Innovative erection methods for long span roofs: two outstanding examples

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Summary

The lens-shaped roof of the S.P. Mukherjee Swimming Pool Complex in New Delhi (India) and the record breaking BC Place in Vancouver (Canada) with its massive 2000 ton cable structure are two outstanding examples of long span roofs supported by cable structures. Most of the characteristics of the two projects are somewhat contrasting: the span (respectively 130 m and 260 m), the cable technology (respectively Cohestrand® and full locked cables), the structural principle (respectively the lens and the bicycle wheel) and the construction methods. However they do have one feature in common: the adoption of an innovative erection method well suited to the constraints of the project (schedule, occupation of the site and available means of erection). All these aspects are presented in the article.

Keywords: Long span roofs, tensile structures, full locked cables, strands, erection methods.

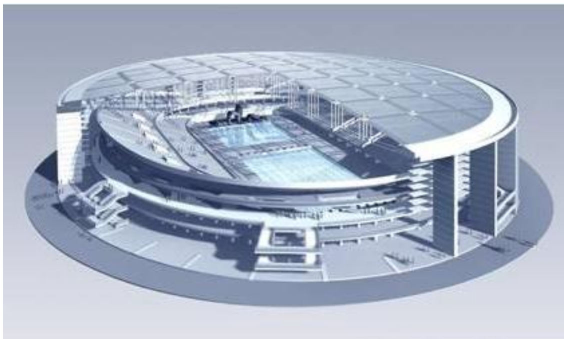

Fig. 1: 3d rendering of the S.P. Mukherjee Swimming Pool Complex

Fig. 2: Photo of the BC Place stadium after completion of the primary roof structure

1. Construction of the S.P. Mukherjee Swimming Pool Complex in New Delhi

1.1 Presentation of the structure

The steel cladding is supported by a lens shaped cable structure, made up of a lower supporting cable net and an upper stabilizing cable net, each being separated from the other by groups of flying masts of varying heights.

With respect to other cable roof structures, the SPM stadium stands out by the technology used: it is based on the Cohestrand® technology, developed and patented by Freyssinet. The Cohestrand® technology derives from the parallel strand cable stay technology, each cable being made up of a bundle of strands indivually sheathed with HDPE. An epoxy resin bonds the HDPE to the wires in order to transfer the longitudinal forces coming from the flying masts to the steel strands.

1.2 Erection methods

In order to cope with the construction planning of the contractor, which imposed that pools and roof be built simultaneously, a two step airborne erection method was developed for the project.

All cable equipment and material was installed on the concrete ring beam, and the strands pulled across the stadium, 30m above the ground, by a back and forth winch system. The strand adjustment followed a similar process to the one used on suspension bridges: absolute sag-

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adjustment of the first strand of every bundle with a surveyor, and relative sag-adjustment of the following strands in reference to the first one. The installation of all strands (more than 1000) was performed in one and a half months. The installation of the clamps, at every intersection of the cable nets was performed in the air, by depositing specifically designed platforms at the working locations.

After completion of step 1, the cable nets resembled a simply suspended structure. The second step consisted in introducing the cable masts in between these two cable nets thanks to temporary structures called “separation towers”. The separation towers consisted of a structural truss column equipped with a pair of strand jacks able to provide the 85 tons of separation force. The separation of the cable nets was performed in 14 steps, using 4 towers, for a total duration of 3 weeks. During the first step, the vertical distance between cable nets was brought from 1.5 to 11.5 m.

2. Innovative methods to build the BC Place stadium roof

2.1 A particular spoke wheel structure

The new roof of the BC Place was a refit, imposing significant constraints on both the design and construction methods. One of the main characteristics of this roof is that the steel structure supporting the cables is not self-stable. The location of the facility, sited snugly within the city, precludes the use of temporary supports from the outside of the stadium. Additionally, the available time for construction prevented erecting the steel structure first and then preparing the cable structure in the field of play, as a “big-lift” would require. Facing all these constraints, it was decided to use a “radius by radius” approach to erect the roof.

2.2 A daring sequence of works

The central node was installed on a temporary tower, 11.5 m higher than its final position. Then the major steel elements (masts and compression ring) were erected in a balanced manner, stabilized with temporary cables.

Thanks to innovative lifting methods, the erection of the cable nets started before closing of the steel compression ring. The lifting was performed by joint use of strand jacks and cranes. To reduce the loads on the incomplete, weak structure, detailed construction engineering was done, planning every step and sub-step of the operation, including temporary cables monitoring and adjustments.

The closing of the compression ring was a major milestone. It was successful thanks to careful geometry control and adjustments. A system of clothe-lines was developed to uncoil, splice and clamp the tension ring cables in their casted connectors. Final closure and adjustments were only possible by pushing the masts bases inwards in order to reduce the length of the polygon formed by the connectors. This sensitive operation was achieved under constant control of forces and movements and offered the precious centimetres required to close the massive cable rings.

The tensioning operations started with the release of the masts bearings. Then the central node was lowered thanks to the telescopic part of the central tower. This was the first step of a nearly uniform loading process. When the central node lifted off its supports, the final steps of tensioning started. The prestressing of the structure was achieved by acting on the lower cord of the cable nets, at the mast connection. Up to 400 tons were required to connect the twin 70 mm cables to the masts.

The structure behaved as expected and the final position of the central node was in perfect agreement with the theory.

3. Conclusion

A majority of the cable roof structures installed around the world are designed for the “Big Lift” erection method. However alternative methods offer additional possibilities, enabling to respect the constraints imposed by the technology, the schedule and the available means. The S.P. Mukherjee Swimming Pool Complex and the BC Place stadium are two striking examples, but certainly not the only examples where alternatives are the solution!