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Architectural and Structural Aspects Influencing the Seismic Response of Buildings

Sina Wanare *

Department of Civil Engineering, College of Coventry, Haiti

Abstract

Strong limitations were provided on building height exceptions could be allowed but not for buildings having special occupancy involving higher risk. Limitations were fair if considering the seismic resistant construction systems used at the time, consisting of masonry walls. Afterwards, when new materials allowed greater and greater strength level, both in compression and in tension, it has been recognized that the height is not, in itself, a negative factor for the seismic response.

Keywords: Building shape; Seismic resistant system; Suitable morphology; Irregular structures; Energy dissipation; Dynamic parameter

Introduction

In fact, a greater height can increase the natural period of the building, shifting it in the range where the response amplification is lower. On the contrary, the ratio height, that is a shape factor, has to be controlled because it influences the overturning of the building and the axial overloading of the external structural elements. Building shape is important because it has a decisive influence on the dynamic behaviour and on the stress concentration [1]. The geometric parameters qualifying the building shape, commonly referred as influence parameters of the seismic behaviour, are the vertical and plan regularity, the symmetry and the compactness. All these aspects are acknowledged by the major codes that provide design criteria penalizing buildings not having regular and compact shape. Penalization can consist of more stringent and detailed evaluation of the response or of a reduction of the allowed ductility factor for taking into account the reduced dissipative capacity [2]. The global shape irregularity can be a negative factor in itself, but, most of all, because it affects the structural system. Irregularities in the seismic resistant system are determinant in reducing the good performance under seismic attack and are the factors especially controlled by seismic codes [3]. For example, Structural Engineers Association of California provides for both vertical and plan irregularities.

Methodology

Vertical irregularities do not only consist of irregular vertical geometry, but also of irregularities of the structural system, stiffness discontinuity, weight irregularity, discontinuity of vertical lateral force resisting elements, strength discontinuity. Also plan irregularities consist of both geometric and structural irregularities. Also compactness is sometimes controlled, for example by euro code when providing to compare the inertia radius of the mass and stiffness [4]. As a consequence of the above mentioned general criteria for earthquake resistant buildings, received by the advanced codes and guidelines, the suitable morphology has to be characterized by regularity. This essentially means that a symmetrical and compact shape should be the target when designing a seismic resistant building [5]. The reasons for wishing regular buildings depend on the need of avoiding unpredictable stress concentration that can cause local collapses and modification of the dynamic behaviour [6]. This is not generally true, in fact, if provisions are adopted for avoiding the dangerous local effects and if the distribution of the lateral force resisting elements fits the global shape and therefore the distribution of masses and inertia forces, the actual disturb given by the irregularity to the lateral response is limited [7].

Discussion

Analyses carried out by faella on morphologically irregular structures, like structures having a L-shaped plan, that can be defined irregular according both to perceptive criteria and to irregularity rules provided by guidelines show that, if the diaphragms are rigid and the columns are distributed according to the shape, the irregularity is apparent and the disturb to the response induced by the irregularity consists of very slight torsional effects that can be accounted for at design stage [8]. The current design philosophy of seismic resistant buildings provides for a resistance, to the forces induced by severe seismic attacks, relied to the capacity of the building to dissipate the energy furnished by the earthquake as shown in (Figure 1). This capacity is associated to plastic deformations that can develop in particular zones of the structural elements in a controlled way [9]. The capacity design allows

Figure 1: Design of seismic resistant buildings.

***Corresponding author:** Sina Wanare, Department of Civil Engineering, College of Coventry, Haiti, E -mail: SinaaW33@yahoo.com

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Figure 2: Dissipative devices located between two adjacent buildings .

designing lateral load resisting systems controlling the sequence of the formation of the plastic hinges optimizing the energy dissipation and avoiding dangerous collapse mechanisms. In the last twenty years new philosophies - resumed in Skinner, naeim, Constantine, Soong based on the application of innovative systems, have been proposed for the seismic resistant structures [10]. They allow for capacity levels larger than that resulting from conventional design methods up to grant to avoid any damages even in the case of the maximum credible earthquake provided for the building. These systems can reduce the structural response thanks to different mechanisms: the reduction of the seismic input interesting the structure, the strong dissipation of the input energy, the active interaction with the motion of the building [11]. Generally the systems are classified in passive, when they modify the dynamic parameter of the structure like mass, damping and stiffness, and active, when they supply energy to the structure. Base isolation Base isolation provides for setting up of special devices between the foundation and the elevation structure allowing for the relative displacements between the superstructure and the substructure [12]. This controlled degree of freedom involves the uncoupling of the movement of the elevation that rigidly moves above the isolators. Several device types can be used, normal or high damping rubber devices, lead core rubber devices, friction devices, and plastic devices. If using elastic devices, their stiffness can be suitably set for having a very high natural period of oscillation, in the frequency range of the lowest seismic energy [13]. The friction and plastic devices limit the transmitted force that is the base shear, to the value of the threshold defined by their sliding or plastic force. Dissipative devices are usually introduced in special bracing systems allowing the dissipation of energy associated to the displacements between two levels of the buildings as shown in (Figure 2). Applications have been also proposed providing for dissipative devices located between two adjacent buildings or two sections of the same buildings and utilizing the relative displacement between the two bodies. Different devices have been developed, the most diffused are based on the flexural plasticization of ductile metal elements, sliding of friction surfaces, shear deformation of viscous-elastic rubber elements, axial displacement of fluid viscous dampers. Moreover, a number of particular devices have been implemented in both experimental and practical applications [14]. The energy dissipation is related to the displacement, therefore these systems can perform at their best if the lateral deformations of the structure are relevant, as it happens in flexible structures, but compatible with their service performance. Instead of passive systems, like base isolation and energy dissipation, which are not sensitive and cannot be regulated according to the instant response to the actual input, active or semi-active systems can be used for reducing the structural response to dynamic inputs [15]. Their principle consists of the application of one or more forces to the structure, having strategic location and suitable value, with the effect of counterbalancing the displacement induced by the excitation. Usually, not active, but hybrid systems are used in practice, because they are characterized by high efficiency of the control, low sensitivity to the site conditions, efficiency against different dynamic actions, and selectivity of the control target. They represent a middle path between active and passive systems, with the aim of optimizing advantages and disadvantages: like passive systems, they modify one or more of the structure parameters and, like active systems, they supply energy to the structure but requiring lower power.

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Conflict of Interest

None

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