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(Report to be presented at the IIIrd World Congress on earthquake engineering)

ON THE PROBLEM OF UNIFICATION OF BASIC REQUIREMENTS FOR THE DESIGN OF EARTHQUAKE RESISTANT STRUCTURES

State or region normative documents governing the designing of earthquake resistant buildings and structures have been elaborated almost in all the countries of the world on the territory of which there are seismic regions.

Consideration of the collection of norms for earthquake resistant construction carried out in Algeria, Argentina, Austria, Canada, Chile, Japan, Greece, India, the USSR, Mexico, New Zealand, Philippines, Portugal, Roumania, Turkey, the USA, Italy and Venezuela, as well as of a number of reports at the 2nd World Congress on earthquake engineering devoted to this problem proves that most norms are of somewhat similar structure and deal with the similar scope of problems.

As a rule, these norms contain principles of designing seismic buildings and methods of estimating design seismic loads. At the some time the norms of various countries considerably differ by the volume and detailing of instructions as well as by the main directions and treatment of individual problems.

This is the result of the influence of local building conditions, traditions of earthquake resistant construction and the direction of research work in specific countries.

In the norms of various countries there is no agreement on such basic problems as the method of calculation for seismic forces. It should be noted that the norms of the USSR, Chinese People's Republic, the USA, Roumania, Yugoslavia and Mexico and partly of Japan require for the dynamic method of calculation (calculation by spectral curves) while in other countries the calculation of earthquake resistance of buildings by the static method is still in force.

Thus, while certain countries work at the improvement of the progressive method of design, other countries applying the less perfect static method take no part in this important work.

It would be desirable to single out of norms the "Principal requirements" which might be adopted as common for all the countries concerned. These unified "Principal requirements" may become the basis for detailed norms on designing earthquake resistant buildings and structures adopted in each country in accordance with technical, economic and specific seismic features of the given country.

It is suggested to adopt as a basis the "Principal (basic) requirements for the design of buildings and structures in seismic regions" now in force in the USSR.*)

These "Principal requirements", apart from the principles to which buildings and structures designed for seismic regions should comply, include the method of determining the value of seismic inertia forces, values of seismic coefficients and a basic table for the estimation of the design seismicity of industrial, public and residential buildings and structures. The main feature of these "Basic requirements" is the method of defining seismic loads with due regard to dynamic characteristics of structures. A report by V.A. Byhovsky, I.I. Goldenblat and I.L. Korchynsky on the IInd World Congress on earthquake engineering, held in 1960 in Tokyo, was devoted to a detailed description of this method. Here it is only necessary to point out the progressive character of this method allowing to soundly take into account the reduction of seismic loads when designing frame buildings, towers, masts and other slender structures and to adopt most economic designs.

The "Principal requirements" are adopted not only in the USSR, but also in Roumania, Bulgaria, the Mongolian People's Republic, the German Democratic Republic, the Hungarian People's Republic and the Czechoslovakian Socialist Republic.

Detailed norms of designing taking into account the specific character of building methods and local conditions are in force or are being elaborated in each of these countries on the basis of the "Principal requirements".

"The norms of the design of earthquake resistant structures" now in force in the USSR serve as an example of the elaboration of such detailed norms to further the adopted "Basic requirements". Some features of these norms are treated below.

Constructional design of buildings and structures in the USSR is realized in accordance with the main normative documents - SNIP (Building norms and rules) approved by the State Committee of Construction (Gosstroy of the USSR) - that are to be observed by all design and building organizations.

The leading role among all the normative documents controlling design and construction in seismic regions belongs

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*) According to the recommendations of the conference on the seismology and earthquake resistant engineering, held by UNESCO in April 1964, the text of these "Basic requirements" is being sent for information to all the member-countries of UNO. When elaborating the unified "Basic requirements" it is also recommended to consider "Basic rules for earthquake resistant design" approved by this conference.

to the SNIP chapter 11-A 12-62 "Construction in seismic regions. Norms for designing" which includes all the additional special requirements that buildings and structures erected under these unusual conditions should satisfy.

These requirements are defined with due regard to the design seismicity of the construction project, defined in its turn according to the seismicity of the building site and the purpose of a building or structure.

In the USSR a twelve-degree scale is adopted. Regions subjected to earthquakes of various degrees were determined and a map of seismic regioning covering the whole territory of seismic activity was compiled and inserted in the norms.

The seismicity shown on the map refers to some average soil conditions. The actual seismicity of the building site is defined more accurately by seismic microregioning according to special instructions. The necessity to exactly determine the seismicity of the building site is stated in the norms and by now in the majority of large towns situated in regions subjected to earthquakes the seismic microregioning has already been carried out. More accurate definition of seismicity of individual building sites is often carried out by design organizations using a simplified method on the basis of concrete instructions given in the norms.

The design seismicity of monumental and specially important buildings the possible damage of which may cause great losses or which collapse may result in numerous casualties is taken one degree higher than the building site seismicity.

On the other hand the reduction of design seismicity by one degree is accepted for single-storey industrial buildings with the number of workers not more than 50 and for single-storey office, commercial and residential buildings, i.e. for buildings which may be quickly evacuated.

Finally, buildings the failure of which will not cause casualties or inflict damage to valuable property, as well as live-stock and temporary buildings are allowed by the norms to be erected without considering seismic effects.

The design seismicity of all the other buildings is accepted as being equal to the seismicity of the building site.

The same principle is observed when defining the design seismicity of bridges and hydro engineering structures, the design seismicity of larger bridges and hydro engineering structures being increased and that of small road and temporary hydro engineering structures being reduced by one degree.

The design norms for earthquake resistant buildings cover only buildings with seismic intensity of 7, 8 and 9. Buildings with design seismic intensity of 6 or less do not need the carrying out of any antiseismic measures.

The norms contain planning instructions, structural requirements and requirements for designing load-bearing structures. It should be noted here that the new norms approved in 1962 contain a direct indication that the whole complex of antiseismic measures ensures the safety of load-bearing structures the failure of which can cause the collapse of the building or its parts. At the same time the norms allow for the possibility of failure of secondary load-bearing elements, not endangering the safety of people or valuable equipment.

The principles of earthquake resistant construction on which the norms are based were defined by analysing failures of buildings and structures due to earthquakes. The following principles reflected in the norms and providing for architectural, planning and structural designs which meet not only earthquake resistance requirements but the economy as well may be formulated:

1. The principle of the uniform distribution of seismic forces according to which the use of simple shapes in plan with the uniform and symmetrical distribution of volumes, masses and stiffnesses of load-bearing elements is recommended.

2. The principle of the smallest seismic forces which can be adhered to by reducing the dead weight of structures and lowering its center of gravity as well as by allowable increase of the slenderness of load-bearing elements.

3. The principle of ensuring resistance to considerable "peak" overloads by allowing the plastic deformations to occur in some cross-sections, joints and connections of the structures.

4. The principle of providing for a maximum possible combined three-dimensional behaviour of all the load-bearing elements of buildings under seismic effects for which the formation of horizontal discs in the form of monolithic or precast floors with the in-situ concreted joints and with reliable connections to vertical load-bearing structures is recommended.

5. The principle of dynamic approach to the determination of values of seismic loads.

The norms require that all the buildings and structures erected in seismic regions be designed, apart from usual loads, for the action of seismic forces. Therefore, the calculation is carried out on the simultaneous action of the structure dead weight, snow load, live load on floors and seismic load. For high structures - towers, stacks, etc. - 30 per cent of wind load is also to be considered.

It should be noted here that the seismic coefficient Kc, being a conditional acceleration in fractions of the acceleration due to gravity "g" and used for the determination of the seismic load value, is taken for the earthquake intensity of

7 as equal to 0.025, of 8 - equalto 0.05; and of 9 - equal to 0.1. It is known that maximum (peak) values of acceleration due to earthquakes of corresponding intensity in most cases are several times higher than the design values. However, this lack of coincidence is not dangerous as a rule. This is mainly due to the fact that local cracks are allowed in the structure and the action of seismic forces is damped by the appearance of non-linear, e.g. plastic deformations.

On the basis of conditional vibrations of soil according to the law of harmonic damping, and processing of the accelerogramme data, the following formula which takes into account the properties of elastic vibrations of a building was obtained and included in the norms:

$$S_{ik} = Q_k K_c \beta_i \eta_{ik}$$

where S_{ik} - design seismic load corresponding to the i-tone of free vibrations.

The value of the dynamic coefficient β_i is determined by the spectral curve included in the norms or by the formula $\beta = \frac{0.9}{T_i}$ (where T_i is a period of free vibrations of a structure). The value of β_i is assumed to be not higher than 3.0 and not less than 0.6. Only for slender structures the β_i value is increased by 1.5.

A simplified formula for the calculation of the value of η_{ik} - coefficient depending on the mode of the structure vibration - is given:

$$\eta_{ik} = \frac{x_k \sum^{n} Q_i x_j}{\sum_{1} Q_j x_j^2}$$

where x_k and x_j are distances from the base of structures to the point "k" under consideration and to all the points "j" where the mass of a structure is assumed to be concentrated.

When designing structures having the ratio of height to the smaller dimension in plan, $\frac{H}{I}<5$, the norms allow to take into account only the first mode of vibration. For slender high structures only the second and the third modes of vibrations should be considered.

The norms also contain simplified formulae for the determination of design forces in structures when taking into account higher modes of vibrations.

The norms specify the values of the products $\beta\eta_k$ for the design of stone and large panel buildings up to 5 storeys high as well as for raised parts of buildings, balconies, canopies and connections between parts of a structure (anchor bolts, etc.).

The norms make it possible for the designer to select a rigid or flexible structural system, recommending to take into account the fact that the flexible system results in the reduction of the seismic load while buildings with a rigid structural system ($T \leqslant 0.5$ sec.) are characterized by a more effective damping of vibrations. Special additional instructions with examples of the determination of seismic loads for different structures are issued to facilitate the work on defining the values of seismic loads taking into account the dynamic characteristics of structures.

Some planning and structural restrictions and instructions are included in the norms since considerable simplifications and assumptions are allowed when designing structures for very complex effects during earthquakes.

The norms specify maximum dimensions of buildings in plan and height depending upon design seismicity. It is pointed out that if the length of a building exceeds the specified restriction, the building should be divided into sections separated by antiseismic joints, thus ensuring the independent vibration of adjacent sections.

The norms also specify maximum values of the storey height and ratios of the storey height to the thickness of walls as well as the maximum distances between the axes of the walls of stone buildings.

Structural instructions cover main parts of buildings-foundations, walls, columns, floors as well as secondary parts of buildings - lintels, partitions, stairs, etc.

The norms contain detail requirements for stone buildings. These requirements have been checked up by the experience obtained during many years of designing and construction as well as by the analysis of damages and failures cuased by earthquakes.

At present the construction of large panel buildings erected by industrial methods is also being widely introduced in the seismic regions of the USSR. In spite of the lack of experience as to the behaviour of buildings with large panel walls during earthquakes, the instructions on designing such buildings for seismic regions are included in the norms. These instructions are founded on the laboratory and field investigations performed, making it possible to assert that the earthquake resistance of large panel buildings, in which the principles of uniform distribution of rigidities are maintained and the resistance against shear and bending stresses is ensured, is higher than the earthquake resistance of buildings with stone walls. Large panel buildings are designed by using a special instruction issued as an aid to the norms. One may expect that buildings erected of large-sized blocks when ensuring reliable connection between blocks (e.g. by welding inserts) may prove to be more safe than buildings with brick walls.

Floors and roofs are to meet, in fact, only one but obligatory requirement: they should be imparted the properties of a rigid diaphragm connected to walls and columns and providing the three-dimensional invariability for load-bearing structures of the building. Cast in-situ reinforced concrete floors connected to walls meet these requirements, while precast reinforced concrete floors are to be joined with cast in-situ concrete, the norms containing the relevant recommendations.

In the case of multi-storey buildings with brick walls the norms require for the provision of the so-called anti-seismic belts. This belt made, as a rule, of reinforced concrete with continuous reinforcement placed along the perimeter of all the load-bearing walls at floor level, does not only combine the precast floor elements into the single whole but also serves as an intermediate member connecting the floors to walls.

Water supply and sewerage facilities as well as heating networks must meet additional requirements only in regions with seismic intensity of 8 and 9, Most requirements refer to water supply facilities since water supply must not fail after the earthquake. The norms mainly recommend the provision of two sources of water supply, scattered location of reservoirs and water towers. The norms also contain recommendations as to the type of pipes and elastic connections between them.

The next, rather extensive, section of the norms deals with road structures, main attention being paid to bridges the safety of which after the earthquake is of great importance. Design seismic loads for road structures are estimated in the same way as for buildings and industrial facilities, i.e., with due regard to the dynamic characteristics of structures. The norms describe in detail all the antiseismic measures necessary for bridges, earth beds, culverts under the embankments and tunnels, account being taken here of the design seismicity of structures.

The last section of the norms covers the design of river and sea hydro engineering structures, power plants, water transport and reclamation facilities. The design seismicity of all large important hydro engineering structures and facilities the failure of which results not only in great material losses but may also have catastrophic consequences for the whole regions is assumed to be one degree higher than the seismicity of the building site.

Particular attention is paid to designing most often used types of arch dams.

Hence, the II-A 12-62 chapter of the SNIP, now in force in this country, named "Construction in seismic regions. Norms of designing", developed to further the adopted "Basic requirements" is a standard document containing all the necessary instructions on the calculation and design of industrial, public and residential buildings and structures, services, hydro engineering and transport facilities erected in seismic regions. It should be pointed out here that the work of designers is also facilitated by publishing albums of typical structural designs of various earthquake resistant buildings.

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The work aimed at improving the norms of designing earthquake resistant structures and facilities is continuously carried out by research and design institutes in this country, the Central Research Institute of Building Structures of the Gosstroy of the USSR and the Institute of structural mechanics and earthquake resistance of the Academy of Sciences of the Georgian Republic mainly contributing to this work. The Institute of Physics of the Earth of the Academy of Sciences of the USSR also continues to work at more accurate compiling of maps of seismic regioning of the USSR included in the norms.

The following problems form the basis of research work and new designs aimed at improving the norms and reducing the costs of earthquake resistant construction:

1. More accurate determination of the seismicity of a site making it possible to rationally select the place of construction.

2. More accurate determination of the category of buildings and structures when defining the design seismicity.

3. Improvements in the methods of calculating buildings and structures for seismic forces on the basis of the analysis of the actual behaviour of structures during the earthquake.

4. Elaboration of new rational structural designs using effective building materials.

All these works are carried out along the directions determined by the "Basic requirements of design of buildings and structures in seismic regions" adopted in the USSR.

Concluding this report it is necessary to stress again the desirability of elaborating unified basic requirements for designing earthquake resistant structures, considering also the fact that these "Basic requirements" allow to take into account in national norms particularities of earthquake resistant engineering of the given country.

We consider it necessary that the Board of the International association of earthquake resistant engineering organize the preparation of draft unified "Basic requirements for the design of buildings and structures in seismic regions" one of the main principles of which will be the method of designing structures for seismic affects with due regard to the dynamic characteristics of these structures. Since this problem is of great importance, it is desirable to finish this work not later than in 1966.

It would be desirable here to enlist the services of several countries having experience of elaborating norms in the field of earthquake resistant engineering, for instance, the USSR, Japan, the USA, Yugoslavia, Chile, New Zealand etc.

The elaboration of unified basic requirements for the design of earthquake resistant structures in accordance with the proposal stated in this report will create conditions for further progress in the elaboration of the normative documentation on the design of earthquake resistant structures since the efforts of scientists and engineers of the countries concerned might be directed towards improving unified principles of designing earthquake resistant structures.

ON THE PROBLEM OF THE UNIFICATION OF BASIC REQUIREMENTS FOR THE DESIGN OF EARTHQUAKE RESISTANT STRUCTURES

BY S. U. DUZINKEVITCH

COMMENT BY: R.L. JAMES - NEW ZEALAND

It is heartening to receive this paper on the need for an international code of design for earthquake resisting structures. Probably this conference can set up a small working committee to provide an interim code for the use of practising engineers. This should be simple enough for common use now by all designers and can be an interim code while more precise research continues.

Engineers as practical men can work internationally in defence against the great forces of nature. Engineers may also be the practical men who can work together internationally in defence against the great forces of men.

AUTHOR'S REPLY: The author replied that he was most gratified that Mr. James was in complete agreement with the views expressed in the paper.

COMMENT BY: R. FLORES - CHILE

It is very gratifying to consider this type of problem in this Conference. Nevertheless I wish to comment that UNESCO appointed a working group to study a world-wide code two years ago. This report, already completed, contains the basic principles upon which a universal code could be based.

AUTHOR'S REPLY: The author agrees with Professor Flores as to the importance of the report prepared by the UNESCO Working Group (of which USSR was a member), on the "Principles of Earthquake Resistant Design".

The document, which is mentioned in the Author's paper, could well be adopted as obligatory by all countries in seismic areas. Nevertheless the Author suggests that urgent attention should now be given to elaborating on the UNESCO document on the lines of the "Principal Requirements" code now in use in the U.S.S.R.