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## VI

### **A New System for Prefabricated Slab Elements**

Un nouveau système d'éléments de dalles préfabriquées

Ein neuartiges System für vorgefabrizierte Deckenplatten

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#### 1. Introduction

On the basis of a demand issued by the owner of the planned "Shopping Center, Glatt AG" in Zurich, Switzerland, our office of consulting engineers investigated the possibility of erecting the projected buildings (tall office building, shopping and parking, a total of approx. 1'000'000 cb.m of buildings) with prefabricated concrete elements, and the building time which could thereby be gained. In conformity with the project - already granted-, the column to column span of 8.0/8.0 meters, as well as the maximum store height had to be observed. Under these conditions, normal precast slabs with conventional primary and secondary elements would have met with difficulties, in particular in connection with the Parking, due to the excessive building height. Thus, a new system without girders had to be developed.

#### 2. Slab Elements

As solution we selected a system admissible for transportation by road consisting of slab elements, of which two each could be connected at the center of the span (their own size amounting to 8x4 m), by means of a steel coupling. The main characteristic of this system was the inclusion of the main beam into the secondary elements together with the coupling of the main beams at the center of the span during the phase of erection. (s.illustration no.1). Thus, two slabs were coupled into a span of 8x8 m between the columns (Fig.2, Isometrics of Element Construction). By an adequate positioning of the two couplings it was possible to obtain an uniform type of elements and to avoid a division into "right-side" and "left-side" elements. In addition, the position of the couplings at the center of the span offers the following advantages: reduction of the couplings to two per field, a minimum of shearing forces, an unequivocal moment direction at this particular spot, and one type of element only per field.



Fig 1: Bottom view of slab elements. At the center of the span, the joint where the elements are coupled is visible.

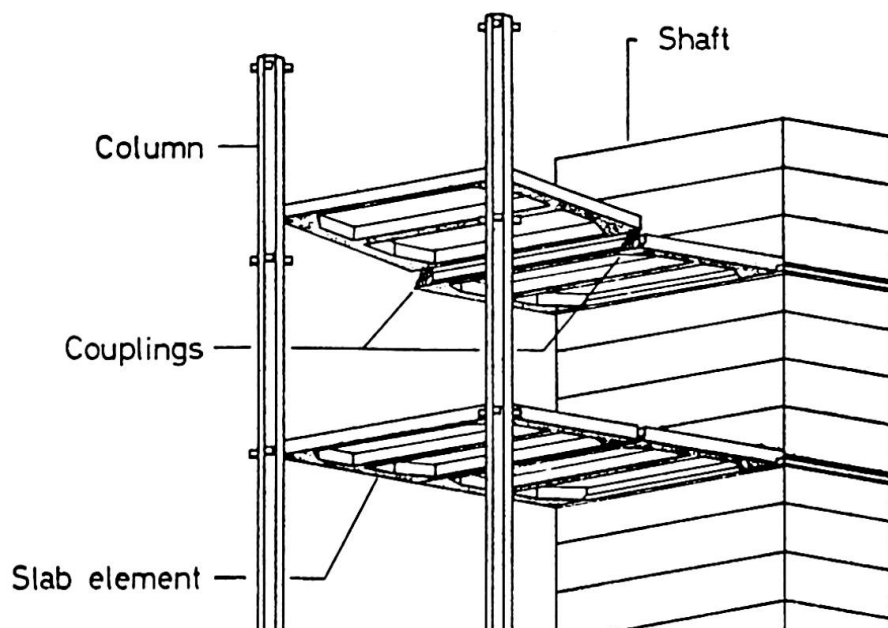


Fig. 2 : Isometrics of Element Construction

The coupling consists of different parallel interlocking steel laminae which are coupled by means of two counteracting cones in the lower (tension) and the upper (compression) area of the slab (see fig. 3 and 4).

The reinforcing rods are directly welded to the laminae, made of St52-3. Each coupling half is factory - made together with the welded reinforcement rods, and is placed into the form as a complete unit.

The slab elements with a slab thickness of 4 cm and a beam height of 35 cm are fitted after assembly with a concrete layer of 7cm thickness, containing a reinforcement with a static effect. The total construction height therefore amounts to 46 cm.

### 3. Tests

A main element of the tests was the coupling of the slab elements. On the basis of a list of priorities, partly resulting from experiences gathered from other already realized constructions, the following prerequisites took shape:

1. Safety of the connections
2. Adjustability of the horizontal and the vertical plains
3. Short assembly time
4. Immediate carrying capacity, i.e. no setting time for concrete or similar properties, no stressing operations with high quality material from the technical point of view and adequate operating personnel during the assembly process.

This novel and now patented system has been verified through detailed series of tests, among other also carried out by the Swiss Federal Laboratory for Testing Materials and Research (EMPA), as to carrying capacity and fatigue.

The following investigations have been carried out in particular:

1. Optical investigation pertaining to mechanical stress of the main coupling element with corresponding perfectioning of its shape;
2. Dynamic tests of the necessary welding connections under different loads;
3. Extended tests with test girders 1:1 with repeated-stress test (vibration test) and final rupture test.

Deflections were essentially investigated under the following loads:

1. Single dead weight momentum;
2. Double dead weight momentum;
3. Maximum momentum;

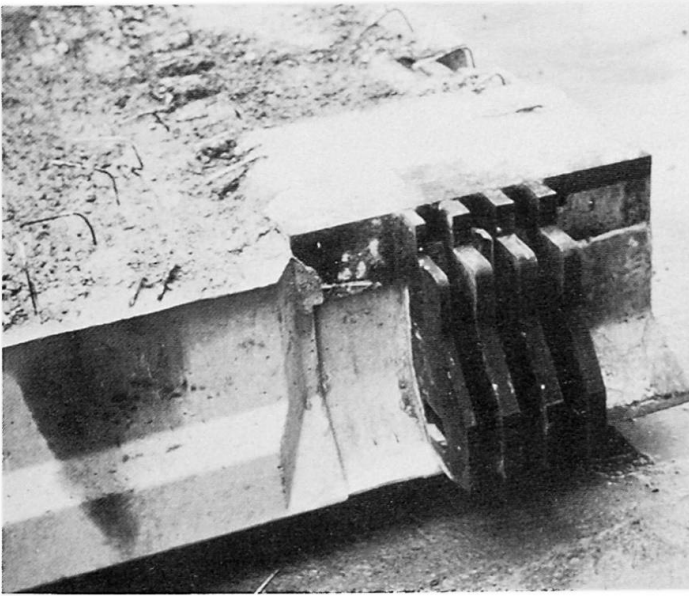


Fig.3: Coupling of Elements.

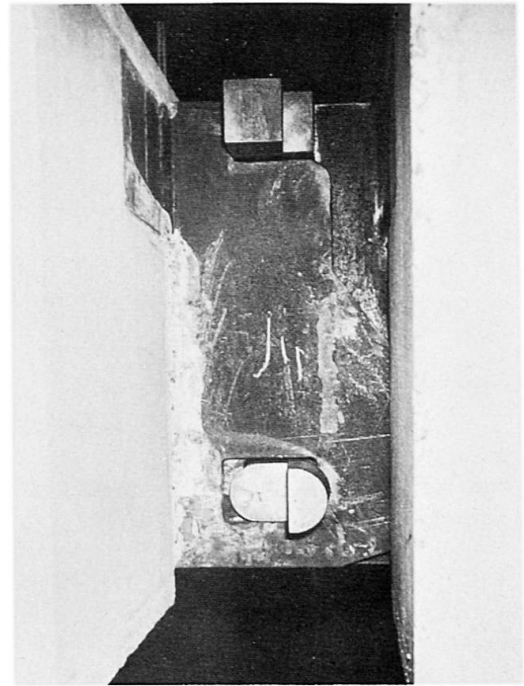


Fig.4: Element Coupling, lateral view showing also the cones on the compression-resp. the tension-side (picture taken during the tests at EMPA).

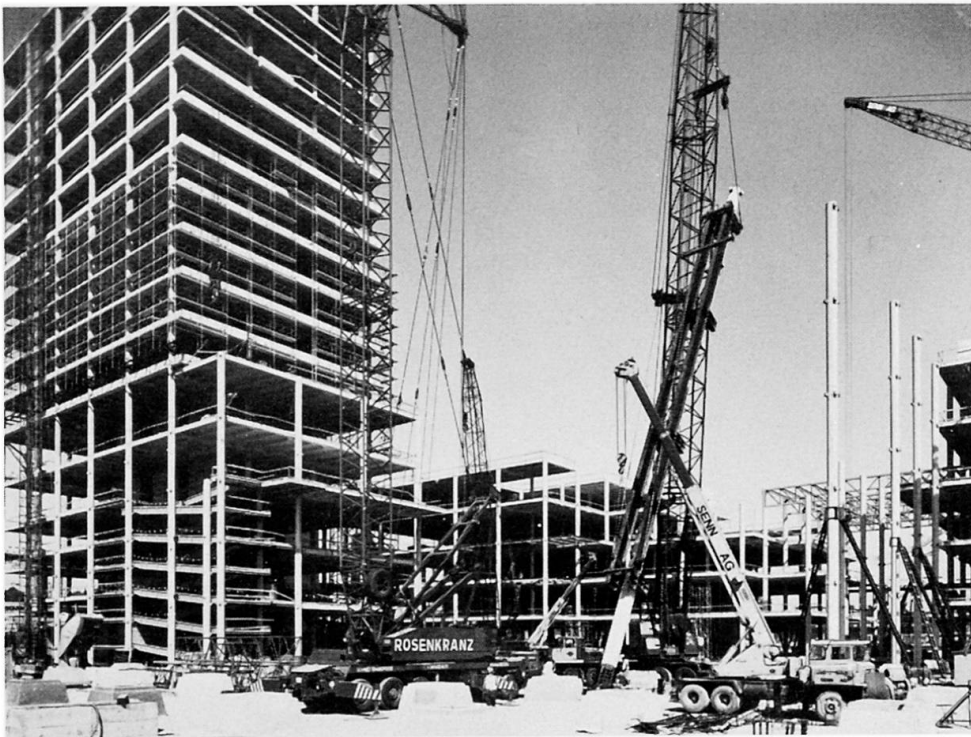


Fig.5: Erection of the Elements.

4. 200'000 oscillations over live load width;
5. Increase of load up to rupture.

As expected, during the first load we met with the cone pressure effect. The deflection at live load width, e.g., amounted during first load to 6 mm, whilst at second load it already decreased to 3 mm. A comparative calculation concerning the E-module of a normal reinforced concrete beam showed a value of  $E = 295'000 \text{ kg/cm}^2$  for second and further loads. An increase of deflection after the 200'000 oscillations attained the value of less than 2 mm, i.e. approx.  $1/3100$ . (For reasons of availability of space, the test beam had a span width of 6.2 m in the test plant).

The final rupture test warranted the following results: up to a load of  $M = 50 \text{ mpm}$  deflections remained linear to a large extent. The stretching-strain limit of reinforced concrete steel was reached between 50 and 55 mpm. By a further consolidation of the coldworked Roll-S-steel, an increase of the momentum stress to 70 mpm became possible, whereafter rupture took place under a load press, i.e. not in the coupling (maximum momentum and shearing force crack). During the subsequent disassembly of the coupling, the cones showed compressed surfaces. Deflections or flow lines on the laminae could not be found.

#### 4. Assembly of the Elements

The sequence of assembly of the elements was carried out in vertical direction. Before application of the covering concrete, the coupling area was reinforced, i.e. supported by especially developed, hydraulic braces, so that the live load and weight of the covering concrete act as a continuous system. By means of an immediate disengagement of the brace after assembly it becomes possible for every slab to be loaded with the dead weight of the ceiling above, in addition to the proper slab weight itself. Thus it became possible to compensate cone compression arising during the first load of the coupling cones over a wide range of the subsequent load width.

From the foundations upward, the entire construction was built with prefabricated elements (s. illustration no. 5). Besides the aforementioned slab elements, also the columns having a height of up to 28 m, and the shafts required for vertical connections (elevators, piping), as well as for the stability of the buildings have been prefabricated.

Assembly of these approx. 12'000 elements started in May 1973 and was terminated for all buildings within one and a half year. This made it possible to finish the construction 10 months earlier than foreseen by the original conventional project.

## SUMMARY

For the prefabrication of a Shopping-center and high-rise office building in Zurich, a new system of prefabricated slabs had to be found. For the column to column-span of 8.0/8.0 m a slab-element of 8.0/4.0 m was developed; two slab-elements had to be connected in the center of the span with steel-couplings. With this kind of prefabrication the assembly time for the building could be reduced by 10 months.

## RESUME

Pour l'exécution d'un centre d'achats et d'une tour commerciale près de Zurich, il était nécessaire de trouver un nouveau système d'éléments de dalles préfabriquées. Pour une distance entre les colonnes de 8.0/8.0 m, on a introduit deux éléments de 8.0/4.0 m qui sont assemblés au milieu de portée par des raccords d'acier.

Une telle construction a permis de réduire le temps de construction de 10 mois.

## ZUSAMMENFASSUNG

Für die Vorfabrikation eines Shopping-Centers mit Bürohochhaus bei Zürich, musste ein neues Elementdeckensystem mit Stützenabstand 8.0/8.0 m errichtet werden, das aus 8/4 m grossen Deckenplatten besteht, von denen je zwei in Feldmitte zusammengekoppelt wurden.

Durch diese Vorfabrikation konnte gegenüber dem ursprünglichen vorgesehenen Projekt 10 Monate Bauzeit eingespart werden.