TAB-SLAB™ - FREELY SUSPENDED SLABS MADE OF STEEL FIBRE REINFORCED CONCRETE

Juergen Mandl [1], Oldřich Vlasák [2]

Abstract

Steel fibre reinforced concrete has been used for many years for concrete elements with low danger potential, especially in flooring and shotcrete applications. In the last few years, interest in SFRC solutions, even in structural applications, has been increasing for many reasons. This article focuses on the relatively new technology of freely suspended elevated slabs made of SFRC, and briefly summarizes the progress from the first ideas and tests to full scale testing and shows the final applications of this technology.

Keywords: steel fibre reinforced concrete, suspended slabs.

1 Introduction

Steel fibre reinforced concrete has been successfully used for many years. The highest volume of SFRC has been used in flooring and shotcrete elements. In the last few years, there has been an increasing interest in SFRC solutions, especially in Europe, mainly because of increasing salaries, insufficient number of experienced job-site workers, requirements of decreased construction time and also because the price of solutions with traditional reinforcement are increasing faster than prices of solutions with fibres.

Besides flooring and shotcrete applications, nowadays SFRC is commonly used in precast elements, walls or foundation plates for housing. In the last few years, SFRC is being used more and more in structural applications such as foundation rafts, slabs on piles and also in the floors of multi-storey buildings, a relatively new technology developed by Arcelor. Before practical usage of SFRC in suspended elevated slabs, it was necessary to carry out a large number of experiments.

2 Testing of SFRC for suspended elevated slabs

2.1. Concrete mix

To be used in structural applications, SFRC has to have full ductility and minimum strain hardening. This cannot be achieved with steel fibre dosage rates under 60 kg/m^3. On the other hand, SFRC with high dosage rates usually leads to workability problems. Therefore

1) Arcelor Bissen, Research and development fibres, B.P. 16, L-7703 Bissen, e-mail: juergen.mandl@arcelor.com
2) Arcelor Commercial Wire Drawing CZ s.r.o., Jesenice 2, 350 02 Cheb, e-mail: oldrich.vlasak@arcelor.com

at first it was necessary to set up a concrete mix that met several requirements. These included: guaranteed full ductility, at least a minimum strain hardening, sufficient saturation of the concrete mix, an easy and more or less uniform integration of fibres, ability to be pumped over long distances without major problems, and was almost self-levelling and self-compacting to avoid segregation during vibration.

A large number of tests with different fibre types were performed, for example workability tests of concrete mix and tests of fracture energy on beams and plates with different thickness and diameters (see fig 1). The best workability, as well as the highest fracture energy, was achieved with concrete C35/45 and 100 kg/m^3 of fibres TABIX 1.3/60.

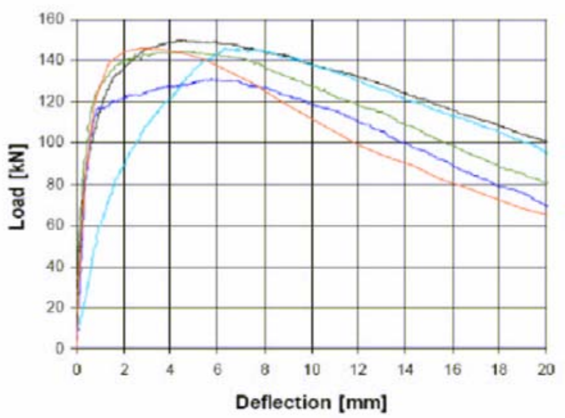

Fig. 1 Plate tests of SFRC with fibres TABIX 1.3/60

2.2. Full-scale test

Design of freely suspended elevated slabs made from SFRC is based on yield-line theory of Johansen and Timoshenko. To prove the yield-line theory, as well as previously acquired material properties of designed SFRC, Arcelor decided to carry out a full-scale test. A slab with dimensions 18.3 x 18.3 m and a thickness of 20 cm was cast. Steel beams in raster of 6x6 m supported the slab. Traditional reinforcement was used only in beam strips, as Anti Progressive Collapse (APC) rebars. APC rebars were installed according to DIN 1045-1 and other international standards.

The slab was loaded in SLS in different load cases by tanks filled with water. Deflection of the slab was measured in several places. In the end, loads were kept for one week. During this time deflections did not increase, no cracks were detected and the slab remained in a fully elastic state.

Also, testing in ULS was performed. The slab was loaded in the middle, the edge and the corner field by hydraulic device (see fig. 2). Loads were increased in increments of 10 kN, deflections and cracks were measured, and the cracks widths were monitored. Deformations were concentrated in yield lines. The ultimate load was more then two times higher than the load when the first crack occurred. In the middle field a maximum load of 470 kN was measured. Final collapse of the slab or its parts could not be reached.

Fig. 2 Full-scale test of freely suspended elevated slab at ARCELOR Bissen – ULS test

APC rebars were tested by removing columns. When the force of the jack was down to zero, the measured settlements were as follows: 25 mm central, 37 mm edge and 35 mm corner column (see fig. 3 - left).

Finally, punching on the central and corner column was tested. During the test of the central column 60% of the slab was cut out (see fig. 3 - right). The maximum loading was 600 kN, but this force was achieved without failure. During testing of the edge column, failure occurred at force of 515 kN.

As all tests were successful and they proved the previously supposed theories, it was possible to use this concept in practical applications.

Fig. 3 Punching test – 60% of slab above central column cut out, no failure even at force of 600 kN (left), removing of corner column – max. settlement 35 mm (right)

3 Selected authentic projects

3.1. Shopping mall Ditton names, Latvia

So far the biggest continuous slab of 1020 m^2 was realized in a shopping mall "Ditton names" in Daugavpills, Latvia. This slab was cast above a cellar; its thickness is 24 cm and spans between columns of 6x6 m. The installation process on the formwork and concreting of the slab were finished in one day (see fig. 4). Since the construction was completed without any problem, the investor decided to cast two other slabs in this building, using the same technology – a balcony (see fig. 4.) and a slab on the first floor.


Fig. 4 Arcelor TAB-Slab^{TM} system in shopping mall in Daugavpills, Latvia – floor above a cellar (left) and balcony (left)

3.2. Triangular office building, Estonia

By the end of 2006 a Triangular office building in Tallinn, Estonia was finished (see fig. 5). All four floors were constructed using TAB-Slab^{TM} system; each floor has an area of 400 m^2.


Fig. 5 Triangular office building in Tallinn, Estonia

3.3. Projects in Western Europe

Even though more than half of the projects were constructed in Baltic countries, the numbers of projects in Western Europe are also rapidly growing. Some of the projects are listed below.

Fig. 5 Housing unit in Bruxelles, Belgium (left), Machinery Hall in Kössen, Austria (right)

Fig. 6 Duffel, Belgium

Fig. 6 Lier, Belgium

4 Conclusions

Now, in the first quarter of 2007, slabs in over 35 buildings have been constructed in Europe, mostly in Baltic countries, but also Belgium, Austria, Denmark, Luxembourg, Spain, Great Britain and the Netherlands. Arcelor already obtained a European patent; other national and international patents are pending.

Due to the consequent use of modern concrete technology it is possible to produce a high dosage SFRC with 100 kg/m^3 that provides a similar behaviour like concrete parts with traditional reinforcement. As in ULS the fibres are pulled out of the matrix of the concrete and do not crack like traditional reinforcement, SFRC has a higher rotation capacity. There is no final collapse even with high crack widths. So even elevated slabs and other concrete parts with a high danger potential can be realized with SFRC. Tests and actual projects proved, that the design methods and the theoretical approach by the yieldlinetheory regarding Johansen and Timoshenko are fully reliable and correct.

References

[1] DBV: *Merkblatt „Stahlfaserbeton", Deutscher Beton- und Bautechnik-Verein e.V.,* Ausgabe Oktober 2001

[2] Richtlinie Faserbeton, *Österreichische Vereinigung für Beton- und Bautechnik*, Ausgabe März 2002

[3] Destrée, X.: *Structural Application of Steel fibres as only reinforcing in free suspended elevated slabs: conditions – design – examples,* sixth RILEM Symposium on fibre reinforced concretes, Varenna, Italy September 04

[4] Gossla, U. und Pepin, R.: *Decken aus selbstverdichtendem Stahlfaserbeton*. Tagungsband zum Braunschweiger Bauseminar 2004

[5] Mandl J., Vlasák O.: S*ystém tab-slab - Volně podepřené stropní desky z drátkobetonu navržené dle teorie plasticity,* 5. Konference Technologie, kontrola a provádění betonových konstrukcí, 2006