Paper No. 337. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

THE WAVE CONCEPTION OF BUILDING SEISMIC RESPONSE ANALYSIS

A. M. KURZANOV

Ihtimanskaja Street, 4-96, Klimovsk Moscow Region, 142080, Russia. Tel.171-23-56.

ABSTRACT

The travelling transverse waves in building are the main cause of its seismic damages. The speed of these waves is about several hundred meters per second and it depends on geometrical and physical characteristics of building. Each many-storeyed building may be represented as a chain of storey-elements and it is the filter of ground motion. The ground storey absorbs most of the high frequency waves, and these waves can be the cause of ground storey constructions endurance failure. The travelling transverse waves of shear, bending or torsion deformations destroy the building before its resonance occurs. The earthquake intensity measure are the displacement and velocity of ground instead of ground acceleration. Observation of travelling waves form and speed in building is an important task of seismic research in earthquake engineering.

KEYWORDS

Building travelling transverse wave; filter of ground motion.

THE ESSENCE OF WAVE CONCEPTION

The necessity of a new conception

Since 1952 up to 1973 the design ground accelerations by Russian standard scale of seismic loads were increased by five times. For example, before 1952 the design acceleration for the earthquake intensity 9 was Y_{01} = 0.05-0.1 g, after 1973 - Y_{0H} = 0.25-0.5 g.

It seems that the old constructions designed with the account of earthquake accelerations are by 5 times less as compared with the up-today accelerations, should have been destroyed in most cases under the heavy earthquakes that the buildings designed by modern scale. Yet the experience of recent heavy earthquakes evidently shows that both the new and the old buildings designed in accordance with the new and the old scale accelerations that differ by five times approximately identically endure the heavy earthquakes having the same quality of engineering.

There may be the only cause that the fivefold increase in earthquake accelerations does not lead to corresponding increase of building seismic resistance. This cause is in uselessness of the spectral method for buildings seismic loads design that is elaborated on the base of doctrine of seismic resonance and does not correspond to the real behaviour of the building under the seismic load. The essence of spectral method is building design as a linear elastic system by means of adding the modes of normal vibrations of this system multiplied by resonance dynamic coefficient. The building seismic load calculated by this way is multiplied then by coefficient $K_1 = 0.25$, i.e. is lessened by 4 times.

Pointing out the inner discrepancy in the main assumptions of the spectral method that are known from full-scale tests and practical impossibility of excitation and support of failure progressive resonance vibration in building, the opponents of spectral method draw the attention of its supporters that in accordance with the letter of the spectral method the building designed by this method for earthquake intensity 9 is capable to work in linear-elastic stage only under load that does not exceed the earthquake intensity 7. It is just what design load decrease by 4 times with the aid of coefficient $K_1 = 0.25$ leads to. Besides the coefficient K_1 there are some similar coefficients in spectral method the value of each of them cannot be determined separately by test methods. Each of these coefficients is not a real physical quantity that could be measured by straight or indirect methods.

As a matter of fact the spectral method as it is presented now is deadlock, that excepts further efficient development of Earthquake Engineering Standards and Codes on the base of further deep theoretical and experimental investigations of seismic-resistant constructions.

The proposed wave conception main point

The proposed wave conception of building destruction by seismic load consists in the following. In common case the seismic load disturbs the moving up transverse waves in the building. The speed and the form of these waves depend upon the character of seismic disturbance, physical and geometrical characteristics of building. The transverse wave velocity size measured by numerous full-scale tests of different buildings is in average several hundred meters per second. For example, in a 10-storey block of flats that presents by itself the spatial system of prefabricated reinforced concrete diaphragms the travelling transverse waves velocity is about 3 hundred meters per second. For frame constructions the velocity of such wave may be considerably less.

When at the first moment the seismic disturbance gives rise to horizontal velocity and displacement of the building foundation the travelling transverse wave that just began its moving up the building leads during initial time to the concentration of the inner forces and deformations in a narrow layer of the ground floor.

Combination of the foundation displacement and the slow transverse wave running up the first frame storey pillars leads to pillars failure before the running wave reaches the top of the building and all the more well before the pillars ultimate strength is reached by the resonance building vibration as a whole. Let us explain this by example of the reinforced concrete columns calculation.

The initial data:

Reinforced concrete columns with section 0.4 x 0.4 m of concrete B25 ($E = 3 \cdot 10^4$ N/m^2, $d = 2.4 \cdot 10^4$ N/m^3); reinforcement index $\mu = 3\%$; reinforcing steel bars ($R_s = R_{sc} = 3.75 \cdot 10^8$ N/m^2); earthquake intensity 8. The seismic influence excites the running up transverse wave in the building with parameters:

- $V_0 = 0.18$ m/s - velocity of the transverse displacement (horizontal velocity) of the building foundation at the initial stage of the motion;
- $A = 0.009$ m - amplitude of the foundation transverse displacement;
- $x = A \sin \omega t$ - approved for use the dependence of foundation transverse displacement under columns from time t with period T;

$\omega = V_0/A = 20$ 1/s, $T = 2\pi/10 = 0.314$ s;
$c = \sqrt{a\omega} = 90.4$ m/s -velocity of travelling flexural wave;
$a = \sqrt{EJ/m} = 4.09 \cdot 10^2$ m/s;
J = column cross section moment of inertia;
m = mass of unit of column length.

In Table 1 are given the design data of spreading deformation and bending moment M in column in dependence with the time t during the first quarter of period T ($t < T/4$). The form of bending deformation is accepted in accordance with the scheme (Fig. 1), in which

$$\ell(t) = ct.$$

It is supposed that the column is rigidly joined in the point O of foundation by the base plate, foundation raft, etc.

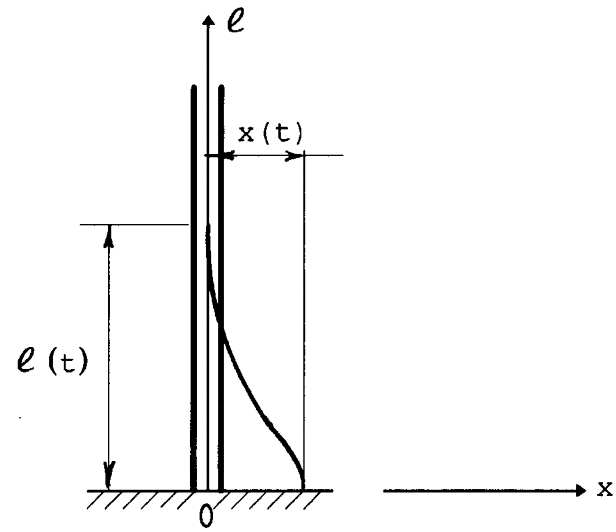

Fig. 1. Column deformation scheme

Table 1. The time-dependent deformation and bending moment in the column

T s	x m	ℓ m	$M = 6\,EJx/\ell^2$ N · m
0.01	0.00179	0.904	$85.7 \cdot 10^4$
0.02	0.00350	1.908	$41.9 \cdot 10^4$
0.03	0.00509	2.712	$27.1 \cdot 10^4$
0.04	0.00645	3.616	$19.3 \cdot 10^4$

The calculated reinforced column bending moment with the characteristics mentioned above is equal to

$$29.8 \cdot 10^4 / \text{N} \cdot \text{m}.$$

Thus during the transverse wave moving up on the column fraction about 2.5 m long from the lower restrained joint the column volume bending moment exceeds the column bending strength and at the same time on the column fraction about one meter long, the condition for column shearing strength is not satisfied.

Let us continue the conception presentation. The running wave being not enough mighty to destruct the construction of a few low storeyes can form the antinode vibration at the level of building top. Such vibration may cause the destruction of the building upper fraction.

The building deformation under the action of running transverse wave has a complicated character. Prevailing of bending or shearing depends upon the magnitude and direction of seismic influence. Deformations of building constructions will be the shearing under the torsional wave action running up along the building.

Along with the travelling waves stimulated by seismic impulsive forces it is necessary to take into account the sinusoidal travelling waves. Upon the calculation it is necessary to take into account the straight and reflected travelling waves interaction, their frequency filtration in the first low floors.

Each many-storeyed building may be considered as a chain of rather similar interconnected storey-elements which is the low-frequency filter. Such filter lets passing the low frequency travelling waves absorbing the high frequency waves in the first low floors. Forced high frequency vibrations of the first low floors have nothing common with their resonance vibrations. These forced vibrations are able to provoke the construction fatigue of the first low floors or at least the appearance of plastic deformations, and along with this to interfere with the linear process of resonance vibration of the whole building.

From the standpoint of proposed conception it is evident that the main seismoresistant measures must counteract to travelling waves destructive influence. The constructive seismic-resistant solutions must provide the weakening of the travelling waves in the building foundation.

From the point of view of the proposed conception the application of seismic protection aimed on the artificial interruption of building linear-reaction in seismic resonance is not effective.

The proposed conception novelty is in that the running slow transverse waves act the role of main seismic destroyers. The velocity of these waves depends on characteristics of seismic excitation and the building construction and so it varies in dependence with them.

The parameter observation of the travelling waves inside the building is a special new task given by the proposed conception to the seismic measurements.

The main attention in full-scale tests must be paid to the study of travelling waves movement in the building due to dynamic loads applied to building base and foundation.

The building full-scale vibration tests permit the determination of travelling wave velocity as the quotient of wave length and its period.

In accordance with the new conception the basis for construction seismic load design should be taken not the spectrum of reaction of one-mass linear oscillators but the wave reaction of oscillators with distributed mass that will provide the possibility of modelling the movement of travelling waves and their filtration in elasto-plastic construction model.

As a measure of earthquake intensity, the ground velocity and the ground displacement volumes should be used instead of acceleration volume.

On the basis of engineering seismometric observations, the investigation of earthquake consequences, full-scale tests, the wave reaction of the oscillators with the distributed mass in each step of the earthquake intensity it is necessary to determine the standard distribution functions of the main parameters of transverse travelling waves that are used for building design with various responsibility.

The standard velocity volume and the displacement of the ground together with geometrical and physical construction characteristics are used for calculation of travelling wave initial parameters and construction wave reaction.

The calculation method in accordance with the given conception must be applied instead of the spectral method and the method using the instrumental data of ground acceleration and the artificial accelerograms.

RESULTS

The widely used spectral method is not able to reveal the real picture of the internal stress state of the building during the earthquake, that is it can not evaluate the actual earthquake resistance of building..

The essence and the characteristic feature of the new conception are in that the main cause of construction seismic failure is the transverse wave movement in construction. Wave velocity depends on characteristics of seismic excitation and the construction itself.

In accordance with the new conception it is necessary to change the aims and investigation methods in the main science sections of earthquake engineering including the methods of design and experimental evaluation of earthquake resistance of buildings.