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APPENDICES

THE
INTEGRATION
OF
SEISMIC
DESIGN
PRINCIPLES
INTO
PRELIMINARY
ARCHITECTURAL
DESIGN

Prepared for the National Science Foundation

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Earthquake causes and effects are reviewed and four basic causes of earthquakes that induce damage are discussed: (1) ground rupture in fault zone; (2) ground failure; (3) tsunamis; and (4) ground shaking. The response of buildings to ground motion, the effects of building shape on response to seismic forces, and the effects of seismic forces on building systems and components are considered. Design and configuration problems are addressed and solutions to these problems are proposed. Commentary on codes which deal with seismic design, a survey questionnaire, and design and evaluation guidelines are provided.

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APPENDIX A

Primer for Interactive Sessions

INTRODUCTION

In the United States, two of the most severe earthquakes did not happen on the West Coast, but in the East and the Midwest (Charleston, South Carolina in 1886 and New Madrid, Missouri in 1811 and 1812). But since seismic activity is more frequent on the West Coast, scientists have concentrated efforts there.

This primer is emphazising how architectural planning design affects the performance of buildings under earthquake conditions. To date, code requirements essentially deal with the structural integrity of a building as it affects life safety. But with much improved structural design methods, building collapse has become less prevalent. This in turn has made architectural (nonstructural) elements more vulnerable to damage, namely, glazing, facades, interior partitions, etc.

This primer is established in conjunction with the workbook which will record the cooperative research project with 3 architects who are chosen among the East Coast architects in dealing with seismic design. It is an interactive association between the researchers and East Coast architects in learning and incorporating seismic designs considerations in the architectural design practice.

CHAPTER I

EARTHQUAKES CAUSES AND EFFECTS

1.1 GENERAL THEORY OF EARTH MOVEMENT

1.1.1 Plate Tectonics

The theory of plate tectonics asserts that the crust and upper mantle of the earth are made up of 6 major and 6 or more minor internally rigid plates (or segments of the lithosphere) which slowly, continuously and independently slide over the interior of the earth. These plates meet in Convergence Zones and separate in Divergence Zones. Plate motion is thought to create earthquakes, volcanoes, and other geologic phenomenal.

Divergence Zones are zones where molten rock from beneath the crust surges up to fill in the resulting rift and forms a ridge. Convergence Zones are zones where subduction occurs, one plate slides under the other forming a trench, and returns material from the leading edge of the lower plate to the earth's interior. Figure 1.1 shows the Plates of Earth's Lithosphere.

Ninety percent of all earthquakes occur in the vicinity of these "Plate Boundaries" where plates push into one another and one slides beneath the other --shallow to deep-seated earthquakes occur. Deep-seated earthquakes are uncommon where plates slide past each other. The other ten percent of earthquakes occur at faults located "Within Plates". They are much less frequent than those at plate boundaries, and their causes are less well understood.

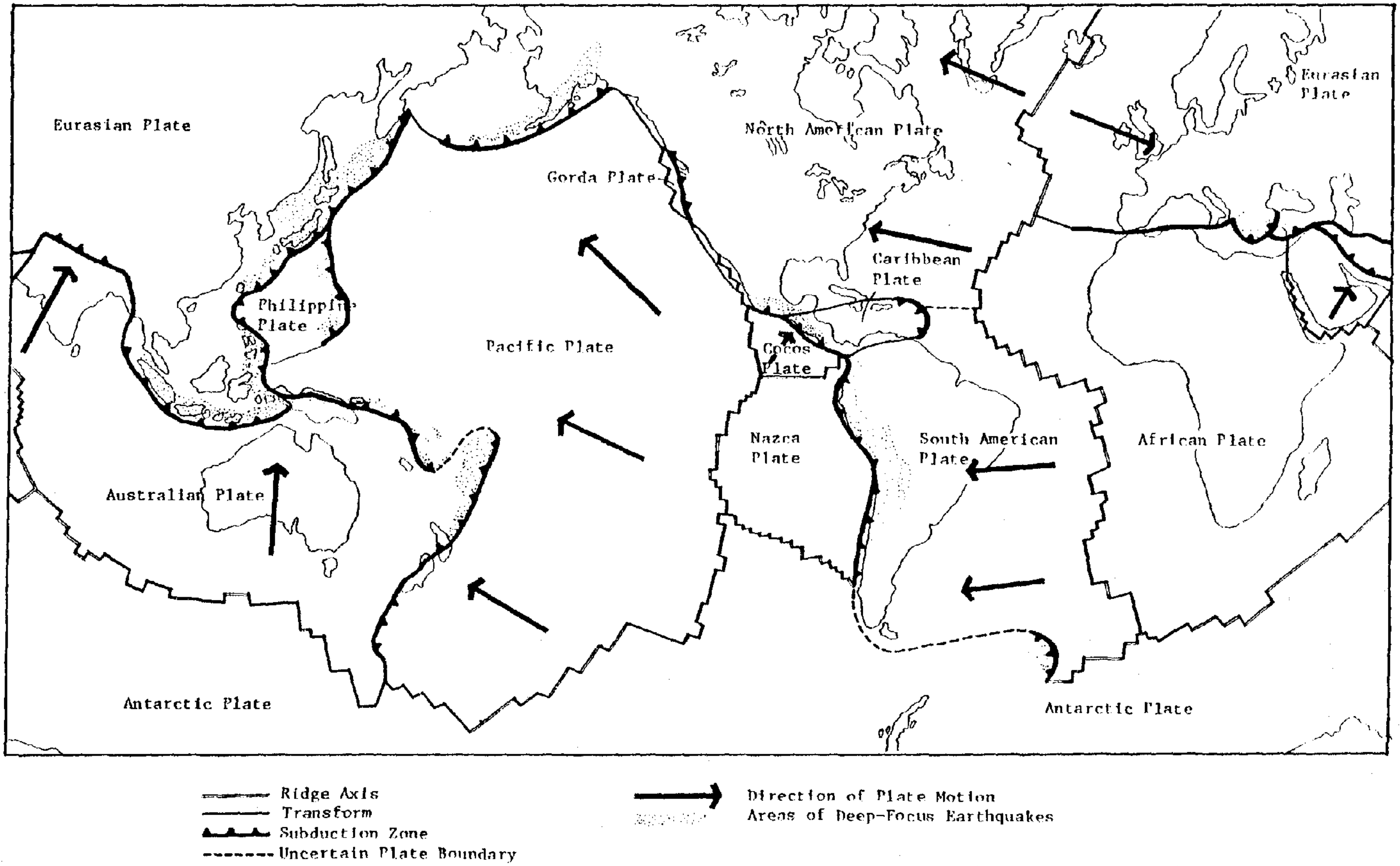
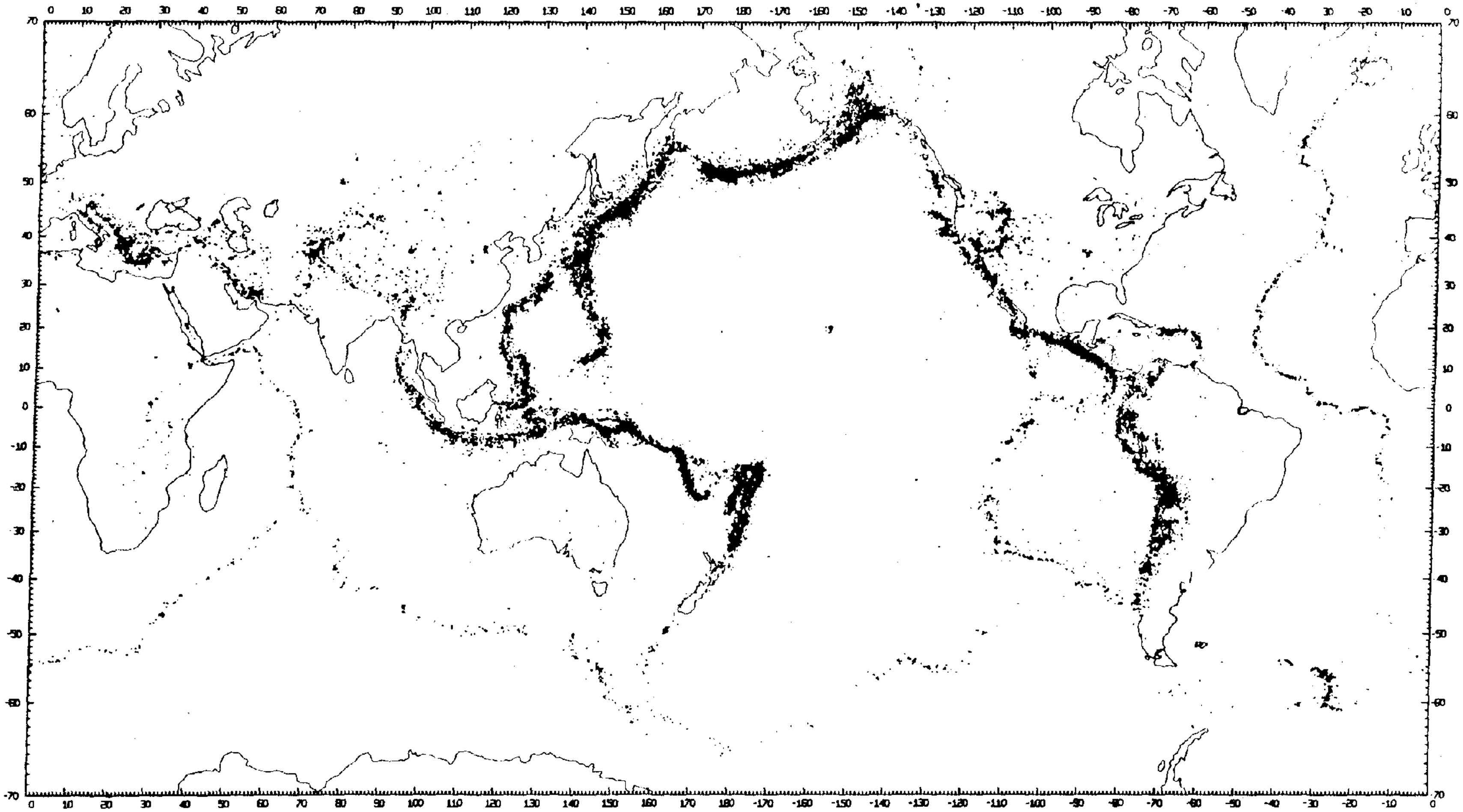

Eurasian Plate
Philippine Plate
Pacific Plate
Gorda Plate
North American Plate
Eurasian Plate
Caribbean Plate
Cocos Plate
Nazca Plate
South American Plate
African Plate
Australian Plate
Antarctic Plate
Antarctic Plate
Ridge Axis
Transform
Subduction Zone
Uncertain Plate Boundary
Direction of Plate Motion
Areas of Deep-Focus Earthquakes

Figure 1.1



World Seismicity Map

Figure 1.2

World's Seismicity Map with epicenters of some 30,000 earthquakes in the years 1961 - 1967, which have focal depths between 0 and 700 km is illustrated in Figure 1.2.

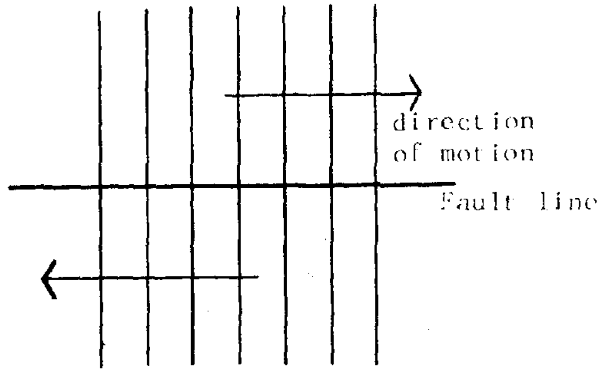
1.1.2 Elastic Rebound Theory

Earthquake theory is generally based on the "Elastic Rebound Theory", proposed by Prof. H.F. Reid. Earthquakes are associated with large fractures or faults in the Earth's crust and upper mantle. Figure 1.3 shows the Elastic Rebound Theory of Earthquake generation.

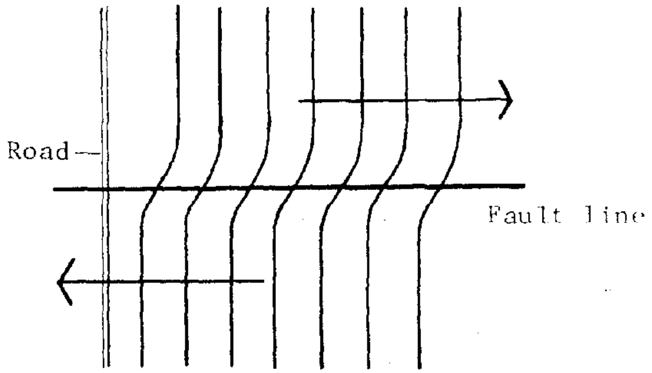
1.2 MEASURING EARTHQUAKES

About 1,000,000,000 erg of elastic strain energy are released from each cubic meter (1.3 cu yards) of rock at the time of an earthquake. If the fault dimension and the distortion on either side are known, the energy released is then computed as the multiplication of those dimensions by 1,000,000,000. Energy release is the most precise way of measuring the size of an earthquake, but it is a long, complicated process to determine the fault dimensions, the slip and the other factors needed to compute it. Therefore, in general, earthquake size is measured by the magnitude and intensity scale.

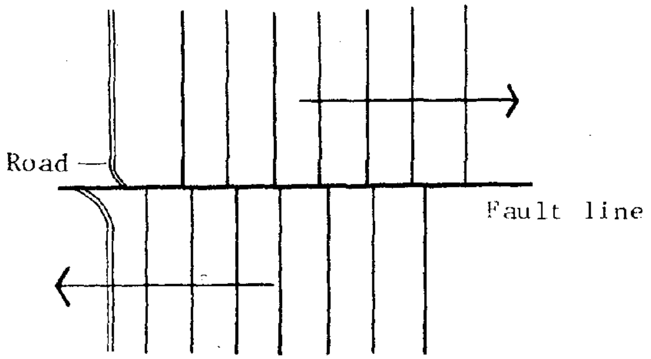
The Richter Magnitude Scale is based on the amplitude of seismic waves recorded by seismographs. These magnitudes are based on a logarithmic scale, so a change in magnitude of 1 unit corresponds to a change in the amplitude of seismic waves by a factor of 10. Thus, a "Richter 6" records 10 times the amplitude of a "Richter 5", and a "Richter 7" records 100 times as much as



a. Before straining



b. Strained - before earthquake



c. After earthquake

Elastic Rebound Theory

Figure 1.3

a "Richter 5".

Table 1.1, Table 1.2 and Figure 1.4 show a statistic and comparison of earthquakes magnitudes, energy and effects.

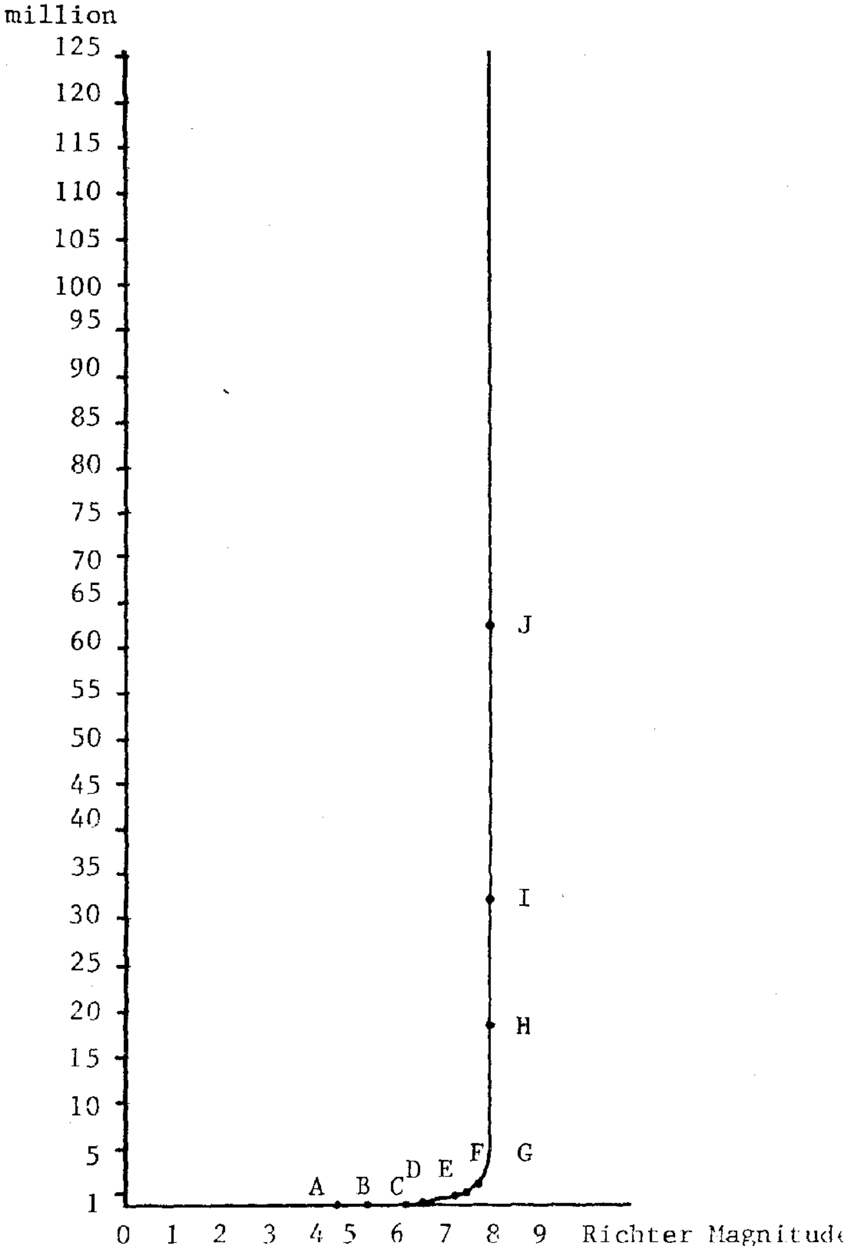
Table 1.1
Energies of Earthquakes (Richter Magnitude 1 - 9)

Earthquake Magnitude	Approximate Earthquake Energy
1	6 ounces T.N.T.
2	13 pounds T.N.T.
3	397 pounds T.N.T.
4	6 tons T.N.T.
5	199 tons T.N.T.
6	6,270 tons T.N.T.
7	100,000 tons T.N.T.
8	6,270,000 tons T.N.T.
9	199,000,000 tons T.N.T.

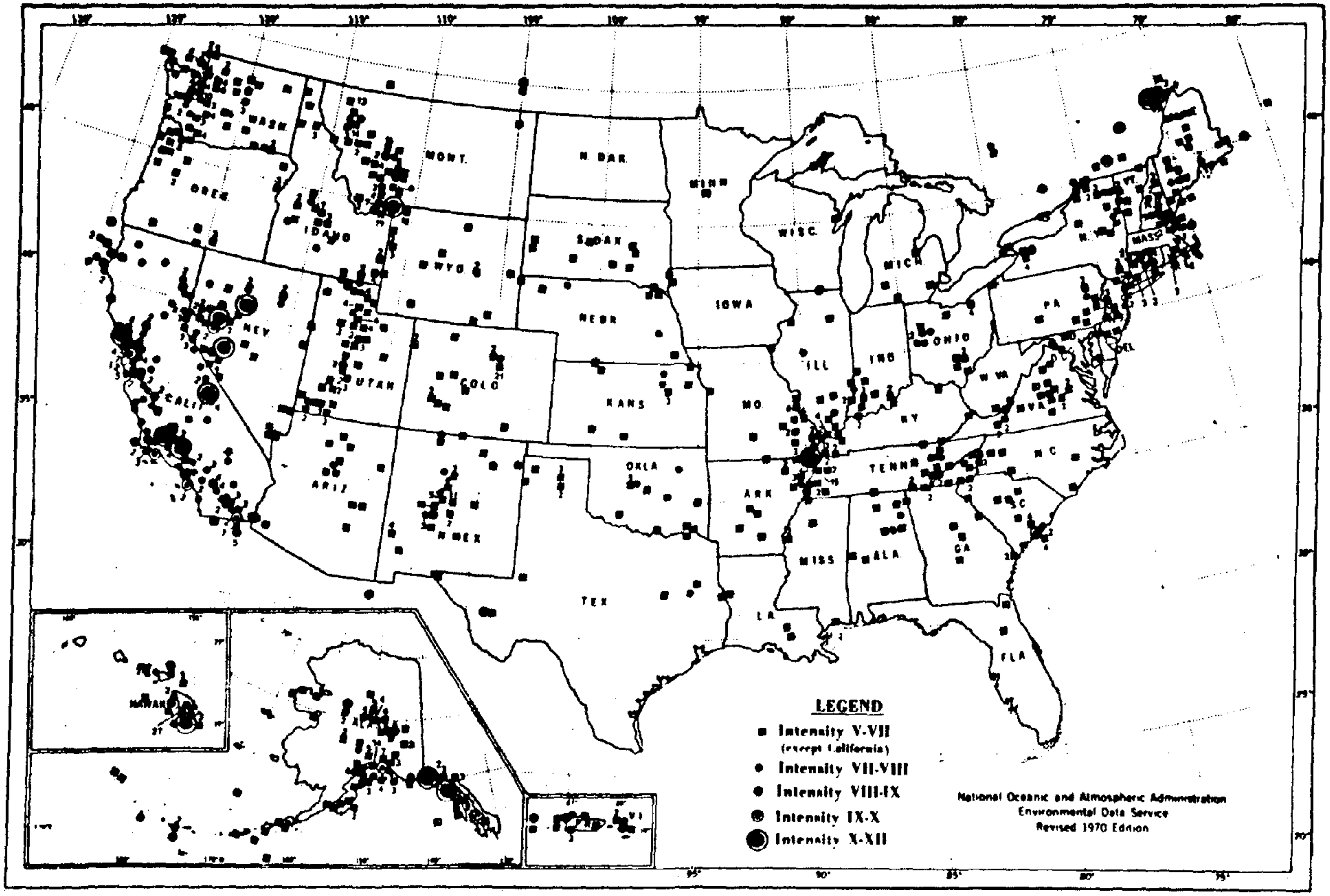
Table 1.2
Earthquake Magnitudes,
Effects, and Statistics

Characteristics Effects of Shallow Shocks in Populated Area	Approximate Magnitude	Number of Earthquakes per Year
Damage nearly total	8 +	0.1 - 0.2
Great damage	7.4 - 7.9	4
Serious damage	7.0 - 7.3	15
Considerable damage to buildings	6.2 - 6.9	100
Slight damage to buildings	5.5 - 6.1	500
Felt by all	4.9 - 5.4	1,400
Felt by many	4.3 - 4.8	4,800
Felt by some	3.5 - 4.2	30,000
Not felt but recorded	2.0 - 3.4	800,000

Modified Mercalli Intensity Scales are expressed in 12 categories ranging from: "Not felt, marginal and long-period effects of large earthquakes" (Intensity I) to "Damage nearly total. Large rock masses displaced. Lines of sight and level



A. Average Tornado
B. 1957 San Fransisco
C. 1933 Long Beach
D. Hiroshima Atomic Bomb
E. 1940 El Centro
F. 1968 Iran
G. 1952 Kern County, Calif.
H. 1906 San Fransisco
I. 1964 Alaska
J. 1950 Himalayas



U. S. Earthquake Intensity V and above through 1970
Figure 1.5

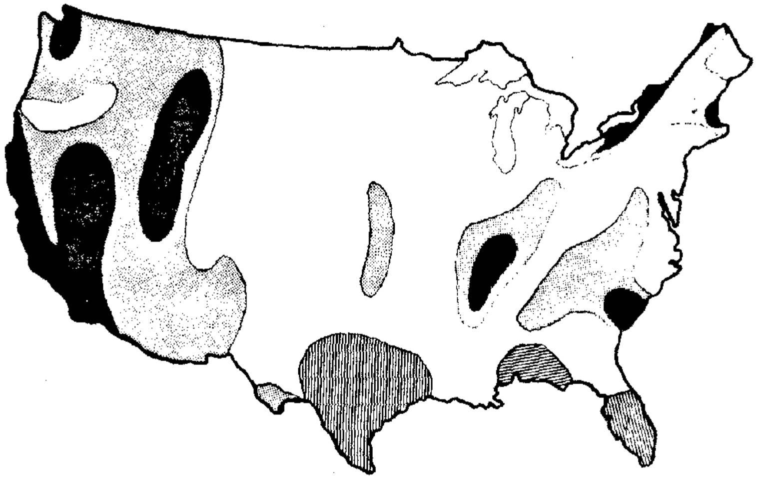
distorted. Objects thrown into the air" (Intensity XII).

Earthquakes in the Midwest and Eastern U.S. are in the category of earthquakes which occur at faults within plates. Table 1.3 compares large Eastern erthquakes with East Coast events, and shows the extent to which energy was dissipated in the East. Figure 1.5 shows the recorded earthquakes (Intensity V and above) in the United States through 1970, while Figure 1.6 shows the Seismic Risk Map of the United States.

Table 1.3
Comparison of Large U.S. Earthquakes

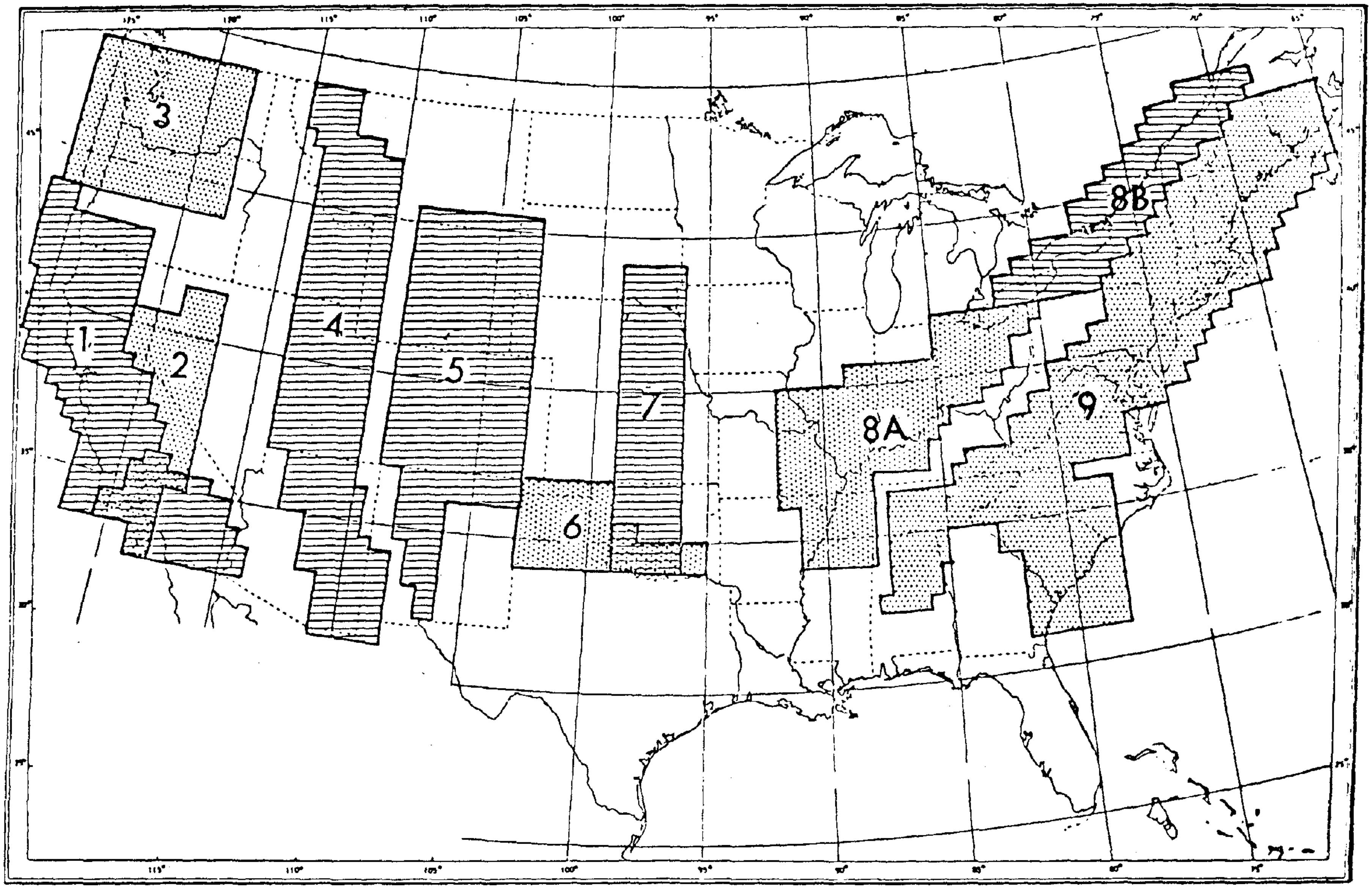
Location	Magnitude	Peak Intensity	Felt Area Sq.miles
New Madrid (1811,1912)	7.1, 7.2, 7.4+	XII	2,000,000
Charleston (1886)	around 7	IX - X	2,000,000
San Fransisco (1906)	8.3	XI	375,000
Alaska (1964)	8.3	IX - X	700,000

The average rate of occurence of earthquakes with minimum Modified Mercalli intensities of VI through VIII in various areas of the contInguous U.S. are given in the Table 1.4 These rates are based on an analysis of the historical seismicity. The areas considered are shown in Figure 1.7. Table 1.4 is given in terms of intensity because the magnitudes of many of the earthquakes in the historical record are unknown. The rate at which large shocks will occur in a particular area depends on the validity of an empirical relationship derived from historical data.



▥ No Damage
☐ Minor Damage
▒ Moderate Damage
■ Major Damage

Seismic Risk Map of the United States
Figure 1.6



Location Map showing the areas for which recurrence formulas were computed

Figure 1.7

Table 1.4
Summary of Earthquakes Recurrence Formulas

Area	Earthquakes per 100 Years per 100,000 km2 V	VI	VII	VIII
1&2 California, Nevada	300	84.6	23.8	6.72
4 Montana, Idaho, Utah, Arizona	64.4	17.7	4.89	1.35
3 Puget Sound, Washington	68.0	16.3	3.92	0.94
8A& 8B Mississippi Valey, St.Lawrence Valey	24.2	7.65	2.42	0.76
7 Nebraska, Kansas Oklahoma	13.0	4.20	1.35	0.45
5 Wyoming, Colorado, New Mexico	32.8	6.85	1.42	0.31
6 Oklahoma, North Texas	13.3	3.73	1.07	0.30
9 East Coast	12.8	3.39	0.88	0.23

CHAPTER II

EFFECTS OF EARTHQUAKES ON STRUCTURES

2.1 Four basic causes of earthquakes that induce damage are:

2.1.1. Ground Rupture in Fault Zones

If a rupture occurs, ground displacement along the fault can be horizontal or vertical or both. A structure directly astride such a break will be severely damaged.

2.1.2. Ground Failure

The result of ground failure may be in the form of landslides, settlement and liquefaction. The phenomenon of liquefaction can occur in sands of relatively uniform size when saturated with water. When this material is subjected to vibration, the resulting upward flow of water can turn the material into a composition similar to "quicksand" with accompanying loss of foundation support. Ground failure is particularly damaging to support systems such as water and gas lines, sewers, communication lines and transportation facilities. This damage then has a serious effect on both health and life safety (causing fires, spreading disease etc.).

2.1.3. Tsunamis

Tsunami is a series of traveling ocean waves of great and long period, generated by disturbance associated with earthquakes in oceanic and coastal regions. Tsunami waves may reach forward speeds exceeding 600 miles per hour. As the tsunami enters the shoaling water of coastlines in its path, the velocity of its waves diminishes and wave height increases. It is in these shallow waters that tsunamis become a threat to life and property, for they can crest to heights of more than 100 feet, and strike with devastating force.

2.1.4. Ground Shaking

As the earth vibrates, all elements on the ground surface will respond to that vibration in varying degres. Vibration and displacement can destroy a structure which is not designed and constructed to be earthquake resistant. Earthquake forces in structures result from the erratic omnidirectional motions of the ground. Vertical motions have customarily been neglected in building design, because most structures have considerable strength in the vertical direction because they are designed to counteract the force of gravity.

2.2 RESPONSE OF BUILDINGS TO GROUND MOTION

Ground motions are normally described in terms of acceleration, velocity and displacement of the ground at a particular location. The cycle of displacement of the structure is a function of the time (duration) of the ground motion. Therefore, the building must be able to undergo these extended periods of ground shaking without failure. See Figure 2.1.

A building acts as a pendulum with respect to the ground, with the rate and frequency of the swing (i.e. the swaying) as a function of building height, mass, cross-sectional area and numerous other factors, as shown in Figure 2.2.

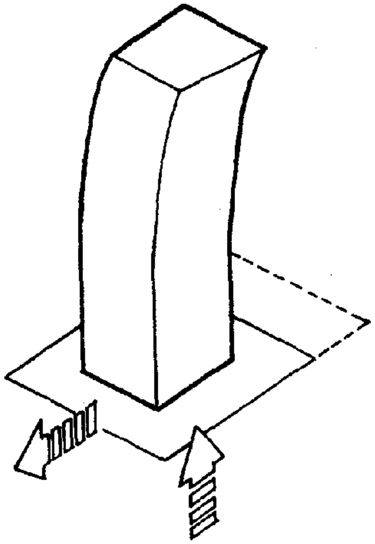
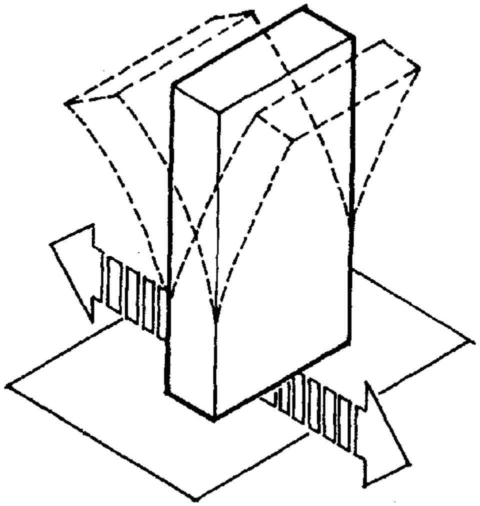


Figure 2.1



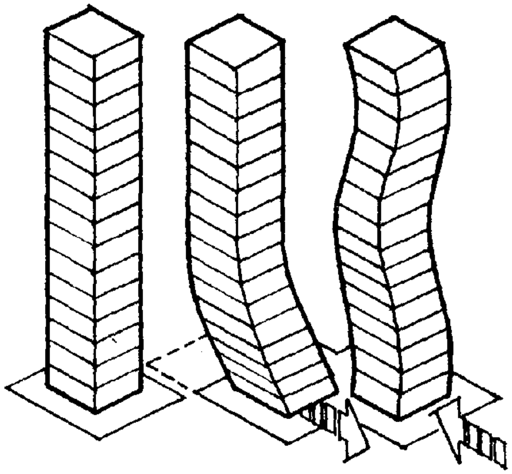
Pendulum Action
Figure 2.2

The rate of oscillation, or "natural period" of a structure, is an extremely important factor because earthquakes do not result in ground movement in only one direction, rather, the ground oscillates back and forth, in all directions. Complex deflections may result as the building vibrates in all its modes of vibration in response to ground motion. The ground motion may coincide with the natural period of the building's motion, resulting a resonance. (Figure 2.3).

The way the structure absorbs or transports the energy released by an earthquake will determine the success or failure of the building's seismic resistant design and construction. The energy transfer and energy dissipation mechanisms involved should be such that no damage would occur. The desired flexibility is illustrated by a flagpole that can sway considerably without fracture or permanent displacement. The opposite situation is represented by a stack of unreinforced bricks whose movements result in permanent displacement of the bricks when a horizontal force is applied, as shown in Figure 2.4.

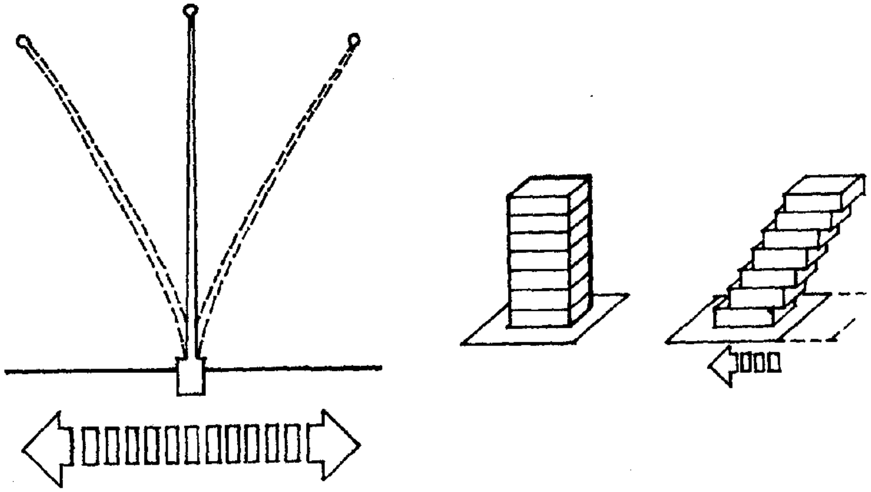
In design, one must deal with structural systems that fall between these 2 conditions, that is, between an infinitely limber buildings versus those that will bend in several parts when earthquakes forces are applied.

The bending is the result of earthquake forces, and therefore, the structural members will absorb or temporarily store some of this earthquake energy when it is imparted to the structure. This capacity for the storage or absobtion of energy depends on whether the material operates in its elastic or inelastic range. When the structure can deform, yet retain the



Effects of Cyclic Reversals of Ground Acceleration

Figure 2.3



Flexibility

Permanent Displacement

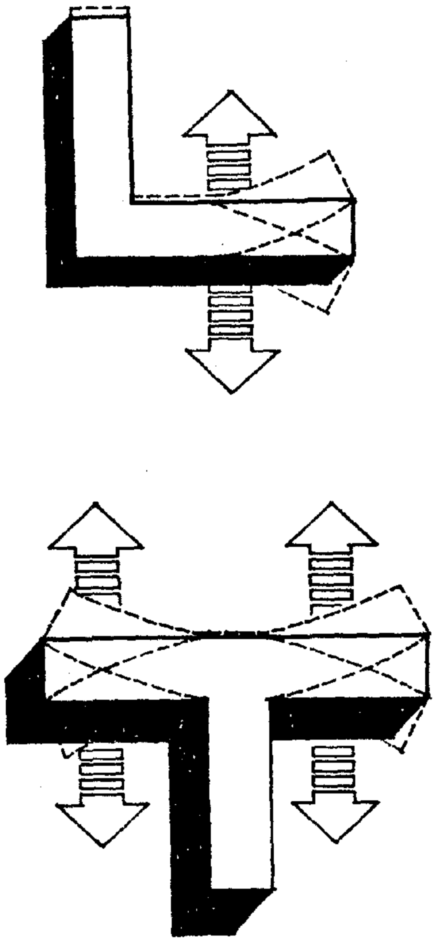
Figure 2.4

ability to return to its original state without permanent deformation, the material has stayed within its elastic range of deformation. The range beyond the elastic range is the inelastic or the plastic range where permanent deformation occurs. In this range fracturing of certain structural building components may occur. The designer should be aware that structural members may fracture before the building experiences maximum energy impact, thus residual energy absorbing mechanisms should be provided in the sturcture.

2.3 EFFECTS OF BULDING SHAPE ON RESPONSE TO SEISMIC FORCES

One of the most critical decisions regarding the ability of buildings to withstand earthquakes is the choice of basic plan shape and configuration. Given that earthquake forces at a site can come from any and all directions, and act upon all elements of the building virtually simultaneously, the obvious "best choice" is a building which is symmetrical in plan and elevation, and, therefore, is equally capable of withstanding forces imposed from any direction. However, given other constraints, such as, shape of site and functional requirements, rarely can the architect satisfy this demand. Therefore, an understanding of how variations in plan and elevation symmetry can affect performance is important. (Figure 2.2 through 2.5).

Since the structure is a unit, torsional movement is created by the earthquake. Torsion is the result of rotation of an eccentric or a less rigid mass about the basic or the more rigid mass of the bulding. Torsion can also occur in regular-shaped buildings whenever the relative stiffness of one part of the



Stiffness of Structure related to Building Plan

Figure 2.5

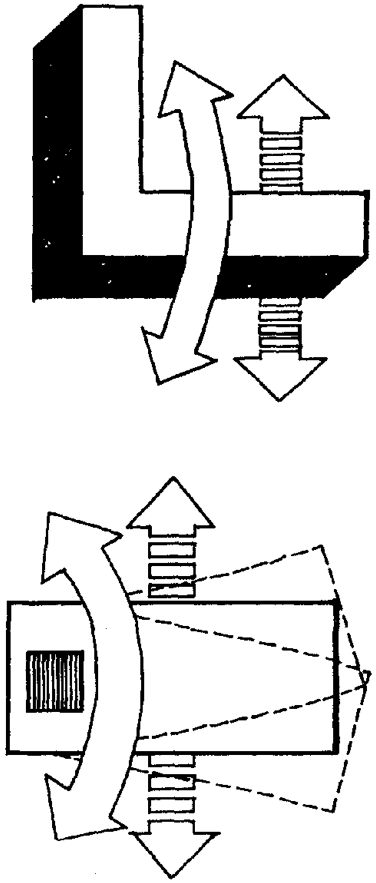
structure is different from another. Regular-shaped buildings with balanced stiffness elements therefore avoid the secondary effects of torsion and differential movement. (Figure 2.6).

Any irregularity in building shape, such as, in plan, section or elevation is subjected to torsion. (Figure 2.7).

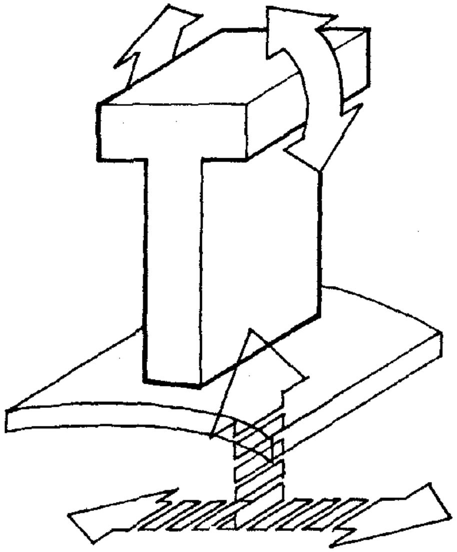
2.4 EFFECTS OF SEISMIC FORCES ON BUILDING SYSTEMS AND COMPONENTS

Most buildings are designed with a combination of flexible and stiff components. The improper combinations of such components may create problems in building performance under earthquake loading. The structural frame may absorb the earthquake forces without significant damage, but the movement of the building induces significant secondary damage to nonstructural components. Nonstructural components must be properly integrated with or effectively isolated from the basic structural frame if excessive damage and loss of life is to be avoided. The interaction between nonstructural components and structural systems can be divided into 2 basic relationships:

2.4.1. The effects of most nonstructural components on the performance of the structure in most cases is neutral, however, in certain cases significant modifications to the building's structural response can occur under seismic loading as a result of nonstructural interaction. These modifications of response generally occur when the nonstructural component has some degree of rigidity and /or mass that causes an unexpected stiffening effect on proportions of the structure. (For example, non-bearing masonry walls and fire walls, spandrels, shaft enclosures and stair framing particularly when intermediate

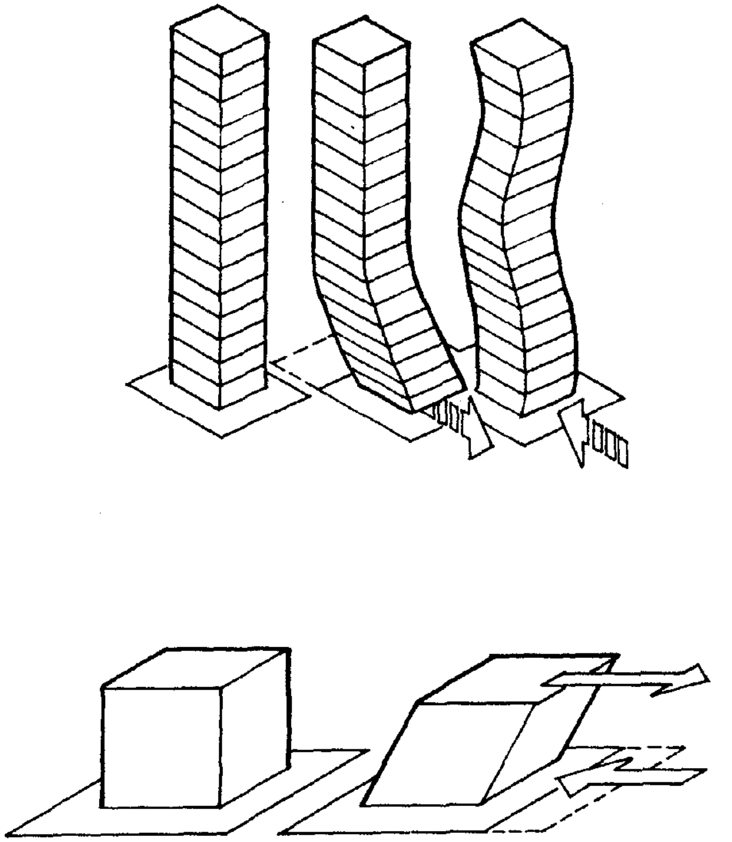


Torsion Effect on Building Plan
Figure 2.6



Oblique View of Vertical Torsion Effect

Figure 2.7



Drift diagram showing lateral displacement and resulting foreshortening

Figure 2.8

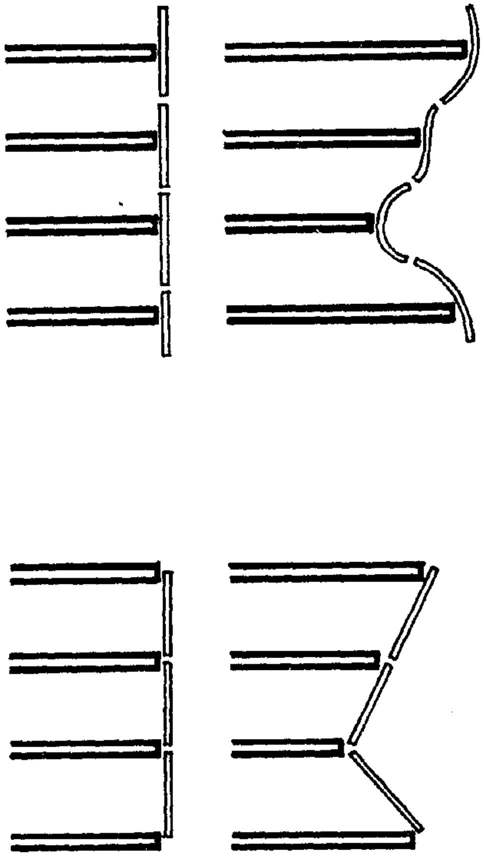
landings are tied to columns.)

2.4.2. The effect of the basic structure movement on the nonstructural components. This includes the effects of building drift, building torsion, displacement of cantilevered members and other factors.

2.5 BUILDING DRIFT

The horizontal displacement of basic structure can cause failure of the nonstructural components in a flexible multi-story building. All floors do not drift at the same rate or time, and this action causes a horizontal displacement between floors. Due to the action of the forces at the base of the structure, some floors of the building tend to move in one direction while floors above or below these tend to move in the opposite direction. (Figure 2.8).

The differential movement between floors can and does affect all full-floor height elements of a building, i.e. exterior curtain walls, interior partitions, window/ door frames etc. The exterior curtain wall that is anchored at each floor slab and is cantilevered both up and down can be severely affected. However, an exterior curtain wall that spans floor-to-floor in a simple span is seldom affected by cummulative action. (Figure 2.9).



Effect of Cantilevered Exterior Walls vs. Simple Span

Figure 2.9

2.6 BUILDING TORSION

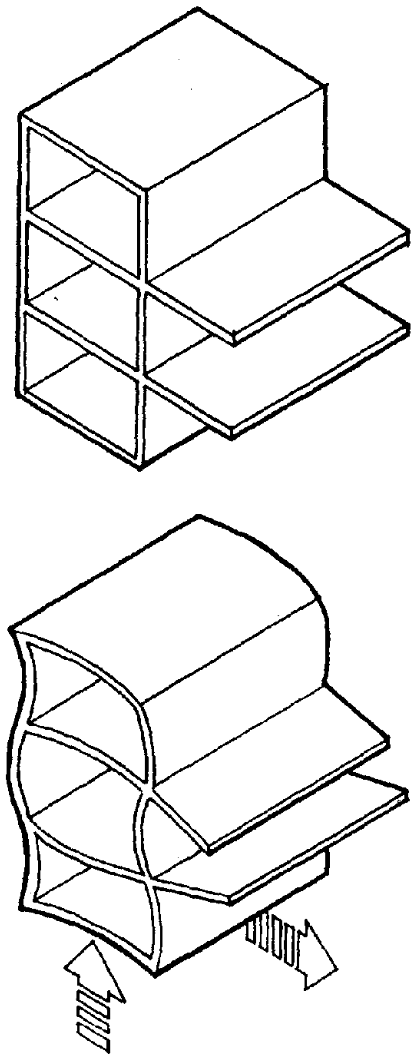
This action is usually brought about by the eccentric lateral resistance or mass of the basic structure, and causes the bulding to twist vertically. It should be noted that torsion in a building sometimes results from the stiffness of rigid or massive nonstructural components, such as, infill walls. The basic effects of torsion on components are quite similar to drift and will result in the same problems as those produced by drift.

2.7 DISPLACEMENT OF CANTILEVERED MEMBERS

The unrestrained end condition of cantilevered members can result in vertical displacement. This vertical displacement can be expected to be in opposite directions on adjacent floor. Since cantilever construction usually involves exterior walls these conditions can create hazard to life safety due to glass breakage and falling wall elements. (Figure 2.10).

2.8 OTHER FACTORS

Seismic forces are time processes in addition to force processes. As such, the various components of a building will not neccessarily move as a unit even within a single floor. All the above actions may commonly take place simultaneously and produce movement between the nonstructural and structural components that are quite complex. It is important that the designer understands that these forces and motions are transmitted to each component of the structure. Understanding the origins of the forces is vital in dealing with them in the design of nonstructural systems.



Displacement of Cantilevered Members

Figure 2.10

CHAPTER III

CONSIDERATIONS IN DESIGN

Earthquake damage to buildings is critcal because it disrupts vital funcitons; it represents economic loses for families, businesses, and most importantly, it threatens injury and death to the building occupants and people in the vicinity of the building.

The consideration in design should include the following:

1. The expected performance of the building as it affects life safety and property damage.

2. Proper integration of the various building components within the basic planning and design parameters, giving attention to appropriate life safety criteria.

3. Establishment of basic planning and design parameters (form, shape) that will best meet the performance criteria.

3.1 PERFORMANCE REQUIREMENTS

3.1.1 Protection of occupants within, and the public adjacent to, a building during an earthquake.

Hazards:

a. Danger of being hit by falling objects (free standing furniture, equipment, suspended ceilings, lighting fixtures, hanging objects, falling parapets, facade panels/elements, glass and other debris.

b. Danger of electric shock, fire and gas in case of failure in utility lines, and danger of flooding if water lines fail.

To protect people from such hazards, building components and systems must be designed with the potential danger in mind. Population densities of buildings also are included in these critical conditions.

3.1.2 Disaster control and Emergency Subsystems must remain operable after an earthquake.

In situations in which people will be unable to escape, they, and the building itself will be subjected to secondary hazards caused by earthquake damage. Among the most critical are:

a. Fire: can begin at various locations of the building during an earthquake, wherever fuel or electric lines rupture.

b. Electrical hazards: collapse of ceilings or partitions or dislocation of electrical appliances may leave wiring exposed which creates danger of shock, or results in sparkling which can lead to fire or explosion.

c. Flooding: broken water pipes or sanitary lines may lead to flooding of various parts of the building.

To prevent such secondary disaster, Control and Emergency systems such as the fire protection system should be designed to remain intact after the earthquake.

3.1.3 Occupants must be able to evacuate a building quickly and safely after an earthquake when it is safe to do so.

Hazards such as secondary disasters (explosions, fires, aftershocks) and other potential hazards to life safety should be mitigated through careful consideration in design. Among them are: Debris of falling objects may hinder safe passage in an exit corridor or on a stairway. A doorway blocked by collapsed objects may also slow egress, or the door itself may not open if the frame has been out of alignment. Elevators are vulnerable to damage in earthquakes. Darkness in a staircase makes it impossible to see missing a stairs and railings. Once outside, the evacuee also risks being struck by loosened debris falling from the builidng's exterior.

3.1.4 Rescue and Emergency workers must be able to enter the building immediately after an earthquake, encountering minimum interference and danger.

Rescue and Emergency Personnel need clear passage ways to remove casualities and must have operable Control and Emergency Subsystems operable in order to cope with fire and flooding, if they exist.

3.1.5 The building must be returned to useful service as quickly as possible.

The total "cost" of earthquakes is measured in two parts. First, cost as the direct consequences of bodily injury or death and property damage. Second, cost of social disruption and economic losses related to the inability of a city to function at full capacity after an earthquake (it includes the loss of business activity and revenues and the cost of having to divert many resources to repair and restore services and buildings). In order to minimize the "costs" above, the architects need to concentrate upon preventive design for these subsystems. Availibility of the following systems is critical in returning a building to service.

Sewage disposal and potable water supply: these subsystems are important in larger buildings and are especially critical in facilities, such as, hospitals. Vertical piping systems are particularly subject to damage due to horizontal forces and over-stressing of connections and joints.

Electric power: many important functions in all types of buildings are critically dependent upon the availability of electrical power, including lighting, communications, heating /cooling, vertical transportation etc.

Mechanical systems should be sufficiently operational to provide at least minimum environmental control, particularly in critical use facilities.

The relative importance of subsystems depends a great deal on factors such as building occupancy, size, location and climate. For example, maintenance of a communications system is more critical in a hospital or police station than in a residential building.

3.1.6 The building and personal property within the building should remain as secure as possible after the earthquake.

Danger of looting and vandalism: Broken windows and doors, and the collapse of any part of lower facades cause a problem in security. Maintaining the integrity of the exterior shell of the building and reducing property damage is important in maintaining security.

3.2 DESIGN STRATEGIES FOR COMPONENTS

Basically 2 design concepts can be utilized in the approach to nonstructural component design. First, the deformation approach, where components are designed with the ability to absorb stress through elastic response. It is very useful when the structure is rigid and the expected movements are small. Most non structural component materials will equal or exceed the basic structural material in allowable deformation. However, consideration must be given to component shapes and connection details, also brittle materials such as glass must be isolated properly to protect them.

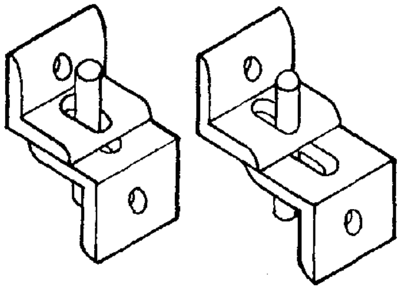
Second, the detached approach, where components are free from movement and thus avoid direct stress. This method extensively uses hinges, slip joints and resilient edge conditions. Consideration must be given to rotation and three dimensional movement in order to avoid any binding action that will negate the effective action of these details.

Other factors to consider in detailing with architectural components are the interworkings of one nonstructural component with another in addition to being able to effectively respond to the basic structural movement. A failure in one component may cause a failure in another or ultimately the entire system. For example, rigidly fastened duct-work or sprinklers penetrating a non-laterally braced suspended ceiling may move, tearing off sprinkler heads, duct-work, and/or ceiling parts. The failure of a masonry wall in a stair enclosure may cause the failure of the elevators, emergency power, as well as make the stairs ineffective for egress.

Importance of connections and fastenings also can not be neglected. Connections are the weakest links in seismic design, both in fastening of non-structural components to the structure and in the basic structural system. Often a connection is designed with structural consideration in its normal position and not in its extended position which is the critical condition when subjected to stress.

Inadequate tolerances for seismic movement will transmit impact load to adjacent parts. Tolerance for movement must be provided in addition to normal construction tolerances. Inadequate bearing on fastenings, such as in screw thread fastenings where the thread reduces the cross section, as well as bearing area of members. In light gauge material, for example: aluminum, excessive bearing pressure may cause screws to "pull out" --like the use of screws in extruded slots.

Improper detailing, in adjustable anchors, such as, the double angle clip is used often on curtain walls. Frequently, the lack of bearing may cause improper distribution of the loads. (Figure 3.1).



Connection of Double Clip Angles

Figure 3.1

Improper welding: welds should be considered as a brittle connection. Welds build up local stresses, particularly at end joints. These residual stresses can increase the chance of failure when the connection is stressed due to movement resulting seismic action. Light gauge welding often results in burn through, especially when a light gauge metal is connected to a heavy structural shape. Tack welds are not considered as structural welds due to their noneffectiveness. Welding light gauge galvanized metal may reduce the strength of the weld due to gas pockets in the weld bead. (Figure 3.2).

3.3 BASIC PLANNING, SEISMIC DESIGN AND BUILDING CONFIGURATION

Building configuration is important in seismic design in two basic ways. First, configuration influences or even determines the kind of resistance system that can be used and the extent to which they will be effective. Second, many failures of engineering detail which result in severe damage or collapse, originate as failures of configuration. That is, the configuration of the building either as a whole or in detail is such that seismic forces place intolerable stress on some structural member or connection causing failure.

3.4 CONFIGURATION DETERMINANTS

Configuration and the formal elements that create it originate in the building program, which can be summarized as a description of the activities that are housed in the building, the services, furniture and equipment they need, and the space that they require. Activities produce a demand for certain

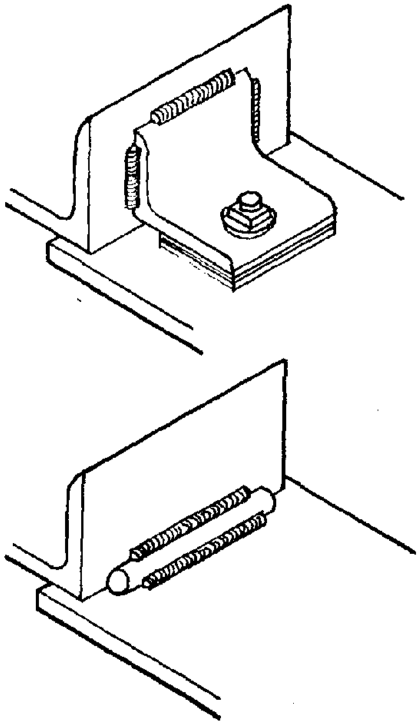


Figure 3.2

settings and kinds of space division connected by a circulation pattern; the combination of activity spaces and circulation lead to certain dimensions which generate a building configuration. But there are other determinants of configuration which sometimes may dominate: site, geology, size and geometry, urban design requirements and architectural stylistic concerns. The final configuration choice is the result of a decision-process which, by some means, balances these varying requirements and influences, and resolves conflicts into a single result.

3.5 CONFIGURATION PROBLEMS

In his article "Configuration and Seismic Design", Christopher Arnold stated that there are eleven problem areas in which configuration is a major issue, that can be identified. These problem areas can then further be divided into two parts:

The first type involves problems intrinsic to the geometry of the overall configuration of the building and is an aspect of the form of the building as a whole.

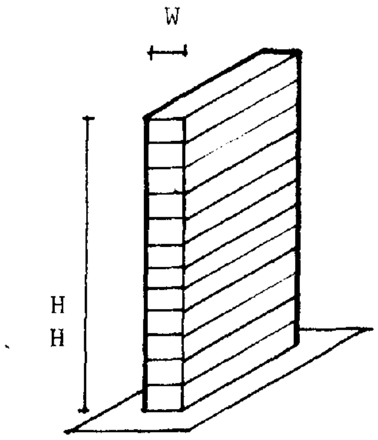
The second type is related to the nature, size and location of the resistant elements within the form.

It should be noted that these problems are not mutually exclusive: on the contrary they can be combined with one another, to the overall safety of the seismic design.

3.5.1 Here are building configurations which present intrinsic seismic problems.

3.5.1.1 Extreme Height/Width Ratio

This condition creates large overturning forces. D. Dorwick in Earthquake Resistant Design suggests limiting the height/width ratio to 3:1 or 4:1. In general, our tall buildings are not as slender as our recollection would have us believe. The World Trade Center towers, with a slenderness ratio of 6.8 to 1 are exceptional, and such unusual buildings can generally afford a very high level of structural design. The common office or apartment up to about 16 stories in height will have little difficulty meeting a slenderness ration of less than 4. Unusual sites may sometimes produce a high slenderness ratio, even though the building is not unusually high. (Figure 3.3).

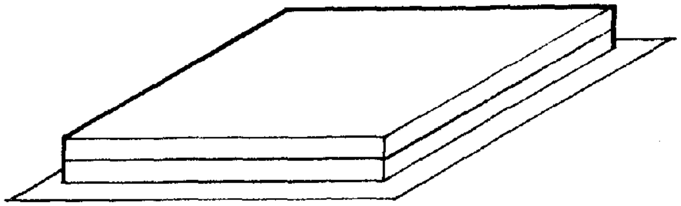


Extreme Height:Width Ratio
High Overturning Forces

Figure 3.3

3.5.1.2 Extreme Plan Area

When the plan becomes extremely large, even if it is a symmetrical, simple shape, the building can have trouble responding as one unit to earth vibration. If the building program requires a large area of building, the solution is to separate the building by, "seismic joints", into smaller buildings of simple form, and reduce the diaphragm forces. (Figure 3.4).



Extreme Plan Area
Build-up of Large Lateral Forces in Diaphragms

Figure 3.4

3.5.1.3 Extreme Elevation Length

This condition may also apply to the large area building, but it can also apply to a long narrow building such as a school, apartment, or hotel. Extreme length allows for the build-up of large shear forces which will seek out members such as stiff short columns or small stiff walls whether designed as shear walls or not. The solution consists of subdividing the building by seismic joints. (Figure 3.5).

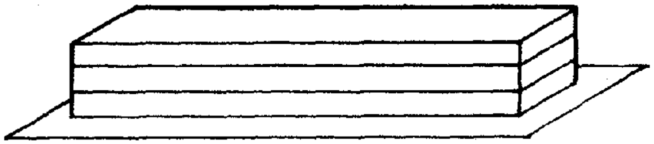
3.5.1.4 Setback

The setback produces a stress concentration at the notch. It also produces a large shear force which must be transfered through the diaphragm at the transition. The narrow tower, setback from a broad base, is a common building form, particularly for hospitals, hotels and offices, in which the broad base is often used as a parking garage. (Figure 3.6).

3.5.1.5 Re-Entrant Corner and Complex Forms

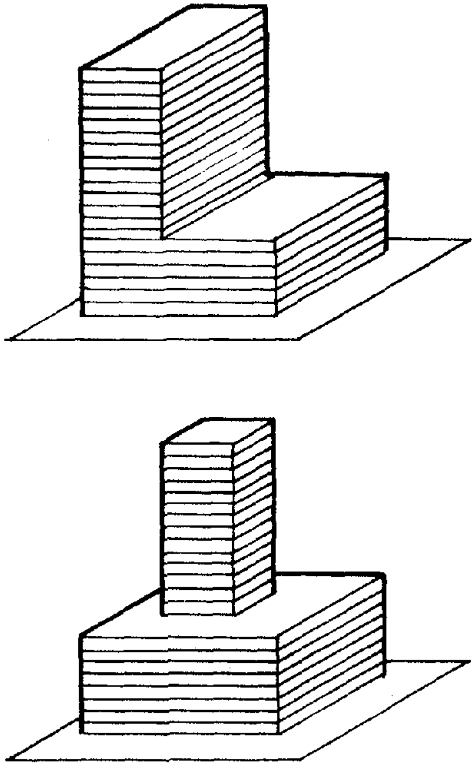
This is a huge family of forms, including L, T, U shapes and their combinations. Curved forms, and courtyard forms are also included. The re-entrant corner acts as a notch, producing a stress concentration; the form also tends to induce torsion since the free ends of the wings are less stiff than the connected ends. The stress concentration at the hinge produces high diaphragm forces --particularly if the wings are long-- but building circulation requirements always tend to place the elevator and staircase core at this location, so that often the diaphragm is perforated at the location where it needs maximum integrity.

The solution is to separate the building into simple forms, taking care to allow adequate separation to obviate pounding. Other solutions, depending on the size and proportion of the building, are to enclose the building in a shear-wall box, or to provide a stiff box at the point of convergence of the wings. Stress concentration at the notch can be relieved by an



Extreme Elevation Length
Build-up of Large Lateral Forces in Perimeter

Figure 3.5



Setback
Stress Concentration at Notch, Extreme
Shear Transfer to Diaphragm at Transition

Figure 3.6

architectural splay that allows a triangulated horizontal framing structure. (Figure 3.7).

3.5.2 Problems due to the size, nature, and location of resisting elements.

3.5.2.1 Discontinuous Shear Walls

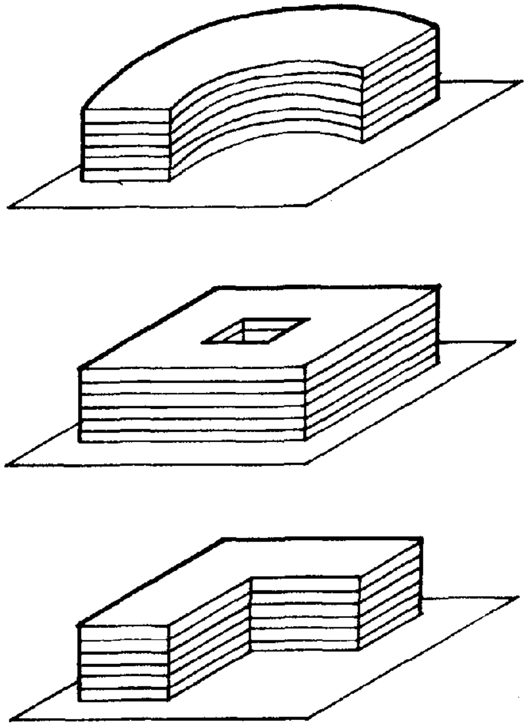
This condition results in a discontinuous load path through walls which are the major resistant elements --and hence most highly loaded-- of the entire structure. The condition may occur in a vertical or horizontal sense, of which the vertical is far more serious.

The solution to this condition is unequivocally to avoid it (at least in the vertical sense). There need be no penalty in design or planning if the structural system is related to the building program requirements at the outset of schematic design. (Figure 3.8).

3.5.2.2 Soft Stories

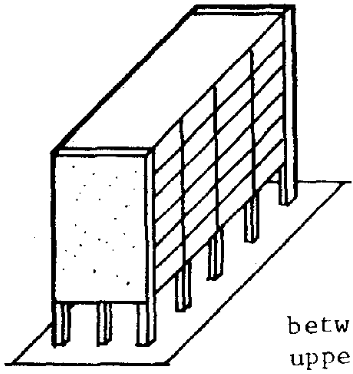
In its commonest form this is created by a programmatic requirement for a high first floor. The result is an abrupt change of stiffness at the transition from long flexible columns to the stiff superstructure, and a concentration of stress at the transition. When the soft story may occur at an upper floor, the condition is not as serious. (Figure 3.9).

Another form of soft story is caused by the discontinuity of veritcal support, created by the need for wide spans at the first floor level. Again, the result is an indirect load path, and stress concentration. Soft story also includes open first floors

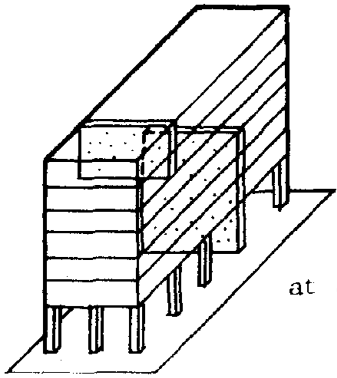


Re-Entrant Corner and Complex Forms
Torsion, and Stress concentration at Notch

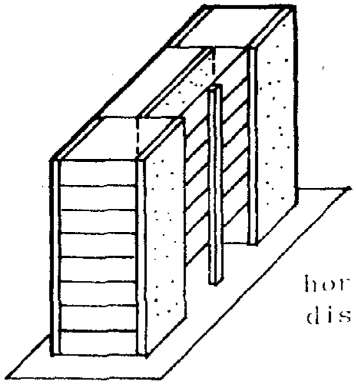
Figure 3.7



between first & upper floors



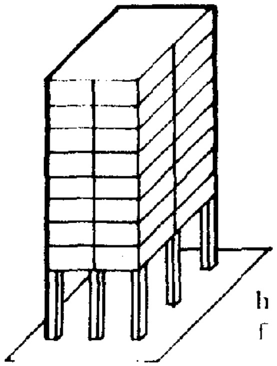
at any level



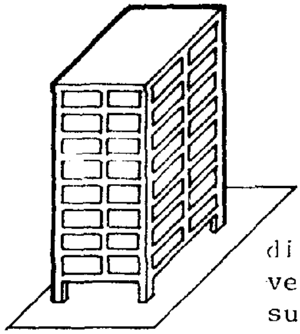
horizontal discontinuity

Discontinuous Shear Walls
Stress Concentration at Transition

Figure 3.8



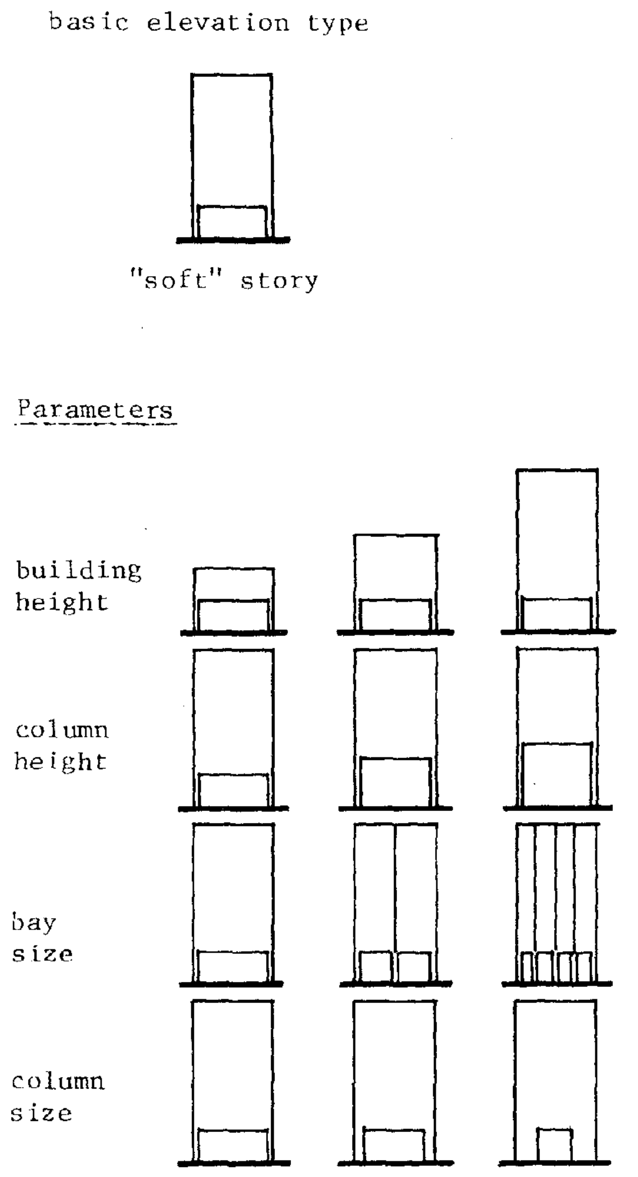
high first floor



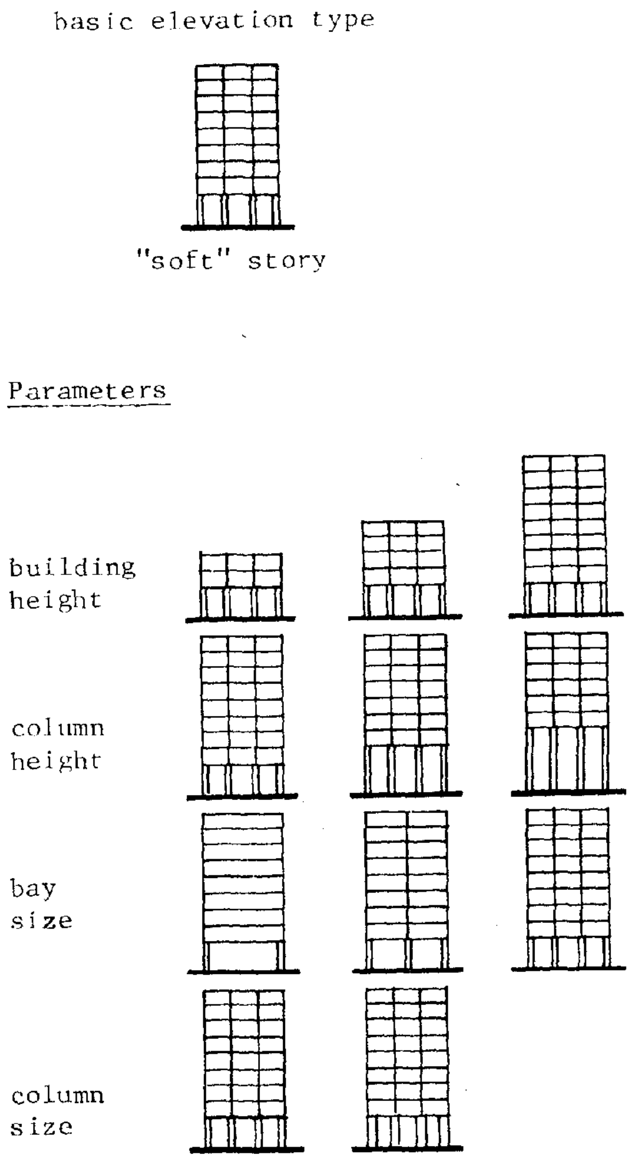
discontinuous vertical supports

Soft Stories
Stress Concentration at Transition

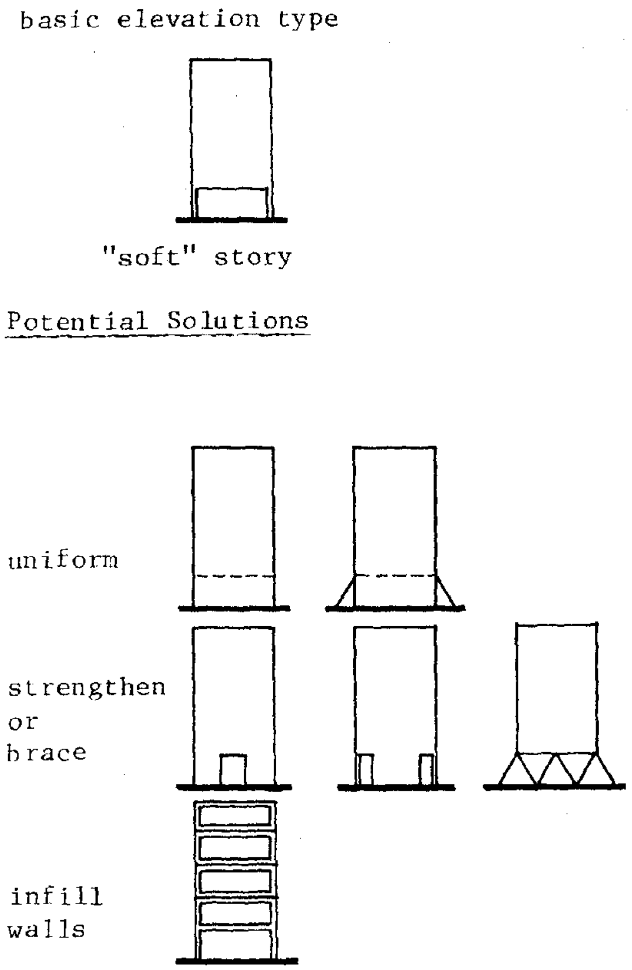
Figure 3.9



Non-Uniform Structural Systems Shear Walls
Figure 3.10 a

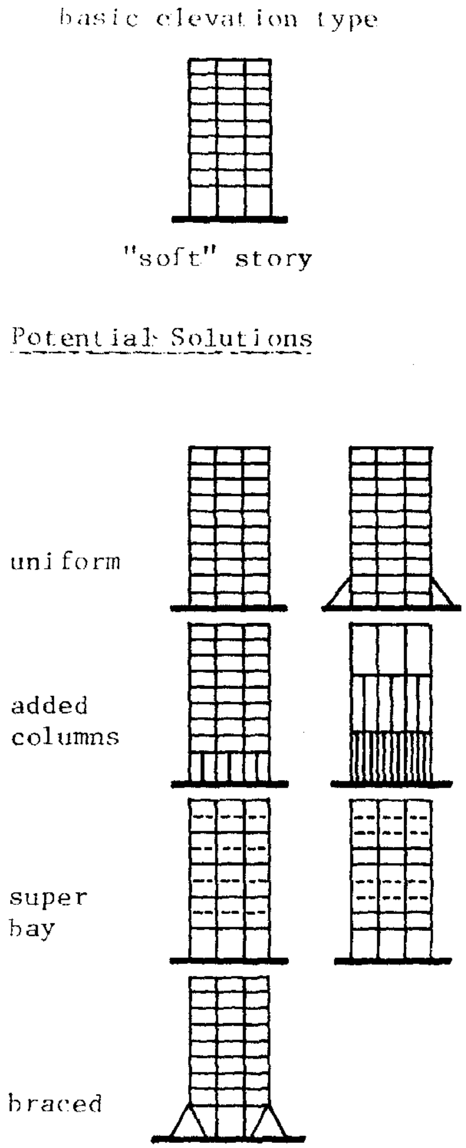


Non-Uniform Structural Systems Frames
Figure 3.10 b



Non-Uniform Structural Systems

Figure 3.10 c



Non-Uniform Structural Systems

Figure 3.10 d

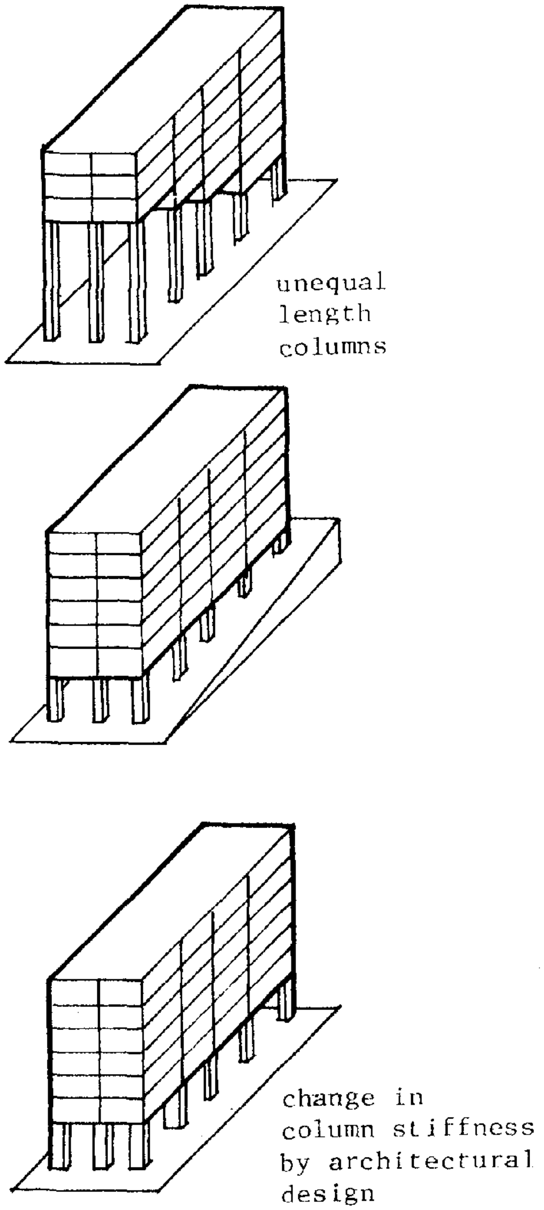
and building on stilts. (Figures 3.10 a, b, c, d).

3.5.2.3 Variations in Column Stiffness

This condition is created when columns of varying length, or of varying architectural design, form the supporting structure. Often a sloping site will result in a variation in first floor columns length; sometimes columns are deliberately exposed free-standing to 2 or 3 stories in length for architectural effect. The seismic forces will seek out and concentrate on the stiff elements; the result is that these may receive a disproportionate share of the loads and may fail. Two particular instances are worth comment. It is a common architectural design approach to place a horizontal wide window between columns to provide high level, or clerestory lighting. Its structural effect is counter intuitive, because the short column looks stronger than its neighbor: in fact its strength is the same, but it will receive far more load.

The other instance of note is that often the same kind of condition is created by an infill wall which, if of masonry will greatly stiffen the panel and leave a short stiff column, with the same detrimental result. Such an infill may be done without the structural engineer's knowledge, either as an architectural element or even as a later remodeling activity. (Figure 3.11).

The solution is to carefully equalize the stiffness of all columns. If long columns are desired for aesthetic effect they can be braced to reduce their effective length. If infill walls are required they must be detached from the columns so that inadvertent stiffening does not occur.



Variations in Column Stiffness
Stress Concentration at Stiff Columns

Figure 3.11

3.5.2.4 Weak Column, Strong Beam

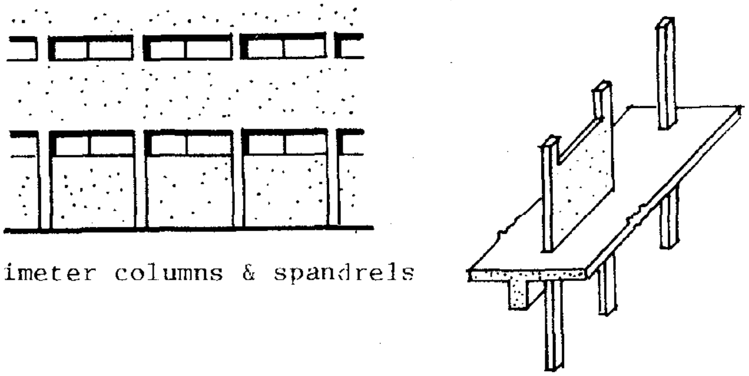
This is a special case of the conditions noted in "Variation in Column Stiffness" above in which a stiff (generally very short) column is rigidly attached or braced by a deep stiff beam. The characteristic condition is that of a deep exterior spandrel between widely spaced brittle columns. The result is that shear forces seek out the stiff columns and subject them to extreme stress. Often the condition is accompanied by conditions of unequal stiffness, as in the above case, and so a small number of columns will be subjected to extreme shear. (Figure 3.12).

The solution is to avoid deep structural spandrels, and to design non-structural spandrels in such a way that they are detached from adjoining columns and cannot act to stiffen them.

3.5.2.5 Variation in Perimeter Strength and Stiffness

This condition occurs in buildings in which there is wide variation in facade structure and materials between the elevations of the building. The reason for this variation is often programmatic: Two common examples are the store, with a glass front and solid masonry side and end walls, and the fire station with large vehicle openings at one facade and solid walls on the others. (Figure 3.13).

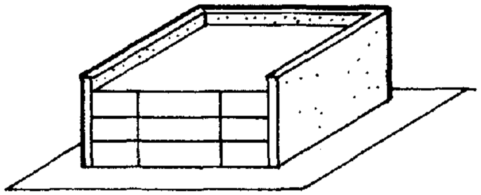
The solution is to equalize the strength and stiffness of the facades dynamically. This is not difficult to do, while still maintaining the desired architectural treatment. If the entire structure is designed as a frame, lightweight cladding can be transparent (glass) or opaque to suit the program requirements while maintaining uniformity of resistance.

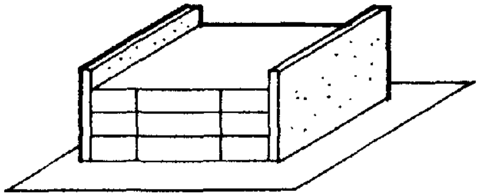

perimeter columns & spandrels

interior beams and wall

Weak Column, Strong Beam
Extreme Shear Stress in Stiffened Column

Figure 3.12


asymmetrical

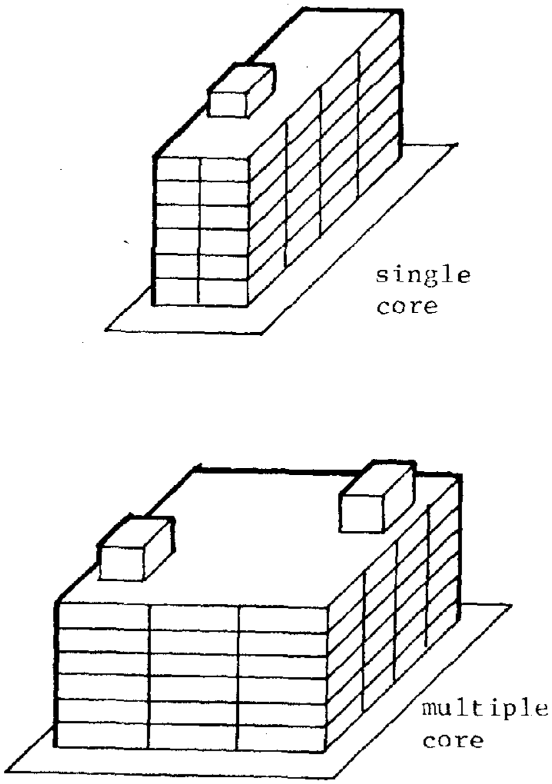

symmetrical

Variation in Perimeter Strength and Stiffness
Torsion and/or Stress Concentration at Transition

3.5.2.6 Asymmetrical Cores

Since the building core is often designed as a major resisting element, its location is critical. If the core is located asymmetrically in an otherwise symmetrical structure the result is to make the entire structure dynamically asymmetrical and to induce torsion. This condition is called "false symmetry" which means superficially the building appears symmetrical but dynamically it is not. Experience has shown that this condition creates major torsional problems: furthermore that relatively small design difference between multiple cores in a builidng may be enough to induce significant torsion. However, it is recognized that the core location has a major impact on the planning and circulation system of the building and it is unrealistic to insist that cores be located solely on seismic requirements. (Figure 3.14).

The solution is to recognize the dynamic conditions that will apply and design the entire resistance system of the building to counteract detrimental tendencies. As part of this strategy it may prove wise not to use the cores as a major resistant element at all: it should be remembered that a core is basically a hole in the diaphragm (which brings its own problems) and the enclosing walls do not necessarily have to be heavy structural walls.



Asymmetrical Core
Torsion

Figure 3.14

SUMMARY

Although seismic activity is not as frequent on the East Coast as it is on the West Coast, the most intense activity has occured on the East Coast. From the discussion of seismic cause and effect, it is apparent that extensive damage to structure and danger to the inhabitants can result from even minor seismic events if the seismic design issue is neglected in the design process.

Because of improvements in structural design methods, total collapse of a building is not probable unless extreme seismic activity occurs. However, danger to life safety and serious damage to the building are still possible even when the structure holds. When considering this possibility, it is obvious that concern in designing for earthquakes goes far beyond assuring the structural integrity of the building. The discussion of the performance of nonstructural architectural components indicates the level at which seismic design must be integrated into the total design.

The objective of this primer is to acquaint architects with the nature of seismic activity and how their designs may be affected by that activity. This knowledge can then be tested and put to practical use by exercises in the workbook. As a product of interactive sessions with East Coast architects, this workbook can "pull together" information relayed in the primer, and after design considerations pertinent to East Coast architects particularly, and to all architects in general.

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[1] Architect and Earthquakes, by Elmer E. Botsai

[2] Earthquake hazard and Risk, in Architects and Earthquakes: Research Needs, by S. Algermissen

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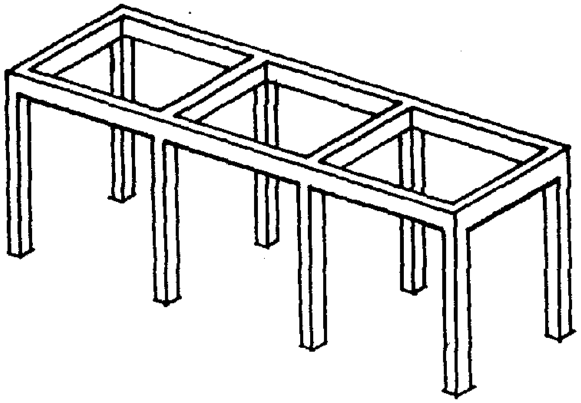
[7] Configuration and Seismic Design: A General Review, in U.S. National Conference on Earthquake Engineering, by Christopher Arnold

APPENDIX B

Workbook and Sketches from Interactive Sessions

EXERCISE ONE



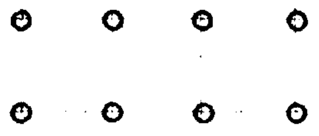
Given: This three-bay post and beam structure

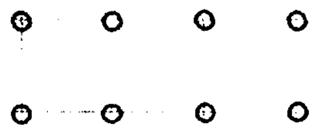
A. Add *one* bay so that the resulting configuration is as stable (or resistant to ground motion) as possible.

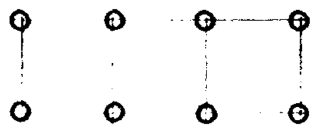
B. Add two bays to make the resulting configuration as stable as possible.

C. Add three bays to make the configuration more resistant to ground motion.

SOLUTIONS

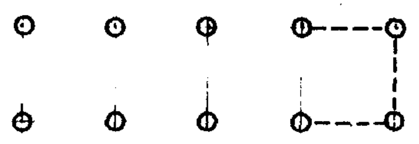


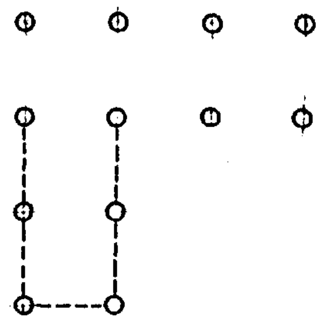


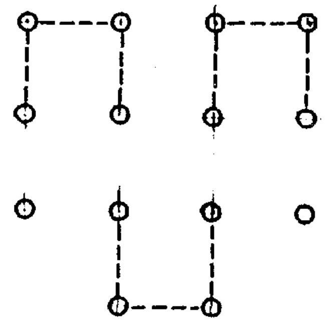


Place your own solutions below, and comment on them

SOLUTIONS

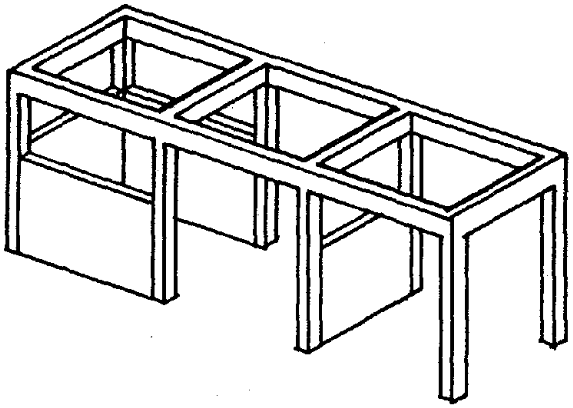






Comment on the solutions above

EXERCISE TWO



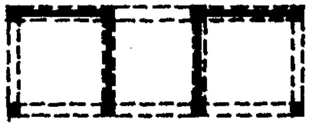
Given : This post and beam structure and four panels (of approximately the same density and allowable stress as the column material).

A. Draw an arrow in the direction where the structure would exhibit its greatest resistance to ground motion.

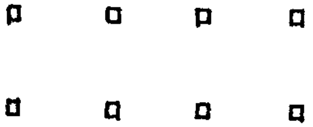
B. Indicate the most vulnerable columns.

C. Change the location of the panels to make the resulting structural- nonstructural combination more resistant to seismic loads.

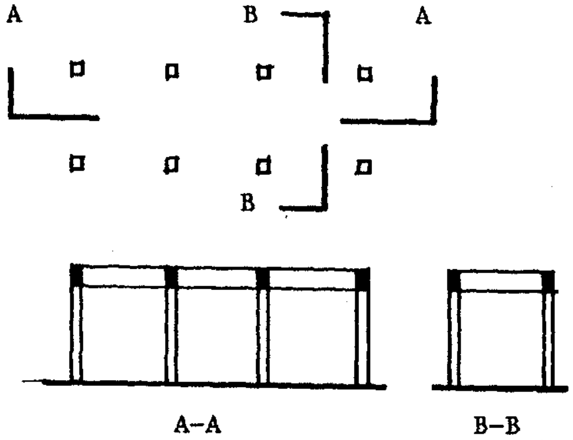
SOLUTIONS



Plan I
Comment on this solution in terms of part A of the exercise. (Draw arrows in direction of greater resistance and explain why).

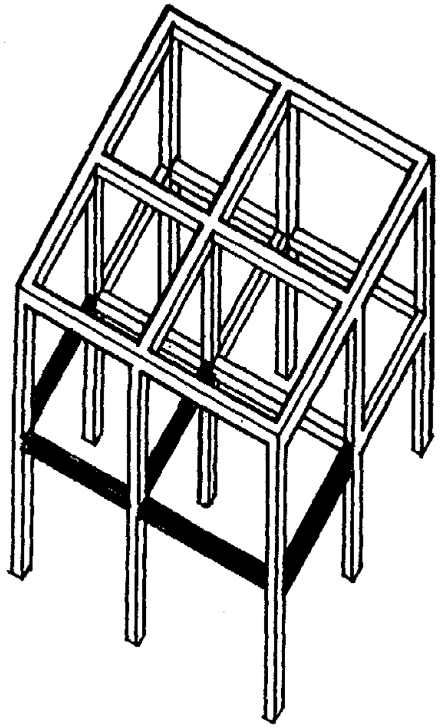


Plan II
Place 4 panels to make the structural-nonstructural combination resistant to ground motion, that is, minimize damage to columns (part C).
Answer A and B also.



Change design of panels and configuration, if desired, so that the result is the best possible combination of panels and columns in terms of seismic resistance.

EXERCISE THREE

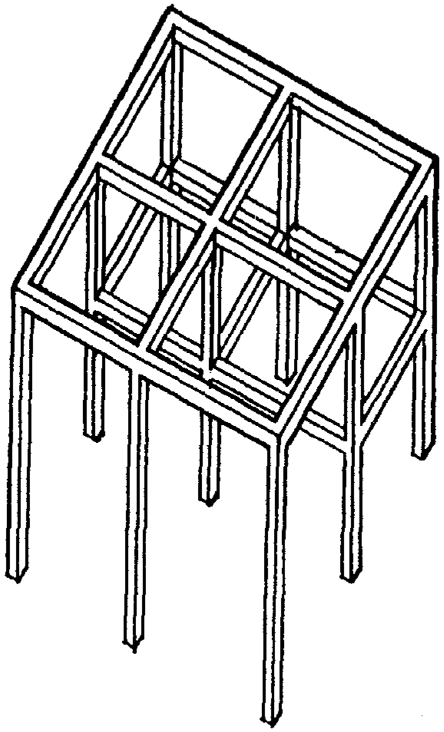


A. If the red beams are removed, what is the effect on columns a, b, and c, in terms of seismic resistance?

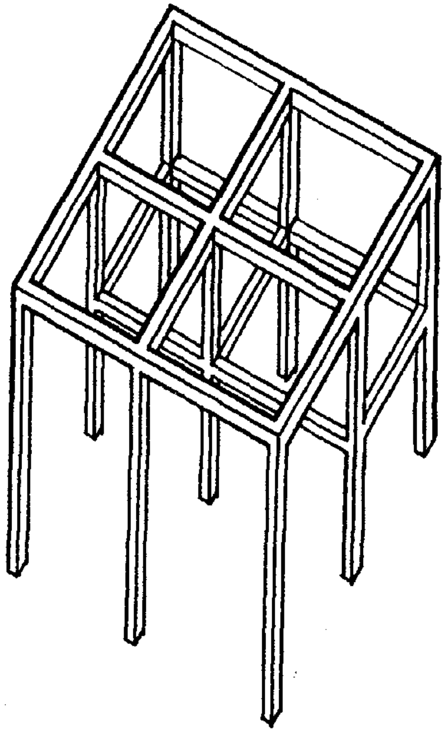
B. What would be the effect on the other columns.

C. Can you "re-balance" the distribution of seismic loading on the structure by adding elements (other than replacing the red beams where they were)?

SOLUTIONS

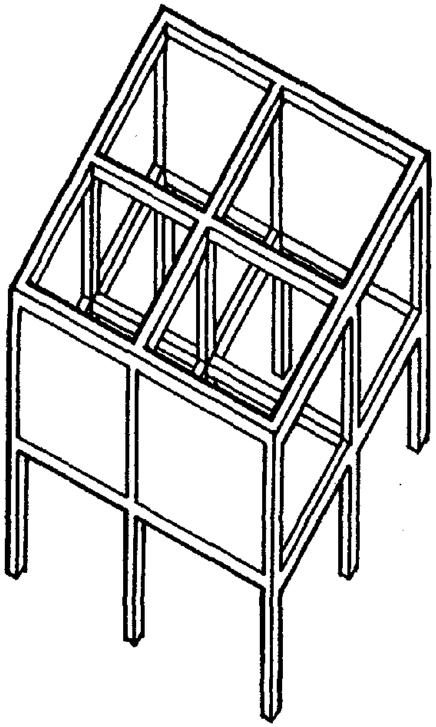


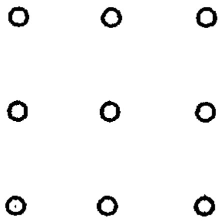
Responding to part C, use one story high column-to-column panels.



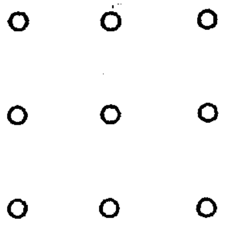
Responding to part C, use deepend beams and/or diagonal bracing.

EXERCISE FOUR





Second level plan



Ground level plan

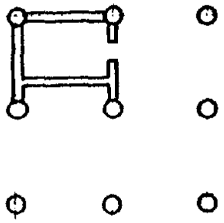
If yellow in-fill panels were concrete block:

A. Indicate which columns would receive greater shear forces under seismic loading, and why?

B. Where would evidence of their failure be observed?

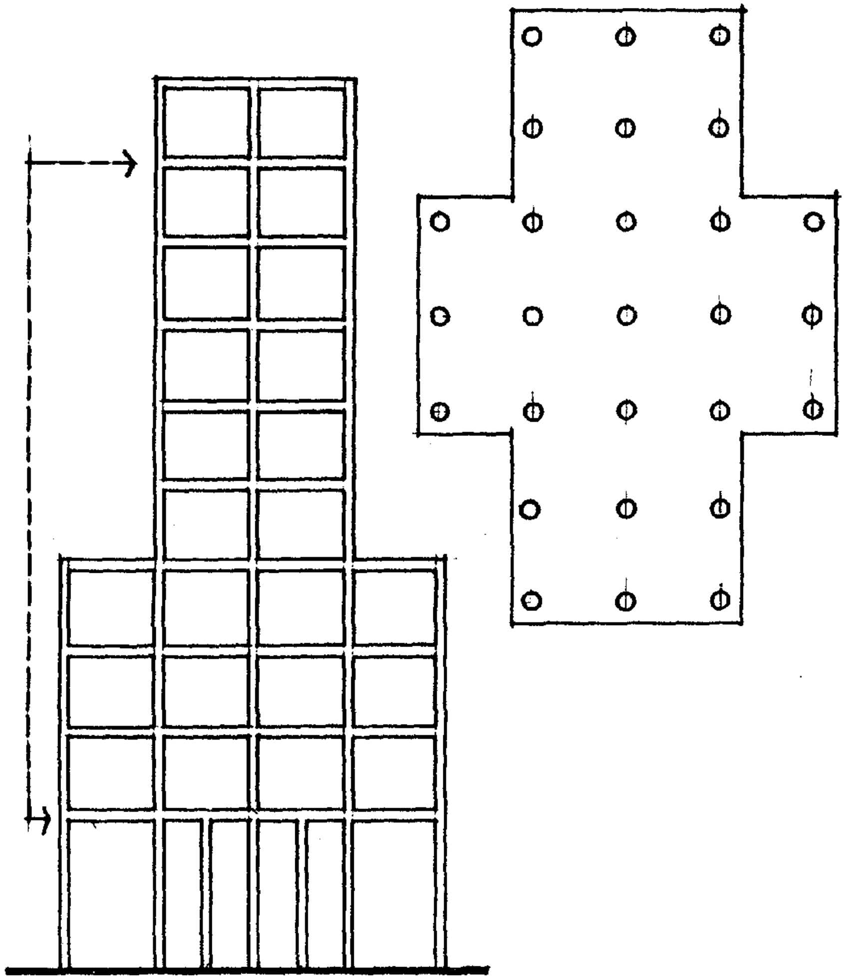
Assuming a metal frame with moment connection. Place 4 panels in the structure to form a shear wall which will give lateral resistance in one direction.

EXERCISE FIVE A



This core has the same plan on both levels.
Show where torsion will develop in the structure

EXERCISE FIVE B



a. Discuss trade-offs between this configuration and one which would have the same number of bays in a simple rectangular configuration. For example, one additional story of 2 x 6 bays.

b. Place continuous shear walls, core, and circulation path as if this were a rental office building. Bay size : 20 x 20 feet.

EXERCISE SIX

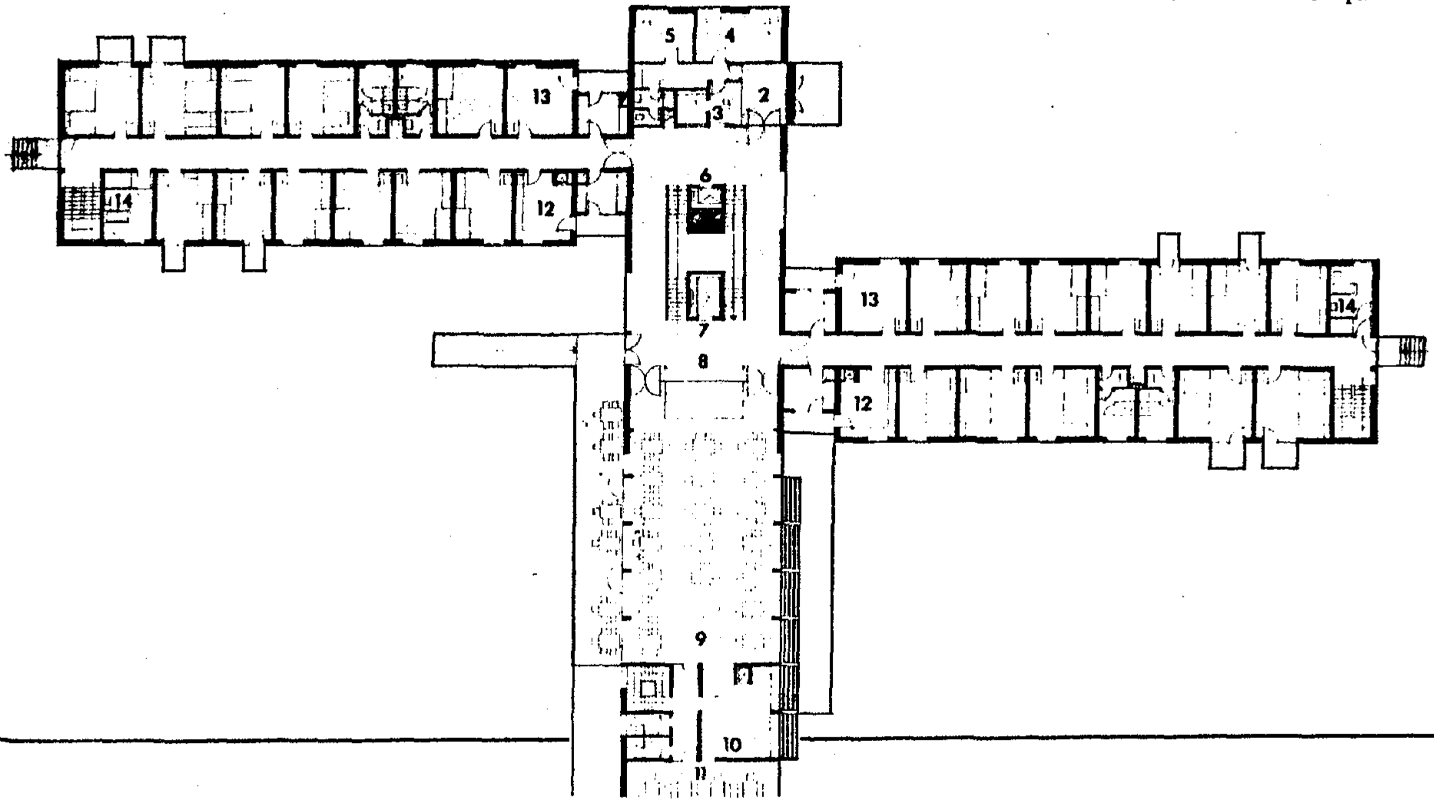
Elderly Housing

This is a three story brick bearing wall structure housing 97 single dwelling units. The overall dimensions are 136' by 224' and each wing is 38' by 102'.

a. Considering the infirmity of the residents, the elevations must remain functional after an earthquake. The likelihood of torsion in this plan reduces the probability of keeping the elevators functional. How can the plan be revised to make the elevators more resistant?

b. A fire in this type of occupancy is extremely dangerous to life safety. The torsional effect and difference in wall strength can damage electrical wiring and cause fire. What measures can be taken to reduce the possibility of fire after an earthquake?

c. Analyze the merits of this plan in terms of access and egress, control orientation, adjacencies, natural lighting, etc. and the disadvantages in terms of the probable response to ground shaking Alter the plan to optimize it for both seismic and non-seismic criteria.



EXERCISE SEVEN

Fire station

This fire station is designed for an urban area. Besides the fire fighting apparatus, the building also houses a communication center, offices for the fire chief and quarters for the fighters. The fire fighters' quarters consist of two stories. The hose-drying tower (which also supports the radio antenna) is 40' high.

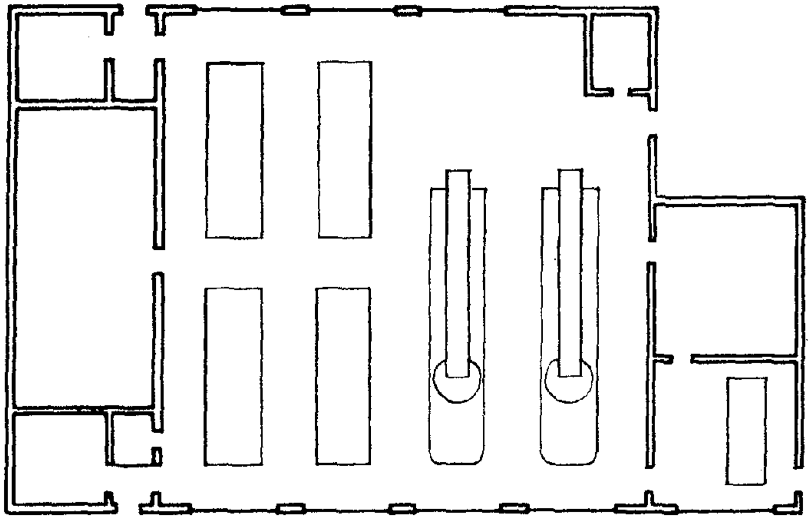
a. Because of the unequal stiffness of the perimeter of the structure, the columns could fail during an earthquake. Failure of the columns could damage or prevent removal of the equipment from the house. Can the design be altered to prevent this?

b. The communication center of the station must be operable at all times. How can the design provide the most resistance to failure of the watch room? Since the radio antenna is also integral to the operation of the fire station, how would you designate the optimal location and support for the antenna to avoid damage to it during seismic activity?

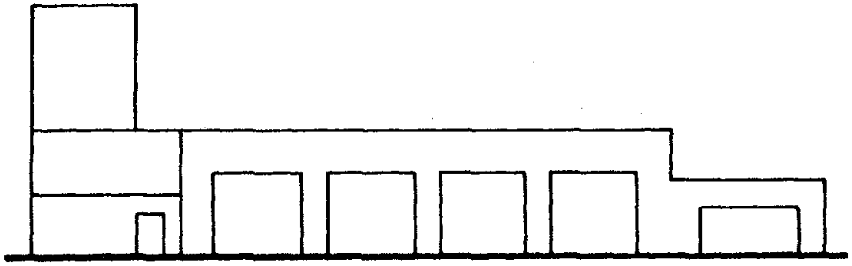
c. A hose tower is essential to the design. But the extreme height in relation to the rest of the structure could cause stress concentrations during an earthquake that could cause the tower to fail. The torsional stresses built-up in the tower could cause damage to other parts of the station; falling debris could injure fire fighters and equipment. Can the preliminary design make the tower more resistant?

EXERCISE SEVEN

plan



elevation



EXERCISE EIGHT

Hospital

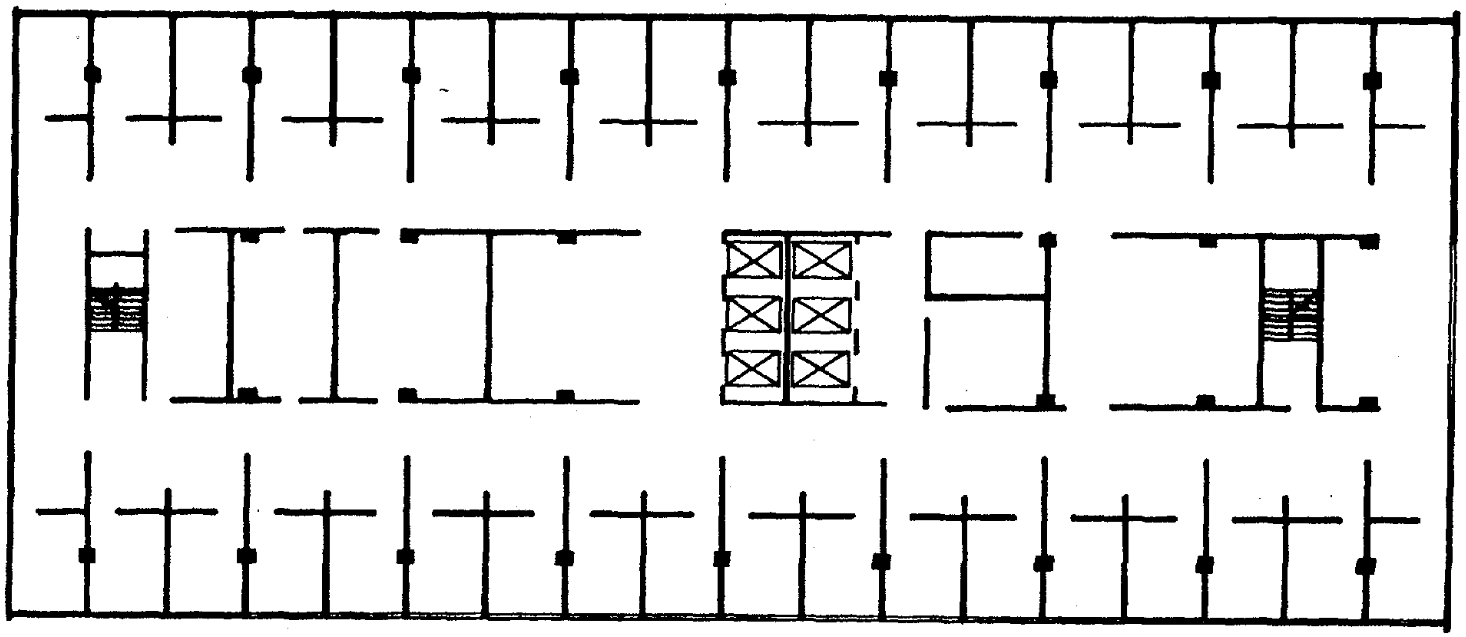
This plan is for a general hospital in an urban area. This 10 story design accomodates 600 patients. The overall dimensions are 82' by 166'.

a. Because of the extreme width/length and height/base ratio of this design, the building is vulnerable to the torsional effects of seismic activity. The support systems (heat, water, electricity) which are critical to the hospital's functioning can be damaged by this motion. Can you design a detail for one of these systems that would make it more resistant to failure? For example, a way of connecting a water pipe to the structure such that seismic activity would not tear it away.

b. The nature of this building type requires reduced noise levels and visually pleasant ceiling surfaces in the patients rooms. However, hung ceilings are very susceptible to earthquake damage. Can you provide an alternate ceiling system or design a detail to make the hung ceiling less likely to fail?

c. Hospitals contain numerous pieces of equipment that must be movable or are placed adjacent to the patient's bed. This equipment can be dislodged during an earthquake, causing injury to patients or discontinuity of care. One particularly dangerous element is the call button/monitoring system hung on the wall above the patient's head. Can you detail a connection to protect this console from damage during an earthquake?

EXERCISE EIGHT



typical plan

EXERCISE NINE

Elementary School

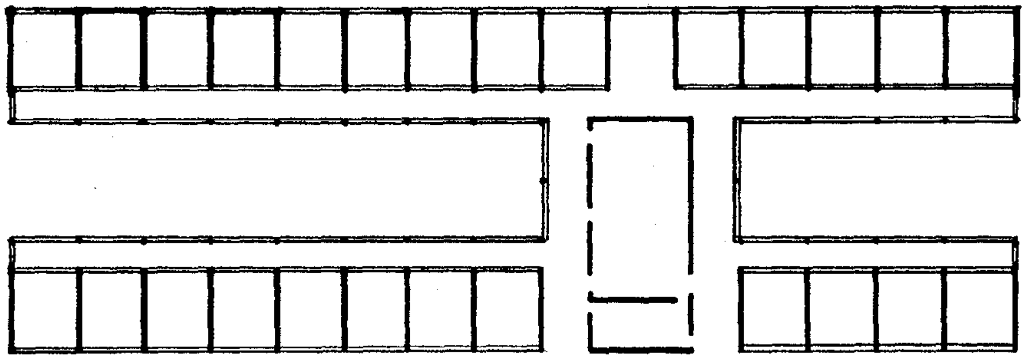
The elementary school is a one story brick bearing wall structure with glazed exterior classroom walls and corridors.

a. The large surface area of glazing allows natural lighting in the classrooms and corridors. In an earthquake, this glazing could fail causing injury to the students. How can you reconcile the benefits of the natural light and the safety of the students?

b. Tile floors in the school are easily maintained and sound absorbing, but the ground-shaking and torsion resulting from an earthquake can destroy this floor surface. Do the benefits of this floor system outweigh the vulnerability to damage?

c. One advantage to this plan type is the ease with which new classrooms may be added. But considering that the longer the classroom wings extend from the core of the building the more vulnerable they become to torsion, do expansion benefits compensate for the vulnerability of the structure?

plan



EXERCISE TEN

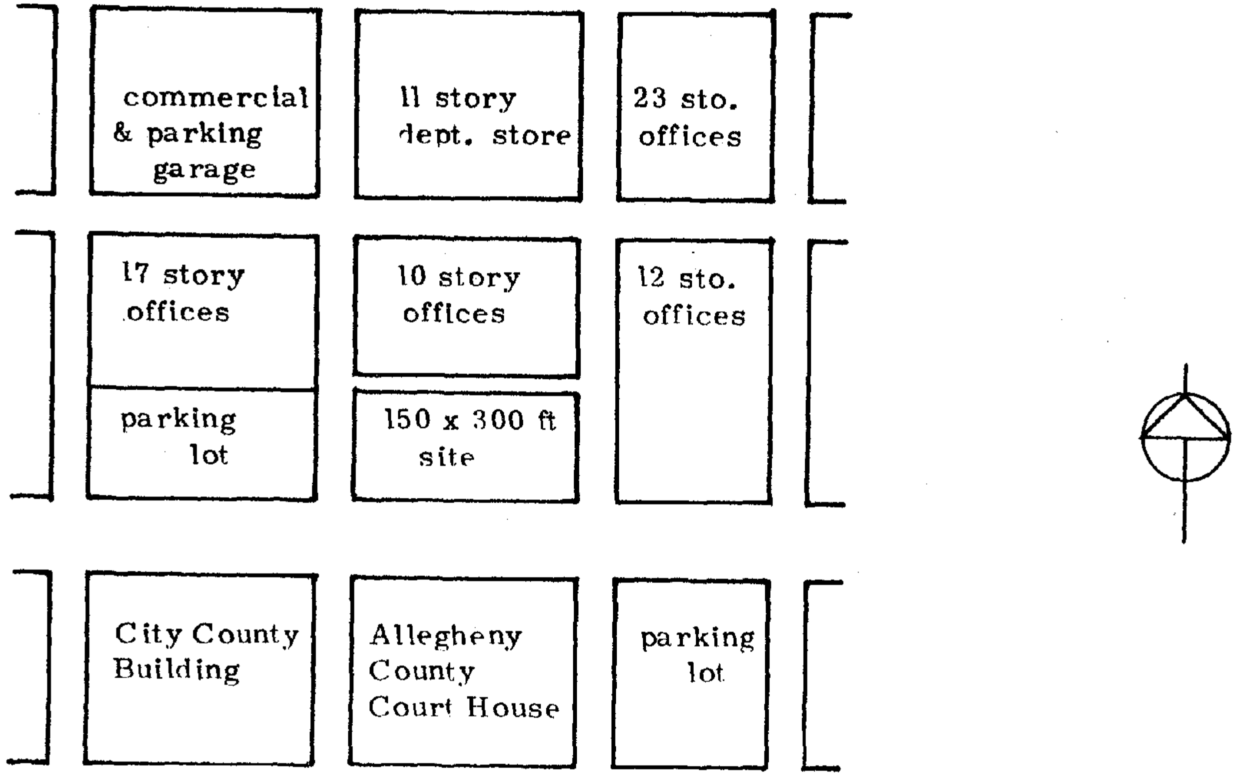
Given:

A site located at downtown Pittsburgh, surrounded by commercial, business and government office buildings. The site is bounded by one-way streets on both sides, an alley, and a major two-way street with a street car lane in the middle. Across this major street is the Allegheny Court House, a Richardsonian building.

Problem:

Design a 450,000 - 500,000 sqft office building which has a one or two story commercial base of approximately 20,000 sqft accessible from three sides of the site. (Alley only for service). Zoning requires maximum of 80% site coverage, 360 ft height limit. Discuss and sketch the choice of building configuration, structure, mechanical system location, access and egress (and some specific details -- exterior walls, material selection, etc.)

EXERCISE TEN



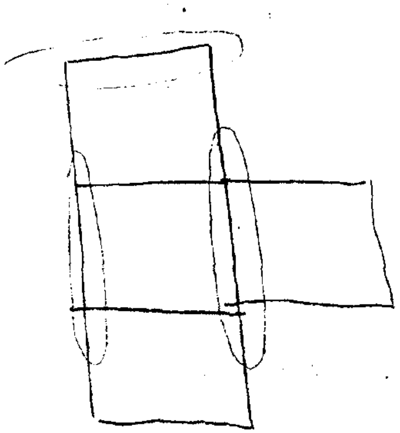
New York Architects

SOLUTIONS

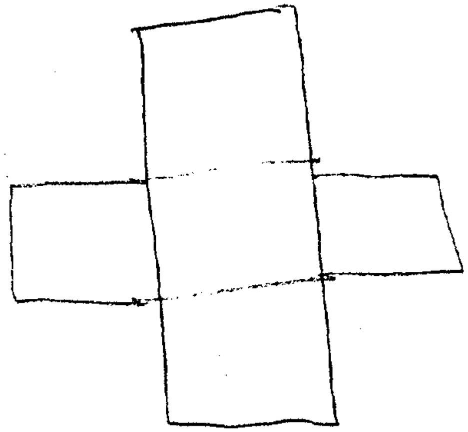
New York, Winder, Bachman, Rothenberg.

EXERCISE #1

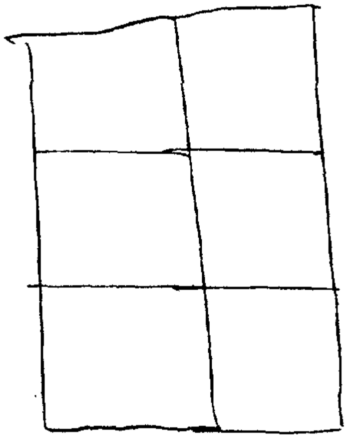
ADD 1 BAY



2 BAYS



3 BAYS



ANALYSIS REQUIRES
THAT 3 DIFFERENT
REGIONS BE CONSIDERED
AS "CRITICAL"

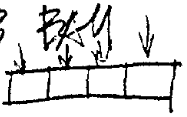
GOOD SYMETRY
PREFERRED DESIGN

SOLUTIONS

EXERCISE 1

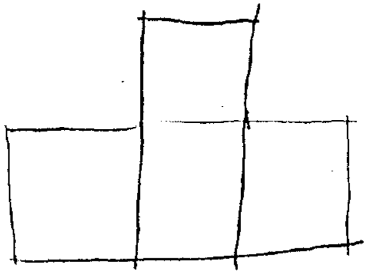
A. ADD ONE BAY

a. LINEAR



ISN'T AS STABLE

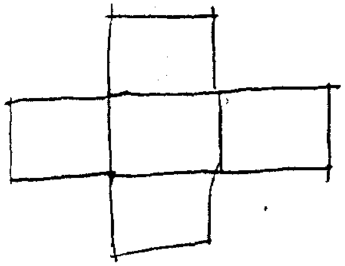
b. RESULTS IN UNBRACED ENDS



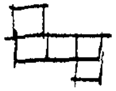
GOALS - ADDED BAYS TO BRACE STRUCTURE

B. ADD TWO BAYS

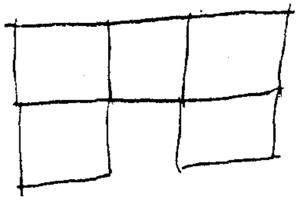
a. SYMMETRICAL -



b. SAME AS A.b (ABOVE)

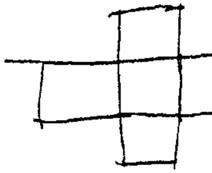


c. RESULTS IN MORE ENG TIME - NOT AS EASY TO REVIEW

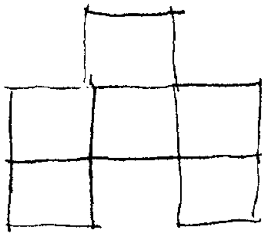


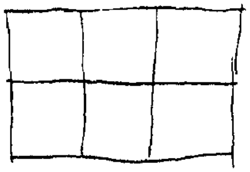
C. ADD 3 BAYS

a. SAME PROB. AS B.C. (ABOVE)



CAN'T BE ALTERED TO 3





NO ~~DESIGN~~ FLEXIBILITY

~~BEST~~ SOLUTION - MIN ENG. TIME

COMMENTS

EXERCISE #1

A. TESTS GRASP OF BUILDING ORIENTATION AND PLAN AS A CONSEQUENCE IN AN EARTHQUAKE.

B. SEEMS GEARED TOWARD STEEL OR DMRSF DESIGN, WOULD PROBABLY BE MASONRY CONSTRUCTION AS A REAL DESIGN.

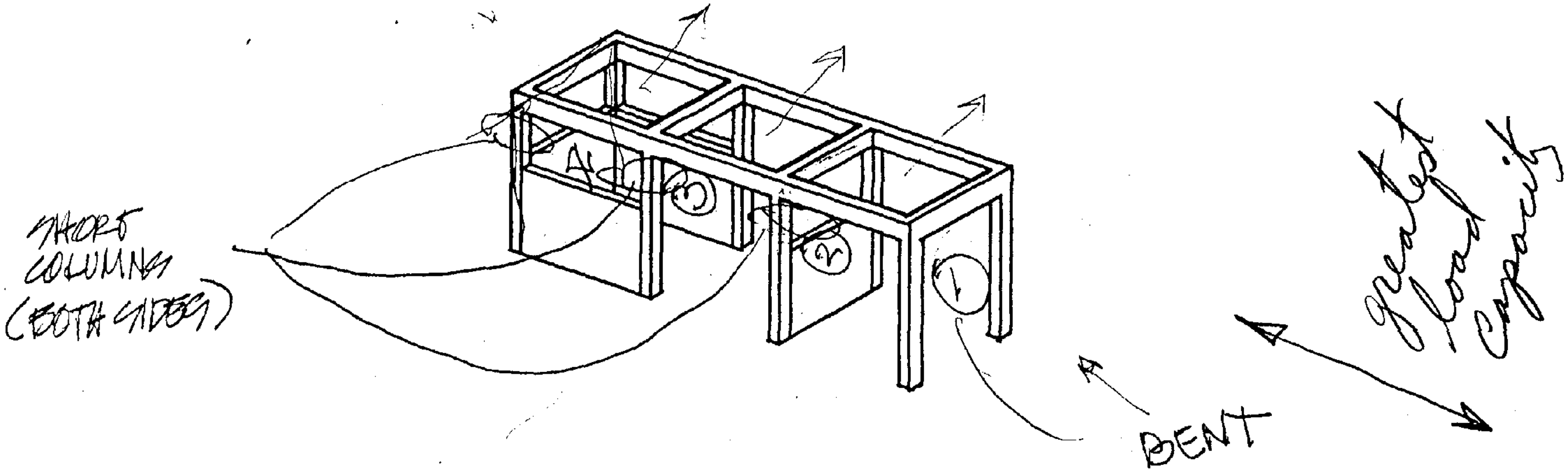
C. DIAPHRAGM CONSTRUCTION WOULD BE A GOOD SOLUTION TO THESE PLANS.

COMMENTS

EXERCISE 1

"BEST" ENGINEERING SOLUTIONS ARE/MAY BE THE SIMPLEST DESIGN SOLUTIONS— IE— SIMPLE, BASIC SHAPES ARE MOST EASILY ANALYZED, BUT MAY NOT BE "BEST" DESIGN ALTERNATIVES

EXERCISE TWO



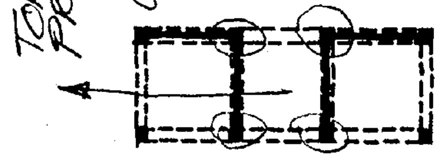
Given : This post and beam structure and four panels (of approximately the same density and allowable stress as the column material).

A. Draw an arrow in the direction where the structure would exhibit its greatest resistance to ground motion.

B. Indicate the most vulnerable columns.

C. Change the location of the panels to make the resulting structural- nonstructural combination more resistant to seismic loads.

SOLUTIONS



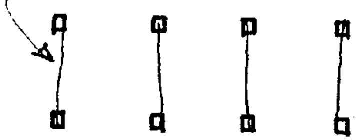
TORSION PROBLEMS

Cracking of walls

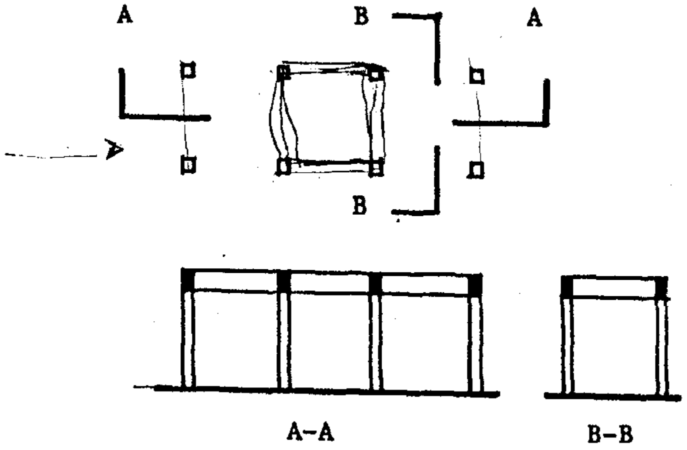
greatest resistance

good distribution of floor

still have differing column height & moment distribution



panels



Plan I
Comment on this solution in terms of part A of the exercise. (Draw arrows in direction of greater resistance and explain why).

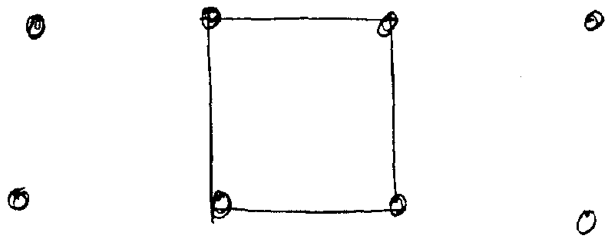
Plan II
Place 4 panels to make the structural-nonstructural combination resistant to ground motion, that is, minimize damage to columns (part C).
Answer A and B also.

Change design of panels and configuration, if desired, so that the result is the best possible combination of panels and columns in terms of seismic resistance.

SOLUTIONS

EXERCISE # 2   SOLUTIONS IN WORK BOOK

LOCATE PANELS TO REDUCE COLUMN DAMAGE



- POSSIBLE ANSWER
- COULD SEVERELY IMPACT THE BUILDING PROGRAM.
- CHOICE DEPENDS ON: FRAME MATERIAL
  SEISMIC ZONE
  PANEL RIGIDITY

COULD BE THAT DMRSF IS ADEQUATE ALONE UNDER F_E

W/o PANEL $K = 0.67$

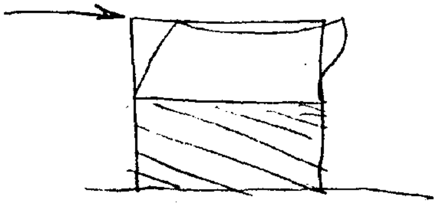
W/ PANEL $K = 1.0 - 1.3$

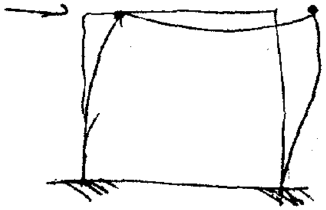
SOLUTIONS

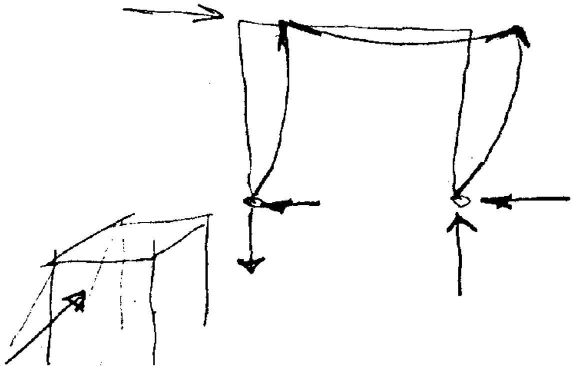
ASSUMPTIONS EXERCISE 2

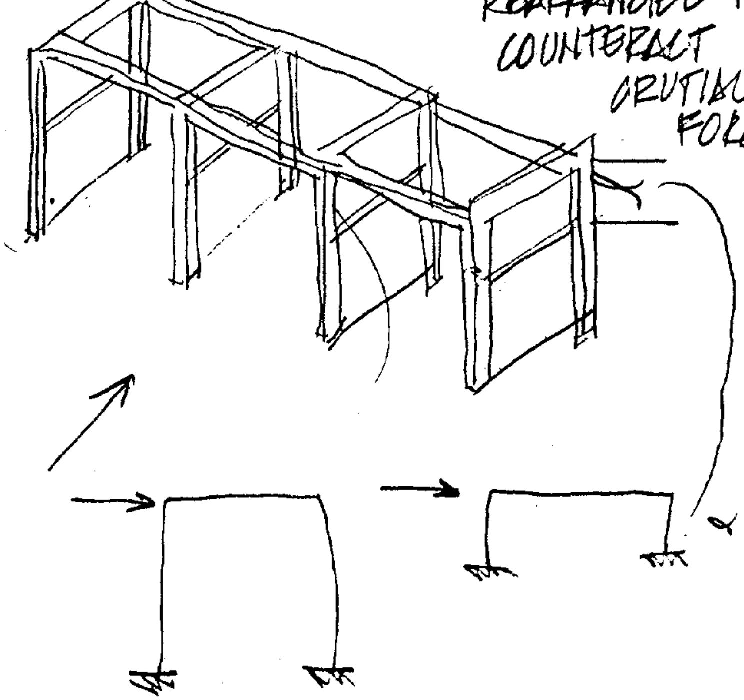
PAGE 1

1. WALLS ARE RIGID
2. ARE FASTENED RIGIDLY TO POSTS
3. MOMENT RESISTING CONNECTION AT. GROUND









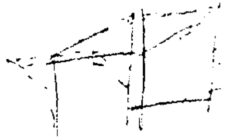
4 PANELS REARRANGED TO COUNTERACT CRUTIAL FORCES

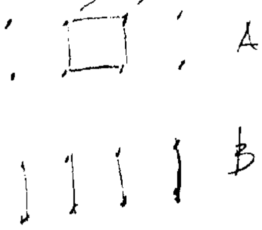
COMMENTS

EXERCISE 2

LAST QUESTION – SOLUTION PAGE – REARRANGEMT OF PANELS: FIXED

a. CHANGED TO FULL HEIGHT
BUT:
b. QUANDRY AS TO WHETHER SOLUTION A OR B RESISTS MORE FORCE ~~&~~ BRACES COLUMNS BETTER





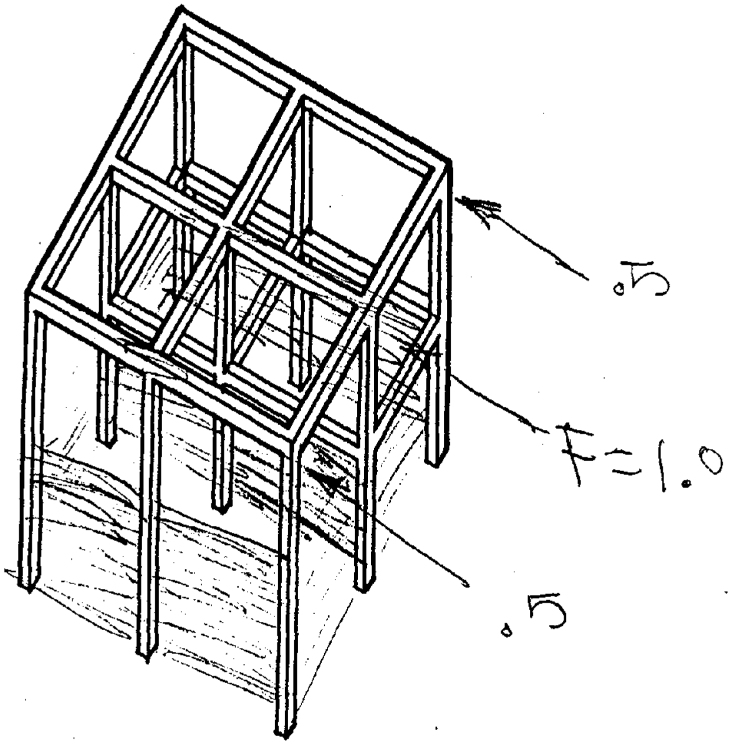
A – ALLOWS MOVEMT OF END COLUMNS FROM ↑ FORCE & → FORCE

B – REINFORCES ↑ MOVEMT BUT NOT → FORCE

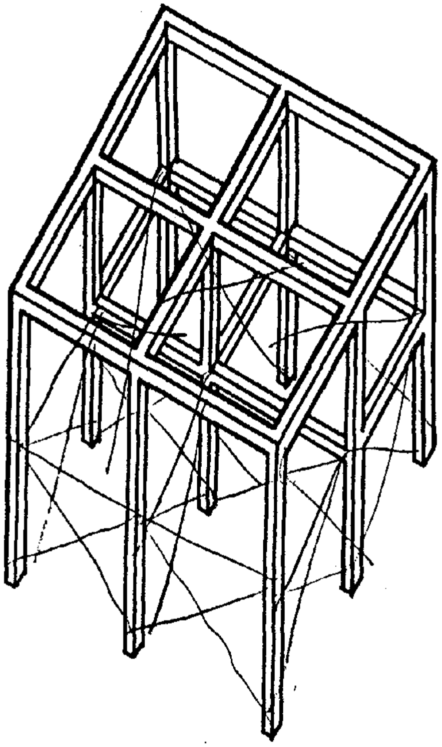
* NOT A QUESTION WHICH CAN BE READILY RESEARCHED AND MUST BE DEBATED OR ANALYZED ON A SPECIFIC BLDG. CASE

SOLUTIONS

Provide shear walls all around



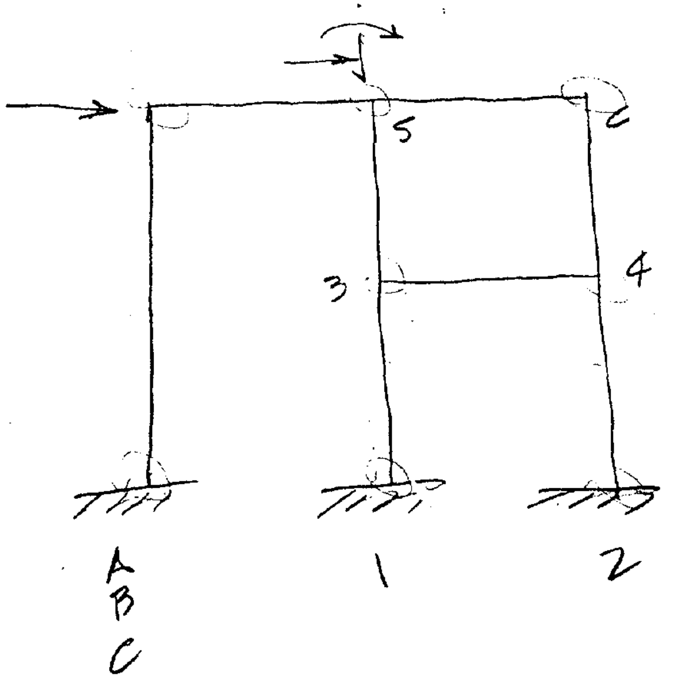
Responding to part C, use one story high column-to-column panels.



Responding to part C, use deepend beams and/or diagonal bracing.

COMMENTS

EXERCISE *THREE*



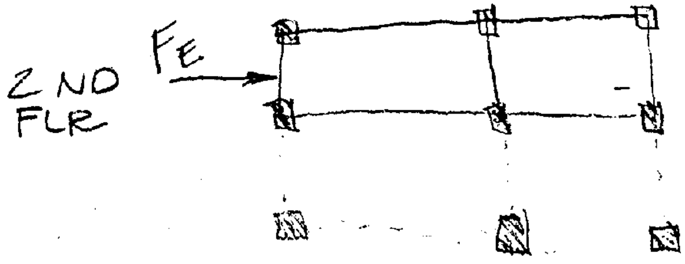
EFFECT ON ADJACENT COLUMNS

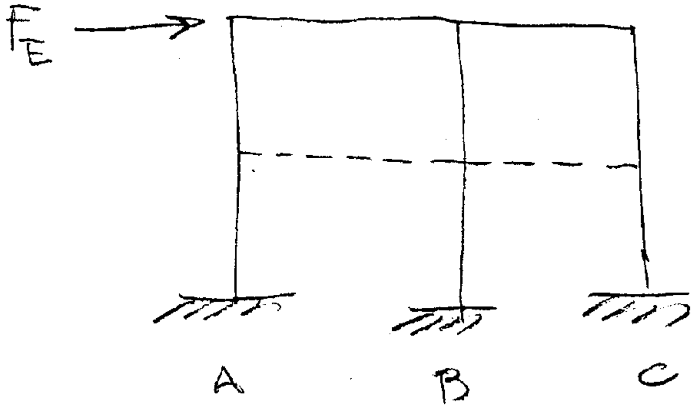
1. HIGHER BASE REACTION
   AT 1 & 2
2. MOMENTS INCREASE AT
   1 2 3 4 5 6
3. COLUMNS NEED MORE
   STEEL FOR STRENGTH
   . AND DUCTILITY 1, 2
   3, 4, 5, 6

ABC BUCKLING LENGTH
INCREASES.

COMMENTS

EXERCISE
3





1. INTRODUCE TORSION AS A DESIGN CONSIDERATION TO WHOLE STRUCTURE.
2. BUCKLING TENDENCY INCREASES ON ABC
3. EFFECT TO OTHER COLUMNS
   1. TORSION INCREASES
   2. BENDING MOMENT INCREASES.

REDESIGN FRAME:

FRAME CAN BE MODIFIED W/ CROSS BRACING OR PANELS AT ALL BAYS ON 1ST FLOOR TO PROVIDE "EQUAL" DISTRIBUTION TO ORIGINAL CASE.

COMMENTS

EXERCISE 3

PART C

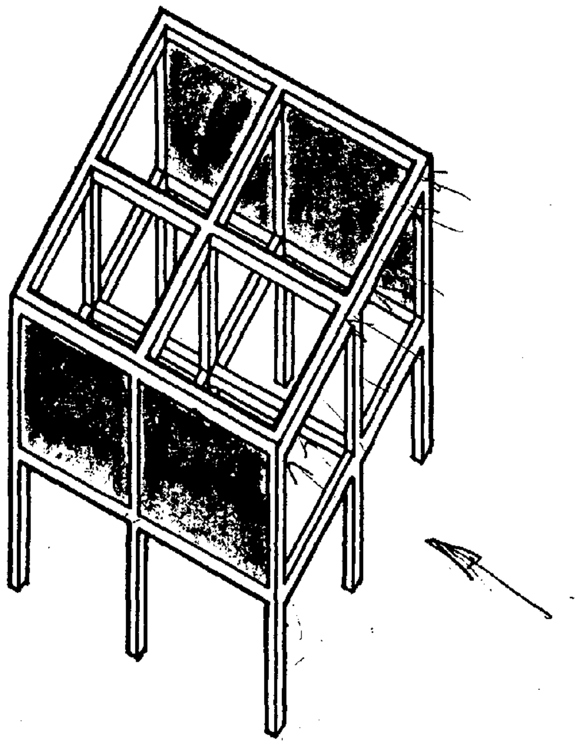
1. PROBLEMS W/ PROPOSED SOLUTION:

   a. CENTRAL COLUMNS (DUE TO REMOVAL OF BMS) ARE TAKING A HIGHER % OF FORCE W/O ADDL BRACING - THEN, NEW SOLUTION - ADD SHEAR WALLS AT ENTIRE 1st FL.

   b. PROBLEM AS IN PREVIOUS QUESTION OF UNBRACED SHORT UPPER COLUMNS

DEEPEND BEAMS NOT ADDRESSED.

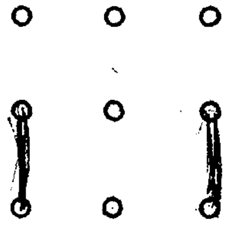
EXERCISE FOUR



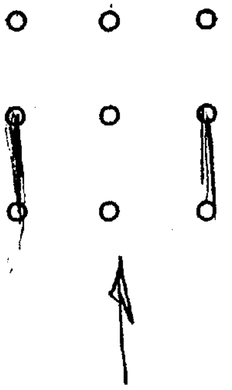
If yellow in-fill panels were concrete block:

A. Indicate which columns would receive greater shear forces under seismic loading, and why?

B. Where would evidence of their failure be observed?



Second level plan



Ground level plan

Assuming a metal frame with moment connection. Place 4 panels in the structure to form a shear wall which will give lateral resistance in one direction.

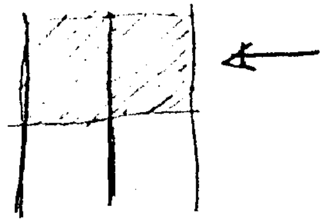
SOLUTIONS

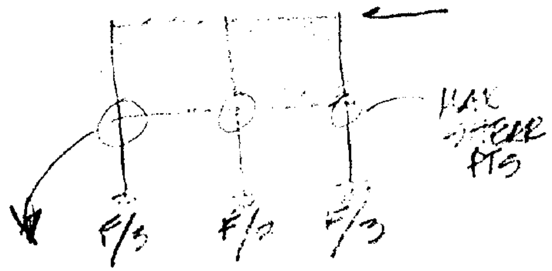
EXERCISE 4

ASSUMPTION: 1. FORCE IS IN DIRECT OF PANEL STRESS
2. COLUMN BASES ARE FIXED

SOLUTION—

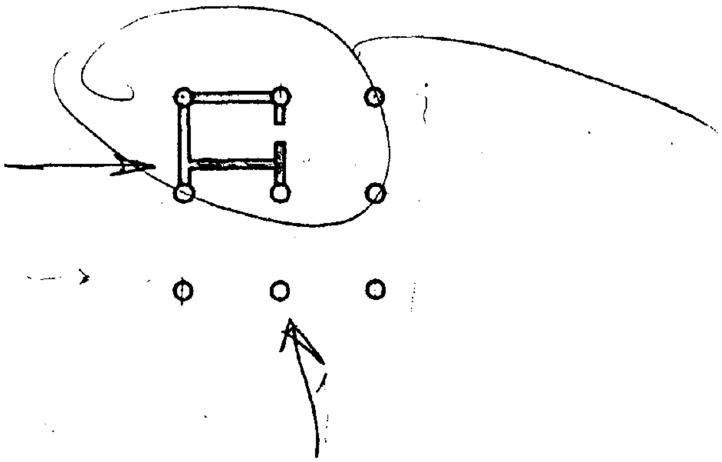
A COLUMNS BELOW SHEAR WALLS RECEIVE GREATER SHEAR FORCES





B. EVIDENCE OF FAILURE WOULD BE OBSERVED AT PTS. OF MAX. SHEAR AND/OR TOPS OF LOWER COLS.—BELOW PANELS

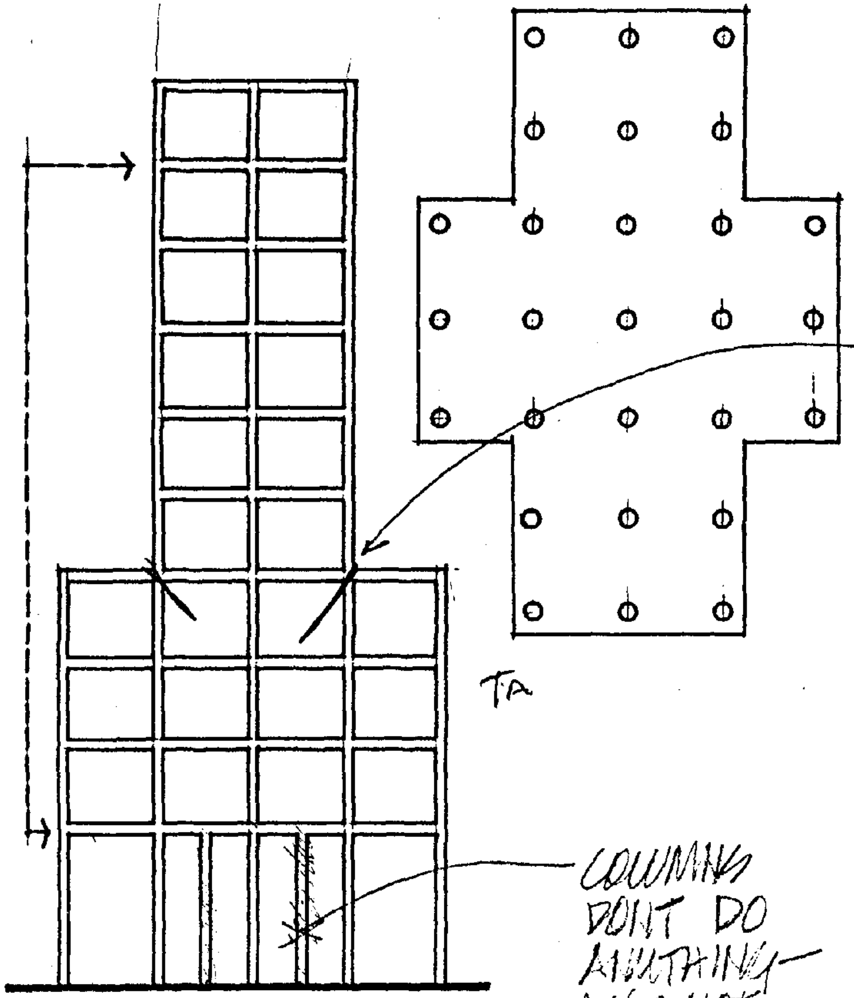
EXERCISE FIVE A



TORSION DEVELOPS AT CORE AS THIS IS THE ONLY ELEMENT CAPABLE OF RESISTING LOAD.

This core has the same plan on both levels.
Show where torsion will develop in the structure

EXERCISE FIVE B



W/ SETBACK

1. LOAD CONCENTRATIONS DEVELOP AT SET BACK
2. DISCONTINUITY IN BUILDING WHICH PRODUCES TWO DIFFERENT PERIODS.
3. CRACKING WILL OCCUR IN SKIN AT JOINT

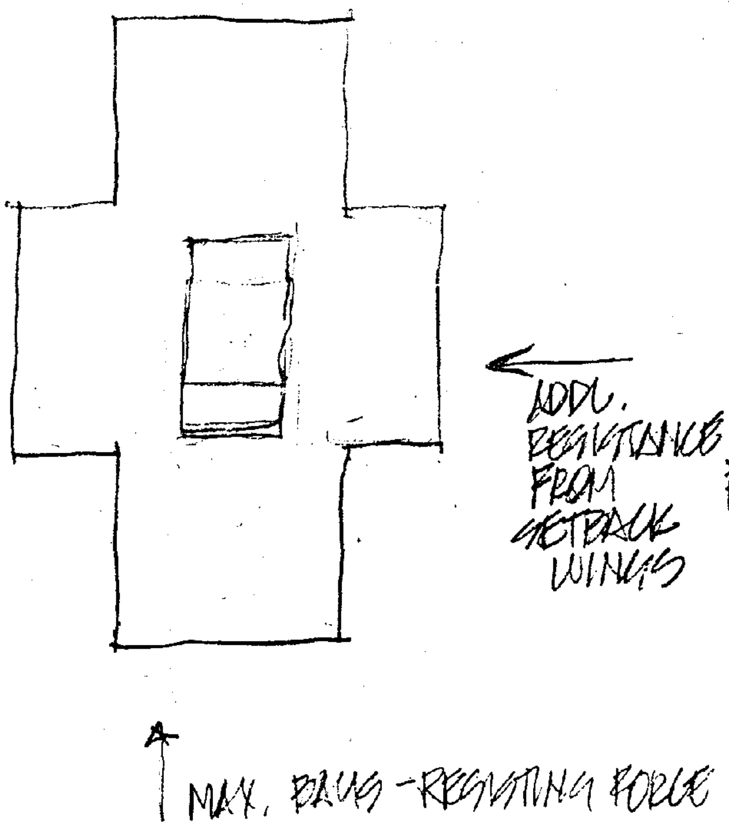
COLUMNS DON'T DO ANYTHING — ALSO NOT INDICATED ON PLAN

a. Discuss trade-offs between this configuration and one which would have the same number of bays in a simple rectangular configuration. For example, one additional story of 2 x 6 bays.

b. Place continuous shear walls, core, and circulation path as if this were a rental office building. Bay size : 20 x 20 feet.

SOLUTIONS

EXERCISE 5B



ASSUMPTION

FULL-STEEL W/ CONC. DECK ACTING AS DIAPHRAGM ~~[illegible]~~-ALL TIED TO CENTRAL CORE

CORE PLACED IN DIRECTION TO PROVIDE MAX RESISTANCE FOR THE FORCE WHICH THE BUILDING IS ~~LEAST~~ "DESIGNED" TO LEAST ACT UPON

CIRCULATION TAKES PLACE AROUND CORE

FLOOR RESISTANCE ALLOWS FOR MAX. EXTERNAL GLAZING & RENTAL

COMMENTS

FIVE B

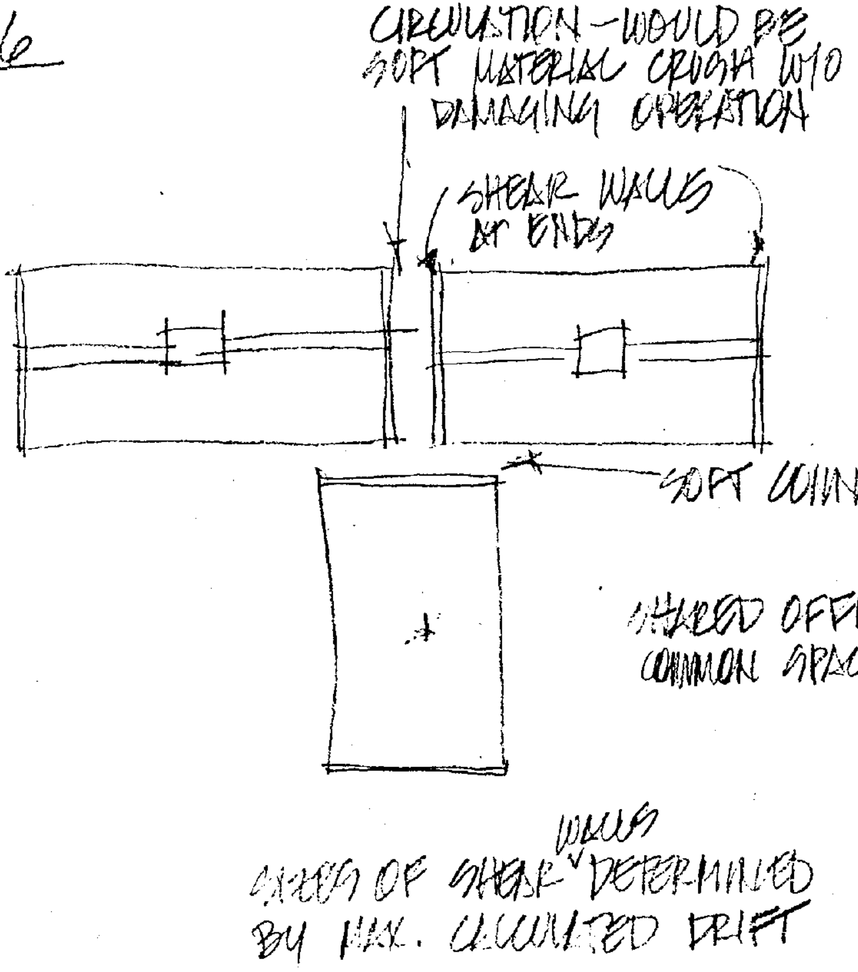
W/ SETBACK

1. 2 PERIODS OF MOTION IS PROBLEMATIC
2. STRESS CONCENTRATION AT SETBACK

W/O SET BACK

TALLER BLG. MEANS GREATER MOMENTS AT BASE
GREATER DRIFT
WOULD HAVE TO BE STIFFENED TO REDUCE
DISCOMFORT.

EXERCISE 6



1. TWO INDEPENDENT DWELLING UNITS
   a. MOVE INDEPENDENTLY
   b. EACH HAS OWN CORE - CENTRAL LOCATION TO ADD RESISTANCE
   c. SHARED SERVICES IN SEPARATE BUILDING

2. CIRCULATION / HAZARDS
   a. LONG CORRIDORS PER CORE
   b. ALL ADDL SERVICES IN NON-LOAD BEARING PARTITIONS AND HUNG CEILING (FIX INT. PARTITIONS TO FLOOR) TO PROVIDE INDEPENDENT MOVEMT - CONCRETE & PLASTERBD / CEILING / WIRING (LIGHTING, WIRING - ALL AT INTERNAL NON-SHEAR POSITIONS)

SOLUTIONS

EXERCISE 6

1. STRUCTURAL CONSIDERATIONS
   ELEVATOR COUNTERWEIGHTS SHOULD BE SECURED ON RIGID TRACKS

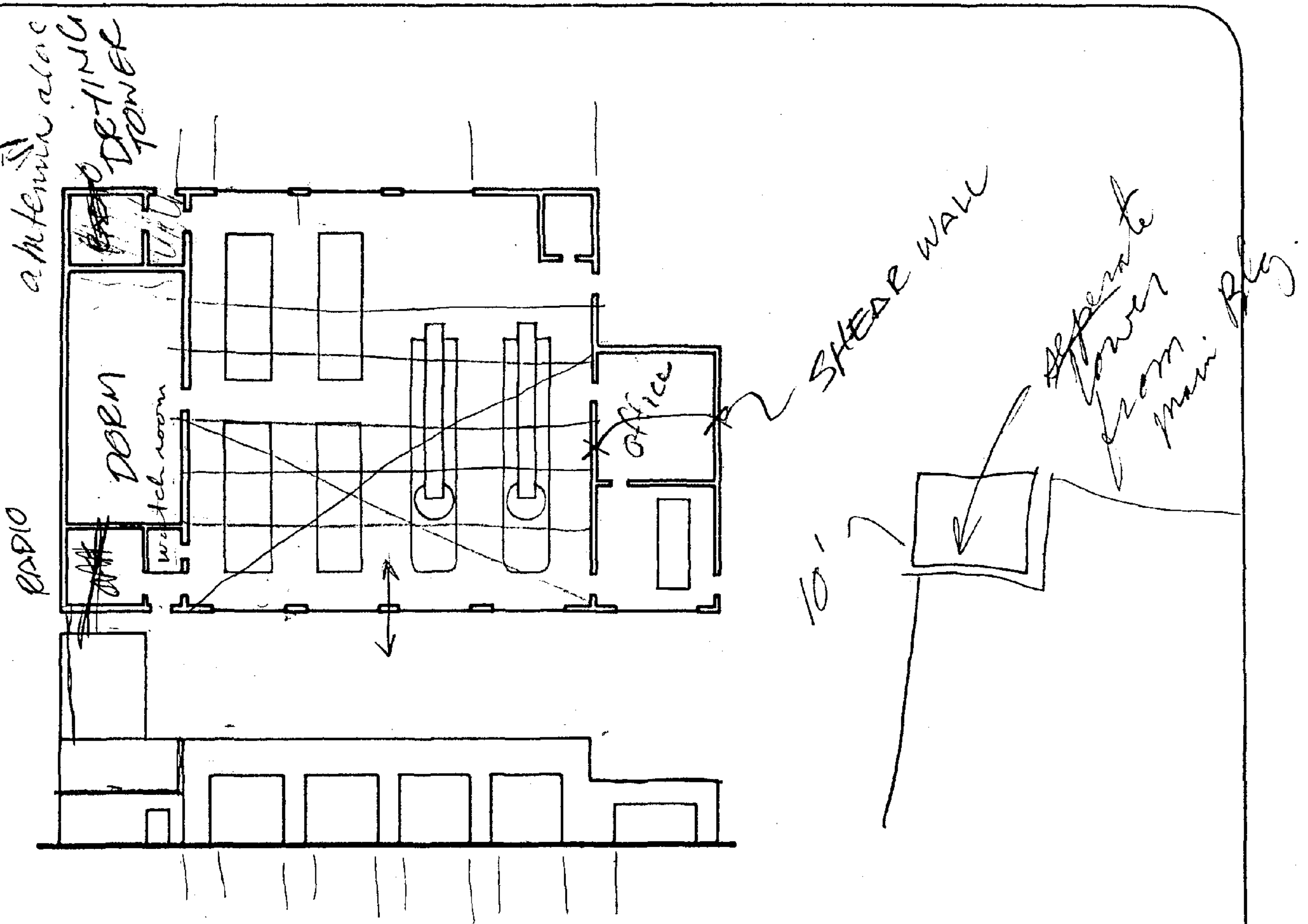
2. USE SHEARWALL & DIAPHRAGM CONSTRUCTION
   LIMIT DIAPHRAGM TO 2:1 L:W RATIO.
   PLAN WILL REQUIRE 2 INTERMEDIATE SHEAR WALLS TO MAKE DIAPHRAGM ACTIVE.

3. DETAIL SHEARWALLS TO REDUCE POUNDING @ SOFT JOINT. MOVE MECHANICAL SYSTEMS TO AN AREA WHERE THEY ARE ISOLATED FROM "OFFICIAL" STRUCTURE, OR DELICATE NON-STRUCTURE.

EXERCISE SEVEN

[illegible]

CEILING IS
A. OPEN WEB JOISTS
B. CONC. SLAB
C. INDIV. GARAGE DOORS



SOLUTIONS

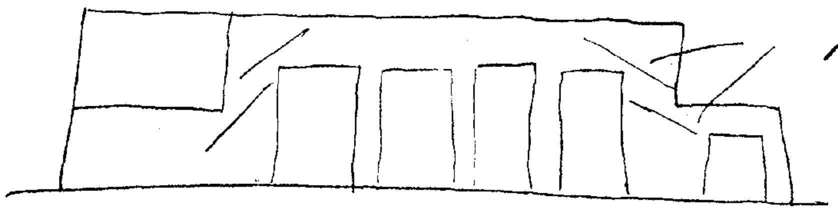
EXERCISE #7

ROOF - LIGHT WEIGHT STEEL JOISTS. W/ X BRACING
WALL MASONRY

TOWER SHOULD BE ISOLATED
PROBABLY WILL BE STEEL W/ SECONDARY
X BRACING. SEPERATE FOUNDATION.

GARAGE DOOR SUPPORTED BY REINFORCED BEAM
THIS BEAM IS TIED INTO ROOF DIAPHRAGM BY
CROSS BRACING.

FRONT & REAR OF BUILDING SHOULD BE
DETAILED TO MINIMIZE CRACKING OF FRAME



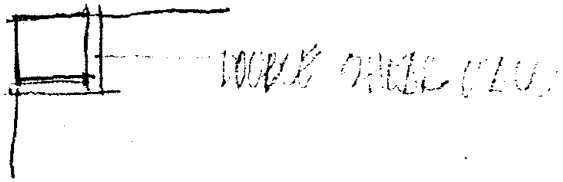
AREAS OF STRESS
RAISERS REQUIRING
TENSION STEEL

COMMENTS

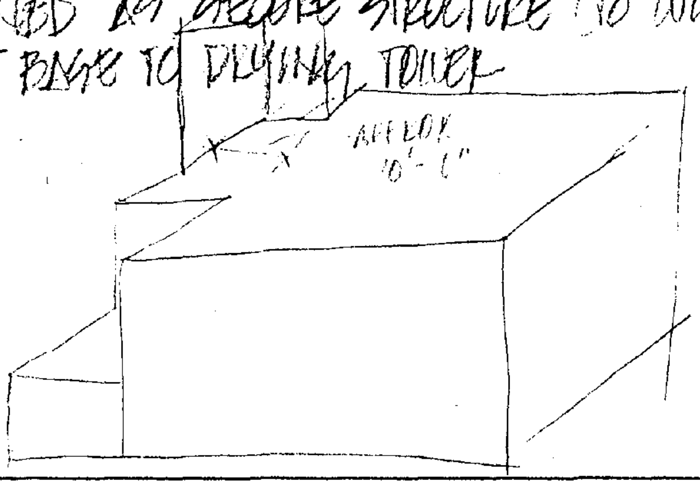
EXERCISE 7

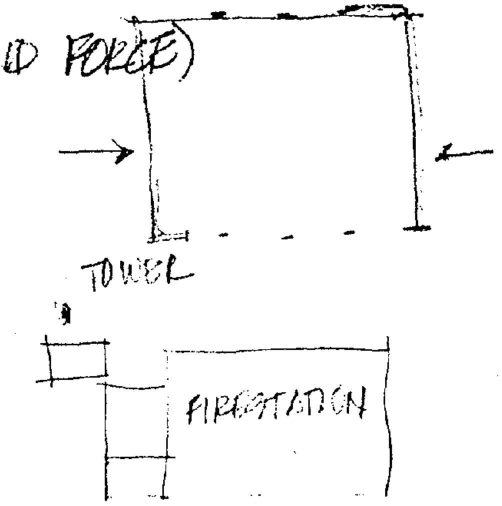
1. HEADER OVER DOORS SPECIALLY REINFORCED
W/ LATERAL TIES – MAY HAVE TO BEHAVE AS FRAME IF COLUMNS AREN'T LARGE ENOUGH TO ACT TOGETHER AS A SHEAR WALL

2. ISOLATE TOWER TO ACT INDEPENDENTLY
USE STEEL TOWER DUE TO ~~HEIGHT~~
ALSO BRACE AS FRAME

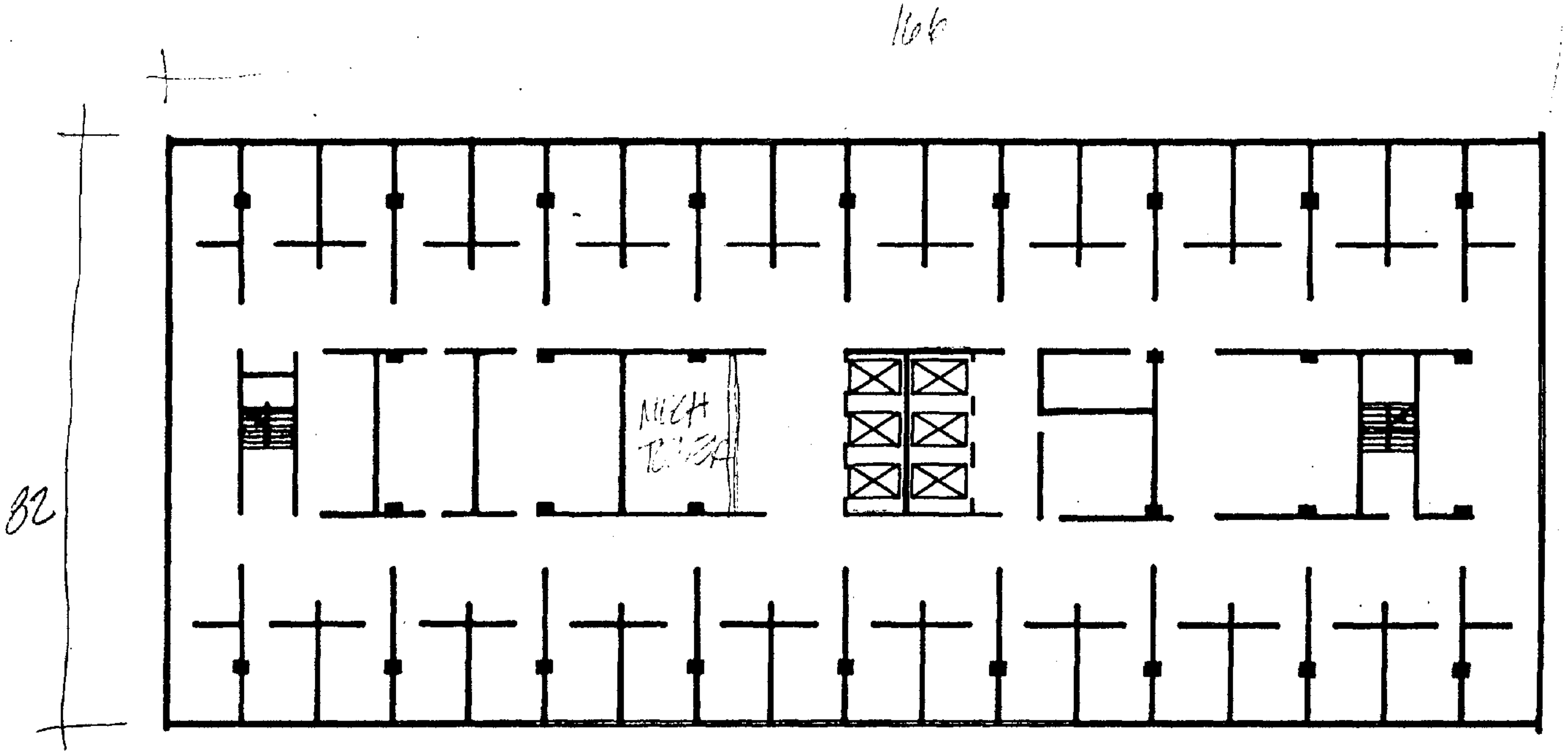


3. MAY REQUIRE INTERMEDIATE COLUMNS
4. FIRETOWER HAS OWN FOUNDATION TO ACT INDEPENTLY
5. STEEL JOISTS
6. TIE COLUMNS TO SHEAR WALLS
7. NON-GARAGE DOOR WALLS ACTING AS SHEAR WALLS
8. ANTENNA DESIGNED AS ~~SECURE~~ STRUCTURE (TO WITHSTAND FORCE)
FASTENED ~~AT~~ BASE TO DRYING TOWER





EXERCISE EIGHT



TOWER (ASSISTS?) IN ADDED RIGIDITY

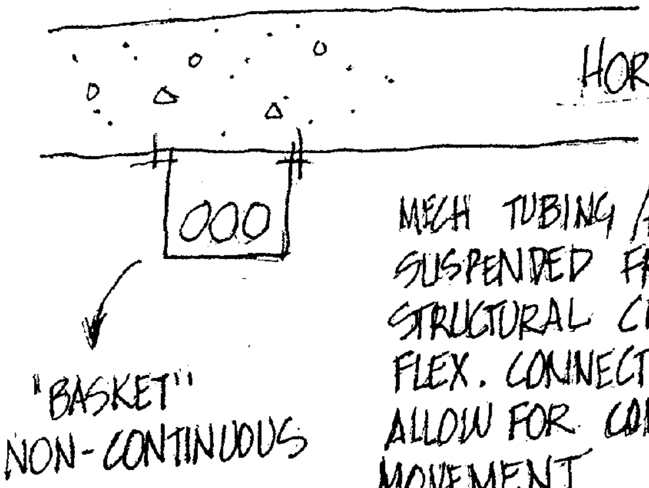
typical plan

ALSO MAKES BLDG SYMETRICAL —
EASIER TO RISIST TORSION

FORCE W/ LEAST
RESISTANCE

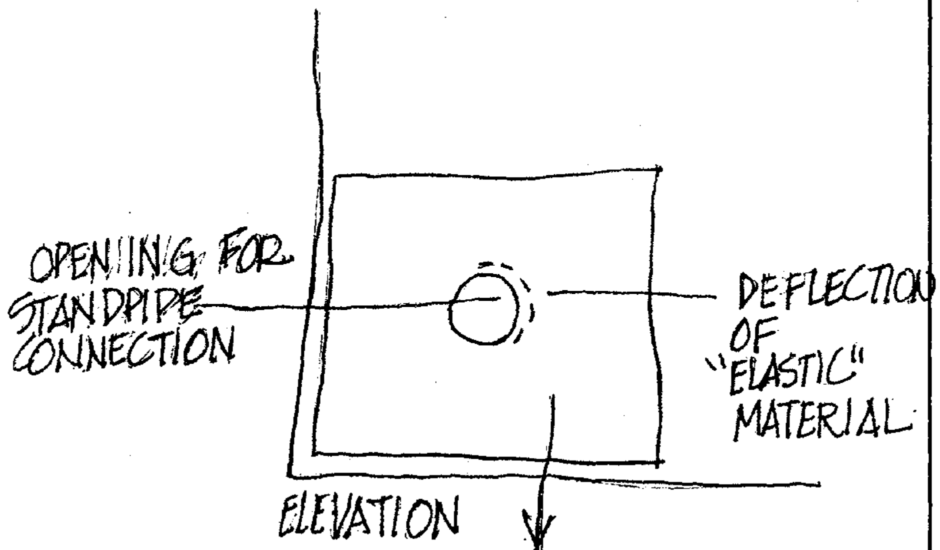
SOLUTIONS

HORIZONTAL



MECH TUBING/PIPING SUSPENDED FROM STRUCTURAL CEILING W/ FLEX. CONNECTIONS TO ALLOW FOR COMPENSATING MOVEMENT

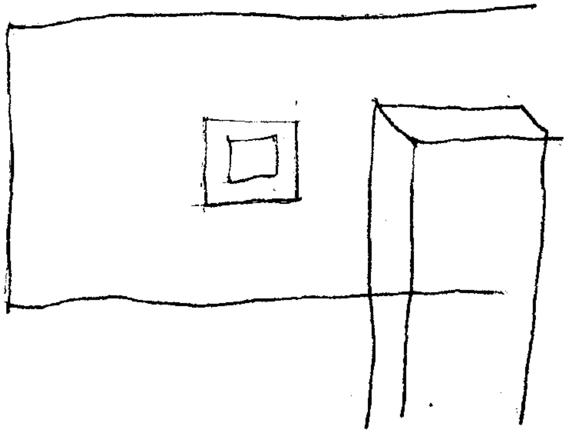
EXTERIOR CONNECTION



HIGH IMPACT FLEXIBLE PLASTIC PANEL DESIGNED FOR WATER PRESSURE MOVEMENT

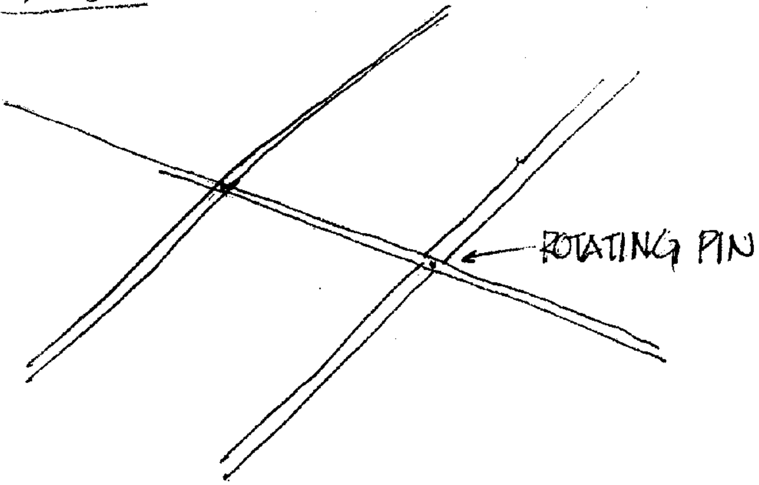
VERTICAL

ADDED MECHANICAL CORE W/4 SHEAR WALLS USED TO PROTECT VERT. PLUMBING IN CENTER - AWAY FROM STRUCTURAL WALLS AND TO BRACE BUILDING

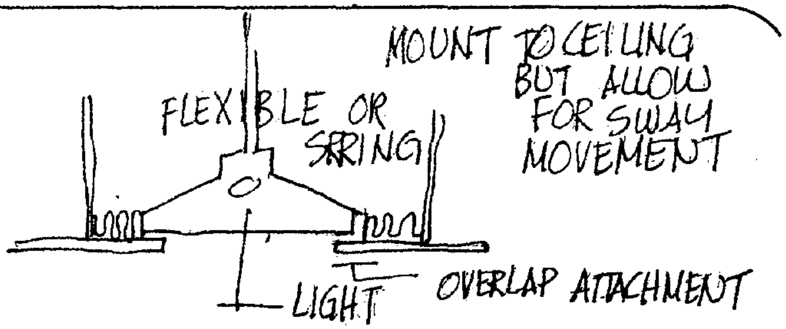


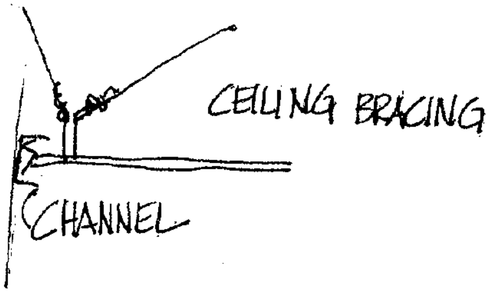
SOLUTIONS

EXERCISE 3

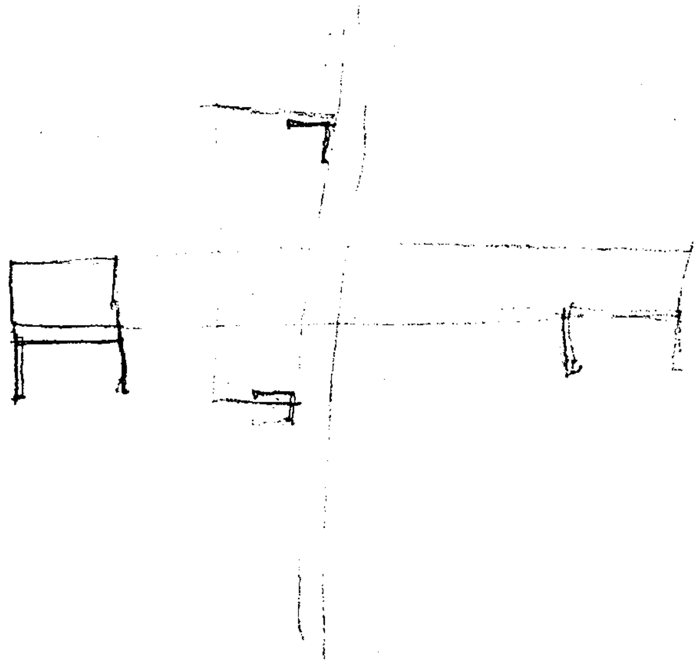


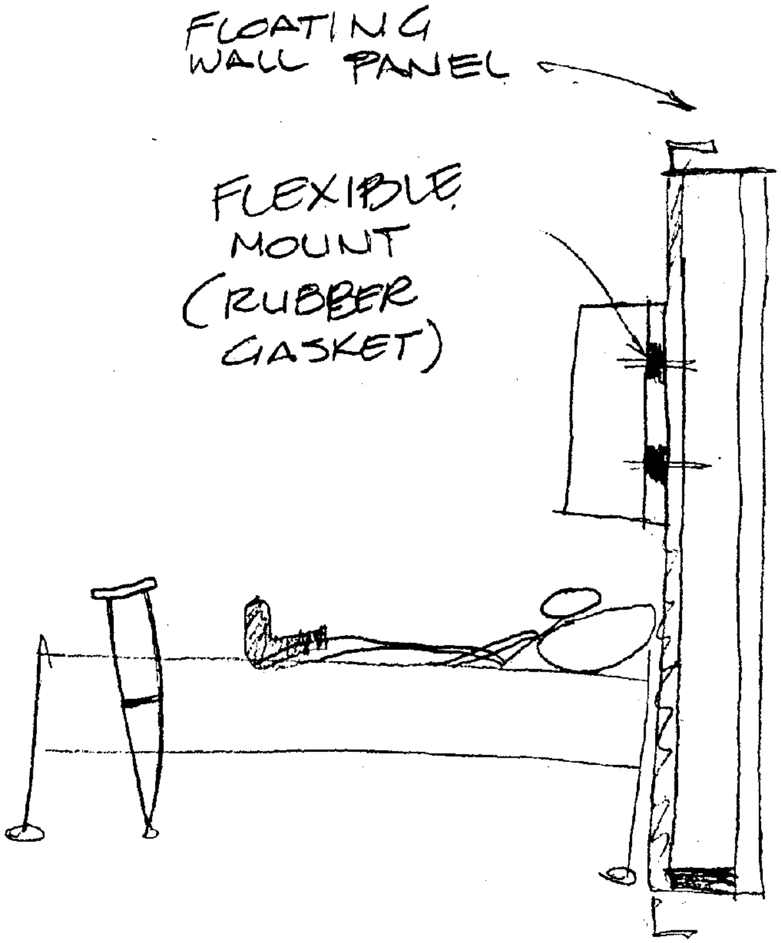
CEILING & FIXTURE INDEPENDENT
NOT SUPPORTING EA. OTHER





EXERCISE 8C





EXERCISE NINE

Elementary School

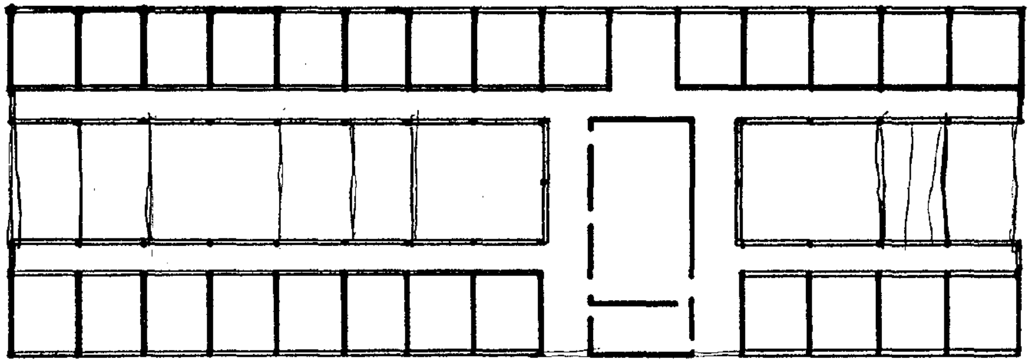
The elementary school is a one story brick bearing wall structure with glazed exterior classroom walls and corridors.

a. The large surface area of glazing allows natural lighting in the classrooms and corridors. In an earthquake, this glazing could fail causing injury to the students. How can you reconcile the benefits of the natural light and the safety of the students?

b. Tile floors in the school are easily maintained and sound absorbing, but the ground-shaking and torsion resulting from an earthquake can destroy this floor surface. Do the benefits of this floor system outweigh the vulnerability to damage?

c. One advantage to this plan type is the ease with which new classrooms may be added. But considering that the longer the classroom wings extend from the core of the building the more vulnerable they become to torsion, do expansion benefits compensate for the vulnerability of the structure?

plan

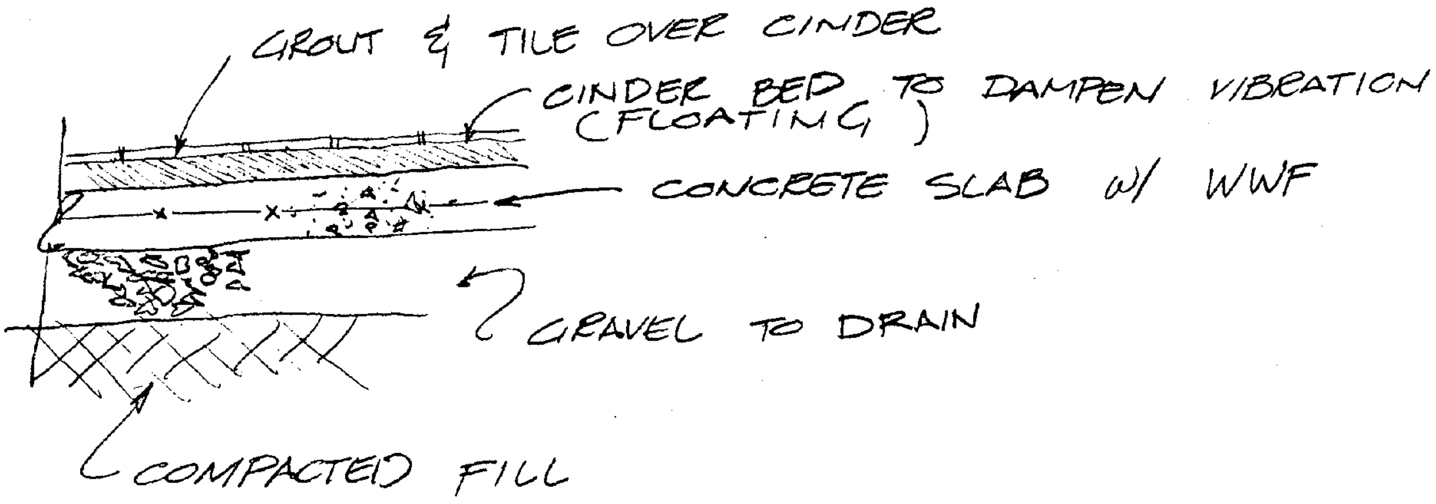


↑ BLDG. HAS/EXERTS LEAST RESISTANCE TO THIS FORCE

SOLUTIONS

EXERCISE 9

FLOOR DETAIL



SOLUTIONS

EXERCISE 9

a. SHORT ATTENTION SPAN - NEED WINDOWS
SOLUTION: USE SHATTERRESISTANT PLASTIC - CAN TAKE MOVEMT, IS MORE ELASTIC TH. GLASS
OR HIGH-IMPACT MESH GLASS, TEMPERED

p214 MANUAL NEOPRENE, GASKET, FLEX. FRAME

b. ASPHALT TILES ARE INEXPENSIVE TO INSTALL, MAINTAIN & REPLACE - IF MOVEMT DESTROYS THE SQUARES, THEY CAN BE REPLACED (AND SUBFLOOR RELEVELED) W/OUT INFLUENCING UNDAMAGED PIECES

c. NEW CLASSROOMS CAN BE ADDED TO INCREASE RESISTANCE TO FORCE INDICATED ON PLAN - NEW ROOMS ALSO ADD SHEAR WALLS, MAKE BLDG BIT MORE SYMMETRICAL & EACH NEW ROOM HAS NAT'L. LIGHT & VENT

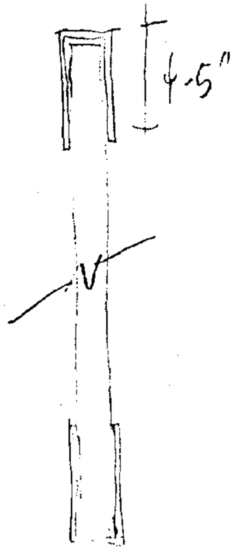
SOLUTIONS

EXERCISE 10

PROBLEM AREA @ PARTITIONS

PARTITIONS - CAN BE MOUNTED AS PREVIOUSLY DISCUSSED:
LOOSELY ATTACHED @ CEILING & FLOOR TO MOVE INDEPENDENTLY OF STRUCTURE
ELECTRICAL RUN THRU INTERIOR PARTITIONS

MAIN MECHANICAL CORE - AT ELEVATOR CORE - ONE CORE SINCE TOWERS CAN BE DONE AT ONCE - WALLS, ETC.
RUN MECH @ CENTER OF VERT MECH. SPACES TO AVOID CONTACT W/ STRUCTURAL WALLS
HORIZONTAL PLUMBING SAME AS HOSPITAL



WALL PARTITION - MOLDED PANELS W/O SCREWS/FASTENERS
SLIDES INTO TRACK - CAN MOVE INDEPENTLY OF BUILDING

PLUMBING (LABS) SURROUNDING CORES & MECH. PORTION OF CORE

SOLUTIONS

EXERCISE 10

36,000 @ 450,000

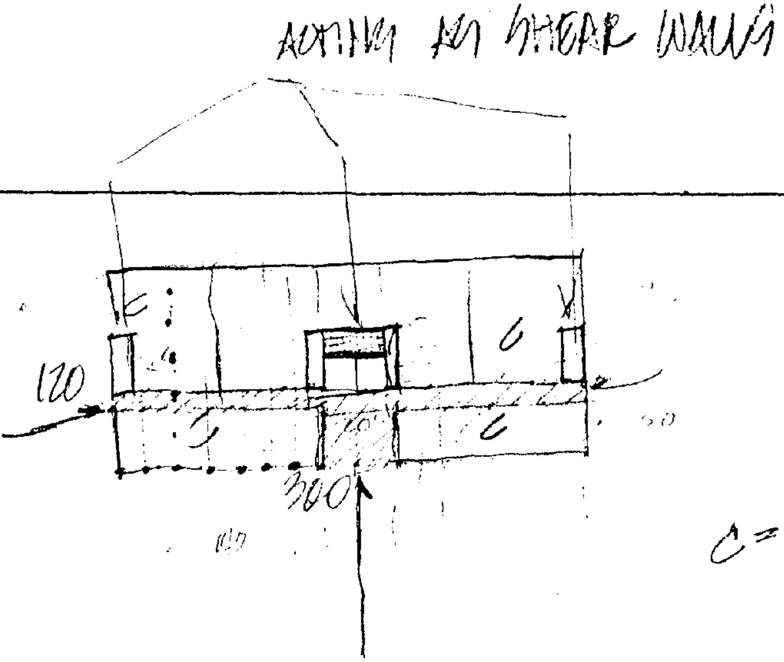
12.5 FLOORS
13 FLOORS

2/3 1st FLOOR 20,000 COMMERCIAL

FRONT PLAZA (80% BERMT) PROPOSED OVER
PRE CAST BLK

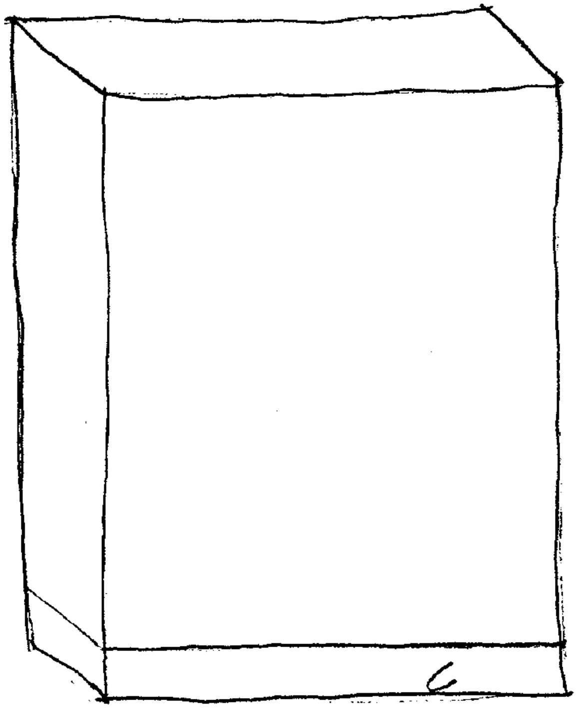
CONCRETE CORE – CENTRALLY LOCATED
FIREPROOFED STAIR TOWERS
20' MODULE – STEEL FRAME

CONCRETE AND
SHEAR WALLS @ STAIR TOWER
3 ACCESS POINTS



36000
400 STAIR
400 ELEV.
35200

C = COMMERCIAL



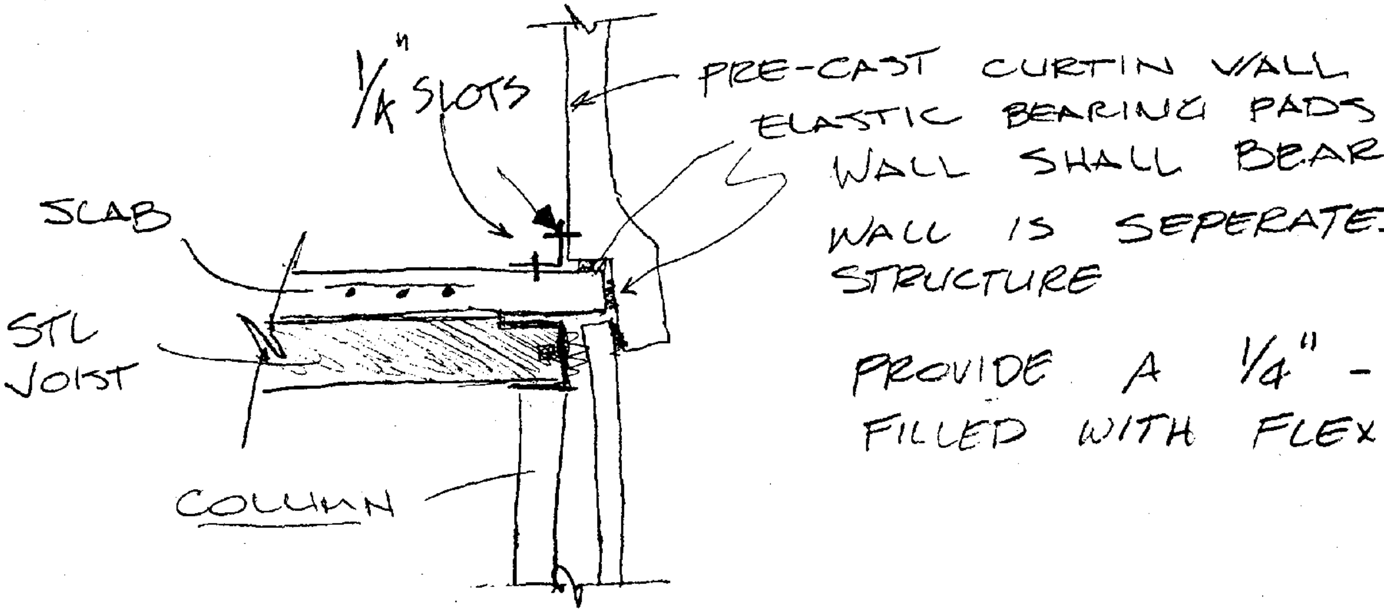
SOLUTIONS

FLOOR SLAB AND HORIZONTAL SYSTEM

STEEL DECK W/ CONCRETE (REINF) SLAB

DIAPHRAGM FLOOR & ELEVATOR CORE CONSTRUCTION AS A REDUNDANT.

DESIGN ALSO AS A FRAME.



WALL SHALL BEAR ON SLAB OR SPAN

WALL IS SEPERATED FROM STRUCTURE

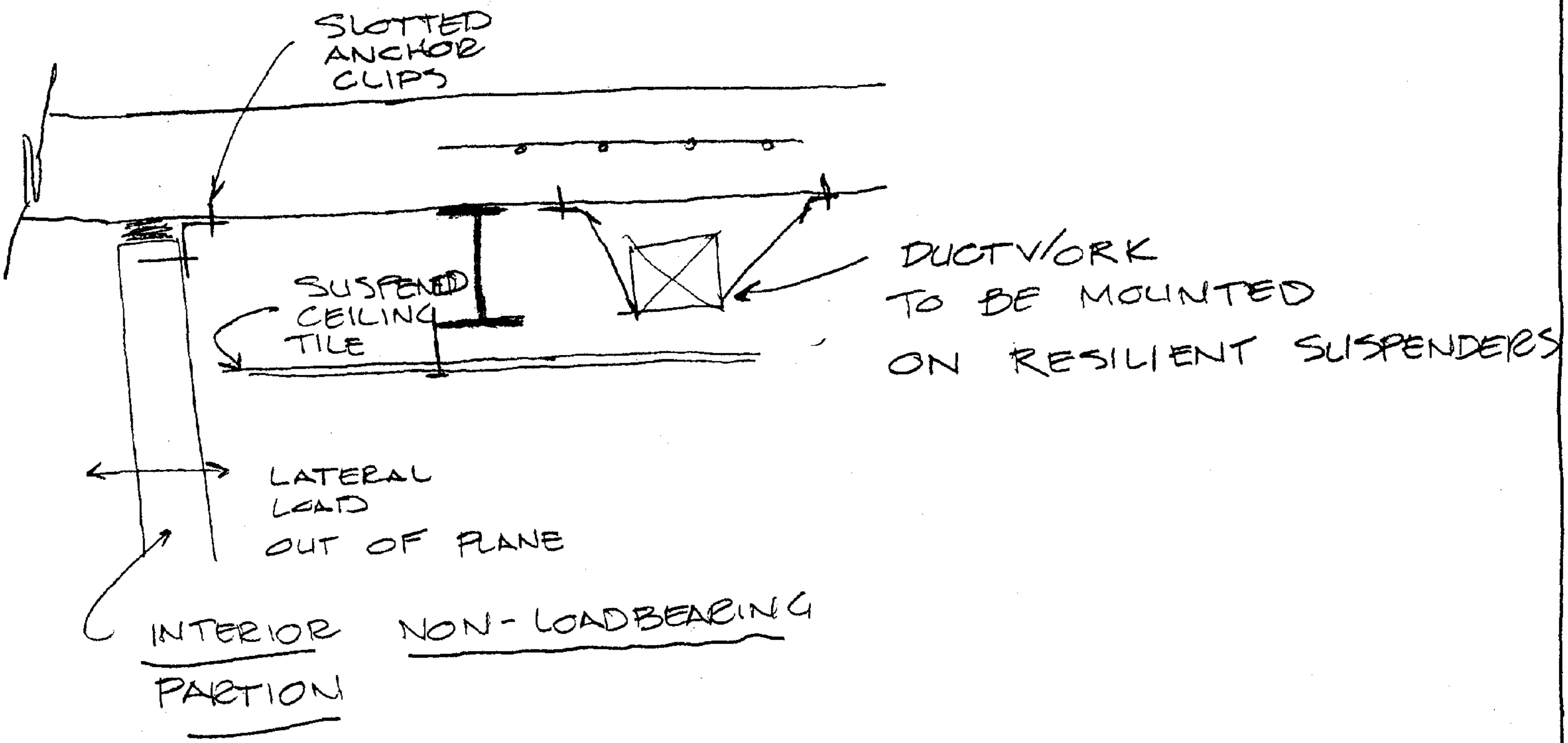
PROVIDE A 1/4" - 1/2" GAB FILLED WITH FLEXIBLE SEALANT

COMMENTS

EXERCISE 10

1. PROGRAM IS NOT COMPLEX ENOUGH TO ISOLATE PROBLEMS IN UNDISCLOSED PROBLEM AREAS
2. NO RESULTS, AS PER WHAT IS WANTED IN THE RESPONSE
3. SITE IS ALMOST IRRELEVANT— PHOTOS ALSO

COMMENTS


SLOTTED ANCHOR CLIPS
SUSPENDED CEILING TILE
DUCTWORK TO BE MOUNTED ON RESILIENT SUSPENDERS
LATERAL LOAD OUT OF PLANE
INTERIOR NON-LOADBEARING PARTION

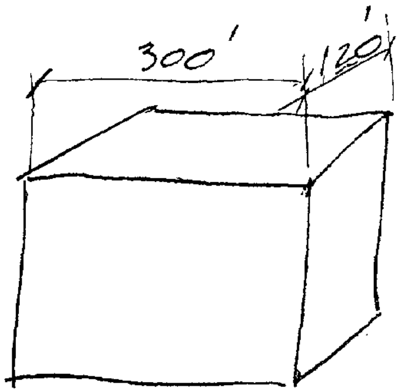
SOLUTIONS

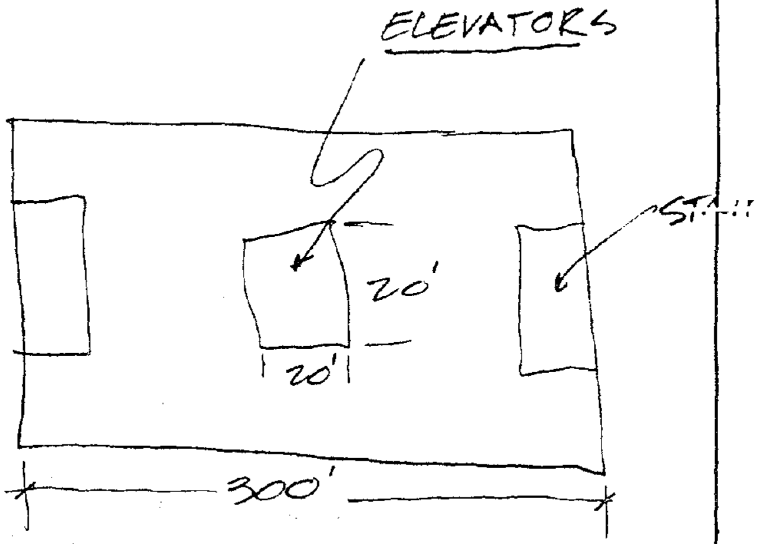
#10

450,000 # REQ'D

150' x 300' = 45000 # , @ 80% = 36000 #

$\frac{450,000 \#}{36000 \#/\text{FLR}} \simeq 13$ FLOORS





STRUCTURE STEEL DMRSF

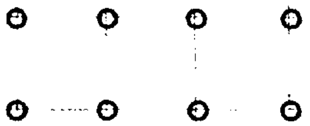
I = 1.5 K = 0.67

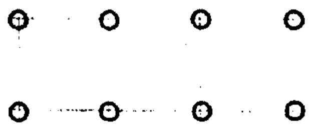
Z = 3/4 CS = 0.14

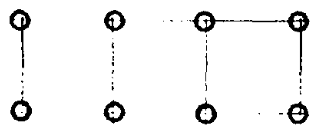
Cambridge Architects

Boston, TAC, Newberg, Notkin.

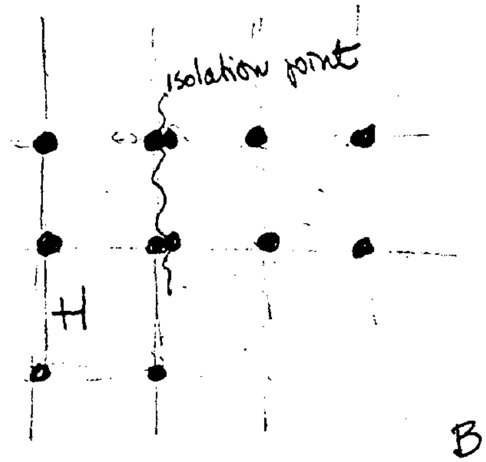
SOLUTIONS #1



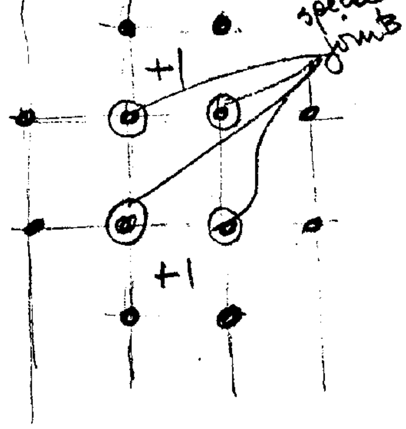




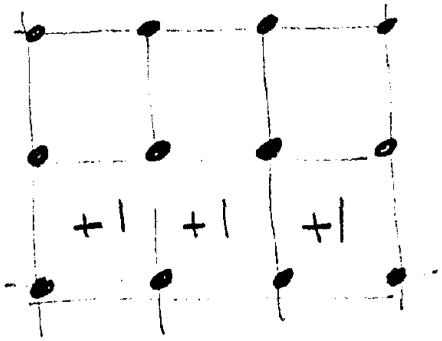
Place your own solutions below, and comment on them



A.



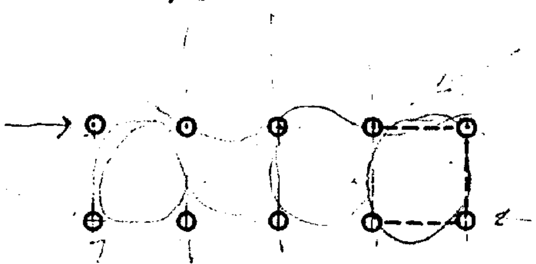
B.



C.

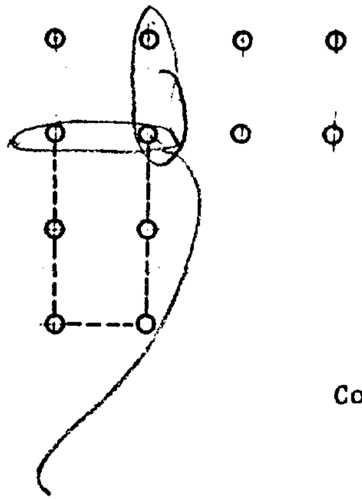
SOLUTIONS #1

A



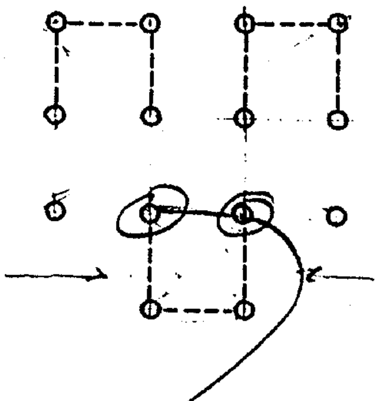
Bldg. too long and thin
may undulate in case of
earthquake causing
unequal distribution
of stresses.
Perhaps each bay
should act
independently

B



Potential
Problem
zones

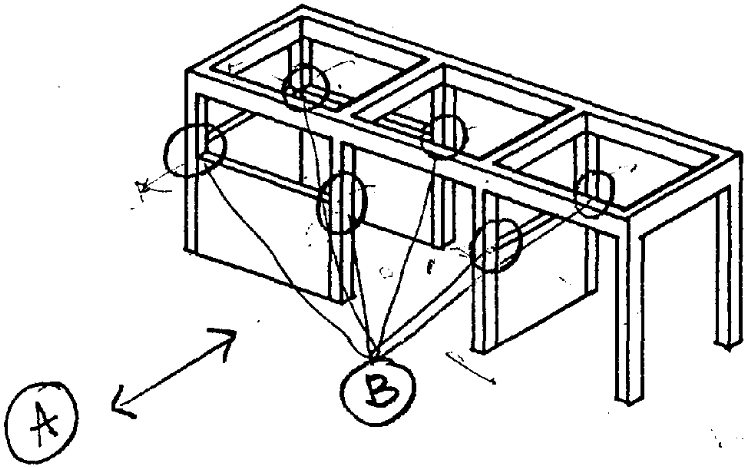
C

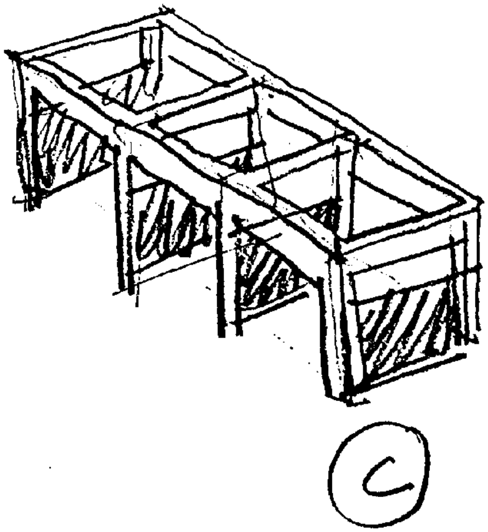


Comment on the solutions above

May need special
joints
not as much a
problem as attached
B because bay,
being a much smaller
unit may not stress
the larger mass as much.

EXERCISE TWO





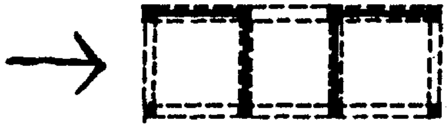
Given : This post and beam structure and four panels
(of approximately the same density and allowable
stress as the column material).

A. Draw an arrow in the direction where the structure would exhibit its greatest resistance to ground motion.

B. Indicate the most vulnerable columns.

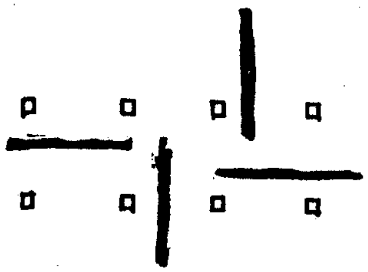
C. Change the location of the panels to make the resulting structural- nonstructural combination more resistant to seismic loads.

SOLUTIONS



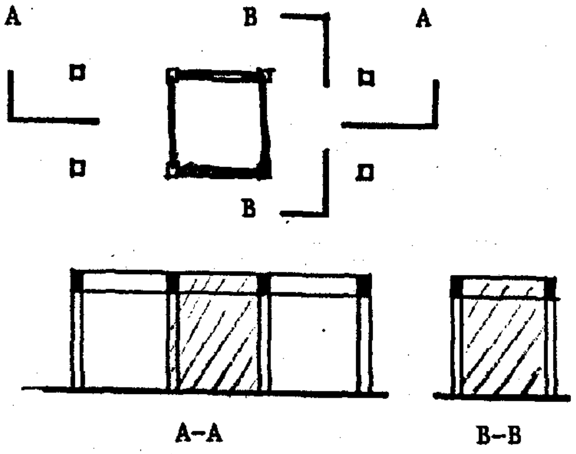
Because would distribute load among larger number of components.

Plan I
Comment on this solution in terms of part A of the exercise. (Draw arrows in direction of greater resistance and explain why).



Keep structural and non-structural elements independent of one another.

Plan II
Place 4 panels to make the structural-nonstructural combination resistant to ground motion, that is, minimize damage to columns (part C).
Answer A and B also.



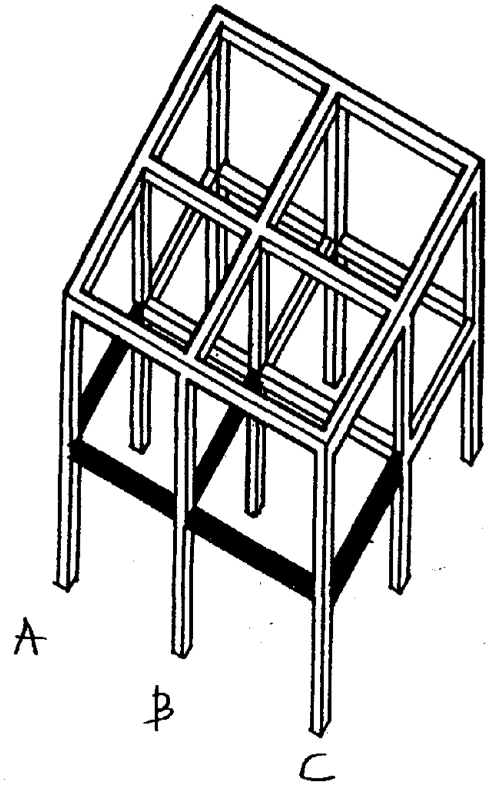
Change design of panels and configuration, if desired, so that the result is the best possible combination of panels and columns in terms of seismic resistance.

#2

COMMENTS Initiated during exercise two.

Figures 3.8 — 3.10 b - captions and notes are unclear; they don't explain what's "good" and "bad" or "how bad". Should show where failure would occur +/or differences in magnitude of problem.

EXERCISE THREE



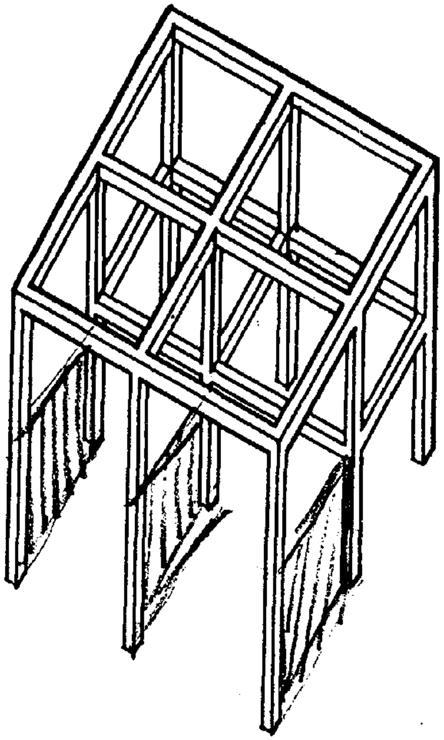
A/B Columns become taller and less stiff
So can bend better, more ductile.
Because they can thus shake better,
they would not react the same way as
the rest of the structure. Therefore
the effect on the whole structure
would be less resistance to earthquake

A. If the red beams are removed, what is the effect on columns a, b, and c, in terms of seismic resistance?

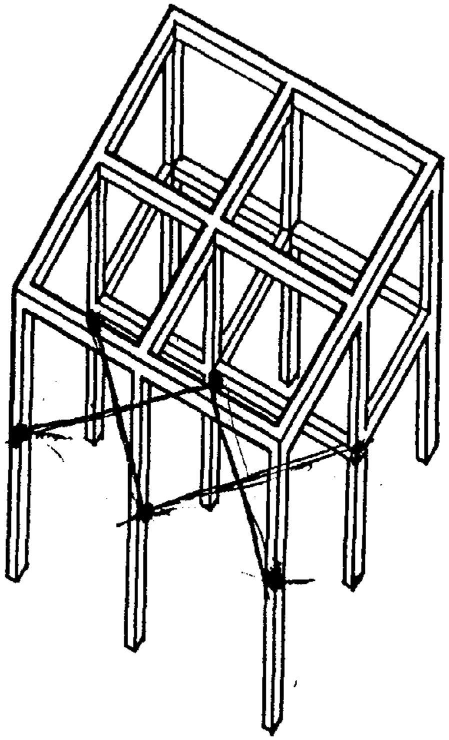
B. What would be the effect on the other columns. Would increase load on others.

C. Can you "re-balance" the distribution of seismic loading on the structure by adding elements (other than replacing the red beams where they were)?

SOLUTIONS

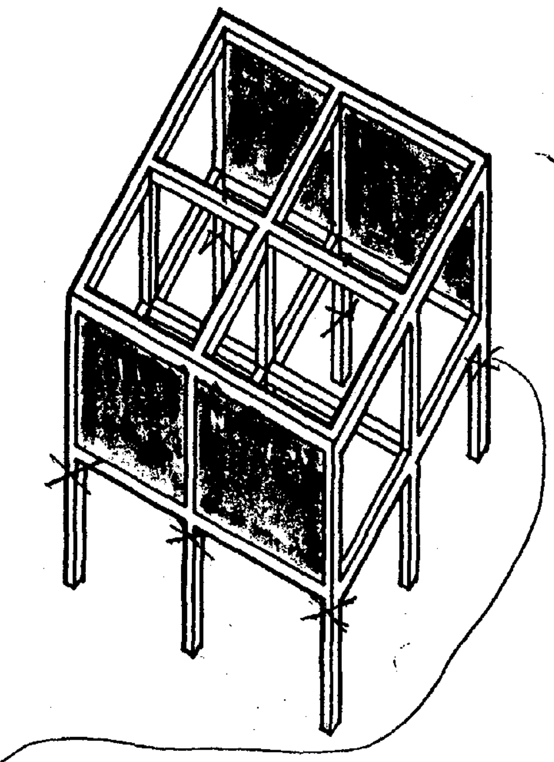


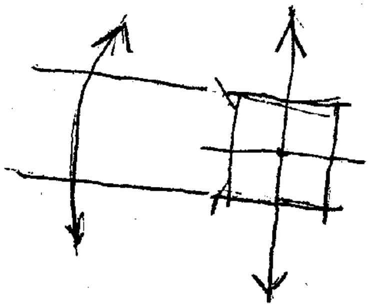
Responding to part C, use one story high column-to-column panels.

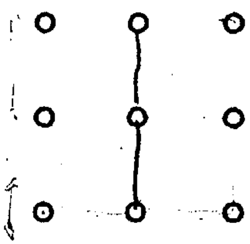


Responding to part C, use deepend beams and/or diagonal bracing.

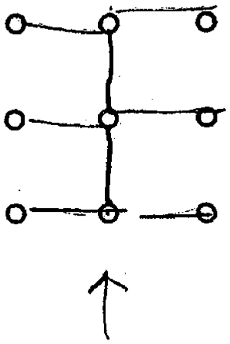
EXERCISE FOUR







Second level plan



Ground level plan

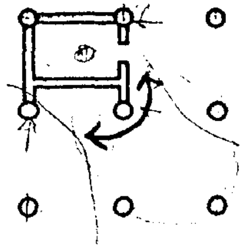
If yellow in-fill panels were concrete block:

A. Indicate which columns would receive greater shear forces under seismic loading, and why?

B. Where would evidence of their failure be observed?

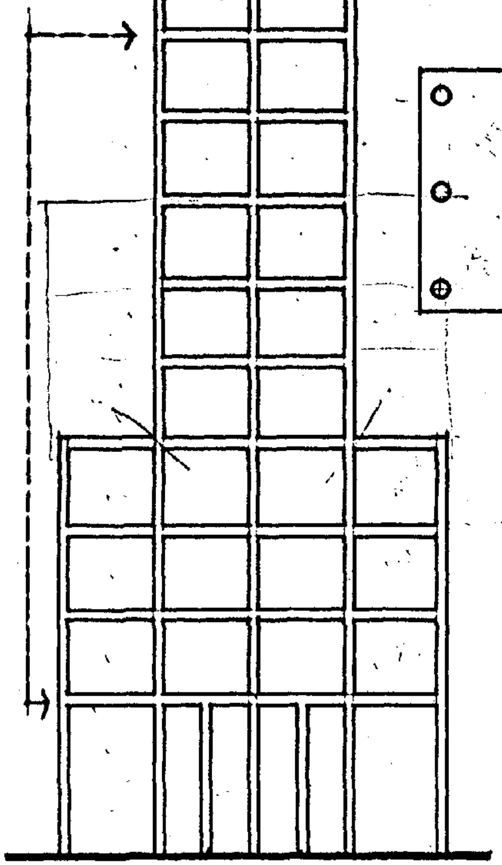
Assuming a metal frame with moment connection. Place 4 panels in the structure to form a shear wall which will give lateral resistance in one direction.

EXERCISE FIVE A

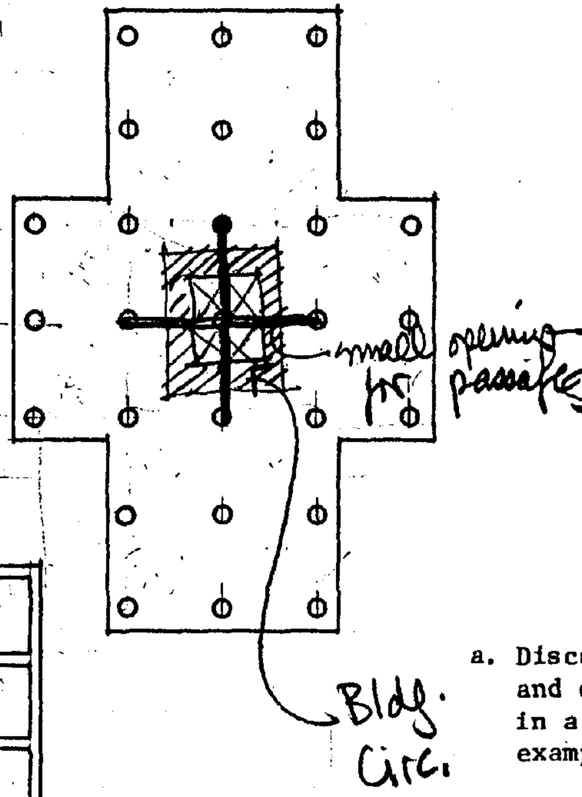


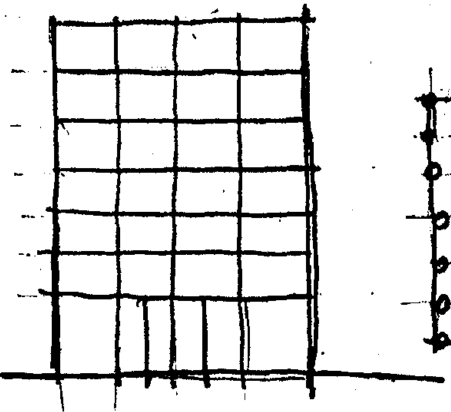
This core has the same plan on both levels.
Show where torsion will develop in the structure

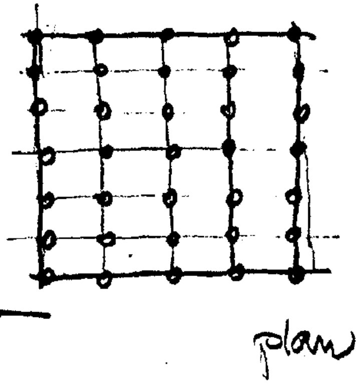
EXERCISE FIVE B



1







2

volume

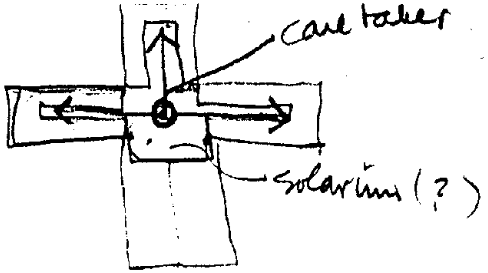
a. Discuss trade-offs between this configuration and one which would have the same number of bays in a simple rectangular configuration. For example, one additional story of 2 x 6 bays.

b. Place continuous shear walls, core, and circulation path as if this were a rental office building. Bay size : 20 x 20 feet.

SOLUTIONS

Five B

a) 2 is more compact and shorter, ∴ would be more stable and stiffer, stress conditions on columns would be more uniform. The narrow upper tower in 1 would tend to oscillate at a different (faster?) rate than the base causing a problem at joint; 2 would avoid this problem.



EXERCISE SIX

Elderly Housing

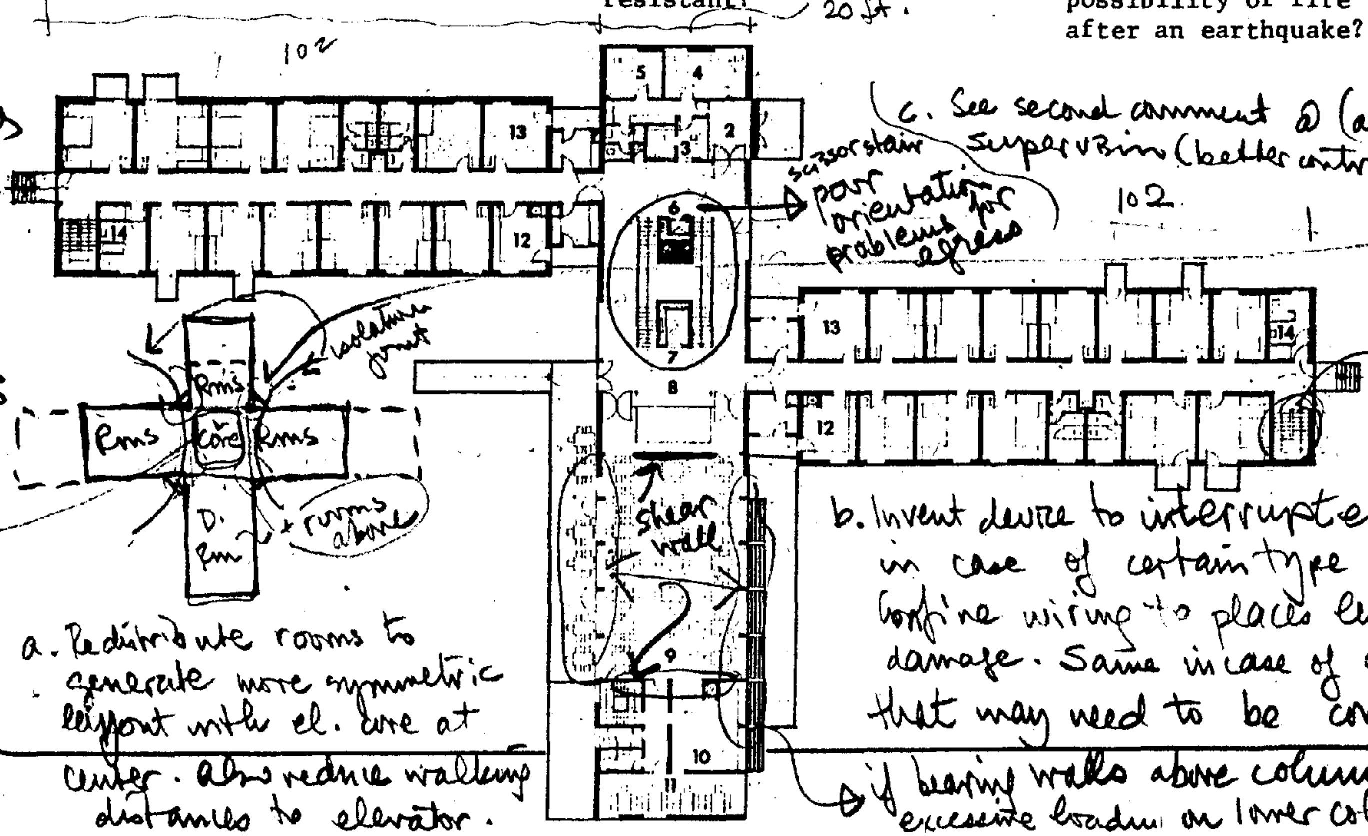
This is a three story brick bearing wall structure housing ~~97~~ single dwelling units. The overall dimensions are 136' by 224' and each wing is 38' by 102'.

? steel skeleton structure with in fill panels] safer

a. Considering the infirmity of the residents, the elevat~~o~~rs must remain functional after an earthquake. The likelihood of torsion in this plan reduces the probability of keeping the elevators functional. How can the plan be revised to make the elevators more resistant?

b. A fire in this type of occupancy is extremely dangerous to life safety. The torsional effect and difference in wall strength can damage electrical wiring and cause fire. What measures can be taken to reduce the possibility of fire after an earthquake?

c. Analyze the merits of this plan in terms of access and egress, control orientation, adjacencies, natural lighting, etc. and the disadvantages in terms of the probable response to ground shaking Alter the plan to optimize it for both seismic and non-seismic criteria.



if core tied in to structure would work better to sq plan building

poor orientation for problems egress

c. See second comment @ (a.) Also. helps visual supervision (better control)

articulate joint to admit daylight into core.

stairs attached to structure may cause problems

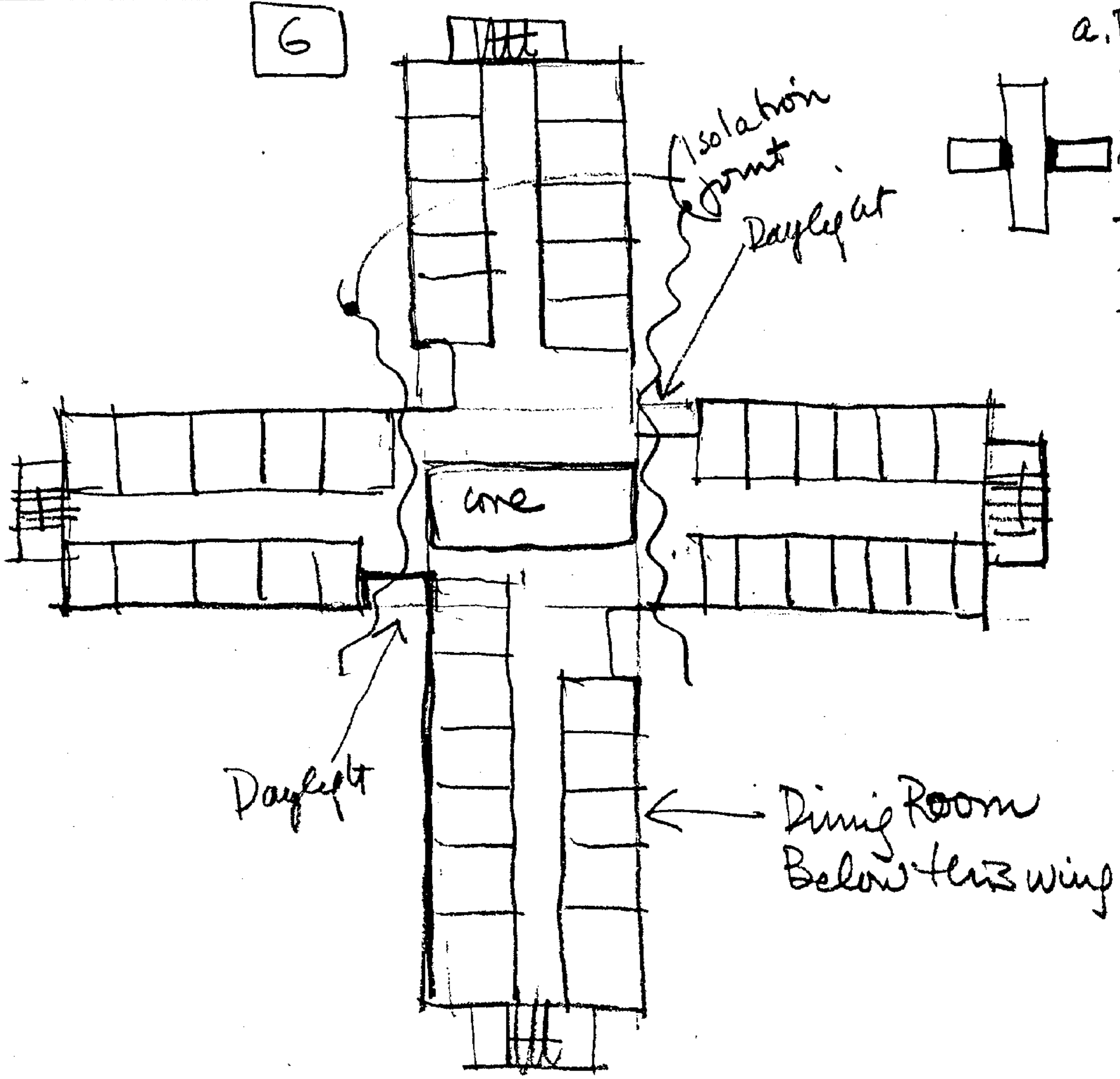
a. Redistribute rooms to generate more symmetric layout with el. core at center. Also reduce walking distances to elevator.

b. Invent device to interrupt electrical service in case of certain type of vibration. Confine wiring to places less likely to receive damage. Same in case of gas, water, etc. that may need to be controlled.

if bearing walls above columns, create "soft story". excessive loading on lower columns in earthquake

SOLUTIONS

6



a. Redistribute Rooms into uniform X shape — el. core @ center. Build in isolation joint to allow side wings to move independently. Tie core into structure to increase stiffness. Isolate egress stairs @ wing ends to avoid problems due to unequal stiffness, Replace bearing wall structure with steel skeleton. Add shear walls into clear span dining room to compensate for "soft story" effect, Float frame of glass [flexible connections to structure] to avoid breakage, Design columns for 'extra' shear load,

SOLUTIONS

6

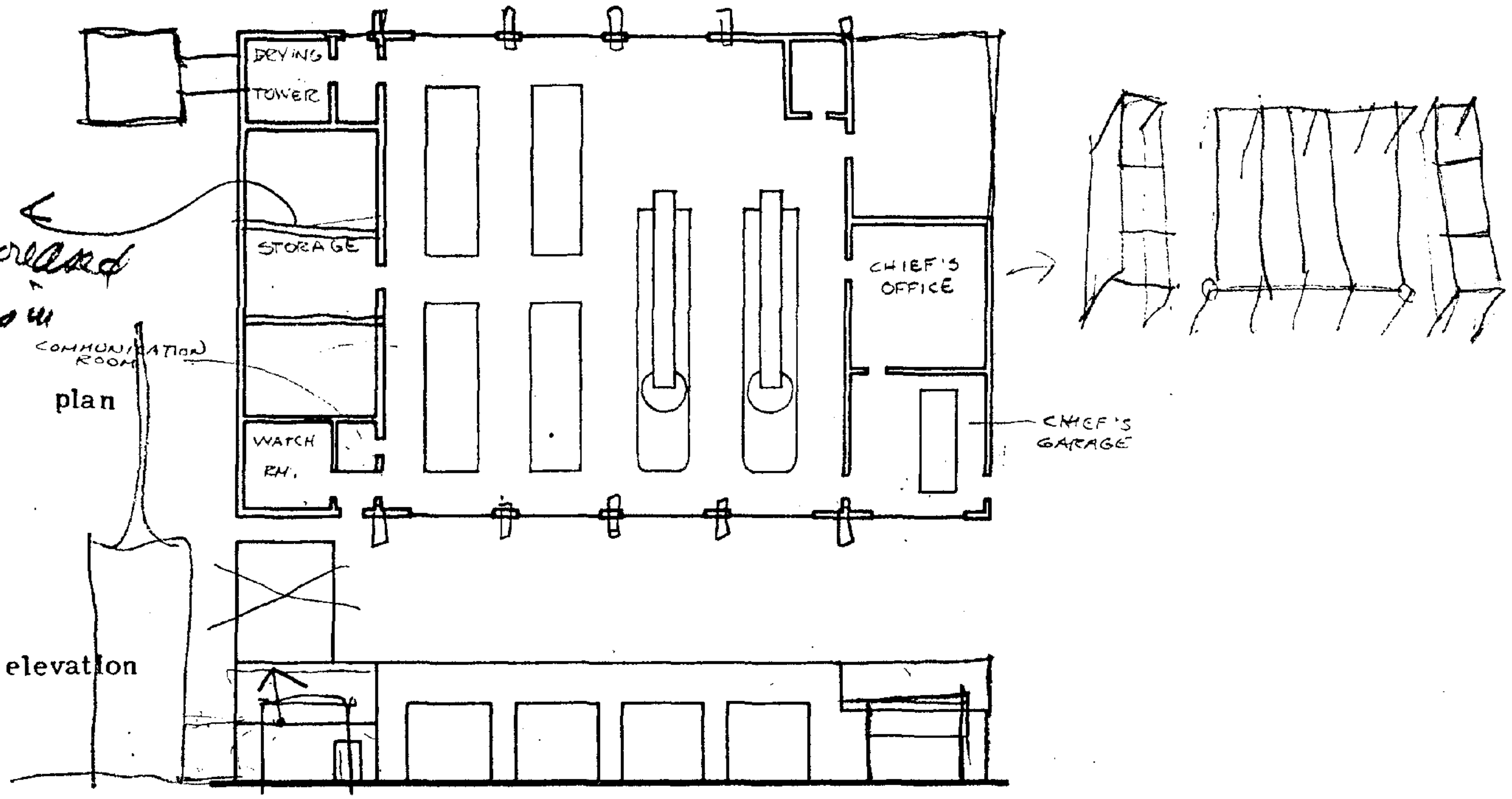
c. altered plan may improve non-seismic criteria as ff:

- Reduce walking distances to elevator core.
- allows better visual supervision and control from central core area.
- Redesigning core to eliminate scissor stairs and symmetric interior elevation design would improve orientation at lobbies and improve egress conditions.

EXERCISE SEVEN

add pilaster to increase stiffness in ↕

add panels for increased stiffness in ↔



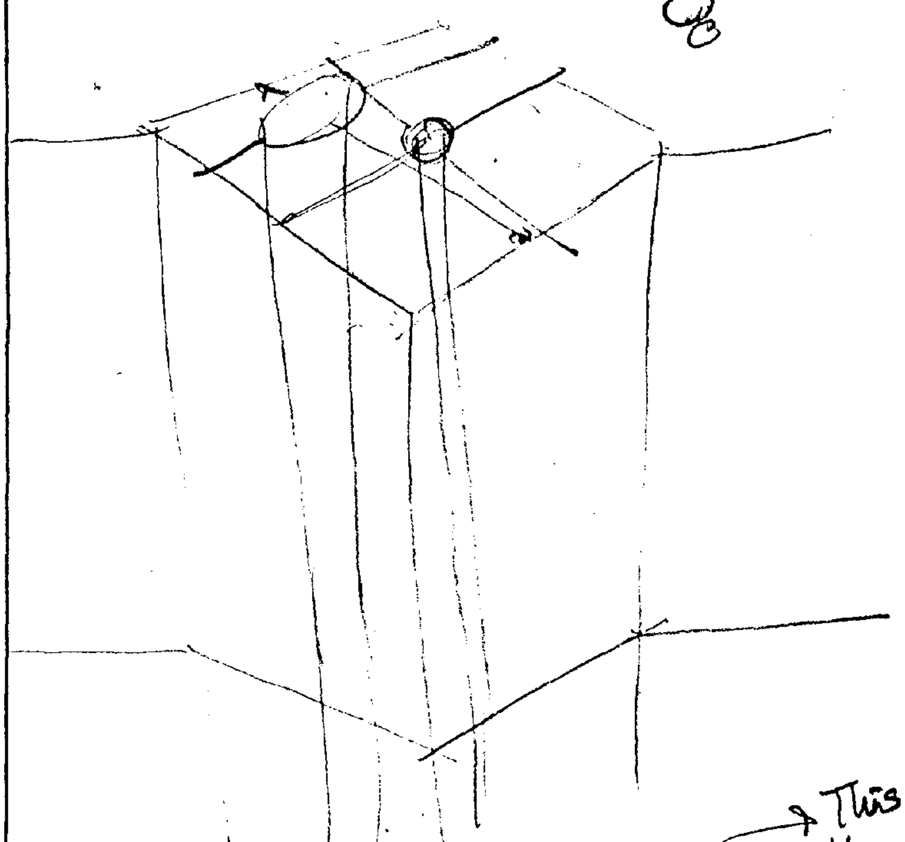
SOLUTIONS

a. Fill out rectangle in plan and elevation, create more compact form.
Add pilasters along direction of structure to increase stiffness.
Alternative suggestions re. drying tower and antennae:
a). Move to a more central location, splitting storage, and stiffen joint with lower mass—or—
b) Seperate out as a free standing form, thus also preventing bricks etc. from falling onto ~~[illegible]~~ rest of bldg.

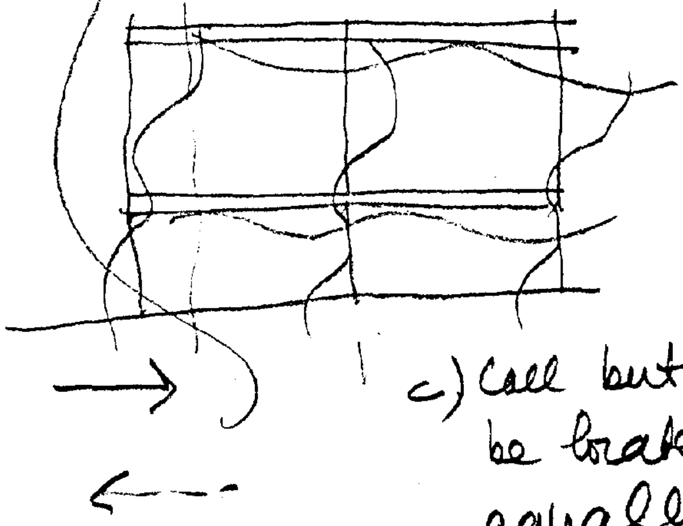
b. Equalizing heights of various units, making plan a simple rectangle, and adding stiffening panels and pilasters would integrate control center into building and increase resistance to failure.

SOLUTIONS

Q8



b) Increase strength of hangers and assembly system,
hang fabric ceiling below
utilities + lights, ~~thus~~



c) Call button should
be located in an
equally accessible
but safer location

a) create a mesh to hold
pipes in place at floor
levels, maintaining the
fire proofing, mesh ties pipes
to rigid frame so pipes
move along with bldg.

This assumes that
the horizontal
displacement is
more critical,
since pipes
have expansion
loops built-in
along their
length.

EXERCISE NINE

Elementary School

The elementary school is a one story brick bearing wall structure with glazed exterior classroom walls and corridors.

a. The large surface area of glazing allows natural lighting in the classrooms and corridors. In an earthquake, this glazing could fail causing injury to the students. How can you reconcile the benefits of the natural light and the safety of the students?

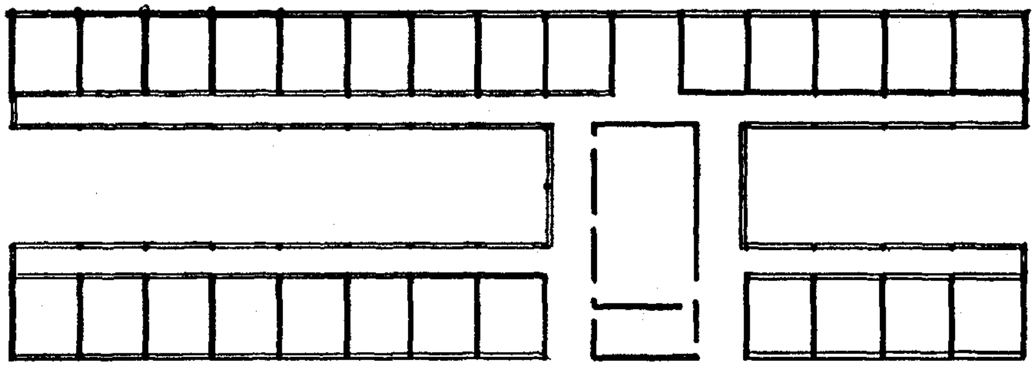
b. Tile floors in the school are easily maintained and sound absorbing, but the ground-shaking and torsion resulting from an earthquake can destroy this floor surface. Do the benefits of this floor system outweigh the vulnerability to damage?

? Terrazzo more appropriate to question

tile, esp, VAT not so vulnerable

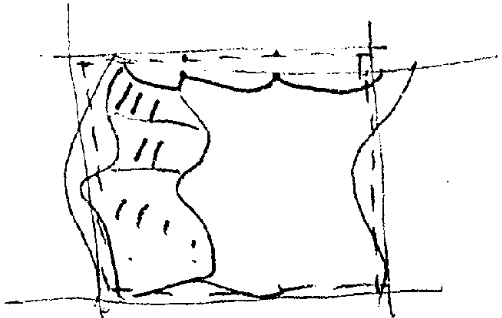
c. One advantage to this plan type is the ease with which new classrooms may be added. But considering that the longer the classroom wings extend from the core of the building the more vulnerable they become to torsion, do expansion benefits compensate for the vulnerability of the structure?

Yes, they may depending on particular problem or local conditions. And, it seems to me that it is possible to design a long narrow building and minimize seismic damage by treating it as a collection of smaller independent rigid sections



plan

SOLUTIONS



a. Believe that natural light is a very desirable condition especially in classrooms and living/working environments. Amount of desirable nat. light should not be sacrificed for seismic reasons alone. Intent of the question, really, is to reduce the risk of bodily injury which could be achieved by using safety glass or wire glass. These, while breaking, will not shatter and explode.

b. If VAT tiles these are flexible and can perhaps deform or crack without really impeding seriously circulation.

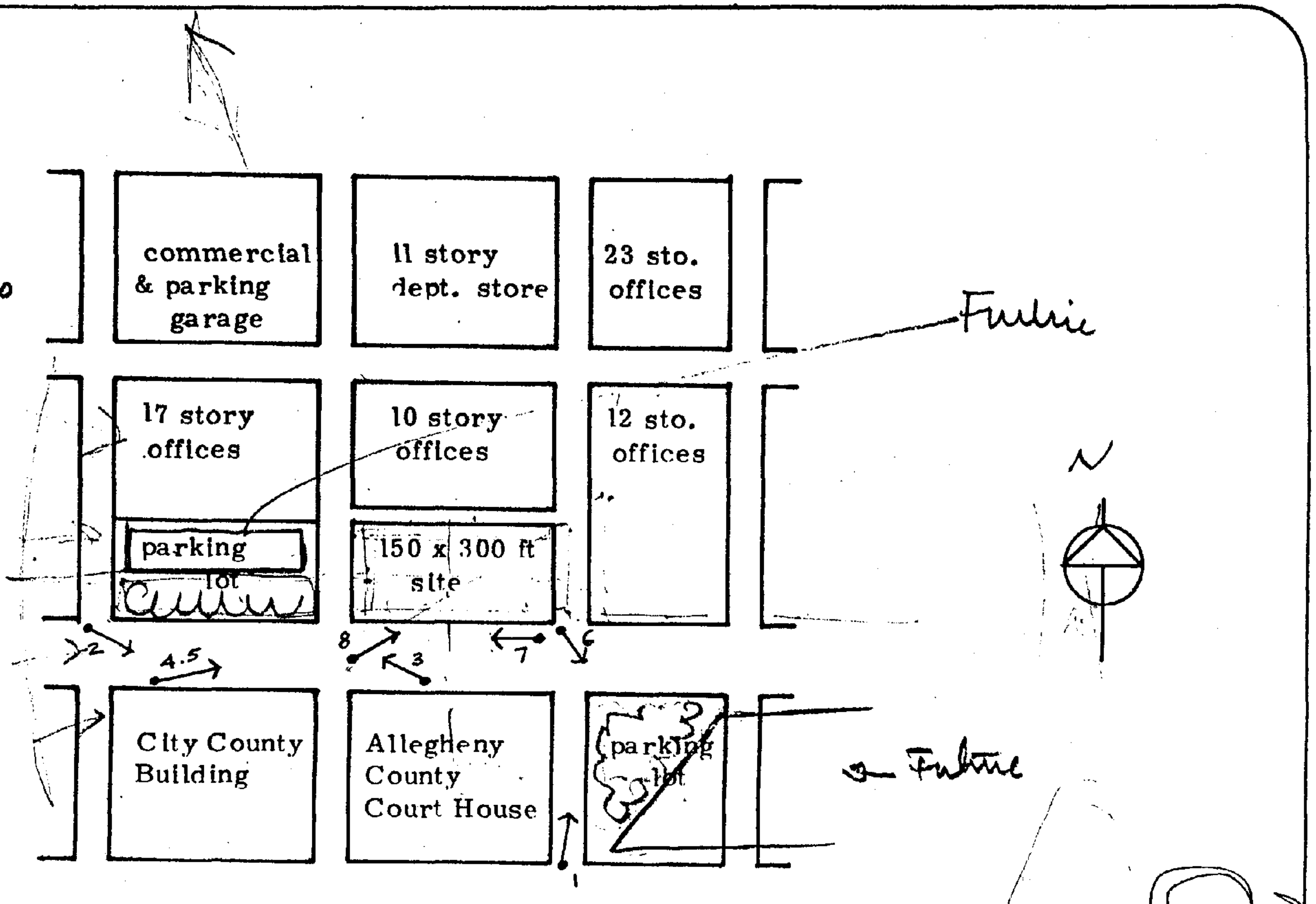
If quarry tile, these may be a more serious problem.

Alternative finish materials may include –

1. Slab itself which also can shatter
2. Terrazzo or epoxy surface would shatter a lot more than tile since have no seam or layer seamless areas,
3. Carpeting may be ~~better~~ but is not necessarily a lasting or appropriate material for school corridors

EXERCISE TEN

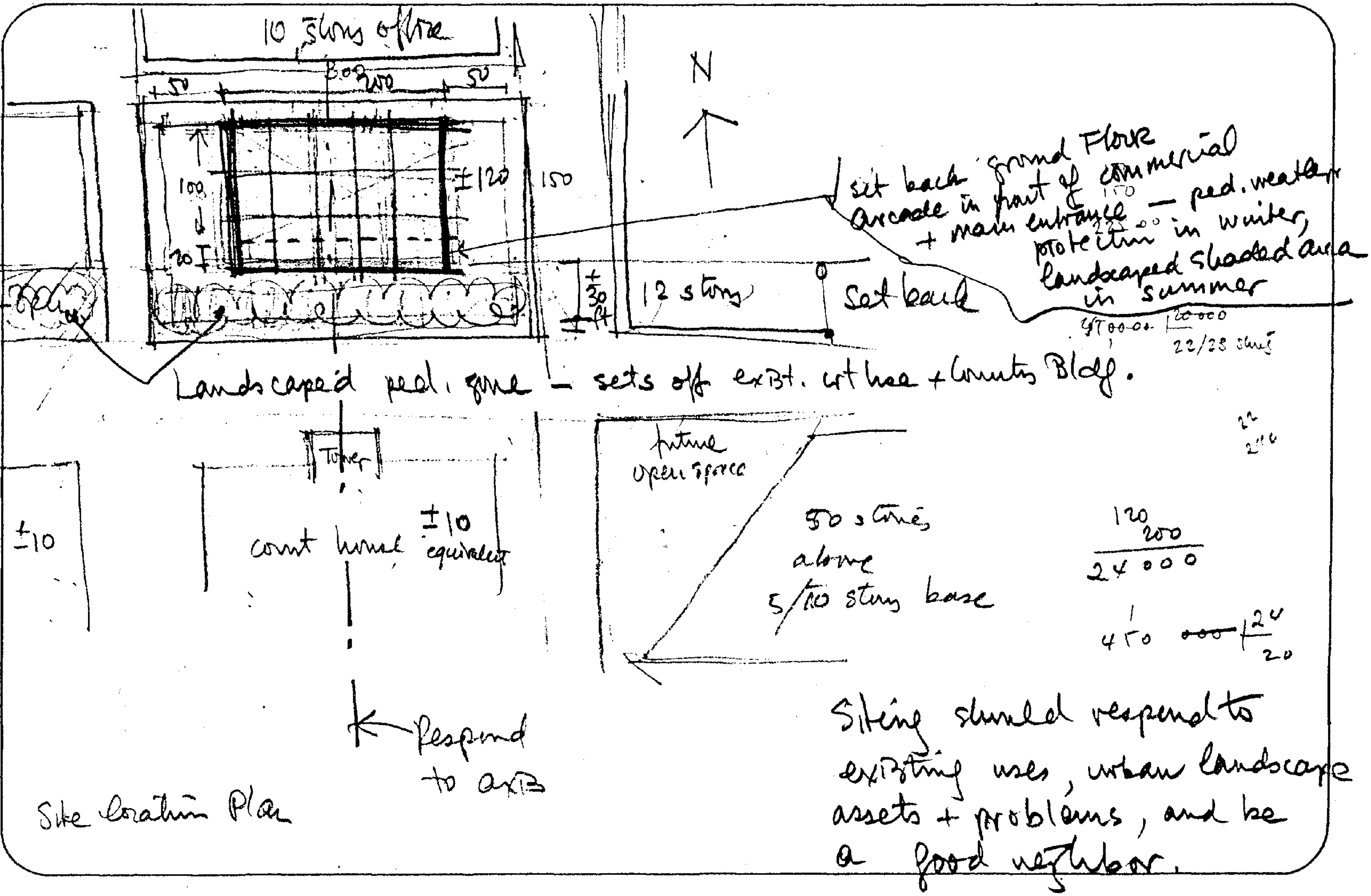
Site Area =
150 X 300 =
45 000 sq ft.
Land cover @ 80%
45000
.80
36,000 ft
open: 9,000 sq. ft.
Commercial base @
20,000.
Assume Fl to Fl
height ~ 12 ft.
360 | 12
30 stories
assume 2 story
1st level. — 29 stories
or 28 story above ground floor



assume 500 000 includes 20 000 commercial.

$\frac{120}{200}$

SOLUTIONS

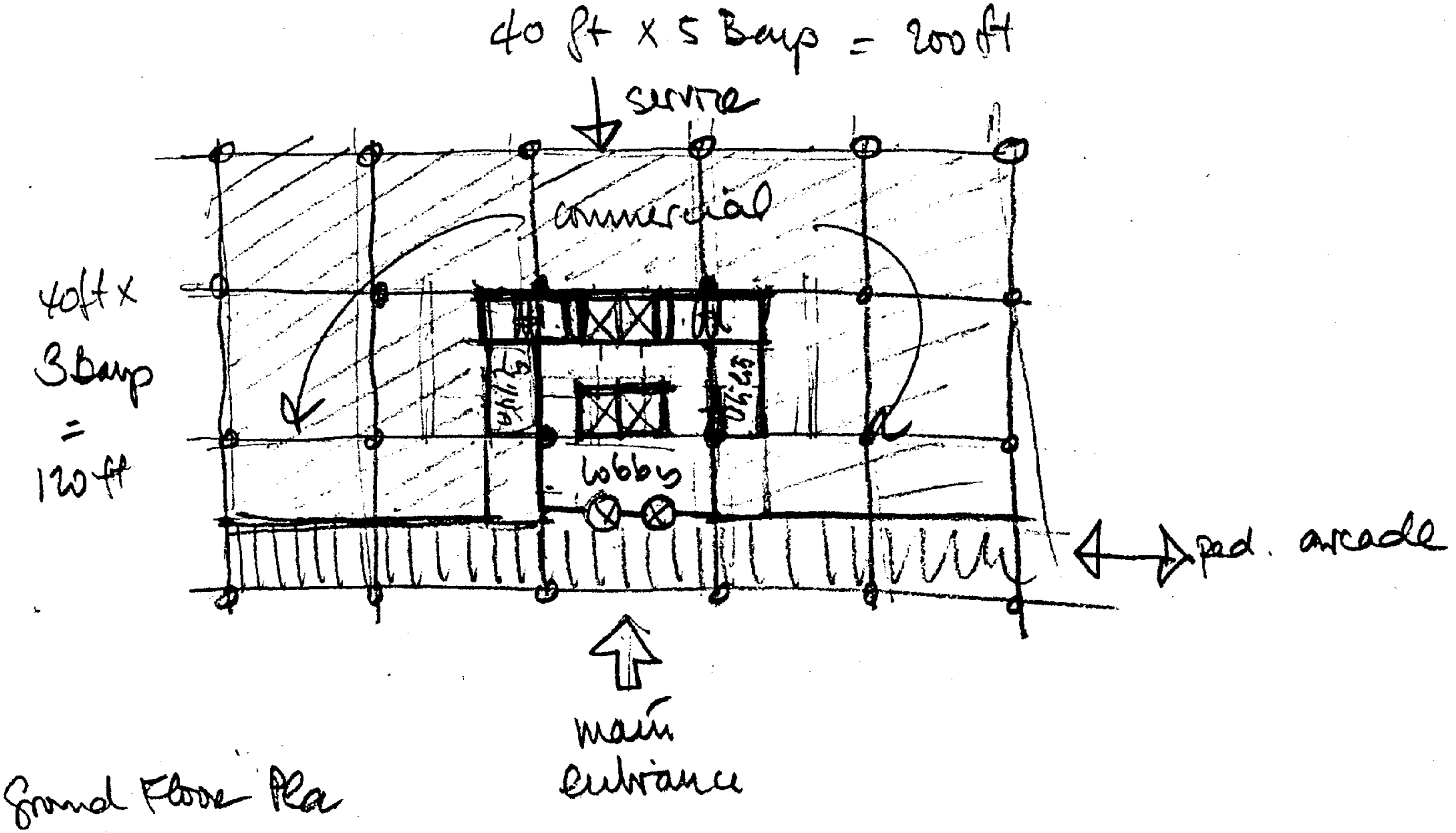


set back ground floor arcade in front of commercial + main entrance — ped. weather protection in winter, landscaped shaded area in summer

Landscaped ped. zone — sets off exist. crt hse + County Bldg.

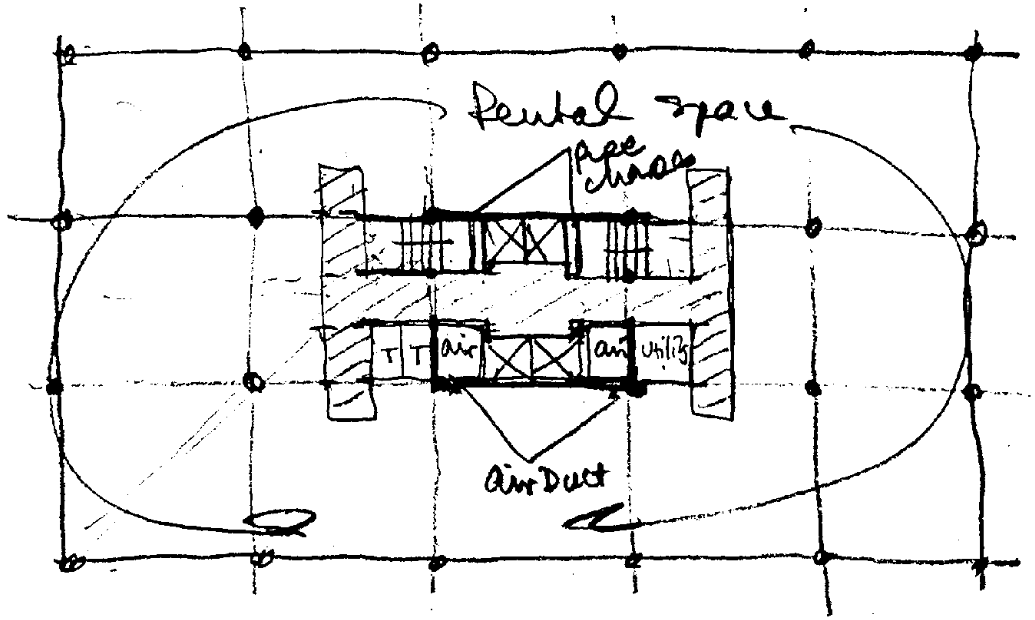
Siting should respond to existing uses, urban landscape assets + problems, and be a good neighbor.

SOLUTIONS



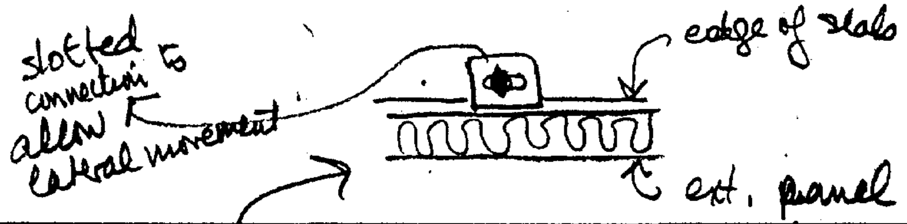
Ground Floor Pla
Plan

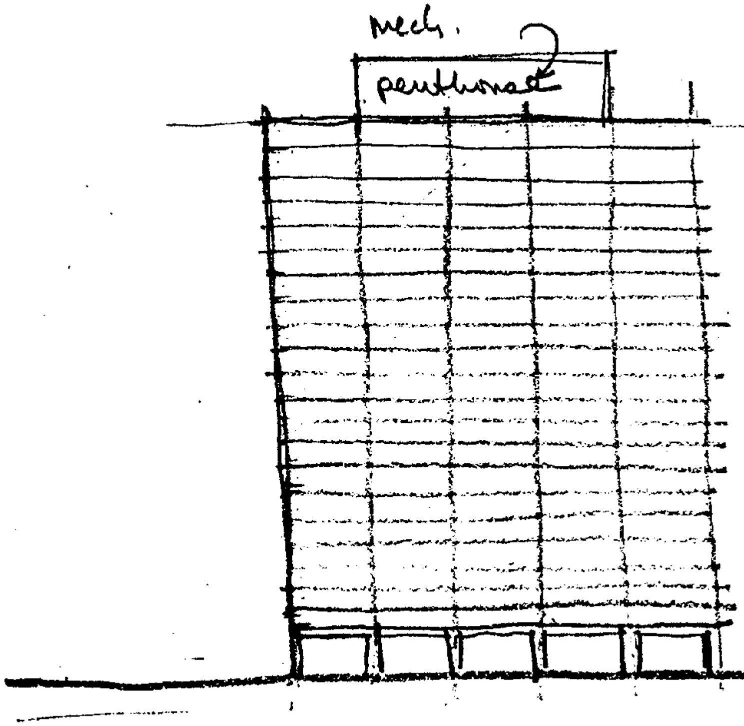
SOLUTIONS

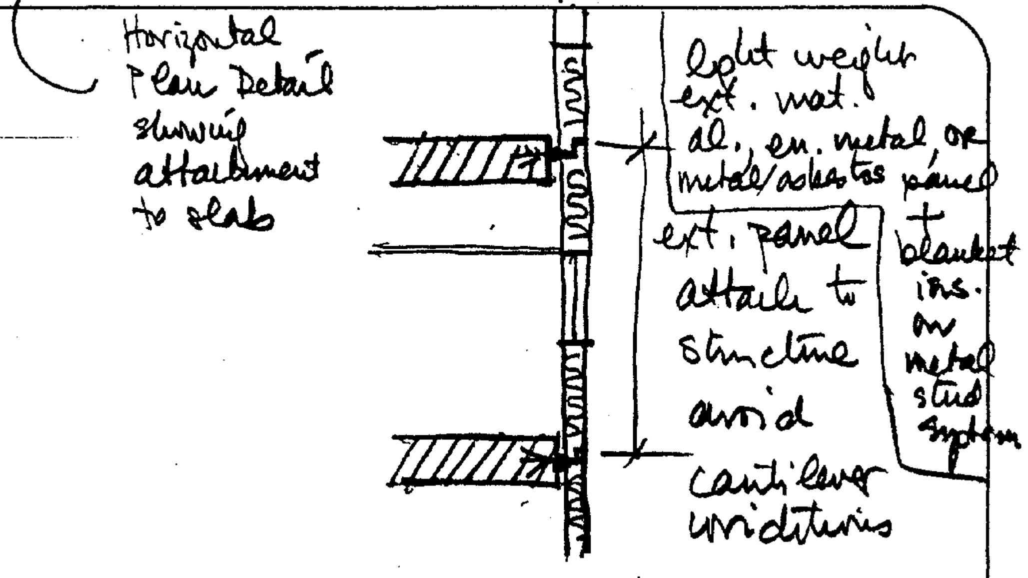


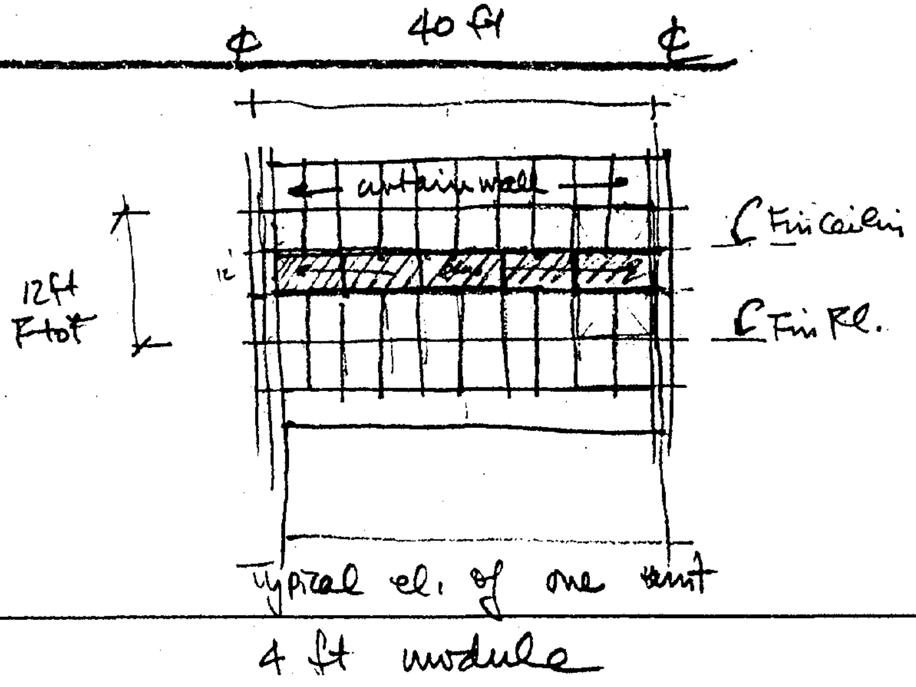
Upper Floor
Plan (Typical)

SOLUTIONS





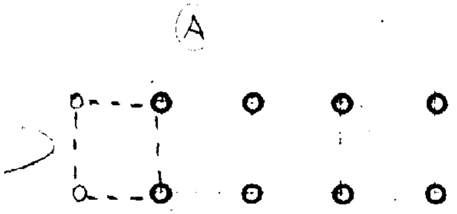


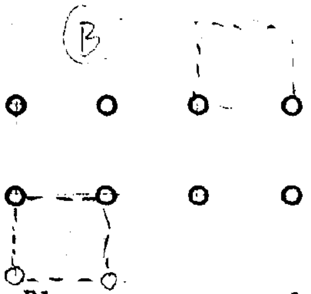


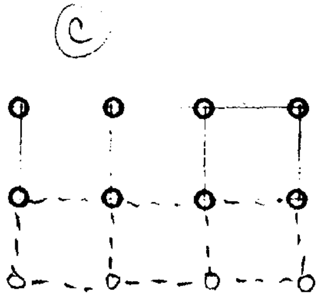
Recessed first floor create soft story but not so bad because recess less than one full bay and in direction along which bldg is most rigid.

Charleston Architect

SOLUTIONS







Place your own solutions below, and comment on them

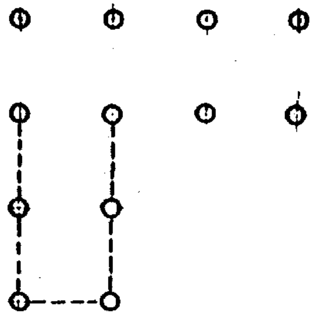
a) position B optimum one direction, if added on site too much torque developed

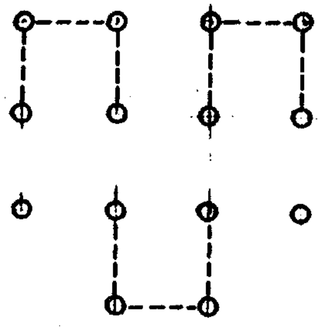
b) positioning of two bays to make as equal in width & length dimension as possible will have some torque however

c) plan dimension (length & width) become more equal so that ground motion in either direction resisted equally

SOLUTIONS

best solution for one additional bay too lessen torque possibility



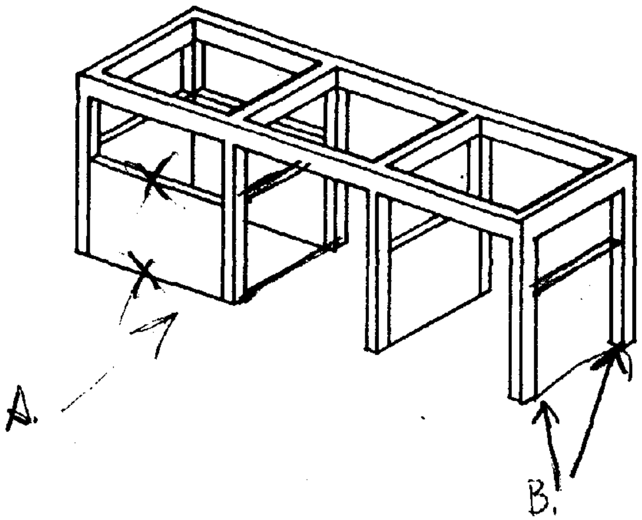


Comment on the solutions above

this is not the best solution for an additional two bays probably will develop great force at internal corner

not the best solution because with unbalanced situation possibility of torque from both axis

EXERCISE TWO



C. best solution would be to assume long direction force neutralized by bents ∴ place panels between columns in short direction to neutralize force in short direction

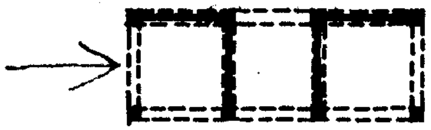
Given : This post and beam structure and four panels (of approximately the same density and allowable stress as the column material).

A. Draw an arrow in the direction where the structure would exhibit its greatest resistance to ground motion.

B. Indicate the most vulnerable columns.

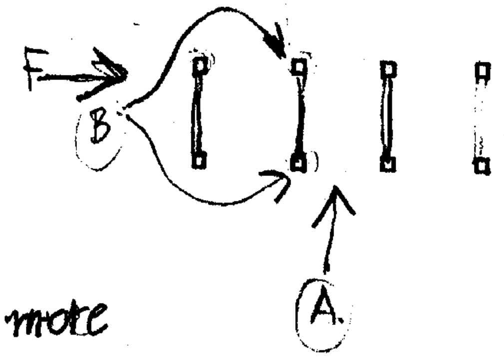
C. Change the location of the panels to make the resulting structural- nonstructural combination more resistant to seismic loads.

SOLUTIONS

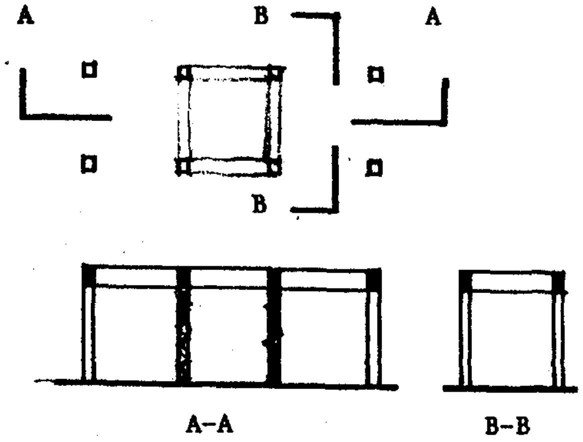


combination of three bays plus two infill panels will develop more resistance

Plan I
Comment on this solution in terms of part A of the exercise. (Draw arrows in direction of greater resistance and explain why).



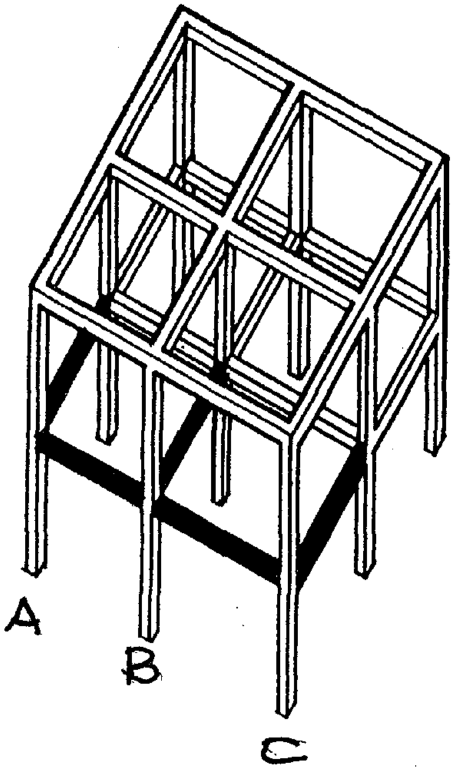
Plan II
Place 4 panels to make the structural-nonstructural combination resistant to ground motion, that is, minimize damage to columns (part C).
Answer A and B also.



Change design of panels and configuration, if desired, so that the result is the best possible combination of panels and columns in terms of seismic resistance.

EXERCISE THREE

9



A. If the red beams are removed, what is the effect on columns a, b, and c, in terms of seismic resistance?

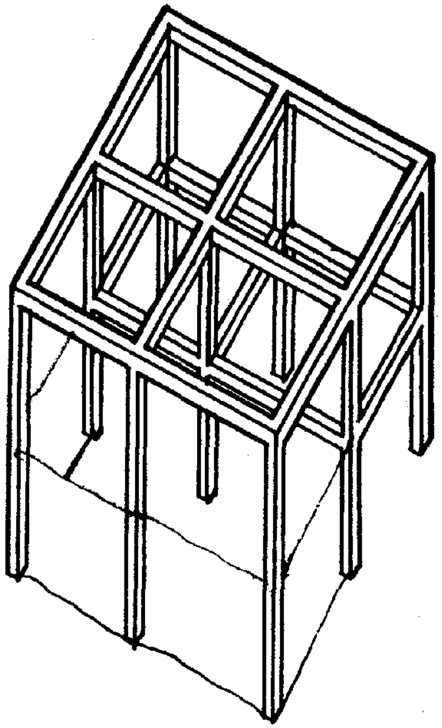
B. What would be the effect on the other columns.

C. Can you "re-balance" the distribution of seismic loading on the structure by adding elements (other than replacing the red beams where they were)? yes

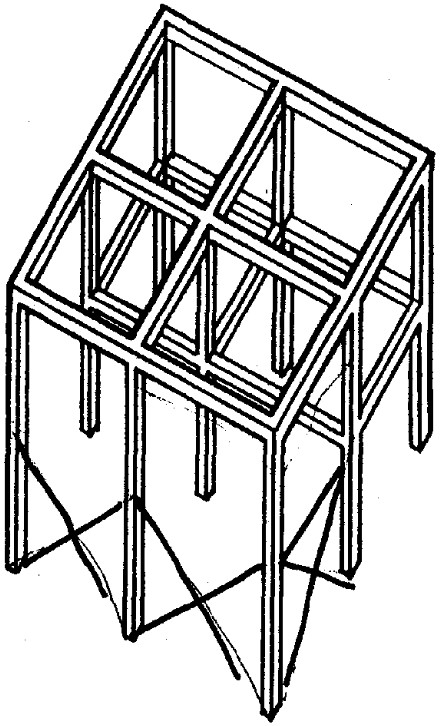
A. seismic load capability will lessen putting more load on The more stiff columns. however the seismic load may be great enough to cause a failure because of its slenderness ratio.

B. other columns because now "stiffer" will take on more load.

SOLUTIONS



Responding to part C, use one story high column-to-column panels.



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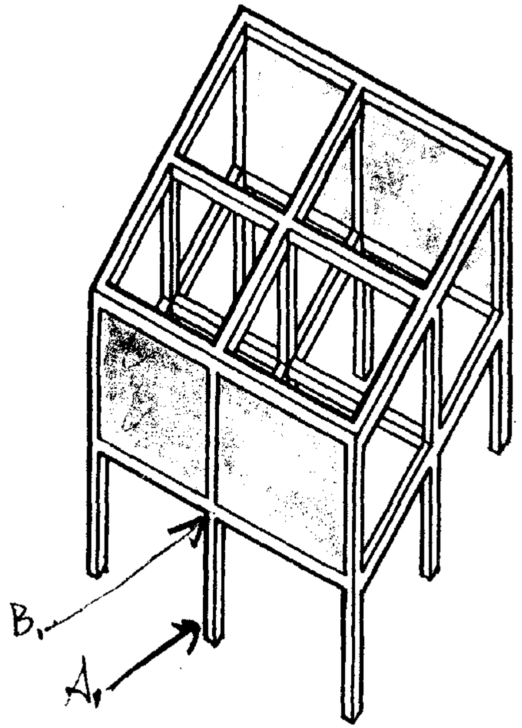
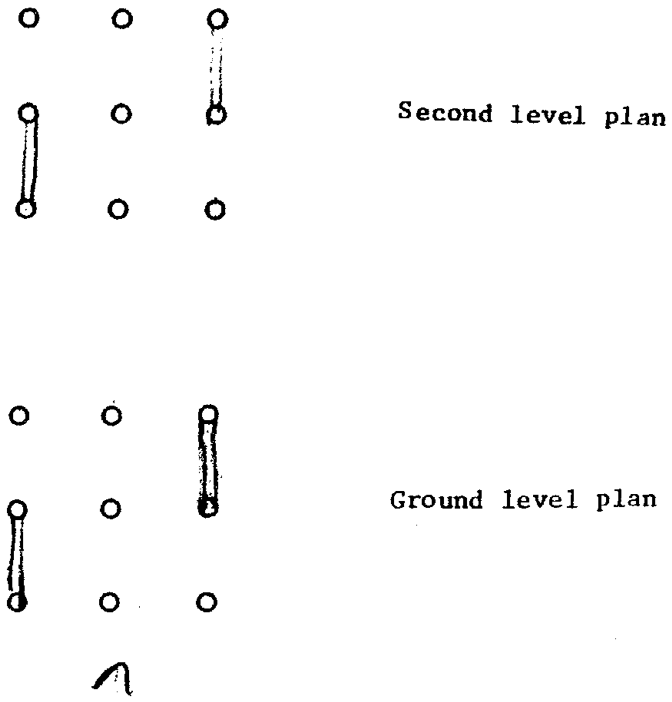
EXERCISE FOUR





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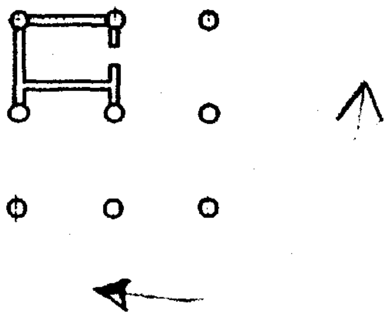
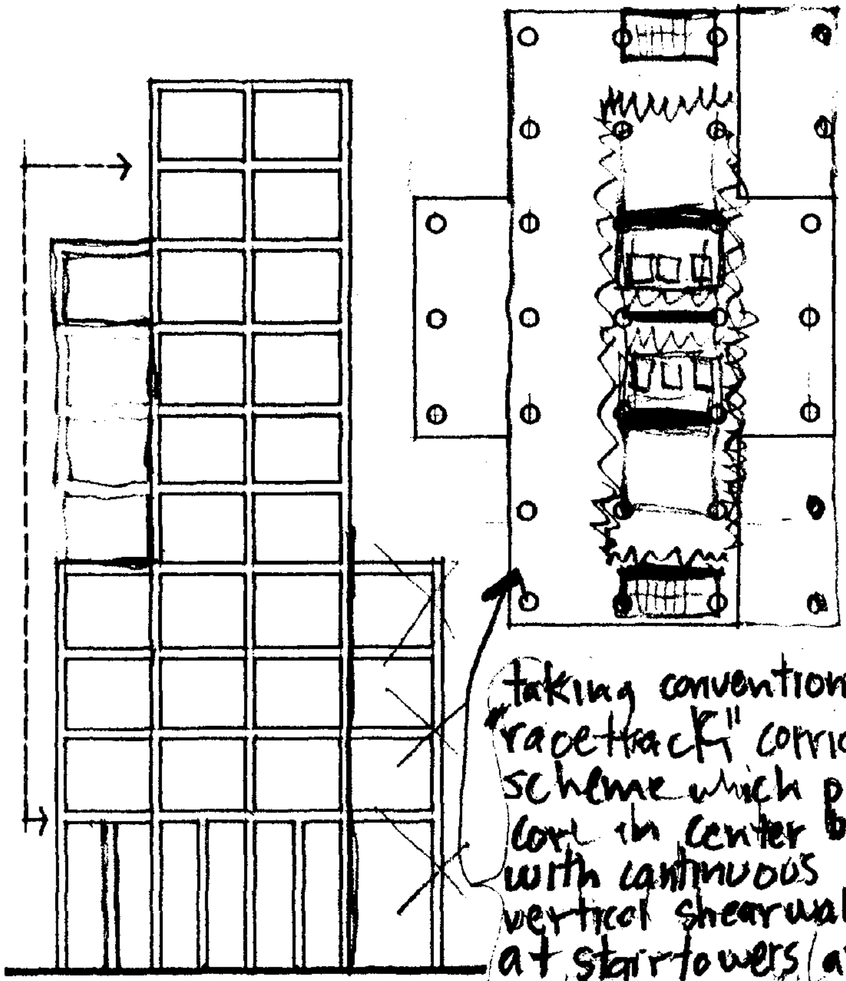
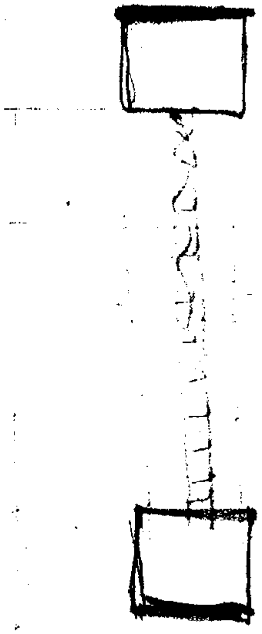


This core has the same plan on both levels.
Show where torsion will develop in the structure

EXERCISE FIVE B





← this plan puts cores with shear walls at each end of rectangle with central corridor move flexible neutral space

taking conventional "racetrack" corridor scheme which puts core in center bays with continuous vertical shearwalls at stairtowers (at end) and within central core

a. Discuss trade-offs between this configuration and one which would have the same number of bays in a simple rectangular configuration. For example, one additional story of 2 x 6 bays.

b. Place continuous shear walls, core, and circulation path as if this were a rental office building. Bay size : 20 x 20 feet.

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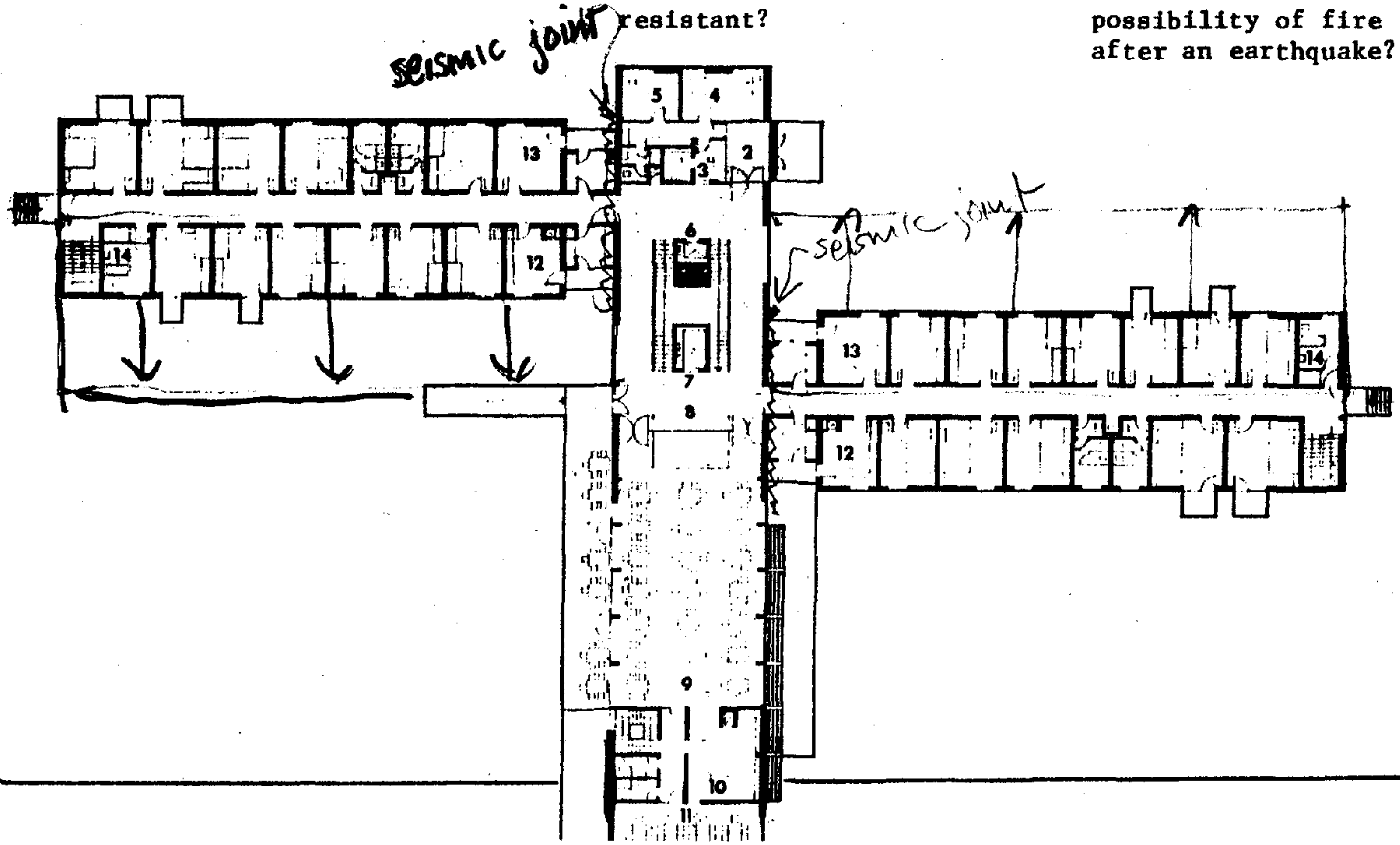
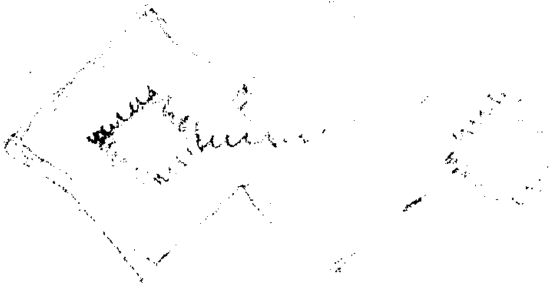
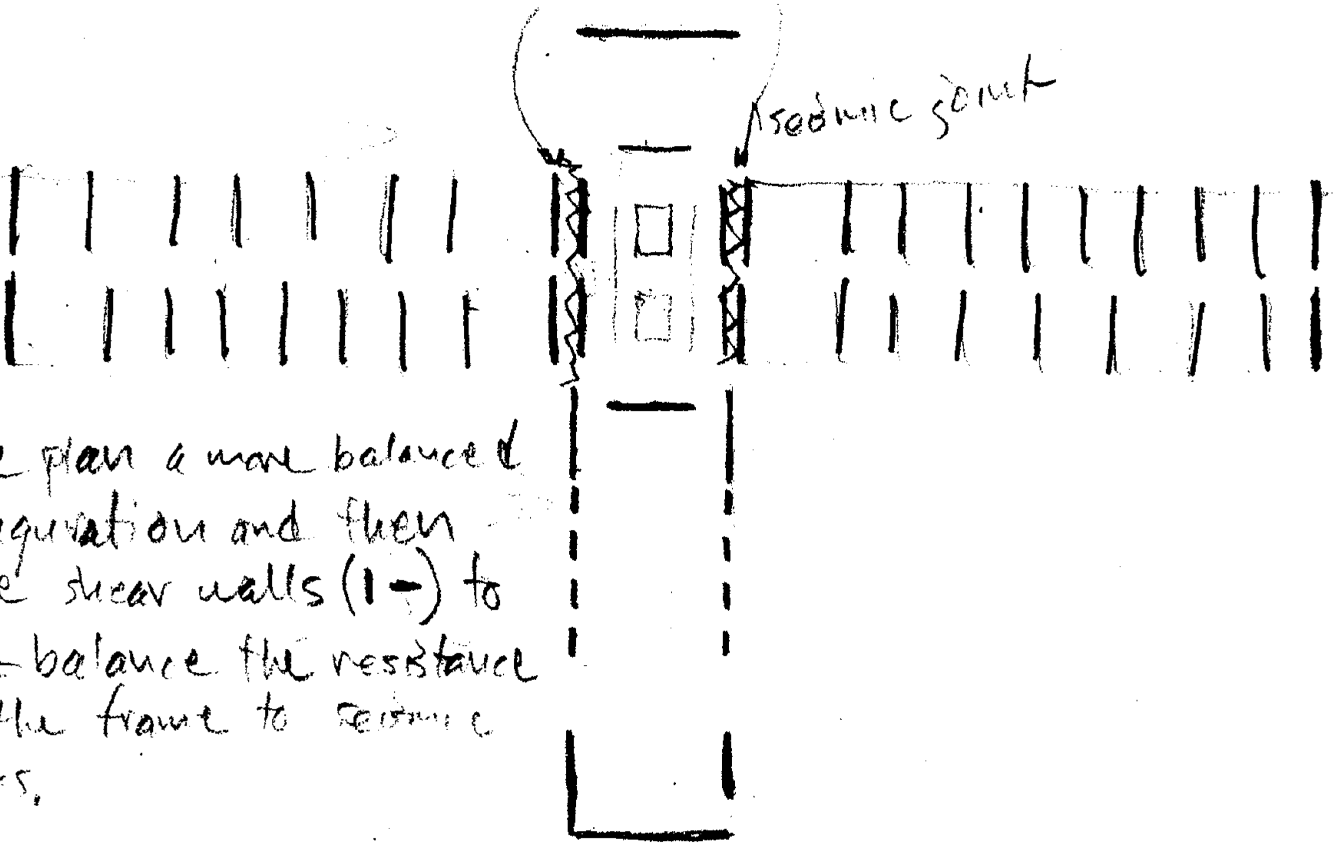
d. Analyze the merits of this plan in terms of access and egress, control orientation, adjacencies, natural lighting, etc. and the disadvantages in terms of the probable response to ground shaking Alter the plan to optimize it for both seismic and non-seismic criteria.



6a.

complete reconfiguration of plan to make it
thereby acting more as a whole ~~[illegible]~~ unit





make plan a more balanced configuration and then place shear walls (I-) to ~~get~~ balance the resistance of the frame to seismic forces.

6. b.

essential idea would be to centralize the electrical conduits and distribution so that it can be placed in areas of relatively equal rigidity. The electrical system should not be allowed to run "all over the building in straight runs" but rather the runs should be carefully placed to negate unequal reactions to seismic forces. This means a close coordination of architectural components such as walls, partitions and ceilings with the electrical components. Ceilings should be carefully detailed to either move totally free of wall systems or should be anchored to develop seismic resistance. Electrical systems should be designed with automatic shut down capability and manual start-up by phasing after building inspection.

6. c. Keeping in mind the cost trade offs between the bldg. functions and the seismic design needs one must conclude this plan as modified above is extremely well laid out as to occupant internal orientation, natural light and egress. There will be trade-offs because of the somewhat uncompact plan but the occupant requirement needs are more important unless the building happens to be located on the San Andreas fault. As shown above to optimize the plan for seismic resistance (shifting the room wings, lessening the dining room glazing etc.) the big pluses that make it a pleasant "home."

EXERCISE SEVEN

Fire station

This fire station is designed for an urban area. Besides the fire fighting apparatus, the building also houses a communication center, offices for the fire chief and quarters for the fighters. The fire fighters' quarters consist of two stories. The hose-drying tower (which also supports the radio antenna) is 40' high.

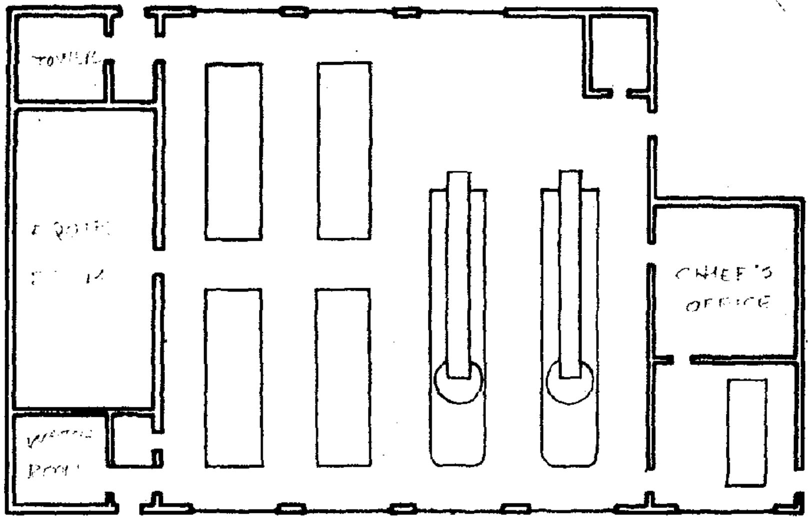
a. Because of the unequal stiffness of the perimeter of the structure, the columns could fail during an earthquake. Failure of the columns could damage or prevent removal of the equipment from the house. Can the design be altered to prevent this?

b. The communication center of the station must be operable at all times. How can the design provide the most resistance to failure of the watch room? Since the radio antenna is also integral to the operation of the fire station, how would you designate the optimal location and support for the antenna to avoid damage to it during seismic activity?

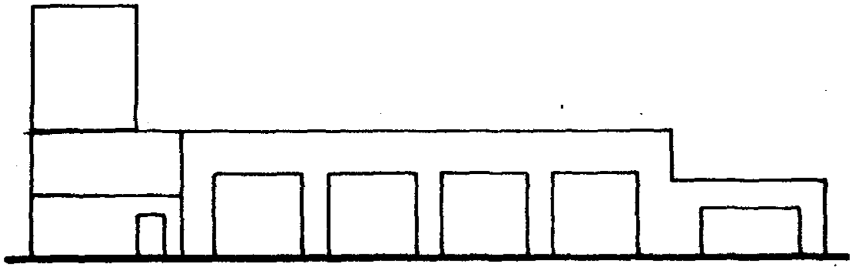
c. A hose tower is essential to the design. But the extreme height in relation to the rest of the structure could cause stress concentrations during an earthquake that could cause the tower to fail. The torsional stresses built-up in the tower could cause damage to other parts of the station; falling debris could injure fire fighters and equipment. Can the preliminary design make the tower more resistant?

EXERCISE SEVEN

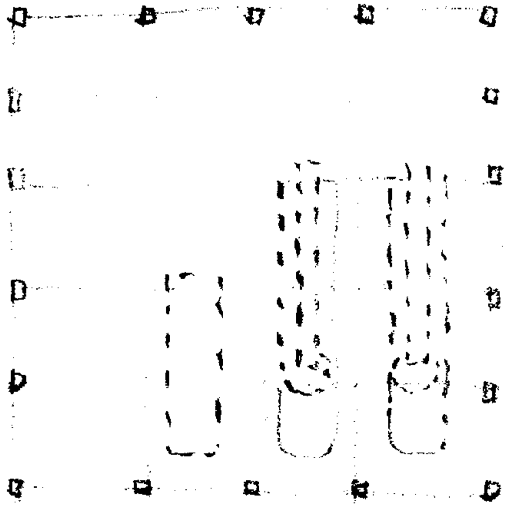
plan



elevation

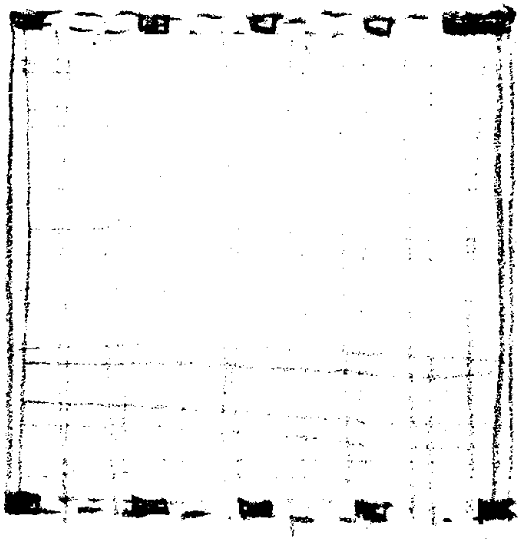


7.9



① (steel) moment resisting frame with infill non-rigid partition & walls.

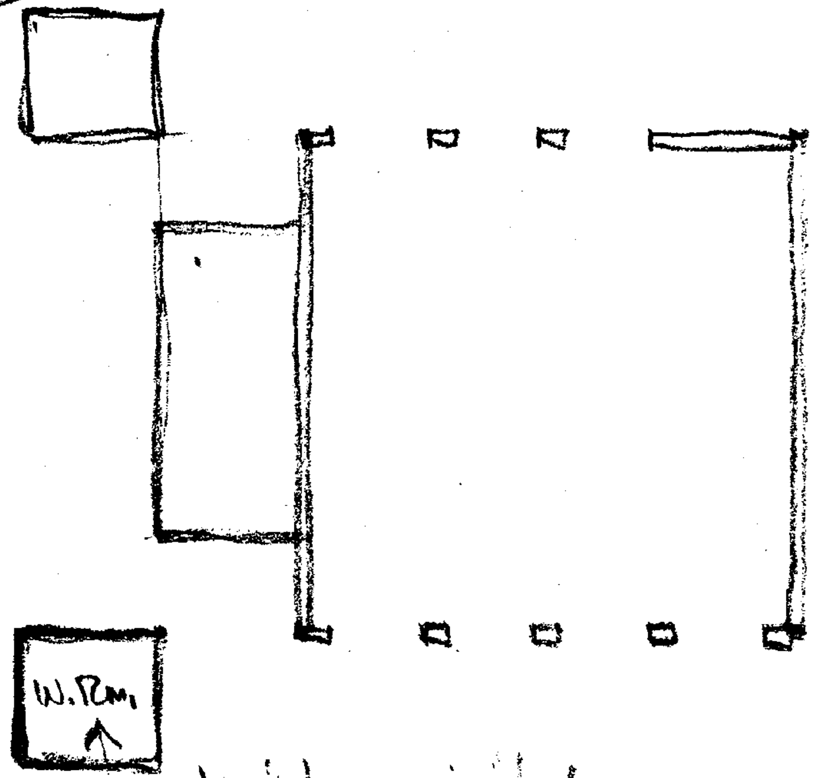
steel moment resisting frame with infill non-rigid partition & walls



② rigid box concept with roof being two way slab & side walls concrete frame & shear walls, with door wall piers made rigid equalling rigidity at side walls

rigid box concept with roof being two- ~~ways~~ way slab & side walls concrete frame shear walls, with door/wall piers made rigid equalling regidity at side walls.
(ed.)

1.b
(3)



build as rigid box place antenna on tip of it ~~for~~ place on ground which ever is easiest to construct optimum is separate location so that support can be specifically designed.

2.c.

to improve the tower first thought would be to isolate it away from the buildings ~~essential~~ critical areas, and then it would be a matter of ~~cost~~ as to how seismic resistant the construction would be.

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build as rigid box place antenna on tip of it ~~for~~ or place on ground which ever is easiest to construct. optimum is separate location so that support can be specifically designed. (ed.)

EXERCISE EIGHT

Hospital

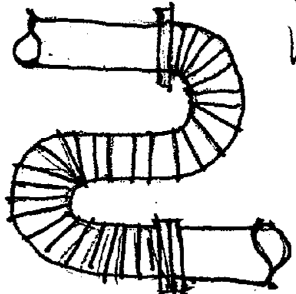
This plan is for a general hospital in an urban area. This 10 story design accomodates 600 patients. The overall dimensions are 82' by 166'.

a. Because of the extreme width/length and height/base ratio of this design, the building is vulnerable to the torsional effects of seismic activity. The support systems (heat, water, electricity) which are critical to the hospital's functioning can be damaged by this motion. Can you design a detail for one of these systems that would make it more resistant to failure? For example, a way of connecting a water pipe to the structure such that seismic activity would not tear it away.

b. The nature of this building type requires reduced noise levels and visually pleasant ceiling surfaces in the patients rooms. However, hung ceilings are very susceptible to earthquake damage. Can you provide an alternate ceiling system or design a detail to make the hung ceiling less likely to fail?

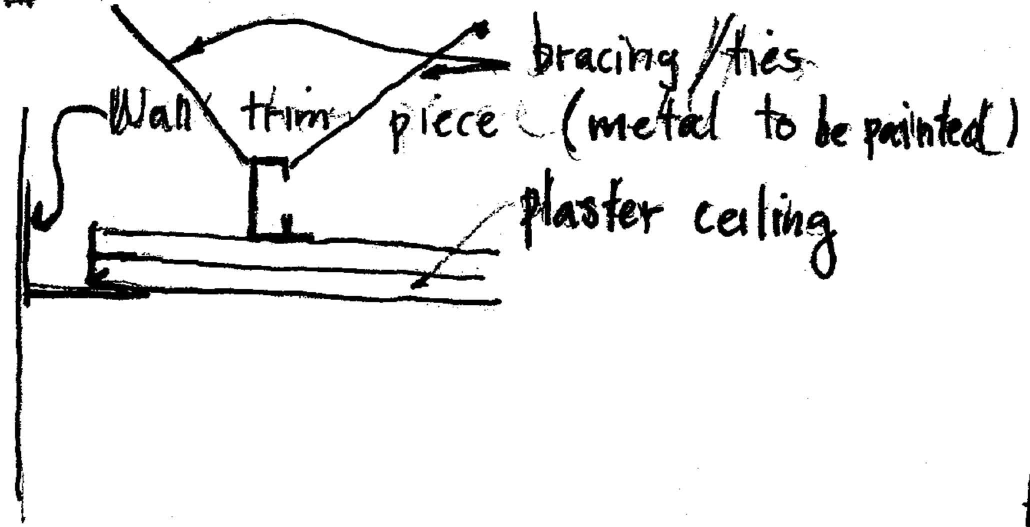
c. Hospitals contain numerous pieces of equipment that must be movable or are placed adjacent to the patient's bed. This equipment can be dislodged during an earthquake, causing injury to patients or discontinuity of care. One particularly dangerous element is the call button/monitoring system hung on the wall above the patient's head. Can you detail a connection to protect this console from damage during an earthquake?

(8).a. flexible electrical conduit
to be locale at transitions
between unequally
rigid building parts
such as at partitions



flexible electical conduit to be located at transitions between unequally rigid building parts such as at paltitions. (ed).

8.b))



8.c.) place console in partition
wall which is flexible which
would have flexible conduit
connections
second option would be
to make this partition as rigid
as surrounding structural frame

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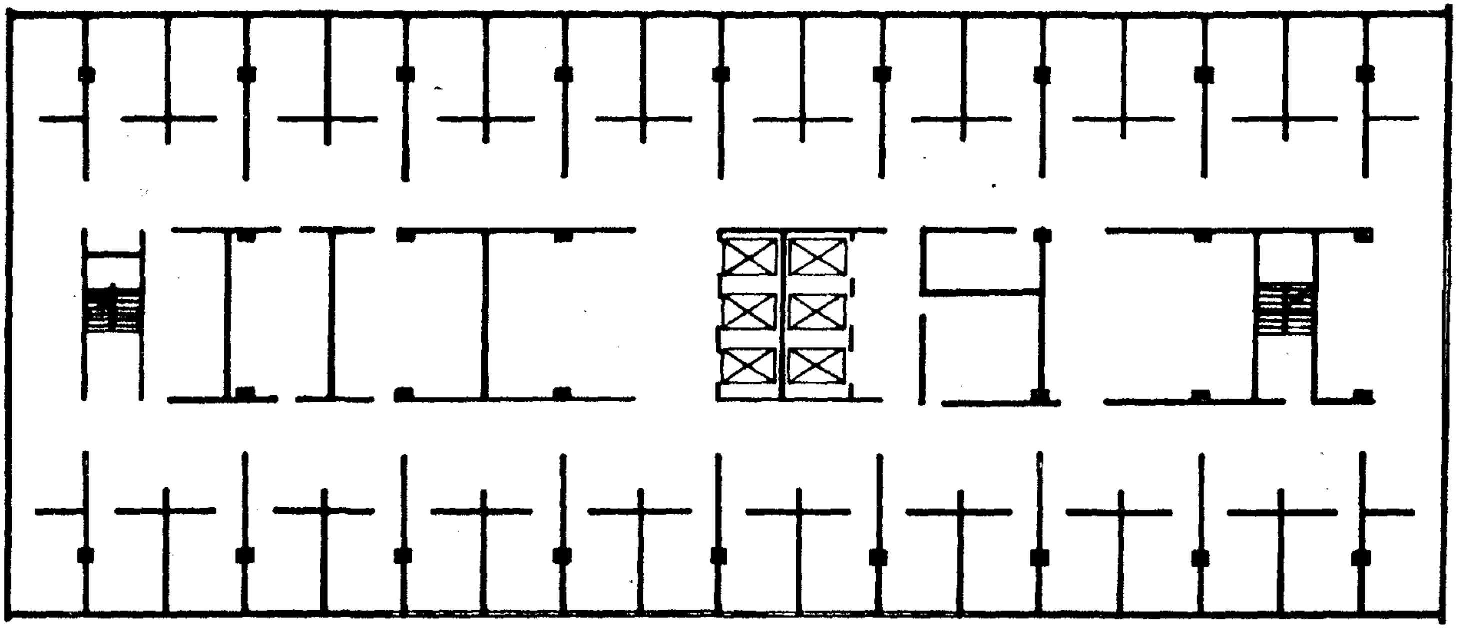
Second option would be to make this partition as rigid as surrounding structual frame. (ed).

EXERCISE EIGHT



typical plan

EXERCISE NINE

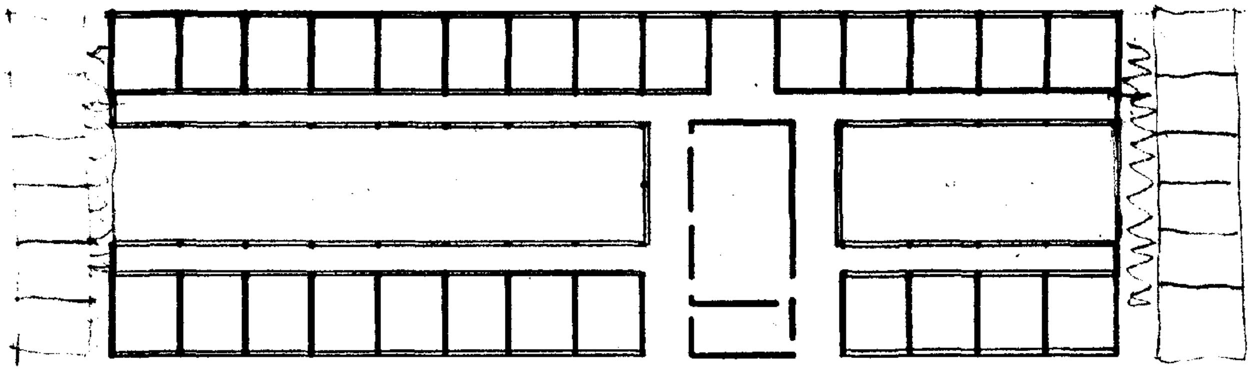
Elementary School

The elementary school is a one story brick bearing wall structure with glazed exterior classroom walls and corridors.

a. The large surface area of glazing allows natural lighting in the classrooms and corridors. In an earthquake, this glazing could fail causing injury to the students. How can you reconcile the benefits of the natural light and the safety of the students?

b. Tile floors in the school are easily maintained and sound absorbing, but the ground-shaking and torsion resulting from an earthquake can destroy this floor surface. Do the benefits of this floor system outweigh the vulnerability to damage?

c. One advantage to this plan type is the ease with which new classrooms may be added. But considering that the longer the classroom wings extend from the core of the building the more vulnerable they become to torsion, do expansion benefits compensate for the vulnerability of the structure?



plan

9a. Relative to where this school is located a number of options come to mind

1.) substitute for the glass laminated glass or lexan

2.) Remove portions of the glass along the corridors ~~and~~ leaving selected glass panels

3.) Remove part of the classroom glass and redesign for lighting / views

4.) with the court yards provide evacuation of classrooms to a safety zone is possible

(b) The tile assuming it is a material such as vinyl asbestos tile would be better replaced by a school grade carpet a which more accepted floor finish, no matter how susceptible the region [illegible] to [illegible] activity.

(c) unless seismic design modifications are accomplished in the interim the possibility of expansion [illegible] does not outweigh the buildings vulnerability. The addition scheme as drawn is based on giving rigidity to the structures and supplying ~~for~~ a reasonable addition square footage while maintaining the court yard which could be excellent out door teaching spaces.

EXERCISE TEN

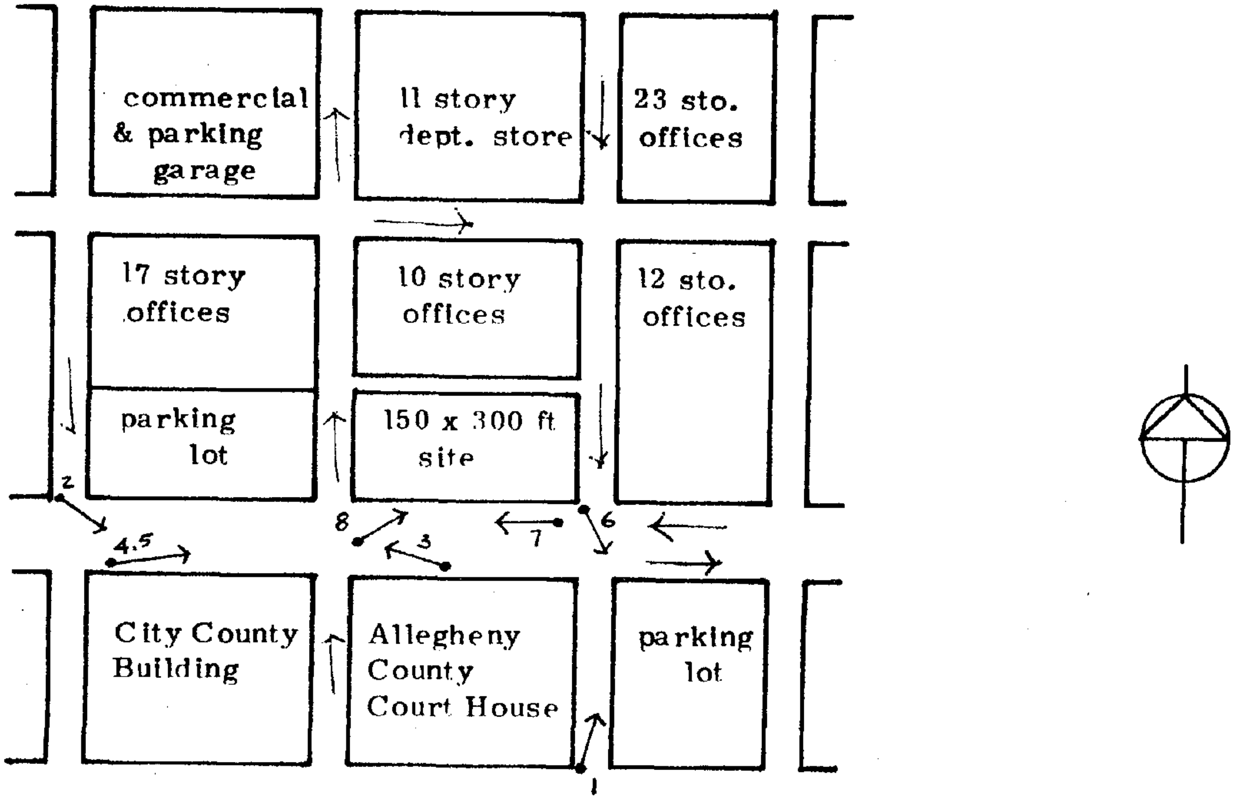
Given:

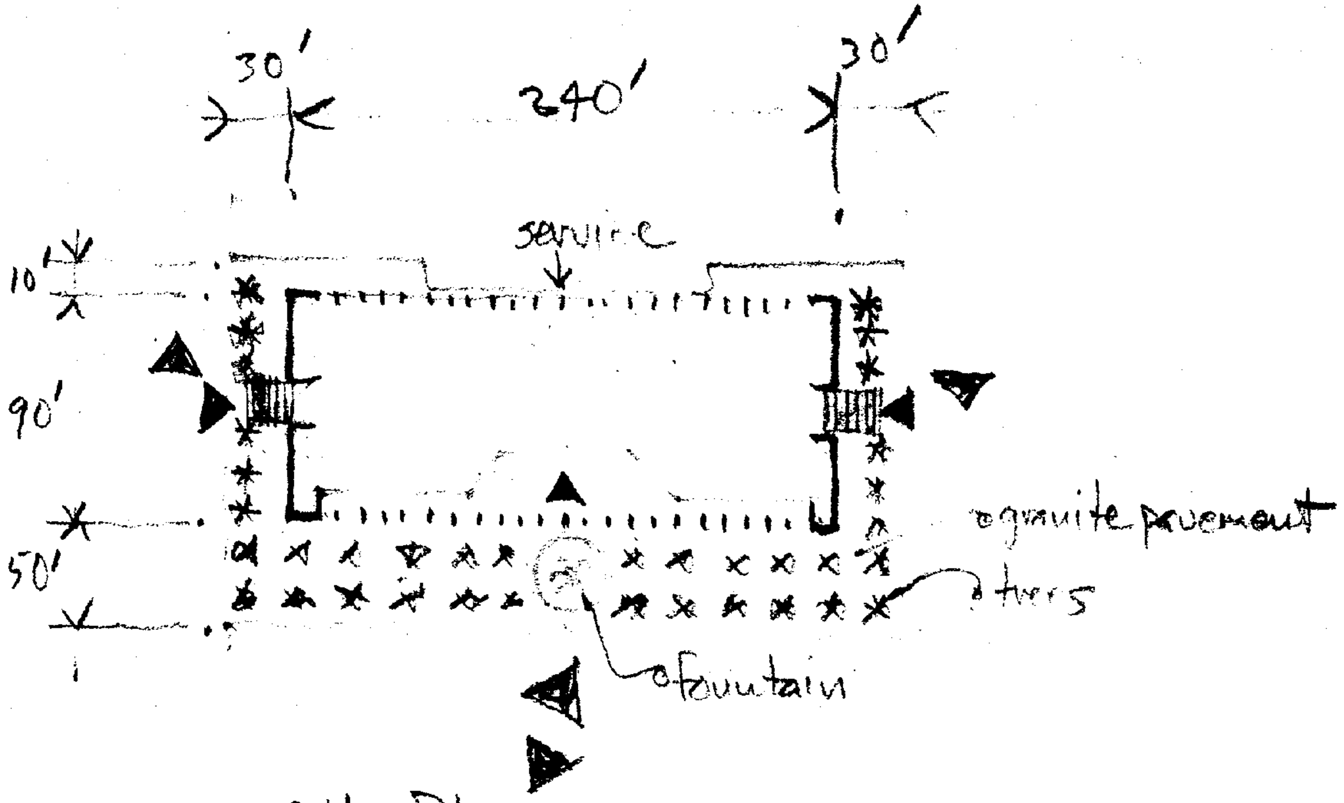
A site located at downtown Pittsburgh, surrounded by commercial, business and government office buildings. The site is bounded by one-way streets on both sides, an alley, and a major two-way street with a street car lane in the middle. Across this major street is the Allegheny Court House, a Richardsonian building.

Problem:

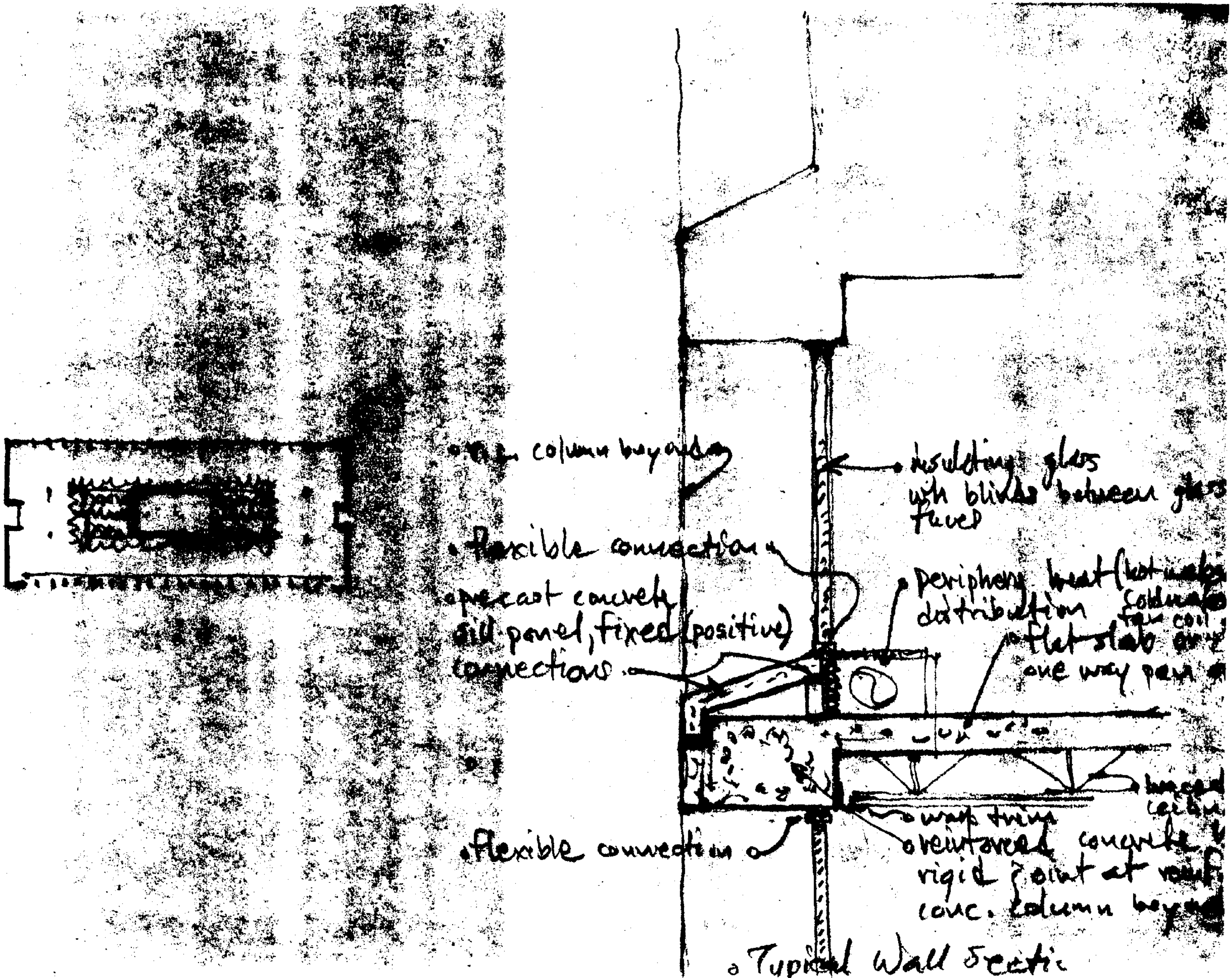
Design a 450,000 - 500,000 sqft office building which has a one or two story commercial base of approximately 20,000 sqft accessible from three sides of the site. (Alley only for service). Zoning requires maximum of 80% site coverage, 360 ft height limit. Discuss and sketch the choice of building configuration, structure, mechanical system location, access and egress (and some specific details -- exterior walls, material selection, etc.)

EXERCISE TEN

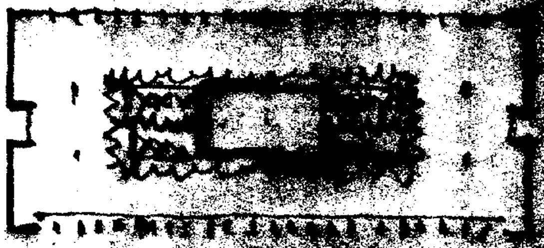


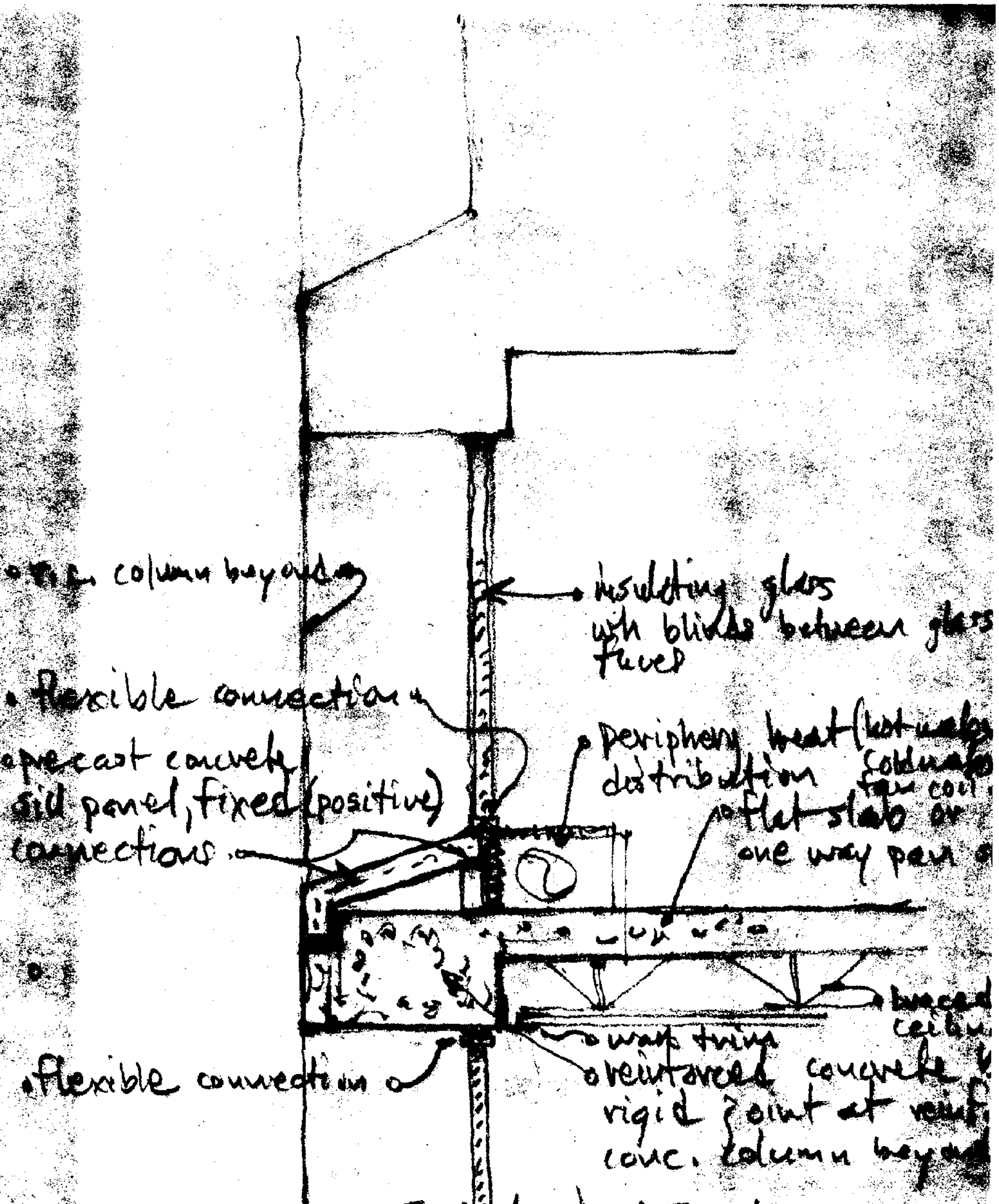


Site Plan

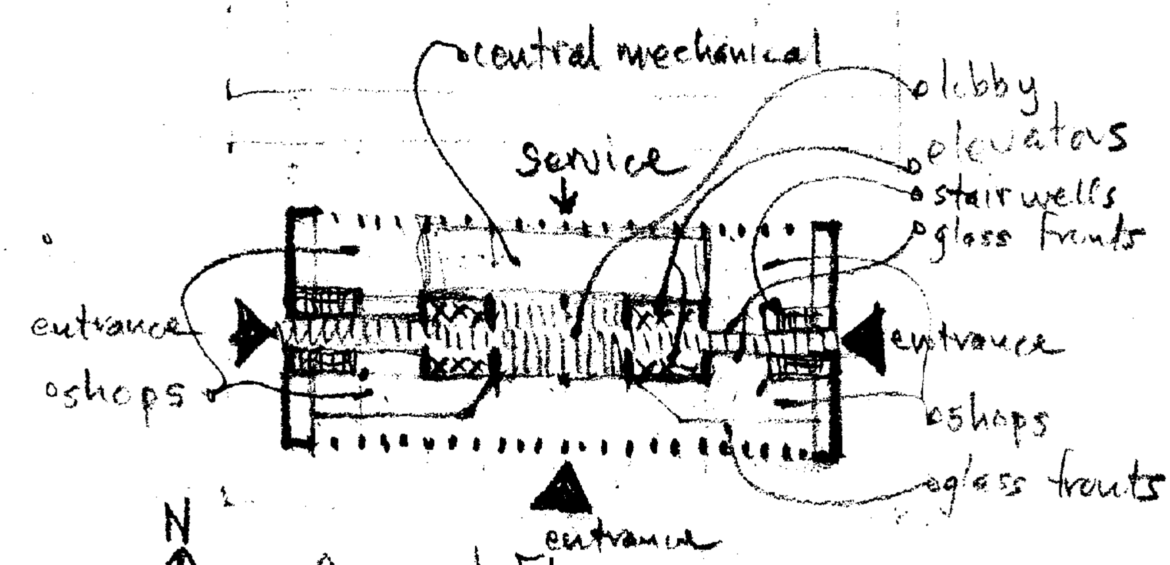


Typical Wall Secti

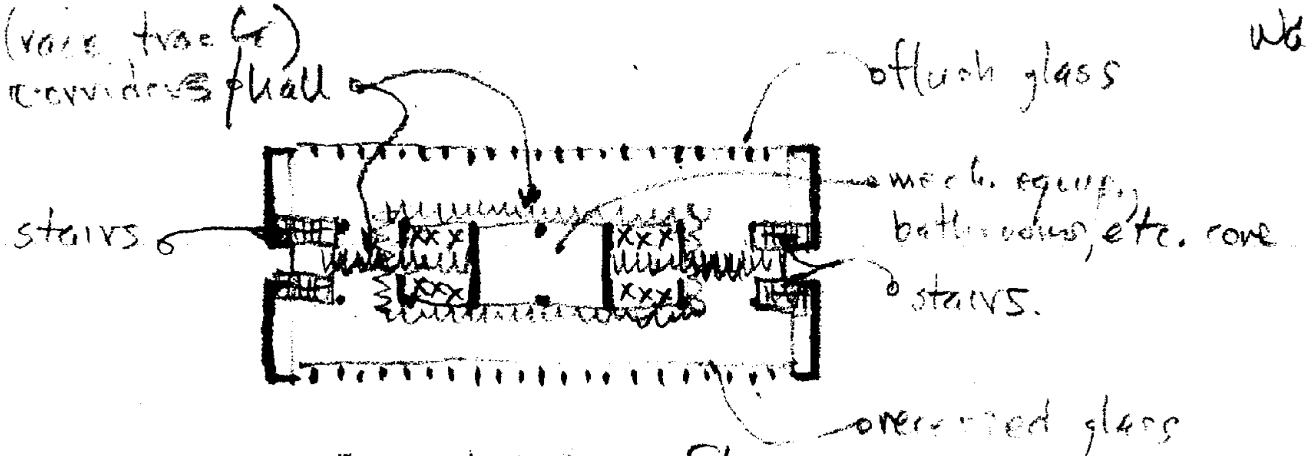




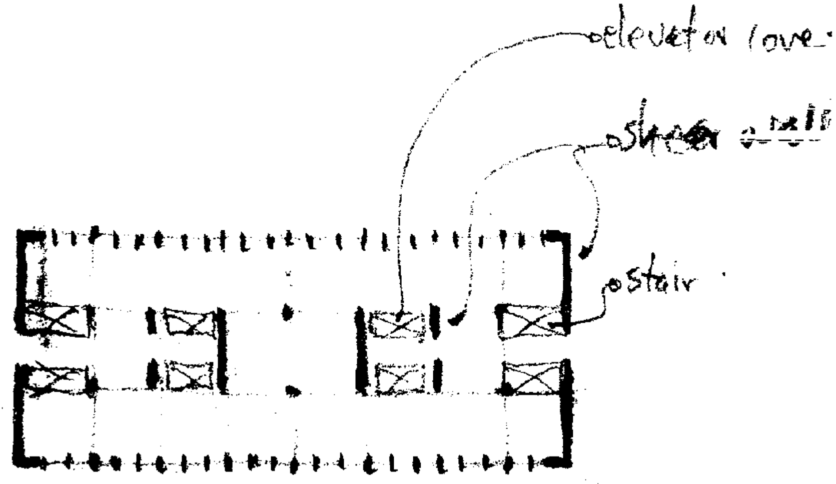
o Typical Wall Section



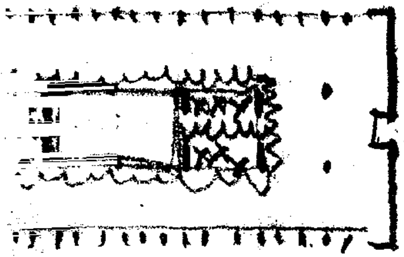
○ Ground Floor ○

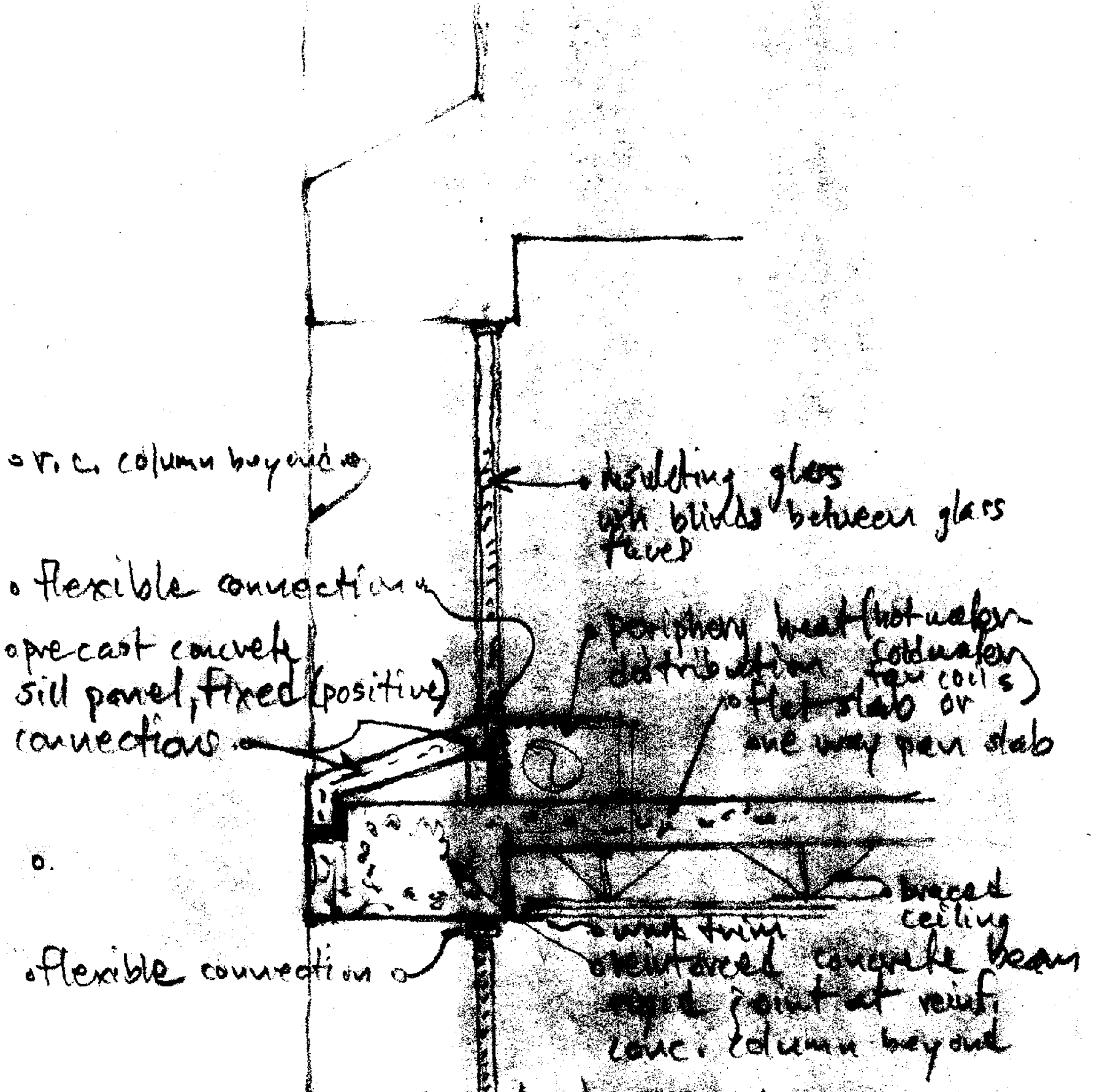


○ Typical Office Floor
(22 stories + ground level)



○ Reinforced Beam Grid
w/ flat slab or one
way pan slab





Typical Wall Section @ South Wall

APPENDIX C

Code Outlines and Commentary

1. APPENDIX C

CODE OUTLINES AND COMMENTARY

Introduction

The codes which deal with the seismic design as it is available now are very general. A great portion of the subject is found in the Structural Engineering Association of California (SEAOC) and the Applied Technology Council (Tentative Provisions) (ATC-3.) The MSBC and the Uniform Building Code (UBC) '79 have some sections on seismic design.

We have tried to gather the necessary information about the code which will aid the architects in the process of design. In SEAOC, we found that the code deals more with the structural design, which is found in the general provision, the commentary section and the appendix of the code book. The ATC-3 deals more with the non-structural design element, such as architecture and mechanical building components, as well as the structural design requirements. The UBC and MSBC have very brief sections on seismic design, and can be considered as cross references of the SEAOC.

A list of topics in SEAOC, ATC-3, and UBC follows on pages 1 to 4.

SEAOC OUTLINE

Recommended Lateral Force Requirements

General Provisions -- Section 2313
p. 15 Minimum Earthquake Forces for structures - part (a)
    structures having irregular shape or framing system - part 2

p. 17 Distribution of Horizontal Shear - part (e)
Horizontal Torsional Moments - part (g)
Overturning - part (h)
Setbacks - part (i)

p. 18 Structural systems - part (j)
    special requirements:
    a) building designed with horizontal force factor (k)
    b) building > 160 ft tall
    c) concrete space frame
    d) framing according distribution horizontal shear (and part e, p. 17)
Design Requirements - part (k)
p. 64 Building separations - part 1
Minor alterations - part 2
Reinforced masonry/concrete - part 3

Combined vertical and horizontal forces
- part 4

Exterior element
specification for connections

Commentary Section of SEAOC

p.42 Minimum Earthquake forces for structures

Total lateral force & distribution of lateral force
base shear V = K C W

p.p. 47,48 Special requirements - K values

P.P. 14,36 Box system

P. 50 Space frame - K values

P. 50 Rigid elements

P. 62 Setbacks (more of this: SEAOC Appendix C - Report on Setbacks)

P.P. 19,64 Design requirements
  Building separations
  Reinforced Masonry/concrete

P. 86 SEAOC Appendix C: Setbacks
  General
  Dynamics K/M value (stiffness/mass)
  Practical code considerations
    if the base portion predominates
    if tower portion predominates
    if intermediate cases

P. 88 Frame action for setbacks

ATC-3 OUTLINE

P. 45 <u>Structural design requirements</u> (Chp. 3.)
  A. Building configuration (sec. 3.4)
    Plan configuration (sec. 3.4.1)
    Vertical configuration (sec. 3.4.2)

P. 49 B. Structural component load effect (sec. 3.7)
    Diaphragms (sec. 3.7.9)
    Bearing Walls (3.7.10)
    Inverted pendulum-type structures (sec. 3.7.11)

<u>Arch., Mech., & Elec. components & systems</u> (chap. 8)

- Non-structural components (Sec. 14.9)
    - Parapets
    - Appendages and Veneers
    - Ceilings
    - Light fixtures
    - Fire escapes
    - Marquees and canopies
    - Non-bearing part-time
    - Mech. & Elec. equipment
    - Stairs
    - Elevators
    - Chimney
    - Water storage tanks

P. 237 Guidelines for emergency post-earthquake & evaluation of earthquakes (Chapter 15)
- damage in buildings
- Emergency Earthquake damage inspection form (Sec. 15.6.1)

P. 409 Arch., Mech., & Elec. Components (ATC Commentary Chapters)
- Background to architectural considerations
- Methodology
    - Architectural components
    - Occupancy classification
    - Performance standards

p. 410 Background to mechanical & Electrical components

P. 411 Design considerations
- General life safety
- Property damage affecting life safety
- Functional impairment of critical facilities imparing recovery
- Safety of emergency personnel

P. 411 Design consideration for non-structural component/systems
- Seismic induced forces acting directly on component/system
- On component/system joints & connections
- Deformation of structural frame & component/system
- Deformation of structural frame & component/system joints/connections

P. 412 Scope
- General requirements (Sec. 8.1)
- Connections & attachments (Sec 8.1.2)

P. 414 Performance criteria (Sec. 8.1.3)

P. 416 Architectural Design Requirements (Sec. 8.2)
- General (Sec. 8.2.1)

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P. 416 Architectural Design Requirements (Sec. 8.2)
- General (Sec. 8.2.1)

Forces – (Fp) (Sec. 8.2.2)

P. 419 Mechanical and Electrical Design Requirements
- General (Sec. 8.3.1)

P. 423 Forces (Sec. 8.3.2)

U.B.C. OUTLINE

P. 126 Eq. Regulations
- Minimum Eq. forces for structures
  - formulas

P. 130
- Distribution of lateral forces
  - Structures having regular shapes or framing systems
  - Setbacks
  - Structures having irregular shapes or framing systems
  - Distribution of horizontal shear
  - Horizontal torsional moments
- Overturning
- Lateral force on elements of structures and non-structural components
  - Fp = 21 Cp Wp
- Drift & building separations
- Alternate determination & distribution of seismic forces
- Structural systems
  - 1. Ductility Requirements
    - a. Building designed with horizontal force factor
      - K = 0.67 / 0.80
    - b. Building > 160 ft. high
    - c. Zone 2,3,4––concrete space frames
    - d. Zone 2,3,4––all framing elements (factor K)
    - e. Moment-resisting space frames
    - f. Necessary ductility for ductile moment-resisting frame
    - g. Zone 3 & 4 for building with I > 1.0 in Zone 2
    - h. Reinforced concrete shear wall
    - i. Structural elements below the base
  - 2. Design requirements
    - a. Minor alterations
    - b. Reinforced masonry/concrete
    - c. Combined vertical & horizontal forces
    - d. Diaphragms

P. 134
  - 3. Special requirements
    - a. wood diaphragms providing later support for concrete or masonry walls
    - b. Pile caps & caissons

c. Exterior elements

P. 135	Essential facilities (Hospital, Fire/Police Stations, etc.)
P. 665	Earthquake-recording instruments

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P. 665	Earthquake-recording instruments

Chapter 3 Structural Design Requirements (p. 45)

This section speaks to the control of individual members for shear, axial forces, and moments produced by seismic forces; development of the strength of connections; deformation limits of the building; and the design of a continuous load path.

It does not cite limits nor describe the use of a linearly elastic model. It does bring attention to the problem areas but requires more research.

Chapter 3.4 Building Configuration

Indicates two classifications for building configuration / regular and irregular. Regular being buildings with approximate symmetrical geometric configurations / building mass & seismic resisting system nearly coincident. (both plan and vertical configuration)

Gives no limits for any variation of the symmetrical configuration. Other sources needed to evaluate degree of variation.

Chapter 3.4.1 Plan Configuration

Addresses diaphragm component forces and distribution of seismic forces to vertical components in terms of "significant" dimensions of re-entrant corners; eccentricity; charges in diaphragm strength in stiffness.

No measure of "significant" in any case.

Chapter 3.4.2 Vertical Configuration (p. 48)

Building considered regular or irregular if there is "significant" change in horizontal off-sets; no "approximate" symmetric geometric configuration about the vertical axis; "significant" variation in mass-stiffness ratios between stories.

Generalized limitations with attention brought to problem areas.

Chapter 3.7 Structural Component Load Effects (p. 49)

Seismic force resistance should be calculated into the strength of all building

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Chapter 8.2.5 Out-of-Plane Bending (p. 79)

See formula 8-1 for force determination: Systems and component forces cannot exceed the delta capacity of their materials.

Chapter 8.3 Mechanical and Electric Design Requirements

Design documents must include the design requirements of the systems (which are designed according to this chapter).

Chapter 8.3.2 Forces (p. 79)

Designed for forces determined by: Fp= AvCcPacAxWc).

Chapter 8.3.3 Attachment Design

Fixed or direct attachment see sec. 8.3.2, cha. 9, 10, 11, 12. Resilient mounting devices required but no limits specified for elastic restraining design based on Form 8-2. Horizontal and vertical devices designed to generate less force than that derived in 8-2.

Chapter 8.3.4 Component Design

Manufacturer's certification required when direct attachments are used for components of specific levels in specific seismic index areas. (also resilient mounting devices). Prescribes stable systems.

Chapter 8 Architectural, Mechanical and Electrical Components

Development of performance standards and examination of critical facilities the aim of the code: from a rational design conception of the "total" building; integration of all components; and stresses importance fabrication methods.

B. Background to Mechanical & Electrical Components

Objective to develop seismic criteria for the design & construction of systems and attachments / to increase protection of life & public welfare; to define an acceptable level of damage.

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Chapter 8.2.5 Out-of-Plane Bending

Conventional limits based on deflection "may be used."

Chapter 8.3 Mechanical & Electrical Design Requirements

Chapter 8.3.1 General

Lists assumed design forces.

Chapter Forces

Formula 8-2 "shall be used" in component and attachment design. Attachments "shall be" either fixed or directly attached. Friction "cannot" be used to resist seismic force. Certification of manufacturer "must be obtained" for components with certain performance levels. Resilient mounting devices "to decelerate movement and forces" generated by it not more than the forces calculated in formula 8-2. Fp = AvCcAcAxWcP

Chapter 8.3.5 Utility and Service Interface

Automatic shut-off devices are "required" for certain groups in specific area.

Systems "must" remain operational in S performance charc. level. (on site mechanical & electrical utility services are recommended). Chapter 9 Wood Reference Documents

Chapter 9.3 Seismic Performance Category A

Specifies materials and procedures.

Chapter 9.4 Seismic Performance Category B (p. 86)

Requirements of A plus more restrictions

Chapter 9.5 Seismic Category C

Requirements of B plus more restrictions.

Chapter 9.5.1 Materials

Chapter 8.2.5 Out-of-Plane Bending

Conventional limits based on deflection "may be used."

Chapter 8.3 Mechanical & Electrical Design Requirements

Chapter 8.3.1 General

Lists assumed design forces.

Chapter Forces

Formula 8-2 "shall be used" in component and attachment design. Attachments "shall be" either fixed or directly attached. Friction "cannot" be used to resist seismic force. Certification of manufacturer "must be obtained" for components with certain performance levels. Resilient mounting devices "to decelerate movement and forces" generated by it not more than the forces calculated in formula 8-2. Fp = AvCcAcAxWcP

Chapter 8.3.5 Utility and Service Interface

Automatic shut-off devices are "required" for certain groups in specific area.

Systems "must" remain operational in S performance charc. level. (on site mechanical & electrical utility services are recommended). Chapter 9 Wood Reference Documents

Chapter 9.3 Seismic Performance Category A

Specifies materials and procedures.

Chapter 9.4 Seismic Performance Category B (p. 86)

Requirements of A plus more restrictions

Chapter 9.5 Seismic Category C

Requirements of B plus more restrictions.

Chapter 9.5.1 Materials

Chapter 12.A.4.5 Holes, Pipes and Conduits

Prescribes sleeving and embedding in masonry per sec. 6.3.ACI standard 318.

Chapter 12.A.6 Design Requirements

Prescribes use of higher stresses; fm and loading age shown on plans; stresses and capacities based on net dimensions, etc.

Chapter 12.A.6.4 Masonry Shear Walls

A. Boundary elements

Prescribes the effective flange width at shear wall intersection with other walls; the overhanging effective flange width for reinforced and un-reinforced masonry.

Performance in consideration of vertical shear at intersection of web and flange of shear wall.

B. Vertical Tension and Compression Stresses (p. 151)

Prescribes formula 3-2A for unreinforced masonry. Performance statement for consideration vertical stresses; minimum vertical loads; allowable tension.

C. Horizontal Elements

Performance standards for shear & flexural effects; allowable shear & tensile stresses; horizontal span of the element - outside reinforcing needed.

Shear reinforcing is prescribed for certain horizontal elements.

D. Wall Shear

Shear wall resistance computed only by the web (unreinforced masonry-depth of web out to flange). No limits given.

Unreinforced masonry prescribed by form 12A-8

Shear resistance based on net area - prescribes the area to be considered.

Chapter 12.A.4.5 Holes, Pipes and Conduits

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Shear resistance based on net area - prescribes the area to be considered.

B. Appendages and Veneers

Describes means of attachment but gives no limits.

C. Ceilings

Gives allowable attachment of plastic ceilings. Describes how hung ceilings may be made more resistant but gives neither prescriptive or performance standards. Nailing by code.

D. Light Fixtures

Must be evaluated for resistance to lateral forces - no limits.

E. Marquees and Canopies

Anchors "should be exposed. Bring up to code requirements.

F. Fire Escapes

"Should" be lateral load tested or visually inspected.

G. Non-bearing Partitions

Anchorage "should" be strengthened; partitions "should" be separated from walls; "should" resist forces normal to the wall.

H. Mechanical & Electrical Equipment

Stability must be evaluated; allows attachment to structural frame; no limits.

I. Stairs

Does not limit material, but specifies for resistance to lateral load.

J. Elevators

Enclosures, guides, anchorage or motor equipment "may" be strengthened and "should" be evaluated. Support beams "analyzed by an engineer."

B. Appendages and Veneers

Describes means of attachment but gives no limits.

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Gives allowable attachment of plastic ceilings. Describes how hung ceilings may be made more resistant but gives neither prescriptive or performance standards. Nailing by code.

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Stability must be evaluated; allows attachment to structural frame; no limits.

I. Stairs

Does not limit material, but specifies for resistance to lateral load.

J. Elevators

Enclosures, guides, anchorage or motor equipment "may" be strengthened and "should" be evaluated. Support beams "analyzed by an engineer."

K. Chimneys

Anchorage of ties "should be evaluated" and reinforcement "may be added." No limits given.

L. Water Storage Tanks

Chapter 15 Guidelines for Emergency post-earthquake inspection & evaluation of Damage

"Investigator" must determine whether structural damage has occurred.

Chapter 15.6.1 Emergency Earthquake Damage Inspection Form

"May" be used by the investigator.

SEOAC COMMENTARY

Recommended Lateral Force Requirements

General Provisions - Section 2313

p. 15 (d) Minimum earthquake forces for structures.
p. 16 2. Structures having irregular shape or framing systems. The distribution of the lateral forces in structures which have highly irregular shapes. Large differences in lateral resistance or stiffness between adjacent stories or other unusual features shall be determined considering the dynamic characteristics of the structure.

p. 17 (e) Distribution of horizontal shear.
Total shear in any horizontal plane shall be distributed to the various element of the lateral force resisting system in proportion to their rigities, considering the rigidity of the horizontal bracing system or diaphragm. Rigid elements that are assumed not to be part of the lateral force-resisting system may be incorporated into buildings provided that their effect on the action of the system is considered and provided for in the design.

p. 17 (g) Horizontal torsional moments.
MSBC p. 262 Provisions shall be made for the increase

(sec 716.4.3) in shear resulting from the horizontal torsion due to an eccentricity between the center of mass and the center of rigidity. Negative torsional shear shall be neglected. Where the vertical resisting elements depend on diaphragm action for shear distribution at any level. The shear resisting elements shall be capable of resisting a torsional moment assumed to be equivalent to story shear acting with an eccentricity of not less than 5% of the maximum building dimension at that level.

p. 17 (h) Overturning

MSBC–p. 263
sec 7.6.4.4

Every building or structure shall be designed to resist the overturning effects caused by the wind forces and related requirements, or the earthquake forces specified in this section, whichever govern.

At any level, the incremental changes of the design overturning moment, in the story under consideration, shall be distributed to the various resisting elements in the same proportion as the distribution of the shears in the resisting system. When other vertical members are provided which are capable of partially resisting the overturning moment, a re–distribution may be made to these members of sufficient strength and stiffness to transmit the required loads are provided.

Where a vertical resisting element is discontinuous, the overturning moment carried by the lowest story of that element shall be carried down as load to the foundation.

p. 17 (i) Setbacks (def: p. 40)

SEAOC(p. 62)
SEOAC(p. 16)

Buildings have setbacks where in the plan dimension of the tower in each direction is at least 75% of the corresponding plan dimension of the lower part may be considered as uniform buildings without setbacks, providing other irregularities as defined in Section 2313 (d)2 do not exist. Buildings having such irregularities shall conform to the provisions of 2313 (d)2. (see appendix G, p. 141)

p. 18 (j) Structural Systems

1. Special Requirements (see appendix F & G)

see table 23–C
(p. 20)

a. All buildings designed with a horizontal factor k = 0.67 or 0.80 shall have space frames – ductile moment resisting.
note: k = Numerical coefficient as set

Principal reinforcement in masonry shall be placed four feet maximum on center except that a maximum two feet shall be used in buildings having a moment resisting space frame. (see Appendix G)

4. Combined vertical and horizontal forces
   In comparing the effect of seismic force in combination with vertical loads, gravity load, stresses induced in members by dead load plus design live load, except roof live load shall be considered.

5. Exterior elements
   Precast non-bearing non shear wall panels or or other elements which are attached to or enclose exterior shall accommodate movements of the structure resulting from lateral forces or temperature changes. The concrete panels or other elements shall be supported by means of poured in place concrete or by mechanical fasteners in accordance with the following provisions:

   a. Connections and panel joints shall allow for a relative movement between stories of not less than 2 times the story drift caused by wind or seismic forces; or one-fourth inch whichever is greater.

   b. Connection shall have sufficient ductility and rotating capacity so as to preclude fracture of the concrete or brittle failures at or near welds. Marks in concrete shall be attached to or hooked around reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

   c. Connections to permit movement in the plane of the panel for story drift may be properly designed sliding connections using slotted or oversized holes or may be connections which permit movement by bending of steel.

p. 20 From table 23 C
Horizontal force factor K for buildings or other structures.

<u>Type of Arrangements of Resisting Elements</u>
Buildings with a dual bracing system consisting of

163

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to the main of the element itself. But for such elements as are effectively connected to the structure. They will participate initially in all of their rigidities.

p. 44 By the action described in the "Reserve Energy" analysis it is anticipated that these elements that possess a relatively low strength to rigidity ratio would crack first. In doing so, it is a part of earthquake engineering design to do details here of elements that do not constitute a hazard either to people or to the structural system. Usually these elements are non–structural in nature. Several things which happen in cracking are:

1) damping is increased quite materially by the frictional energy generated by movement of the surfaces along the plane of the cracks.

2) the natural period of vibration of the structure is lengthened and it is progressively lengthened as various cracks form and propagate.

3) Some incremental shear is transformed to non–broken structural and probably non–structural elements.

Let it be assumed that this lateral force resisting system is composed of 2 basic systems:

1) a shear wall system
2) a moment resisting space frame

Because the preponderant rigidity usually resides in the shear wall system it would be expected that in the middle stages of the earthquake the shear imposed would be resisted primarily, if not entirely, by this system. Should the earthquake be of such intensity and duration as to overstress these shear elements, it is expected that these would crack. In cracking the same 3 phenomena described earlier for the cracking of the low strength/rigidity ratio elements would occur. Some incremental shear would be transferred to the more flexible moment resisting space frame.

In the final stages of the earthquake it is conceivable that the integrity and safety of the structure and its occupants would be relying primarily upon the action of this moment resisting space frame. The action might be called upon only in the elastic range but in a major earthquake it is to the main of the element itself. But for such elements as are effectively connected to the structure. They will participate initially in all of their rigidities.

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K=1.33 Buildings with a box system as defined in section 2313 (6) page 14.

p. 14 Box system is a structural system without a complete vertical load carrying space frame. In this system, the required lateral forces are resisted by shear walls or braced frames as hereinafter defined.

p. 49 This type of structural system is characterized by shear wall lateral force resisting system and a substantial part of the vertical load carried on bearing walls, which may or may not be a significant part of the shear wall system. (max height 160 feet)

p. 50 The space frame (def: p. 35)
It is imperative that the vertical load carrying space frame be substantially complete in order to qualify the structure for some K value less than 1.33. It is not required that the entire vertical load space frame be designated the lateral force resisting system.

Requirements:

a. The ductile moment resisting space frame must be so deployed that, independent of other structural elements of the building, it is stable under vertical loads combined with lateral loads applied from any direction.

b. It must not be jeopardized in its vertical or lateral load carrying capabilities by the action or failure of more rigid elements of the building including shear walls.

c. For a K=0.67 building, the entire torsional as well as direct shears shall be resisted by the ductile moment resisting frame, neglecting such shear walls as may exist.

d. K=0.80 buildings must be capable of withstanding torsional moments corresponding to its polar moment of inertia compared to the polar moment of inertia of the total structure considering interaction of component parts or to the "accidental torsion," if greater; direct shear resisted by the frame shall be distributed to the elements of the frame

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Some codes have gone further by insisting that buildings be separated to avoid interference and possible destructive hammering between buildings. The amount of separation recommended, or in some cases required, depends upon the movement to be accommodated. For more flexible types of construction separation = 1.5 times the expected combined deflections of the 2 units or buildings separated.

Prior to 1961, the UBC required..."all portions of structures shall be be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally by a distance of at least one inch + .5 inch for each 10 feet of height above 20 feet.

p. 65 Reinforced Masonry or concrete
All elements of masonry or concrete whether part of the structural system or the lateral force resisting system or not, are required to be reinforced to qualify as reinforced masonry or reinforced concrete in accordance with the appropriate sections and chapters of the code of which these sections, 2313- General Provisions, p. 34, 2630- Concrete Ductile Moment REsisting Space Frames, p. 66, and 2631- Concrete SHear Walls and Braced Frames, p. 74. Minimum reinforcing is required to assure that a reasonable "basketing" exists which will prevent cracked walls from loosing broken pieces and thus preventing a hazard to building occupants. Such "basketing" is especially important for all walls around exit passages and for walls which have veneer or precast attachments.

p. 86 Appendix C
Report on setbacks

General
Setbacks in practice can be symmetrical or asymmetrical about the base portion in 1 or both axes. Towers and bases can vary in types of construction, the amount of setback, and the height of the tower as compared to the base can cover a wide range.

In addition to the dynamic conditions between 2 (or more) building portions, the "notch" effect must be considered in design, particularly where the tower framing does not extend downward through the base. A shear wall type of design for both a tower and a base could produce sever stresses at and about the 90 degree notches.

Dynamics
The relative values of the k/M of the tower and base

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Dynamics

The relative values of the k/M of the tower and base

portions are basic in the problem.
K= stiffness
M= mass
Relative damping is also important. Unfortunately for general code purposes, K depends upon many things such as ration of shear to flexure resistance, the mass, etc. However, a tower is more apt to have flexure as an important action than is the base.

If the values of the K/M and damping should be the same in tower and base it is conceivable that outside of any "notch" effect the building would essentially act as a unit dynamically. The K/M values could be similar because of variations in wall openings and other factors.

Practice COde Considerations
For simplicity 3 basic conditions have been considered:

a. The base portion predominates and the tower may may be considered as an appendage subject to a ground motion which is equal in acceleration to that of the top of the base portion.

b. The tower portion predominates and the portion of the base not encompassed by the tower extension to the ground is essentially a structural "lean-to" which goes along for the ride, but also contributes additional mass and resistance.

c. The intermediate cases which are difficult in determination. IN this category we have to consider the situation where the 2 portions may average out to act as 1 building of the full height or where they may act as independent units but in such a manner as to affect each other.

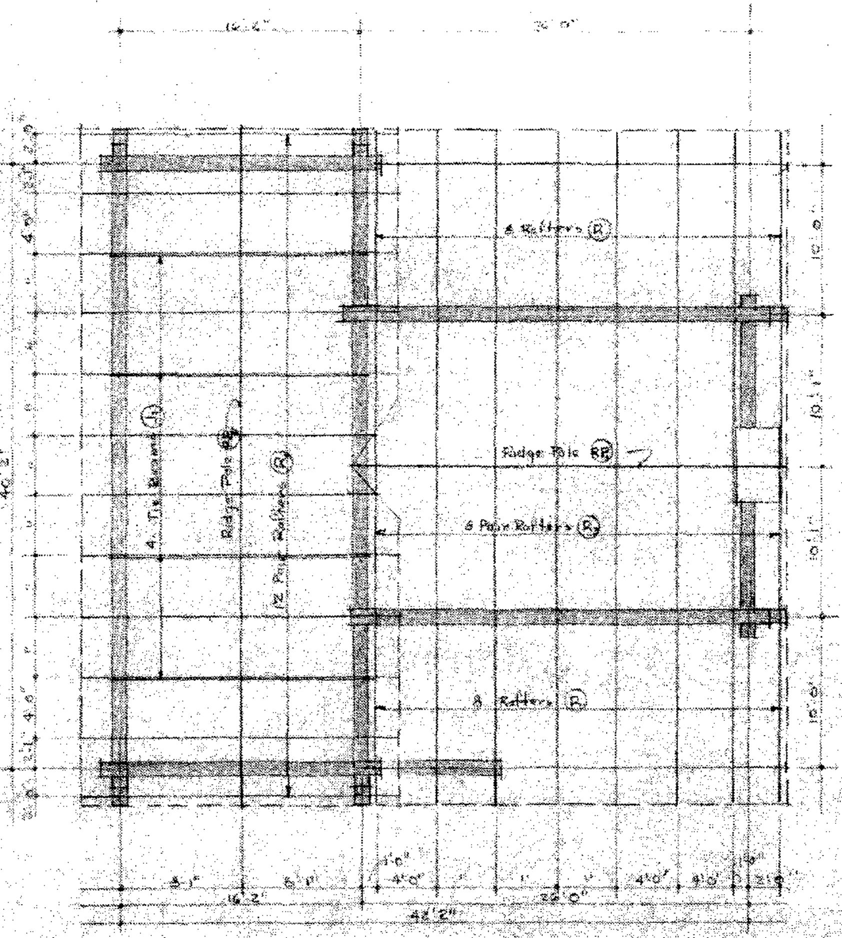
p. 88 Frame Action for Setbacks

Some setbacks may consist of simple 1 story penthouses. However, most setbacks are important structural elements. In view of the dynamic and also the notch effect phenomena that may occur, it is recommended that structural frames, either moment resisting or braced or combinations, be required for both tower and base of any setback building with more than 1 story of setback. In addition it should be required that the columns supporting the setback be carried straight down from the setback columns all the way to the foundations or a special analysis be submitted to demonstrate that column offsets are fully compatible with the setback conditions.

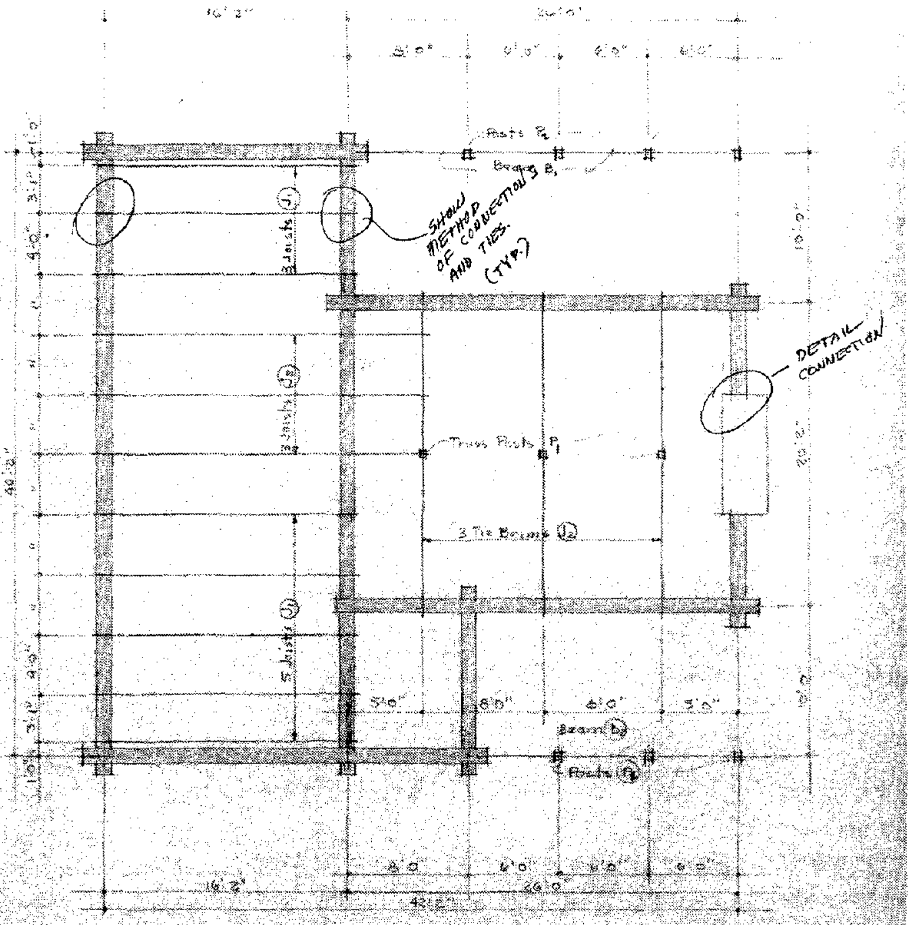
APPENDIX D

Preliminary Design Drawings

New York Architects



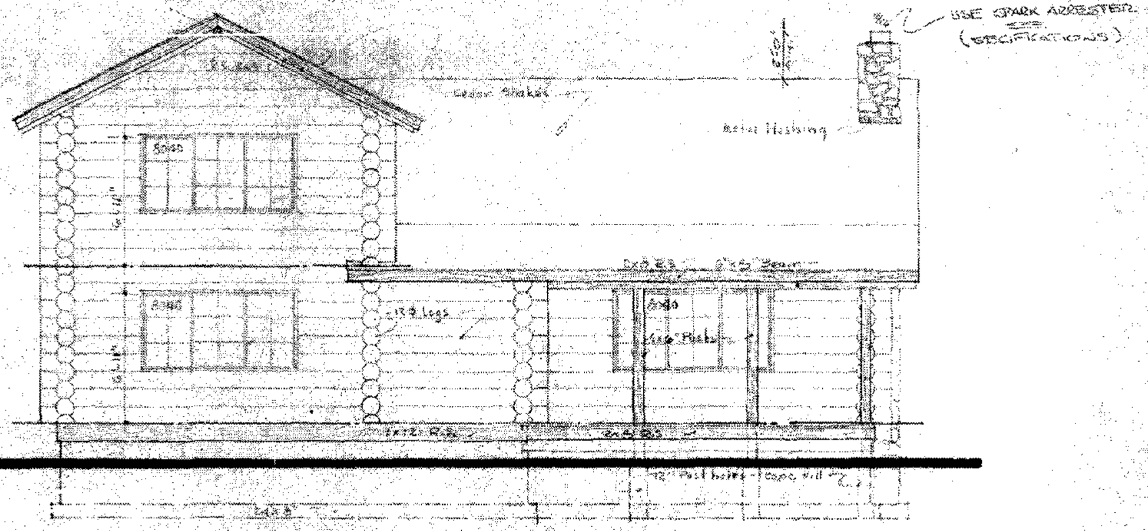
ROOF FRAMING PLAN Scale 3/16"=1'0"



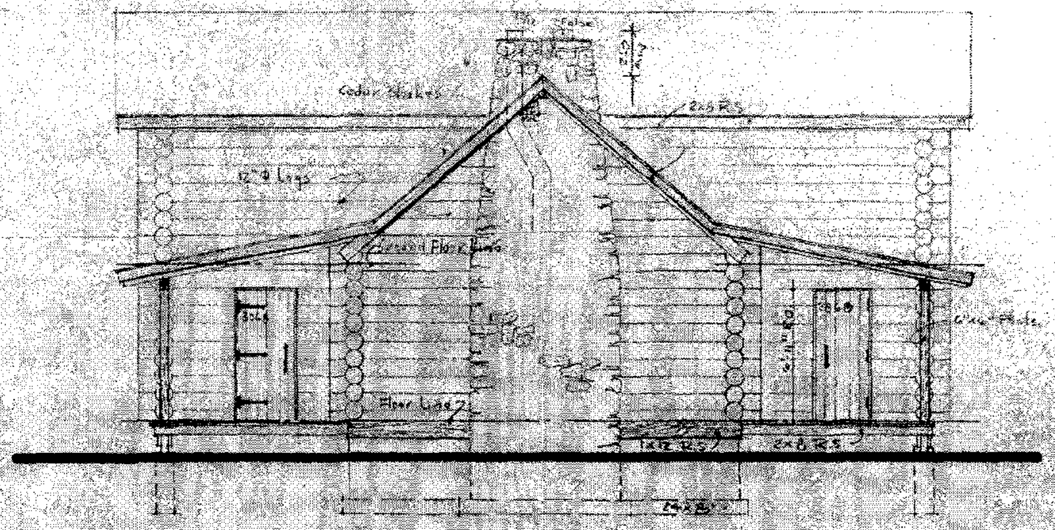
SECOND FLOOR FRAMING & TIE BEAMS

STANDARD - RMO17

SHEET
4 of 5



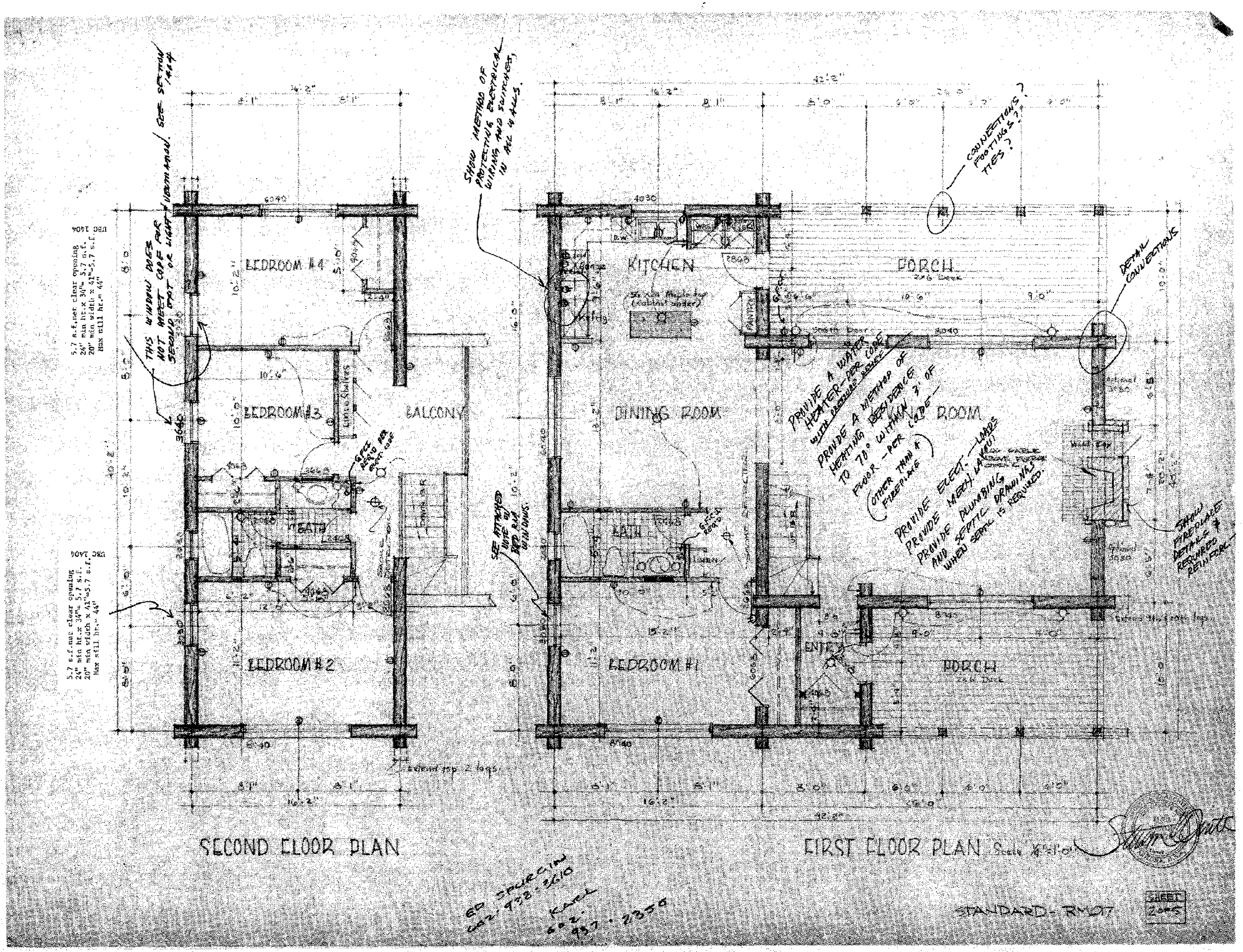
FRONT ELEVATION Scale ⅛"=1'-0"



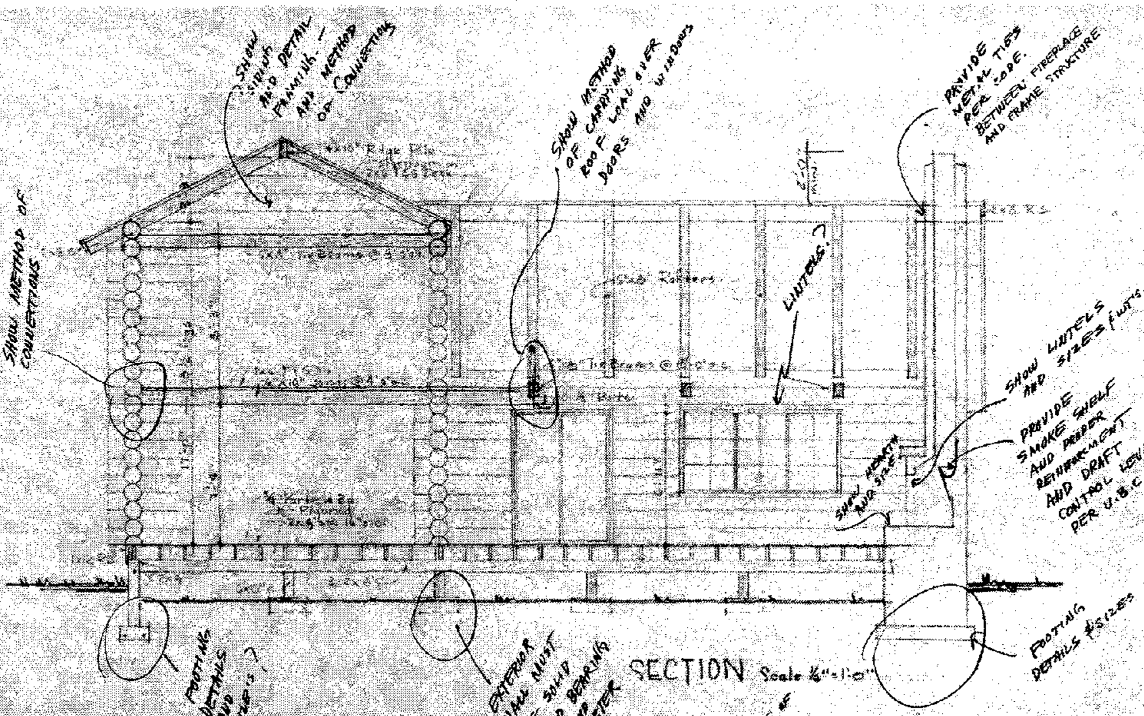
RIGHT SIDE ELEVATION Scale ⅛"=1'-0"

STANDARD-RM017

SHEET
3 of 5


THIS WINDOW DOES NOT MEET CODE FOR SECOND EXIT OR LIGHT & VENTILATION. SEE SECTION 1404
5.7 s.f.net clear opening
24" min ht.x 34"= 5.7 s.f.
20" min width x 41"=5.7 s.f.
Max sill ht.= 44"
UBC 1404
5.7 s.f.net clear opening
24" min ht.x 34"= 5.7 s.f.
20" min width x 41"=5.7 s.f.
Max sill ht.= 44"
UBC 1404
BEDROOM #4
BEDROOM #3
BALCONY
BATH
BEDROOM #2
Linen Shelves
GFCI REQ'D PER BATH CODE
SHOW METHOD OF PROTECTING ELECTRICAL WIRING AND SWITCHES IN ALL WALLS.
SEE ATTACHED NOTE ON REQ'D EXIT WINDOWS.
KITCHEN
DINING ROOM
BATH
BEDROOM #1
ENTRY
LIVING ROOM
PORCH
2x6 Deck
PORCH
2x6 Deck
PANTRY
G.F.C.I. REQ'D
CONNECTIONS FOOTINGS ? TIES ?
DETAIL CONNECTIONS
PROVIDE A WATER HEATER-PER CODE WITH PRESSURE RELIEF
PROVIDE A METHOD OF HEATING RESIDENCE TO 70° WITHIN 3' OF FLOOR -PER CODE- (OTHER THAN A FIREPLACE)
PROVIDE ELECT.-LOADS
PROVIDE MECH. LAYOUT
PROVIDE PLUMBING AND SEPTIC DRAWINGS WHEN SEPTIC IS REQUIRED.
SHOW FIREPLACE DETAILS & REQUIRED REINFORC.
Wood Box
Optional 3050
Optional 3050
Sheath Door
Extend top 2 logs
6040
4030
3640
3040
3040
8040
6040
8'1"
16'2"
8'1"
8'0"
6'0"
26'0"
6'0"
9'0"
42'2"
10'0"
10'2"
10'6"
12'0"
15'2"
19'6"
9'0"
SECOND FLOOR PLAN
FIRST FLOOR PLAN Scale ¼"=1'0"
ED SPURGIN 602 938-2610
KARL 602 937-2350
STANDARD-RM07
SHEET 2 of 5

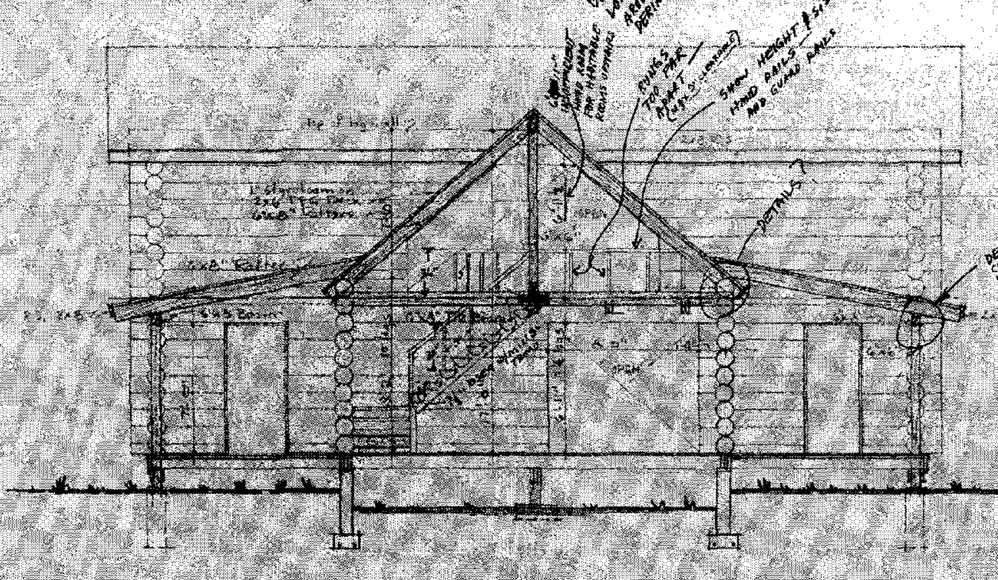
177



SECTION Scale ¼"=1'-0"

NOTE:
This set of Standard 017
Plans is drawn with 12"Ø
Logs.

Please refer to the construction manual to obtain
the correct number of
courses and the correct
stack height for your log
diameter.

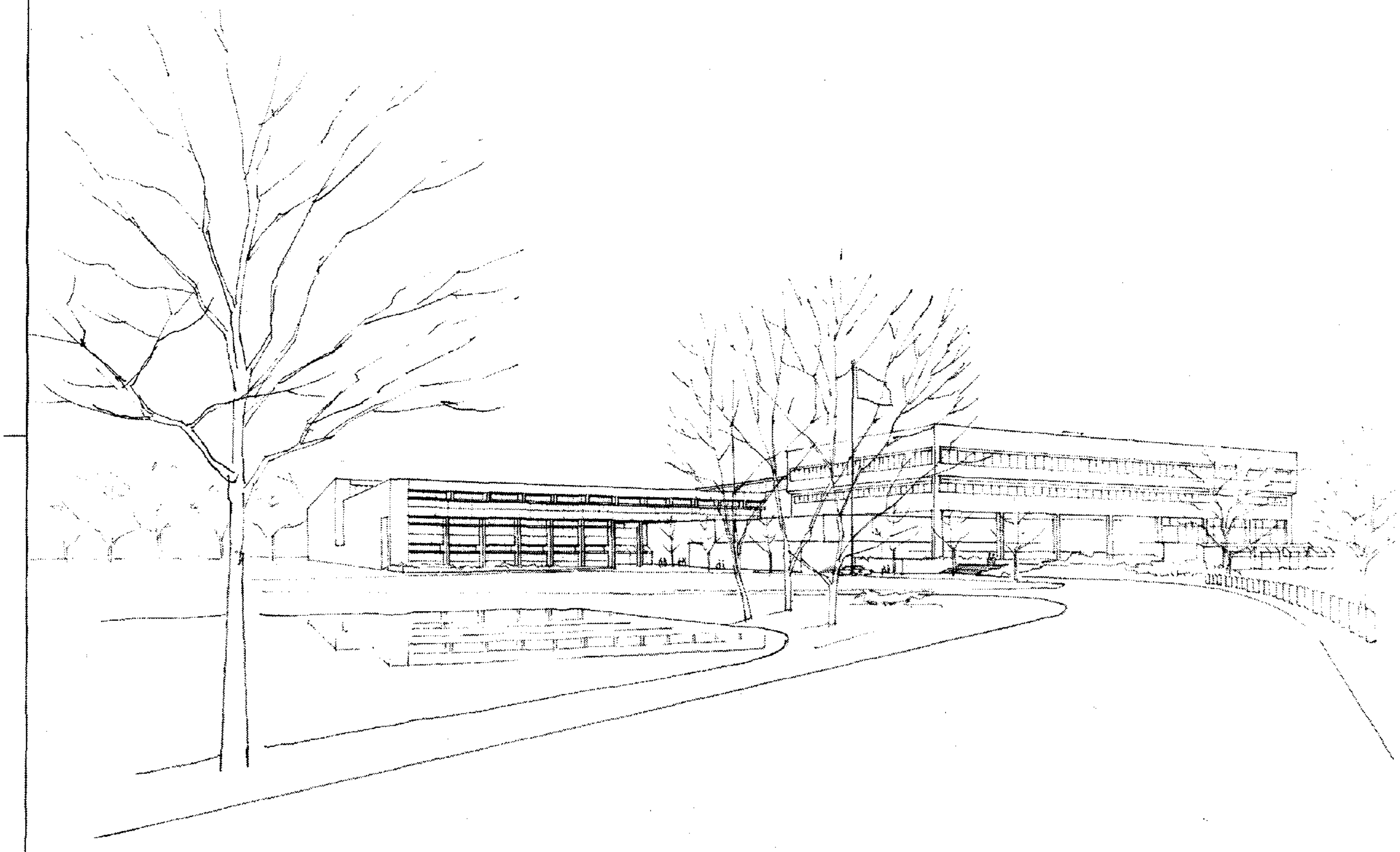


SECTION Scale ¼"=1'-0"

STANDARD - RM017

SHEET 5 of 5

Cambridge Architects



NOTES:

TAC

THE ARCHITECTS COLLABORATIVE INC.
46 BRATTLE STREET, CAMBRIDGE
MASSACHUSETTS 02138

PROJECT TITLE

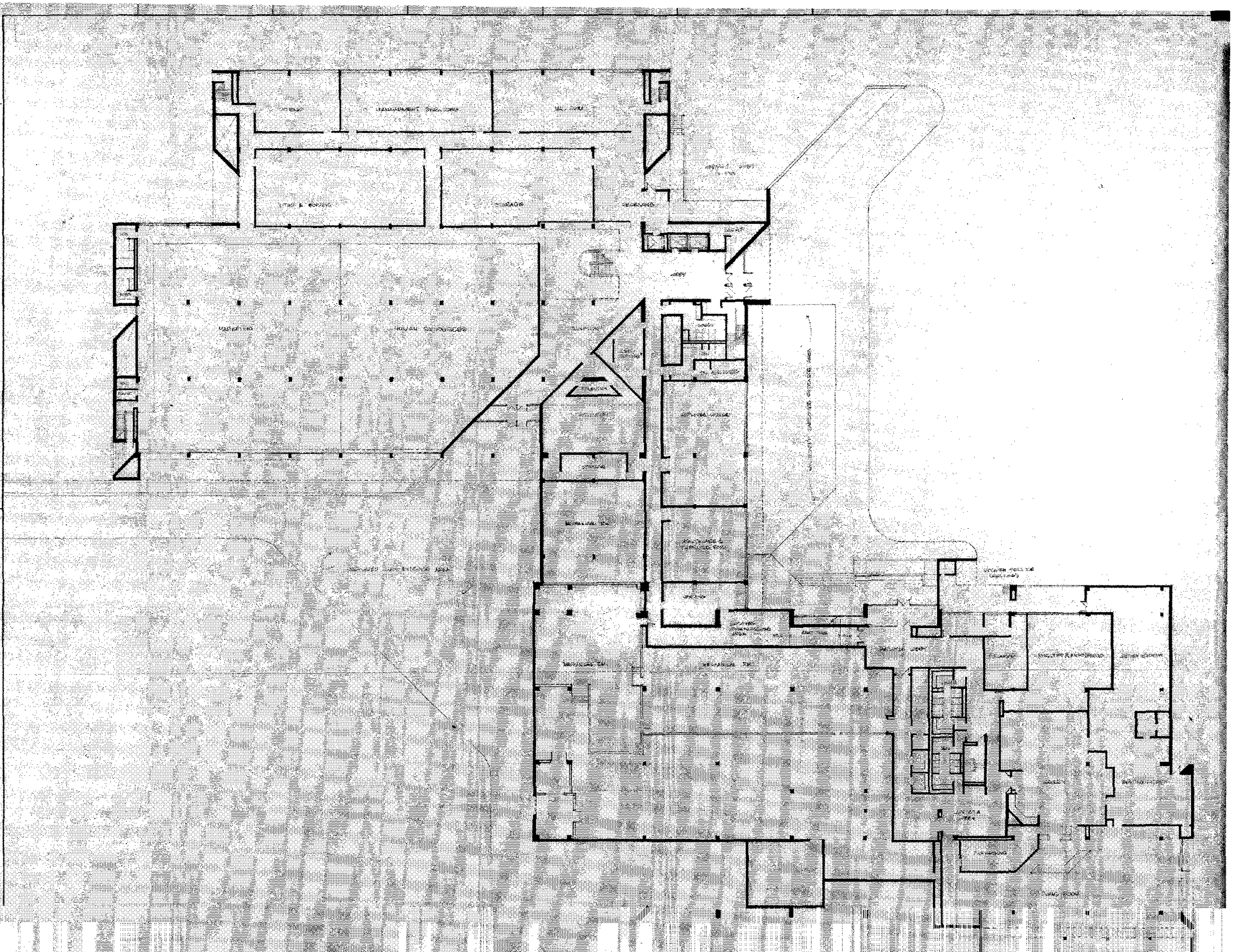
Blue Cross
Blue Shield
of Connecticut

CORPORATE HEADQUARTERS

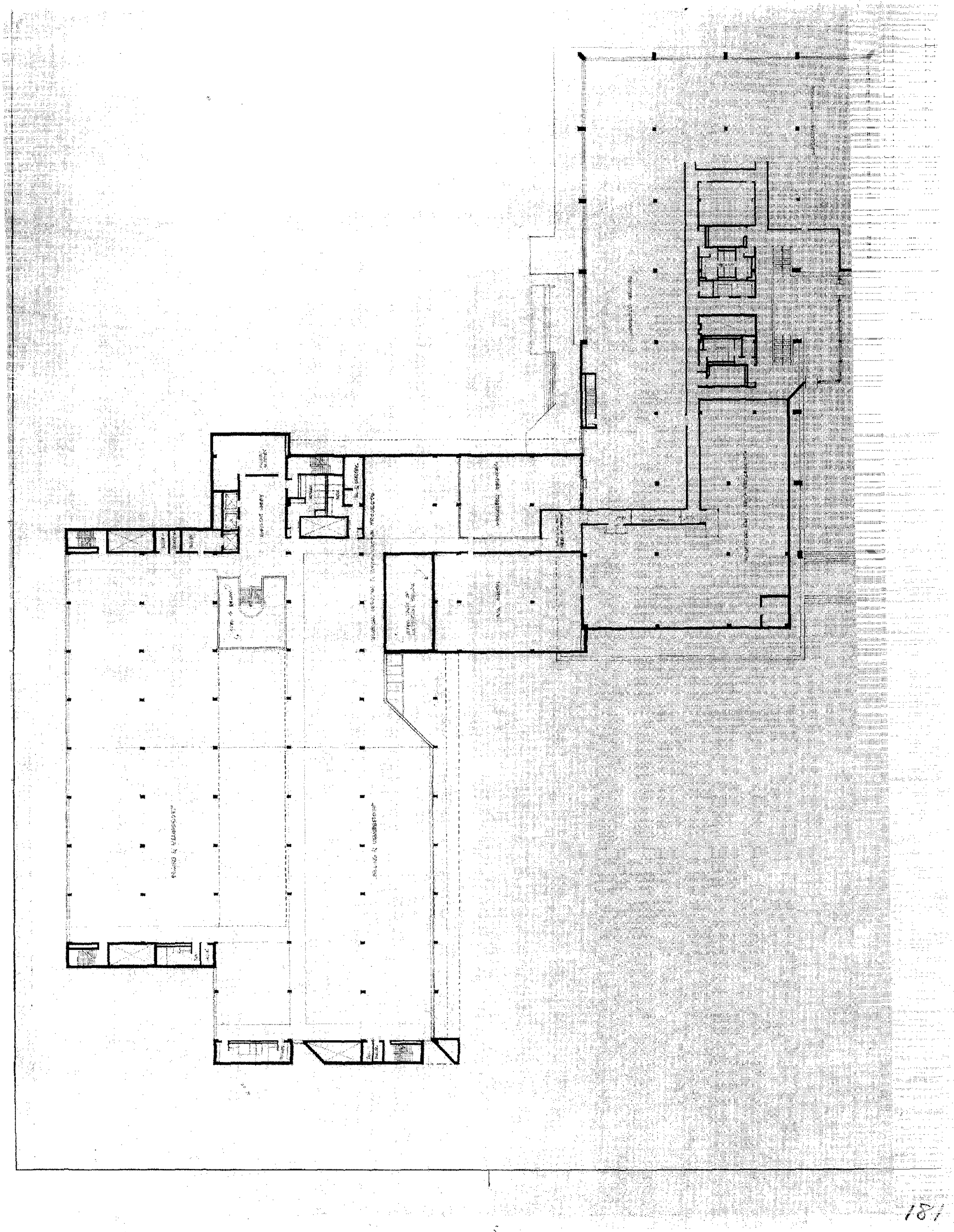
PROJECT NO.	
DRAWN	
CHECK	
SCALE	
DATE	

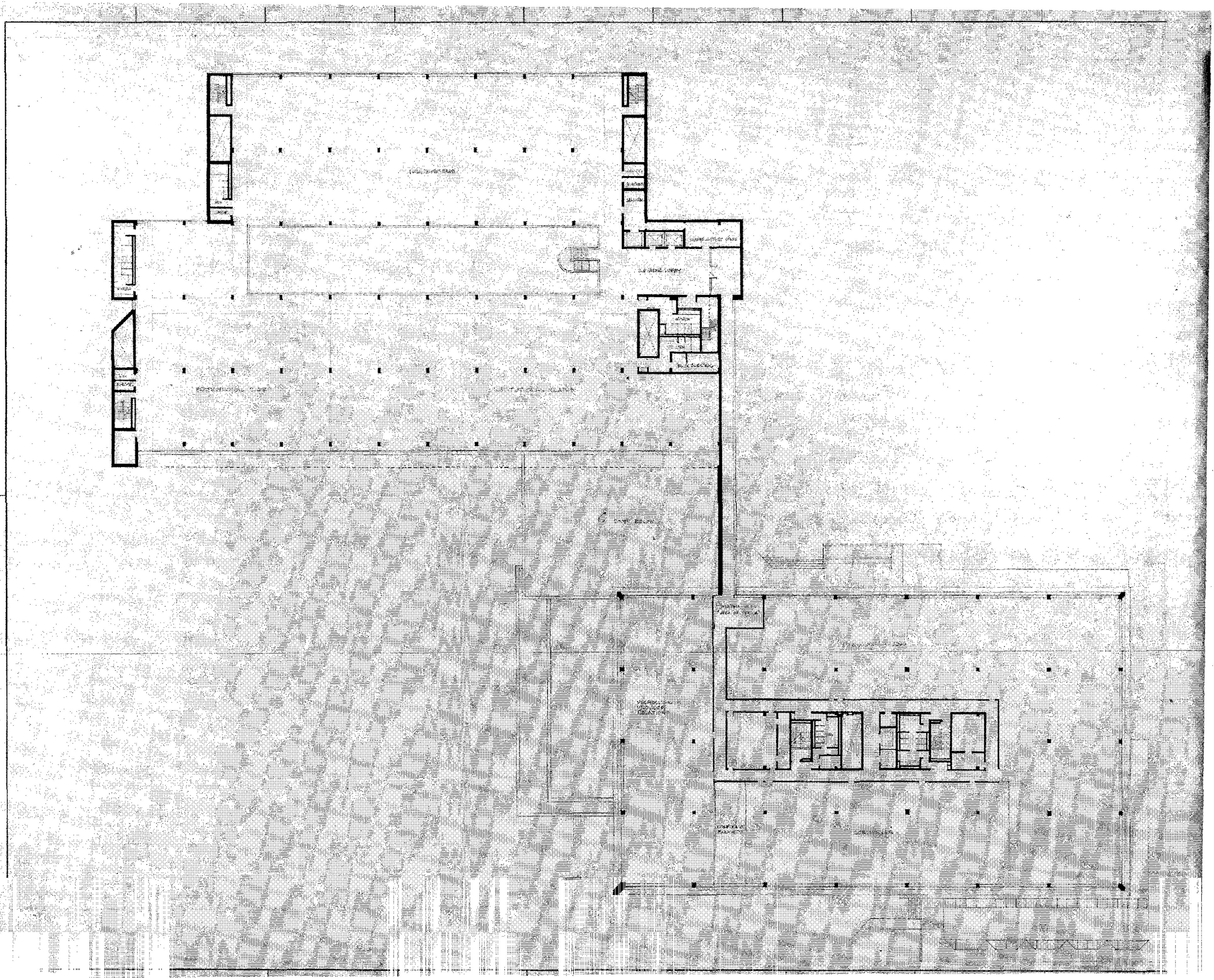
DRAWING TITLE

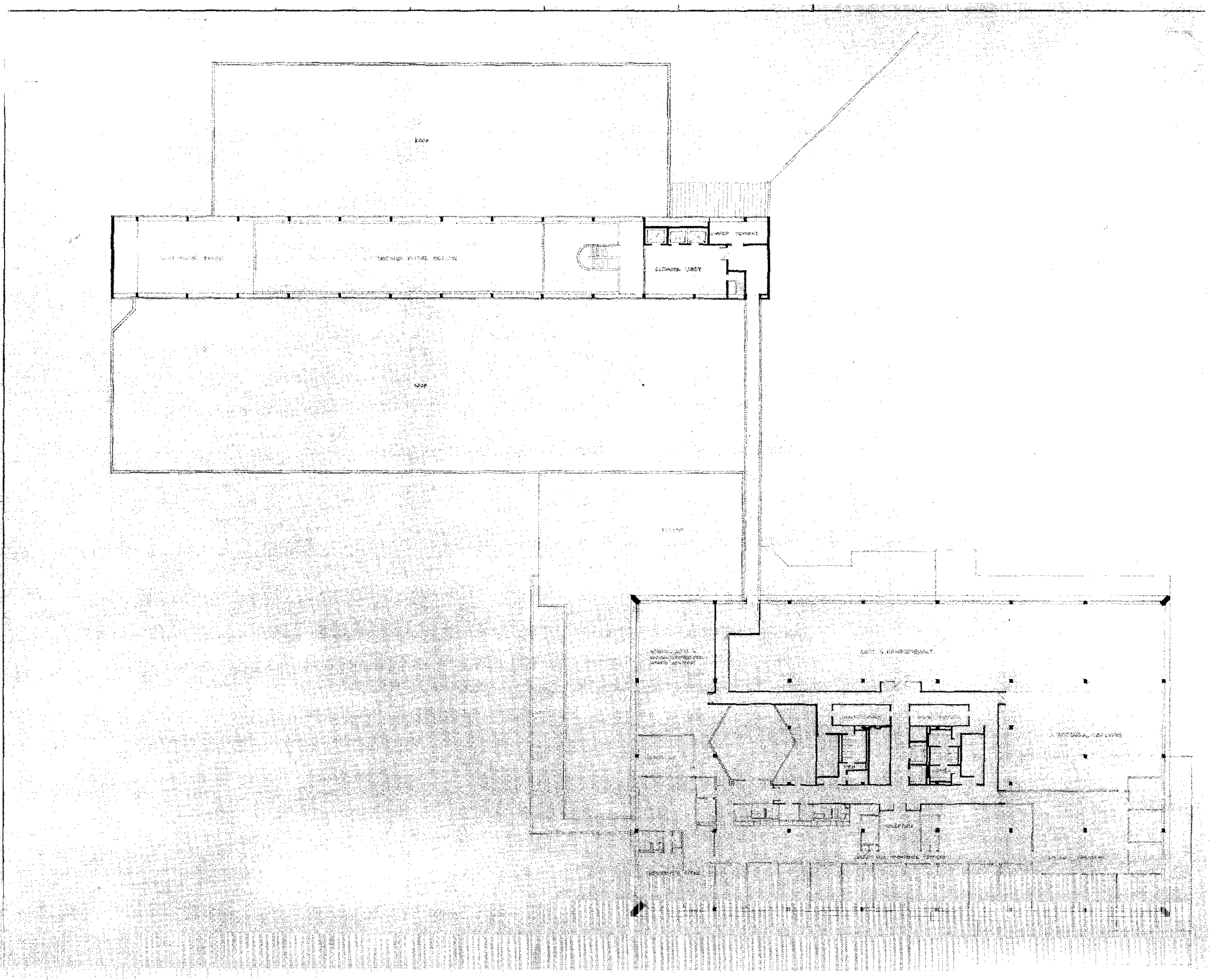
DRAWING NO.



MANAGEMENT SERVICES
STORAGE
RECEIVING
LOBBY
HUMAN RESOURCES
DINING ROOM






ROOF
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ELEVATOR LOBBY
RECEPTION

APPENDIX E

Survey Questionnaire, Design and Evaluation Guidelines

SURVEY QUESTIONNAIRE

PROJECT: The Integration of Seismic Design Principles Into Preliminary Architectural Design

NSF PFR 7900007 K. BRITZ, PI

This survey is taken as part of an architectural research project sponsored by the National Science Foundation. Its purpose is to assess the general level of awareness about eastern U.S. earthquake activity, and knowledge about seismic design among architects practicing in the eastern U.S. This questionnaire is not meant to be a test of knowledge or skill. In fact, if there is a lack of general knowledge about seismic design we want to know that. Therefore please answer all questions candidly, and where written replies are requested, please try to be concise and brief. Individual qeustionnaires will not be published and respondents will remain strictly anonymous. Thank you.

1. If you have a professional degree in architecture name the institution which granted you the degree ______________________________
2. In what state(s) are you registered? ______________________________
3. How long have you been registered? ______________________________
4. Do you have a NCARB certificate? Yes_____ No_____
5. Have you had any experience with applying seismic design principles either in school or in professional practice (aside from questions on the professional licensing exam)? Yes_____ No_____
6. If so, how recent?

   within past 2 years _____ within past 5 years _____ longer _____
7. Please respond to each term by indicating whether you: a) basically know its definition; b) have heard or read the term but are not knowledgeable about its meaning; c) have not seen or heard the term.

	know it a.	heard of it b.	haven't heard of it c.
accelerograph	_____	_____	_____
ductility	_____	_____	_____
epicenter	_____	_____	_____
fault line	_____	_____	_____
fundamental period	_____	_____	_____
liquefaction	_____	_____	_____
modified mercalli intensity	_____	_____	_____
moment frame	_____	_____	_____
return period	_____	_____	_____
seismicity	_____	_____	_____
seismic surface wave	_____	_____	_____
story drift	_____	_____	_____
tsunami	_____	_____	_____

8. In your current practice how much do you consider seismic safety during preliminary design? Check one:
   a) High priority among constraints ________
   b) Among the more important constraints ________
   c) Among the lessor constraints ________
   d) Very low priority among constraints ________

9. Can you identify at least four architectural (non-structural) building components which have been found to be particularly vulnerable to earthquake forces? That is they are likely to be damaged to the point of non-functionality in the event of a moderate to severe earthquake?

   a.______________________________ b.______________________________

   c.______________________________ d.______________________________

10. Can you describe a general type of geometry (shape, plan configuration) for a building which would be particularly advantageous in resisting earthquakes?______________________________

    ____

11. Can you name at least two areas in the eastern U.S. which have had several earthquakes in the past?______________________________

12. Are you aware of any seismic zone classification given to the area(s) in which you practice?

    a. Geographic area____________________ classification____________________

    b. Geographic area____________________ classification____________________

13. If so, is this classification recent?

    within past 2 years _____ not recent _____ don't know _____

14. Do you know whether your state has mandated local building ordinances requiring design provisions to mitigate against earthquake hazards?

    State has _____ State has not _____ Don't know _____

15. Have you become aware of specific research efforts involving the performance of architectural (non-sturcutral) components under earthquake loads?

    Yes _____ No_____

16. If so, from what research organization?

    NSF _____ ASCE _____ AIA/RC _____ Other____________________

17. If so, how did you become aware of such research.
    Through colleague(s) ________
    Through AIA publication ________
    Through engineering publication ________
    Through architectural professional journal ________
    Through attendence in a class ________
    Through information received at a conference ________
    Other, please specify______________________________

18. Can you identify which aspects of preliminary (or schematic) design might be affected by the consideration of earthquakes?

    ____

    ____

    ____

19. Suppose you were now practicing in an area known to have strong earthquakes perhaps once within every fifty years. Also suppose that area was not strictly regulated by seismic codes. Under these circumstances, rank order seismic safety among the rest of the following design criteria.

______ Fire safety
______ Minimizing construction cost
______ Functional organization
______ Aesthetic issues
______ Energy conservation
______ Seismic safety
______ Site context
(1 most important, 7 least important)

20. With your currest knowledge about earthquake design, how concerned are you that seismic design provisions might constrain the aesthetic aspects in your design work?

Very concerned ______ Mildly concerned ______ Not concerned ______

21. Do you believe that having to comply with seismic codes will usually make architectural design more difficult?

22. In what manner would you think it best to integrate seismic design into preliminary architectural design? Check one or more:

a) After first design iteration, use a checklist to determine whether seismic safety has been effectively considered ______

b) Have structural engineer review and comment on seismic integrity of the plans ______

c) Use a systematic process of trade-offs to decide whether seismic criteria will overide other conflicting criteria in the design ______

d) Use a checklist of seismic criteria as you begin and proceed with preliminary design work ______

e) Merge seismic structural design and schematic space adjacency and hierarchy as a synthesis of two parallel - but initially separate design processes. ______

f) None of the above. ______

23. How often do you come across news of significant technological developments such as solar energy design, people moving systems, new structural systems, new building materials and finishes, etc.

Regularly ______ Frequently ______ Infrequently ______ Rarely ______

24. In general, where do you gain new technical knowledge?

Classes ______, Textbooks or Manuals ______, Manufacturer's brochures ______,

Visiting Products Representatives ______. Other ______________________________

25. In general, do you find it easy to assimilate new technological information into your practice? Usually easy ______, Usually difficult ______.

26. Are you generally apprehensive about trying a new technique or product for fear of poor results or uncertainty about performance?
Yes ______ No ______

27. What would be the best means for you to learn about seismic design?
Lectures at conferences ________
Carefully prepared brochures ________
Classes at architectural school ________

NSF PROJECT PFR 7900007
"THE INTEGRATION OF SEISMIC DESIGN PRINCIPLES INTO PRELIMINARY ARCHITECTURAL DESIGN"

Ken Britz, P.I.

The following list of questions and instructions should be answered during the course of preliminary design, where seismic principles as discussed with the researchers are considered in the design process.

To make the experiences of the three firms comparable, we have listed and categorized a set of general questions about the project, the design team, the design objectives, seismic design considerations, and the design process.

We have also requested that a "log" of decision making be recorded and be returned to the researchers, along with the answers to the project related questions.

General Questions About the Project:

1. What is the building type?
2. What is the square footage involved in the program?
3. What is the basic program?
4. Who is the client?
5. Who is the user/s?
6. Where is the location (or intended locations)?
7. What are the particular site conditions?
8. If a system or prefabricated approach is involved, explain how it is to work (i.e., manufacturing, transportation, erection, finishing process)?
9. Is there any extraordinary budget constraints or opportunities present?
10. Is the time of design or time until completion an unusually important factor in this project?

General Questions About Design Team:

1. Is a principle or associate of the firm directly involved in the design?
2. List the other in-house people directly assigned to the project.
3. Was an engineer involved in the preliminary design?
4. Can the roles of the individual members of the design team be described?

Design Objectives

1. List, in terms of desired activity and physical solution, any special aesthetic and/or functional criteria which are particularly important in this building.
2. Who identified these criteria or objectives?
3. Was there any significant discussion about criteria? Were clearly opposing or alternative viewpoints stated?
4. Which, if any, design issues were identified during a review of design work already sketched or drawn hardline?

Seismic Considerations During Preliminary Design

1. Was there initial confusion about what seismic criteria were?
2. Did the client have any reservation about seismic criteria?
3. Did codes give any quide to architectural design vis a vis seismic problems?
4. Was the client aware of potential seismic problems?
5. Was it anticipated that seismic criteria would conflict with other criteria, and if so how would they conflict?

Design Process

1. Was a seismic criteria "checklist" formulated a priority?
2. Was there confusion about how seismic criteria would be incorporated into the design?
3. Was there apparently a situation or situations where other design criteria conflicted with seismic resistant design?
4. Was an engineer consulted during preliminary design, and how much involvement did he have?
5. Did he provide an explanation with his input? Was it he who offered the solutions?
6. How far could seismic strategy prevail before it was considered too impractical or costly given the perceived level

At the appropriate time/s during the preliminary design process, please record:

A paraphrasing or capsulization of the points made in each case of deliberative design-decision-making regarding a seismic related design issue. Relevant points to record would include comments related to the points listed above under "Seismic Considerations" and "Design Process".

What we would like is a set of these seismic-design-decision-related discussions for each instance when they occurred and in the order in which they occurred. The result should be the design teams "log" of seismic design decision making.

NSF PROJECT PFR 79-00007

"THE INTEGRATION OF SEISMIC DESIGN PRINCIPLES INTO PRELIMINARY ARCHITECTURAL DESIGN"

EVALUATION GUIDE

As a final contribution from the participating architectural firms, we are asking for your evaluation of your experience in attempting to integrate seismic design in preliminary architectural design. As a guide to evaluating your experience and as a means to obtain comparable comments from the three participating firms we have provided a list of questions evaluative in nature. Even though some of these may not be applicable to your experience, please answer as best as possible those questions which are relevant. In general we are asking you to evaluate your experience in utilizing seismic design strategy in the recent project targeted for this research effort. Please feel free to add comments additional to the responses we are eliciting.

Please respond to the following questions. If a response cannot be made please explain why.

1. Do you believe you have ascertained the appropriate level of design response to the seismic hazards in your area of practice, or the area where your project was located?

2. In terms of difficulty where did the resolution of seismic criteria rank relative to the other criteria listed here?
(Most difficult = 1 Moderate difficulty = 4,5 Least difficult = 8)

_____ fire safety
_____ minimizing construction cost
_____ functional organization
_____ aesthetic issues
_____ energy conservation
_____ seismic safety
_____ site constraints
_____ other natural hazards

3. If a design checklist were appropriate for seismic provisions, what major points would it necessarily contain?

4. Suggest (in outline form) the contents of a useful seismic building code with respect to non-structural components.

5. Can you describe the easiest or most practical way to integrate seismic design principles into the preliminary design process.

6. Can you estimate the dollar cost for providing seismic design (as part of the architect's fees) at this point in time?

7. Do you believe the cost (Question 6) will be reduced in the future, assuming the same complexity of project and same level of seismic reinforcement attempted?

8. Suggest the best means and format to learn more about seismic design.

9. How would you present the case for seismic design to other clients and local building officials?

10. What would you need in the way of information and supporting materials to make a case for seismic design?