# Concept to predict crack initiation and crack development in fairfaced concrete screeds

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## ABSTRACT

Within a research project of the Laboratory of Solid Structures of the University of Luxemburg, a design concept to predict cracks in various concrete structures will be developed. The current paper presents the numerical investigation of crack initiation and crack development of an unreinforced cementitious fairfaced concrete floor. Thereby cracking of concrete is divided into cracking of an early stage and into cracking of a later stage. The present study deals with cracking of an early stage. Taking into account shrinkage and the chronological strength development of the used C20/25 concrete and with the use of the Element Failure Method (EFM) it will be possible to predict, within a Finite Element Analysis, a possible crack path spatial as well as temporal.
For this purpose a finite element model, based on a commercial FE-Software is developed. The program is tested on H-shaped concrete specimen (Fig. 1) with an unfavorable size ratio between surface and volume. Besides, shrinkage on this specimen is hindered so that unplanned restrain forces has to occur. Using an algorithm the finite element program is able to calculate the model gradually for several load steps within a loop. Furthermore the net dependency of the EFM can be excluded by the use of suitable load steps.

**Keywords:** concrete; crack development; Finite Element Analysis; shrinkage; chronological strength development.

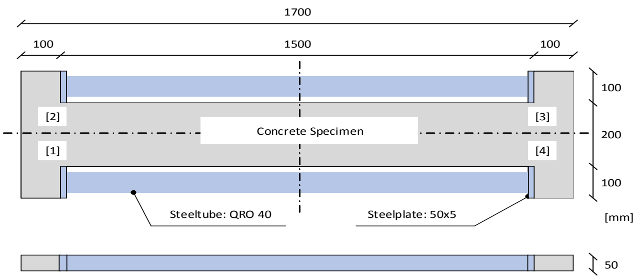


**Fig. 1.** H-shaped concrete specimen

## 1 Test program

The visual inspection of cracking and crack growth on the specimens took place twice a day, so that the crack evolution could be documented. (Fig. 2) to (Fig. 5) show the fully cracked state of all four corners. For a better view, the resulting crack paths are traced with red lines.

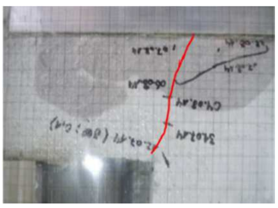

**Fig. 2.** Corner [1]

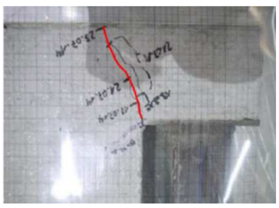

**Fig. 3.** Corner [2]

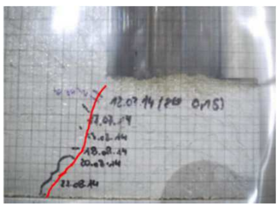

**Fig. 4.** Corner [3]

**Fig. 5.** Corner [4]

## 2 Finite element model

The simulation was performed with the finite element program ANSYS. To simulate the H-shaped shrinkage specimen only a quarter of the concrete sample is constructed with respect to symmetry

properties. Boundary conditions such as symmetry axes and storage conditions of the model were set. The inserted steel tube with welded head plates is simulated by a block. Between the block and the concrete model a contact surface is defined.
To calculate a possible crack path, the crack initiation and the crack development of the H-shaped shrinkage specimen is simulated with the help of the element failure method (EFM). Shrinkage is simulated by a thermal load case according to the "DIN Fachbericht 104". The EFM is applied in a loop, so that successively all thermal load cases could be set in accordance to the progressive tensile strength development.
At every computing step the algorithm checks, if one or more elements of the model fulfil the selected failure criterion. An element fails only when each of the eight nodes of the element meets the required failure criterion. There is a strong net dependency for the element failure method: the smaller the used elements, the earlier the elements will fail. But if the load steps are chosen sufficiently fine, such a net dependency is no longer given. (Fig. 8) shows the situation for 50 load steps and (Fig. 7) shows the situation for 250 load steps. The evolution of the crack path is shown in Fig. 10 to Fig. 12.

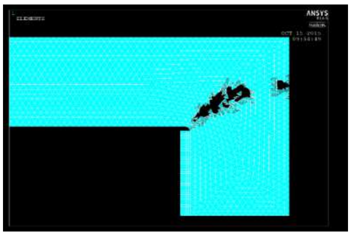
**Fig. 6.** 50 load steps

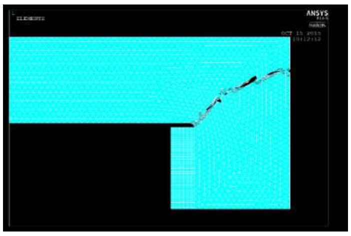
**Fig. 7.** 250 load steps

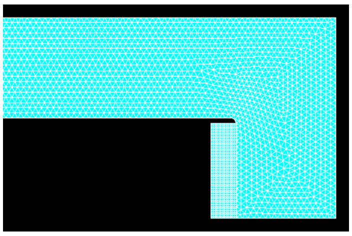
**Fig. 8.** Load step 2

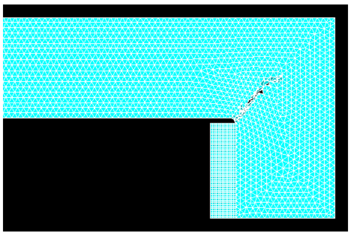
**Fig. 9.** Load step 52

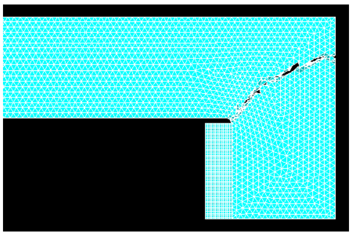
**Fig. 10.** Load step 227

## 3 Conclusion

With the use of the element failure method (EFM) it was possible to calculate the crack path. Taking into account shrinkage and the developing tensile strengths, realistic results could be realized within the simulation compared to the cracking results from the experimental analysis of the H-shaped shrinkage specimen. The high deviation of the chronological appearance and the crack growth can be due to the heterogeneous properties of the concrete combined to boundary conditions.
A net dependence of the EFM can be excluded by the use of very fine load steps.
The depiction of shrinkage by equivalent temperature cooling (DIN Fachbericht 104 2009) within the simulation produced realistic results.
In future the model will be further developed in order to allow different boundary conditions. Furthermore, mechanical stresses, e.g. live loads will also be considered within the simulations.