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FIELD TESTS OF BLAST PERFORMANCE OF REINFORCED CONCRETE AND FIBER REINFORCED CONCRETE SPECIMENS

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Abstract: *According to recent publications, from 2005 to 2008 there were more than 13000 terrorist attacks around the world which took more than 73000 human lives. The attacks were targeted mainly on the technical and civic infrastructure, like governmental buildings, bridges, etc. Due to improved ductility, fibre-reinforced concrete (FRC) shows better performance under blast and impact loading than conventionally reinforced concrete. Field tests of FRC and reinforced concrete specimens were performed in cooperation with the Czech Army corps and Police of the Czech Republic in the military training area Boletice. The tests were performed using real scale precast slabs and 25 kg of TNT charges placed in distance from the slab for better simulation of real in-situ conditions. The paper presents primary results of the tests.*

Keywords: ***Blast loading, fiber concrete, reinforced concrete.***

1. Introduction

Recent terrorist attacks in Moscow (2011), Stockholm (2010), London (2005), Madrid (2004), etc. show great vulnerability of civil and transport infrastructure to this kind of threat. Attacks on structures like airports, railway and subway stations, bridges and governmental building can cause great casualties. These causalities multiply when the explosion causes collapse of the entire structure.

One of the ways of improving the blast performance of civil and transport infrastructure is the use of progressive materials like fiber reinforced polymer composites (Buchan & Chen, 2007). In case of building new structures, the needed ductility can be achieved by using plastic fibers in the concrete mix. Even bigger increase of blast and impact performance can be achieved by the use of ultra high performance fiber-reinforced concrete or engineered cementitious composites (Millard & al., 2010).

This paper presents the primary results of field tests of blast performance of reinforced concrete and reinforced concrete specimens with plastic fibers. The tests were performed in cooperation with the Czech Army corps and Police of the Czech Republic at the military training area Boletice using real scale precast slabs and 25 kg of TNT charges placed in distance from the slab for better simulation of real in-situ conditions.

2. Field tests of blast performance of reinforced concrete and reinforced concrete specimens with plastic fibres

2.1. Specimens

Dimensions of the specimens were designed in real scale of a small span bridge in as concrete slabs, 6 m long, 1.5 m wide and 0.3 m thick.

The specimens were made of C30/37-X0 concrete. Both specimens were reinforced by conventional reinforcement (B500B according to EN 1992-1-1 design code) at both surfaces, longitudinally by 11∅16 mm reinforcing bars (every 140 mm), transversely by ∅10 mm (every 150 mm). The shear reinforcement was provided by ∅8 mm links (9 pcs/m^2).

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Polypropylene 54 mm long synthetic fibers at 4.5 kg/m^3 were used in the second specimen. The dosage of the fibers was kept low as it can be achieved on-site.

2.2. Layout of the experiments

The experiments were carried out at the military training area Boletice in cooperation the Czech Army corps and Police of the Czech Republic. The blasts were performed on former artillery practice target area (900 m above sea level) which is now used for dismantling obsolete ammunition and ammunition from WW2 which is still found in the Czech Republic during construction works.

The slabs were placed on timber posts which were fixed in position by steel tubes. The ground under the slabs was removed; 5 m in diameter and 1 m deep excavation was prepared under the slabs so the results of the experiments would not be influenced by rebound of the pressure wave.

The 25 kg TNT charges were placed on steel "chairs" (3∅10 mm links, 3 mm thick S235 plate) in the middle of the slabs. The "chairs" provided off stand of 450 mm from the slab. This value was chosen as the most usual height of car trunk.

The charges were covered by a woolen blanket. According to the cooperating pyrotechnist, the blanket would concentrate the blast wave by 10-20%. The woolen blanket represents the camouflage, as the charge would not be discovered by routine police road check.

Layout of the experiments can be seen in Fig. 1.

Fig. 1: Layout of the experiments.

The charges were fired remotely by radio impulse.

The overpressure in the blast wave was recorded by four pressure sensors PCB®-type ICP 137A23, the signal was converted on a four-channel oscilloscope Tektronix®-type TDS3014B; the bus was located c.60 m far in a former gun bank. The sensors were dug in to the ground level, in order to minimize the possibility of damage by flying debris, but keeping the reading optimal. The sensors were placed on a helix with center at the location of the charge in distances 15, 20, 25 and 30 m.

2.2. Results of the experiments

The experiments showed the beneficiary effect of added fibers on blast performance of the specimens. The differences in puncture and spalling of concrete on the soffit of the slabs can be found in Tab. 1. The different effect of the blast on the surface closer to the explosion can be seen in Fig. 2 and 3.

Tab. 1: Comparison of blast performance of RC and RC with plastic fibers.

Damage	***RC specimen***	***RC with plastic fibers***	***RC with fibers / RC***
Puncture – top surface	*0.43 m^2*	*0.26 m^2*	*60%*
Permanent deflection	*0.31 m*	*0.378 m*	*122%*
Concrete spalling (soffit) - < concrete cover	*2.35 m^2*	*1.89 m^2*	*80%*
Concrete spalling (soffit) - > concrete cover	*1.71 m^2*	*1.09 m^2*	*64%*
Concrete spalling (left side) - < concrete cover	*0.35 m^2*	*0*	*-*
Concrete spalling (left side) - > concrete cover	*0.52 m^2*	*0.05 m^2*	*10%*
Concrete spalling (right side) - < concrete cover	*0.23 m^2*	*0.11 m^2*	*48%*
Concrete spalling (right side) - > concrete cover	*0.34 m^2*	*0.16 m^2*	*47%*

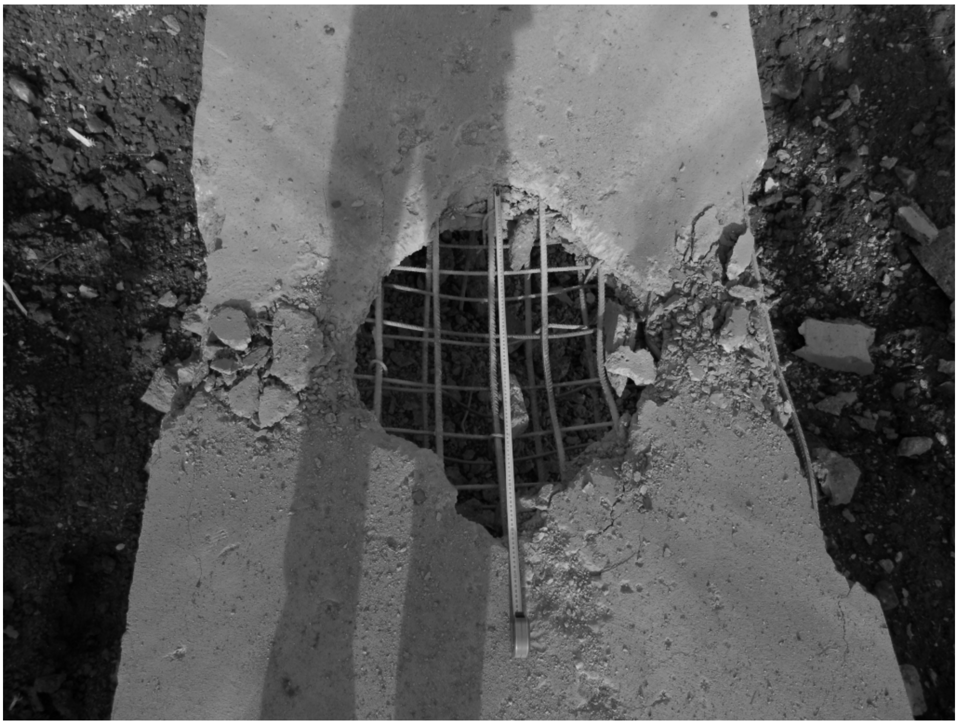

Fig. 2: Top surface of the RC specimen after the blast.

Fig. 3: Top surface of the RC specimen with plastic fibers after the blast.

In both cases, one longitudinal rebar and two transverse bars were torn by the explosion. The links did not show any effect on the shear capacity of the specimens; they were dislocated and remained hanging at the reinforcement or fell in the debris under the specimen.

3. Conclusions

The paper presented primary results of the field experiments targeted on comparison of blast performance of reinforced concrete and reinforced concrete with plastic fibers. The tests were performed using real scale precast slabs (0.3 x 1.5 x 6 m) and 25 kg of TNT charges placed in distance from the slab for better simulation of real in-situ conditions.

The results proved the beneficiary effect of added fibers on blast performance of the specimens. The puncture on the surface closer to the charge was reduced by 40% in area, the concrete spalling at the soffit of the specimen by 20% in area.

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References

Buchan, P.A. & Chen, J.F. (2007) Blast resistance of FRP composites and polymer strengthened concrete and masonry structures – A state-of-the-art review. Composites: Part B 38, pp. 509-522.

Coughlin, A.M. & al. (2010) Behavior of portable fiber reinforced concrete vehicle barriers subject to blasts from contact charges. International Journal of Impact Engineering, 37, 5, pp. 521-529.

Foglar, M. & al. (2011) Blast performance of reinforced concrete and fiber-reinforced concrete specimens (in Czech). Natural hazards (optimalisation of protection, interaction with structures). CTU Press, Prague, pp. 155-162.

Foglar, M. & al. (2010) The use of fibre reinforced concrete in blast and impact design (in Czech). Beton TKS, 10, 2, pp. 71-73.

Millard, S.G. & al. (2010) Dynamic enhancement of blast resistant ultra high performance fiber-reinforced concrete under flexural and shear loading. International Journal of Impact Engineering, 37, 4, pp. 405-413.

Schenker, A. & al. (2008) Full-scale field tests of concrete slabs subjected to blast loads. International Journal of Impact Engineering, 35, 3, pp. 184-198.

Wu, C. & al. (2009) Blast testing of ultra-high performance fibre and FRP-retrofitted concrete slabs. Engineering Structures, 31, 9, pp. 2060-2069.