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STRENGTH AND DEFORMATION OF MATERIALS AND INDIVIDUAL STRUCTURES UNDER REPEATED DYNAMIC LOADING

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ABSTRACT

Using real records of seismic impacts with the maximum amplitude of acceleration and the spectra of these impacts, the reactions of a steel frame idealized as a system with one degree of freedom were calculated on an analog machine. In this case, the reactions were determined in the elastic and elastoplastic stages.

Forces were applied to the prototype, corresponding to the calculated values of deformations of the extreme fibers of the frame columns.

The results of testing all samples at a constant amplitude of deformations are plotted on the graph.

KEYWORDS

Strength, deformation, dynamic load, elastic, amplitude, low-cyclic, compression, tension, elastic-plastic, testing, destruction.

INTRODUCTION

Further development of the theory of seismic resistance is characterized by the use of methods for

analyzing seismic loads and calculating structures, the wider use of probabilistic methods, the assessment of

the parameters of buildings and structures beyond the limits of elasticity, the spatial nature of deformation and etc.

METHODS OF RESEARCH

Much attention is paid to the study of the strength and deformation characteristics of traditional and new effective building materials under dynamic influences, new design solutions for buildings and their elements and interfaces.

The low-cycle fatigue of steel cylinders subjected to repeated compression-tension was studied by Y. Jaoten and K. Mitsuata [12]. analog reaction machine of a steel frame, idealized as a system with one degree of freedom. In this case, the reactions were determined in the elastoplastic stages [1].

Forces were applied to the prototype, corresponding to the calculated values of deformations of the extreme fibers of the frame columns. The program included testing at a constant amplitude (series I), at various random levels of deformations corresponding

to the calculation of the reaction of frames in the elastic (series II) and elastic-plastic (series III) stages.

The results of testing 13 samples with a constant amplitude of deformations are plotted on the graph in Fig. 1. in logarithmic coordinates - $\Delta \epsilon - N$ ($\Delta \epsilon$ residual deformation; N is the number of cycles to failure). The equation of the drawn correlation straight line has the form.

$$\Delta \epsilon \cdot N^{0,346} = 0,0624 \quad (1)$$

at $N=1$; $\Delta \epsilon = 0,0624$. Note that the residual elongation under static tension $\Delta \epsilon_{\text{OCT}} = 0,18$.

The order of loading of the samples at random variable strains corresponded to the nature of the force spectrum determined from real accelerograms. For each tested sample was calculated $\sum \frac{n_i}{N}$ (where n_i - number of cycles at the corresponding level of deformations).

Its average value was 1,51.

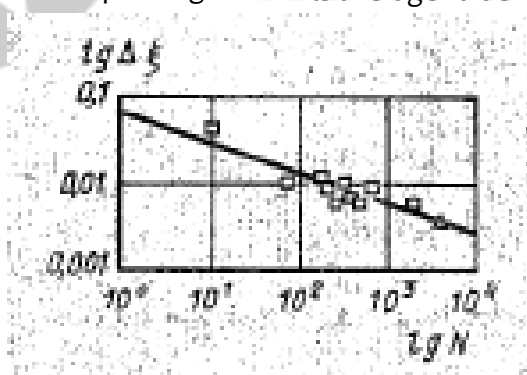


Fig.1. Test results of specimens under repeated loading

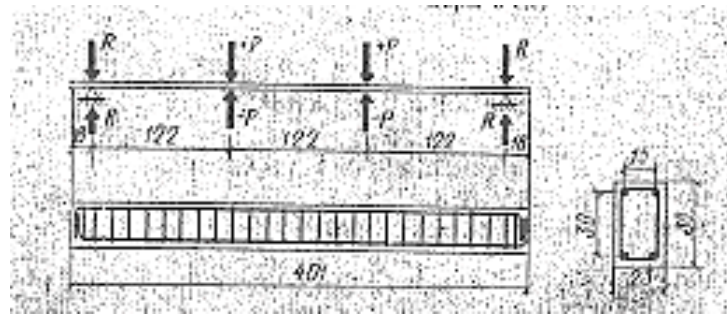


Fig.2. Testing a reinforced concrete beam with a repeated alternating load (dimensions in cm)

In accordance with the theory of fatigue failures by Miner and Sachs, the number of cycles to failure was determined analytically. The nature of the destruction of the samples tested by repeated loading in appearance corresponds to the destruction of the statically tested samples, although some features are noted. Static tensile specimens failed, most often anywhere in the middle and very rarely at the end.

Samples of series I failed, as a rule, at the end of their working length, for samples of series II and III, the formation of two cracks is characteristic - in the middle and at the end of the working length [11].

The influence of the loading rate on the behavior of reinforced concrete beams, as well as the efficiency of repairing damaged elements, was considered by V. Bertero, D. Ria and et al. [5]. For reinforcement, steel grade A-V was used with yield and strength limits of 323 and 576 MPa and a relative elongation of 21%. The strength of concrete is 28 MPa. Initially, the influence of the loading rate on steel and concrete was studied separately. With an increase in the strain rate, an increase in the yield strength of steel was observed from 16 to 28% and the tensile strength of concrete from 12 to 20% compared with static loading.

Beams (4 pieces) during testing were placed on two supports (Fig. 2), one of them was fixedly connected to the beam. The test was carried out at two loading speeds: 0.254 and 25.4 cm/s. The first corresponds to the condition of static loading, the second is typical for seismic effects.

Tests of two beams at different speeds showed an increase in the lower and upper yield strengths by 11 and 22% compared to the results of static loading (Fig. 3a).

The influence of the loading rate decreases with increasing deformation, the loading rate does not affect the nature of the destruction of the beams. A significant effect of the loading rate on the yield strength was noted, which increased by 22% compared to static loading (Fig. 3b). Beams No. 3 and 4 were not brought to destruction. The cracks that appeared during testing in the middle third of the span were eliminated by injection of epoxy compositions under pressure. The repaired beams (3R and 4R) were again tested to failure. The yield strength of the 3R beam increased by 12% compared to the 4R beam during the first loading at different rates [7].

The hysteresis curves of the beams 3R are unstable compared to the similar curves of the beams 1-4. This,

apparently, is explained by the fact that it was not possible to restore the initial rigidity of the beams and the completely broken adhesion of the reinforcement to concrete. Beams 3R and 4R had cracks similar to those of beams 3 and 4, but not in the places where they were sealed with glue. With an increase in the amplitude of the deflection, the nature of the

destruction changed in comparison with the nature of the beams No. 1 and 2. Significant diagonal cracks appeared outside the middle third of the span, and the destruction occurred during shear. The loading rate contributed to an increase in the dynamic modulus of elasticity by more than 10% compared to the static one.

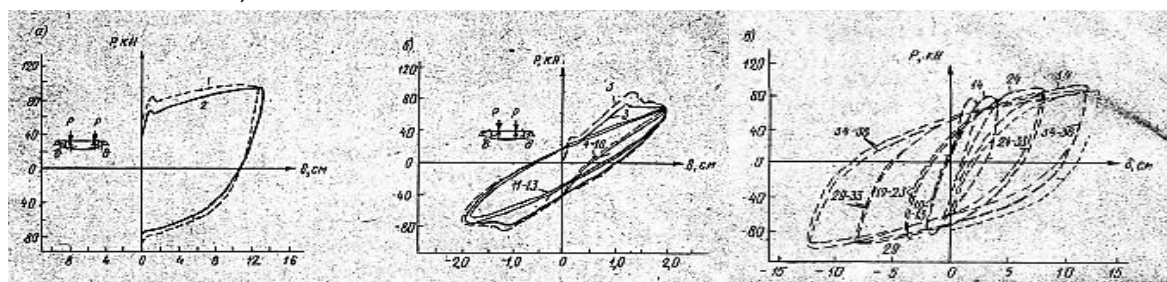


Fig. 3. Results of testing the beams for alternating repeated loading

a - hysteresis curves for beams No. 1 and 2 during the first loading cycle: 1 - loading speed 25.4 cm/s; 2 - the same, 0.0254 cm/s; b - hysteresis curves for beams No. 3 (dotted line) and No. 4 (solid line); c - the same for the 3R series beam. The numbers indicate which load number the hysteresis curve corresponds to.

The crack resistance of dynamically tested beams was obtained by 25%, higher than that of statically loaded elements. Under dynamic loading, the absorption and dissipation of energy increased by 5 and 20%, respectively, compared with the conditions of static loading. The bearing capacity of the repaired beams did not decrease.

American specialists [13] investigated the bearing capacity and the nature of the destruction of steel I-beams made of mild steel under repeated alternating loading. The magnitude of the repeated load (amplitude) corresponded to stresses exceeding the elastic properties of the sample material. The deformations were estimated by the ratio of the maximum deflection in each direction to the deflection corresponding to the yield moment. During tests, this ratio significantly exceeded the value expected during seismic action.

Samples of series I (short) withstood 72% of the load corresponding to the yield strength of the sample material. In comparison with them, long specimens (II series) with increasing number of loadings more intensively reduced the bearing capacity and rigidity. Samples of series III (with a horizontal connection) differed from the previous ones only in that in the center of the span the lower shelf was fixed motionless. Although the horizontal deformations were constrained by the bond, the hysteresis loops proved to be unstable. With an increase in the number of loadings, they became asymmetric, having a larger load peak at the moment of flange compression from the connection side.

Columns with a length of 105.9 cm (IV series) were tested by repeated loading with additional exposure to a static load applied along the sample axis.

The axial compression was 30% of the load corresponding to the axial compression yield strength. The deflection amplitude was 3.71 cm. When loading from one to three cycles, some increase in the bearing capacity was observed. Under subsequent loading, the decrease in the bearing capacity was more intense compared to similar samples tested without axial loading. The reason for the destruction of the samples is the loss of stability of the shelves, and the walls of the I-beam from buckling.

In some cases, the loss of stability was caused mainly by torsion, axial loading contributed to an increase in deformation and fracture rate. In the vast majority of cases, buckling of the wall and cross-sectional flanges was observed at the sample embedment boundary [4]. The buckling of a number of samples was observed at

one of the shelves at some distance from the embedment (local buckling). The greatest damage was noted in the case of a combination of buckling in buckling and torsion. Additional axial loading contributed to the rapid destruction.

B. Kato, H. Akiyama et al. [14] tested the simplest model on a vibrating table to determine the restoring force in the inelastic stage of its operation. The calculation scheme of the model is represented by a single-mass system (Fig. 4). The constant mass 3 is located on the crossbar 2 and creates an axial force in the column 5 equal to $0.33 R_u$ (R_u is the yield strength in the column under compression). The crossbar rests on two supports, one of them is plate 4, and the other is a prototype of an I-section 3x3 cm and 25 cm high.

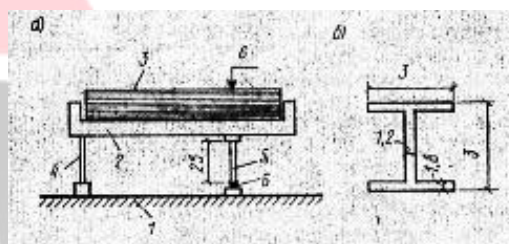


Fig. 4. Scheme of testing a prototype

a - scheme of the pilot plant; 1-vibration stand; 2-crossbar; 3- mass located on the crossbar; 4-support in the form of a plate; 5-experimental sample of I-section; 6 accelerometer; b-section of the prototype

Samples A0, A1, A2 and A3 were tested. Mechanical characteristics of steel: modulus of elasticity 0.211 106 MPa, yield and strength limits 258 and 304 MPa. Sample A0 was tested statically. In (Fig. 5, a), the dotted line in the coordinates horizontal force –

displacement shows the behavior of the model under static loading [8,9].

A1, A2 and A3 were tested on a vibrating table with the reproduction of the recording of the El Tsontro earthquake, 1940. The maximum accelerations were respectively 210, 250 and 360 cm/s. Torsional and horizontal transverse oscillations of the model were eliminated by auxiliary pinching. The period of natural oscillations and the attenuation of the model were 0.17 and 0.2% (critical). The samples were destroyed from bending along the longitudinal axis with local destruction in the section of the sample. The restoring force in the elastic stage is in complete agreement with the calculation results. When calculating it for the inelastic stage, the following equation was used:

$$mx'' + cx' + f(xx') = -mx_0'' \quad (2)$$

The curvilinear dependence was introduced into the calculation by three linear functions (Fig. 5, a). The effect of the P-Δ system was estimated as:

$$Q_{p-\Delta} = -m_g \cdot x/h$$

It can be seen from the graph in (Fig. 5, b) that with the appearance of local destruction in the section of the A3

sample, the restoring force significantly decreased. An increase in the yield strength caused by the influence of the loading rate is noted. A good agreement between the analytical and experimental curves is observed (Fig. 5c).

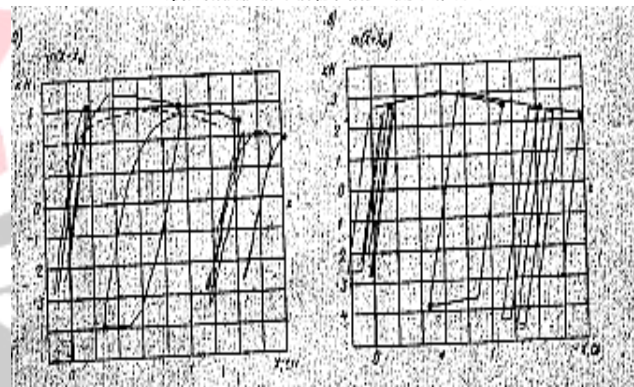
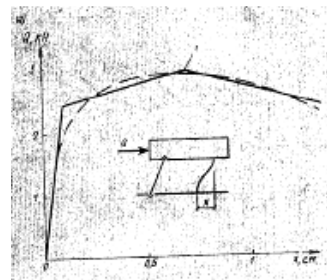


Fig. 5. Test results

a - static loading (A0), ----- experimental curve; _____ calculated curve% 1 - occurrence of local destruction; b, c – experimental and calculated curves of restoring force change (A3), _____ - static loading

The work [15] is devoted to the study of the bearing capacity of reinforced concrete columns, reinforced with a spiral, under repeated dynamic impact of the seismic type [6]. The prototypes were 1/2 scale models of the column (Fig. 6). Its prototype was the column of the main building of the medical center in California.

A transverse reload P_n was applied at the ends of the column in opposite directions. In the termination

(increased section), moments of the opposite sign simultaneously appeared. In addition to repeated loading (12 cycles), the columns were loaded [10] with a constant axial compressive load equal to 457 or 914 kN. 6 samples were tested, differing among themselves in the percentage of longitudinal reinforcement. Spiral diameter 9.5 mm. The maximum deflection during loading was 6 times higher than the allowable value.

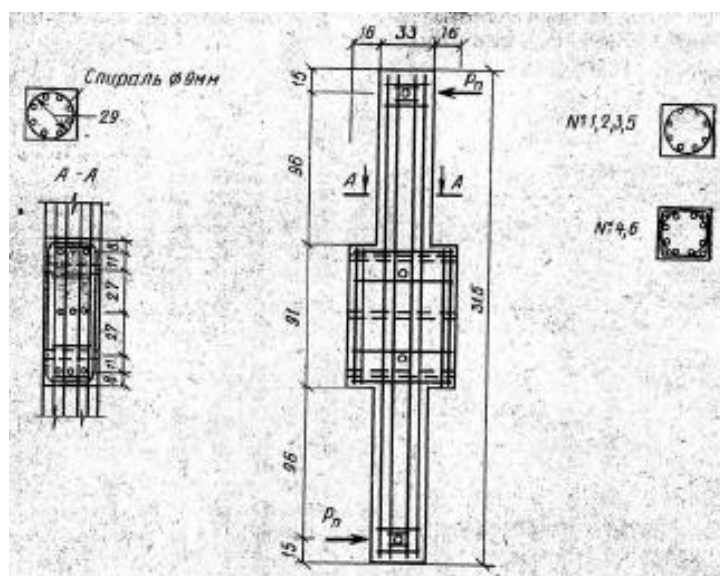


Fig. 6. Dimensions (in cm) of the prototype and reinforcement options

Calculations are made for the limit state, taking into account the bearing capacity of the compressed zone of concrete in the limit state. The deformations of the longitudinal reinforcement of the column reached a significant value, which ensured the determination of the boundary conditions for the analytical dependence. Sufficient results showed that the load of the first cycle was significantly less than the calculated one.

Reinforcement with spirals is very effective both in combination with longitudinal reinforcement and without it. The maximum deformations in the spirals did not exceed the values corresponding to the deformations upon reaching the elastic limit of the material. Longitudinal reinforcement with rods outside the helix at the corners of the section (samples 4.6, see Fig. 6) is effective only during the 1st cycle.

For samples without longitudinal rods outside the helix (samples 1-3.5), the hysteresis curve turned out to be stable even after the appearance of cracks in the concrete.

The deformation of the longitudinal rods (close to failure) at a relatively high level of axial load increased with an increase in the number of load repetitions. Inspection of the tested columns led to the conclusion that the concrete within the spiral is completely painted.

CONCLUSION

1. The behavior of bending elements is determined mainly by the mechanical properties of the reinforcement. For a complete representation of the behavior of bending elements under an alternating load, it is necessary to know at least two dependencies: moment - curvature, shear force - shear deformation. The use of large-diameter rods prevents the reinforcement from buckling, but increases the risk of it pulling out under alternating loading. Pulling out the reinforcement significantly reduces the rigidity.
2. The decrease in the rigidity of the bending elements after the first loading and in subsequent



cycles at the same amplitude is explained by the accumulation of shear strains.

3. The increase in the strength of the crossbars when the floor slabs are put into operation should be taken into account in the calculation.

REFERENCES

1. Alexander C.M., Heidebrecht A.C. Tso W.K. Cyclic Load Tests on Shear Wall Panels.
2. Corley W.Y., Hangan I.M. Design of Earthquake – Resistant Structure Walls.
3. Cardenas A.E. Shear Walls – Research and Design Practice.
4. Barda F., Hanson I.M., Corley W.Y. An Investigation of the Design and Repair of Low – Rise Shear Walls.
5. Bertero V.V., Rea D., Mahin S., Atalay M.B. Rate of Loading Effects on Uncracked and Repaired Reinforced Concrete Members.
6. Ifrim M., Dobrescu A. Simplified Analysis of Shear Walls in Tall Buildings to Earthquake Action.
7. Jirsa I.O. Factors Influencing the Hinging Behaviour of Reinforced Concrete Member under Cyclic Overloads.
8. Борджера Дж., Равера А. Проектирование железобетонных конструкций для сейсмических районов (перевод с англ.) М.: Стройиздат, 1998, с.135.
9. Бондаренко В.М., Бондаренко С.В. Инженерные методы нелинейной теории железобетона. М.: Стройиздат, 1992, с. 362.
10. Завриев К.С. (и др.) Основы теории сейсмостойкости зданий и сооружений. М.: Стройиздат, 1980, с. 224.
11. Николаенко Н.А., Назаров Ю.П. Динамика и сейсмостойкость сооружений. М.: Стройиздат, 1998, с. 312.
12. Gyoten Y., Mizuhata K., Tsuyama I. Experimental Study of how Cyclic Fatigue of a Structural Member Subjected to Earthquake loads.
13. Vanm W.P., Thompson E., Whalley L.E. Ozier L.D. Cyclic Behaviour of Rolled Steel Members.
14. Kato B., Ariyama H., Suzuki H. Dynamic Collapse Tests of Steel Structural Models.
15. Karlson B., Aoyama H., Sozen M. Spirally Reinforced Concrete Columns Subjected to Loading Reversals Simulating Earthquake Effects.