Detection of Fibers Content in UHPC Slabs

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ABSTRACT

Ultra high performance concrete (UHPC) is a cementitious material with steel fiber, which is becoming more and more widely employed in building construction. The advanced mechanical behavior of the UHPC structural elements significantly depends on the steel fiber content and steel fiber orientation.

In this study, the test result of UHPC slab under punching shear was previously tested by the Author is used herein to check the fiber amount and orientation at the failure plane. A method presented by John Long is presented to do this goal.

It was found, that the fiber content in the failure plane is differ from the fiber volume fraction used in constructed the specimen.

السقوف الخرسانية الفائقة الكفاءة- ايجاد تشتت ودوران الالياف

الخلاصة

الخرسانة الفائقة الكفاءة هي مادة اسمنتية مع الياف الحديد بدأت تستخدم بصورة واسعة في انشاء الابنية. التصرف الميكانيكي للخرسانة الفائقة الكفاءة تعتمد بدرجة كبيرة على كمية الياف الحديد وعلى دوران الياف الحديد.

في هذه الدراسة, نتائج الفحوصات لسقوف خرسانية فائقة الكفاءة تحت تأثير قص النفاذ تمت بواسطة الباحث قد استخدمت لايجاد كمية الياف الحديد ودوران الياف الحديد عند مستوي الفشل. طريقة جون لونك قد استعرضت هنا لهذا الهدف.

لقد وجد ان كمية الياف الحديد عند مستوي الفشل يختلف عن كمية الياف الحديد المستخدمة في انشاء النماذج.

INTRODUCTION

The idea of using discrete fibers to reinforce brittle materials such as concrete is not new with many studies having been undertaken over the past five decades. Early studies indicated that the tensile strength of concrete can be improved by providing suitably arranged and closely spaced wire reinforcement [3]. The low tensile strength of concrete matrix is primarily due to the propagation of internal cracks and flaws. And that, if these flaws can be locally restrained from extending into the adjacent matrix, the initiation of tension cracking can be retarded and a higher tensile strength of the material achieved [4] . In addition to increasing the tensile strength, the inclusion of

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fibers may also enhance a number of other material properties such as fatigue resistance, energy absorption and toughness, ductility, durability and improve the service life of the material. By adding fibers to a concrete mix the objective is to bridge discrete cracks providing for some control to the fracture process and increase the fracture energy [5] .
Early Research of fiber normal reinforced concrete (FRC) has a long history, including the recent development and practical use of strain hardening cement composites (SHCC) and Ultra high performance fiber reinforced concrete (UHPFRC), which have been actively studied domestically and internationally. However, estimation of the dispersion and orientation of fibers in the matrix and their effect on the mechanical behavior of concrete have been recognized as key problems that have yet to be solved since the development of FRC [6]. Major reasons for this are the difficulty of observing the dispersion and orientation of fibers within a concrete or mortar matrix and the current absence of technology to control their dispersion and orientation during placing. With this as a background, this study attempted to visualize fibers in concrete specimens by using John Long method to calculate the fiber dispersion and orientation on the failure plane of flat slab under punching load previously tested by the Author [1].

Experimental Program

The experimental program was made by the author [1] on G1Ufib0.5 slab (UHPC slab with 0.5% steel fiber) to study the punching shear behavior of UHPC flat slabs. This test was done in structural engineering department in Kassel University / Germany. The property of tested slab is shown in Table 1.

Table (1): Details of tested slab

Slab	Concrete type	f_c(MPa)	f_{tm} (MPa)	f_{te} (MPa)	H (mm)	fiber content %	E (MPa)	d_{bar} (mm)	ρ (%)	f_y (MPa)
G1Ufib0.5	UHPC	198.9	5.9	3.9	100	0.5	51810	10.5	2	1320

In Table 1, f_c means compressive strength of concrete, f_{tm} is the matrix tensile strength of concrete, f_{te} is the fiber efficiency of the fiber concrete as a second tensile strength value in the post cracking range, h is the thickness of the tested slabs, d_{bar} is the diameter of reinforcement bars, ρ is the reinforcement ratio, and f_y is the yield stress of tension reinforcement.
Figure 1 shows test specimen dimension with reinforcement, Figure 2 and 3 shows the test arrangement and slab under test respectively. After the test was finished, the punching shear failure plane was clearly appeared. On this failure plane, the fiber distortion and orientation will be detecte

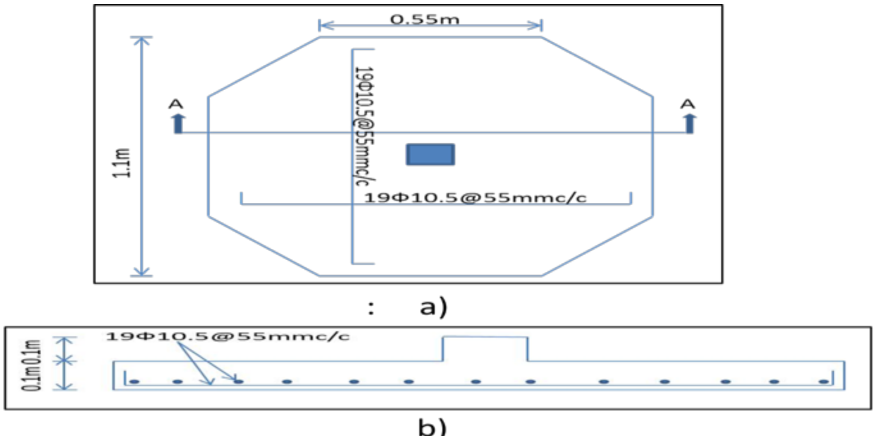


Figure (1) a.Slab specimen ,b.Section A-A in tested slab

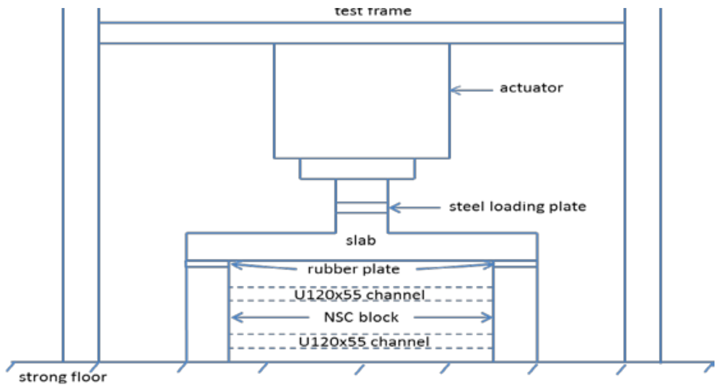
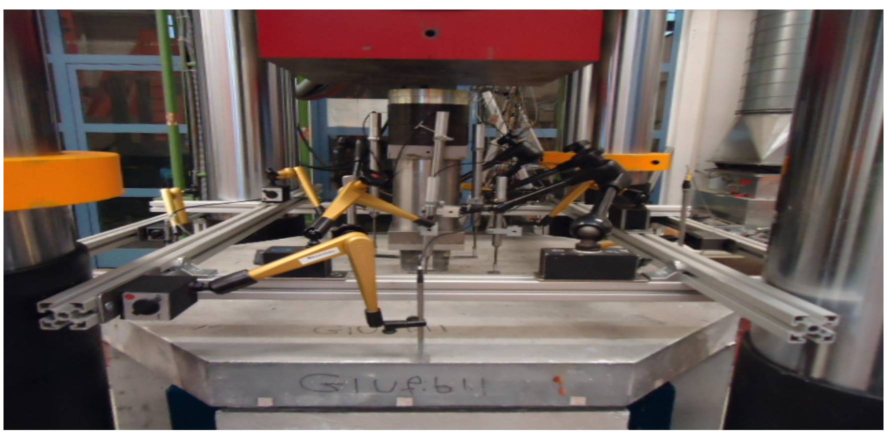


Figure (2): Test arrangement



Figurte (3): Slab under test

The plane of failure in punching shear test means, the plane of inclined shear crack. Figure 4 shows this plane after a radial section is made at the slab.

Figure(4): inclined shear crack plane

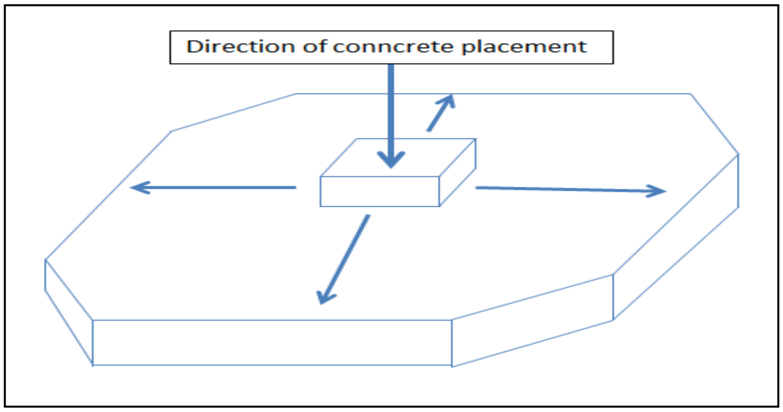
Steel Fiber

Figure 5 shows the steel fiber type that was used in this analysis. This fiber has length of 20 mm, diameter of 0.25 mm, aspect ratio of 80 and the ultimate tensile strength of 2000 MPa.

Figure(5): Steel fiber used in constructed the specimens

Concrete Placement

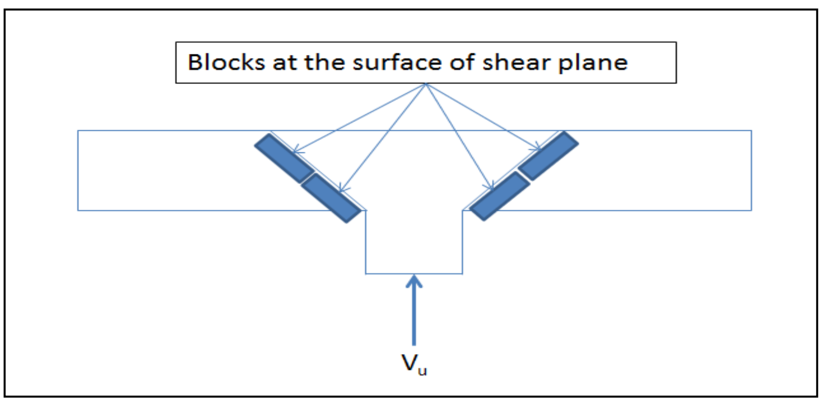
By pouring the concrete in different ways, the orientation of steel fibers is influenced. Barnett [2], found that the fibers tended to align perpendicular to the direction of flow. Also, panels poured from the center were significantly stronger than the panels poured by other methods because the alignment of fibers led to more fibers bridging the radial cracks formed during mechanical testing. Consequently, The UHPC slab used in this analysis was poured from the center of the slab as can be shown in Figure 6.



Figure(6): The way of concrete placement

Detection of Fibers Content and Orientation

As previously pointed, to determine the steel fibers content and orientation at the plane of inclined shear crack, a program **ElliFaserSTEEL** detected by Dipl.-Ing. John Long was used. The main purpose of this analysis is to compare the fiber content at the inclined shear crack with the fiber content added to the specimen and also to check the fiber orientation. After testing is finished, a radial section in G1Ufib0.5 slab was made (see Figure 4) and four pieces at the surface of inclined shear crack were taken with different size, see Figure 7. These four blocks were smoothed to clearly see the steel fiber on the surface of these blocks.



Figure(7): Four pieces of UHPC taken at the surface of inclined shear crack

The program is required NETBibliotheken Microsoft, which is loaded automatically and free of charge from the Microsoft server in the Structural Engineering Institute / University of Kassel. The pictures used in this program have a high resolution of 13.8 MP. The camera is slightly inclined and the pictures taken with an angle of 5^o-10^o with the vertical axis, as shown in Figure 8.

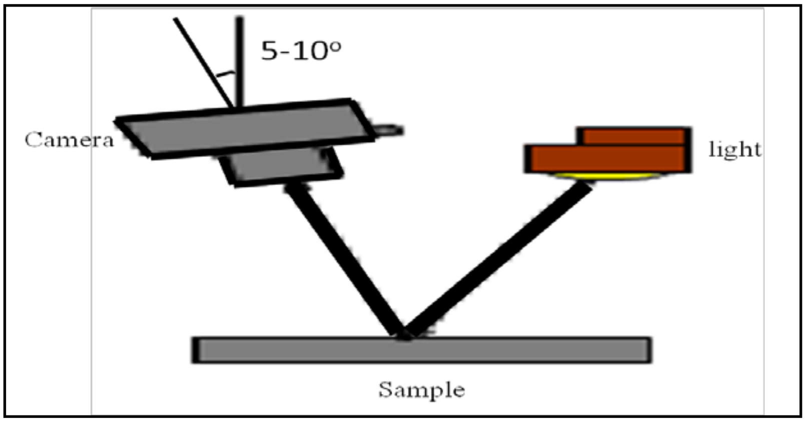
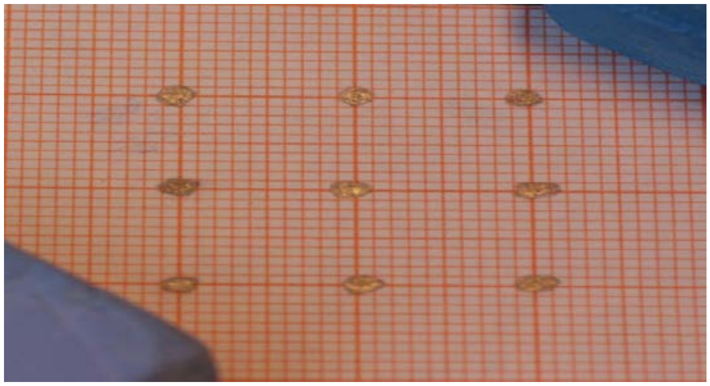


Figure (8): Arrangement to take photos to the pieces of shear crack surface (1)

The camera must be set in a way, where the picture that take it to each piece must be clearly appear the fibers on the surface, it is called original picture, see Figure 9. In this picture, the white points represent the steel fiber. The different size of these points is due to orientation of steel fiber. Additional picture with calibration sheet is taken with the same setting of the camera, it is called calibration picture, see Figure 10. On the calibration sheet 9 points were marked for the later analysis. The pictures in Figure 9 and 10 are used in software analysis.

Figure(9): original pictures used in ElliFaserSTEEL program



Figure(10): calibrated pictures used in ElliFaserSTEEL

The above pictures and later procedure is applied to all 4-blocks on the surface inclined shear crack.

The **ElliFaserSTEEL** program consists of two main parts, first is the calculation of the number ellipses in original picture and second is the calculation of a calibration.

Later, the calculation in Excel sheet belong to **ElliFaserSTEEL** program is used to measure the number of fibers and the orientation factor (the angle of orientation of the fibers with the loading direction) on the surface of inclined shear crack. The results of 4-blocks are listed in Table 2.

Table (2): Number and orientation of steel fiber in 4-blocks at inclined shear plane

Piece No	No of steel fiber	Orientation factor
1	137	0.412
2	85	0.523
3	48	0.396
4	67	0.393

In best design approach, both the material composition and the casting process to the anticipated structural performance, by making the orientation of fibers to match as close as possible with the direction of the principal tensile stress within the structural element when in service. In this way a more efficiency structural use of the material can be reliable achieved. According to Table 2, the average orientation factor found to be 0.43.

Using simple calculations to find fiber content at the plane of inclined shear crack as follows:

- According to Table 2, the summation of number of steel fiber in the inclined shear crack in 4-blocks is 337.
- The volume of 4-blocks are:
  - ➢ Volume of first piece (t=4.1cm) is 7.7x7.6x4.1= 236.8cm^3
  - ➢ Volume of second piece (t= 5cm) is 5x(6.4x6.6-2.8x2.8)= 172cm^3

- Volume of third piece (t= 5cm) is 5x(6x5.4)= 162cm^3
- Volume of fourth piece (t= 4.1cm) is 4.1x7.6x7.5= 233.7cm^3

- The volume of one piece of steel fiber is (π/4)x0.25^{2}x20=0.98mm^3

- The theoretical number of of fibers in 4-blocks=

$$\frac{\text{total fiber volume in 4-blocks}}{\text{volume of one piece of fiber}} = \frac{0.5\%\text{x}804.5\text{x}103}{0.98}\text{x1000}= 4104.6$$

- If the fibers are distributed in vertical direction, the number of fiber layers in each block is:

- Block 1; $\frac{4.1}{2}$ = 2.05
- Block 2; $\frac{5}{2}$ = 2.5
- Block 3; $\frac{5}{2}$ = 2.5
- Block 4; $\frac{4.1}{2}$ = 2.05

Where;
2 cm is the fiber length
The summation of vertical layers in the four blocks is 9.1.

- The theoretical number of fibers in one layer of 20 mm

$= \frac{4104.64}{9.1}$ x 0.431=1046.54

- Finally, the actual fiber content in the inclined shear crack represents about one third ($\frac{337}{1046}$) of the theoretical content. This means, that the fiber content of the punching zone is = 0.5% x $\frac{337}{1046}$= 0.16%

CONCLUSION

- According to the analysis in this study, the fiber content in the diagonal shear plane is 0.16% which is differ from the fiber volume fraction 0.5% used in constructed the specimen. This means, that there is a big difference between the fibers added in constructed the specimen and the fibers in the failure plane.
- The author believed; that the way of concrete placing affects on the fiber content, fiber distribution and fiber orientation. So another result may be obtained for with another way of concrete placing.
- The efficiency of the steel fiber in the failure plane may be represented by the orientation factor for 0.43 in this analysis.

REFERENCES

[1]. Al-Quraishi H and Fehling E; punching shear behavior of UHPC flat slabs; Ph.D thesis; University of Kassel/Germany; 2014.

[2]. Barnett J, Lataste J, Parry T, Millard S, and Soutsos M; Assessment of fiber orientation in ultra high performance fiber reinforced concrete and its effect on flexural strength; Material and structures; 2010.

[3]. Ferrara L, Faifer M, and Toscani S; A magnetic method for non destructive monitoring of fiber dispersion and orientation in steel fiber reinforced cementitious composites- part 1: method calibration; Material and Structures; October 2011.

[4]. Liu J, Li C, Liu J, Du Z and Cui G; Characterization of fiber distribution in steel fiber reinforced cementitious composites with low water-binder ratio; India Journal of Engineering and Material Science; December 2011.

[5]. Ezeldin A. and Hsu C; Optimization of reinforced fibrous concrete beams; ACI Structural Journal; 1992.

[6]. Craig, R.; flexural behavior and design of reinforced fiber concrete member; fiber reinforced concrete properties and applications; SP-105; ACI; Detroit; 1987.

[7]. Hussein A. Azeez, (Modeling of shear strength in rectangular reinforced concrete beams), Engineering and Technology Magazine, Vol.27, No. 12, 2009

[8]. Al-Shaarabaf I., Al-Bayati N., (Nonlinear Finite Element Analysis of Reinforced Concrete Beams with Large Opening under Flexure), No.5, Vol.25, 2007