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XI

Local Unexpected Settlements on the Multy-Storey Structure SAB in Berlin

Tassements locaux imprévus de la superstructure SAB à Berlin

Unerwartete örtliche Setzungen bei der Überbauung SAB in Berlin

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SUMMARY
In West-Berlin for a stretch of about 600 m, the structure of a 15-storey building with two highway tunnels passing through has been completed in summer 1980. Local unexpected settlements required special treatments for the soil and the structure itself. By means of grouting the soil with cement injections the settlements could be stopped and by means of high pressure (soil fraction) a 150 MN heavy part of the structure was lifted. The structural response to the settlements has been treated theoretically and by field measurements.

RESUME
A Berlin-Ouest, l'autoroute a été recouverte sur une longueur de près de 600 m par 7 immeubles d'une hauteur de 15 étages. A la suite de tassements imprévus du terrain pour 2 des 7 immeubles, il a fallu prendre des mesures relatives au sol et à la superstructure. Des injections de ciment ont permis d'arréter les tassements du sol et de lever les immeubles de quelques millimètres. Le comportement de la construction a été étudié théoriquement et également mesuré.

ZUSAMMENFASSUNG
In West-Berlin wurde auf nahezu 600 m Länge die Stadtautobahn mit 7 Wohnblöcken mit Höhen bis zu 15 Stockwerken überbaut. Der Verkehr fliesst in 2 Tunnelröhren darunter hindurch. Unerwartet grosse und sprunghaft eingetretene Setzungen bei zwei von den insgesamt sieben Wohnblöcken erforderten zusätzliche Massnahmen für den Boden und die Überbauung. Durch Zementinjektionen im Boden konnten die Setzungen gestoppt und ein ca. 150 MN schwerer Teilabschnitt der Überbaukonstruktion mit einem Druck von 25 bar um einige Millimeter angehoben werden (soil fraction). Das Bauwerksverhalten unter den extremen Setzungsdifferenzen wurde rechnerisch und durch Messungen am Bauwerk untersucht.

1. General

In spring of 1980 as part of the city-freeway of West-Berlin two 600 meter tunnels were opened for traffic. The unique situation of this first project in Europe is that seven residential blocks, 46 meter high, with 15 levels and more than 1000 apartments rise above the autobahn-structure. The model fig. 1 gives an overall view of the housing project and the tunnel entrance.

This report deals with unexpected settlements in 2 of the 7 apartment-blocks where the absolute and the relative settlements started to increase after the structure itself was almost completed. With special methods, called soil-fraction, the settlements could be stopped while various measurements and treatments had to be given to the structure in order to learn which biggest differential settlements could be allowed without damaging the stiff wall-frames.

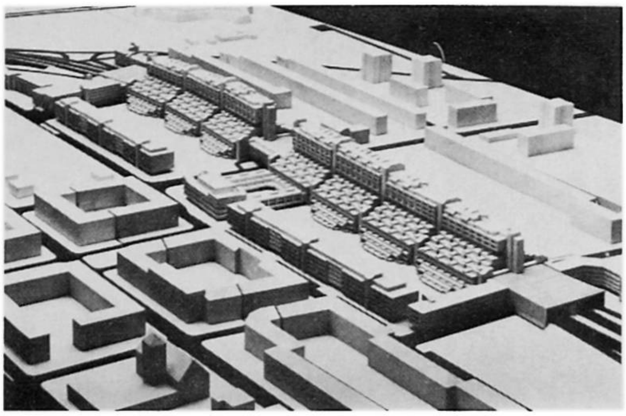

Fig. 1 Model of the SAB-Project

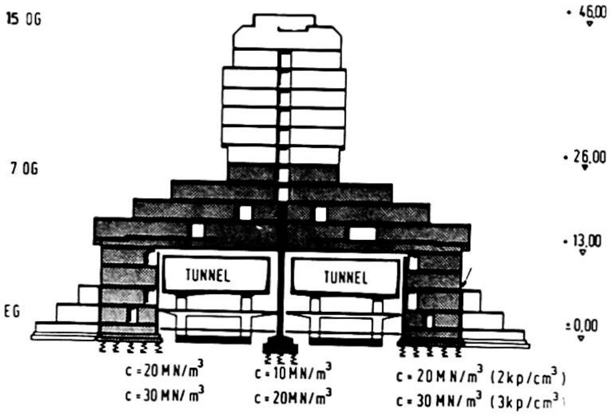

Fig. 2 Cross-section, foundation-moduli

2. Description of the Structure

The structure of the multy-storey apartment complex consists altogether of 77 three legged stiff wall-frames carrying a total load of 35 000 kN. Fig. 2 gives a cross-section of the housing structure. According to soil expertise the foundation mainly consists of sand and partly of loamy soil. The unsuitable soil at the top level was replaced by 1 to 2 m of sand. With this material exchange the soil condition could be represented by foundation moduli using upper and lower bounds over the total length of the structure. The figure also gives a view of the tunnels and the parkdecks.

The governing influence for the stiff wall-frames is the differential settlement of the soil.For estimating actual frame performance and the stresses,three loading conditions were selected and checked by different approaches. The frame, made up of plate-like elements was calculated on a finite element approach. It was also analysed by frame analysis and by linear theory. The influence of openings in walls on the deformation behaviour of the frame was checked by model analysis on a Plexiglass model.

The comparisons showed that the variation in action forces was small - 3 % to 6 %, the most critical forces being tension in the beams and compression in the outer joints of the frame.

Detailed calculation showed that, depending on the structural stiffness in the various stages of construction, the stiffness of the soil has different influences on the distribution of reactions in the frame.

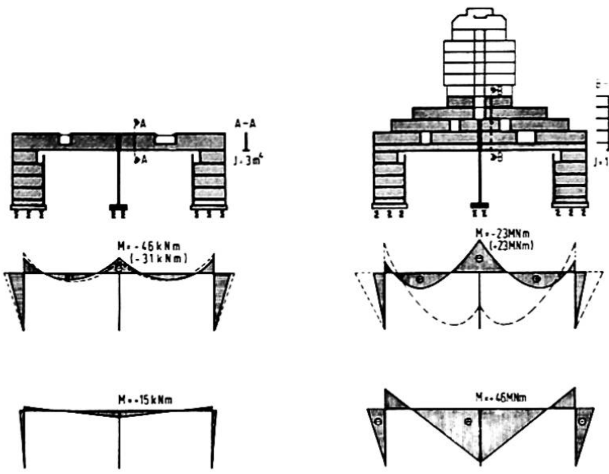

Fig. 3 Influence of elastic supports on frame action forces

Figure 3 shows that in the early stage when the strut only consisted of one storey, moments assuming rigid supports amounted to only 30 % of those assuming elastic supports. However, during the final stage when the structural stiffness of the frame was enlarged by a factor of about 50 there was a tremendously increased influence of differential settlements between the outer and the inner supports as shown on the right hand side of the figure. It may be mentioned that this relation is only valid for a completely elastical behaviour of the structure. [1, 2, 3]

3. Unexpected settlements in 2 blocks in the centre of the structure

In order to compare the design assumptions with the real structural behaviour field measurements were made for this comparison. There was a good accordance between field measurements and calculated values during construction. However, in the winter of 1978 to 1979, when construction was stopped due to cold weather condition, unexpected large non-linear settlements and differential settlements between inner and outer supports required special treatments for the structure.

First it could not be explained why these untypical and non-linear settlements developed. However, when additional deep soil controls down to 20 meters were made, it was found that the soil in this depth was soft and porous and therefore not any longer comparable with the data of the soil expertise given at the beginning of construction. From this a series of questions arose:

- What will be overall settlement and what will the differential settlement be between inner and outer supports?

- What will the reaction of the stiff wall frames due to differential settlements be and what can be done to avoid damage to the structure?

- One of the most important questions was the speed of settlements because the reduction of action forces in the structure due to creep and relaxation is mainly influenced by the speed of the settlement?

- What treatments could be used in order to stop the settlements as fast as possible and which were the possibilities to inverse differential settlements?

4. Treatments for the soil and the structure

Figure 4 shows the soil condition over the whole length of the structure and also the absolute and differential settlements of the 7 blocks. Evident is the untypical settlement in the centre part of the housing structure. Extensive investigations yielded in the decision to treat the soil and structure as follows:

4.1 Treatments for the soil

- Construction of pile walls on both sides of the centre foundation.
- Injection of the non-dense layers with cement mortar in order to reduce settlements.
- Injection of cement mortar under high pressure - called 'soil fraction method' - reducing extreme settlements to permissible values by lifting the foundation. From figure 5 the main steps and the concept of the soil fraction method can be observed.

4.2 Measurements on the structure

- Measurements of concrete deformation in extreme zones of tension and compression.
- Strain measurements on cast-in rebars in zones of high compression.
- Permanent observation of crack formation and crack width variation.

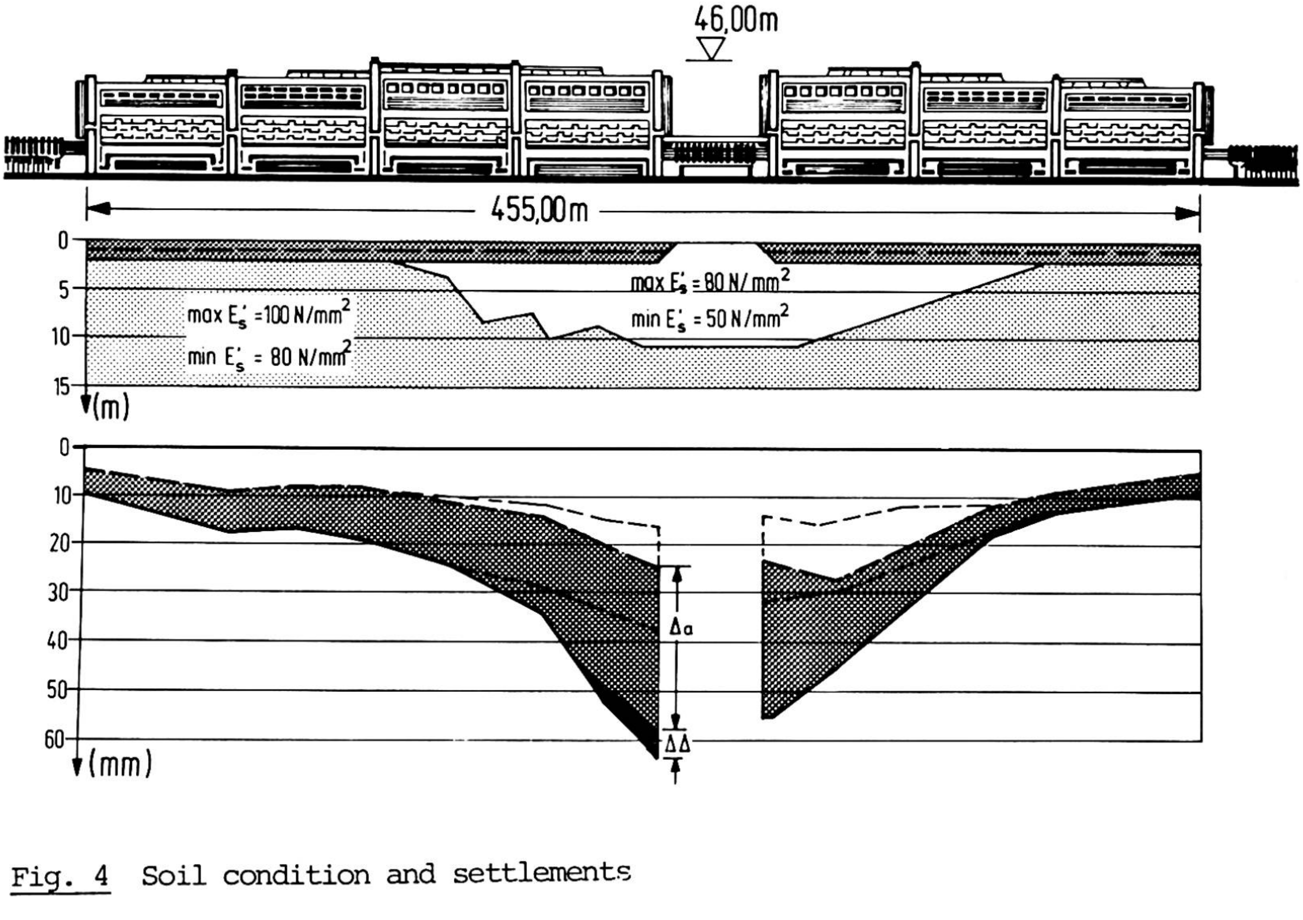

Fig. 4 Soil condition and settlements

4.3 Treatments for the structure

- Laboratory investigations to define the actual concrete tensile and compressive strength, the moduli of elasticity, and the behaviour of the concrete with respect to creep and relaxation. Figure 6 shows the development of restraint actions due to creep and relaxation under sudden and slow settlements assuming various conditions of the structure.[4]
- Theoretical calculations to define the permissible maximum deformation of the stiff wall frames taking into consideration the influence of bending, shear, of the cracked state II, as well as deformations due to creep and the reduction of actions due to relaxation. [5]
- Temporary installation of latteral props in walls to avoid instability.

5. Differential settlements and reactions in the frame

Reinforced concrete walls are generally very sensitive to differential settlements. Figure 7 gives possible responses of the structure to the actual measured settlements. In the uncracked elastic structure only a few millimeters of differential settlement would theoretically unload the centre support completely. The contribution of shear and a cracked state II increases the deformability by more than 200 %. However, the main effect will be gained by creep. Line cc represents the influence of creep established by laboratory tests. The main reason why it can be assumed that the reaction in the structure due to the settlement will follow the line of cc is based on the fact that the speed of the settlement being observed within two years corresponds more or less to the creep capability of the concrete used.

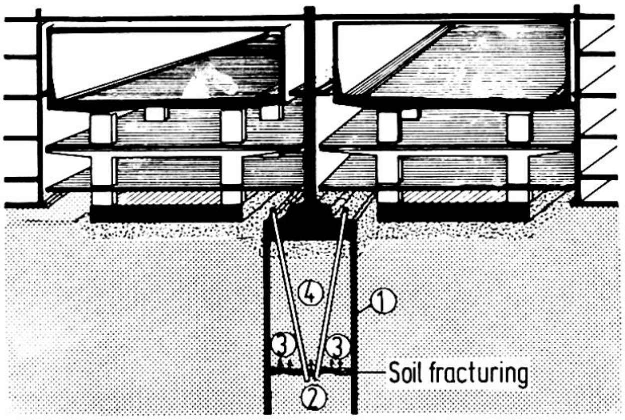

Fig. 5 Cement injection - soil fraction method

It was possible to stop the settlements in the region of the centre foundation with the method of soil fraction. The main question to be

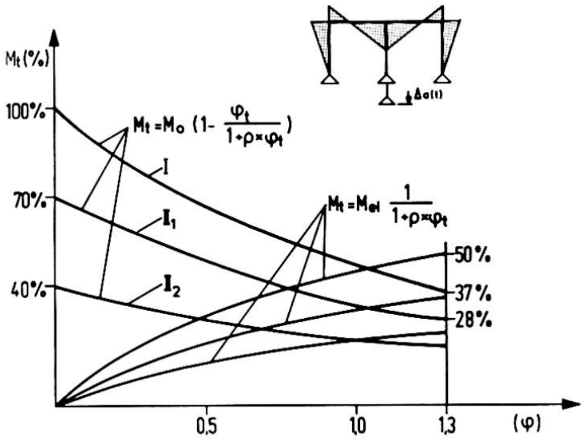

Fig. 6 Restraint forces due to settlements

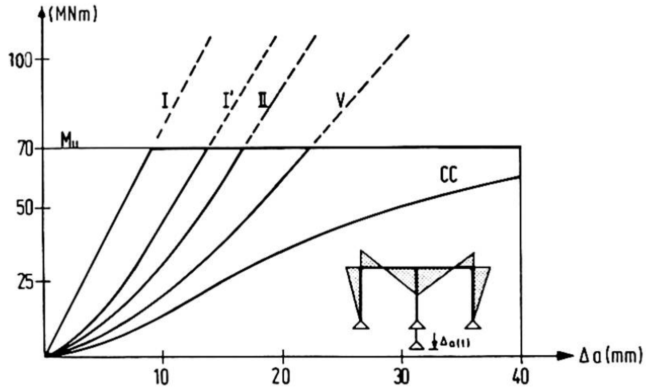

Fig. 7 Structural responses to settlements

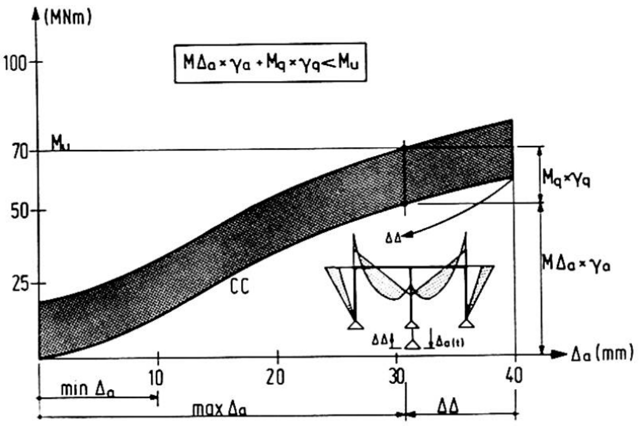

Fig. 8 Action forces to settlements and loads

answered is, how the required safety will be reached. In figure 8 possible residual actions in the structure due to settlements are superimposed onto those of the total load of the structure itself. Using a lower bound assumption of the relation between the reaction due to settlements and the reaction in the structure it seems that the present settlements should be reduced from 40 mm down to about 32 - 35 mm. It will be the task of the following months to investigate the long-time behaviour of the soil during a long obervation period.

6. Outlook

By means of soil fraction, that means injections with cement fluid, the local settlements of the appartment complex could be stopped. With high pressure it was possible to lift the centre foundation by about 3 mm. Further observations with respect to long time effect of the soil and the structural behaviour will result in a final definition of a stabalized settlement configuration.

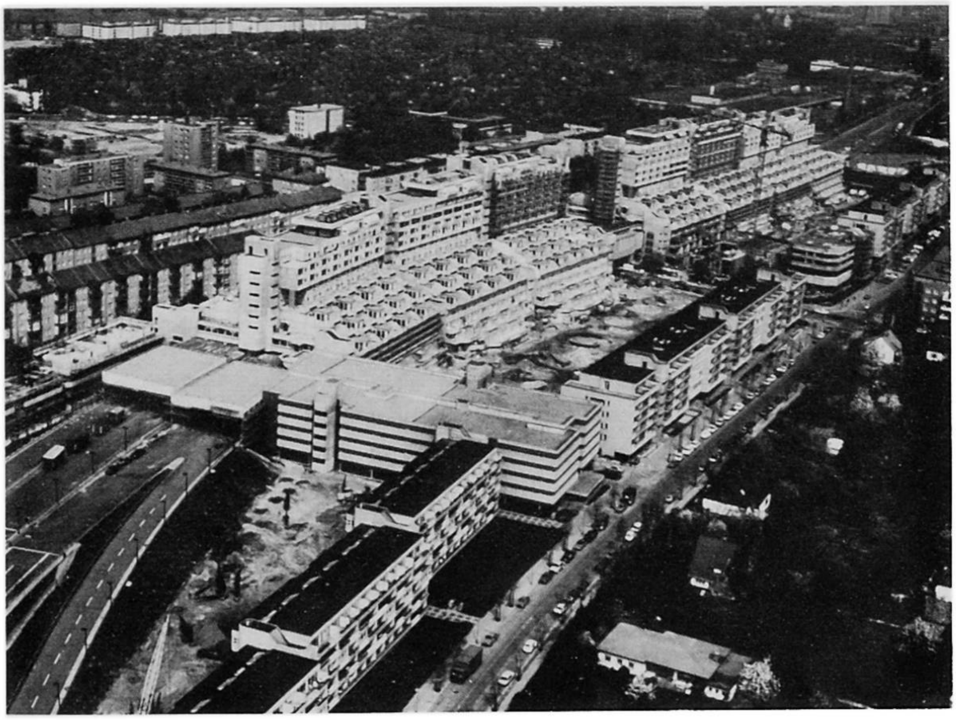

Fig. 9 SAB-Structure in summer 1980

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