DOCKING SOLUTION BETWEEN A STEEL TRUSS AND A CONCRETE TOWER AT THE SKI JUMP IN INNSBRUCK

C. Aste, aste konstruktion, Innsbruck, Austria
A. Glatzl, aste konstruktion, Innsbruck, Austria
G. Huber, aste konstruktion, Innsbruck, Austria

ABSTRACT

The crucial challenge in MBT (Mixed Building Technology) are the connection elements between the different construction systems. A typical example of an MBT realisation is the ski jump tower in Innsbruck where a steel cage of hollow section trusses is cantilevering up to 12,5 m from the central concrete tower in a height of about 35 m above ground. The transfer of the localised truss forces into the concrete box section was solved by special pre-stressed docking devices.

INTRODUCTION

The ski jump in Innsbruck known for the famous annual New Year ”Four-ski-jump-tour“ was renewed. The original jumping tower (built for the 1976 Olympic winter games) was pulled down and a new landmark similar to a lighthouse was erected. Zaha Hadid (London) won the international architectural competition for this significant building. The constructional realisation was ordered from aste konstruktion and was honoured with the “Austrian State Award for Consulting 2002”. A speciality of this MBT are the high tension docking devices between the cantilevering steel cage and the concrete tower.

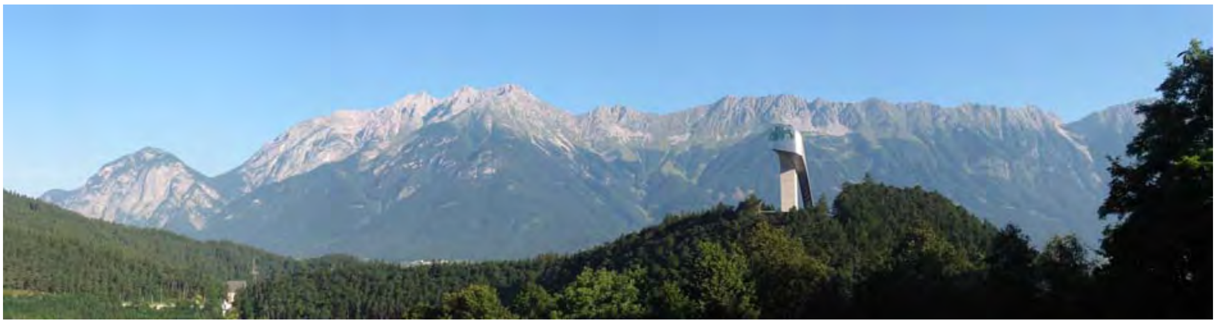

Figure 1. Panoramic view of “Bergisel” with the new jumping tower.

PROJECT OVERVIEW

“Bergisel” - a glacier hill located to the south of Innsbruck (Figure 1) – has a significant history: Offering place of the Celts, path marking for the roman-german emperors moving to Rome, battle field of the Tyrolean war of liberation, centre of the Olympic Winter Games in 1964 and 1976 with the two flame basins and – already since more than 50 years - scene of the international Four-ski-jump-tour at New Year. In the years 2001 and 2002 these facilities were fully renewed and extended by new buildings (Figure 2, 3):

- ***Concrete tower and cantilevering tower top***: described in detail in the following paper sections.
- ***Approach ramp bridge***: sagging fish-bellied steel truss girder with suspension over a direct span of 69 m, bend with a radius of 100 m, inclination of 35°, overall length including the take-off building 98 m, approach lane of trapezoidal composite slabs, erection with a temporary pier within 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.
- ***Front building***: three-storey concrete building with bent roof below the jump platform – flown-over by the jumpers, technical equipment, power supply, common rooms.
- ***Landing hill***: concrete fixing and border bead or retaining wall, transverse ribs, holding devices for the snow nets and the plastic mats for summer jumping, mat sprinklers.
- ***Reporter cabin tower***: four storeys for 31 cabins, steel tube frame.
- ***Coach platform***: grate platform close to the take-off building, steel tube frame.
- ***Funicular railway***: automatic cabin inclination corresponding to the slope.
- ***Judge tower***: redevelopment of the old timber construction.

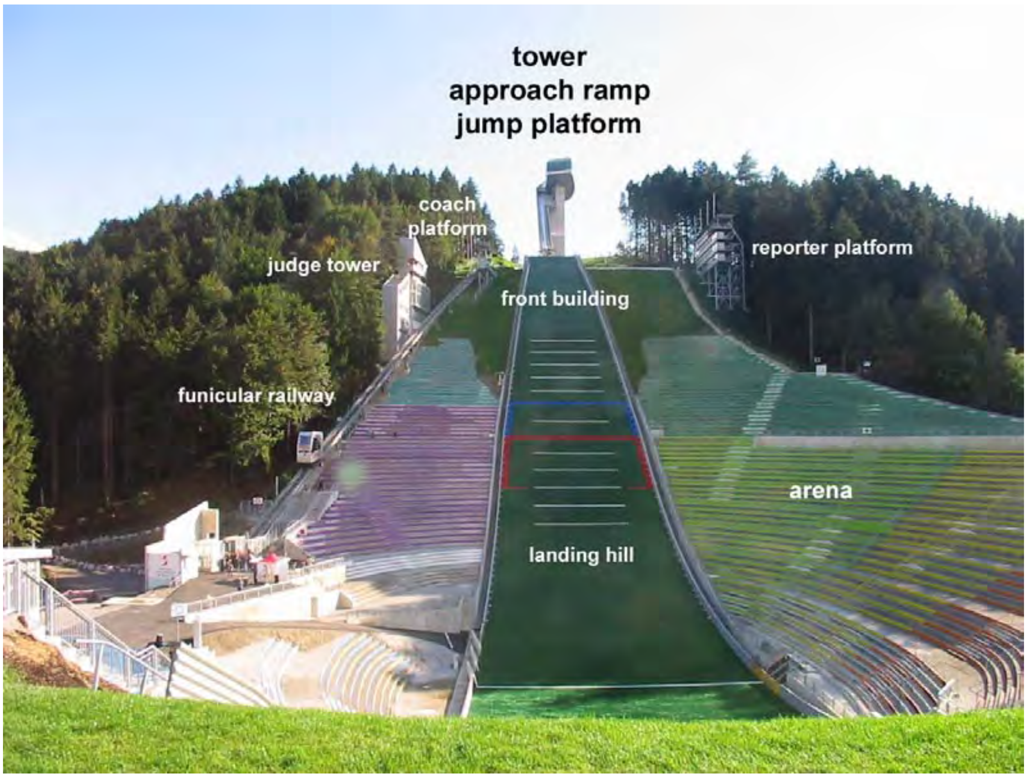

Figure 2. Project overview.

Office / Company	***City / Country***	***Function***	***Competence***
Bergisel Management Assoc.	Innsbruck / A		client
Hadid	London / UK	architect	ski jump incl. tower
aste konstruktion	Innsbruck / A	design office	design calculations and detailing
Pichler	Bozen / I	steel construction	approach ramp and tower top
IMO-Bau	Leipzig / D	sub-steel constr.	erection of ramp and tower top
Vorspann-Technik	Oberndorf / A	bridge equipment	pre-stressing, ramp suspension

Figure 3. Construction board (tower).

CONCRETE TOWER

With 49 m above ground the ridge height of the concrete tower reaches 791 m above sea level (Figure 4). The foundation was solved with a plate of 20 x 20 x 1,0 m at a level of –11 m below ground with three basement storeys. The standard cross section of 7 x 7 m and a wall thickness of 40 cm rises up for about 40 m above the foundation, stabilised with wall diaphragms to the base plate limits. It contains the two elevators, the stairway and the supply pit. From 29 m above ground the cross section tapers to 3,7 x 7 m making place for the jumping access stairway.

Also at this level of cross section change the support girder for the ramp bridge cantilevers 4,5 m with a height of only 1,45 m. This slenderness was necessary to hide this girder in between the steel truss flanges of the bridge.

The demand of fair-faced concrete in combination with the difficult access and supply conditions resulted in the choice of a climbing formwork. Concreting started in June 2001.

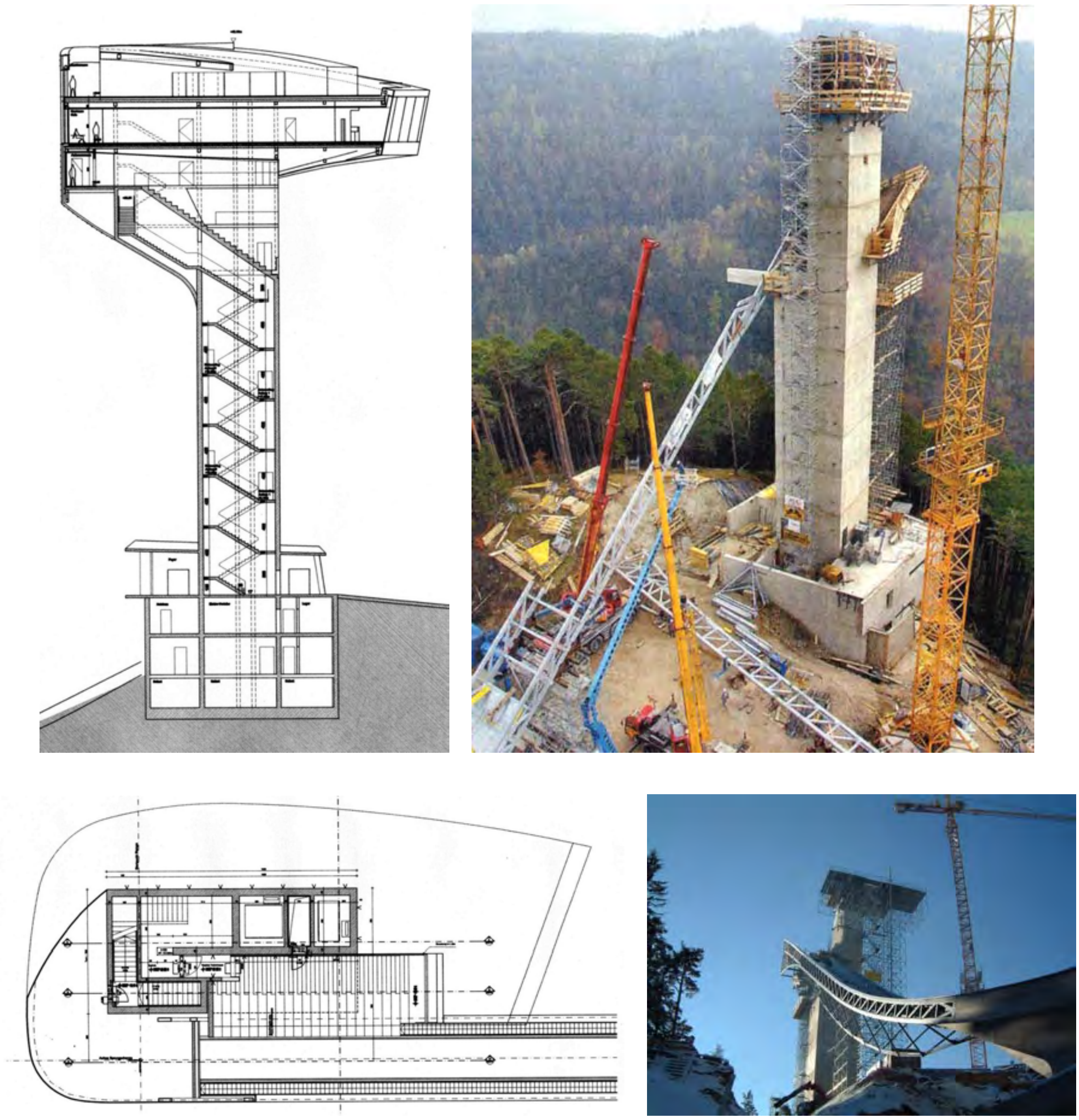

Figure 4. Concrete tower.

STEEL-COMPOSITE TOWER TOP

The tower top is not ordinary - neither in architectural nor in constructional respect. A three-level steel cap with a rescue level, a restaurant and an observation platform is docked to the central concrete tower (Figure 5). Being 250 m above the city centre one has a fantastic view on Innsbruck and the surrounding mountains.

The levels are cantilevering around the concrete core up to 12,5 m. Together with the steel hollow section frames and the diagonal suspension tubes anchoring back to the concrete core a steel cage is built (Figure 6). The horizontal stiffening to the core is realised by the trapezoidal composite slabs. The transparency and elegance of the facade is supported by the fact that diagonal bars within the front could be avoided and huge glass elements were placed into the facade.

Figure 5. Tower top – an architectural challenge.

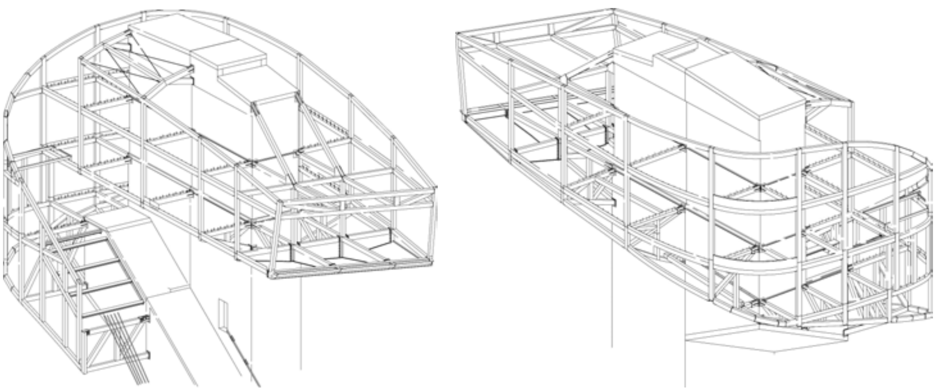

Figure 6. Tower top – sketch of the steelwork construction.

DOCKING DEVICES

The crucial challenge in MBT construction are the connection elements between the different construction systems. Thanks to the common, material-independent design and safety concept of the constructional Eurocodes the interface problems at the level of design methods and internal forces lost its deterrent effect and MBT solutions become more and more usual in daily design practice. The effect is a more economical use of different materials related to their constructional benefits (strength, stiffness, weight, prefabrication, strengthening, dismanteling,...) and more innovative architectural solutions.
For the actual case of the Bergisel Ski Jump the considerable docking forces between the steel cap and the concrete core had been a crucial challenge which was solved by special pre-stressed steel brackets (Figure 7). These elements of at maximum 550 kg weight were integrated into the formwork with a tolerance of less than 1 cm.

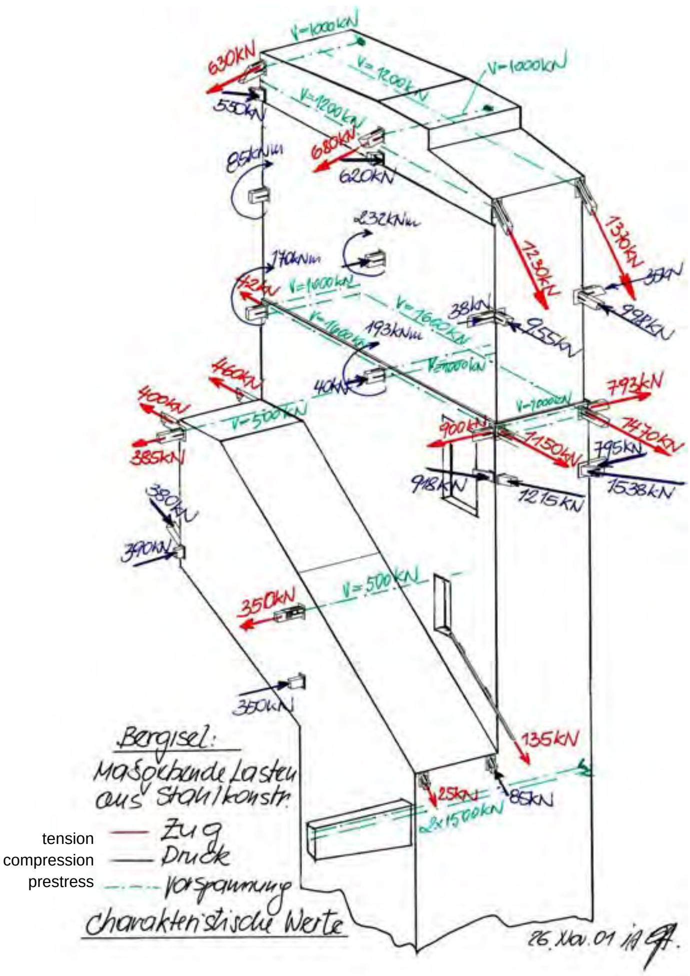

Figure 7. Pre-stressed docking devices. Figure 8. Characteristic docking forces.

The load transfer into the concrete walls was handled with mutual pre-stressing cables (interior tendons) from one docking point to the opposite one going through the tower. Additional concentrated rebars in the local load introduction zones were provided to cover the bursting forces and for crack distribution. The characteristic docking forces can be taken from Figure 8.

Pre-stressing was applied from the opposite side of the fixed anchor after hardening of the concrete and before connecting the steel sections. Depending on the tension forces either one or two strands were provided. The conduits were then filled with injection grout against corrosion.

The resulting necessary welding length led to the geometry of these docking brackets. By the use of four longitudinal ribs which were welded on site to the slotted push-over hollow sections the total bracket length could be minimised. The eventual negative influence of the high welding temperatures on the end anchorage of the pre-stressing strands could be dispelled by a test specimen. The maximum heat increase was measured to be only 50 degrees.

Attention has to be paid to the fact that the tendon head is no more accessible after positioning of the steel cage. Therefore this application type is limited to quasi-static loading.

Figure 5. Slotted hollow sections welded to the docking brackets.

Figure 6. Cantilevering steel cage during construction.

CONCLUSIONS

The new building at Bergisel proved to be 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 steel-concrete mixed building technology: concrete core with climbing formwork, pre-stressed steel docking brackets for the steel frame cage on the tower top, a pre-stressed 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.

Figure 7. Illuminated structure at night

REFERENCES

(1) Aste, C., Glatzl, A., Huber, G. (2002). *Ski jump „Bergisel" – A new landmark of Innsbruck*. 3rd Eurosteel Conference, ISBN 972-98376-3-5, Lisbon.

(2) Aste, C., Glatzl, A., Huber, G. (2002). *Schisprungschanze „Bergisel" – Ein neues Wahrzeichen von Innsbruck*. Stahlbau Heft 3/02, S.171-177, ISSN 0038-9145, Ernst&Sohn, Berlin.

(3) Aste, C., Glatzl, A., Huber, G. (2003). *Steel-concrete mixed building technology at the ski jump tower of Innsbruck, Austria*. International Journal on Steel and Composite Structures, ISSN 1229-9367, Technopress, Korea.

(4) Aste, C., Glatzl, A., Huber, G. (2003). *Innsbruck ski jump: a triumph of mixed building technology*. Concrete Journal, The Concrete Society, Berkshire.

(5) Aste, C., Glatzl, A., Huber, G. (2003). *Schisprungschanze „Bergisel" – Ein neues Wahrzeichen von Innsbruck*. Zement + Beton, www.zement.at, Wien.

Key words: Steel-concrete construction, mixed building technology, cantilevering steel-composite platforms, docking connection devices between steel hollow section trusses and concrete tower.