THE NEW CHALLENGE IN BRIDGE BUILDING

ABDUS SALAM, P.S.E.*

1. INTRODUCTION

The Third Five Year Plan has a sizeable allocation for new Bridges. A sum of Rs. 24 crores has been provided for specific bridge projects, and in addition to this new bridges costing Rs. 3.84 crores are also to be built though not provided in the plan. Besides these, a large number of small and medium span bridges are to be built as part of new highways. Considering the greta improvements necessary in our communication system (which calls for many new highways and a great number of small, medium and long span bridges), it is obvious that our future Five-Year Plans would have greater and still greater allocation in this sector.

The rivers in West Pakistan criss-cross the Province. The construction of new roads and major river bridges in particular has not kept pace with the tremendous increase in traffic and general development in the country. The few existing road bridges over our rivers are generally either rail-cum-road bridges or bridges over the Irrigation Headworks. There are hardly any proper road bridges capable of carrying modern traffic. Consider in this context, the Jhelum river. At present there is no proper road bridge available along the entire length of this river which can carry heavy loads with speed. River Ravi is no better in this respect and in its entire length of 380 miles in West Pakistan, it has only two proper road bridges—one at Sidhnai and the other at Chichawatni; both of these have been built only recently. Other rivers in the Province present an equally dismal picture. A start has been made only recently but a great lot is required to be done in this field, as so far we have confined ourselves to the construction of only a few "inescapable bridges." Existing bridges are a severe bottleneck to fast and heavy traffic and where even such inadequate pucca bridges are not available, the traffic has to make a long detour which is both expensive and time-consuming. The agricultural goods and local industries on which the common man thrives, do not receive economical exit. This results in economic backwardness which hampers the advancement of the country.

The picture is far from rosy in respect of smaller bridges on the existing

*Director Bridges, West Pakistan Communication and Works Department, Lahore.

roads. A number of old bridges have narrow roadway and are designed for lower class of loading. These structures have been under strain in the past years due to heavy traffic loads passing over them and many of them are now showing signs of distress and need urgent replacement. A good may existing roads need to be upgraded and improved. Bridges with heavier class of loading are required to be built to cater for modern traffic. Causeways on such roads which were acceptable a number of years ago, no longer fit in the modern highway system and it is necessary to replace them with bridges on all important highways. The rail-cum-road level crossings on all important highways also need to be substituted with over-head bridges as both the roads and the Railways are now far more busy than they were a few decades ago. Long and frequent waiting at the level crossings does not keep up with the fast tempo of the present-day life.

The Main Highways passing through cities like Gujranwala, Gujrat and Jhelum would need to have elevated bridges in the near future, as at present they offer severe bottlenecks to the traffic. Making by-passes would not only be expensive but also pose formidable problems due to extensive built-up areas.

The future poses a great challenge in the realm of bridge building and in spite of increased future allocations for bridges, money would fall short of our requirements due to the magnitude of the work. Bridges are the most expensive single item in the highways and as such they have often been delayed, postponed and more often than not treated half-heartedly. It is necessary now that we forestall our future requirements, find ways and means to finance the building of bridges and consider carefully the various aspects which need attention and organize suitable agencies to meet the future challenge. Careful planning and expert handling of the bridge projects pay dividends in the shape of less expensive structures with greater reserve of strength.

It is intended to discuss briefly in this paper certain problems in the realm of bridge financing, planning and construction and suggest measures to tackle the issues involved. There is no intention to put forth standard solutions and only certain suggestions are offered. These problems are not formidable and working assiduously with dedication, it is possible to effect a break through.

2. FINANCING OF BRIDGES

The paucity of funds has been a great stumbling-block in the past and this would remain to be so in the future, as the magnitude of the work defies our resources. The necessity for Chichawatni, Ravi and Jhelum Bridges was recognized soon after the Independence, but availability of funds has held up their construction. It is gratifying to note the recent decision of the Government that certain specified bridges would be toll bridges. This is a happy augury for the future and it is necessary that this decision is extended to all major bridges. The cost of our bridges would be recovered in a few years and then this money can be ploughed back in the construction of more bridges.

To quote a specific example as to how the toll receipts can pay back the capital cost in a reasonably short time, the case of new Ravi Bridge at Lahore can be cited. Traffic count made on 17-5-67 at the Old Ravi Bridge, Lahore recently reconstructed as two-lane bridge) showed a total of 7983 motorized vehicles per 24 hours. Their break-up is as under :—

Cars, Taxis and Vans	2794
Rickshaws and Motor Cycles	1915
Buses and Trucks	3274

If cars and motor-cycles are charged at Rs. 1/- and buses and trucks at Rs. 2/- (the present rates on our boat bridges are Rs. 3/- for cars sand Rs. 4/- for trucks) the daily income would be about Rs. 11257/- say Rs. 10,000/- allowing for vehicles returning the same day. Reckoned. on this, the yearly income would aggregate to Rs. 36,50,000/-. The complete cost would be recovered in less than 5 years, keeping in view the increase in traffic. The upgrading of Lahore-Lyallpur-Sheikhupura-Khushab Road and the Lahore-Multan Road would not only generate more traffic but would also attract sizeable volume of traffic over this crossing.

If money had been borrowed at 6% per annum and maintenance is counted at Rs. 50,000/- per year, with 10% compound increase in traffic, the cost would be paid back in about 4 years after opening the bridge, assuming two years period of construction.

Now consider the new Jhelum bridge. The 24-hour traffic count made at the existing bridge on 7-6-1966 has indicated the following traffic :—

Motor-cars, Taxis and Vans	709
Motor-cycles and Rickshaws	251
Passenger Buses and Trucks	2167

The existing narrow bridge which allows only one-way traffic at a time has severely restricted the capacity of this crossing. The traffic would get a sudden fillip when the new bridge is opened. The Lahore-Rawalpindi Highway is being widened to 24 feet which would increase the capacity of this highway considerably. Various firms of Consulting Engineers have investigated the future growth of traffic on our roads in the Punjab area. *M/s Louis Berger of New York have worked out that traffic would grow to 9 times its present volume in the next 20 years on Lahore-Khushab Road. **M/s Amman &

*Economic and Engineering Feasibility Report, Vol. 1 April 1964, Louis Berger.

**Lahore, Multan Highway Feasibility Study, Vol. 1 March 1964, Amman and Whitney.

Whitney in their feasibility report for Lahore-Multan Road have found out that traffic in the next 20 years would increase to 10-11 times the present volume. Considering that on Lahore-Rawalpindi Road, the traffic increases to 9 times the present volume in 20 years and assuming that money has been borrowed at 6% and that maintenance charges are Rs. 50,000/- per annum, the cost would be paid back in about 6 years.

Now consider Chichawatni Bridge. In this case based on past figures and assuming a traffic growth of 9 times the present volume at the end of 20 years, the cost of bridge is reckoned to be paid back in 10 years assuming 6% interest on capital outlay. In these computations, the period of construction has been taken as 2½ years and maintenance charges per annum as Rs. 30,000/-.

This all eloquently points out that it is well within the realm of possibility to go in for self-liquidating projects. The Government has recently decided to levy tools on few specified bridges which are being built against our own resources and on few major river bridges which are being partly financed by the World Bank. So far our bridge building activity has generally remained confined to the construction of a few "inescapable bridges." If we are to make leeway in the domain of bridge building, it is necessary that toll is realized on all major new bridges costing more than 25 lakhs, till the price is recovered. It is preferable to do so rather than to postpone building these bridges and fail to connect the area so far economically severed or imperfectly linked. There should not be any objection to this general practice, as we already collect toll on temporary boat bridges for an imperfect service. In a rich country like U.S.A., several major bridges have tolls and most of the ambitious bridge schemes have been launched as self-liquidating projects under a public authority specially constituted by legislation. To quote few examples, one can cite San Fransisco-Oakland Bay Bridge, cost 7.8 crore dollars, length 22720 ft. and Triborough bridges, cost 15.63 crore dollars. Both these gigantic projects were financed through the sale of revenue bonds. As a result of superior crossing facility, the traffic on Triborough bridges increased from 0.496 crore vehicles in 1936 (when the bridge was commissioned) to 3.652 crore vehicles in 1940.

We have thus two alternatives, either to await finances, build few bridges and continue to cross rivers by boat bridges, ferries or on foot (with all the attendant hazards) or build bridges and pay tolls. As a developing country, we must follow the second alternative and it is time that we had a public authority for administering self-liquidating road and bridge projects which otherwise would be kept on being postponed if reliance is placed on our own general revenues or foreign loans (which are becoming increasingly difficult to obtain). The public authority would be responsible for raising funds, assessing and collecting income, liquidating loans and assuming responsibility for further new projects.

This would provide a great impetus to bridge building activities in the country by utilizing internal sources, make us independent in our planning and also cut down the capital costs, as the foreign loans generally increase the cost of bridge projects and are rather heavy in foreign exchange component of the project. The following figures substantiate the statement :—

	Name of Bridge.	Percentage of foreign exchange.
1.	Malir Bridge near Karachi ..	9.4%
2.	Jehangira Bridge over Kabul River ..	10.0%
3.	Chichawatni bridge over Ravi River ..	4.15%
4.	Old Ravi Bridge at Lahore.	4.25%

The above bridges have been built against our own resources. Bridge at items 3 and 4 were designed in the Directorate of Bridges at Lahore. With local production of anchorages and sheath and increasing competition it should be possible to cut down the foreign exchange component to something between 3 to 4% of the total cost of the bridge project.

3. STANDARD DESIGN OF BRIDGES AND STANDARD BEAM SECTIONS SMALL BRIDGES.

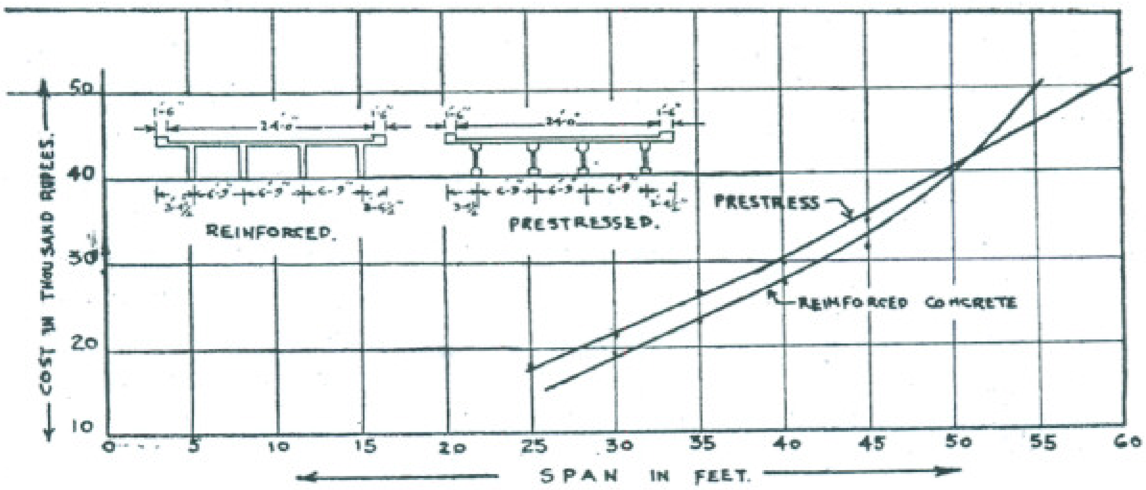
The medium span and small span bridges exceed by far in number and it is necessary that they receive sufficient attention in matter of design and execution. With the development of "limited access" concept a great deal of bridge building would be required in the form of over passes and under passes. In addition to the grade separations, the new roads would need a multitude of bridges over streams. A considerable number of new bridges of small span would be required as replacement of the old bridges on our existing roads. To meet this future load of work, it is not only time saving but also economical to have standard designs for various common spans from 30′ to say 70′. Before this is done, it is necessary to standardize the width of roadway and safety walks (if any), for the various classes of roads. At present the widths of roadway on different roads and at different locations, is anything from 22′ to 28′ with varying width of footpaths. The standard designs should be in R.C.C. and prestressed concrete both for *in situ* and precast work. It is generally desirable to adopt prestressed concrete standard designs beyond a certain span where it is advantageous over R.C.C. spans in matter of cost. The limiting span depends on unit price of high tensile steel, anchorages and reinforcing steel. The border line keeps on wandering with variation in prices. A comparison was made in the Bridge Directorate on the basis of following unit prices :—

High Tensile Steel	=	Rs. 2800/- per ton.
Anchorage Cones 12/0.2	=	Rs. 80/- per set.
Reinforcing Steel	=	Rs. 900/- per ton.

In this analysis, the steel in all the R.C.C. sections is about 10 lbs. per cft. of concrete. The ratio of the depth of rib to effective span varies from 1.21 to 1.26 for all the R.C.C. spans. For prestressed concrete spans the high tensile steel is 2.5 to 3 lbs/cft. of I-beam sections and the ratio of the depth of I-beam to effective span varies from 1.0 to 1.2 in all the prestressed spans.

The graph indicates that this border line span is at about 50 ft. beyond which prestressed concrete bridge spans are cheaper. This span length would be greater if the price of reinforcing steel comes down. It would thus be seen that this limit would need to be redetermined whenever there is a marked variation in prices.

While analysing the sections, some points come to the fore. First, deeper sections (with slightly greater depth span ratio compatible with other requirements) need to be aimed at both for prestressed and reinforced concrete sections as this reduces the amount of steel. Second, buried anchorages may be considered as for lower range of small spans, cost of anchorage is a significant part of the total cost. Third, in R.C.C. sections use of high-grade steel requires consideration as the increase in cost per ton is small in comparison with the saving due to higher allowable stresses.



Beam sections also need to be standardized for various good reasons. The principle reason is the repetitive use of steel forms which are an expensive item of construction. If certain sections are designed in one central office, they would not only reflect the expert handling of the job but would also save time and labour in various regional offices who may be otherwise designing them to meet their local needs. Such standard sections need official approval so that contractors are tempted to stock strong steel forms for repetitive use on different projects.

These standard designs for various spans and the standard beam sections may need revision after a few years when the geometrical standards are changed, or the bridge loading revised or other improvements through the general advancement in bridge design and construction are required to be incorporated. The need is for continuous improvement in design and construction bearing in mind that such designs are to be repeated many times and any saving per span would be multiplied by the number of such bridges.

Such standard span and standard sections are generally used in various advanced countries. In U.S.A. standard beam sections have been produced by a joint committee of American Association of State Highway officials and the Prestressed Concrete Institute. They are 4 types of beam sections *viz.*, type I, type II, type III and type IV as shown in Figure I to cover the range of spans from 30 to 100 ft. Each type has an upper and lower span range. The spacing of the beams in the 28 ft. roadway is varied to fit a particular beam section in the relevant span range.

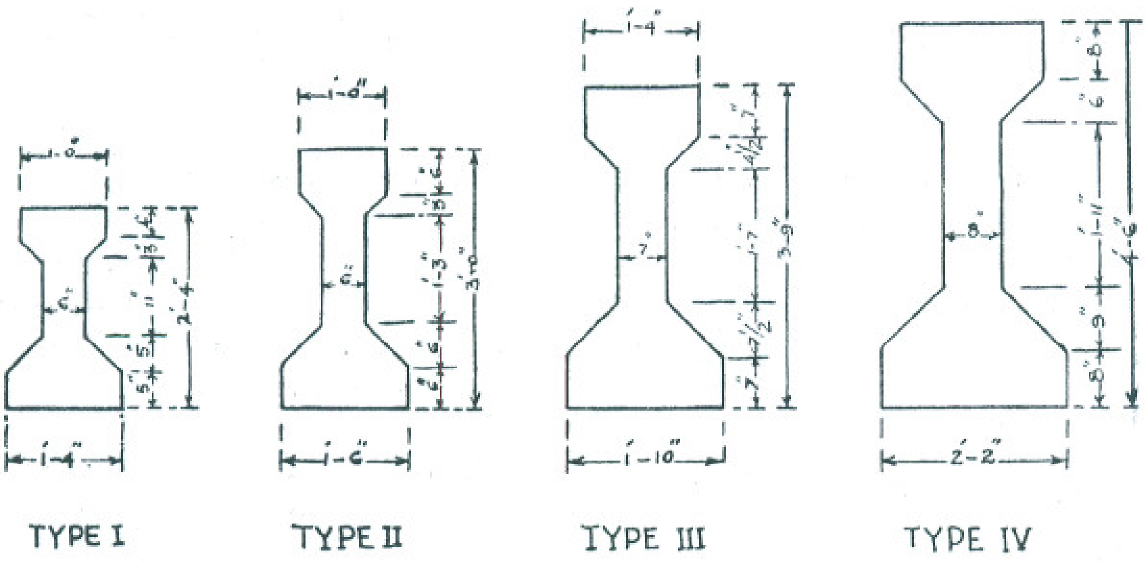


Fig. 1

It can be seen with reference to the standard sections that one bottom flange shutter with the necessary filling strips can be used for all the 4 types, two types of shuttering are needed for the top flange and three sets of web shutters cover all the 4 beam types.

In Britain the Prestressed Concrete Development Group in conjunction with the Ministry of Transport has introduced standard beam section for use in composite slab bridges. The span range is from 25′ to 55′ and these are shown in Fig. 2. In this case, both types of beams have the same top and bottom flange shapes and web thicknesses with different depths, variation of overall depths may be obtained in both sections by varying the top flange only.

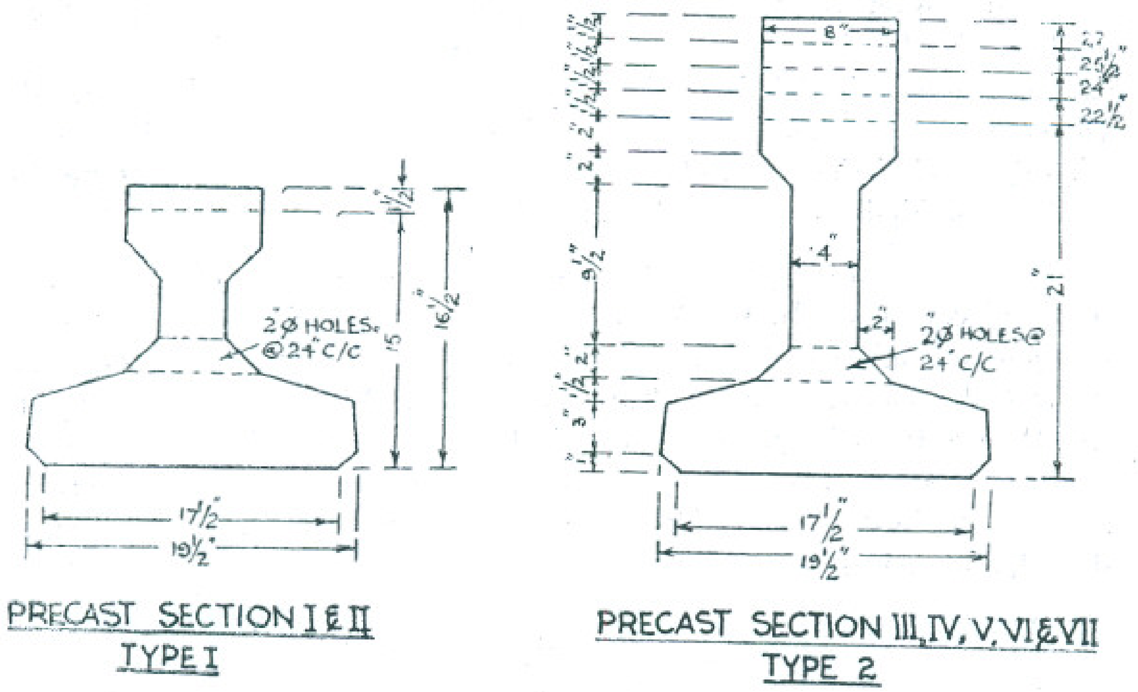


Fig. 2

We can profit from the above practices, but we must have our own sections, because firstly, our highway loading is different and secondly, in order to cut down the cost of imported materials we need to have deeper sections. Increasing cost of anchorages makes it necessary to go in for pretensioning beds. Portable beds are now available and they can be installed near the vantage point on a road project or close to the site where such girders can be economically transported.

The above steps would go a long way to increase the efficiency both in the design office and in the field. It should be possible to supply the design almost just off the rack. In the field due to similar type of work being repeated again and again, the supervising staff would have better turn out and the contractor's personnel would find it easier to work with.

It is time that we also standardize railing, bearings, expansion joints and other details. These would not only simplify working but also bring down the prices.

Besides standard spans and standard sections for the superstructure, it is necessary in the interest of economy to explore new design and constructional techniques. Pile bents for instance afford considerable economy *vis-a-vis* our conventional well foundation. Not only they are cheaper, they also effect considerable saving in construction time. For our Canal Bridges where there is regime flow and excessive scouring does not occur, pile bents offer a handy solution. As well foundations are slow and time-consuming in construction, it is felt that increasing use of piles in case of streams with favourable strata is made. They are considerably cheaper in certain locations. In the case of the proposed Hub River Bridge near Karachi, detailed analysis made in the Bridge Directorate indicated that with 25″ dia pile foundations, the cost of one pier with foundation was Rs. 52,400/- compared to Rs. 68,400/- for well foundations. In this particular bridge the total saving is Rs. 3,20,000/-.

Due to the high cost of reinforcing steel and the fact that a lot of foreign exchange goes into its procurement, it is essential that we adopt designs which consume the minimum amount of steel. Besides using gravity sections in brick or mass concrete for the substructure where possible, it is necessary that standard designs are evolved for the superstructure. Revival of brick or stone arch bridges for say up to 40 feet spans is desirable. Where suitable bricks are not available or good workmanship is not forthcoming, plain concrete arches can be employed and standard designs prepared for this. For many years to come, Pakistan would remain dependent on imported steel and it is necessary to keep this aspect of bridge planning foremost in mind as it is a national problems to conserve foreign exchange. Arch bridges have a great aesthetic appeal and a long life. Their come-back would be particularly welcome.

Bridges afford a unique diversity of types and they demand an imaginative approach for design and construction.

4. RIVER TRAINING WORKS, WATERWAY, SCOUR DEPTHS ETC.— NEED for RESEARCH

For major river bridges, guide banks with or without spurs are a major item of construction. In the case of new Ravi Bridge, the cost is Rs. 48,11,000/-, in the case of Chichawatni Bridge the cost is Rs. 26,30,500/- and for Sutlej Bridge the price is Rs. 50,87,800/-. These are sizeable amounts and are about 30.8%, 28.6% and 31% respectively of the cost of the bridge project. The historic works of Sir Francis Spring, Sir Robert Gales and others are still authoritative documents on the subject of river training. But in view of the fact that river training works for the bridges involve large sums of money both in construction and maintenance, it appears necessary that the field data on their behaviour are collected, analysed, difficulties investigated and conclusions in the light of experience gained recorded for future guidance. Hitherto the emphasis has been on a pair of guide banks for river training works with their length proportional to the length of the bridge. Recently, there have been attempts to utilize spurs in conjunction with relatively short length of guide banks. It is time that a methodic approach was made to develop modern design concepts in the realm of river training, so that better performance can be assured with lesser cost.

Our knowledge of river guide banks for submontannous streams with gravel bed is far from complete and it is necessary to include this in this special study. The Directorate of Irrigation Research Lahore has done a yeoman job in the field of model studies and a programme can be chalked out with their help for further studies on this subject.

Although certain amount of work has been done on scour in alluvial beds by various research workers, (the notable being Lacey, Inglis Laursen and Mushtaq Ahmad), the knowledge is still far from complete and the results only provide rough guides for the design depth of foundations. The Research work has remained confined to sandy beds and little guidance is available for streams with gravel beds. The result is that the designer has to use his judgement and prefers to err on the safe side. In our rivers with deep scouring beds, a more precise estimate would reflect greatly in the cost and time of construction. It is therefore necessary that a programme of field observation studies is launched and the actual scour data collected during floods for existing bridges are analysed and the results interpreted for future guidance.

Our streams and rivers with widely varying discharges offer peculiar problems. The existence of shoals and Islands blocking the waterway of bridges often makes one feel, if the correct length of bridge was provided for. It really needs to be sorted out whether the design discharge should be the maximum recorded discharge or the ruling discharge of the stream or a proportion of the former. Further, it needs to be known as to what concentration factor for flow in the bridge spans needs to be taken for the assessment of scour. All these questions and many more ask for solutions and it is time that work was done in this field to arrive at suitable design rules.

Our knowledge about the hydraulic behaviour of causeways is still far from perfect. Due to lack of funds, causeways would continue to be used on many of our unimportant roads. Failures of causeways at various places in the Province point towards the inadequacy of the present design rules and indicate the need for research in this field to study their hydraulic behaviour under various conditions, so as to evolve sound rules of design.

Many a time ungauged streams are to be bridged. For the purpose of design discharge, recourse is made to theoretical computations and some of the popular empirical formulae are used. These formulae involve only one factor, *i.e.*, the area of catchment and all the so many other factors that affect the run off are taken care of in selecting an appropriate value of the coefficient. This is really an over-simplification of the problem and cannot be expected to yield accurate results.

A correct value of the coefficient can only be devised for a given region from an extensive study of the measured flood discharges *vias-a-vis* catchment areas of streams in the region. Any value of the coefficient will be true for the region for which it has been determined. As each basin has its own peculiarities effecting the run off, the formulae leave much to the judgement of Engineers.

In recent years theories have been put forward which bring out rational formulae comprehending the effect of catchment characteristics or run off. Relationship has been developed between run off and rainfall under various conditions. It is necessary that the Meteorological Department is requested to supply information about the total precipitation and the duration of a number of heavy storms recorded at as many places in West Pakistan as possible. When this information is available, it will be possible to analyse it and recommend values of one-hour rainfall for various parts of West Pakistan for storms of different frequencies.

Most of the above problems are common with the Railway and it would be most helpful to invite their cooperation.

Statistically indeterminate structures which afford considerable economy in certain cases have been a taboo in this province for fear of settlement and upsetting of the computed stresses. It should be necessary to measure periodically the pier levels on old and new major river bridges to find out the extent of settlements. They may be insignificantly small.

5. TEMPORARY BRIDGES

In view of the fact that the resources of the country cannot afford many expensive structures for a long time to come, it would be possible in many cases where traffic is light to go in for temporary bridges with limited load carrying capacity. Such crossing facilities would be a great boon to the public till such time that the traffic can develop and the financial resources of the country allow a permanent structure. Such temporary bridges can then be shifted to some other suitable location.

There are a number of such temporary bridges available in the World Market and require substantial foreign exchange for their purchase. The type commonly used in this country is the boat bridge made out of local deodar timber. A single 29′ bridge span including boat costs Rs. 19,500/- *i.e.*, Rs. 672.41 per foot compared to a concrete bridge which would cost about 3 times this amount. Boat bridges do not require any training works nor do they need expensive approaches, but they have the snag of low carrying capacity of 7 tons besides impact and need dismantling during floods. A great deal cannot be done to improve the life of the bridge because while this can be made safe during floods the approach roads in the river bed leading to the bridge would get submerged with the rise of water. Improvements can however be effected in its load carrying capacity. It is sad that since 1942 when Gunwale loading was changed into central loading, no improvements have been made in this type of bridge. The boat has a surplus capacity and its present use is rather wasteful, when it is called upon to take only 7.0 tons live load-total 8 tons inclusive of 15% impact.

The standard bridge boat is 48 feet long, 12 feet wide at top and 9′-6″ at bottom. Its height is 5′. Its self-weight is 6.0 tons and the weight of superstructure it has to carry *i.e.*, cross beams, long beams, tussed beams, planks etc., is another 6 tons. Now if the boat is allowed a submergence of 2.5 feet leaving a free board of 2′-6″, the weight of water displaced $= \frac{40 \times 9.5 \times 2.5 \times 62/5}{2240}$ $=26.5$ tons. This means that theoretically the safe live load carrying capacity of the boat is about 15.5 tons. This has to be checked against the structural safety of the bridge boat. Structural calculations for the boat indicate that worst case for the boat occurs when it sits on the sand in shallow water. While the flexural stresses in the boat planks are very safe the shear and bending stress in the boat ribs really govern the design. This limits the live load to 11 tons (inclusive of impact) without modifying the present structure of the boat. Thus without altering the boats, the existing bridge boat can safely allow about 30 per cent extra live load.

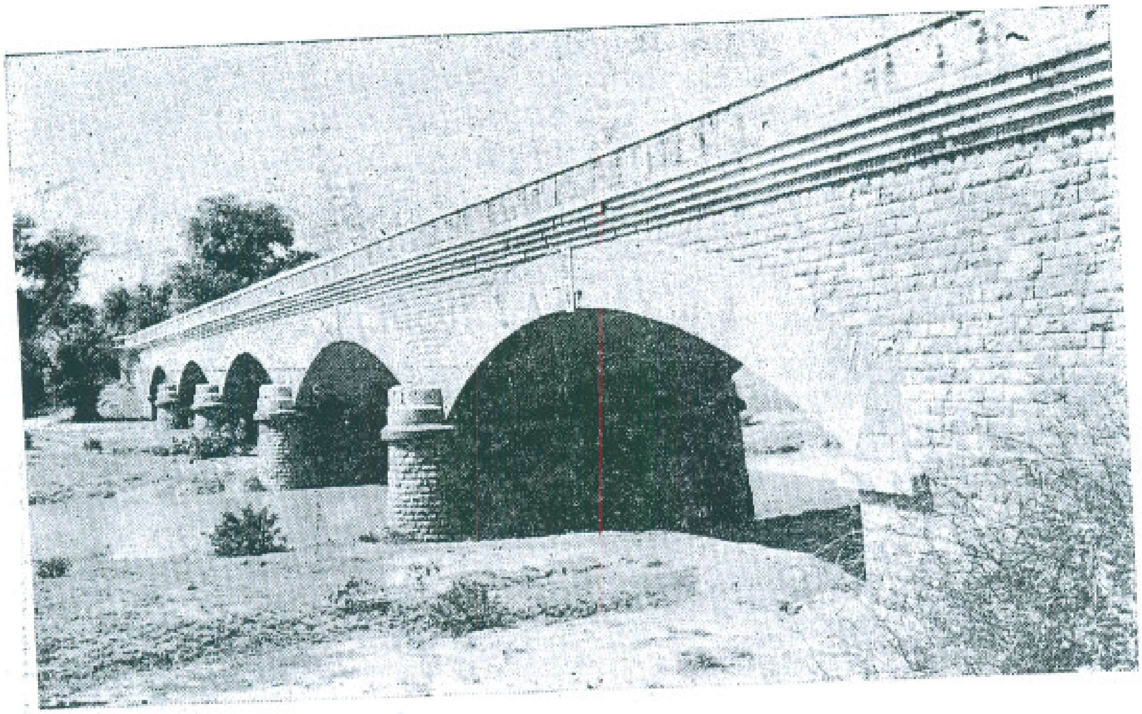
It would be thus seen that the superstructure offers a great opportunity for improvement. At present the assembly of the boat bridge is done manually and it is necessary that the beams are not made heavy. On certain occasions the dismantling has to be done at a short notice and it is desirable that any beam which accidentally falls into the river does not get sunk and can be picked up easily. With these considerations in view, future improvement can be investigated on the following lines :—

(*i*) Spans to be kept the same, but beam made stronger to improve load classification. In this context possibility of using flitched beams *i.e.*, steel plate sandwiched between timber scantlings can be investigated not only for the trussed beams but also for the cross beams and long beams.

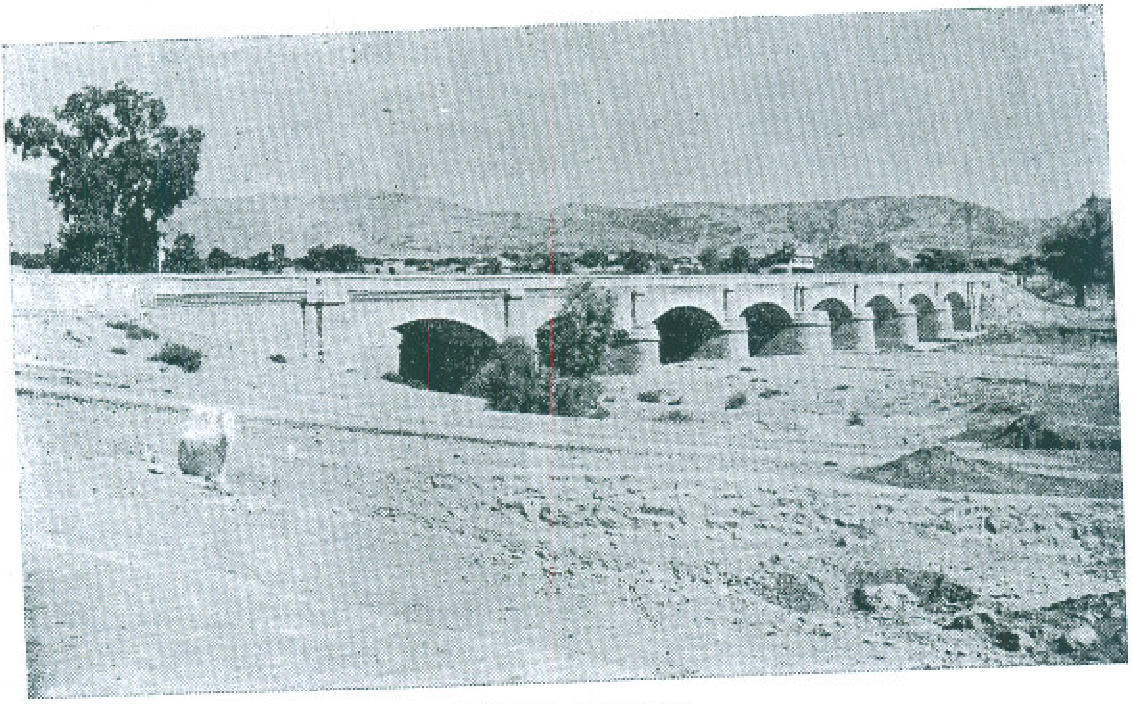
(*ii*) Where load classification is not important, longer spans can be used maintaining the same classification thus reducing the number of boats in a given length, bearing in mind that boats are expensive item of construction. Stronger beams would be required as in (*i*) above.

(*iii*) Steel trusses can replace timber beams and thus greatly increase the load carrying capacity of the bridge. This is recommended on certain locations *i.e.*, over canals, perennial streams and rivers where dismantling is not often done and is possible with good advance notice.

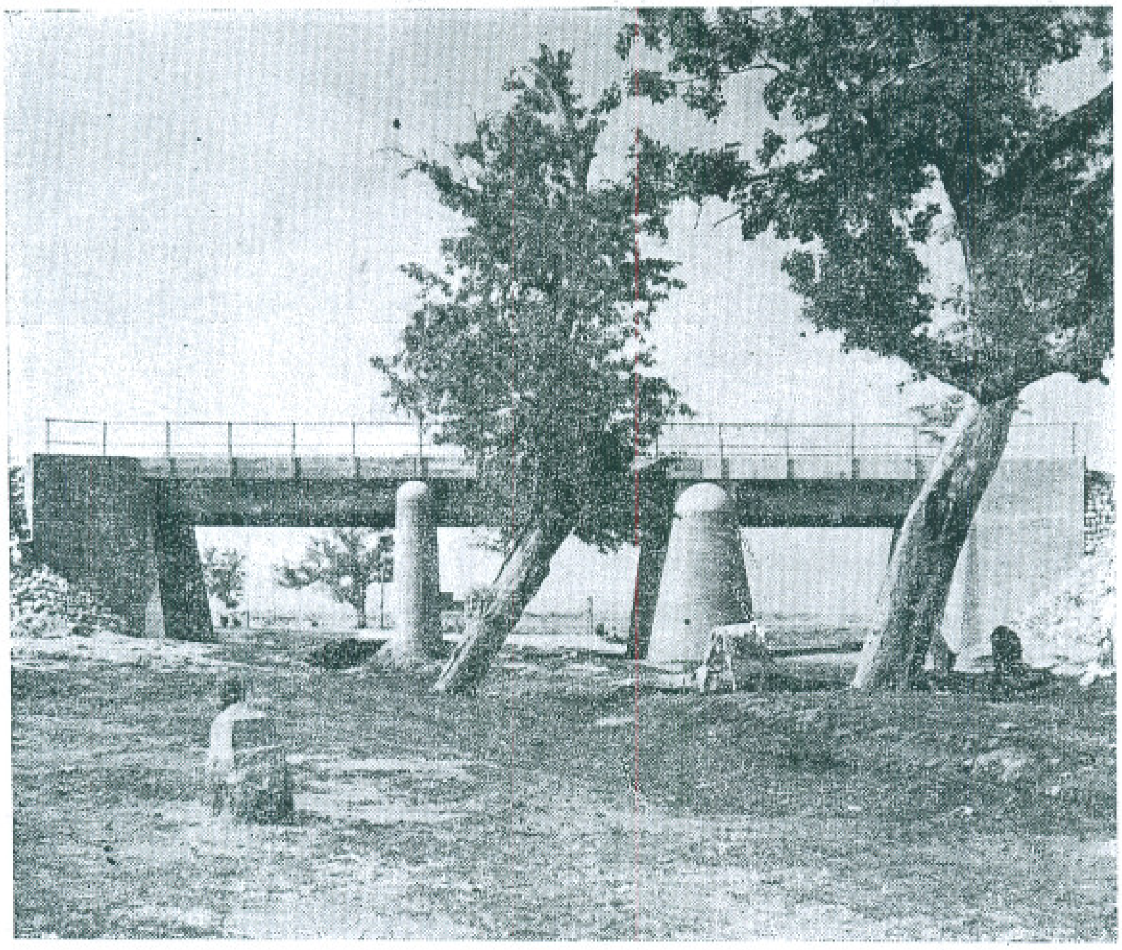
(*iv*) In order to cut down the construction cost of beams use of laminated timber beams needs to be investigated.



CHAMBLAI BRIDGE
Mile 47/1 Peshawar-Kohat-Bannu Road



JARMA BRIDGE
Mile 43/5 Peshawar-Kohat-Bannu Road



Such Bridges are an ugly scar on our landscape.

6. THE AESTHETIC ASPECT OF BRIDGES

The need for aesthetically pleasing bridges to suit our landscape is not generally recognized and in this context very little attention has been paid in the past. It is not uncommon to hear that the bridges are not looked at really and that the road users just cross them. Other opine that railing is the only part which attracts attention and this is what really needs treatment in matter of appearance. This trend of thinking is rather disconcreting. It needs to be realized that the creation of major bridges is the most spectacular of all Civil Engineering Achievements. Dominating the land scape, a bridge may make or mar the surroundings for centuries to come. Therefore it is a social obligation with the bridge designers to achieve beauty of form and harmony with the surroundings. Efforts thus need to be made to marry the new structure with the natural scenry rather than to desecrate the land-scape.

The bridges must have character and individuality to reflect the local setting. The writer cannot agree with the idea of repeating similar designs for bridges on the same or different rivers in the province. Apart from the fact that improvements in structural design are possible in later bridges reflecting economy in cost of construction, the structure must have variety of forms to show its individuality. Instead of "one of those stock bridges" crossing a river we should have a particular bridge crossing the river.

This however may not be possible in case of super highways where a great number of underpasses or over-passes require standard designs in the interest of speed and economy of construction. Such standard designs have been dealt with in sub-head 3. In such cases, however, it is particularly important that the type design shall be good enough to stand up to frequent repetition.

It is thus in the realm of major river bridges that the question of good appearance both in the structure itself and in relation to its surroundings offers a wide scope in thought and effort. As mentioned before a major bridge should exhibit character and individuality in design and a natural and permanent association with its setting. This latter consideration calls for special attention to scale, to form and choice of materials. A bridge suitable for a rocky gorge would hardly suit a town centre. Another important consideration is proportion, the ratio of height of span to the length of span, of width of structure to span etc. This requires careful judgement. It is agreed that the main dimension of any bridge would be largely dictated by structural economics but a variation is usually possible within certain limits and this should be exploited for the sake of good proportions.

An aesthetically pleasing bridge needs to be simple to have wide appeal. By beauty of bridge it is not meant that it should be made full of fun and ornamentation. A well proportioned structure, simple and elegant without trimming or ornamental parapets is a beauty and will remain a joy for ever.

It is erroneous to think of the architectural treatment to bridge design as being something added after the structural design has been completed. This works out usually as an ill considered after-thought. The architect should be associated at the initial stages to get full advantage of his special training and experience. Scale models and perspectives also go a long way to decide on the form and proportion.

7. CONTRACT DOCUMENTS

The standard contract forms were drafted a long time before independence, when major projects used to be few and far between. With the increase in the tempo of development activities and the advent of more sophisticated projects, it has become necessary to develop good firms of local contractors who can work on the lines of their European counterparts. In this context, it is essential that we redraft standard conditions of contract, as the present ones are claimed to lean heavily on Government side and do not keep the scales even between the contractor and the department. Take for instance, the standard arbitration clause. Here the arbitrator specified is an officer of the same department with whom the contractor has dispute. Contract agreements in other advanced countries do not specify employees of the client as arbitrators. The standard forms also lay down that the decision of Superintending Engineer in charge in a number of cases shall be final. Here again the officer is a part of the local administration intimately connected with the project. Further again while there is a penalty clause in the contract, the bonus clause is omitted. Such clauses and many more make the contractors feel insecure, even after they have provided for these by quoting rather high rates. With a view to attract qualified Engineers of good standing to this profession (which would not only improve the quality of work but also foster greater competition), it is necessary to redraft our outdated contract forms in the light of conditions of contract in vogue in other advanced countries.

In order to cut down the capital outlay and cash lock-up on major contracts, it is desirable that the department advances mobilization expenses against bank guarantees and that this is allowed as a matter of policy rather than as a condition put forth by the contractor. We have been doing this in case of our international contracts and it is time that this facility was granted to Pakistani firms of repute on our local contracts. Similarly security deposit of the contractors (which runs into a sizeable figure at the end of contract) can be returned at the completion of the project against bank guarantee. Further, if, as a matter of normal routine, advances can be paid on the value of constructional materials of imperishable nature (actually brought to site), this would reduce the lock-up capital of the contractor.

The present practice in the PWD contract system does not allow for any rise or fall in the cost of labour and materials during the contract. As the question of fall in prices is only academic, the contractor initially quotes high to cover the risk of increase in prices. If it is provided that any increase in price of materials or Railway freight due to Government decree would be payable as the net difference reckoned from the date of increase, the contractor would quote realistic rates. In case of no such decree forthcoming, the Government would not have to pay extra.

Such measures, while they do not jeopardize Government interests, would go a long way to bring down unit contract prices. In this context, it may be of interest to mention that the cost per sq. ft. of new Jhelum Bridge (on which such facilities had been granted) is less than the cost per square foot of a number of small bridges built by this department over small rivers and streams. This was partly due to such facilities having been offered to the contractor.

In this connection, the following figures may be of interest :—

New Jhelum Bridge over River Jhelum	=Rs. 90/- per sq. ft.
Jehangira Bridge over Kabul River	=Rs. 123/- per sq. ft.
Wazirabad bridge over Palkhu creek	=Rs. 111/- per sq. ft.
Balakote Bridge over Kunhar River	=Rs. 122/- per sq. ft.

It is suggested that a committee be appointed to study these problems and redraft our contract forms in keeping up with our present-day requirements.

8. BRIDGE DESIGN AND CONSTRUCTION

In the preceding paragraphs only a few aspects of the future bridges are discussed. In order to tackle successfully the problem which future bridges pose and to handle their design and construction satisfactorily, it is of paramount importance to have a good organization—a strong design office and a good construction team. We must realize that a bold and imaginative approach is required to meet the challenge in this field and pennywise, pound foolish policy cannot pay dividends.

A design office must be well equipped with drawing-office equipment, a well-stocked library and should be on the mailing list of all important technical journals on prestressed concrete and concrete in general and bridge engineering in particular. It needs to have a Survey team well equipped with Surveying instruments who can fill up small details in the local survey of the bridge site for approaches and guide bank details. In order to make this organization self-contained and compact to be able to perform its functions with minimum of effort in an efficient way, it should have a cell attached to it to fix up agencies for detailed survey and soil investigations and closely supervise their work. It can also help in collecting hydraulic data and general information about quarries, unit price of materials and labour etc.

Continuity of working is a matter of prime importance in a specialist office. Officers can only contribute substantially in the field of design, if they stay long enough. To attract good talent and to induce officers to stay in the design office for a reasonable long time, it is essential to make these attractive by suitably compensating the incumbents. It is not a bad proposition either for the Finance Department, as past expenditure on the preparation of projects in the Bridge Directorate has not exceeded 0.9% of the cost of project and this is indeed quite a low figure. It is not only this financial comparison which puts this propsal at a premium but also the valuable training ground it offers to the Pakistani Engineers. The writer has no means to assign any rupee value to the trained Engineers who can only become proficient in this field by working on specific projects in a design office. Such training personnel when deputed abroad for advance training can really benefit in view of their experience and training which they already possess.

The future load of bridge work in the years to come would keep a good design office fairly occupied. It is, therefore, necessary that the bridge design office is put on sound footings to pursue this specialized work. Working assidiously, it should be possible not only to provide suitable designs for future bridges but also tackle various problems mentioned under the previous sub-heads.

A good implementation of the projects prepared in the design office is equally important. It is essential that for all sizeable bridges there are full-time qualified Engineers in charge of construction who should preferably had previous experience of similar work. The idea of full-time resident type supervision is new at present and it is time that this type of supervision was introduced in view of the complexity of the bridge projects we are handling and the more sophisticated designs which in the interest of economy are bound to be introduced.

It is a fallacy to think that the design Engineers and Supervising Engineers belong to two separate and distinct categories. Established firms of Consulting Engineers send their design Engineers to the field to supervise the jobs and that revert back to the design office after the completion of project. A design Engineer cannot become a good practical designer unless he becomes fully conversant with the constructional techniques and difficulties. Similarly a Supervising Engineer cannot appreciate unanticipated site conditions and any intentional or unintentional departure from the drawings, if he has not good design office background. In order, therefore, to improve on design and construction standards it is necessary that there is an inter-flow of officers between the design office and the construction staff.

After focussing the attention on the future load of work in the domain of bridge building, the writer has tried to highlight some of the problems. There has been no intention to put down any standard solutions or any ready-made formulae for the various problems, but suggestions have been put forth which it is felt can improve the working and be helpful in meeting the great challenge which lies ahead.