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New football stadium with precast concrete structure for Belgium football club KV Ostend

Grandstands in precast concrete

When football club KV Ostend (Belgium) in June 1981 was founded after the fusion of former clubs VG Ostend and AS Ostend, it inherited the facilities dating back from the early 60's. Due to the old facilities, the club was not allowed to play after its qualification for the European competitions in 2014. Important renovations had to be done to acquire a European license. To fulfill the modern requirements and regulations in terms of safety and accessibility, new stadium grandstands with precast concrete were built.

A need to comply

For the construction works of the new stadium of KV Ostend an investment of 18 million € was needed. The new stadium structure was initially foreseen in steel. The general contractor however, proposed an alternative in precast concrete; this would result in short term cost reduction (no fire protection needed) and long term cost reduction (less maintenance). Eventually it was decided to build in precast concrete.

The work started in February 2016 with the demolition of the main grandstand and two smaller grandstands. The rebuilding

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1 The new main grandstand
2 Situation sketch

of the new main grandstand and a E-grandstand behind one of the goals was finished just before the start of the new football competition, end of July 2016. The brand new grandstand can accommodate 3700 football fans. The total capacity has increased to around 8432, (3000 standing and 5125 sitting seats) and the stadium has become more comfortable. Underneath the new grandstand a space for commercial activities was created. The stadium now complies with the international UEFA standards and KV Ostend is ready to participate in European competitions.

The precast structure

Ostend is a city on the North Sea, and the football stadium is located less than 300 m from the Belgian coastline. The environmental class for the exterior concrete elements is XF1, XC4, XS1. The wind class is category 0 and the wind speed taken into account is 26 m/s. The main grandstand has a length of 123.30 m, 27.90 m wide and has a height of 18.80 m. The E-grandstand is 75.60 m long, 9.00 m wide and 11.10 m high. The structure is created by using portals each 7.75 m; rafters are connected with a fixed connection to the raker beams, which are supported by several columns (fig. 3 and fig 5.).

Portal action is taken into account for the stability perpendicular to the grandstand, in the other direction there is a wind bracing in between the second and third axe. The prefabricated concrete structure with curved façade and bulb roof is made of columns that continue over several floors.

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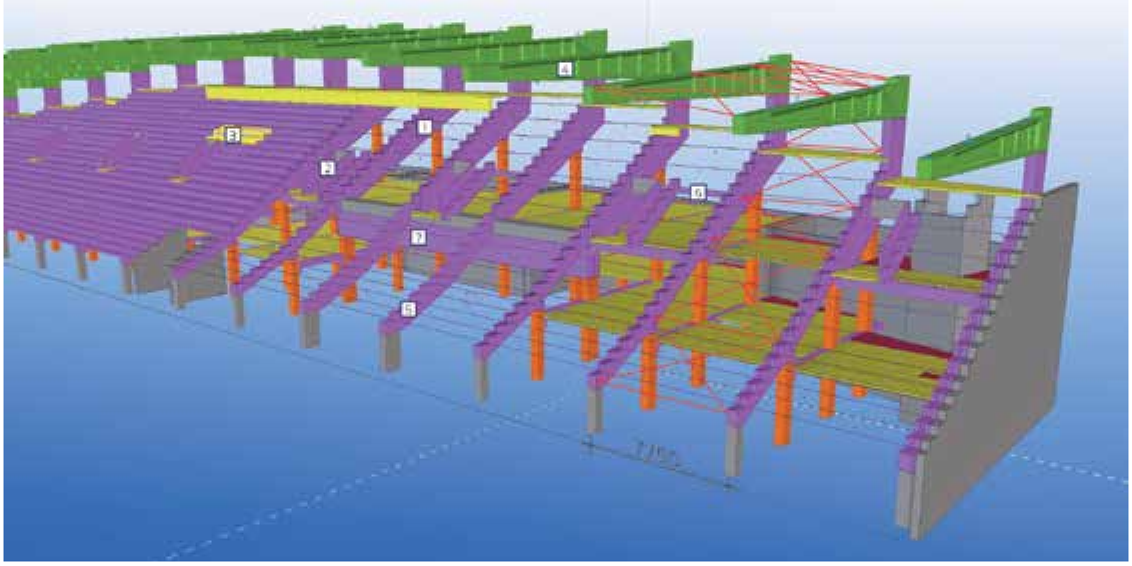


Legend:
1. raker beam
2. vomitory
3. terrace
4. rafter
5. buckled lower raker beam
6. trimmer beam
7. double beam above VIP lounge

3 3D view of the structural model
4 Connection raker-rafter beam
5 Cross section grandstand

Very short erection time

The erection of this 'not your everyday precast concrete structure' had to be completed in less than six weeks! A good organization was required because of the great number of different subcontractors present at the same time on a limited site area. The erection was done with a mobile, 400 tons crane LTM 1400.

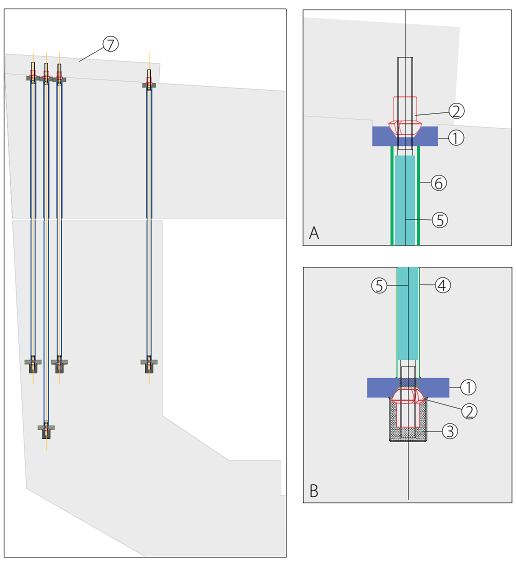
Inside the building there are two levels of beams and - compared to standard slabs - a more performant type of hollow core slabs, with a thickness of 200 mm in order to obtain a floor as slim as possible. There is a VIP space with overhanging beams for the mezzanine floors and a party hall with double beams with a height of 1.90 m, a width of 0.54 m and a length of 23.75 m. Instead of one, two beams were used since one beam was too heavy for the erection crane. Even the weight of those two beams is already 61 tons each. These beams support the raker beams so that some columns under the raker beam in the party hall could be avoided (fig. 2).

Building of the stands

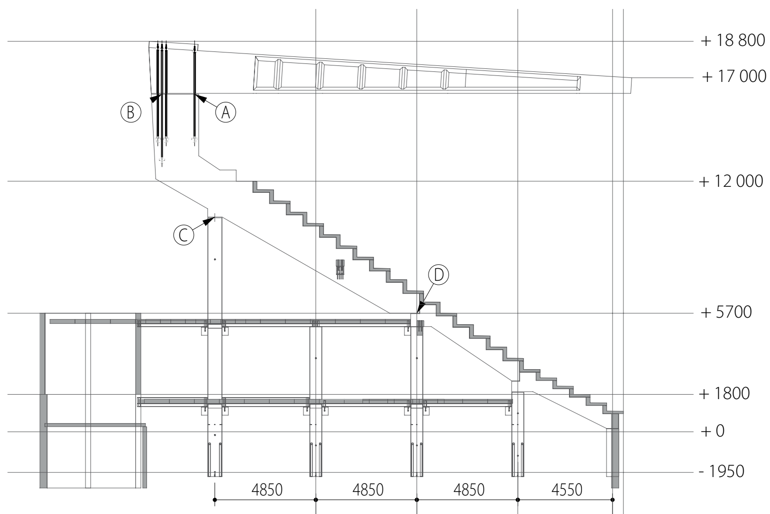
The raker beams with denticulation - some of them even buckled in the longitudinal direction - weigh up to 42 tons and determine the shape of the exterior terrace. They hang over the outer facade in order to create a support for the rafter beams.

The rafter beams have to be able to absorb both positive and negative moments, caused by wind pressure and wind suction or snow. This has resulted in rafter beams with a tensile reinforcement of three layers of five bars Ø 40 on one side of the beam and eight bars Ø 40 on the other side of the beam.

The rafter beams with variable height and section (rectangular at the beginning and the end and I-section in the middle) mainly have pre-tensioning at the top (fig. 5). They were fabricated upside down because this is more safe in production and as such the prestressing steel could be horizontal. They have a length between 15.50 m and 23.00 m. These cantilevering beams are anchored in an end block through specifically designed bars of high-quality steel f_{yk} 950 N/mm² (fig. 4). The choice for this type of steel was made because the tensile force was too high to work with normal steel. These bars, protected by a thermal shrink layer, are screwed blind in the button headed nut of the cast in tube with a grease reservoir at the bottom. The nuts are anchored with distribution plates and splitting reinforcement in the concrete. To absorb the tolerances, these bars are blocked on top with a button headed nut in a hollow steel plate. The button headed nut is used to be sure that only normal forces can occur in the bar so parasitic moments are excluded. Afterwards, the bars were post-tensioned by a jack in several steps with forces over 100 tons. Thus a tensile force of 5400 kN could be absorbed with only six bars Ø 40. The self-



Legend:
1. hollow steel distribution plate
2. button headed nut
3. grease
4. steel straight tube
5. bar
6. ribbed steel tube
7. protecting concrete



weight of the beams during erection was retained with only two bars, thus facilitating a smooth execution. The post-tensioning is needed to get the crack-width in the connection within the boundaries for a sea environmental. On top of the beam a sufficient concrete cover for the entire connection was provided. The rafter has ribbed tubes so there is a better collaboration between the bar and the beam.
Because each beam is different in length and load, each one was calculated separately, e.g. the minimum and maximum reaction forces of the rafter beam on the raker beam (table 1 and fig. 5).

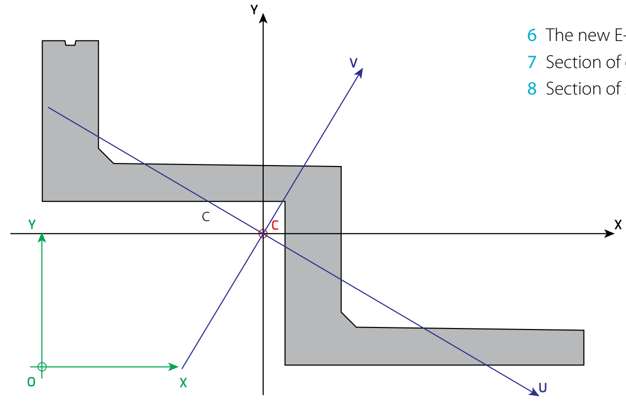
Table 1 Reaction forces raker and rafter beams in connections

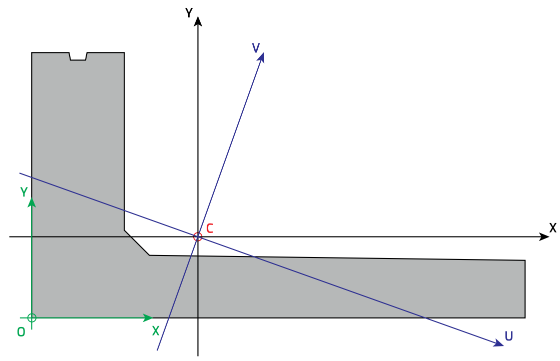
location	force	minimum	maximum
A	V_{Ed}	4790 kN (compression)	2790 kN (tension)
B	V_{Ed}	2640 kN (compression)	4085 kN (tension)
C	V_{Ed}	1480 kN (compression)	1205 kN (tension)
	M_{Ed}	4787 kNm	5041 kNm
D	V_{Ed}	5041 kN (compression)	181 kN (tension)

The 219 terraces exist of two heights in order to create a variable slope. In most cases they were executed with two stairs per element (fig. 7 and fig. 8), in order to reduce the production and erection time; this last one being the most important. In order to get the terraces visually horizontal, they were fabricated bending up 15 mm. The seats are interrupted by eight vomitories, which are hung up through sloping walls with denticulation and a trimmer beam construction between the raker beams. The first natural frequency of the terrace is 7.1 Hz, which is enough for a terrace with seats on it to avoid annoying movement. By making elements with two stairs they are a little bit more stiff because of a small rotation of the main inertia axis.

Innovation through 3D

The design was done using the Tekla 3D drawing program, thus preventing fitting mistakes in this double curved structure. This also facilitated the control of the structure by the architect and was used gratefully in a later phase by the other subcontractors. Our 3D model was awarded with the prize of the Construsoft BIM Award 2016 for the Benelux in the category 'Sports and recreation'.
In order to use less materials, where possible, high-quality steel





6 The new E-grandstand
7 Section of double terrace
8 Section of single terrace

f_{pk} 1860 N/mm^2 for pre-tensioning and concrete with high strength up to C70/85 was used. With an equivalent capacity of the elements and less material, the $C0_2$ footprint is reduced. By using this superior concrete quality, it was also possible to reduce the amount of compressive reinforcement. The durability was also a consideration: an open stand with sea vista and the accompanying briny environment and chances of storms. The same goes for the strict requirements, norms and regulations of the Football Association in order to create a stand where soccer fans can safely gather to enjoy their idols play in a brand new arena. ☒

PROJECT DETAILS

architects abv+ architecten - Antwerp
engineer SBE - Sint Niklaas
general Contractor BAM Contractors - Brussels
project developer Groep Versluys - Ostend
client KV Ostend
precasters CRH structural concrete Belgium, Ergon - Lier, Prefaco - Lommel, Houthalen