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Autor: Raj, Mahendra

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A Few Large Span Structures in India

Quelques structures à grande portée en Inde

Einige weitgespannte Tragwerksbauten in Indien

Mahendra RAJ
Managing Director
Mahendra Raj Consultants
New Delhi, India

Mahendra Raj, born 1924, received his civil engineering from Punjab Univ., Lahore and masters degree from Univ. of Minnesota. He has been involved with various type of large span structures in India and USA.

SUMMARY

India has seen significant construction activity in the last 25 years. A number of large span structures have been built during this period. The author has been involved in several such projects in the capacity of structural consultant. Two such projects are described here, one of them is an exhibition hall while the other one is an indoor stadium with a seating capacity for 5'000 persons.

RÉSUMÉ

Pendant les dernières 25 années, l'Inde à fait preuve d'une activité considérable dans le génie civil. Plusieurs structures à grande portée ont été réalisées pendant cette période. L'auteur a participé à la réalisation de plusieurs de ces projets en tant qu'expert. Deux de ces projets sont décrits dans ce rapport, l'un étant un hall d'exposition et l'autre un stade couvert de 5'000 places assises.

ZUSAMMENFASSUNG

In den letzten 25 Jahres verzeichnet Indien eine rege Bautätigkeit. Eine Anzahl weitgespannter Tragwerksbauten wurden während diesr Zeit errichtet. Der Autor wurde als Konstruktionsberater bei mehreren Projekten beigezogen. Zwei solche Projekte werden in diesem Bericht beschrieben, das eine ist eine Ausstellungshalle und das andere ein gedecktes Stadium mit einer Kapazität von 5000 Sitzplätzen.

1. HALL OF NATIONS AT NEW DELHI

An international trade fair to be held at New Delhi in 1972, required large exhibition halls. The main hall was required to have a free and unobstructed space of 6700 sq. m. with an approximate height of 30 m. and was named as the "Hall of Nations".

1.1 Shape and Form

For covering such a large area several options e.g. shells, folded plates, hypar shells were considered and rejected on the ground of economics. Eventually the solution narrowed down to a double layered space frame. The "Hall of Nations" had a base dimension of 73mX73m which reduced to almost half at the roof. While investigating the configurations of the space frame it was identified that the most appropriate system to create space frame was the one which used pyramid as the basic element. Geometry for the "Hall" is shown in figure 1.1. Steel and concrete were given due consideration and it was found that concrete was the most economical material, with structural steel being 30% more expensive. Thus concrete was the final choice. For cladding, gunited triangular plates were provided while roof of the hall was covered with precast light weight concrete planks.

1.2 Analysis Design and Construction

A study of the configuration revealed that the structure would be stable only after construction had reached at level 5, where it received the first alround continuity (fig. 1.1) and before that it would rest on scaffolding erected from ground. However this resulted in five different configurations with introduction of each additional ring beyond level 5. Therefore analysis was carried out for all five different configurations to fix final member sizes. The analysis was done assuming pinned joints, as the members were slender and it was believed that significant moments would not develop. An independent analysis done later confirmed this assumption as the moments in members were very small. The space frame was analysed for earthquake and wind loads using a three dimensional pin jointed model. Most important point for selecting a member shape was strength and ease of fabrication. Several alternatives for member section were considered and finally a rhombic section with chamfered edges having an area of 585 sq. cm. was adopted. The analysis also revealed that horizontal deflections of nodes near central line of symmetry would be large. To contain these deflections, horizontal diaphragms were introduced between inner and outer faces of the space frame at levels 3, 6 and 8.

The obvious choice of construction was precast construction technique. It was visualised that the members and joints would be precast separately and put together with the help of bolts and field welding of shim plates. Details of such a precast joint are shown in figure 1.2. Unfortunately no contractor came forward to construct this structure using precast technique, hence in-situ concrete was adopted. The development of in-situ joint was difficult owing to congestion of bars at the joint element. On an average, nine members met at one joint and even with four bars per member, there would be thirtysix bars meeting at the joint, some carrying tension while others were in compression. In the precast joint some assistance was available from steel plates embedded in concrete, but in the in-situ joint that would not be possible. Finally a system was evolved wherein only twenty bars passed through the joint element. Bars from lower four members were lapped with four upper member bars, thus catering to eight members. Bars for ninth member were taken through the joint and anchored in one of the eight members. Figures 1.3 and 1.4 show arrangement of reinforcement at one such joint and a typical joint profile respectively. The sequence of construction was to cast straight length of member from joint to joint, place in position partially pre-assembled form work of the joint alongwith placed in position short length curved bars. These bars were welded with straight bars of members, formwork of the member upto next joint erected and the member and joint concreted. This sequence was followed upto roof level. The construction of space frame was taken on all the four sides simultaneously.

1.3 Foundations

The structure was supported on cast in-situ driven piles tied together with grade beams. Horizontal forces in grade beams at any stage were dependant on the extent of structure erected by that time. To contain horizontal forces some grade beams were post-tensioned in stages as the structure went up. The structure is in service since 1972. Figure 1.5 shows completed structure.

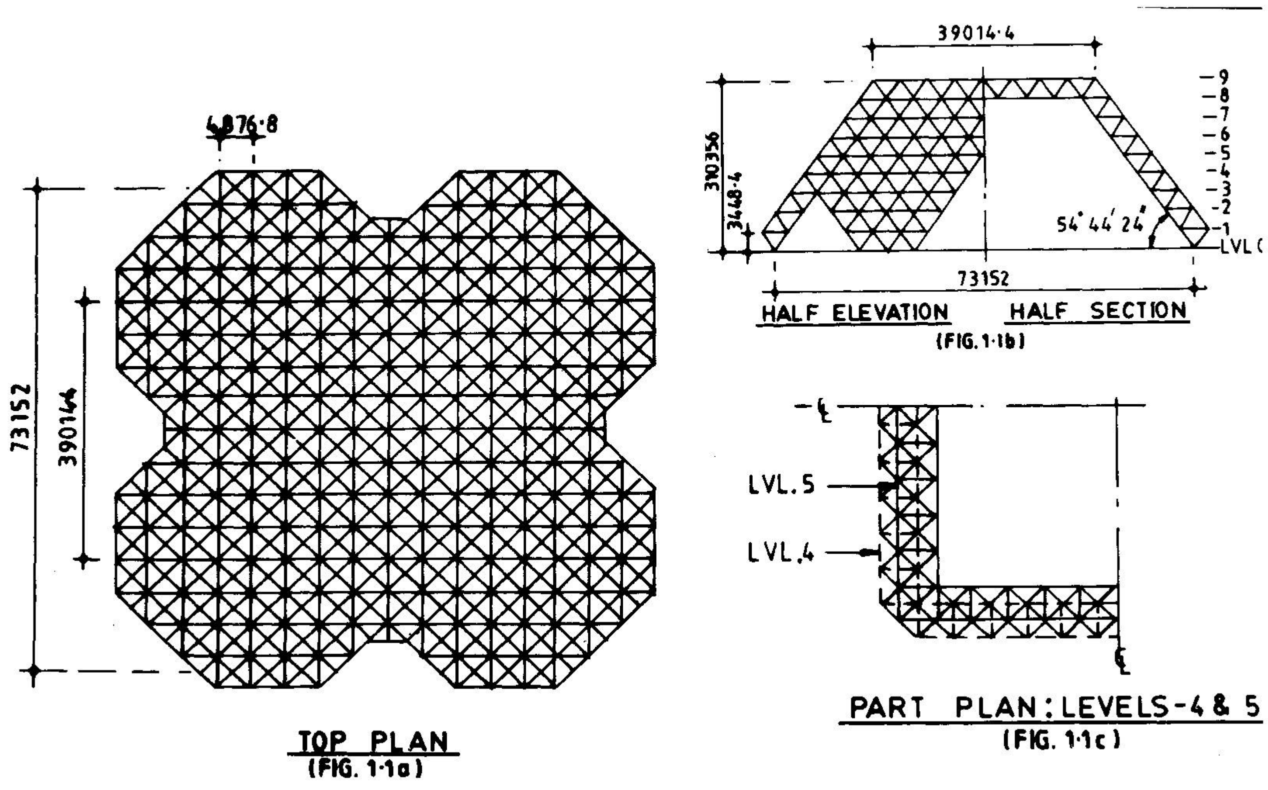

Fig. 1.1 Plan and Section of Hall of Nations

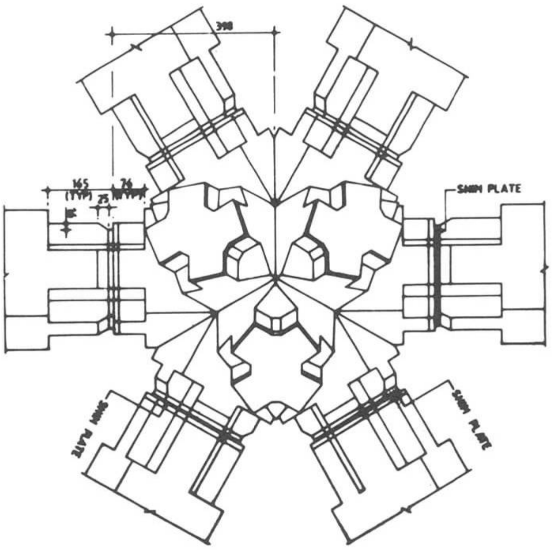

Fig. 1.2 Precast Joint Detail

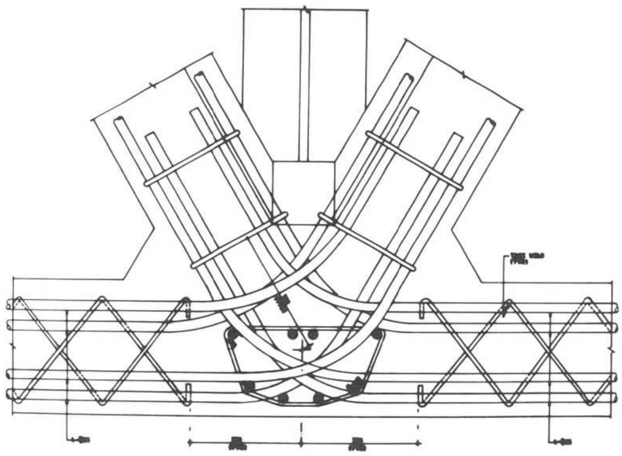

Fig 1.3 In-Situ Joint, Typical Reinforcement Detail

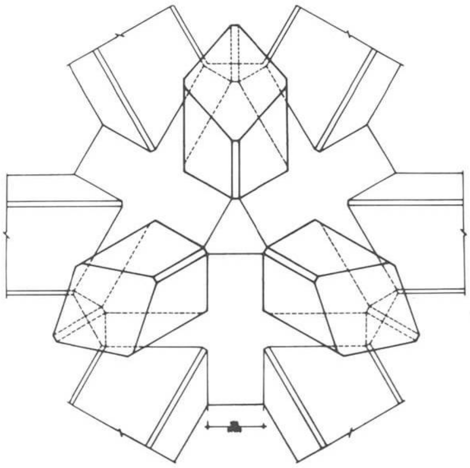

Fig. 1.4 In-Situ Joint Profile

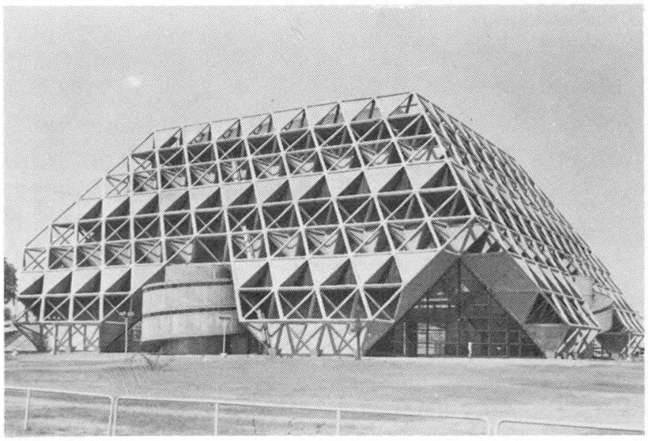

Fig 1.5 Hall of Nations Completed Structure

2. INDOOR STADIUM AT SRINAGAR

This stadium was constructed during 1980-84 at Srinagar in Jammu and Kashmir for holding indoor games tournaments. Planned in the shape of a cross with maximum dimension of 62.0 m, the stadium is provided with a seating capacity of 5000.

2.1 Plan Geometry

Site of this stadium is seismically active and dictated a simpler plan geometry. Box like rectangular or square pattern would be simpler but architecturally they were not acceptable. Finally a cross shaped plan was chosen as it was better than any other box like shapes and possessed desired seismic qualities too.

2.2 Structural System

For covering this large area our effort was to evolve a system which could create the entire enclosure without any intermediate support. The structural system for the stadium consisted of inclined plates connected together with seating frames. The plates on outer periphery were inclined outward from the foundations at level 0 to the elbow at level 3, and then inward till level 5. Plates on each internal corners were inclined inward. These plates were created with intersecting precast reinforced and post-tensioned concrete members on a triangular grid. The triangles thus formed were infilled with gunited and glazed cladding plates. Figure 2.1 and 2.2 show plan and elevation of stadium,respectively. Seating frames carrying precast seating elements were provided around the central arena and connected with the inclined plates at level 3. Thus seating frames were an integral part of the system. For the roof of stadium, steel lattice frame was chosen which echoed the configuration of main structure. Analysis of the structure was carried out for different stages. The analysis revealed that the plates transferred all the loads axially but had significant out of plane bending moments too. Further plates on outer periphery caused large tensile forces in the inwardly inclined plates at each fold. To contain these tensile forces post-tensioning was adopted. Figure 2.3 shows typical cross section of a member. All members except the edge members were precast and all joints were in-situ. Details of one such joint are shown in figure 2.4.

2.3 Foundations

This structure is supported on bored cast in-situ piles tied together with plinth beams. Large horizontal forces are transferred to foundations by folded plates. These forces are carried by a network of post-tensioned plinth beams. Post-tensioning was carried out in stages to balance the thrusts. The structure is in service since 1984. Figure 2.5 shows completed structure.

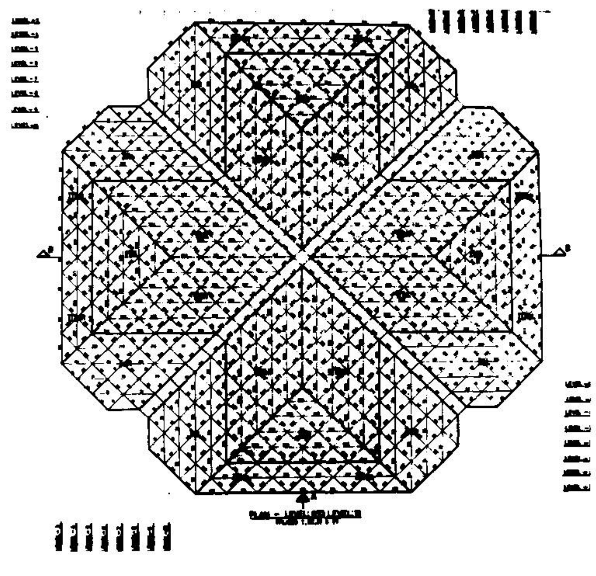

Fig. 2.1 Plan

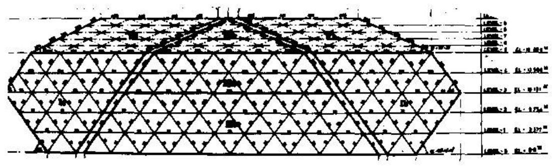

Fig. 2.2 Elevation

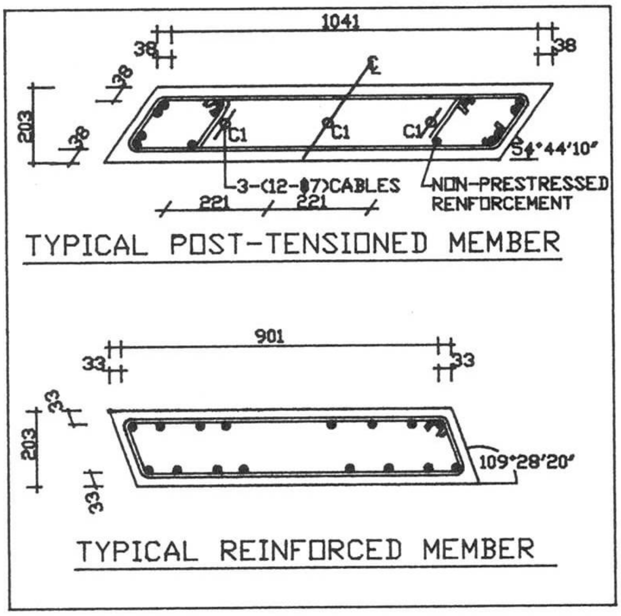

Fig. 2.3 Cross Section of Members

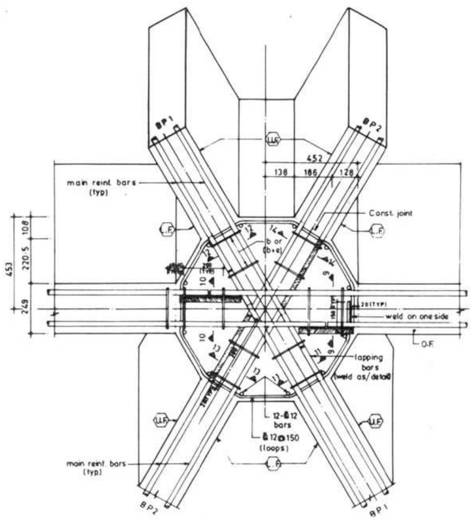

Fig. 2.4 Joint Details

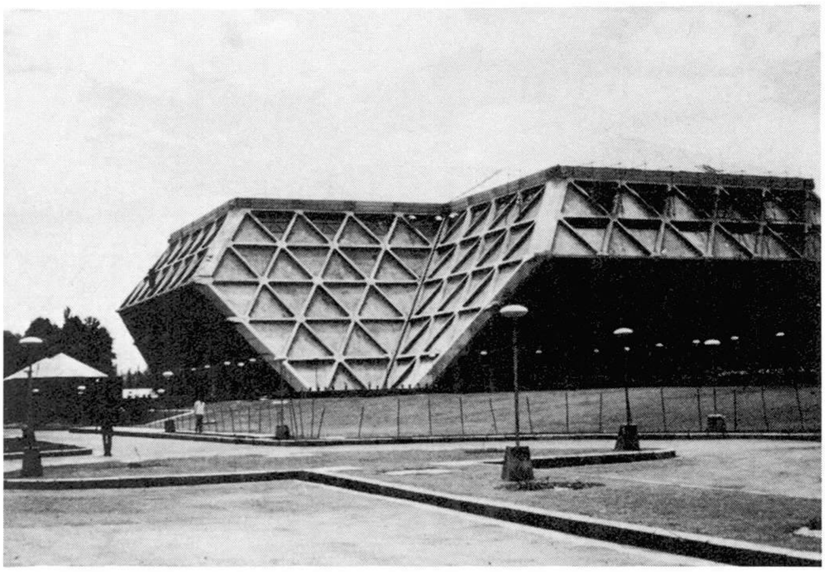

Fig. 2.5 Exterior View of Stadium