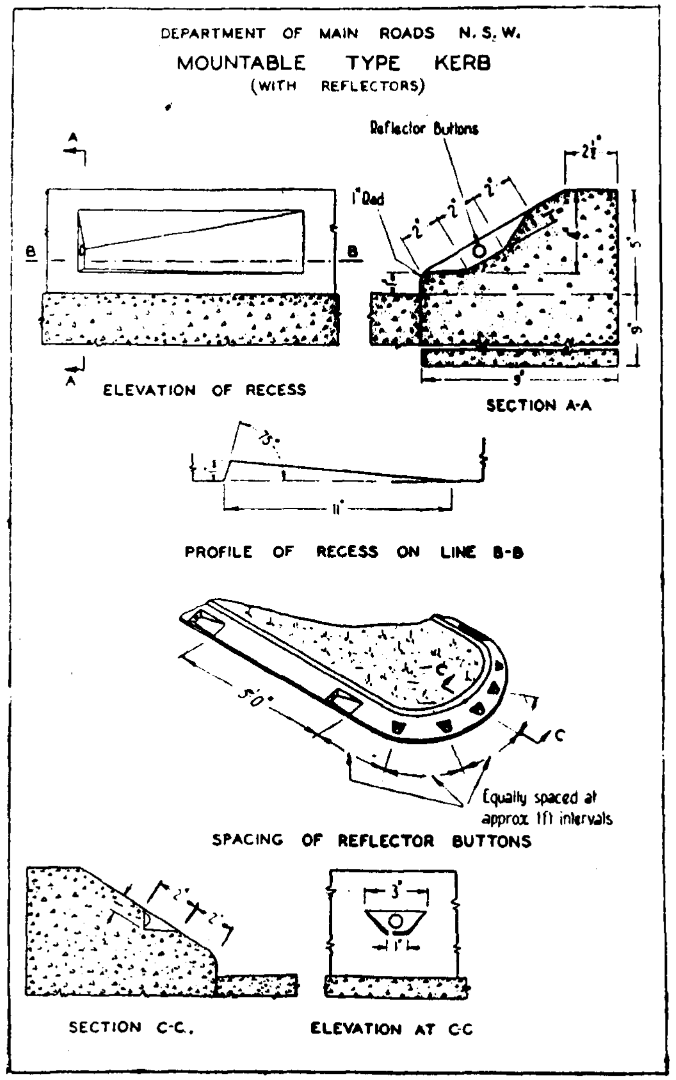


Fig. 1

It was not originally intended that these roads should have a median or parting strip to divide the carriageway, and they are somewhat narrow for this. However, a median is now considered most desirable, being seen to have the following advantages:—

(a) Minimises risk of head-on collisions of opposing traffic.

(b) Provides a safety refuge for pedestrians crossing the road.

(c) Prevents indiscriminate U-turning movements.

These advantages are considered to outweigh the disadvantages of installing them in 60 feet wide carriageways, and it has become the policy of the Department to install a median in every six-lane urban Main Road. It should be added that the six-lane roads referred to normally have the two kerbside lanes used by standing vehicles, but in peak hours the full width of carriageway may be used for moving traffic.

On account of the limited carriageway width, it has been necessary to keep the width of medians to a minimum, and the Department has adopted a median dividing strip with a minimum width of 3 feet except where a pedestal for traffic lights has to be installed, in which case the width is usually increased to 4 feet.

During the last 15 years, when further six-lane roads have been planned, they have usually been based on the provision of a divided carriageway, each half of which is 33 feet wide, with a median at least 5 feet wide. Latest practice is to provide on urban Main Roads sufficient width for medians of 10 to 15 feet width, 15 feet being aimed at where it is desired to provide a separate lane for right turning traffic.

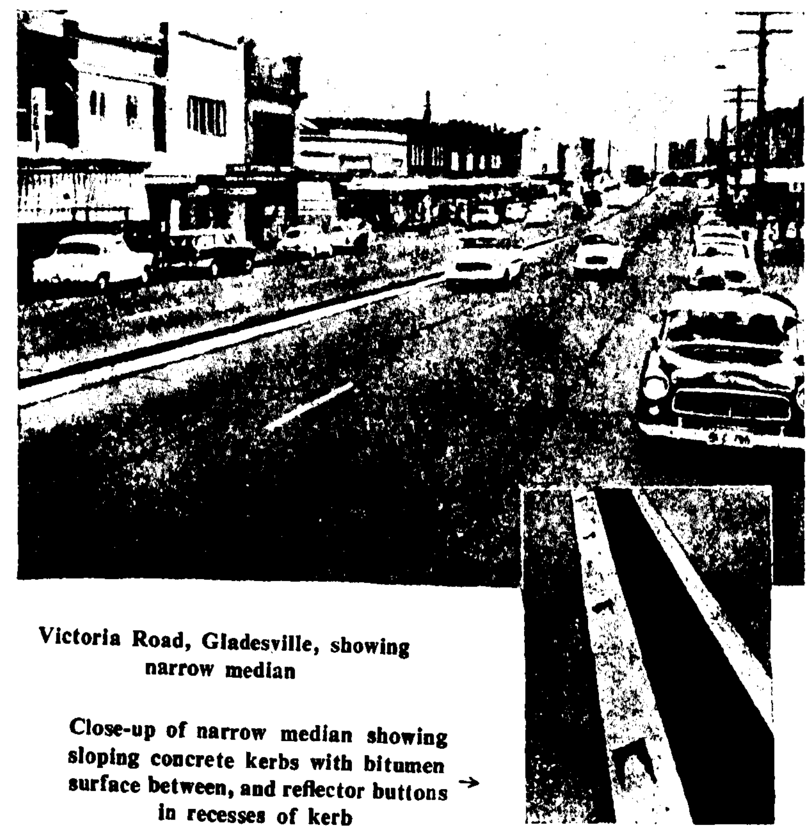
The narrow medians have a concrete kerb five inches high with a sloping kerb-face, and are provided with a concrete or bitumen surface between kerbs. The type of surface is dictated by the nature of the adjoining road surface, as maximum contrast in appearance between the carriageway and median surface is sought. The medians are not wide enough to permit the growing of plants or shrubs. Where medians of 5 feet or more in width are possible, they are usually grassed.

As an aid to night visibility, reflector buttons have been installed in recesses on the face of the median kerbs, as shown in Fig. 1. However, the buttons quickly become coated with dirt and lose much of their reflecting power. Various methods including the reflectors (see Fig. 2) are being tried out to improve the visibility of medians at night.

It is necessary to restrict the number of openings or gaps in medians in the interests of safety and to secure improved traffic flow. Openings opposite private vehicular entrances or lanes are not provided. Some intersecting streets including cul-de-sacs do not carry sufficient traffic to warrant an opening, or in some cases minor streets may be close to other streets where openings are provided. Accordingly, it is the Department's policy to leave openings only where considered necessary at selected intersections.

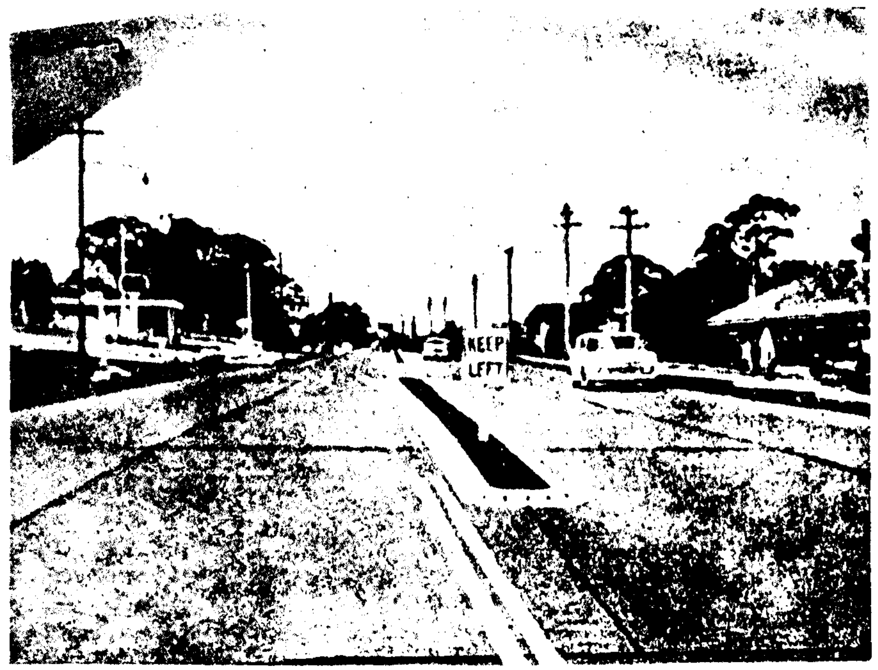
In approach to a section of road where a median is provided a warning sign "Divided road" is erected. Double centre lines painted on the pavement give a guide to a smooth transition from the normal centre line to the left side of the median. The lines are marked over a length of at least 200 feet wherever practicable.

A "Keep Left" sign is erected to face approaching traffic on and near the end of a median. Special attention is given to the provision of satisfactory illumination of the



Victoria Road, Gladesville, showing narrow median

Close-up of narrow median showing sloping concrete kerbs with bitumen surface between, and reflector buttons in recesses of kerb →



Commencement of a narrow median, showing line marking and sign board

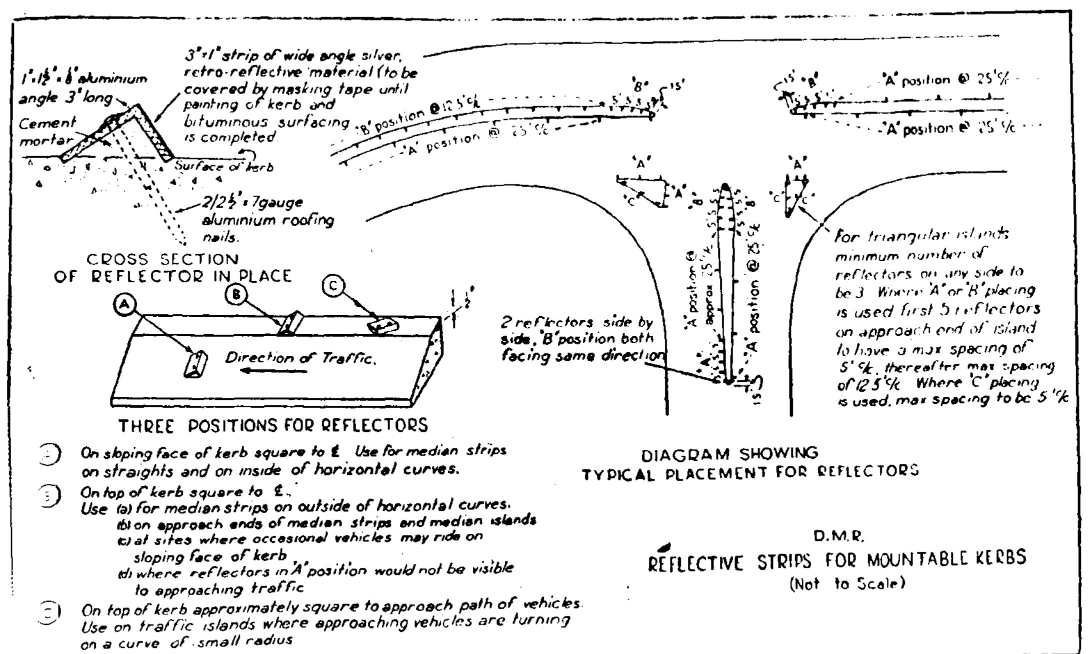


Fig. 2

end of a median, at night. Near the end of a section of road with a median, a warning sign "Divided road ends" is erected.

Where a median is constructed, the carriageway is marked in lanes. As most of the six-lane carriageways are only 60 feet wide, the width of the half carriageways after construction of a median seldom exceeds 28 feet 6 inches. If there is no prohibition of vehicles standing against the kerb, a lane adjoining the median is marked not less than 9 feet wide, and the balance of the width is unmarked. If however, standing is prohibited during any part of the day and the road is required to carry three moving streams in each direction, the three lanes are marked, that adjoining the footpath being 10 feet wide, and the other two each having half of the remaining carriageway width.

The minimum lane width used is 9 feet and to achieve this it has sometimes been necessary for the width of the kerbside ane to be less than 10 feet.

Narrow medians of the type described have now been constructed in the Sydney metropolitan area on several roads:

Detailed studies of the effect of the provision of medians in these roads have not yet been completed, but observations to date show that traffic flow is smoother after median construction and lane lining than before. In a number of cases vehicle placement studies were made before the median was installed, and these are being repeated after the median has been provided. Similar action is being taken in respect to travel times, volumes and accidents. A preliminary check of accidents indicates a reduction in severity of injury particularly to pedestrians, but present information is insufficient to deduce reliable conclusions. However, experience so far indicates that despite the fact that the carriageways widths are somewhat narrower than desirable for conversion to divided roads, the advantages by way of reduction in hazard and smoothing of the traffic flow outweigh any apparent disadvantages.

(*From "Main Roads" December, 1960.*)

DESIGN STANDARDS ADOPTED FOR AUCKLAND (NEWZEALAND) BRIDGE

(a) **Live-load**: The bridge was designed to carry either:

(i) H 20-S16-44 standard AASHO loading with the appropriate reductions when more than two lanes are loaded, or

(ii) tank loading, consisting of 160,000 lb tanks either self-propelled, or on carriers (total weight 230,000 lb) spaced at 150 ft nose to tail with no other loading on the roadway at the time.

(b) **Impact**: For the design of superstructure and bearings live-load stresses due to H20-S16-44 loading only were increased by an impact factor of 5,000/L+125%, where L is the loaded length in feet, upto a maximum value of 30%.

(c) **Braking forces**: A longitudinal force equal to 5% of the total live-load on all the lanes, without impact, was taken as acting horizontally at the level of the roadway surface.

(d) **Wind**: The adopted wind pressure was 30 lb/sq. ft. reduced to 20 lb/sq. ft. when used in combination with earthquake effects, and during erection. Wind records for Auckland Harbour show that high winds are predominantly easterly. Winds exceeding 31 m.p.h. are common, and gusts of 40 m.p.h. or more are not infrequent throughout the year. Gusts exceeding 60 m.p.h. are uncommon. The maximum recorded gust in the period January 1939 December, 1948, was 73 m.p.h.

(e) **Temperature effects**: Allowance was made for a temperature range of ±35°F about a mean temperature of 65°F and a differential temperature of 15°F.

(f) **Earthquake effects**:

(i) *on superstructure*: Static forces were assumed equal to 0. 1 of the weight of the structure and live-load (if any) on it, acting in any direction, and applied at the respective centres of gravity of each element (8 points on the Rossi-Forel scale).

(ii) *on foundations*: Static forces were assumed in any direction equal to 1/10 of the weight of the superstructure and live-load (if any) and of the foundation and virtual mass of surrounding water or mud. The virtual mass is defined as the mass contained in the volume whose horizontal cross-section at any level is a circle of diameter equal to the equivalent projected width of the foundation in the direction of motion.

Loading combinations: The following combinations of forces were considered :—

A. Dead load, live load, and impact.

B. Combination A plus longitudinal forces and effects of wind, temperature, and frictional resistance of expansion bearings.

C. Combination B plus earthquake, but with live-load of only 50% intensity, and wind pressure of 20 lb/sq. ft.

D. Erection Maximum stresses produced by forces in Combinations B, C and D were allowed to exceed the appropriate basic permissible stresses for Combination A by 25, 50, and 35% repectively.

Steel-Work

Allowable stresses and detailing generally were in accordance with B.S. 153, Parts 3B and 4.

Concrete

For reinforced concrete work two classes of concrete were specified: Class A with a cylinder strength of 4,500 lb/sq.

in. at 28 days for the main bridge piers and the viaduct superstructure; Class B with a cylinder strength of 3,500 lb/sq. in. for the bridge deck slab, the main anchorages, and the viaduct piers. The exact proportions of the mix were left to the contractor, the quality of concrete as placed being controlled entirely by tests and careful supervision of the mixing and placing. All concrete was mechanically vibrated. Works tests on four samples from each quality were taken every 3 days or whenever there was a change in the source or nature of the materials used. Allowable stresses and detailing were generally in accordance with C.P. 114 (1948). All tests were in accordance with New Zealand Standard Specification No. 192.

Foundations

From the results of the site investigation it was decided that the foundations should penetrate the rock at least 6 ft. and that the pressure on it should be limited to 7 tons/sq. ft. under dead and live-loads, or $8\frac{3}{4}$ tons/sq. ft. when the effects of wind and temperature were added. Under earthquake conditions transient pressures not exceeding 14 tons/sq. ft. were permitted.

Navigation Opening

The navigation opening with its centre approximately a quarter of the way across the harbour from north to south was required to provide a clear opening of at least 750 ft between piers, with headroom of 137 ft above H.W.O.S.T. over the central 500 ft and 142 ft at the centre.

Roadworks

Most of the approach roads were designed to motorway standards for a design speed of 60 m.p.h. (although a 40 m.p.h. speed limit has in fact been imposed) with a maximum gradient of 1 in 20 and a minimum curve radius of 960 ft. The adopted sighting distance at 4 ft 6 in. above road-level on an object 6 in. high was 750 ft for two-way roads and 550 ft for one-way roads. The roadway surface was specified to be laid to an accuracy of $\frac{1}{4}$ in. on a 10-ft straight or shaped templet.

(*Extracted "The Institution of Civil Engineers" April, 1961.*)

TWO-WAY SLABS AND THEIR SUPPORTING BEAMS

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THE OBJECT of this paper is to give a brief non-mathematical discussion of stress distribution in two-way slabs and their supporting beams. Tables of bending moment coefficients, collected or adapted from other sources, are given. These tables are based on the equations developed by Dr. H. Marcus. A somewhat different form of tables, also based on the equations by Dr. Marcus, are included in the 1960 issue of the National Building Code. This paper is otherwise intended for clarification of that section of the Code and as a brief survey of two-way slab problems. There seems to be a scarcity of literature of this kind. The more scientific approach used in advanced literature is not sufficiently useful for those who have not made a special study of two-way slab theory and have too little time available to do so when a problem is encountered.

The writer was a member of the Revision Committee who decided to adopt the Marcus theory for the new edition of the National Building Code. It should be pointed out, however, that the responsibility for statements and opinions expressed in this paper are the writer's own and that the opinions may not in every detail be shared by other committee members.

Introduction

The mathematical theory of stress distribution in two-way slabs is quite complex even for a simply supported slab. When, in addition, such slabs are more or less continuous and of variable span ratios, an exact calculation of bending moments and stresses becomes impracticable for design purposes. Many of the most able engineers in Europe beginning with Lagrange in 1813 have worked on these problems and obtained correct solutions for specific cases. Valuable contributions to the theory and its practical application have also been given by North American Engineers particularly during the last decades. Among these contributors may be mentioned H. M. Westergaard,[1] S. D. Lash,[2] N. M. Newmark,[3] C. P. Siess,[4] and others. A bibliography on two-way slab publications has been collected by the Department of Civil Engineering, University of Illinois.

An exact mathematical solution generally involves integration of a partial differential equation of the 4th order. Usable particular solutions may also be obtained by dividing the slabs into narrow strips in two directions and writing an equation for each point of intersection of these strips. Since deformation at these intersections are interdependent, a statically indeterminate system will result requiring the solution of a large number of simultaneous equations.

For those who are interested in the study of the mathematical theory of two-way slabs reference is given to the books by S. Timoshenko and S. Woinowsky-Krieger,[5] H. Marcus,[6] and K. Girkman.[7]

To obtain mathematically correct values of bending moments and shears by means of the theory of elasticity is both difficult and time absorbing. Many attempts have, therefore, been made to work out approximate methods of solution. In order to be usable, such methods should give stresses in substantial agreement with actual ones and should not have too limited applicability. Several such approximate methods have been proposed and used.

Load Distribution from Equal Deflection

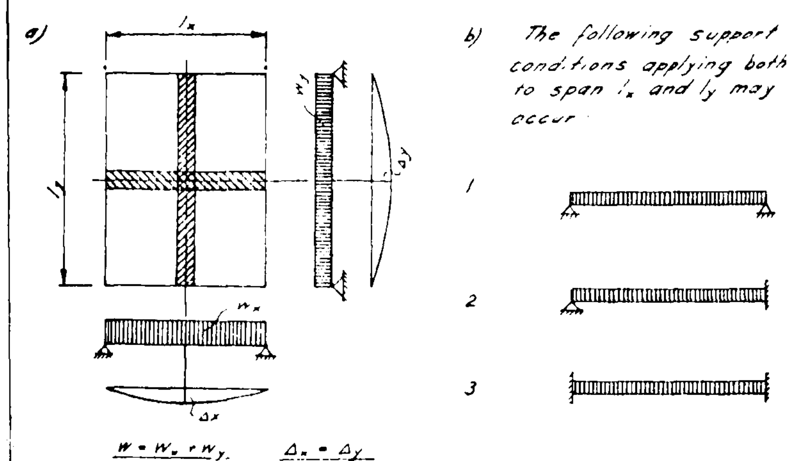
An early method of calculating bending moments in two-way slabs was based on the fact that when two centrally located slab strips cross each other, the deflection at the point of intersection must be the same for both strips. Fig. 1 (a), (b), and (c)

shows details of this method and formulae for load distribution coefficients for different fixities of supports.

Actual Conditions

The above equal deflection method assumes that the load on each strip is uniform along its complete length. That is not true, however. The load carried by the strip decreases in some manner from the full slab load at the support to a minimum load somewhere near the centre of the span. It is clear that under these circumstances the actual deflection of a slab cannot generally be found by means of an assumed uniform loading along the complete length of the strip. The method gives, however, bending moments that err on the safe side for the ordinary span length ratios of 1 to 2.

The bending moment does not necessarily depend on the actual deflection, but more on the curvature of bending at the section in question. In a very long slab we may have a considerable deflection at the centre of the long span strip, but there will be



$w = w_x + w_y$. $\Delta_x = \Delta_y$

Maximum bending moments and deflections for uniform loading will be as follows for the above support conditions

Span l_x:

1. $M_x = \frac{w_x l_x^2}{8}$ $\Delta_x = \frac{5 w_x l_x^4}{384 EI}$

2. $M_x = \frac{9 w_x l_x^2}{128}$ $\Delta_x = \frac{2 w_x l_x^4}{384 EI}$

3. $M_x = \frac{w_x l_x^2}{24}$ $\Delta_x = \frac{w_x l_x^4}{384 EI}$

Equations for M_y and Δ_y can be obtained in a similar manner.

c) When deflections for spans l_x and l_y are equated we get

$w_x = C w$ and $w_y = (1-C) w$

C may be obtained from the following table.

Support Condition	1	2	3	4	5	6	7	8	9
C	$\frac{l_y^4}{l_x^4+l_y^4}$	$\frac{5l_y^4}{2l_x^4+5l_y^4}$	$\frac{2l_y^4}{5l_x^4+2l_y^4}$	$\frac{l_y^4}{l_x^4+l_y^4}$	$\frac{5l_y^4}{l_x^4+5l_y^4}$	$\frac{l_y^4}{5l_x^4+l_y^4}$	$\frac{2l_y^4}{l_x^4+2l_y^4}$	$\frac{l_y^4}{2l_x^4+l_y^4}$	$\frac{l_y^4}{l_x^4+l_y^4}$

Fig. 1

little or no longitudinal bending moment at the centre of span if there is little or no curvature of bending at that point in the longitudinal direction such as is indicated on Fig. 2. If there is no curvature of bending there is evidently no longitudinal loading along such part of a strip and this indicates that the complete load on this centre portion is carried by the strip spanning in the transverse direction. However, even in such a case where there may be no two-way slab action at the centre portion of slab, such action will occur near both ends of the long span and the slab will still need reinforcement on these portions. The approximate value of such bending moments is indicated on Fig. 2. The maximum positive bending moment in the longitudinal direction for a long slab is, according to Dischinger,[8] located at a distance of about lx/4 from the support regardless of support restraint. For a slab with ly/lx = 2 simply supported, Marcus[6] gives the location of maximum positive bending moment from the support as lx/2. This location will likely apply also to slabs with lesser span ratios than 2.

Both the exact and approximate theories assume the material to be homogeneous and the slab to have the same moment of inertia in both directions. This assumption is not correct for reinforced concrete. The moments of inertia are influenced by the extent of cracking of concrete in the tension zone and by the amount and location of reinforcement. These properties are of necessity different even for square slabs because the steel in one layer is placed on top of the reinforcement placed in the opposite direction.

We usually determine the amount of reinforcing steel in each direction on basis of the bending moments and allowable steel stresses. This is not generally correct for two-way slabs. We can only get the calculated stress if the curvature of bending and the effective depth correspond to the assumed steel stress. The angular curvature of bending is generally less in the long direction and the steel stress cannot, therefore, simultaneously reach the same value as in the short direction. It can only reach working stress intensity after the short span steel has been stressed to a higher value. The ultimate strength of the slab may not, however, be greatly affected by this condition. The reason for this is that the reinforcement having the least stress will receive additional load after the most highly stressed reinforcement has started to yield.

Plastic deformation of concrete, being approximately proportional to the compressive stress, will also tend to transfer stress to the least stressed reinforcement. This plastic deformation is also beneficial in another respect. It makes it unnecessary to reinforce for the absolute maximum positive and negative bending moments, but allows the use of a more average bending moment on a certain width of slab. This is a condition utilized in some code provisions for stipulation of bending moment coefficients.

In the case of a slab continuous over supports we have the additional condition of variable torsional resistance of the beams supporting the slab. Near the intersection of two beams or at a column the torsional resistance will be largest and will decrease towards the centre of the beam span. This will influence the effect of uneven loading on adjacent slab panels and the assumption of knife edge support is in most cases even less true than for one-way slabs. In general it may be said that the influence of uneven loading is less on a two-way slab system than on one-way slabs because of the division of loading in two directions.

It should be mentioned that the Poisson ratio of transverse deformation has an effect on the magnitude of bending moments. There is some uncertainty what the Poisson ratio is for concrete as this will depend to a certain extent on concrete strength and stress intensity. Figures of $\frac{1}{5}$ to $\frac{1}{8}$ are sometimes given. Assuming a ratio $\frac{1}{6}$ and a square panel simply supported, the effect would increase the bending moment as derived from Table I from $wL^2/27.4$ to $wL^2/23.4$. For steel with a Poisson ratio of 0.3 the corresponding bending moment would be $wL^2/21.1$. In cases where very accurate stress analysis is required it may be advisable to investigate the effect of the Poisson ratio. A study of such problems has been made by F. Czerny and others.[9] Considering the beneficial effect of plastic deformation and of torsional resistance of supporting beams, it is probably sufficiently safe in most cases of building construction to assume the Poisson ratio equal to zero. Further more, it is also usual to design for an average bending moment in a panel strip instead of the absolute maximum value of the bending moment. Most of the published tables of coefficients are based on Poisson's ratio being zero and this simplification also applies to the tables given in this paper.

The Effect of Torsion

The principal source of error in the "Equal Deflection Method" is the neglect of the influence of torsional resistance of the slab against deflection. If we assume a strip of a certain width located in a position away from the centre line of slab, it is clear that the deflection on both sides of the strip is not the same excepting at its supports. The reason for this is the interconnection with the adjacent strips which do not have an equal deflection. The deflection at any point must correspond to the general curvature of deformation of the slab in a transverse direction, but the deflection on each side of a strip will in general not be equal excepting at a valley of deflection and at an unflexed support. This applies, of course, only if the strip ends are fastened to the supports in such a manner that they cannot rotate freely, but are forced to follow the same elevation as the supporting beam. Fig. 3 illustrates this condition.

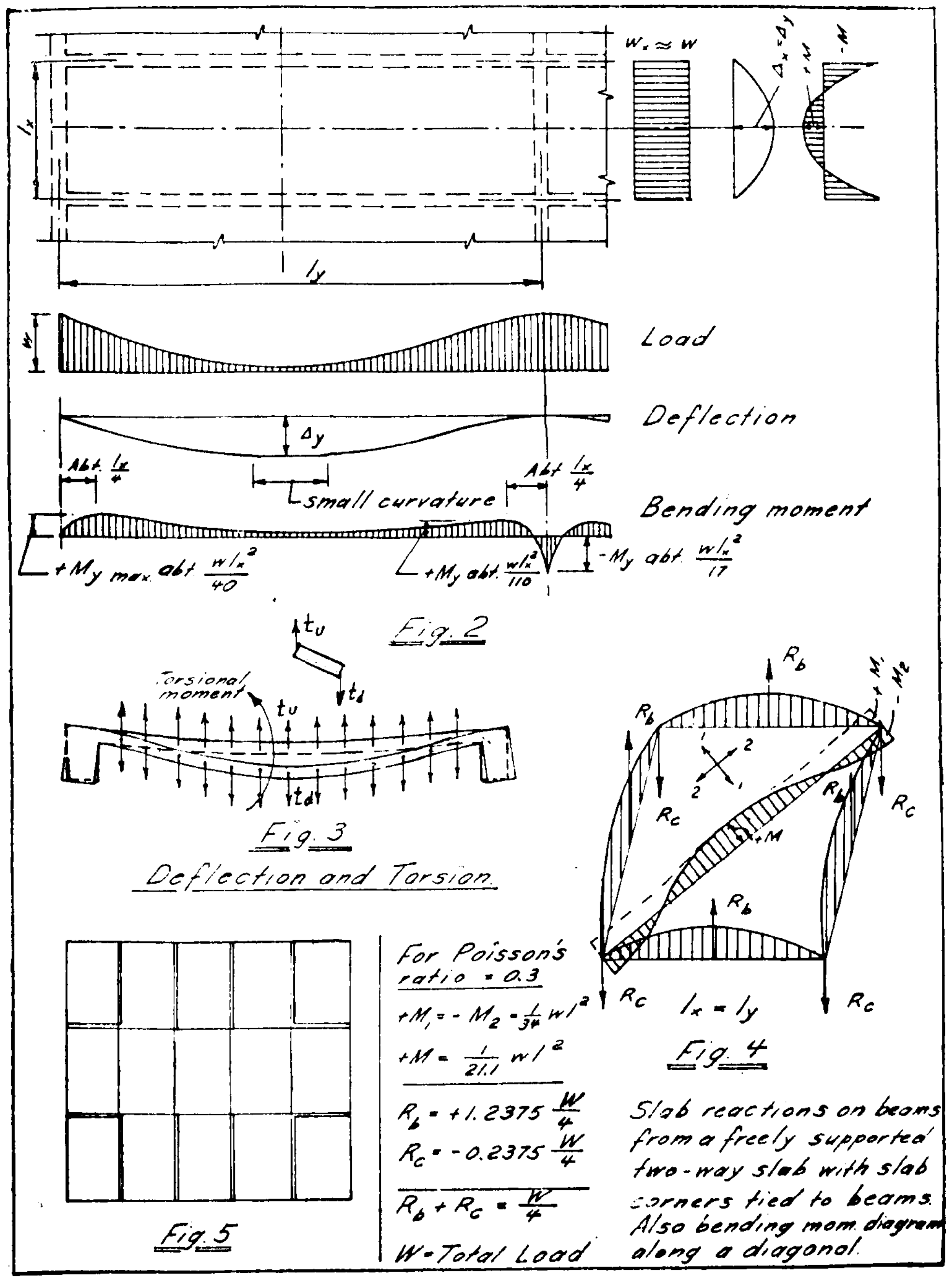
The result is that in most locations each strip in addition to longitudinal bending is also subject to torsion. The sum of torsional resistance of the slab strips will decrease the total deflection and consequently also decrease the bending moment in the slab. This reduction is sometimes very considerable. For instance, in the case of a square slab simply supported, the load distribution is equal in both directions. If we disregard the effect of torsion, the maximum bending moment for uniform loading would then be: $M = wL^2/16$. The effect of torsion, however, with Poisson's ratio equal to zero reduces the bending moment to $wL^2/27.4$. This torsional effect is greatest for simply supported slabs and decreases for continuous construction due to a much smaller total deflection and consequently a smaller angular rotation. The effect of torsion on a square slab uniformly loaded and with simple supports (Case 1) is to reduce the bending moment by about 49% while in a case with built-in edges (Case 9) the maximum positive bending moment reduces from $wL_x^2/48$ to $wL_x^2/55.7$ or only about 15%.

It will be understood from the above discussion that it is not practicable to carry out exact calculations of bending moments in two-way slabs for design purposes. The best we can do is to obtain by some approximate method design figures which are fairly realistic and which will give about equal safety factors for different cases of span proportions and support restraints. Several attempts have been made to work out acceptable approximate methods. Some such have proven to be fairly accurate but rather work absorbing. That applies for instance to Method I of the American Concrete Institute Building Code (A.C.I. 318-56). Method II of the same Code is easier to apply but is not very satisfactory as far as accuracy is concerned. Method II which was used in the National Building Code of 1953 will, therefore, not be included in the 1960 edition of that Code.

The Marcus Method

Dr. H. Marcus has made an extensive study of two-way slab problems and published a number of papers on the subject. In a book first published in 1924 and in revised form in 1932[6] he outlines the mathematical theory and gives his own particular method for solving such problems. A paper published by him in 1924 contained approximate methods for solving two-way slab problems.[10] This method was adopted for the German Reinforced Concrete code of 1925 and is still in use in that country. An outline of the method was given in the September, 1944, issue of the Journal of the American Concrete Institute.

The approximate equations by Dr. Marcus were used to work out tables of coefficients for different span ratios and support conditions. Such tables may for instance be found in the German "Beton-Kalender."[11] The tables there are made up for six support conditions. This makes it necessary to reverse some cases of span proportions which increases the possibility of making mistakes. It is much more convenient to use nine support conditions and that has been done for the tables contained in the new reinforced concrete specifications of



the 1960 National Building Code. The tables contained in that code are based on the Marcus theory and have been supplied by Mr. Paul Rogers, Member of the American Concrete Institute.

Tables of coefficients based on the more mathematically exact theory by Kirchhoff have been worked out by F. Czorny and may be found in the 1959 edition of the "Beton-Kalender". The figures, even though more accurate, do not seem to differ materially from those found by the more approximate Marcus theory.

Dr. F. Dischinger published in 1942 a

very thorough discussion of load intensity and distribution on supports for two-way slabs.[12] He also included new tables of coefficients for slab moments based on the Marcus theory. These tables are set up in a somewhat different form from those in the National Building Code and are worked out for much closer intervals so that interpolation becomes unnecessary. The coefficients for bending moments in both directions are made a function of the short span only and that makes it necessary to square one length only when calculating bending moments. The coefficients in the Dischinger tables are divisors which contain only one decimal figure and for that reason appear to be best suited for ordinary slide rule calculations. Tables 1 and 4 have been adopted from Dischinger's work. The tabulated coefficients in Table 3 are for calculation of negative bending moments across the supporting beams. This table has been worked out by the writer from the basic equations for negative bending moments in Table 5.

It should be mentioned that the negative bending moments from the Marcus equations do not represent maximum theoretical values but are more like an average on the middle strip over the supports. The decrease from the maximum value is about 15%. The positive bending moments represent, however, maximum values for zero Poisson's ratio. Considering the middle strip as a whole, there is about an average balance of moment at support and some average over-design at the centre of span. Such an adjustment in bending moments is considered to be quite in order.

Table 2 contains coefficients for live load positive bending moments. The condition for such bending moments is checkerboard loading on adjacent spans and knife edge supports are generally assumed. These load and support conditions are not very likely to occur, so the coefficients should only be considered as approximate. This table has been worked out by the writer on basis of the corresponding table 4.5.5.C contained in the National Building Code, but has been changed into the same form as used by Dischinger. All bending moments are functions of the short span only and intervals have been determined from graphs.

The resulting bending moments found by means of all the tables should be in a substantial agreement with those obtained by using the Rogers tables. It might be pointed out that the coefficients contained in these tables need adjustment if adjacent spans differ much in length.

Table 5 gives equations for both positive and negative bending moments in accordance with the approximate Marcus theory.

Table 4 shows dead load bending moment coefficients for four support conditions. These apply where there are one or more free corners which are not fixed to the supports in such a manner that the existing bending moment in the slab can be taken and where the slab is not securely held down to prevent uplift of the corner. There may be cases where omission of such reinforcement is most convenient. Corner cracks, are, however, likely to occur under such conditions. The coefficients in Table 4 can be derived from the general equations in Table 5 as follows. The parts of the equations inside the brackets represent the torsional effect which we may call T. To get the coefficients in Table 4 substitute a new function $(1 + T)/2$ instead of T. In the case of a so-called waffle slab, these terms should be assumed as $T = 1$, since such a slab cannot be assumed to have an equal torsional resistance to a solid slab.

The Code allows concrete joists with fillers of hollow concrete units or clay tile with or without concrete top slabs and concrete joists with top slabs placed monolithically with the joists to be treated the same as solid slabs in calculating bending moments. The writer does not consider this to be justified, because such hollow slabs will evidently have far less torsional rigidity than solid slabs. It would seem advisable in such cases to neglect the effect of torsion.

Conditions at Free Corners

Bending conditions at corners would seem to justify some detailed explanation. Figure 4 indicates how the bending moment acts along a diagonal. M_1 is the bending moment in a transverse direction to the diagonal. It is a positive bending moment giving tension in the bottom of the slab. M_2 is a negative bending moment in the direction of the diagonal giving tension on top of the slab at or near the corner. At centre of slab, both M_1 and M_2 are positive and of equal magnitude to the positive bending moment parallel to the sides of slab. It should be noted that both M_1 and M_2 are of the same magnitude but with opposite signs at the slab corner. From there M_1 increases slowly towards the centre of slab while M_2 decreases until it reaches a point of inflection from which it becomes positive. Unless sufficient reinforcement exists in the slab both at bottom and top to resist M_1 and M_2 cracking may result which will destroy the lever action of the corner and this will result in an increased positive bending moment at the centre of slab. The same will occur in case the corner is not held securely to the marginal beam and, therefore, can lift free off the beam. It may be noted that M_1 remains relatively large all the way to the corner and will generally require more positive reinforcement near this than what corresponds to a bending moment parallel and close to a marginal support.

case of concrete beams of ordinary proportions, we will in most cases have near fixity at a corner against rotation. The Code provision will then, as a rule, suffice provided, of course, that there is a sufficient amount of positive and negative reinforcement present on top and bottom end of slab. Figure 6 will illustrate why the corner reinforcement is so important. The contours of deflection will not be parallel to the sides, but follow a circular pattern near the corners. The slab here is quite rigid in a direction transversely to the diagonal because the slab span here is short. A kind of " beam " will, therefore, form across the slab at and near the corner. This " beam " will not only carry its own direct load, but will also receive load from the central portion of slab. Furthermore, since the slab corner generally is held down, it will, in addition, load the " beam " by adding a

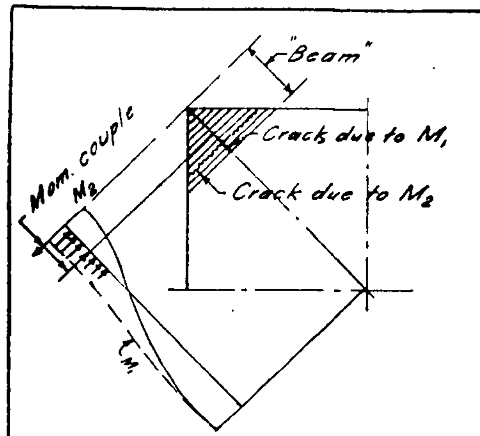


Fig. 6

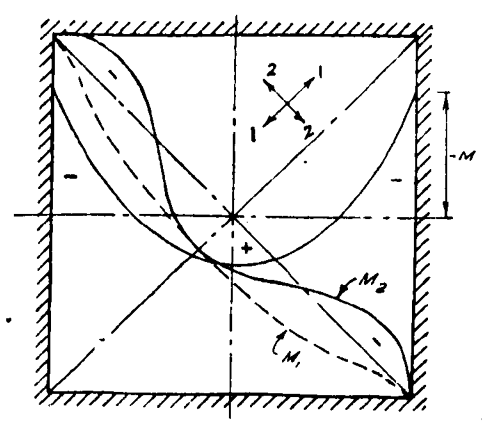


Fig. 7

The Code states that " where the slab is not securely attached to the supporting beams or walls, special reinforcement shall be provided at exterior corners in both the bottom and top of the slab ". It would appear that this clause is somewhat unclear. It is in the writer's opinion not sufficient to attach the slab to its support unless the support has a sufficient torsional resistance to provide a near fixity against rotation in the vicinity of the corner. That is not always the case if the slab is supported on a steel beam or on a brick wall. In the

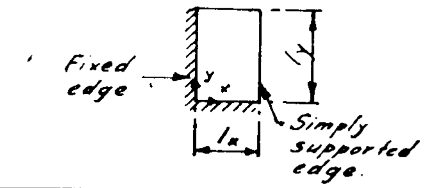
negative bending moment parallel to the diagonal.

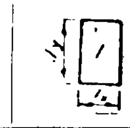
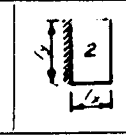
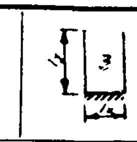
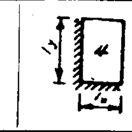
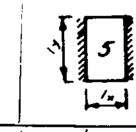
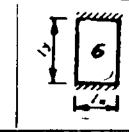
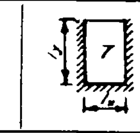
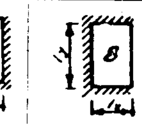
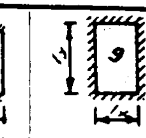
The negative bending moment may be thought of as a force couple of which the innermost force will be a direct load on the " beam ". This load condition creates the bending moment shown on Fig. 4 as M_2. If there is insufficient reinforcement at the bottom of slab, a diagonal crack may form, the slab will settle and M_2 will disappear since there is no longer a " beam " to carry the load mentioned above. If on the other

TABLE 1.

Coefficients for Dead Load Positive Moments

Max. $M_x = \dfrac{w\, l_x^2}{n_x}$. Max. $M_y = \dfrac{w\, l_x^2}{n_y}$



TYPE OF SLAB																		
$\Sigma = \frac{l_y}{l_x}$	n_{1x}	n_{1y}	n_{2x}	n_{2y}	n_{3x}	n_{3y}	n_{4x}	n_{4y}	n_{5x}	n_{5y}	n_{6x}	n_{6y}	n_{7x}	n_{7y}	n_{8x}	n_{8y}	n_{9x}	n_{9y}
1.00	27.4	27.4	29.9	36.8	36.8	29.9	37.2	37.2	37.5	55.7	55.7	37.5	44.2	50.6	50.6	44.2	55.7	55.7
1.02	26.4	27.4	29.0	37.2	34.9	29.7	35.7	37.2	36.7	57.0	52.4	36.8	42.9	51.1	48.3	43.8	53.6	55.8
1.04	25.4	27.4	28.2	37.7	33.3	29.5	34.4	37.2	36.0	58.4	49.4	36.2	41.9	51.8	46.0	43.4	51.8	55.9
1.06	24.5	27.5	27.4	38.2	31.8	29.3	33.2	37.3	35.4	59.8	46.8	35.7	40.7	52.5	43.8	43.1	49.9	56.1
1.08	23.6	27.5	26.7	38.8	30.3	29.2	32.1	37.5	34.7	61.2	44.2	35.1	39.7	53.2	42.0	42.8	48.3	56.3
1.10	22.8	27.6	26.0	39.3	29.0	29.0	31.1	37.6	34.2	62.6	41.8	34.7	38.8	53.9	40.2	42.6	46.8	56.6
1.12	22.0	27.6	25.4	40.0	27.9	28.9	30.1	37.8	33.7	64.1	39.8	34.2	38.0	54.8	38.7	42.5	45.4	57.0
1.14	21.3	27.7	24.8	40.6	26.8	28.8	29.3	38.0	33.2	65.7	37.8	33.8	37.3	55.7	37.2	42.4	44.1	57.4
1.16	20.7	27.8	24.3	41.3	25.7	28.7	28.5	38.3	32.7	67.3	36.0	33.5	36.5	56.6	35.9	42.3	43.0	57.8
1.18	20.0	27.9	23.8	42.0	24.8	28.7	27.7	38.6	32.3	68.9	34.4	33.2	35.9	57.5	34.6	42.2	41.9	58.3
1.20	19.4	28.0	23.3	42.7	23.9	28.6	27.0	38.9	31.9	70.6	32.9	32.9	35.3	58.5	33.5	42.2	40.9	58.7
1.22	18.9	28.1	22.9	43.5	23.1	28.6	26.4	39.2	31.6	72.4	31.5	32.6	34.7	59.6	32.4	42.3	40.0	59.4
1.24	18.4	28.3	22.5	44.2	22.3	28.6	25.8	39.6	31.2	74.1	30.2	32.4	34.2	60.6	31.4	42.3	39.1	60.1
1.26	17.9	28.5	22.1	45.0	21.6	28.6	25.2	40.0	30.9	76.0	29.0	32.2	33.7	61.7	30.5	42.5	38.3	60.9
1.28	17.4	28.6	21.8	45.9	21.0	28.6	24.7	40.4	30.6	77.9	27.9	32.0	33.2	62.9	29.7	42.6	37.6	61.6
1.30	17.0	28.8	21.4	46.6	20.3	28.6	24.2	40.8	30.3	79.8	26.8	31.8	32.8	64.1	28.9	42.7	36.9	62.3
1.32	16.6	29.0	21.1	47.5	19.8	28.6	23.7	41.3	30.1	81.7	25.8	31.7	32.4	65.3	28.2	42.9	36.2	63.2
1.34	16.2	29.2	20.8	48.4	19.2	28.7	23.3	41.8	29.8	83.7	24.9	31.6	32.0	66.5	27.5	43.2	35.7	64.0
1.36	15.9	29.4	20.6	49.3	18.7	28.7	22.9	42.3	29.6	85.7	24.1	31.4	31.7	67.8	26.8	43.4	35.1	64.9
1.38	15.5	29.6	20.3	50.3	18.2	28.8	22.5	42.8	29.4	87.8	23.3	31.4	31.3	69.2	26.2	43.7	34.6	65.8
1.40	15.2	29.8	20.0	51.2	17.8	28.9	22.1	43.4	29.2	89.8	22.6	31.3	31.0	70.5	25.7	44.9	34.1	66.8
1.42	14.9	30.1	19.8	52.2	17.4	28.9	21.8	43.9	29.0	91.9	21.9	31.2	30.7	71.9	25.1	44.3	33.6	67.8
1.44	14.6	30.4	19.6	53.2	17.0	29.0	21.5	44.5	28.8	94.1	21.2	31.2	30.4	73.3	24.6	44.6	33.2	68.8
1.46	14.4	30.6	19.4	54.3	16.6	29.1	21.2	45.1	28.6	96.2	20.6	31.2	30.2	74.7	24.2	45.0	32.8	69.9
1.48	14.1	30.9	19.2	55.3	16.2	29.2	20.9	45.8	28.5	98.5	20.1	31.1	29.9	76.2	23.7	45.4	32.4	71.0
1.50	13.9	31.2	19.0	56.4	15.9	29.4	20.6	46.4	28.3	100.8	19.5	31.1	29.7	77.7	23.3	45.8	32.0	72.1
1.52	13.6	31.5	18.9	57.5	15.6	29.5	20.4	47.1	28.2	103.1	19.0	31.1	29.5	79.2	22.9	46.2	31.7	73.3
1.54	13.4	31.9	18.7	58.6	15.3	29.6	20.1	47.8	28.0	105.4	18.6	31.2	29.3	80.8	22.6	46.7	31.4	74.5
1.56	13.2	32.2	18.5	59.7	15.0	29.8	19.9	48.5	27.9	107.8	18.1	31.2	29.1	82.4	22.2	47.1	31.1	75.7
1.58	13.0	32.6	18.4	60.9	14.7	29.9	19.7	49.2	27.8	110.3	17.7	31.2	28.9	84.0	21.9	47.6	30.8	76.9
1.60	12.9	32.9	18.2	62.0	14.5	30.1	19.5	49.9	27.7	112.7	17.3	31.3	28.7	85.7	21.6	48.1	30.5	78.2
1.62	12.7	33.3	18.1	63.2	14.2	30.3	19.3	50.7	27.5	115.2	16.9	31.4	28.6	87.4	21.3	48.6	30.3	79.5
1.64	12.5	33.7	18.0	64.4	14.0	30.5	19.1	51.4	27.4	117.8	16.6	31.4	28.4	89.1	21.0	49.2	30.0	80.8
1.66	12.3	34.1	17.9	65.6	13.8	30.6	19.0	52.2	27.3	120.3	16.2	31.5	28.2	90.8	20.8	49.7	29.8	82.2
1.68	12.2	34.5	17.7	66.8	13.6	30.9	18.8	53.0	27.2	122.9	15.9	31.6	28.1	92.6	20.5	50.3	29.6	83.5
1.70	12.1	34.9	17.6	68.1	13.4	31.1	18.6	53.8	27.1	125.5	15.6	31.7	28.0	94.3	20.3	50.9	29.4	85.9
1.72	11.9	35.3	17.5	69.4	13.2	31.3	18.5	54.7	27.0	128.1	15.3	31.8	27.8	96.2	20.1	51.5	29.2	86.4
1.74	11.8	35.7	17.4	70.7	13.0	31.5	18.3	55.5	26.9	130.8	15.0	31.9	27.7	98.0	19.8	52.1	29.0	87.9
1.76	11.7	36.2	17.3	71.9	12.8	31.7	18.2	56.4	26.9	133.6	14.8	32.1	27.6	99.9	19.6	52.7	28.8	89.4
1.78	11.6	36.6	17.2	73.3	12.7	32.0	18.1	57.3	26.8	136.4	14.5	32.2	27.5	101.8	19.5	53.4	28.7	90.9
1.80	11.5	37.1	17.2	74.6	12.5	32.2	17.9	58.2	26.7	139.2	14.3	32.3	27.4	103.7	19.3	54.1	28.5	92.4
1.82	11.3	37.6	17.1	76.0	12.3	32.5	17.8	59.1	26.6	142.0	14.1	32.5	27.3	105.7	19.1	54.8	28.4	93.9
1.84	11.2	38.1	17.0	77.4	12.2	32.8	17.7	60.0	26.6	144.9	13.9	32.7	27.2	107.6	18.9	55.5	28.2	95.6
1.86	11.1	38.6	16.9	78.9	12.1	33.1	17.6	60.9	26.5	147.9	13.7	32.8	27.1	109.5	18.8	56.2	28.1	97.2
1.88	11.0	39.1	16.8	80.3	11.9	33.4	17.5	61.9	26.4	150.8	13.5	33.0	27.0	111.7	18.6	56.9	27.9	98.8
2.00	11.0	39.6	16.8	81.8	11.8	33.7	17·4	62.9	26.4	150.8	13.3	33.2	26.9	113.8	18.5	57.7	27.8	100.5
2.02	10.9	40.1	16.7	83.2	11.7	33.8	17.3	63.9	26.3	156.8	13.1	33.4	26.8	115.9	18.4	58.4	27.7	102.2
2.04	10.8	40.6	16.6	84.7	11.6	34.3	17.2	64.8	26.3	159.8	12.9	33.6	26.7	117.9	18.2	59.2	27.6	103.9
2.06	10.7	41.2	16.6	86.1	11.5	34.6	17.1	65.9	26.2	162.9	12.8	33.8	26.7	120.0	18.1	60.0	27.5	105.6
2.08	10.6	41.7	16.5	87.6	11.4	34.9	17.1	66.9	26.1	166.1	12.6	34.0	26.6	122.2	18.1	60.8	27.4	107.4
2.10	10.6	42.3	16.5	89.2	11.3	35.2	17.0	67.9	26.1	169.3	12.6	34.3	26.5	124.4	17.9	61.6	27.3	[illegible]

hand there is sufficient steel at the bottom of slab but none at the top, a crack may form there perpendicular to the diagonal. The " beam " would still carry some load but there would be no reduction of positive bending moment at the centre from the destroyed force couple equal to M_2.

The Code requires an amount of negative reinforcement equal to $\frac{3}{4}$ of that for the positive bending moment along discontinuous edges. This relatively high requirement would not appear to be necessary for the centre strip unless the support has an unusual torsional rigidity and we want to avoid a visible crack between slab and beam. It is the writer's opinion that such cracks should be avoided but it is difficult to give a definite rule how much reinforcement is necessary for that purpose. For the centre strip of half the slab width one-half of the positive reinforcing should suffice in most cases. It is a different case with the side strips. Here the three-quarter reinforcement for negative bending moment is not too high as is evident from an inspection of the bending moment diagrams on Fig. 4. The high bending moment at free corners cannot evidently be taken proper care of without addition of extra corner reinforcement. In doubtful cases of support restraint it would seen advisable to use Table 4 for calculation of positive bending moments.

It might be of interest to compare the freely supported slab with a square slab fixed against rotation along all edges and loaded uniformly. The bending moments along a diagonal and transversely to this are shown on Fig. 7. It may be noted that both M_1 and M_2 are zero at the corner. M_1 increases slowly from the zero value at the corner and can be taken care of by the ordinary negative reinforcement. There is no problem in this case with the slab lifting free of its support.

Concentrated Loads on Two-way Slabs

The exact mathematical analysis of two-way slabs with concentrated loads is far more difficult than an analysis for uniform loading. Neither is there, as far as the writer knows, any approximate method of analysis comparable in accuracy to the Marcus equations for uniform loading. There is, of course, no real point loads but rather loaded areas of variable extent and shape. One special type is the line loading such as may be caused by partition walls in a building.

The problem of stress analysis due to concentated loading is of considerable importance in connection with design of bridge decks and a great deal of analytical work has been done in this connection. Since it is not possible to express bending moments explicitly in formulae, a complete analysis has to be made for any particular load position. From a series of such analyses, it is possible to draw area influence contour lines for bending moments at significant points of slab. Several such influence area diagrams have been worked out and published. Of such publications might be mentioned that by Pucher.[13] (See also Reference 5, Chapter 10.)

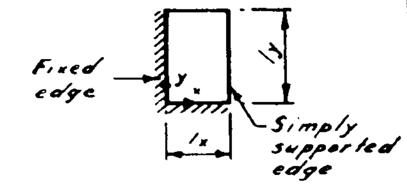
For ordinary building design an exact analysis of bending moments in two-way slabs due to concentrated loading would be too time absorbing, but it is necessary even here to get some idea of the bending moments and shearing stresses. The writer thinks that in the case of walls this might be done about in the same manner as outlined on Fig. 1 for uniform loading. Two strips perpendicular to each other can be assumed to carry the load. There is considerable uncertainty how wide a strip parallel to a wall can be considered as effective. Perhaps a reasonable assumption is a width of one-third the span length on each side of the wall plus the thickness of the wall itself. Transversely to the wall the effective width would, of course, be the length of the wall. One strip would then have a uniform load and the other a concentrated load. By equating the deflection at the point of intersection the approximate load distribution could be found. If in addition we disregard the effect of torsion, the result should err on the safe side.

It is evidently impracticable in most cases to obtain an accurate analysis of partition wall loading. The walls, even if of tile or other kinds of masonry, will not follow the floor slab completely if the slab deflects either due to live-loading or due to long time plastic deformation. It is not unusual to see the floor deflect free of the base of wall for a comparatively long stretch. This bridging effect may continue until a crack forms in the wall and that occurs particularly at door openings.

Table 2.

Coefficients for Live Load Positive Moments

Max. $M_x = \frac{wl_x^2}{n_x}$. Max. $M_y = \frac{wl_x^2}{n_y}$.



Type of Slab	1		2		3		4		5		6		7		8		9	
$\Sigma = \frac{l_y}{l_x}$	n_{1x}	n_{1y}	n_{2x}	n_{2y}	n_{3x}	n_{3y}	n_{4x}	n_{4y}	n_{5x}	n_{5y}	n_{6x}	n_{6y}	n_{7x}	n_{7y}	n_{8x}	n_{8y}	n_{9x}	n_{9y}
1.00	As in Table 1		28.6	31.3	31.3	28.6	31.3	31.3	31.3	37.1	37.1	31.3	33.4	35.8	35.5	33.4	37.0	37.0
1.02			27.8	31.4	29.9	28.4	30.3	31.3	30.5	37.2	35.3	31.2	32.4	35.9	34.1	33.4	35.4	37.0
1.04			26.9	31.5	28.5	28·2	29.3	31.3	29.8	37.3	33.5	31.0	31.4	36.0	32.9	33.3	33.9	37.0
1.06			26.0	31.6	27.3	28.1	28.3	31.3	29.0	37.5	31.9	30.8	30.4	36.1	31.6	33.3	32.5	37.0
1.08			25.1	31.7	26.3	28.0	27.3	31.3	28.3	37.7	30.6	30.6	29.4	36.2	30.4	33.2	31.2	37.0
1.10			24.2	32.9	25.4	28.0	26.3	31.3	27.5	37.9	29.3	30.4	28.4	36.4	29.1	33.2	30.0	37.0
1.12			23.5	32.2	24.5	28.0	25.3	31.3	26.7	38.1	28.1	30.2	27.5	36.6	28.0	33.2	29.0	37.0
1.14			22.8	32.5	23.7	27.9	24.6	31.4	25.9	38.3	27.0	30.0	26.9	36.8	26.9	33.1	28.2	37.0
1.16			22.2	32.8	22.9	27.9	23.9	31.5	25.2	38.5	25.9	29.8	26.3	37.0	25.8	33.1	27.4	37.2
1.18			21.6	33.1	22.2	27.9	23.2	31.6	24.5	38.7	25.0	29.7	25.7	37.1	24.8	33.0	26.7	37.2
1.20			21.0	33.4	21.6	27.8	22.5	31.7	24.0	39.0	24.1	29.6	25.2	37.3	24.2	33.2	26.0	37.3
1.22			20.4	33.7	20.7	27.8	21.9	31.9	23.5	39.4	23.5	29.5	24.6	37.5	23.6	33.4	25.3	37.4
1.24			19.8	34.0	20.0	27.9	21.2	32.1	23.0	39.8	22.6	29.4	24.1	37.7	23.0	33.6	24.7	37.5
1.26			19.4	34.3	19.4	28.0	20.6	32.3	22.5	40.2	21.9	29.4	23.5	38.0	22.4	33.8	24.1	37.6
1.28			19.1	34.6	18.9	28.1	20.3	32.6	22.1	40.6	21.3	29.4	23.0	38.4	21.9	34.0	23.6	37.8
1.30			18.7	34.9	18.5	28.2	19.9	32.9	21.7	41.1	20.6	29.5	22.6	38.8	21.3	34.2	23.1	38.0
1.32			18.4	35.2	18.1	28.3	19.5	33.1	21.4	41·6	20.0	29.6	22.1	39.2	20.7	34.4	22.6	38.2
1.34			18.1	35.4	17.7	28.4	19.1	33.5	21.1	42.1	19.4	29.7	21.6	39.6	20.2	34.6	22.1	38.5
1.36			17.8	35.9	17.3	28.5	18.7	33.8	20.8	42.6	19.0	29.8	21.3	40.0	19.8	34.9	21.7	38.8
1.38			17.4	36.4	16.9	28.6	18.4	34.2	20.4	43.1	18.5	29.9	20.9	40.4	19.5	35.2	21.3	39.1
1.40			17.1	36.9	16.5	28.7	18.1	34.5	20.1	43.6	18.1	30.0	20.5	40.5	19.1	35.5	20.9	39.4
1.42			16.8	37.4	16.1	28.8	17.7	34.8	19.8	44.1	17.7	30.1	20.1	41.5	18.7	35.8	20.6	39.7
1.44			16.6	37.9	15.7	28.9	17.4	35.2	19.5	44.6	17.3	30.2	19.8	42.2	18.4	36.1	20.3	40.0
1.46			16.4	38.4	15.4	29.1	17.1	35.6	19.2	45.1	17.0	30.3	19.5	42.8	18.1	36.4	20.0	40.4
1.48			16.2	39.0	15.1	29.3	16.9	36.0	18.9	45.6	16.6	30.4	19.3	43.6	17.8	36.8	19.7	40.8
1.50			16.0	39.7	14.8	29.6	16.6	36.4	18.6	46.1	16.3	30.5	19.0	44.2	17.5	37.1	19.4	41.2
1.52			14.9	40.4	14.5	29.9	16.3	36.8	18.4	46.6	15.9	30.6	18.8	45.0	17.2	37.4	19.1	41.6
1.54			15.8	41.1	14.2	30.2	16.1	37.2	18.2	47.1	15.6	30.7	18.6	45.7	16.9	37.7	18.8	42.0
1.56			15.7	41.6	14.0	30.5	15.9	37.6	18.0	47.6	15.3	30.9	18.3	46.4	16.6	38.0	18.6	42.4
1.58			15.5	42.3	13.8	30.7	15.8	38.0	17.8	48.1	15.0	31.1	18.0	47.0	16.4	38.4	18.4	42.8
1.60			15.3	43.0	13.7	30.9	15.6	38.4	17.6	48.6	14.8	31.3	17.8	47.7	16.2	38.7	18.2	43.2
1.62			15.1	43.7	13.5	31.1	15.4	38.8	17.4	49.1	14.5	31.4	17.6	48.4	15.9	39.0	18.0	43.6
1.64			14.9	44.3	13.3	31.4	15.2	39.2	17.2	49.6	14.2	31.4	17.3	49.1	15.7	39.3	17.8	44.0
1.66			14.7	44.9	13.1	31.6	15.1	39.6	17.0	50.1	14.0	31.5	17.1	49.8	15.5	39.6	17.6	44.5
1.68			14.5	45.5	12.9	31.9	14.9	40.0	16.8	50.6	13.7	31.6	16.9	50.5	15.3	40.0	17.4	45.0
1.70			14.3	46.0	12.7	32.1	14.7	40.4	16.6	51.2	13.5	31.7	16.7	51.3	15.1	40.4	17.2	45.5
1.72			14.2	46.6	12.5	32.4	14.5	40.9	16.4	51.8	13.3	31.8	16.5	52.0	15.0	40.9	17.0	46.0
1.74			14.1	47.2	12.3	32.6	14.4	41.4	16.3	52.6	13.1	31.9	16.4	52.8	14.8	41.3	16.8	46.6
1.76			14.0	47.8	12.1	32.9	14.2	41·8	16.2	53.4	12.8	32.1	16.2	53.5	14.7	41.8	16.6	47.4
1.78			13.9	48.4	12.0	33.1	14.0	42.3	16.1	54.2	12.6	32.2	16.0	54.3	14.6	42.2	16.4	48.2
1.80			13.8	48.7	11.9	33.4	13.9	42.7	16.0	55.0	11.4	32.3	15.9	55.0	14.4	42.7	16.2	49.2
1.82			13.7	49.0	11.8	33.6	13.8	43.2	15.9	55.8	11.3	32.5	15.7	55.8	14.3	43.2	16.1	50.2
1.84			13.6	49.2	11.7	33.9	13.7	44.0	15.8	56.5	12.2	32.7	15.6	56.5	14.1	43.9	16.0	51.4
1.86			13.5	49.3	11.6	34.2	13.6	44.7	15.7	57.2	12.1	32.8	15.5	57.2	14.0	44.7	15.9	52.6
1.88			13.4	49.4	11.4	34.4	13.5	45.5	15.6	58.0	12.0	33.0	15.4	58.0	13.9	45.4	15.8	53.8
1.90			13.3	49.5	11.3	34.6	13.4	46.2	15.5	58.7	11.9	33.2	15.3	58.7	13.8	46.1	15.7	55.0
1.92			13.2	49.6	11.2	34.9	13.3	47.0	15.4	59.5	11.7	33.4	15.2	59.5	13.7	46.9	15.6	56.2
1.94			13.1	49.7	11.1	35.1	13.2	47.7	15.3	60.2	11.6	33.6	15.1	60.2	13.5	47.7	15.5	57.5
1.96			13.0	49.8	11.0	35.3	13.2	48.4	15.2	61.0	11.5	33.8	15.1	61.0	13.3	48.4	15.4	58.8
1.98			12.9	49.9	10.9	35.6	13.1	49.2	15.1	61.8	11.4	34.0	14.9	61.7	13.2	49.2	15.3	61.2
2.00			12.8	50.0	10.8	35.8	13.0	50.0	15.0	62.6	11.3	34.3	14.9	62.5	13.1	50.0	15.2	62.6

TABLE 3.

Coefficients for Negative Moments

$M_x = -\dfrac{wl_x^2}{n_x}$. $M_y = -\dfrac{wl_x^2}{n_y}$. Note: $W = D.L. + L.L.$

TYPE OF SLAB	2		3		4		5		6		7		8		9	
$\Sigma = \frac{l_y}{l_x}$	n_{2x}	n_{2y}	n_{3x}	n_{3y}	n_{4x}	n_{4y}	n_{5x}	n_{5y}	n_{6x}	n_{6y}	n_{7x}	n_{7y}	n_{8x}	n_{8y}	n_{9x}	n_{9y}
1.00	11.2			11.2	16.0	16.0	14.4			14.4	18.0	24.0	24.0	18.0	24.0	24.0
1.02	11.0			11.0	15.5	16.0	14.3			14.1	17.6	24.4	23.0	17.8	23.3	24.1
1.04	10.8			10.9	15·0	16.1	14.1			13.8	17.2	24.8	22.0	17.6	22.5	24.2
1.06	10.6			10.8	14.5	16.2	14.0			13.4	16.9	25.2	21.0	17.4	21.7	24.3
1.08	10.4			10.6	14.0	16.2	13.8			13.1	16.5	25.6	20.0	17.3	21.0	24.4
1.10	10.3			10.5	13.5	16.3	13.6			12.8	16.1	26.0	19.0	17.2	20.2	24.5
1.12	10.1			10.4	13.2	16.4	13.6			12.6	15.9	26.5	18.3	17.2	19.7	24.7
1.14	9.9			10.4	12.9	16.6	13.5			12.4	15.6	27.0	17.6	17.1	19.2	24.9
1.16	9.7			10.3	12.5	16.8	13.4			12.2	15.4	27.5	17.0	17.1	18.8	25.1
1.18	9.6			10.2	12.2	16.9	13.3			12.0	15.1	28.0	16.3	17.0	18.3	25.3
1.20	9.5			10.2	11.9	17.1	13.2			11.8	14.9	28.6	15.6	17.0	17.8	25.6
1.22	9.4			10.1	11.7	17.3	13.1			11.6	14.8	29.2	15.2	17.0	17.5	25.9
1.24	9.3			10.1	11.5	17.5	13.0			11.5	14.6	29.9	14.8	17.1	17.1	26.2
1.26	9.2			10.1	11.2	17.8	13.0			11.4	14.4	30.5	14.4	17.1	16.8	26.6
1.28	9.15			10.1	11.0	18.0	12.9			11.3	14.3	31.2	14.0	17.2	16.5	27.0
1.30	9.1			10.1	10.8	18.3	12.8			11.2	14.1	31.8	13.6	17.3	16.2	27.4
1.32	9.1			10.2	10.7	18.6	12.8			11.1	14.0	32.6	13.3	17.3	16.0	27.8
1.34	9.0			10.2	10.5	18.9	12.8			11.0	13.9	33.5	13.0	17.4	15.8	28.3
1.36	9.0			10.2	10.4	19.2	12.7			10.9	13.8	34.0	12.7	17.5	15.5	28.8
1.38	8.9			10.3	10.2	19.5	12.7			10.8	13.7	35.8	12.4	17.7	15.3	29.2
1.40	8.8			10.3	10.1	19.8	12.6			10.8	13.6	34.5	12.2	17.9	15.1	29.7
1.42	8.8			10.4	10.0	20.1	12.6			10.8	13.5	36.4	12.0	18.0	15.0	30.2
1.44	8.8			10.5	9.9	20.5	12.6			10.8	13.4	37.2	11.8	18.2	14.8	30.7
1.46	8.7			10.6	9.8	20.8	12.6			10.8	13.3	38.0	11.6	18.4	14.7	31.3
1.48	8.7			10.7	9.7	21.2	12.5			10.8	13.3	38.5	11.3	18.6	14.5	31.8
1.50	8.6			10.7	9.6	21.6	12.5			10.8	13.2	39.5	11.1	18.8	14.4	32.3
1.52	8.6			10.8	9.5	22.0	12.5			10.8	13.2	40.5	11.0	19.0	14.3	33.0
1.54	8.6			11.0	9.4	22.4	12.4			10.8	13.1	41.4	10.9	19.3	14.1	33.6
1.56	8.6			11.2	9.4	22.8	12.4			10.8	13.0	42.3	10.7	19.5	14.0	34.2
1.58	8.5			11.2	9.3	23.2	12.4			10.8	13.0	43.2	10.6	19.7	13.9	34.8
1.60	8.5			11.3	9.2	23.6	12.4			10.8	12.9	44.1	10.4	20.0	13.8	35.4
1.62	8.5			11.4	9.2	24.1	12.3			10.9	12.9	45.1	10.3	20.3	13.7	36.1
1.64	8.4			11.6	9.2	24.6	12.3			10.9	12.8	46.1	10.2	20.6	13.6	36.7
1.66	8.4			11.7	9.1	25.0	12.3			11.0	12.8	47.1	10.1	20.9	13.6	37.4
1.68	8.4			11.9	9.1	25.5	12.3			11.0	12.8	48.0	10.0	21.2	13.5	38.1
1.70	8.4			12.0	9.0	26.0	12.3			11.1	12.7	49.0	9.9	21.5	13.4	38.8
1.72	8.3			12.2	9.0	26.5	12.3			11.1	12.7	50.0	9.9	21.8	13.3	39.6
1.74	8.3			12.3	8.9	27.0	12.3			11.2	12.7	51.0	9.8	22.1	13.3	40.3
1.76	8.3			12.5	8.9	27.5	12.3			11.3	12.6	52.1	9.7	22.5	13.2	41.0
1.78	8.3			12.7	8.8	28.0	12.3			11.4	12.6	53.2	9.6	22.8	13.2	41.8
1.80	8.3			12.8	8.8	28.4	12.25			11.5	12.6	54.3	9.5	23.1	13.1	42.6
1.82	8.3			13.0	8.8	29.0	12.2			11.6	12.6	55.4	9.5	23.5	13.1	43.4
1.84	8.25			13.2	8.7	29.5	12.2			11.7	12.6	56.6	9.4	23.8	13.0	44.2
1.86	8.25			13.4	8.7	30.0	12.2			11.8	12.6	57.7	9.3	24.2	13.0	45.0
1.88	8.25			13.6	8.6	30.5	12.2			11.9	12.5	58.8	9.2	24.6	12.9	45.8
1.90	8.25			13.8	8.6	31.1	12.2			12.0	12.5	60.0	9.2	25.0	12.9	46.6
1.92	8.2			14.0	8.6	31.7	12.2			12.1	12.5	62.6	9.2	25.4	12.8	47.5
1.94	8.2			14.2	8.6	32.3	12.2			12.2	12.5	65.2	9.1	25.8	12.8	48.4
1.96	8.2			14.4	8.6	32.8	12.2			12.3	12.4	68.0	9.1	26.2	12.8	49.2
1.98	8.2			14.6	8.5	33.4	12.2			12.4	12.4	70.8	9.0	26.6	12.7	50.1
2.00	8.2			14.8	8.5	34.0	12.15			12.6	12.4	73.2	9.0	27.0	12.7	51.0

A lot of cracking has been experienced in this connection with two-way slabs because of too great flexibility Since the compressive strength of the concrete can be utilized in two directions there is a tendency to make such slabs too .thin. The ultimate strength of a properly designed two-way slab will, therefore, almost always depend on the strength of the steel reinforcement.

Another problem encountered is to find the bending moment from load concentrations such as file cabinets and accounting machinery. A somewhat similar method to that proposed for distribution of wall load might be used. The effective slab strips can, according to some code rules, be assumed as either the width of the load plus two-thirds the span length, or alternatively as twice the distance from the load centre to the closest support in the direction of span. The smallest of these values to be used. Solving equations for equal deflection of two perpendicular slab strips will then give the load distribution between the two strips. Any great accuracy by such a method can hardly be expected but the result will likely be safe.

Beam Loading from Two-way Slabs

The load distribution obtained from the equations in Fig. 1 was used for some time to obtain the loading on the supporting beams. The result was not bad as far as the beams in the long direction were concerned. For the short span beams the uniform loading found by this load distribution method was far from correct and the corresponding bending moment in the beams might only be a small fraction of the true values. A better division is to assume load distribution to each beam from the tributary areas of the panel bounded by the intersection of 45° lines from the corners with the median line of the panel parallel to the long side. This is an approximate load distribution used in most building codes. Even this method is not accurate especially for the short span beams. The method makes the loading of the short span beam independent of the slab length and that is not quite correct. The actual conditions are as follows :

We have found that the effect of torsion is to reduce the bending moment in the slab greatly. However, this effect is not obtained without some extra loading of the supporting beams. Considering Fig. 3 it is clear that in addition to the direct load from the slab each slab strip superimposes a torsional effect on the beams. This effect tends to transfer the reaction of each strip in the same direction as the slab twists, that is, towards the centre of span. Each strip presses down at one edge of its support and has an uplift effect at the other edge. The total effect of twisting of all the slab strips is to transfer the load on the beam to some extent towards its centre. This effect is, of course, only present where there is a torsional effect and would, for instance, not be of any importance on the central portion of a long slab such as is shown on Fig. 2. The shifting of load towards the centre of beam will, of course, increase the bending moment in the beam.

In the case of a rectangular slab simply supported it can be proven that there is a force creating uplift at the corner and there must, therefore, be a corresponding increase in the downward reaction of the slab on the beam since the algebraic sum of all the loads and forces acting on the beam must be equal to the weight of slab and its superimposed load. This can only be the case when the load on the beam, apart from the corner force, is greater than the gravity load. The loads shown in connection with Fig. 4 have been taken from Dischinger's work. An elementary consideration of Fig. 6 will also make it clear that the central loading must be greater than the gravity loading.

It should be noted that the corner force indicated on Fig. 4 is not present at continuous corners and we do not, therefore, have the same increase in beam loading where the slab is continuous. Even with continuous slabs there may be some shifting of load towards the centre caused by torsion, but the effect is generally small due to less deflection.

The correct way of calculating the bending moment in a beam would be to analyse the slab panel with the parallel supporting beams as a unit. The bending moment carried by the slab in that direction would then be subtracted from the total bending moment in order to find how much of the total bending moment the beams have to carry. Such analyses have been made by Dr. Dischinger. They show that the trian-

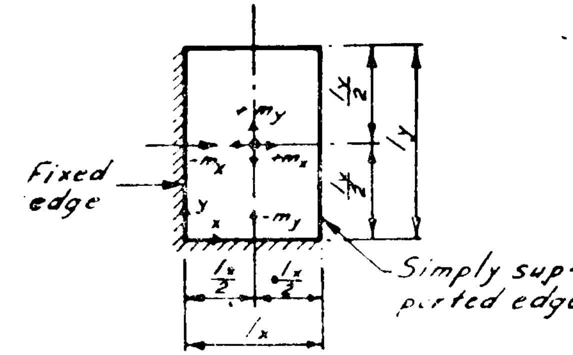
TABLE 4.

Coefficients for dead load positive moments for condition of no attachment to supports and no special corner reinforcement

TYPE OF SLAB	1		2		3		4	
$\Sigma = \frac{l_y}{l_x}$	n_{1x}	n_{1y}	n_{2x}	n_{2y}	n_{3x}	n_{3y}	n_{4x}	n_{4y}
1.00	20.2	20.2	23.9	31.8	31.8	23.9	32.2	32.2
1.02	19.4	20.2	23.3	32.3	30.1	23.6	31.0	32.2
1.04	18.7	20.3	22.8	32.8	28.6	23.3	29.9	32.3
1.06	18.1	20.3	22.3	33.4	27.2	23.1	28.9	32.4
1.08	17.5	20.4	21.8	34.0	26.0	22.9	27.9	32.6
1.10	16.9	20.5	21.4	34.6	24.8	22.7	27.0	32.7
1.12	16.5	20.6	21.0	35.2	23.8	22.6	26.3	32.9
1.14	16.0	20.8	20.6	35.9	22.8	22.4	25.5	33.2
1.16	15.5	20.9	20.2	36.6	21.9	22.3	24.9	33.5
1.18	15.1	21.0	19.9	37.3	21.1	22.2	24.2	33.6
1.20	14.7	21.2	19.6	38.1	20.3	22.2	23.7	34.1
1.22	14.4	21.4	19.4	38.8	19.6	22.1	23.2	34.5
1.24	14.1	21.6	19.1	39.6	19.0	22.1	22.6	34.9
1.26	13.8	21.8	18.9	40.5	19.3	22.1	22.2	35.3
1.28	13.5	22.1	18.7	41.4	17.8	22.1	21.8	35.7
1.30	13.2	22.3	18.5	42.2	17.3	22.1	21.4	36.2
1.32	13.0	22.6	18.3	43.1	16.8	22.2	21.0	36.7
1.34	12.7	22.9	18.1	44.0	16.4	22.2	20.7	37.2
1.36	12.5	23.2	17.9	45.0	15.9	22.3	20.4	37.7
1.38	12.3	23.5	17.8	45.9	15.5	22.4	20.1	38.2
1.40	12.1	23.8	17.6	46.9	15.2	22.5	19.8	38.8
1.42	11.9	24.1	17.5	47.9	14.8	22.6	19.5	39.4
1.44	11.8	24.4	17.3	49.0	14.5	22.7	19.3	40.0
1.46	11.6	24.8	17.2	50.0	14.2	22.9	19.1	40.7
1.48	11.5	25.1	17.1	51.1	13.9	23.0	18.9	41.3
1.50	11.3	25.5	17 0	52.1	13.6	23.2	18.8	42.0
1.52	11.2	25.9	16.9	53.3	13.4	23.3	18.5	42.7
1.54	11.1	26.3	16.8	54.4	13.2	23.5	18.3	43.4
1.56	11.0	26.7	16.7	55.5	12.9	23.7	18.1	44.1
1.58	10.8	27.1	16.6	56.7	12.7	23.9	18.0	44.8
1.60	10.7	27.5	16.5	57.9	12.5	24.1	17.8	45.6
1.62	10.6	27.9	16.4	59.1	12.3	24.3	17.7	46.4
1.64	10.5	28.3	16.4	60.3	12.2	24.6	17.5	47.1
1.66	10.4	28.8	16.3	61.6	12.0	24.8	17.4	48.0
1.68	10.4	29.3	16.2	62.9	11.8	25.1	17.3	48.8
1.70	10.3	29.7	16.2	64.1	11.7	25.3	17.2	49.6
1.72	10.2	30.2	16.1	65.4	11.5	25.6	17.1	50.5
1.74	10.1	30.7	16.0	66.7	11.4	25.9	17.0	51.4
1.76	10.1	31.2	16.0	68.1	11.3	26.1	16.9	52.2
1.78	10.0	31.7	15.9	68.5	11.2	26.4	16.8	53.1
1.80	9.9	32.2	15.9	70.8	11.0	26.7	16.7	54.0
1.82	9.9	32.7	15.8	72.2	10.9	27.0	16.6	55.0
1.84	9.8	33.2	15.8	73.7	10.8	27.4	16.5	55.9
1.86	9.7	33.7	15.7	75.0	10.7	27.7	16.4	56.9
1.88	9.7	34.3	15.7	76.5	10.7	28.0	16.4	57.9
1.90	9.6	34.8	15.6	78.0	10.6	28.3	16.3	58.8
1.92	9.6	35.4	15.6	79.4	10.5	28.7	16.2	59.8
1.94	9.5	36.0	15.6	80.8	10.4	29.0	16.2	60.8
1.96	9.5	36.5	15.5	82.4	10.3	29.4	16.1	61.9
1.98	9.5	37.1	15.5	84.0	10.2	29.8	16.0	62.9
2.00	9.4	37.7	15.5	85.4	10.2	30.1	16.0	64.0

TABLE 5.

Equations by H. Marcus for Bending Moments in Two-Way Slabs carrying a uniformly Distributed Load.



Note: The equations are based upon Poisson's ratio being equal to zero.

$$\Sigma = \frac{l_y}{l_x}$$

TYPE OF SLAB	MAXIMUM BENDING MOMENTS			
	POSITIVE BENDING MOMENTS		NEGATIVE BENDING MOMENTS	
	$+m_x$	$+m_y$	$-m_x$	$-m_y$
1	$\frac{1}{8}\cdot\frac{\Sigma^4}{1+\Sigma^4}\left(1-\frac{5}{6}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	$\frac{1}{8}\cdot\frac{\Sigma^2}{1+\Sigma^4}\left(1-\frac{5}{6}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	—	—
2	$\frac{45}{128}\cdot\frac{\Sigma^4}{2+5\Sigma^4}\left(1-\frac{75}{32}\cdot\frac{\Sigma^2}{2+5\Sigma^4}\right)Wl_x^2$	$\frac{1}{4}\cdot\frac{\Sigma^2}{2+5\Sigma^4}\left(1-\frac{5}{3}\cdot\frac{\Sigma^2}{2+5\Sigma^4}\right)Wl_x^2$	$-\frac{5}{8}\cdot\frac{\Sigma^4}{2+5\Sigma^4}Wl_x^2$	—
3	$\frac{1}{4}\cdot\frac{\Sigma^4}{5+2\Sigma^4}\left(1-\frac{5}{3}\cdot\frac{\Sigma^2}{5+2\Sigma^4}\right)Wl_x^2$	$\frac{45}{128}\cdot\frac{\Sigma^2}{5+2\Sigma^4}\left(1-\frac{75}{32}\cdot\frac{\Sigma^2}{5+2\Sigma^4}\right)Wl_x^2$	—	$-\frac{5}{8}\cdot\frac{\Sigma^2}{5+2\Sigma^4}Wl_x^2$
4	$\frac{9}{128}\cdot\frac{\Sigma^4}{1+\Sigma^4}\left(1-\frac{15}{32}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	$\frac{9}{128}\cdot\frac{\Sigma^2}{1+\Sigma^4}\left(1-\frac{15}{32}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	$-\frac{1}{8}\cdot\frac{\Sigma^4}{1+\Sigma^4}Wl_x^2$	$-\frac{1}{8}\cdot\frac{\Sigma^2}{1+\Sigma^4}Wl_x^2$
5	$\frac{5}{24}\cdot\frac{\Sigma^4}{1+5\Sigma^4}\left(1-\frac{25}{18}\cdot\frac{\Sigma^2}{1+5\Sigma^4}\right)Wl_x^2$	$\frac{1}{8}\cdot\frac{\Sigma^2}{1+5\Sigma^4}\left(1-\frac{5}{6}\cdot\frac{\Sigma^2}{1+5\Sigma^4}\right)Wl_x^2$	$-\frac{5}{12}\cdot\frac{\Sigma^4}{1+5\Sigma^4}Wl_x^2$	—
6	$\frac{1}{8}\cdot\frac{\Sigma^4}{5+\Sigma^4}\left(1-\frac{5}{6}\cdot\frac{\Sigma^2}{5+\Sigma^4}\right)Wl_x^2$	$\frac{5}{24}\cdot\frac{\Sigma^2}{5+\Sigma^4}\left(1-\frac{25}{18}\cdot\frac{\Sigma^2}{5+\Sigma^4}\right)Wl_x^2$	—	$-\frac{5}{12}\cdot\frac{\Sigma^2}{5+\Sigma^4}Wl_x^2$
7	$\frac{1}{12}\cdot\frac{\Sigma^4}{1+2\Sigma^4}\left(1-\frac{5}{9}\cdot\frac{\Sigma^2}{1+2\Sigma^4}\right)Wl_x^2$	$\frac{9}{128}\cdot\frac{\Sigma^2}{1+2\Sigma^4}\left(1-\frac{15}{32}\cdot\frac{\Sigma^2}{1+2\Sigma^4}\right)Wl_x^2$	$-\frac{1}{6}\cdot\frac{\Sigma^4}{1+2\Sigma^4}Wl_x^2$	$-\frac{1}{8}\cdot\frac{\Sigma^2}{1+2\Sigma^4}Wl_x^2$
8	$\frac{9}{128}\cdot\frac{\Sigma^4}{2+\Sigma^4}\left(1-\frac{15}{32}\cdot\frac{\Sigma^2}{2+\Sigma^4}\right)Wl_x^2$	$\frac{1}{12}\cdot\frac{\Sigma^2}{2+\Sigma^4}\left(1-\frac{5}{9}\cdot\frac{\Sigma^2}{2+\Sigma^4}\right)Wl_x^2$	$-\frac{1}{8}\cdot\frac{\Sigma^4}{2+\Sigma^4}Wl_x^2$	$-\frac{1}{6}\cdot\frac{\Sigma^2}{2+\Sigma^4}Wl_x^2$
9	$\frac{1}{24}\cdot\frac{\Sigma^4}{1+\Sigma^4}\left(1-\frac{5}{18}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	$\frac{1}{24}\cdot\frac{\Sigma^2}{1+\Sigma^4}\left(1-\frac{5}{18}\cdot\frac{\Sigma^2}{1+\Sigma^4}\right)Wl_x^2$	$-\frac{1}{12}\cdot\frac{\Sigma^4}{1+\Sigma^4}Wl_x^2$	$-\frac{1}{12}\cdot\frac{\Sigma^2}{1+\Sigma^4}Wl_x^2$

gular and trapezoid loadings as contained in the codes will give substantially correct results for interior panels of two-way slab systems but should be corrected for exterior panels. Referring to Fig. 5 Dr. Dischinger proposed that the beams marked with double lines should have the bending moments increased as follows:

In the X-direction for $Ly/Lx = 1$

Increase by 25%

for $Ly/Lx = 2$ Increase by 35%

In the Y-direction for $Ly/Lx = 1$

Increase by 25%

for $Ly/Lx = 2$ Increase by 0

For values between these limits obtain the percentage increase by interpolation.

Since the actual loading on the beam in certain cases is greater than the gravity loading and generally greater than the load triangle on the short span beams, it follows that the shear in such beams is correspondingly higher. It is, therefore, recommended that the shear reinforcement be increased corresponding to the greater loading.

References

1. H. M. Westergaard: *Formulas for the Design of Rectangular Floor Slabs and Supporting Girders*, Proceedings American Concrete Institute, Vol. 22, 1926.
2. S. D. Lash: *Notes on Analysis and Design of Rectangular Reinforced Concrete Slabs Supported on Four Sides*, Engineering Journal, Vol. 24, No. 9, September, 1941.
3. N. M. Newmark: *Distribution Procedure for Analysis of Slabs Continuous over Flexible Beams*, Bulletin 304, University of Illinois, June 17, 1938.
4. C. P. Siess and N. M. Newmark: *Rational Analysis of and Design of Two-Way Concrete Slabs*. Journal, American Concrete Institute, Dec., 1948. C. P. Siess and N. M. Newmark: *Moments in Two-Way Concrete Floor Slabs*, Bulletin Series No. 385; Feb., 1950.
5. S. Timoshenko and S. Woinowsky-Krieger: *Theories of Plates and Shells*, 2nd edition, McGraw-Hill Book Co., Toronto, 1959.
6. H. Marcus: *Die Theorie elastischer Gewebe und ihre Anwendung auf die Berechnung biegsamer Platten*, Julius Springer Verlag, Berlin, 1932.
7. K. Girkman: *Flachentragwerke*, Springer Verlag, Vienna, 1948.
8. F. Dischinger: *Massivbau* page 833 to 835 in "Taschenbuch fur Bauingenieure" by F. Schleicher Erster Band, Springer Verlag, Berlin, 19 5.
9. F. Czerny: *Uber den Einfluss der Querdehnungszhal auf die Momentenwerfe querbelasteter Quadratplatten*, Oesterr, Bauzeitschrift Bd. 7 (1952), Heft 9, S. 150 and Bd. 8 (1953), Heft 5, S. 103.
10. H. Marcus: *Die vereinfachte Berechnung biegesamer Platten*, Bauingenieure Bd. 5, Heft 20/21, 1924.
11. *Beton-Kalender, 1959*: Withelm Ernest and Sohn, Berlin.
12. F. Dischinger: *Kritische Betrachtung zu den deutchen Bestimmungen fur die Berechnung der Traegerroste Kreuzweis gestpanter Platten und Vorschlaege eine neue Berechnungsweise*, Beton u. Eisen, Heft 9/10, 11/12 and 13/14, Berlin, 1942.
13. A. Pucher: *Einflussfelder elastische Platten*, Springer Verlag, Vienna, 1958

(From "The Engineering Journal—April, 1961.")

INDIAN ROADS CONGRESS - TECHNICAL COMMITTEES

1. BITUMINOUS PAVEMENTS COMMITTEE

The Committee, under the Chairmanship of Shri S. Sujan Singh, held its meeting at New Delhi on 11th August, 1961. After clause by clause discussion they approved the Draft specification for ¾ in. thick bituminous carpet. The approved draft will now be submitted to the Council of the I.R.C. for their approval.

The Committee also approved the questionnaire on bituminous pavements other than surface dressed pavements to collect information for framing specifications.

2. BRIDGES COMMITTEE

The Committee held their meeting under the Chairmanship of Shri S. L. Bazaz, Additional Consulting Engineer (Bridges), on 28th and 29th August, 1961 at New Delhi

Given below are the proceedings :—

(i) Section VI of the I.R.C. Bridge Code—Prefabricated and Composite Construction for Road Culverts and Medium Span Bridges, was completed and is now under disposal for finalization.

(ii) Modification of Clause No. 209.1 of Section II of the I.R.C. Bridge Code pertaining to loading on footpaths on bridges at places near pilgrimage centres, etc., where the bridges are likely to be crowded very much was discussed.

(iii) The question regarding allowance for the transformed area of cables in calculating the properties of prestressed concrete girders was gone into.

(iv) Procedure to be adopted in evaluating the passive resistance of the soil below the maximum scour level in the design of well foundations was discussed.

3. CONCRETE ROAD CONSTRUCTION SUB-COMMITTEE

The Committee held its meeting under the Chairmanship of Shri K.K. Nambiar on 7th September, 1961 at Bombay. The Committee discussed and finalised clause by clause, the code of Practice for the construction of concrete roads in India. This is now being processed for approval of the Council.

4. CEMENT CONCRETE ROAD SURFACING COMMITTEE

The Committee held its meeting under the Chairmanship of Shri E.A. Nadirshah on 8th September, 1961 at Bombay. After detailed discussion they arrived at their recommendations for the thickness of concrete pavements for roads in India. These recommendations are being submitted to the Executive Committee of the I.R.C. for finalisation.

IMPROVING NATIONAL HIGHWAYS

At present only 2,000 miles out of 15,000 miles of National Highways are double-lane. The Indian Roads Congress recommended to the Government of India that along with the completion of missing bridges, two axial roads should be made double-lane after considerably improving their geometrics. One should run from North to South and the other from East to West covering important places in the country. The following two routes were recommended by the Indian Roads Congress :

(i) **North to South**, i. e., Delhi-Agra-Jaipur-Ahmedabad-Bombay-Bangalore-Madras-Cape-Comerin

(ii) **East to West**, i. e., Calcutta-Barhi-Varanasi-Allahabad-Kanpur-Agra-Delhi Ambala-Jullundur-Amritsar-Pakistan Border.

The Government of India in their reply have intimated that in view of the tight financial position, it will not be possible to give effect to the suggestion of the Indian Roads Congress during the Third Five-Year Plan.

HERE AND THERE

1. GOOD ROADS SAVE MONEY

● U.S. URBAN motorways are estimated to have reduced driving distances by half and saved upto 3¼d. a mile on costs. An example quoted was that of Boston where runs that formerly took from 18 to 25 minutes, now take three minutes on the new motorway.

This was the opinion of Mr. Fred Burggraf, Director of U.S. Fed. Highway Research Board given at a London meeting held by the British Road Federation.

(From " World Highways" London)

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2. NON-USERS SHOULD PAY

● " WHILE much of the burden must fall inevitably on highway users, we should remember that good highways benefit all Americans.

Thus I believe the highway programme should be financed on a shared basis between taxes on the users and general revenues."

—*Senator John F. Kennedy*

" As a general rule I believe it is a sound principle that users should pay a substantial part of a facility (referring to the Federal—State Road Building Programme). The present ratio of about 70 per cent of the cost paid by users and 30 per cent by non-users seems equitable at the moment.

—*Vice-President Nixon*

These views by presidential candidates were reported in the organ of the National Highways Users Conference, U.S.A.

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3. REFLECTION CRACKS IN BITUMINOUS SURFACING

● A COPY of a report on the reflection cracks in bituminous surfacing conducted in the Department of Civil Engineering, University of Toronto, in co-operation with the Ontario Department of Highways as part of the Ontario Joint Highway Research Programme has been received :—

Given below is brief synopsis.

It has become general practice in the years since World War II to resurface old concrete pavements, whose condition is no longer satisfactory because of scaling, cracking, roughness, inadequate width, or slipperiness with bituminous concrete. Unless there is serious lack of structural strength, this bituminous resurfacing (with widening where required) usually constitutes a perfectly satisfactory rehabilitation.

However, one problem remains with this resurfacing. Within a few years most of the cracks and joints in the concrete pavement have broken through the bituminous resurfacing. No completely satisfactory method has been found for treating these cracks. Furthermore, particularly where traffic is heavy, the repair of cracks is not only hazardous, but also a nuisance to traffic.

Therefore, highway engineers have been searching for some method of preventing the cracking of the bituminous resurfacing. Experiments and trial sections in the United State indicate that the placing of steel reinforcing in the bituminous resurfacing can definitely mitigate the problem of crack reflection.

The Ontario Department of Highways decided to install a test section of reinforced bituminous resurfacing to determine its feasibility under the climatic and service conditions existing in this Province. The University of Toronto, through the Ontario Joint Highway Research Programme, was asked to make the detailed study of this experimental project.

This report outlines the theory of behaviour, describes the test side and initial condition of the road, and outlines the construction techniques, problems, and recommendations. The effectiveness of the treatment will not be known for a period of years. Annual performance surveys will be conducted and will be reported later.

(Extract from A Report of an Investigation conducted in the Department of Civil Engineering, University of Toronto.)

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4. ROAD TAR AND BITUMEN EMULSIONS—A NEW METHOD OF PRODUCTION

● BUSH Beach and Segner Bayley Limited., of St. James House, 44, Brazennose Street, Manchester, 2, have been appointed British representatives for the sale of two types of emulsifying machines manufactured by Messrs. A. Mannesmann, of Remscheid, Western Germany.

The larger machine, known as the Mannesmann Ultra-Emulsor, is driven by an explosion-proof motor rated at 38 h.p. and taking 35 to 40 amps. and has been found capable of producing a stable road-tar emulsion when running at 4,500 r.p.m.

An hourly output of 5 tons is obtainable and when dealing with tar a special emulsifying agent is first mixed thoroughly with water and tar at 70 added to the premix This procedure has been found to have a considerable influence on the stability of the emulsion.

Bitumen emulsions are produced more easily than tar and in this case an alkali liquor and bitumen are fed separately into the machine.

The smaller type of emulsifying machine is known as the Industrie-Emulsor but its speed is limited to 3,000 r.p.m. It is unsuitable for making tar emulsions which require the higher speed of the Ultra model.

(From "Highways' Bridges and Engineering Works," 26th April, 1961)

BUDGETS AND ADMINISTRATION REPORTS

ANDHRA PRADESH GOVERNMENT BUDGET FOR THE YEAR 1961-62

(A brief review with reference to Civil Works)

THE estimates for 1961-62 anticipate Revenue and Expenditure of Rs 8512.54 lakhs and Rs 8762.93 lakhs respectively, resulting in a deficit of Rs 250.39 lakhs. The corresponding revised estimates for 1960-61 stand at Rs 8779.76 lakhs and Rs 8612.05 lakhs showing a surplus of Rs 167.71 lakhs. The actuals for 1959-60 are Rs 8194.40 lakhs and Rs 7462.81 lakhs giving a surplus of Rs 731.59 lakhs.

The estimated expenditure on Civil Works for 1961-62 is Rs 575.02 lakhs. The corresponding revised estimate and actuals for the years 1960-61 and 1959-60 are Rs 569.09 lakhs and Rs 590.26 lakhs respectively.

Expenditure on Communications (Original Works) is estimated at Rs 160.84 lakhs. The corresponding revised estimate for 1960-61 is Rs 151.69 lakhs. The actual expenditure in 1959-60 was Rs 104.17 lakhs.

The expenditure on Civil Works Outside the Revenue Account for the year 1961-62 is estimated at Rs 482.76 lakhs.

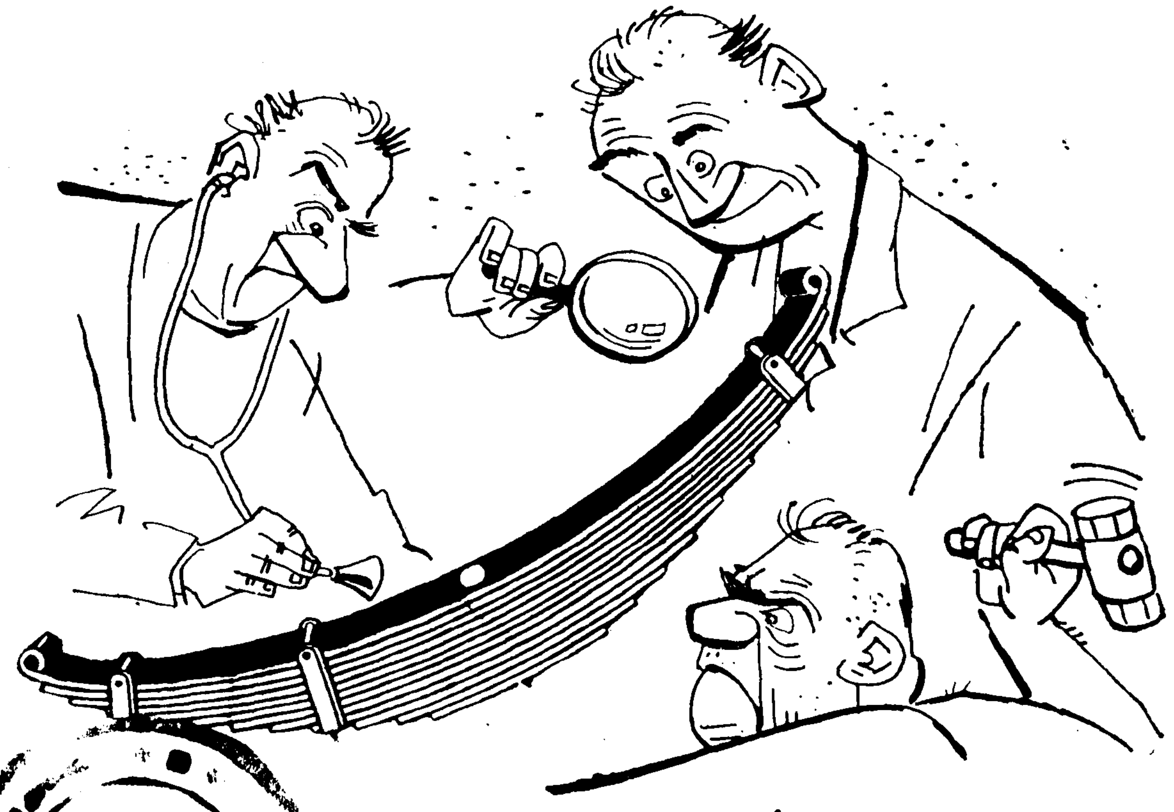
LIST OF APPROVED WORKS ON NATIONAL HIGHWAYS

S. No.	Job No.	Name of the work	Amount (Rs in lakhs)
		DELHI	
1.	2675-DLH-24	Raising of marginal bund of the Yamuna river due to the afflux that will be caused by the construction of the proposed rail and road bridges—Fresh experiments.	.65
		GUJERAT	
2.	2679-GR-8A	Providing second layer of metal and 3/4" thick premixed asphalt carpet on Wankaner-Morvi Road. Section of N.H. No. 8A, length 4-14 miles.	4.24
3.	2682-GR-8A	Construction of a bridge across the river Matelio near Wankaner on N.H. No. 8A.	3.66
4.		Two works each costing less than 2 lakhs	1.41
		MAHARASHTRA	
5.	2666-MRG	Widening formation width to 38 feet in miles 97/0 to 112/2 of N.H. No. 6 in Amravati Distt.	1.11

S. No.	Job No.	Name of the work	Amount (Rs in lakhs)
6.	2665-MRG	Widening formation width to 38 feet in miles 89/0 to 94/6 of N.H. No. 6 in Amravati Distt.	.60
7.	2681-MR-7	Resectioning, widening and black topping in miles 39/7 to 48/8 of Umri Pardharkawada-Dhoki Road—Section of N.H. No. 7, Yeotmal District.	5.14
		PUNJAB	
8.	2680-PB-2	Constructing a bridge on Gaunchi Drain crossing DM Road in Gurgaon Distt.	4.51
9.	2672-PBI	'B' Class level crossing to be converted into special class at mile 0/15-16 on Phagwara Nawanshahr Section in mile 214 of Grand Trunk Road.	.26
		RAJASTHAN	
10.	2674-RJ	Improvements of Bharatpur. Fatehpur Sikri to Rajasthan Border—Section of N.H. No. 11.	5.58
		UTTAR PRADESH	
11.	2671-UP-28	Constructing of a bridge over river Sarju at Ayodhya on N.H. No. 28.	117.00
12.	2673-UP-29	Construction of a high level bridge across the Gomti river at Mohanaghat on N.H. No. 29.	24.00
13.	2677-UP-28	Construction of approaches to the proposed bridge over river Sarju on Lucknow-Gorakhpur Road, N.H. No. 28, Ayodhya.	4.92
14.	2678-UP-28	Construction of Tamkohi-Salamgarh—Section (Missing Link) of N.H. 28.	11.94
15.	2683-UP-28	Improvement in P.W.D. Inspection House at Ramsanehi Ghat on Lucknow-Gorakhpur, N.H. No. 28 in Baranbanki Distt.	.02

STATEMENT OF ACCEPTED TENDERS

Name of State	Name of work.	Name of accepted tenderer.	Amount of work.	REMARKS
			Rs.	
KERALA	(1) Constructing a bridge at Porakkatteri Ferry on Pudiyangadi - Ulleri Road Kozhikode District.	Sri K. M. Poulose, Contractor, Perumbavoor.	2,31,612	This bridge is proposed to be constructed across Porakkatteri river on Pudiyangadi - Ulleri road in Kozhikode district. The bridge will have ten clear spans of 40′ each simply supported on R.C.C. Tee beams cum slab with a beam thickness of 16″ I.R.C. standard loading.
	(2) Construction of a bridge across Mangalam river in Palghat District.	Sri M. C. Menon, Govt. Contractor, P.O. Kazhani, Palghat.	2,02,328	This design for bridge is proposed to be constructed near the ferry known as Plazhikkadavu in Palghat District. The bridge is of 5 spans of 40′ clear. The bridge is designed for a clear road way of 22′-00, between korbs, simply supported Tee beams at 8′-3″ centre to centre and the R.C.C. deck slab 7½″ thick.
	(3) Improvements to Karukutty - Moozhikulam Road.	Sri K. Velayudhan Nair.	47,199	
	(4) Reconstructing damaged R.C.C. Bridge at the West end of K.V. canal at Vaikom.	Sri R. Balakrishnan.	56,913	
	(5) Improvements to N.H. 47 Blacktopping portion 1/0 to 8/5 of Alwaye-Edappalli Road.	Eloor Industrial Co-operation.	2,87,528	
	(6) Constructing of Kennetil bridge in 13/5 of Quilon-Alleppy road.	Shri M. Balakrishna Pillai, P.W.D. Contractor, Choppattil House, Chavra Post, Quilon.	6.93	
	(7) Improvements to Trivandrum - Quilon road mile 15/0 to 15/4.	Shri N. Velayudhan Pillai, P.W.D. Contractor, Nemom, P.O. Pravachambalam, Trivandrum District	54,420	



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