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Potsdamer Platz: Steel Fibre Concrete for Underwater Concrete Slabs

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Summary

For the erection of a new multifunctional town centre in the heart of Berlin, in the area of Potsdamer Platz, the construction of deep building pits becomes necessary. As, due to environmental protection requirements, sealing injection layers can not be carried out for the deeper parts of these building pits, back anchored underwater slabs have to be constructed. In order to increase the overall safety of these slabs, steel fibre instead of plain concrete was used. This paper gives a short description of the tests carried out concerning the load carrying and deformation behaviour and of the site tests carried out for the erection of these slabs.

1. General

One of the first major construction measures in Berlin after the reunification is the development of the „Potsdamer Platz“ by Daimler Benz. In the former border area between the western and eastern part of the city, this building project has total dimensions of 560 m length and beween 100 and 270 m width.

This building project, with foundation depths between 9 and 18 m, has to be founded in the ground-water, which has a level approximately 2 to 3 m below the surface. At the same time a connection between this building project and a new regional railway station is planned. This station has a foundation depth of up to 21 m, resulting in a water maximum pressure on the foundation slab of 180 kN/m^2.

Not only the building project discussed here, but all other building projects in the „Central Region“ of Berlin have to be erected in the ground-water. It has to be mentioned here, that Berlin gets it drinking water from this ground-water reservoir and therefore any encroachment into the fragile ground-water balance has to be avoided. For this reason any ground-water lowering must, on principle be excluded. In general, the follwoing construction principles for the erection of deep building pits can be used (Fig. 1).

- The building pit walls reach into a deep, naturally sealing soil layer.
- Building pit walls in connection with a deep-laying injected soil layer which has to be arranged in such a depth that the dead soil weight compensates the water pressure with sufficient safety.
- Building pit walls in connection with an underwater concrete slab, anchored against the water pressure with tension piles in the underlying soil (wall/slab system).

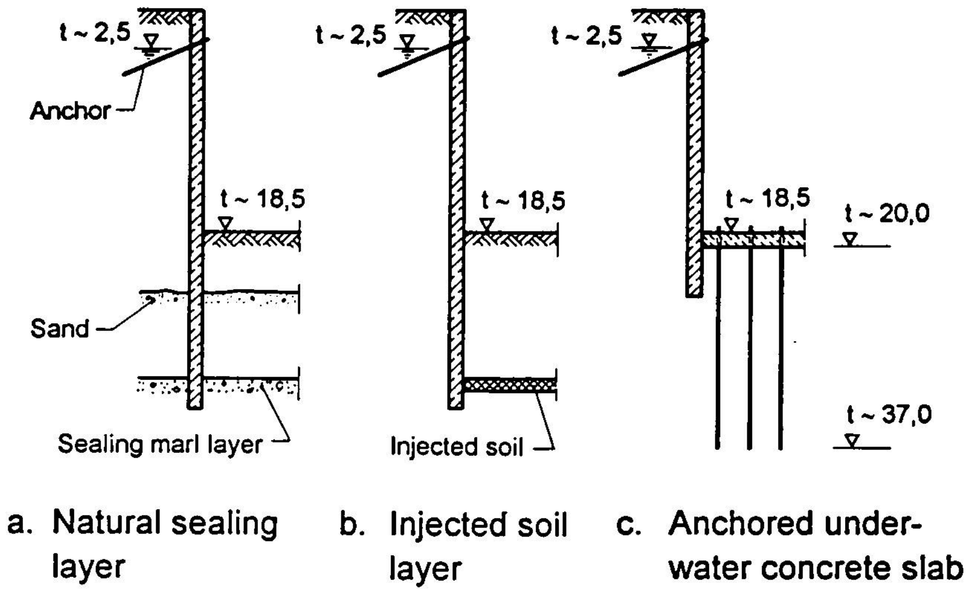

Fig. 1: Construction principles for deep building pits

The first two construction methods presented here, can, as the geological preconditions are not fulfilled, normally not be carried out. Furthermore, the deep building pit walls would interfere considerably with the ground-water flow. Therefore, this construction method can only be applied for those parts of the building pit with a depth of up to 14 m. The advantage of this method is that the excavation can be carried out in a dry building pit.

For greater depths only the so called wall/slab system can be used. This paper deals with new technologies and developments applied in the construction of the deepest parts of the building pits, where steel-fibre concrete was used on a large scale for the first time.

2. Wall/Slab System

According to Fig. 2c the construction of the building pit comprises the following steps.

- Driving of the sheet piling or construction of the slotted walls
- Excavation of the building pit to the ground water level and setting of the anchors
- Further underwater excavation down to the required level
- Driving of the tension piles from a pontoon, in this case steel profiles as vibration injected piles
- Concreting of the underwater concrete slab
- Pumping out of the building pit, after hardening of the underwater concrete slab
- If necessary, local defects have to be sealed by injections

The task of this underwater concrete slab, in connection with the tension piles, is to secure the overall stability as well as the water tightness of the building pit.

3. Steel Fibre Reinforced Concret Slabs

Normally the verification of such an underwater concrete slab is based on a simple computational model. It is assumed, that the external loading is carried by spatial arches within the slab towards the anchoring points of the tension piles, whereas the resulting horizontal force is balanced by the

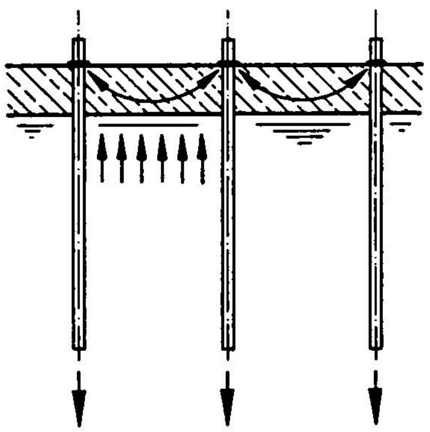

Fig. 2: Simple computational model for the verification of underwater slabs

external earth and water pressure on the surrounding walls. These anchoring points are normally considered to be fixed (Fig. 2).

Such a simple computational model is under normal circumstances sufficient for the successful erection of underwater slabs in smaller, straight building pits. For large area building pits with irregular shapes and misalignments within the slab, it has to be assumed and was shown by calculations that bending moments within the slab due, to a different load deformation behaviour of 2,000 piles, water pressure and the external normal force are unavoidable. Therefore, it was intended to avoid the brittle behaviour of a plain concrete slab and to obtain a robust and ductile construction, using steel fibre concrete.

3.1 Tests on Plain and Steel Fibre Reinforced Concrete Slabs

In order to carry out additional laboratory tests on larger scale test specimens, funds were made available by the client in order to examine the load carrying and deformation behaviour of these slabs. These tests were carried out at the iBMB laboratory on one plain and two steel fibre reinforced slabs with dimensions of 3 • 3 m and a thickness of 28 cm. One important feature of these tests, the simulation of an evenly distributed high water pressure was realized with the simple but reliable concept of a layer of cork plates underneath the test specimen. The load was applied by 9 hydraulic jacks as indicated in Fig. 3. For the first fibre reinforced slab the fibre content was 60 kg/m^3 DRAMIX 60/0.8 and for the second 40 kg/m^3 DRAMIX 50/0.6.

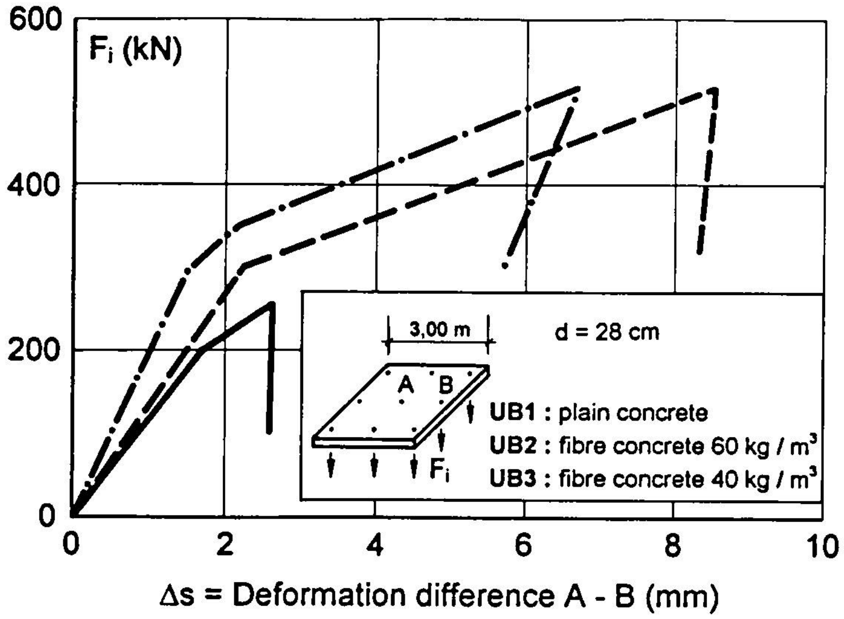

Fig. 3: Results of test loading - plates with plain and steel fibre concrete

The test results (Fig. 3) can be summarized as follows. The ultimate load bearing capacity of the plain concrete slab was reached by exceeding the conrete tensile strength. At this point, an unannounced and sudden brittle failure occured, the slab broke up into several pieces (Fig. 4). In comparison to this failure mode, the fibre reinforced slabs showed an entirely different behaviour. It can be seen from Fig. 3 that in comparison to the plain concrete slab, the ultimate load bearing capacity of the steel fibre reinforced slabs was more than doubled.

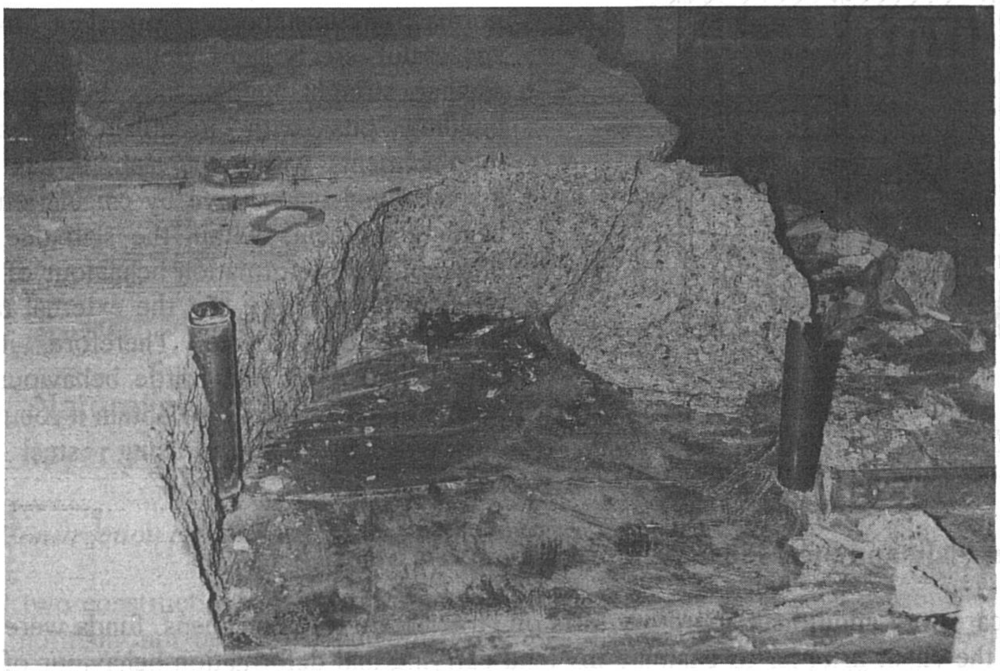

Fig. 4: Remains of the plain concrete slabs after failure

One other important aspect is the high deformability of the steel fibre reinforced slabs. It can be seen from Fig. 3 that the deformation of these slabs reached during the test is 3 to 4 times larger compared to those of the plain concrete slab. This means that steel fibre reinforced concrete slabs show an extremely ductile deformation behaviour which - as different deformations due to ground movements in such a large building pit can not be excluded - will add to the overall safety and reduces or even excludes the risk of a sudden failure.

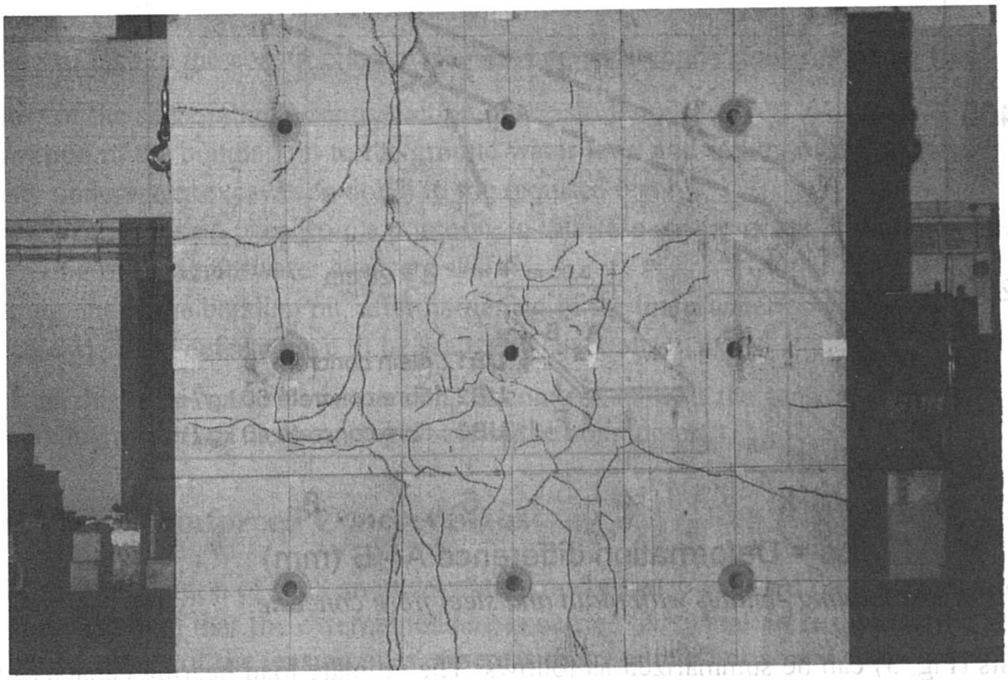

Fig. 5: Specimen with steel fibre content of 40 kg/m³ concrete

These results showed clearly, that steel fibre reinforced concrete slabs have an inherent additional redundancy and therefore possess a higher degree of performance safety. The fibre reinforced slabs did not break into several pieces, in contrary, they could be lifted as a whole from the test floor. One of the fibre reinforced test slabs can be seen in Fig. 5, were the yield lines are clearly recognizable. From this yield line pattern a simple model was developed for the dimensioning of these slabs.

4. Large Scale Tests on the Building Site

Under German building regulations, building materials which are not covered by normal buildung standards and/or codes have to be obtain a special permission. This ensures that the new building material or method conforms with existing standards. In this context, it had to be proven in a large scale test under building site conditions that the following conditons could be met:

- Pumping of steel fibre concrete over long distances
- Concrete hardening and compacting under water
- Aggregate and fibre distribution over the cross-section
- Enclosure of the pile-heads
- Low heat of hydratation.

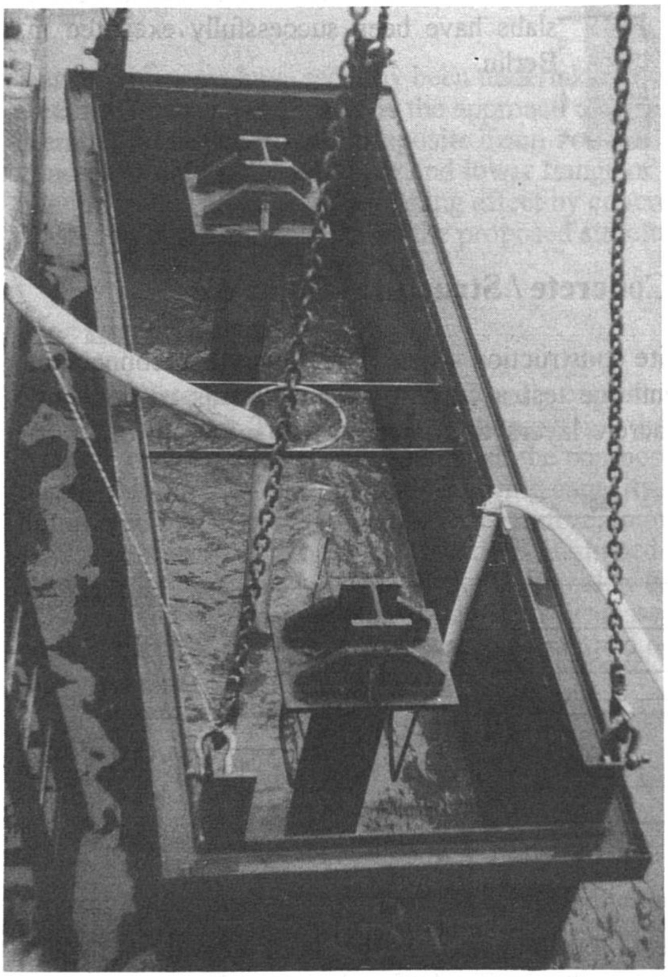

Fig. 6: Steel container with two pile heads

These additional tests were carried out by a test concreting with different concrete mixes into steel containers. Fig. 6 shows the steel container of one test specimen prior to lowering into the building pit. The cross-section of these containers was 1.2 • 1.2 m with a total length of 4.0 m.

A total of 6 underwater concreting tests, together with 4 additional pumping tests, had to be carried out. The six underwater concreting tests were necessary as - even though the concrete mixes were based on extensive preliminary laboratory tests with regard to the concrete properties, composistion and slump - some of the first mixes showed an extremely high retarding time. Even if these concretes reached their intended strength (C 20/25) in the end, such an unpredictable behaviour could not be to tolerated. Therefore, these test proved to be really valuable, as they showed the behaviour of the different concrete mixes under building site conditions in comparison to defined laboratory conditions. In order to prove, that the heads of the tension piles were totally enclosed by the steel fibre concrete and, additionally, that there was an even steel fibre distribution over the cross section, the test specimen had to be cut through the pile head.

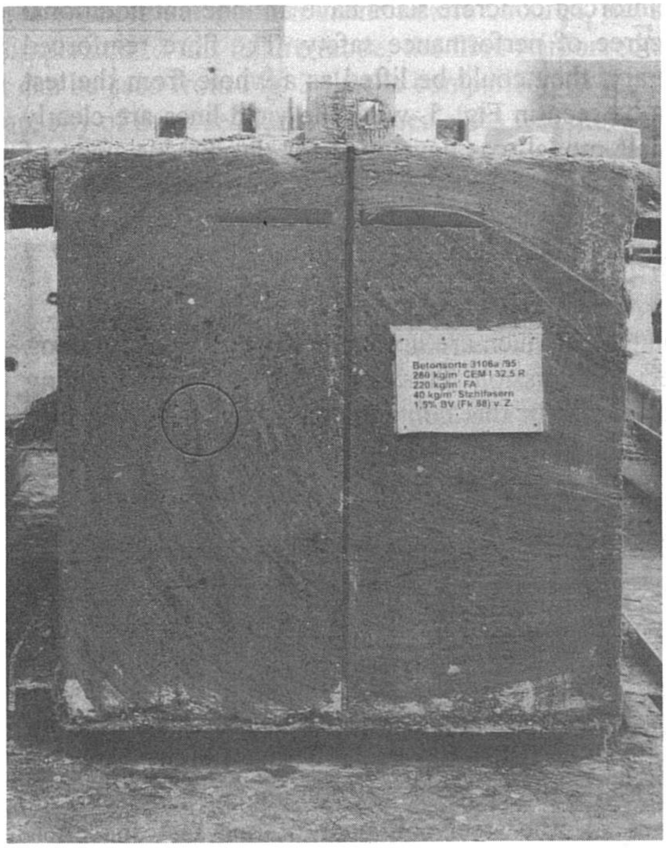

Fig. 7: Cross-section of a test specimen

Fig. 7 shows the cross section through such a test specimen which was cut with a diamond saw. The close inspection showed, that the pile head was properly enclosed by the steel fibre concrete, an even fibre distribution over the cross section can be achieved and no disintegration of the concrete structure did occur.

The laboratory tests and the concreting tests on the building site showed that all required preconditions set for the special approval could be met. Therefore, it was finally decided to use this new technology for the deep building pits at the Potsdamer Platz.

In the meantime more than 40,000 m^2 of underwater steel fibre reinforced concrete slabs have been successfully executed in Berlin.

5. Composite Behaviour - Steel Fibre Concrete / Structural Concrete

In order to examine the behaviour of a composite construction - steel fibre concrete in connection with the overlaying structural concrete - a tentative test according to Fig. 8 was carried out. During the test the joint between the two concrete layers was injected with water in order to simulate the later water pressure.

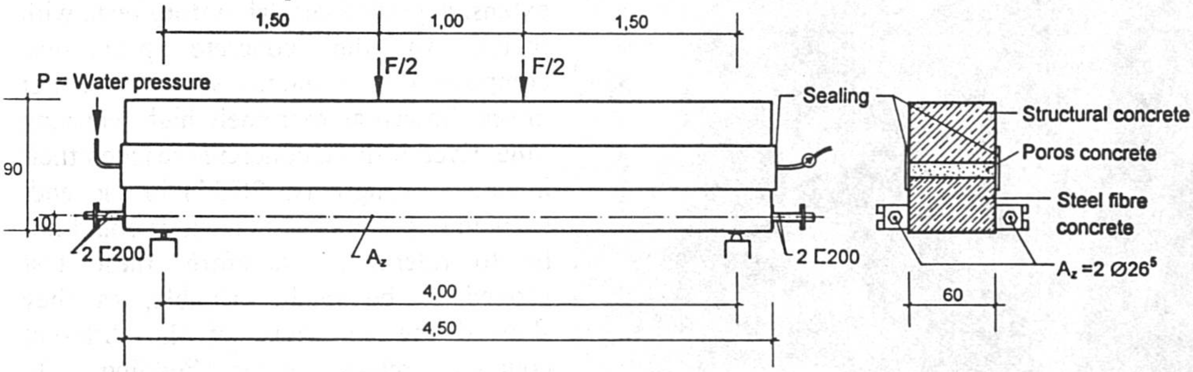

Fig. 8: Composite beam test set-up

The test results can not be discussed here in detail, but they showed that both parts of the beam act more or less monolithically together and that the ultimate load of such composite construction is close to that of a monolithical beam. This means, that the consideration of such a composite behaviour in the actual design would lead to a more economical construction due to a reduction in the overall thickness and a reduction in excavation work.