The Beginning: The Tramway in Szeged

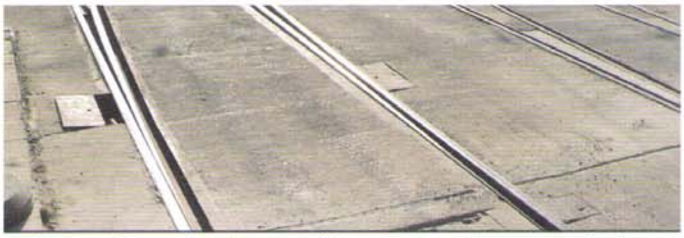
In 2010 and 2011, during the extension and reconstruction process of the A and C sections of tram line Nr. I. in Szeged and the construction of the tram line Nr. II., we had to solve a typical problem: in the areas of the so-called loops, providing tramway priority, the concrete slabs could not contain reinforcement. Therefore, we came up with the idea of using synthetic fibre-reinforced concrete in these sections. At that time, only synthetic microfibres were used for concrete reinforcement in Hungary, the effects of which are mostly seen in the case of fresh concrete: through reducing the rate of plastic shrinkage cracking. However, in hardened concrete only macrofibres have any structural impact. This important distinction is set out fully in the EN 14889-2: 2006 harmonized European standard. While exploring foreign technologies, we found a suitable building material for this purpose, a Japanese-developed macrofibre, namely the EPC Barchip 48 fibre. During the design process it turned out that traditional reinforcement could entirely be replaced by using this macrofibre in this application. After technical and financial analysis it also became clear to the general contractor that the desired structure could be built more economically and faster, furthermore: not only could it be applied in the critical sections where no reinforcement was allowed, but also in the whole section of the tram tracks. Based on the above, a unanimous consensus was reached on trying out the new technology by the Client, the General Contractor, and the Designer. The new technology was designed for and tested on track disk structures (RAFS-CDM) at road junctions, turn-outs, current tracks, bus bays and vibration damping tram tracks.

Szeged, city centre, line I; EPC vibration damping fibre-reinforced concrete, structural and track disk cover. CDM system superstructure

Szeged, line II; inductive loop built in EPC fibre-reinforced concrete structural plate, grassy track section

Static analysis design

From the point of view of static analysis, the tramway is an embedded flexible plate structure, so its design is similar to that for industrial flooring, which can be considered a good point of reference. The British Concrete Society publication TR34 is one of the most



Szeged, Dugonics Square after construction; ORTEC Isolast track with EPC fibre-reinforced concrete cladding

widely used internationally recognised guide for fibre-reinforced industrial floor designs. In its directives, the unit of measurement is the Re3 value, as defined in the JSCE-SF4 technical specification. This value is also referred to as ductility (energy absorption). The Re3 value is mostly determined by the added fibre volume and the strength class of concrete for which the manufacturer provides the input data and is tested using a standardised beam test. After the test-site mixing, we tested the sample beams and determined the Re3 numbers in the Adolf Czakó Laboratory, Department of Mechanics, Materials and Structures, BME. The tests allowed us to verify the previously registered calculation values from the manufacturer. During the design process, the dynamic loads of trams and buses were taken into account, then the load-bearing capacity, serviceability and fatigue limits were checked, in accordance with the Eurocode. These elements were then used as inputs in concordance with the TR34 guidelines for industrial floors. In addition, finite element analysis based design models were also made on the basis of the recorded material model recommended by the RILEM TC 162-TDF. According to both types of calculations, the tramway met the standard loads and load combinations.

Further success in Hungary and abroad

The Szeged tramway project was a huge success, and its fame even reached the fibre distribution Elasto-Plastic Concrete (EPC) parent company. After the system proved to be fully functional, several other tram tracks were constructed applying very similar solutions, using Barchip 48 synthetic macrofibres, in St. Petersburg (Russia) and Tallinn (Estonia). The success also continued in Hungary: the partial reconstruction of the Budapest tramlines 18 and 1, as well as the complete track reconstruction of the Nr. 3 tramline were carried out with this solution.

A well-functioning structure has many advantages over the conventional reinforced concrete structures:

- No corrosion caused by stray currents as in the case of reinforced concrete structures, and the possibility of short circuits between the rails is preventable.
- No quality complaints regarding concrete cover.
- No need for reinforcement steel shipment, assembly, bending or concrete cover adjustment for shuttering, thus execution is cheaper and faster.
- The life of the concrete structure is prolonged.
- This fibre option is more resistant to dynamic (resonance) load than the steel reinforced concrete structures.
- It can be applied in conjunction with reinforcement.
- The application of synthetic macrofibres terminates the disk and beam edge cracking, crumbling, surface pouching, crumbled edge roll-off and cracked edge detachment.
- It can be applied for reconstruction, as well as repairing of the old structures.
- As for environment protection, due to 1 VFM, the energy demand is reduced.
- In case of appropriate planning, static analysis, proper application of technologies and implementation, a lifetime of 35 years can be guaranteed for tram track primary structures.

Making plans

Imagine a tramway where the concrete structures do not need to be repaired for 35 years, where no money would be spent on maintenance. It will not crack 3 years later and is not going to suffer any frost damage causing splitting in 5 years' time. The flexible seal will not protrude and the rail will not move in the rail plate or beam. It is not over-reinforced. We have imagined and designed it, then the contractors have carried out the construction work.

During the design process it is necessary to prepare detailed plotting based on general layout. In addition to the construction site plan, it is also important to accurately determine dilatations and construction in grassy and disk track structures, as well as the reinforcement plans, the allocation of the beam linking elements, the drainage and seepage plans, which must show the intake points, track drainage and seepage, rail lubrication, welding, and the power driving hardware as well. Developing comprehensive manufacturing and detail plans, as well as the elaboration of specific design regulations/requirements are of utmost importance too. The specific requirements should be designed for places that are not covered by a standard, technical specification or design aid. Our principle is that the contractor should be able to compile the plan-based structures, as we cannot allow on the spot improvisation during construction. It is as much as saying that a thoughtful and realistic detailed plan should be drawn to avoid any mistakes by the contractor.

We have taken great care to address the issues of dilatation. In the case of grassy lines we determined the size of dilatation gaps necessary for the beam lengths, taking into account the construction temperature. We designed the beam-beam, beam-plate and the plate-plate connections. Furthermore, we developed the structural connections between the CDM and the ORTEC ISOLAST track disc structures and inter-slab ironing system. We also designed the crack-free connections of structures with various levels of flexibility.

Debrecen's Nagyerdei Stadium, prestressed Barchip 48 synthetic fibre-reinforced concrete grandstand elements

Other engineering structures beyond tramways...

The use of fibre-reinforced concrete is a more and more accepted solution to eliminate concrete material rigidity, i.e. to prevent the propagation of cracks. Construction experience has shown that fibre reinforced concrete performs much better in reality than is usually verified by calculations. In this regard, further research is being conducted around the world, and in our country too, to explore other application options. Consequently, the grandstand element of the stadium in Debrecen was the world's first example of replacing complex shear reinforcement by macro-synthetic fibres in construction. Due to our advanced finite element calculations, we have succeeded to partially or completely eliminate the use of reinforcement in prefabricated elements, so the ABB transformer stations are completely switched to using only fibre-reinforced concrete. In addition, we must mention here the precast piling elements for embankments, where shear reinforcement was also replaced by Barchip 48, as well as macrofibres were used for the reinforcement of the 5-cm-thick masking concrete. ●

NAGY ÉS TÁRSAI

FIBERGURU

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