EXPERIMENTAL BALLISTIC LOADING OF STEEL FIBRE REINFORCED CONCRETE SLABS AND UNREINFORCED CONCRETE SLABS BY PLASTIC EXPLOSIVES PLHX 30.

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Abstract

The article presents the results of experimental tests carried out on steel fibre reinforced concrete slabs and unreinforced concrete slabs. The aim of the experimental test was determine its suitability for anti-spalling layer by using effects of plastic explosive PlHx 30 explosion. Slabs of steel fibre reinforced concrete and plain concrete were made according to the same recipe. For this experiment was used high-strength concrete labelled C70/85. For mixing steel fibre reinforced concrete were added 30 kg/m3 fibres type DRAMIX RC-65/50-BN. The interior surface of shelters walls must be protected against the concrete spalling, which are caused by detonations on the outside surface. The results of the carried out tests proved that steel fibre reinforced concrete is not suitable material for anti-spalling layer.

Keywords: Steel fibre reinforced concrete, anti-spalling layer, ballistic loading, PlHx 30

1. Introduction

Concrete, widely used material especially at construction business possesses two fundamental disadvantages: low strength at tensile stress and fragility while damaged. Such two disadvantages are partly removed in common constructions by placing in the conventional reinforcement that has been inserted into building blocks as individual steel rods, mesh and/or grids. Both mentioned disadvantages are eliminated using this reinforcement because of rightly placed reinforcement that is capable of to take up resultant force of tensile stresses as well as to avoid the failure of individual fragile construction elements.

By employing the conventional reinforcement the structure behaviour changes, however the concrete properties remain the same. We can reach increase in tensile strength and

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change of fragile character in concrete failure only by direct reinforcement of concrete structure. To achieve such reinforcement there is a necessity to use reinforcing elements meeting the size of components that create its structure.

The reinforcing element is a fibre. The important advantage of concrete is that all production technologies enable its reinforcement by fibres. Not only fibres influence the properties of hardened fibre-concrete but the fibre-concrete hardening in process and finally yet importantly, the properties of fibre-concrete mixture of newly made steel fibre reinforced concrete.

From this point of view is the conjunction of fibre reinforced concrete and armoured concrete very advantageous. Reinforced concrete itself is resistive nevertheless; its structure remains fragile especially in the armature area.

Presently, there is a research in the area of use of fibre concrete for protective constructions at the department of Engineer Corps under way. As an experimental examination of the dynamic load, the tests of fibre concrete slabs have been carried out with the PIHx 30 plastic explosive.

The search for new materials used for building of protective constructions is a result of development of new weapons that have been used against resistive targets. This is why it is necessary to look for the new materials for new and existing structures as well and adapt such structures to the new requirements [1].

2. Loading the test slabs by PlHx 30 plastic explosive blast

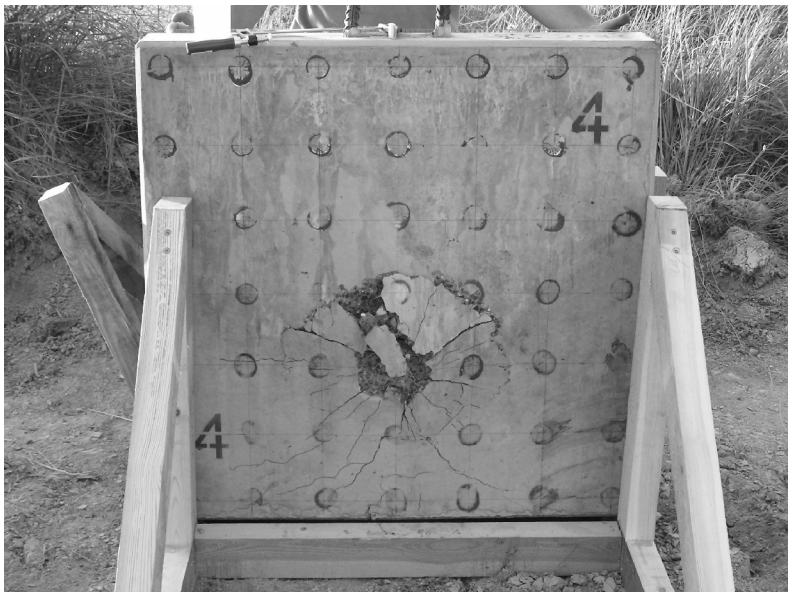


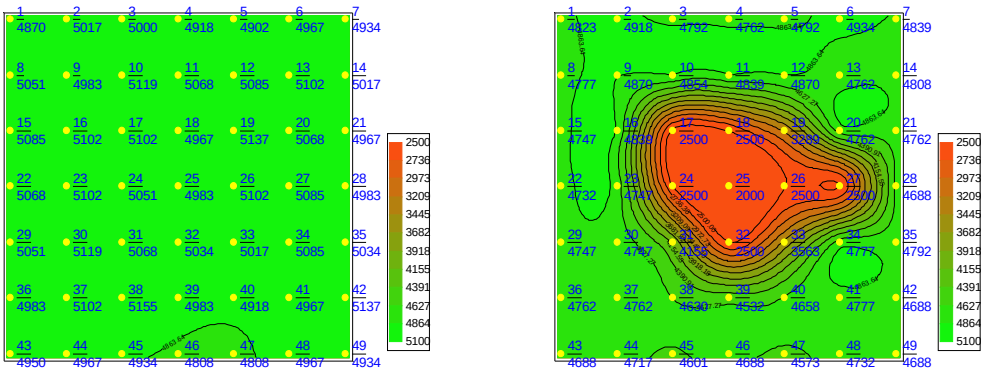
Fig. 1: Tested fibre-concrete slab after being loaded by plastic explosive blast

Some test slabs were manufactured of conventional concrete and of fibre concrete, too. To set the guaranteed concrete strength, the test objects for strength tests were being made simultaneously such as 150 mm edge test cubes and for tensile strength tests, the 150 × 150 × 600 mm test squared logs. The test body dimensions were selected with respect to the used DRAMIX RC-65/50-BN fibre.

The dimension of test slabs was determined with regard to material properties of fibre concrete and slab manipulation while being tested. The tested slabs dimension was 1000 × 1000 × 150 mm and weighted approximately 370 kg (Fig. 1).

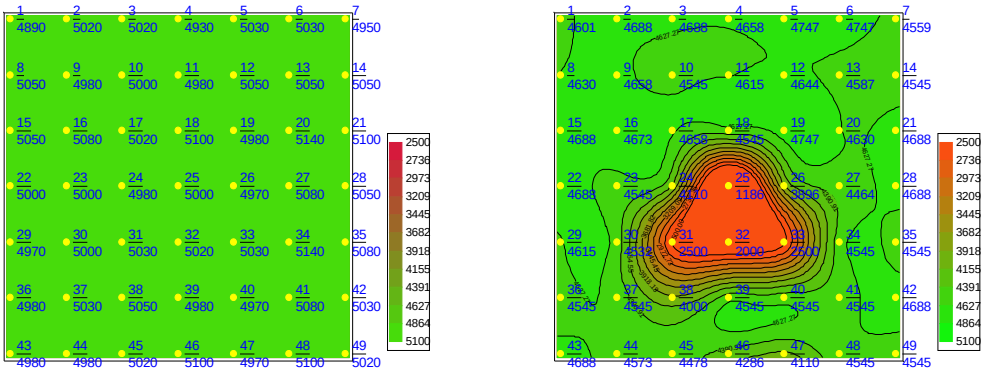
2.1 Measuring of slab quality by impulse ultra sound method

The quality of used concrete and fibre concrete was stated prior to dynamic loading by plastic explosive by impulse ultrasound method. The reason to determine quality of material and changes to come after the slab has been loaded by plastic explosive lead to selection of above mentioned method. This very method was also employed to learn about dynamic modulus of elasticity of concrete and fibre concrete used. Measurement was taken twice – once just before the initial test of loading by blast and for the second time after the intrinsic blast test. The test was carried out and evaluated according to standard CSN 73 1371 [2]. Layout of the concrete slab izovels prior and after blast loading of 70 g of the plastic explosive PlHx 30 you could see on the figure no. 2. and for the fibre concrete slab on the figure no. 3.



a) b)

Fig. 2: Layout of the concrete slab izovels prior and after blast loading of 70 g of the plastic explosive PlHx 30. (a) prior b) after



a) b)

Fig. 3: Layout of the fibre concrete slab izovels before and after blast loading of 70 g of the plastic explosive PlHx 30 a) prior b) after

The coefficient of variation - Allows you to compare the variability of different selections. It is a relative measure of dispersion (dimensionless). It is calculated by the following formula [4]:

$$v = \frac{s}{n} \cdot 100 \quad [\%] \tag{1}$$

Where is: σ ……. standard deviation of the data set for reinforced concrete and concrete separately,

n ……. the mean value of all samples,

Variation factor was calculated separately for fibre concrete slabs and concrete slabs Variation factor for fibre concrete slabs:

$$v = \frac{s}{m} \cdot 100 = \frac{91{,}98}{4927} \cdot 100 = 1{,}87\%$$

Variation factor for concrete slabs:

$$v = \frac{s}{m} \cdot 100 = \frac{96{,}55}{5078} \cdot 100 = 1{,}90\%$$

Considering the results of ultra sound measuring and the result of variation factor (for concrete slabs v=1.9%, fibre concrete slabs v=1.87%) we can conclude the conventional concrete slabs as well as the fibre concrete slabs were made of high quality material. In respect to the variation factor we can say that despite the fact they were manufactured out of lab they were of laboratory quality (up to v=2.5%).

Having the results taken after the loading of slabs by PIHx 30 plastic explosive blast, we could assess what way the specific charge had influenced the existing slab. It was stated there were great differences between the conventional and fibre concrete slabs.

2.2 Assessment of spalling

After preparation of slabs, the loading was carried out by plastic explosive blasting. Firstly, the conventional concrete slabs were loaded. After being assessed, the charges for fibre slabs were set. Graphic assessment of relation between the spalling volume and the used explosive is mentioned in Fig.4.

Distribution of fibres on the spalling surface is somehow equal. The number of fibres matches the size of spalling and indicates the distribution of fibres in the test body. When conventional slabs were loaded by 50g of plastic explosive, the spalling did not occur. Only some fissures with little fragments appeared on the slab surface. The spalling occurred after the second test was performed. With increased load the volume and depth of spalling rose. Looking at the graph of relation between spalling volume and used explosive (Fig.2) you will find the spalling had risen up to the value of 200g after the destruction of slab took place two times consecutively.

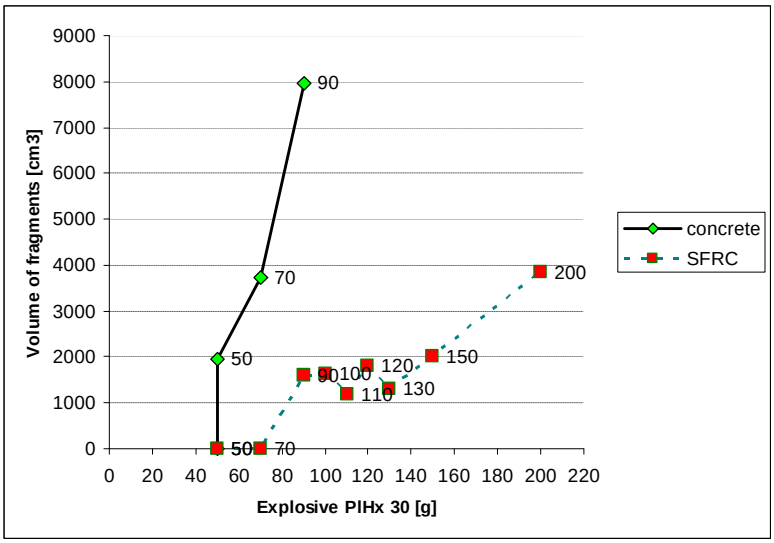


Fig. 4: Relation between spalling volume and use explosive

It also happened that the spalling did not occur in fibre concrete slabs while being loaded by 50g and next by 70g of explosive. In the first case, only micro fissures appeared and in the second case the fissures with little fragments showed up. Further, while being loaded the spalling volume had increased rather slowly as seen in Fig.4

3. Anti-spalling layer

The inner surface of buildings walls must be prevented from the concrete flaking. This flaking is caused by detonations on the outer face of the material. There is a tensile stress due to the elastic deformation of wave reflection from the inner face of the wall. These tensile stresses exceed the tensile strength of the material and it cause flaking of the concrete. To prevent of the spalling concrete it is essential to adjust the interior walls side by using anti-spalling layer. For this purpose could be used solid or soft anti-spalling layers. [3]

3.1 Solid anti-spalling layer

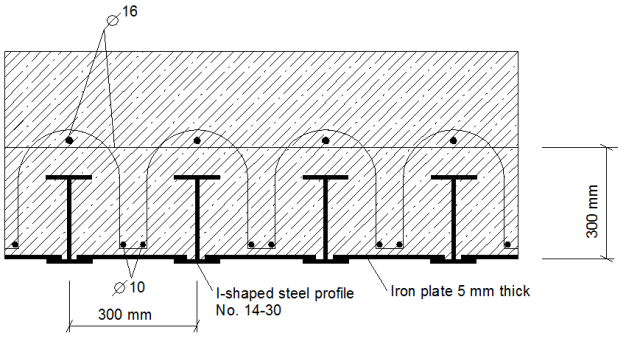


Fig. 5: Solid Anti-spalling layer

Steel built into the anti-spalling layer has to be possible, used statically as part of the main bearing function of reinforcement. Figure no. 5 shows example of the anti-spalling layer

creation. This anti-spalling layer is called solid because the main load-bearing elements are solid steel beams. Gaps between them are bridged with steel plates and rods ∅ 10mm and ∅16 mm reinforced concrete in the space between the beams.

3.2 Soft anti-spalling layer

Soft anti-spalling layer is created only by concrete reinforcement rods. Usually is consisted from several net which is construct from rods ∅ 12mm and ∅16 mm. The reinforcement steel net has square or rectangular meshes. The distance between its rods is 10-50 cm. Densest grid is close to the surface and in the depth of concrete the mesh networks is increasing. Networks must be thoroughly embedded in the inner layers of concrete clips. Soft Anti-spalling layer see on the figure no. 6.

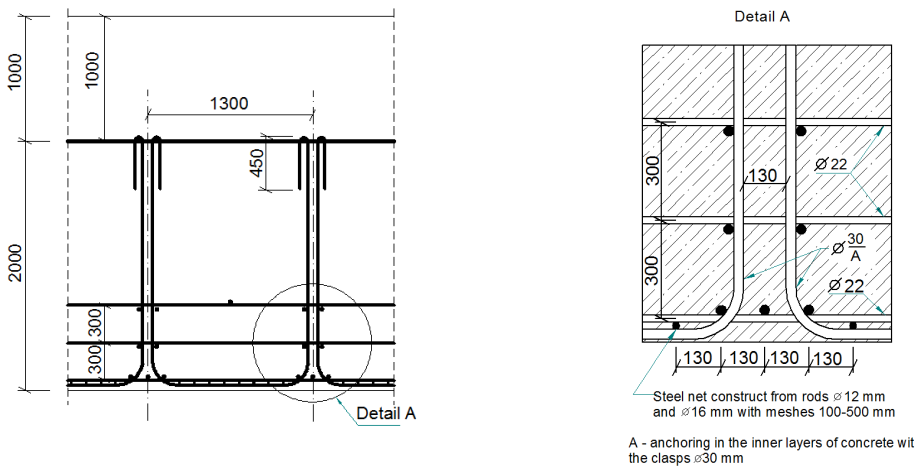


Fig. 6: Soft Anti-spalling layer

4. Conclusions

Fibre concrete is one of concrete materials with fibre reinforced structure. It is a concrete that varies from others by structure reinforced by scattered steel fibres. This fact – while being reinforced by certain minimal amount of fibres – is a ground for important change of properties that have been marked as basic drawbacks of conventional concrete. Such reinforcement results in more strength and resistance against dynamic load.

The results revealed the fibre concrete is not suitable for anti-spalling layer. When loaded by blast strength there is considerable tension on inner face that the fibre concrete is not capable to carry, thus resulting in spalling.

The right way to find new materials used for anti-spalling layer could be the sandwich structure. It also applies to armoured vehicles where basically the same effect at protective constructions takes place while being hit by high explosive ammunition.

Well, it is necessary to conclude that fibre concrete probably will not replace the armouring that has been used for reinforcing the protective constructions. However, being compared with conventional concrete the fibre concrete has displayed up to three times higher endurance. Such a fact predetermines afore mentioned material to be used at protective constructions. More resistant structure (main supporting structure) will be

created by incorporation of reinforced concrete and fibre concrete. This way created structure should prove higher endurance against penetration of bombs and projectiles designed to destroy resistant targets.

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