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MONTHLY REVIEW

JANUARY 1955—No. 93

INDIAN ROADS CONGRESS
TRANSPORT IS CIVILIZATION

INDIAN ROADS CONGRESS, NEW DELHI

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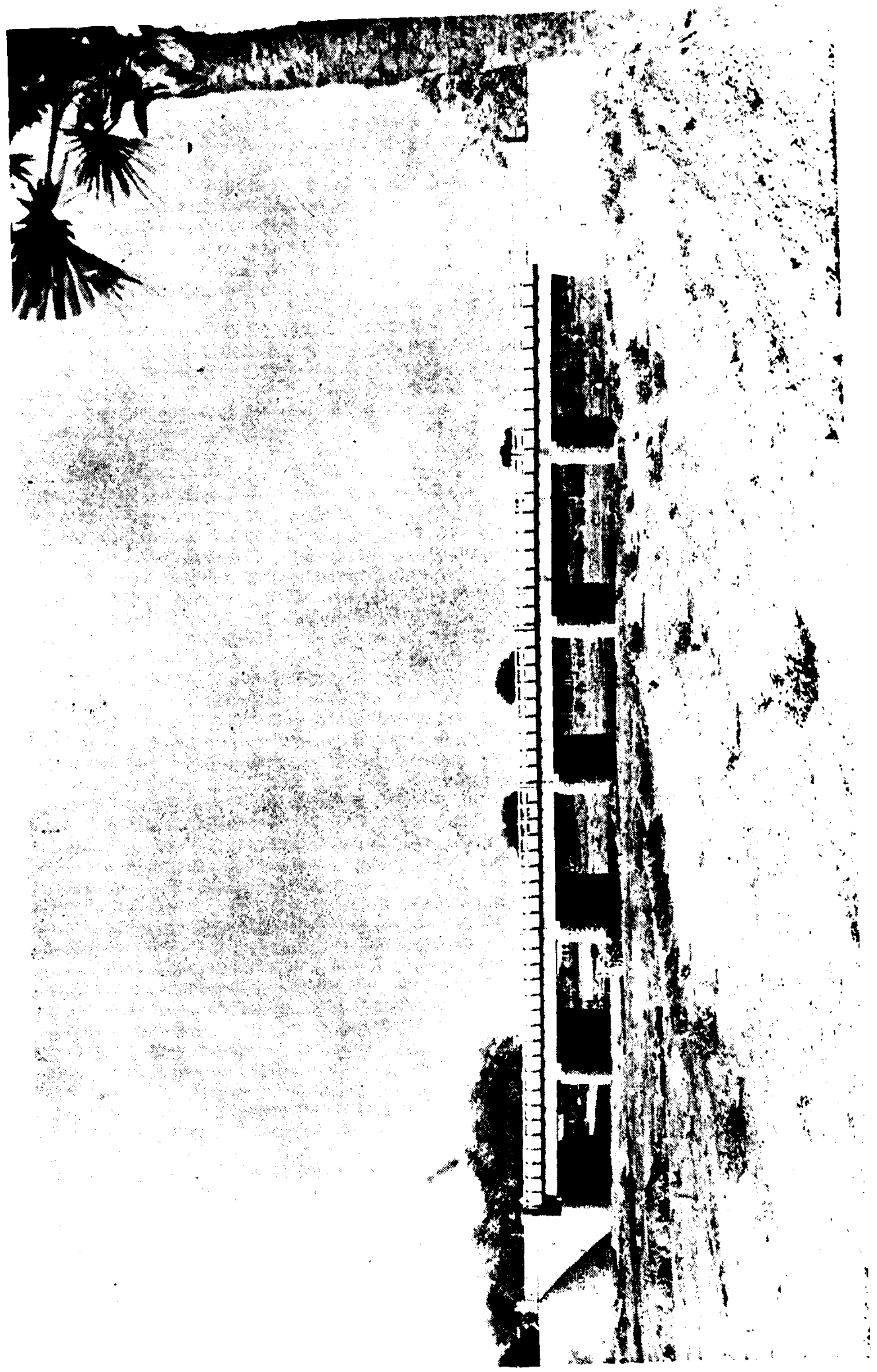


THE KODAVANAR BRIDGE

TRANSPORT-COMMUNICATIONS MONTHLY REVIEW

A REVIEW OF
ROAD ENGINEERING, DEVELOPMENT & TRANSPORT

JANUARY 1955

BRIDGING INDIA'S RIVERS

THE KODAVANAR BRIDGE

THE Kodavanar Bridge in Madras State is situated in mile 6/1-2 of the Dindigul-Karur Section of National Highway No. 7 (Benares-Cape Comorin Road). Prior to the construction of the bridge traffic between the two important trading centres of Dindigul and Karur used to be very much inconvenienced during the rainy season whenever the river was in floods. The Five Year Plan provided for the construction of a bridge across this river and in view of the importance of this link for through traffic between the two areas on both sides of the river, work on the construction of this bridge was taken up in 1951. The bridge was completed early in 1952.

Photo 1. Excavation in Foundation and Baling out water.

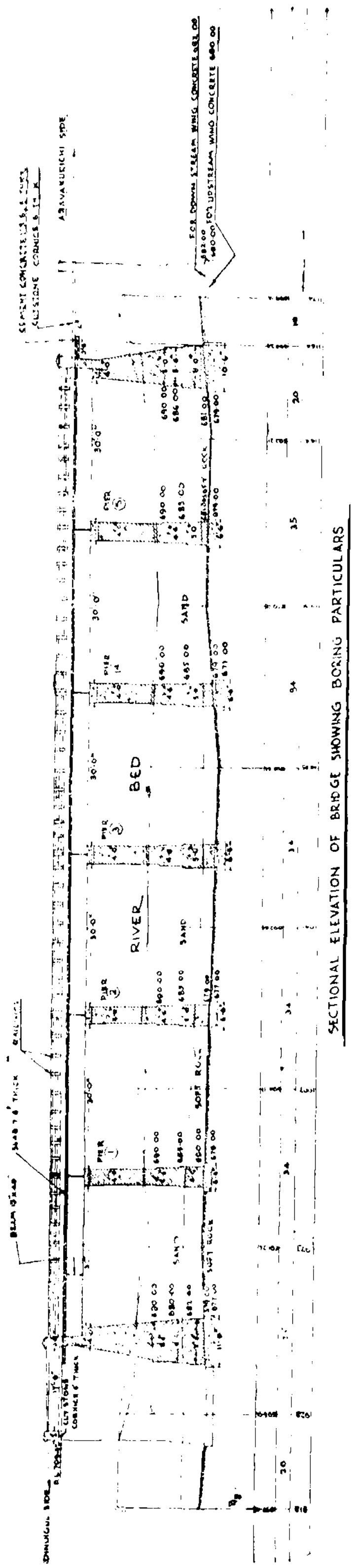
Photo 2. Concreting of Foundations.

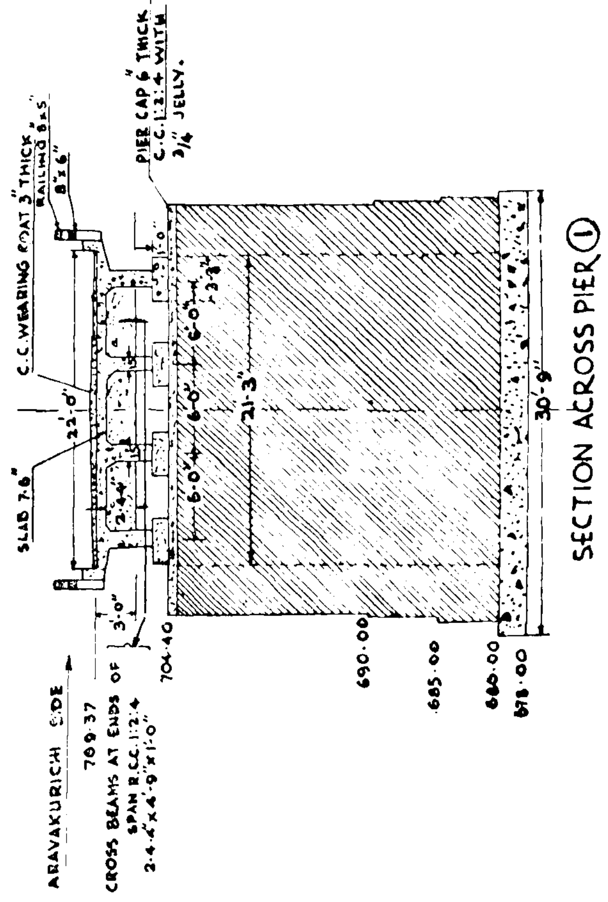
Site

The road, as it existed before the construction of the bridge, crossed the river quite close to its confluence of a tributary stream. This site was therefore considered unsuitable for the construction of a bridge and a site downstream of the confluence was selected.

Hydraulic Particulars

The catchment area of the river above the bridge site is 228 sq. miles and the bridge has





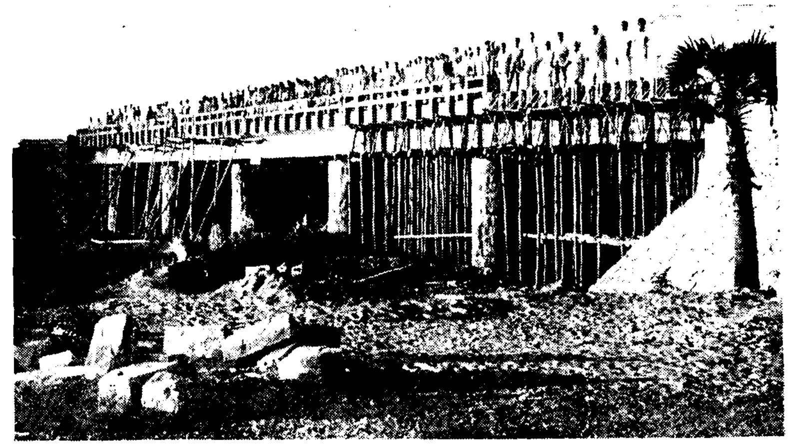


Photo 3. Centering for the deck.

been designed to pass a maximum discharge of 16,800 cusecs with a velocity of flow of about 9.4 ft per second. The maximum H.F.L. at the site is 701.4.

The bed of the river is sandy, overlying soft rock. The banks are well defined and stable.

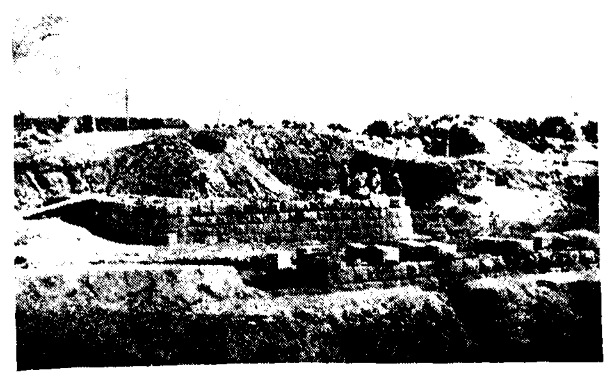


Photo 4. Masonry in piers and abutment in progress.

Design features

The bridge consists of 6 spans of 30 ft clear each, carried over piers 4 ft wide at top, constructed in coursed rubble masonry. Since rock was available at depths varying from about 10 ft to 15 ft below bed, open foundations were adopted.

The decking is carried on four R.C.C. Tee beams spaced 6 ft centers. Continuous spans were not adopted as it was felt that there would be practically no economy by providing for continuity in such small spans. Details of the bridge are given in the figures on page 4.

Costs

The total cost of the bridge is about Rs 2,10,000/- as detailed below :

	Rs
Foundation and substructure up to bed level ...	58,000
Substructure (Pier, abutments, etc.) above bed level	35,000
Superstructure	71,000
Approaches	21,000
Miscellaneous (Protection works, sheds, etc.) ...	25,000
Total ...	2,10,000

The overall cost per running foot of bridge works out to about Rs 1,050/-, the cost per sq. ft of carriageway, about Rs 48/- and the cost per sq. ft of elevation area, Rs 37/-.

ROAD AND RAIL IN DEVELOPING TERRITORIES

All economic development demands adequate and suitable transport facilities. This article examines the relative economic merits, and the efficacy as development agents, of road and rail transport in newly developing economies. Railways require relatively heavier initial capital investment than roads and are more expensive to maintain. Of prime importance is the preservation of flexibility in the transport pattern so that future extensions of the transport network may be readily and economically made at the time and place that they are required. In general, a diffuse road network will meet this need much better than the building of railway trunk lines, and will at the same time bring numerous social and general economic advantages to the much wider areas which it serves.

The general question presents itself as to the circumstances in which railway construction can be justified in newly developing territories. Some of the major factors affecting the choice between railways on the one hand and roads on the other, are discussed below.

Initial Expenditure

A railway will require, initially, expenditure of a much higher order of magnitude than a road capable of handling an equivalent volume of traffic. This follows from a number of considerations. The unit of traction, typically a locomotive, is many times heavier than a road vehicle. This difference is critical only where curves are involved, but the general inability of locomotives to maintain tractive effort up relatively minor inclines means that curves on railway routes occur comparatively frequently. The inability of locomotives to surmount sharp gradients entails also the construction of cuttings, tunnels, embankments and bridges. Again, the need to maintain the distances between rails, laterally and longitudinally, within narrow tolerances introduces an element of precision which is absent in road construction. Since the thrust on the rails, and so on the ballast and roadbed, varies with the square of the speed, it follows, too, that the cost of railway construction mounts rapidly as the planned speeds of trains increase. A line planned to carry slow, heavy mineral trains will be cheaper to construct than one destined to carry fast freight. If passengers are to be carried, allowance for higher speeds coupled with the need for much higher safety margins than freight traffic requires gives to much higher costs.

Not only is the construction of the railbed and permanent way more elaborate than that of a road, it is more laborious. Modern roadmaking equipment is available for earthmoving, grading, compacting, rolling and surfacing, so that comparatively few men are required for very large projects. The development to be expected in the technique of stabilization by soil-cement processes and the like in the near future will further increase the "productivity" of labour on road construction. By contrast, railway construction can only hope to employ such wholesale methods for certain tasks and over limited sections of the line free from gradients, curves, cuttings and tunnels. Where these exist, gang labour is unavoidable.

The construction of a railway system tends to be more expensive than a road system for two other reasons. Spurs, or feeder routes on the railway system have to be as carefully and substantially constructed as the main line, because the same rolling stock and loads will, generally, be using them. It is therefore common today for feeder roads rather than feeder railways to be built to serve an already existing railway system. In the case of a road system, spur and feeder roads can be of much lighter construction than trunk roads. Similarly, the railway has to be built from the start, at the critical points, of a robustness commensurate with the traffic it will bear ultimately, although in the early years of its life the load it will carry may be light. By contrast not only may road systems be constructed in relation to immediate traffic expectations and strengthened as necessary later, but the early traffic will, in many cases, itself

contribute to the fundamental strength of the foundation of the road by progressive compaction.

Operating Costs

A road system, as such, in general has no operating costs. (Maintenance of roads is discussed below as a separate factor.) Traffic policemen and traffic signals may be required at some points but this will usually be only in towns. In one sense, the operating of fuel-filling stations could be regarded as an operating cost, but this service is invariably provided by the seller of the fuel and does not constitute any charge upon the State or other provider of the roadbed.

The users of the road system have, of course, to meet their own operating costs. Reduced to simple terms these comprise depreciation and repairs of vehicles, the cost of tyres, fuel and lubricants, and the payment of drivers and of other labour. Vehicle and fuel costs will mainly be determined by world prices, but also by local conditions, loads carried, etc. In regard to the labour requirement it is noteworthy that the driving of a motor vehicle is easily learned by people of all races and of wide differences in intelligence and education.

For purposes of argument, it can be assumed that the day-to-day operating costs of a railway working at or near capacity will be lower than for the road transport of a comparable volume of traffic. But it is important to bear in mind that operating costs on roads are borne by the commercial users of the roads and not, as in the case of railways, by the State or other owners of the railway system. In the case of road transport, too, labour is committed only as the traffic warrants, whereas operation of a railway calls for a large permanent labour force of varying skills irrespective of the intensity of the traffic.

In railway operation, depreciation and fuel costs may or may not be less than those arising for road vehicles; this depends on a host of possible factors. The labour costs of railway operation per unit of traffic are likely to be lower than for road transport if the railway is working under favourable conditions in respect of load and capacity. The labour costs differ, however, in many characteristics which may be important in a newly developing country. Railway labour requirements are essentially inflexible. The standard of skill required of locomotive drivers is higher than for road vehicle drivers and longer training is essential. Drivers, guards, firemen, station-men, loaders, shunters, and signalmen may have to be moved to points convenient for the operation of the railway and housed and maintained there. Railway workers are required in numbers sufficient to cope with peak loads and the full period for which the track and stations are in use. Since no railway is under full load at all times over all relevant points, it follows that some under-employment of the personnel is unavoidable. So long as the railway is fully occupied railway operation may yield higher 'productivity' per individul than road transport. But any material fall in the level of traffic would produce a marked change.

The amount of labour committeed to the operation of a railway system is much higher when passengers are carried than when the railway only deals with goods traffic. Further, it is notorious in railway experience that the volume of passenger traffic is more subject to short-term and long-term fluctuations than that of goods.

Maintenance

In the case of both roads and railways, maintenance is, of course, necessary both of vehicles and permanent ways. Comparison of the maintenance costs of vehicles as between the two systems, however, while important in specific cases, is not amenable to general treatment. The maintenance required for road vehicles depends on the quality and nature of the vehicles, the loads they carry, the types of surface of the roads they use, and the policies in respect of obsolescence adopted by their operators. Maintenance expenditure can also be greatly affected by the degree of standardisation adopted and by the availability of spares. The maintenance necessary for railway locomotives and rolling stock is considerably less than that for road vehicles for equivalent ton-mileages. This follows from the robustness of construction and the controlled conditions of operation. But when important maintenance is necessary it calls for heavier equipment and very special skills, which must, of course, be kept in being. Otherwise, maintenance is of the character of cleaning and oiling, and the skills involved are low.

The situation in respect of the road—or rail-bed is, generally speaking, reversed. Provided the roads are adequately engineered initially and constructed to withstand particular climatic vagaries such as torrential rains, there is considerable latitude as to the intervals at which maintenance work need be done, except in extreme cases. Neglect will not be without its effects upon vehicular maintenance, but considerable deterioration in the roads can be recovered quickly if necessary. Further, maintenance can be done on the same large-scale basis as road construction, without important interruption to traffic, and, if so desired, at small direct labour costs. Maintenance of the railway track in large units and machines and available to be continuous, if the small working tolerances are to be preserved and accidents and derailments avoided. The maintenance work is not particularly amenable to mechanization. Equipment exists for relaying track in large units, and machines are available for removing, cleaning and relaying ballast. But, unless the railway consists of two or more tracks, the use of this equipment involves the closing of the railway to all traffic for considerable periods of time. Where two tracks exist, some form of single line shuttling must be employed, with a drop in the traffic capacity of the whole system. Most railways, therefore, rely on gang labour for the permanent way maintenance of large sections of their mileage. While the level of skill is not high, the numbers of men involved in total may be considerable and they will have to be located and housed where the work is to be done.

Economic Implications

The economic implications of adopting either roads or railways for transportation and communication in newly developing territories derive from two problems characteristic of such areas: shortage of money to invest in equipment only indirectly productive, and difficulties associated with the diversion of labour. In these territories capital for roads or railways for general use, and therefore not of a directly productive character, is not forthcoming today from foreign private investors, even where they may be interested in investing in extractive industries, plantations, and selected manufactures. Nowhere have roads figured as important outlets for private investment for a very long time, while the generally low rate of return from railways has discourged investment in them, as independent enterprises, in the past quarter century. The capital for both roads and railways has therefore to be provided, guaranteed, or obtained by the local community or State. Today, there is substantial recourse to national or international funds, which are, in the main, cautious providers of capital and faced with a multitude of competing demands.

Labour in a developing country can with deceptive ease be attracted from prior activities by the offer of money wages which if apparently low are yet higher than their previous earnings. But the local economy may not yet be flexible enough nor efficient enough to spare any substantial manpower for a new and additional activity, especially when this is not immediately productive of food. Thus, especially in the short-term, the money income of the newly employed workers may not be matched by a comparable increase in the supply of food and of other consumption goods. This can lead to a rise in food prices and disturb the local economy.

Comparative Needs

In respect of both initial capital investment and requirements of local labour for construction, operation and maintenance, railways make heavy demands. Further, the labour employed is dislocated, in the sense that it must move to, and live by, the railways. When these characteristic problems are coupled with the fact that economic and efficient operation of railways depends on high volumes of traffic, it is easy to understand the general tendency for railways in newly developing territories to be single track. Spur or branch lines are few and where the trunk routes are only marginally profitable branch lines are likely to be uneconomic. Their traffic per mile tends

to be only a fraction of that on the trunk routes, while the constructional maintenance, and operating costs per mile must be more or less the same. When spur lines carry passenger traffic, this anomaly is likely to be intensified. It follows that there is strong economic pressure to run a railway only between two productive railheads, e.g., between a mining area and a single harbour.

A railway so constructed will, however, lock up a lot of the available capital in a single narrow strip of territory and may well benefit only a few industries to the detriment or denial of others. Further, the railway or the port at the railhead, will impose a rigid upper limit on the volume of traffic which can be moved. Recently, examples have occurred at the ports of Mombasa in Kenya, Beira in Mozambique and Lobito in Angola. The scale of existing investment in a railway may in some cases mean that alternative ports or relief routes cannot be developed either because the capital is not available or because the traffic in sight, while more than the single trunk line can handle, is yet not sufficient, or is deemed insufficient, to justify the heavy capital expenditure on a second trunk route

By contrast, equivalent expenditure in money, and a smaller diversion of labour to inflexible employment on transport could provide two or more trunk roads and a diffuse pattern of feeder roads. Much wider areas would thus be served, because the amount of capital that need be invested at any one time in any given stretch of road is extremely flexible, ranging from that needed for graded earth roads to that required by surfaced permanent highways. Road extension or development can be made in comparatively small steps to suit changing circumstances, particular needs, and available funds. Thus industrial and other development can occur where best suited, with a minimum disruption of the indigenous economy and a much lower investment in new social capital in the way of housing, etc.

Capital Investment

In a developing economy, however, a decision not to invest, or to make a lower capital investment, in railways, is likely to mean higher capital investment in motor vehicles. Most if not all the capital and labour content in these must be imported, and over a period the resulting total expenditure abroad is almost bound to be higher than would be incurred in the case of the alternative of a railway. But the capital which will be spent on motor vehicles would not necessarily be available for railways. Under-developed areas are able to develop mainly because external investors are willing to sink capital in specific projects. These investors are not disinterested. They will sink capital to the extent that they can see not only an early return on it but good prospects for a widening scope in the future. Today, road development and road communications are an essential feature of a developing area, and are needed to provide the flexibility and immediate scope for expansion of which new enterprises must be assured.

New railways, as against new roads, must tend to give a too rigid pattern to the economy of a developing territory. They tend to concentrate that development into a narrow belt. Local labour is drawn into the belt and held there. The new communities thus created disrupt the old and continue to enlarge because ancillary and other industries have also to come to the railway. In the extreme instances, cities and their slums are created, sharply distinct from the local village communities. Differences in standards of living and ways of life are created, perpetuated, and emphasised. There may be created a body of railway labour and management closely cohesive and possessed of identical interests, and upon whom the whole community becomes vitally dependent.

The unfortunate results which may follow from inflexibility in a country's transport system are evident from the past experience of countries now at a comparatively advanced stage of economic development. The narrow channels to which these countries' transport was confined in its early stages (in part to avoid the extensive use of costly land) have now been made permanent by the agglomeration of buildings alongside the channels and at points of junction, etc. As a consequence, further expansion of the transport capacity between any two given points has become in most cases expensiveland often make-shift in character, necessitating long detours and complex arrangements. The integration of different forms of transport also is made more difficult by this hardening of a developed transport system into a set mould. It is, for example, quite common to spend more time travelling to an airfield located near a large city than in flying to another country.

Flexibility

Soundly conceived road development in a newly developing territory will avoid some of these maladjustments and minimise others. With the consideration of maximum flexibility in mind, newly developing territories may avoid as far as possible the building of trunk routes whether road or rail, favouring instead diffuse patterns of road transport. Roads, unlike railways, can be built as and where they are needed and of a size adequate to the traffic which they are immediately required to carry, without entailing any commitment as to the country's future transport pattern. A network of even poor roads will open up far wider areas of the countryside, create many new markets, and, by no means the least important consideration, will nourish the desire to possess a motor vehicle and thus provide a powerful incentive to work harder. By placing reliance primarily upon roads, thus leaving transport in the hands of many operators rather than in one monopoly of vested interest it will be possible, too, in the long run, to enjoy both lower costs of transport and freedom from the servility which the preservation of a large fixed capital investment may impose.

Defence considerations will, of course, vary widely. But the fact that a railway is specially vulnerable to easy and frequent interruption is another aspect of the question which cannot be entirely ignored.

However, while it would seem that, in general, the interests of newly developing territories will be better served by roads than by railway. The railways that are being constructed in Venezuela and Labrador to tap the very rich iron deposits can be an exception. Such a railway can handle regular heavy tonnage between two given distant points more cheaply than road transport. When a railway for such a specific purpose is built as a commercial adjunct to a larger commercial project which is its sole justification, little objection can be raised. They are, in effect, pipelines, essential parts of the process of extraction and transportation of a mineral resource. The capital is supplied by outside investors; the investment will be kept to a minimum consistent with the economic exploitation of the mineral resources being tapped. Any monopoly interest created is commercial, not social, affecting the enterprise directly concerned and not the community.

In other circumstances, however, provided that the roads are built with modern construction and maintenance equipment and techniques and to suit only the immediate and foreseeable traffic, the economic and social arguments are, on balance, in favour of roads.

(Extracted from 'British Road Federation Monthly Bulletin No. 210,' August 3rd, 1954)

DEFINITIONS OF HIGHWAY ENGINEERING TERMS

TANGENT POINT:	The point where a straight alignment ceases and curvature begins; also a point of reversal of curvature.
TRANSITION LENGTH:	The length of the transition curve connecting a straight length of road with another main curve which may be circular or transitional.

DEVELOPMENT OF COMMUNICATIONS IN BRAZIL

BRAZIL is a country with the most rapid industrial development that the world has ever known, but without road or rail links between many of its most important centres. Once away from the state of Sao Paulo, which is exceptionally well served, and the South, there is literally nothing that is generally understood as a road or rail system, which is one of the reasons that number one means of travel in Brazil today is by air, which traffic has become almost phenomenal, there being planes taking off and landing every two minutes at Sao Paulo and Rio de Janeiro for or from some other part of Brazil.

But this has not solved the problem of goods transport, one of the things that has handicapped agricultural development. By the time produce has reached the consumer in the city, it has cost more than the imported commodity and often is in a condition unfit for consumption.

More than 22,000 miles of rail track have been laid in Brazil, working out at one mile per 2,400 inhabitants and 0.67 miles per 100 square miles of land. Minas Gerais, Sao Paulo and Rio Grande de Sul are the states with the most rail-roads, but in general the network is only expanding slowly (2,700 miles from 1934 to 1950) nor is the rolling stock keeping pace with the increasing traffic.

It has, therefore, been decided to reorganise the whole system, not so much in the way of extending it as in improving running conditions and operational technique and in tying up the lines with highways, waterways and seaports.

New railroads are, however, being planned with a view to ensuring and extending international communications, opening up the central hinterland and above all linking together the various local railroads.

The roads and railways already in existence are disconnected, stretching inland from the coast, where the population has always tended to accumulate on account of the barrier or the Serra do Man.

Total milage of roads and railways in Brazil at the end of 1952 was of the order of 200,000 miles. Large though this figure may seem, it is far below the needs of the huge Brazilian territory.

So far as roads are concerned, up to 1945, construction work went rather haphazardly. With the creation of a fund derived from taxes on fuels, the situation improved considerably, and there are now 130,000 miles of roads in Brazil, national highways accounting for 7,500 and state highways for 32,000 miles.

31,000 Miles of National Highways Planned

It is now planned to build 31,000 miles of national highway criss-crossing the country from north to south and east to west with connecting roads and others radiating out from Rio and Sao Paulo.

A good example of modern highway construction is the recently-inaugurated second section of the "Via Anchieta", linking Sao Paulo with the port of Santos.

This super highway, which runs less than fifty miles, required excavation of about two hundred million cubic feet of solid rock and the construction of five tunnels, one of which was over 2,400 feet in length.

Road building takes top priority in Brazil. In the 1954 budget funds assigned to the Ministry of Transport and Public Works, which gets the largest share of government revenues, had been upped about seventy per cent over the figure for 1953.

When finally completed, the first stage of highway development alone will include direct connecting arteries entering or reaching the borders of eight countries which share a common frontier with Brazil-Uruguay, Argentina, Paraguay, Bolivia, Peru, Venezuela, British Guiana and French Guiana.

(Extracted from "Highways and Bridges and Engineering Works" October 20th, 1954)

SUCCESSFUL SURFACE DRESSING

THE principal points to be observed for successful surface dressing are given below.

Treatment before application

(1) Careful treatment of all depressions and weak places in the areas to be dressed. It is essential upon the completion of this work to brush cold asphalt or an appropriate brushing grit into the interstices of the new macadam used for the patching, bearing in mind that a layer of cold asphalt on the new macadam may lead to fatting up when the spraying work has been carried out. When carrying out this type of work arrange for ¼-in. chippings to be brushed in to absorb the binder. These are applied after the first pass of the roller engaged on patching and before final consolidation. Failure to do this will permit the binder for the surface dressing to pass down below existing road level and the chippings forming the final surface to be provided by the surface dressing will be whipped off by traffic.

(2) Vigorous brushing of the surface before applying the binder. This is an operation given scant attention and often neglected.

Binder

(3) Careful control of the temperature on the machine applying the binder and the rate of application. Checks for blocked jets should be made and the machine to be used should be capable of meeting the requirements of the specification of work. In any contract for the application of binder it is an advantage to have a clause incorporated in the contract documents specifying that the spraying machine is to be tested. Whatever type of binder is used the selection of the most suitable type for the work in hand is imperative if long life is to be expected of surface dressing. On major roads the high penetration binder will retain its qualities for up to five or six years provided a durable stone is used. On minor roads a medium penetration binder is better than a high penetration type; the binder will be more malleable, and retain its texture longer than one of high penetration giving longer life to the surface dressing. An essential requirement is the careful control of the rate of coverage of the binder at the correct temperature. When the bulk spraying tank is ready to spray the temperature of the binder must be checked and frequently checked as spraying continues and maintained at its correct temperature at all times, but overheating must not be permitted.

Choice of Chipping and method of chipping

In selecting the type of stone for blinding the binder on hills subject to heavy traffic a ¾-in. good granite chipping with 15 per cent of ⅜-in. size added is very satisfactory. When the chippings are finally embedded in the binder it is found that the larger chipping is parted by an occasional smaller chip which provides rugosity on the surface but leaves the larger chippings to carry the weight of traffic.

On heavy trafficked roads a single sized chipping will be found after two or three years to be in perfect condition from a sealing point of view, but under wet conditions skidding occurs. Careful inspection will show that the chippings have worked down to a level surface very similar to mosaic paving and this is obviated if mixed sizes of chippings are used.

On secondary roads carrying heavy local traffic ½-in. granite is the best material, used with a medium penetration binder, and on lighter trafficked roads of this class a good limestone will give long life. On minor roads ⅜-in. gravel will give a satisfactory result but care must be exercised to spread the gravel in as dry a condition as possible. This type of material must be kept free from fines otherwise bleeding will occur due to the fines dusting the film of binder and preventing the gravel from adhering thereto. Gravel provides a change of colour from the darker granites and other rocks, often at a lower cost than granite, and is not so rough to pedestrians' feet.

The spreading of chippings often leaves a great deal to be desired, but aim to apply about one per cent more than necessary and remove this two or three days later when the traffic has worked it off to the side of the road.

(Extracted from 'Highways and Bridges', September 8th, 1954).

THE STRUCTURAL DESIGN OF CONCRETE ROADS

(Extracted from " Magazine of Concrete Research," September, 1954)

THIS Paper reviews present knowledge of the thickness, length and width of concrete road slabs, the use of reinforcement and the functions and design of joints. Consideration is given to the factors causing stresses; while approximate estimates may be made of the stresses caused by wheel loads, temperature gradients and changes in the mean temperature of the slab, it is not possible to calculate the stresses caused by certain other factors. It is therefore necessary to rely on the knowledge gained from experience and experiment when making recommendations for future designs.

The thickness recommended for five different traffic conditions and for three soil divisions are given. It is considered that the strength properties of the soil are of less importance than the uniform behaviour of the soil and the avoidance of differential deformations. It is contended that the base only serves a useful purpose on poor soils and to resist the effects of frost.

The spacing recommended for joints is a compromise between the desire to reduce the number of joints as much as possible and the need for providing some facility for the slabs to expand and contract. The recommended spacings are given.

Reinforcement is necessary if the effect of cracking is to be minimized or eliminated. Consideration is given to the position and the amount of the reinforcement, and the recommended quantities for different soil and traffic conditions are enumerated.

The functions of the various types of transverse joint used in concrete road construction are discussed and details are given of suitable designs for transverse and longitudinal joints.

INTRODUCTION

The structural design of concrete roads considered here concerns the design of the slabs and not the layout, curvature, superelevation, alignment, amenities and other factors. There are five aspects to be considered: thickness, length and width of slabs, the use of reinforcement and the function and design of joints. Before discussing the practical implications, it is desirable to deal briefly with the theoretical aspect.

FACTORS PRODUCING STRESS

Stresses are produced in a road or runway slab by traffic loads and by restrained warping, expansion and contraction, arising from changes in the temperature and moisture content of the concrete.

TRAFFIC LOADS

Estimates of the stresses produced by wheel loads were first developed by Westergaard[1]. These were based upon certain assumptions which are not strictly valid throughout the life of the road, especially the assumption that the slab is fully supported by the subgrade over the whole of its area. Teller and Sutherland[2] carried out tests on slabs when there was some reduction in the support at corners and edges, such as happens in practice when the continual upward and downward warping plus the deflection due to wheel loads cause some consolidation of the subgrade to take place at these points. The original Westergaard formulae were modified to include the effect of partial support and are now used to calculate stresses in concrete slabs caused by wheel loads.

WARPING

When the temperature varies through the depth of the concrete, the slab warps and, since the warping is resisted, by the weight of the slab, stresses are produced. These may be estimated by Thomlinson's theory[3]. The highest stresses due to restrained warping occur when a hot day follows a cold night, and their value may then be of similar magnitude to those caused by wheel loads.

Expansion and Contraction

When the mean temperature of the slab rises, expansion takes place; when the

* The index refers to the numbers in the list of references on page 23.

mean temperature falls, the slab contracts. These movements are resisted by the friction between the slab and the subgrade or base resulting in compressive stresses during expansion and tensile stresses during contraction. An estimate of the stresses so caused may be made from data published by Teller and Sutherland[2] and by Sparkes[4]. For slabs upto 100 ft or so long, the friction stresses are relatively low, but they become progressively higher with longer slabs. For slabs of 300 to 400 ft long, the stresses may become almost as large as those caused by wheel loads.

STRESSES DUE TO MOISTURE CHANGES

It is not possible to calculate the stresses caused by moisture changes in the concrete. They are probably of low value and, since in general they will cause a reduction in the maximum total stress, they may be ignored for purposes of calculation.

Certain other factors producing or affecting stress are imperfectly understood. These include the effects of moving (as distinct from static) wheel loads, of impact, of multiple wheel and axle assemblies and of frequency of loading (intensity of traffic).

The use of theoretical methods is of value in helping to assess the cause of failures and in giving an indication of suitable designs in novel circumstances. It is better, however, to rely on the knowledge gained from experience when making recommendations for future designs.

THICKNESS OF CONCRETE AND BASE

The thickness of concrete and base required in any set of circumstances depend on the nature of the traffic the road is expected to carry and to a lesser extent on the type of subgrade on which it is to be laid. It has been shown by theoretical analysis that, provided the concrete is fully supported by the soil over the whole of its area, variations in the strength of the soil make little difference to the stresses in the concrete. Practical observation has also shown that slabs which are of moderate thickness on poor soil, but which are fully supported, have often given excellent performance. The performance is not quite so satisfactory, however, when differential settlement or movement occurs so that the slabs are no longer fully supported by the soil. Thus, while the same thickness of concrete may be used on a large variety of soils which may be expected to behave with reasonable uniformity as regards shrinkage and swelling, special arrangements must be made to deal with the cases where (a) the subgrade is very strong and stable and (b) the moisture movements may be so variable or the supporting power so weak as to constitute an exceptionally poor foundation.

As regards traffic, it is now well established that heavy loads damage roads of all kinds by an amount much greater than the increase in load would suggest. It is not mere coincidence for example, that concrete roads which have given excellent service for some 20 years have begun to show signs of distress at the same time as the intensity of traffic and the magnitude of wheel loads have increased. It has also been demonstrated by a full-scale experiment in the United States of America that even small increases in axle loads cause a disproportionately large increase in the rate of crack development. For example, when a single axle load was raised from 18,000 lb to 22,400 lb the number of cracks produced in a given length of time was increased by 600 per cent. A tandem axle load of 36,000 lb caused about four times as much cracking as an 18,000 tandem axle load with only two-thirds of the number of load repetitions.

It is also considered by German engineers that certain defects now appearing in the motor roads can be attributed to a a post-war increase in the permitted axle loads from 8 to 10 metric tons. (17,600 to 22,000 lb).

It is therefore important that the concrete thickness shall be chosen in relation to the potential traffic requirement of the road after it is built. It is necessary, before recommending the thicknesses to be used, to define the various intensities and classes of traffic and types of subgrade. This has been done in Table 1 and the same definitions apply to Table 3.

Higher loading stresses will occur at the edges than at the centre of slabs and, in the United States of America, it was for long the custom to make the concrete thicker at the edges than in the centre in an endeavour to achieve a cross-section of uniform strength. However, thickening the edges results in restrained temperature stresses of greater magnitude and may also reduce the thickness of the prepared subgrade or base. There is thus no overall advantage to be gained by edge thickening and slabs are now usually constructed of a uniform thickness in the United States of America, as they have always been in Great Britain.

Effective strengthening of the slab edges is advisable and two methods are recommended. One is to extend the base for about 2–3 ft beyond the slab edges; this provides the edges with better support and, if the base is of stabilized material, will help to keep surface water clear of the foundation. The second method is to keep traffic off the slab edges by laying kerbs on the slab surface with the kerb line about 1 ft inside the edges. This arrangement will simplify the provision of a watertight seal between slab and kerb, but the kerbs must be securely fixed if knocking out of alignment by traffic is to be avoided.

Table I. Thickness of Concrete (In inches)

Subgrade	Traffic: Very Heavy	Heavy	Moderate	Light	Housing estates
Good ...	8	7	6	5	4
Average ...	9	8	7	6	5
Poor ...	10	9	8	7	6

Very heavy traffic: City streets and main roads carrying exceptionally large amounts of commercial traffic; roads carrying heavy indivisible loads.

Heavy traffic: Main streets in towns; most main roads.

Moderate traffic: Main roads of lesser importance; main roads carrying mostly cars and coaches; secondary roads.

Light traffic: Minor roads; bus and through routes in housing estates.

Housing estate traffic: Traffic from residential area only.

Good subgrade: Old road formations which have been thoroughly compacted by traffic; sound rock; well compacted and well graded gravels and gravel-sand-clay soils.

Average subgrade: All soils falling between the conditions classed as good and poor.

Poor subgrades: Organic clay and other clays and silts of high plasticity; peat.

The recommended thicknesses* of concrete for various traffic and soil conditions are given in Table I.

In deciding on the thickness, allowance should be made, if possible, for any increase in the weights and numbers of vehicles likely to use the road. In conditions where the water-table rises higher than 2 ft below formation, or where the road is on an embankment more than 4 ft high, or where frost heave must be guarded against, the thicknesses of concrete used should be as for those on poor soil.

The Base

It has often been considered in the past that it was necessary to provide a base to a concrete road and that the thickness of the base should be increased as the supporting value of the soil decreased. It was thought that in this way the shear stress in the poorer soils could be reduced to a safe value because of the greater load-spreading characteristics associated with a thicker base. However, experience and experiments have shown that this concept is only partially valid. In concrete roads of adequate design (i.e. with reinforcement, dowel-bars at transverse joints and tie-bars at longitudinal joints) it is now considered that the base only serves a useful purpose with poor soils and to resist frost.

In general a base need only be thick enough to provide a smooth, hard working face over the formation so that, during the construction work, the subsoil is not deformed or otherwise damaged. On any but a poor soil, such as clays of high plasticity, having a California Bearing

* For conditions in the U. K.

Ratio of 2 per cent or less, it is of advantage to increase the thickness to 6 in. because (a) any thinner layer is difficult to compact adequately on such soils, (b) the thicker layer provides greater protection to soils which are susceptible to the effects of water penetrating through poorly maintained joints and cracks and (c) the thicker layer provides greater protection to the soil from the damaging effects of weather during the construction period. The modern method of protecting the soil is to surface-dress it at formation level as soon as this has been exposed by removal of top soil, or as soon as the embankment has been built up to its final level. In the case of very firm and stable soils or rocks, no base need be provided; although it may be necessary to cover the irregularities left by the trimming of the surface in a rock cutting by applying a thin layer of sand-cement.

The base should be constructed with a granular material of suitable grading so that it becomes a closely knit homogeneous mass of even density. The requirements have been dealt with by Maclean [5]. It need only be mentioned here that a variety of materials may be used such as hoggin, gravel-sand mixtures, crushed stone, crushed blast furnace slag, or similar material. It has long been common practice to use clinker but care is needed in the selection and compaction of this material: it should be well-burnt, of hard quality, suitably graded, free from sulphur and capable of being compacted to a dense and stable condition. Ashes should not be used as a base material.

Stabilized soil and lean concrete have been used as bases and they are of particular value from the constructional aspect on clays and silts. It has, however, been reported that in some instances more cracking has occurred in slabs laid on such bases. One explanation which has been put forward is that the rigid base, being unable to accommodate itself to the changing shape of the slab as it warped by temperature changes, provides less uniform support than that given by a flexible base. It is considered that a rigid base should be used where it will facilitate construction and provide protection for the subgrade, even at the risk of more cracking.

SPACING OF JOINTS

If expansion joints are omitted, the concrete may buckle after a time; if contraction joints are omitted, the concrete will crack at more or less regular intervals. Both types of joint are therefore necessary, but their inclusion provokes delays and difficulties in constructing the road, necessitates careful maintenance to prevent the leakage of surface water into the subgrade and requires the most careful workmanship in construction if poor riding quality is to be avoided and if spalling is to be prevented at their edges. The problem is, therefore, to use the minimum number of all types of joint by spacing them as far apart as possible without encouraging buckling or cracking.

The spacing of transverse joints depends principally on the co-efficient of thermal expansion of the concrete, the temperature at which it is laid, the thickness of the slab, the amount of reinforcement used (if any), the resistance to movement produced by the frictional resistance of the subgrade or base, the degree of cracking which can be tolerated and the tensile strength and elasticity of the concrete. There is thus no single spacing which will suit all conditions.

The co-efficient of thermal expansion of concrete depends essentially on the nature of the aggregate used and on the mix proportions. A gravel concrete has a relatively high co-efficient; the value for granite and basalt is about 80 per cent and that of limestone about 65 per cent of that of gravel. However, in practice, it is not usual to vary the spacing in relation to the type of aggregate used.

If concrete is laid in hot weather, the general tendency will be for the slab to contract subsequently both because of a drop in the temperature and, to a much lesser extent, because of drying shrinkage. There will thus be no need to provide much, if any, room for expansion, and expansion joints may then be placed at long intervals. If laid in cold weather, however, the expansion caused by a subsequent rise in temperature will be only slightly offset by the drying shrinkage and expansion joints will therefore need to be more closely spaced. It is not necessary for the joint spacing to vary

according to the continuously changing temperature and for practical purposes it is sufficient to use the more closely spaced joints in winter and the more widely spaced ones in summer.

The effect of reinforcement on joint spacing is related to the nature and degree of cracking which can be accepted as being not harmful to the behaviour of a concrete road. In unreinforced concrete, a crack soon develops into a major defect because of spalling of the joint edges under the effects of traffic and relative moment on each side of the crack. In reinforced concrete on the other hand, cracks will not usually develop into such failures but will remain closed and unspalled. There is no reason why such cracks should not be accepted as a harmless feature of reinforced concrete roads. If a number of fine cracks are so accepted, the joint spacing may be increased. In unreinforced concrete the joints should be at a sufficiently close spacing to prevent the formation of cracks.

When a slab expands and contracts with changes of temperature and moisture, its movement is resisted by the so-called friction between it and the subgrade or base. A stress is then developed which will be compressive when the slab expands and tensile when it contracts. In the case of a slab moving symmetrically about the centre of its length the stress will be a maximum at the centre and zero at the ends. The stress will increase as the length of the slab increases and as the interface between the concrete and base becomes rougher. If joints are spaced at long intervals, therefore, it is important to ensure a low frictional restraint by providing a smooth regular profile to the surface of the subgrade or base, or by using a layer of waterproof paper beneath the concrete, or some other such means.

It is to be expected that concrete having a high flexural strength will crack less under similar conditions than one with a low flexural strength. Instances are known where unreinforced slabs up to 70 for 80 ft long have remained uncracked for a reason which, by a process of deduction, can only be attributed to the use of concrete with a high flexural strength. There is clearly a need for a method of designing concrete mixes on the basis of flexural strength rather than, as at present, of compressive strength*. It might also be argued on theoretical grounds that, other things being equal, a concrete having a low modulus of elasticity will crack less than one with a high modulus. Such a concrete has not yet been produced but future research might well lead the way to the use of a concrete with high flexural strength and low elastic modulus so that the number of joints may be reduced without any increased risk of buckling or cracking.

It has been a not uncommon practice in the United States of America to omit expansion joints entirely except at bridge abutments or road junctions. The general experience has been that no trouble occurs at first but that, after 8 to 10 years, buckling may take place at intervals of about 1 to $1\frac{1}{2}$ miles along the road. If contraction joints are also omitted, transverse cracks occur at about 12 to 15 ft centres in unreinforced concrete. It is contended that the omission of expansion joints prevents the opening of contraction joints or cracks and so provides better load transfer because the interlocking aggregate is kept in close contact.

British engineers are less prone to accept a condition where buckling is likely to occur and expansion joints are not usually omitted from roads in the U.K. In one case, however, where a road 2 miles long was not provided with expansion joints, two serious buckling failures occurred when the road was 17 and 18 years old respectively. This must surely justify highway engineers in not accepting such risks.

How, then, should the highway engineer reconcile the need to reduce or eliminate joints and at the same time prevent buckling and reduce or eliminate cracking? The only satisfactory solution is to space the joints at the greatest distance compatible with the avoidance

* See article "The Design of Concrete Mixes on the Basis of Flexural Strength"—T. C. M. R. August, 1954-p. 12.

of buckling or cracking. These requirements can be met by spacings which are wider than was the custom before the war. The spacings recommended by the Committee for Co-operative Research between the Road Research Laboratory U. K. and the Cement and Concrete Association are shown in Table 2 and may be accepted as the best advice which can be offered for general purposes.

Table 2. Spacing of Joints

Thickness of slab (in.)	Whether reinforced	Maximum spacing of expansion joints (ft) Summer construction	Maximum spacing of expansion joints (ft) Winter construction	Spacing of dummy and contraction joints (ft)
6 and 7	Unreinforced	90	45	15
8 and 9	Unreinforced	120	60	15
6 and 7	Reinforced*	120	60	30–40
8 and 9	Reinforced*	150	60	50–60
10 to 12	Reinforced*	180	60	60

REINFORCEMENT

The purpose of reinforcement in a concrete road is to ensure that such cracks as occur are held tightly closed so that they do not, in effect, constitute a structural weakness. The presence of reinforcement in econmical amounts does not, in itself, result in any significant increase in the strength of the slab. It can be shown for example that, on the simple beam theory, the use of reinforcement at the rate of, say, 14 lb per sq. yd. will result in an increase in the maximum bending moment which can be taken by the slab of only some 5 per cent. It can also be shown that, before the concrete cracks, the stress in the steel wires will not exceed about 4,500 lb per sq. in. It is important to recognize therefore that a reinforced concrete road cannot be designed in the same way as a reinforced concrete beam or floor slab, neither does the same concept of the function of the reinforcement hold in the two cases. In the road the tensile strength of the concrete must be allowed for in assessing its performance whereas in a structure the design methods normally allow only the compressive strength of the concrete to be taken into account and sufficient steel is included to carry all the tensile stresses.

Practice in using reinforcement in road slabs varies widely. In amount it has varied from about 4 lb per sq. yd.; its position in the slab may be near the top, near the bottom or at both top and bottom; bars may be of round, deformed or twisted secton; either mild or high tensile steel may be used, and the shape of the mesh may vary. These factors are considered below.

In general, and for given conditions of subgrade and traffic, the greater the quantity of steel the less likelihood there is of cracks opening and developing. Increasing the amount of steel does not reduce the frequency of cracking — it may even increase it by allowing a re-distribution of the stress. There is no doubt, however, that large amounts of steel prevent such cracks from becoming important and may, indeed, make it difficult to discern them even after a road has had many years of use by heavy traffic. It is good practice to use the larger quantities of steel in slabs laid on poor soil such as heavy clay or peat. For general purposes the weights of steel given in Table 3 may be considered adequate.

Table 3. Quantities of Reinforcement (lb per sq. yd.) for Different Soil and Traffic Conditions

Sub-grade	Traffic: Very heavy	heavy	Moderate	Light	Housing estate
Good	10	7	5	5	4
Average	14	10	7	5	5
Poor	21	14	10	7	7

For definitions of subgrade and traffic, see notes under Table 1.

The position of the reinforcement in the depth of the concrete slab depends to some extent on the quantity used. Where the weight can be accommodated in a single layer —i.e. up to 14 lb per sq.yd. — it is preferable to place it near the top of the slab. Only for the heaviest quantities is it necessary to use two layers, and it should then be equally divided between the top and bottom. There are a number of reasons for placing the steel in a single layer near the top of the slab. In the first place, it has been a common misconception that, if placed near the bottom, it will accommodate the tensile stresses imposed when a wheel load is applied to the surface; in fact, tensile stresses may occur either in the top surface or the bottom surface depending on the temperature gradient in the concrete and the position of the wheel load on the slab. Even if, therefore, the steel could be designed to take the tensile stress — and we have seen that it cannot — there would still be no argument as to whether it would be better placed near the bottom or the top — either would be equally satisfactory, as shown by experimental slabs laid in this country (U. K.) and abroad. The second reason for using a single layer in the top is an essentially practical one. If placed near the bottom, the mesh may be trodden or worked down to the base (that is, beneath the concrete); when near the top there can be no doubt that it is in fact bonded into the concrete. Thirdly, in constructing roads by mechanical methods, it is found to be more convenient, and less complex organization is necessary, to lay a thick bottom course (up to reinforcement level) and a thin top course. Fourthly, top reinforcement will provide a greater insurance against the opening of cracks at the surface—where spalling is most likely to occur — than will bottom reinforcement. Finally, where concrete is not fully compacted, honeycombing occurs at and near the bottom of the slab and if the reinforcement is placed in this position there will be little or no bond between the concrete and steel.

In placing the reinforcement, it is usual to allow $1\frac{1}{2}$—2 in. cover of compacted concrete. The procedure is first to spread the concrete to a depth which, after compaction, will be the prescribed depth at which the mesh is to be placed, next to lay the reinforcing mats on this concrete, then to lay the top course of concrete to the correct surcharge and finally to compact the whole depth from the top surface, preferably using a vibrating beam.

As far as the relative advantages of round and deformed bars are concerned, there is no published evidence to show that any one type is better than another. Some engineers prefer the deformed or twisted bars as being more likely to develop adequate bond strength and therefore more likely to prevent the opening of cracks. The section of bar used in road reinforcement is at present a matter of personal preference and no definite recommendations can be made until information is available on the behaviour of various types of bar in roads.

Most, if not all, proprietary meshes of road reinforcement are made from cold-worked mild steel which has the effect of raising the yield point, the ultimate tensile strength and the elastic limit by a considerable amount. It has often been contended that, since the yield point determines the point at which the reinforcement will cease to hold the cracks together, the amount of high tensile steel used may be less than that of mild steel. There is no doubt that this is true for normally designed reinforced concrete structures where the factor of safety used is such as to ensure that stress in the steel will not normally exceed a value of half the stress at its yield point and hence that the cracks will not open to any extent. The special requirements for roads, where limitation of crack width is most important, make it doubtful whether the same considerations apply. Since the steel only carries a very low stress up to the point at which cracking occurs there can be no advantage of one or the other. After cracking has occurred, and up to the point at which the crack opens to the extent that the elastic limit of mild steel is reached, the width of the crack will not differ for mild and high-tensile steel reinforcement having similar sizes and spacings of bars since the modulus of elasticity is essentially the same for both types of steel. If, however, the crack continues to widen beyond this point then, in the case of mild steel reinforcement, the steel may yield and so become ineffective, whereas the high-tensile steel may still exert considerable control by

* By "reinforced" is meant at least sufficient reinforcement in a longitudinal direction to control cracking (i.e., to prevent the opening of cracks). The minimum amount of reinforcement required to do this is not known, but experience indicates that it would be at least 7 lb per sq. yd.

virtue of its higher elastic limit. Ultimately, therefore, it may be expected that the high tensile steel may exert greater control over the widening of cracks than an equal quantity of mild steel. As far as reinforced concrete roads are concerned, it is unlikely that the steel will reach a stress of this magnitude, and there is no practical evidence that the high tensile steel will produce any significant improvement in crack formation or development compared with mild steel. Until such evidence becomes available, it is better to use the same weight of steel in the two cases.

In regard to the shape of the mesh, it is now generally accepted that the major part of the steel should be in the form of longitudinal bars, that is, the mesh should be oblong with relatively narrow spacing between longitudinal bars and wide spacing between transverse bars. A common mesh is 3 in. by 16 in. (or 12 in)

The fabric is usually made in the form of sheets up to 17 ft long and of 7 ft width, and certain sizes are also supplied in rolls. It is essential that the reinforcement is quite flat when used as, otherwise, trouble may be experienced with steel showing through the surface of the slab. For this reason, sheets of reinforcement, which should be checked for flatness on delivery, are preferable to rolls, even though extra laps are needed. In placing, the longitudinal bars should be overlapped by the equivalent length of 40 diameters. There is no need to overlap the mats transversely but merely to lay them side by side so that the required spacing of the longitudinal bars is maintained.

The use of fabric reinforcement generally satisfies all the requirement for crack control. Occasionally, however, it is desirable to strengthen the corneres of slabs either because the subsoil may deteriorate and allow corners to deflect excessively, or because of the use of a relatively thin slab. In these cases it is common practice to use "hairpin" reinforcement at the corners consisting of 5/8 in. diameter bars, one bent with two legs at right angles and the other with two legs forming an angle of 30 degrees. These are placed with the bends at the corner of the slab, each leg being 4 to 5 ft long and provided with a standard hook at the end.

JOINTS

Concrete expands and contracts with changes in its temperature and its moisture. Concrete slabs also warp if the temperature or moisture content changes through the depth. If these movements are resisted, stresses are developed and in extreme cases the concrete may either buckle due to resistance to its attempt to expand, or crack because of resistance to its attempt to contract. To prevent excessive stresses, joints are installed to allow for expansion, contraction and warping to take place under controlled conditions. Joints may be either transverse to or parallel with the line of the road and the functions of these two types will be considered separately.

All joints must ideally satisfy certain functional requirements. First, and perhaps the most important, they should be waterproof at all times so as to prevent the softening of the subsoil by the passage of surface water through defective joints. They should permit the free expansion, contraction and warping of the concrete slab so as to prevent the stresses imposed by restraint to these movements. They must be economical to install and constructed in such a way as to avoid local disturbance to the true longitudinal profile of the road (that is, they should not detract from a good riding quality). They should be designed so as to prevent excessive deflexions at the edges of slabs. This usually requires the provision of some device for transferring load from one side of the joint to the other. The materials used for filling joints should be of a type which does not extrude under pressure, and those used for sealing should not permit stones and grit to become wedged in the gap.

Transverse Joints

Transverse joints may be of four kinds expansion, contraction, construction and warping joints.

Expansion joints. Expansion joints provide space for the concrete to expand

beyond its original length. They consist of a gap in the length of the concrete which is usually filled with highly compressible material. Because the presence of joints at short intervals constitutes an undesirable feature of concrete roads it is common practice to use expansion joints as widely spaced as possible. While this will not produce excessively high compressive stresses, the use of long slabs may induce tensile stresses of sufficient magnitude to cause cracking and this is prevented by installing contraction joints.

Contraction joints. Contraction joints enable the concrete to contract and, if spaced at suitable intervals between the expansion joints, they may be used to prevent or control cracking. Theoretically, after the concrete has contracted, it is free to expand again when it desires to do so, up to the original length. In practice, however, when a contraction joint opens, it may admit some dust and grit. With repeated opening, sufficient detritus may enter the joint to prevent complete closure. Contraction joints are of two kinds, a complete break in the continuity of the slab for the full depth, or for part of the depth; the latter are usually called dummy joints.

Full depth contraction joints were often used in alternate bay construction but are not normally installed in roads constructed on the continuous bay principle. Dummy joints are suitable for the latter condition and they provide the break in continuity by means of a slot extending to about one-third of the depth of the concrete. This constitutes a plane of weakness and determines the position at which the transverse cracks will occur.

Construction joints. Construction joints are installed when unavoidable interruptions occur in the progress of the work due to breakdown of plant, adverse weather and other causes. They may be of either the normal expansion or contraction joint type. It was once the practice simply to make a vertical full depth butt joint in the concrete without rounded arises, but this practice is not now favoured since it may well lead to serious trouble as the road is punished by traffic and weather.

Warping joints. Warping joints are similar in form to contraction joints, but steel reinforcement or tie-bars are placed across the line of the joint or expected crack so that warping of the slab is permitted without excessive opening of the joint.

Longitudinal joints and slab Width:

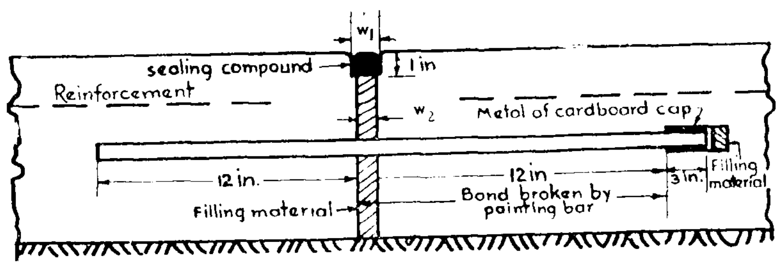
The longitudinal joint is both a warping and a construction joint. It is constructed when the width of the road exceeds 15 ft so as to facilitate construction and to prevent the formation of longitudinal cracks which will occur in slabs of greater width. Tie-bars should be provided, particularly where the road is on a clay or silt soil. Where reinforcement is used (with an appreciable amount of steel in the transverse direction), greater widths may be used and slabs 30 ft wide have successfully carried traffic for more than 20 years to date when reinforced with square mesh steel weighing 10 lb per sq. yd. over the middle third and 7 lb per sq. yd. over the two outside thirds.

In modern road construction it is convenient to use slab-widths of 12 ft for dual carriageway roads and 15 ft for 30 ft wide single carriageway roads. This avoids the use of the excessively heavy machines which would be required to span greater widths and simplifies construction by enabling batching and mixing plants of economical size to be used while maintaining a steady and adequate forward speed.

DESIGN OF JOINTS

Suitable designs of the various types of joint are shown in Figures 1 to 5. The relatively wide groove at the top to receive the sealing compound is provided to reduce the amount of extrusion which might otherwise occur.

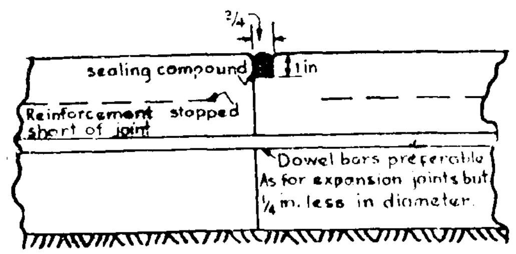
In all cases where dowel-bars are used, it is especially important that they are individually quite straight and free from burred ends and other deformities, and that they are fixed in good alignment parallel with each other and with the centre line of the road. In no case should the end of a dowel be more than 1/8 in. from its correct position. The dowels must be rigidly tied in place so as not to



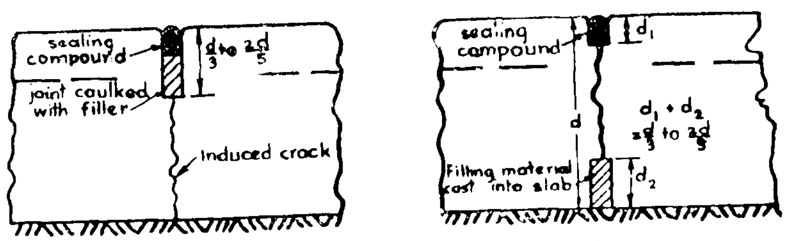
Length of slab ft	W_1 in.	W_2 in.
Up to 50	$\frac{3}{4}$	$\frac{1}{2}$
50 to 100	1	$\frac{3}{4}$
Above 100	$1\frac{1}{4}$	1

Thickness of slabs inches	Dowel bars	
	Diameter in.	Spacing in.
6 and 7	$\frac{3}{4}$	12
8 and 9	1	12
10 to 12	$1\frac{1}{4}$	15

Fig. 1. Expansion joint.



Type A. Full width



Type B. Dummy (alternative designs)

Fig. 2. Contraction joint.

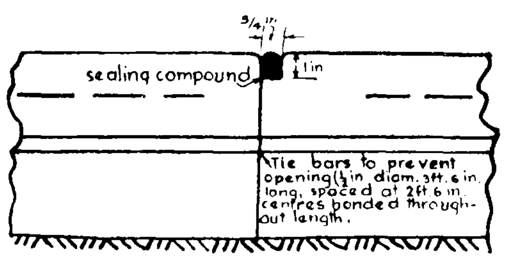


Fig. 3. Construction joint.

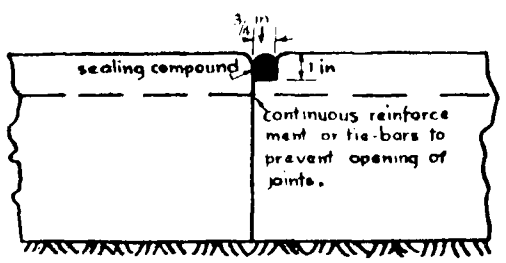


Fig. 4. Warping joint. Dummy joints, with tie-bars or continuous reinforcement, may be used as an alternative.

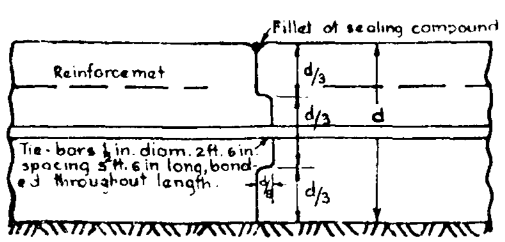


Fig. 5. Longitudinal joint.

be disturbed by the passage of spreading and compacting machinery ; it is a good plan to compact concrete around the dowels ahead of the main compacting operation, using special equipment such as internal vibrators. The sliding half of the dowel-bar should be painted with a thin layer of bitumen to prevent bond with the concrete and the end of this half of the bar should be provided with a steel or cardboard cap to allow for closure of the joint. The bituminous paint should conform to the following approximate specification :

	per cent by weight
200 penetration bitumen	66
Light creosote oil	14
Solvent naphtha	20

The bitumen and light creosote oil should be blended hot and this mixture blended cold with the solvent naphtha. The resulting material is volatile and inflammable and suitable precautions should be taken in its storage and use. It is most important that only a thin coating of the bituminous mixture is used; a thick layer will greatly reduce the effectiveness of the dowel-bars in transferring load. Likewise the use of cardboard sleeves or paper wrappings is not recommended.

ARRANGEMENT OF JOINTS

The transverse joints on each side of a longitudinal joint should be in line with each other and not staggered. Otherwise sympathetic cracking may develop in line with the staggered joints. It was once the practice to place the transverse joints at an angle of 70-80 degrees to the centre line of the road in the belief that this would minimize stress by allowing one wheel to cross the joint just ahead of its companion on the same axle; it is now known that the stress is not, in fact, reduced by this expedient. Skew joints also involved the use of acute-angled corners which often cracked and sometimes caused opening of the longitudinal joint when the slabs were in compression. Because of the lack of any real advantage, coupled with the difficulty of forming skew joints when using mechanical methods of construction, transverse joints should be placed at right angles to the centre line of the road.

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LET THE OTHER FELLOW PASS

The driver who races with cars that are trying to pass him on the highway is endangering his own life and the lives of others. When being passed, slow down, pull over to the right a little, and let the other fellow pass.

HERE AND THERE

1. ROAD FINANCE ADMINISTRATION AND CONSTRUCTION IN OTHER COUNTRIES

● FRANCE is spending 60 per cent of motor taxation on roads with nearly 5000 bridges completely reconstructed since World War II. Italy uses 32 per cent of motor taxation for highway purposes and has built over 9,900 miles of new roads and 260 new bridges in the same period. Holland has built 190 miles of roads including motorways since 1945 and Western Germany is to construct 370 miles of new **autobahnen** in seven years. Further afield, New Zealand is constructing two 4-lane express highways, one at Wellington and another at Auckland, each 40 to 50 miles long.

Sweden spends on roads some 80 per cent, Australia about 85 per cent, and the U.S.A. nearly 70 per cent of motor taxation, while New Zealand actually spends more than what is collected.

Four European countries and three Commonwealth countries have Road Funds formally established or working in practice. Sweden has decided to use vehicle and fuel taxation solely for road purposes while in New Zealand proceeds of such taxation are paid direct into a National Roads Fund.

National Highway Boards are already at work in France, South Africa and New Zealand. France's "Board" includes government and road user representatives, as does New Zealand's.

2. WEST GERMANY PLANS BIG AUTOBAHNEN EXPANSION

● FOR the first time since the war, the West German government is budgeting money for an expansion of the Hitler-built autobahn system. These super highways, totalling 1,350 miles, were badly damaged, and efforts and money up to now have been concentrated on reconstructing destroyed bridges and repairing pavements. Now, however, a new finance law accepted by the government at the first reading includes funds for new construction, and a total of 370 miles will be built within the next eight years, provided the law passes again at the second reading.

Compared with the 5,000-mile system planned by Hitler in the West German area (8,800 miles in the whole of pre-war Germany) the new expansion is not very great. Nevertheless, still further expansions have been mapped in the first and second priority additions, so that they will be ready should additional funds be available.

The present expansion programme lists eight projects, all to be started at the same time, which will complete the autobahn net existing up to now and which will follow the original plans outlined about 20 years ago.

The eighth project located between Stuttgart and Ulm consists of a second lane for the existing highway on a distance of 5 miles where the two lanes run separately around the mountains.

The cost of the expansion programme will be about 280 million pounds. For the next 14 years the federal government will contribute 20 million pounds per year, and a financing company will be founded which will administer the sums granted by the government and in addition be entitled to raise a loan of 100 million pounds for the purpose of intermediate financing.

It is expected that the German states will be willing to loan these 100 million pounds. This way, 30 to 35 million pounds would be available per year for autobahn expansion, which means that construction work could be finished within eight years, while during the following years the 20 million pounds per year coming in from the federal government could be used to pay back the loans granted by the states.

All new autobahn will be constructed to conform with the existing ones—two 25-ft lanes plus 2.5 ft paved edge strips on both sides. A 10 to 16 ft grass strip with shrubs divides the lanes, while outside shoulders 11 ft wide are partly surfaced and partly grass. The bulk of the paving will be concrete, but asphalt will be used where it is considered desirable to eliminate cross joints.

(*Extracted from "Engineering News-Record" October 7, 1954*).

3. RECORD FEDERAL-AID IN THE U.S.A.

● CONGRESS has passed and sent to the President the largest federal-aid highway bill in history. A conference committee of the House and Senate agreed on and both houses passed authorizations totalling 1,932,000,000 dollars (Rs 960 crores) for the fiscal years 1956 and 1957. The measure approved by the house provided 1,750,000,000 dollars; the Senate bill called for 2,040,000,000 dollars for highways. The final bill was a compromise between the two versions.

Authorizations under the 1952 Act for the federal aid primary, secondary, urban and inter-state systems total 575,000,000 dollars for each of the fiscal years 1954 and 1955. The new bill provides 875,000,000 dollars for the four systems for the 1956 and 1957 fiscal years. The federal primary system will get 315,000,000, the secondary system 210,000,000, the urban system 175,000,000 and the inter-state system 175,000,000 dollars. Under the 1952 act, 25,000,000 dollars was authorized for the inter-state system.

The existing 50-50 matching basis is retained for the federal-aid primary, secondary and urban systems. The matching basis for inter-state fund was changed to 60-40, with the federal government paying the 60 per cent. Congress changed the traditional apportionment method for federal-aid funds to the extent that 50 per cent of the inter-state funds will be allotted on the basis of population alone, and the other 50 per cent on the basis of area, milage and population. Authorizations for the primary, secondary and urban systems will continue to be apportioned on the basis of area, mileage and population.

(*Extracted from 'Better Roads'—May 1954.*)

4. DIRECTION BY COLOUR SIGNS

● GUIDE signs with colour backgrounds which Arizona highway engineers adopted nearly a year ago have made driving safer and easier, in the belief of the State Highway Engineer. The colours tell drivers at a glance—day and night—whether the highway they are travelling is headed north, south, east or west.

The colours—on route markers as well as distance-and-direction signs—are orange for north, green for south, brown for east and blue for west. The messages are silver on all but the orange backgrounds where black is used. The signs are overall reflectorized for night-time visibility.

Each of the four colours represents cardinal compass points to help the motorist maintain his sense of direction. A maximum of four colours helps keep the system simple—more might confuse the driver.

A stranger on a north-bound highway knows he is travelling the right general direction through town because he follows orange route markers. If he stops for gas or for a meal and loses his sense of direction he looks for an orange route marker instead of guessing. If for some reason he loses his route he can follow other orange markers to the edge of town—knowing he is travelling the right direction—and find his highway outside the congested traffic areas.

(Extracted from 'Roads and Streets'—September, 1954.)

5. HINTS FOR INSTALLING PIPE CULVERTS

● THE proper location of a pipe in culvert is very important. An improperly located pipe can be a liability rather than an asset. The pipe should be so located that all the water to be carried by the pipe can get into it quickly and easily. The pipe should be self-cleaning.

If a pipe is not properly installed it will not function as intended. To ensure good results the following factors should be considered:

1. The inlet should be placed in such a position that the water can enter the pipe without any interference.

2. The pipe should be placed as nearly as possible in line with the average *flow direction of the water*.

3. A pipe installed with sufficient fall will be self-cleaning, and no sediment or debris will lodge in the pipe.

4. The flow line should be a straight grade, if possible, and in no instance should a grade of the flow line change from a steep grade to a flatter grade. There is no objection to changing from a flat grade to a steeper grade.

5. The grade of the outlet or tail ditch should be equal to, or greater than, the grade of the pipe. Otherwise the outlet ditch will be filled with sediment.

A paved spillway or flume is needed at the outlet end of many pipe culverts to protect the fill slope and prevent undermining of headwalls. The same applies to cut slopes at inlet end when the water runs straight down the slope to the pipe.

6. The grade of the inlet ditch should be the same as the inlet end of the pipe, this will aid the water in getting into the pipe.

7. The grade of the flow line of pipe culverts, except in cut sections, should conform with the average old ground line, or the average channel grade, otherwise erosion or sedimentation will result.

8. A pipe culvert should not be installed at a point in a cut of fill section where there is any indication of slides, slips or settlements, because only a slight movement will pull the joints apart, permitting water to leak into and thus accelerate the movement of the soil, thereby causing a surface failure in the road.

9. All pipe culverts should have some type of headwall, at least at the inlet end and preferably at both ends. Headwalls prevent under-scour at the ends of the pipe, facilitate water getting into and out of the pipe, show the location of the inlet and outlet of the pipe.

(Extracted from "Proceedings of the Kentucky Highway Conference," Bulletin No. 4, June 1952).

6 THE BEARING CAPACITY OF FOOTINGS

● THE method of estimating the bearing capacity of footings described in "Applied Soil Mechanics" by Professor Housel is summarised below.

The method is based upon tests and relates the bearing pressure to the area and shape of a footing and the settlement. The tests showed that the total load (W) on the footing could be expressed as $W = mP + nA$, in which P is the perimeter of the footing, A is the area of the footing, n is the direct bearing pressure, and m is a force acting around the perimeter of the footing; m and n are determined empirically. By dividing the equation throughout by A the average unit pressure (w) on the area of the footing is obtained, that is $w = \frac{W}{A} = m\frac{P}{A} + n$. The area of the footing is thus eliminated and the ratio of the perimeter to the area $\left(\frac{P}{A}\right)$ is introduced. The effect of the forces around the perimeter is thus expressed as an equivalent uniformly distributed pressure $\left(m\frac{P}{A}\right)$ which is added to the direct pressure (n). The tests showed that, for any given settlement, m and n are constant for each size of footing and depend on the ratio $\frac{P}{A}$.

For example, for a footing 2 ft square $\frac{P}{A} = 2$ and for a given settlement $\frac{P}{A} \times w = 2m + n$, but for a footing 10 ft square $\frac{P}{A} = 0.4$ and for the same settlement $w = 0.4\ m + n$. The difference between the bearing capacities is dependent upon the forces around the perimeter of the footing, and in sandy soils the differences would not be so great as in clays.

The constants m and n have to be determined and this may be done by load tests using at least two, and preferably more, plates of different sizes. For each size of plate the settlement is plotted against the load, and from the resulting curves the values of m and n for any particular settlement are calculated by substituting in the equation $w = m\frac{P}{A} + n$ the observed values w and $\frac{P}{A}$, the equations thus obtained being solved simultaneously. Knowing m and n, the value of w for a given settlement of a proposed foundation can be calculated by trial and error.

(Extracted from 'Concrete and Constructional Engineering,' November, 1954.)

7. AUTOGENOUS HEALING OF CONCRETE IN COMPRESSION

● CONCRETE that has failed in compression (or tension) possesses the property of healing, providing the fractured parts are maintained damp and in intimate contact. The experimental work was carried out to ascertain if any quantitative results could be found concerning healing in compression and how it was connected with the general hardening process in concrete. It was found that the healing followed the same form as the general hardening process in concrete and it is thought probable that the healing is dependent upon the damage sustained by the initial compression test.

The following conclusions have been reached. Healing takes place in concrete specimens at ages of from 3 days to 3 years. It probably takes place beyond this period but this was the limit of the experimental work. A number of healings can take place and it would appear that the healed strength is dependent on the damage sustained during testing, and is a function of the total age of the specimen, although no particular relationship appears to exist between healed strength and original strength. The ultimate deformation of concrete in compression is in the region of 0.2 per cent or 0.002 and this figure holds for most or all ages of concrete whether healed or original concrete. As far as visual observation goes, the behaviour of healed concrete, is the same as ordinary concrete, following the same process of hardening.

Applications of Healing in Practice

The fact that concrete will heal offers possibilities on site, but the operation should only be carried out under expert supervision. There is no reason why members that have cracked or failed should not be healed to enable them to carry further stresses. One of the problems is that of ascertaining the degree of healing that has taken place. It is necessary to maintain damaged parts thoroughly wet by water spray or damp hessian so that the fractured surfaces in the concrete are kept moist, and to continue the treatment for one to three months in general. The engineers should then satisfy himself that the healed section is of sufficient strength to carry on with its job of work. This would probably be by a load test. The formation of the white deposit at the fracture will probably be present as an indication that healing is taking place. The most frequent cause of failure is with green concrete in precast members. Often precast slabs, etc., are lifted or moved at too early an age with the result that failure takes place. Usually it is in the form of a tensile crack (very visible) and this extends through the unit or member being visible at the compression face, where local compression failure is present. This takes place at an age of 1 to 3 days and such members when cured are of adequate strength for their intended purpose. In such cases the moisture for healing is still contained in the green concrete.

Another situation where a similar process takes place is at the construction or day joint. The lapse of time between pouring one section of concrete and another is sometimes only a day or two but quite often a matter of a week or two. In extreme cases, it may be months. The healing process is quite probably a contributory factor to efficient bond between old and new concrete in such cases. It is suggested that better concrete construction would be achieved if more care and attention was paid to construction joints. The following points are important.

1. The old concrete should be thoroughly hacked to expose raw concrete, i.e., concrete below the surface and which has not been exposed to the air.

2. This surface must be thoroughly saturated with water to ensure that it is moist enough to allow the bonding (or healing if the term is used in this connection) to proceed.

3. A layer of grout should be placed against the raw concrete face and allowed to "go off" before new concrete is placed.

4. The new concrete should be worked well into place and consolidated.

(*Extracted from 'The Structural Engineer,' September, 1954*)

8. RADIO ACTIVITY AND THE STRENGTH OF CONCRETE

● A METHOD of assessing the strength of concrete by measuring its resistance to the penetration of radio-active particles or rays was proposed at the conference on non-destructive testing of concrete held in January, 1954, in Paris and reported in a recent number of the French journal "La Technique Moderne-Construction." The resistance of any material to the passage of electro-magnetic rays or particles depends on its density and thickness. If its thickness is known, then with a constant and known radio-active emission it is possible by measuring the intensity of radio activity on the opposite side of the material from the source of emission to calculate the density of the barrier. It is stated that the density may be thus obtained with an accuracy of one or two per cent and that it is possible to relate the compressive strength to the density.

(*Extracted from "Concrete and Constructional Engineering," September, 1954*).

CURRENT LITERATURE

ABSTRACTS

U.D.C. No. 690.4 MODEL ANALYSIS OF STRUCTURES by T. M. Charlton. E. & F. Spon Limited, London, 1954.

THIS book, which is mainly written for the practising engineers and post-graduate students in civil engineering, contains seven chapters. Chapter 1, Introduction to Model Analysis, deals with the basic features of what are known as the direct and indirect methods and enumerates the advantages of employing models for analysis of structures. The theories of the direct and indirect methods are dealt with in Chapters 2 & 3.

Chapter 4 deals with the technique of indirect method using Muller-Breslau's principle. Chapter 5 illustrates the use of the indirect method in analysis of portal frames and Chapter 6 deals with some of the direct methods of model analysis.

A comprehensive bibliography is included.

U.D.C. No. 690.4 SOME RECENT DEVELOPMENTS IN STRUCTURAL ANALYSIS AND DESIGN by A. J. Francis, Proceedings of the Engineering Conference, Melbourne, 1953.

SOME of the developments in structural analysis and design over the past twenty years or so are discussed. The Paper opens with a reference to elastic methods of analysis of pin-jointed frameworks and describes a direct method of design of frameworks with redundant members. The elastic analysis of unbraced rigid-jointed frames is then considered, and some recent developments in structural form, such as cellular and shell construction, are mentioned.

A reference to riveted joints serves to show that the present interest in the post-elastic behaviour of structures and their ultimate strength is a logical, though not entirely novel, development in the search for more rational design methods. Design based on conditions at collapse is usually simpler and more economical than conventional elastic design procedures, and has the great advantage in redundant structures of being direct; recent relevant research on triangulated frameworks, rigid steel frames and reinforced concrete frames, shells and slabs is described.

The Paper concludes with a discussion of the most neglected aspect of structural design—the margin of safety which should be provided—and some of the directions in which opinion is developing are indicated. Finally a reference is made to the position of Australia in regard to structural research. (Author's Summary)

U.D.C. No. 666.3 ENGINEERING PROPERTIES OF EXPANSIVE CLAYS by W. G. Heltz and H. J. Gibbs, Proceedings of the American Society of Civil Engineers, Separate No. 516.

LABORATORY facilities for making microscopic examinations, X-ray diffraction determinations, and differential thermal analyses are quite valuable in determining the presence of objectionable clay minerals which may ultimately cause expansions. In addition to these more complex tests, relatively simple tests which can be performed in the average soil mechanics laboratory give excellent indices on expansion properties. Three such tests are those to determine colloid content, plasticity index, and shrinkage limit.

Numerous actual expansion tests have been performed to determine the actual volume change values for various types of clay soils and the uplift pressures which can be developed when the volume is maintained at a constant amount. The volume change data have been correlated with the three index values referred to above. In addition to these laboratory tests, the load-expansion and stability characteristics of a considerable number of soils have been studied. Methods of controlling expansion in remoulded soils have been worked out by controlling placement moisture and density conditions.

Included in the paper is a discussion of several design and operation experiences on projects where difficulties were encountered or were anticipated in connection with the foundations of hydraulic structures. These include the uplift of the piers, the cracking and uplift of concrete canal linings, instability of clay slopes, remedial measures inaugurated on later work in this area, the use of belled-out piles to resist uplift and the examination of bentonitic soils the spillway subgrade of a proposed dam.

It has been found that expansive clay soils can produce detrimental uplifts to hydraulic structures placed on them. The amount of expansiveness is dependent upon the amount of montmorillonite mineral present in the soil and the kind and amount of exchangeable bases.

The increased moisture and decreased density resulting from the expansion of montmorillonite clay soils have a tendency to reduce the shearing strength of these soils. Under very light load conditions the cohesion of the soils can be reduced to practically zero upon saturation, even though the soils may have fairly high cohesive strengths at moderate moisture conditions.

When hydraulic structures are to be constructed in areas where expansive clays exist, it is necessary to take special precautions against uplift unless the structure loads are sufficient to resist the uplift forces. Stability should also be checked. Where structure loads are not sufficient to prevent expansion of the subgrade soils, the following measures may be adopted :

a. The natural subgrade expansive clays may be removed and replaced with non-expansive soils to a depth sufficient to provide loadings that will resist uplift.

b. When the subgrade is a remoulded expansive soil, the volume change may be controlled by compacting the soil at high moisture contents and low densities as predetermined laboratory tests unless large periodic changes in moisture are anticipated. It may be necessary to check for consolidations during any pre-saturation period, however.

c. The saturation of the foundation soils may be prevented by cutting off all sources of water supply, although this may be difficult and impossible in some cases.

d. Piles anchored in an inactive zone below a structure provide good assurance against uplift if properly incorporated into the structure base.

It may be possible to control the expansions of montmorillonite clays by changing their exchangeable bases, as changing a sodium clay to a calcium clay. This however, has not been attempted in actual construction practice.

The Soils Laboratory can be of assistance to designers in identifying clay soils which may produce detrimental uplifts to their structures. By means of proper field explorations and laboratory tests any dangers can be recognized, quantitative uplift values determined, and recommendations for protective measures can be made. (Author's Summary)

U.D.C. No. 691.3 AN INVESTIGATION OF THE EROSIVE EFFECT ON CONCRETE OF SOFT WATER OF LOW pH VALUE by P. E. Halstead. Magazine of Concrete Research, September, 1954.

An investigation is described in which the effect of soft moorland water on concrete has been studied by tests on 4 in. concrete cubes. Cubes were immersed in moorland water or tap water for periods of up to four years and were then weighed and crushed to determine their compressive strength. After immersion in soft water, all types of concrete lost strength and weight to an extent which increased as the immersion was prolonged. Cubes made of Portland cement concrete of very high strength or high alumina cement concrete lost about one-third of their

(Continued on page 34)

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(Continued from page 30)

strength after four years' immersion. Cubes of concrete of all other types, irrespective of strength or kind of cement used, lost about half their strength after four years' immersion. Concrete containing entrained air behaved similarly, but concrete painted with bitumen maintained its strength whilst the coating was intact.

U.D.C. No. 691.3 HEAT OF HYDRATION IN CONCRETE by **Erik Rrastrup. Magazine of Concrete Research, September, 1954.**

THE Paper traces the development of a function between time and temperature, which makes it possible to refer the process of hardening of concrete at varying temperature to hardening at constant temperature.

It is further shown that it is possible to pre-determine the temperature of concrete during hardening when properties of concrete, sizes and shape of the specimen, insulation and external temperature are known. The time temperature function can also be applied to the development of strength. The validity of the theory is demonstrated by the results of tests upon 27 American and 3 Danish cements.

U.D.C. No. 691.3 A PRELIMINARY INVESTIGATION OF THE USE OF FIBRE-GLASS FOR PRESTRESSED CONCRETE, by **Professor Ivan A. Rubinsky and Andrew Rubinsky; Magazine of Concrete Research, September, 1954.**

THE article discusses the feasibility of using fibre-glass reinforcement for prestressed concrete, summarizing the physical properties of fibre-glass and some experimental work carried on by the authors. It also gives practical suggestions for future research and concludes with a comparison between fibre-glass and conventional steel reinforcement.

HURRY IS DANGEROUS

Hurried driving is a great cause of accidents. The reason is that a sense of being in a hurry clouds a driver's judgment and often causes him to take chances.

—o—

BUDGETS AND ADMINISTRATION REPORTS

Government of Assam Budget for 1954-55

The following extracts have been taken from the Government of Assam Civil Works Budget for the year 1954-55.

(All figures are in lakhs of rupees)

	Budget Estimates 1954-55	Revised Estimates 1953-54	Actuals 1952-53
Civil Works (Revenue)			
Rents	2.58	2.52	2.50
Ferry Receipts	4.64	4.60	4.62
Tolls on Roads	0.60	0.55	0.44
Recoveries of Expenditure	0.23	0 23	0.35
Transfer from Central Road Development Account	33.06	68.00	132.25
Miscellaneous	4.06	2.05	7.35
Transfer from Post War Reconstruction Fund	—	0.24	0.56
Contribution from the Government of India towards the cost of construction of certain roads and bridges	35.00	19.25	—
Deduct–Refunds	-0.46	-0.46	-0.54
Total	79.71	97.58	147.53
Civil Works (Expenditure)			
A. **Original Works**			
(*a*) Buildings	84.68	65.62	53.69
(*b*) Communications	188.87	102.43	118.09
(*c*) Miscellaneous Works	—	0.09	-0.05
B. **Repairs**			
(*a*) Buildings	18.23	16.48	15.26
(*b*) Communications	87.44	75.70	75.76
(*c*) Miscellaneous Works	10.27	12.88	3.86
(*d*) Amount transferred to Capital Account	—	-3.65	—
C. Stock and other Suspense Account	-1.59	-2.69	4 27
D. Grants-in aid for Communications	12.10	11.87	15.81
Total A to D.	400.00	368.73	286.69
E. Establishment charges	33.78	N. A.	N. A.
F. Tools and Plant	7.02	N. A.	N. A.
Total A to F.	440.80	N. A.	N. A.

N. A. means 'not available'.

Capital Account of Civil Works outside the Revenue Account

Buildings	16.95	0.80	—
Communications	110.33	0.25	—
Establishment charges	11.66	N. A.	—
Tools and Plant	2.94	N. A.	—
Total	141.88	N. A.	—

Continued

	(All figures are in lakhs of rupees)		
	Budget Estimates 1954-55	Revised Estimates 1953-54	Actuals 1952-53
Revenue from Roads			
Receipts under the Indian Motor Vehicles Act	9.00	8.00	9.79
Receipts under the Assam Motor Vehicles Taxation Act	25.12	25.12	19.67
Recoveries of over payments	0.24	0.24	0.01
Fees and other receipts	0.06	0.06	0.21
Deduct-Refunds	-0.03	-0.30	-0.03
Total	34.39	33.12	29.65
Taxes on sale of motor spirit	20.94	20.44	20.46*
Taxes on sale of lubricants	3.06	3.06	2.81*
Total Revenue from Road	58.39	56.62	52.92

* These figures do not cover the Sixth Schedule (Part-A) Areas.

GOVERNMENT OF ASSAM BUDGET FOR 1954-55.

(A brief review with reference to Civil Works)

The budget of the government of Assam for 1954-55 estimates Revenue Receipts of Rs 1442 lakhs against an estimated Revenue Expenditure of Rs 1670 lakhs leading to a deficit of Rs 228 lakhs. The Revised Estimates for 1953-54 placed Revenue Receipts at Rs 1440 lakhs and Revenue Expenditure at Rs 1493 lakhs indicating a deficit of Rs 53 lakhs. Actuals for 1952-53 revealed Revenue Receipts of Rs 1428 lakhs and Revenue Expenditure of Rs 1258 lakhs resulting in a surplus of about Rs 170 lakhs.

Revenue Expenditure on Civil Works excluding Establishment, Tools and Plant for 1954-55 is estimated at Rs 400.00 lakhs which works out to about 27.7% of the total State Revenue. It was Rs 368.73 lakhs in 1953-54 (Revised Estimates) and Rs 286.69 lakhs in 1952-53 (Actuals) which amounted to 25.6 % and 20.1% of the State revenue for the corresponding years.

Expenditure for communications alone (Original Works and Repairs only) for 1954-55 is placed at Rs 276.31 lakhs which is 19.2% of the estimated total State revenue. The corresponding ratios for 1953-54 (Revised Estimates) and 1952-53 (Actuals) were 18.6 % and 13.6% respectively.

Apart from the revenue expenditure a sum of about Rs 127.28 lakhs has been provided for Civil Works (excluding Establishment and Tools and Plants) for 1954-55 on account of Capital Expenditure outside the revenue account as against Rs 1.05 lakhs for 1953-54 (Revised Estimates). A very large share of the increased provisions for the year 1954-55 is towards Communications.

DID YOU KNOW?

You can shorten a tire's life by as much as 600 miles if you drive it continually at only one pound under recommended pressure?

LIST OF APPROVED WORKS ON NATIONAL HIGHWAYS

S. No.	Job No.	Name of work	Amount (Rs in Lakhs)
		ORISSA	
1.	1001 RS 6	Construction of a bridge over the Harad-Jore on N. H. No. 6 with approaches	3.56
2.	1012 RS 42	Black-topping miles 54/0 to 174/0 of N. H. No. 42 in Sambalpur Division	19.29
3.	102 RS 43	Black-topping N. H. No. 43 miles 4/6 + 360′ to 61/6,-Itikavalsa Jeypore Section	7.28
		BIHAR	
4.	1003 BR 31	Widening the metalled portions of Bihar Bakhtiarpur Road from 31st mile to 47th mile of N. H. No. 31	5.69
5.	1019 BR 30	Widening of the Patna-Baktiarpur Road N. H. No. 30	3.72
		UTTAR PRADESH	
6.	1006 UP 28	Improvement of miles 41–44 of Lucknow-Gorakhpur road, N. H. No. 28	1.81
		MADRAS	
7.	1007 MD 49	Land acquisition for bye-pass at Manamaduri on N. H. No. 49	0.10
8.	1008 MD 49	Land acquisition for byepass at Partibanur on N. H. No. 49	0.10
9.	1011 MD 46	Construction of a bridge across the Palar river at Ranipet on N. H. No. 46	19.75
		RAJASTHAN	
10.	1009 RJ 8	Widening ghat section (Chirwaka Ghata) of Udaipur-Nathdwara road, N. H. 8 in miles 13, 14 & 15	0.15
11.	1015 RJ 8	Providing sanitary fittings, constructing barbed wire fencing, providing pump and constructing a well at Inspection House, Kishangarh on Jaipur - Ajmer section of N. H. No. 8.	0.16
12.	1021 RJ 8	Providing 3 ft wide shoulder on either side with kankar (moorum) marinda, on quarry rubbish on Jaipur-Delhi Road N. H. No. 8	1.59

LIST OF APPROVED WORKS ON NATIONAL HIGHWAYS—(Continued)

S. No.	Job No.	Name of work	Amount (Rs in Lakhs)
13.	1022 RJ 8	Widening and tarring road near village lorry stands on Jaipur-Delhi road, N. H. No. 8	0.21
		SIKKIM	
14.	1010 SK 31-A	Providing water supply and sanitary installation in the Inspection Bungalow at Melli on N. H. No. 31-A	0.07
		HYDERABAD	
15.	1013 HD 7	Upgrading Adilabad-Kamai Section (mile 184/0 to 193/4 + 470 ft) of Hyderabad Nagpur Road — N. H. No. 7 in Adilabad Distt.	2.93
		WEST BENGAL	
16.	1005 BG 31	Construction of a road bridge over the river Leesh on N. H. No. 31	11.27
17.	1014 BG 34	Construction of a bridge over the river Jalangi on N. H. No. 34 near Krishnagar	17.25
		BOMBAY	
18.	1016 BM 8	Providing cross drainage works in Karjan-Wareria Section of N. H. No. 8	0.44
19.	1017 BM 3	Land acquisition for the diversion of the Bombay-Agra Road in mile 131 near Kokangaon village.	0.09
		UTTAR PRADESH	
20.	1018 UP 28	Painting miles 95-118 of National Highway No. 28, (Lucknow-Gorakhpur Road)	10.92

SENIORITY COUNTS

At a matrimonial agency he picked out a picture of a luscious 24-yr.-old and said, "I'll take her."

"No, you have to take this lady," said the manager, showing a picture of a gray-haired woman of 65.

"Why do I have to take her?" thundered the labour leader.

"She," said the mgr., "has seniority."