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DAMPING MONITORING OF CONCRETE ELEMENTS DAMAGED BY STATIC AND DYNAMIC LOAD

SLEDOVÁNÍ VELIKOSTI ÚTLUMU BETONOVÝCH PRVKŮ POŠKOZOVANÝCH STATICKÝM A DYNAMICKÝM ZATĚŽOVÁNÍM

Abstract

The paper describes the investigation of damping changes of reinforced concrete elements in dependence on their damages. The cumulative damage of the concrete was induced by static and dynamic loading of elements in several load steps. After each load step, a complete experimental modal analysis was carried out and modal characteristics were estimated. The changes of elements damping in dependence on damage state of the elements were evaluated.

Abstrakt

V článku je popsáno sledování změn útlumu betonových stavebních prvků v závislosti na jejich poškozování. Nárůst poškození betonu byl vyvolán statickým a dynamickým zatěžováním betonových prvků. v několika zatěžovacích krocích. Po každém zatěžovacím kroku byla provedena kompletní experimentální analýza a byly vyhodnoceny modální charakteristiky prvku. Byla vyhodnocena změna útlumu jednotlivých prvků v závislosti na jejich stavu poškození.

1 INTRODUCTION

Modal characteristics of the structure (natural frequencies, natural modes and damping) determine its dynamic individuality influenced only by its immediate state, especially by the stiffness and the mass. One of the important characteristics of the structure is also its damping. The paper describes the investigation of damping changes of two types of structural elements, three reinforced concrete beams and four reinforced concrete slabs, in dependence on their damages.

2 DESCRIPTION OF THE REINFORCED CONCRETE ELEMENTS

For the purpose of the first dynamic study, three same reinforced concrete beams were made with dimensions 0,2 m x 0,3 m x 4,5 m (Fig. 1). Beams were made from concrete B25. A main reinforcement consisted of four longitudinal steel bars (type R) with 12 mm diameter. The beam was put on cast steel bearing to achieve a good agreement with theoretical boundary conditions. It was a simply supported beam with the length of a span 4.0 m with cantilevered ends 0.25 m on both sides.

Four reinforced concrete slabs with dimensions 3.2m x 1.0 m x 0.1 m were prepared for the purpose of the second dynamic study (Fig. 1). The slabs were made from concrete B25. The main reinforcement was formed by eleven bars of the diameter 8 mm. Slabs were simply supported on two opposite sides with the span 3.0 m and cantilevered ends 0.1m.

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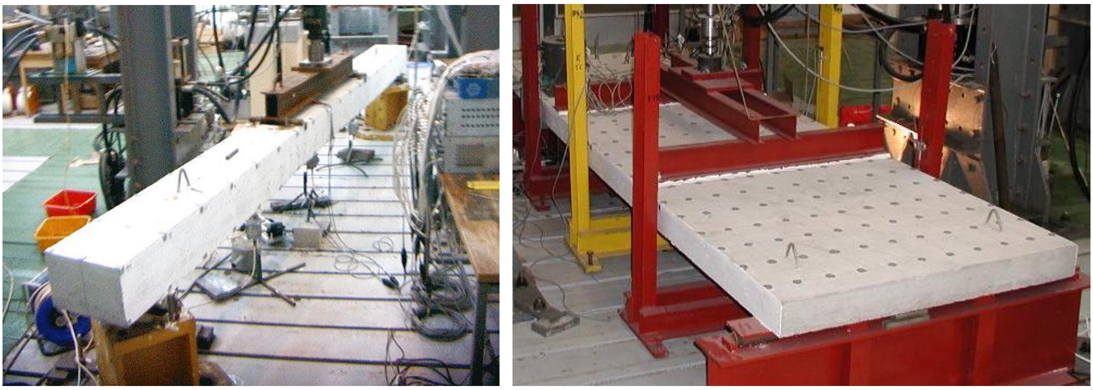

Fig. 1 The investigated reinforced concrete beam and slab.

3 LOADING OF THE REINFORCED CONCRETE ELEMENTS

Tests of the beams were carried out in laboratories of Faculty of Civil Engineering CTU in Prague. The damage of the beam was induced by static and dynamic load in eight different steps. Static loading were done in four steps (A – virgin state-dead load only, B – loading to the theoretical limit of the crack initiation, C – loading to the real first crack, D – loading to the half of the ultimate moment). Then we continued with a dynamic fatigue load, which were done in two steps for the first beam (load to half of a theoretical lifetime and load to the end of a lifetime). The static and dynamic loading was arranged by a lever (Fig. 1) to get a constant bending moment in the mid-section of the beam.

Fatigue load of the beam was induced by harmonic force. The amplitude of the dynamic load was chosen to achieve a stress range in the main reinforcement $\Delta\sigma$ = 220 MPa, which would caused the end of a service life of the beam after 500 000 cycles. Because the real end of a service life of the first beam came after 260 000 cycles, we decided to divide fatigue loading steps for the remaining beams to the smaller parts (E - load to the 65 000 cycles, F - load to the 130 000 cycles, G - load to the 195 000 cycles, H – load to the 260 000 cycles, I - load to the end of the real lifetime).

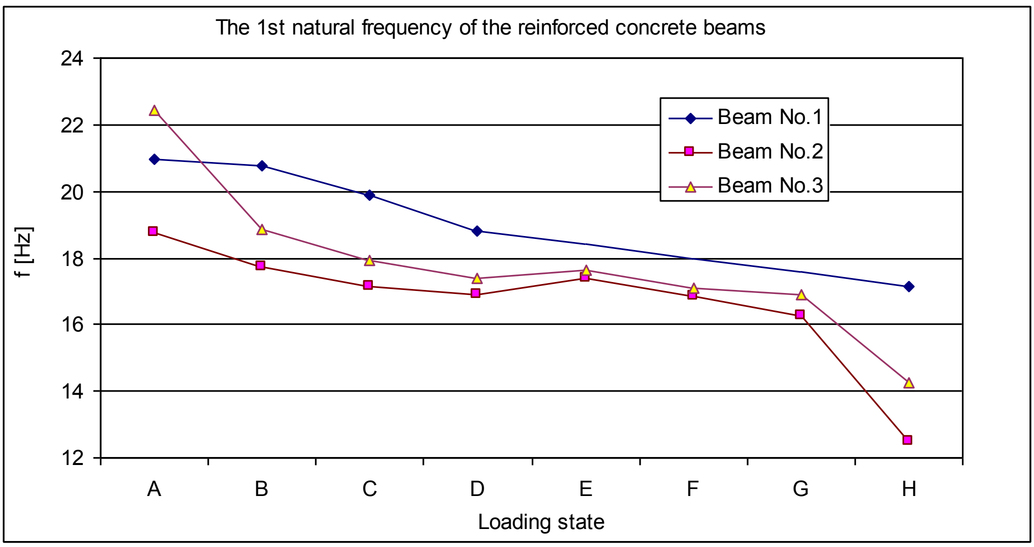

Fig. 2 The change of the 1st natural frequency of the RC-beams No. 1-3 in dependence on their loading state.

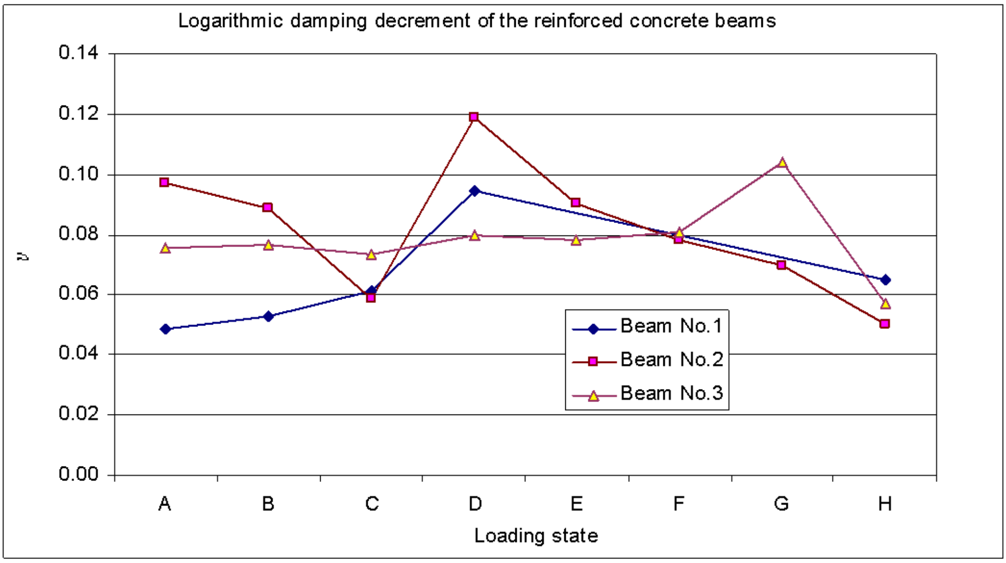

Fig. 3 The change of the logarithmic decrement of the RC-beams No. 1-4 in dependence on their loading state.

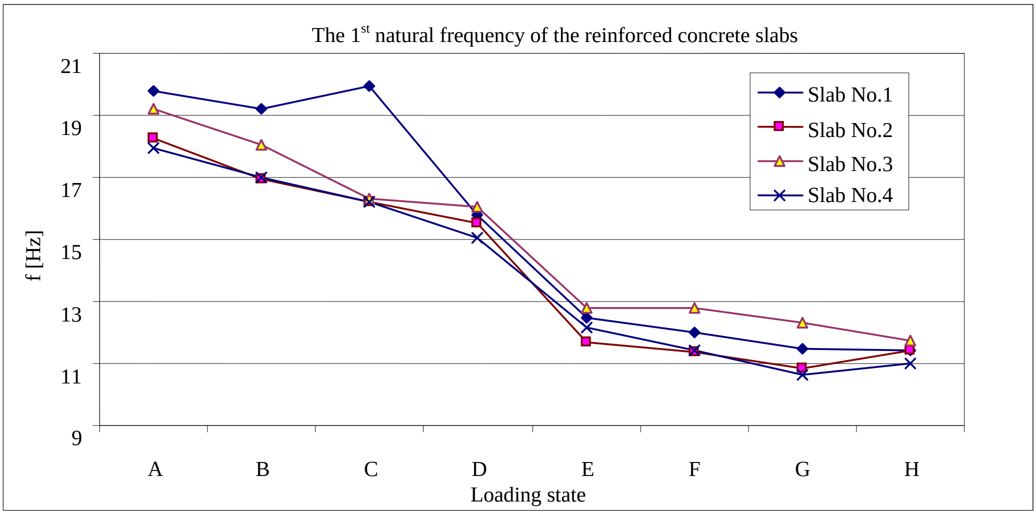

Fig. 4 The change of the 1st natural frequency of the RC-slabs No. 1-4 in dependence on their loading state.

Slabs were loaded by static and dynamic fatigue loading too. Static loading of the slabs was imposed in the same four steps as for the beams. The dynamic fatigue loading was done in five steps (E - load to the half of the theoretical lifetime – 250 000 cycles, F - load to the theoretical lifetime - 500 000 cycles, G - load to the 750 000 cycles, H – load to the double of the theoretical lifetime – 1 000 000 cycles, I - load to the end of the real lifetime).

4 DAMPING OF THE REINFORCED CONCRETE ELEMENTS

After each load step of the static and dynamic loading a complete experimental modal analysis was done. According to the frequency range (0 to 200 Hz) four natural frequencies, damping frequencies and modes of vibration were evaluated for each load step of the beams and five natural frequencies, damping frequencies and modes of vibration were evaluated for the each load step of the slabs.

The first natural frequency and corresponding damping frequency of the reinforced concrete beams No. 1-3 for each loading step are shown in the graphs in Figures 2 and 3. The first natural frequency and corresponding damping frequency of the reinforced concrete slabs No. 1-4 for each loading step are shown in the graphs in Figures 4 and 5.

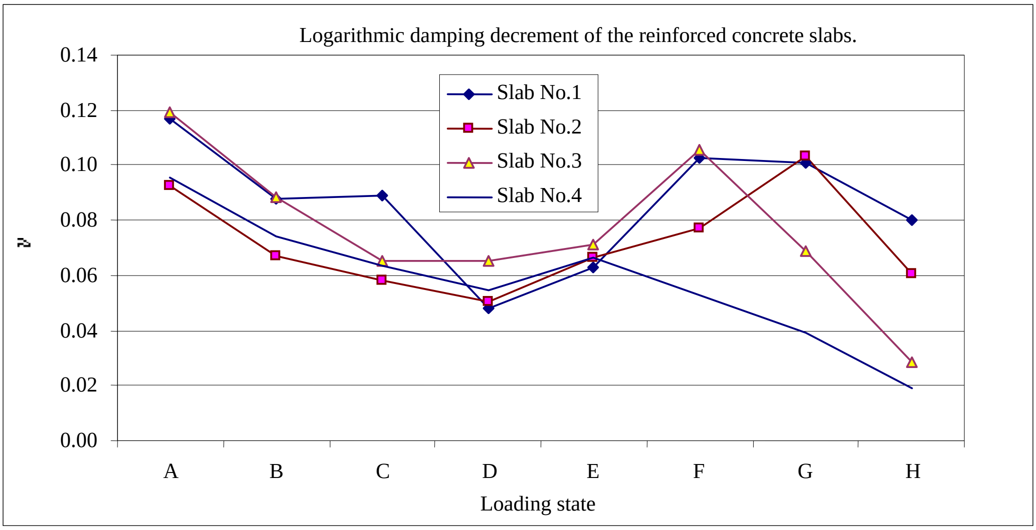

Fig. 5 The change of the log. decrement of the RC-slabs No. 1-4 in dependence on their loading state.

5 CONCLUSION

The evaluation of the damage accumulation influence to damping change of reinforced concrete elements, three reinforced beams and four reinforced concrete slabs, was done.As it can be seen in previous figures, the differences among results of the beams are big. The bigger differences in properties of the beams (Fig. 2) caused also the bigger differences in their damping (Fig. 3) and no unambiguous trend can be seen in damping changes of the beams.

As it can be seen in Figures 4 and 5, we obtained better results for the slabs, results for all slabs well correspond each other. The damping of the slabs decrease in dependence on the static load growth (states A-D). After the beginning of the dynamic fatigue loading, the damping a little bit increase (states E-G) and before the collapse (state H) it decrease again. The results show that reinforced concrete slab damaged by cracks loses its positive ability to transform the kinetic energy of its vibration to other kinds of energy.

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