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Fragmentation and declining quality in civil engineering

Vasudev V. Nori

Today the fragmentation of our profession is complete. Each professional is working in his own watertight compartment. He is totally disinterested in other disciplines. Each professional is interested only in his field of so called specialisation. The result is that there is nobody to take an overall view of the problems and challenges that lie ahead. Inevitably this has resulted in decline in the quality of civil engineering. In this paper, I would like to share our firm's experience in this regard and highlight what needs to be done to arrest this decline of quality in civil engineering.

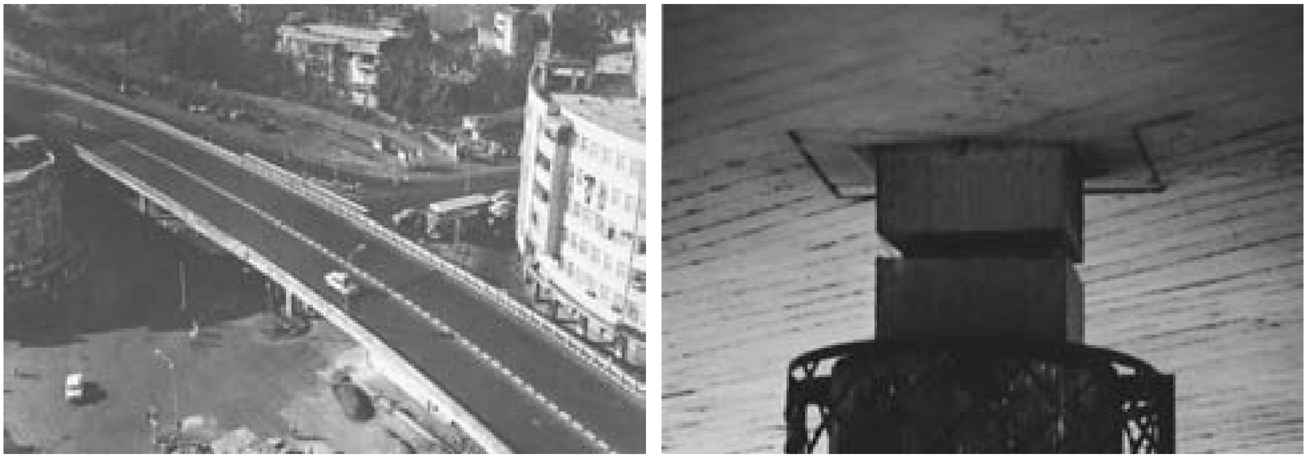
In the current scenario projects have become increasingly complex in nature with participation of many specialist consultants and suppliers. In the civil engineering fraternity itself we have design engineers, site engineers, contractor's engineers, client's engineers and geotechnical engineers working in watertight compartments. Each professional is totally disinterested in other disciplines. As a result there is nobody to take an overall view of the problem. What is convenient to design may not always be easy to build. Overemphasizing on ease of construction and ease of design may lead to structures that are difficult to maintain.

*This paper is based on the presentation given by Dr. V.V. Nori at the 'ICJ 80 years celebration' seminar.

Involvement of design engineers in construction problems

During the period 1960 – 1966, it was our practice to rotate engineers between design office and construction sites. This enabled engineers to appreciate design and construction problems and evolve an integrated design approach. For instance, when Kemp's Corner flyover was being constructed, our engineer was at the site full time designing the concrete mixes and formwork and actively participating in the prestressing and grouting operations. Special field trials had to be made for casting of concrete hinges because these were heavily reinforced.

Unfortunately, this practice had to be discontinued since clients were no longer prepared to pay for the service of a full time engineer from the consultant's office. Alternatives had therefore to be found so that design engineers are trained in finding solutions to construction problems. This was achieved by encouraging design engineers to visit the sites once in a week. They were required to design the mixes at site in the laboratory by carrying out sieve analysis, measuring moisture contents, silt content, etc. Volumetric mixes most commonly used were replaced by mixes proportioned by weight. A standard weighing machine that is used on railway platforms was used for checking weights. The



(a) (b)

Figure 1. (a) Kemps Corner flyover (b) Concrete hinges (first time in India - 1965)

actual batching was done by the same wooden boxes but calibrated by weight. This was preferred to weigh batchers which were not only expensive, but difficult to handle. For example, how does one correct if more sand is added inadvertently into the weigh batcher. All test cubes were statistically analysed and evaluated on the basis of 5 % failure. We were able to demonstrate that it was possible to achieve M20 grade concrete with quantity of cement that would have been consumed for producing 1:2:4 nominal volumetric mixes. Statistical evaluation was very useful in demonstrating that with good quality control the current margin could be reduced and in fact quality work pays for itself.

Figure 2. GESC apartment building - 1967

Figure 2 shows an apartment building built in 1967 where mixes proportioned by weight but batched by volume and statistically evaluated, were first used. It was possible to achieve good quality without sophistication in equipment. M20 was the minimum grade specified (M15 required by IS code). Also minimum clear cover to slabs was 20 mm (12 mm required by IS code). These features started appearing in the IS codes almost 20 years later!

Petit Hall apartment buildings constructed during 1968-1973 was the first major application of large panel wall slab construction for multistoried buildings in India. We had to also design a full scale mock up and subject the same to vertical and horizontal loads of 24 storied building which was achieved with the help of prestressing cables. We had to also design the moulds for various elements, the casting yard and erection methodology.

It is very important for design engineers to appreciate the contractor's point of view. For the Raoli tank dome with a span of 44 m, we had suggested temporary supports at crown as well as at two intermediate locations because of the slenderness of the structure. However, the steel erector who had considerable practical experience observed that he has erected a dome of 30 m diameter with only one central support. We rechecked and realised that even with single central support the locked

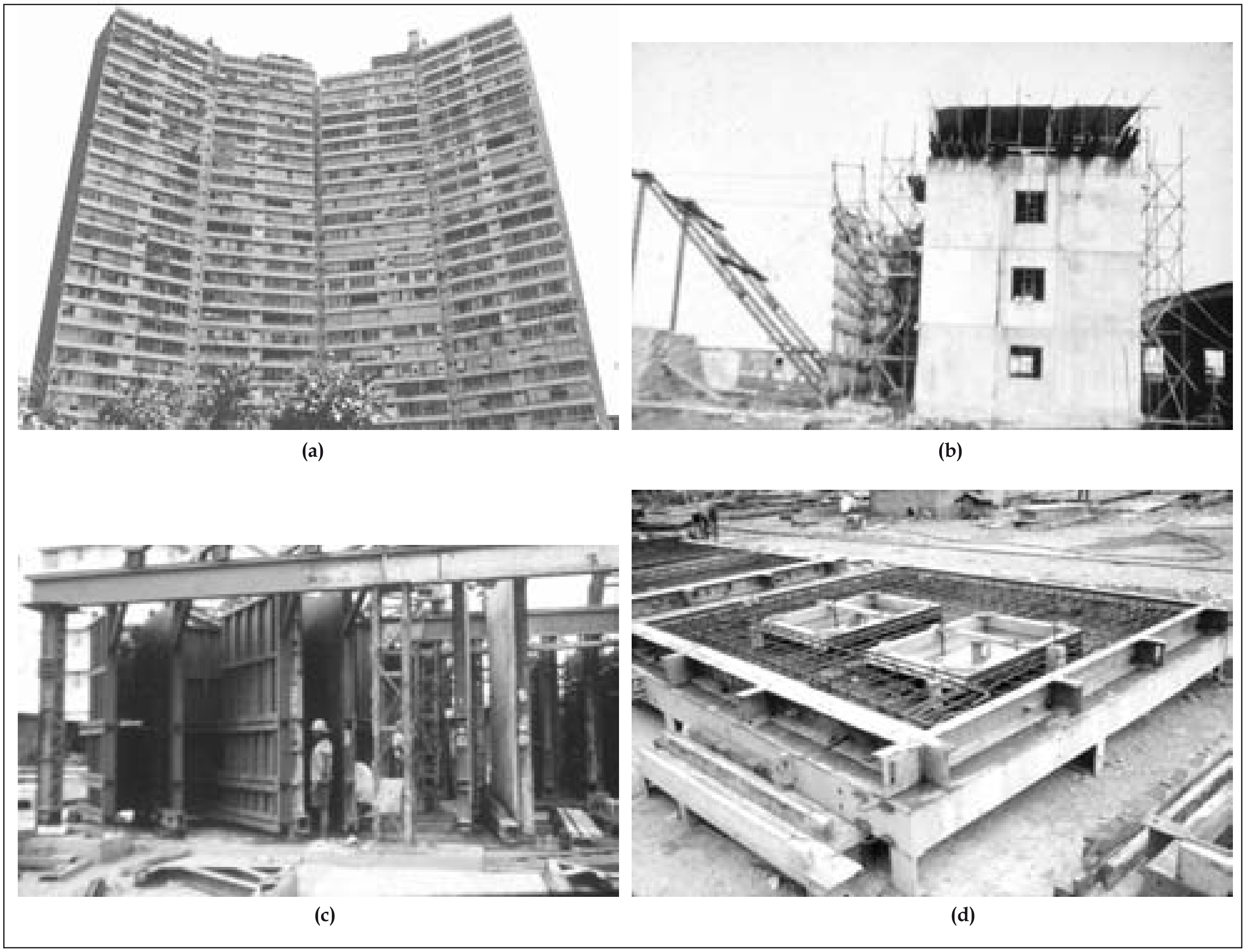


Figure 3. (a) Completed view of Petit Hall (b) Mock up testing with prestressing cables (c) Battery moulds for internal walls (d) Moulds for external walls with permanent finish on exterior

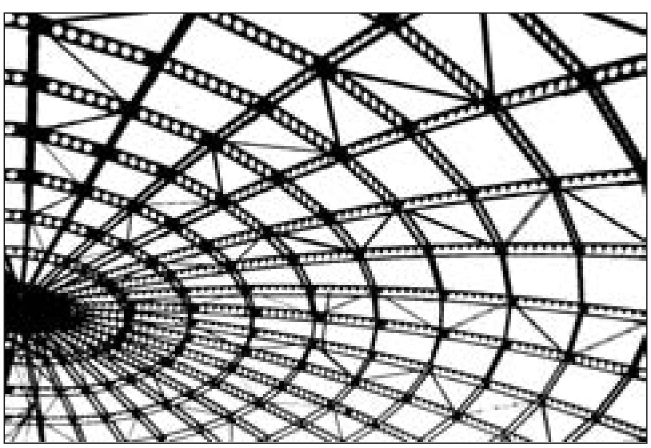
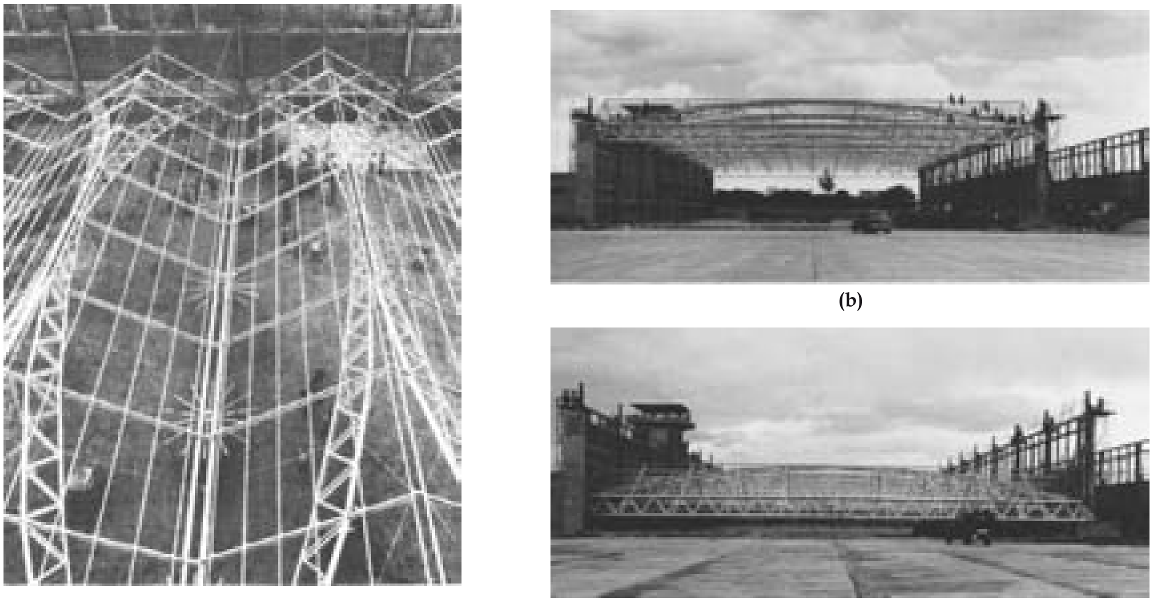


Figure 4. 44m diameter Raoli hill dome - 1980

up bending moments were still within the permissible limits. The construction of the dome thus became much simpler.

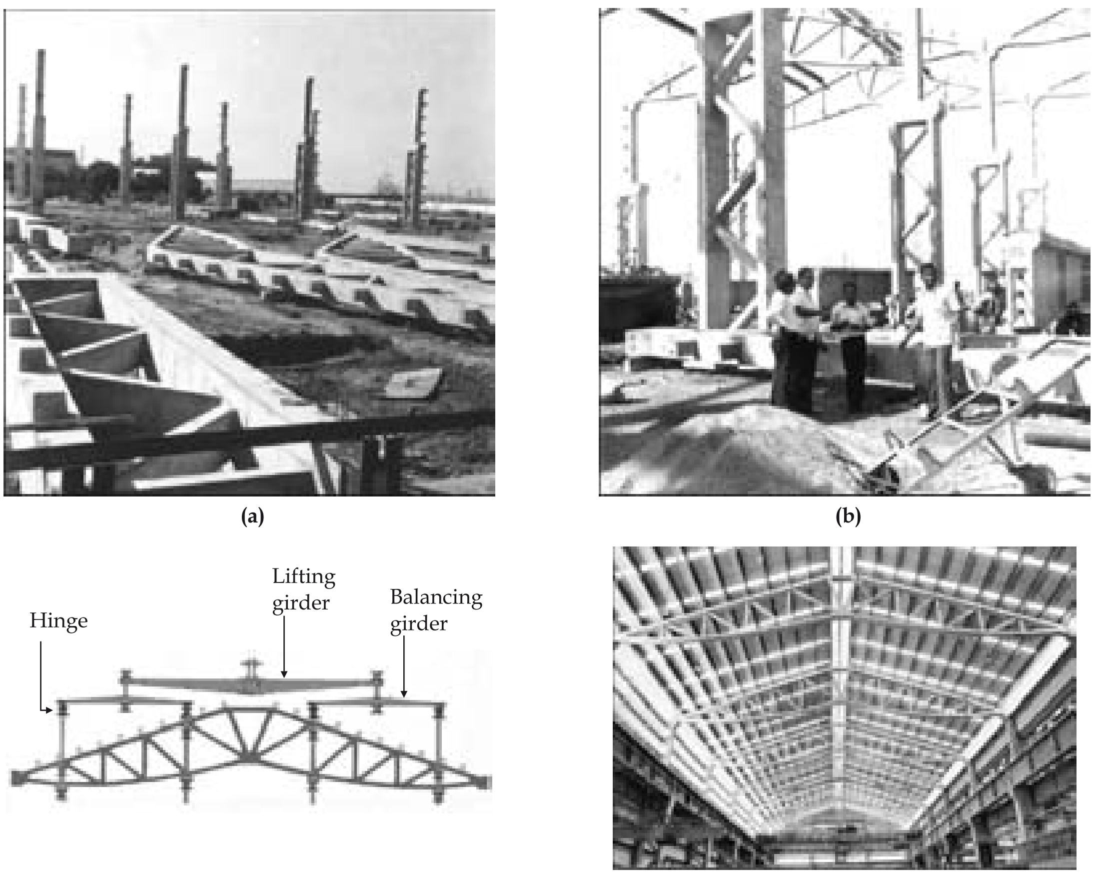
Importance in listening to contractor's point of view resulted in simplifying the construction procedure, Figure 4.

It is equally important to adopt the erection methods to suit the equipment easily available with the contractors. For example, ASTE hangar for HAL had plan dimensions of 45.75 m x 91.5 m. The roof, a folded plate type roof of structural steel, was fabricated and erected at ground level so that all the welds could be easily inspected. The entire roof was raised by about 12 m to its final position



(a) (b) (c)

Figure 5. (a) HAL ASTE hangar - 1981 (b) & (c) Jacking of 45.75 m x 91.5 m span hangar using simple equipment locally available



(a) (b) (c) (d)

Figure 6. (a) Precast columns and trusses (b) Erection of columns and trusses in progress (c) Tilting and lifting arrangement of trusses (d) Finished view of one the 30 m bays (BHEL, Hyderabad - 1982)

(a) (b)

Figure 7. (a) Strip lighting, structural steel roof - 1980 (b) Strip lighting, precast concrete roof - 1990

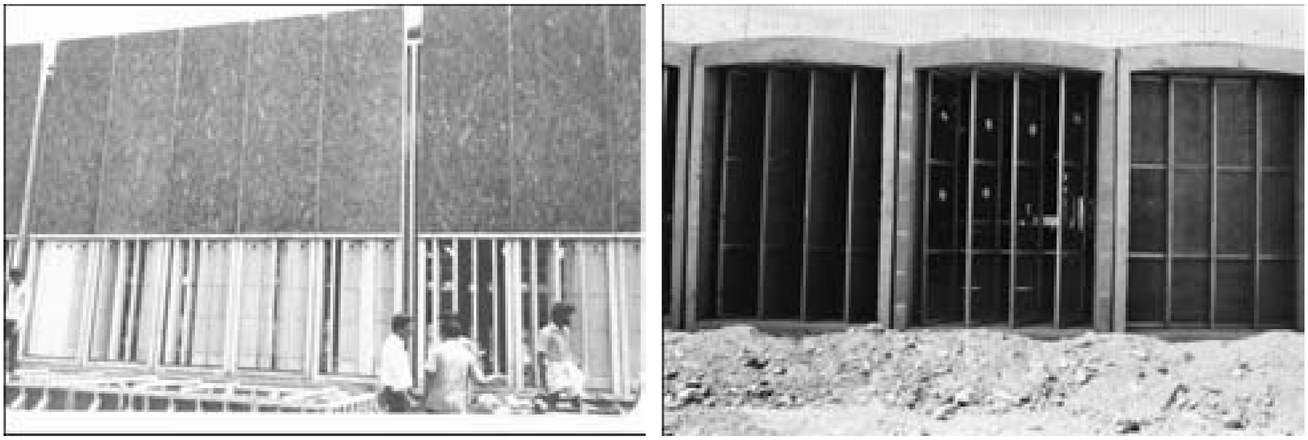
using standard truck jacks that were easily available. The suspenders consisted of mild steel channels that were later reused for the sliding doors. It was the first time that such a roof was erected in India. This solution was offered as an alternative design by the contractor.

It is very important to address all the erection problems in the design office. The design of BHEL's bowl mill manufacturing unit, built in 1983, was offered as an alternative design by the contractor. The original design proposed by the owner's designers was a standard north light roof in structural steel. We proposed precast post tensioned funicular trusses spanning 30 m and supporting 50 mm thick pretensioned L shaped concrete purlins spanning 12 m, and 17.6 m high trussed branched columns also in precast concrete, Figure 6. The crane girders were post tensioned I girders. All the elements were very easy to cast since the work was at the ground level. The tilting and erection methods were also designed by us so that the structures could be erected safely. Another notable feature is that there are no internal drains for the building with plan dimensions of 84 m x 160 m. The roof gutters cum purlins are pretensioned U shaped elements spanning 12 m. The entire roof is drained only at the gable ends.

Ensuring overall quality

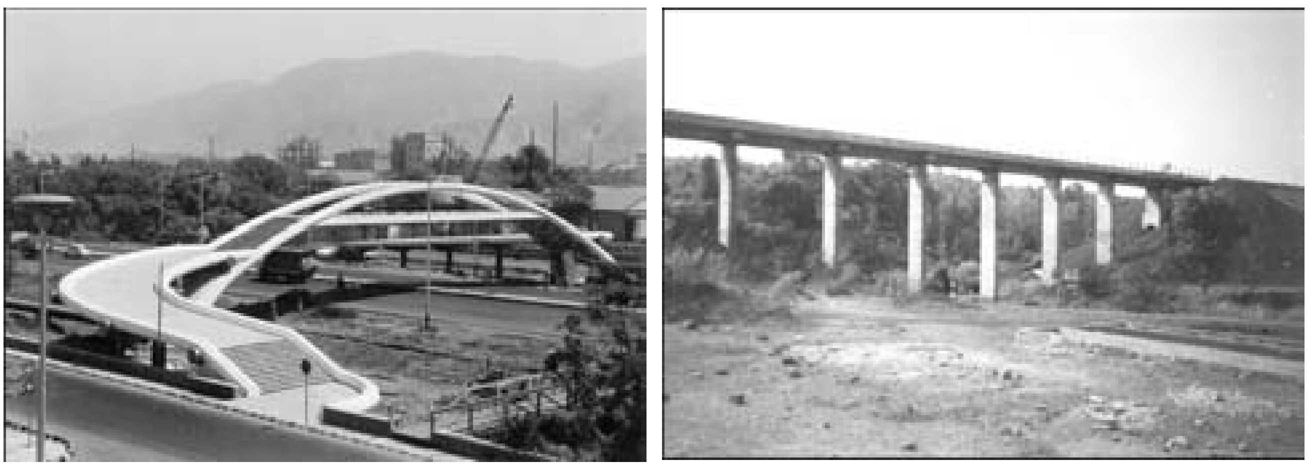
Client is interested only in the overall quality. Good solutions cannot emerge if we work in watertight compartments as we often do today. Overall quality can be achieved only by appreciating all aspects of building design. This must necessarily include lighting and ventilation. North light roofs are most commonly used in our country. While working in Bangalore we realised that in winter we cannot cut out direct sunlight coming in through the north light roof. Besides, we have generally a very bright sky. Skylights incorporated in standard asbestos cement sheets could not be used in factory buildings because they create a hot patch which moves with the sun causing extremely uncomfortable working conditions to anyone working in the hot patch. This led us to introduce strip lighting where a plane ribbed glass was glued to standard wired glass leading to excellent diffused lighting which is much cheaper than north lights. Internal gutters as in north light roofs are no longer required. North light roofs also require platforms for cleaning the glass which is no longer required in case of strip lights as they cleansed by the rain because of their slope.

Figure 8. Larsen & Toubro Ltd., Bangalore - Hydraulic excavator project - 1975. Fixed concrete louvres in precast concrete wall panels



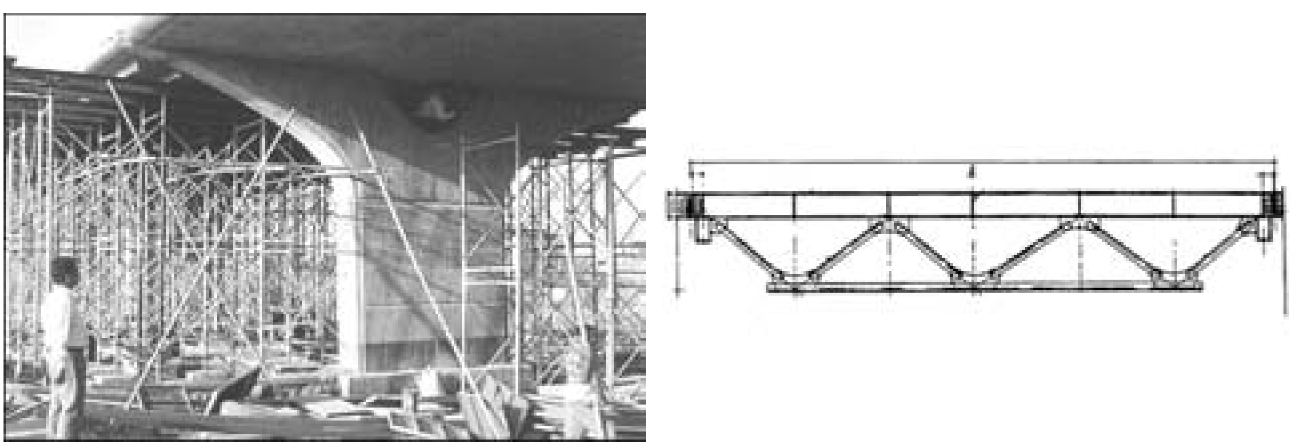
(a) (b)

Figure 9. (a) A vertical rotating louvres of precast concrete at L&T, Bangalore (b) Vertical rotating louvres in galvanised iron with 'khus' for evaporative cooling - 1987



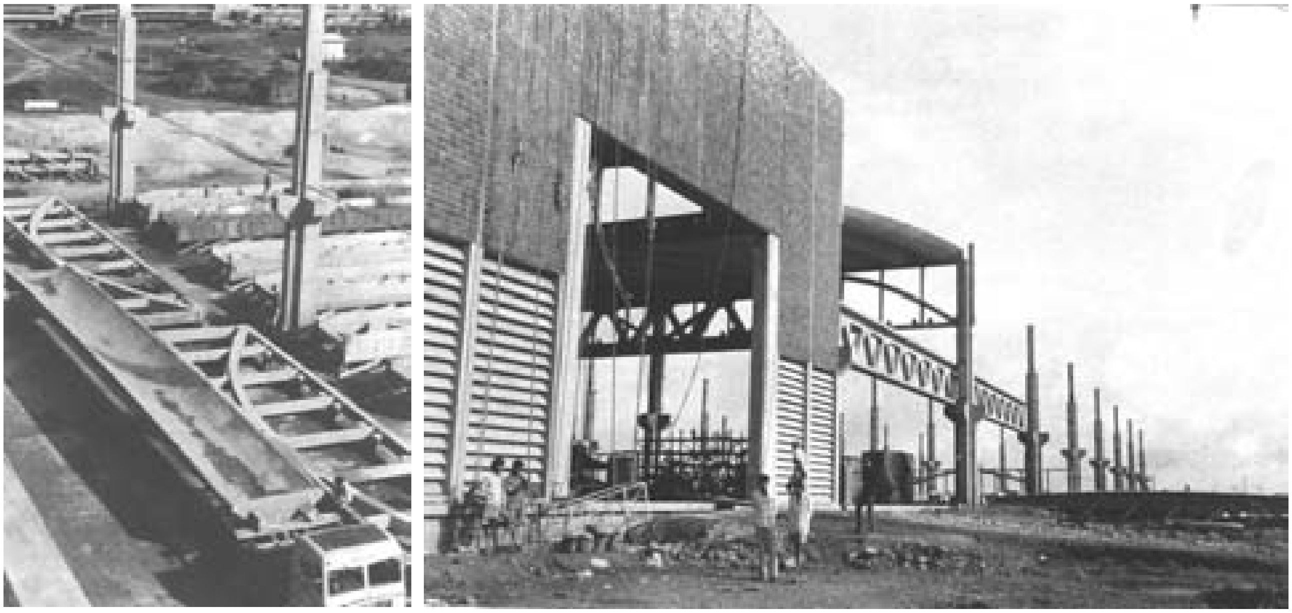
(a) (b)

Figure 10. (a) Juinagar footbridge - 2002 (b) Berdewadi Nullah railway bridge



(a) (b)

Figure 11. (a) Khandeshwar bridge - 2001 (b) Kapurthala Rail Coach Factory - 1987



(a) (b)

Figure 12. (a) 50 mm thick pretensioned shells (2.5 m x 20 m) being transported (b) Construction in progress

Ventilation often draws even lesser attention from designers. In our conditions ventilation is best obtained by allowing cold air to enter at floor level. For Larsen & Toubro's hydraulic excavator project designed by us, we used fixed concrete louvres which provide excellent ventilation. However, in the winter months it does get a bit uncomfortable. This led to the introduction of vertical precast concrete louvres to provide controlled ventilation.

For the new integral rail coach factory at Kapurthala which has extreme climatic conditions, galvanised iron louvres were designed incorporating 'khus'. The water dripping into 'khus' provides excellent evaporative cooling in summer months.

Importance of aesthetics

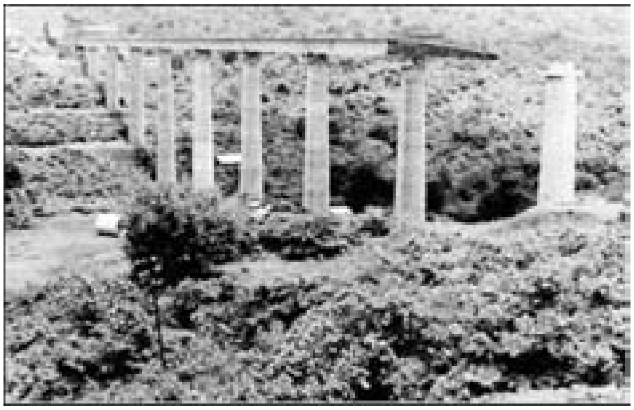
Civil engineers must learn from architects the aesthetic aspects of the project. Construction of ugly structures leads to hurting the aesthetic sense of the viewer. Engineers have to be very careful when they design bridges and other engineering structures where there is no architect involved. Juinagar foot bridge designed by us in 2002 is a good example of appreciation of aesthetics by engineers. Several railway bridges were designed by us for the Konkan Railway Corporation Ltd. (KRCL). In many cases standard designs could not be adopted. Simple structural forms with monolithic piers were not only more economical than standard designs but also were more elegant in appearance.

At times aesthetics of simple structural forms could be enhanced by fluted surfaces or introducing curves in gusset plates as can be seen in the crane girders for the Kapurthala Rail Coach Factory, (Figure 11). Such profiles incidentally also improve the performance of crane girders against fatigue.

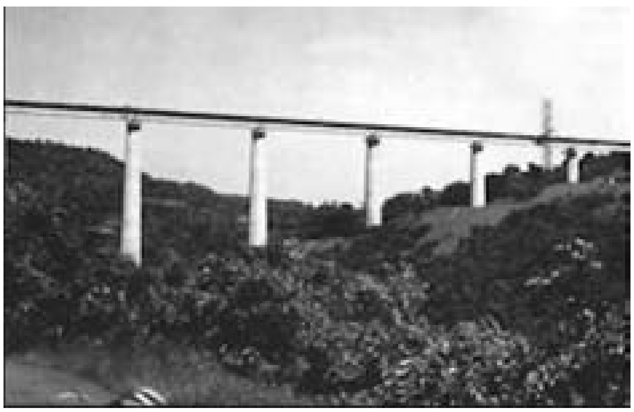
Importance of mutual trust

The importance of mutual trust and cooperation can never be underestimated. The credit for our best projects goes to the entire team including the client who plays a very crucial role in the success of the project.

Figure 13. ECC administrative building



(a)

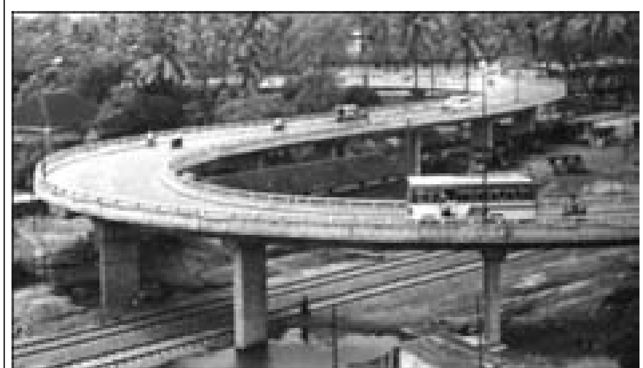


(b)

Figure 14. Panval Nadi viaduct (a) Incremental launching in progress (b) View of the completed viaduct

Figure 15. DMRCL 6.5 km long elevated viaduct - 2004

(a)



(b)

(c)

Figure 16. (a) TEC Trombay flyover - 1980 (b) KRCLroad over bridge, Madgaon - 1995 (c) KRCL Ghatsila road over bridge, Jharkhand - 2006

Larsen and Toubro's hydraulic excavator project (1975) incorporated several innovations. The entire building is in precast concrete designed for future extensions lengthwise and widthwise in a simple manner. Since completion, the building has already been extended using the same wall panels which are 2.5 m wide and 14 m high. The roof is very light consuming just 0.097 m^3/m for covering a span of 20 m x 20 m.

Engineering Construction Corporation's (ECC) administrative building in Chennai is yet another example of excellent team work between the architect, the designer and the contractor who in this case was also the owner.

The building was constructed in two phases, Figure 13. It was occupied in 1984 with two floors complete. Two more additional floors were added in 1991. This building was the recipient of the most outstanding structure award in 1994 at the XII FIP Congress held in Washington.

Konkan Railway's Panval Nadi viaduct (1994) is another example of importance of mutual trust and cooperation

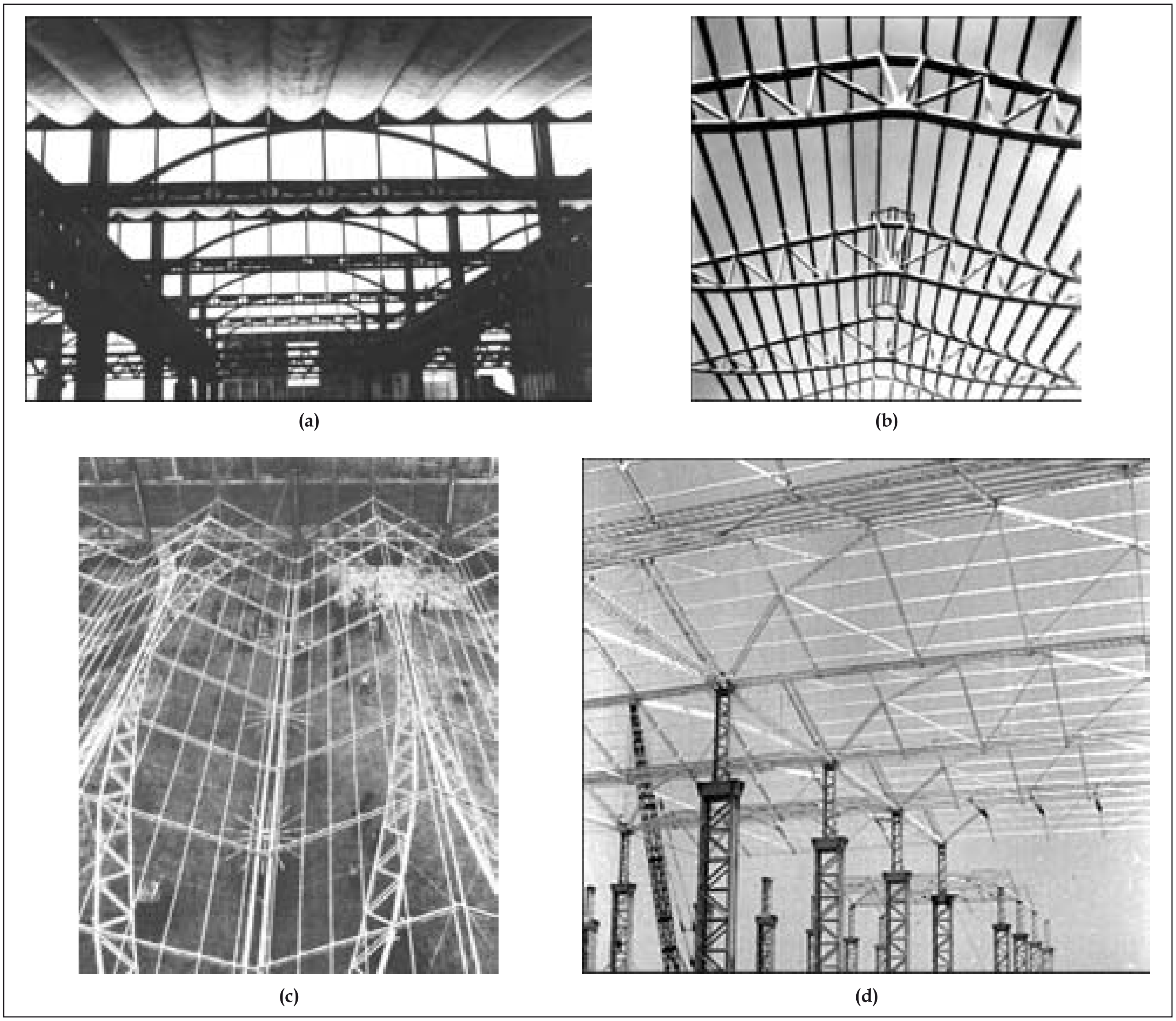


Figure 17. (a) Concrete roof, covering 20 m x 20 m square grid - 0.097m^3/m^2 (L&T, Bangalore - 1975) (b) Concrete roof trusses, 30 m span and 12 m span pretensioned purlins - 0.05 m^3/m^2 (BHEL, Hyderabad - 1982) (c) Structural steel roof, covering 41.75 x 91.5 m hangar - 29 kg/m^2 (HAL, Bangalore - 1981) (d) Structural steel roof, spanning 12 m x 20 m - 24 kg/m^2 (New Rail Coach Factory, Kapurthala - 1987)

that easily comes to mind. This was the first application of incremental launching of prestressed box girder supporting single ballasted broad gauge railway track. The tallest of the piers is about 64 m above foundation level. These are tapered hollow octagonal shaped with a wall thickness of 325 mm. Since incremental launching was being adopted for the first time in India, we made it a point to share with the client's and contractor's engineers whatever information was available with us about the subject.

Consideration for long term aspects

There is no doubt that simply supported bridges are not only easier to design but also easier to build. But, experience has shown that these structures are difficult to maintain. They also need frequent repairs. Continuous bridges with monolithic piers are more difficult to design but these are certainly more elegant, economical and durable. We have been designing continuous bridges in reinforced concrete and prestressed concrete with monolithic piers for over 25 years now.

The 6.5 km long viaduct in Dwarka for the Delhi Metro Rail Corporation Ltd (DMRL) with full span continuous precast post tensioned girders is the longest stretch of integral form of construction in India, Figure 15. 15 road over bridges with post tensioned girders and monolithic piers designed by us have been executed by Konkan Railway Corporation Ltd, (KRCL). This clearly demonstrates the versatility of this form of construction, Figure 16.

Curbing excessive consumption of construction materials

We have consistently focused on making optimum use of construction materials. This requires considerably more engineering effort and innovative spirit. This also results in elegant structures and at the same time offers considerable cost savings to the owner, Figure 17.

Responsibility to the society

The quality of civil engineering structures will be judged by the society in which we live. Every civil engineer has two clients:

- The immediate client
- The trustful society

Civil engineers are no longer leaders. They have become subservient to the administrators, architects, management consultants, builders, etc. Civil engineers have completely forgotten the second client 'the trustful society'. They cannot think beyond the narrow confines of the codes of practice. Neither can they innovate nor can they command quality !

Selection of consultants

Consultants are increasingly being appointed on the basis of lowest fees. They are treated like contractors and are required to pay earnest money. Do clients ever dare follow such an approach while selecting a lawyer, a surgeon or a chartered accountant? To make matters worse preferential treatment is given to to public

(a) (b)

Figure 18. (a) Continuous U girder in prestressed concrete, 2003 (left). Simply supported U girder, 2001 (right).
(b) Continuous U girder with monolithic pier in the foreground and simply supported U girder with wall piers in the background.

sector and multinational companies through complex prequalification procedures. Only turnover and number of heads is relevant and not the track record and the innovative spirit. We are often asked where is the incentive for the consultant to save costs when his fees are paid on a percentage basis! The answer lies in the ethical conduct of the consultant and his track record of innovations. The client needs to appreciate that selection of the consultant on the basis of lowest fee and then appointing a contractor with the lowest bid does not invariably lead to the lowest total project cost.

Two identical bridges for the same loading and identical site conditions constructed side by side is illustrated below, Figure 18. The first one consists of two simply supported spans of 18.3 m. The structural system comprises of prestressed U girders. We were approached by a contractor to design the second bridge. He had secured the job on a lump sum basis (without any designer!). This was the first time he was constructing a bridge! He was hoping that we would repeat the design of the first bridge. If our organisation was driven only by commercial considerations then we would have repeated the first design. But, our love forour profession and our concern about the declining quality in civil engineering compelled us to take a fresh look at the problem and design a continuous prestressed U girder structure with a central monolithic pier.

Fragmentation

We isolate ourselves watertight compartments and then blame everybody else for the problems created by us! It is our civil engineering fraternity which

is responsible for the situation. We have neither love nor respect for our noble profession and it is time for us to wake up and do some introspection.

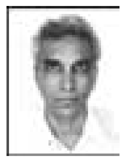
Today, civil engineers are being offered salaries few would have dreamt a couple of years ago! In a society where money is the only measure of earning respect, the situation is very good. But, will they be able to design and build elegant structures? Let us not lose sight of the fact that we are way behind China.

Conclusion

The importance of taking an integrated approach by consulting engineers cannot be underestimated. Such an approach combined with our love for our profession and our commitment to the trustful society will certainly pave a more challenging and better future for civil engineers.

Acknowledgements

None of the examples cited in this article would have peen possible without the inspiring and able leadership provided by Mr. Shirish B. Patel, Chairman Emeritus with whom the author continues to have a patently fruitful relationship. We would like to express our gratitude to Dr. M.N. Patel , Managing Director, Michigan Engineers Pvt. Ltd. who has shared our innovative spirit and executed many of the structures mentioned in this paper. Our thanks are also due to Mr. S. Sreedharan (former Chairman and Managing Director of Konkan Railway Corporation Limited) for giving us an opportunity to design the Panval Nadi viaduct and to Mr. S.C. Gupta (former Chief Engineer, Ratnagiri South) for reposing confidence in us and giving us an opportunity to design a number of bridges with monolithic piers which proved to be economical and elegant.



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