Lancaster County Bible Church

Manheim, Pennsylvania

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Executive summary

This proposal includes encompasses a redesign of the gravity system of Lancaster County Bible Church. The existing open-web steel joist floor framing system will be replaced by composite steel on metal deck design. While the steel framing will remain it will be redesigned using the LRFD design method. Existing foundations should not be affected due to the minimal impact of the redesign. However, all footings will be checked for their ability to resist column loads. Cross-bracing in the later system will be redesigned using the new loads but the existing lateral system layout will remain.

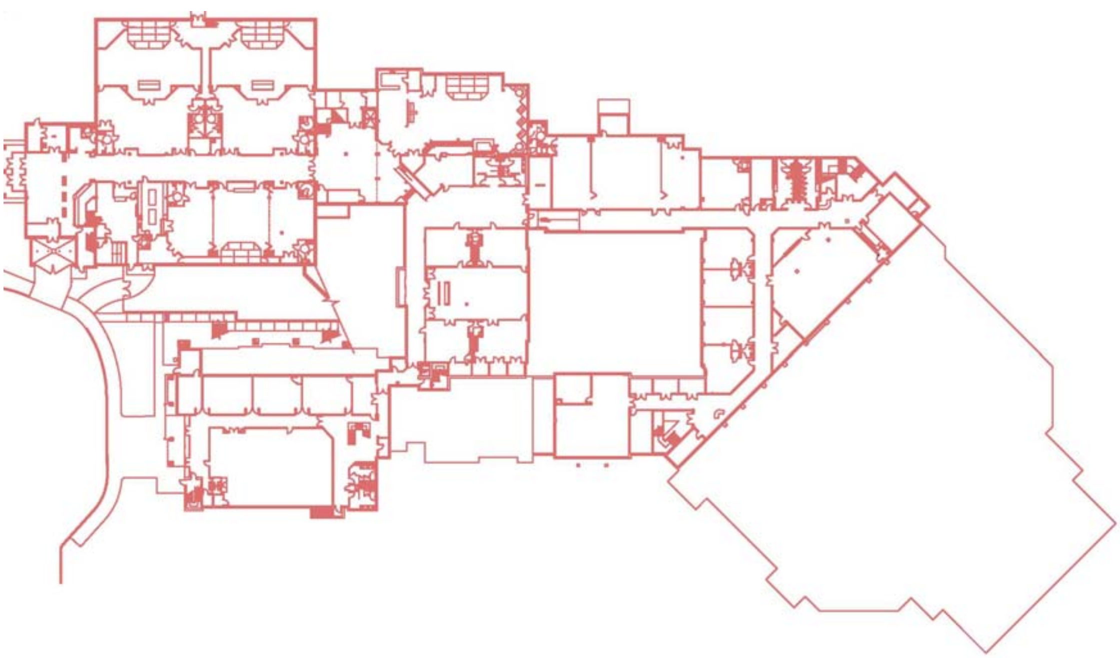
Two breadth studies will be performed. The first of the two breadth studies will explore the architectural impact the new floor framing system has on the ceiling. Possible alternative ceiling systems will be selected and compared. Lastly, a new ceiling system will be chosen to replace the existing ceiling system. The second breadth topic will explore the impact that the proposed structural system has on cost and the construction schedule. Original construction schedules and cost estimates will need to be obtained and analyzed. A cost estimate and construction schedule will be developed for the proposed structural system. Then a comparison will be made between the existing structural system and the proposed structural system.

Introduction

LCBC (Lancaster County Bible Church) needed to expand its existing facility to accommodate the increased number of guests at it Sunday mass. The new expansion to LCBC would be focused towards the youth population and would include classrooms and youth performance areas. A three story, 78,000 square foot addition was designed by Mann Hughes Architecture. Construction began May 2008.

The new addition comprises three levels of multi-functional space. On the 100-level of the addition there is a large classroom and arcade areas for the younger children. Office spaces for the church's staff are the focus of the 200-level with executive offices for the pastor. In order to accommodate the needs of the adolescent population of LCBC a large performance and lounge area are provided on the 300 level. The 100-level, 200-level, and 300-level enjoy a 14'-0", 14'-0", and 15'-4" story height respectively. Total above grade height is 48'-0" to the top of the addition's parapet.

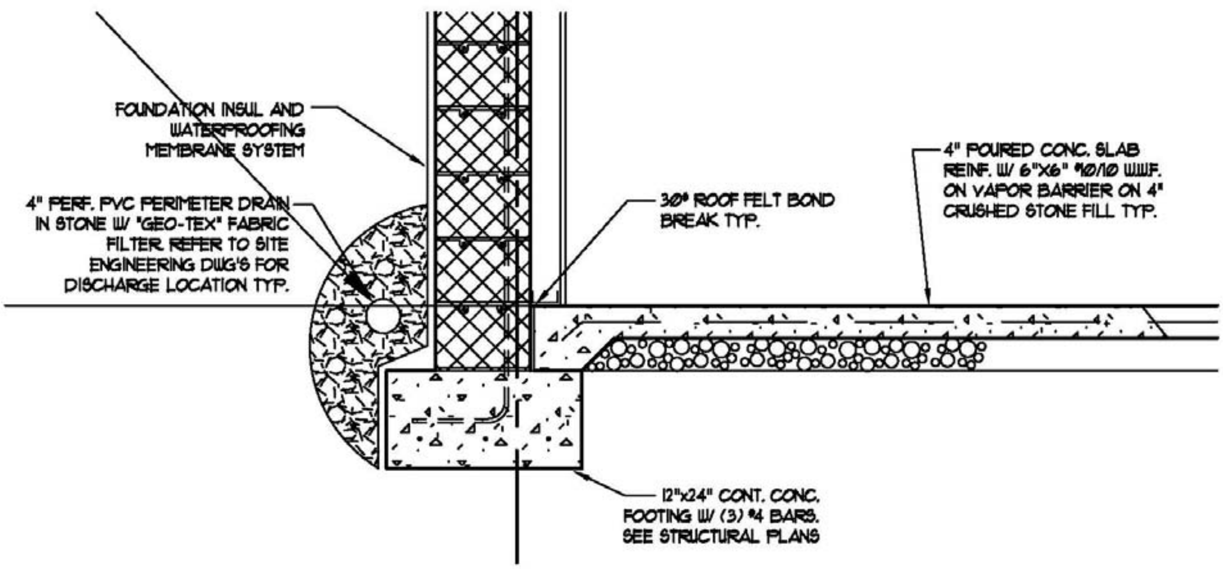
Land was not a restrictive component when the design of LCBC was made. Therefore the design of LCBC is a low profile sprawling structure with 100-level exhibiting a building footprint of 28,000 square feet. Successive levels step back from the 100-level's initial footprint giving the building its unique shape. Stucco panels were chosen as the exterior finish for the addition to complement the existing facilities façade.



100-Level Layout

Foundations

Various sized spread footings were designed to support column loads at LCBC. An F20, 2’x2’x12”, is the smallest spread footing found at LCBC. Reinforcing for an F20 footing is provided by (3) #4 bars in each direction. Interior columns require the largest spread footing and exhibit F110’s, 11’x11’x2’. Reinforcing for F110 is provided by (18) #7 bars in each direction. Typically spread footings are square however there are two rectangular footings, F 70x90 and F50x60. Load bearing masonry walls are supported by continuous spread footings that measure 24”x12”. Horizontal reinforcing for the continuous footings is provided by (3) #4 bars. Vertical reinforcing is provided by #6 dowels with 4” hooks @ 8” O.C.



Typical Foundation Detail

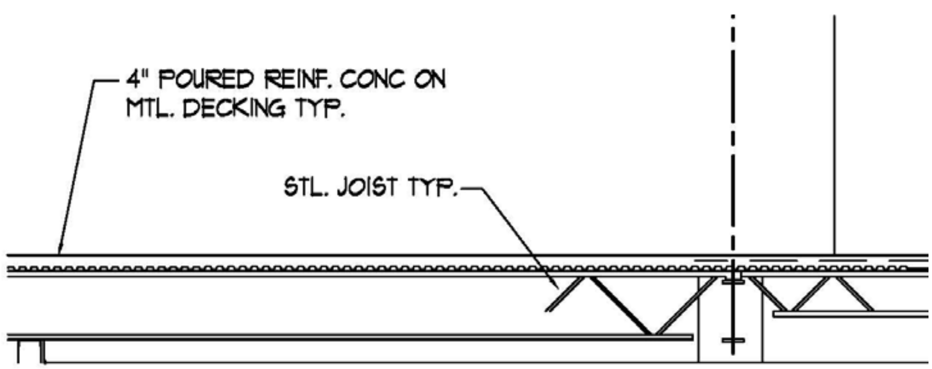
Flooring System

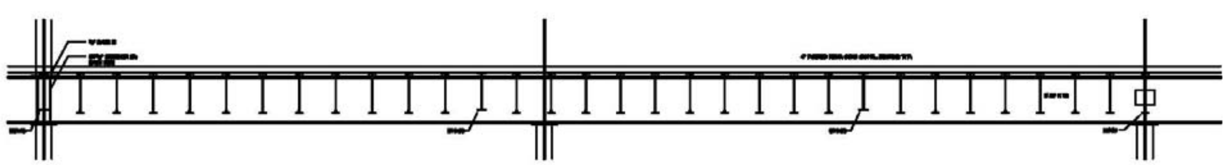
Reinforced concrete on metal decking was selected as the primary flooring system for LCBC. A 4" concrete slab is reinforced with 6x6 10/10 welded wire mesh. 1 ½", 26 gauge metal deck provides additional strength for the concrete deck. This one-way floor system transfers gravity loads to supporting girders and columns. Concrete used be 3,000 psi strength.

The typical bay size at LCBC is 38'-4" x 25'-0", however bay sizes vary to reflect the multi-functional nature of the building. On the 200-level floor framing the smallest bay size is 10'-9" x 16'-10" while the largest bay is 65'-0" x 38'-8". The 300-hundred level roof framing is dominated by a massive 67'-0"x 63'-4" frame which provides a large open space required for the performance area below.

Framing for the flooring is provided by various open web steel joists. Longer spans at LCBC, typically 38'-4", demand 26K9 or 26K10 open web steel joists. Shorter spans, typically 18'-25', are typically supported by 18K4 open web steel joists. The lightest open web steel joist is an 8K1. In contrast the long spans located in the roof framing implement a 36LH12.

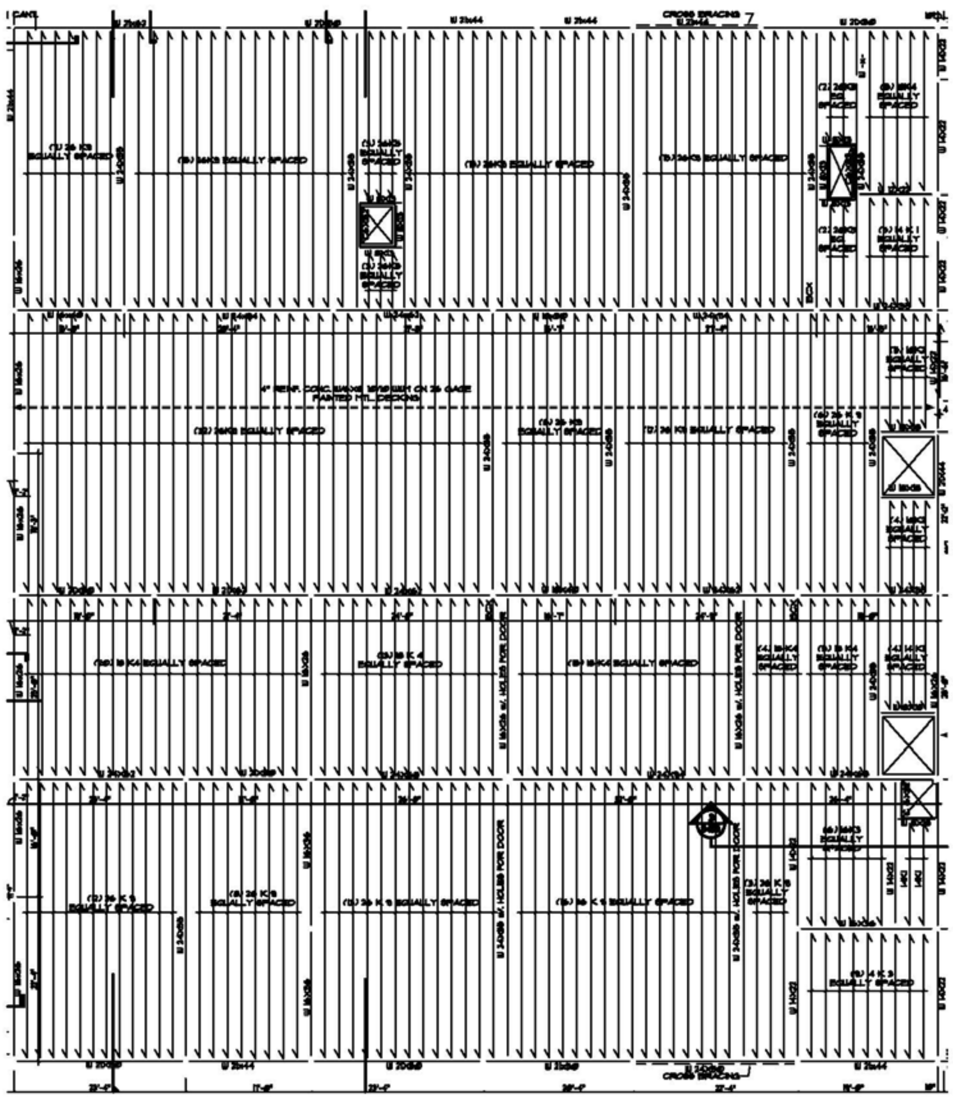
The 100-level flooring system is a slab on grade system. A 4" thick concrete slab is poured over a 6mm polyurethane vapor barrier. Underneath the vapor barrier on 4" of crushed stone on compacted earth.





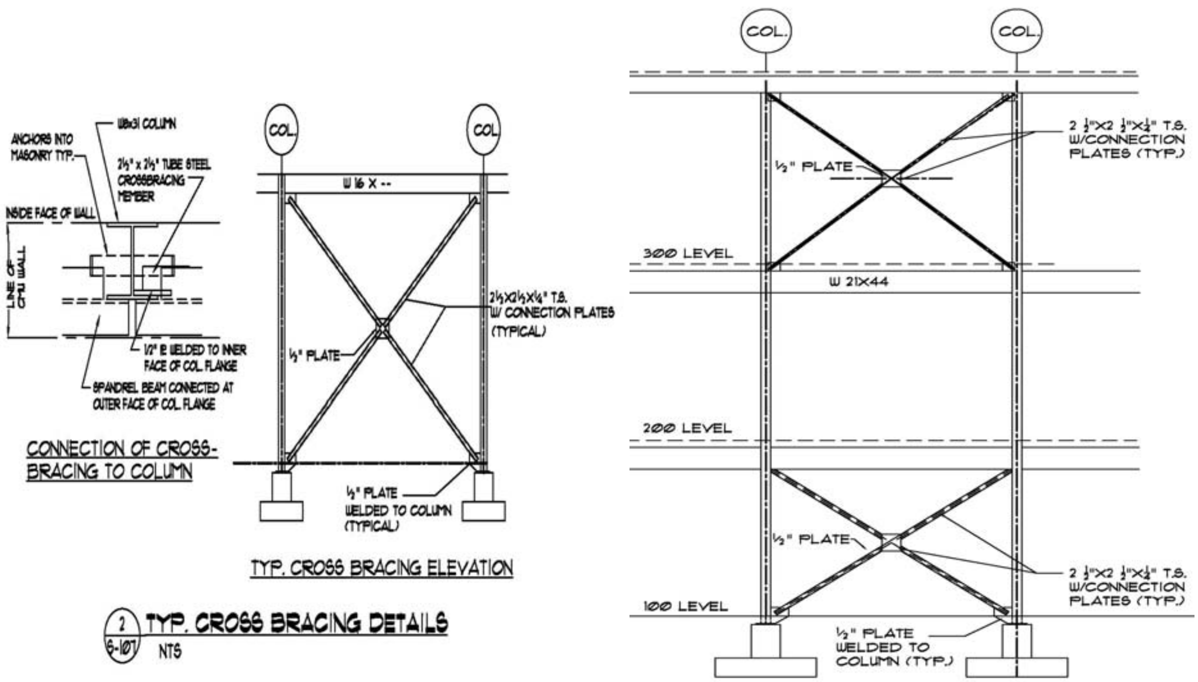
Gravity System

Gravity loads at LCBC are resisted by a simple steel framing system. The majority of the columns are W-shaped with the exception of a few HSS 4x4x3/8 columns. Typically columns will start 7" below grade and continue to the roof level. There are a few columns that start on the 200-level but they are the minority. Column sizes vary depending on how many floors the column supports and if they are interior or perimeter columns. A W10x60 is the heaviest column at LCBC and a W8x31 is the lightest. Beams and girders are W-shaped and range from a W12x16 to a W30x99.

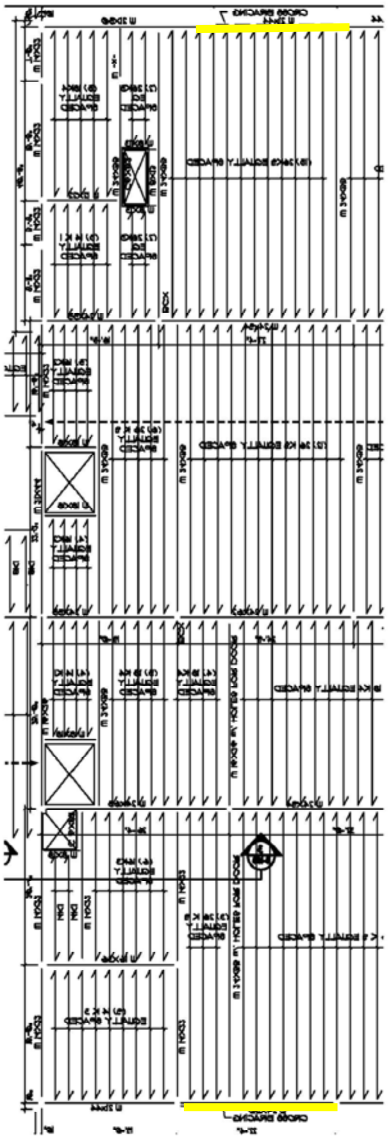


Lateral System

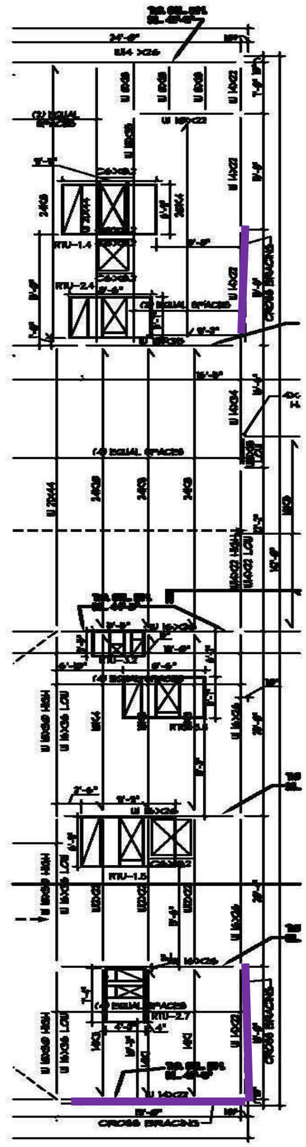
Lateral loads at LCBC are resisted by 5 braced frames. These 5 frames are all located on the perimeter column lines. The placement of the braced frames varies but is concentrated in the Southeast corner. Bracing is accomplished by welding (2) ½” steel plate to base of the column and (2) ½” steel plates the top of the same column. Then 2 ½” x 2 ½” tubular steel is welded to the steel plates in a cross arrangement. Lastly, a piece of ½” steel plate connects the cross bracing in the middle by means of welding.



Typical Cross-Bracing Detail



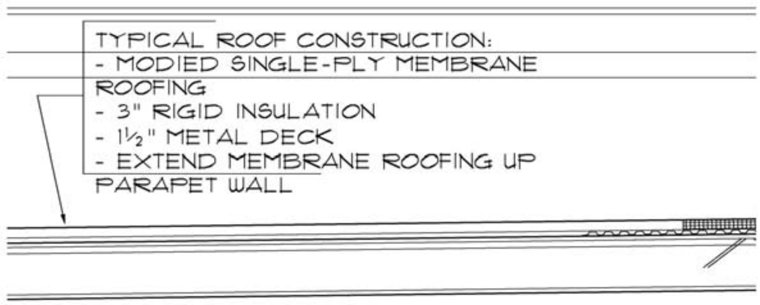
Cross-Bracing Layout 100-Level



Cross-Bracing Layout 300-Level

Roofing

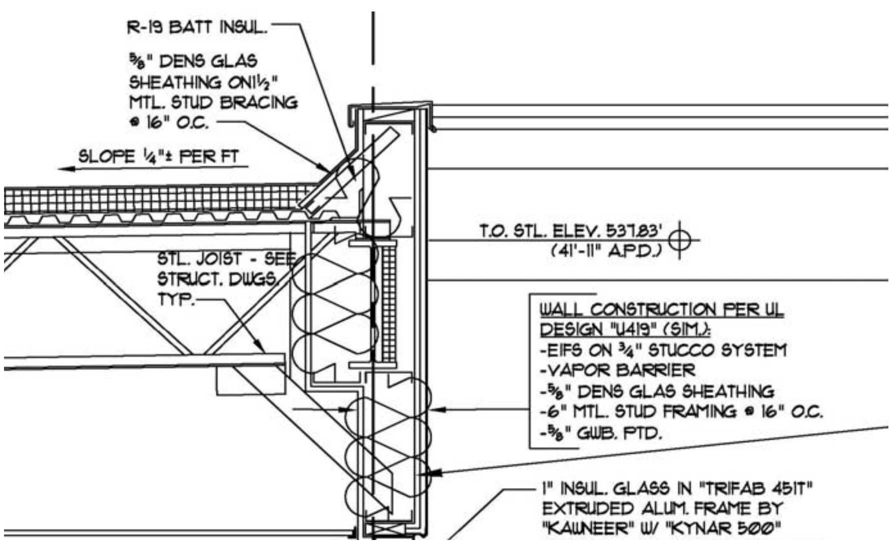
Two different flat roofing systems are implemented at Lancaster County Bible Church. The first flat roof system uses three-inch rigid insulation supported by 1 ½” metal decking. A single ply roofing membrane provides moisture protection. Tectum “E” structural roofing panels are used above the youth performance area. The panels are 6-inces thick and are constructed of: OSB sheathing, EPS insulation, and substrate.



Typical Roof Construction Detail

Building Envelope

The predominate façade of Lancaster County Bible Church is stucco. A ¾”prefabricated stucco panel called EIFS is installed on top of 5/8” dense glass. A vapor barrier provides moisture protection. 6” metal studs placed 16” on center provide support for the building’s façade. R-19 batt insulation provides thermal resistance for the wall construction. Gypsum board is used for the interior finish.



Typical Wall Section

Codes:

Building Code
IBC 2003

Structural Steel
AISC Specification for Structural Steel Buildings
AISC Manual of Steel Construction – Allowable Stress Design, 9th Addition
Vulcraft Steel Joist and Steel Girders 2003

Concrete
ACI Details and Detailing of Concrete Reinforcement, ACI 315
ACI Manual of Engineering and Placing Drawings for Reinforced Concrete Structures, ACI 315R

Design Loads
International Building Code 2000
American Society of Civil Engineers (ASCE), ASC- 7

Gravity Loads (Dead & Live Loads):

Live Loads	
Area	Design Load (psf)
Corridor	100
Office	100
Stairs	60
Storage Rooms	80
Roof	30
Dead Loads	
Description	Design Load (psf)
Floor Dead Load	50
Partitions	20
Framing	8
Ceilings	3
Mechanical Ductwork	3

Problem Statement

The existing flooring structural system at Lancaster County Bible Church consists of a 4” concrete floor on 1 ½” metal deck. Floor framing consists of open web steel joist typically sized at 26K9. Five braced frames on the perimeter of the structure resist lateral forces and keep the structures deflections within code limits. Lancaster County Bible Church is located in Manheim Pennsylvania where the primary building method is steel frame construction. Therefore, a structural redesign of the gravity, flooring, and lateral system will be done using steel frame construction.

Proposed Solution

Alternative flooring systems were studied in-depth during Technical Report 2 resulting in no clear beneficial alternative. However, the structural engineer designed the gravity system using ASD (Allowable Strength Design). LRFD (Load and Resistance Factor Design) is a more efficient design method. Redesigning the gravity system using the LRFD design method will yield a more efficient system. A composite flooring system will be designed for each level of the structure. The composite flooring system utilizes the strength of the concrete floor slab producing a flooring system that rivals the efficiency of the existing flooring system. Additionally, all beams, columns, and girders will need to be redesigned according to the LRFD design method. The result of this redesign will be a simplified structural system that should not affect existing foundations while being more efficient than the existing gravity system.

Solution Method

A preliminary slab thickness will need to be determined using design guides provided by a steel decking manufacturer. Once the most efficient slab thickness is determined with respect to serviceability, vibration control, cost, and strength requirements the design of the floor framing will begin. Beam spacing for the floor framing will be determined based upon the preliminary slab thickness. Floor framing must resist gravity loads while maintaining original spans. Girders will then be designed to support the new floor beam loads. A computer model will be generated with Staad Pro.2007 using existing column sizes and new floor framing system. All pertinent forces will then be applied to the computer model to determine floor loads. After calculating floor loads columns will be designed to support these loads. Foundations will then be checked for their ability to resist column loads. The existing lateral system layout will remain. However, new cross-bracing will be designed to resist lateral loads.

Breadth Topics

Changing the floor framing affects the ceiling which is a major architectural feature. The open web steel joists at Lancaster County Bible Church are exposed structural elements providing a unique industrial look. Replacing the steel joist with structural steel will impact the appearance of the ceiling. A study will be done on possible ceiling alternatives. After a comparison a new ceiling system will be selected from the possible alternatives.

The new structural layout designed using LRFD and utilizing a composite flooring system will impact the construction schedule and cost. An analysis of the changes to construction schedule and cost will be performed. Upon completion of this analysis the impact of cost and scheduling will be compared and contrasted to the existing construction schedule.

Tasks

1. Design of Composite Steel on Metal Deck
   a.) Determine most efficient floor beam spacing
   b.) Determine slab thickness from metal decking manufactures
   c.) Determine number of shear studs needed for full composite action

2. Design of Floor Framing
   a.) Apply floor loads to determine maximum moment in floor beams
   b.) Select appropriately sized steel member from Steel Manual
   c.) Apply floor beam loads to girders to determine maximum moment
   d.) Select appropriately sized steel member from Steel Manual
   e.) Check deflections

3. Generate Computer Model
   a.) Model new floor framing
   b.) Use existing column layout as a preliminary column lay to determine column forces
   c.) Apply building loads using the appropriate load combination

4. Foundation Design
   a.) Apply forces generated by the computer to foundations
   b.) Check foundations for shear capacity
   c.) Resize foundation system

5. Lateral System
   a.) Use existing lateral system layout
   b.) Select cross-bracing member using forces from computer model
   c.) Check later system deflection

Breadth Topics

1. Architecture (Ceiling System)
   a.) Locate a case study building that exhibits composite steel on metal deck
   b.) Find alternative ceiling systems
   c.) Compare and contrast ceiling system alternatives
   d.) Select best alternative

2. Construction (Scheduling and Cost Analysis)
   a.) Obtain existing structure's steel package estimate and schedule
   b.) Generate estimate and schedule for alternative design
   c.) Pro/Con study of existing system versus alternative design

Schedule

Tasks	Jan 11 - 15	Jan 18 - 22	Jan 25 - 29	Feb 1 - 5	Feb 8 - 12	Feb 15 - 19	Feb 22 - 26
Slab Design							
Det. Floor Beam Spacing							
Det. Floor Slab Thickness							
Det. # Shear studs							
Floor Framing							
Find Max. Moment Floor Beams							
Select Appropriate Member							
Find Max Moment Floor Girders							
Check Floor Framing Deflections							
Breadth Studies		Locate a case study building that exhibits composite steel on metal deck					
		Obtain existing structure's steel package estimate and schedule					

Tasks	Mar 1 -5	Mar 8 -12	Mar 15 - 19	Mar 22 - 26	Mar 29 - Apr 2	Apr 5 - 9	Apr 12 - 16
Generate Computer Model							
Model New Floor Framing							
Model Existing Column Layout							
Apply Loads							
Foundation Design							
Apply Computer Forces							
Check Shear Capacity							
Resize Foundations if Necessary							
Lateral System							
Keep Existing Layout and Apply Loads							
Select Cross-Bracing Members							
Check Deflections							
Breadth Studies	Find alternative ceiling systems						
		Compare and contrast ceiling system alternatives					
			Generate estimate and schedule for alternative design				
						Pro/Con study of existing system versus alternative design	

Conclusion

Through computer modeling and various hand calculations the gravity system of Lancaster County Bible Church will be redesigned. Architectural impacts will be minimized by retaining the existing bay sizes and column layout. Additional breadth topics will explore the proposed structural redesigns impact to cost and construction scheduling.