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TESTING THE MODEL OF THE RINGS OF CEMENT COMPOSITES IN THE BLAST

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1.Introduction

In connection with the proposal of structural material of underground structures, arise a question about endurance of used materials under extreme conditions. It means a stress induced shock wave which was caused by explosion, for example due to accidents or terrorist attacks.

The most commonly used material of underground structures is currently concrete and composite material based on concrete, i.e. the fiber concrete.

The fiber concrete is characterized by cement matrix. It contains fibers that are uniformly distributed and randomly oriented of different materials, shapes and sizes (synthetic, steel, glass etc.), which leads to stiffening the whole structure of the element. Due to the specific properties, this composite has a higher resistance to cracking (in the initial stage and after loading) against mechanical and thermal stress and ultimately increases the strength of concrete in tension.

2.Description of test specimens

Models of test specimens were made at a scale 1/20 with regard to the explanatory value of the experiment and manipulation options. This is a group of a circular tunnel of 12 rings which are linked on a half-groove. Due to the compactness, the rings were connected by a cement screed near the sensors – see ***Fig. 2*** *The group of a circular tunnel* (indicated by darker color). The groups were made from three types of materials – plain concrete, synthetic fiber reinforced concrete, and steel fiber reinforced concrete.

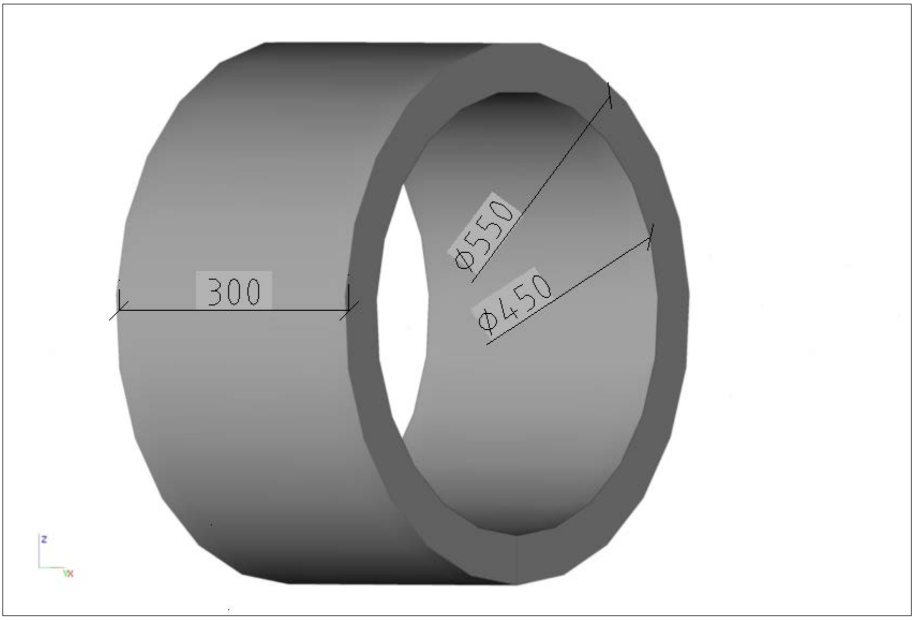

Fig. 1 *Size and shape of the specimen*

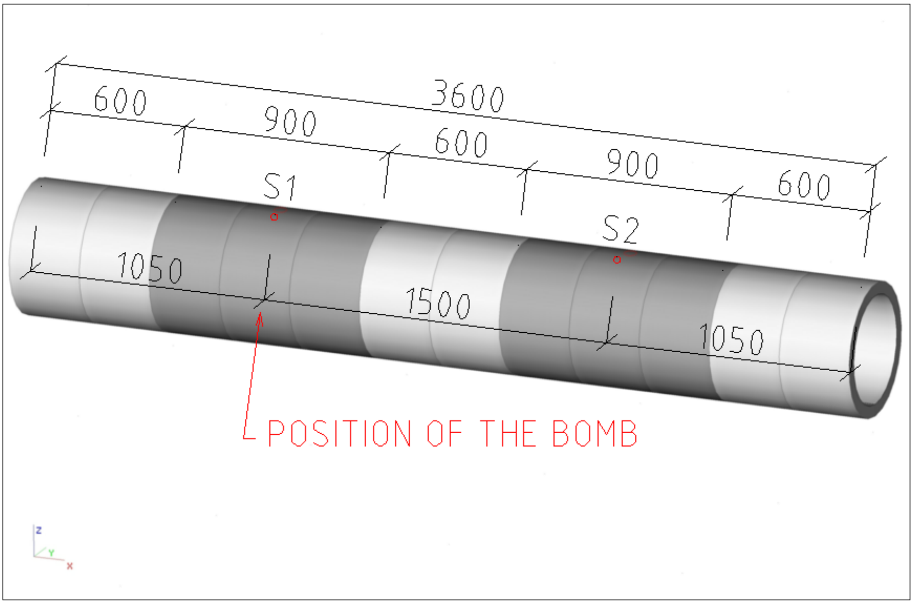

Fig. 2 *The group of a circular tunnel*

For test specimens of plain concrete, class of concrete C 25 / 30 was elected. For synthetic fiber reinforced concrete was the volume of dispersed synthetic fibers 3,0 %, and for steel fiber reinforced concrete, the type of wires Dramix RC 65/35 B-N were used and dispersed of the same volume as for the synthetic fiber concrete. The length of the wires was 35 mm, diameter 0,55 mm, class of performance 35 / 0,55 = 60.

3.Process of experiments

The physical model was placed into the made groove of the cross-section 1 x 1 m^2 excavating in loamy soil. Once that was done, it was filled with soil. The thickness was 500 mm. Each set was fitted with 12 rings, the total length of 3600 mm. On the edges of the model, there were 2 pushed rings followed by 3 bonded rings (position sensors S1 and S2) and two open rings. In the research, were represented sets of plain concrete, synthetic fiber reinforced concrete, and steel fiber reinforced concrete. Two bombs were gradually detonated in each set. Synthetic fiber reinforced concrete was exposed to repeated loads.

Fig. 3 *The view of the made groove*

Sensors S1 and S2 were placed in a nylon box in the model. Sensor S1 was used to measure the pressure on the inner surface loaded lining in the plane of the bomb. Out of the plane of the bomb, Sensor S2 had only a control character. It was used for measuring pressure behind the front of the shock wave which was spread toward the open end.

A bomb of the plastic explosive in a round shape, with a nominal weight of 20 g, was fixed in the axis of the tunnel in the level of the sensor S1. This location approximately corresponds to the gap in the technical solution. Due to launching of the bomb, the model of the liner was exposed to pressure. SEMTEX 1A was used. Generated pressures ranging from 0,7 to 1,2 MPa were measured, the average value was 0,92 MPa.

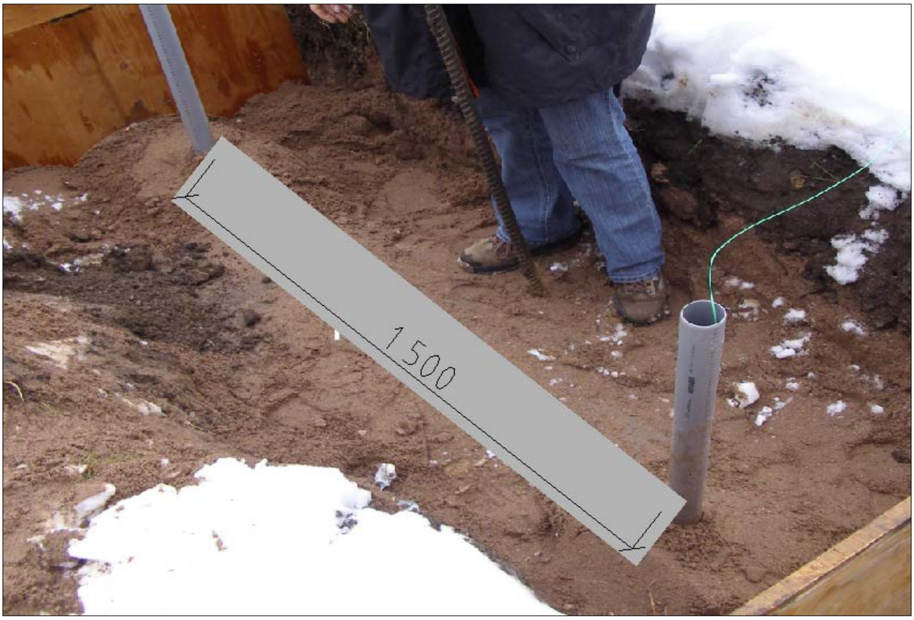

Fig. 4 *The distatance of sensors*

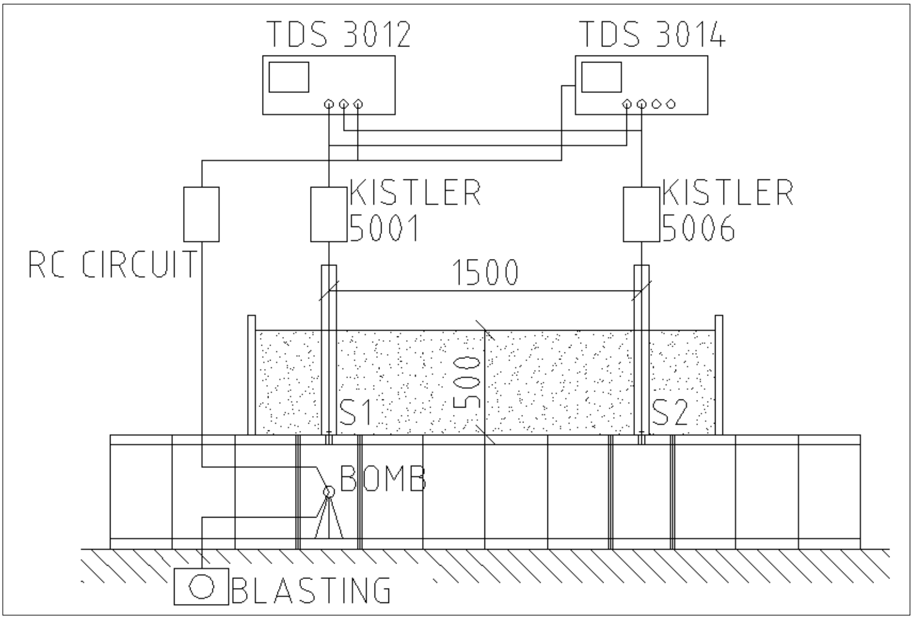

Fig. 5 *Schematic layout of the workplace*

4.List of measurement techniques

The bomb was initiated by detonator SO No. 8 (medium resistance) with the help of condenser blasting. In the bomb, was placed a special senzor for creating synchronization signal in the RC circuit. Pressure and thermal effects of exhaust lead to shorting of the switching sensor. It initiates an operation of a pair of synchroscopes with independent record of signals. A two-channel synchroscopes TDS recorded signals from a pair of pressure sensors KISTLER 6201 B. A pair of signals was processed thanks to the charge amplifiers KISTLER.

5.Evaluation of the experiments

Due to the specific conditions of the tests, records of the two-channel oscilloscope were marred by several types of distortion.

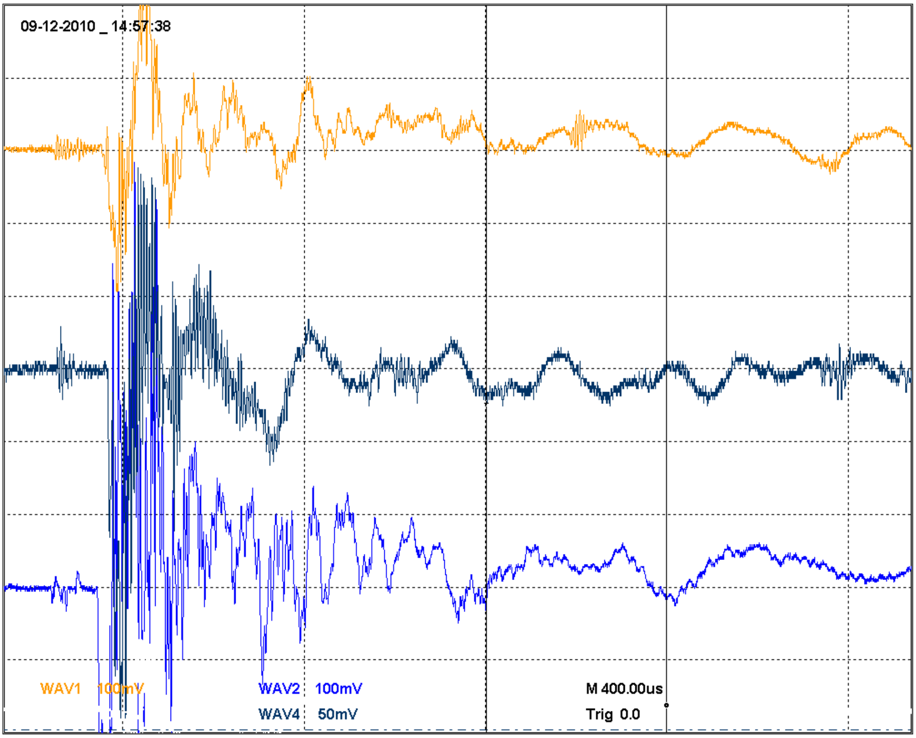

Fig. 6 *Records of pressure sensors in position S1*

The response of the sensors is composed of a wide range of oscillatory signals which control pressure drop of gases in the space of the rings. The basic signals are superimposed by a series of periodic and aperiodic signals, which reduce their informative value. The objective causes include reflections inside the ring. Their frequency can be estimated at 2,5 kc/s. This frequency can be subtracted from the measured signals.

The cause of unwanted signals is mainly sensitivity of the sensors on their axial and radial acceleration. These impulses are probably the causes of the emergence of superimposed signals at frequencies from 11 to 16 kc/s. In limited possibilities of tests, they can not be effectively suppressed. Partial improvement is achieved by the filtration.

Parameters of shock wave can be determined by the system of experimentally and analytically assembled equations which suit the conditions of the model of geometric similarity of the processes. The distance between the explosion and the radius of wave front of a spherical blast wave is expressed as a reduced radius:

$$\overline{R} = R / \sqrt[3]{m_x}, \quad (1)$$

where:

$\overline{R}$ .... reduced radius,
R .... radius of wave,
m_x .... weight of a bomb.

$$\overline{R} = 0{,}225 / \sqrt[3]{0{,}020} = 0{,}829\, m.kg^{-1/3}, \quad (2)$$

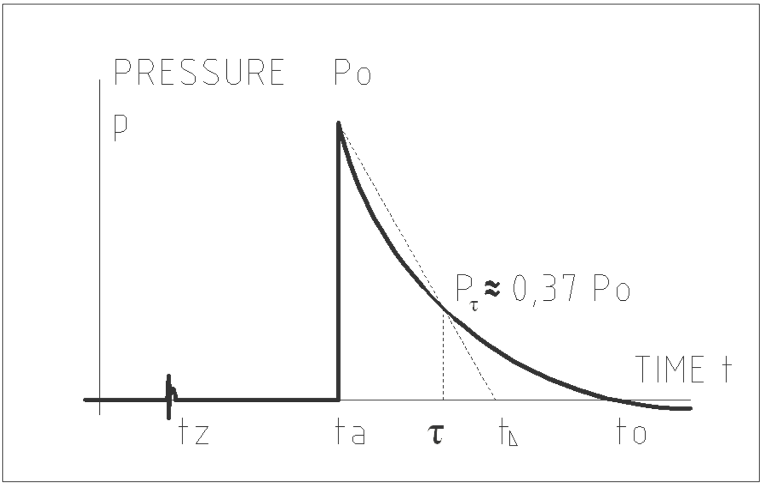

Fig. 7 *Time course of the pressure behind the impact of the blast wave*

The time course of pressure drop for the wave front:

$$P(t) = P_0.e^{-t/\tau}, \quad (3)$$

where:

τ .... time constant,
P_0 .... pressure at the head of the incident,
t .... time.

The time course of pressure after detonation wave reflection from the rigid obstacles:

$$P_r(t) \approx P_r.e^{-t/\tau}, \quad (4)$$

where:

τ .... time constant,
P_r .... pressure at the interface,
t .... time.

The time constant of the transition part of the exponential function:

$$\tau \approx {(t_0 - t_a)}/{2,2} , \qquad (5)$$

According to reference No. 1:

$$(t_0 - t_a) = 210\ \mu s \rightarrow \tau \approx 95\ \mu s , \qquad (6)$$

where:

t_a .... running time of detonation waves (the distance R,

t_0 .... end of pressure phase.

Pressure in time t :

$$t = t_a + \tau \rightarrow P_\tau \approx 2,8\,Mpa . \qquad (7)$$

6.Experimental results

Evaluated time interval $(t_a - t_z)$, which was needed to move the blast wave from the point of initiation to the inner surface of the ring, was not very different from the value – see ***Tab. 1*** (according to reference No. 2). The value of the pressure at the head of the impact of the shock wave from images could not be evaluated.

The value of pressure P_τ at time $t = (t_\alpha + \tau)$ reaches about triple value compared to the measured data. The coefficient of reflection of blast wave reduces with a pressure drop which is not taken into account. More over, the used sensors are characterized by a negative temperature coefficient.

When applying the model of similarity, shock wave was a necessary confrontation with alternative models. It was useful to compare data with (according to reference No. 2).

After firing the first bomb, the rings of plain concrete cracked. After firing the second bomb, they were completely torn.

Fig. 8 *Plain concrete after firing first bomb, the thickness of the cracks was maximum 11 mm*

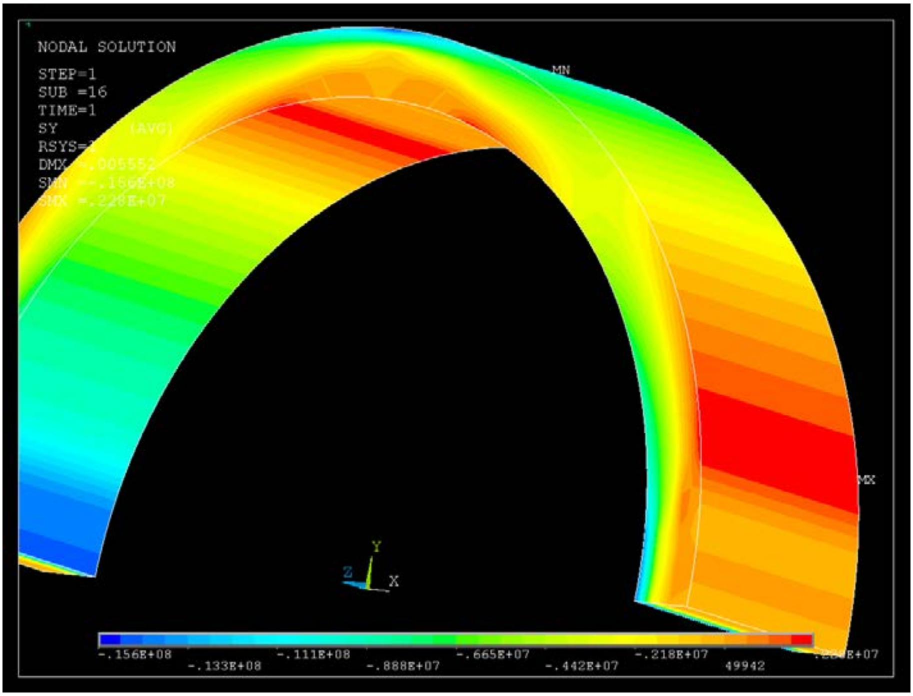

Fig. 9 *Model of finite element method*

Tab. 1 shows that the most durable material for the rings can be synthetic fiber reinforced concrete. Test specimens of this material resisted to repeated stress caused by shock wave. After firing the first bomb, the final damage can be characterized as thin cracks, and after firing the second bomb, as cracks which were slightly widened. The material of rings stayed compact.

After firing the first bomb, the rings of steel fiber reinforced concrete showed significant cracks which did not pass the full wall thickness of rings. After firing the second bomb, the compactness of material of rings was disturbed.

Tab. 1 *Parameters evaluated in the position S1*

The material of the specimes	Parameters evaluated from images				
	Time interval $(t_a - t_z)$ $[\mu s]$	Pressure in time P_T $[Mpa]$	Oscillation – higher frequencies $f_h\left[\frac{l}{s}\right]$	Oscillation – lower frequencies $f_d\left[\frac{l}{s}\right]$	Damage of the concrete
Plain concrete	-	1,10	-	3 100	Deep cracks
	75	0,80	13 000	-	Completely torn
Synthetic	90	1,20	12 000	5 000	Thin cracks
	-	0,75	11 000	3 100	Cracks slightly widened
Steel fiber reinforced concrete	112	0,95	16 000	2 300	Cracks slightly widened
	114	0,70	-	4 100	Completely torn

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Resumé

TESTOVÁNÍ MODELŮ SKRUŽÍ Z CEMENTOVÝCH KOMPOZITŮ PŘI VÝBUCHU

Vladimír Doležel, Jiří Pokorný, Vladimír Suchánek

Příspěvek se zabývá popisem a zhodnocením výsledků dosažených experimentálním testováním skruží podzemních staveb při extrémním zatížení – výbuchu.

Modely skruží byly zhotoveny v měřítku 1/20 z cementových kompozitů ve tvaru kruhového tunelu. Použitými materiály byl prostý beton, vláknobeton a drátkobeton. Zkušební tělesa byly zhotoveny z prstenců, vzájemně spojených, umístěných do zemní rýhy. V každé sestavě byly umístěny 2 snímače.

V článku je uvedena použitá měřící technika, parametry rázové vlny a parametry vyhodnocené ze snímků signálů. Výsledky experimentů ilustrují přiložené grafické přílohy a porovnání použitých materiálů pro ostění podzemních staveb.

Summary

TESTING THE MODEL OF THE RINGS OF CEMENT COMPOSITES IN THE BLAST

Vladimír Doležel, Jiří Pokorný, Vladimír Suchánek

This paper deals with the description and evaluation of experimental results obtained by testing rings of underground structures under extreme loads – blast.

Models rings were made at a scale of 1/20 of cementitious composites in the shape of a circular tunnel. The materials used were plain concrete, synthetic fiber reinforced concrete, and steel fiber reinforced concrete. Test specimens were made of rings, joined together and placed into the made groove. In each group, were placed 2 sensors.

The article gives a measurement technique used, shock wave parameters, and the parameters evaluated from the image signals. The experimental results illustrate the attached annexes and graphical comparison of the materials used for underground structures.

Zusammenfassung

DAS GETESTETE MODELL VON ZEMENT COMPOSITES GERÜSTBAU IN EXPLOSION

Vladimír Doležel, Jiří Pokorný, Vladimír Suchánek

Dieses Papier befasst sich mit der Beschreibung und Bewertung der experimentellen Ergebnisse von Tests Ringe von unterirdischen Bauwerken unter extremen Belastungen erhalten – Explosion.

Models Ringe wurden in einem Maßstab von 1/20 der zementären Composites in einem kreisförmigen Tunnel gemacht. Die verwendeten Materialien waren reinem Beton, Faserbeton und wirecutted Beton. Die Prüfkörper wurden von Ringen, miteinander verbunden sind, in natürlichen Falten gelegt. In jeder Gruppe wurden 2 Sensoren platziert.

Der Artikel gibt eine Messtechnik verwendet, Druckwelle und die Parameter aus den Bildsignalen ausgewertet. Die experimentellen Ergebnisse zeigen die beigefügten Anlagen und grafischen Vergleich der Materialien für die Verkleidung unterirdischen Bauwerken verwendet.