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Dynamic Characteristics of Reinforced Concrete Beams Made of Carbonate Concrete

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Abstract. The ability of solid structures to absorb a certain part of the energy of dynamic impacts has not been properly reflected in impact theories. Meanwhile the effect of material properties on the various structures in the impact is so much that ignoring it when the solution of a large number dynamic problems makes it impossible to explain without distorting quantitatively and qualitatively, many of the actually observed phenomena, for example, equalization of dynamic stresses in places of their concentration and fluctuation of other parameters. In the article, two independent parameters for conventional reinforced concrete beams and those made of limestone concrete are compared, namely dynamic coefficient and the values of elastic rebound in impact. The effect of the reinforcement is not discussed in the paper.

Introduction

Research were carried out in the field of dissipative properties under different aspects of concrete and the use of screenings for crushed carbonate rocks and other staff for use as a filler in the preparation of fine-grained concrete to be the solid staff of reinforced concrete beams at different treatment as well as in view of crack resistance [1,2,3]. The main criterion of concrete properties considered in there were dissipative properties, enclosed by the area of crack resistance and critical stress intensity factors. In addition to internal forces, dissipative forces also resist the action of loads, which cause energy dissipation in structures during vibrations. These forces, which are non-conservative, are divided into external and internal. External dissipative forces include aerodynamic and bond-drag forces that occur during deformations of the base of the structure. Internal forces (or internal friction) are caused by microplastic deformations of the particles of concrete and bonds with reinforcement and friction in the joints of the elements (structural hysteresis). The influence of all these contra-forces on the work of structures is different and depends on many factors [4,5,6]. For example, at relatively small impact (cyclic) loads, weak bonds between elements carried out by dry friction intensively affect the energy dissipation. Under certain conditions, friction in the joints can dissipate energy several times greater than the internal friction in the construction material [7,8]. The aerodynamic drag for conventional structures is insignificant and it can be ignored. It was also shown in papers that limestone aggregate and filler together with a superplasticizer increases crack resistance and reduces creep deformations, which makes fine-grained carbonate concrete durable material [9]. Knowledge of the stress-strain distribution in concrete through the crack-bound energy dissipation with limestone aggregate and filler in impact is necessary when designing certain types of reinforced concrete structures. These

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structures are made with the addition of limestone filler which performs elastic energy absorbing effect, critical in impacts. The last consists in increasing the level of crack-forming-stress extinguishing areas [10], plastic by nature and creepy, contributing to dynamic features of reinforced concrete structures.

Experiment

In the process of deformation in impact, the beam passes, as in case of static loading, three stages, prior to the formation of cracks, after the formation of cracks, until the yield is reached in the longitudinal stretched reinforcement; after the yield is reached until destruction. At the same time, a number of significant features occur during shock loading. In general, they depend on the dynamic properties of the structure (usually characterized by the lowest natural frequency ω_1), the ratio of the masses of the impactor and the beam, the impact velocity v_0, the impact time and a number of other factors. For a complete understanding of the mechanisms of failure in impact, data on mechanical properties are combined with some parameters describing the patterns of destruction. Such are dynamic coefficient, the values of elastic rebound. All this data can be obtained in dynamic and, partly, static tests. For the experiment, a class A300 reinforcement was taken, longitudinal with a diameter of 12 mm, transverse-8 mm. The coupling of the frame was performed using electrodes that are designed to connect low-carbon and ordinary steels by manual arc welding. They are metal rods with a length of 350 mm and a diameter of 3 mm. Longitudinal rods were 1.45 m. The rutile coating ensures stable arc burning regardless of the type of current. Before welding, dirt and dust are removed from the reinforcement. With a small amount of work, they are cleaned to a metallic shine, which has a positive effect on the quality of the seam. The preparation of the concrete mixture of components was carried out by semi-dry mixing. At first, cement and sand were filled into a mixing container with subsequent water filling. Everything was mixed until there were no lumps and dry sediment on the bottom visually. After that, granite rubble was slowly dosed down. The whole mixture was mixed for about 10-15 minutes, with one pause of 5-6 minutes. Compositions per 1 m^3 consisted of cement – 414 kg., water-201.4 kg., sand (limestone filler – 515-762 kg., aggregate (granite and limestone) -968-1170 kg. Sledgehammer tip weighed 5 kg. The following are the 6 beams (Fig. 1), three – conventional (to obtain a medium value), three – made of carbonate concrete and impact device (Fig. 2).

Fig. 1. *Formwork with reinforcement (left) and test 6 beams (right)*

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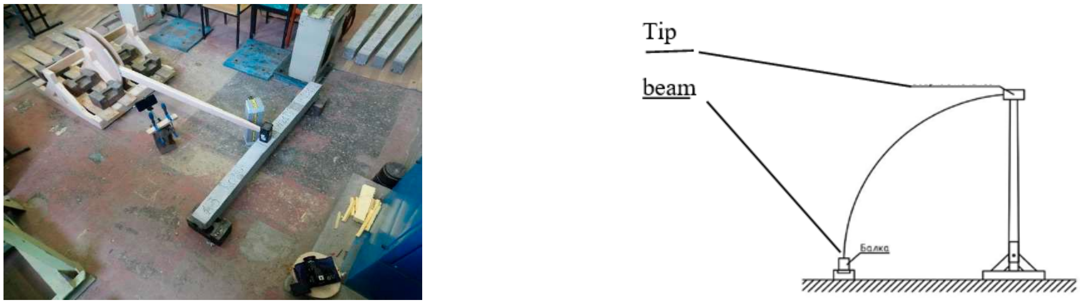

Fig. 2. *Impact device (overall view) with a beam (left)) and impact device scheme (right)*

Photo and video documentation were made using a camera aimed at a measuring scale, which is a measuring tape measure, tied with glue tape to a concrete beam. With the help of the recording on the camera, a storyboard was made in order to determine the rebound of the tip from the beam after a dynamic impact. Rebound values were obtained from direct measurement (Fig. 3).

Fig. 3. *Sledgehammer tip rebound measurement technique*

The table 1 represents Medium sledgehammer tip impact rebounds.

Table 1. *Medium sledgehammer tip impact rebound, mm*

N b/o	Beam	Medium impact rebound, mm
1	Of conventional concrete	72,5
2	Of carbonate concrete	38,5

According to the obtained data of the impact experiment, it can be concluded that the rebound of ordinary concrete is almost twice as much as that of carbonate concrete, extinguishing the elastic part of the total inner energy of microcracking process.

The following is a procedure to determine dynamic coefficient. Let's determine the impact force by the formula

$$F_d \cdot \Delta t = m \cdot V; \quad (1)$$

Hence,

$$F_d = m \cdot V/\Delta t$$

here, F_d - is an impact force, m – tip weight, V – tip impact velocity, Δt - contact time in seconds. It is the period within one rebound (taken from video frames interim time) of the impact

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part of the impact machine, we can take this time equal to half the time of one video frame, i.e. 0.01 seconds.

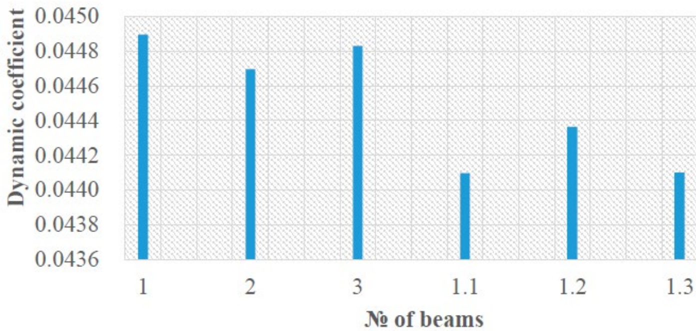

Fig. 4. *Dynamic coefficient values for conventional concrete beams (1,2,3) and carbonate concrete beams (1.1,1.2,1.3)*

Hence, the dynamic coefficient (Fig. 4) medium values in relation to the impact force according to the results obtained from the formula above:

Table 2. *Dynamic coefficient medium values*

N b/o	Beam	dynamic coefficient medium value
1	Of conventional concrete	0.0448
2	Of carbonate concrete	0.0441

From the table 2 it is obvious that dynamic coefficient of carbonate concrete is less than that of conventional concrete.

This means that the “dynamic versus static” mechanical parameters (failure-forces, deflections) of carbonate concrete in general are less and therefore better than those of an ordinary concrete. This also indicates that carbonate-cement matrix of carbonate beams, even apart from steel reinforcement effects, is a good external impact energy absorber.

Conclusions

The carbonate filler helps to seal the cement stone and strengthen the contact zone between the cement stone and the filler, accumulates part of the water, increases the degree of hydration of cement and, on the other hand, contributes to the formation of microplastic centers, absorbing the impact energy, thereby reducing elastic rebounds and the values of dynamic coefficient, making the beams on carbonate concrete more resistible to impact loads. It is established that the introduction of a fine limestone filler into the mixture about 50% of cement contributes to the extinguishing the local stress concentrators effect on internal micro crack formation, a great deal due to internal friction. In this case, a more uniform and durable composite structure is formed between the filler and the binder. This increases the crack resistance of carbonate concrete and the dynamic strength and reduces the level of elastic canvas failure, which leads to an increase in the efficiency and improvement of the physical and mechanical properties of carbonate concrete. It is shown that the use of carbonate concrete allows achieving more uniform inner matrix and crack good resistance by increasing the operational and technological properties of carbonate concrete and at the same time reducing the energy and material costs of its production and contributing to

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an increase in the efficiency of carbonate concrete. The limestone filler has a wide range of granule sizes, which contributes to filling the voids between the cement particles during processing, which leads to a reduction in the need for water, improving the uniformity of the mixture and unifying the microstructure of the composite. Due to the short-term volumetric plastic deformation of the matrix, the volumetric alignment of the composite microstructure improves the dynamic characteristics of carbonate concrete, restraining the growth of deformations, especially in the long term, without significant losses of technological properties at the initial stage. Higher dynamic parameters of carbonate concrete also occur due to better packing of particles inside the concrete matrix and a decrease in porosity caused by the transfer of microcracks from air and capillary regions to micro-subzones and compression of microcracks to internal microstructural nuclei, depriving the composite structure of microplastic energy-consuming regions. This makes the base composite (ordinary heavy concrete) more brittle and unconnected at the micro level than the carbonate composite.

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