TIME DEPENDANT BEHAVIOUR OF SFRC ELEMENTS UNDER SUSTAINED LOADS

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Keywords: SFRC elements, long term load, creep, shrinkage.

Summary: The benefits of steel fibre reinforced concrete in combination with ordinary reinforcement are well proven in many structures. Decreasing deformations and increasing the number of cracks by decreasing their width are the main reasons for its usage. Up until now, many experiments have been performed on SFRC elements subjected to short term load. Concrete is a material whose properties are changing due to aging and the behaviour of concrete elements depends also on the time duration of the load. There are some long term experiments performed on SFRC elements in the past, but with different conclusions. Somewhere it is stated that fibres do not have a big influence on creep and shrinkage strains and somewhere that they do have one. This is probably the result of different test setups, types of fibres, temperature and humidity. We have chosen hooked-end steel fibres with \( l=50\text{mm} \) and \( d=1\text{mm} \). Previous theoretical and experimental investigations using reinforced, prestressed and high strength concrete elements, performed at Ss. Cyril and Methodius University, [8] and [9], have proven that creep and shrinkage have significant influence on the stress state of the elements, increasing the deformations and crack widths. In this context, it is expected that the addition of steel fibres in reinforced concrete will improve these negative characteristics. The experimental program consists of 24 full scale beams made from reinforced and SFRC (C30/37) with 30\( \text{kg/m}^3 \) and 60 \( \text{kg/m}^3 \) fibres and additional reinforcement. On part of the beams, short term ultimate load testing will be performed on 40 and 400 days. Other beams will be pre-cracked and long term load will be applied on them, while on other beams, beside the permanent, specific variable repeated load will be applied with 8h loading and 16h unloading each day within one year, trying to simulate a realistic load history.

1 INTRODUCTION

The current research in new technologies and new materials is one of the key determinants of the modern and up to date science related to civil engineering. Self-compacting concrete (SCC), high-strength concrete (HSC) etc. have opened new chapters in the use of this most used material in the construction industry. Apart from these types of concrete, there are several continuously ongoing investigations for many other types of materials taking place over an extended period of time. One of the materials that were used from the beginning of the last century is the steel fibre reinforced concrete.

There is no doubt about the positive influence of the steel fibre reinforcement on some of the properties of concrete. One of the main improvements is the decreasing of crack widths. With this improvement, durability of the concrete elements and structures is increased, which is one of the main goals in the current research in up to date civil engineering.

The crack widths and their further opening are in direct correlation with the long term effects in the concrete, creep and shrinkage. The experimental investigations in this area are still rare, so every contribution in increasing the data base in this area is a big step further.

With the proposed experimental program, detailed investigations in both areas and their correlation
are planned. The long term effects and the crack widths are in the group of common investigation areas in concrete structures and their further opening is connected with the use of steel fibre reinforcement in the concrete. Therefore, the results from this research will help toward more detailed design and modeling of this kind of problems.

2 THEORETICAL BACKGROUND

2.1 Volume changes of concrete

Volume changes of concrete, shrinkage and creep, depend on the mix composition, surrounding environment and the level of permanent stress in the elements.

Shrinkage of concrete is a combination of several types of shrinkage: plastic, autogenous, drying, thermal and carbonic shrinkage. The most important type is the drying shrinkage, Figure 1, which appears because of the movement of the water through the hardened concrete, i.e. evaporation of the internal water in the external environment. It starts after curing of concrete is finished.

When concrete is subjected to permanent load, instantaneous strain appears which gradually increases with time due to the creep of concrete, Figure 1. When the load is removed, instantaneous creep recovery appears followed by delayed elastic creep recovery. The only irreversible component after unloading is the flow creep.

In general case the total strain $\varepsilon_c(t)$ at time $t$, at uniaxially loaded concrete element at time $t_0$ ($t_0 > t_0$) with constant stress $\sigma_c(t_0)$ and at constant temperature can be presented as sum of the separated strains:

$$\varepsilon_c(t) = \varepsilon_{ci}(t_0) + \varepsilon_{cc}(t) + \varepsilon_{cs}(t)$$

Where:

$\varepsilon_c(t)$ – is the total strain in concrete at time ($t$);

$\varepsilon_{ci}(t_0)$ – is instantaneous strain in concrete at loading at time ($t_0$);

$\varepsilon_{cc}(t)$ – is strain from concrete creep at time ($t$);

$\varepsilon_{cs}(t)$ – is strain from shrinkage at time ($t$).

The restraint provided by aggregate particles to the shrinkage of concrete is well recognized [10]. On the other hand, addition of fibres in concrete provide additional restraint. But, the shrinkage matrix has a tendency to slide past the length of the fibre and restraint is only possible through the fibre-matrix interfacial bond strength [10]. The coefficient of friction at the fibre-matrix interface $\mu$, depends on the type of fibre and mix proportions and for ordinary concrete and hooked-end fibres it is ranging
from 0.08 to 0.12 [10]. Mangat and Azari proposed theoretical expression to predict shrinkage of SFRC, based on a knowledge of the shrinkage of ordinary concrete $\varepsilon_{oc}$, coefficient of friction $\mu$, fibre volume $v_f$ and aspect ratio of the fibres $l/d$:

$$\varepsilon_{is} = \varepsilon_{oc} \left(1 - 2.45 \mu v_f \frac{l}{d} \right) \quad (2)$$

With this expression the decreasing of shrinkage of SFRC, when compared to plain concrete, is ranging from 0 to 40%.

The addition of steel fibres does not significantly affect the instantaneous and delayed elastic component of creep, but they provide restraint to the sliding action of the matrix due to the flow component of the creep [11]. Steel fibres become more effective in restraining creep as the age under load increases [11]. This is due to the fact that they affect only the flow component, which is bigger at later ages, while the instantaneous and delayed elastic components are dominant at early ages [11]. The same authors, Mangat and Azari, proposed theoretical expression to predict the creep strain of SFRC at a stress-strength ratio of 0.3, based on a knowledge of the creep of ordinary concrete $\varepsilon_{oc}$, coefficient of friction $\mu$, fibre volume $v_f$ and aspect ratio of the fibres $l/d$:

$$\varepsilon_{ic} = \varepsilon_{oc} \left(1 - 1.96 \mu v_f \frac{l}{d} \right) \quad (3)$$

With this expression the decreasing of creep of SFRC, when compared to plain concrete, is ranging from 0 to 30%.

2.2 Long term deflections and crack widths

Deflections and crack widths predicted on the basis of short term tests do not provide satisfactory results for verifications in the serviceability limit states. That is why long term experiments of reinforced concrete elements under sustained loads are very important. The long term sustained load cause significant increase of the deflections and crack widths. In addition, the long term variable repeated load cause additional increase.

Steel fibers are known to aid in deflection and crack width control. Several studies have been conducted on long term behavior of SFRC beams under sustained loads, while studies which include the effect of variable repeated load are uncommon. To define the influence of the variable repeated load to the long term behavior of SFRC elements, a method of replacement of the variable load with quasi-permanent load determined by the quasi-permanent coefficient $\psi_2$ will be used, i.e. part of the variable load to act as permanent load [12]. The coefficient will be obtained at the end of this current research by following expression:

$$a_{t,exp}(g + q) = a_t(g + \psi_2 q) + a_t(g + \psi_2 q) \quad (4)$$

Where:

- $a_{t,exp}(g+q)$ – is experimentally obtained deflection under the effect of sustained load $g$ and repeated variable load $q$;
- $a_t(g+\psi_2 q)$ – is analytically obtained instantaneous deflection under the effect of sustained load $g$ and quasi-permanent load $\psi_2 q$;
- $a_t(g+\psi_2 q)$ – is analytically obtained time dependant deflection under the effect of sustained load $g$ and quasi-permanent load $\psi_2 q$.

3 EXPERIMENTAL PROGRAM

Because of the importance of the experimental results in this type of investigations, an experimental program was planned. It consists of 24 full scale beams from reinforced concrete and
steel fibre reinforced concrete with additional reinforcement. The beams have cross section dimensions 15/28cm and total length l=300cm, Figure 2. Together with each series of beams, control specimens were cast, in order to test the compressive strength, flexural tensile strength, splitting tensile strength, elastic modulus and the deformations due to creep and shrinkage. Beside the concrete mechanical and time dependant characteristics, the used reinforcement was also tested.

Figure 2: Geometry, reinforcement and loading scheme of the full scale beams

All 24 beams were manufactured with concrete class C30/37, and according to the type of material they were divided in three series:
- Series A, reinforced concrete (RC);
- Series B, SFRC with 30 kg/m³ steel fibres and additional reinforcement (SFRC1);
- Series C, SFRC with 60 kg/m³ steel fibres and additional reinforcement (SFRC2).

In order to find out the influence of the different fibre dosages on the behavior of the elements with time, the investigated parameter is the fibre dosage. Steel fibres were hooked-end HE1/50, Arcelor Mittal with diameter 1mm and length of 50mm.

The beams from the reinforced concrete were used for comparison with the beams from the steel fibre reinforced concrete.

Regarding the loading history the beams were divided in four groups:
1. The beams from all three series from group “1” (A₁, B₁, C₁) have been tested under short term ultimate load at the age of concrete of 40 days (Figure 3). With this testing, relevant dependences should be found out for this age of concrete and the behavior of the reinforced concrete and two types of steel fiber reinforced concretes should be compared.
2. The beams from all three series from group “2” (A₂, B₂, C₂) will be tested also under short term ultimate load, but at the age of concrete of 400 days (Figure 3). This will be done in order to find out the influence of the age of concrete on the behavior of the beams.
3. The beams from group “3” (A₃, B₃, C₃) have been pre-cracked with permanent and variable load "g + q", and afterwards a long term permanent load with intensity "g" was applied on the age of concrete of 40 days, to be held up to 400 days, when a short term ultimate load testing will be performed (Figure 4). In the mean time the strains, deformations and crack widths will be measured.
4. On the beams from group “4” (A₄, B₄, C₄) long term permanent load with intensity “g” has been applied on the age of concrete of 40 days, to be held up for one year as a long term load. On the fortieth day, variable cyclic repeated load “± q” was also applied in an interval of 8 hours +q and 16 hours –q, for one year (Figure 4). It means that for 8 hours every day the beams will be loaded additionally with load “q” and the strains, deformations and crack widths will be measured. After 8 hours the beams will be unloaded from the load “q” and all the measurements will be performed again. This will be repeated every day for one year in order to simulate a realistic load history.
The mixture proportioning was done so that it is the same for the three types of concrete and it is presented in Table 1. The experimental program is presented in detail in Table 2.

The long term load, which consists of permanent sustained load “g” and variable repeated load “q”, was applied by gravitation lever (Figure 5), which enabled an increase of the load for 13 times. The permanent load acts all the time, while the variable load was applied and removed each day by secondary hand gravitation lever. The bending moments are as follows: from self weight of the beam, \( M_{sw}=1\text{kNm} \), from permanent load “g”, \( M_g=5.0\text{kNm} \), from variable load “q”, \( M_q=3.1\text{kNm} \), from self weight, permanent and variable load (service) \( M_{sw+g+q}=9.1\text{kNm} \). The bending crack moment was \( M_{cr}=6.1\text{kNm} \), while the ultimate bending moment \( M_u=15.6\text{kNm} \). The intensity of the load was chosen so that the \( M_{cr} \) is bigger than \( M_{sw+q} \) and smaller than \( M_{sw+g+q} \). The permanent load is 0.39 times the flexural strength, while the service load is 0.58 times the flexural strength of the beam without fibres.
Table 1: Mixture proportions for RC, SFRC1 and SFRC2

<table>
<thead>
<tr>
<th>Mixture proportions</th>
<th>(kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement CEM II/A-M 42.5N</td>
<td>410</td>
</tr>
<tr>
<td>Water</td>
<td>215</td>
</tr>
<tr>
<td>Aggregate:</td>
<td></td>
</tr>
<tr>
<td>0-4 mm</td>
<td>875</td>
</tr>
<tr>
<td>4-8 mm</td>
<td>350</td>
</tr>
<tr>
<td>8-16 mm</td>
<td>525</td>
</tr>
<tr>
<td>Fibres:</td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>0</td>
</tr>
<tr>
<td>SFRC1</td>
<td>30</td>
</tr>
<tr>
<td>SFRC2</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 2: Experimental program

<table>
<thead>
<tr>
<th>Series</th>
<th>Group</th>
<th>Number of elements</th>
<th>Type of concrete (C30/37)</th>
<th>Steel fibres (kg/m³)</th>
<th>Tensile Reinforcement μ (%)</th>
<th>Type of long term load</th>
<th>Time of ultimate load testing</th>
<th>Time of observing of the elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 2</td>
<td>RC</td>
<td>0</td>
<td>0.37</td>
<td>/</td>
<td>t=28</td>
<td>t=28</td>
<td>t=400</td>
</tr>
<tr>
<td></td>
<td>2 2</td>
<td>RC</td>
<td>0</td>
<td>0.37</td>
<td>/</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 2</td>
<td>RC</td>
<td>0</td>
<td>0.37</td>
<td>&quot;g&quot; *</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 2</td>
<td>RC</td>
<td>0</td>
<td>0.37</td>
<td>&quot;g ±q&quot;(Δt=8h)</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1 2</td>
<td>SFRC 1</td>
<td>30</td>
<td>0.37</td>
<td>/</td>
<td>t=28</td>
<td>t=28</td>
<td>t=400</td>
</tr>
<tr>
<td></td>
<td>2 2</td>
<td>SFRC 1</td>
<td>30</td>
<td>0.37</td>
<td>/</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 2</td>
<td>SFRC 1</td>
<td>30</td>
<td>0.37</td>
<td>&quot;g&quot; *</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 2</td>
<td>SFRC 1</td>
<td>30</td>
<td>0.37</td>
<td>&quot;g ±q&quot;(Δt=8h)</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1 2</td>
<td>SFRC 2</td>
<td>60</td>
<td>0.37</td>
<td>/</td>
<td>t=28</td>
<td>t=28</td>
<td>t=400</td>
</tr>
<tr>
<td></td>
<td>2 2</td>
<td>SFRC 2</td>
<td>60</td>
<td>0.37</td>
<td>/</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 2</td>
<td>SFRC 2</td>
<td>60</td>
<td>0.37</td>
<td>&quot;g&quot; *</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 2</td>
<td>SFRC 2</td>
<td>60</td>
<td>0.37</td>
<td>&quot;g ±q&quot;(Δt=8h)</td>
<td>t=428</td>
<td>t=400</td>
<td></td>
</tr>
</tbody>
</table>

RC - reinforced concrete; SFRC 1 - Steel fibre reinforced concrete with 30 kg/m³ (0.38%) steel fibres and additional reinforcement 2Ø10; SFRC 2- Steel fibre reinforced concrete with 60 kg/m³ (0.76%) steel fibres and additional reinforcement 2Ø10; Δt=8h (8h loading, 16h unloading).

*pre-cracked with load "g + q"

The casting of the beams was done by a series from 8 beams in wooden moulds in October and November 2011. Each time 42 control specimens were taken for testing of the mechanical and time...
dependant characteristics of concrete at 40 and 400 days. The beams and control specimens were
cured for 8 days and than they were transported to the Laboratory at the Faculty of Civil Engineering –
Skopje where they were kept under almost constant temperature ranging from 17-20°C and constant
relative ambient humidity of 60%, which was regulated with special humidifiers and dehumidifiers. The
mechanical characteristics of the three series were tested at 40 days and the beams were loaded at
the same age, each according to the previously specified loading history. The drying shrinkage was
measured immediately after opening of the moulds of the control specimens. Compression creep was
applied with creep frames and the stress level of the 12x12x36cm prism specimens was the same as
the stress in the full scale beams from the sustained load, which is 7.5MPa.

4 TEST RESULTS

The mixture proportioning was done according to all the recommendations, [5], [6] and [7] in the up
to date literature, so the slump of the concrete without fibres was 120mm. Since the fibres are
decreasing the workability, the slump decreased to 75mm and 50mm with addition of 30 and 60 kg/m³.

<table>
<thead>
<tr>
<th>Type of concrete</th>
<th>Slump (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Concrete (RC)</td>
<td>120</td>
</tr>
<tr>
<td>Steel fiber reinforced concrete with 30 kg/m³ (SFRC1)</td>
<td>75</td>
</tr>
<tr>
<td>Steel fiber reinforced concrete with 60 kg/m³ (SFRC2)</td>
<td>50</td>
</tr>
</tbody>
</table>

Mechanical properties at the age of 40 days were tested on 3 specimens for the compressive
strength, splitting tensile strength and Modulus of Elasticity and 6 specimens for the flexural tensile
strength, according to RILEM TC 162-TDF, [2] and [3]. The average results are presented in Table 4.

<table>
<thead>
<tr>
<th>Mechanical properties</th>
<th>RC</th>
<th>σ (St.dev.)</th>
<th>SFRC1</th>
<th>σ (St.dev.)</th>
<th>SFRC2</th>
<th>σ (St.dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression strength (MPa) (cubes 15/15/15cm)</td>
<td>42.89</td>
<td>0.18</td>
<td>41.63</td>
<td>4.79</td>
<td>44.59</td>
<td>1.83</td>
</tr>
<tr>
<td>Splitting tension strength (MPa) (cubes 15/15/15cm)</td>
<td>3.51</td>
<td>0.1</td>
<td>3.22</td>
<td>0.14</td>
<td>4.00</td>
<td>0.31</td>
</tr>
<tr>
<td>Flexural tensile strength (MPa) (beams 15/15/70cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- σ₁ (stress at δ₁=0.05mm)</td>
<td>5.18</td>
<td>0.56</td>
<td>4.95</td>
<td>0.34</td>
<td>5.30</td>
<td>0.66</td>
</tr>
<tr>
<td>- σ₂ (stress at δ₂=0.06mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- σ₃ (stress at δ₃=3.00mm)</td>
<td>1.53</td>
<td>0.4</td>
<td>2.33</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus of Elasticity (MPa) (cylinders 15/30cm)</td>
<td>26956</td>
<td>127.2</td>
<td>26771</td>
<td>93.2</td>
<td>26120</td>
<td>423.2</td>
</tr>
</tbody>
</table>

Since the experiment is still ongoing, only the results from the first 150 days for the drying
shrinkage and creep are presented in this paper (Figure 6 and Figure 7).

The measured drying shrinkage strains after this time period are: 664[10^6]μs for RC, 650[10^6]μs

for SFRC2, while the creep strains after this time period are: 561[10^6]μs for RC, 529[10^6]μs for
The time dependant deflections, as well as the time dependant crack widths for the beams from group 3 and 4, on which specific loading history is applied, are presented for the first 100 days in Figure 8 to Figure 11.

The instantenous deflections at the load level of “g” for the beams from group 3 are: 1.94mm for RC, 1.56mm for SFRC1 and 1.31mm for SFRC2, while the deflections after 100 days of loading at the same load level are: 2.99mm for RC, 2.46mm for SFRC1 and 2.16mm for SFRC2.

Time dependant crack widths are presented for load level “g” and the values for the beams from group 3 are: 0.12mm for RC, 0.11mm for SFRC1 and 0.07mm for SFRC2. 0.085 0.10 0.045

The instantenous deflections at the load level of “g+q” for the beams from group 4 are: 1.91mm for RC, 1.77mm for SFRC1 and 1.48mm for SFRC2, while the deflections after 100 days of loading at the same load level are: 4.05mm for RC, 3.39mm for SFRC1 and 2.96mm for SFRC2.

Time dependant crack widths are presented for both load levels “g” and “g+q” and the values at the load level “g+q” for the beams from group 4 are: 0.17mm for RC, 0.13mm for SFRC1 and 0.07mm for SFRC2.
Figure 8: Time dependant deflection for the beams from group 3 for RC, SFRC1 and SFRC2

Figure 9: Time dependant crack widths for the beams from group 3 for RC, SFRC1 and SFRC2

Figure 10: Time dependant deflection for the beams from group 4 for RC, SFRC1 and SFRC2
On the 6 full scale beams from all three series from group 1, ultimate load test was performed in 29 load steps (Figure 12). A data acquisition system from Hottinger Baldwin-HBM, Germany, was used for recording of the force, middle deflection, strains in the compression and tensile reinforcement and the bottom and top of the concrete with f=1Hz. The Load cell and the LVT, as well as the strain gages were a product of Kyowa, Japan. In each step, the strains in the concrete in the middle section of the beam through the thickness as well as on the top of the beam were measured with mechanical deflection meter, type Hugenerberger, Switzerland, with base of 250mm. The mechanical measurement of the deflections is done in 5 points through the length of the beam with deflection meters Stopani, Italy. The crack widths were also measured in each load step with crack microscope of Controls, Italy. On the other 18 beams from the groups 2, 3 and 4, after 400 days of observing, an ultimate load test will be performed in the same manner as described above.
5 CONCLUSIONS

Because of the scarcity of investigations in the area of long term behaviour of steel fibre reinforced concrete elements, the aim of this still ongoing research is to contribute to the creation of a data base, which will help in the definition of a computational model, which will present the influence of creep and shrinkage on the behavior of steel fibre reinforced concrete elements.

In order to obtain the mechanical characteristics of the three different concretes, tests were done and the results show that with addition of 30 kg/m$^3$ fibres there is no significant improvement, except for an increase in toughness. With 60 kg/m$^3$ fibres, the compressive strength was already increased for 4%, the splitting tensile strength for 14% and flexural tensile strength for 2.3%. On the other hand, the slump decreased from 120 mm of RC to 75 mm of SFRC1 and 50 mm of SFRC2.

After measuring of the drying shrinkage strains in the first 150 days, it can be noticed that the addition of 30 kg/m$^3$ or 60 kg/m$^3$ steel fibres does not have any influence on the drying shrinkage.

On the other hand, the addition of 30 kg/m$^3$ steel fibres reduced the creep strain for 5.7%, while the addition of 60 kg/m$^3$ reduced the total creep strain for 12.1% when compared to ordinary concrete.

After obtaining the final results from the drying shrinkage and creep, based on the Theory of the creep of steel fibre cement matrices under compression, developed by Mangat and Azari, it is expected that a certain improvement of the viscous (flow) compliance in the Model B3 will be made, which is Creep and shrinkage prediction model for an analysis and design of concrete structures, developed by Prof. Bazant.

The time dependant deflections on the beams from group 3 after 100 cycles of loading are for 17.7% smaller for SFRC1, while 27.8% smaller for SFRC2 when compared to RC.

The time dependant crack widths on the beams from group 3 after 100 cycles of loading are for 8.3% smaller for SFRC1, while 41.7% smaller for SFRC2 when compared to RC.

The time dependant deflections on the beams from group 4 after 100 cycles of loading are for 16.3% smaller for SFRC1, while 26.9% smaller for SFRC2 when compared to RC.

The biggest improvement up to now, was achieved at the time dependant crack widths on the beams from group 4, which are 23.5% smaller for SFRC1, while 58.8% smaller for SFRC2 when compared to RC.

From the load – deflection relationship obtained during the short term ultimate load test, shown in Figure 12, it can be noticed that the beams behave similarly up to the moment of cracking, and after that the more significant increase of the cracks width at the RC beams results in steeper degradation of their stiffness.

At the end of the experimental program, using the AAEM method, a certain value for the coefficient $\psi_2$ for Steel fibre reinforced concrete will be proposed, defining the quasi permanent value of variable load according to Eurocode 2, for structures like warehouses, parking garages or bridge girders.

ACKNOWLEDGEMENTS

I would like to thank my co-mentor Prof. Peter Mark from Ruhr-University Bochum, Germany for the support during my work on the thesis. Many thanks to the Deutscher Akademischer Austausch Dienst (DAAD) and SEEFORM PhD studies for the scholarship and the financial support.

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