Ultimate design

Here, a Twintec Ultimate seamless ground-bearing floor slab was recently constructed for VE Commerce, in The Netherlands on behalf of PVH Europe (left image also).

The Concrete Society TR34 Third Edition[1] notes that "an ideal floor would be perfectly flat and have no joints". The Twintec Ultimate floor slab has taken floor slab design and construction to a new level with no saw-cut joints and no opening construction/expansion joints, resulting in a totally seamless floor slab.

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Steel fibre combined with traditional reinforcement has been in use for more than a decade now and incorporates the beneficial properties of both traditional and fibre reinforcement. Twintec Ultimate is a combined reinforcement technology that is now very popular in the construction of slabs and raft floors throughout mainland Europe.

Crack width and deformation

To limit crack width in normal construction, numerous, relatively thin reinforcement bars are often used in the form of a fabric. This provides sufficient anchoring length of the steel to transfer the tensile forces to the surrounding concrete. For steel fibres, the anchoring length is about one-hundredth of that necessary to anchor bars. This is due to the relatively large bond area compared with the diameter. With hybrid reinforcement, the addition of bars or fabric to the design reduces slippage of fibres. Any potential cracks are therefore limited as the fibres, in combination with the bars or fabric, absorb the majority of the tensile forces.

Benefits

A key benefit of this new floor slab is that expansion–contraction movement joints are no longer needed. Twintec Ultimate has already been installed in a number of slabs of up to 64,000m^2 in Europe. The combination of reinforcement with a small diameter and decreased bar-to-bar spacing, together with the fibres, limits the crack width to a maximum of 0.3mm. In a typical normal slab, the sub-base restrains the movement. For a slab cast on a plastic sheet, joints to accommodate movement are required at, say, 40–60m spacing. Without a plastic sheet, the resulting friction is greater, hence the Twintec Ultimate slab is not restricted to these joint spacings and can be infinite.

Flooring designers are very familiar with the yield line cartwheel envelope pattern resulting from both a negative and a positive moment. Fibres are ideally located throughout the concrete's cross-section but a local deviation of fibre quantity is not considered a problem as localised stress will redistribute to another part of the flow line pattern, so the overall behaviour of the plate will follow the average material behaviour.

The disadvantage of the yield line theory is that nothing is said about the crack width in the serviceability loading state (SLS). With a non-linear finite-element analysis (NL-FEA[2]) the crack growth can be calculated for the floor in service over time.

The size of the fibres is important. As a rule of thumb, a minimum of 30kg/m^3 fibres with a maximum fibre length of 60mm should be used. In non-plate construction with a lower redistribution capacity (eg, beams supporting the slabs or columns in buildings), it is advised to increase the fibre content to 40 or 50kg/m^3.

Production process

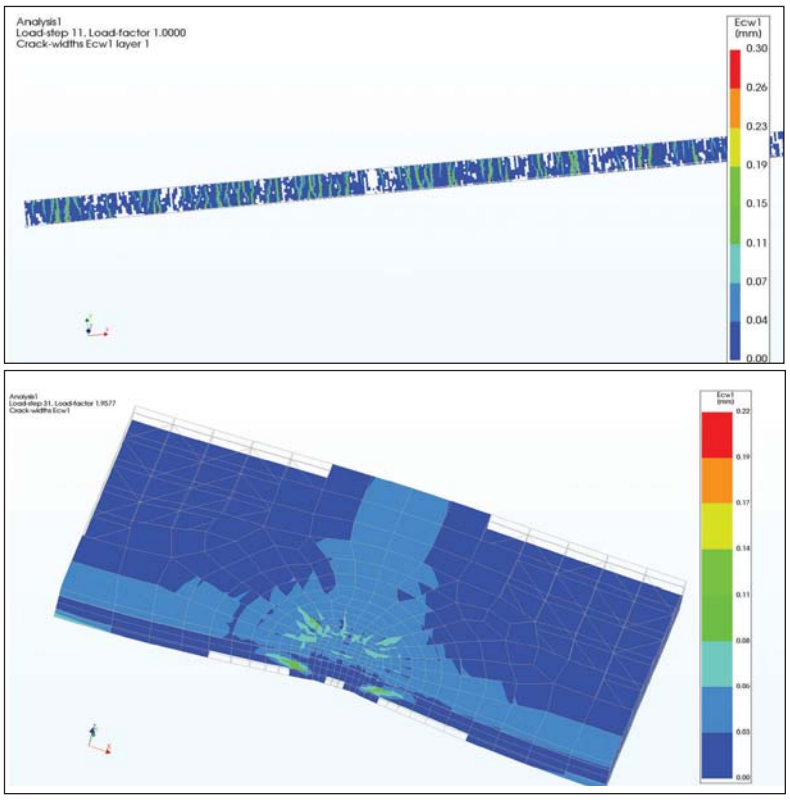
Critical success factors in the production process include: concrete, planning, skilled/experienced workers and high levels of quality control. Successful construction requires the expertise and experience of a specialist steel fibre flooring contractor to ensure that the combination of fabric and steel-fibre-reinforced concrete is placed correctly. Essentially, the specification of the mix needs to be carefully controlled and managed – the steel-fibre concrete can be pumped or directly discharged as required. Robust quality and site control is paramount to successful construction. The application of a dry-shake topping via a mechanical topping spreader will ensure surface fibres are suppressed and improve abrasion resistance.

Control of shrinkage cracks

Adding fibres to concrete brings an improvement in the toughness and wearing strength and reduces shrinkage

cracks. Fibres also limit the fatigue in the concrete, which occurs when cracks and cavities become unstable and may lead to weakening or serious damage to the floor slab. This crack growth is greatly limited by the combination of the fibres and the traditional reinforcement. The fibres act on a micro-scale and the reinforcing bars reduce the macro cracking.

For thicker (raft) slabs or foundation plates, the tensile strength of the concrete is not taken into account in a traditional reinforced design. Using combined reinforcement technology, the tensile strength is also retained after first cracking. Therefore it is acceptable to use a certain concrete tensile strength, increasing shear and punching capacity. In a lot of cases, the punching reinforcement and/or stirrups can be completely omitted. The ultimate bending strength is increased depending on the amount of traditional reinforcement. With lower ratios less than 100kg/m^3 this effect is more visible.



Top: Increasing bending and punching capacity about the piles or columns.
Above: Example of crack width distribution over a slab longer than 50m.

Reduced life cost and construction time

As well as all the functional advantages, cost reductions are also achieved. The slab thickness can be reduced compared to traditional fabric slabs, resulting in less concrete and traditional reinforcing steel. The cost of the structure is reduced, less and simpler-shaped traditional reinforcement enhances consistence. Omitting stirrups and/or punching bars is very cost effective. The lack of construction–expansion joints and saw-cut joints, and with a guaranteed design crack width of maximum 0.3mm, the Ultimate slab will reduce year-on-year maintenance costs of the floor slab and the material handling equipment, as well as increasing operational efficiencies.

In comparison with traditional fabric floor slabs, the combination of fibres and traditional reinforcement saves construction time. The high production speed is achieved because the fibres make it possible to build with lighter reinforcing fabric and cages, which can be placed more quickly and ergonomically. With specially adapted execution methods by an experienced and specialist flooring contractor, it can be as fast as fibre-only reinforced concrete.

Sustainability

Only very high tensile strength fibres can be used in the Twintec Ultimate slab design. Twincon high tensile strength steel fibre is one such material. As they are recovered from used car tyres they provide 'green' benefits that more environmentally conscious clients demand. Developing a complete process to recycle lean steel fibres from used tyres and mixing them with other fibres can reduce the total evolution stages of cracks. The thin (0.2mm) Twincon fibres are numerous and spread throughout the concrete and therefore reduce the first crack initialisation. The macro fibres tend to enhance the capacity of the after-peak tensile stress of concrete and, together with the traditional reinforcement, reduce the crack width for visible cracks from 0.05mm.

Case study

A Twintec Ultimate seamless ground-bearing floor slab was recently constructed for VE Commerce, in Venlo, The Netherlands on behalf of PVH Europe. Loading factors considered for the design were uniform distributed load (UDL) of 50kN/m^2 and racking leg load of 80kN. The design solution was a 150mm slab, single top fabric (7mm diameter, 100mm bar-to-bar) with 40mm top cover and steel fibre reinforcement of 30kg/m^3 (wire strength >1400MPa). The total area placed was 59,887m^2, with average daily pours of 2495m^2, and was finished by Twintec in 24 days.

Conclusion

As shown in a lot of projects, hybrid solution reinforcements have benefits for quality as well as costs and sustainability. Twintec Ultimate is based on this solution and together with powerful NL-FEA software one can really design for both the SLS crack patterns and the ultimate collapse failure point. It makes sense to use these designs in other parts of the world. ■

References

1. THE CONCRETE SOCIETY. *Concrete industrial ground floors – a guide to design and construction*. Technical Report 34, Third Edition, The Concrete Society, Camberley, 2003, Fourth Edition August 2013, Revised March 2016.
2. THE DIANA MANUAL. Available at: *http://dianafea.com/manuals/d101/Diana.html*, 2016.