SOME COMMENTS TO THE NEW SEISMIC DESIGN REGULATIONS FOR COSTA RICA

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SUMMARY

The current design provisions for Costa Rica are commented. Its main requirements and general philosophy are reviewed. Code implementation and its effects in the construction industry are discussed. Recent related research is mentioned as well as the new Code version that is being drafted at the present time.

INTRODUCTION

The "Colegio Federado de Ingenieros y Arquitectos de Costa Rica", the national professional engineering and architectural organization, set out in May 1973 a Code Committee to draft a Seismic Code for Costa Rica. At that time there was serious concern among structural engineers about the lack of seismic regulations, specially after the earthquakes of Managua, Nicaragua of December 1972 and Tilaran, Costa Rica of April 1973. The Committee members were R. Herrera (Chairman), E. Hernandez, L. Lukowiecki, F. Sauter and the author. They presented, in October 1973, a final draft that was reviewed, discussed and aproved by the professional engineers. This document was published in January, 1974 (Gutierrez et al., 1974).

Since that date, the Committee, with the additional collaboration of H. Meltzer (current Chairman), R. Castro, F. Mas, and R. Picado was given permanent responsabilities of study and review as well as divulgation and consultation.

GENERAL ORGANIZATION OF THE ACTUAL CODE

The Code is divided in two parts and twenty one chapters. The first part, with twelve chapters, includes the analysis regulations whereas the remaining nine chapters of the second part are related to design requirements. With 91 pages, the Code is quite extensive. It was considered necessary to allow for a good understanding of the concepts underlying the regulations, to produce a rational use and avoid dogmatic interpretations. A brief review of the most important regulations is now presented.

Seismic Zoning

Given the small size of the country (50000 Sq.Km.), the short time available and the lack of reliable information about the region seismicity, the Code defines the country as seismically uniform. This is certainly not correct and the new version will include a seismic zoning based in seismic risk studies as well as local recopilations of historic events and local soil condition effects.

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Structural Classifications

The structures are classified according to their importance in Class A, B or C. There is a "Use Coefficient" α with values of 1.2, 1.0 or .70 respectively, that modifies the seismic forces. Besides, there are more severe limitations regarding drift for the Class A structures.

The structures are also classified according to their structural system in five Structural Types. This classification gives explicit condideration to their ductility and damping capacities. Table 1 presents each stuctural type with their assumed ratio of critical damping and ductility.

Table 1. Classification of Structures According to their Structural System.

Type	Structural System	Damping Ratio	Ductility
1	Ductile Frames	.05	6
2	Ductile Frame-Wall Systems	.07	3
3	General Frame Wall Systems	.07	2
4	Wall or Masonry Systems	.10	1
5	Single Defense Line Systems	.05	1

Soil Classification

The soil is classified into alluvial and non-alluvial. There are two sets of Design Response Spectra corresponding to them.

Design Response Spectra

The Design Response Spectra for each soil and structural type are presented in Fig.1. These spectra were derived from standard procedures (Newmark et al., 1969) for their assumed ductility and damping. The maximun effective acceleration of .15g and .17g were chosen quite arbitrarily in view of the lack of information at the time. In particular, the .15g value may be obtained from the well known Esteva equation

$$a = 1230 \exp(.8M) / (R + 25)^2 \qquad \text{(Eq.1)}$$

for the following values of M and R, which are consistent with the geology of the country, specially for the Central Valley where 70% of the population lives

M (Richter)	Epicentral Distance R (Km)	a/g
6.0	7.	.15
6.5	14.	.15
7.0	22.	.15
7.5	33.	.15

Obviously, these numbers can be critisized given the scatter associated with empirical equations like Eq.1, specially in the short epicentral distances. However, the response spectra are similar to Zone 3 in the SEAOC Specifications, Zone A of the New Zealand Code, β=1.5 in the Indian Code or MMI=8 in the URSS Code (International Association for Earthquake Engineering, 1973). Nevertheless, comparisons among Codes regarding Seismic Coefficients is not significative given the lack of correlations regarding geografic seismicity in terms of maximun effective accelerations or any other parameter related to the design spectra.

Load Factors

Earthquake excitation is an extreme condition and consequently it has a unit load factor. For reinforced concrete structures the required load combinations are

$$
\begin{aligned}
UL &= 1.4\ DL + 1.7\ LL \\
UL &= .75\ (1.4\ DL + 1.7\ LL) \pm EL \qquad \text{(Eq.2)} \\
UL &= .9\ DL \pm EL
\end{aligned}
$$

where UL= Ultimate Load, DL= Dead Load, LL= Live Load and EL= Earthquake Load. The second equation is severe in the load factor applied to the live load and the main reason was to reduce the number of combinations of dead and live load combinations for design purposes. The third equation is very critical for foundations specially because of the conservatism inherent in the calculation of maximun stress and supporting soil capacity.

Methods of Analysis

The Code specifies three methods of analysis. Method 1 is a simplified static analysis assuming a triangular first mode, an empirical value for the corresponding period and an upper story additional load. Given the approximations of the method, its use is restricted to buildings with the following limitations: a) Regular distribution of inertia and stiffness properties, both in plant and height, and b) Number of stories less or equal to seven. The first limitation is usual in most seismic codes. The second limitation seems quite severe. However, parametric studies have shown that, even for regular buildings, the error of Method 1 increases monotonically with the number of stories (Gonzalez, 1977). Besides, with high speed computers, the additional calculations have a neglegible effect in the design cost.

Method 3 is applicable to complex non-building structures that can not be classified as Structural Types 1 to 5. In this case, it becomes necessary to derive an Spectrum with considerations of site characteristics, return period and structural ductility and damping capacity. Step by step analyses, both linear and non-linear, are also included in this method.

Displacements

As it was mentioned earlier, ductility requirements associated with each Structural Type are explicitly considered in the Design Spectra. Consequently, the elastoplastic displacements must be calculated multiplying the elastic displacements associated with the reduced lateral loads by the corresponding ductility. Maximun interstory drift is limited to .005 times the story height for Class A structures and to .010 for Class B structures.

Design Considerations

The Second Part complements the First, trying to produce a structure with the balance between strength and ductility that is implicit in the analysis regulations. The Code emphasizes the fact that the analysis procedure is only a way to produce a structure that, if properly designed, detailed and constructed, will have enough ductility and strength to survive strong ground excitations without significant displacements. The design and detailing are based in the actual strength of the mechanical elements instead of the requirements obtained from the analysis.

Single Family Dwellings

In order to allow for creativity and innovation in the design and construction of single family dwellings, the Code specifies some basic requirements that, if satisfied, will guarantee an adequate seismic behavior. However, the designer is free to develop new structural systems if he can show its safety with adequate analysis and design.

CODE IMPLEMENTATION

Early in 1974, when the Code was first aproved by the professional community, there was no legal requirement for its application. However, correct use of the Code has been a part of the oath of ethics that every engineer must honor. During the early years it became necessary to organize several seminars, lectures and debates, regarding the correct use of the Code and the meaning of its fundamental concepts. Most structural engineers reacted very positively and in a short time they were able to use the Code adequately. In this sense, the Code benefitted the profession and the community by promoting the formation of a specialized group of structural engineers.

After some years the Code Committee felt the need for a formal reglamentation of its application. The problem was that there is a tendency towards dogmatism and rigidity in this type of reglamentations. On the other hand the national investment, both public and private, needed effective protection. In consequence, the Code Committee lobied in the National Congress for a Law that merely stated the need for earthquake protection and requested to the President of the Country to issue an Executive Decree containing the Code regulations and defining its implementation. Because Executive Decrees are faster to produce than Congress Laws, it will be relatively easy to modify the Code at regular periods of time.

In order to help the professional community in the correct application of the Code, the Committee prepared Commentaries and Solved Examples with complete and extensive design of typical buildings. At the same time, the Civil Engineering Department at the University of Costa Rica has been offering a course in Structural Design, in addition to the regular concrete and steel design courses, where all the basic concepts are studied and applied.

RESEARCH ACTIVITIES AND CODE REVISION

The momentum created by the Code publication and the permanent activities of the Code Committee produced a positive effect in the community towards an effective earthquake risk reduction policy. A study of Seismic Risk for Costa Rica (Morgat et al. 1977), was financially supported by several governmental agencies. Eventhough the seismological data available for the study was quite reduced and not very reliable, most of it was obtained from world cathalogues and based on teleseismic records, it was an important first step towards a rational earthquake zoning for design purposes. Incidentally, it is interesting to note that the maximun effective acceleration reported for the Central Valley, where 70% of the population lives, was .15g for a return period of 50 years and .175g for a 100 years return period (Fig.2). These values are in complete agreement with the Design Response Spectra of the Code (Fig.1) for non-alluvial soils with α= 1.0 and 1.2 respectively. Recently, an earthquake insurance study, that makes extensive use of the seismic risk report, has been presented to the National Insurance Institute (Sauter and Shah, 1978).

At present time several seismological networks are operating. The Department of Geology at the University of Costa Rica keeps an extensive network in the Central Valley and the "Instituto Costarricense de Electricidad", governmental agency in charge of electric generation, maintains several more at the site of present and future hydroelectric projects. Strong motion instrumentation with permanent maintenance has also been placed at several places.

The Civil Engineering Department at the University of Costa Rica has done considerably amount of research related to the Code. Several regulations related with the analysis procedures have been studied and corroborated (Gonzalez, 1977). In other cases, new regulations have been recommended (Cruz, 1978). Structures designed according to the Code have been analyzed with linear and non-linear computer programs (Gonzalez and Baeza, 1980), and the adequacy of their design has been evaluated. Soil exploration has provided important information regarding dynamic characteristics of the sites and different procedures are being used to generate artificial accelerograms for the sites of important projects.

At present time all this information and the feedback generated by the professional community from six years of code application are being considered by the author who is in charge of a complete review of the current Code. This review is in its early stages and it will be well advanced at the time of the Conference.

FINAL REMARKS

Six years after publication, the Costa Rican Seismic Code has produced a series of positive changes in the design and construction paractices. Construction costs have not been significatively increased by the earthquake resistant methodology implicit in the Code. Most of the changes are in the detailing of structures and not in additional strength requirements and they only request good care in design, additional calculations and good construction workmanship. The largest economical impact has been on foundations where the conservatism implicit in geotechnical calculations is very severe when applied to extreme events.

Although no major earthquakes have struck the region since its publication, it is quite obvious that the Code and its related activities have considerably reduced the earthquake risk of the country.

ACKNOWLEDGMENTS

The author wishes to acknowledge the concern and dedication of his colleagues in the Code Committee. He also wishes to thank the Research Vice-Rectory at the University of Costa Rica for their continuous support to the Earthquake Engineering Research Program.

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COEFICIENTE SISMICO

SUELO NO-ALUVIAL

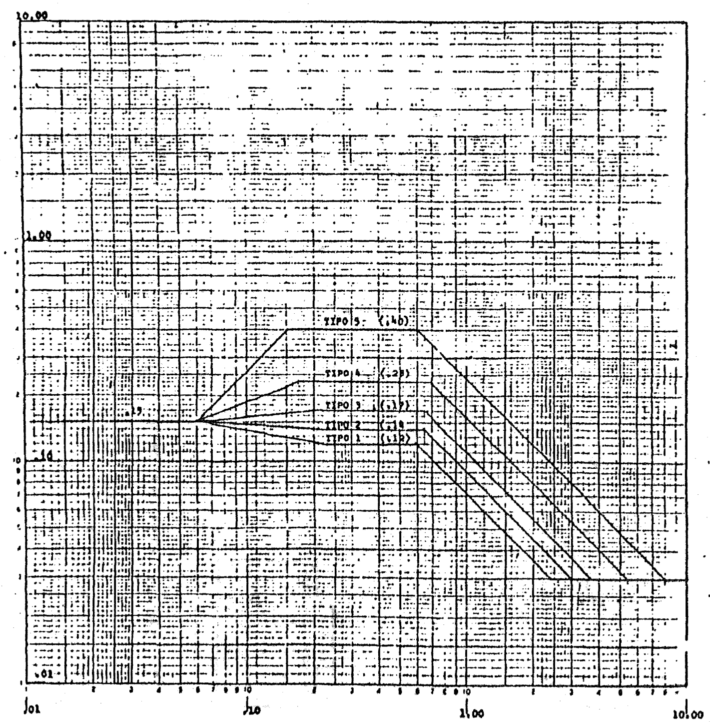

Fig. 1 a

COEFICIENTE SISMICO

SUELO ALUVIAL

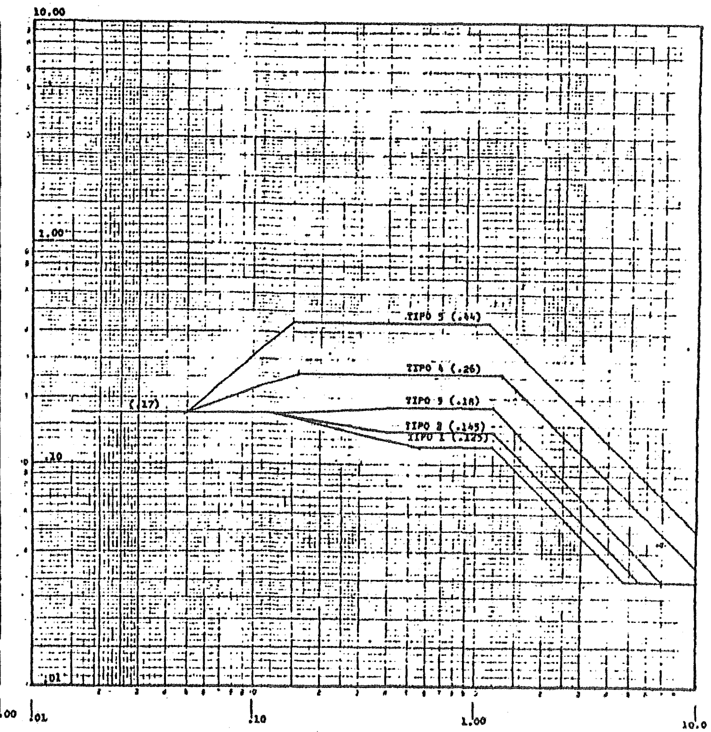

Fig. 1 b

Fig. 1.- Costa Rican Seismic Code. Earthquake Response Design Spectra.

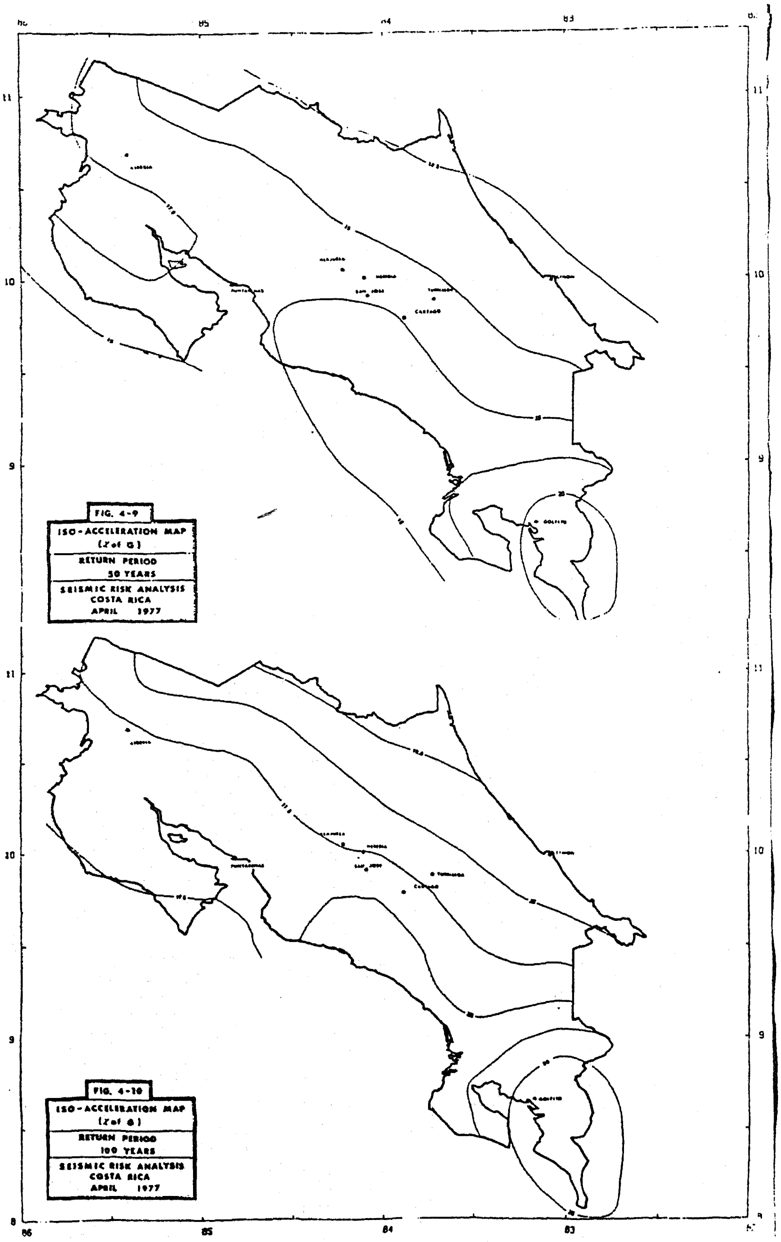

Fig. 2.- Seismic Risk Analysis for Costa Rica. Iso-acceleration Maps. (After Mortgat et al., 1977)