5.0 TECHNICAL ANALYSIS #2
Precast Hollow Core Concrete Planks vs. Composite Slab

5.1 Problem Statement

The structure for the Women's Center and Inpatient Tower is primarily a cast-in-place concrete system; however, part of the structural system is composed of structural steel framing with precast hollow core concrete panels. Because part of the new patient tower is being built over-top of an existing mechanical room, a structural steel truss system was used in this area to support the patient tower. The steel framed truss supports the area above the existing mechanical room for levels three through eight and the penthouse level. This area of the building is illustrated in Figure 21. The top right image taken from the patient tower side shows the structural steel truss being erected. The bottom right image taken from the existing hospital side shows the steel beams that will support the precast plank system. For this area, precast hollow core concrete planks were used for the flooring of the structure. The precast planks were chosen because they require no formwork or shoring in the construction process. Because this area of the building is located in a congested area on the inside corner of the tower, the erection of the precast panels was somewhat difficult. The technical analysis will look at eliminating precast hollowcore concrete planks from this area, and using a composite slab system for the flooring system. This analysis will focus on the cost impact, schedule impact, and constructability.

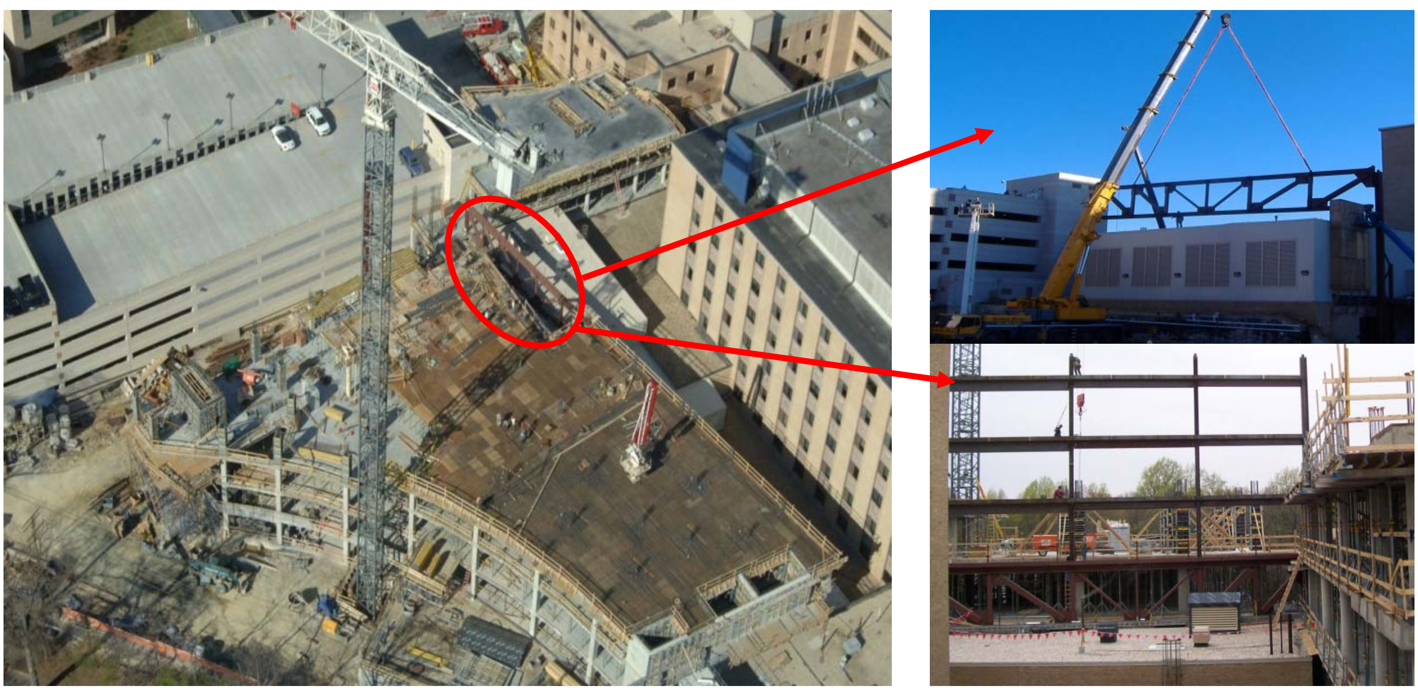

Figure 21: Photos from Patient Tower illustrating the steel truss above the mechanical room

5.2 Goal

The goal of this technical analysis is to demonstrate that a composite slab can be used as a viable option for the area above the existing mechanical room. This analysis will focus on the cost impact, schedule impact, and constructability. By using the composite slab, the precast concrete can be eliminated from the project. The costs of the precast panels will be removed from the project budget, and the costs of the structural steel beams, metal decking and additional concrete will be added to the budget. To determine the cost impact of changing the structural flooring system, the cost of using composite slab will be compared to the cost of precast concrete planks. Along with the cost impact, the constructability of the two systems will be reviewed. The review will consist of an analysis of the structural performance of the composite decking and slab. This analysis will then be compared to the precast concrete planks performance. The review will also look at the various challenges that may exist for constructing each of the structural systems. The change from precast concrete planks to a composite slab may also have an impact on the project schedule. This alternative system may potentially reduce the project schedule duration for the structural system of the patient tower. Because cast-in-place concrete is used for the rest of the tower, the time required to get the concrete is minimum. By using a composite slab, the concrete planks will be eliminated; therefore, the time needed to order and deliver the planks can be reduced. Also, because the concrete slab is placed using a pump, the structure can continue to go up without the use of the crane. With the precast panels, the crane is needed to erect the panels; therefore, the work needed to be completed on specific days when the crane was not in use. Due to this issue, the schedule may be shorter with the composite slab. The schedule and sequencing differences between the two systems will be illustrated using a 4D model. Because this analysis requires design of the composite slab, it will be used for a structural breadth for my thesis research.

5.3 Analysis Steps

1. Compile all information that corresponds to the steel truss and precast concrete panel structural system. This information will include the original budget and the project schedule.
2. Details pertaining to the construction of the precast panels and a description of the precast panels will also be reviewed. This may include any issues that occurred with placing the precast concrete panels.
3. Discuss the structural design with structural professors and students.
4. Design and analyze the composite metal decking and concrete slab system.
5. Create a schedule and budget for the alternate system.
6. Develop a 4D model to illustrate the schedule sequencing.
7. Compare the costs and durations of the alternate system to the original system.

5.4 Resources and Tools

1. Whiting-Turner Team- Bruce DeLawder's Health Group
2. Architectural Engineering Faculty (Professor Parfitt and Professor Hanagan)
3. Belfast Valley Contractors- Chris Miller
4. WT Steel
5. Vulcraft

6. RAM Structural System
7. Steel Construction Manual
8. Microsoft Excel
9. Microsoft Project
10. Whitney, Bailey, Cox, and Magnani- Mike Stasch

5.5 Composite Slab Design

5.5.1 Beam Design in RAM Structures

The design of the composite slab began with the layout of the structural steel beams in RAM Structural System. The area of the building that was being redesigned was set up in RAM Structures. The sizes and layout of the existing structural steel columns and beams remained the same throughout the design. The beams for the composite slab were only pieces being designed in RAM Structural Systems. To design the correct size beams for this area, a composite slab was chosen from the Nucor Vulcraft Group online catalog. The slab that was used for this design has a total slab depth of 6". The concrete used is normal weight concrete (145PCF). The metal decking has a clear span of 12'1" and has a self weight of 2.50PSF. The shear studs used are ¾" in diameter and 4.5" long. Please see Appendix C for an image of the Deck/Slab Property Information window from RAM. The dead and live loads were also applied to the slab before the beams were designed. The live load was taken directly from structural drawings for the BWMC Patient Tower. The dead load was calculated using the composite slab described above and other various dead loads listed in the structural drawings. Equations 1 and 2 show the dead and live loads used for this design.

Eq. 1: Dead Load Equation

DL= 5psf (MEP Equip.) + 2psf (Ceiling Load) + 2psf (Misc.) + 75psf (Comp. Slab)* = 84

*Composite Slab= 6" Concrete Slab (Normal Weight- 145pcf) + Metal Decking (2.5 psf)

= .5' x 145pcf + 2.5psf= 75psf

Eq. 2: Live Load Equation

LL= 80psf + 20psf (partition walls) = 100psf

Please see Appendix C for an image of the Surface Load Properties from RAM. Based on the composite slab and loads used, the beams that were designed in RAM consisted of five 8x10 wide flange beams. In order to be within the metal decking span of 12'1", these 8x10 wide flange beams were spaced 12' apart. The beam and shear stud design is illustrated in Figure 22. Once the beams were designed in RAM, the connections were designed using the Steel Construction Manual.

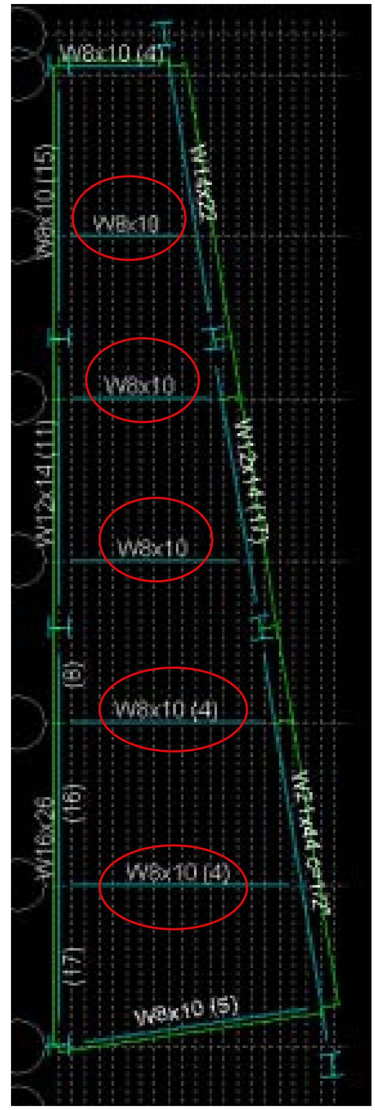

Figure 22: Plan View of 8x10 Beams Designed in RAM Structures

5.5.2 Connection Design

Now that the steel beams have been designed, the connection between the steel beams and concrete slab needs to be designed. The left end of the steel beam is connecting to a 16" concrete beam. The connection was designed using Table 10-9a- Single Plate Connections in the Steel Manual. As stated in Table 10-9. Single-Plate Connections, the single plate connection is welded to the support and bolted to the supported beam. The bolts and plates tabulated in Table 10-9a consider bolt shear, bolt bearing on the plate, shear yielding of the plate, shear rupture of the plate, block shear rupture of the plate, and weld shear. In order to design the connection, the shear force at the end of the beams needs to be calculated. As shown in Equations 1 and 2, the dead load was calculated to be 84psf and the live load was 100psf. Equations 3-5, show the calculations for the

reactions at each end of the beam. Because each beam is a different length, the longest beam length was used to calculate largest reaction on the beam.

Eq. 3: Factored Loads

FL=1.2DL + 1.6LL

FL=1.2 (84psf) + 1.6 (100psf) = 261psf

Eq. 4: Reaction Force

R= (wl)/2= (3132psf x 17')/2= 26622lbs ~ 26.6kips

w= FL x trib. width of beam

w= 261psf x 12' = 3132plf

l= length of longest beam

l= 17'

Eq. 5: LFRD

LFRD= ϕ R= (.75) (26.6kips) = 19.95 ~ 20.0kips

Φ= .75

Once the reaction forces were calculated, the single plate connection can be determined in Table 10-9a. Because the beams are only 7.89" deep, the connection needs to have a length smaller than or equal to 7.89". Based on the LFRD and L≤7.89", a connection using a ¼" thick plate that is 5 ½" long with (2) ¾" bolts and a 3/16" weld was chosen. The bolts used for the connection are threaded A325 with standard holes. The detailed section of this connection is shown in Figure 23.

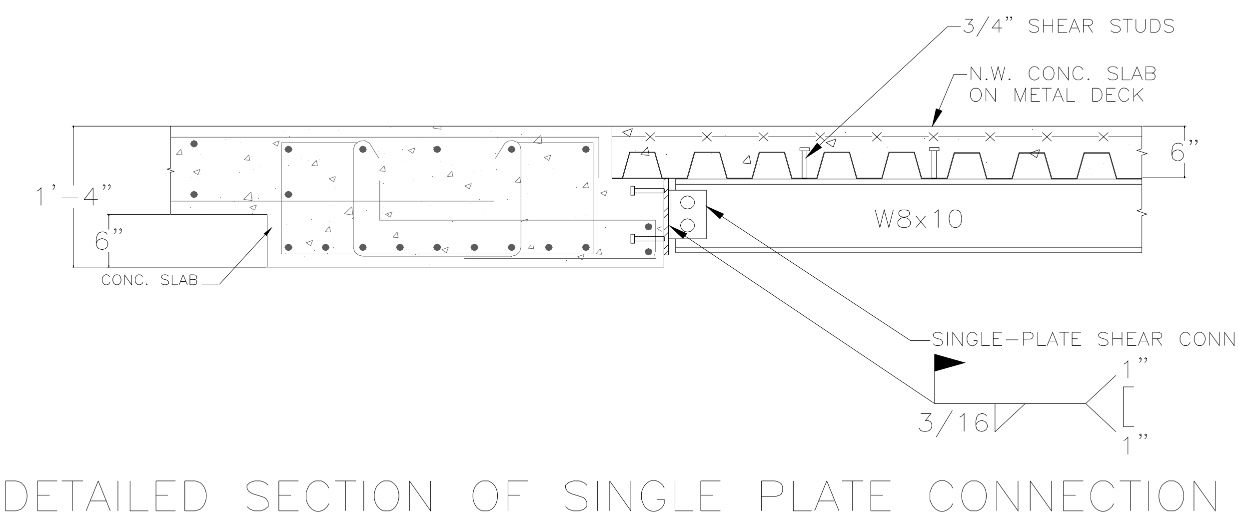

Figure 23: Section View of Connection Detail between cast-in-place beam and composite slab system

5.6 Cost Analysis

*Please see Appendix D for material quantity takeoffs

The cost estimates for the two systems were calculated using primarily estimates provided by the actual subcontractors who worked on the BWMC Patient Tower. The cost for the W8x10 beams is the only item where R.S Means was used. The precast system as shown in Table 3, includes the precast hollow core planks and a 2"concrete topping with 6"x6" W.14xW1.4 W.W.F. The composite slab alternative system in Table 4, includes W8x10 beams, a 6" concrete slab with 6"x6" W.14xW1.4 W.W.F., and metal decking. The equipment cost for the precast concrete planks was taken from the tower crane rental cost for the project. The equipment costs for the concrete and metal decking is included within the material or labor cost. For the concrete, the equipment used is a concrete pump. The equipment used to erect the metal decking is a mobile crane.

Table 3: Precast Planks Cost Estimate

Precast Concrete Hollow Core Planks Estimate										
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Quantity	Equip. Cost	Total Item Cost
8" Hollow Planks	planks	70	$1,500.00	$105,000	$200.00	$14,000	$974/Day	10 days	$9,740	$128,740
2" Concrete Topping w/ 6"x 6" W1.4 x W1.4 W.W.F	sf	7252	$5.00	$36,260	$0.00	$0	$0.00	-	$0	$36,260
Total Precast Concrete Planks Estimate:										$165,000

Table 4: Composite Slab Cost Estimate

Composite Slab Estimate									
Item	Units	Quantity	Unit Mat'l	Mat'l Cost	Unit Labor	Labor Cost	Unit Equip.	Equip. Cost	Total Item Cost
W 8x10 Beams	lf	469	$11.30	$5,300	$3.77	$1,768	$2.58	$1,210	$8,278
6" Concrete Slab w/ 6"x 6" W1.4 x W1.4 W.W.F	sf	7252	$6.00	$108,968	$0.00	$0	$0.00	$0	$108,968
3" 20 Gauge Metal Decking	sf	7252	$2.10	$15,229	$0.90	$6,527	$0.00	$0	$21,756
Total Composite Slab Estimate:									$139,002

Table 5: Cost Comparison of Structural Systems

Cost Comparison of Structural Systems	
Item	Cost
Precast Hollow Core Planks	$165,000
Composite Slab	$139,000
Difference in Cost :	**$26,000**

Based on the cost comparison in Table 5, the cost of the composite slab system is somewhat less than the precast system. The difference between the two systems is about $26,000. The cost of the tower crane added a large cost to the precast system whereas the composite slab only required a mobile crane so the cost was not nearly as high.

5.7 Schedule

*Please see Appendix B for more images of the Structural 4D Model.
*Please see Appendix E for project schedules of the two different systems created in Microsoft Project

The schedule durations were calculated using actual data from the concrete and steel subcontractors on the project and also R.S. Means. The durations for each item within the two systems are shown in Tables 6 through 9. Because many of the durations only took an hour or two, some items were combined so that they could be completed on the same day. As shown in Tables 5 and 7, the placing of the wire mesh and concrete can be completed on the same day for both the precast planks system and the composite slab system. The concrete can also be finished on the same day that the wire mesh and concrete is placed. With the composite slab, the metal decking can be placed the same day as the W8x10 beams. See Tables 6 through 9 for the durations of both structural systems in hours and days.

Table 6: Precast Plank Durations in Hours

Precast Concrete Panels Schedule Durataions				
Items per Level	Units	Quantity	Daily Output	Durations (Hours)
Precast Concrete Panels	planks	10	10	8
Place Wire Mesh	csf	10.36	35	2
Place 2" Concrete Topping with Pump	cy	7	160	1

Table 7: Precast Plank Durations in Days

Precast Concrete Panels Schedule Durations	
Levels 3-9	Duration (Days)
Precast Concrete Panels	1
Place Wire Mesh and Concrete	1
Total Duration (Levels 3-9) :	**14**

Table 8: Precast Plank Durations in Hours

Composite Slab Schedule Durataions				
Items per Level	Units	Quantity	Daily Output	Duration (Hours)
Erect Structural Steel (8x10)	lf	70	600	1
Erect Metal Decking	sf	1036	3200	3
Place Wire Mesh	csf	10.36	35	2
Place Concrete by Pump	cy	20	160	1

Table 9: Precast Plank Durations in Days

Composite Slab Schedule Durations	
Levels 3-9	Duration (Days)
Erect Steel Beams and Metal Decking	1
Place Wire Mesh and Concrete	1
Total Duration (Levels 3-9) :	**14**

Because the precast planks can be placed in the same amount of time as the steel beams and decking, the schedule durations for the two systems will take about the same amount of time. The estimated duration for the two systems as illustrated in Table 10 is about 14 days.

Table 10: Schedule Duration Comparison of Structural Systems

Schedule Duration Comparison for Structural Systems	
	Duration (Days)
Precast Planks	14
Composite Slab	14
Difference (Days) :	**0**

Even though the durations are about the same, the sequencing for these two systems is considerably different. The precast planks are erected using the tower crane whereas the steel beams and metal decking are erected using a mobile crane. Because the concrete subcontractor had rented the tower crane, the precast planks needed to be erected on an off-day when the crane was not utilized by the concrete subcontractor. The precast planks were typically placed on a Saturday, and the concrete topping was placed in the following week. With the composite slab, the cast-in-place concrete for the surrounding structure would need to be placed and cured first before the steel beams could be erected. Because the conventional 28-day strength needs seven days before it can support any load, the steel beams can be erected seven days after the surrounding concrete is poured. Once the steel beams and metal decking are erected, the wire mesh and concrete could be placed the following day.

5.8 Constructability

Even though the schedule durations for the two systems proved to be about the same, the alternative system using a composite slab is the best system in terms of constructability. The precast plank system was chosen based on the fact that there is no need for formwork and shoring. However, with the composite slab system, minimal formwork will be needed seeing as though the metal decking replaces much of the formwork and shoring if needed will be minimal. Even though there is no need for shoring and formwork with the precast system, there are still other constructability issues with the precast planks. As illustrated in Figure 9, this area of the building is located on the inside corner of the Patient Tower; therefore, it is difficult to reach the area using a tower crane. The placing of the planks on the bottom floors within this area are especially hard to reach. With the composite slab, the metal decking is considerably lighter than the precast planks; therefore, a mobile crane can be used instead of the tower crane to place the metal decking. Because this mobile crane has some flexibility with where it is placed, it is much easier to place the metal decking. In order for the mobile crane to reach this area, it would be placed at the north edge of the tower. Because there is already a mobile crane on site, there will be no additional cost for renting an additional mobile crane. Figure 24 shows an image of the site layout for the construction of this redesigned area.

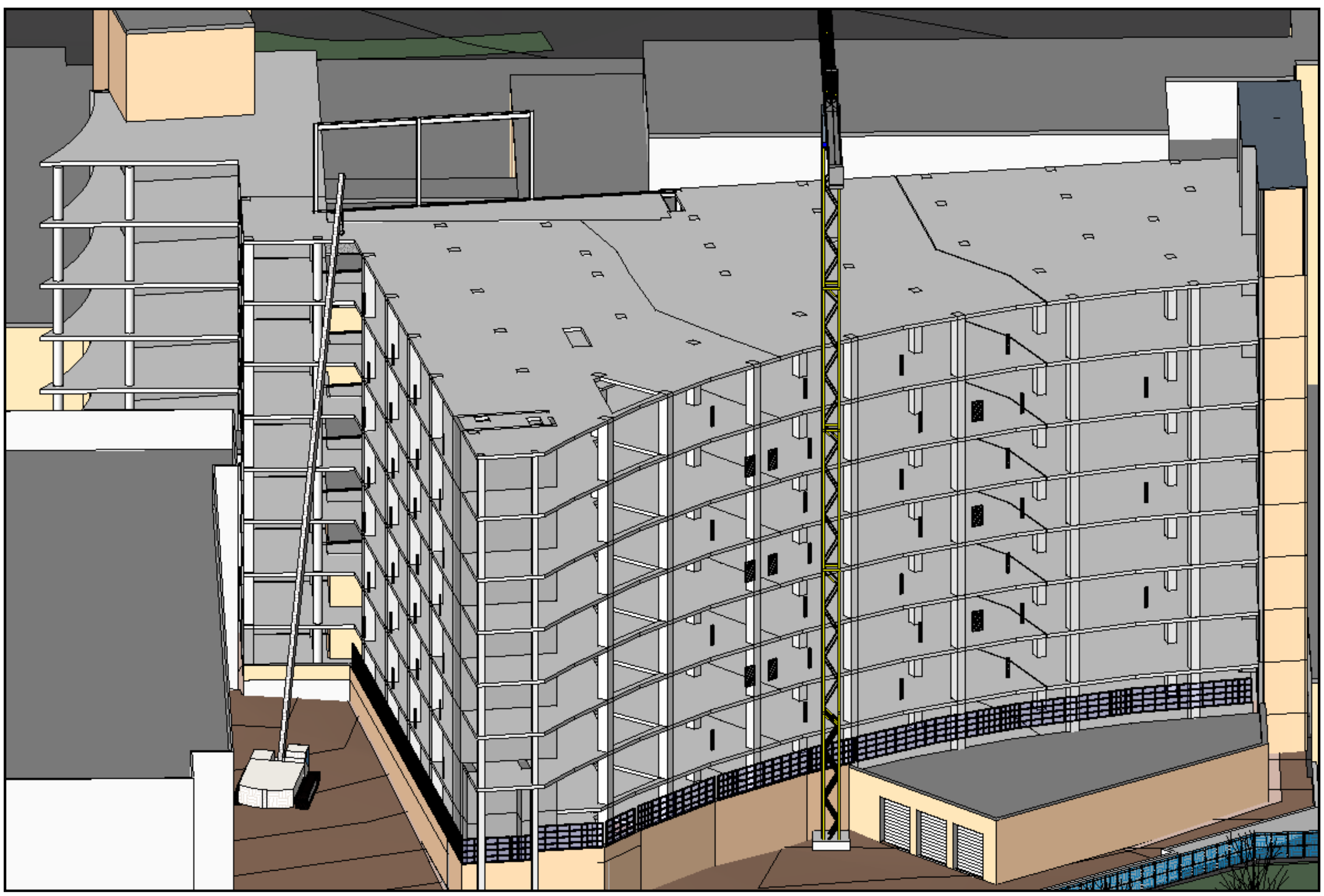

Figure 24: Site Logistics of Mobile Crane for Area above Ex. Mechanical Room

5.9 Conclusion and Recommendations

Based on my analysis of the precast concrete planks versus the composite slab, I conclude that the alternate design using the composite slab system is the best option for this area of the Patient Tower. The idea for this analysis area arose when I talked to a project engineer from the project team. We discussed that it made little sense to use precast planks when the rest of the structural system was designed using cast-in-place concrete. After further investigation with this area, the precast planks did not appear to be the best solution. When the precast planks were compared to the composite slab, the composite slab proved to be the best option in terms of cost and constructability. Using the composite slab system, an estimated $26,000 would be saved in cost. Because a mobile crane can be used to place the metal decking, the placement of the metal decking would be much easier than the precast concrete planks. The concrete slab for the composite slab and the concrete topping for the precast planks would both be pumped using a pump truck so the constructability of the concrete appears to be the same. As far as the schedule durations, the two systems would take about the same time to complete. For BWMC-Women's Center and Inpatient Tower, it is recommended to use the composite slab in place of the precast hollow core concrete planks.