# TESTS ON THE APPLICATION OF HIGH STRENGTH SELF-COMPACTING FIBRE REINFORCED CONCRETE IN FOUNDATION ELEMENTS

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## 1. Introduction

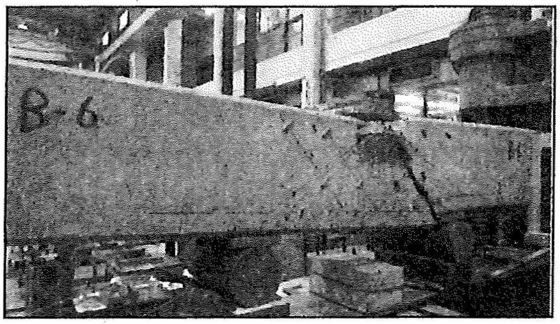
Traditional industrial foundation elements for oil and gas facilities are currently constructed with regular reinforced concrete and due to the combination of different reinforcement requirements, the production process of these foundation elements is complex and labour intensive. Hence, in order to be able to build at the site with higher speed, less effort, less quantities and lower construction costs, it was investigated in this contribution if the construction process of these foundation elements can be optimized. In this respect, a study was carried out to assess whether the use of self-compacting high performance fibre reinforced concrete (SCHPFRC) for these foundation elements could be beneficial for the project execution. SCHPFRC was chosen for the following three main reasons.

Firstly, by adding adequate type and quantity of steel fibres to the concrete mixture, the height of the foundations can be reduced significantly and the reinforcement design including the shear reinforcement, the reinforcement in the anchorage areas, the splitting reinforcement and various types of minimum reinforcement can be eliminated. An introductory study carried out by Falbr & Tirimanna (2017) demonstrated that especially a solution with a concrete compression strength C90/105 is very promising. By applying this high strength concrete not only the height of the foundation blocks could be reduced from 1 m to 0.45 m (i.e. > 50 %), but also the main reinforcement could be limited to the bottom of the foundation block in case no major bending moments occur at the top of the foundation blocks. FEM calculations demonstrated that the steel fibres are strong enough to take over the role of other types of reinforcement such as for instance the reinforcement in anchorage areas, minimum and splitting reinforcement. Hence when using the SCHPFRC only traditional reinforcement is designed to take up the main bending moments whereas for all other load mechanisms such as shear forces, splitting and spalling, the stresses will be transferred by the steel fibres in the concrete. As a consequence, the manual labour work to form the reinforcement cage can significantly be simplified and reduced and the excavation works reduce as well.

A second advantage of SCHPFRC is that the combination of the high strength concrete with the steel fibres creates a concrete wherein the development of the cracks and the crack widths can be well controlled. The latter is very beneficial regarding the durability and sustainability of the foundation elements which are subjected to various environmental aggressions. Thirdly as the concrete is self-compacting no labour is necessary to compact the concrete and labour costs are further reduced. Based on the aforementioned, the application of SCHPFRC for foundation elements seems very promising.

However, to validate the numerical conclusions and to get further experience with this material, two extensive test series have been executed at the Magnel Laboratory for Concrete Research of Ghent University (Droogné 2017, Walraven 2018). As foundation elements are in general subjected to very large local point loadings, the shear capacity and punching resistance are of particular interest in this study. The first test series consisted of the development of a mix design for the SCHPFRC, 12 CMOD tests on SCHPFRC prisms, 6 full scale loading tests on SCHPFRC beams subjected to a concentrated load to test the shear resistance and 6 full scale loading tests on SCHPFRC slabs (2.5m x 2.5m x 0.5m).

In the second test series additional tests are performed to confirm the findings from the first test series, to investigate the influence of the steel fibres on the anchorage length of steel rebars and to investigate the punching resistance and the three-dimensional load-transfer of the foundation elements in more detail. Next based on the outcome of the experiments, the applicability of SCHPFRC is evaluated and practical design guidelines are derived for industrial foundation elements.



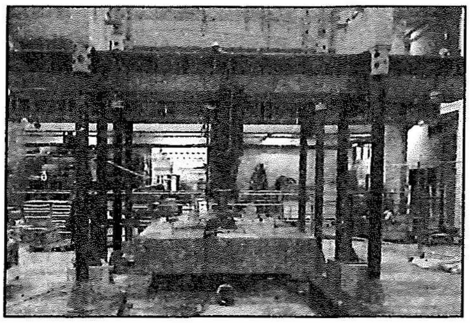


Figure 1. Beam element B-6 at the end of the test (left) and slab element S-1 at the end of the test (right).

## 2. Conclusions

The developed concrete mixture in this contribution fulfilled the basic requirements regarding easy casting, self-compacting properties, homogeneous distribution of the fibres and lack of visible deficiencies after hardening while achieving a high strength and a ductile behaviour as required.
The experiments on 6 short SCHPFRC beams, showed a consistent and reliable behaviour. Furthermore, a good prediction of the shear capacity of these elements could be obtained by extending the equations of fibre reinforced concrete slender beams to short beams as is done for RC beams without fibres. The extension of these equations, validated by tests, will be very helpful to design new industrial SCHPFRC foundation elements.

The tests on slab elements, supported on three or four supports and loaded by a single centric load, showed a capacity which is much higher than expected on the basis of strut and tie modelling. One of the reasons for the high bearing resistance is the confinement of the concrete compression zone in the case of load transmission into three directions. By virtue of the three-axial compression of the load introduction area the behaviour is considerably more favourable than in the case of load transmission in only two directions. Since the shear bearing capacity of short deep structural concrete members in codes of practice is solely based on short deep beams, this effect has never been incorporated in codes. The second reason is the large effect of the steel fibres, reducing the widths of the shear cracks, and increasing in this way the effect of aggregate interlock, which is a significant component in the bearing mechanism. As a result of the unexpected good structural behaviour, the tests on the slabs could not be continued up till failure, because of the limitation of the loading capacity of the test set-up to 4000 kN. Only in the case of a test, carried out on a slab with only steel fibres and without traditional reinforcement, failure was observed, at a remarkably high load of 3316 kN. Although the experimental failure load is unknown for most of the slabs, from the tests it can be concluded that the use of steel fibres allows to reduce the thickness of foundation elements and to skip several ordinary reinforcement requirements. This construction method will result in simplification of below-ground foundation works and will reduce the complexity of rebar and volume of concrete and civil works significantly. Furthermore, to develop the practical knowledge and experience with SCHPFRC foundation elements, a second test series has been performed in September 2018 for which the results are being analysed while writing this contribution.

## References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