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Technical Assignment 2

EXECUTIVE SUMMARY

This report is a comparison study of the existing floor system of the Hyatt Regency to four possible alternatives. The alternatives being considered are: one-way slab with concrete joists, two-way flat slab with drop panels, non-composite steel framing, and open-web steel joist framing. A preliminary design of each system is included along with corresponding layout sketches. Each system's advantages and disadvantages are discussed to compare which may be the best alternative and to contrast to the existing design.

The first alternative, 1-way concrete slab with joists, resulted in a 15" floor, but also had the advantage of being a more typical construction technique for contractors.

The second alternative, a 2-way concrete flat slab with drop panels, resulted in a slab thickness of only 9", but near columns, the required drop panels increased the thickness to 17.5".

The third alternative, non-composite steel framing accommodated faster construction along with a lighter building; however, the floor thickness increased to 14.3" at beams and 18" at girders as well as increasing the cost of fire-protection.

The fourth alternative, open-web steel joists, resulted in decreased building weight and faster construction, but had a very deep, 22.5" floor thickness. The joists are also very difficult to fire-proof.

After comparing the various systems, the open-web steel joists have been removed from further consideration. The advantages you gain from using the joists are similar to those that you gain with the non-composite steel beams; however, the system has the greatest disadvantages of all the systems: 22.5" floor thickness and very difficult fire-proofing. These factors would greatly increase cost and height of the building. The other systems can be further investigated. Although the filigree system that was used in construction may be the most suitable for the conditions, the other systems could be adapted for use in the building with further analysis.

EXISTING FLOOR SYSTEM:
FILIGREE SLAB

The existing floor system for the Hyatt Regency tower is a pre-stressed filigree slab system. The system has a typical bay size of 27' x 24' with average pre-stressing of 8 foot-kips per foot in the long span. The plan showing void layout can be seen in Figure 1. A section view through the system is detailed in Figure 2. The voids are laid out in the bay between a 6'-0" typical column strip. The pre-cast panel is $2^1/_4$" thick, with 2'-0" wide by $3^1/_2$" deep polystyrene voids spaced 8" apart. The 4500psi cast-in-place portion of the slab is placed $2^1/_4$" deep over the voids, for a total slab thickness of 8". Loads are transferred between the top and bottom of the section via anchors in the pre-cast panel.

As opposed to regular cast-in-place concrete floor systems, the filigree system reduces the amount of shoring required and virtually eliminates field formwork. This reduces the amount of labor required on site, reducing the construction time and possibly reducing the labor construction costs. These types of systems also result in thinner slabs than solid concrete floors. For this project, FAA requirements limit the building height, so thin floor slabs are a great advantage to the construction of the building.

While the time savings and floor thickness are major advantages, other advantages are also gained by using the filigree slab. Since the slab is concrete, the use of pre-cast sections allows more quality control of that section of the floor. This ensures the concrete is cast properly and can also allow the finishing to be done at the fabricator, providing a better aesthetic than cast-in-place floors over a plywood formwork. Filigree structures can also be easily fire-rated and acoustically-rated similar to traditional concrete construction.

The major disadvantage of the system is that many contractors are inexperienced in the construction of these systems. From this lack of experience, improper construction can result, which may compromise the integrity of the system. Along the same lines, cost may also increase if a more experienced contractor is required, so during bidding, the most economical choice may not be the most appropriate for construction. Another disadvantage to this system is that while this system is lighter than traditional cast-in-place concrete floor systems, it still results in a thick floor and with concrete columns; the building weight is greater than that of a steel structure.

While this system may be the most appropriate choice for the design conditions, the alternative systems reviewed are chosen for their similar advantages to the filigree system as well as to address the disadvantages inherent in the system.

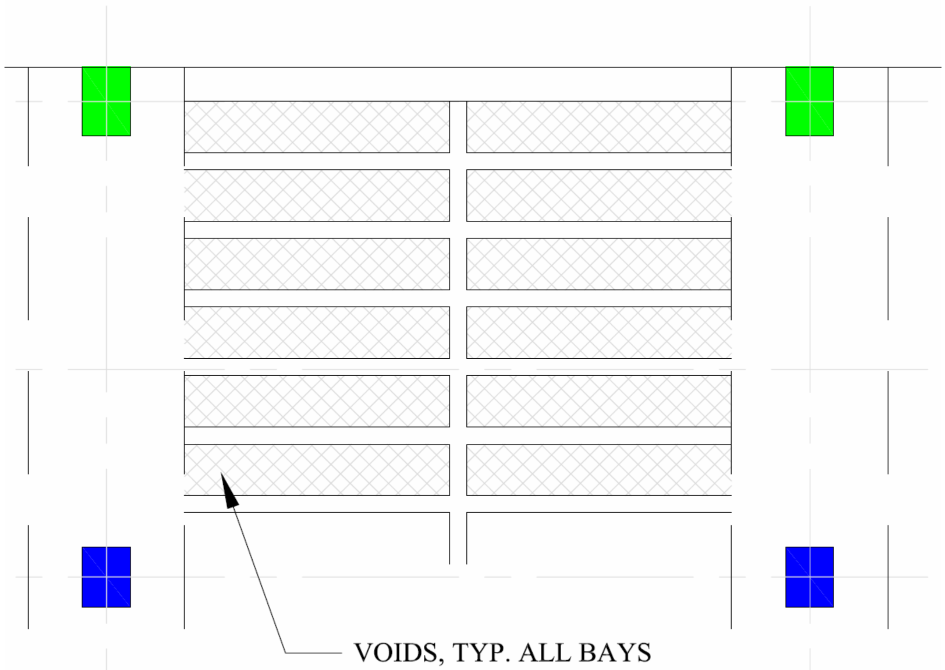

Figure 1. Filigree slab system void layout in a typical bay.

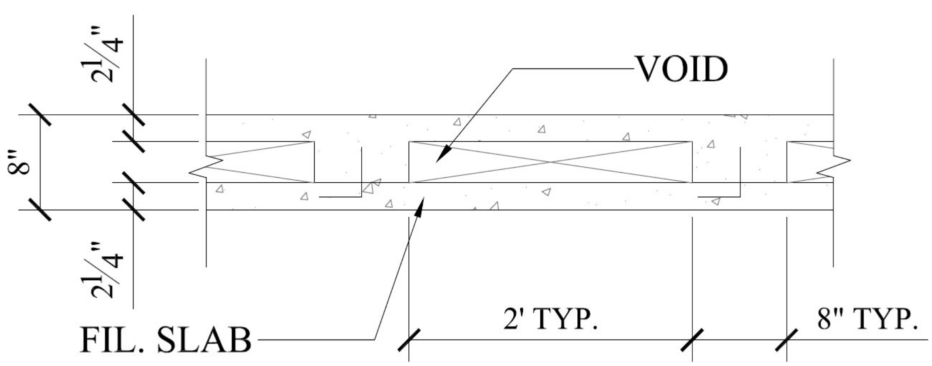

Figure 2. Section through filigree slab.

ALTERNATIVE 1:
ONE-WAY SLAB WITH CONCRETE JOISTS

The first alternate floor system reviewed is a concrete floor slab with joists spanning in one direction. This system is a more traditional cast-in-place floor system than the filigree system. Many of the same advantages of the filigree system are the same as those of the filigree system. Since this system is constructed of concrete, the fire-rating is easy to achieve, and it has better vibration and acoustical isolation than steel structures. This system is more typical than filigree, so construction is simpler. There are also many disadvantages associated with this system. The system is very massive, so increases the weight of the building, and may require larger foundations. The total depth of the floor is greatly increased over the thickness of the filigree system. Also, due to formwork and shoring requirements, there is increased construction time and possibly cost.

The system was analyzed using the Concrete Reinforcing Steel Institute Handbook (CRSI). The CRSI details various combinations of slab depth and rib depth; a layout was selected that met the design criteria below.

Design Criteria used:
- Factored Superimposed Load (psf) = 1.4(20psf) + 1.7(80psf) = 164 psf
- f'_c = 4000 psi
- f_y = 60,000 psi
- Clear span for bay of 26'-0"

CRSI design (for layout of dimensions, see Figures 3 & 4):
- 30" form width
- 5" rib width
- 12" rib depth
- 3" slab thickness
- 15" total depth
- End span reinforcement (for 176 psf allowable factored load):
    - Top reinforcement – #5 @ 9.5" o.c.
    - Bottom reinforcement – (2) - #6
- Interior span reinforcement (for 204 psf allowable factored load):
    - Top reinforcement – #5 @ 10.5" o.c.
    - Bottom reinforcement – (2) - #
- For span between 20' and 30', a 4" distribution rib is required with 1 #4 bar. This rib is placed at the mid-span of the bay.

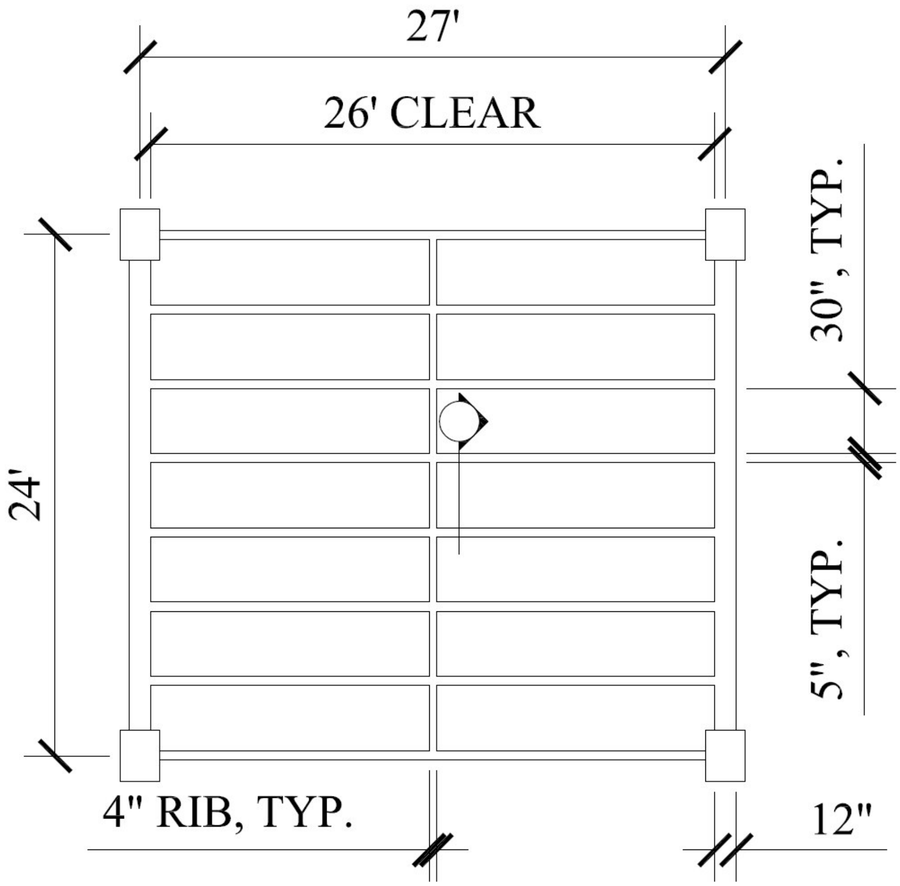

Figure 3. Plan view of one-way slab. For section, see Figure 4.

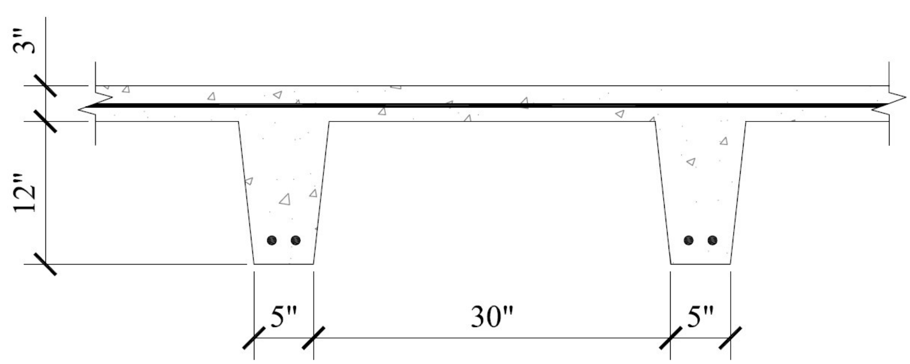

Figure 4. Section cut through one-way slab.

ALTERNATIVE 2:
TWO-WAY FLAT SLAB

The second alternate floor system reviewed is a two-way concrete flat slab with drop panels. This system also has many of the same advantages as the filigree system. A major advantage of this system is that it results in a slab thickness close to that of the filigree system; however, at drop panels, the total thickness is greatly increased. As with the other concrete construction, fire-rating is easy to achieve and it has better vibration and acoustical isolation than steel structures. This system is very easy to construct, and formwork is much simpler than that of the one-way slab with joists. Since the typical bay size is close to square, a two-way slab can be easily implemented. This system also greatly increases the weight of the building, as the slab is thicker and the drop panels are much thicker; this may also increase foundation sizes. The depth of the drop panels is a major disadvantage, but since their location is at the corners of the guest rooms, the impact could be minimal.

This system was also analyzed using the CRSI. The CRSI details various slab depths between drop panels and allowable factored loads based on drop panel size; a layout was selected that met the design criteria below.

Design Criteria used:

- Factored Superimposed Load (psf) = 1.4(20psf) + 1.7(80psf) = 164 psf
- f'_c = 4000 psi
- f_y = 60,000 psi
- Assumed a square bay of size 27'-0" x 27'-0" (actual bay is 27'-0" x 24'-0")
- Assumed the use of drop panels based on large span

CRSI design (for layout of dimensions, see Figure 5):

- 9" total slab depth between drop panels
- 8.5" drop panel depth
- 17.5" total depth at drop panels
- 9'-0" x 9'-0" drop panel size centered around columns
- 15" square column required

- Edge panel reinforcement (for 200 psf allowable factored load):
  - Column strip
    - Top exterior – (15) - #4
    - Bottom – (11) - #8
    - Top interior – (14) - #6
  - Middle strip
    - Bottom – (9) - #7
    - Top interior – (10) - #6
- Interior panel reinforcement (for 200 psf allowable factored load):
  - Column strip
    -
    - Top – (18) - #5
    - Bottom – (9) - #7
  - Middle strip
    - Top – (13) - #5
    - Bottom – (11) - #5

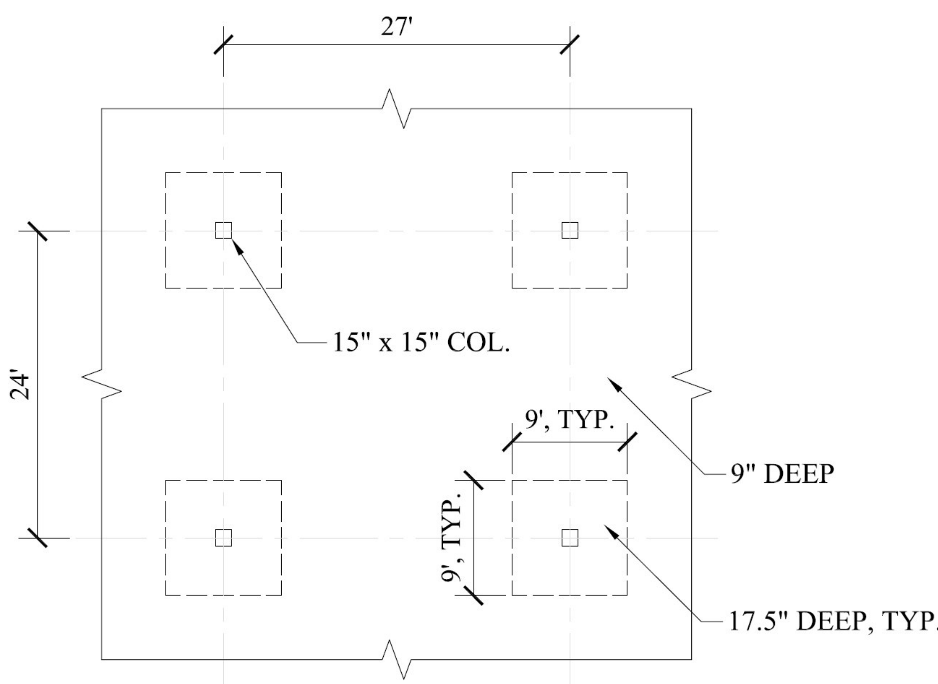

Figure 5. Plan of two-way flat slab with drop panels for typical bay.

ALTERNATIVE 3:
NON-COMPOSITE STEEL FRAMING

The third alternate floor system reviewed is non-composite steel framing. This system reduces the weight issues that are common in a concrete building. By switching the framing to steel, the overall building weight is reduced, which may reduce the foundation size. This type of construction is fast, and doesn't require the time for concrete curing as in the first two alternatives. The major disadvantages in this system are that fireproofing is more expensive and that the beams will result in larger floor-to-floor heights.

Design Criteria used:

- 1.5" Non-composite steel deck
- A992 Steel Beams
- f'_c of slab is 3000psi
- Assumed beam spacing of 5'-0"
- Assume typical bay size of 27'-0" x 25'-0" for simplicity
- Assume suitably sized steel columns are present
- Unfactored service load is 20psf (DL) and 80psf (LL)
- Neglect self weight of beams for preliminary design
- Assume full lateral bracing for beams provided for preliminary design
- Assume simple connections for preliminary analysis

Design results:

- From Vulcraft Steel Roof and Floor Deck design guide, with a 1.5" non-composite deck, with 5'-0" beam spacing:
  - Total slab thickness required = 4"
  - Slab reinforcement required is 6X6-W2.9XW2.9 W.W.F.
  - Provides allowable superimposed uniform load of 119 psf
  - Slab and deck weight = 44psf
- w_u = [1.2(44psf+20psf)+1.6(80psf)]*5' = 1.024 k/ft
- $M_u = w_u l^2/8$ = (1.024k/ft)$(27')^2$/8 = 93.3'k
- $V_u = w_u l/2$ = 13.8k
- From AISC Steel Manual, possible selections are W12x22 or a W10x26
  - Select W10x26 for minimum section depth
    - ΦM_p = 110'k > Mu (OK)
    - ΦV_n = 72.3k > Vu (OK)
    - Section depth = 10.3"
  - Total floor depth at beams = 14.3"

- For girder supporting 4 equally spaced beams:
    - Mu = 0.6PL = 0.6(13.8k)(24’) = 199’k
      (where P = load from 1 of 4 beams)
    - Vu = 2(P) = 2(13.8k) = 27.6k
    - From AISC Steel Manual, possible selections are W16x31 or W14x34
        - Select W14x34 for minimum section depth
            - ΦM_p = 203’k > Mu (OK)
            - ΦV_n = 108k > Vu (OK)
            - Section depth = 14.0”
        - Total floor depth at girders = 18”

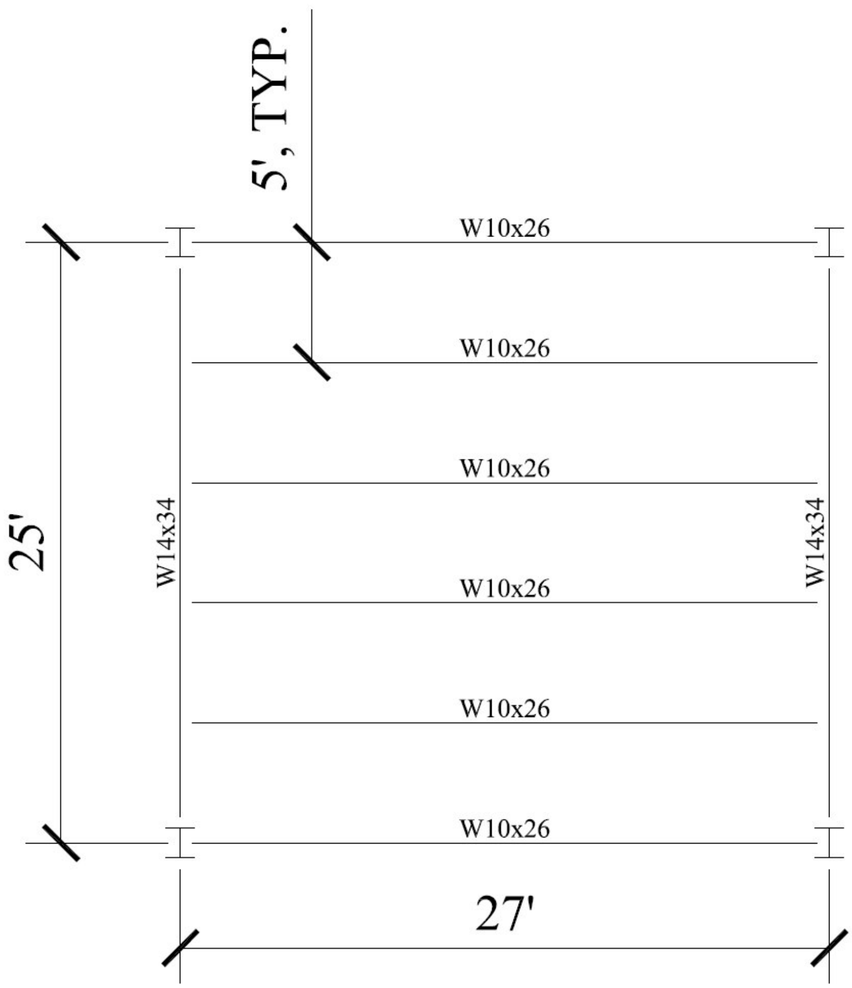

Figure 6. Typical layout of non-composite steel framing.

ALTERNATIVE 4:
OPEN WEB STEEL JOIST FRAMING

The fourth alternate floor system reviewed is open-web steel joist framing. This system also reduces the weight issues that are common in concrete buildings. With joist framing, the reduction in weight may also reduce the foundation size. This system allows additional room for mechanical and lighting equipment in the floor space than the other systems studied. This system is economical to build and also fast to construct. The major disadvantages in this system are that fireproofing is difficult and expensive and that the joist depth required for the bay size greatly increases the floor thickness.

Design Criteria used:

- 1.0" Non-composite steel deck
- Standard open-web steel joists, using Vulcraft Steel Joist and Joist Girder design guide
- f'_c of slab is 3000psi
- Assumed joist spacing of 2'-0"
- Typical bay size of 27'-0" x 24'-0"
- Assume suitably sized steel columns are present
- Unfactored service load is 20psf (DL) and 80psf (LL)
- Neglect self weight of joists for preliminary design

Design results:

- From Vulcraft Steel Roof and Floor Deck design guide, with a 1.0" non-composite deck, with 2'-0" joist spacing:
  - Total slab thickness required = 2.5"
  - Slab reinforcement required is 6X6-W2.1XW2.1 W.W.F.
  - Provides allowable superimposed uniform load of 140 psf
  - Slab and deck weight = 25psf
- Load = 20psf (DL) + 25psf (slab) + 80psf (LL) = 125 psf (2') = 250 plf
- For deflection criteria, LL = 80psf (2') = 160 plf
- From Vulcraft Steel Joist and Joist Girder design guide:
  - 16K5 required for 27' span.
  - Allowable load = 302 plf
  - Allowable live load for deflection = 173 plf
  - Floor depth at joists = 18.5"

- Joist girders
  - 12 Joist spaces @ 2'-0" each, over 24'-0"
  - At each joist bearing location, P = (250plf+7.5plf)24' = 6.2k
  - From Vulcraft Steel Joist and Joist Girder design guide:
    - Use 20G12N7K (20" depth, 12 joist spacings, 7k load per joist)
    - Floor depth at joist girders, 22.5"

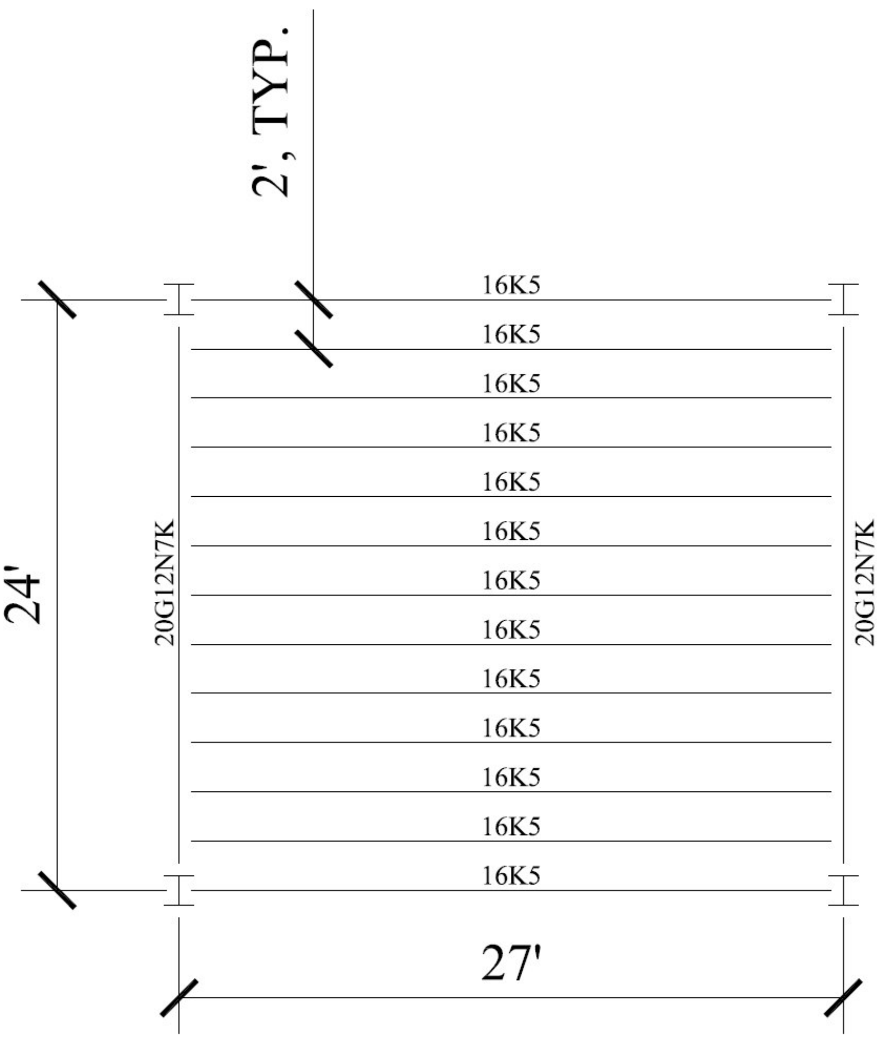

Figure 7. Typical layout of open-web steel joists and joist girders

FLOOR SYSTEM COMPARISON:

Table 1. Comparison of advantages and disadvantages of the five floor systems. Conclusions have been drawn to which systems to pursue studying, with deciding factors.

System:	Major Advantages:	Major Disadvantages	Further Consideration?
Filigree Slab *(existing)*	- Thin Slab - Floor-to-floor height reduced - Fast construction	- Contractors may be unfamiliar with construction procedure	n/a
1-way Concrete Slab w/ Joists	- More typical construction procedures - Fire-rating easily achieved	- Deeper floor - Slower construction - Increased building weight	Yes
2-way Concrete Flat Slab w/ Drop Panels	- Thin slab away from drop panels - Simple construction - Fire-rating easily achieved	- Thick slab at drop panels - Increased building weight	Yes
Non-composite Steel Beams	- Fast construction - Light system - Simple construction	- Costly fireproofing - Increased floor-to-floor height	Yes
Open-web Steel Joists	- Light system - Additional mechanical space - Fast construction	- Very deep member sizes - Fireproofing costly and difficult	No

CONCLUSIONS:

After analyzing the various floor systems, some conclusions can be drawn as to which to consider further and which can be eliminated from consideration. It is clearly apparent from the analysis that the original floor system of filigree concrete slab resulted in the thinnest slab thickness, which is probably why it was selected to be the system used.

The first alternative, 1-way concrete slab with joists, resulted in a 15" floor, but also had the advantage of being a more typical construction technique for contractors. The second alternative, a 2-way concrete flat slab with drop panels, resulted in a slab thickness of only 9", but near columns, the required drop panels increased the thickness to 17.5". The third alternative, non-composite steel framing accommodated faster construction along with a lighter building; however, the floor thickness increased to 14.3" at beams and 18" at girders as well as increasing the cost of fire-protection. The fourth alternative, open-web steel joists, resulted in decreased building weight and faster construction, but had a very deep, 22.5" floor thickness. The joists are also very difficult to fire-proof.

Based on the results from analysis, most of the systems seem like they would be possible replacements for the filigree. The open-web steel joists have been removed from further consideration because the advantages you gain from using the joists are similar to those that you gain with the non-composite steel beams; however, the system has the greatest disadvantages: 22.5" floor thickness and very difficult fire-proofing.

The other systems can be further investigated. Although the filigree system that was used in construction may be the most suitable for the conditions, the other systems could be adapted for use in the building with further analysis.