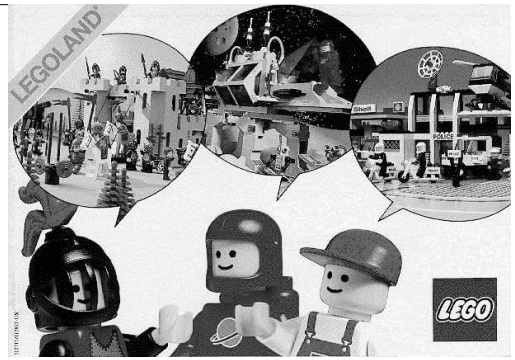
APPLIED ACHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2013

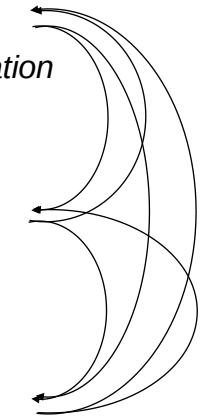
lecture
fourteen



structural planning

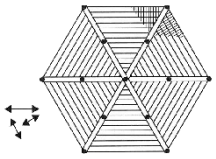
Structural Design Sequences

- *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*

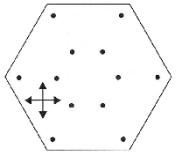


Systems

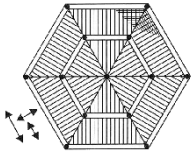
- *total of components*
- *behavior of whole*
- *classifications*
  - *one-way*
  - *two-way*
  - *tubes*
  - *braced*
  - *unbraced*



(a) One-way radial beam-and-column system for a hexagonal or circular configuration.

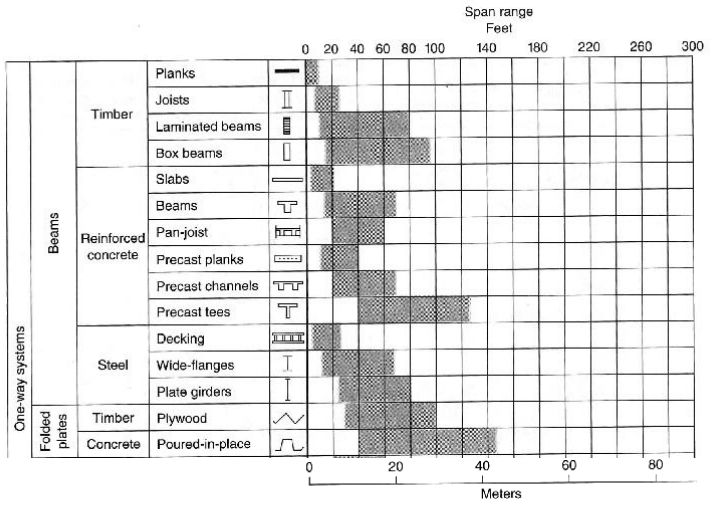


(c) Two-way flat-plate system (without beams) for a hexagonal or circular configuration.

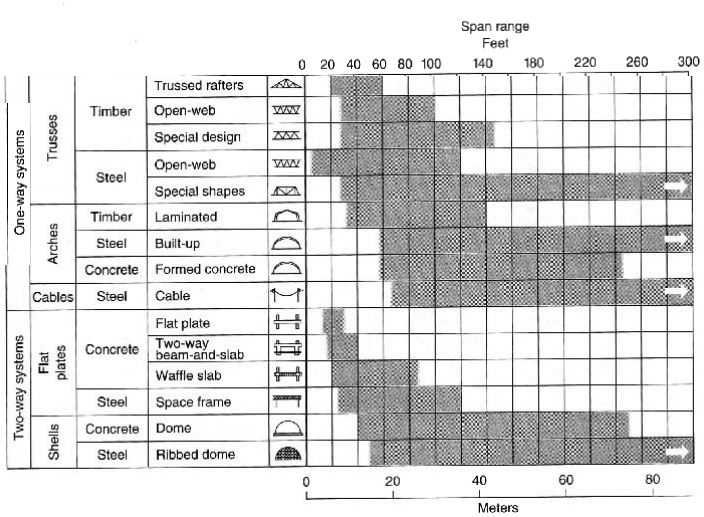


(b) One-way circumferential beam-and-column system plan for hexagonal or circular configuration.

Systems & Spans



Systems & Spans

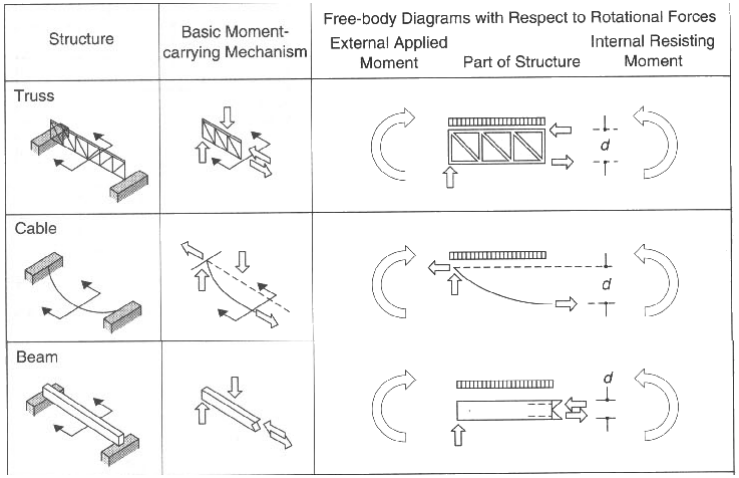


Span Lengths

- *crucial in selection of system*
- *maximum spans on charts aren't absolute limits, but usual maximums*
- *increase L, increase d^2 required (ex. cantilever)*
- *deflections depend on L*

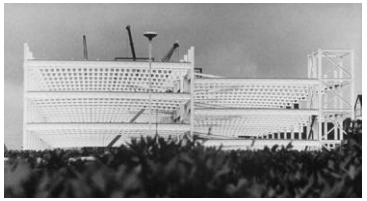
$$f_{b-max} = \frac{WL}{bd^2/6}$$

Moments in Members



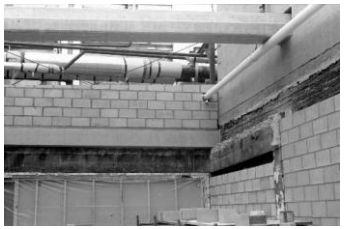
Spans

- *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*



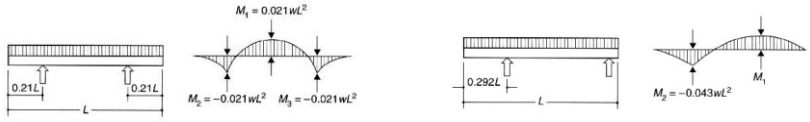
Spans

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



Moving Supports

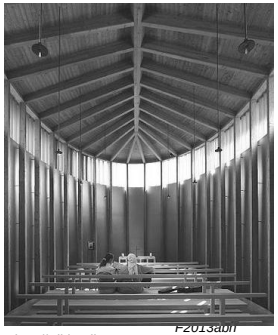
- *location of supports can redistributed the moments*
  - *reduced section size*
- *using cantilevers & continuous beams*
  - *rule of thumb for simple supported beam*
    - *move L/5 in both ends*
    - *move L/3 one end*



Support Density

- *concentrated structure*
  - *fewer columns*
  - *few large beams*
- *distributed structure*
  - *many columns*
  - *more smaller beams*
- *efficiency vs. character of interior space*
- *loads*

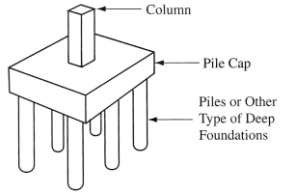
http://www.acsa-arch.org

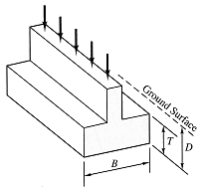


http://wikipedia.org

Foundation Influence

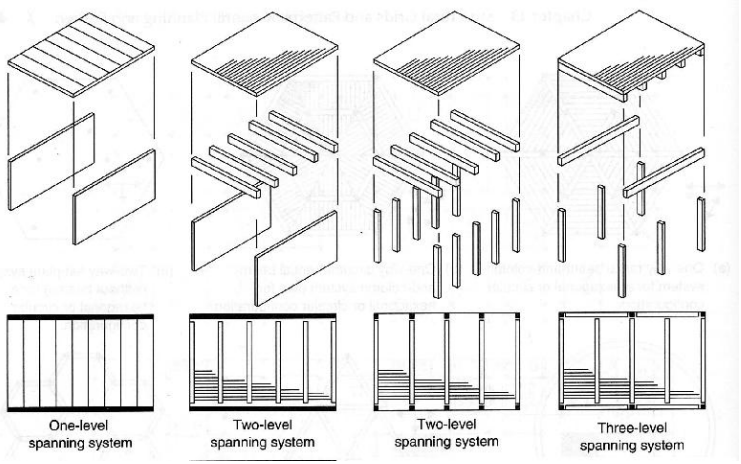
- *type may dictate density*
  - *piles vs. mats vs. spread*
  - *capacity of soil to sustain loads*
    - *high capacity – smaller area of bearing needing and can spread out*
    - *low capacity – multiple contacts and big distribution areas*





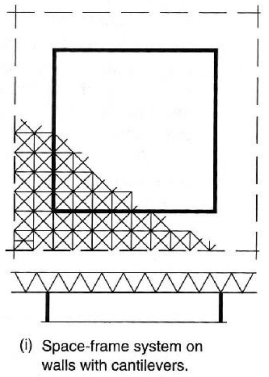
One-Way Systems

- *horizontal vs. vertical*

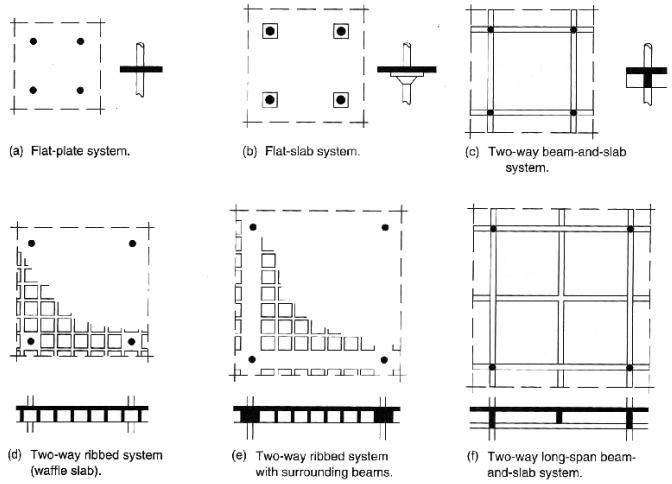


Two-Way Systems

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

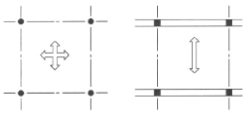

(i) Space-frame system on walls with cantilevers.

Two-Way Systems

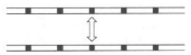

(a) Flat-plate system.
(b) Flat-slab system.
(c) Two-way beam-and-slab system.
(d) Two-way ribbed system (waffle slab).
(e) Two-way ribbed system with surrounding beams.
(f) Two-way long-span beam-and-slab system.

Square Bays

- *two-way systems rely on square-ness*
  - *peripheral wall system or columns*
  - *columns extending 2 ways common*
  - *for low & intermediate span ranges*

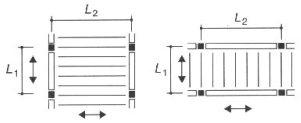


- *one-way systems <u>can</u> be used*
  - *don't have 4 walls*
  - *columns extending 1 way only*



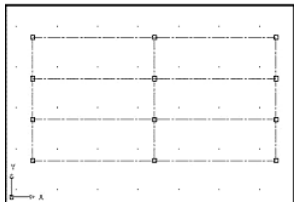
Rectangular Bays

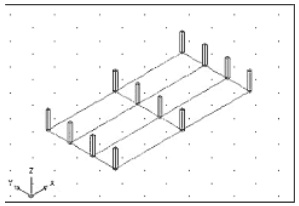
- *1:1 to 1:1.5*
- *direction of joists & beams not obvious*
  - *run comparison for material amounts*
- *generally:*
  - *with no collectors, span the short way*
    - *lightweight joists or trusses*
  - *with collectors, try the short way*
    - *same tributary load over shorter span*



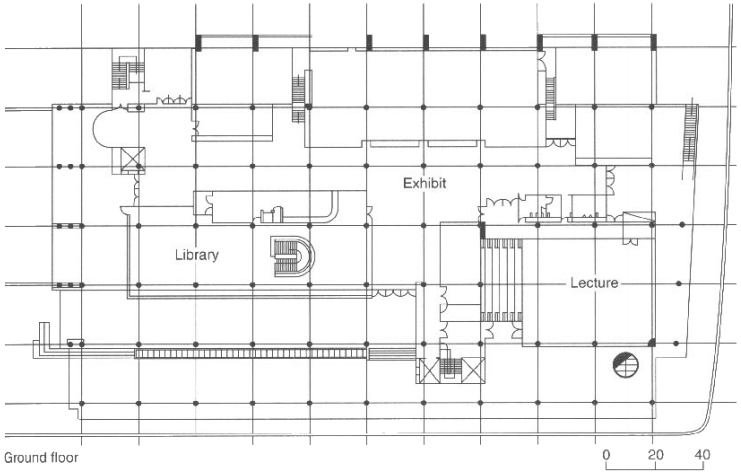
Grids and Patterns

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





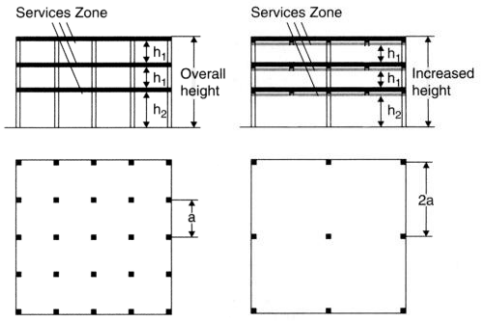
Grids and Patterns



(a) Square column grid.

Grid Dependency on Floor Height

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



Non-Uniform Grids

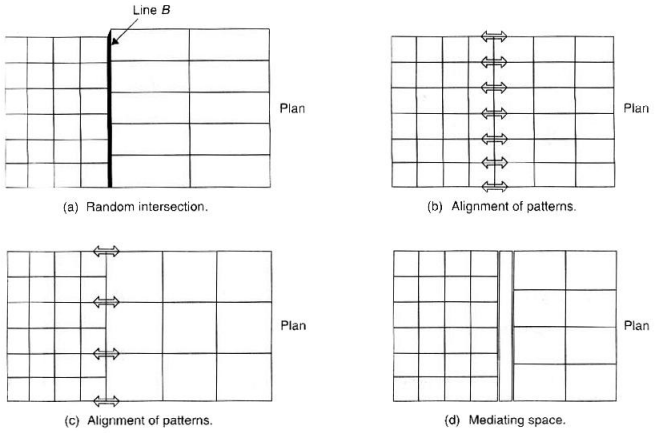
- *irregular column placement*
  - *concrete & flat slabs adaptable*
- *long spans*
  - *complex*
  - *increased story heights*

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*

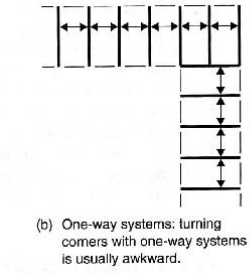
Meeting of Grids

- *horizontal choices*



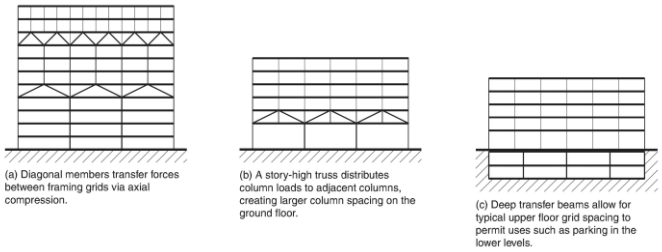
Corners

- *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.

Meeting of Grids

- *vertical choices*



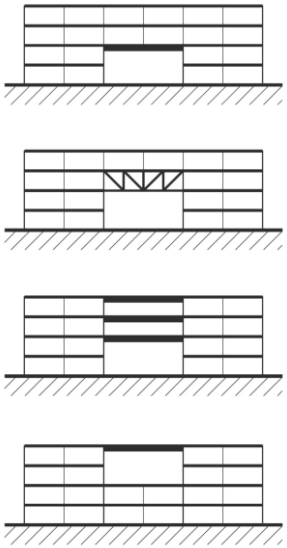
(a) Diagonal members transfer forces between framing grids via axial compression.

(b) A story-high truss distributes column loads to adjacent columns, creating larger column spacing on the ground floor.

(c) Deep transfer beams allow for typical upper floor grid spacing to permit uses such as parking in the lower levels.

Large Spaces

- *ex. auditoriums, gyms, ballrooms*
- *choices*
  - *embed in finer grid*
    - *high up, less load transfer*
    - *low – more load transfer & heavy girders or deep truss*
  - *staggered truss*

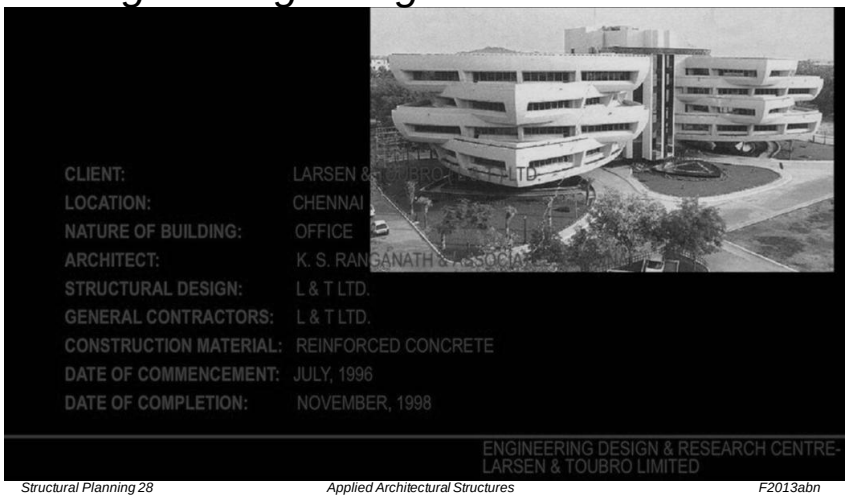


Case

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

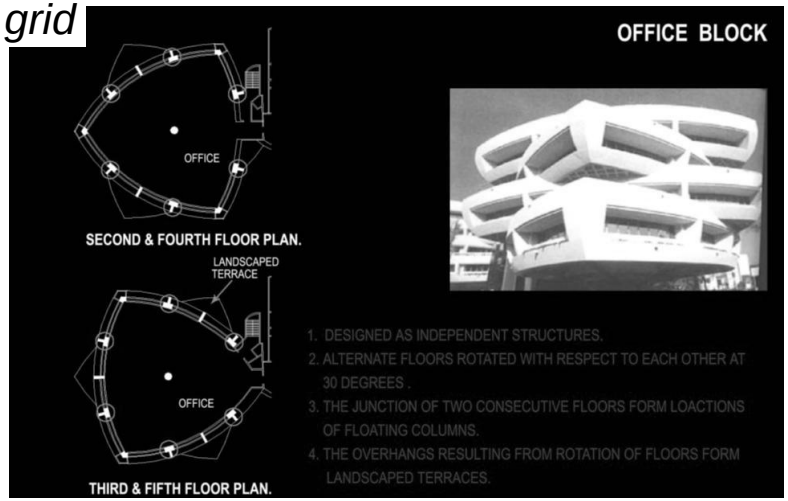
Case

- *Engineering Design & Research Center*



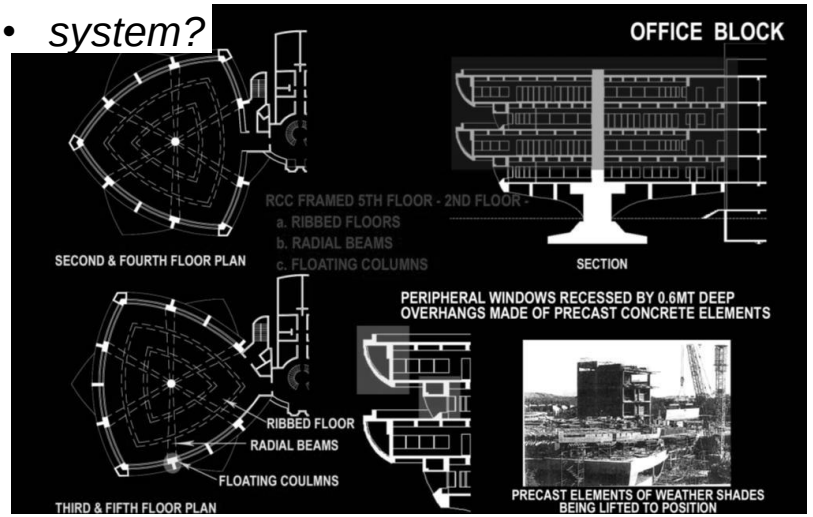
Case

- *grid*



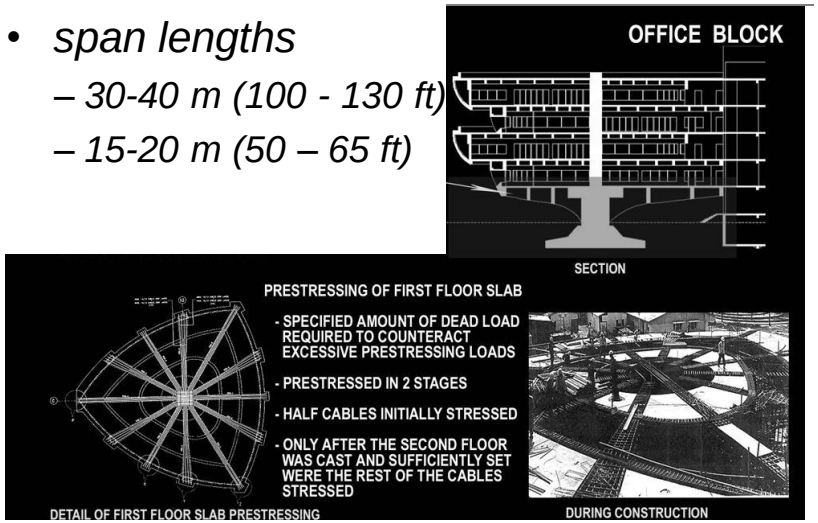
Case

- *system?*



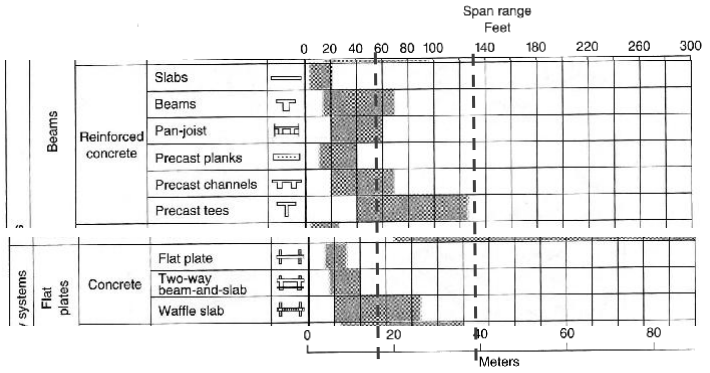
Case

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

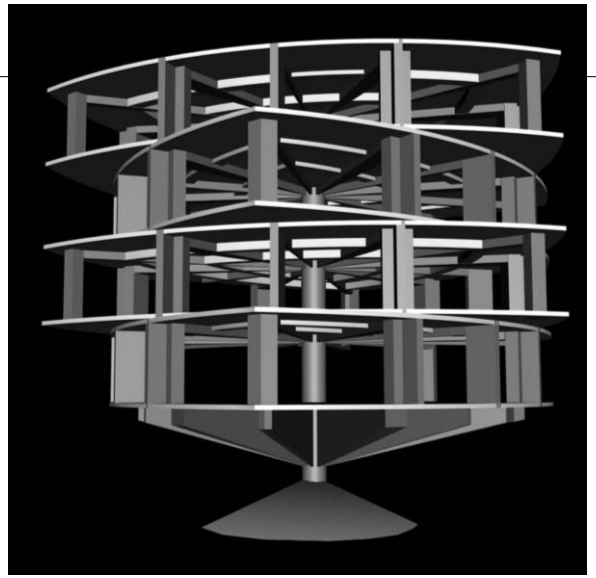


Case

- *pre-stressing & loading type*

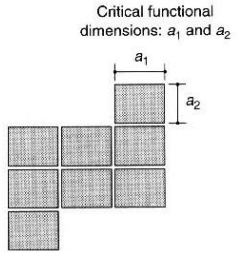


Case



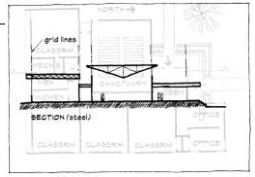
Design Issues

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



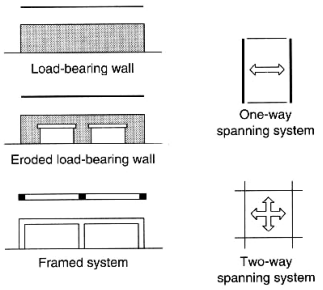
Design Issues

- *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*



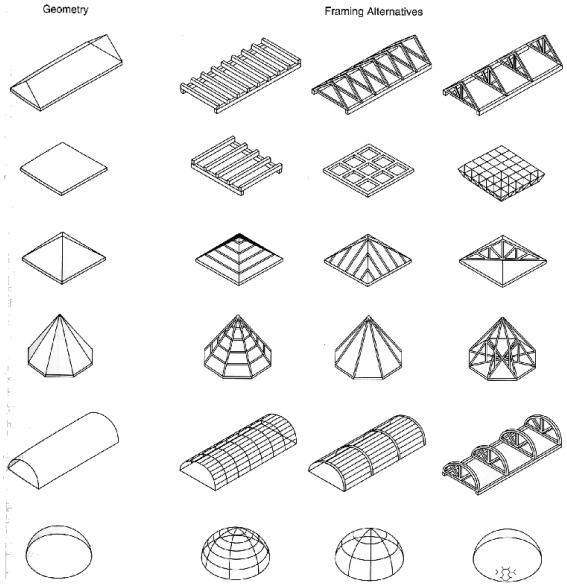
Spatial Implications

- *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*



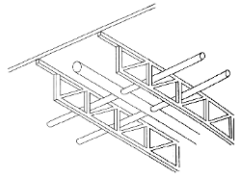
Roof Shapes

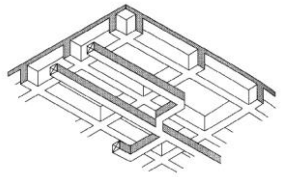
- *coincide*
- *within*



Other Conditions

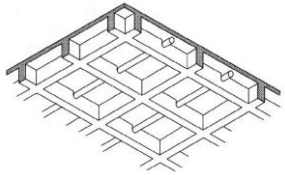
- *circulation*
- *building service systems*
  - *one-way systems have space for parallel runs*
  - *trusses allow for transverse penetration*
  - *pass beneath or interstitial floors*
    - *for complex or extensive services or flexibility*

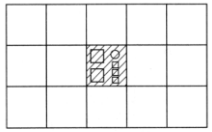




Other Conditions

- *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*





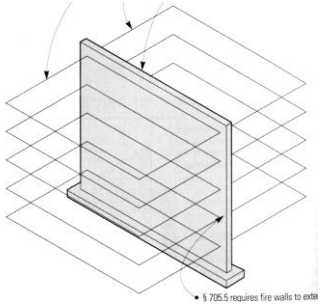
Fire Safety & Structures

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

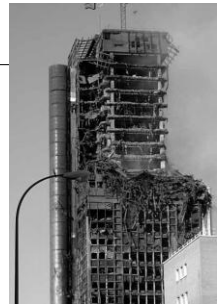
http://www.nfpa.org

Fire Safety & Structures

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



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 <u>do not pertain</u> to usefulness of structure after a fire*