# INFLUENCE OF SHEAR FAILURE OF FLEXURAL FIBRE CONCRETE BEAMS REINFORCED WITH REBARS OF TWO DUCTILITY CLASSES

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## Abstract

*The paper deals with types of failure of fibre reinforced beams with standard reinforcement of two ductility classes. It is shown in the graphs of relation between the force and deflection. The types of failure are discussed. There are the basic recommendations how to protect brittle failure of flexural concrete beams.*

**Keywords: shear failure, flexural failure, fibre-reinforced concrete, ductility class of steel, ductility of beams.**

## 1. Introduction

To check possibilities of replacement of shear reinforcement at the reinforced concrete structures by the steel fibres were draft destruction tests simulated the failure due to flexural - shear strength by bending of reinforced concrete beams with the size 100/150/1800mm, with the effective span $l$ = 1500mm, according the Fig.1. All the beams are reinforced by two longitudinal rebars (2 Ø 10) - strength class of reinforcing steel B500, in two variants of ductility class A and C (i.e. B500 A and B500 C e.g. EPSTAL – see Fig. 2).

To cause rather shear failure than the failure caused by bending moment for test loads were moved the symmetrical forces $F/2$ to the mid point of beam closer to supports – on the distance $c$ = 600mm between the forces, i.e. on the critical shear slenderness of the beam $\lambda_v = a / h = 450 / 150 = 3{,}0$ (see Figure 1). (For testing flexural failure of beams the distance between the forces $c$ = 200mm, was used, i.e. $\lambda_v = 650 / 150 = 4{,}33$.)

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For the verification of the influence of steel fibres on the shear load capacity there were compared concrete beams reinforced not only by rebars (2Ø10) but also by steel fibres of three types (see Table 1 - notation SFRC) with concrete beams without fibres reinforced only by longitudinal rebars (2Ø10) (see Table 1 - notation RC). The volume ratio $\rho_{v,f}$ for all types of steel fibres is equal $\rho_{v,f}$ = 0,5% (i.e. $m_f \approx 40 kg/m^3$).

For the three used types of steel fibres was demonstrated the influence of type of fibres on the characteristic strengths of concrete in compression and tension by macro-cracking (see Table 1).

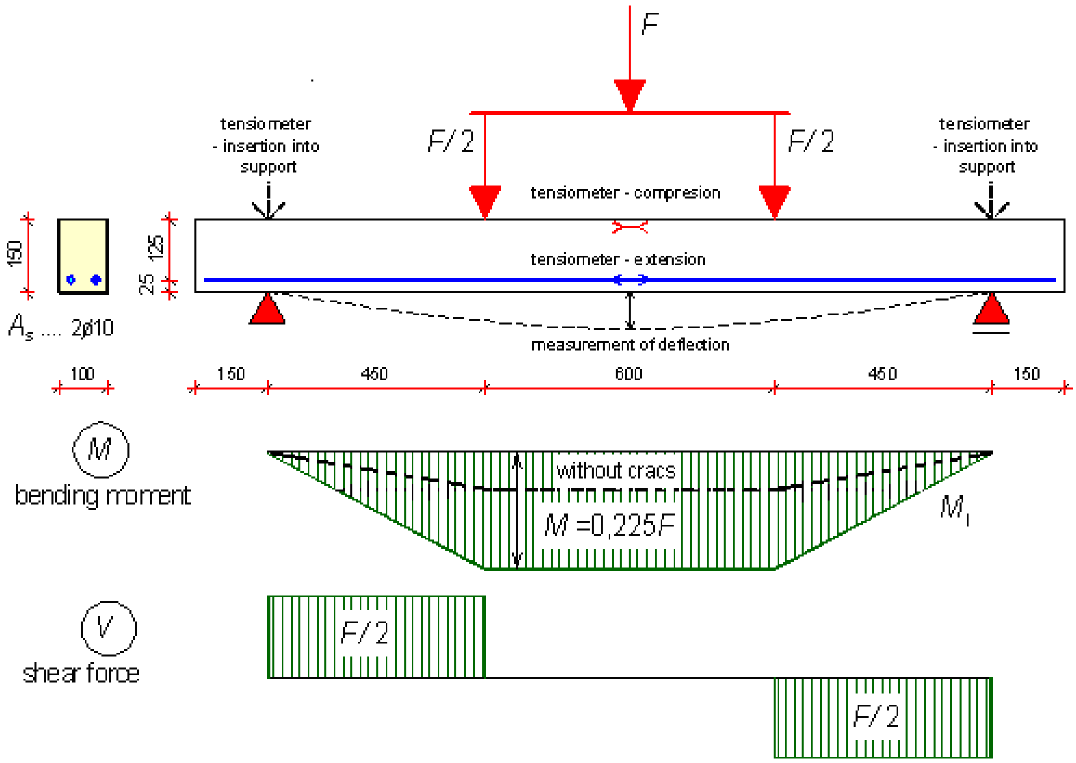



*Fig. 1* Adjustment of test flexural – shear strength by bending

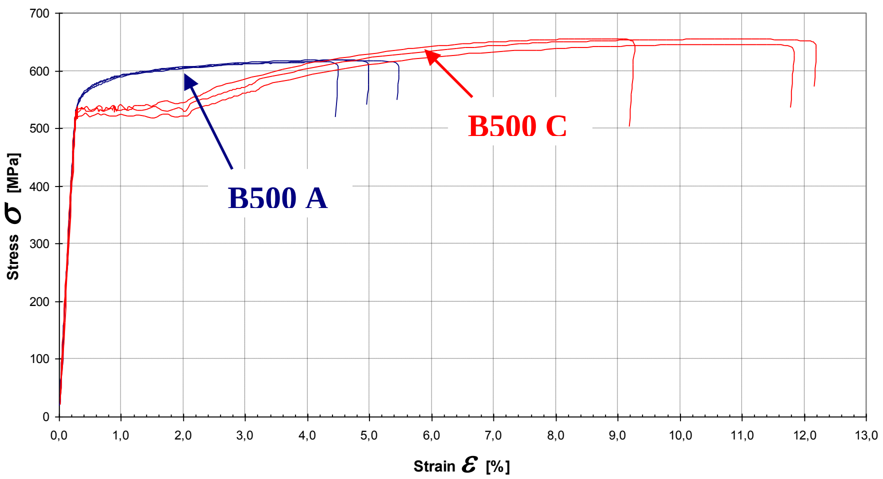



*Fig. 2* Tensile stress-strain diagrams of reinforcing steel B500 – initial tests of rebars Ø10 of steel class ductility B500 A and B500 C (3 test specimens)

Tab. 1 Influence of the type of steel fibres with $\rho_{v,f}$ = 0,5% on characteristic strengths steel fibre reinforced concrete (SFRC) composite and the comparison with verified reinforced concrete (RC) composite without fibres

<table>
<tr><td colspan="3">Reinforced concrete</td><td>RC - 2Ø10</td><td colspan="3">SFRC - 2Ø10 + steel fibres</td></tr>
<tr><td colspan="3">Type of steel fibres</td><td>-</td><td>TT 50</td><td>D 35</td><td>D 60</td></tr>
<tr><td colspan="2">Volume ratio of fibres</td><td>$\rho_{v,f}$ [%]</td><td>-</td><td colspan="3">0,5</td></tr>
<tr><td rowspan="4">Characteristic strength of RC or SFRC in axial [MPa]</td><td rowspan="2">compression</td><td>$f_{c,k}$</td><td>55,0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>$f_{fc,kc}$</td><td>-</td><td>60,0</td><td colspan="2">67,0</td></tr>
<tr><td rowspan="2">tension (cracking)</td><td>$f_{ck,t}$</td><td>3,0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>$f_{fck,t}$</td><td>-</td><td>3,5</td><td>3,8</td><td>4,1</td></tr>
<tr><td rowspan="2">Ratio [%]</td><td colspan="2">$f_{fc,kc} / f_{c,k}$</td><td>100</td><td>109</td><td colspan="2">122</td></tr>
<tr><td colspan="2">$f_{fc,kt} / f_{ck,t}$</td><td>100</td><td>117</td><td>127</td><td>137</td></tr>
</table>

All used types of steel fibre have nearly the same anchoring end-bend and differ in lengths, in diameter, in slenderness of the fibre and in characteristic tensile strength of the fibre-steel (see Table 2).

Tab. 2 Characteristics of steel fibres

| Type of steel fibres | TT 50 | D 60 | D 35 |
|---|---|---|---|
| Marking of the producer | TriTregg<br>CE 50 | Dramix<br>RC 80/60 BN | Dramix<br>RC 80/35 BP |
| Fibre :<br>Length $l_f$ [mm] | 50 | 60 | 35 |
| Diameter $\phi_f$ [mm] | 1,05 | 0,75 | 0,45 |
| Slenderness $l_f / \phi_f$ | 47,6 | 80,0 | 77,8 |
| Strength of steel $f_{f,k}$ [MPa] | 1200 | 1300 | 2300 |

## 2. Load bearing capacity of tested beams

The load bearing capacity of tested beams was affected by nature of failures. The shear failures as shear cracking, anchoring failure or crushing of concrete due to interaction of shear and compression stresses are mostly brittle failures (see Fig. 3.1 and 3.2), contrary to flexural cracking failures that are ductile when the rebars of high ductility are used (B500 C – see Fig. 4.2 and 6.2). Rebars with low ductility (B500 A) have many times caused the tensile failure of rebars (see Fig. 4.1, 5.1 and 6.1).

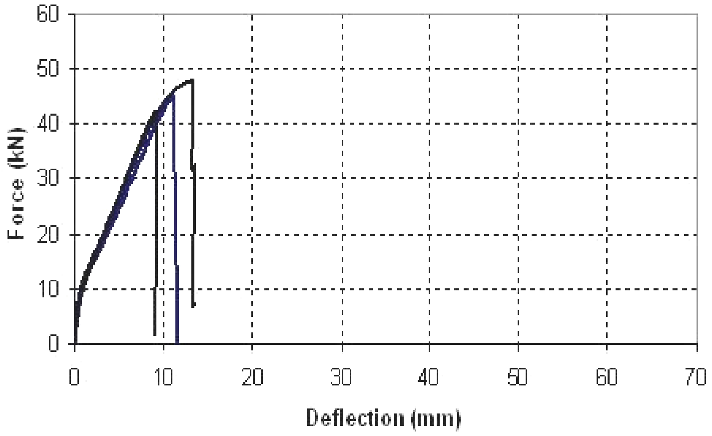



*Fig. 3.1* RC beam (2Ø10 of ductility class B500 A) without fibres

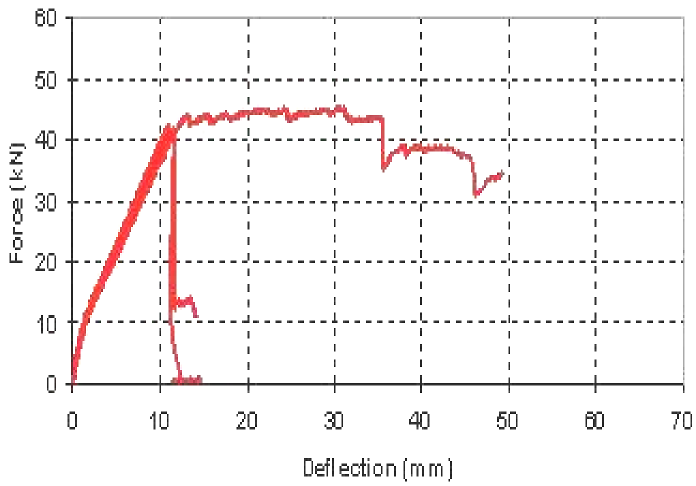



*Fig. 3.2* RC beam (2Ø10 of ductility class B500 C) without fibres

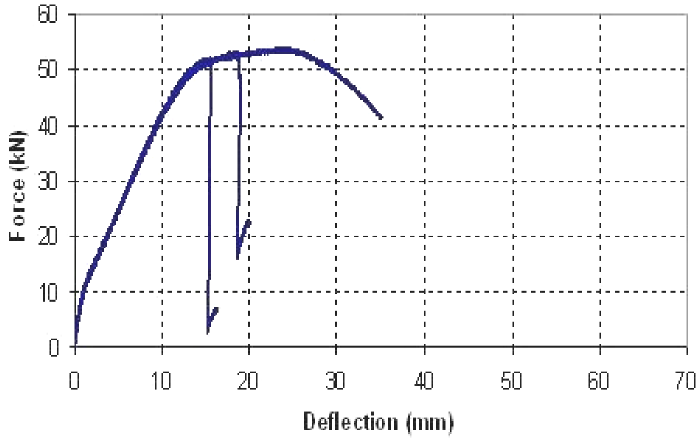



*Fig. 4.1* SFRC beam with TriTreg fibres (2Ø10 of ductility class B500 A)

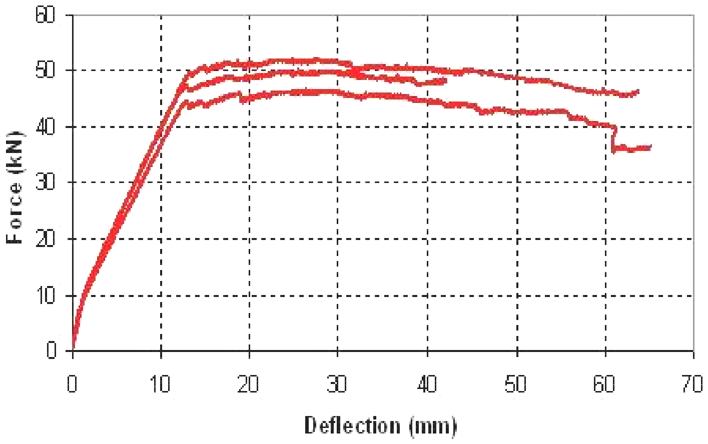



*Fig. 4.2* SFRC beam with TriTreg fibres (2Ø10 of ductility class B500 C)

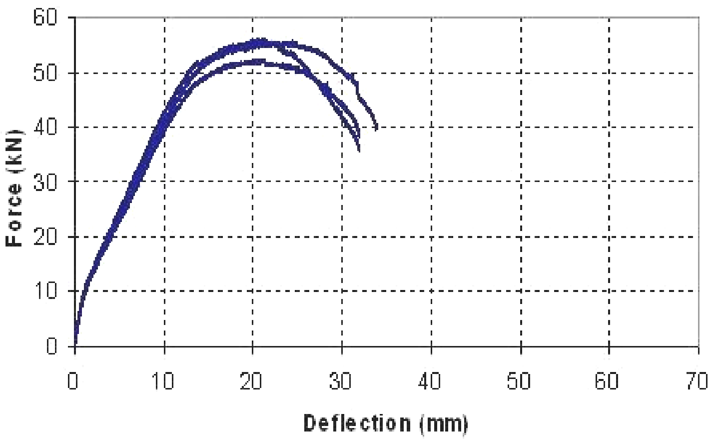



*Fig. 5.1* SFRC beam with Dramix 60 (2Ø10 of ductility class B500 A)

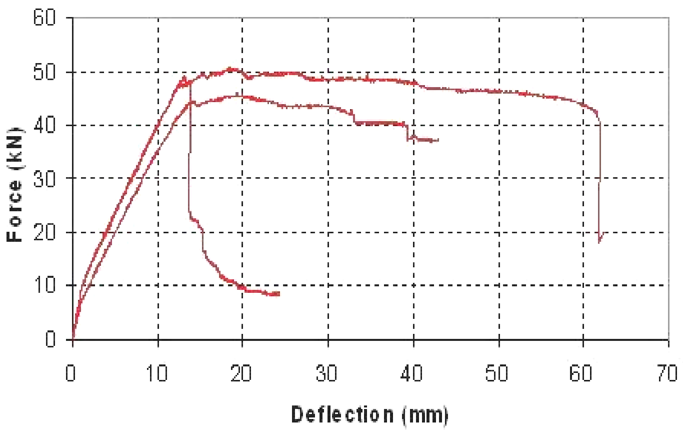



*Fig. 5.2* SFRC beam with Dramix 60 (2Ø10 of ductility class B500 C)

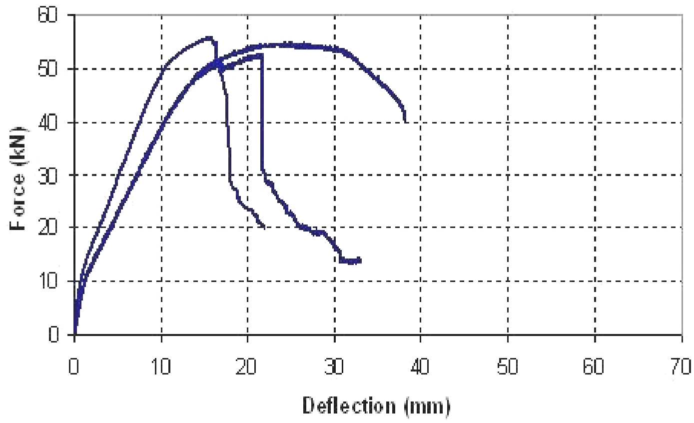



*Fig. 6.1* SFRC beam with Dramix 35 (2Ø10 of ductility class B500 A)

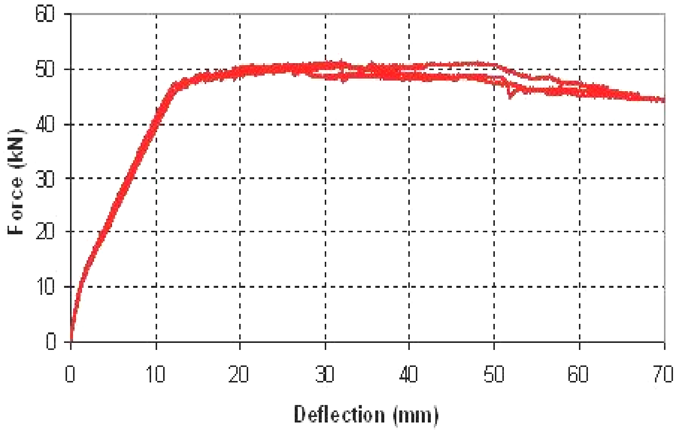
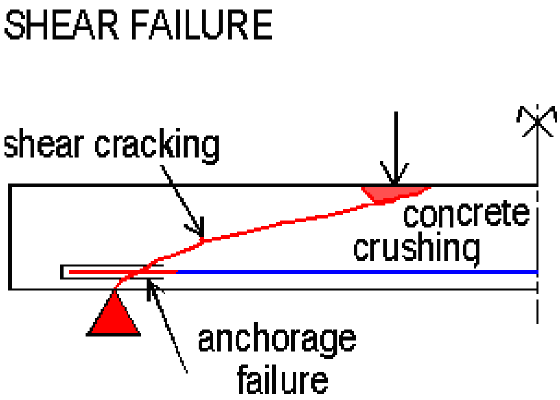



*Fig. 6.2* SFRC beam with Dramix 35 (2Ø10 of ductility class B500 C)

We have two types of failure – shear and flexural failure (see *Fig. 7* and *Fig. 8*). The load bearing capacity of SFRC beams ($\rho_{v,f}$ = 0,5%) is about 10-20% bigger than of RC beams (without fibres) – see Table 1.

The ductility of SFRC beams denoted by the influence of the deflection at beams load bearing capacity is greater than that of RC beams about 100% (for B500 A) to 165% - 300% (for B500 C), see Tab. 3 .

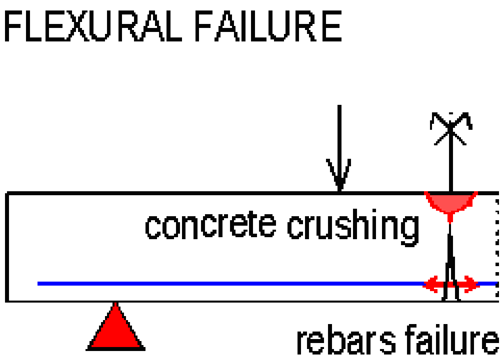



Shear cracking

Anchorage failure

Crashing of concrete

*Fig. 7* Types of failure – shear failure



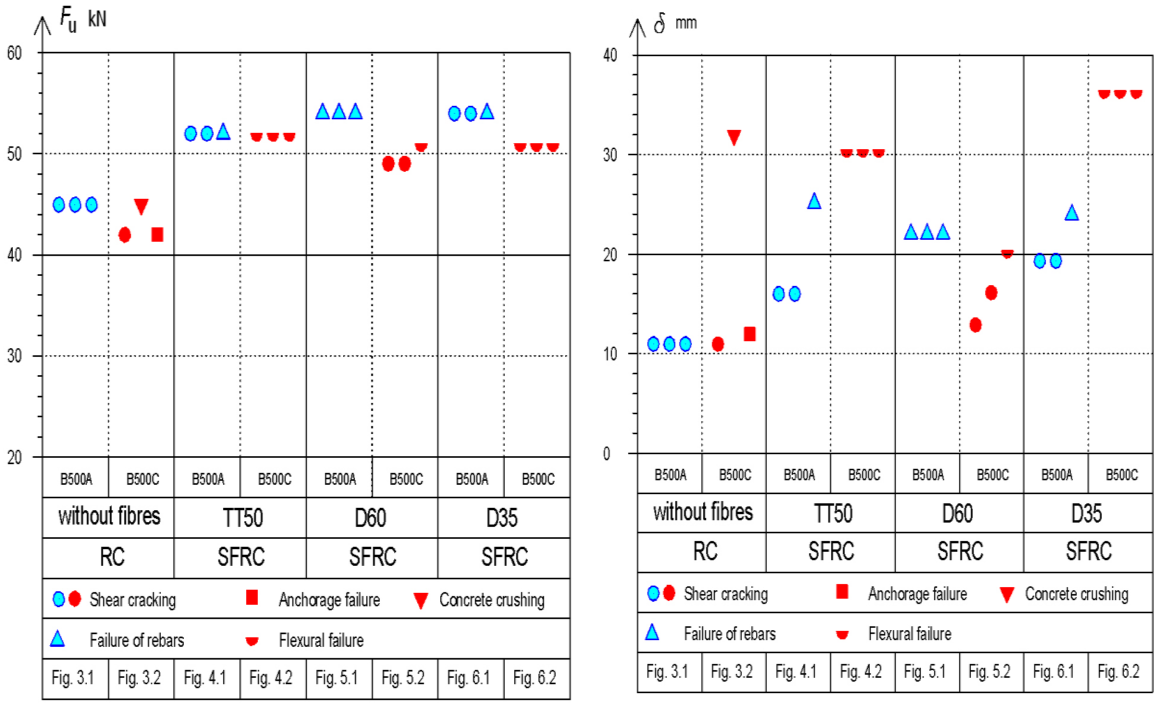

Flexural cracking failure

Rebars tension failure

*Fig. 8* Types of failure – flexural failure

Summary of load bearing capacity and ductility of RC and SFRC beams are shown in the table 3.

Tab. 3 Type of failure and load bearing capacity $F_u$ [kN] and deflection $\delta$ [mm] of RC and SFRC beams




## 3. Conclusions

With regard to the brittle shear failure it is necessary to prevent its existence. That can be attained by using:

- higher volume ratio of fibres $\rho_{v,f} > 0,5\%$,

- combination of fibres and shear reinforcing steel stirrups of high ductility.

To prevent the primary brittle failure in transverse shear of flexural beams consideration should be given to interaction of fibre-reinforced concrete with stirrups made of steel with high ductility class and ensure the high deflection of beams at flexural failure.

### Acknowledgements

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# 4. References

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