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MANAGEMENT OF STRAINS AND DEFORMATIONS IN CONSTRUCTIONS FOR SEISMIC-RESISTANT BUILDINGS AND STRUCTURES WITH PLIANT TIES

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ABSTRACT

Some proposals for management of state of different structures are given in this paper. The management is obtained by using the pliant ties. It gives possibility to reduce the forces in main structural elements when static and especially dynamic loading.

The examples of using the pliant ties are adduced for such structures as building with suspended floors, underground pipeline with pliant gasket around the pipe, bridge with elastic inserts on supports. The solution for bridge with nonlinear deforming inserts on the supports as a system with many degrees of freedom was obtained by the Direct Numeral Discrete-Step Method.

The high efficiency of these structural solutions under earthquake conditions is shown for raising the seismic resistance of constructions.

KEYWORDS

Force; gasket; pliancy; relaxation; resonance; shift; stiffness; tie; vibration.

Creation of the seismic resistant buildings and structures includes two methods of approach: a) application of solid, hard and light constructions; b) application of pliant, flexible constructions. The second method found a great spreading last time. It gives a possibility to decrease greatly the constructional efforts from seismic influence, to raise a seismic resistance of buildings and structures by using the pliant ties. They are buildings with suspended floors, buildings on sand layer, structures with turning out ties, systems of amortization and seismic isolation.

An application of the pliant constructions demands to improve the design methods. They must ensure both the strength and ability of elements to deformations within limits. Some proposals of that for different constructions are given below.

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When a load is dynamic all constructions are statically undetermined. For such systems equations of the Force Method has canonical form (Kiselyov, 1969):

$$\sum_{i=1}^{n} X_i \delta_{ki} + \Delta_{kp} = 0, \qquad (1)$$

where: n= amount of ties in system; X_i = forces in ties (i=1,...,n); δ_{ki} = coefficients of tie pliancy (k=1,...,n); Δ_{kp} = cargo members.

The force of i-th tie is determined by the formula:

$$X_i = D_1/(a D_2/B_i + D_3), \qquad (2)$$

where: D_1, D_2, D_3 = determinants of system canonical equations (1) received from its coefficients; a = geometrical coefficient; B_i = stiffness of i- th tie.

The adduced formula (2) shows: when stiffness of a tie decreases its effort decreases too, it takes place a redistribution of efforts to other more rigid ties.
The mentioned circumstance gives an opportunity to manage the structural state to get the effective using of the full strength for all elements. Just it is the aim of systemic optimization.

The author's work (Penkovsky, 1986) includes different cases of operating state for simple and complicated constructions with pliant and energy- absorbing ties when loads are statical and dynamical.

For presentation of seismic influence in spectrum form of accelerations and frequencies the deformations in system with one degree of freedom are determined by resonance frequency (Uniform Building Code, 1994). When the resonance takes place within time t and an amplitude of forced vibrations for base A is constant then raising deformations in system are determined by formula of comprising maximum shifts (Fig.1):

$$\pm\bar{X}(t)=\bar{X}_0 \exp(-\alpha t) + (A \pi/T) (1-\exp(-\alpha t))/\alpha, \qquad (3)$$

where: $\bar{X}_0$ = initial shift; α = relaxation coefficient; T = period of own vibrations for system ($T=2\pi/\omega$); ω = frequency of own vibrations that depend on regulated rigidity of tie C in operating process ($\omega = \sqrt{C/M}$); M = system mass.

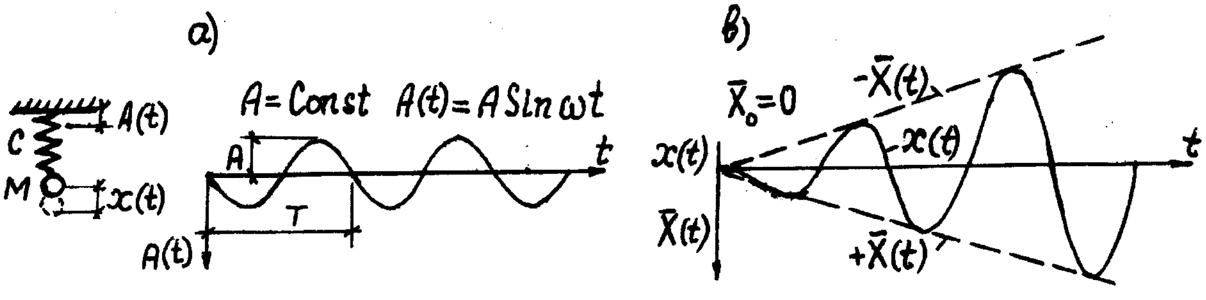

Fig.1. Vibrations of base (a) and mass M in system (b) when resonance.

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For building with suspended floors on tie of length L the period T is determined by the formula:

$$T = 2\pi\sqrt{L/g}, \qquad (4)$$

where: g = earth acceleration.

Increasing length L increases period T and decreases the shifts when resonance.

A peculiarity of bridges and viaducts is a large vulnerability on vertical dynamic loads. When the Northridge Earthquake the most of all bridges were destroyed by the vertical loads. There were destroyed the supporting columns and parts of span structures near columns where large transverse forces took place (Cooper et al., 1994).

Since the main seismic influence to structures of bridges and viaducts is passed through supports by shifts of an earth surface then it is reasonable to introduce the pliant ties into contact of supporting columns with span structure (Fig.2,a). The longitudinal and transversal in plane stability are ensured by the bridge body.

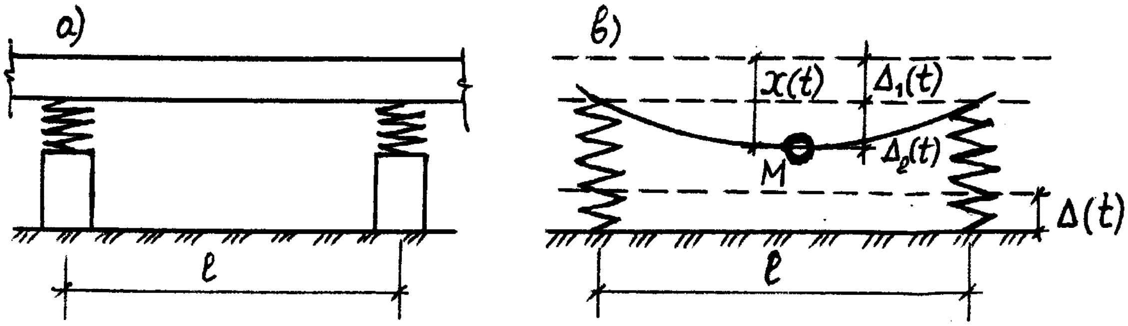

Fig.2. Scheme of bridge with pliant ties on supports (a) and its approximated design scheme (b).

When a bridge structure has the pliant ties on supports then its design scheme may be represented as a beam with distributed mass that leans on the pliant supports. These supports receive the forced earth motion (for example in form of seismogram).

Designing this construction has some difficulties. It is unregulated loads (on size and frequency of vibrations), complication of structures, which have many degrees of freedom, nonlinear nature of real pliant ties, necessity to avoid the resonance.

Solution of this problem was developed as the following (Synitsin, Penkovsky, 1977).The beam is devided into row of sections with concentrated mass for each section. Pliant supports have an arbitrary nature of deforming and may have elastic and viscous resistance. Bases of the supports have an arbitrary nature seismic shifts during time. Decision is obtained by the Direct Numeral Discrete-Step Method with use of computer. Motion of each system mass is examined while little time Δt from beginning seismic activity to definite time t. It was suggested also methods of ensuring exact and stable calculations and economy of computer time.

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In particular case when design scheme of bridge may be approximately represented as a system with one degree of freedom (Fig.2,b) a vertical shift of span bridge mass M consist of two parts:

$$x(t) = \Delta_1(t) + \Delta_2(t), \qquad (5)$$

where: $\Delta_1(t)$ = compression of insert with stiffness C ; $\Delta_2(t)$ = bend deformation of beam. In this case the frequency of own vibrations is determined by the formula:

$$\omega = \sqrt{\frac{1}{m\ell\left(\frac{1}{C} + \frac{\ell^3}{2kEI}\right)}}, \qquad (6)$$

where: m = unite-length mass; ℓ = span of beam; EI = its bend stiffness; k=48.6 - for simply supported spans; k=250 -for beam with continuous spans.
Design of bridge structure and supports is produced on equivalent static distributed load

$$q_{es} = q\,k_d, \qquad (7)$$

where: q = load from own bridge weight; k_d = dynamic coefficient which is determined as follows:

$$k_d = 1 \pm \bar{X}\ \max / \Delta_{st}. \qquad (8)$$

Here: $\bar{X}$ max = maximum amplitude $\bar{X}(t)$ for time of seismic activity determined by the formula (3); Δ_{st} = system deformation when static load of own bridge weight.

For underground pipeline the inertia forces may not be considered. If unmonotonous ground has some seismic dislocations (Fig.3), then a pipe bending moment is determined by the formula:

$$M = \Delta \frac{CDS^2}{4} + \Theta \frac{CDS^3}{8}, \qquad (9)$$

where: Δ = cross shift; Θ = turning of earth surface; S = elastic characteristics of pipe in the ground ($S = \sqrt[4]{4EI / CD}$); EI = bend stiffness of pipe; C= bed coefficient; D = diameter of pipe.

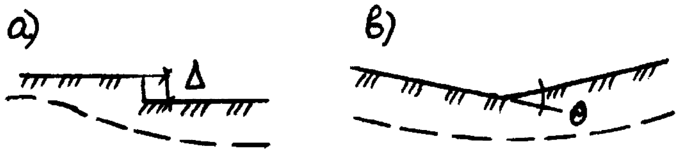

Fig. 3. Dislocations of ground in form shift (a) and turning (b).

An arrangement of a pliant gasket around the pipe and change of pipe rigidity (change C and EI) gives a possibility to decrease the efforts in the pipe and to raise its seismic resistance.

Conclusion.

The pliant ties afford the opportunity to manage the state of different constructions and to decrease the forces in main structural elements of seismic resistant buildings and structures. Calculations have shown the high efficiency of using pliant ties . So arrangement of inserts with thickness 0.5 m and stiffness 6000 tn/m on supports for reinforced concrete bridge with span 20 m decreases the vibration frequency by three times and the structural forces by two times. In many cases the efficiency of pliant ties may be much more.

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REFERENCES

Cooper J.D.,I.M. Friedland, I.G. Buckle, R.B. Nimis and N.M. Bobb (1994). The Northridge Earthquake: Progress made, lessons learned in seismic-resistant bridge design. J. *Public Roads*, Vol.58, N1, 26-29.

Kiselyov V.A. (1969) Constructional Mechanics. Build. Publ. Moscow.

Penkovsky G.F. (1986) Pliant Constructions of Special Structures. Def. Min.,USSR, Leningrad.

Synitsin A.P., G.F. Penkovsky (1977). Management of stress state for beam on elastic footing when forced dynamic deformations in this footing. *J. Constr. mech. and design of structure*, N1, Moscow, 47-50.

Uniform Building Code (1994). Vol.2. Whittier, California.