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OBJECTIVES AND FUNDAMENTAL PRINCIPLES OF A SEISMO-RESISTANT ARCHITECTURE

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SUMMARY

The work only seeks the formulation in general terms of the reasons, backgrounds, objectives, fields of action, fundamental principles and compatibilization rules of Structural Design with Architectural Design that have allowed the statement a Seismo-resistant Architecture and will enable its development and further study.

SEISMIC-RESISTING ARCHITECTURE: 1. PRESENT APPROACH

Presently the importance of the architectural design on seismic safety of buildings is acknowledged and a series of standards have been elaborated by engineers.

Most architects simply fulfill such standards avoiding those situations that could arise them.

When the problem is approached this way, the real sense and possibilities of seismic-resisting architectural design are ignored.

There are relevant publications and papers which go deep into the subject, however (A.I.A., 1975; Arnold and Reitherman, 1982; Refs. 1, 2, 3).

2. INTENDED APPROACH

Developing a Seismic-Resisting Architecture that shall comprise the advances of Seismic-Resisting Engineering from an overall conception of the building where both, structural and architectural design shall be bound to seismic safety of the building. Such aproach calls for the development of four study lines:

a) Stating and improving of the Seismic-Resisting Structural Design in terms of constrains of Architectural Design.

b) Founding of the basic principles generatives of Seismic-Resisting Architecture.

c) Stating and improving of the interrelations and their compatibility between Structural and Seismic-Resisting Architectural Designs.

d) Developing a Seismic-Resisting Architecture based on the compatibilized interrelations of every and each of the interacting subsystems.

3. ARCHITECTS AND ENGINEERS SHALL SHARE RESPONSABILITIES.

Certainly, it is not easy to assume this approach in fullness, since it requires to modify the mental attitude of those engineers and architects who regard the subject as an Engineer's Responsability, being enough for the Architect to fulfill those recommendations prescribed by seismic resisting engineering to architecture.

The architect must share the resposabilities for the seismic safety of the building with a deep conceptual knowledge of the seismic effect on the whole building and on each of the interrelated elements.

This calls for redefining those aspects and their methodology with which the architect should know about Seismology, Engineering and Seismic-Resisting Structural Design. Only this way he will be able, in each case, to design the seismic resisting building efficiently and with creativeness.

4. BASIC PRINCIPLES OF SEISMIC RESISTING ARCHITECTURE

Fundamental criterion of Seismic-Resisting design The seismic-resisting structural elements shall yield the stiffness, strength, ductility and synchronization anticipated by the structural design and analysis when submitted to seismic action. That is, they shall be able to exhibit their seismic resisting capability practically simultaneously. Otherwise, the resisting capability will step up and thus eventually will cause the failure.

The stepping down of seismic strength may be developed by several reasons, i.e. :

- Stiffness/Strength Ration (causes due to the structural design itself).
- Seismic Torsion.
- Soft First Stories.
- Short Column and Short Beam.
- Non-Structural Elements.
- Constructive Imperfections.
- Erroneous Structural Calculation.
- Irregular Spatial Configurations.
- Sudden Changes of Building Stiffness.

Seismic-Resisting Architectural Design shall compatibilize the functional, spatial configuration, constructive and economical aspects, in order to fulfill such principle.

Effectiveness and optimization of the seismic resisting response in buildings. Essentially this object may be achieved both, decreasing the seismic forces or encreasing the efficiency of the seismic capability of buildings.

Reduction of values of seismic forces may be achieved by several ways, i.e.:

a) Using ligthweight materials or avoiding those not essential fillings and finishings.
b) Relocating the heavier weights, that is trying to situate those rooms that will bear heavier weights (e.g. archives, swimmings pools, meeting rooms) in lower levels. Seismic bending moments and shearing acting on the structure are thus reduced and consequently the size of the resisting elements. It is very important to take this fact into account in the Architectural Design.
c) Avoiding the pseudo-resonance. This means to prevent the fundamental period of the building from coinciding with the main one of the foundation soil.

With regard to optimizing the seismic-resisting capability of the building, must be using spacial shapes that lead to a building with a clear and simple structure having its torsion center coincident with its center of mass.

This purpose, of effectiveness and optimization, certainly is a clear challenge to Architecture since it involves the study of methodologies to enable the Architectural Design to make significant contributions for the best solution of the seismic problem.

The SEISMIC FACTOR encreases with building height It shall be avoided in the architectural design to locate swimming pools, heavy equipment, archives, etc., in upper levels of the building.

The SEISMIC FORCES are proportional to the building weight It is a good practice to reduce, as far as possible, the weight of the elements conforming the building.

Unlike the structural design for vertical loads, in Seismic-Resisting Design the resisting elements may be located according to the designer's criterion with some independence from vertical loads Such details greatly facilitate both structural and architectural design. In fact, we are allowed to locate the principal resisting elements in the most convenient way to reduce the torsional effects and fulfill the architectural requirements.

5. COMPATIBILITATION OF INTERRELATIONS AMONG THE INTERACTING ELEMENTS

Since not only the resisting structure, but all the connected elements conforming the building are responsible of its response to the earthquake, it is essential to consider the building as a whole comprehending an integral system of Seismic-Resistance where each element is regarded as being interacting with every other one. This fact, in its turn, leads to analyze the interrelations among the interacting elements for their compatibilization so that during the seismic action no disarragements will reduce the seismic-resisting capability nor its stepping down will occurred and safety of building will be put in danger.

Three lines of study are necessary to satisfy this principle:

- Stating and improving Seismic-Resisting Structural Design, in terms of constrains of Architectural Design.
- Stating and improving the interrelations among the interacting elements or subsystems.
- Stating of guide lines and criteria for compatibilization from Architectural Design Standpoint.

For develop these studies in order, the grid shown in Figure 1 is proposed, both to enact the interrelations as well as their corresponding compatibilizations.

6. SEISMIC RESISTING ARCHITECTURE THEORY

In short, the theory, methodology and research which will help to develop a Seismic-Resisting Architecture, shall inevitable fulfill the requirements of these basic principles. This way, the Architectural Design must sought for the reciprocal compatibility of all its interacting systems, i.e., structural - technological constructive - nonstructural components - functional - economical - aesthetic and morphological.

7. FACTORS CONTRIBUTING TO PARTIAL OR TOTAL BUILDING FAILURE

Distinction must be made between seismic-resisting constructions and those ones which are not so. In the first case, and if there is not an error in the structural calculus, bad-construction or misunderstanding of seismic-resisting standards, neither a partial nor anything like a complete failure, may be expected. However, they do happen mainly by one of the following causes:

- The seismic forces exceed the anticipated ones Such a fact may happen on account of some circunstantially observed characteristics which are very difficult

of avoidance. It did so happen during the last earthquake in Mexico. The main cause is unexpected amplification of seismic action as a function of the dynamic properties of the building and the kinetic pecularities of the earthquake.
Such characteristics greatly depend on the dynamic properties of the foundation soil, the surrounding geological structure and the epicentral distance. Being the first responsible of the frecuencies introduced in the earthquake and the second because the higher frecuencies are gradually absorbed, as the distance travelled by seismic waves increases.

- Stepping down of seismic-resisting capability, that is when the fundamental principle of structural design has not been fulfilled Such situation is always imputed to a bad structural design or to a lack of compatibilization with the architectural design. The result is unpredictable, since it does not depend on the resisting capability that should have been foreseen complying with standards in force, but on its stepping down grade.

The above mentioned situation has been the other cause of most of the failures during the Mexico earthquake. The addition of these causes have produced the astonishing disaster in Mexico City.

All this proves that the fundamental principle of Structural Design shall be fulfilled in every case. This, in turn, calls for an answer of the Architectural Design thus turning to be the Fundamental Principle of Seismic-Resisting Architecture.

Undoubtly, mistakes in structural calculus or faults in building techniques may, by themselves, cause the partial or total failure. In such cases, they become factors that reduce the seismic capability and cause its stepping down. If buildings have no seismic-resisting provisions, probably partial or total failure will happen. A complete lack of seismic-resisting capability is the determining reason. Causes which particularly produce the failure is that the circumstantial seismic capability is exhausted, the fact being aggravated by the alredy stated reasons which produce the stepping down of such precarious capability.

Those cases where mistakes in structural calculation have been made or seismic-resisting regulations have been misunderstood or wrongly used are not discussed in this opportunity, but it is worth mentioning that they are an exclusive responsability of the designing engineer.

8. SEISMIC-RESISTING CAPABILITY STRENGTHENING OF EXISTING BUILDINGS

Last earthquakes that have affected cities which had been built fulfilling up to date seismic-resisting regulations have shown plainly a fact that can no longer be disregarded, that is, many buildings presently thought to be seismic-resisting actually lack an adequate compatibilization between Structural Design and Architectural Design, thus being able to deliver the stepping down of their seismic resistance and the resulting partial or total failure.

The disaster in Mexico City by the earthquake of September 1985 has shown the importance, presently unknown, of Seismic-Resisting Architecture, with regard to seismic resistance and strengthening of buildings as a real contribution to earthquake effect prevention.

In short, facing the need of assess the capability of seismic resistance of an already built construction, and from our point of view, it shall be first detected every interference from the Architectural Design which can produce the stepping down of its capability and then to propose the solution by an interdisciplinary staff avoiding to affect the functionality of the architectural Design.

Finally, convenience of strengthening the seismic-resisting structure itself to safisfy a greater seismic factor, will be accounted.

9. METHODOLOGICAL PROPOSAL

In short: THE METHODOLOGY PROPOSED IS PRIMARILY BASED ON A TOTALIZING AND INTEGRATING APPROACH WHICH TAKES INTO ACCOUNT THAT THE SEISMIC RESPONSE OF A BUILDING DEPENDS NOT ONLY ON THE RESISTING STRUCTURE BUT ON EVERY ELEMENT CONFORMING THE BUILDING AND THE CITY, SPATIAL-CONFIGURATION, FUNCTIONAL AND ECONOMICAL ASPECTS. IN SECOND PLACE, ON THE COMPATIBILIZATION BETWEEN ARCHITECTURAL AND STRUCTURAL DESIGN, THAT IS FULFILLING THE "FOUNDING PRINCIPLE" IN EVERY CASE AND WITH NO EXCEPTION BESIDES SATISFYING EFFICIENCY AND OPTIMIZATION ASPECTS OF THE SEISMIC CAPABILITY FROM THE ARCHITECTURAL DESIGN.

Next, the conditioning aspects of a building designing process, are summarized:

A- Referential Variables:

a. The dynamic nature of seismic excitation.
b. The prevailing period of soil..
c. Near and far epicenter.
d. Seismic intensity.
e. Structural systems.
f. Ductility. Flexible or stiff buildings.
e. Constructive systems.

B- The Seismic-Resisting Structural Design requires:

a. Tridimensional resisting systems (spatial behaviour).
b. Lightweight buildings, as a function of materials and resisting systems that avoid unnecessary masses.
c. Buildings with a simple configuration, preferably symetric both in plan and elevation.
d. To avoid excentricities between mass and stiffness center.
e. To determine the "sharing degree" of the various building components in the seismic-resistance phenomenon.
f. Balanced stiffness-strength ratios among the various elements and/or sub-systems of the seismic-resisting mechanism, avoiding dangerous incompatibilities.

C- Compatibilizing Constants are:

a. Spatial behaviour of buildings under seismic loads.
b. Seismic forces proportional to building weight.
c. Each resisting element absorbs an horizontal seismic force, independently of its location in plan, proportional to its horizontal stiffness (case of null torsional moment).
d. Mass excentricities, both in plan and elevetion, produce undesirable torsional effects.
e. The resisting mechanisms shall be proyected so that all their elements will act simultaneously.
f. Ductility and Hyperstatics characteristics.
g. Stiffness and flexibility (soil-structure interaction).

10. CONCLUSIONS

From this prospect, Seismic-Resisting Design of buildings cannot be centered only on Structural Design but on the global concept of SEISMIC-RESISTANCE SYSTEM, where STRUCTURAL DESIGN and ARCHITECTURAL DESIGN are engaged.

Though the resisting structure is the decisive element and the most important one in the seismic-resisting response of the building, from Architectural Design standpoint it shall be conceived as an interacting part of the whole system.

Seismic-Resisting Engineering and Seismic-Resisting Architecture shall, this way, share responsabilities in the common purpose of obtaining the seismic response from buildings without disarrangements among their components and improving it.

Seismic-Resisting Architecture shall research the interrelations and compatibilization guide lines of all the interacting elements and so to elaborate an architectural answer to achieve the common object proposed.

Seismic-Resisting Engineering shall also base the seismic response on interrelations compatibilization with the Architectural Design, regarding the resisting structure as an interacting part of the "Whole". This makes evident the need for an interdisciplinary action and the effect feedback in both ways.

Seismic-Resisting Architecture is so stated as well as the need to elaborate a theory to base it upon for its development. This involves to define: objectives, basic principles, interrelations among the interacting elements, contents and scope and so to define general and particular guide lines of Seismic-Resisting Architectural Design.

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