

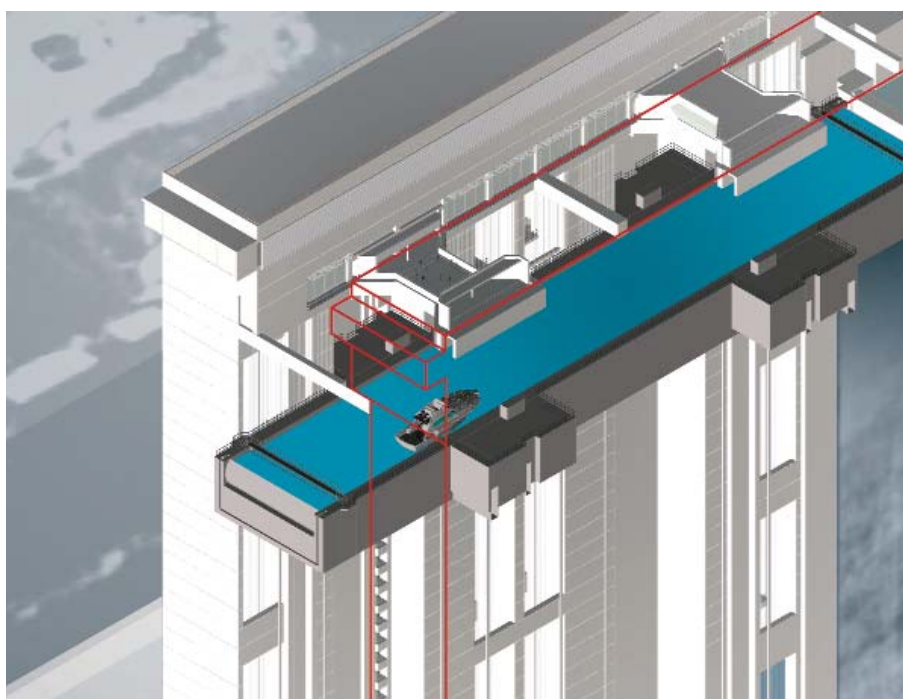
Ship lift at Three Gorges Dam, China – design of steel structures

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KREBS UND KIEFER

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The vertical ship lift at the Three Gorges Dam in China will consist of a reinforced concrete structure with an internal steel ship chamber. The chamber will be a self-supporting orthotropic plate structure, continuously suspended from ropes with counterweights. Its components, such as segment gates, drive, horizontal guiding systems in the longitudinal and transverse directions plus locking and safety mechanisms are described here. A special procedure for reducing the tolerances of the steel components embedded in the reinforced concrete structure is explained.

1 Introduction

The Three Gorges reservoir dam was designed as a reinforced concrete gravity structure with a length of approx. 2.3 km and a height of 175 m. The dam itself was finished in May 2008. The maximum difference between the upstream and downstream water levels is 113 m. The Yangtze River is one of the busiest waterways in the world. At present, shipping traffic can only pass the dam by means of a two-lane, five-chamber lock chain. The last component in the dam complex is the ship lift (Fig. 1), which has been under construction since 2008 and will be used mostly for passenger ships. It will shorten the time taken for ships to pass the dam from more than 3 hours at present to approx. 1 hour (lifting time 21 minutes). With a lifting height of up to 113 m, internal dimensions of 120 × 18 × 3.5 m (useable space) and moving mass of approx. 34 000 tonnes, the vertical ship lift will be the largest of its kind in the world [1].

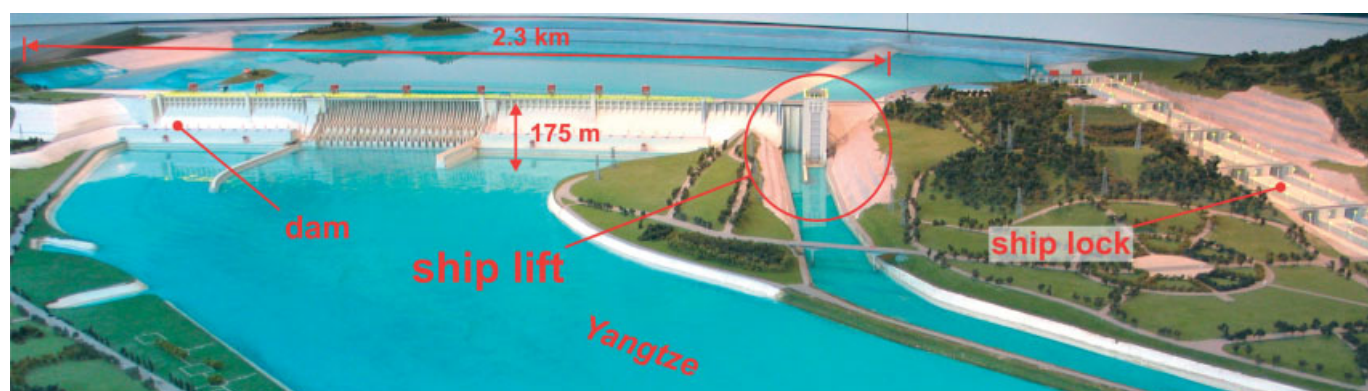


Fig. 1. Model of the Three Gorges Dam on the Yangtze River

2 Overall structure

The main components of the structure are four 169 m high reinforced concrete towers each measuring 40 × 16 m on plan (Fig. 2). The four towers are built on a continuous foundation slab measuring 119 × 57.8 m, directly on granite rock (Fig. 3). Between the towers the steel ship chamber (Fig. 4), which is 132 m long, is suspended from 256 ropes that are connected with counterweights via 128 double rope pulleys at the tops of the towers. Each pair of towers on the long sides of the ship chamber is flanked by shear

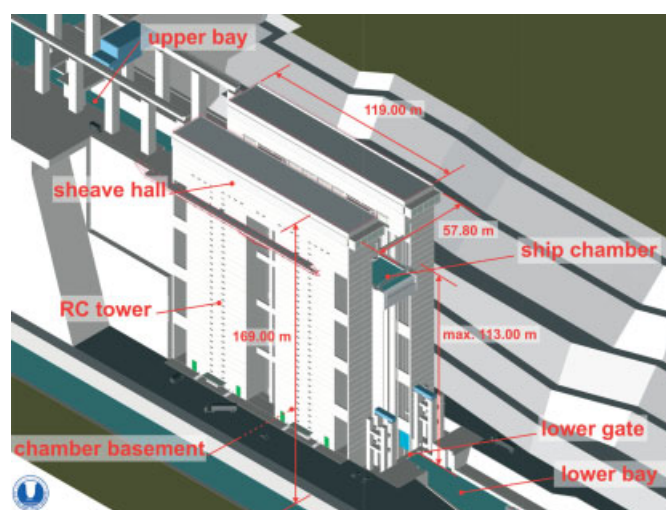


Fig. 2. Isometric view of the ship lift

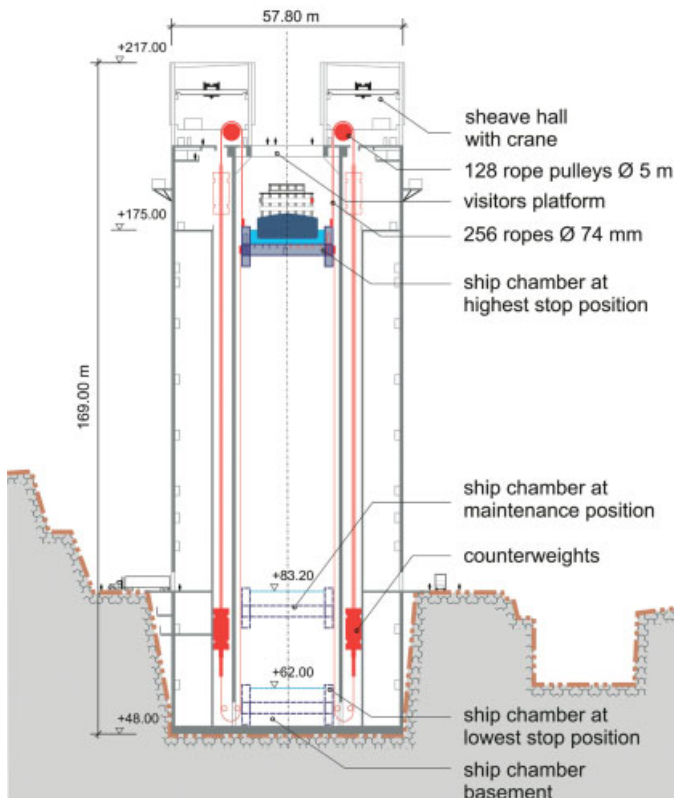


Fig. 3. Vertical section

walls. The walls and towers are connected by coupling beams distributed evenly over the height. Two bridges between the towers are located above the ship chamber, one for the central control room and one for a visitor platform. The guided counterweights, made of high-density concrete, run in shafts inside the towers. The ropes are deflected by rope pulleys at the top of the structure which are supported by reinforced concrete girders mounted on the shear walls and the towers. The rope pulleys are protected by sheave halls, two steel structures on the top of the building with crane runways (Fig. 3). The cranes can also serve the machine rooms on top of the ship chamber.

The ship lift is different from other structures of the same type realized up to now:

- Hitherto, nothing near the maximum lifting height of 113 m has ever been realized.
- The moving mass of approx. 34 000 tonnes (water + ship chamber + counterweights + ropes) and useable space of 120 × 18 × 18 m are larger than in any similar structure completed to date.
- As part of a dam complex with power stations, flood protection and two chains of locks, the ship lift is subjected to short-term operational water level fluctuations of up to 50 cm per hour on the downstream side.
- Hydrological water level fluctuations of 30 m on the upstream side and 11.8 m on the downstream side require special gate equipment at the upper and lower bays.

At the request of the owner, the China Three Gorges Project Corporation (CTGPC), which also operates the entire dam complex, the structure was designed according to German industrial standards, taking into account regional conditions such as seismic loads [2] and the building materials available.

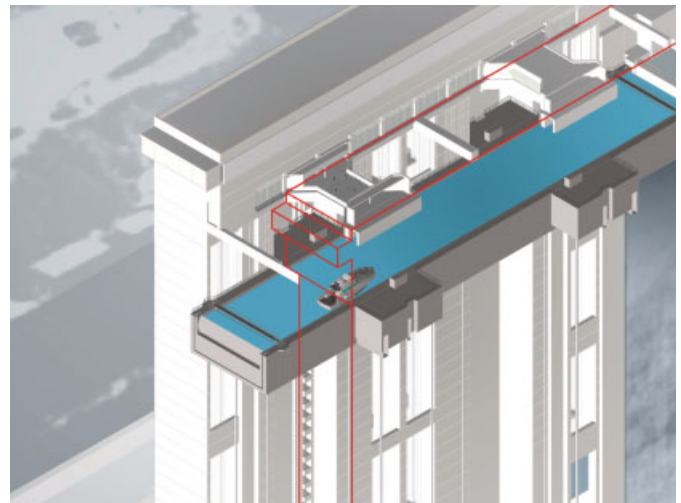


Fig. 4. Isometric view of ship chamber

3 Ship chamber

The ship chamber is designed for passenger ships with a max. water displacement of 3000 tonnes, max. length of 84.5 m, max. width of 17.2 m and max. draught of 2.65 m (Fig. 5). A pushed chain of barges with a water displacement of 1500 tonnes, length of 109.4 m and width of 14 m was taken into consideration as an alternative. The useable length inside the chamber between the anti-collision devices in front of the gates is 120 m. The clear distance between the fenders on the long sides is 18 m. Ships with a height up to 18 m above the waterline can use the ship lift.

3.1 Chamber structure

The 132 m long and 23 m wide ship chamber structure will be built as a self-supporting steel construction. The depth of water in the chamber is 3.5 m and there is a free-board of 80 cm. On each side, 128 approximately evenly distributed ropes are connected to the counterweights, with 16 ropes in each counterweight group. This results in a very even load transfer into the chamber. The ends of the chamber and the machine rooms are the only areas where no ropes can be located (for structural reasons). The ship chamber extends into the lower and upper bays at the ends.

The design of the chamber was based on DIN 19704 ‘Hydraulic steel construction’, DIN 18800 and a ‘Guideline for Design’ agreed with the owner. The ‘Guideline for Design’ specifies all the loading cases for the project.

The chamber floor is an orthotropic plate (Fig. 8). The main beams on the long sides are three-cell box girders 10.0 m deep and 2.3 m wide. These very rigid main beams guarantee that the entire construction is stiff enough to ensure correct functioning in all operational situations. The box girders include lateral openings to provide adequate ventilation and reduce the uplift volume. Evenly spaced cross-girders with an average thickness of 18 mm are located beneath the floor of the chamber. In these areas the longitudinal girders are stiffened by compartments to ensure correct load transfer. Open sections are used for the cross-girders and the longitudinal stiffeners under the floor plate in order to prevent increasing the uplift (in the

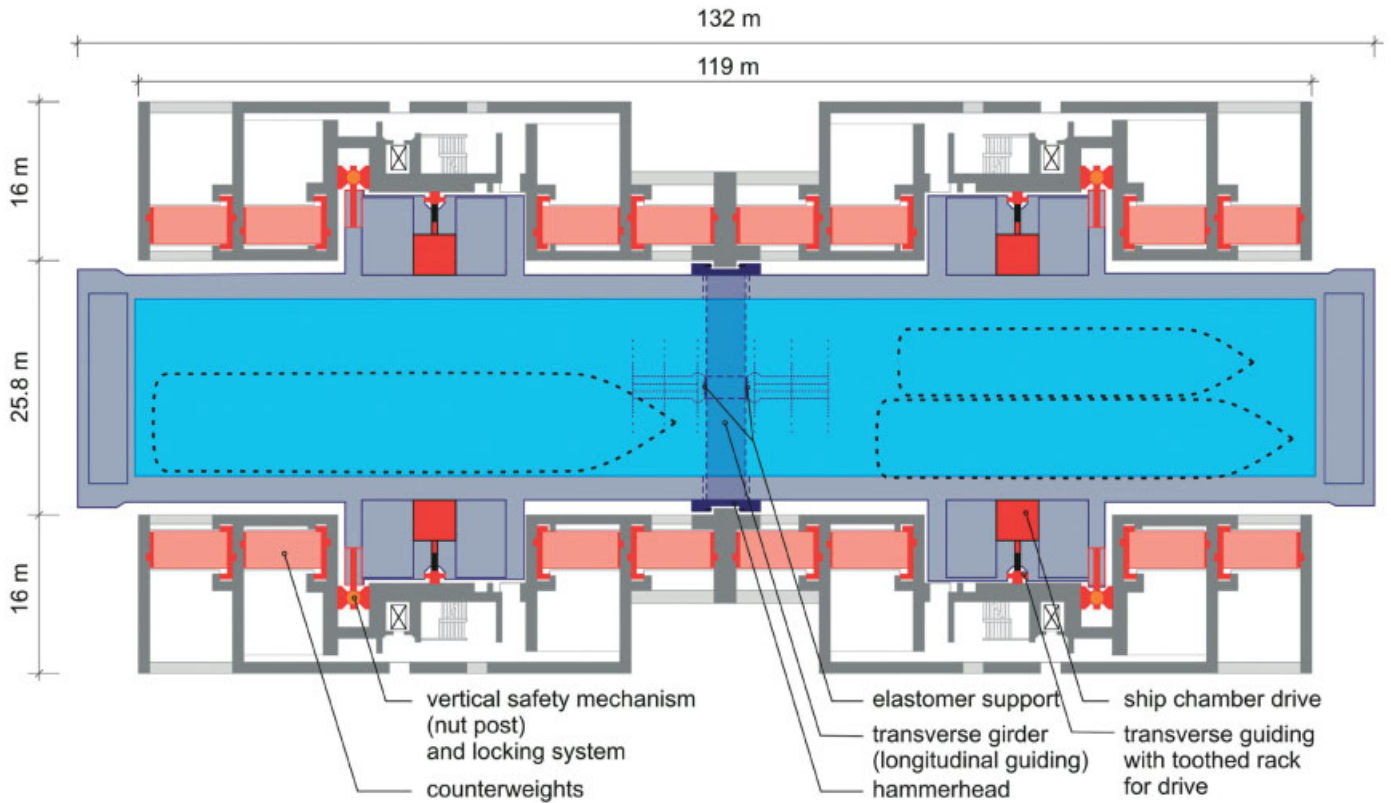


Fig. 5. Horizontal section

catastrophic loading case of a water-filled chamber basement with an empty chamber). This also ensures that there are no unwanted hollow spaces.

The design is based on Chinese steel grade Q 345 D, which is similar to German steel grade S 355. However, the yield strength values for Chinese steel decrease steeply, compared with the nominal value, as the plate thickness increases (Tab. 1). The impact toughness corresponds to class K2 (S 355 K2).

Table 1. Material properties of steel grade Q 345 D to GB 1591-94

| Plate thickness [mm] | < 16 | 16–35 | 35–50 | 50–100 |
|---|---------|-------|-------|--------|
| Modulus of elasticity [N/mm ²] | 210 000 | | | |
| Yield strength $f_{y,k}$ [N/mm ²] | 345 | 325 | 295 | 275 |
| Impact toughness at -20°C [J] | 34 | 34 | 34 | 34 |

3.2 Ropes and counterweights

Each rope is connected to one counterweight. The ropes are fixed to the outer web of each longitudinal girder by end fittings with eyes. Every two ropes are guided over a pair of rope sheaves on one rope pulley and connected to two individual weights. This method of handling the loads ensures that all ropes carry the same load. The individual weights are combined to form groups of 16 using a sling frame which ensures that each individual weight is prevented from falling should its rope break. Each group of counterweights is guided inside a reinforced concrete shaft. To compensate for uneven stretching of the ropes, each pair of ropes is connected to two counterweights via

a rocker that can even out small tolerances. The ropes have a nominal strength of 1960 N/mm² and a diameter of 74 mm.

3.3 Anti-collision device

At the ends of the ship chamber, an anti-collision device is positioned at a distance of 4.5 m from the back plate of the chamber gate to prevent damage by ships that do not stop in time. This device takes the form of a rope 50 cm above the waterline. The rope is installed below a rope barrier beam which also serves as a walkway. The maximum impact energy for the design was 1600 kNm.

3.4 Horizontal guiding

Horizontal guiding of the ship chamber is achieved by two independent systems, one in the longitudinal and one in the transverse direction.

The transverse guiding system is located beneath the machine rooms of the ship chamber drive (Fig. 6). Guide carriages are fixed to the sides of the toothed rack of the drive (see section 4.1) by means of prestressed rollers in such a way that they can resist compression and tension forces. The carriages are connected to the ship chamber via twin-chamber hydraulic cylinders. A reverse connection with the hydraulic system of the opposite cylinder ensures simultaneous movement of the cylinders (Fig. 6). The ship chamber is therefore always centred between the towers, even if the deformations of the towers differ.

The longitudinal guiding system (Fig. 7) has to absorb normal operational loads, such as water pressure when the chamber gate is open on one side, and pressure from the sealing mechanism (see section 4.4), together approx. 9000 kN,

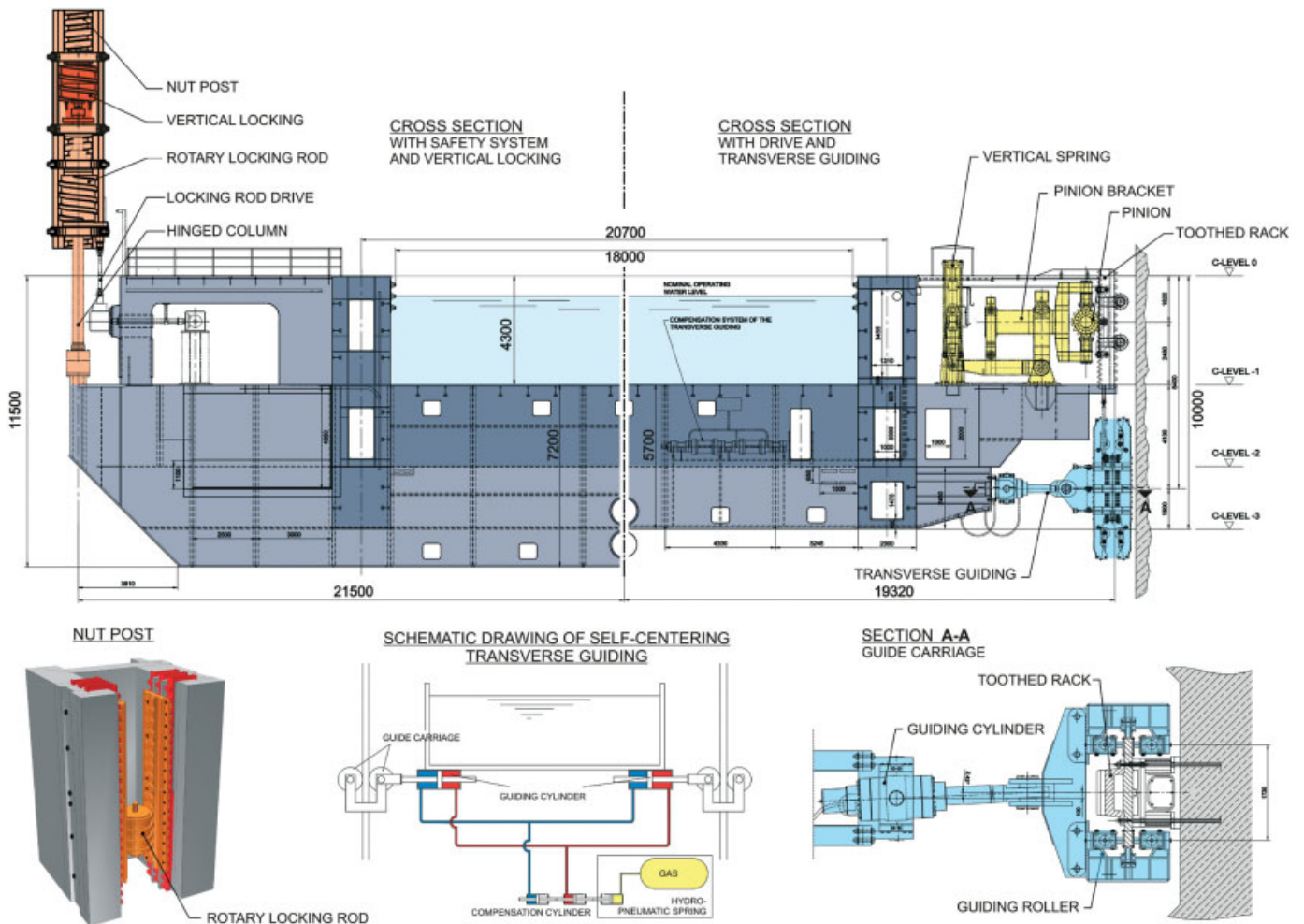


Fig. 6. Section through ship chamber: left – safety mechanism and vertical locking; right – drive and transverse guiding

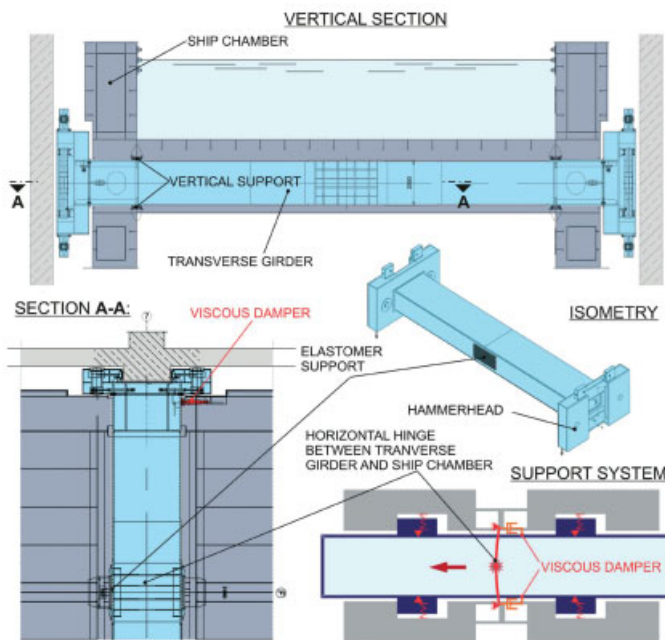


Fig. 7. Longitudinal guiding system with transverse girder

as well as abnormal loads such as ship impacts or earthquakes. To ensure that the high stiffness of the towers and the ship chamber do not lead to constraining forces because they deform differently, the longitudinal guiding system is statically determinate. A hollow section steel beam

measuring 4×2 m spans transversely beneath the chamber floor and crosses the main longitudinal girders. The transverse girder is connected to the ship chamber by a horizontal hinge on the central axis of the chamber. This hinge takes the form of two conventional elastomer bearings, well known from bridge supports. In the hinge area, the transverse chamber floor girders are connected by additional steel plates to form a box girder and ensure load transfer. Hammerheads with rollers and sliders are located at both ends of the transverse girder. These hammerheads grip vertical reinforced concrete corbels on the side walls on the central axis of the whole structure. To lock the chamber at the stop position, the sliders in the guiding mechanism are mechanically pressed onto the corbel via eccentric sheaves. While the chamber is moving, there is a gap of 5 mm between the sliders and the roller rails. The rollers are supported by springs, which ensure that the sliders also come into contact with the corbels in case of high horizontal loads, e. g. due to earthquakes.

Two viscous hydraulic dampers are located between the hammerheads and the longitudinal girders of the ship chamber (Fig. 7). During normal operation, these viscous systems remain unloaded and the load transfer in the longitudinal direction takes place via the transverse girder only. During motion, there is a phase shift between the viscous forces and the elastic forces so that the bending forces on the transverse girder are decreased significantly. This means that for the design of the transverse girders, fa-

tigue considerations are more important than earthquake loads [3]. Furthermore, earthquake loads on the central wall of the concrete structure could be significantly reduced.

3.5 Design calculations

In addition to the ‘normal’ actions on building structures such as dead and imposed loads, the following special load cases also had to be taken into consideration:

- incorrect operation of the drive
- sunken ship
- ship collision
- ropes breaking
- buoyancy
- earthquakes
- different water levels
- water pressure when one gate is open
- chamber completely full/empty

The calculations for the ship chamber structure were carried out using 3D FEM computations, modelling 1/4, 1/2 or the entire structure (Fig. 8). Within these calculations, the main structures were modelled using 3D shell elements.

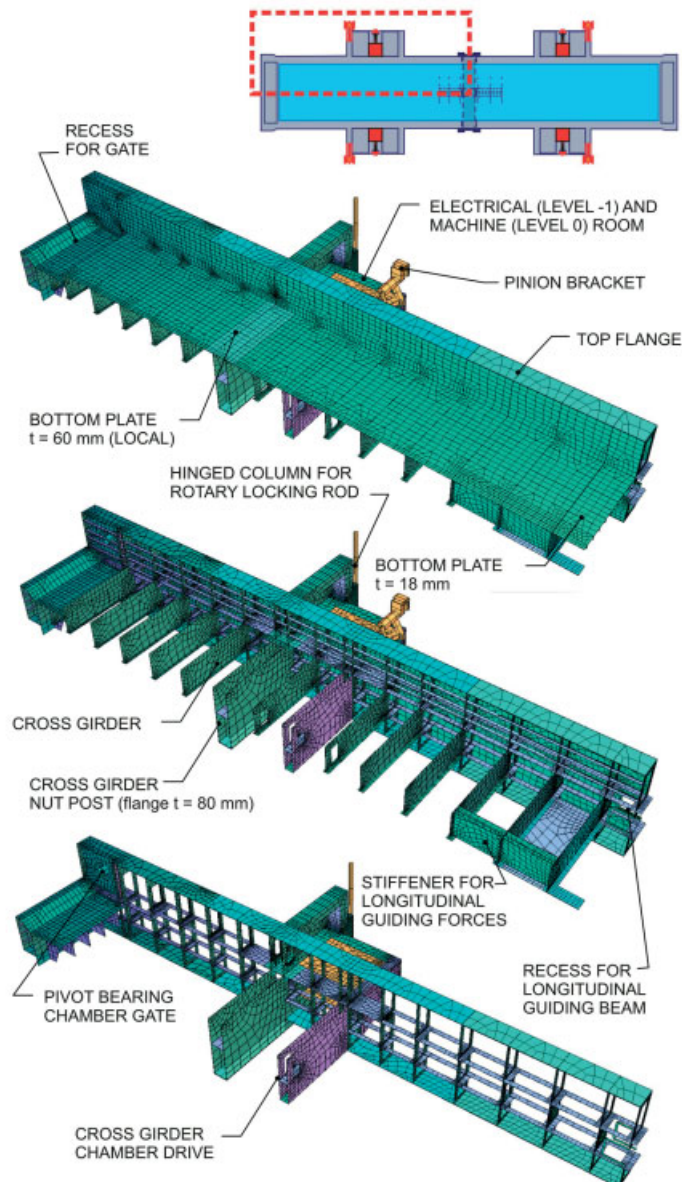


Fig. 8. FEM model of 1/4 of the ship chamber

Smaller parts, e. g. stiffeners, were modelled using coupled beam elements. Stability aspects such as buckling were investigated separately in detail.

4 Mechanical parts

By combining the drive and transverse guiding systems and the vertical locking and safety systems, it was possible to optimize the design so that the length of guide rails could be almost halved, thus reducing costs.

4.1 Ship chamber drive

The four drives are installed on the long sides of the chamber, two on each side at a distance equal to about a quarter of the chamber length from each end (Fig. 5). The machine rooms

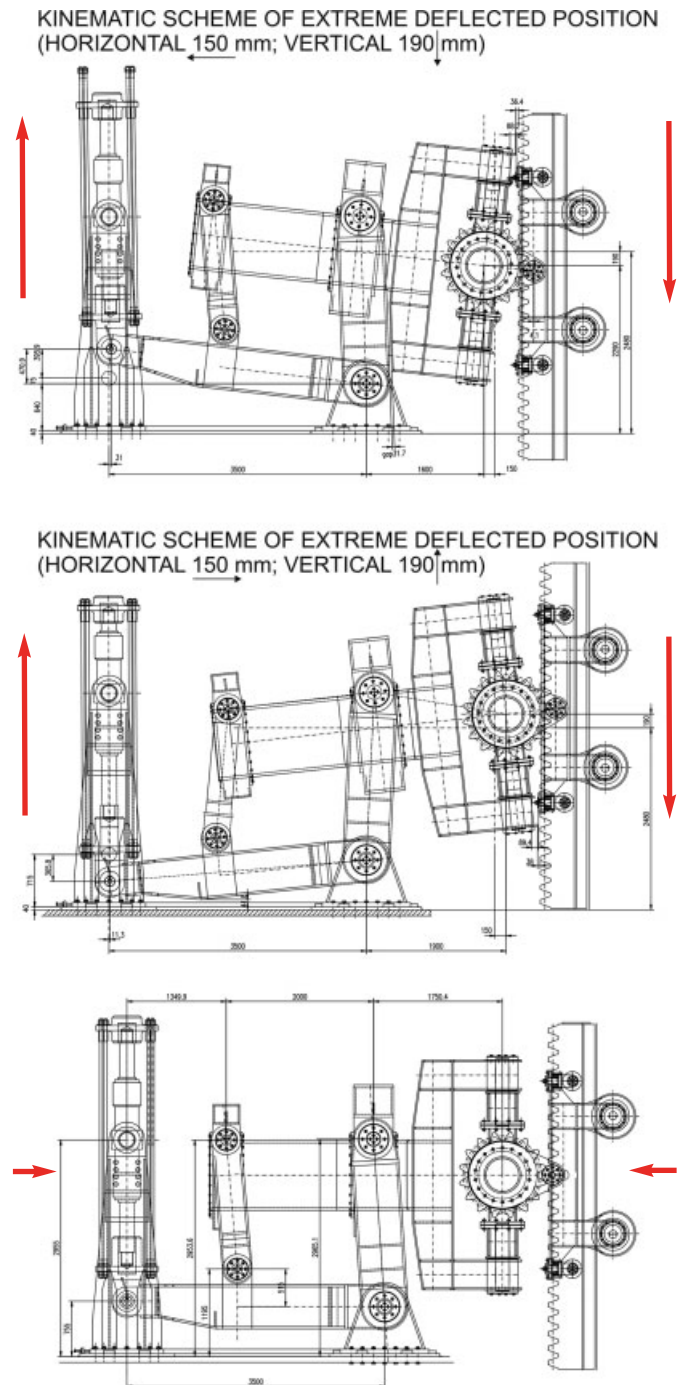


Fig. 9. Kinematics of chamber drive

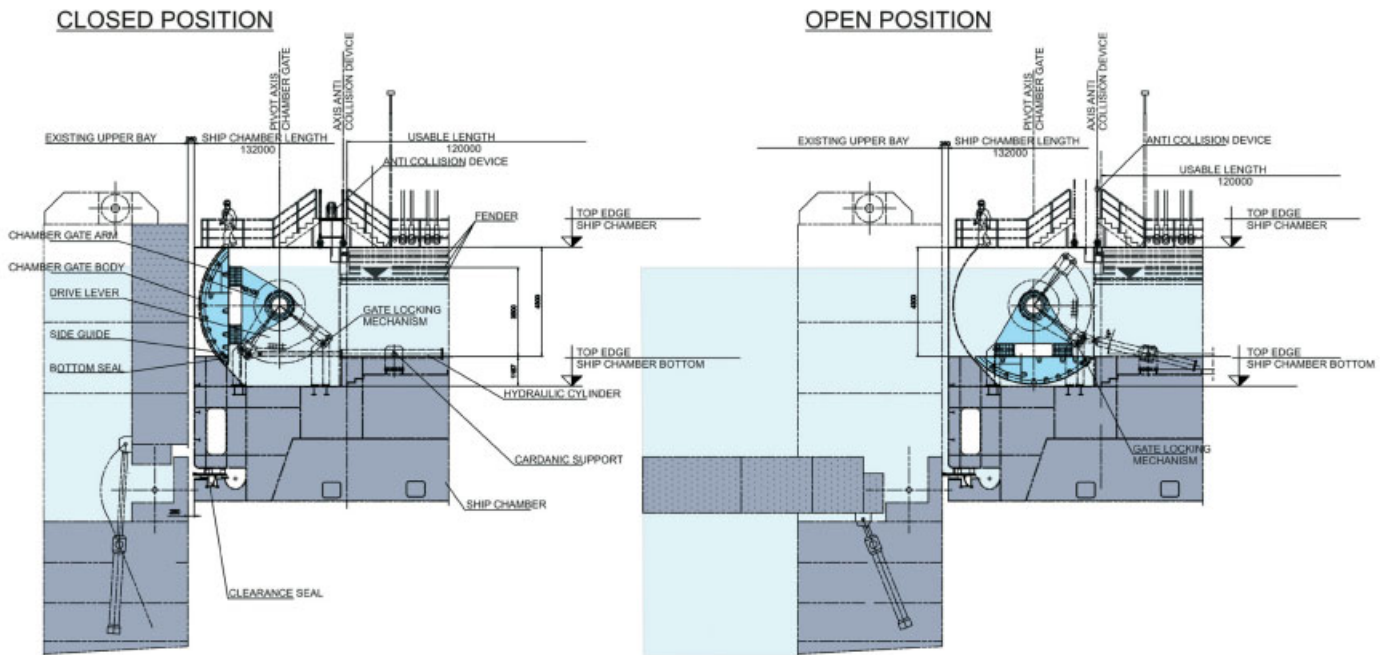


Fig. 10. Ship chamber gate – closed and open

are in this area and extend into the towers so that the forces from the ship chamber can be transferred into the reinforced concrete structure. The transverse guiding system and the safety mechanism (see section 5) are also located here in order to concentrate the mechanical equipment in one area. Two watertight electricity rooms are located below the machine rooms.

The chamber is driven by four pinions that engage with toothed racks built into the towers. Each pinion is driven by two electric motors and is elastically mounted on a bearing bracket in the machine room (Figs. 6 and 9). All drives are interconnected via synchronizing shafts under the chamber so that if a motor in one drive station is out of action, the missing drive moment is transferred by the shafts to the affected area. The shafts are arranged in an H-form and are connected with each other on the chamber axis. This prevents unequal torsion in the shafts.

The pinion is supported by the bracket in such a way that both vertical and horizontal deformations are compensated (Fig. 9). The kinematics of the mounting ensures that only minor relative deformations can occur between the pinion and the toothed rack. Guide carriages behind the toothed rack ensure that the pinion is always gripped by the rack. This purely mechanical configuration renders complex and expensive control technology unnecessary. A vertical prestressed spring is located at the other end of the bracket. This spring is designed for normal operational loads only, such as friction, acceleration forces and small water level differences. In case of higher loads, the spring locks and the safety mechanism starts to react (see section 5).

During the lifting operation, the chamber accelerates at 0.01 m/s^2 up to a velocity of 0.2 m/s . This results in a net drive time of approx. 10 minutes.

4.2 Water level control

To ensure control during operation, the chamber is motor-driven during both ascent and descent. On the ascent, the chamber is moved with a slightly higher water level than

the nominal value of 3.50 m. On the descent, the chamber is slightly less full so that the motors must always be in operation. The construction is, however, designed in such a way that the lift can also be operated in generating mode. Motor-driven mode leads to alternating stresses on the pinions, which were taken into consideration in the design process. After a ship has entered the chamber, the chamber gate is closed and the water level is adjusted to the nominal level within 5 minutes by pumps at a rate of $250 \text{ m}^3/\text{s}$. Once the outer gate is closed, the water in the gap between the gates (around 100 m^3) is evacuated within 90 seconds and temporarily stored in a pipe system below the chamber. While the chamber is moving, the water is pumped steadily back into it, which takes 9 minutes. This keeps the flow speed in the chamber low and avoids additional forces on ship hawsers.

4.3 Vertical locking system

Since the drive cannot support very high loads because of fatigue considerations, an additional vertical locking system has been designed. This locking system ensures stability at the stop position and transfers the additional loads resulting from water level fluctuations in the lower bay (approx. 50 cm/h). An additional locking rod (Fig. 6) is located above the rotary locking rod of the safety mechanism. During the movement of the chamber, this vertical locking rod rotates freely in an internal thread (nut post, see section 5). The rod consists of two separate vertical segments which are spread apart and pressed against the nut post at the stop position. This prevents any vertical movement of the ship chamber and ensures that the connection to the bay is sealed.

4.4 Chamber gates

The chamber gates are designed as segments with a radius of 3.1 m. In the open position, the gate disappears into a recess in the chamber floor (Figs. 8 and 10). The gate is

moved by supporting arms that are located in recesses in the main longitudinal girders. The supporting arms are connected to the gate drive via torsion tubes which pass through the main girders. The gate drives are located in the main girder and are thus protected against external influences. Each gate includes a hollow space so that buoyancy reduces the drive forces required. The gate can be moved into a vertical position for maintenance purposes and is locked mechanically in all end positions.

The gap between ship chamber and upper/lower bay is closed by a clearance sealing mechanism at each end of the chamber. This sealing mechanism consists of a C-shaped steel plate connected to the chamber floor and the main girders. At the stop position, the plate, fitted with an edge seal, is moved outwards and pressed against the gate of the upper/lower bay.

4.5 Counterweight guiding

The counterweights must be guided horizontally. This is especially important in the case of seismic loads because otherwise a counterweight group may behave like a pendulum and cause severe damage to the reinforced concrete structure. The guiding system is statically determinate to avoid constraints (Fig. 5): in the transverse direction, the sling frame is supported at two points; in the longitudinal direction, the counterweights are guided on one side only in a way that resists tension and compression forces.

5 Safety mechanism

In the event of an accident, a special safety mechanism ensures that the ship chamber is supported vertically in a controlled manner at any height. During normal operation, four short screw sections, which are connected to the ship chamber vertically and are known as rotary locking rods, rotate continuously, synchronously and unloaded in an internal thread (nut post) that is fixed to the towers

over their entire height (Fig. 6). If an accident occurs, this rotation is blocked and traction is achieved that supports the ship chamber independently of the ropes.

The safety mechanism also prevents overloading of the pinion and the brakes in the event of an accident by safely securing the ship chamber to the four nut posts via the four rotary locking rods. This situation may occur if the ship chamber is emptied or overfilled. The ship chamber will be emptied routinely about once a year for maintenance or repair work.

The nut posts each consist of two internal thread segments anchored in the RC towers (Figs. 11 and 12). They

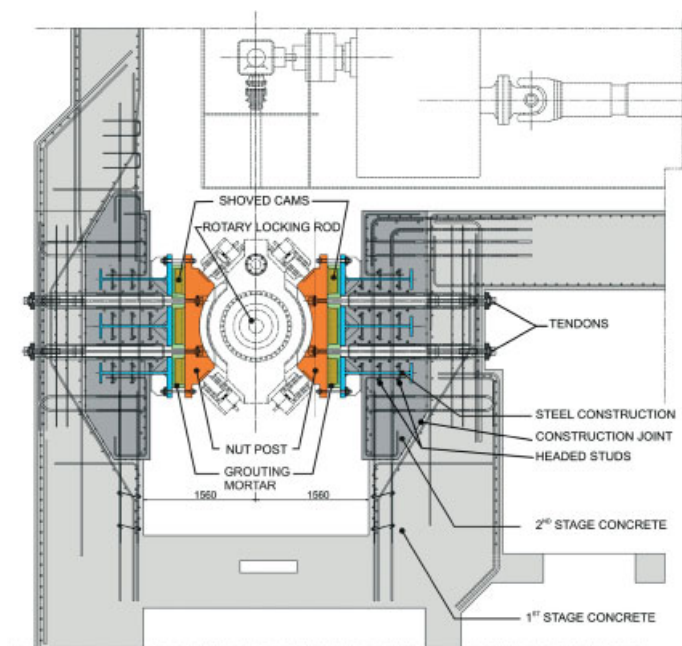


Fig. 11. Embedded nut post for safety mechanism and vertical locking

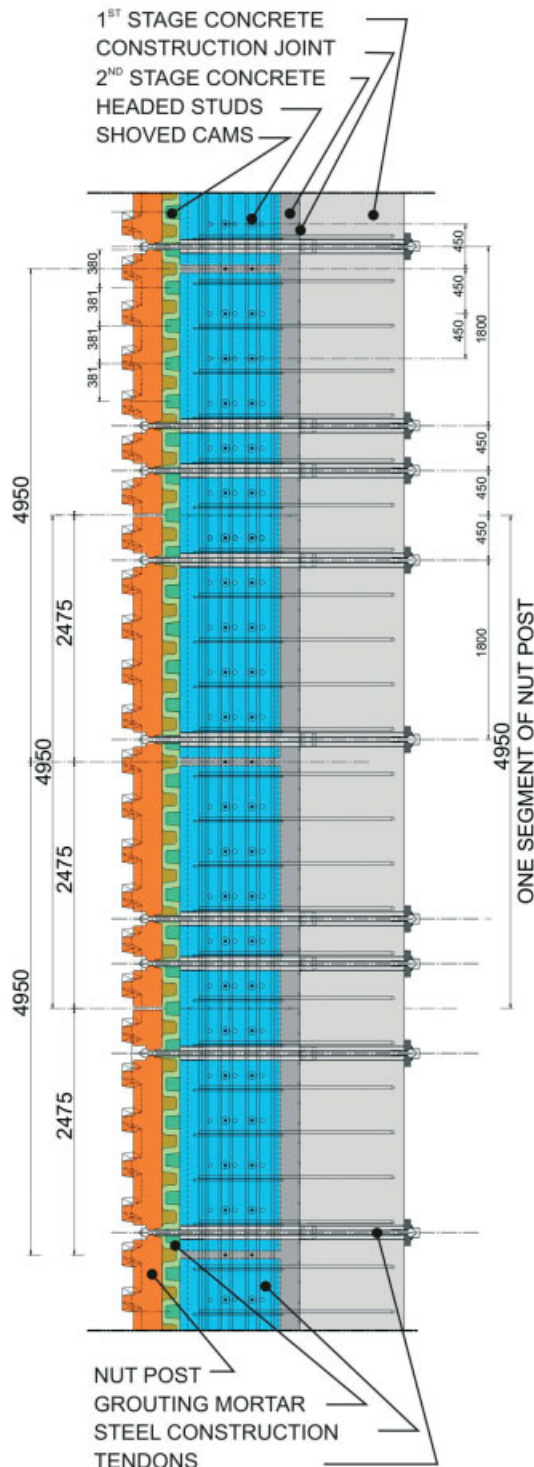


Fig. 12. Nut post, vertical section

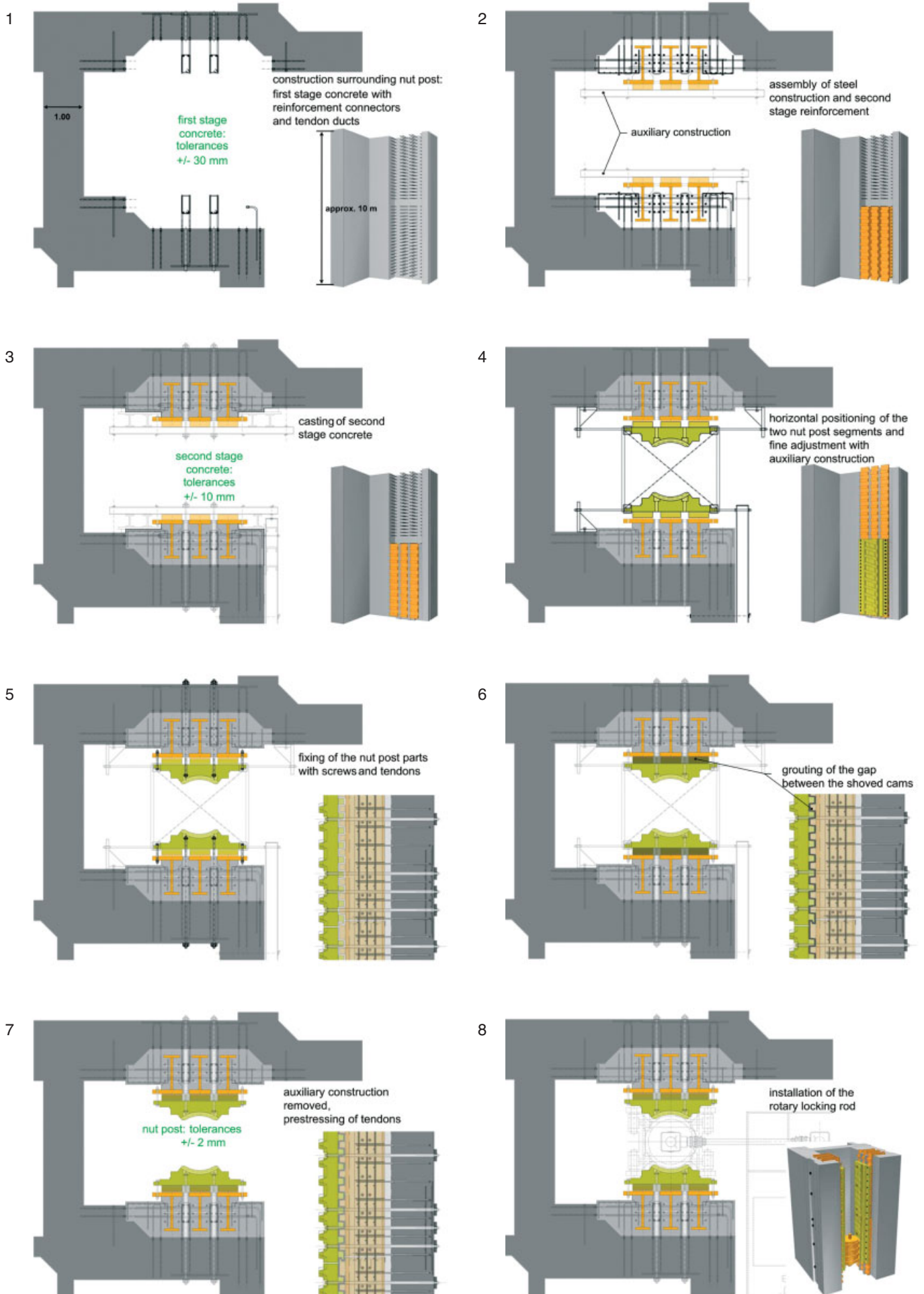


Fig. 13. Nut post erection procedure

are made of GS 25 CrNiMo 4 V cast steel, hardened and tempered in accordance with DIN EN 10083, and have a thread pitch of 450 mm. The four rotary locking rods are made of 42 CrMo 4 V steel, hardened and tempered; they are connected to the ship chamber by hinged columns. They have four thread turns, a height of 1.8 m and an external diameter of 1535 mm.

During normal operation the rotary locking rod rotates freely due to a coupled system of synchronized shafts. The force in the pinion is constantly monitored. The load on the pinion corresponds to the force in the vertical spring, in accordance with the lever principle. If the pinion force increases due to water loss (for example) and reaches the switching point (approx. 1600 kN), chamber movement will be stopped. If the load continues to increase, the prestressing force of the vertical spring will be exceeded (approx. 1650 kN). The pinion will then begin to deflect, preventing the drives and the rotary locking rod from rotating. During the deflection of the pinion, the force in the pinion increases further, up to approx. 2000 kN depending on the characteristics of the spring. Rotation of the pinions is prevented by the stopping brakes. Once the gap between the rotary locking rod and nut post has closed so that traction is achieved, any further load increases will mainly be transferred into the nut post by the safety mechanism.

The maximum design load for the safety mechanism is reached in the case of a ship chamber that is empty due to maintenance and simultaneous unplanned filling of the ship chamber basement with water. In this case the ship chamber is subjected to strong buoyancy with an upward force of up to 123 000 kN that must be resisted by the four safety mechanisms. During normal maintenance, the force on the nut posts will be up to 87 000 kN (upwards). In the case of a sunken ship, the additional load will be 30 000 kN (downwards).

6 Embedded parts

It is necessary to connect mechanical parts to the reinforced concrete structure at three main places:

- the toothed rack (cast steel) of the drive with rails on the sides for transverse guiding,
- the sliding plates for longitudinal guiding, and
- the nut posts of the safety mechanism.

The fitting and operation of the drive and the guiding and safety mechanisms place great demands on the construction tolerances for these components. The usual dimensional tolerances for buildings or civil engineering structures must be adjusted to meet mechanical engineering requirements. The expected tolerances for the reinforced concrete construction in the range of ± 40 mm were reduced to values of ± 2 mm (as required for the mechanical parts) by means of a construction procedure with first- and second-stage concrete as well as high-strength grouting between the steel substructure and the cast mechanical components.

6.1 Mounting of the nut post

The construction procedure is explained below using the nut post as an example (Figs. 11, 12 and 13).

1. Construction of the reinforced concrete towers
During construction, the four towers with concrete walls that are normally 1.0 m thick (C25/30) are adjusted in accordance with the predicted deformations due to creep and shrinkage. Reinforcement splices and ducts for later prestressed tendons of grade St 950/1050 are provided. An accuracy of ± 30 mm is expected here.
2. Embedding of steel substructure in second-stage concrete
Embedded steel parts of grade Q 345 D are installed using positioning devices. These embedded parts transfer their loads via headed studs evenly distributed over the height. Between these, connecting rods are installed and the gaps are filled with second-stage concrete. This reduces the tolerances to ± 10 mm.
3. Fitting the nut post cast elements
In a last step to achieve a tolerance ± 2 mm, the cast sections of the nut post, each of which is 4.95 m long, are fixed to the embedded steel parts using fit-up aids. Both the embedded parts and the nut post have horizontal shoved cams at intervals of 381 mm which are mounted in such a way that they interlock with a gap of 50 mm between them. Fine adjustment is carried out by means of M30 grade 10.9 bolts. The gap is filled with a high-strength, low-shrinkage, low-expansion mortar so that force transmission is possible. Finally, the nut post sections are secured to the concrete structure by prestressed tendons.

6.2 Grouting mortar investigations

In the 'buoyancy' loading case (see above), an upward load of up to 15 400 kN may occur on each half of a nut post. For the individual cast elements, i. e. for each half of a nut post, it was shown that the most unfavourable loading point is at the lower end of the section (Fig. 15). In this case, approx. 70 % of the force is borne by the last tooth of the thread.

This loading case has been investigated in detail using FEM calculations with non-linear constitutive equations for the grouted mortar (Fig. 14) and spring elements that take into account the friction between the mortar and the steel, including spring failure in the case of tensile strain. Here, it was observed that due to the high stiffness of the mortar, force transfer through the mortar primarily takes place via only a few shoved cams in the vicinity of the loading point. Furthermore, a horizontal load component results from the friction between the inclined thread of the rotary locking rod and the nut post (friction coefficients of up to $\mu = 0.2$) and this tries to 'peel' the nut post away from the embedded part (Fig. 15). However, it has been shown that the forces do not reach the strength of the mortar (> 90 MPa after 28 days).

To validate this system, a special testing programme was developed for CTGPC that investigates both the handling and the loadbearing capacity of the grouting (Fig. 16). Vertical grouting over a height of more than 4 m was a new challenge even for the manufacturers of such mortars. The tests showed that it is not necessary to install the mortar in layers as originally planned. Adequate distribution of the

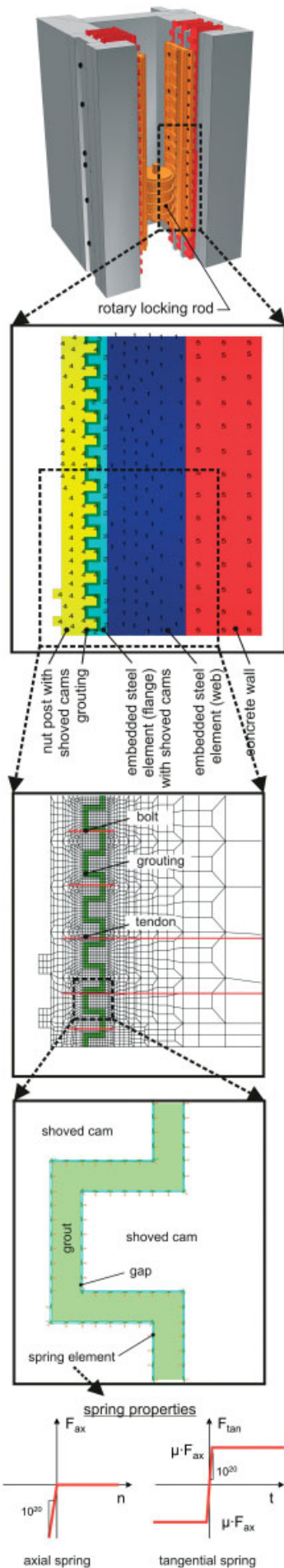


Fig. 14. Non-linear FEM calculation for mortar grouting between embedded steel element and nut post

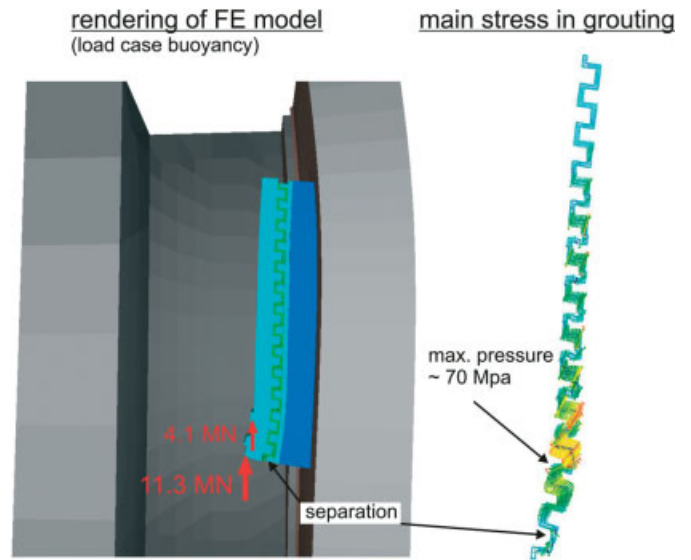


Fig. 15. Results of FEM calculation for mortar grouting

mortar is ensured by designing the grouting channel with a central duct to distribute the mortar, which is injected from below, in conjunction with the chosen distance between the block dowels. Grouting from below prevents separation of the mortar. The only prerequisite is that the construction must be designed for the higher injection pressure. However, this also speeds up the construction process significantly.

This form of jointing using grouted mortar, which is well known from bridge supports, machine foundations in

Table 2. Project Partners

| | |
|---|---|
| Owner/operator works planning/construction | China Three Gorges Project Corporation, Yichang, China |
| General planning/project management | Joint venture: Krebs & Kiefer International/Lahmeyer International |
| Design of RC towers | Lahmeyer International, Bad Vilbel |
| Structural design: RC towers, ship chamber, earthquakes, embedded parts | Krebs & Kiefer, Karlsruhe |
| Design of longitudinal guiding system, ropes, counterweights, chamber gates | IRS – Ingenieurbüro Rapsch & Schubert, Würzburg |
| Design of ship chamber, drive, transverse guiding system, locking mechanism | SBE – Spezialbau Engineering, Magdeburg |
| Design of electrical equipment | DriveCon, Dettelbach |
| Validation of design, computational fluid dynamics, | Germanischer Lloyd, Hamburg |
| Grouting mortar test programme | Krebs & Kiefer Karlsruhe/MPA (Materials Testing Institute), University of Karlsruhe |
| Advice to the owner | BAW – Federal Waterways Engineering & Research Institute, Karlsruhe |

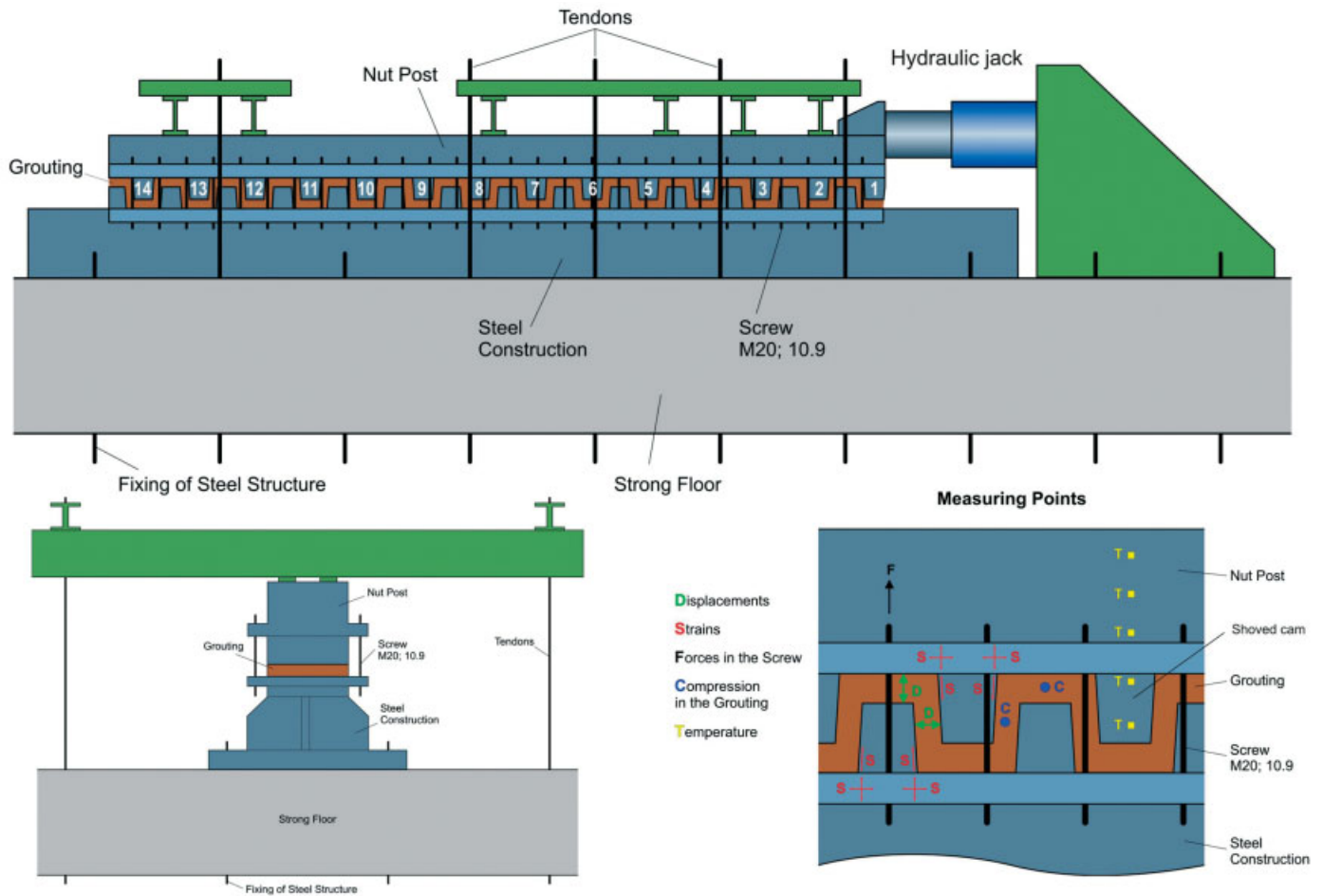


Fig. 16. Testing setup for mortar grouting

plant engineering [4] or point fittings in glass structures, for example, is therefore a worthwhile alternative, not only for load transfers from steel to concrete but also from steel to steel.

7 Acknowledgements

The Three Gorges ship lift is a structure that is not only unusual in its purpose, but also in its components. With its enormous dimensions and complex engineering solutions, the ship chamber effectively represents a ‘moveable building’!

A project on this scale can only be successfully realized with the full cooperation of all those involved, not only within the contractor’s general planning team but also on the client side and from external advisers. Many consultancies and institutions (Tab. 2) share responsibility for the design presented here and for many of the details shown. The authors would like to take this opportunity to express their gratitude to all those concerned for their excellent cooperation. We would especially like to thank the owner, China Three Gorges Project Corporation, for its confidence and for its constant promotion of the project. The planning of the work and the construction process will take place under the direction of CTGPC.

In particular, we are deeply indebted to Prof. Dr.-Ing. *Albert Krebs*, who initiated our participation in this challenging project and actively supported the team with the experience gained during his long and successful career in civil engineering.

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Keywords: ship lift; hydraulic steel construction; embedded parts; mortar grouting

Authors:

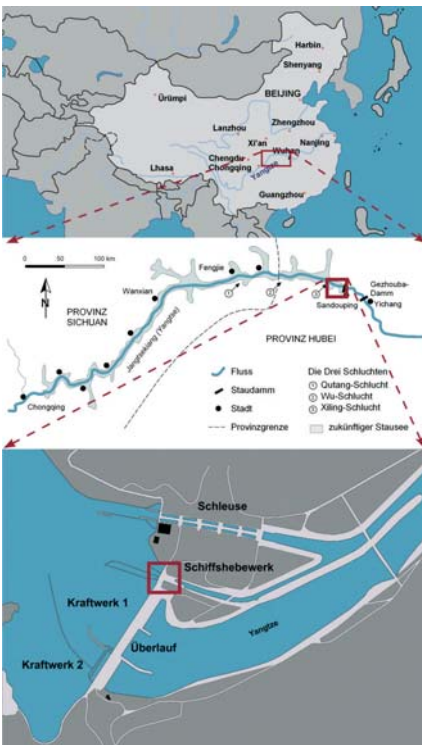
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Shiplift at the Three Gorges dam in China



Visualisation of the overall project with marking of the planned ship lift

The Three Gorges Hydropower project at the Yangtze river is the largest hydro-power project in the world, featuring 26 Francis turbines each with 700 MW installed capacity. The power station will generate ca. 85 TWh of electricity per year. To allow ships to overcome the height difference of 113 m, there is a two-lane chain of locks consisting of five lock chambers, and in future there will also be a vertical ship lift based on the counterweight principle.



Geographical location of the ship lift at the Three-Gorges-Dam at the river Yangtze



Cruising on the river Yangtze

In May 2004 the „German Design Group“, a German Joint Venture incorporating the two companies Krebs und Kiefer International and Lahmeyer International has been entrusted with the design and technical specifications for the ship lift.

Mainly for reasons of operational safety, the Chinese Government decided in 2003 in favour of a ship lift with a pinion drive and a safety mechanism combined of rotary Archimedean screw and nut post, and against a rope winch system, which had been implemented in the PR of China before. This decision was based on a feasibility study by the German Federal Waterways and Research Institute,



Upper lock access with view into the lock chamber of the double lock

Owner / Client

China Yangtze Three Gorges Project Corporation

Construction period

1993 - 2013

Project data

- Maximum dimensions of structure (L/B/H):
119,0 m / 57,8 m / 169,0 m
- Maximum dimensions of chamber (L/B/H):
132,0 m / 23,0 m / 11,5 m
- Maximum / minimum lift height: 113,0 / 71,2 m
- Maximum water level differences:
 - Upstream: 30,0 m
 - Downstream: 11,8 m
- Maximum water level fluctuations: 0,5 m/h
- Effective length / - width / - height:
120,0 m / 18,0 m / 18,0 m
- Maximum service load: 3.000 t
- Overall chamber weight: 16.000 t
- Movable mass: 34.000 t
- Maximum journey time (without drive-in and -out): 21 min.
- Operations / day:
18 ascents and descents

Shiplift at the Three Gorges dam in China

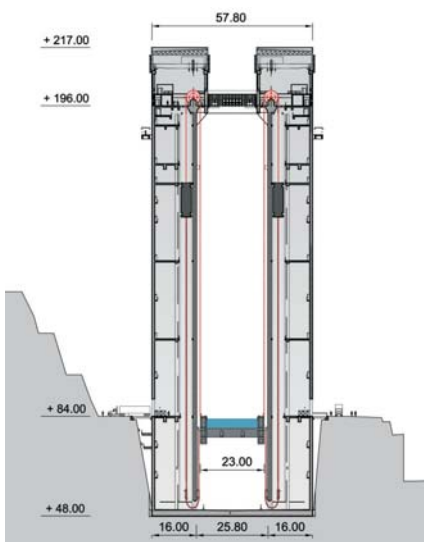


Overview of the overall construction with marking of the contours of the ship lift in 2004

which was prepared by Krebs und Kiefer in cooperation with Spezialbau Engineering and Germanischer Lloyd.

The ship lift in the Three Gorges Project has special constructional characteristics that are significantly different from those of all known ship lifts build up to now:

- The maximum lifting height of 113 m is around three times that of German ship lifts
- The chamber dimensions and therefore the weights to be moved using the counterweight principle (ca. 34.000 t) are greater than in any ship lifts built up to now



Cross section

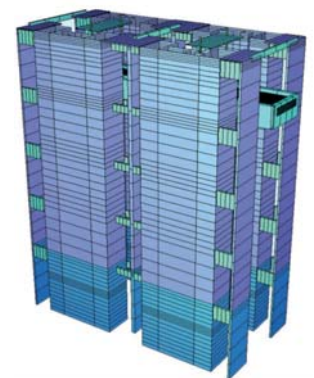
- As part of an enormous dam complex the ship lift is subject to short term operational water level fluctuations of up to 50 cm per hour on the downstream side
- Hydrological water level fluctuations of 30 m on the upstream side and 11,8 m on the downstream side require special construction measures at the upper and lower bays
- Since the ship lift is primarily for use by passenger ships, particularly high safety standards are required
- The ship lift design incorporates earthquake loads of Zone VI of the Mercalli scale according to the Chinese earthquake norms for hydraulic structures. In addition to the loads resulting from moving masses, information about the height of the waves in the chamber is significant in order to be able to judge whether water can slosh out of the chamber.

The transition structure to which the ship lift will be connected at the upstream side have already been completed. The construction pit for the ship lift is excavated and the slope support has been installed.

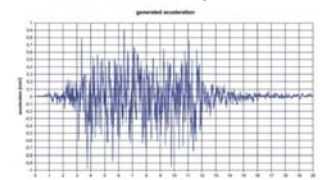
Therefore, construction of the ship lift can commence immediately after tender design has been completed and the respective supply and construction contracts have been awarded. The Chinese owners expect to put the ship lift, the world's largest at that date, into operation in 2013/2014.

Krebs und Kiefer services

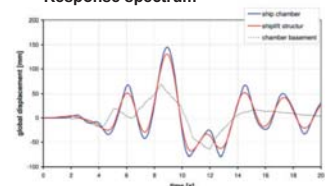
- 1999 - 2000: Feasibility study
- 2004 - 2008: General layout, intermediate and final design in Joint Venture with Lahmeyer International



Generated time-history



Response spectrum



Earthquake analysis on a 3d-model



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