
# ANALYSIS 2:
# FLOOR SUB-SYSTEMS

## *Problem Statement:*

Top of the line mechanical and electrical systems are vital for LEED certification and the longevity of the building. The interior finishes are important to keep the quality of the Geisinger medical office to their higher standard. In an attempt to lower building costs, the next most costly system – the metal and concrete structural system – should be re-evaluated. The metal and concrete systems account for 16% of the building costs while the mechanical (26%), electrical (16%), and finishes (13%) account for over half of the building costs.

## *Proposed Solution:*

While providing information comparing the benefits and drawbacks of the three slab systems, the objective is to lower the total building costs through value engineering the concrete slabs and still maintaining the structural integrity of the medical office building.

Although both lightweight and normal-weight concrete can fulfill the same structural function, there is a significant cost premium for lightweight concrete. With the comparison of the concrete slabs, the structural steel design will need to be re-evaluated for the normal weight concrete as well as a cost comparison. With over 60,000 SF of lightweight concrete being used for the slabs, a lower material cost could have substantial impacts on the project.

| | Unit Weight ($lbs/ft^3$) | Strength (psi) | Material Costs ($/SF) |
|---|---|---|---|
| Normal Weight Concrete | 145 – 150 | 3,000 – 5,000 | 1.85 |
| Lightweight Concrete | 90 – 115 | 2,500 | 2.20 |

Lightweight and normal weight concrete comparison. Costs from RSMeans 2007.
(2 ½ " thick floor slab including finish, no reinforcing.)

In addition, another floor system will be analyzed. An investigation of a form deck slab construction on steel joists will be completed for value engineering. This option would require even heavier girders than the normal weight concrete option because they will no longer be composite girders, but form deck construction can be less expensive.


## *Methodology:*

To begin this analysis, an evaluation of the current system is required. Consisting of LW concrete on 2" decking, the floor system is supported by structural steel beams, girders, and columns. Also considered is the amount of spray-on-fireproofing required for the building.

From here, two suggestions were made to reduce cost by pin-pointing the more costly components: lightweight concrete and the decking with structural steel beams. Redesigning the structural systems and providing a cost analysis will then be done using Microsoft Excel.

Lastly, to complete a thorough investigation, a constructability review and any changes that the varying systems may have on the project schedule will be discussed.

## *Resources and Tools:*

Dr. Andres Lepage

Microsoft Excel

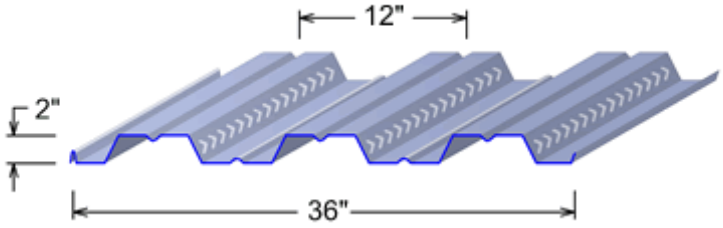
Structural Steel Manufacture/Installer – Altoona Pipe and Steel

Decking Manufacturer – United Steel Deck, Inc.

Structural Engineer - EwingCole

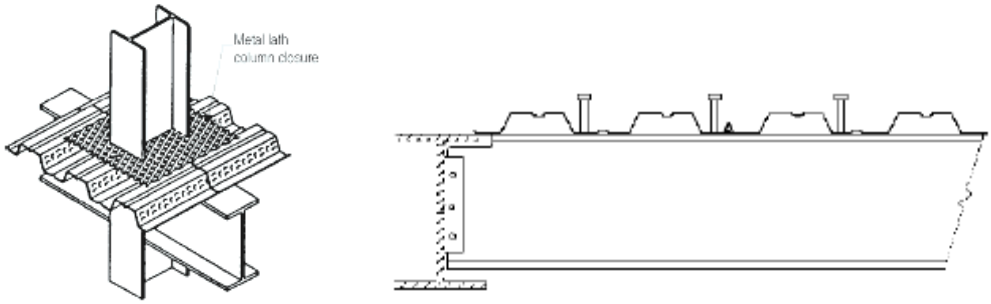
## *Existing Conditions:*

As stated previously, the current structural design consists of LW concrete on 2" decking and structural steel beams, girders, and columns.




2" Composite Decking

Typically throughout the building, 3 ½" of lightweight concrete is placed on 2" LOK composite decking for the floor and roof slabs. Steel beams, girders, and columns (W 16x26, W 24x55, and W 10x68 respectively) build the frame of each 30' x 30' bay. Beams are spaced at 10'. This system is typically called composite beam decking.

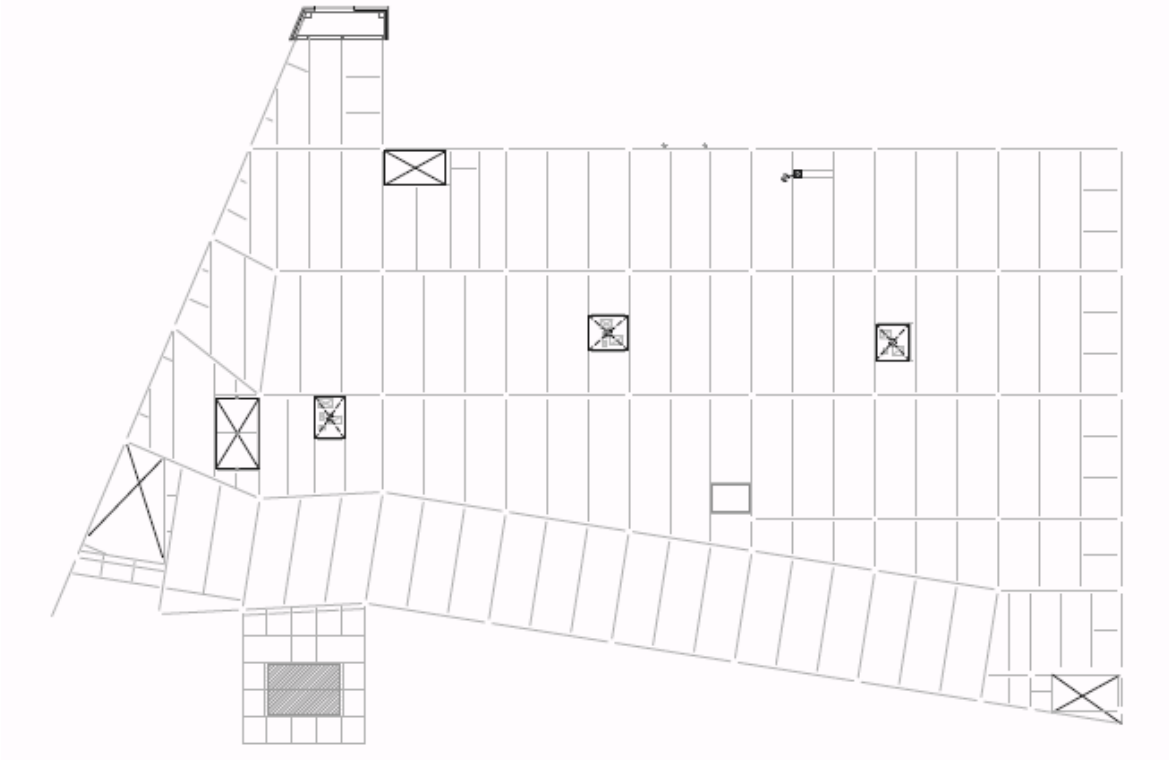




Typical Details of Composite Floor Deck Slabs

Overall, there are twenty-six (26) 30' x 30' bays within the first and second floors while other areas (south and west perimeters of the building) are not consistent with this bay size. The structural steel system designed for the building was initially chosen for two reasons: lightest floor system for the required fireproofing necessary and to have the least amount of vibrations for the medical equipment in building.

View from first floor of structural bays during construction.

With Alexander Building Construction's concrete division alongside Centre Concrete Company completing the concrete work, Altoona Pipe and Steel Supply, Inc. provided the structural steel for the project. Spray-on fireproofing for the elevator and stair shaft areas was completed by the fire protection subcontractor – Preferred Fire Protection.

Basic Second Floor Structural Drawing of current structural system design.

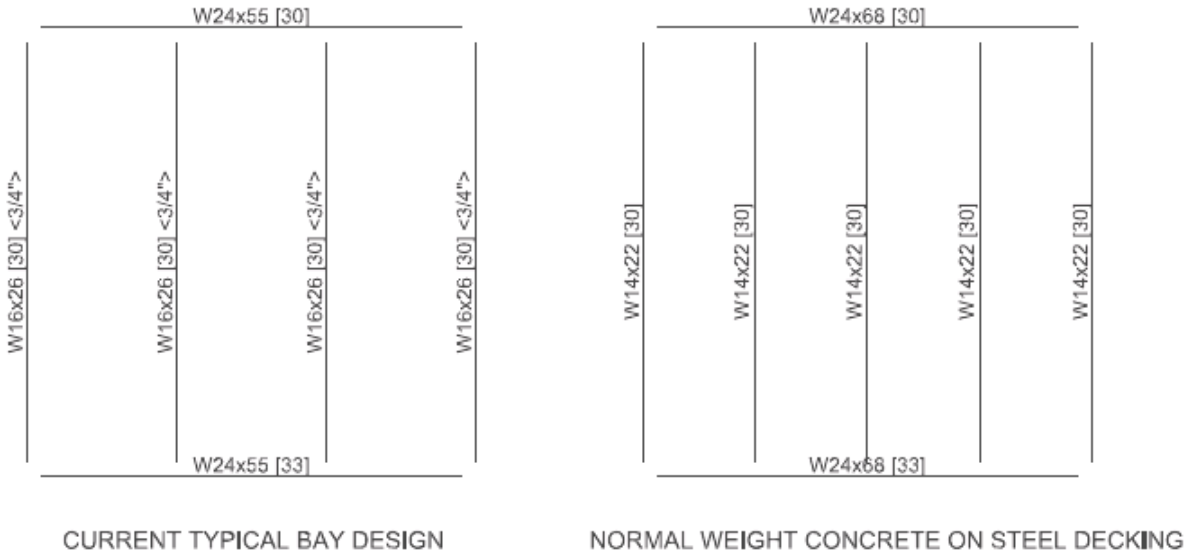
## *Structural Impacts:*

### *Lightweight Concrete to Normal Weight Concrete*

When redesigning the structural system to normal weight concrete, the typical bay size (30' x 30') was kept constant so it would not interfere with column spacing and interior architectural layouts. In order to have adequate fireproofing (only needed for the elevator, mechanical, and stairway shafts), the redesign includes a 4 ½" normal weight concrete slab on the same 2" LOK decking for the second floor and roof.

2" Composite LOK Decking


With a heavier concrete slab, beams will now be spaced at 7'-6" and will be W14x22s with the same shear connections. Additionally, girder sizes will increase to W24x68s for each typical bay. Steel column sizes also increase to W10x88.




Lightweight concrete and Normal Weight Concrete Typical Bay
Structural Drawings.

Changing the light weight concrete to normal weight concrete adds a beam (per bay) but the beam is slightly lighter now. Regardless, this comes out to be about ½ ton additional steel per bay and only about 3 more cubic yards of concrete. Steel connections would be the same for both systems.

| ***CURRENT DESIGN*** | Size | |
|---|---|---|
| LW Concrete | 3.5" | |
| Concrete Placing | < 6" thick | |
| Steel Decking | 2" LOK | |
| Steel Beams | W 16x26 | 3 |
| Steel Girders | W24x55 | 1 |
| Steel Columns | W10x68 | 2 |
| Fireproofing | | |

| ***NW CONCRETE*** | Size | |
|---|---|---|
| NW Concrete | 4.5" | |
| Concrete Placing | < 6" thick | |
| Steel Decking | 2" LOK | |
| Steel Beams | W14x22 | 4 |
| Steel Girders | W24x68 | 1 |
| Steel Columns | W10x88 | 2 |
| Fireproofing | | |

Light weight concrete and normal weight concrete composite beam system comparisons for a typical 30' x 30' bay.

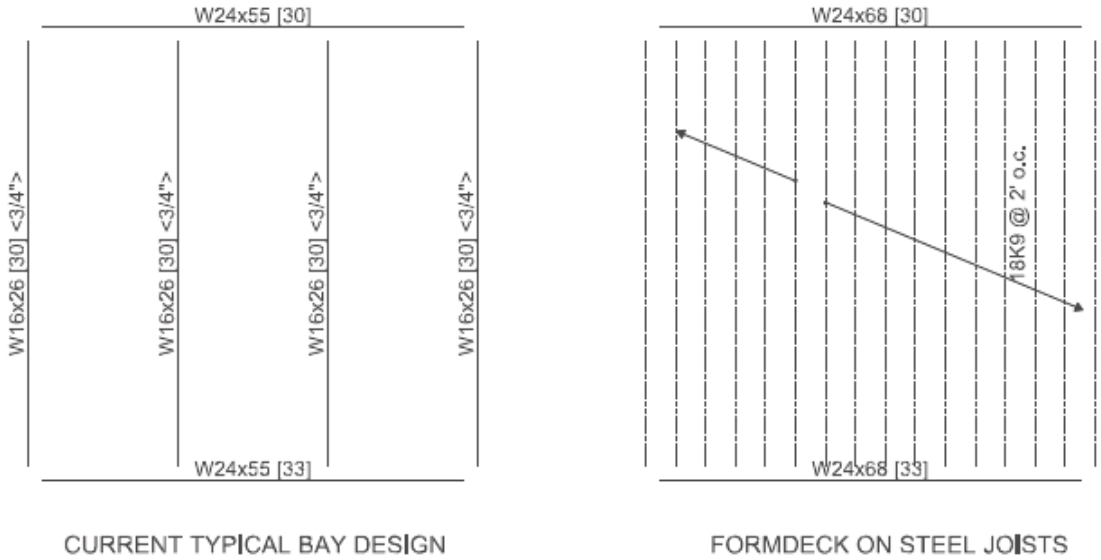

*Composite Beam Decking to Form Decking*

Similar to the last analysis, the bay size was also kept constant for the form decking analysis so to not interfere with the column spacing and interior architectural layouts. With a redesign of 3" normal weight concrete on 9/16" form decking for the second floor and roof slabs, spray-on fireproofing is still only prescribed for the elevator, mechanical, and stairway shafts.

9/16" Form Deck

Typically form deck systems include structural steel joists and joist girders. For the typical 30' x 30' bay of Gray's Woods Medical Office, 18K9 joists spaced at 3' on center will be used with W24x76 steel girders. Steel column sizes also increase to W10x88.

Form deck is the common name of deck products that are mainly used as stay-in-place forms for structural concrete slabs. The deck can act as a diaphragm both with and without concrete and provides resistance to lateral loads caused by wind or earthquake.




Composite Decking and Form Decking Typical Bay Structural Drawings.

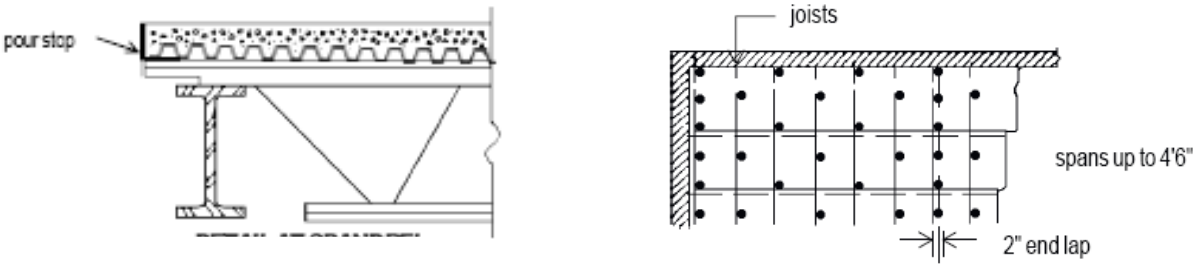

When using the form deck and joist option, steel girders are slightly heavier because the girders can no longer be composite girders. The three rooftop air handling units will now need to sit on steel dunnage for more support. Another design issue would be that the form deck and joist system may cause design problems for the atypical bays on the south and west perimeters, although it is capable of being done. As mentioned earlier, on the south and west perimeter of the building, the building geometry and grid becomes complicated. For the form deck option, about a ½ ton of steel is added to each bay but the amount of concrete needed is reduced by 3 cubic yards.

| ***CURRENT DESIGN*** | Size | |
|---|---|---|
| LW Concrete | 3.5" | |
| Concrete Placing | < 6" thick | |
| Steel Decking | 2" LOK | |
| Steel Beams | W 16x26 | 3 |
| Steel Girders | W24x55 | 1 |
| Steel Columns | W10x68 | 2 |
| Fireproofing | | |

| ***FORMDECK*** | Size | |
|---|---|---|
| NW Concrete | 3" | |
| Concrete Placing | < 6" thick | |
| Steel Decking | 9/6" FD | |
| Steel Joists | 18K9 | 10 |
| Steel Girders | W24x76 | 1 |
| Steel Columns | W10x88 | 2 |
| Steel Dunnage | | |
| Fireproofing | | |

Composite beam decking and form decking comparisons for a typical 30' x 30' bay.

Connection details and welding patterns will be slightly different with the form deck option due to the decking being different and the use of steel joists.




Typical Details of Form Deck Slabs.

## *Cost Analysis:*

There are many different components considered for the structural system budget. For this analysis, the following areas were taken into account: concrete material and placement, all structural steel (including connections), and fireproofing.


All concrete material costs were obtained from Centre Concrete Company with concrete placement from RSMeans 2007. United Steel Decking Inc. supplied the decking prices, while all steel W-shapes and joists prices are from RSMeans 2007 and Altoona Pipe and Steel Supply (steel subcontractor on project). The project manager from Alexander Building Construction supplied the fireproofing costs.

The current design of the building costs a little over $13,300 per 30' x 30' typical bay. Below is a Microsoft Excel spreadsheet of the current structural system. Prices include the cost of labor.

Table 1: 2" Decking with Lightweight Concrete (Current Design of Building)

| 2" Decking with LW Concrete | | | | | | |
|---|---|---|---|---|---|---|
| | Size | | Amount | | Cost | Total |
| LW Concrete | 3.5" | | 12.5 | CY | 142 /CY | 1,775 |
| Concrete Placing | < 6" thick | | 12.5 | CY | 29 /CY | 363 |
| Steel Decking | 2" LOK | | 0.09 | 100 Sq | 16,000 /100 Sq | 1,440 |
| Steel Beams | W 16x26 | 3 | 30 | Ft | 40.5 /Ft | 3,645 |
| Steel Girders | W24x55 | 1 | 30 | Ft | 88 /Ft | 2,640 |
| Steel Columns | W10x68 | 2 | 15 | Ft | 103.23 /Ft | 3,097 |
| Fireproofing | | | 900 | SF | 0.47 /SF | 423 |
| | | | | | PRICE | ***$13,382*** |

With the redesign of lightweight concrete to normal weight concrete, the price per typical bay increased greatly. For a normal weight concrete system, a typical bay costs about $14,700. Below is a table of the normal weight concrete system costs. Prices again include the cost of labor.

Table 2: 2" Decking with Normal Weight Concrete

| 2" Decking with Normal Weight Concrete | | | | | | |
|---|---|---|---|---|---|---|
| | Size | | Amount | | Cost | Total |
| NW Concrete | 4.5" | | 15.3 | CY | 97 /CY | 1,484 |
| Concrete Placing | < 6" thick | | 15.3 | CY | 29 /CY | 444 |
| Steel Decking | 2" LOK | | 0.09 | 100 Sq | 16,000 /100 Sq | 1,440 |
| Steel Beams | W14x22 | 4 | 30 | Ft | 35 /Ft | 4,200 |
| Steel Girders | W24x68 | 1 | 30 | Ft | 97 /Ft | 2,910 |
| Steel Columns | W10x88 | 2 | 15 | Ft | 127 /Ft | 3,810 |
| Fireproofing | | | 900 | SF | 0.47 /SF | 423 |
| | | | | | PRICE | ***$14,711*** |


Redesigning the system to a form deck system, however, results in a slight decrease of cost per typical bay. For a form deck system, a typical bay costs just over $12,700. Additional costs for steel dunnage were added for the typical bay, but would only actually be used on the roof slabs (half of the typical bays). Prices also include the cost of labor. Below is a table of the form deck systems typical 30' x 30' bay.

Table 3: 9/16" Form Decking with Normal Weight Concrete

| 9/16" Formdecking w/ NW Concrete | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Size | | Amount | | Cost | | Total |
| NW Concrete | 3" | | 8.3 | CY | 97 | /CY | 805 |
| Concrete Placing | < 6" thick | | 8.3 | CY | 29 | /CY | 241 |
| Steel Decking | 9/6" FD | | 0.090 | 100 Sq | 9500 | /100 Sq | 855 |
| Steel Joists | 18K9 | 10 | 30 | Ft | 229 | /Ea | 2,290 |
| Steel Girders | W24x76 | 1 | 30 | Ft | 108 | /Ft | 3,240 |
| Steel Columns | W10x88 | 2 | 15 | Ft | 127 | /Ft | 3,810 |
| Steel Dunnage | | | 900 | SF | 1.2 | /SF | 1,080 |
| Fireproofing | | | 900 | SF | 0.47 | /SF | 423 |
| | | | | | | PRICE | ***$12,744*** |

To compare all systems equally, each systems typical bay cost has been multiplied by 26 (the amount of typical bays in the building). The remaining areas (south and west perimeter) that have not been included would have effects on the complete cost of the system. For this analysis, these additional areas have been assumed to have the same price for each system. Below is a table of the cost of each system for all of the typical bays with the difference of cost from the current design. The difference was found by subtracting the current systems cost from the proposed systems cost.

Table 4: 2" Decking with Lightweight Concrete (Current Design of Building)

| System | Cost | Difference |
|---|---|---|
| 2"Decking with LW Concrete - *Current Design* | $347,942 | - |
| 2" Decking with NW Concrete | $382,481 | $34,538 |
| 9/16" Form Decking with NW Concrete | $331,339 | -$16,604 |

As seen in the table above, by changing the light weight concrete to normal weight concrete it results in a more expensive structural system – about $34,500 more. Although the concrete costs of this system are less than the current design, the fact that you need about ½ ton more steel per bay greatly increases the systems costs.


Also developed from the table above, by changing the composite decking to form decking, the cost of the structural system was only slightly lower – about $16,600 less. With the concrete slabs for this system being cheaper and the costs of joist systems being less than steel beams, the typical bays of a form deck system cost less than composite decking. However, when looking at the areas not included in the analysis, having a complicated grid that does not comply with a joist construction, these savings may be lost to accommodate a more complicated design.

## *Conclusions and Recommendations:*

Redesigning the structural system with normal weight concrete does not result in any costs savings for the project. However, by using the form deck system, a small savings can be gained. So as there is no visible difference to the exterior and interior finishes, the form deck option should be used for the typical bays (to gain savings) and the other area should be designed using the composite beam and decking option. Therefore the calculations conclude that by using both the form deck and composite decking designs together, the project can save over $16,000 to either be returned to the owner or used in another design area of the building.

Negligible time would be added to the project regarding the structural portion. However, with the formdeck system with floor joists, additional time may be added during the overhead MEP installation for additional coordination due to the reduced plenum space.