BUILDING CONFIGURATION: PROBLEMS AND SOLUTIONS

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SUMMARY

Some building configurations are an intrinsic source of problems in seismic design. This paper presents in chart form an outline of problem building configurations, together with a summary of their architectural and structural implications and some suggestions for dealing with the problem.

INTRODUCTION

For purposes of seismic design building configuration has been defined elsewhere (1). In order to assist in a structured approach to the range of problems presented by inappropriate configurations, this paper consists primarily of a chart which identifies and classifies such configurations.

The intention of this chart is to encourage a systematic approach towards understanding the relationship between configuration and seismic design. For this reason the chart outlines the relationship between architectural determinants in configuration and their structural consequences. In addition, the chart shows suggestions for alleviating the problem, recognizing that in many instances the simple solution of avoiding the problem configuration may not be possible. The critical issue is to develop an understanding by architects and engineers that a problem exists: once recognized, the problem can be dealt with by a variety of methods.

PROBLEM EXAMPLE

The Imperial County Services building is a six story reinforced concrete structure, built in 1969, which suffered a major structural failure in the Imperial Valley earthquake of October 1979 (Figure 1). Detailed study of the building damage shows that the four free-standing columns at the East end of the building failed by overturning, since the outer pair of columns show more distress than the inner.

The condition at the East end represents a classic instance of shear wall discontinuity, in which an abrupt change of strength and stiffness occurs at the point where the shear wall, weighing approximately 300 tons, terminates at the second floor.

Figure 2 schematically indicates the East end's two horizontal load paths: to resist translation, shear stresses can be carried in the plane of the second level floor structure in to an interior ground level wall. However, rotational (overturning) forces (which are perpendicular to the second floor) are not transferred across in this manner, and only the columns beneath the end wall can supply the tension-compression couple required to resist the overturning moment. The corner columns take the bulk

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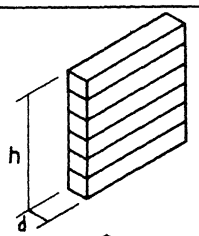
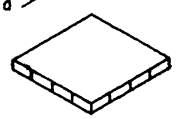
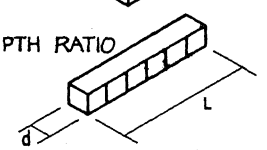
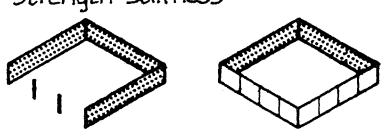
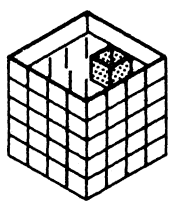
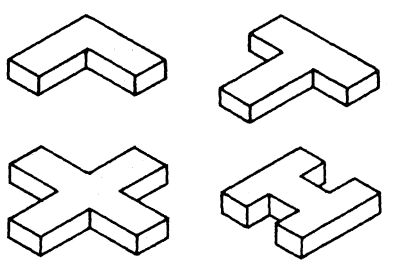
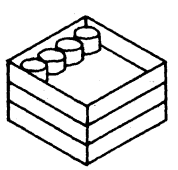
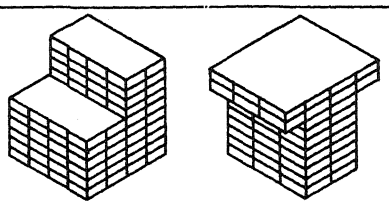
PROBLEM CONFIGURATION	
A. PROBLEMS IN EXTREME DIMENSIONS	1. EXTREME HEIGHT-DEPTH RATIO  2. EXTREME PLAN AREA  3. EXTREME ELEVATION LENGTH-DEPTH RATIO (ASPECT RATIO) 
B. PROBLEMS OF HORIZONTAL LAYOUT	1. SIMPLE PLAN CONFIGURATION a. variations in perimeter strength-stiffness  b. false symmetry  2. RE-ENTRANT CORNERS  3. MASS ECCENTRICITIES 

ARCHITECTURAL STATEMENT	STRUCTURAL PROBLEM STATEMENT	SOLUTION
function of planning or constricted site	high overturning forces, large drift causing non-structural damage	revise proportion or special structural system
common in warehouses, industrial buildings, shopping centers	build-up of large diaphragm forces	subdivide building by seismic joints
common in older schools, multistory residential	build-up of large lateral forces in perimeter: big difference in resistance of two axes	subdivide building by seismic joints
often result of program: e.g. fire station, store front. need for blank walls on corner	torsion caused by extreme variation in strength and stiffness	add frames and disconnect walls, or use frames and lightweight walls
program requirements, relating vertical circulation to use spaces	torsion caused by stiff asymmetric core	disconnect core, or use frame with non-structural core walls
program requirements for narrow wings, e.g. residential, hospital, and tight urban site. common in older buildings, pre air-conditioning and fluorscent lighting	torsion, and stress concentration at the notches	separate walls  uniform box  center box  architectural relief 
programmatic requirements: book stacks in libraries, special equipment, elevated swimming pools	torsion, stress concentrations	reprogram, or add resistance around mass to balance resistance and mass

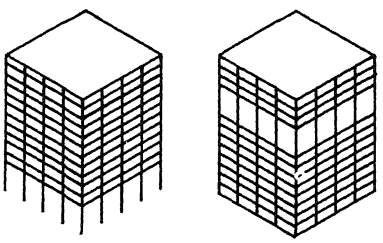
PROBLEM CONFIGURATION

C. PROBLEMS OF VERTICAL LAYOUT

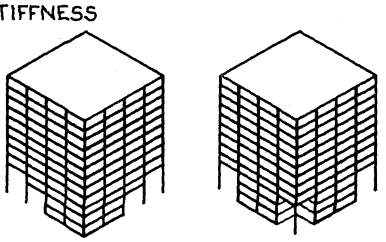
1. VERTICAL SETBACKS & REVERSE SETBACKS



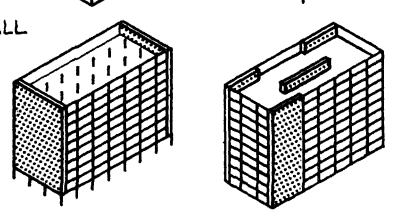
2. SOFT STORY -frame



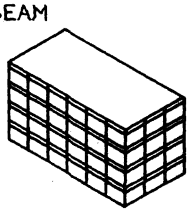
3. VARIATIONS IN COLUMN STIFFNESS -within a story



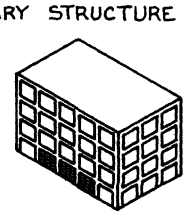
4. DISCONTINUOUS SHEAR WALL

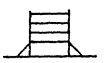
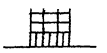
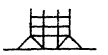


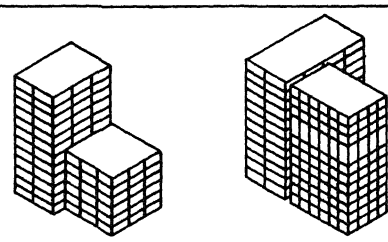
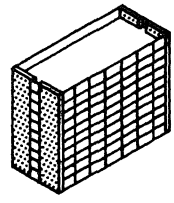
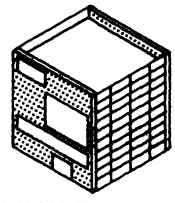
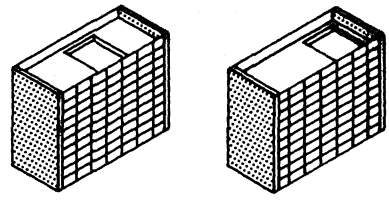
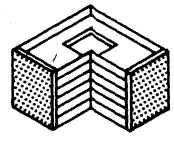
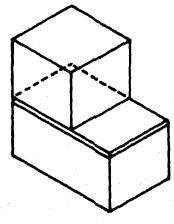
5. WEAK COLUMN - STRONG BEAM

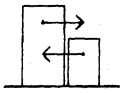
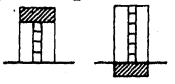


6. MODIFICATIONS OF PRIMARY STRUCTURE



ARCHITECTURAL STATEMENT	STRUCTURAL PROBLEM STATEMENT	SOLUTION
vertical setbacks result of program or site: reverse setback almost always an image requirement (fashion)	stress concentration at notch, different periods for different parts of building, high diaphragm forces to transfer at setback	special structural systems, careful dynamic analysis
programmatic: need for open first floor plazas or large spaces at any floor: often image requirement (fashion)	causes abrupt change of stiffness at point of discontinuity	add bracing  add columns  braced 
programmatic: need for variety of spaces and ceiling heights: often image requirements	causes abrupt change of stiffness, much higher forces in stiffer columns	redesign structural system to balance stiffnesses
result of program: planning restricts use of shear walls on entrance floor, or image "floating cube"	results in discontinuities in load path and stress concentration for most heavily loaded elements	NO
common in buildings with large window areas - schools, hospitals, offices - wide span beams, deep spandrels	column failure occurs before beam, short column must try and accommodate story height displacement	NO add full walls to reduce column forces, or detach spandrels from columns, or use light weight curtain wall with frame
programmatic: requirement for high window: common as remodel, sometimes by building management (maybe interior condition also)	most serious when masonry in-fill modifies structural concept. creation of short, stiff columns results in stress concentration	detach in-fill, or use lightweight materials

PROBLEM CONFIGURATION	
D. PROBLEMS OF ADJACENCY	1. BUILDING SEPARATION (POUNDING) 
E. SHEAR WALLS	1. COUPLED  2. RANDOM OPENINGS 
F. DIAPHRAGM	1. OPENINGS  2. SHAPE  3. TOWER 

ARCHITECTURAL STATEMENT	STRUCTURAL PROBLEM STATEMENT	SOLUTION
may be different parts of same building (setback) or buildings on adjacent sites	possibility of pounding dependent on building period, height, drift, distance	ensure adequate separation, assuming opposing building vibration 
common expression for end of double-loaded corridor plan	incompatible deformation between walls and links	NO with weak link design adequate link  or repairable system
requirement for windows, doors, holes for ducts	seriously degrade capacity at point of maximum force transfer	careful design, adequate space for reinforcing design for non-linear behavior
need for vertical circulation, light wells, skylights	seriously degrade diaphragm capacity	NO unless careful design for non-linear behavior
planning almost always requires vertical circulation at 'hinge' of re-entrant corner plans	weakens diaphragm at most critical location	NO unless careful design for non-linear behavior
see setbacks	diaphragm at setback must transfer full tower loads	careful design, recognizing diaphragm problem

of these alternating axial forces.

At the West end, the stiff ground level shear wall beneath the upper wall prevents large axial forces from reaching the columns, and this end of the building suffered negligible damage. Thus the major differences in damage between the West and East ends of the building are paralleled by a major difference in architectural configuration.

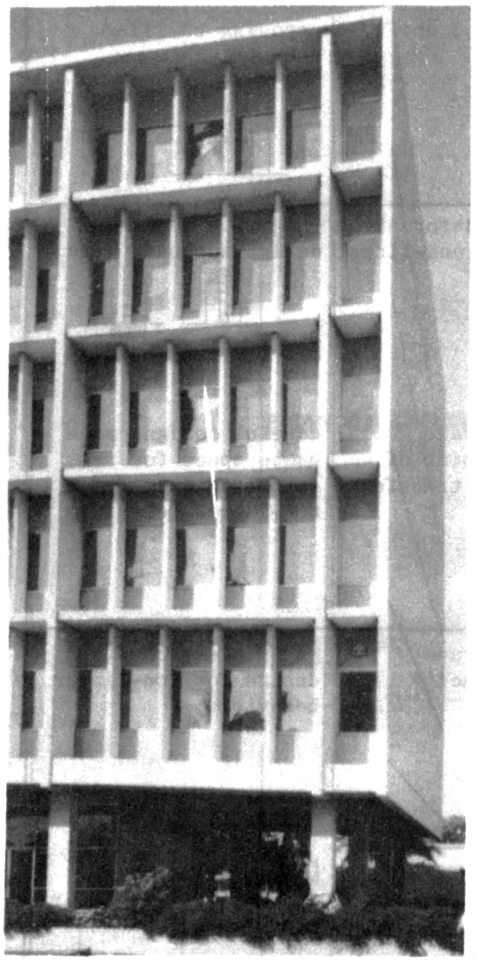


Figure 1

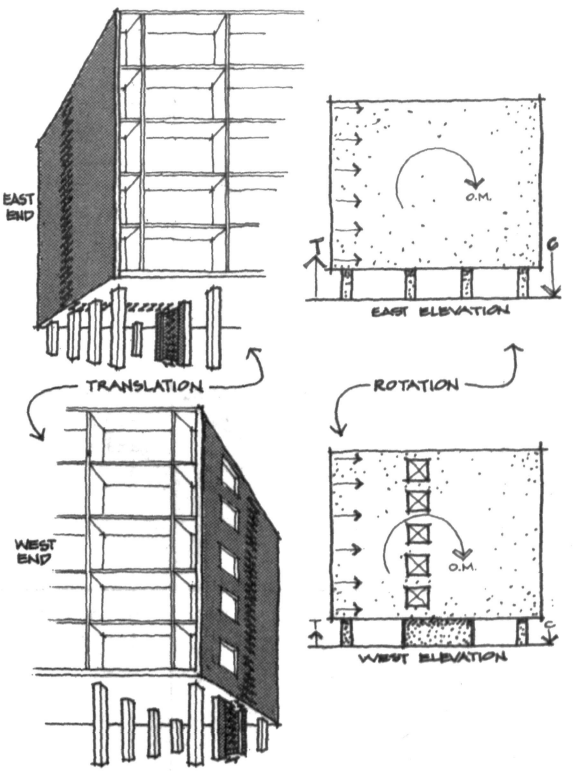


Figure 2

ACKNOWLEDGEMENTS

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REFERENCES

1. Christopher Arnold, 1980, Building Configuration: Characteristics For Seismic Design, 7th World Conference On Earthquake Engineering.