LONG-IN-PLAN STRUCTURAL SYSTEMS UNDER THE ACTION OF SEISMIC EXCITATION

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Summary

Long-in-plan structural systems are those length of which in plan is comparable with the length of seismic wave. In this paper are discussed some problems the more important of which are: which are the main factors imposing the necessity a given structure to be investigated as a "long-in-plan" structural system; the possibility of appearence of beating phenomena and their influence on the design siesmic loading. On the base of the improved method for determining the design seismic loading are proposed respective recommendations and formulae.

x x x

A characteristic pecularity in the dynamic behaviour of the long-in-plan structural systems is the existance of inversely symmetrical (in plan) modes of their natural vibration called "torsional" vibration even when the mass centre coincides complitely to the rigidity centre.

When the base motion is assumed to be a translational one the corresponding ground accelerations are equal for the whole system their maximum amplitude values being $a_o \omega^2$. For long-in-plan structures, depending on the kind of the structure and on the character of the seismic excitation, the base motion can be rotational and the end supports can vibrate in opposite phases. That is why we propose the maximum amplitude value of the acceleration to be $a_o \omega^2 f(x)$. With this "loading function" f(x) it is possible a more exact analysis of the seismic excitation to be carried out. Its physical nature is that the nonuniform distribution of the amplitude values of seismic loading along the structure length is considered. The presence of f(x) does not change [1] the general view of the wellknown formula for determining the design seismic loading - $S_{ik}=K_c \beta_i \eta_{ik} Q_k$. The function is included in the mode coefficient

$$\eta_{ik}=X_{ik}\frac{\sum_{j=1}^{n} f(x) Q_j X_{ij}}{\sum_{j=1}^{n} Q_j X_{ij}^2}$$

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where X_{ik} and X_{ij} are the amplitudes of the displacements of the k and j points corresponding to the i mode of vibration.

In Fig.1 are given three mathematical models convinient for different structures (Fig.1a - for bridge structures and girders of one-space frames;Fig.1b - for structures on many supports with approximately equal stiffness as girders of multi-space frames,floor slabs,bridges; Fig.1c - for buildings which tair-wall towers are more rigid than other diaphragms) [3].

In table 1 are given expressions of f(x) for various mathematical models and different kinds of vibration.For example,when the structures are rigid and their deformability has not essential influence on the displacement due to the seismic loading it is expetient to use the expressions (5) and (6).For important structures as well as for flexible ones which deformation takes an essential part in their displacement the expressions (1) and (2) or (3) and (4) could be used.

The existance of translational and torsional vibrations in the long-in-plan structures condenses their frequency spectrum and this leads inevitable to appearance of "beating" [7],i.e.to the summation of the corresponding modes.As a result the vibration has a varying amplitude gradually increasing and decreasing,its maximum being almost equal to the sum of the amplitudes of both modes.

As a result of the analysis [3] the following conclusions could be given:the occurence of "beating" is not characteristic phenomenon for all long-in-plan structures; the length of the system is not the basic factor for occurence of this phenomenon but the existance of many yielding supports as well as the deformability of the structure in comperison with the yielding of the supports; when the deformability of the structure is very small (Fig.1c) it is possible the torsional vibrations to be the fundamental mode of natural vibrations.

From engineering point of view a two dimensional model 6 is more convinient for many long-in-plan structures.For buildings built in Bulgaria it ie shown in [5] that the design seismic loading acting on any point (x,y) is:

at translational vibrations

$$S_{L,tr}(x,y) = S_k(x) \frac{\sin \frac{\pi L}{\lambda}}{\frac{\pi L}{\lambda}}$$

at torsional vibrations

$$S_{L,t}(x,y) = S_k(x)\,3\,\frac{\sin\frac{\pi L}{\lambda} - \frac{\pi L}{\lambda}\cos\frac{\pi L}{\lambda}}{\left(\frac{\pi L}{\lambda}\right)^2}\left(1-2\frac{y}{L}\right)$$

where $S_k(x)$ is the loading determined with traditional mathematical model – cantilever beam; L is the structure length and λ is the seismic wave length.

Using the upper expressions it is shown [6] that buildings can be treated as long-in-plan when $L/\lambda \geq 0,10$.

As a conclusion it is necessary to mention that the absolute value of the length L is not deterministic for the classification of the building as long-in-plan. The dynamic characteristic of the soil-structure system and the geological conditions of the site determine when a given building is long in plan.

REFERENCES

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Table 1

MATHEMATICAL MODEL	MODE OF NATURAL VIBRATION	EXPRESSIONS OF f(x)
BEAM ON TWO SUPPORTS	TRANSLATIONAL	(1) $f(x)=\cos\frac{\pi L}{\lambda}\geq 0.5$
	TORSIONAL	(2) $f(x)=\left(1-2\frac{x}{L}\right)\sin\frac{\pi L}{\lambda}$
BEAM ON SEVERAL SUPPORTS	TRANSLATIONAL	(3) $f(x)=\frac{\sin\frac{\pi L}{\lambda}}{2L/\lambda}\sin\frac{\pi}{L}x$
	TORSIONAL	(4) $f(x)=\frac{\sin\frac{\pi L}{\lambda}-\frac{\pi L}{\lambda}\cos\frac{\pi L}{\lambda}}{(2L/\lambda)^2}\cos\frac{\pi}{L}x$
RIGID BEAM ON SEVERAL SUPPORTS	TRANSLATIONAL	(5) $f(x)=\frac{\sin\frac{\pi L}{\lambda}}{\pi L/\lambda}$
	TORSIONAL	(6) $f(x)=3\frac{\sin\frac{\pi L}{\lambda}-\frac{\pi L}{\lambda}\cos\frac{\pi L}{\lambda}}{(\pi L/\lambda)^2}\left(1-2\frac{x}{L}\right)$

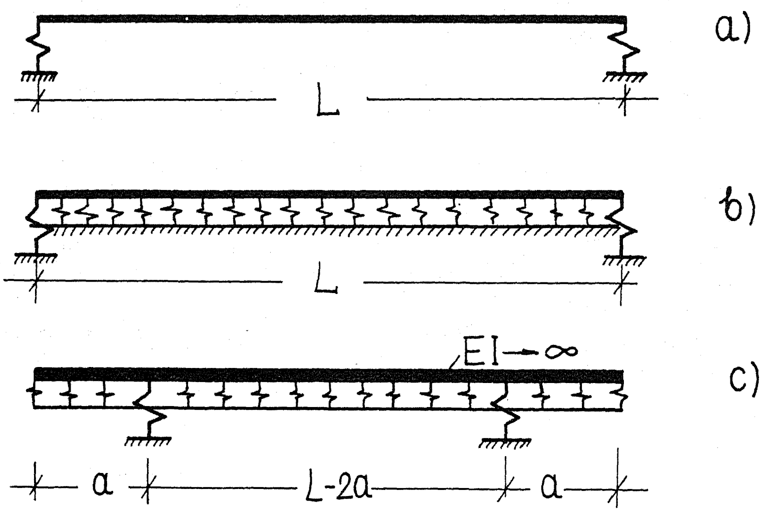

Fig.1