A Large Span Roof made of Cable Stayed Arches

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Summary

A large span roof made of cable stayed arches is presented. If compared to a traditional tied arch, the pre-tensioned cable stayed arch presents: (a) a strong reduction of the bending moments; (b) a general increase of the stiffness; (c) a strong increase of the limit multiplier associated with the eulerian critical load.

Keywords: large span roofs, arches, cable stayed structures, optimization.

1. Introduction

A large span roof, which covers a new smelter of green coke in the Alba Bahrain Plant in Sitra (Kingdom of Bahrain), is presented. The plant (Figure 1) is made up of a primary unit that, rotating around a pivot supported by a truss tower, covers an angular sector of 128°, and of a secondary unit, hinged at the end of the upper stringer of the primary unit, which is able to rotate of 270°. The secondary unit carries the terminal part of the conveyor belt, from which the born material is released. The design issues were:

- search for a shape that allowed to cover the widest surface compatible with the area restraints;
- design of a retaining wall which, at the same time, had to work also as a support for the roof;
- design of a cover of minimum weight;
- set up of erection procedures, made more complicated by the scale of the building, that would allow to carry out more jobs at the same time, so as to respect the 18 months schedule.

2. Shape definition

After a series of comparative evaluations, the plant shown in Figure 1 was drawn. Behind the 84.00m wide N-W front, there is a rectangular area with a depth of 42.00 m. The two sides remain parallel from alignment 1 to alignment 3, then they bend, so that side B (internal) is (42.00 + 38.68) = 80.68 m long, while side A (external) is (42.00+158.00) = 200.00 m long. The two sides follow irregular curves, each one having many curvature centres in different positions. This results in the fact that the distance between the two lateral alignment varies considerably, passing in a first stage from 84.00 m to 91.00 m (alignment A5-B5), then from 91.00 m to 60.00 m (alignment A9-B9).

Although the scale, the shape of the building and the loads were such that special attention had to be paid to every single design phase, the most delicate issues were posed by the roof.

Different configurations were examined: the first idea was that of a roof sustained by parallel beams running from alignment A to alignment B; in a second time, a radial lay-out was considered. In both cases, the structure was too heavy. Trying to reduce the steel weight, trussed arches were taken into consideration. In order to avoid lateral thrust at the top of the columns, these arches had to be of the tied type. None the less, the envelope of load conditions presented flexural components that required cross sections of remarkable area. Cable stayed arches were finally examined [1], [2] (Figure 2). As tied arches, with respect to external constraints they behave like isostatic simple beams and do not convey lateral thrust, but they are also characterized by a set of internal

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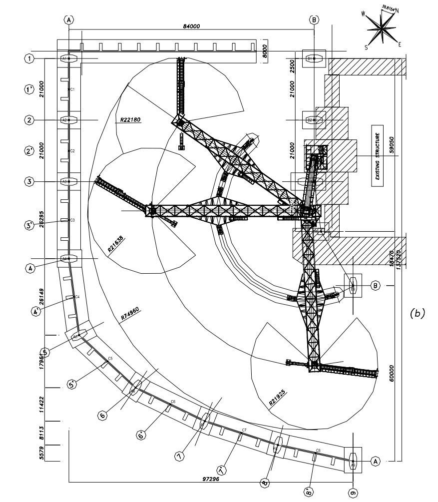

Figure 1: Geometry and dimensions of the plant

Figure 2: The assembly of the arches

Figure 3: The building after completion

constraints that reduces axial force eccentricity, increases the critical load value and reduces the structure deformability. These constraints are provided by adequately pre-tensioned cables radiating from a focus.

3. The cable stayed arches

The criteria for the best choices in shaping a cable stayed arch are nor simple, neither immediate. For instance, the simple addition of a bundle of stays starting from the centre of the tie of a normal tied arch, gives little improvement to the structural performances: the tie attracts the highest force contribution in containing the arch thrust, while the others stays remain little engaged. A significant evolution of the static behaviour and of the buckling performances under different load distributions, appears by moving the pin position along the segment normal to the middle of the chord. Other potentially positive effects can be achieved by properly choosing the stiffness of the stays, in function of their position, and by impressing suitable imposed pre-tensions to the stays [3].

For the sake of simplicity, two separate optimisation procedures have been carried out. The first one was exploratory and referred to a simpler arch, symmetrical and having an horizontal chord. Such procedure was focussed to find, under several loading distributions, the optimal position of the central pin, the optimal distribution of the stays stiffness and of pre-tensioning in the stays [2], [4]. The second one, applied to the actual geometry of the stayed arches, was focussed to optimize the pre-tensioning of the stays.

Thanks to the efficiency of this structural system, the 60 m to 91 m spans were covered with a competitive, although unusual, solution (Figure 3).

4. References

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