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A new approach for the integral solution of building design

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ABSTRACT: This paper presents a new approach for earthquake resisting design of building, based on the compatibility of all their elements which interact during the seismic action.
Fundamentals, objetives, basic principle, methodology and criteria for making architectural design consistent with seismic resistant structural design, are given.

1 INTRODUCTION

The interaction-not provided of the resistant structure with other non structural elements in the building modify the resistance-stiffness relations-ship of structural elements. In such situation it may happen that the structure does not offer all the resistance capacity simultaneously and as it required along the seismic action. The result of this stepping of the building seismic-resistant capacity is their partial damages or total collapse of it.

That is why the pure structural analysis becomes insufficient to assert the seismic invulnerability of building.

An adding-up approach becomes necessary, regarding the seismic-resistant system as a whole, where all the structural, non structural and space forming elements conforming a building are considered to be intereacting among them and being responsible for its seismic-resistant capacity.

According to this approach, such responsability is shared by structural analysis and design and the architectural design as well.

As a matter of fact, it is not tried to obtain from the computing engineer a cuantitative consideration of the positive and negative effects of all the interacting elements that compose a building, but to make them consistent with the structural design.

This means that the designing architect, with his own knowledge on "Seismic-resistant Architecture, together with the assistance of the computing engineer, will be able to produce a consistent architectural and structural project, thus avoiding every possibility of a stepping up of its seismic-resistant capacity.

In short, the result of such proposal is not only the structural system, but its consistency with architectural design.

It becomes evident that is necessary to develop a "Seismic-resistant Architecture" with identical basis, so architects will be able to face the mentioned responsability.

2 BASIC PRINCIPLE

The theory, methodology and research which will help to develop that aproach, shall inevitable fulfill the requirements of this basic principle: "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.

From the structural analysis point of view, and for the cases of stiff slabs or floors, this is achieved by distributing seismic shear proportionally to each resistant-element stiffness and torque proportional to stiffness and distance to the center of torsion.

But mainly, the structural and architectural designs shall achieve the necessary compatibility among all the structural elements that from the building, in order to satisfy this basic principle.

3 RASONS PRODUCTING THE STEPPING OF THE SEISMIC RESISTANT CAPACITY OF BUILDING.

For which the maximun earthquake resistant capacity of building be not equal to the sum of the capacities of each element.

1. Causes inherent to structural design: The need of conciling resistance-stiffness of the structural elements pases numerous cases of difficult solution in the earth-

quake structural design practice, introducing an uncertainty factor may facilitiate the earthquake-resistant disminution and its later collapse.

2. Earthquake torsion: The fact of the seismic-shear in a column caused by a torsion moment is proportional to the distance to the center of torsion or stiffness(C.T) gives a result that for columns dimensionally equal but placed at different distances from C.T seismic stresses are different. This may, doubtless, be the fundamental cause of the seismic resistance capacity disminution especially if the torsional effect has not been foreseen.

Undoubtly, this may be the cause of a stepping up of seismic resistance, especially if the torsional effect has not been adequately forseen. There are some other cases where the development of a moment is due to an unforseen deformability of floors.

Finally, even when torsion is taken into account in the structural analysis, it is still difficult to maintain the stiffness resistance ratio for columns.

3. Flexible floor: A flexible floor greatly decreases the seismic shear on the remaining stiffer floors, together with an increment of it on the floor itself. Here, again, we have a stepping up of seismic resistance. Taking it into account during the structural analysis demands a ductility and a resistance which are very difficult to be achieved in practice. It would be better to give the necessary stiffness-resistance ratio to such floor rejecting the possibility of using it to improve the seismic-resistant perfomance of the whole building.

4. Short beams: When in portal one of the beams in a certain floor or level is of a remarkable lesser length than the rest, the so called case of short beam occurs. Here the problem arises because angular stiffness is inversely proportional to its length, i.e.

As for the previous cases, the difficulty is to achieve the required resistance-stiffness relationship.

The obvious concentration of bending moment may cause its breaking, and therefore make easier the reduction of the structural set seismic-resistant capacity.

5. Not structural elements: It is known that not-structural elements such as walls, separating walls, installations, etc. interfere in the behavior foreseen for the resistant structure. This interference may be both in a positive and negative sense. Many are the cases in which this has been the principal reason of the reduction of the building total seismic capacity.

6. Constructive defects: It is obvious that a localized constructive defect of the resistant structure besides diminishing the sismic-resistant capacity, may be the cause of its stepping. In fact it may give rise to an unexpected torsion moment.

7. Erroneus structural design: On the same way that construction defects, this may be the cause of reduction of seismic-resistant capacity and unexpected stepping of it.

4 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.:

1. Using ligthweight materials or avoiding those not essential fillings and finishings.
2. 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 ans consequently the size of the resisting elements. It is very important to take this fact into account in the Architectural Design.
3. 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 spatial shapes that lead to a building with 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 METHODOLOGICAL PROPOSAL

The methodology proposed is based, on the compatibilization between architectural and structural design, that is fulfilling the "Basic Principle" in every case, and with no exception besides satisfying efficiency and optimization aspects of their seismic-resistant capacity.

This methodology requires three classes of study:

1. Statement and improvement of seismic-resistant structural desing, in terms of architectural design stipulations.
2. Statement and improvement of the interconnections among the interacting elements.
3. To found the guide lines and criteria to achieve consistency from the architectural design point of view.

For a methodical development of these studies, the plan shown in Figure 1 is propesed, both, to found the interconnections as well as the corresponding compabilities.

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

1. 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 building.
   - g-Constructive systems.
2. The Seismic-Resisting Structural Design requires.
   - a-Tridimencional resisting systems(spatial behaviour).
   - b-Lightweight building, as a function of materials and resisting systems that avoid unnecessary masses.
   - c-Buildings whith 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.
3. Compatibilizing Constants are:
   - a-Spatial behaviour of buildings under seismic loads.
   - b-Seismic forces proportional to building weight.
   - c-Each resisting element absorbs and 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 hyperstatic characteristics.
   - g-Stiffness and flexibility (soil-structure interaction).

6 GUIDE LINES FOR ARCHITECTURAL AND SEISMIC-RESISTANT STRUCTURAL DESIGN CONSISTENCY.

Stipulations:

a) Short column.
b) Building weight
c) Ductility
d) Seismic Torsion
e) Simmetry
f) Joints
g) Flexible floor
h) Foundation Soil
i) Epicentral Distance
j) Stiff or flexible floor

Each of the above mentioned stipulatins interact with the architectural design through the following subsystems:

a) Functional - spatial configuration
b) Constructive
c) Structural - spatial configuration
d) Constructive - functional and spatial configuration
e) spatial configurations, functional and constructive.
f) Functional and spatial configuration
g) Structural, constructive and spatial configuration
h) Structural and constructive
i) Structural and constructive
j) Structural, constructive and spatial configuration

The corresponding guide lines to achieve consistency are briefly commented:

a) It shall be eliminated from the very architectural design.
b) Lightweight materials shall be preferred heavy elements shall be located in the lower part of the building.
c) When highly flexible structures are used, they shall show a high degree of hyperstability.
d) Torsion and moment centers shall coincide Simple and symmetrical forms. L, T, U shaped plant forms shall be avoided.
e) Symmetrical and modulated altimetry and plane surveying.
f) Expansion joints shall be reduced or, if possible eliminated, by a clear separation of building units.
g) The flexible floor shall be provided with a stiffness/resistance ratio similar to that of the remaining floors by means of appropiate structural elements.
h) The fundamental period of the building shall be far from the predominant period of the foundation soil by an adequate structural-constructive system. Building on soils that may undergo liquefaction shall be avoided, unless such soils can be economically turned into not liquefiable ones.

i) It modifies the predominant period of the soil and it must be drawn away by means of the structural-constructive system.

7 CONCLUSION

The point of view and methodology, briefly commented in this paper, allow to systematize and reinterpret seismic-resistant engineering knowledges necessary to revalue and to engage structural as well as architectural design in order to achieve an integral solution of the seismic-resistant problem in buildings.

Besides, it is also the way to develop a "Seismic-resistant Architecture" capable to colaborate with the present proposal from the very architectural project itself.

From Architectural Design stand point it shall be conceived as an interacting part of the whole sistem.

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

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·SUBSISTEMS VARIABLES AND CONSTANTS INTERACTING DURING SEISMIC ACTION	STRUCTURAL	CONSTRUCTIVE	SPATIAL CONFIGURATION	ECONOMICAL	FUNTIONAL	ESTHETIC	INSTALLATIONS	DUCTILITY	SEISMIC TORSION	- - - - - - - -
STRUCTURAL		o	o	o	o	o	o	o	o	o
CONSTRUCTIVE	o		o	o	o	o	o	o	o	o
SPATIAL CONFIGURATION	o	o		o	o	o	o	o	o	o
ECONOMICAL	o	o	o		o	o	o	o	o	o
FUNTIONAL	o	o	o	o		o	o	o	o	o
ESTHETIC	o	o	o	o	o		o	o	o	o
INSTALLATIONS	o	o	o	o	o	o		o	o	o
DUCTILITY	o	o	o	o	o	o	o		o	o
SEISMIC TORSION	o	o	o	o	o	o	o	o		o
- - - - - - - - -	o	o	o	o	o	o	o	o	o	

Figure 1