BUILDING CONFIGURATION: CHARACTERISTICS FOR SEISMIC DESIGN

Christopher Arnold[I]

SUMMARY

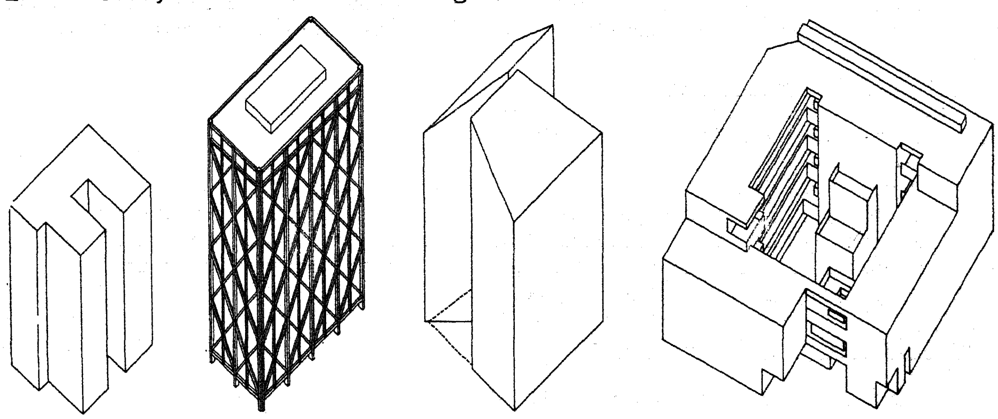
The seismic resistance of buildings is directly related to building configuration. Although configurations are extremely varied their derivation is not random. This paper discusses the derivation of configuration, and presents a method for its definition: both these issues are related to seismic design. By way of example, the recent history of the office building is outlined in terms that relates major configuration determinants to seismic design.

INTRODUCTION

Building configuration may be defined as the overall size and shape of a building, together with the size, nature and location of those elements of the building that are significant to its seismic performance.

Building configurations are extremely varied but are not random. There are three major influences: the requirements of site, the requirements of the building occupancy, and the requirements of imagery, or aesthetic aims.

In order to illustrate the interaction of these determinants it is useful to study building configuration as it is expressed in the recent history of a familiar contemporary building type: the office. Since its origin as a building type in the early nineteenth century we can identify four distinct phases in the development of office building shape. These are tabulated below, and illustrated in Figure 1.



Phase I Phase II Phase III Phase IV

Figure 1 The four phases of the evolution of office building design.

I. Architect, President, Building Systems Development, Inc., San Francisco, California.

THE EVOLUTION OF OFFICE BUILDING DESIGN

Phase I until early 1940's

Site, Occupancy And Image Determinants	Seismic Implications
• increasing urban site congestion creates: light wells, courts, re-entrant corners; vertical set-backs for light and air.	re-entrant corners & set-backs increase tendency to stress concentrations, torsion
• natural ventilation, daylighting, result in narrow widths, multiple wings.	
• continued use of classical motifs: parapets, cornices, ornamentation.	tendency towards dangerous parapets, falling materials.

Phase II until about 1965

Site, Occupancy And Image Determinants	Seismic Implications
• increased site value, need to increase site coverage, large floor areas, eliminate narrow wings. Code changes to allow open plazas in lieu of set-backs.	larger buildings outside range of shear wall design, 'soft' first stories to create plazas.
• new patterns of office organization need large unobstructed floors, facilitated by developments in air-conditioning & fluorescent lighting.	use of wide span frames for interior flexibility, increased forces, less redundancy.
• desire for unadorned cubistic forms; facilitated by industry development of the curtain wall.	large, ductile frame buildings result in flexible structures, high non-structural damage.

Phase III 1965 - to date

Site, Occupancy And Image Determinants	Seismic Implications
• continued need for maximum site coverage.	
• similar to Phase II	
• continued desire for pure geometric forms, but variations from rectilinear forms: use of prismatic shapes, 45° angle in plan.	more complex geometry results in increased structural irregularity, discontinuity.

Phase IV late 1970's - 1980's

Site, Occupancy And Image Determinants	Seismic Implications
• continued need for maximum site coverage.	
• demand for energy conservation: reversion to daylighting results in re-use of narrow forms, set-backs, skylights, courts. Use of high mass materials.	reversion to re-entrant corners, set-backs, results in stress concentration, torsion. Heavy materials increase forces.
• reversion against large scale simple forms.	

CONFIGURATION DEFINITION

In considering building configuration in relation to seismic design we need a method of classification that can serve as a reference for the discussion and analysis of configuration on a systematic basis.

A basis for such a classification system is provided by the geometrical concepts of convexity and concavity, Figure 2. By using these concepts in relation to building plan and building elevation (or section) a useful distinction is at once made between buildings of simple, or regular shape, and those of complex shape involving re-entrant corners or curves, in both plan and elevation. The latter are intrinsically more prone to suffer stress concentrations and torsion. Figure 3 shows the matrix of shapes created by combining simple and complex form in plan and elevation. All building configurations can be related back to this matrix.

Figure 4 illustrates for one particular L-shape configuration a set of dimensional attributes that can be applied to any configuration. The definition of these attributes and their seismic significance follows. It should be noted that, for seismic design, proportion (relative dimensions) is often more important than absolute size. These attributes are independent of structural systems, which are selected at the next stage of concept design.

Aspect Ratio

Relative dimensions in plan for rectangular or near rectangular portions of building (square, circular or regular polygonal plans have aspect ratio of 1). Seismically significant in determining intrinsic difference in resistance capacity along different building axes.

Height/Depth Ratio

Relative dimensions in elevation or section between base and height of building. Rectangular building or wing have two H/D ratios. Seismically significant for P-Δ effect and overturning; for latter, ratios over about 3:1 regarded as significant.

Area

Absolute dimension in plan. Seismically significant in determining build-up of diaphragm forces, shear forces in elevation, need for building subdivision to reduce force build-up.

Bulk

Absolute dimension in three dimensions. Seismically significant in determining building mass and three-dimensional distribution of forces.

The system of classification summarized above, together with a dimensional method for defining angular properties of splays in plan and section, and for defining curves, provides an organized format for the comparative analysis of any building configuration.

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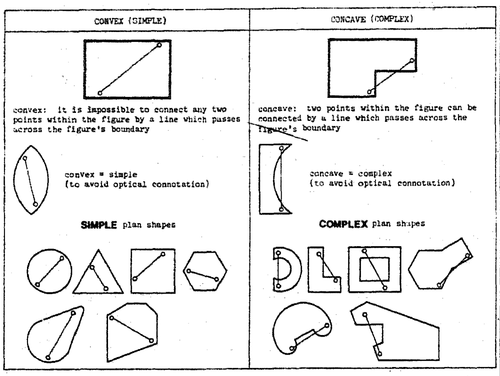

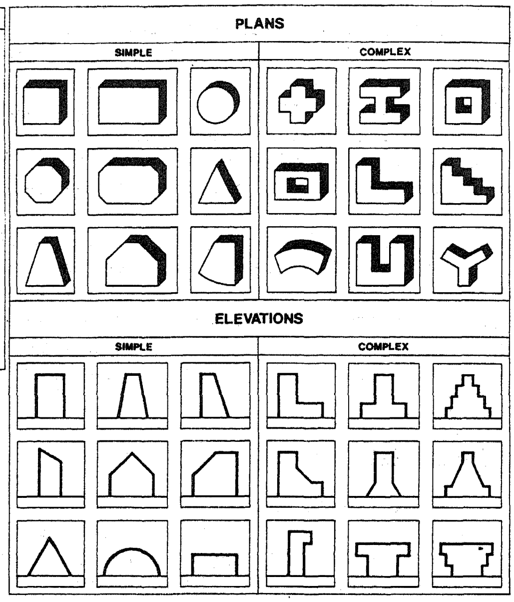

Figure 2 Plan definitions: simple and complex ↑

Figure 3 Matrix of simple and complex plans and elevations →

Figure 4 Dimensional attributes ↓