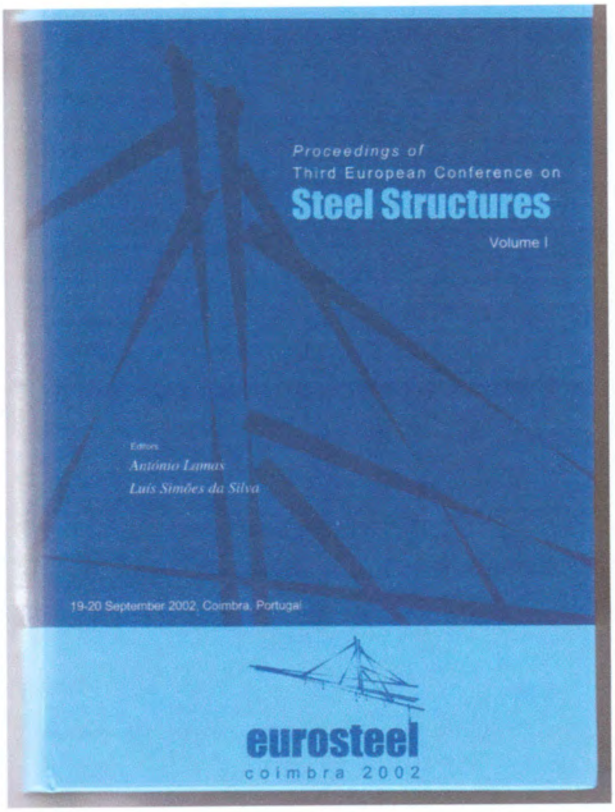

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SKI JUMP "BERGISEL"
A NEW LANDMARK OF INNSBRUCK, AUSTRIA

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ABSTRACT

The ski jump in Innsbruck known for the famous annual New Year "Four-ski-jump-tour" has been fully renewed. The original jumping tower (built for the 1976 Olympic winter games) was fully pulled down and a new landmark similar to a lighthouse has been erected located on a small hill at the border of the city. Zaha Hadid (London) won the international architectural competition for this significant building. The constructional realisation has been ordered from Aste Konstruktion, Innsbruck. After a very strict timetable the building was already handed over to the owner (the Bergisel Management Assoc.) for the jumping event in January 2002.

Key Words: *Steel and composite construction, truss bridge, cantilevering platforms*

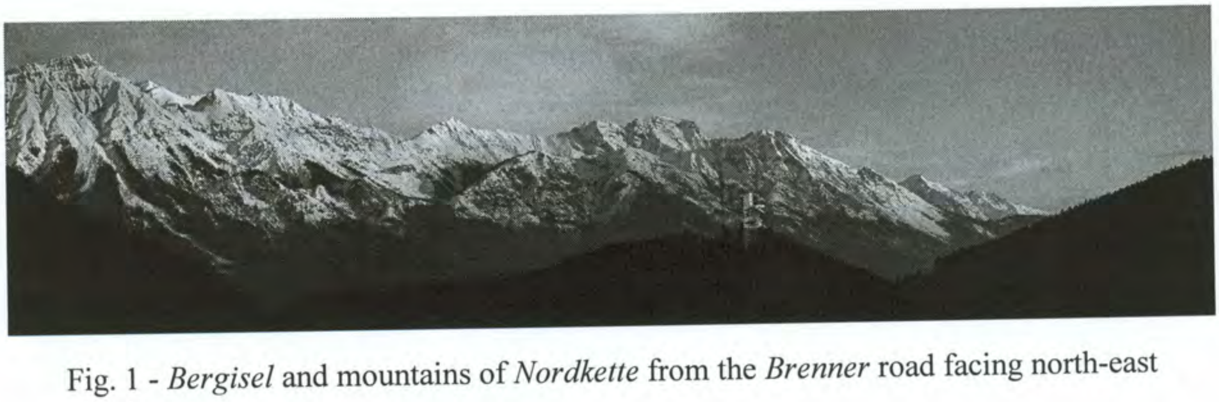

Fig. 1 - *Bergisel* and mountains of *Nordkette* from the *Brenner* road facing north-east

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1. INTRODUCTION

"Bergisel" (Fig. 1) - a glacier hill located to the south of the city of Innsbruck – has a significant history: Offering place of the Celts, path marking for the roman-german emperors moving to Rome, battle field of the Tyrolese war of liberation under *Andreas Hofer* 1809, centre of the Olympic Winter Games in 1964 and 1976 with the two flame basins and since 50 years scene of the international Four-ski-jump-tour at New Year. This event takes place annually in Oberstdorf, Garmisch-Partenkirchen, Innsbruck and Bischofshofen.

The jump facilities of the year 1976, designed by *Prachensky and Passer* [1] did no more meet the requirements of the international ski competition rules. An unfavourable longitudinal section of the approach and the landing hill, a bad access and departure situation for the spectators and an outdated infrastructure for the media led to an ultimatum of the *International Ski Federation (FIS)* in the year 1999.

The city of Innsbruck handed over the facilities to the *Austrian Ski Federation (ÖSV)*, arranged an invited architectural competition, which was won by *Zaha Hadid* (London) (Fig. 2), and takes an interest in the costs. Also the Province of Tyrol and the Federal Republic are co-financing.

Fig. 2 - Photomontage of the new Bergisel ski jump

Fig. 3 - Blasting of the old olympic ski jump on March 25th 2001

By that the Austrian way of privatising of public buildings and competence now reached the Olympic buildings going back to the years 1964 and 1976. The *Austrian Ski Federation* manages the Bergisel facilities with a subsidiary company aiming at a gentle all-year activity including night and summer jumping.

The lower part of the stadium, the "Arena" or "Audience basin", was already subject of an international architectural competition in the year 1991. A wide-spanning roof and drawer-like stages should initiate a weather independent sportive and cultural multi-functionality. The realisation in those days was prevented by the indecision of the city government – for the time being. The contribution by *Aste/Honold* intended a textile fan-like roof with a cable-suspension over 120 m, which could be opened [2].

On March 25th 2001 the old concrete tower including the approach ramp had been sensationally blasted during a scheduled train break [3] (Fig. 3). The noble and selected place became free for a new landmark.

2. DESCRIPTION OF THE TOTAL PROJECT

The total jump competition facilities – not only the demanded new longitudinal section – had been fully renewed and extended by new buildings, which will briefly be listed in the following overview (Fig. 4). The steel and composite construction parts – the tower top and the approach ramp – are treated in detail in sections 3 and 4.

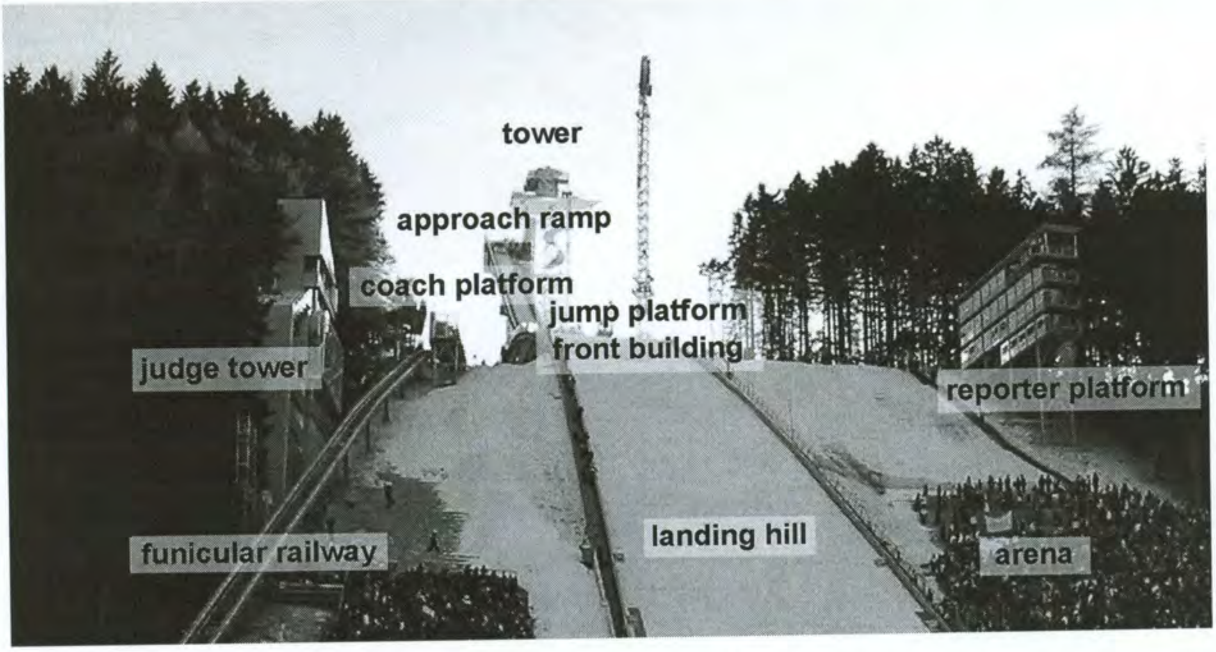

Fig. 4 - Full project *Bergisel* ski jump

- Tower: 48,5 m above ground, Top 791 m above sea level – 13,8 m higher than the old tower, concrete box type section, 7 m x 7 m, wall thickness 40 cm, local prestressing at the top and prestressed slender bearing cantilever for the approach ramp, climbing formwork, fair-faced concrete, start of concreting in June 2001.
- Tower top: three levels, steel hollow section space frame, prestressed docking brackets at the concrete tower, trapezoidal composite slabs, concrete cantilevers, glass and metal sheet facade, construction during winter 2001 and spring 2002 (restaurant for more than 100 guests).
- Approach ramp: sagging fish-bellied steel truss girder with suspension over a direct span of 68,5 m, bend with radius of 100 m and ramp with an inclination of 35°, overall length including the take-off building 97,6 m, approach lane as trapezoidal composite slab, erection with temporary support within only four weeks.
- Take-off building and ski-jump platform: concrete abutment looking like the knee of a ski jumper, length 24 m, fix support of the approach ramp bridge, 10 m higher than the previous state, measurement facilities for the Sports Institute of the University of Innsbruck.
- Front building: three-storey concrete building with bent roof below the jump platform – flown-over by the jumpers, technical equipment, power supply, common rooms and storeroom.
- Landing hill: concrete fixing and border bead or retaining wall, transverse ribs in a 30 m distance, underfloor transverse drainage, holding devices for the snow nets and the plastic mats for the summer jumping, mat sprinkler system.
- Tower for the reporter cabins: four storeys for 31 cabins, steel tube frame.

- Coach platform: grate platform close to the take-off buidling, steel tube frame.
- Funicular railway with three stops, capacity up to 350 persons/hour, automatic cabin inclination corresponding to the slope.
- Judge tower: redevelopment of the old timber construction, internal finish work, VIP rooms, new facade.

The multitude of new structures and building contractors, the narrowness and steepness of the construction place and of the tower access, the extremely short construction time schedule and the weather conditions – during winter with ice and snow – had to cause conflicts. But by tolerance, co-ordination and improvisation also these problems could be solved. The construction board is shown in Fig. 5.

Office / Company	*City / Country*	*Function*	*Competence*
Bergisel Management Assoc.	Innsbruck / A		client
Hadid	London / GB	architect	ski jump incl. tower
Fuchslueger	Trofaiach / A	design office	planning
Aste	Innsbruck / A	design office	design of construction and details
Malojer	Innsbruck / A	management office	construction management
Schrempf	Schladming / A	planning office	service eng./sanitary/ventilation
Puercher	Schladming / A	planning office	electrical installations
Alpine-Mayreder / Ast-Holzmann	Innsbruck / A	constr. partnership	concrete building construction
Froeschl-Swietelsky	Innsbruck / A	sub-partnership	earth works and civil eng. constr.
Martin	Braz / A	steel construction	platforms (coaches, reporters)
Pichler	Bozen / I	steel construction	approach ramp and tower top
IMO-Bau	Leipzig / D	sub-steel constr.	erection of ramp and tower top
Leitner	Sterzing / I	cable cars	funicular railway
Vorspann-Technik	Oberndorf / A	bridge equipment	prestressing and suspension

Fig. 5 - Construction board

3. APPROACH RAMP BRIDGE

The preliminary design of the competition contribution for the approach ramp intended a continuous four-span girder with three piers – similar to the old state. The actual project succeeded without any intermediate support for the slanting distance of 68,5 m with an inclination of up to 35° as a fish-bellied trough bridge with steel trusses and suspension (Fig. 6 and Fig. 7). The preloading leads to compression in the trough girder. The transverse distribution of the central preloading into the string trusses is solved by the end cross girders together with space tubes within the support areas (Fig. 8).

The initial objections about this backbone-shaped approach bridge could soon be dispelled. The innovative shape of the ramp - being the main design element – contributed a lot to the general motivation and identification with the project. Comparing costs the concrete continuous girder and the column-free steel trough bridge were quite similar. However the argument that the intermediate piers would seriously restrict the building site was decisive. Doubts remained concerning the dynamic behaviour due to strong wind and earthquake. Dynamic investigations of the oscillation frequency proofed that the actual three bar system consisting of the two steel trusses and the centric suspension provides a sufficient tube effect. Furthermore the catenary sag of the longitudinal section positively affects the equilibrium position. The architects had been very co-operative and sensitive: so the original slender four-span concrete girder was transformed to the actual free-spanning organic "vertebrate".

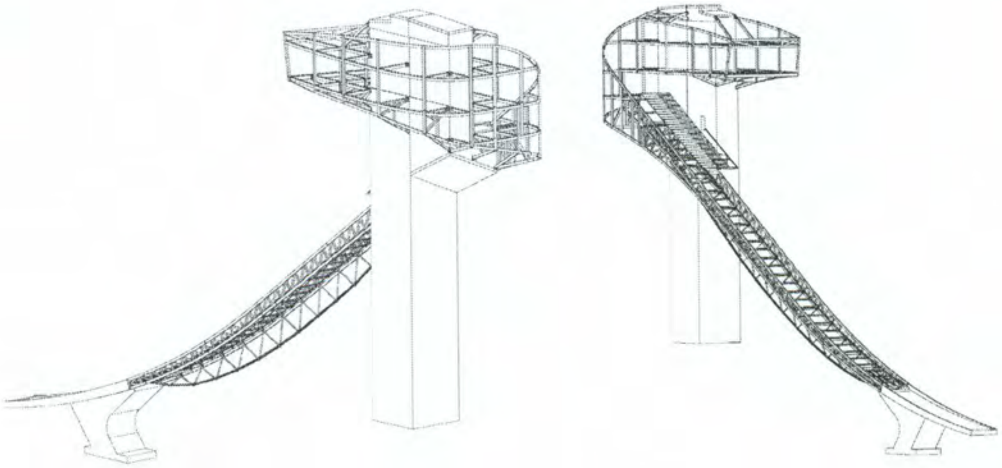

Fig. 6 – Sketch of the steelwork construction

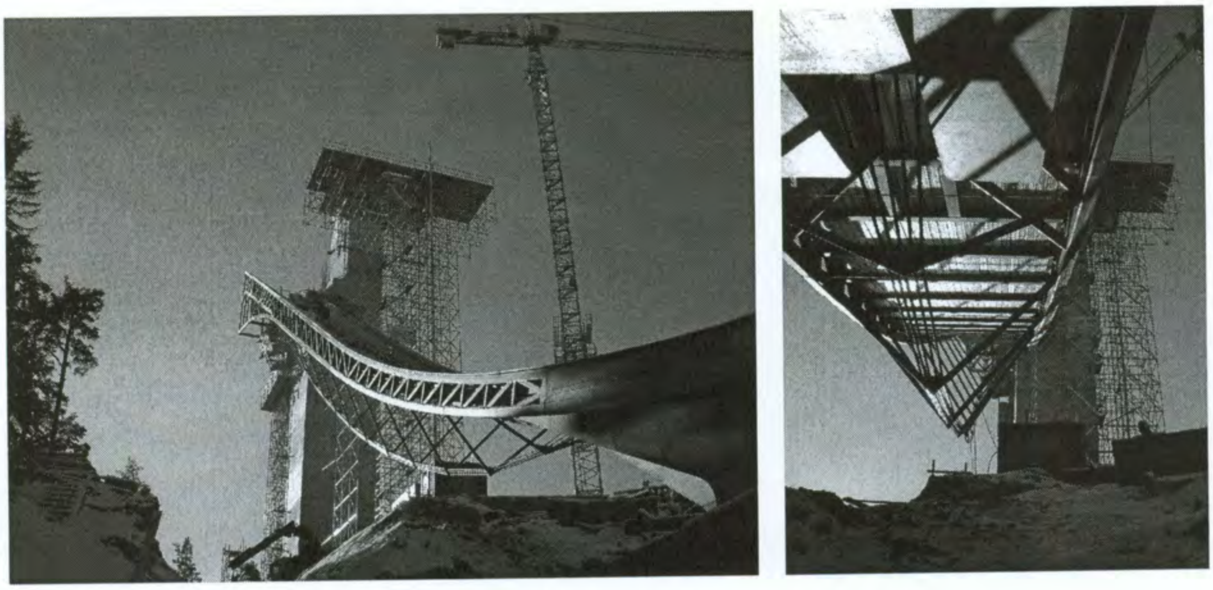

Fig. 7 – Tower and column-free approach ramp

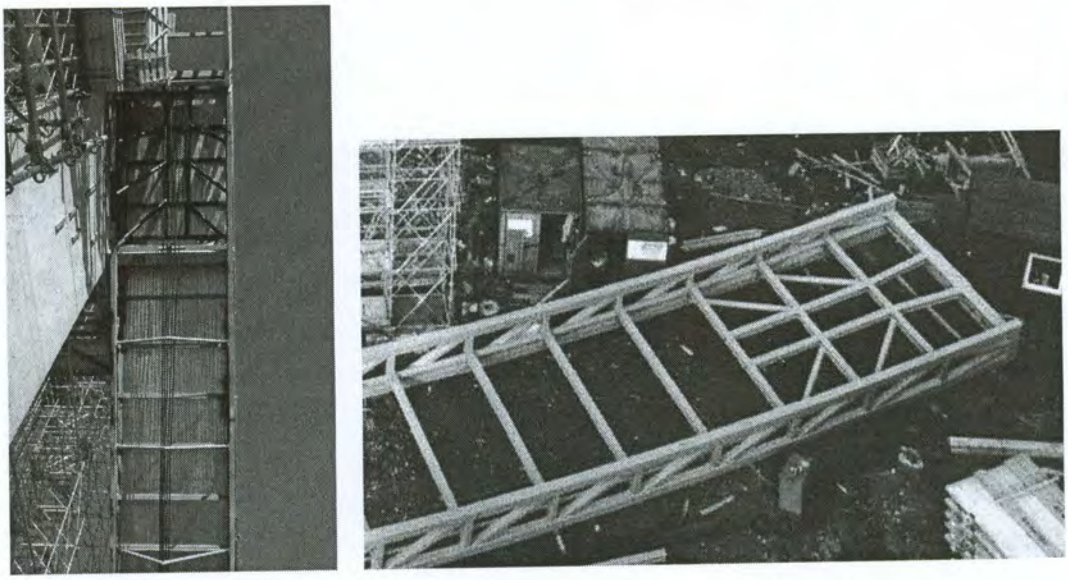

Fig. 8 - Space diagonals within the support areas for load distribution

The constructional design calculations were performed by *Aste Konstruktion*, Innsbruck. The executive steel contractor *Pichler* performed checking calculations. The agreement between the results was perfectly satisfying.

Actions on the structure are the dead load, snow (35 cm pressed with 9 kN/m³), wind, earthquake and service load (e.g. a track preparation machine). Strict serviceability requirements had been prescribed and controlled by the *International Ski Federation* because of the severe influence of even small section deviations on the jumper's flight parabola. The actual deflection difference between full load and dead load is 8,1 cm what corresponds nearly to L/1000.

The bridge cross section consists of rectangular hollow section trusses (construction height between 1,15 and 1,80 m) in a horizontal distance of approx. 4,5 m. These trusses are finally covered by alloyed steel sheets and glass. The standard rectangular hollow section for the upper and lower flange measures 300 x 200 x 14,2 mm, that of the filler beams is 180 x 180 x 12,5 mm (Fig. 9). The approach track is 2,5 m wide with grate staircases on both sides. For the summer jumping a porcelain track is provided.

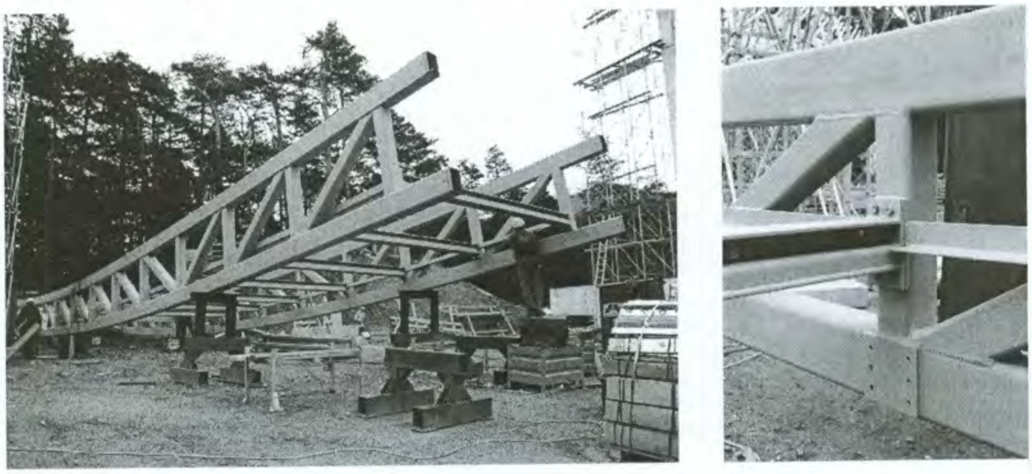

Fig. 9 - Approach ramp – steel truss trough bridge

Special attention had to be paid to the erection order of this steep bridge with a difference in altitude of 31,5 m between the supports. The lower part of the trough with a length of about 30 m was mounted on ground from the two string trusses (each consisting of two parts, which had been welded on site), the end cross girder and the standard cross girders each in a distance of 2 m. It was lifted on November 24th by means of a truck-mounted crane and positioned on the take-off building and the temporary pier (Fig. 10), which gave exactly the desired position for dead load (desired *FIS*-geometry). After two weeks the upper string truss (40 m length) closer to the concrete tower was lifted after pre-welding on ground, was thread on the very slender pre-stressed concrete cantilever (140 x 40 cm) and finally put together with the lower string truss (Fig. 11). Afterwards the external string truss followed in the same way. Within only one day all cross girders then were mounted to the string girders by bolted end-plate-connections, the desired longitudinal section was adjusted and finally the lower and the upper string truss parts were welded together close to the temporary pier.

It followed the mounting of the distance triangles for the cable suspension. These were temporarily braced against each other for the friction forces during prestressing. Afterwards the five cable stays were thread through the wholes in the triangles (Fig. 12) and the re-entrant steel profile decks with end anchoring deformations were placed between the 2 m spacing cross girders – the concrete topping had to wait until half of the prestress (1000 kN) was arranged.

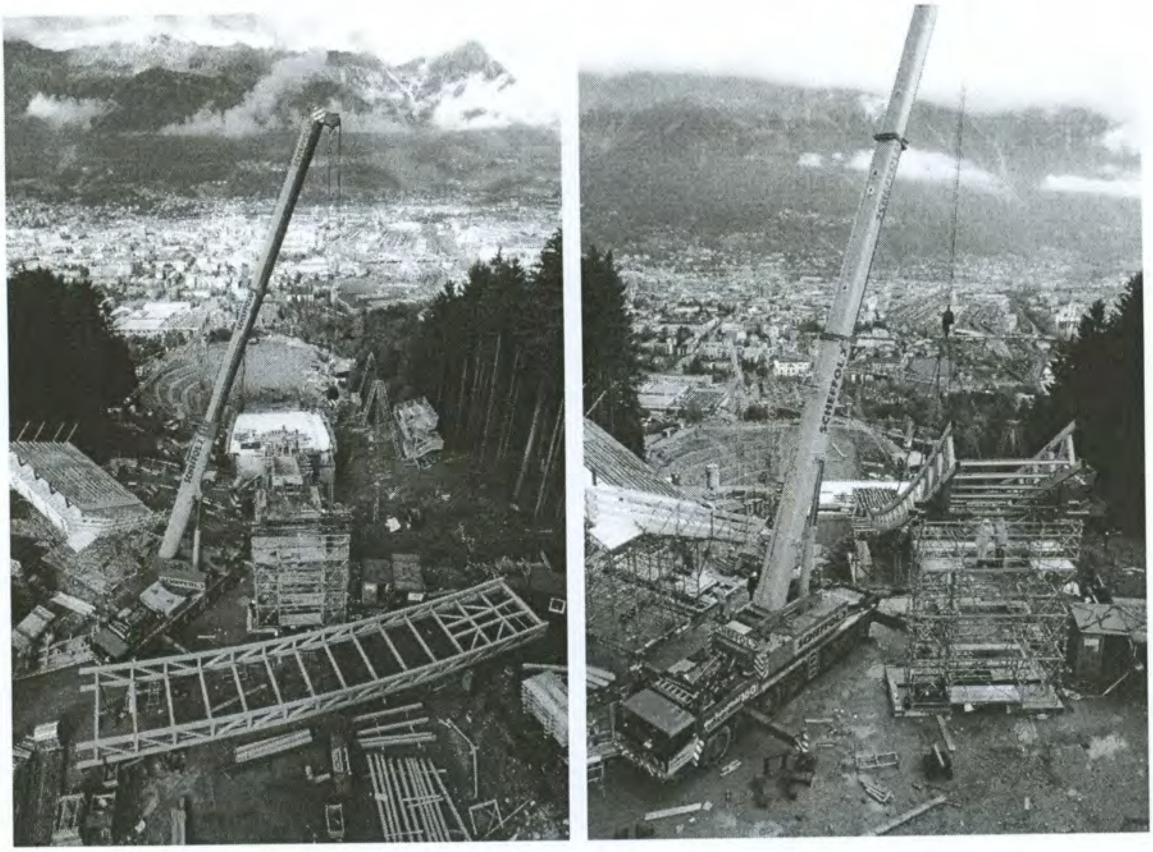

Fig. 10 - Lifting of the first part of the approach ramp

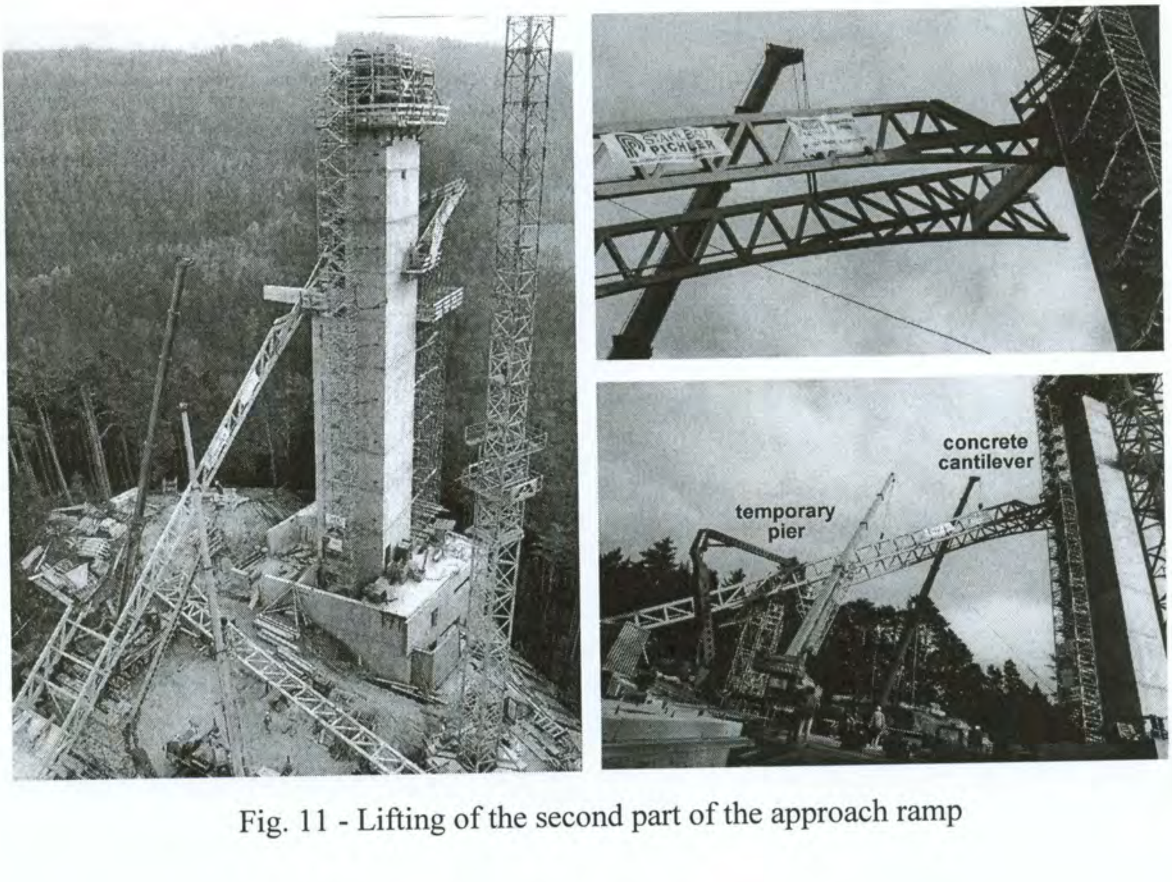

Fig. 11 - Lifting of the second part of the approach ramp

Fig. 12 - Distance triangles for the cable suspension

The structure loosened out of the temporary support as expected. Due to concreting of the approach track the fish-bellied girder again settled on the temporary pier and was lifted up for 1,5 cm by the second half of the prestress. The calculations were correct! The auxiliary pier was removed.

The bridge structure comprises approximately 80 tons of constructional steel grade S355J2G3. The five prestressing cables are frictionless covered mono-strands of *Vorspanntechnik* (special system VT-M01) with a design prestress of 400 kN per strand. The erection of the approach ramp including concreting could be realised within only four weeks.

4. TOWER TOP

The tower top by *Hadid* is not ordinary - neither in architectural nor in constructional respect. On the top of the concrete section a three-level steel cap with a rescue level, a restaurant and an observation platform is docked (Fig. 13). Being 250 m above the city centre one has a fantastic view on Innsbruck and the surrounding mountains.

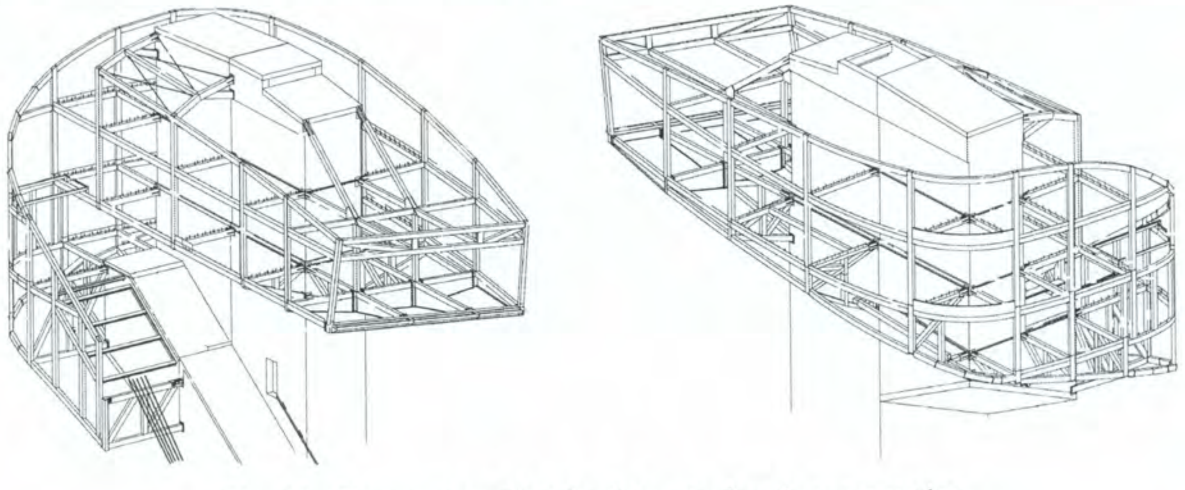

Fig. 13 - Tower top - Sketch of the steelwork construction

The levels are cantilevering around the concrete core up to 11,5 m. Together with the steel hollow section frames and the diagonal suspension tubes anchoring back to the concrete core a steel cage is built. The horizontal stiffening to the core is realised by the composite slabs of these three levels. The transparency and elegance of the facade is supported by the fact that diagonal bars within the front could be avoided.

The docking brackets between the steel cap and the concrete core (Fig. 14) had been a crucial challenge: on the one hand they should not disturb the climbing formwork and on the other hand they should provide sufficient welding length for the introduction of the considerable tension forces. The eventual negative influence of the high welding temperature on the end anchorage of the prestressing strands could be dispelled by a test specimen ($\Delta T_{max} = +50°C$).

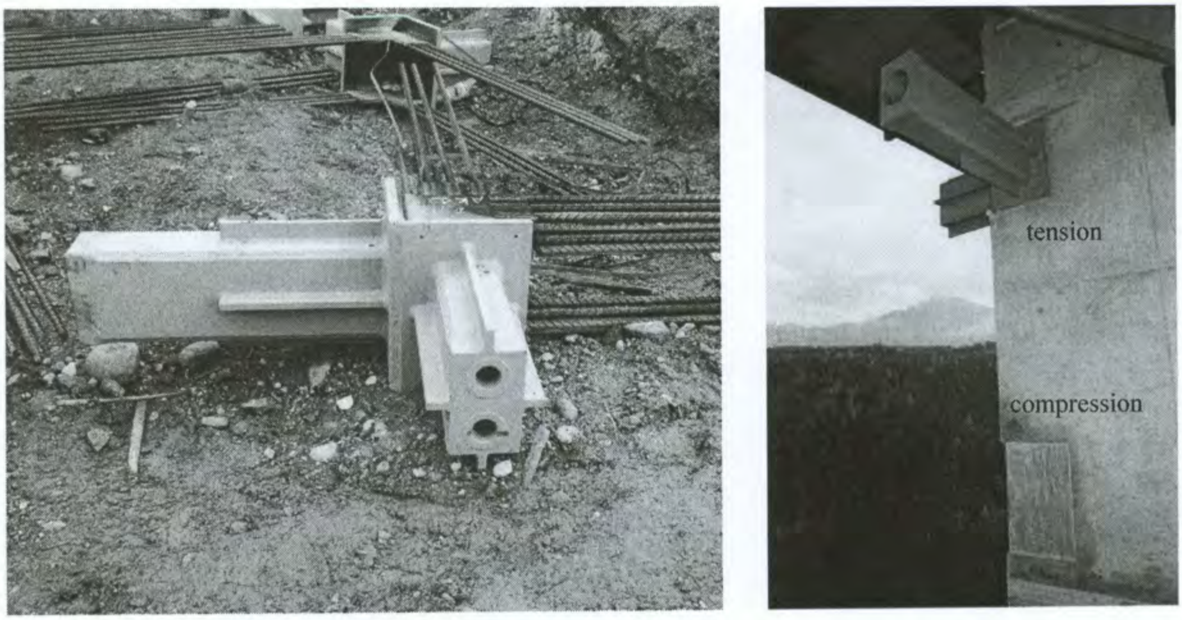

Fig. 14 - Prestressed bearing brackets for the steel frame docked to the concrete tower top

The positioning, adjustment and fixing of these pre-fabricated brackets (max. weight 550 kg/piece) within the formwork and finally the prestressing had been an extraordinary effort considering the remarkable height and the icy-cold temperature. Also the strength development of concrete at these constantly low temperatures became significant. Postponement of prestressing dates initially caused nervousness – so also the pedagogical competence of the structural engineer was required.

The design calculations were performed on the basis of the Austrian standards and the Eurocodes 3 and 4. The scaffolding of *Doka* and *Peri* sometimes even was a competitor in view of slenderness aside the primary structure. The tower top weighs approximately 90 tons of steel grade S355J2G3. Fireproofing coats are provided to obtain a fire resistance of 90 minutes.

5. CONCLUSION

The new building at *Bergisel* became an excellent combination of architectural shape and constructional design. Fair-faced concrete, steel and glass together with the harmonious longitudinal section and the top view are showing the worldwide appreciated style of *Zaha Hadid.* Construction and erection were based on modern technology: concrete core with climbing formwork, prestressed docking brackets for the steel frame cage on the tower top, a prestressed very slender concrete cantilever as upper support of the approach ramp, three-level widely cantilevering steel frame cage on top, approach ramp in the form of an organic fish-bellied and suspended trough bridge – all in all “Toccata and Fugue in major F” for a civil engineer and his orchestra.

The sports event on January 4th 2002 (Fig. 15) produced a cheered hero – Sven Hannawald. He won with a record of 134,5 m. The jump facilities passed its baptism of fire brilliantly. The real heroes were watching from the terraces – the reinforcing workers, formwork carpenters, steelwork erectors, foremen and labourers, who mastered the extremely rough timetable, the continuously frozen scaffolds and roads and the dizzy working places.

The final task – the top restaurant – could be finalised more stress-free in spring 2002. The “lighthouse” of Innsbruck is a new landmark and a symbol for sports, youth, progress and against fears.

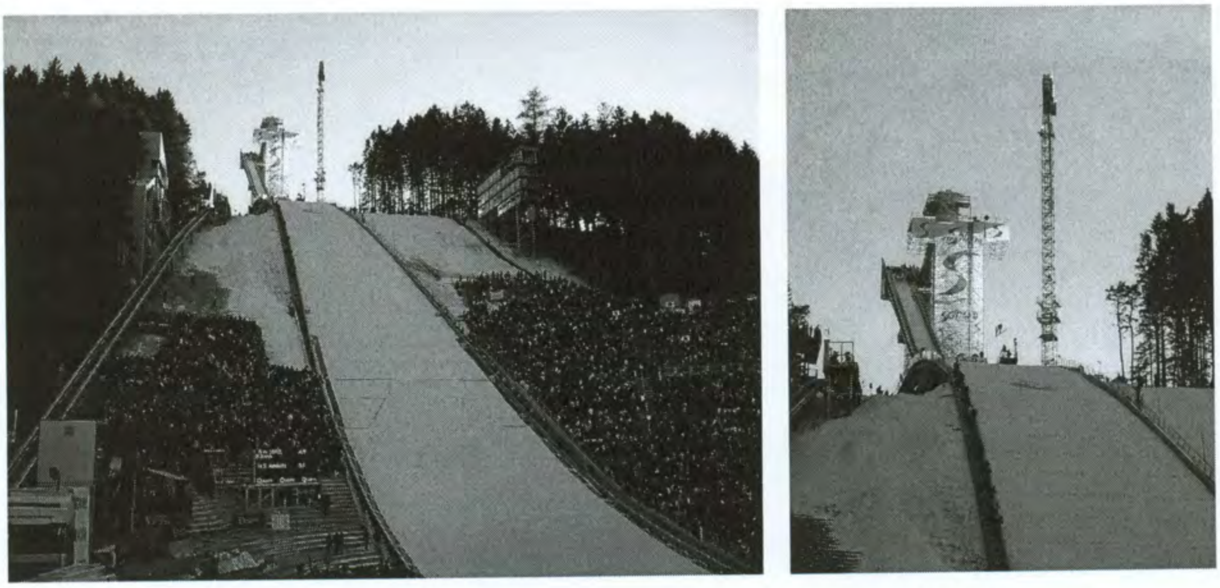

Fig. 15 - Four-ski-jump-tour: Competition on January 4th 2002

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