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NEW POSSIBILITIES OF THE ACTIVE DAMPING OF VIBRATIONS

SUMMARY

In presented paper a new proposition of granular structure, composed on the basis of granular materials placed in hermetic space with underpressure, as a damping material for vibrated steel beam has been described. Three different types of laboratory tests have been described: fundamental strength properties of granular testing specimen, bending of granular beam and damping of the steel beam vibrations using special granular structures. Obtained results revealed that the behavior of such a structure could be easily controlled by underpressure parameter. Also damping characteristics of vibrated steel beam could be controlled by changing internal underpressure value.

Keywords: *granular materials, laboratory tests, underpressure, beam vibrations*

NOWE MOŻLIWOŚCI AKTYWNEGO TŁUMIENIA DRGAŃ

W artykule zaprezentowano zastosowanie struktury, zbudowanej na bazie luźnego granulatu umieszczonego w szczelnej przestrzeni z podciśnieniem, do tłumienia drgań belki stalowej. Omówiono trzy typy badań eksperymentalnych: podstawowe badania wytrzymałościowe próbki struktury granulowanej, badania zginania belek granulowanych oraz badania tłumienia drgań belki stalowej za pomocą wspomnianych materiałów. Wyniki przeprowadzonych eksperymentów jednoznacznie potwierdzają możliwość wpływania na parametry fizyczne granulowanych konglomeratów za pomocą parametru podciśnienia i tym samym na postacie charakterystyk tłumienia drgań swobodnych belki stalowej.

Słowa kluczowe: *materiały granulowane, badania eksperymentalne, podciśnienie, drgania belki*

1. INTRODUCTION

Presented paper is an initial probe of adaptation of the new "smart" structures, built on the basis of a loose material, encapsulated in a thigh sleeve, where in the next stage, so called underpressure has been generated, for the active (semi-active) damping of vibrations.

There is a lot of methods which provide a prevention against results of undesired vibrations. The most popular group of them is called passive. They mainly consist of isolating of a construction from existing excitations or dissipation of provided external energy by different kinds of damping elements, which characteristics are in this case non-controllable. Their main advantage is lack of necessity of supplying to the vibrated system an additional external energy. However, they could not compare, from the quality point of view, with the systems which are controllable. An active methods enable for controlling a process of vibrations and its suitable accommodation to actual external conditions. Nevertheless, they demand a considerable amount of energy which has to be provided to the vibrated system. The indirect solution between the previously cited methods of vibrations damping are semi-active damping possibilities. System provided with a semi-active damping source is partly controlled and for example a damping force could be minimized. At the same time an energy consumption is much lower than in case of active methods. The new active (semi-active) method could be developed taking into consideration, specially performed, granular structures.

The "control factor" for the changing of mechanical and rheological features of the previously mentioned granular material is so called underpressure. It is generated inside the sleeve, surrounding loose grains. The increasing of the intermolecular friction forces, connected with a growing of the internal underpressure value, causes a considerable changes of the dissipative properties of the granular media in special conditions.

2. OBJECTIVES AND THE RANGE OF THE PAPER

Currently discussed paper will provide a description of three different kinds of laboratory tests.

The main objective of experiments was to confirm the possibility of controlling internal physical processes taking place in the granular concrete and at the same time to proof the possibility of applying them as a suitable materials for active (semi-active) vibration dampers.

Previous works of authors have been focused on determining the fundamental mechanical properties and developing a suitable constitutive model for description of non-linear properties of a granular concrete [1–6].

As it is a continuations of a former works, related to special granular structures, built on the basis of granular materials, enclosed in a hermetic space with underpressure, we will restrict ourselves only to presenting the basic information connected with this innovatory structural materials. Paper [7] provides detailed information about such a granular con-

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crete. Also there, particular problems related to structural and experimental problems have been discussed.

In the first part of the paper, the fundamental strength experiments will be introduced and some of encountered problems will be discussed.

In the second part of a paper, results of experiments taking into consideration bending of the beam, made of granular materials will be presented.

In the third and the last section of a paper, detailed description of experiments, carried out for a beam covered by the granular sleeve will be presented. Acquired results for vibrated beam, damped by three different types of granular media and a wide range of applied underpressures will be compared to the free vibrations of a steel beam (without the granular damping). The influence and the efficiency of such a kind of damping of vibrations will be emphasized.

3. EXPERIMENTS

The range of experimental research presented in this paper has been split into three, quite separate parts. The final conclusions will reveal their mutual connections and pertinence.

3.1. Strength experiments

The specially performed sample of the granular structure in a special conditions (Fig. 1) has been tested in uniaxial experiments using the universal strength machine (MTS).

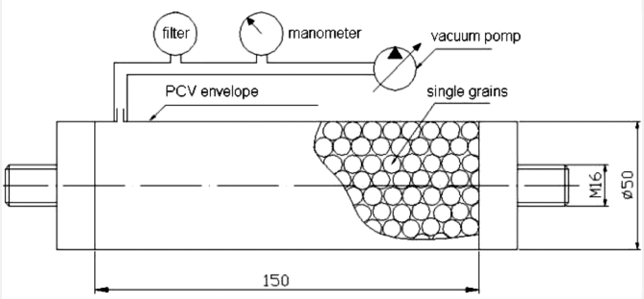

Fig. 1. Testing specimen

The main problem which had been encountered in this part of laboratory tests was connected with establishing the representative shape and dimensions of a testing probe. The second one; how to define de quasi-static strain rate for this group of structural materials.

The biggest handicap for authors was lack of any instructions related to carrying out of laboratory research.

All of uniaxial tensile experiments were carried out on samples filled with a four different types of granular materials (polypropylene, polystyrene, polymethacrylate and ABS). They were a typical semi-finished products used in production of liquid beverages, ever burning fires, plastic containers etc. The shape and the diameter of a single grain were almost similar for all considered granular materials; small cylinders having diameter about 1 mm and length 2 mm.

Results have revealed the influence as well of a kind of granular material as the value of generated underpressure on the main mechanical properties of the examined structures [4, 6].

Characteristic of the elastic force versus deformation is called in the theory of vibrations as a restitute characteristic. For the considered granular structures it is nonlinear. For the larger deformations of a granular system, the packing phenomenon exist and in the final stage elastic deformations of grains occur.

Additionally, increasing of the underpressure values causes increasing of all mechanical parameters for such structures. In the Figure 2 changing of Young modulus values at various underpressures, in unaxial tensile tests, has been depicted.

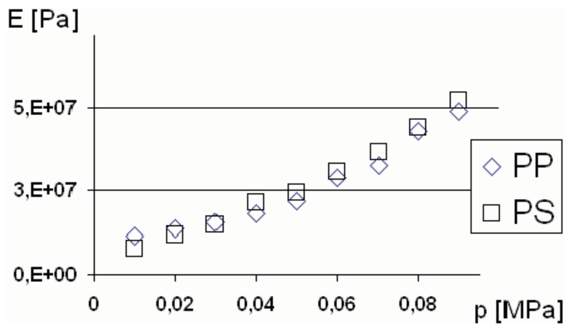

Fig. 2. Young modulus values at various underpressures; polypropylene (PP) and polystyrene (PS) grains in tensile tests

3.2. Granular beam bending

Beams created on the basis of four different kinds of granular materials have been examined on the same MTS machine. The scheme of a typical sample has been depicted in the Figure 3.

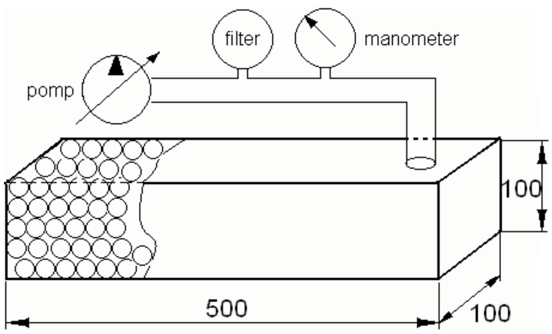

Fig. 3. Granular beam sample

The main aim of these laboratory tests was to verify the previously mentioned results, acquired for a testing sample (Fig. 1), and to confirm the influence of the underpressure parameter on a "real" object.

There is a necessity for conduction of such experiments to eliminate or to estimate the significance of so called "scale effect" existing in almost each structural material.

Typical results of the granular beam bending have been depicted in the Figure 4. The beam filled with a polypropylene grains (the same as previously applied in testing specimen) has been placed is special handles and mounted on the MTS tensile testing machine. In the next step, it was subjected to the loading force, necessary to deform the specimen by 15 mm.

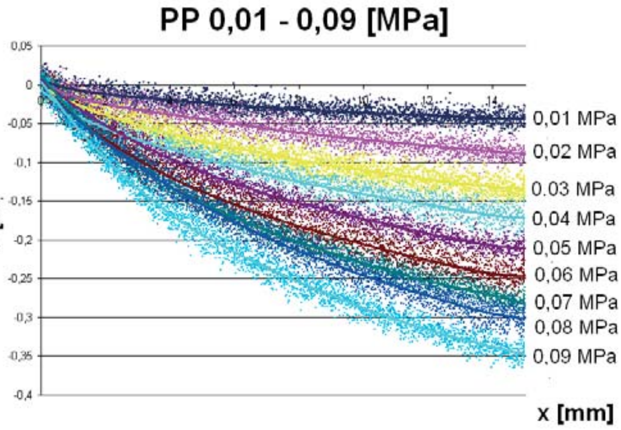

Fig. 4. Bending results of the polypropylene beam at various underpressure values

During the each measurement cycle, the value of the internal underpressure, generated inside the wrap surrounding loose grains increased.

Results of experiments confirm the great influence of the underpressure value, on the mechanical properties of the granular structure.

3.3. Controlled damping of vibrations

As well as research of fundamental strength properties of granular specimens as bending of granular beams, filled with different types of loose material, unambiguously confirmed possibility of mechanical properties controlling of such type of granular structures. The most suitable controlling factor is underpressure, generated inside a hermetic wrap.

In accordance with a scheme of paper presented in section one, now the authors are presenting results and details of experiments concerning damping of free vibrations of beam element by a granular concrete. Such laboratory tests should provide a reliable data for analysing the possibility of applying the special granular conglomerate with underpressure for damping of vibrations in real systems.

In the region of a rectangular beam, made of a spring steel, special granular structures in underpressure conditions have been situated.

An assumption has been made, that the granular material is placed uniformly along the beam. The sleeve has been made of a soft plastomer, similar to that applied in the previously mentioned experiments.

Laboratory stand has been depicted in the Figure 5. The decision has been made to use a beam fixed on the one side, and free on the other. For the fixation, the special handle has been designed and developed.

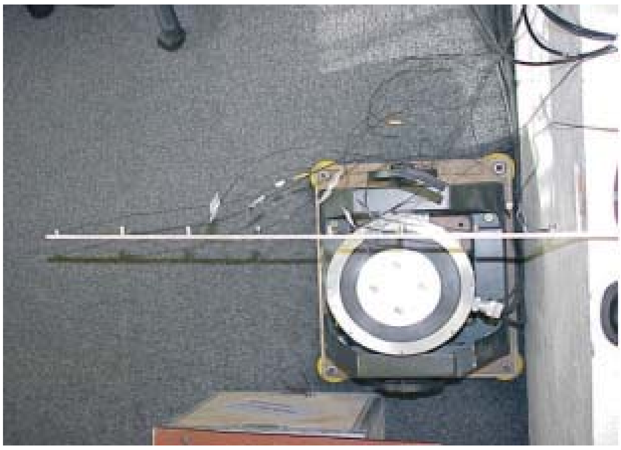

Fig. 5. Laboratory stand for investigations of free vibrations of damped beam

Thanks to the application of eight-channel digital tape recorder SONY® PC208Ax, equipped with multi-channel measurement amplifier, simultaneously recording of time-runs in eight measurement points was possible. During experimental research the acceleration of the tip of a beam has been recorded. Acquired data has been analysed in a measurement system PULSE®. Piezoelectric vibrations transducers have been applied (miniature, very light, accelerometers type 4393 B&K).

Such a selection was conditioned by their weight, which didn't influence on the free vibrations of a beam. At the same time the sensitivity of transducers ought to be good enough for vibrations accelerations recording. The mass of a transducer, mounted on a testing beam, was less than 10% than the mass of the object. Although eight separate transducers have been applied in experiments (uniformly on the free length of a beam – Fig. 6), only signal from the last one, fixed on the free tip of a beam, has been analysed in this paper. The dimensions of the beam were 25 × 5 × 900 mm (width, thickness and length) 200 mm of a beam was fixed, so the length of a free beam taken into consideration in experimental research was 700 mm (Fig. 6).

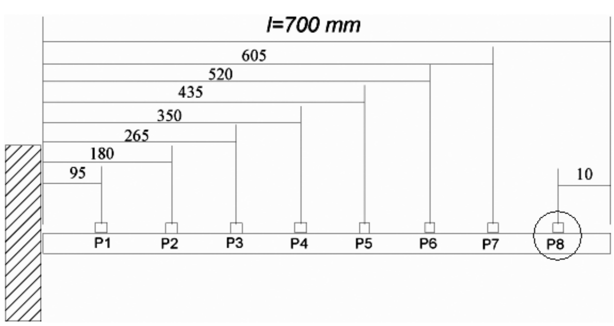

Fig. 6. Mounting scheme of accelerometers

Initial condition for the free end of a beam was a deflection by 8 mm. It was measured every time by the Microtrak II laser sensor, having precision 20 mm.

Each experimental result has been acquired for the same initial conditions. In this paper, results of damping of vibrations for polypropylene grains at various underpressure parameters will be discussed.

Typical results have been depicted in the Figure 7, where results of the steel beam free vibrations and these damped by polypropylene grains have been compared.

Three different values of internal underpressure have been taken into considerations.

Application of a granular damping caused decreasing of vibrations accelerations amplitude about five times.

Also increasing of the underpressure causes a considerable minimization of vibrations amplitude.

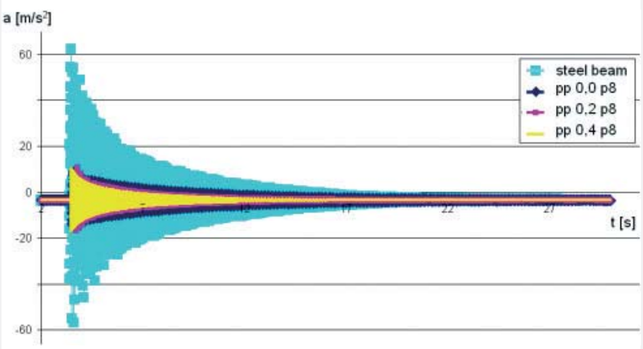

Fig. 7. Experimental results of laboratory tests

4. CONCLUSIONS

The main objective of the paper wasn't a particular proposition of the active vibration damping system, but analysing of new possibilities for vibration controlling by special granular structures. Examples of laboratory tests presented in section 3, confirmed the possibility of changing the mechanical properties of granular media by the underpressure parameter.

This paper could be a base for a further experimental research and mathematical description of physical processes related to energy dissipation and damping of vibrations of different types of systems. It is also the first step for a development of fully active damping system, based on e granular materials placed in a hermetic envelope.

Observing a quick development of measurement electronics and minimisation of transducers dimensions, it seems, that designing of such a active damping systems shouldn't be difficult.

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