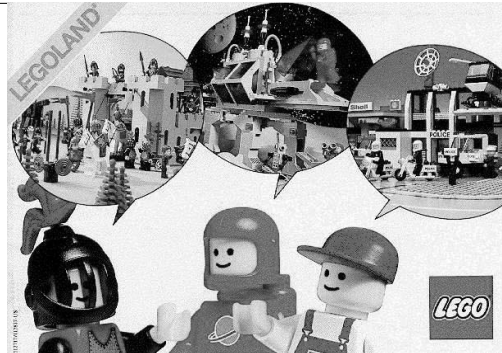


lecture
fourteen



structural planning

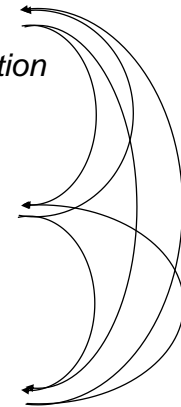
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Structural Design Sequences

- first-order design
 - structural type and organization
 - design intent
 - contextual or programmatic
- second-order
 - structural strategies
 - material choice
 - structural systems
- third-order
 - member shaping & sizing



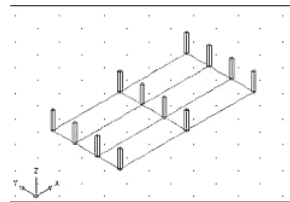
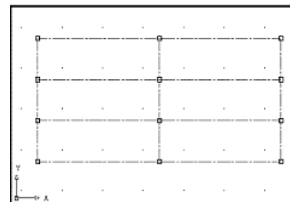
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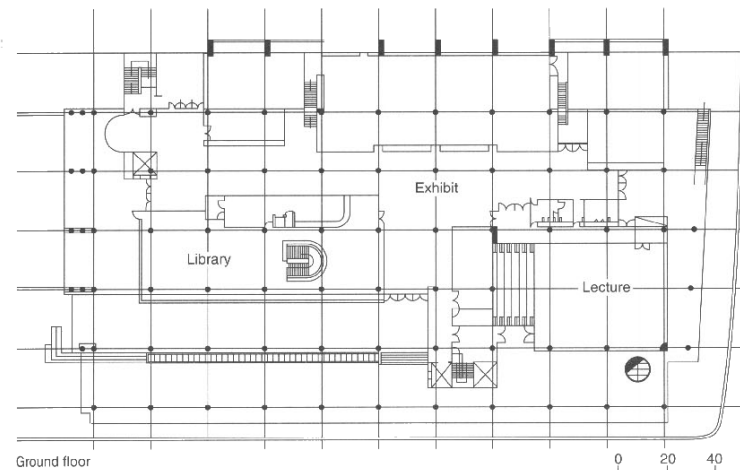
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Grids and Patterns

- often adopted early in design
 - give order
 - cellular, ex.
- vertical and horizontal
- square and rectangular
 - single-cell
 - aggregated bays



Grids and Patterns



(a) Square column grid.

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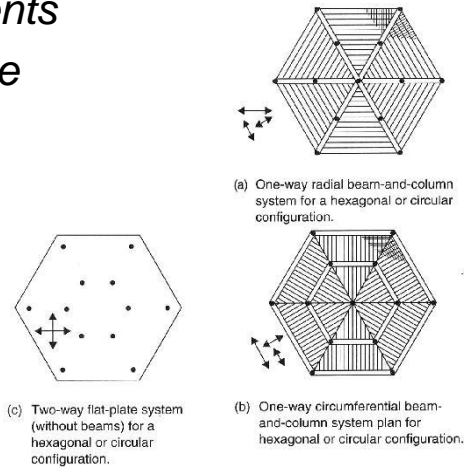
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Systems

- total of components
- behavior of whole
- classifications
 - one-way
 - two-way
 - tubes
 - braced
 - unbraced



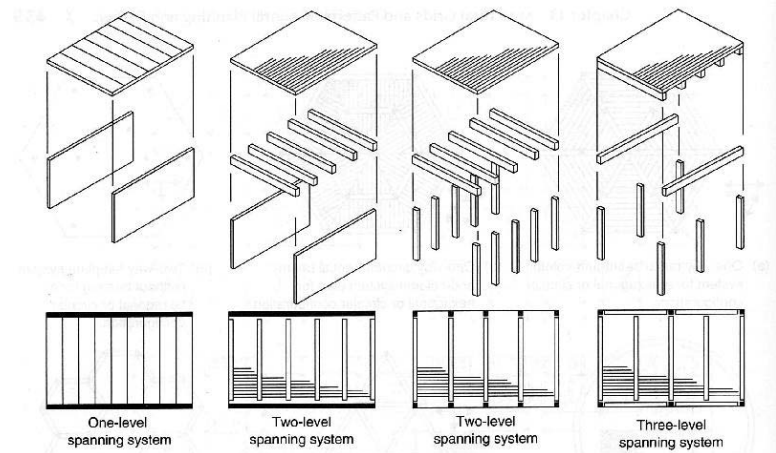
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One-Way Systems

- horizontal vs. vertical



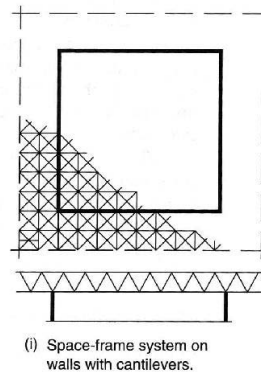
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Two-Way Systems

- spanning system less obvious
- horizontal
 - plates
 - slabs
 - space frames
- vertical
 - columns
 - walls

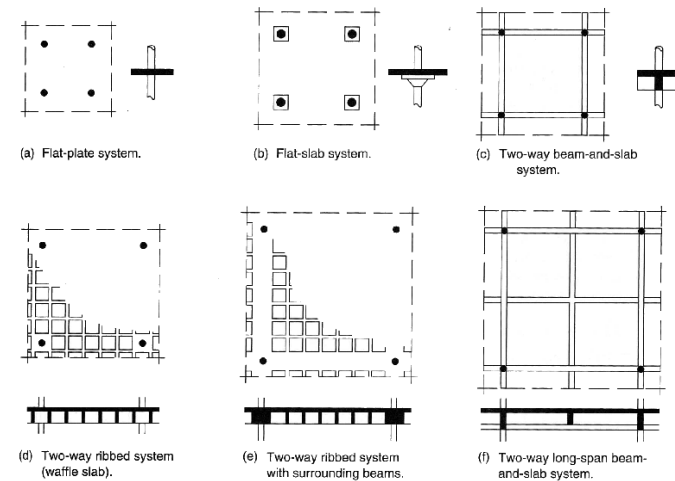


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Two-Way Systems



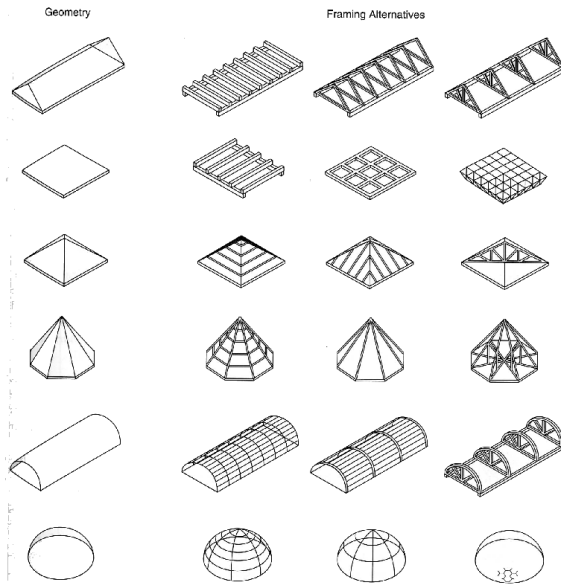
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Roof Shapes

- coincide
- within

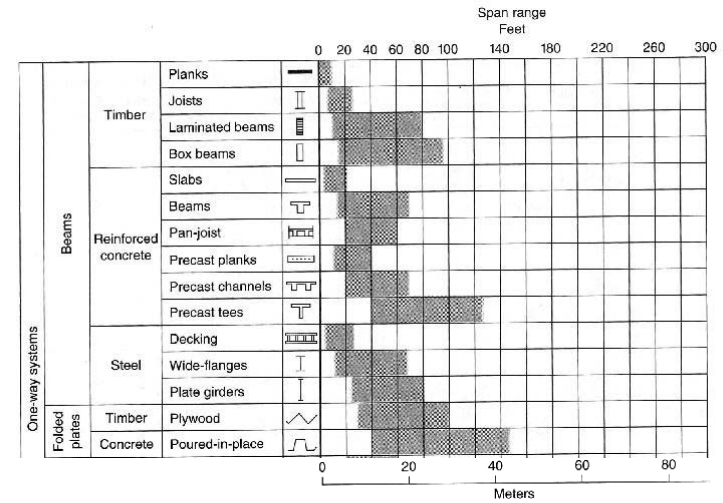


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Systems & Spans

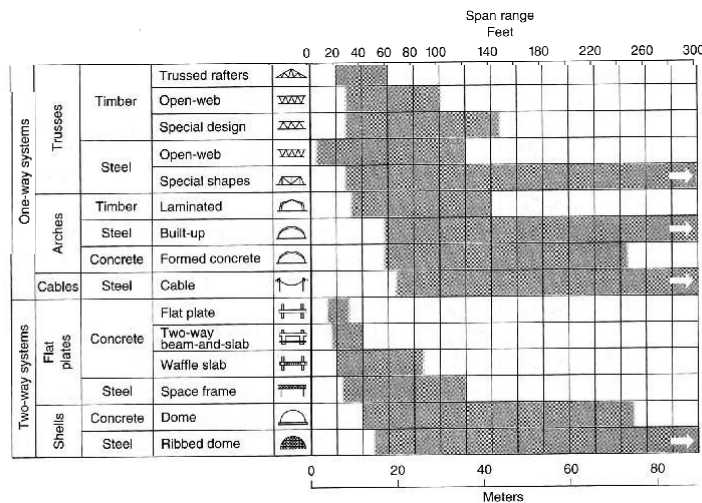


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Systems & Spans



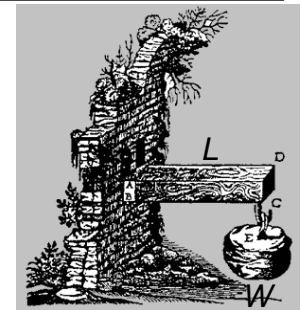
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Span Lengths

- crucial in selection of system
- maximum spans on charts aren't absolute limits, but usual maximums
- increase L, increase d² required (ex. cantilever)
- deflections depend on L



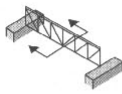
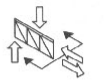
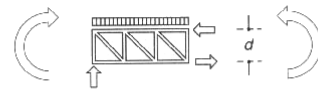
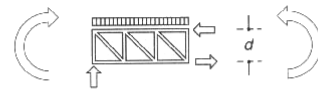
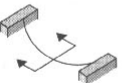
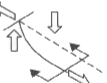
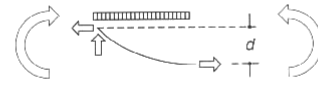
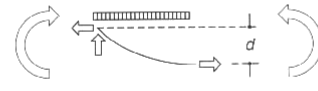
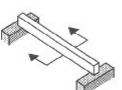
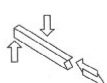
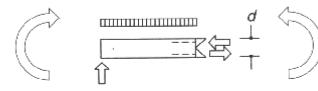
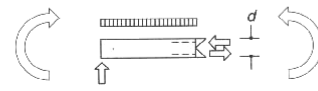
$$f_{b-max} = \frac{WL}{bd^2} \cdot \frac{1}{6}$$

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Moments in Members

Structure	Basic Moment-carrying Mechanism	Free-body Diagrams with Respect to Rotational Forces	
		External Applied Moment	Internal Resisting Moment
			
			
			

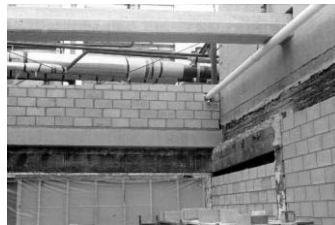
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Spans

- *intermediate- and low-span systems*
 - 15' – 40' or 5 – 15 m
 - more common
 - good for planar surfaces
 - lots of options
 - cost usually dictates



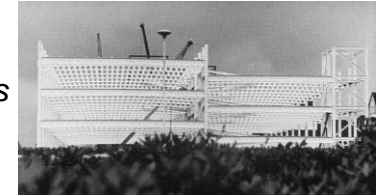
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Spans

- *long-span structures*
 - over 60' or 20 m
 - depths are large compared to span
 - usually shaped
 - trusses, arches, cables, nets, pneumatics & shells
 - common for roofs
 - camber
 - flat systems not as efficient
 - deflections can govern size



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Loading Type and Structure Type

- *light uniform loads*
 - surface forming elements
 - those that pick up first load dictate spacing of other elements
- *heavy concentrated loads*
 - member design unique
- *distributed vs. concentrated structural strategies*
 - large beam vs. many smaller ones



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Case

- *grid*
- *system orientation*
 - *one-way or two?*
- *span lengths*
- *loading type*
 - *concentrated vs. distributed*



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Case

- *Engineering Design & Research Center*

CLIENT:	LARSEN & TOUBRO LIMITED
LOCATION:	CHENNAI
NATURE OF BUILDING:	OFFICE
ARCHITECT:	K. S. RANGASWAMI
STRUCTURAL DESIGN:	L & T LTD.
GENERAL CONTRACTORS:	L & T LTD.
CONSTRUCTION MATERIAL:	REINFORCED CONCRETE
DATE OF COMMENCEMENT:	JULY, 1996
DATE OF COMPLETION:	NOVEMBER, 1998

ENGINEERING DESIGN & RESEARCH CENTRE:
LARSEN & TOUBRO LIMITED

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Case

- *grid*

OFFICE BLOCK

SECOND & FOURTH FLOOR PLAN.

LANDSCAPED TERRACE

THIRD & FIFTH FLOOR PLAN.

1. DESIGNED AS INDEPENDENT STRUCTURES.
2. ALTERNATE FLOORS ROTATED WITH RESPECT TO EACH OTHER AT 30 DEGREES.
3. THE JUNCTION OF TWO CONSECUTIVE FLOORS FORM LOACTIONS OF FLOATING COLUMNS.
4. THE OVERHANGS RESULTING FROM ROTATION OF FLOORS FORM LANDSCAPED TERRACES.

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Case

- *system?*

OFFICE BLOCK

RCC FRAMED 5TH FLOOR - 2ND FLOOR -

- a. RIBBED FLOORS
- b. RADIAL BEAMS
- c. FLOATING COLUMNS

PERIPHERAL WINDOWS RECESSED BY 0.6MT DEEP OVERHANGS MADE OF PRECAST CONCRETE ELEMENTS

PRECAST ELEMENTS OF WEATHER SHADES BEING LIFTED TO POSITION

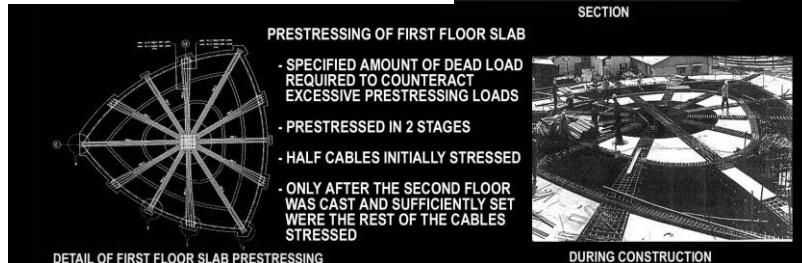
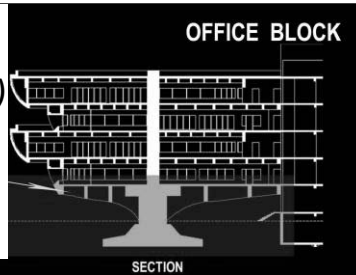
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Case

- *span lengths*
 - 30-40 m (100 - 130 ft)
 - 15-20 m (50 – 65 ft)



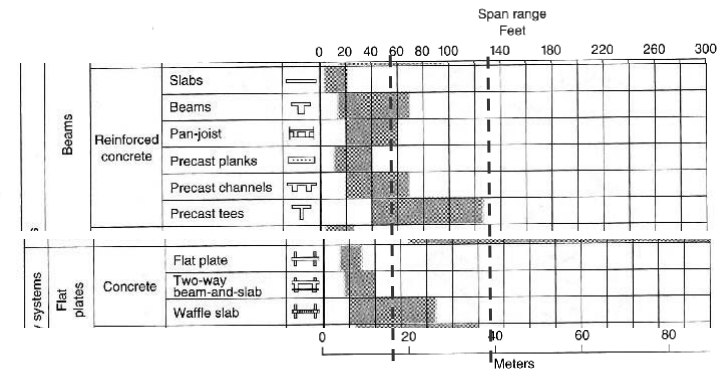
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Case

- *pre-stressing & loading type*

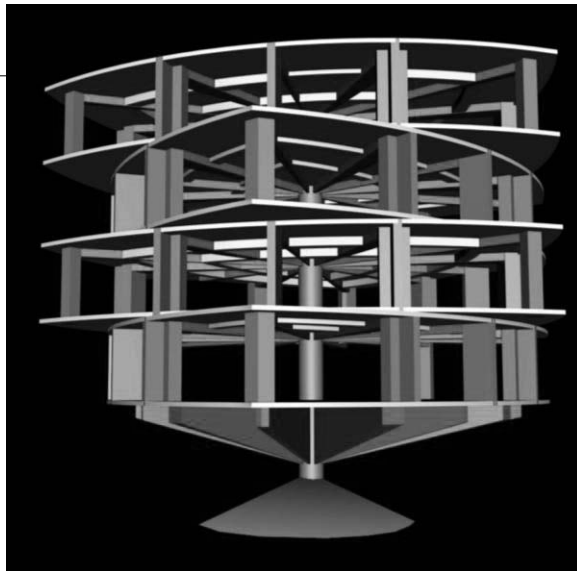


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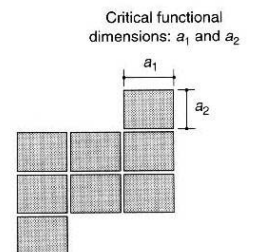
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Case



Design Issues

- *critical programmatic dimensions*
 - *minimum clear spans for functional areas*
 - *determines selection of beam, or roof/ floor systems*
 - *vertical support elements*
 - *match clear span or greater*



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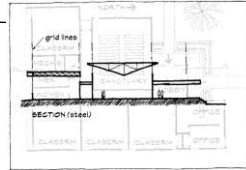
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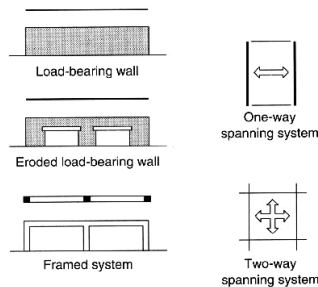
Design Issues

- degree of fit
 - single (1:1)
 - multiple (2:1, etc.)
 - any number of patterns possible
 - simple patterns generally more “elegant”
- one-on-one fit
 - good for large spans
 - material selection influences short span fit
 - steel & concrete for “looser” fits



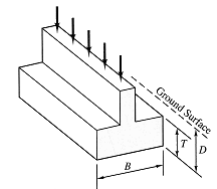
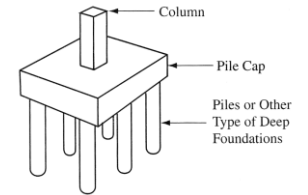
Spatial Implications

- one-directional or linear space
 - load bearing walls
 - beams & columns
 - column shape & orientation
 - long spans
- two-way, relatively neutral space
 - flat plate
 - beams & slabs
 - space frames



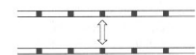
Foundation Influence

- type may dictate fit
 - piles vs. mats vs. spread
 - capacity of soil to sustain loads
 - high capacity – smaller area of bearing needing and can spread out
 - low capacity – multiple contacts and big distribution areas



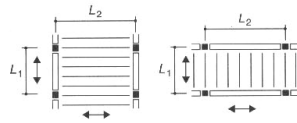
Square Bays

- two-way systems rely on square-ness
 - peripheral wall system or columns
 - columns extending 2 ways common
 - for low & intermediate span ranges
- one-way systems can be used
 - don't have 4 walls
 - columns extending 1 way only



Rectangular Bays

- 1:1 to 1:1.5
- direction of joists & beams not obvious
 - run comparison for material amounts
- generally:
 - with no collectors, span the short way
 - lightweight joists or trusses
 - with collectors, try the short way
 - same tributary load over shorter span



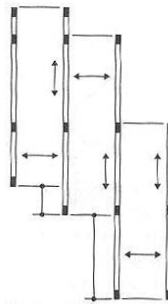
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Slipped Units

- usually one-way systems
- bearing walls allow unlimited slip
- columns allow slip by
 - column to column distance
 - columns can shift



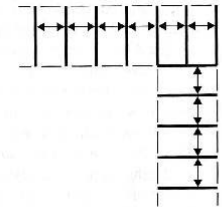
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Corners

- terminate system & change
- transition, rotation, or two-way system
- depends on vertical elements
- prefer constant member sizes AND spacings with steel & wood
- can use cast-in-place concrete



(b) One-way systems: turning corners with one-way systems is usually awkward.

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Moving Supports

- location of supports can redistributed the moments
 - reduced section size
- using cantilevers & continuous beams
 - rule of thumb for simple supported beam
 - move $L/5$ in both ends
 - move $L/3$ one end



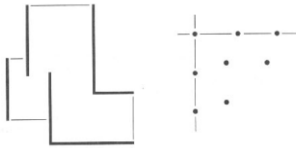
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Non-Uniform Grids

- *irregular column placement*
 - concrete & flat slabs adaptable
- *regular vertical supports required for most long span systems*



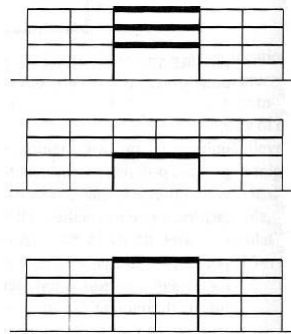
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Large Spaces

- *ex. auditoriums, gyms, ballrooms*
- *choices*
 - separate two systems completely and connect along edges
 - embed in finer grid
 - high up, less load transfer
 - low – more load transfer & heavy girders
 - staggered truss



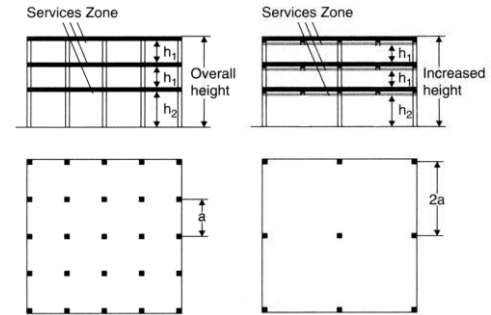
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Grid Dependency on Floor Height

- *wide grid = deep beams*
 - increased building height
 - heavier
 - foundation design
- *codes and zoning may limit*
- *utilize depth for mechanical*



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Meeting of Grids

- *common to use more than one grid*
- *intersection important structurally*
- *can use different structural materials*
 - need to understand their properties
 - mechanical
 - thermal



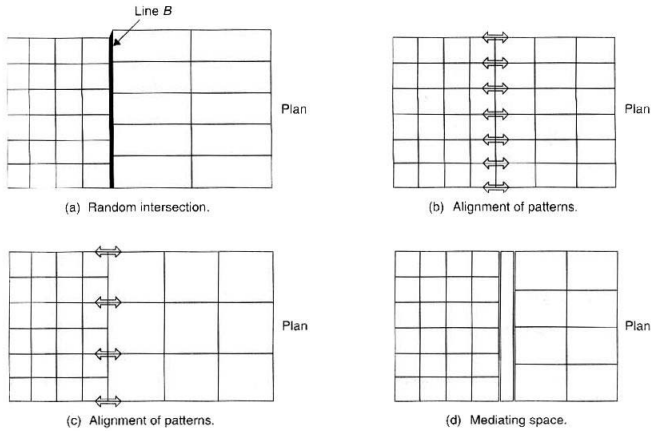
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Meeting of Grids

- horizontal choices



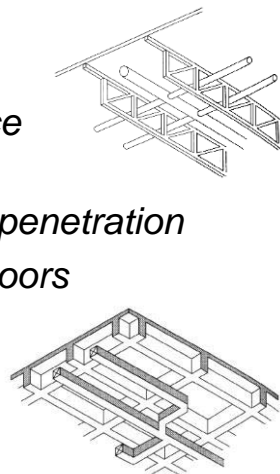
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Other Conditions

- circulation
- building service systems
 - one-way systems have space for parallel runs
 - trusses allow for transverse penetration
 - pass beneath or interstitial floors
 - for complex or extensive services or flexibility



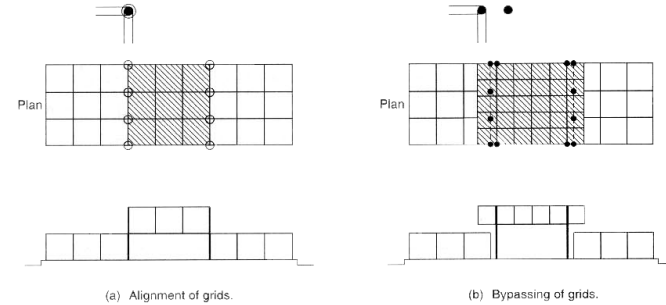
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Meeting of Grids

- vertical choices



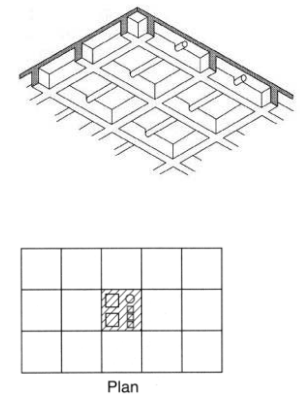
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Other Conditions

- poking holes for member services
 - horizontal
 - need to consider area removed, where removed, and importance to shear or bending
 - vertical
 - requires framing at edges
 - can cluster openings to eliminate a bay
 - double systems



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Fire Safety & Structures

- fire safety requirements can impact structural selection
- construction types
 - light
 - residential
 - wood-frame or unprotected metal
 - medium
 - masonry
 - heavy
 - protected steel or reinforced concrete



<http://www.nfpa.org>

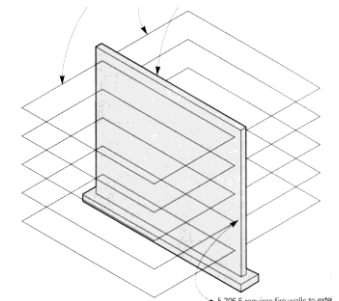
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Fire Safety & Structures

- degree of occupancy hazards
- building heights
- maximum floor areas between fire wall divisions
 - can impact load bearing wall location



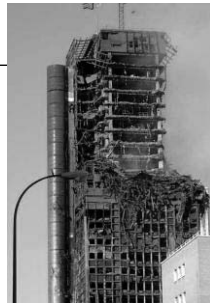
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Fire Safety & Structures

- resistance ratings by failure type
 - transmission failure
 - fire or gasses move
 - structural failure
 - high temperatures reduce strength
 - failure when subjected to water spray
 - necessary strength
- ratings do not pertain to usefulness of structure after a fire



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