NATIONAL HARBOR BUILDING M

OXON HILL, MARYLAND

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Structural Option

Technical Report 2

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EXECUTIVE SUMMARY

This is a report analyzing and evaluating the current Composite flooring system and four proposed flooring systems (Non-Composite, Longspan Steel Joist, Concrete Flat Plate with Drop Panels and One-Way Concrete Beam and Slab) for National Harbor Building M. The report starts out with a description of the each floor system and diagram of a typical bay from each respective system. A number of evaluating criterions are introduced and each system is judged on their performance in each. The results of the evaluation are summarized in a comparison chart and conclusions are drawn for viable flooring systems as they apply to this project.

In conducting this analysis it was clear that there is a defiant relationship between amount of material used and overall cost of the system. That being said the Composite and Flat Plate Systems were the lightest and least expensive among the steel and concrete systems respectfully. Another inference which can be drawn from the comparison table is that with additional weight or mass of a building the better the vibration control becomes and the more critical the seismic lateral loads become. In the end it was clear that the Composite System's price and performance over the other steel systems made it the most viable out of that group. Additionally, while both concrete systems preformed well the savings in cost and building load the Flat Plate System boasted over the One-Way Beam and Slab System made it the best concrete option.

STRUCTURAL SYSTEMS OVERVIEW

Floor System:

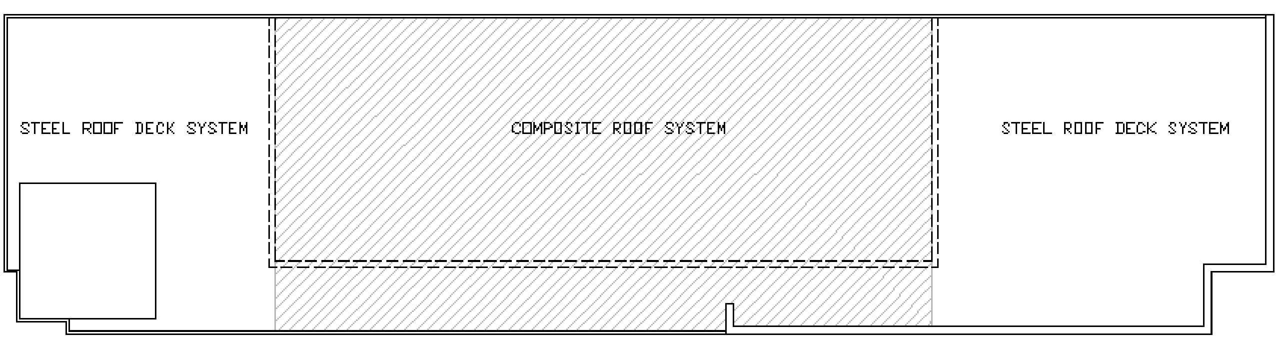
The typical floor is a 6-1/4" thick composite concrete system. It is comprised of a 3-1/4" light weight concrete slab with 3000 psi compressive strength and 3"-20 gauge A992 (50 ksi) composite steel deck. The slab is reinforced with 6x6-10/10 draped welded wire mesh (WWM) and gains it composite properties from ¾" diameter 5-1/4" long steel studs. This composite floor system is supported by A992 wide-flange beams which are typical spaced at 10' on center, span 30'-5-1/2" in a normal bay, and have a 1" camber. These beams range in size from W14-22 to W16x26 and are in turn supported by a grid of wide flange girders. The girders typically are spaced at 30'-5-1/2" with a 30'-0" span ranging from W18x50 to W24x84 with a 1" camber.

Column System:

The columns are ASTM 572, grade 50 or A992 steel wide flanges and are laid out in fairly square bays (30'x30'-5-1/2" typ.) forming a mostly rectangular grid of 9 bays by 2 bays. They are the main gravity resisting members of the structure as well as a portion of the lateral resisting system. The purely gravity resisting columns range from W12x65 to W14x109 at the bottom level and are spliced 4' above the third floor level. There are lateral force resisting columns in both moment and braced frames which range from W14x99 to W14x211 at the bottom level, however they tend to be on the order of W14x150's. These columns are also spliced at a distance 4' above the third floor level.

Roof System:

The roof of this structure is constructed in two different systems: typical flat roof steel deck and a composite slab roof construction. The main roof is 3" 18 gauge wide rib, type N galvanized steel roof deck which is uniformly sloped. The other roof system is a 4-1/2" normal weight composite concrete slab with 3000 psi compressive strength and reinforced by 6x6-10/10 draped WWM supported by 3" 18 gauge composite steel deck. The composite action in this slab as in the standard floor slabs comes from ¾" diameter 5-1/4" long equally spaced studs.



ROOF CONSTRUCTION PLAN

Foundation System:

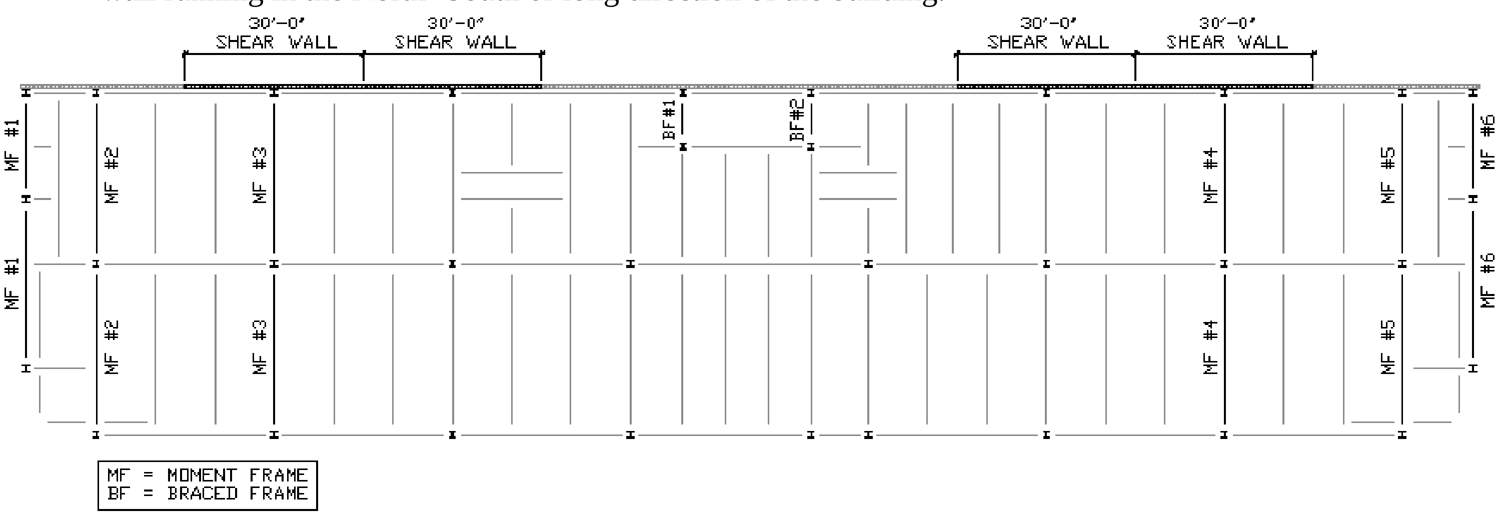
The ground floor is constructed of a 4" thick slab on grade with a compressive strength of 3000 psi and reinforced with 6x6-10/10 WWM. The columns are supported by concrete footings, compressive strength of 4000 psi, which are in turn supported by driven 14" square precast prestressed concrete piles. The piles, which have an axial capacity of 110 tons, uplift capacity of 55 tons and a lateral capacity of 7.5 tons, are typically arranged in three pile pile group under the exterior columns. These pile group and footing combinations are connected by reinforced concrete gradebeams running around the exterior of the foundation system. The columns which form the braced frames around the elevator core are additionally supported by a reinforced concrete pedestal and a 43 pile mat-pile group footing.

Masonry Wall System:

The Eastern wall of the structure is backed up by a full height 8" CMU masonry wall running the length of the building, 243'-8". The wall acts as a barrier between the office building and an adjacent parking garage being concurrently constructed. It separats the two with a 4" expansion joint on the parking garage side and ties into the structure at every floor level with a standard bent plate connection every 32" on center. The wall is reinforced with one or two #6 bars at a spacing of 8"-24" on center depending on the location. It is additionally reinforced with bond beams for an impact loads from the parking garage of 6000lbs at a height of 1'-6" above the floor levels. In addition to being a barrier sections of the CMU wall also act as (4) 30'-0" masonry shear walls to aid in the lateral force resisting system.

Lateral System:

This building's lateral force resisting system is a combination of multiple system types which act together to laterally support the building. It contains (6) moment frames which run in the East-West or short direction of the building. They are arranged symmetrically with (2) moment frames at each end of the grid and another at one full bay in from each end. The structure also has 2 braced frames running in the short direction centrally located flanking the elevator core. These braced frames are comprised of wide flange columns, beams, and diagonal members with the diagonal resisting members ranging from W12x79 – W12x190. The final components of the system are (4) 30'-0" reinforced masonry shear walls located in the 8" CMU wall running in the North- South or long direction of the building.



TYPICAL FRAMING PLAN

LOADS

Live Loads:

Area	Design Load	ASCE 7-05 Minimum
Lobbies	100 psf	100 psf
Offices	100 psf	50 psf
1st Floor Corridors	100 psf	100 psf
Corridors above 1st Floor	100 psf	80 psf
Future Retail Tenant	100 psf	100 psf

Roof Live Loads:

Item	Design Load	Code Reference
Minimum Roof Load	30 psf + snow drift	
Ground Snow Load (Pg)	25 psf	IBC 2003 1608.2
Snow Exposure Factor (Ce)	1.0 (Exposure D, Partially exposed)	IBC 2003 1608.3.1
Thermal Factor (Ct)	1.0	IBC 1608.3.2
Snow Importance Factor (Is)	1.0	IBC 1608.4
Flat Roof Snow Load (Pf)	17.5 psf + snow drift	IBC 1608.3
Minimum (Pf) used	20 psf + snow drift	

Dead Loads:

Item	Design Load
Floor	25 psf
Composite Roof	35 psf
Non-Composite Roof	25 psf
M/E/P	25 psf
Canopies	25 psf
8” CMU Wall	40 psf
Additional Loadings	As Noted in Calculations

Wall Loads:

Item/Location	Design Load (per foot along floor level)
Partition	150 plf
Glass Tower	320 plf
2nd Floor Front Glass	230 plf
3rd Floor Front Glass	150 plf
3rd Floor Architectural Precast	300 plf
3rd/4th Floor Brick	650 plf
5th Floor Front Glass	620 plf
5th Floor Brick	730 plf
5th Floor Architectural Precast	620 plf
Typical Glass Wall	280 plf
Typical Parapet	260 plf
Brick Parapet	260 plf

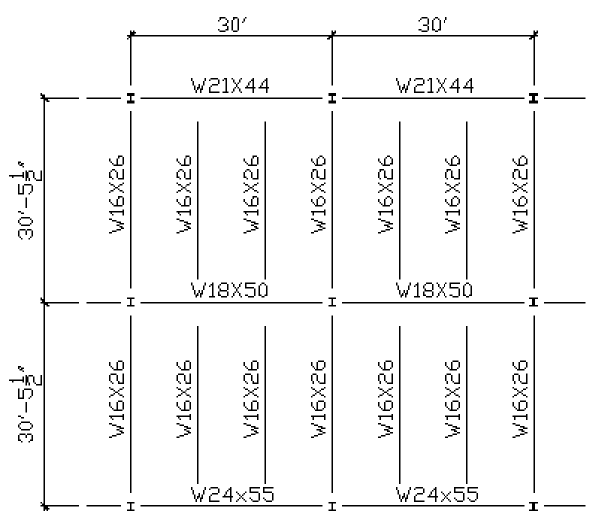
FLOOR SYSTEMS OVERVIEW

Introduction:

This report will analyze five separate floor systems for their effectiveness as viable floor options in National Harbor Building M. The original steel composite floor system will be rated against four proposed systems, two steel based and two concrete based, comparing them on a number of categories. Building M has a general bay layout of 2 bays by 9 bays with the 2 exterior bays having relatively short spans (11'-10") and the center bay having a relatively long span (40'-0"). The 6 remaining typical bays are relatively square spanning 30'-0" by 30'-5 ½". In this report a 2 bay by 2 bay interior section of the typical bays was designed for each system. After the design was completed an analysis and comparison was done on a 1 bay by 2 bay section of each design and the results extrapolated for the entire building.

Steel Composite Floor (Existing Design):

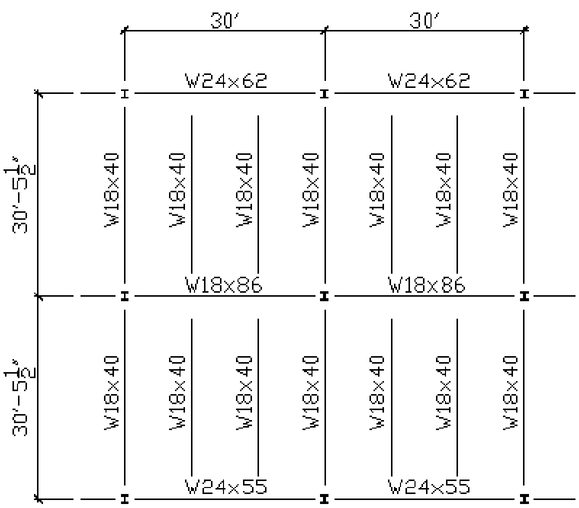
The existing composite floor system was analyzed as shown on the project drawings in RAM Structural System. The computer software was used in an attempt to match the designed sizes of the members in the actual building. All noted assumptions of the floor system as described in the structural overview were used and the majority of the members matched the engineer's design. The members that did not match closely were off because of minimum and maximum depth limitations dictated by the architecture of the building. When these size restrictions were implicated into the model the members in question more closely matched those of the design drawings. Further detailed information used in the analysis of this system (i.e. member cambers, shear stud counts, etc.) can be found the Appendix A.



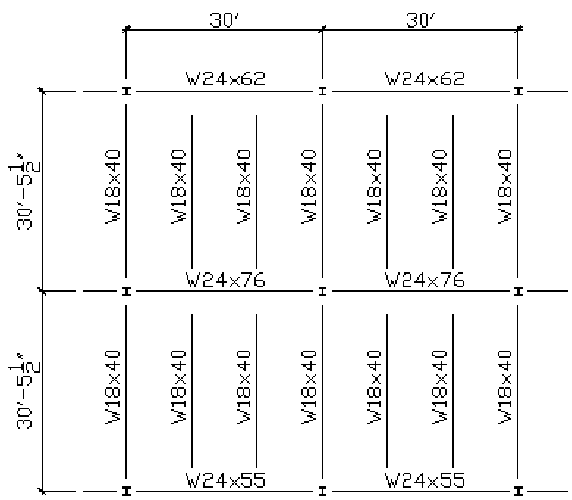
COMPOSITE WITH SIZE RESTRICTIONS (AS BUILT)

Steel Non-Composite Floor:

The Non-Composite Floor System was analyzed using RAM Structural System and incorporated many of the same parameters and assumptions as the building's original composite system. This was done in an attempt to isolate the changes caused only by the restrictions of composite action in the beams and girders. Some of the parameters which remained the same included the metal deck, the slab properties, and the dimensional layout of all members. Additionally, the model was run twice: once with size restrictions from maximum depth of the girders as dictated by the building's architecture, and once with no size restrictions. This restriction's affect can be seen in the main girder which was set to a maximum depth of 19 inches and changes the design from a W24x76 to a W18x86. For sake of accuracy of comparison in this report the output from the size restricted model will be used seeing that the composite design used was under similar restrictions. Further detailed information used in the analysis of this system (i.e. member cambers, deflections, etc.) can be found the Appendix B.



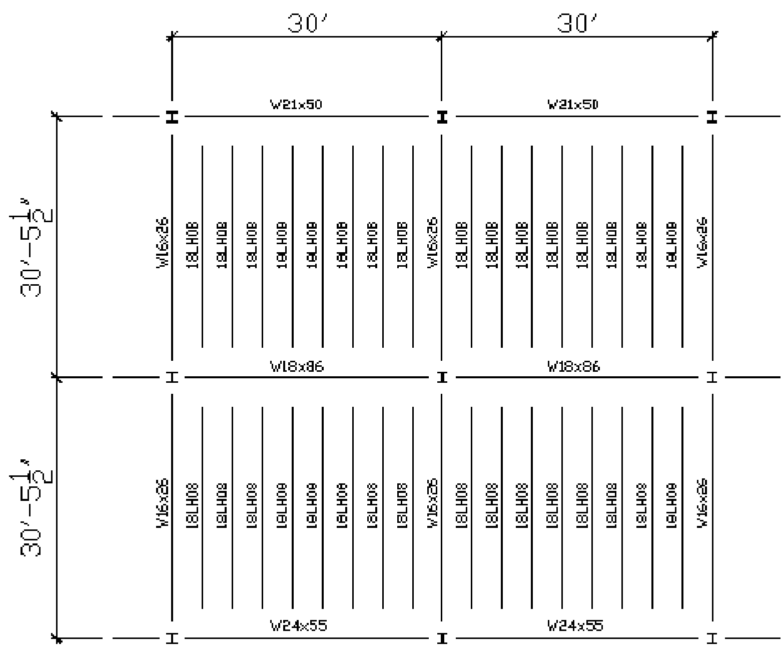
NON-COMPOSITE WITH SIZE RESTRICTIONS



NON-COMPOSITE WITH NO SIZE RESTRICTIONS

Longspan Steel Joist:

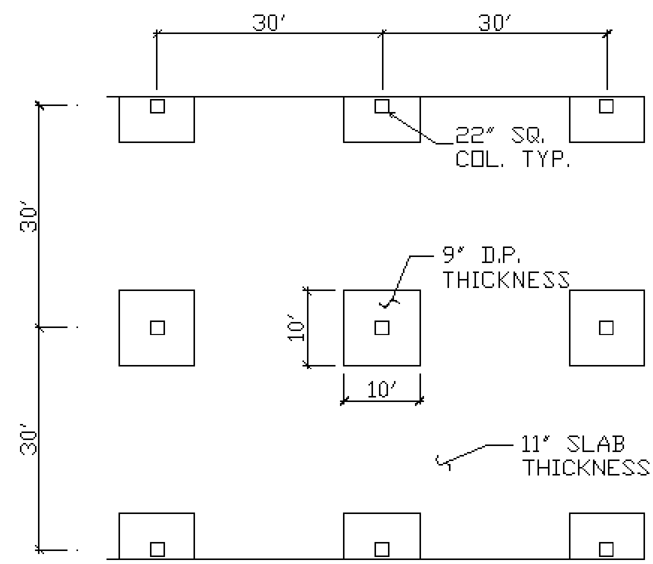
The Longspan Steel Joist System is comprised of non-composite steel beams running along the column lines and LH series long span joists spanning the 30'-5 ½" direction between them. They are set up on the same grid layout and support the same slab and deck combination as the Composite and Non-Composite Floor Systems. Additionally, the size restrictions previously discussed were placed on this system to make a direct comparison of member sizes more applicable. The spacing of the joist system was calculated using SJI standard specifications catalog and was dictated by its loading, span distance, live load deflection criteria and the aforementioned size restrictions. Once a minimum spacing was obtained RAM Structural System was used and a typical 18LH06 joist was selected for the transverse direction. Further detailed information used in the analysis of this system can be found the Appendix C.



LONGSPAN STEEL JOIST
WITH SIZE RESTRICTIONS

Flat Plate Concrete Slab with Drop Panels:

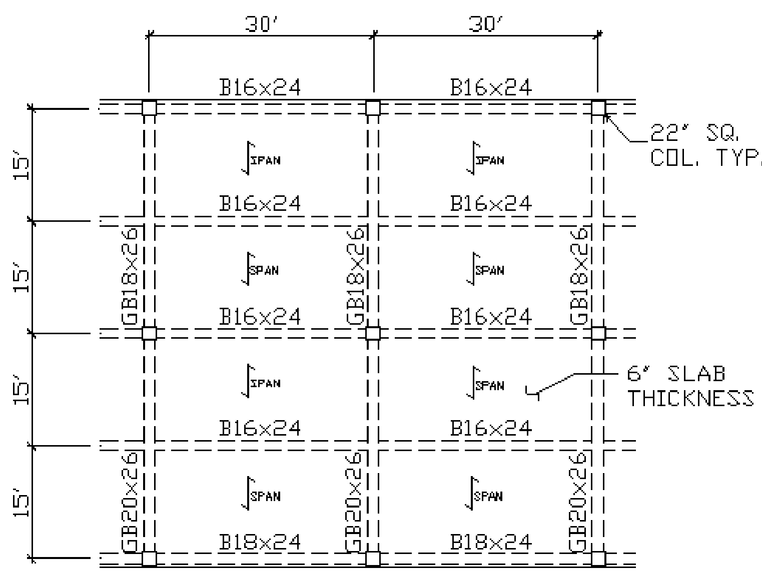
The Flat Plate Concrete Slab with Drop Panel System is also laid out on a 30'x30' grid supported by 22 inch square columns which were assumed based on general column loads generated in Technical Report 1. The CRSI Handbook was used to get a general starting point for the slab thickness, drop panel thickness, and drop panel dimensions dictated by the spans and loads of the system. However, since the bay layout of National Harbor Building M does not comply with the handbook's assumption that the system contains at least 3 bays in each direction the actual reinforcing steel was not taken from the handbook's charts. The general numbers from CRSI were used to amass a slab model in PCA slab. In an attempt to decrease the weight of the 11" thick slab required a lightweight concrete to be used in the design. The PCA model was run and used to generate reinforcing bar sizes and layouts. Further detailed information on slab properties and reinforcing schedules for this system can be found in Appendix E.



FLAT PLATE WITH
DROP PANELS

One-Way Concrete Beams and Slab:

The Concrete Beams and Slab System is laid out on a 30’x30’ grid and is supported by 22 inch square columns which were sized from general column loads generated in Technical Report 1. The beams, which run in both directions, and their reinforcement were designed using CRSI handbook tables. The CRSI Handbook was then used to design the 6” thick one way slab which spans in the transverse direction 15’-0”. The system is comprised of 18x26 interior and 20x26 exterior girder beams running transversely through the bays on the column lines and 16x24 beams running longitudinally through the bays on the column lines and at the midpoint of the spans. The beam running along the front face of the building was increased in size to an 18x24 in order to support an additional wall load of 650 plf. While an attempt to follow size restrictions used in the original design of the floor system was made some spans dictated these restriction be broken. Further detailed information on the system and its specific reinforcing can be found in appendix D.



1-WAY CONCRETE BEAM
AND SLAB

FLOOR SYSTEMS COMPARISON

Introduction:

Having described the five floor systems in the overview section, an analysis of each must now be performed. Included in this detailed analysis will be comparisons and contrasts between each respective system in an attempt to determine which is ultimately the most appropriate system for this application. This analytical survey will be conducted by judging each system in all of the following categories: cost, slab thickness, total structural depth, system weight, lateral system effects, deflection, fire rating, vibration, column grid changes, aesthetics, and construction issues. Following the analysis a comparison chart will rate each floor system in all given categories and determine the results.

COST:

Cost is arguably the most critical variable to be considered when evaluating and comparing each respective floor system. All things being equal the cheapest floor system which can adequately carry loads and perform to the projects standards will be chosen. Understanding the importance of the analysis of each system's cost, effort must be put forth to carefully consider and evaluate all factors affecting the total prices. For this report the base price for a typical two bay transverse section was estimated using R.S. Means Cost Data Handbook. For both concrete systems price per cubic yard quantities were used which priced each system as a whole including all components. For the steel systems a component by component take off was preformed pricing every member of the systems separately and as accurately as possible. Listed below are the component take off lists used to enter the R.S. Means Handbook.

Floor System	**Components Used in R.S. Means**
Steel Composite Floor	W- Shapes + Studs + 3" 20 gauge Steel Deck + 6" Slab
Steel Non-Composite Floor	W- Shapes + 3" 20 gauge Steel Deck + 6" Slab
Longspan Steel Joist	LH Joists + W-Shape Girders + 3" 20 gauge Steel Deck + 6" Slab
Concrete Flat Plate with Drop Panels	Elevated Slabs- Flat slab with drops, 30' span
One-Way Concrete Beams and Slab	One Way Beam and Slab, 15' span

It should be noted that the pricing for shear studs was done using the assumption that each stud is equivalent to 10lbs. of structural steel with the price of steel coming from the W-shape prices. Also worth noting is that an estimate of the concrete slab price used in the steel systems is based off of a 6" slab number while the actual slab is 6-1/4" over the 3" steel deck. The take off lists were used to generate a two bay cost for each system based off of a 2008 bare costs combination of material, labor, and equipment. It is realized that because every bay in the floor layout is not typical and each system would handle atypical circumstances differently, an extrapolation for the building's entire floor system price would not be totally accurate. However, I believe that this pricing approach is more than adequate to achieve numbers capable of an accurate comparison between the respective floor system prices. The following table outlines the price break down for each floor system and the overall cost of each.

Cost Summary:

Floor System	W-Shapes/Joists	Studs	Decking	Slab	Overall
Steel Composite Floor	$14,483	$3,393	$4,313	$5,537	$27,726
Steel Non-Composite Floor	$20,920	--	$4,313	$5,537	$30,770
Longspan Steel Joist	W-Shapes - $12,125 LH - $9,469	--	$4,313	$5,537	$31,444
Concrete Flat Plate with Drop Panels	--	--	--	--	$29,718
One-Way Concrete Beams and Slab	--	--	--	--	$37,723

The results of the cost evaluation show that the Composite Floor is the cheapest steel system while the Flat Plate with Drop Panels is the cheapest concrete system. Since the order from cheapest to most expensive is consistent with the order from lightest to heaviest for each respective building material (see weight summary below) it is safe to say the system cost is fairly proportional to the amount of material required.

Slab Thickness:

The thickness of the slab is an important variable in that it has an effect on many other comparable issues. A thicker slab can drive up the weight, cost, and structural depth of a flooring system. Also, if the building's height is set at a predetermined maximum a thicker slab can noticeably decrease floor to floor height. Conversely a thicker slab can also prove to be a positive in the case of floor vibrations which can be very problematic in buildings with thin slabs.

The original design of the Composite Floor System called for a 3-1/4" LWC slab on top of 3" metal deck for a total of 6-1/4" slab depth. This slab was carried through to the Non-Composite and Longspan Steel Joist Systems for consistency in sizing members. While this carry over allowed for a more direct comparison between member sizes it limits comparability between these system's slab thickness. However, it is understood that if a proposed steel system is selected for redesign a check of slab thickness may result in the selection of a thinner slab for the respective system.

In the design of the concrete systems it was determined that staying with a similar bay size (30'x30') and designing a thicker slab was a more viable option than adding column rows thus decreasing bay size to approximately 20'x22'-4" and maintaining a thin slab. This decision was based on the open layout style of the office occupancy of the building. It was concluded that greater spans allowing for a greater flexibility of office space was of more importance than possibly decreasing the floor to floor height and driving up the previously mentioned factors.

Slab Thickness Summary:

Floor System	Slab Thickness
Steel Composite Floor	6-1/4”
Steel Non-Composite Floor	6-1/4”
Longspan Steel Joist	6-1/4”
Concrete Flat Plate with Drop Panels	11”
One-Way Concrete Beams and Slab	6”

Total Structural Depth:

Total structural depth is an important variable worth comparing in that it directly affects the amount of usable space in the building. This variable becomes particularly more important in buildings with height restrictions because every additional inch of space taken up by the structure is one less inch of space accessible by the occupant. In National Harbor Building M while height is not a specifically controlling factor, maintaining a reasonable structural depth should still be a main priority. The total structural depth of a flooring system is the combination of its slab or horizontally spanning element and the members which support it. In the original design of the building some size restrictions which controlled the overall structural depth were set. The design of the proposed systems attempted to maintain the depth limitations and thus may not being as telling of a variable as member weight in this case. It is also worth noting that a direct comparison between steel systems and concrete systems’ structural depth is not always applicable. The placement of mechanical and other equipment located in the ceilings of buildings may be forced to run below a concrete system effectively increasing its structural depth were as it can pass through the members of some steel systems.

Since the three steel system described above all contain a 6-1/4” slab their total structural depth will differ as a result of their framing members. The one way concrete beam and slab system’s total structural depth will be determined by the depth of beams only. This measurement does not include slab thickness because the top of the slab and the top of the beams are poured at the same elevation. In the Flat Panel System the total structural depth will be a combination of slab thickness and drop panel thickness because the drop panels extend below the slab around the columns.

Total Structural Depth Summary:

Floor System	Maximum Depth	Depth of Main Span Elements
Steel Composite Floor	30-1/4” (6-1/4” slab + W24)	22-1/4” (6-1/4” slab + W16)
Steel Non-Composite Floor	30-1/4” (6-1/4” slab + W24)	24-1/4” (6-1/4” slab + W18)
Longspan Steel Joist	30-1/4” (6-1/4” slab + W24)	24-1/4” (6-1/4” slab + LH18)
Concrete Flat Plate with Drop Panels	20” (11” slab + 9” D.P.)	11” (slab)
One-Way Concrete Beams and Slab	26” (Girder Beams)	24” (Interior Beams)

SYSTEM WEIGHT:

The weight of a floor system can effect an overall building directly when considering seismic forces and foundation loads and indirectly through cost analysis. In the case of National Harbor Building M the two direct effects will have significant impacts on the design process. The lateral system of Building M is already controlled by seismic forces in the longitudinal direction. Because of this any increase in seismic weight, or dead load of the building, will drive up the controlling force in that direction. Additionally, the building's foundation system is comprised of driven prestressed precast concrete piles which carry up to 110 tons in axial force each. A calculated number of piles are driven at the base of each column to support the respective load of the column. A significant increase in building dead load could lead to greater loads at the column footings thus requiring more piles per footing. Both of these conditions play into the indirect effect floor system weight has on cost. While cost will be more thoroughly examined in another section it is apparent that it will increase. This is partly a result of weight per square foot of building but additionally because of enhancement to other building systems as a result of an increased load.

The weights of each respective floor system were calculated for a typical 2 bay transverse cut of building section which totals 1828 SF for the steel systems and 1800SF for the concrete systems. This section of Building M makes up about 1/8 of each floors total area. Considering there are four levels being framed by this system, discounting the ground level which is slab on grade and the roof framing, this section is representative of approximately 1/32 of the total floor framing area. For comparison purposes each system was also evaluated as a percentage of the building's originally designed weight. It is understood this approximation does not take into account special conditions like the longer spanning central bay or the cantilevered corner conditions which may affect member sizes and slab depths of each respective system differently.

The three steel floor systems were calculated to be within 6% of each others respective weights. The composite system as would be predicted averaged out to be lighter than the non-composite system and the open-web steel joist system. The joist system while comprised of much lighter members requires a significantly tighter spacing for load carrying capacities than the beams supporting the wide flange systems thus increasing its weight.

The two concrete systems predictably have a much higher unit weight than the steel systems mainly because of the amount of material required. The weight of the Flat Plate Drop Panel System was driven up as a result of the decision to maintain the 30' spans of the original building at the cost of increasing slab thickness to 11". An attempt to minimize this weight increase was made by choosing a lightweight concrete mixture, however this system still ended up being the heaviest floor system. Had the decision to compromise the openness of the office space layout been made the design would have included more columns framing smaller spans. This would have allowed for a much thinner slab and thus much less weight in the system. Similarly, the one-way concrete beam system would have seen a reduction in beam size and a slight reduction in slab thickness with a shorter span column layout.

Weight Summary:

Floor System	System Unit Weight (psf)	Percentage increase of base weight
Steel Composite Floor	51.9	base
Steel Non-Composite Floor	54.7	+5.3%
Longspan Steel Joist	56.1	+8.1%
Concrete Flat Plate with Drop Panels	115	+118%
One-Way Concrete Beams and Slab	127	+141%

LATERAL SYSTEM EFFECTS:

The lateral system of a building can be dictated based upon which resisting techniques work well with that building's floor system material. A building with a mainly steel constructed floor and framing system is likely to have moment and braced frames while a concrete constructed floor system would typically have shear walls as its lateral resisting element. National Harbor Building M as designed originally implements the use of both moment and braced frames which take the load transversely and masonry shear walls which take loads longitudinally.

The three steel systems would lend themselves well to maintaining the current lateral system design. Conversely some redesign of the lateral system would be required for the two concrete floor systems. The masonry wall which separates the office building from the parking garage and contains the four 30' shear walls would probably be redesigned as a concrete wall. These walls capacity would need to be checked for their ability to resist an increase in seismic lateral loads which already control in their direction. The increase in seismic forces could come as a result of increasing seismic weight of the building with the switch from steel to concrete. Additionally, shear walls running in the transverse direction would need to be looked into as a replacement for the steel moment and braced frames which previously resisted lateral forces in that direction.

DEFLECTION:

Code dictates that all members should deflect no more L/360 under live loads and L/240 under total loads. While all members and systems proposed in this report meet those criteria it is safe to say that the less deflection a system allows the better. With that being said a comparison between the deflections of each respective system would prove an important variable in their analysis.

Deflection Summary:

Floor System	Max Deflection (Live Load)	Max Deflection (Total Load)
Steel Composite Floor	0.872”	1.405”
Steel Non-Composite Floor	1.009”	1.306”
Longspan Steel Joist	0.856”	1.485”
Concrete Flat Plate with Drop Panels	0.098”	0.200”
One-Way Concrete Beams and Slab	0.245”	0.509”

The two concrete systems clearly evaluated much better than the steel systems in this category. As for the steel systems the Longspan Steel Joist System resulted in the poorest total deflections numbers. It is reasonable to assume this is a result of the lack of initial camber imposed on the joist members as opposed to the Composite and Non-Composite Systems’ members that see approximately ½” – 1” of camber prior to loading.

FIRE RATING:

Fire rating is an important variable in the comparison process in that it could represent a hidden or unforeseen cost of a floor system. National Harbor Building M requires all floor construction including beams and joists receive a two hour fire protection rating. The Non-Composite Steel System and the base Composite System will achieve this rating through spray-on fire proofing to a code dictated thickness. While this may be a slight hindrance to the construction process it is a fairly typical procedure and its economical implications are not extremely significant. Both the One-Way Concrete Beam and Slab and the Flat Plate Drop Panel System will require no additional fire proofing if a minimum slab thickness is provided and all reinforcing cover guidelines are followed. This is a plus for each system in that no additional costs will occupancy the base price for the system. The Longspan Joist System however will present problems to achieve the desired rating. The configuration of the open-web joist members makes it extremely difficult to apply a spray on fire proofing. To combat this problem either the entire system would have to be closed off by a fire proof barrier or the individual webs would need to be enclosed and then coated with the spray fire proofing. Any way the fire proofing is applied to these members will require additional labor and materials producing a large hidden cost to the system. Fire proofing defiantly proves to be a huge negative factor when evaluating the effectiveness of the Lognspan Steel Joist System.

VIBRATION:

The office occupancy of National Harbor Building M dictates that vibration probably won’t be as key of a factor as it would be if the building had a mixed use occupancy. Regardless of the amount of impact it will have on the final floor system decision, vibration and each system’s ability to control it is still an important topic to evaluate. The relative vibrations transmitted through a system are approximately proportional to that system’s relative stiffness and depth. Based on those criteria it is apparent the two concrete systems with their thick slabs and stiff frames will control vibrations relatively well as compared to the steel systems. The size restrictions limiting the depth of the members of the Composite and Non-Composite steel

Systems could possibly make them susceptible to vibration issues. Further research on their ability to resist vibrations would need to be done if one of these systems were chosen for implementation.

COLUMN GRID/BUILDING CHANGES:

While designing proposed flooring systems for National Harbor Building M an attempt was made to maintain the building's original layout. Two main areas emphasized in this decision were in the column grid layout and the size restrictions of main framing members. Since some systems characteristics did not lend themselves to the original design parameters as well as others there were some instances where minor adjustments had to be made.

The decision to remain with the open floor layout of the column grid, only one line of interior columns running transversely, was made based on the function of the building's occupancy. Since the building was designed for future office tenants it was felt that an open layout increased space flexibility making it more appealing to prospective tenants. Additionally, the architecture of the space dictated that certain overall limits on structural depth be maintained along the column lines running longitudinally throughout the building.

Since the design of the original system was done in steel it was no surprise that the additional proposed steel systems had little trouble conforming to these restrictions. While some additional weight was added as a result of controlling the depth of the steel members it seemed a reasonable trade off to maintain the original integrity of the design. The concrete systems which typically would perform better in a shorter span application saw more significant increases in their system weight as a result of the restrictions. A minor adjustment in the column grid was made changing the bay size from 30'-5 ½"x30' to 30'x30' to slightly simplify the design application. It was decided this adjustment could be made without affecting the integrity of the architecture laid out in the original design.

ASETHETICS:

A floor system's construction can affect a building's overall aesthetical qualities through its structural depth and overall appearance depending on the ceiling type. Since higher ceilings are desirable when possible a smaller overall structural depth would provide more possibilities for aesthetic freedom. In the situation where the structure is exposed above the system's physical aesthetics this must be taken into consideration.

National Harbor Building M's primary space is for office occupancy with roughly 3/4 of ceiling being designed as a drop tile ceiling and the other 1/4 as exposed structure in the original design. This layout would lend itself well to the proposed Non-Composite System seeing that it contains basically the same structural member types as the current design. The look of the two concrete systems may not coincide with architect's design of the area, in which case it may be necessary to extend the drop ceiling over the entire area. Additionally the layout of mechanical and other equipment contained in the ceiling cavity may need to be reworked in the concrete systems to maintain the current floor to ceiling height of the office space.

CONSTRUCTION ISSUES:

The ease and speed at which a floor system can be constructed is a huge factor to consider when selecting a system. The Composite and Non-Composite Systems are fairly straight forward systems which go up relatively easy and fast. This process will require some staging area but the speed at which it can be up will prevent large amounts of steel and other materials from accumulating on site. Both concrete systems will require formwork construction, pouring of the concrete, and some curing time before another level can be built. While neither are extremely tough systems to construct for qualified contractors the process will probably take longer then the steel systems. The Longspan Steel Joist System may pose time and construction issue when it comes to the application of its fire protection, which is discussed in more detail in the fire rating section of the report.

OVERALL COMPARSION BREAKDOWN

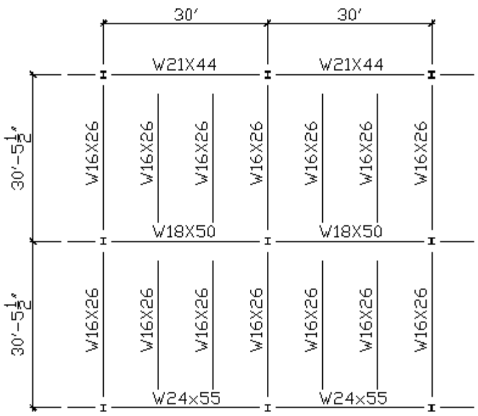
Item	Steel Composite	Steel Non-Composite	Longspan Steel Joist	Concrete Flat Plate with Drop Panels	One-Way Concrete Beams and Slab
Cost (per 2 bays)	$27,726	$30,770	$31,444	$29,718	$37,723
Slab Width	6-1/4”	6-1/4”	6-1/4”	11”	6”
Total Structural Depth	30-1/4”	30-1/4”	30-1/4”	20”	26”
Weight	Base Weight	+5.3%	+6.4%	+118%	+141%
Lateral System Effects	None	None	None	Concrete Shear Walls each way	Concrete Shear Walls each way
Deflection	LL – 0.872” TL – 1.405”	LL – 1.009” TL – 1.306”	LL – 0.856” TL – 1.485”	LL – 0.098” TL – 0.200”	LL - 0.245” TL - 0.509”
Fire Rating	Spray-On	Spray-On	Expensive Special Detailing	No Additional	No Additional
Vibration	Average	Average	Good	Excellent	Excellent
Column Grid Changes	None	None	None	Change to 30’x30’ bays	Change to 30’x30’ bays
Aesthetics	Deep System	Deep System	Issues in exposed area	Shallow System	Mech. Eq. Penetration issues
Construction Issues	Simple Construction	Simple Construction	Difficult Fire Proofing	Time/ Labor Issues	Time/Labor Issues
Viable Floor System?	**Yes**	**No**	**No**	**Yes**	**Yes**

CONCLUSIONS

It is not hard to argue with the original decision to select the composite system as the flooring solution of choice for this project. The results of this analysis show no reason to choose either of the other steel systems as a replacement for the composite system. While all three systems rate fairly similar in most performance evaluations, with the exception of the Longspan Steel Joist fire-proofing issues, neither of the newly proposed systems outperform the composite system in any category. Additionally, the composite system is lighter and therefore a decent percentage cheaper then the Non-Composite or Joist Systems. With all things being equal or slightly leaning towards the composite system already, the roughly 10-12% price break the composite floor presents clearly makes it the most logical steel choice.

A comparison between the Flat Plate Drop Panel and the One-Way Beam and Slab Concrete Systems seems to favor the Flat Plate Drop Panel System. While both systems seem capable of performing adequately the Flat Plate system is considerably lighter and less expensive. The depth of the structures is a tricky criterion by which to judge and compare these two systems. While the Flat Plate System has a very thick slab there are no beams protruding down throughout the entire span as in the One-way Beam and Slab System. Considering all variables I feel the Flat Plate System would be a more viable concrete floor system for National Harbor Building M. Now that the most appropriate steel and concrete systems have been decided, a comparison between the two can be conducted to determine which is the overall best fit for this project. Since the price of both systems is on roughly the same magnitude a comparison of their performance and physical characterizes can be considered. The main drawback of the Flat Plate System is definitely its weight and thus its effect on the lateral system. A possible way to combat these issues would be to tighten the column grid and thus the spans allowing the system to be designed with a smaller slab thickness. The smaller slab thickness would open up more overhead space and help decrease some of the building weight which is increasing the longitudinally controlling seismic forces. Also a determination on how to work in a transverse lateral reinforcement system with the absence of the steel moment and braced frames must be addressed. Shear walls may be hard to implicate in the transverse direction with the occupancy of the building favoring open, flexible spaces. In comparison to the Steel Composite System which has few if any glaring weaknesses the Flat Plate System may not seem a viable replacement. However, if some of its issues are able to be reasonably and economically addressed it definitely does look like a viable flooring system for the project.

APPENDIX A
(Composite System)



COMPOSITE WITH SIZE
RESTRICTIONS (AS BUILT)

Member	Studs	Camber
W16x26	22	1”
W21x44	19	--
W18x50	48	1”
W24x55	18	--

<u>System Weight (per two bay section)</u>

Steel:	-(8) W16x26 @ 30’-5 ½”	= 6,335 lbs
	-(1) W21x44 @ 30’-0”	= 1,320 lbs
	-(1) W18x50 @ 30’0”	= 1,500 lbs
	-(1) W24x55 @ 30’-0”	= 1,650 lbs
		= 10,805 lbs
Slab:	(30’ x 60’-11”)x(46psf)	= 84,065 lbs

TOTAL = 94,870 lbs

Beam Deflection Summary

RAM Steel v11.0
DataBase: typbays
Building Code: IBC

10/19/07 20:15:54
Steel Code: AISC LRFD

STEEL BEAM DEFLECTION SUMMARY:

Floor Type: typ

Composite / Unshored

Bm #	Beam Size	Initial in	PostLive in	PostTotal in	NetTotal in	Camber in
1	W18X35	1.223	0.499	0.824	1.297	3/4
7	W12X19	1.946	0.872	0.959	1.405	1-1/2
19	W16X26	1.467	0.662	0.740	1.207	1
18	W16X26	1.467	0.662	0.740	1.207	1
2	W18X35	1.223	0.499	0.824	1.297	3/4
9	W16X26	1.467	0.662	0.740	1.207	1
13	W16X26	1.467	0.662	0.740	1.207	1
15	W16X26	1.467	0.662	0.740	1.207	1
11	W12X19	1.946	0.872	0.959	1.405	1-1/2
3	W18X55	1.331	0.585	0.671	1.003	1
8	W12X19	1.946	0.872	0.959	1.405	1-1/2
20	W16X26	1.467	0.662	0.740	1.207	1
17	W16X26	1.467	0.662	0.740	1.207	1
4	W18X55	1.331	0.585	0.671	1.003	1
23	W16X26	1.467	0.662	0.740	1.207	1
16	W16X26	1.467	0.662	0.740	1.207	1
14	W16X26	1.467	0.662	0.740	1.207	1
12	W12X19	1.946	0.872	0.959	1.405	1-1/2
5	W18X35	1.223	0.612	0.760	1.233	3/4
6	W18X35	1.223	0.612	0.760	1.233	3/4

APPENDIX B
(Non-Composite System)

System Weight (per two bay section)

Steel:	-(8) W18x40 @ 30'-5 ½"	= 9,747 lbs
	-(1) W24x62 @ 30'-0"	= 1,860 lbs
	-(1) W18x86 @ 30'0"	= 2,580 lbs
	-(1) W24x55 @ 30'-0"	= 1,650 lbs
		= 15,837 lbs
Slab:	(30' x 60'-11")x(46psf)	= 84,065 lbs

TOTAL = 99,902 lbs

*** Note: The differing beam shapes and their corresponding deflections should be ignored in the following deflection chart. They are the exterior beams / girders on the two bay model and do not see the load they would have the entire floor been modeled.

Beam Deflection Summary

RAM Steel v11.0
DataBase: typbays NC-SR
Building Code: IBC

10/20/07 23:55:48
Steel Code: AISC LRFD

STEEL BEAM DEFLECTION SUMMARY:

Floor Type: typ

Noncomposite

Bm #	Beam Size	Dead in	Live in	NetTotal in	Camber in
1	W24X62	0.739	0.490	0.729	1/2
7	W16X31	0.797	1.009	1.306	1/2
19	W18X40	0.846	0.936	1.282	1/2
18	W18X40	0.846	0.936	1.282	1/2
2	W24X62	0.739	0.490	0.729	1/2
9	W18X40	0.846	0.936	1.282	1/2
13	W18X40	0.846	0.936	1.282	1/2
15	W18X40	0.846	0.936	1.282	1/2
11	W16X31	0.797	1.009	1.306	1/2
3	W18X86	0.917	0.773	1.189	1/2
8	W16X31	0.797	1.009	1.306	1/2
20	W18X40	0.846	0.936	1.282	1/2
17	W18X40	0.846	0.936	1.282	1/2
4	W18X86	0.917	0.773	1.189	1/2
23	W18X40	0.846	0.936	1.282	1/2
16	W18X40	0.846	0.936	1.282	1/2
14	W18X40	0.846	0.936	1.282	1/2
12	W16X31	0.797	1.009	1.306	1/2
5	W24X55	0.613	0.562	1.176	
6	W24X55	0.613	0.562	1.176	

APPENDIX C
(Longspan Steel Joist System)

System Weight (per two bay section)

Steel:	-(16) 18LH08 (19plf) @ 30'-5 ½"	= 9,259 lbs
	-(4) W16x26 @ 30'-5 ½"	= 3,168 lbs
	-(1) W24x65 @ 30'-0"	= 1,950 lbs
	-(1) W18x86 @ 30'0"	= 2,580 lbs
	-(1) W21x50 @ 30'-0"	= 1,500 lbs
		= 18,457 lbs
Slab:	(30' x 60'-11")x(46psf)	= 84,065 lbs

TOTAL = 102,522 lbs

Maximum Spacing Calculation

- d < 19" max
- 18LH08 (19 plf) @ 31' => 680/351
- Loads: SIDL = 25 psf, DL = 46 psf (slab SW), LL = 100psf, S = spacing
- Total Deflection: 680 = 71S + 19 + 100S, S = 3.87' max
- Live Load Deflection: 351 = 100S, S = 3.51' max <= controls
- 30'/ 9 spaces = 3.33' < 3.51', use 8 joists @ 3.33' o.c.

*** Note: The differing beam shapes and their corresponding deflections should be ignored in the following deflection chart. They are the exterior beams / girders on the two bay model and do not see the load they would have the entire floor been modeled.

STANDARD LOAD TABLE
LONGSPAN STEEL JOISTS, LH-SERIES

Based on a Maximum Allowable Tensile Stress of 30 ksi
Adopted by the Steel Joist Institute May 25, 1983;
Revised to May 1, 2000 – Effective August 1, 2002

The black figures in the following table give the TOTAL safe uniformly distributed load-carrying capacities, in pounds per linear foot, of **LH-Series** Steel Joists. The weight of DEAD loads, including the joists, must in all cases be deducted to determine the LIVE load-carrying capacities of the joists. The approximate DEAD load of the joists may be determined from the weights per linear foot shown in the tables.

The RED figures in this load table are the LIVE loads per linear foot of joist which will produce an approximate deflection of 1/360 of the span. LIVE loads which will produce a deflection of 1/240 of the span may be obtained by multiplying the RED figures by 1.5. In no case shall the TOTAL load capacity of the joists be exceeded.

This load table applies to joists with either parallel chords or standard pitched top chords. When top chords are pitched, the carrying capacities are determined by the nominal depth of the joists at the center of the span. Standard top chord pitch is 1/8 inch per foot. If pitch exceeds this standard, the load table does not apply. Sloped parallel-chord joists shall use span as defined by the length along the slope.

<u>**Where the joist span is in the RED SHADED**</u> area of the load table, the row of bridging nearest the midspan shall be diagonal bridging with bolted connections at chords and intersection. <u>Hoisting cables shall not be released until this row of bolted diagonal bridging is completely installed</u>.

<u>**Where the joist span is in the BLUE SHADED**</u> area of the load table, all rows of bridging shall be diagonal bridging with bolted connections at chords and intersection. <u>Hoisting cables shall not be released until the two rows of bridging nearest the third points are completely installed</u>.

The approximate moment of inertia of the joist, in inches^4 is;

$I_j = 26.767(W_{LL})(L^3)(10^{-6})$, where W_{LL} = RED figure in the Load Table, and L = (clear span + .67) in feet.

When holes are required in top or bottom chords, the carrying capacities must be reduced in proportion to the reduction of chord areas.

The top chords are considered as being stayed laterally by floor slab or roof deck.

The approximate joist weights per linear foot shown in these tables do not include accessories.

Joist Designation	Approx. Wt in Lbs. Per Linear Ft (Joists only)	Depth in inches	SAFE LOAD* in Lbs. Between	CLEAR SPAN IN FEET															
			21-24	25	26	27	28	29	30	31	32	33	34	35	36				
18LH02	10	18	12000	468	442	418	391	367	345	324	306	289	273	259	245				
				313	284	259	234	212	193	175	160	147	135	124	114				
18LH03	11	18	13300	521	493	467	438	409	382	359	337	317	299	283	267				
				348	317	289	262	236	213	194	177	161	148	136	124				
18LH04	12	18	15500	604	571	535	500	469	440	413	388	365	344	325	308				
				403	367	329	296	266	242	219	200	182	167	153	141				
18LH05	15	18	17500	684	648	614	581	543	508	476	448	421	397	375	355				
				454	414	378	345	311	282	256	233	212	195	179	164				
18LH06	15	18	20700	809	749	696	648	605	566	531	499	470	443	418	396				
				526	469	419	377	340	307	280	254	232	212	195	180				
18LH07	17	18	21500	840	809	780	726	678	635	595	559	526	496	469	444				
				553	513	476	428	386	349	317	288	264	241	222	204				
18LH08	19	18	22400	876	843	812	784	758	717	680	641	604	571	540	512				
				577	534	496	462	427	387	351	320	292	267	246	226				
18LH09	21	18	24000	936	901	868	838	810	783	759	713	671	633	598	566				
				616	571	527	491	458	418	380	346	316	289	266	245				
			22-24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
20LH02	10	20	11300	442	437	431	410	388	365	344	325	307	291	275	262	249	237	225	215
				306	303	298	274	250	228	208	190	174	160	147	136	126	117	108	101
20LH03	11	20	12000	469	463	458	452	434	414	395	372	352	333	316	299	283	269	255	243
				337	333	317	302	280	258	238	218	200	184	169	156	143	133	123	114
20LH04	12	20	14700	574	566	558	528	496	467	440	416	393	372	353	335	318	303	289	275
				428	406	386	352	320	291	265	243	223	205	189	174	161	149	139	129
20LH05	14	20	15800	616	609	602	595	571	544	513	484	458	434	411	390	371	353	336	321
				459	437	416	395	366	337	308	281	258	238	219	202	187	173	161	150
20LH06	15	20	21100	822	791	763	723	679	635	596	560	527	497	469	444	421	399	379	361
				606	561	521	477	427	386	351	320	292	267	246	226	209	192	178	165
20LH07	17	20	22500	878	845	814	786	760	711	667	627	590	556	526	497	471	447	425	404
				647	599	556	518	484	438	398	362	331	303	278	256	236	218	202	187
20LH08	19	20	23200	908	873	842	813	785	760	722	687	654	621	588	558	530	503	479	457
				669	619	575	536	500	468	428	395	365	336	309	285	262	242	225	209
20LH09	21	20	25400	990	953	918	886	856	828	802	778	755	712	673	636	603	572	544	517
				729	675	626	581	542	507	475	437	399	366	336	309	285	264	244	227
20LH10	23	20	27400	1068	1028	991	956	924	894	865	839	814	791	748	707	670	636	604	575
				786	724	673	626	585	545	510	479	448	411	377	346	320	296	274	254

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Beam Deflection Summary

RAM Steel v11.0
DataBase: typbays joist-3
Building Code: IBC

10/23/07 11:52:51
Steel Code: AISC LRFD

STEEL JOIST DEFLECTION SUMMARY:

Floor Type: typ

Standard Joists

Bm #	Beam Size	Dead in	Live in	Total in
30	18LH05	0.604	0.822	1.427
120	18LH08	0.629	0.856	1.485
121	18LH08	0.629	0.856	1.485
122	18LH08	0.629	0.856	1.485
123	18LH08	0.629	0.856	1.485
124	18LH08	0.629	0.856	1.485
125	18LH08	0.629	0.856	1.485
126	18LH08	0.629	0.856	1.485
127	18LH08	0.629	0.856	1.485
32	18LH08	0.629	0.856	1.485
104	18LH08	0.629	0.856	1.485
105	18LH08	0.629	0.856	1.485
106	18LH08	0.629	0.856	1.485
107	18LH08	0.629	0.856	1.485
108	18LH08	0.629	0.856	1.485
109	18LH08	0.629	0.856	1.485
110	18LH08	0.629	0.856	1.485
111	18LH08	0.629	0.856	1.485
34	24K7	0.515	0.701	1.217
31	18LH05	0.604	0.822	1.427
112	18LH08	0.629	0.856	1.485
113	18LH08	0.629	0.856	1.485
114	18LH08	0.629	0.856	1.485
115	18LH08	0.629	0.856	1.485
116	18LH08	0.629	0.856	1.485
117	18LH08	0.629	0.856	1.485
118	18LH08	0.629	0.856	1.485
119	18LH08	0.629	0.856	1.485
33	18LH08	0.629	0.856	1.485
96	18LH08	0.629	0.856	1.485
97	18LH08	0.629	0.856	1.485
98	18LH08	0.629	0.856	1.485
99	18LH08	0.629	0.856	1.485
100	18LH08	0.629	0.856	1.485
101	18LH08	0.629	0.856	1.485
102	18LH08	0.629	0.856	1.485
103	18LH08	0.629	0.856	1.485
35	24K7	0.515	0.701	1.217

APPENDIX D
(Flat Plate with Drop Panel System)

System Weight (per two bay section)

Slab:	(30’ x 60’-11”)x(11”/12)x(115pcf)	= 189,750 lbs
Drop Panels:	(10’x10’)x(2 eff. Panels)x(9”/12)x(115)	= 17,250 lbs

TOTAL = 207,000 lbs

Load Calculation used to enter CRSI

- SIDL = 25psf, LL = 100 psf => reduces to 75psf
- 1.4(25psf) + 1.7(75psf) = 162.5 psf
- Obtain basic parameters of 11” slab and 9” (10’x10’) Drop Panels to enter into PCA Slab

f'_c = 4,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM

SQUARE EDGE PANEL — With Drop Panels — No Beams

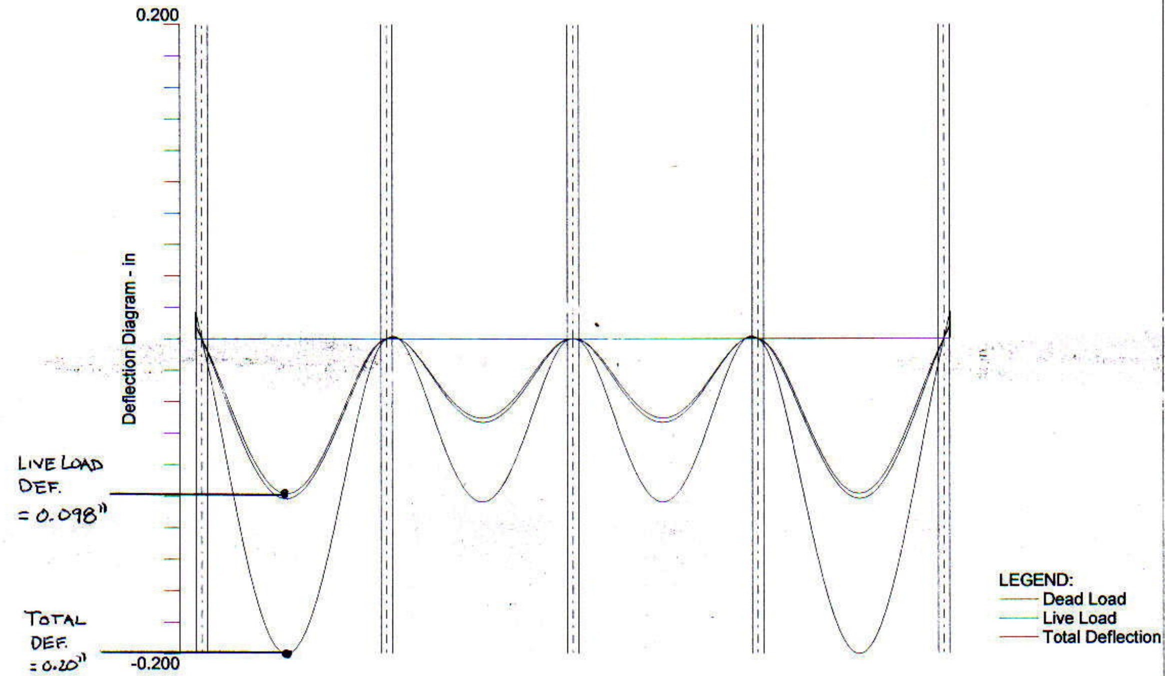
SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	(3) Square Column Size (in.)	γ_f	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	+	Column Strip Bottom	Column Strip Top Int.	Middle Strip Bottom	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (–) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (–) (ft-k)
h = 11 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS															
28	100	7.00	9.33	12	0.761	13-#5	2	19-#5	18-#5	13-#5	11-#5	2.77	196.6	393.2	529.4
28	200	7.00	9.33	16	0.777	13-#5	4	10-#8	23-#5	16-#5	10-#6	3.42	253.9	507.8	683.6
28	300	9.00	9.33	18	0.643	13-#5	1	16-#7	18-#6	14-#6	12-#6	4.07	313.6	627.2	844.3
28	400	11.00	9.33	20	0.634	14-#5	1	12-#9	27-#5	10-#8	14-#6	4.94	372.5	744.9	1002.8
28	500	11.00	11.20	22	0.696	16-#5	3	14-#9	13-#8	12-#8	10-#8	5.76	430.5	861.0	1159.1
29	100	7.00	9.67	12	0.797	13-#5	3	11-#7	14-#6	10-#6	12-#5	2.94	219.0	438.0	589.7
29	200	9.00	9.67	16	0.688	13-#5	3	15-#7	23-#5	10-#7	15-#5	3.64	283.9	567.9	764.5
29	300	9.00	9.67	18	0.776	14-#5	5	14-#8	15-#7	12-#7	10-#7	4.52	350.0	699.9	942.2
29	400	11.00	11.60	21	0.698	15-#5	4	17-#8	16-#7	11-#8	12-#7	5.28	416.4	832.8	1121.1
29	500	11.00	11.60	23	0.740	17-#5	4	16-#9	14-#8	13-#8	11-#8	6.17	479.4	958.9	1290.8
30	100	9.00	10.00	12	0.710	14-#5	1	17-#6	14-#6	11-#6	13-#5	3.03	244.0	488.0	656.9
30	200	9.00	10.00	16	0.751	14-#5	4	16-#7	18-#6	20-#5	12-#6	3.81	315.5	631.0	849.4
30	300	11.00	10.00	19	0.638	14-#5	3	13-#9	15-#7	10-#8	11-#7	4.79	388.7	777.3	1046.4
30	400	11.00	12.00	21	0.747	17-#5	4	19-#8	14-#8	10-#9	18-#6	5.72	463.2	926.5	1247.2
30	500	11.00	12.00	26	0.735	19-#5	5	18-#9	16-#8	14-#8	12-#8	6.64	528.7	1057.4	1423.4
31	100	9.00	10.33	12	0.767	14-#5	3	11-#8	16-#6	12-#6	14-#5	3.20	269.8	539.7	726.5
31	200	11.00	10.33	16	0.639	14-#5	2	14-#8	18-#6	12-#7	19-#5	4.08	350.2	700.4	942.8
31	300	11.00	10.33	19	0.693	16-#5	3	14-#9	17-#7	12-#8	13-#7	5.21	430.5	861.1	1159.2
31	400	11.00	12.40	24	0.739	18-#5	6	17-#9	15-#8	11-#9	12-#8	6.20	508.9	1017.8	1370.1
31	500	11.00	12.40	29	0.737	15-#6	4	20-#9	14-#9	13-#9	13-#8	7.23	577.8	1155.5	1555.5
32	100	9.00	10.67	12	0.811	15-#5	5	15-#7	17-#6	19-#5	11-#6	3.38	297.4	594.9	800.8
32	200	11.00	10.67	16	0.688	15-#5	3	20-#7	15-#7	13-#7	11-#7	4.34	386.4	772.9	1040.4
32	300	11.00	10.67	20	0.756	17-#5	6	16-#9	18-#7	16-#7	18-#6	5.51	474.0	948.0	1276.2
32	400	11.00	12.80	27	0.694	20-#5	4	23-#8	17-#8	12-#9	16-#7	6.57	557.5	1115.0	1500.9
33	100	11.00	11.00	12	0.753	15-#5	4	13-#8	17-#6	11-#7	13-#6	3.61	328.1	656.2	883.4
33	200	11.00	11.00	16	0.765	15-#5	5	17-#8	22-#6	11-#8	12-#7	4.68	425.1	850.1	1144.4
33	300	11.00	11.00	23	0.721	19-#5	5	17-#9	16-#8	11-#9	12-#8	6.04	517.4	1034.9	1393.1
33	400	11.00	13.20	30	0.689	22-#5	5	21-#9	18-#8	13-#9	11-#9	7.02	604.0	1207.9	1626.1

SQUARE INTERIOR PANEL

With Drop Panels(2) — No Beams

Factored Superimposed Load (psf)	(3) Square Column Size (in.)	Reinforcing Bars (E. W.) Column Strip Top	Column Strip Bottom	Middle Strip Top	Middle Strip Bottom	Total Steel (psf)	Concrete (cu. ft / sq. ft)
h = 11 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS							
100	12	17-#5	13-#5	11-#5	11-#5	2.53	0.981
200	19	15-#6	16-#5	13-#5	11-#5	2.98	0.981
300	22	23-#5	14-#6	15-#5	13-#5	3.51	1.000
400	24	13-#7	17-#6	10-#7	11-#6	4.23	1.019
500	27	15-#7	12-#8	11-#7	18-#5	4.91	1.063
100	12	13-#6	14-#5	12-#5	12-#5	2.64	0.981
200	19	15-#6	18-#5	10-#6	12-#5	3.08	1.000
300	22	26-#5	12-#7	12-#6	15-#5	3.91	1.000
400	25	15-#7	11-#8	11-#7	18-#5	4.58	1.063
500	27	13-#8	10-#9	10-#8	20-#5	5.28	1.063
100	12	18-#5	11-#6	12-#5	12-#5	2.63	1.000
200	19	17-#6	20-#5	11-#6	13-#5	3.30	1.000
300	22	26-#5	10-#8	10-#7	16-#5	4.04	1.019
400	25	22-#6	10-#9	12-#7	14-#6	4.93	1.063
500	27	15-#8	14-#8	11-#8	12-#7	5.75	1.063
100	12	20-#5	17-#5	13-#5	12-#5	2.69	1.000
200	19	17-#6	22-#5	12-#6	15-#5	3.46	1.019
300	22	15-#7	15-#7	15-#6	18-#5	4.39	1.019
400	25	14-#8	11-#9	18-#6	12-#7	5.35	1.063
500	29	16-#8	13-#9	12-#8	13-#7	6.19	1.063
100	12	16-#6	19-#5	15-#5	13-#5	2.93	1.000
200	19	26-#5	13-#7	19-#5	16-#5	3.70	1.019
300	22	17-#7	22-#6	13-#7	20-#5	4.70	1.019
400	25	16-#8	12-#9	12-#8	13-#7	5.81	1.063
100	12	16-#6	11-#7	16-#5	14-#5	3.07	1.019
200	19	15-#7	11-#8	11-#7	18-#5	4.06	1.019
300	22	15-#8	11-#9	11-#8	12-#7	5.30	1.019
400	28	17-#8	13-#9	16-#7	11-#8	6.08	1.063

NOTES: (1) 50 percent of these bars may be placed in the middle third of column strip. (2) Drop panels same size as for edge panels. (3) Same column size above and below slab.



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Project: National Harbor Building M

Frame: B

Engineer: Ryan Sarazen

APPENDIX E
(One-Way Concrete Beam and Slab System)

System Weight (per two bay section)

Slab:	(30’ x 60’)x(6”/12)x(150pcf)	= 135,000 lbs
Beams:	-(4)x(30’)x(16”x18”)x(1/144)x(150pcf)	= 36,000 lbs
	-(2)x(30’)x(20”x20”)x(1/144)x(150pcf)	= 25,000 lbs
	-(2)x(30’)x(18”x20”)x(1/144)x(150pcf)	= 22,500 lbs
	-(1)x(30’)x(18”x18”)x(1/144)x(150pcf)	= 10,125 lbs
		= 93,625 lbs

TOTAL = 228,625 lbs

Load Calculations used in CRSI tables

Interior Beams:

- DL = (6”/12)x(150pcf) = 75psf, SIDL = 25 psf, LL(reduced) = 96psf
- Estimate Beam Size = (18”x24.5”)x(150pcf)x(1/144) = 459plf
- Load factors: 1.4(100psf x 15’) + 1.7(96psf x 15’) + 1.4(459plf) = 5.19klf
- Sized a 16x24 interior span beam

Exterior Beams carrying wall load:

- Typical brick wall load = .650klf => 5.19klf + 1.4(.650klf) = 6.1klf
- Sized a 18x24 interior span beam for exterior wall

Girder:

- Clear span = 28.33’, depth limitation of 27”
- Concentrated load on Girder = 5.19klf x 30’ = 156K
- Girder Self Weight = (18”x24.5”)x(150pcf)x(1/144) = .459klf
- Concentrated Factored Moment = (156K x 28.33’)/8 = 552 ft-K
- Equivalent Uniform Girder Load = w = (11xM)/ln^2, w = (11 x 552) / (28.33^2) = 7.6klf
- Total Factored Uniform Load = 7.6klf + .459klf = 8.06klf
- Sized a 18x26 interior span girder and a 20x26 end span girder

*** Note: The procedure for finding equivalent loadings for the beams and girders was taken directly from the CRSI handbook. End span conditions are for beams or girders perpendicularly framing into the end of an exterior bay. Interior spans encompass other cases, thus the reason an interior chart was used to size the exterior beam running parallel to the edge of the building.

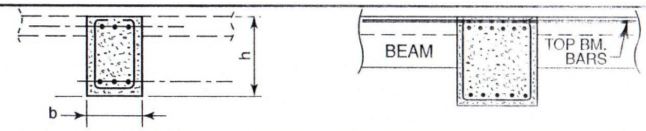
Beam Deflection Calculations taken from CRSI charts

- Total Factored load = 5.2klf (see above), Factored Live Load = 1.7(96psf) = 2.5klf
- Deflection coefficient (C) from CRSI beam chart = 249 x 10^-9
- Deflection equation from CRSI handbook = C x (w/1.6) x (ln)^4
- TLdef = (249 x 10^-9) x (5.2klf/1.6) x (28.167)^4 = 0.509"
- LLdef = (249 x 10^-9) x (2.5klf/1.6) x (28.167)^4 = 0.245"

*** Note: The deflection calculations were carried out for a typical interior 16x24 beam spanning 30'.

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, END SPANS



TOTAL CAPACITY $U = 1.4D + 1.7L$[3]

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BARS[1] BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 24 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 26 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) × 10^{-9} in.
		2# 9		1	3# 8	3.8	113I	9	-	348	3.2	123I	9	-	376	2.8	123I	8	-	399	2.4	123I	8	-	422	199	500
				1			184F	35	1.3	507		204F	34	1.2	553		214F	34	1.2	588		234F	33	1.2	633	234	
		2#11		1	3# 9	5.0	134I	9	-	543	4.3	133I	9	-	523	3.7	143I	8	-	561	3.2	143I	8	-	594	299	459
				1			185F	35	1.2	772		205F	34	1.2	843		214F	34	1.2	741		234F	33	1.2	797	290	
	14	2#11	1#11	1	3#11	7.4	135I	9	-	823	6.3	145I	9	-	885	5.5	154I	8	-	873	4.8	164I	8	-	930	428	360
				1			295C	35	1.2	1193		205F	34	1.2	1074		215F	34	1.2	1141		235F	33	1.2	1228	428	
		2#11	1#11	1	4#11	8.2	135I	9	-	913	7.0	145I	9	-	981	6.0	165I	8	-	1063	5.2	165I	8	-	1119	428	352
				2			295C	35	1.2	1283		315C	34	1.2	1376		215F	34	1.2	1244		235F	33	1.2	1336	504	
		2#10		1	3# 8	4.1	113I	11	-	395	3.5	113I	11	-	421	3.0	123I	10	-	452	2.6	123I	10	-	479	251	424
				1			165G	43	1.4	657		184G	42	1.4	587		214F	42	1.4	650		234F	42	1.4	700	236	
		2#11		1	3#10	5.8	134I	11	-	593	4.9	134I	11	-	629	4.2	143I	10	-	616	3.7	143I	10	-	652	302	406
				1			165G	43	1.4	793		185G	42	1.4	868		195G	42	1.4	924		205G	42	1.3	979	364	
	16	2#11	1#11	1	3#11	7.6	135I	11	-	827	6.5	145I	11	-	890	5.6	154I	10	-	876	4.8	164I	10	-	934	436	343
				1			245D	43	1.4	1116		265D	42	1.4	1204		195G	42	1.3	1117		205G	42	1.3	1186	436	
		6# 6	6# 6	2	3#14	9.0	145FdI	11	-	1007	7.7	145I	11	-	1068	6.6	165I	10	-	1156	5.8	165I	10	-	1217	471	301
26				1			245D	43	1.4	1282		265D	42	1.4	1382		285D	42	1.3	1481		305D	41	1.3	1581	590	
		2# 8	1# 8	1	3# 9	4.5	113I	13	-	410	3.9	113I	13	-	437	3.3	113I	13	-	464	2.9	123I	13	-	496	238	377
				1			165G	52	1.5	682		184G	51	1.5	609		194G	51	1.5	649		264E	50	1.5	763	296	
		2#10	1#10	1	3#10	6.4	134I	13	-	638	5.5	134I	13	-	678	4.7	143I	13	-	667	4.1	143I	13	-	707	368	363
				1			165G	52	1.5	846		185G	51	1.5	926		195G	51	1.5	986		205G	50	1.5	1046	368	
	18	2#11	1#11	1	3#14	8.4	135I	13	-	959	7.2	145I	13	-	1030	6.2	154I	13	-	1023	5.4	164I	13	-	1089	442	292
				1			245D	52	1.5	1260		265D	51	1.5	1358		285D	51	1.5	1455		305D	50	1.5	1553	602	
		2#11	2#11	1	3#14	10.5	155FeI	13	-	1101	8.9	165FdI	13	-	1182	7.7	165I	13	-	1249	6.7	165I	13	-	1315	568	268
				1			295C	52	1.5	1475		265D	51	1.5	1481		285D	51	1.5	1588		305D	50	1.5	1695	602	
		2# 9	1# 9	1	3# 9	5.2	113I	15	-	463	4.4	113I	15	-	495	3.8	123I	15	-	531	3.3	123I	15	-	562	298	345
				1			155H	61	1.7	724		165H	61	1.7	777		175H	60	1.7	829		185H	59	1.6	881	298	
		2#10	1#10	1	3#11	7.1	134I	15	-	694	6.0	134I	15	-	738	5.2	143I	15	-	729	4.5	143I	15	-	773	371	328
				1			215E	61	1.7	1015		225E	61	1.7	1079		175H	60	1.6	1018		185H	59	1.6	1082	447	
	20	2#11	2#11	1	3#14	10.6	145FdI	15	-	1092	9.1	155FcI	15	-	1173	7.8	155I	15	-	1240	6.8	165I	15	-	1321	576	259
				1			295C	61	1.7	1495		265D	61	1.7	1499		285D	60	1.6	1607		265E	59	1.6	1632	612	
		3#11	2#11	1	4#14	13.3	295C	15	-	1573	11.3	175EhI	15	-	1486	9.8	175FfI	15	-	1573	8.5	185FfI	15	-	1673	696	219
				1			485A	61	1.7	2156		315C	61	1.7	1888		345C	60	1.6	2037		365C	59	1.6	2164	776	

(1) See "Recommended Bar Details", Fig. 12-1. For girders, use tabulated beam depth — 2 inches (b — 2").
(2) In "Layers" column, first line is number of layers for bottom bars, second line is for number of layers for top bars.
(3) For superimposed factored load capacity, deduct 1.4 x stem weight.
(4) Total capacities tabulated causing deflection in excess of $\ell_n/360$ are designated thus: * — $\ell_n/360$ < deflection < $\ell_n/240$
X — $\ell_n/240$ < deflection < $\ell_n/180$
Y — deflection > $\ell_n/180$

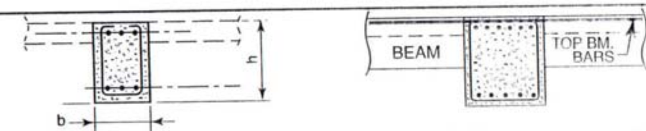
(5) For each beam design, first line is for open stirrups, secondline is for closed ties. See Fig. 12-4. At free ends, use stirrups tabulated for "Interior Spans". For b > 24 in., provide 4 legs (two stirrups) of size and spacing tabulated. For stirrup nomenclature, see page 12-13.

Other notation: N/A — STIRRUPS ARE NOT REQUIRED
** — MAXIMUM SPACING IS LESS THAN 3 INCHES. NOT RECOMMENDED
*** — SHEAR STRESS IS GREATER THAN $10\sqrt{f'_c}$
**** — TORSION STRESS EXCEEDS ALLOWABLE

(6) $+\phi M_n$ and $-\phi M_n$ are design moment strength capacities for rectangular section b × h.
(7) Midspan elastic deflection (in.) = C x (w/1.6) x ℓ_n^4, where w = tabulated load (k/ft.), ℓ_n in ft.
"Average service load" is taken as w/1.6.

$f'_c = 4{,}000$ psi
$f_y = 60{,}000$ psi

RECTANGULAR BEAMS, INTERIOR SPANS



TOTAL CAPACITY $U = 1.4D + 1.7L$[3]

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BARS[1] BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN ℓ_n = 24 ft LOAD (4) k/ft	24 ft STIR. TIES (5)	24 ft ϕT_n ft-kips	24 ft $A\ell$ sq. in.	24 ft STEEL WGT lb.	SPAN ℓ_n = 26 ft LOAD (4) k/ft	26 ft STIR. TIES (5)	26 ft ϕT_n ft-kips	26 ft $A\ell$ sq. in.	26 ft STEEL WGT lb.	SPAN ℓ_n = 28 ft LOAD (4) k/ft	28 ft STIR. TIES (5)	28 ft ϕT_n ft-kips	28 ft $A\ell$ sq. in.	28 ft STEEL WGT lb.	SPAN ℓ_n = 30 ft LOAD (4) k/ft	30 ft STIR. TIES (5)	30 ft ϕT_n ft-kips	30 ft $A\ell$ sq. in.	30 ft STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-n}$ in.
24	12	2# 8		1	2# 9	3.4	113H	6	-	286	2.9	113H	6	-	305	2.5	113H	6	-	325	2.2	123H	6	-	349	144	399
				1			214E	24	1.0	464		224E	24	1.0	494		244E	24	1.0	535		264E	23	1.0	576	179	
		2# 9		1	2#11	5.0	123H	6	-	387	4.3	133H	6	-	419	3.7	143H	6	-	451	3.2	143H	6	-	479	179	407
				1			214E	24	1.0	562		224E	24	1.0	600		244E	24	1.0	649		264E	23	1.0	698	266	
		2#11		1	2#14	6.9	134H	6	-	610	5.9	144H	6	-	660	5.1	154H	6	-	709	4.4	164H	6	-	758	266	332
				1			364B	24	1.0	890		394B	24	1.0	964		424B	24	1.0	1037		444B	23	1.0	1100	361	
		2#11		1	4#10	7.1	154EdH	6	-	656	6.1	144H	6	-	693	5.2	154H	6	-	745	4.6	164H	6	-	797	266	339
				2			364B	24	1.0	921		394B	24	1.0	997		424B	24	1.0	1073		444B	23	1.0	1138	373	
	14	2# 8		1	3# 8	4.0	113H	8	-	306	3.5	113H	8	-	328	3.0	123H	8	-	353	2.6	123H	8	-	375	145	354
				1			184F	31	1.2	460		204F	31	1.2	503		214F	31	1.1	536		234F	30	1.1	579	213	
		2#10		1	3#10	6.2	134H	8	-	525	5.3	134H	8	-	559	4.6	143H	8	-	548	4.0	143H	8	-	582	225	340
				1			185F	31	1.2	747		205F	31	1.1	818		215F	30	1.1	870		235F	30	1.1	941	325	
		2#11		1	3#11	7.4	134H	8	-	624	6.3	144H	8	-	674	5.4	154H	8	-	724	4.7	154H	8	-	767	271	306
				1			185F	31	1.1	846		205F	31	1.1	925		215F	30	1.1	985		235F	30	1.1	1064	386	
		2#10	1#10	1	3#14	9.0	145H	8	-	837	7.7	145H	8	-	892	6.6	155H	8	-	959	5.8	165H	8	-	1026	325	256
				1			295C	31	1.1	1184		315C	31	1.1	1275		345C	30	1.1	1383		235F	30	1.1	1238	513	
	16	2# 9		1	3# 9	5.1	113H	10	-	379	4.3	123H	10	-	411	3.7	123H	9	-	438	3.3	123H	9	-	465	182	320
				1			185F	39	1.3	671		204F	38	1.3	590		214F	38	1.3	628		234F	37	1.3	679	267	
		2#10		1	3#10	6.3	124H	10	-	519	5.4	133H	10	-	511	4.6	133H	9	-	545	4.0	143H	9	-	584	228	314
				1			185F	39	1.3	760		205F	38	1.3	832		215F	38	1.3	885		235F	37	1.3	957	330	
		2#10	1#10	1	4#11	9.2	135H	10	-	802	7.8	145H	10	-	867	6.7	155H	9	-	932	5.9	164H	9	-	919	330	249
				1			295C	39	1.3	1177		315C	38	1.3	1267		215F	38	1.3	1131		235F	37	1.2	1220	501	
		2#14		1	3#14	10.1	145EcH	10	-	932	8.6	145H	10	-	993	7.4	155H	9	-	1068	6.5	165H	9	-	1142	378	235
				1			295C	39	1.3	1294		315C	38	1.3	1393		345C	38	1.3	1510		365C	37	1.2	1609	529	
	18	2# 8	1# 8	1	3# 9	5.1	113H	12	-	392	4.4	113H	12	-	421	3.8	113H	11	-	449	3.3	123H	11	-	482	216	266
				1			165G	47	1.4	656		185G	46	1.4	723		194G	46	1.4	628		264E	45	1.4	740	269	
		2# 9	1# 9	1	3#11	7.5	124H	12	-	587	6.4	134H	12	-	635	5.5	144H	11	-	683	4.8	143H	11	-	667	269	271
				1			245D	47	1.4	953		185G	46	1.4	877		195G	46	1.4	936		205G	45	1.4	995	400	
		2#11	1#11	1	3#14	10.4	135H	12	-	902	8.8	145H	12	-	976	7.6	155H	11	-	1049	6.6	165H	11	-	1122	400	221
				1			245D	47	1.4	1196		265D	46	1.4	1295		285D	46	1.4	1393		305D	45	1.4	1492	542	
		2#11	1#11	1	4#14	11.1	155EdH	12	-	1052	9.5	145H	12	-	1108	8.2	155H	11	-	1192	7.1	165H	11	-	1275	400	199
				1			295C	47	1.4	1415		265D	46	1.4	1427		285D	46	1.4	1536		305D	45	1.4	1645	678	

(1) See "Recommended Bar Details", Fig. 12-1. For girders, use tabulated beam depth — 2 inches (b — 2").
(2) In "Layers" column, first line is number of layers for bottom bars, second line is for number of layers for top bars.
(3) For superimposed factored load capacity, deduct 1.4 x stem weight.
(4) Total capacities tabulated causing deflection in excess of $\ell_n/360$ are designated thus: * — $\ell_n/360$ < deflection < $\ell_n/240$
X — $\ell_n/240$ < deflection < $\ell_n/180$
Y — deflection > $\ell_n/180$

(5) For each beam design, first line is for open stirrups, secondline is for closed ties. See Fig. 12-4. At free ends, use stirrups tabulated for "Interior Spans". For b > 24 in., provide 4 legs (two stirrups) of size and spacing tabulated. For stirrup nomenclature, see page 12-13.

Other notation: N/A — STIRRUPS ARE NOT REQUIRED
** — MAXIMUM SPACING IS LESS THAN 3 INCHES. NOT RECOMMENDED
*** — SHEAR STRESS IS GREATER THAN $10\sqrt{f'_c}$
**** — TORSION STRESS EXCEEDS ALLOWABLE

(6) $+\phi M_n$ and $-\phi M_n$ are design moment strength capacities for rectangular section b × h.
(7) Midspan elastic deflection (in.) = C x (w/1.6) x ℓ_n^4, where w = tabulated load (k/ft.), ℓ_n in ft.
"Average service load" is taken as w/1.6.

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, INTERIOR SPANS

BEAM | TOP BM. BARS

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 24 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 26 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) $\times 10^{-9}$ in.
		2# 9		1	3# 9	5.5	113I	9	-	381	4.7	113I	9	-	408	4.1	123I	9	-	439	3.5	123I	9	-	467	199	287
				1			185F	35	1.3	671		204F	35	1.3	590		214F	34	1.2	628		234F	34	1.2	679	290	
		2#10		1	3#10	6.9	124I	9	-	522	5.8	124I	9	-	557	5.0	134I	9	-	599	4.4	133I	9	-	581	248	272
				1			185F	35	1.3	760		205F	35	1.3	832		215F	34	1.2	885		235F	34	1.2	957	359	
	14	2#10	1#10	1	4#10	8.8	125I	9	-	729	7.5	135I	9	-	789	6.5	144I	9	-	778	5.6	144I	9	-	825	359	226
				1			295C	35	1.3	1112		205F	35	1.2	990		215F	34	1.2	1055		235F	34	1.2	1140	460	
		2#14		1	3#14	11.0	264C	9	-	967	9.3	145FcI	9	-	998	8.1	145I	9	-	1059	7.0	155I	9	-	1134	411	200
				1			295C	35	1.3	1294		315C	35	1.2	1393		345C	34	1.2	1510		365C	34	1.2	1609	574	
		2# 9		1	3# 9	5.6	103I	11	-	378	4.8	113I	11	-	409	4.1	113I	11	-	437	3.6	123I	11	-	468	200	245
				1			165G	44	1.4	645		185G	43	1.4	711		195G	43	1.4	758		204G	42	1.4	653	294	
		2#11		1	3#11	8.3	125I	11	-	685	7.1	124I	11	-	666	6.1	134I	11	-	717	5.3	144I	11	-	769	302	232
				1			245D	44	1.4	988		265D	43	1.4	1069		195G	43	1.4	976		205G	42	1.4	1038	436	
	16	2#14		1	3#14	11.3	145FdI	11	-	942	9.6	135I	11	-	989	8.3	145I	11	-	1064	7.2	155I	11	-	1139	418	190
				1			245D	44	1.4	1217		265D	43	1.4	1317		285D	43	1.4	1417		305D	42	1.4	1517	590	
		2#14		1	5#11	11.6	145FeI	11	-	1000	9.9	145FdI	11	-	1066	8.5	145I	11	-	1132	7.4	155I	11	-	1212	418	191
				2			245D	44	1.4	1275		265D	43	1.4	1380		285D	43	1.4	1485		305D	42	1.4	1590	627	
26		2# 8	1# 8	1	3#10	6.6	113I	13	-	438	5.6	113I	13	-	470	4.9	113I	13	-	502	4.2	123I	13	-	539	238	218
				1			165G	53	1.6	711		185G	53	1.6	783		195G	52	1.5	835		205G	51	1.5	887	368	
		2# 9	1# 9	1	3#11	8.2	114I	13	-	583	7.0	124I	13	-	632	6.1	134I	13	-	681	5.3	133I	13	-	666	296	216
				1			245D	53	1.6	970		185G	52	1.5	889		195G	52	1.5	949		205G	51	1.5	1009	442	
	18	2#11	1#11	1	3#14	11.5	135FdI	13	-	912	9.8	135I	13	-	971	8.5	145I	13	-	1045	7.4	145I	13	-	1105	442	179
				1			245D	53	1.6	1212		265D	52	1.5	1313		285D	52	1.5	1413		305D	51	1.5	1513	602	
		2#10	2#10	1	4#14	13.3	145FfI	13	-	1057	11.3	155FeI	13	-	1142	9.7	155FdI	13	-	1213	8.5	155I	13	-	1284	477	157
				1			295C	53	1.6	1444		315C	52	1.5	1556		285D	52	1.5	1566		305D	51	1.5	1677	759	
		2# 8	1# 8	1	3#10	6.7	103I	16	-	435	5.7	113I	16	-	472	4.9	113I	15	-	504	4.3	113I	15	-	535	239	189
				1			155H	63	1.7	701		165H	62	1.7	754		175H	61	1.7	807		185H	61	1.7	859	371	
		2#10	1#10	1	3#11	8.5	114I	16	-	647	7.3	124I	15	-	701	6.3	124I	15	-	746	5.5	133I	15	-	743	371	190
				1			215E	63	1.7	986		225E	62	1.7	1051		175H	61	1.7	992		185H	61	1.7	1058	447	
	20	2#11	1#11	1	4#14	12.4	135FdI	16	-	1038	10.6	135I	15	-	1108	9.1	145I	15	-	1193	7.9	145I	15	-	1263	447	154
				1			295C	63	1.7	1456		265D	62	1.7	1463		285D	61	1.7	1575		265E	60	1.7	1603	776	
		2#14	1#14	1	4#14	14.8	265C	16	-	1385	12.6	155FfI	15	-	1309	10.9	155FeI	15	-	1392	9.5	165FdI	15	-	1489	612	141
				1			485A	63	1.7	2011		315C	62	1.7	1739		345C	61	1.7	1885		305D	60	1.7	1884	776	

← NOT USED

(1) See "Recommended Bar Details", Fig. 12-1. For girders, use tabulated beam depth — 2 inches (b — 2").
(2) In "Layers" column, first line is number of layers for bottom bars, second line is for number of layers for top bars.
(3) For superimposed factored load capacity, deduct 1.4 x stem weight.
(4) Total capacities tabulated causing deflection in excess of $\ell_n/360$ are designated thus: * — $\ell_n/360$ < deflection < $\ell_n/240$
X — $\ell_n/240$ < deflection < $\ell_n/180$
Y — deflection > $\ell_n/180$

(5) For each beam design, first line is for open stirrups, secondline is for closed ties. See Fig. 12-4. At free ends, use stirrups tabulated for "Interior Spans". For b > 24 in., provide 4 legs (two stirrups) of size and spacing tabulated. For stirrup nomenclature, see page 12-13.

Other notation: N/A — STIRRUPS ARE NOT REQUIRED
** — MAXIMUM SPACING IS LESS THAN 3 INCHES. NOT RECOMMENDED
*** — SHEAR STRESS IS GREATER THAN $10\sqrt{f'_c}$
**** — TORSION STRESS EXCEEDS ALLOWABLE

(6) $+\phi M_n$ and $-\phi M_n$ are design moment strength capacities for rectangular section b × h.
(7) Midspan elastic deflection (in.) = C x (w/1.6) x ℓ_n^4, where w = tabulated load (k/ft.), ℓ_n in ft.
"Average service load" is taken as w/1.6.

SOLID ONE-WAY SLABS—END SPAN

$f'_c = 3{,}000$ psi — Grade 60 Bars — Top Steel for $-M_u$, $\rho \approx 0.0050$

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#4	#5	#5	#5	#5	#5	#6	#6	#6	#6
Spacing (in.)	12	12	11	9	12	11	10	10	9	12	11	10	10
Bottom Bars	#4	#4	#4	#4	#4	#5	#5	#5	#5	#5	#6	#6	#6
Spacing (in.)	12	11	10	8	8	12	11	11	10	9	12	11	11
Top Bars Free End	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	12	12	12
T-S Bars	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel (in.^{2}/ft) Top Interior	.200	.200	.218	.267	.310	.338	.372	.377	.413	.440	.480	.528	.528
Bottom	.200	.218	.240	.300	.300	.310	.338	.338	.372	.413	.440	.480	.480
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	**FACTORED USABLE SUPERIMPOSED LOAD (psf)**												
6′-0″	700	906											
6′-6″	586	761	967										
7′-0″	496	645	821										
7′-6″	423	552	704	988									
8′-0″	363	475	608	856	986								
8′-6″	314	412	528	747	861	976							
9′-0″	272	359	462	656	757	858							
9′-6″	237	314	405	579	669	759	916						
10′-0″	207	276	357	513	593	674	814	890					
10′-6″	158	191	248	364	481	591	722	790	957				
11′-0″	138	167	218	323	429	528	647	708	859	987			
11′-6″	120	146	192	287	383	473	582	636	774	890			
12′-0″	105	127	169	256	343	426	524	574	700	806	952		
12′-6″	91	111	149	228	308	383	473	518	634	731	865		
13′-0″	79	97	131	204	277	346	428	469	575	664	787	937	999
13′-6″	68	84	115	182	249	312	388	426	523	605	719	857	914
14′-0″	58	73	101	162	224	282	352	386	477	552	657	785	837
14′-6″	49	62	88	145	202	256	320	351	435	505	602	721	769
15′-0″	42	53	76	129	182	231	291	320	397	462	552	662	707
15′-6″		45	66	115	163	209	264	291	363	423	507	610	651
16′-0″			56	102	147	190	241	265	332	388	466	562	600
16′-6″			48	90	132	171	219	241	304	356	429	519	554
17′-0″			40	79	118	155	199	220	278	327	395	479	511
17′-6″				69	105	140	181	200	255	300	363	442	473
18′-0″				60	94	126	164	182	233	275	335	409	437
18′-6″				51	83	113	149	165	213	253	309	378	405
19′-0″				44	73	101	135	149	195	232	284	350	374
19′-6″					64	90	122	135	178	213	262	324	347
20′-0″					56	80	109	122	162	195	241	300	321

Note: See Fig. 7-1 for reinforcing bar details.

CONCRETE REINFORCING STEEL INSTITUTE

APPENDIX F
(COST CALCULATIONS)

Composite Floor

Item	Amount	R.S. Means Quantity Price	Total Cost: (Labor + Equipment + Material)
Steel:			
W16x26	8x(30.458')	35.41/L.F.	$8,628
W18x50	(30')	66.08/L.F.	$1,982
W24x55	(30')	71.09/L.F.	$2,133
W21x44	(30')	57.99/L.F.	$1,740
			= $14,483
Studs:			
261 studs	2,610 lbs	$1.30/lb	**= $3,393**
Decking:			
3" Deep Galvanized 20 gauge	1828 S.F.	$2.36/S.F.	**= $4,313**
Concrete:			
6" slab	1828 S.F.	$3.03/S.F.	**= $5,537**
		TOTAL	**= $27,726**

Non-Composite Floor

Item	Amount	R.S. Means Quantity Price	Total Cost: (Labor + Equipment + Material)
Steel:			
W18x40	8x(30.458')	53.80/L.F.	$13,109
W18x86	(30')	109.66/L.F.	$3,290
W24x62	(30')	79.59/L.F.	$2,388
W24x55	(30')	71.09/L.F.	$2,133
			= $20,920
Decking:			
3" Deep Galvanized 20 gauge	1828 S.F.	$2.36/S.F.	**= $4,313**
Concrete:			
6" slab	1828 S.F.	$3.03/S.F.	**= $5,537**
		TOTAL	**= $30,770**

Longspan Steel Joist

Item	Amount	R.S. Means Quantity Price	Total Cost: (Labor + Equipment + Material)
Steel:			
18LH08	16x(30.458')	19.43/L.F.	$9,469
W16x26	4x(30.458')	35.41/L.F.	$4,314
W18x86	(30')	109.66/L.F.	$3,290
W24x62	(30')	79.59/L.F.	$2,388
W24x55	(30')	71.09/L.F.	$2,133
			= $21,594
Decking:			
3" Deep Galvanized 20 gauge	1828 S.F.	$2.36/S.F.	**= $4,313**
Concrete:			
6" slab	1828 S.F.	$3.03/S.F.	**= $5,537**
		TOTAL	**= $31,444**

Flat Plate with Drop Panels

Item	Amount	R.S. Means Quantity Price	Total Cost: (Labor + Equipment + Material)
Slab:			
	61.11C.Y.	$445.75/C.Y.	$27,240
Drop Panels:			
	5.56 C.Y.	$445.75/C.Y.	$2,478
		TOTAL	**= $29,718**

One-Way Beam and Slab

Item	Amount	R.S. Means Quantity Price	Total Cost: (Labor + Equipment + Material)
Slab:			
	33.33C.Y.	$685.50/C.Y.	$22,848
Beams:			
	21.70 C.Y.	$685.50/C.Y.	$14,875
		TOTAL	**= $37,723**

05 12 23 – Structural Steel for Buildings

05 12 23.75 Structural Steel Members		Crew	Daily Output	Labor-Hours	Unit	Material	2008 Bare Costs Labor	Equipment	Total	Total Incl O&P
0720	x 26	E-2	600	.093	L.F.	31.50	3.91	2.61	38.02	44
0740	x 33		550	.102		40	4.26	2.85	47.11	54.50
0900	x 49		550	.102		59.50	4.26	2.85	66.61	75.50
1100	W 12 x 14		880	.064		16.95	2.66	1.78	21.39	25
1300	x 22		880	.064		26.50	2.66	1.78	30.94	36
1500	x 26		880	.064		31.50	2.66	1.78	35.94	41
1520	x 35		810	.069		42.50	2.89	1.93	47.32	53.50
1560	x 50		750	.075		60.50	3.13	2.09	65.72	74
1580	x 58		750	.075		70	3.13	2.09	75.22	84.50
1700	x 72		640	.088		87	3.66	2.45	93.11	105
1740	x 87		640	.088		105	3.66	2.45	111.11	125
1900	W 14 x 26		990	.057		31.50	2.37	1.58	35.45	40.50
2100	x 30		900	.062		36.50	2.60	1.74	40.84	46.50
2300	x 34		810	.069		41	2.89	1.93	45.82	52.50
2320	x 43		810	.069		52	2.89	1.93	56.82	64
2340	x 53		800	.070		64	2.93	1.96	68.89	77.50
2360	x 74		760	.074		89.50	3.08	2.06	94.64	106
2380	x 90		740	.076		109	3.17	2.12	114.29	128
2500	x 120		720	.078		145	3.26	2.18	150.44	168
2700	W 16 x 26		1000	.056		31.50	2.34	1.57	35.41	40.50
2900	x 31		900	.062		37.50	2.60	1.74	41.84	48
3100	x 40		800	.070		48.50	2.93	1.96	53.39	60
3120	x 50		800	.070		60.50	2.93	1.96	65.39	73.50
3140	x 67		760	.074		81	3.08	2.06	86.14	96.50
3300	W 18 x 35	E-5	960	.083		42.50	3.53	1.77	47.80	54.50
3500	x 40		960	.083		48.50	3.53	1.77	53.80	61
3520	x 46		960	.083		55.50	3.53	1.77	60.80	69
3700	x 50		912	.088		60.50	3.72	1.86	66.08	75
3900	x 55		912	.088		66.50	3.72	1.86	72.08	81.50
3920	x 65		900	.089		78.50	3.77	1.89	84.16	95
3940	x 76		900	.089		92	3.77	1.89	97.66	110
3960	x 86		900	.089		104	3.77	1.89	109.66	123
3980	x 106		900	.089		128	3.77	1.89	133.66	150
4100	W 21 x 44		1064	.075		53	3.19	1.60	57.79	66
4300	x 50		1064	.075		60.50	3.19	1.60	65.29	74
4500	x 62		1036	.077		75	3.27	1.64	79.91	90
4700	x 68		1036	.077		82.50	3.27	1.64	87.41	98
4720	x 83		1000	.080		100	3.39	1.70	105.09	118
4740	x 93		1000	.080		113	3.39	1.70	118.09	132
4760	x 101		1000	.080		122	3.39	1.70	127.09	142
4780	x 122		1000	.080		148	3.39	1.70	153.09	170
4900	W 24 x 55		1110	.072		66.50	3.06	1.53	71.09	80
5100	x 62		1110	.072		75	3.06	1.53	79.59	89.50
5300	x 68		1110	.072		82.50	3.06	1.53	87.09	97.50
5500	x 76		1110	.072		92	3.06	1.53	96.59	108
5700	x 84		1080	.074		102	3.14	1.57	106.71	119
5720	x 94		1080	.074		114	3.14	1.57	118.71	132
5740	x 104		1050	.076		126	3.23	1.62	130.85	145
5760	x 117		1050	.076		142	3.23	1.62	146.85	163
5780	x 146		1050	.076		177	3.23	1.62	181.85	201
5800	W 27 x 84		1190	.067		102	2.85	1.43	106.28	119
5900	x 94		1190	.067		114	2.85	1.43	118.28	132
5920	x 114		1150	.070		138	2.95	1.48	142.43	159

05 31 Steel Decking

05 31 13 – Steel Floor Decking

05 31 13.50 Floor Decking		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total incl O&P
0010	**FLOOR DECKING** R053100-10									
3200	Open decking, 3" deep, wide rib, 22 gauge, galvanized, under 50 squares	E-4	3600	.009	S.F.	2.21	.39	.04	2.64	3.18
3250	50-500 squares		3800	.008		1.77	.37	.03	2.17	2.65
3260	over 500 squares		4000	.008		1.59	.35	.03	1.97	2.42
3300	20 gauge, under 50 squares		3400	.009		2.58	.41	.04	3.03	3.61
3350	50-500 squares		3600	.009		2.06	.39	.04	2.49	3.01
3360	over 500 squares		3800	.008		1.85	.37	.03	2.25	2.74
3400	18 gauge, under 50 squares		3200	.010		3.32	.44	.04	3.80	4.48
3450	50-500 squares		3400	.009		2.66	.41	.04	3.11	3.70
3460	over 500 squares		3600	.009		2.39	.39	.04	2.82	3.37
3500	16 gauge, under 50 squares		3000	.011		4.39	.46	.04	4.89	5.70
3550	50-500 squares		3200	.010		3.51	.44	.04	3.99	4.69
3560	over 500 squares		3400	.009		3.16	.41	.04	3.61	4.26
3700	4-1/2" deep, long span roof, over 50 squares, 20 gauge		2700	.012		4.13	.52	.05	4.70	5.50
3800	18 gauge		2460	.013		5.30	.57	.05	5.92	6.95
3900	16 gauge		2350	.014		3.98	.59	.06	4.63	5.50
4100	6" deep, long span, 18 gauge		2000	.016		7.60	.70	.07	8.37	9.70
4200	16 gauge		1930	.017		5.70	.72	.07	6.49	7.65
4300	14 gauge		1860	.017		7.30	.75	.07	8.12	9.50
4500	7-1/2" deep, long span, 18 gauge		1690	.019		8.35	.82	.08	9.25	10.80
4600	16 gauge		1590	.020		6.25	.88	.08	7.21	8.50
4700	14 gauge		1490	.021		8.05	.93	.09	9.07	10.65
4800	For painted instead of galvanized, deduct					2%				
5000	For acoustical perforated, with fiberglass, add				S.F.	1.09			1.09	1.20
5200	Non-cellular composite deck, galv., 2" deep, 22 gauge	E-4	3860	.008		1.53	.36	.03	1.92	2.37
5300	20 gauge		3600	.009		1.69	.39	.04	2.12	2.60
5400	18 gauge		3380	.009		2.15	.41	.04	2.60	3.15
5500	16 gauge		3200	.010		2.69	.44	.04	3.17	3.79
5700	3" deep, galv., 22 gauge		3200	.010		1.67	.44	.04	2.15	2.66
5800	20 gauge		3000	.011		1.86	.46	.04	2.36	2.93
5900	18 gauge CN		2850	.011		2.29	.49	.05	2.83	3.45
6000	16 gauge		2700	.012		3.06	.52	.05	3.63	4.35

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05 21 Steel Joist Framing

05 21 16 – Longspan Steel Joist Framing

05 21 16.50 Longspan Joists		Crew	Daily Output	Labor-Hours	Unit	2008 Bare Costs Material	Labor	Equipment	Total	Total incl O&P
2040	Average	E-7	13	6.154	Ton	1,675	261	141	2,077	2,450
2080	Maximum		11	7.273	-	1,975	310	166	2,451	2,900
2200	18LH04, 12 Lb/LF		1400	.057	L.F.	10.05	2.42	1.31	13.78	16.7
2220	18LH08, 19 Lb/LF		1400	.057		15.90	2.42	1.31	19.63	23
2240	20LH04, 12 Lb/LF		1400	.057		10.05	2.42	1.31	13.78	16.7
2260	20LH08, 19 Lb/LF		1400	.057		15.90	2.42	1.31	19.63	23
2280	24LH05, 13 Lb/LF		1400	.057		10.85	2.42	1.31	14.58	17.6
2300	24LH10, 23 Lb/LF		1400	.057		19.25	2.42	1.31	22.98	26.5
2320	28LH06, 16 Lb/LF		1800	.044		13.40	1.88	1.02	16.30	19.1
2340	28LH11, 25 Lb/LF		1800	.044		21	1.88	1.02	23.90	27.5
2360	32LH08, 17 Lb/LF		1800	.044		14.20	1.88	1.02	17.10	20
			[illegible]	[illegible]		25	1.88	1.02	27.90	32

03 30 Cast-In-Place Concrete

03 30 53 – Miscellaneous Cast-In-Place Concrete

03 30 53.40 Concrete in Place		Crew	Daily Output	Labor-Hours	Unit	2008 Bare Costs Material	Labor	Equipment	Total	In
1240	Maximum reinforcing	C-14A	13.77	14.524	C.Y.	695	555	55	1,305	1
1300	20" diameter, minimum reinforcing		41.04	4.873		265	187	18.35	470.35	
1320	Average reinforcing		24.05	8.316		445	320	31.50	796.50	1
1340	Maximum reinforcing		17.01	11.758		695	450	44.50	1,189.50	1,
1400	24" diameter, minimum reinforcing		51.85	3.857		251	148	14.55	413.55	
1420	Average reinforcing		27.06	7.391		445	284	28	757	
1440	Maximum reinforcing		18.29	10.935		685	420	41	1,146	1,
1500	36" diameter, minimum reinforcing		75.04	2.665		254	102	10.05	366.05	
1520	Average reinforcing		37.49	5.335		425	205	20	650	
1540	Maximum reinforcing		22.84	8.757		665	335	33	1,033	1,
1900	Elevated slabs, flat slab with drops, 125 psf Sup. Load, 20' span	C-14B	38.45	5.410		263	207	19.60	489.60	
1950	30' span		50.99	4.079		275	156	14.75	445.75	
2100	Flat plate, 125 psf Sup. Load, 15' span		30.24	6.878		242	264	25	531	7
2150	25' span		49.60	4.194		249	161	15.20	425.20	5
2300	Waffle const., 30" domes, 125 psf Sup. Load, 20' span		37.07	5.611		375	215	20.50	610.50	7
2350	30' span		44.07	4.720		335	181	17.10	533.10	6
2500	One way joists, 30" pans, 125 psf Sup. Load, 15' span		27.38	7.597		450	291	27.50	768.50	9
2550	25' span		31.15	6.677		410	256	24	690	8
2700	One way beam & slab, 125 psf Sup. Load, 15' span		20.59	10.102		264	385	36.50	685.50	9
2750	25' span		28.36	7.334		246	281	26.50	553.50	7
2900	Two way beam & slab, 125 psf Sup. Load, 15' span		24.04	8.652		253	330	31.50	614.50	8
2950	25' span		35.87	5.799		216	222	21	459	6(
3100	Elevated slabs including finish, not									
3110	including forms or reinforcing									
3150	Regular concrete, 4" slab	C-8	2613	.021	S.F.	1.36	.73	.28	2.37	
3200	6" slab		2585	.022		2.02	.73	.28	3.03	
3250	2-1/2" thick floor fill		2685	.021		.87	.71	.27	1.85	
3300	Lightweight, 110# per C.F., 2-1/2" thick floor fill		2585	.022		1.19	.73	.28	2.20	
3400	Cellular concrete, 1-5/8" fill, under 5000 S.F.		2000	.028		.79	.95	.36	2.10	
3450	Over 10,000 S.F.		2200	.025		.76	.86	.33	1.95	
3500	Add per floor for 3 to 6 stories high		31800	.002			.06	.02	.08	
3520	For 7 to 20 stories high		21200	.003			.09	.03	.12	
3540	Equipment pad, 3' x 3' x 6" thick	C-14H	45	1.067	Ea.	45.50	40.50	.55	86.55	11
3550	4' x 4' x 6" thick		30	1.600		67	60.50	.83	128.33	16
3560	5' x 5' x 8" thick		18	2.667		116	101	1.39	218.39	28
3570	[illegible]									