Matthew Haapala

PSU AE Structural Option

Foreman Field Game Day Building

Norfolk, VA

Thesis Proposal

1/19/2008

Consultant: Prof. Hanagan

Table of Contents

Executive Summary

The Foreman Field Game Day Building is a new four story reinforced concrete stadium complex. It is located at the south end-zone of Old Dominion University's existing football field in Norfolk, VA. It houses primarily luxury boxes, training and support facilities, and some bleacher seats. The Game Day Building is approximately 55,000 square feet and 50 feet tall. The existing gravity system is 12" flat plate slabs supported on 18"x18" concrete columns. The lateral system is composed of seven cast-in-place concrete shear walls. The foundation is provided by nearly 200 precast concrete friction piles driven to a depth of 100'.

This thesis study will focus on redesigns of the Game Day Building's existing gravity and lateral systems and the resulting impacts on the foundation system requirements. The floor system will be redesigned as a one way slab system supported on post tensioned beams. Analysis of a typical bay indicates that such as system will optimize the use of materials reducing the building's weight. The lateral system will be redesigned using concrete moment frame system. The existing shear walls will be eliminated if possible. The effects on the foundation of the change in dead load of the gravity system and forces distribution in the lateral system will be studied in detail.

A detailed study of the cost and schedule impacts of the redesigned systems will be performed as a breadth. Special attention will be paid to finishing by the current completion deadline. Current Industry information and RSMeans data will be used to complete this study.

A second breadth study will focus on upgrading the lighting system in typical enclosed areas. The lighting systems in the scholarship lounge and a typical luxury box will be redesigned to create a more luxurious abeyance while still adhering to IES, ASHRAE, and owner RFP requirements.

Background

Introduction

The Foreman Field Game Day Building is Old Dominion University's new stadium facility in Norfolk Virginia. It is a four story 55,000 sq-ft reinforced concrete building with a curved plan and cantilevered seating. The Game Day Building is intended to be an iconic addition to the existing stands. Currently under construction the building is scheduled to be completed at the end of summer 2009 in time for ODU's first football season in nearly 70 years. It houses primarily luxury boxes, training and support facilities, and bleacher seats. The estimated cost of the project is approximately $11.9 million. The site is zoned as an Institutional Campus District which does not impose any notable occupancy or construction limits. The project is being built under a Design-Build contract between Old Dominion University and a collaboration of Ellerbe Becket Architects, Clark Nexsen Engineers, and S.B. Ballard Construction Company.

Building Envelope

The majority of the façade is clad in brick masonry with cast stone trim. Additionally there are portions clad in cast stone masonry, storefront glazing systems with anodized aluminum framing, painted metal railings, and cast in place concrete with a rubbed finish. The south face of the building is accentuated by five one story and one three story entry archway clad in cast in stone masonry adorned with two aluminum flag polls. The north façade is distinguished by the cantilevered balconies with seating, large areas of glass curtain wall, and a scoreboard. The roofing system is provided by a 12" concrete slab topped with single-ply EPDM membrane over cover board and roof insulation.

Foundations

Forman Field Game Day Building rests primarily on square precast prestressed concrete (SPPC) piles. The subsurface soil conditions across the site are a combination of wet sands and clays down to a depth of 110 ft. The soil conditions necessitate a deep foundation of friction type piles to achieve required bearing capacities. A total of 199 (SPPC) piles, all 12" wide and 100' long from tip to cutoff, are located below columns and shear walls in groups of one to 18. Individual piles have capacities of 85 tons in axial compression, 40 tons in axial tension and 5 tons in lateral resistance. The piles are topped with 36" to 40" deep pile caps. A half wall on the east side of the ground floor is supported by spread footings designed to bear on soil with an allowable bearing pressure of 1500 psf at least 18" below grade.

Gravity System

The Game Day Building's typical floor system is a 12" deep reinforced concrete flat plate slab. #5 reinforcing spaced between 3.5" to 12" on center both top and bottom is used to reinforce the flat plate slab. A typical bay size is 31'-6" by 17'-0". In plan a majority of the building is a shallow curve with column lines being radial spokes in the short direction and curves at set radii in the long direction. This leads to many bays not being exactly rectangular. Embedded three foot long shear rails in both directions at every column corner except along the slab edges provide additional shear capacity to combat punching shear. The slabs are held up by the columns and load bearing walls. Columns are typically 16"x16", with eight #7 vertical bars and #3 ties at 12" on center. Most of the roof is also 12" concrete flat plate with typical reinforcement. The first floor is a slab on grade. Some atypical areas are the bleacher seating area and the kitchen roof. The stepped down seating area on the north side of the second floor is supported by 14"x19" to 36"x21"concrete beams and sloped girders. The kitchen roof is supported by cold formed steel framing.

Typical Floor Framing Plan

Figure 1

Columns and Shear Walls are in Red

Lateral System

Seven, building height, reinforced concrete shear walls are designed to provide the building's lateral stiffness. They are reinforced with two curtains of #5 rebar at 12" on center for shear resistance. Flexural reinforcement is provided by 2 #6 to 7 #9 vertical rebar varying between walls and decreasing with height within a wall. No boundary elements were used in the shear wall flexural design. Additional vertical, horizontal, and diagonal rebar is located surrounding openings cut through the shear walls for M.E.P ducts and doorways. The Game Day Building is designed so that lateral loads flow from the façade into the 12" slabs on every floor which act as rigid diaphragms distributing the load amongst the seven shear walls based on relative stiffness. The shear walls all rest directly on pile caps or grade beams between pile caps. Several piles per shear wall are 'tension piles' with broom ends of prestressing strands extending into the pile caps allowing them to take tension load and resist overturning moment. The lateral stiffness inherently present in the frame formed by the columns and slabs was neglected in the design of the buildings lateral system.

Problem Statement

The current design of the Game Day Building utilizes 12" deep flat plate reinforced concrete floor slabs on all elevated floors including the roof. When considered in combination with the high live load of 100psf required by the building's function the 150psf dead loads of the 12" flat plates result in high gravity loading. These high gravity loads are very likely partially to blame for massive amount of 100' deep friction piles required for the foundation. Analysis performed in course of Tech Report 2 determined that because the aspect ratio of most bays approach or exceed 2:1 a two way flat plate is inherently not the most structurally efficient system.

Seven shear walls compose the Game Day Building's lateral system currently. Analysis preformed in Technical Report 3 found that the shear walls had significant excess capacity in resisting shear, flexure and deflection. The Stiffness of the equivalent moment frames created by the concrete columns and flat plate slabs was neglected in the design of the shear walls. They were neglected because they are relatively flexible compared to the shear walls and therefore take very little load. The shear wall system's excess capacity indicates decreasing the building stiffness is permissible. This indicates that the lateral system could be optimized.

Proposed Solution

Tech Report 2 indicated that a one way slab in the short direction supported by beams in the long direction could reduce the average slab depth and thus dead load significantly. In typical bays the use of one way slabs can reduce the slab depth to 8". To further minimize the dead load the supporting beams and possibly atypical bay slabs will be post tensioned when possible.

With the increase in moment frames' stiffness due to the addition of beams along column lines to support the one way slabs neglecting their stiffness in the lateral design would be a waste. Therefore the building lateral system will be re-designed utilizing moment frames only and eliminating the excessively stiff shear walls. The moment frame will be compared in structural performance and efficiency to the existing shear walls.

A breadth study on the cost and schedule ramifications of these redesigns will be performed. A second breadth investigation will focus on upgrading the lighting system in typical enclosed areas. A more in depth discussion of the breadth topics can be found in the Breadth Options section.

Solution Methods

The gravity and lateral systems will be designed in accordance with the requirements of the 2006 International Building Code and ASCE 7-05. The design of the new floor system will begin by laying out beam locations and span directions. Then the one way slabs will be initially designed with PCA Slab and checked with hand calculation methods. The superimposed gravity loadings will be determined by hand based on tributary area in accordance with the design values used in the initial design and ASCE 7-05 requirements. The self weight will be iteratively calculated assuming normal weight concrete. The post tensioned beams will be designed by a combination of hand calculations and RAM Concept analysis in accordance with ACI 318 and the PTI handbook and technical design notes. A RAM Concept finite element model will be used to determine initial beam sizes and tendon layout requirements. The design outputs will be checked and refined by hand calculations.

The lateral system redesign will be done with a 3D RAM Structural System model and verified by hand calculations and other software analysis as required. Wind loadings will be determined in accordance with ASCE 7-05 section 6.5 the analytic procedure. Seismic loadings will be determined in accordance with ASCE 7 -05 section 12.8, the equivalent lateral force procedure. IBC 2006 requirements for concrete moment frames incorporating post tensioned beams will be adhered to. An overall system analysis will be performed with RAM Frame to determine member loadings. These lateral loading member forces will be considered in conjunction with gravity loading forces to design the lateral system elements. The columns designs will be verified by a combination of hand calculations and PCA Column analysis. The beams designs will be verified by hand calculations. This process will be repeated until a system with satisfactory lateral performance is designed.

Once the gravity and lateral systems have been redesigned their foundation demands will be compared to those of the existing systems. Where significant differences are found the foundation system will be redesigned in accordance to ACI 318 using the soil conditions stated in the geotechnical report.

Breadth Options

As a breadth a detailed study of the cost and schedule impacts of the system redesigns will be performed. This study will include assemblies cost estimates and unit cost estimates of the original and redesigned structural systems. The costs will be based on actual supplier and vendor price quotes when available. RSMeans Assemblies and Building cost guides will be used when actual quotes are unavailable. The effects on the schedule of the redesigned systems will be determined with special attention paid to the completion deadline. Input from contractors and comparative case studies dealing with post tensioned concrete floor systems and concrete moment frames will be used to help determine the cost and schedule implications.

The choice to use a somewhat structurally inefficient concrete flat plate by the original designers was driven by constructability issues. Specifically the contractors desire for a flat slab to economize the forming of the slab system. The proposed one way slab system will require additional formwork and shoring and introduce post tensioning. This will clearly increase the construction cost and schedule requirements of the floor slabs by some extent.

A second breadth study will focus on upgrading the lighting system in typical enclosed areas. The Game Day Building designs were produced under a Design-Build project delivery method with a guaranteed max price. Therefore, the original designer's primary objective was to meet the minimum design standard in the cheapest way possible. A redesign of the lighting systems in the scholarship lounge and, time permitting, a typical luxury box will be performed. The goal of redesign will be to create a more luxurious abeyance while still adhering to IES, ASHRAE, and owner RFP requirements. AGI-32 or an equivalent program will be used to perform lighting calculations and create renderings. Control systems and electrical requirements will be addressed as well.

Tasks and Tools

I. Gravity System Redesign

1. Establish Trial Member Sizes
    a. Layout beams and determine slab directions
    b. Determine slab depth based on deflection span to depth ratios
    c. Determine Beam sizes based on typical PT beam span to depth ratios
2. Determine Floor Loads
    a. Find self weight based on trial member sizes
    b. Apply superimposed live and dead loads in accordance with existing design
    c. Calculate uplift wind loads in accordance with ASCE 7-05
3. One Way Slab Design
    a. Design the one way slabs with PCA Slab
    b. Check PCA slab, slab designs compliance with PT beam interaction requirements by hand calculations and with RAM Concept analysis as necessary
4. Gravity Beam Design
    a. Create a RAM Structural System model of the Game Day Building
    b. Import a RAM Concept finite element model of the floor system using the trial beam sizes and the designed one way slabs from the RAM Structural System model
    c. Analyze and refine the trial beam sizes in RAM Concept until a viable design is determined
    d. Analyze and refine the beam designs found in RAM Concept by hand considering PTI recommended design criteria

II. Lateral System Redesign

1. Establish Trial Member Sizes
    a. Layout beam and column combinations to be used as lateral moment frames.
    b. Set column and beam sizes to maximum required for gravity loading cases
2. Determine Lateral Loads
    a. Determine wind loading in accordance with ASCE 7-05 section 6.5
    b. Determine seismic loading in accordance with ASCE 7 -05 section 12.8
3. Model and Analyze the System
    a. Create a model of the lateral system in RAM, and Etabs if necessary, using the trial member sizes
    b. Apply the wind loadings at the center of pressure at each floor

c. Apply the seismic loadings at the center of mass at each floor
d. Analyze the lateral system in RAM FRAME, and possibly Etabs, assuming rigid diaphragms
e. Determine critical lateral loading per member with RAM or Etabs model
f. Asses the performance of the trial system and resize members as required

4. Integrate Lateral and Gravity Loading
    a. Determine critical combinations of lateral and gravity loadings on lateral system members
    b. Design columns with a combination of hand calculations and PCA Column
    c. Design the beams with a combination of hand calculations and RAM Concept

III. Foundation Analysis and Design

1. Compare redesigned and original buildings foundation requirements
2. Perform analysis and design as necessary to change foundation from original design

IV. Cost and Schedule Analysis

1. Research Cost and Schedule Information
2. Perform cost take offs of existing and redesigned structural and cladding systems using actual quotes and RSMeans cost guide data
3. Perform Schedule Impact analysis of the redesigned systems using Microsoft Project or Pimavera scheduling software

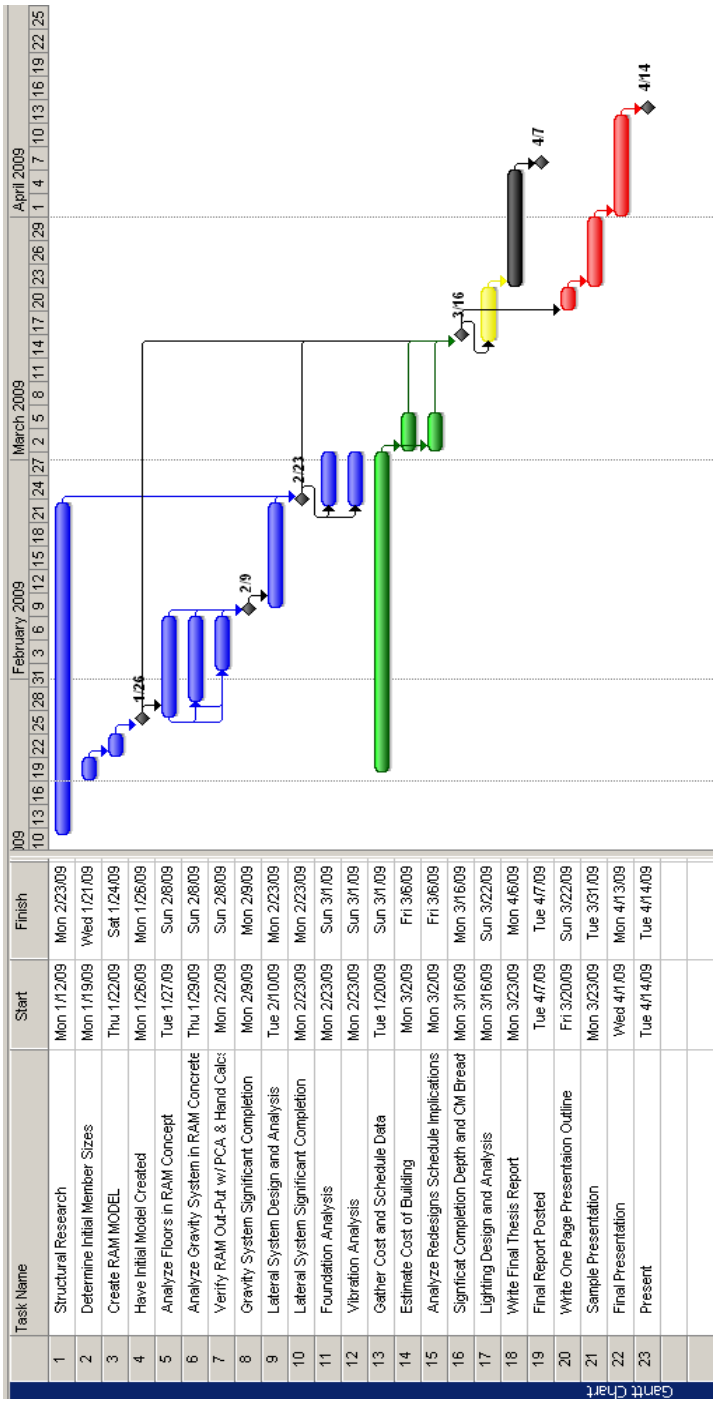
V. Lighting Redesign

1. Create AGI model of the scholarship lounge and luxury box
2. Select lamps, fixtures and control system
3. Generate renderings of before and after redesign
4. Check impact on electrical system of redesigned lighting.

VI. Research summarization

1. Write Thesis Final Report summarizing findings and drawing conclusions of the redesigns' feasibility.
2. Prepare Thesis Power Point presentation

Time Table



	Task Name	Start	Finish
1	Structural Research	Mon 1/12/09	Mon 2/23/09
2	Determine Initial Member Sizes	Mon 1/19/09	Wed 1/21/09
3	Create RAM MODEL	Thu 1/22/09	Sat 1/24/09
4	Have Initial Model Created	Mon 1/26/09	Mon 1/26/09
5	Analyze Floors in RAM Concept	Tue 1/27/09	Sun 2/8/09
6	Analyze Gravity System in RAM Concrete	Thu 1/29/09	Sun 2/8/09
7	Verify RAM Out-Put w/ PCA & Hand Calcs	Mon 2/2/09	Sun 2/8/09
8	Gravity System Significant Completion	Mon 2/9/09	Mon 2/9/09
9	Lateral System Design and Analysis	Tue 2/10/09	Mon 2/23/09
10	Lateral System Significant Completion	Mon 2/23/09	Mon 2/23/09
11	Foundation Analysis	Mon 2/23/09	Sun 3/1/09
12	Vibration Analysis	Mon 2/23/09	Sun 3/1/09
13	Gather Cost and Schedule Data	Tue 1/20/09	Sun 3/1/09
14	Estimate Cost of Building	Mon 3/2/09	Fri 3/6/09
15	Analyze Redesigns Schedule Implications	Mon 3/2/09	Fri 3/6/09
16	Significat Completion Depth and CM Bread	Mon 3/16/09	Mon 3/16/09
17	Lighting Design and Analysis	Mon 3/16/09	Sun 3/22/09
18	Write Final Thesis Report	Mon 3/23/09	Mon 4/6/09
19	Final Report Posted	Tue 4/7/09	Tue 4/7/09
20	Write One Page Presentaion Outline	Fri 3/20/09	Sun 3/22/09
21	Sample Presentation	Mon 3/23/09	Tue 3/31/09
22	Final Presentation	Wed 4/1/09	Mon 4/13/09
23	Present	Tue 4/14/09	Tue 4/14/09