The influence of low-hard dispersed additives on impact strength of concrete

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Abstract

The article presents the results of experiments on the use dispersed components with reduced stiffness in concrete mixtures to assess their influence on the dynamic strength of concrete. A crushed ceramic bricks, the polystyrene foam, cellular glass and expanded clay sand were used components with reduced stiffness. Samples-cubes were subjected to various dynamic loads, and then measured their strength and were compared with the results obtained for a control sample. Furthermore by vertical dynamic koper were measured impact strength of the obtained compositions. The results of experimental studies are showing the possibility of increasing the impact strength of concrete by introducing into the concrete mix an additive with reduced stiffness. In the same time there is some reduction in other properties of the resulting concrete. Has been defined the optimum additive and its amount to use in the concrete that subjected to dynamic loads.

1. Introduction

There are many articles devoted to the study of the influence on the concrete properties the components with...
reduced stiffness. It is assumed that such inclusion (damping additives) can inhibit the development of cracks. The current theory this effect is due to "sequestration" growing cracks by the additive with reduced stiffness, which is not able to return the energy expended in the deformation. Also less hard dispersed additives are used for other purposes, for example, to reduce the sound transmission concrete walling and ceilings or to increase frost resistance [1-3].

Another action mechanism of the less hard inclusions is the improving the uniformity of the stress distribution in the structure of composite materials and reducing stress concentrations. This causes, first, to the increase in impact strength and stamina of concrete. It is leaves open the question about criteria of the effectiveness of the different additives with reduced stiffness from the point of view of their influence on the concrete resistance to various types of dynamic loads [4-6].

The use of inclusions with stiffness, that relatively low than at aggregate (sand), cannot be considered as a full replacement of the reinforcement fiber, but this technique can be an effective supplement to improve the compositions of concrete according to the criterion "price-quality". In addition, due to rheological properties the fiber reinforced concrete maybe unacceptable for certain types of construction units and methods of concreting.

The aim of this work was the accumulation of empirical data about the change of the residual static strength of concrete with less hard supplements after cyclic application of impact and compressive loads. These types of additives are chosen in view to cover a wide values range of elastic properties.

2. Materials and research methods

Consider in more detail the change in concrete properties when included in its mixture an additives with reduced stiffness. For these experiments, as such components were used crushed ceramic bricks, polystyrene foam (the fraction of 0.8-5.0 mm), expanded clay sand (fraction 0.63-5 mm) and cellular glass (fraction 0.63-5.0 mm). Particles of expanded clay sand and cellular glass with a size of less than 0.14 mm were excluded to minimize the participation of the fine fractions in the chemical reactions in the hydration process and to make the emphasis on the effect of damping.

For the preparation of concrete mixes used Portland cement CEM I 42.5 n, river sand quartz-feldspar (fineness modulus M_k=2.3). The distribution of particle size studied of additives with reduced stiffness and aggregate shown in table 1. In table 2 properties of components are presented.

| Table 1. The particle size distribution of components with reduced stiffness. |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                               | 5-2.5 mm        | 2.5-1.25 mm     | 1.25-0.63 mm    | 0.63-0.315 mm   | 0.315-0.14 mm   | <0.14 mm        |
| Quartz-feldspar sand          | 6               | 21              | 14              | 44              | 13              | 2               |
| Polystyrene foam              | 10              | 35              | 20              | 26              | 8               | 1               |
| Cellular glass                | 36              | 45              | 10              | 7               | 2               | 0               |
| Expanded clay sand            | 40              | 46              | 8               | 5               | 1               | 0               |
| Crushed ceramic bricks        | 40              | 35              | 12              | 9               | 4               | 0               |

Preparation of solutions was to manually stirring the mixture of dry ingredients followed by the addition of mixing water. Water-cement ratio of all compounds within the series remained unchanged and was 0.5. With the introduction less hard additives the sand was replaced so that the volume ratio of cement/(aggregate+additives) remained the same (1:3).
### Table 2. Properties of the mineral components.

| Additive with reduced stiffness | Bulk density, $\text{Mgm}^{-3}$ | Particle density, $\text{Mgm}^{-3}$ | Modulus of elasticity, GPa |
|-------------------------------|-------------------------------|-------------------------------|-------------------|
| Quartz-feldspar sand          | 1.600                         | 2.60                          | 72.8              |
| Polystyrene foam              | 0.018                         | 0.038                         | 0.01              |
| Cellular glass                | 0.210                         | 0.35                          | 0.8               |
| Expanded clay sand            | 0.665                         | 0.88                          | 10                |
| Crushed ceramic bricks        | 0.750                         | 1.65                          | 25                |

The experiment was conducted according to the following scheme:

1. Manufactured samples-cubes with size 7.07 cm (in accordance to national standard of the Russian Federation) – 12-15 samples for each composition.
2. Determine the compressive strength of samples with different content of additives. The determination was carried out on six cubes, were calculated the average value and the uncertainty of the arithmetic mean method. With a relative uncertainty exceeding 12%, the experiments were repeated.
3. Another three samples were subjected to low-cycle dynamic loadings at level up to 70% of the breaking load specified in the previous step. After 50 cycles of loading in these samples was also measured static compressive strength.
4. Another part of the samples were subjected to cyclic impact loads on vertical dynamic koper. Cargo weight - 3.5 kg, height of drop shipping is 20 cm, the number of strokes – 50 times (the amount of energy in one hit was equal to 19.6 joules). Afterwards the samples were tested under static compression strength.
5. The remaining samples were tested on vertical dynamic koper when the mass of a freely falling body of 5 kg from a height of 10 cm. Impact strength was evaluated by the number of blows to failure.

### 3. Results and discussion

The results are presented in the graphs (Fig 1). From the obtained results, it is clear that with increasing the amount of additives compressive strength decreases. This is an expected effect, because these porous components have a difference from the cement paste in elastic properties. Consequently, its leads to heterogeneity of concrete and appearance defects in the concrete matrix, which in turn increases crack formation. A similar situation is observed when using all four types of additives. We can see that for components such as the crushed ceramic bricks and the expanded clay sand minimum value of the compressive strength lie in the region of 20-25 MPa, whereas for polystyrene foam and cellular glass they are less than 5 MPa.

By the angle of inclination of the curves in the graphs it is seen that the more amount of the components with reduced stiffness, the smaller the difference in compressive strength between control sample and the samples, previously subjected to dynamic loads. This indicates that at high content of additives the volume of micro defects in the concrete structure in the samples does not increase or increases slightly after dynamic loads. These experiments clearly show that the effect of the less hard additives really takes place.

The next step is to assess the influence of these additives on impact strength. Indeed, when you replace a certain amount of aggregate by less hard supplements there is an increase in impact strength of the samples. The maximum value obtained when replacing about 30% of expanded clay sand - an increase of impact strength at $(22\pm3)$%. For other additives, the values are about the same, the best results are obtained when replacing $(20-40)$%, and impact strength is increased by $(10-15)$%.

The less hard components for concrete, that have been Investigated, have significant differences in physico-mechanical characteristics. This results in differences in the magnitude of the damping effect, and the degree of reduction of the static compressive strength (tab. 3).
Obviously that is requires a quantitative assessment of the parameters of damping in depending on properties of the less hard additives and the clarification of the mechanism damping for the generation of design methods concrete.

With increasing shock strength up to 22% the decrease the static compressive strength is only 14%. For ease of comparison supplements let us introduce the coefficient showing the ratio of increase of impact strength to decrease in the compressive strength. For expanded clay sand it is \(22/14=1.57\) mm, for crushed ceramic bricks 1.07, for cellular glass is 0.75 and for polystyrene foam – 0.35.

![Graphs showing the compressive strength from the amount of additives for the control sample and samples subjected to dynamic loads.](image)

**Fig. 1.** A graph of the compressive strength from the amount of additives for the control sample and samples subjected to dynamic loads. Supplements: a - crushed ceramic bricks, b - polystyrene foam, c - cellular glass, d - expanded clay sand.
Fig. 2. A graph of dependence number of blows to failure from the amount of various additives in the concrete mix.

| Additive with reduced stiffness | The proportion of the additive from the volume of aggregate, % | The increase in impact strength, % | The reduction of compressive strength of control sample, % | The decrease of the compressive strength of the sample after cyclic shock loads, % | The decrease of the compressive strength of the sample after cyclic compressive loads, % |
|-------------------------------|-------------------------------------------------|---------------------------------|----------------------------------------------------------|---------------------------------------------------|----------------------------------------------------------|
| Polystyrene foam              | 40                                             | 13                              | 37                                                       | 36                                                 | 37                                                       |
| Cellular glass                | 20                                             | 15                              | 20                                                       | 18                                                 | 17                                                       |
| Expanded clay sand            | 30                                             | 22                              | 14                                                       | 13                                                 | 10                                                       |
| Crushed ceramic bricks        | 30                                             | 14                              | 13                                                       | 10                                                 | 8                                                        |

4. Conclusions and outlook

Thus, the results of experimental studies confirmed the possibility of increasing the impact strength of concrete by introducing additives with reduced stiffness. However, the effectiveness of the use of various additives is very different. The experimental results show that the most promising is the using of expanded clay sand at equivalent replacement of 30% of the volume of the aggregate.

Those inexpensive components allow you to extend the life of the concrete under dynamic loads, and could be used in combination with the fiber reinforcement to an optimization of composites by the "price-quality" criterion.

On the properties of concrete is influenced by a number of factors, which complicates designing of a material with predetermined properties based on the application of components with reduced stiffness. To solve this problem, the next phase of work involves the application of the method of structural-simulation, which allows
identifying the main factors to assess their impact and to develop main directions in obtaining of concrete with predictable characteristics.

References

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