IMPACT RESISTANCE OF STEEL FIBRE REINFORCED CONCRETE

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Abstract

Fibre-reinforced composite materials are becoming important in many areas of technological application. In addition to the static load, structures may be stressed with short-term dynamic loads or even dynamic impact loads during their lifespan. Dynamic effects can be significant especially for thin-walled shell structures and barrier constructions. It is clear that reinforced concrete with fibres has a positive impact on increasing the resistance to impact loads. However, the assessment of the increase of this resistance has not been sufficiently verified experimentally. Laboratory load tests, aiming not only to determine the appropriate shape of test specimens, but also to evaluate and select appropriate ways to support the test specimens are presented. Also the results of impact load tests and modulus of elasticity of concretes tests are presented.

Keywords: (Impact resistance, steel fibre, concrete)

1. Introduction – Project objectives and progress

The goal of the project is to establish new procedures for evaluating the impact resistance of steel fibre reinforced concrete. An appropriate shape of test specimens, ways to support the test specimens and the method of measurement were chosen on the basis of experiments. A suitable form of test specimens was selected on the basis of static load tests of unreinforced test specimens.

The load tests of specimens reinforced with different fibre content of reinforcement were made afterwards.

2. Choose of the appropriate shape of test specimens

Based on the literature search, two types of specimens were selected for testing. The first one is a square plate of side 500 mm and the second one is a circular plate with a diameter of 500 mm. In both cases, the thicknesses of the specimens were 50 mm. The test results

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were subsequently verified by the static analysis. The specimens were supported along the perimeter. The surface area on which the load was applied was circa 7850 mm2. The test arrangement is shown in Figure 1 and Figure 2.

Fig. 1: Test arrangement. Square plate.

Fig. 2: Test arrangement. Circular plate.

Test results in the form of the dependency graph between deflection and a force are shown in Figure 3.

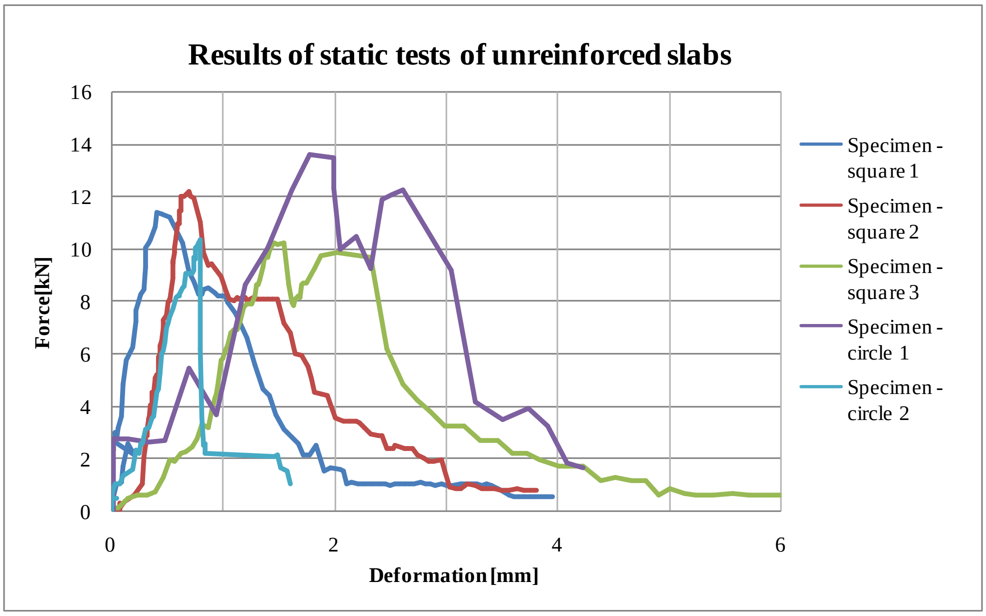

Fig. 3: Results of static test of unreinforced specimens.

The specimens in shape of a circular plate with a diameter of 500 mm and 50 mm thickness were selected for further examination on bases of the tests results.

3. Static tests of reinforced specimens

The next step was to determine the static load of the specimens with different amounts of reinforcement. Each recipe, with different amounts of reinforcement is given in Table. 1. The steel wire Fibers with hooked ends (KrampeHarex DE50/1,0 N) of diameter 1,0 mm and length of 50 mm were used.

Tab. 1: Mixtures A, B and C

MIXTURE		A	B	C
Concrete component		[kg/m^3]	[kg/m^3]	[kg/m^3]
CEM II/A-S 42,5 R – Čížkovice		350	350	350
Aggregate:	Fine 0 - 4mm, Kaznějov	1195	1189	1181
	Coarse 4 - 8mm, Kaznějov	644	641	636
Superplasticizer, Chysofluid Optima 208		8,75	8,75	8,75
Steel wire Fibers KrampeHarex DE50/1,0 N		20	40	80
Water		157,5	157,5	157,5

The test results of reinforced specimens in the form of a dependency graph between deflection and applied force are shown in Figure 4. Marking of specimens A, B, C corresponds to the mixture in Table 1.

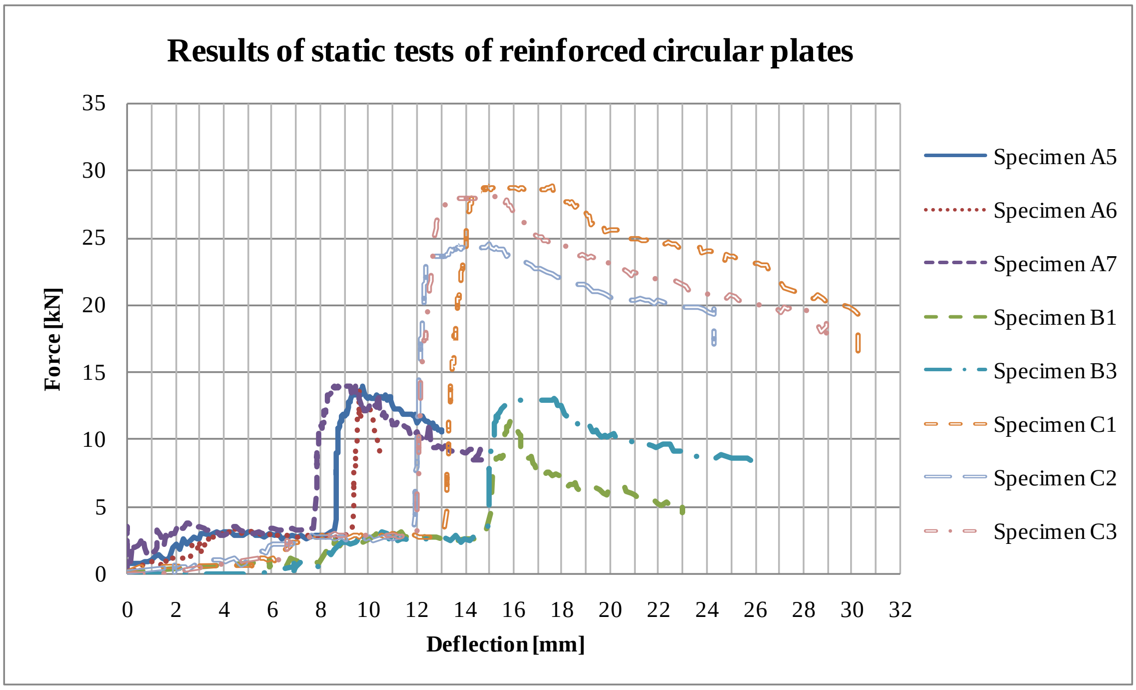

Fig. 4: Results of static test of reinforced circular specimens.

4. Dynamic tests of reinforced specimens

Dynamic load test was carried out at loading speed 70 mm/s. The maximum force at the failure and deflection were monitored. The specimens in shape of a circular plate with a diameter of 500 mm and 50 mm thickness were supported along the perimeter.

The test results of reinforced specimens in the form of a dependency graph between deflection and applied force are shown in Figure 5 to 7.

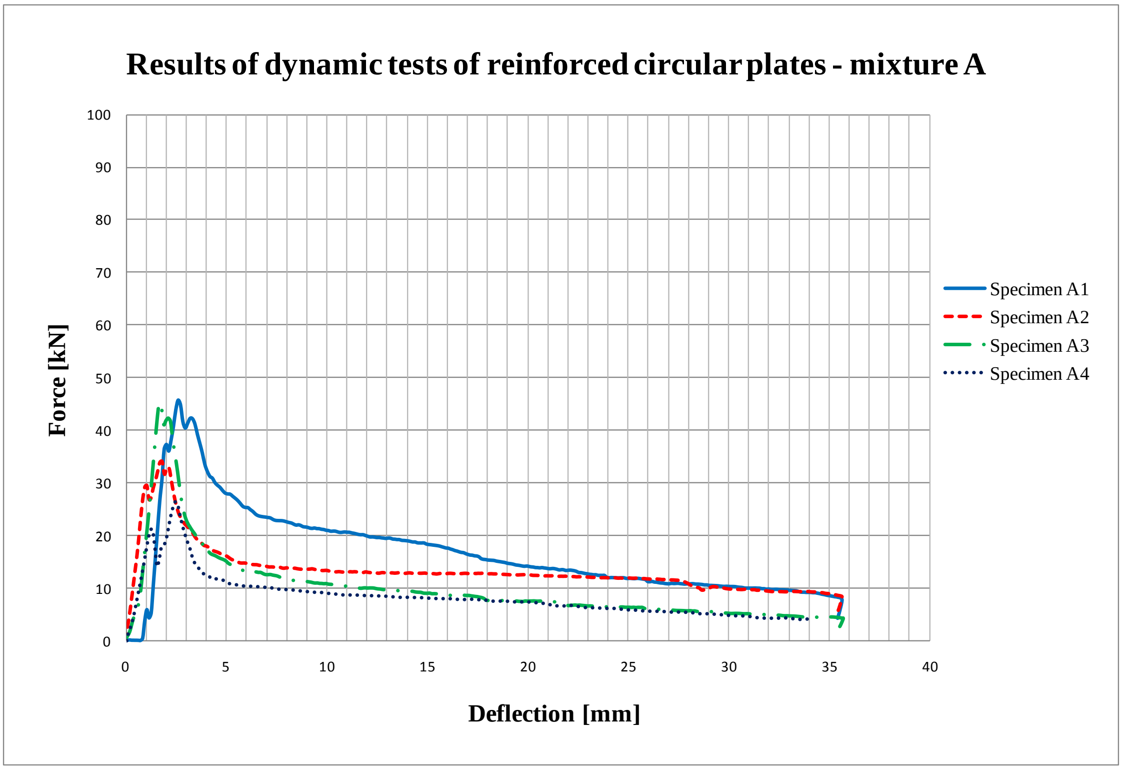

Fig. 5: Results of dynamic test of reinforced circular specimen – mixture A.

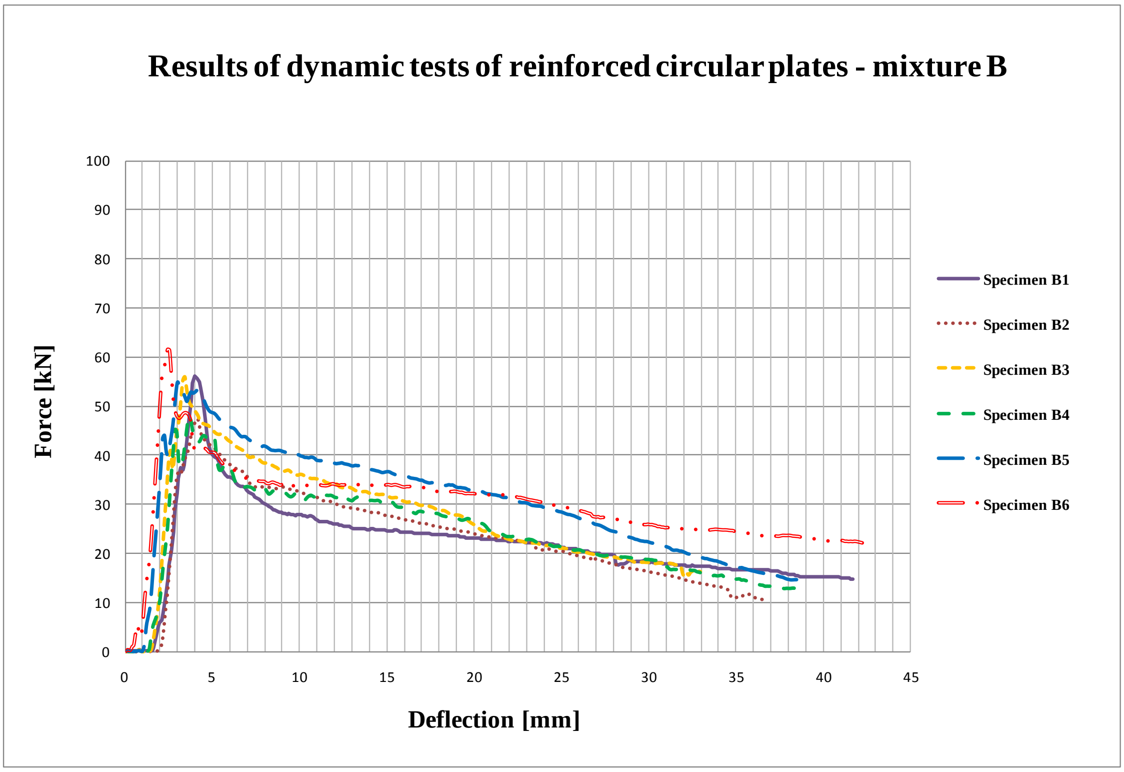

Fig. 6: Results of dynamic test of reinforced circular specimen – mixture B.

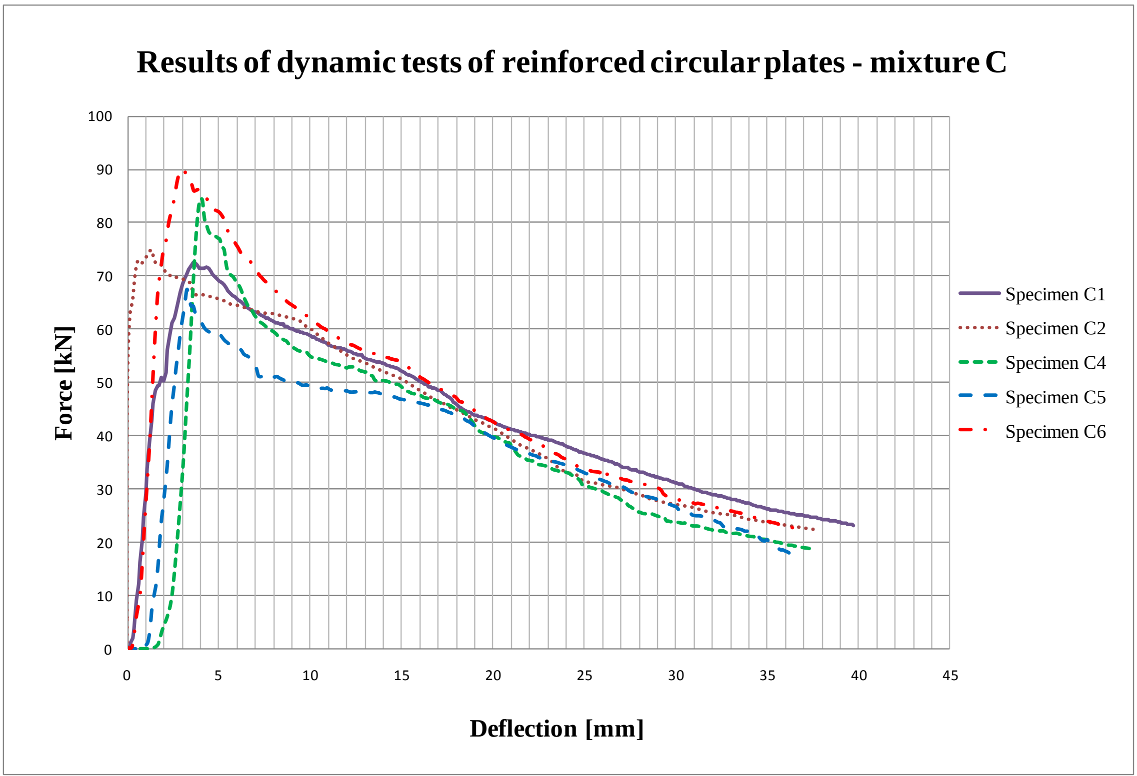

Fig. 7: Results of dynamic test of reinforced circular specimen – mixture C.

5. Modulus of elasticity

Test specimens were (prism 100x100x400 mm) made into steel moulds, compacted on vibratory table, were demoulded after 24 hours and the samples are stored in water according to ČSN EN 12390-2 up to the test, which takes place within 28 days. Before testing, the specimen is taken out of the water, the surface is left to dry, measured and weighed. The measurement of the static modulus of elasticity is conducted in accordance with ČSN ISO 6784.

This is the most commonly used test in practice for the determination of modulus of elasticity. Modulus of elasticity is determined from the deformations that occur between the basic tension 0,5 MPa and at the upper tension which is equal to one third of compressive strength of concrete. Strain sensors must be placed on at least two opposite sides of the specimen and must comply with the condition, see Figure 8. The first test cycle checks the centric location of the specimen in the testing machine. After centring, the concrete specimen is subjected to load at least two prior cycles, followed by a measured cycle for calculating of the modulus of elasticity. Modulus Ec is then calculated from the formula (1).

$$E_c = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} = \frac{\Delta\sigma}{\Delta\varepsilon} \qquad (1)$$

Where σ_2 upper tension in MPa,

σ_1 basic tension in MPa,

$\Delta\varepsilon$ average change in the relative strain between σ_2 and σ_1

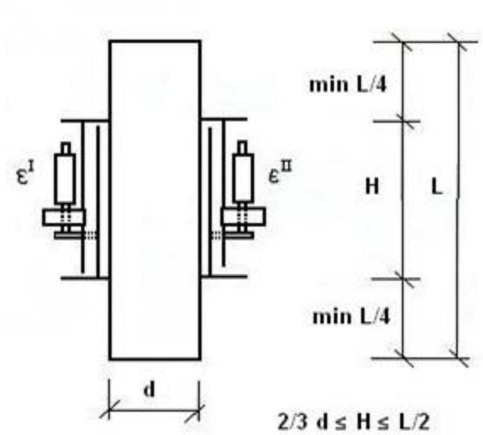

Fig. 8: Location of test equipment on test specimen.

The test results in the form of a dependency graph between Compressive Strength and Modulus of elasticity are shown in Figure 9. The Compressive Strength test was carried out at cubes (150x150x150 mm).

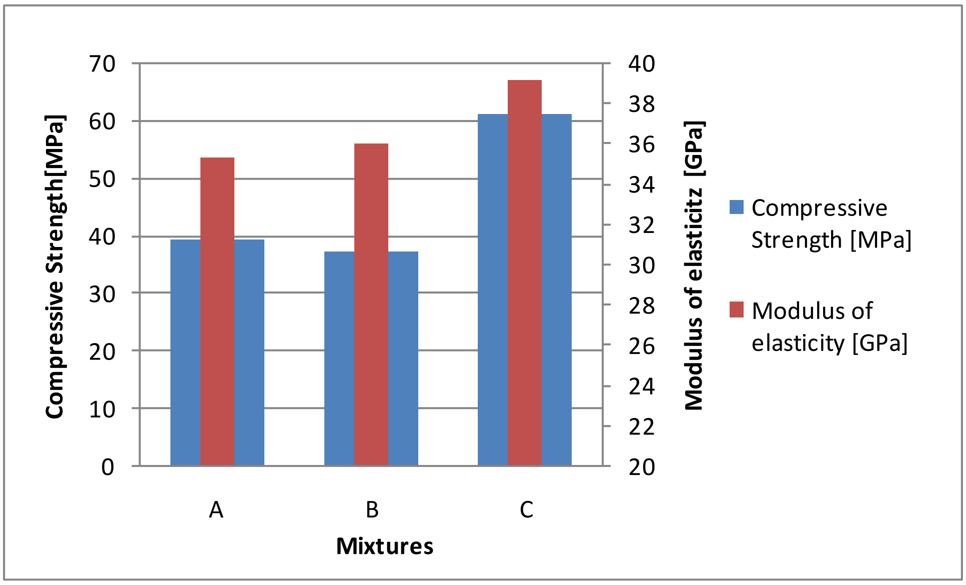

Fig. 9: Results of Modulus of elasticity and Compressive Strength.

6. Conclusions

The percentage increase of the different ways of loads, modulus of elasticity and different mixtures are shown in Table 2. As a basis for comparison, mixture A and unreinforced mixture are chosen.

Tab. 2: Comparing the tests results

Type of test	Parametr	Mixture			
		Unreinforced	**A**	**B**	**C**
Static load test - circular plates	Max. Force [kN]	11,58	12,91	13,2	27,05
	Increse [%]	-	**11,5**	**14,0**	**133,6**
Dynamic load test - circular plates	Max. Force [kN]		37,8	54,0	76,6
	Increse [%]		-	**42,7**	**102,6**
Dynamic load test - circular plates	Energy [kNm]		0,430	1,092	1,711
	Increse [%]		-	**154,0**	**297,9**
Modulus of elasticity - prism	Modulus of elasticity [GPa]		35,3	36,0	39,2
	Increse [%]		-	**2,0**	**11,0**
Compressive Strength - cube	Compressive Strength [MPa]		39,2	37,3	61,3
	Increse [%]		-	**-4,8**	**56,4**

The results obtained so far can be summarized as follows:

- Circular plate of diameter 500 mm and 50 mm thickness was selected as the optimum form of the specimen.
- Increase of the fibre reinforcement 40 kg/m^3 does not affect the increase in static load, modulus of elasticity and compressive strength, but allows further increase in deflection. It also significantly increased dynamic load resistance of the specimens.
- Increase of the fibre reinforcement 80 kg/m^3 leads to a significant increase in static load and compressive strength. It also significantly increased dynamic load resistance of the specimens. The overall increase (static and dynamic load, compressive strength) ranges from 55 - 300%, compared to specimens with reinforcement around 20 kg/m^3.
- The energy needed to reach deflection 35 mm was evaluated from the force-displacement relationship. The overall increase of energy for specimens with reinforcement 40 kg/m^3 is around 150%, compared to specimens with reinforcement 20 kg/m^3. The overall increase of energy for specimens with reinforcement 80 kg/m^3 is around 300%, compared to specimens with reinforcement 20 kg/m^2.

The impact resistance testes with different amounts of reinforcement will be followed. The plan is to prepare two new Mixtures with reinforcement around 60 and 70 kg/m^3. Impact resistance of concrete with different degrees of reinforcement will be evaluated by setting the shock energy in failure of the specimens.

Acknowledgements

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7. References

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