FINAL REPORT

Gen*NY*Sis Center for Excellence in Cancer Genomics

Rensselaer, NY

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Structural Option
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April 9, 2008

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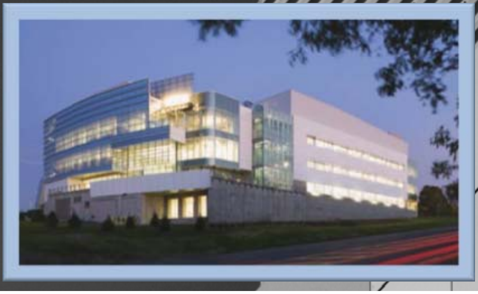
Structural Thesis Portfolio

http://www.engr.psu.edu/ae/thesis/portfolios/2008/mgk145/



ARCHITECTURE

→Signature Building of East Campus

→Good, sound, environmentally sensitive design and materials

→Floor-to-floor height of 16’-0” with basement level at 20’-0”

→Two-story atrium

STRUCTURAL

→Composite decking and steel beams

→Typical bay size of 21’-0” by 27’-0”

→Foundation includes 9’x9’x25” footings, 1’ deep x 2’ wide wall footings and 20” thick foundation walls

→Typical live load of 70 psf applied

→Steel braced frames to resist wind and seismic lateral loads

→Allowable net soil bearing pressure of 4 ksf

LIGHTING/ELECTRICAL

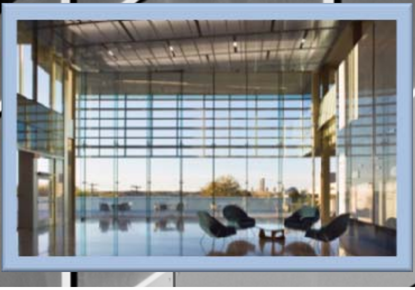
→3200 A, 277/480V distribution sections

→0.5 watts/SQ. FT. emergency life safety lighting

→1200 Maximum Capacity Busway

→208/120 V 3-phase 4-wire 208/120 V Step Down Transformer

→Generator provides power to emergency side of each transfer switch



BUILDING INFORMATION

Owner: University at Albany, SUNY

Construction Manager: U.W. Marx/Gilbane Building Company/Erdman Anthony

Architect/Engineer: Einhorn Yaffee Prescott Architecture & Engineering P.C.

Cost: $45 million

Size: 117,400 S.F.

Height: 4 stories, 70-90 feet

CONSTRUCTION MANAGEMENT

→Fast Track Delivery Method

→Groundbreaking: June 24, 2003

→Grand Opening: October 18, 2005

→Good, sound environmentally sensitive design and materials

MECHANICAL

→100% outdoor supply air to all laboratory spaces

→Minimum of 20 cfm per person of ventilation air provided through 3 AHUs

→Gas-Fired Water-Tube High-Pressure Steam Boilers

→Hot-Water Reheat

→Steam Preheat

Executive Summary

The Gen*NY*Sis Center for Excellence in Cancer Genomics was built as the signature building of University at Albany's East Campus of Biotechnology. The conditions of the site prior to construction included the old Sterling Winthrop Facility just off the Columbia Turnpike in East Greenbush, NY. A four-story steel framed laboratory, the Cancer Research Center falls on 117,400 square feet of space with about 26,000 square feet per floor. The Ground Floor is mostly below grade and houses laboratory space, an animal facility, mechanical rooms, and a loading dock. Just above on the First Floor, there is more laboratory space, offices, public space and a seminar room. The remaining Second and Third floors accommodate additional offices and laboratories.

The structural system is comprised of conventional framing with composite decking and composite steel beams at the floor levels and the roof. Column placement along exterior walls and on both sides of a ten-foot wide corridor allows for minimized foot-traffic vibration from the corridor to adjacent lab spaces and maximizes vertical space in the corridor. This column grid creates bays sizes of 21-feet by 27-feet. Upon exploration, structural steel was selected over reinforced concrete.

A new system of precast panels has been calculated and designed to research the difference in vibration control. Currently, steel braced frames are used to resist lateral forces and four concrete shear walls have been tested to take the job of resisting lateral forces. In this case, the wind load governs for the lateral forces and drift. The shear walls have been designed as 12 inches thick with columns as the boundary elements, which are 20 inches by 20 inches.

Further research into the redesign using precast concrete, the site, schedule and cost has been conducted to expose that while the concrete system was cheaper overall, the cost of the lateral concrete shear wall system was more expensive than the original lateral braced framing.

In addition to a green roof being added, the entire building has been fitted out to meet the approval of the Penn State LEED requirements, and to demonstrate some key elements of green building.

Introduction

As part of the Engineering program at Penn State University, a senior year project is required to graduate. Specifically in the major of Architectural Engineering, the senior project is molded into a year-long thesis research project which is based on the study of a newly constructed or a current construction project somewhere in the continental United States. A complete set of construction documents and specifications are donated by industry professionals to fully understand the inner-makings of the building, and execute a change in its original layout. During the fall semester, three technical reports are written to comprehend the structural, mechanical, lighting/electrical and construction management issues encountered by the professionals. An emphasis of analysis is completed based on the student's option: structural, mechanical, lighting/electrical or construction management. Based on this research, an idea to change and improve the original design is proposed for research throughout the spring semester. The proposal consists of a depth in the student's option and two breadth topics from other areas of architectural engineering.

This final report is a compilation of the technical reports and research completed throughout the past year on the Gen*NY*Sis Center for Excellence in Cancer Genomics at the SUNY University at Albany. The proposal consists of a change of lateral system from steel lateral braced frames to concrete shear walls. The overall structural system has been changed from composite metal deck with normal weight concrete and structural steel columns to precast planks and precast columns. The breadth topics include an addition of sustainable building concepts and a construction management evaluation.

All information pertaining to this research can be found on the following website: http://www.engr.psu.edu/ae/thesis/portfolios/2008/mgk145/. This report and all materials posted on this website are intended for educational purposes only.

General Information

The Gen*NY*Sis Center for Excellence in Cancer Genomics (abbreviated as CFG in this report) is a cancer research center for the University at Albany's East Biotechnology Campus located at the old Sterling Winthrop Facility. The Gen*NY*Sis program encourages collaboration between research institutions and emerging as well as established companies. The sharing of knowledge along with facilities and equipment has been shown to accelerate research discoveries and therefore the development of new techniques and products. In this particular building, cancer research is done at the center as a cooperative effort that links private biotech businesses with academia and government to conduct groundbreaking research and development in state-of-the-art facilities. Located at One Discovery Drive Rensselaer, NY 12144-2345, which is just off of Columbia Turnpike in East Greenbush, NY, the project was designed as the signature building of East Campus. The CFG features spaces for research laboratories with supports spaces, offices, seminar spaces, circulation spaces and a two story atrium.

Architecture

This 117,400 square foot building is four stories with a ground floor mostly below grade. Overall, the building stands between 70 and 90 feet above grade. Arranged at the entrance of East Campus, the CFG is the signature building of the new Biotechnology Park of the University at Albany as well as a symbol of hope for all those afflicted with cancer. Designed as a Business Occupancy (use Group B), the construction class is Type 2B (noncombustible) but with 2-hour rated construction to account for the storage of large amounts of chemicals in the research labs. Floor-to-floor heights of 16'-0" are proposed with an 18'-0" floor-to-floor height at the basement level.

National Codes

- New York State Building Code 2002
- The Comprehensive Zoning Law of the Town of East Greenbush New York (last revised on August, 11 1999)
- Minimum Design Loads for Buildings and Other Structures (ASCE 7)
- Building Code Requirements for Reinforced Concrete (ACI 318)
- Specifications for Structural Concrete for Buildings (ACE 301)
- Specifications for Structural Steel Buildings (AISC)
- Seismic Provisions for Structural Steel Buildings (AISC)
- Code of Standard Practice for Steel Buildings and Bridges (AISC)
- Structural Welding Code—Steel (AWS D1.1)

Building Envelope

The main exterior walls are comprised of solid Phenolic Resin wall panels, metal furring, 5/8" dense-glass gypsum sheathing, 1" rigid insulation, 6" LGMF, 6" fiberglass insulation, reinforced Polyethelene sheeting vapor retarder and 5/8" painted gypsum wall board.

The exterior of the CFG has been formed to give a sleek, clean look. It is comprised of a couple of different systems: exposed concrete site walls, Phenolic resin panels (installed over a metal furring rain-screen system), 2 different glazed systems, a curtain wall system (north façade and south end offices), a storefront system, and a glass wall panel (trusswall system at northwest wall).

The roof contains a composite metal panel system which rests upon open web steel roof joists with some slab on deck framing supported by steel beams to account for substantial amounts of HVAC equipment. In addition to the penthouses, a screen wall around the entire roof perimeter is installed to shield the view of the equipment from view.

Construction

A joint venture between U.W. Marx and Gilbane Building Company served as the construction manager for this project. The CFG was constructed on a fast-track delivery method to build the 2005 Project of the Year—Honorable Mention by the Construction Management Association of America, NY-NJ Chapter. Construction was designed around a module system of 10'-6" with a structural bay to provide for a clear dimension of approximately 21'-0" and a 7'-0" clear corridor width.

Structural

The structural system of the CFG is designed to justify future adaption to changes in laboratory use or space needs, with special provisions for location of future plumbing and infrastructure demands. The foundation uses typical footings 9'-0"x9'-0"x25" and 20" thick basement walls that retain 20'-0" of soil. Typical slab-on-grade is 5" thick and increased to 6" for mechanical equipment slab-on-grade. The floor and roof system are typically 6 ½" slab of normal weight concrete on 2", 20-gauge composite metal deck and 6x6-W2.9xW2.9 wire-welded-fabric reinforcement. Floor and roof filler beams are typically W16x31 spaced 7'-0" apart with 20 shear connectors and a frequency of 8 Hertz. Whereas the penthouse system is 1 ½", 22-gauge, galvanized wide-rib (type B) roof decking. The preliminary size of a penthouse roof joist spanning 40'-0", spaced 4'-0" apart is 30K10. Columns are placed along the exterior walls to form rectangular bays of 21'-0" by 27'-0". Columns are also put on either side of a 10'-0" corridor in order to minimize foot-traffic vibrations into adjacent lab spaces. The column placement also maximizes vertical space for utilities located in the corridor.

The lateral force resisting system uses steel braced frames to resist wind and seismic loads. An expansion joint at the intersection of the two building wings isolates the two sections from each other. The expansion joint requires a row of columns along each side of the joint, with the building structures separated by a distance sufficient to provide seismic isolation—approximately 6"-8". Each building section has braced frames across the ends and two bays of bracing along the length of each exterior wall. Bracing diagonals are typically tube-shaped steel members (HSS8x8x5/16) in non-moment-resisting eccentrically braced frames. The building is designed for wind loading drift criteria of H/400, including second order effects.

Mechanical

The Research Center's mechanical system is designed to support offices, laboratories, and a vivarium to operate respectively, 10 hours/day, 10 hours/day and 24 hours/day, and respectively 5 days/week, 5 days/week and 7 days/week. In general, supply air to laboratory and laboratory animal spaces are 100% outdoor air. Ventilation rates are based on sensible cooling load, minimum dilution ventilation requirements, and/or exhaust air requirements. The ventilation rates for other spaces are based on minimum dilution ventilation requirements for occupant comfort, occupant density, pressurization criteria, and/or exhaust air requirements. Ventilation air is provided at a minimum rate of 20 cubic feet per minute per person. The air handling units serving the offices, laboratories and vivarium supply air through 30% ASHRAE efficient prefilters and 95% ASHRAE efficient afterfilters.

In general, the HVAC control system provides individual thermostat control for each laboratory. During "occupied" hours, systems maintain minimum air change rates. Room temperature is controlled using a wall-mounted thermostat, connected to a reheat coil control valve. Supply airflow exceeds exhaust airflow to assure positive pressure in barrier animal spaces relative to adjacent spaces. During "unoccupied" hours, the control system allows an energy-efficient reduction in supply and exhaust airflows provided that system maintains relative pressure within the laboratories. This design includes moisture addition for relative humidity control at the central station air handling unit and satisfies the requirements for the majority of the spaces served, but there is no individual room humidity control.

The calculated cooling, heating and process loads for the Research Center are respectively, 1100-tons, 18,500 MBH, and 5100 MBH. For cooling, there are three 375-ton, high efficiency water-cooled electric centrifugal water chillers to provide 42^0F chilled water throughout the building via a primary-secondary chilled water pumping system. The primary pumps provide a constant flow of 600-gpm while the secondary pumps' flow is at a constant 1700-gpm (100% of the intended building-cooling load).

The heating plan consists of gas-fired, water-tube high-pressure steam boilers, and hot-water reheat with steam preheat coils. Two 250-BHP flexible water tube high-pressure steam boilers equipped with dual fuel burners provide100-psig steam with only a natural gas connection. The hot-water system is complete with an expansion tank, air separator complete with necessary apparatuses for a hot-water heating system. The high-pressure steam system and boiler system are complete with deaerator, chemical treatment system, four-pump feed water system, flash tank, condensate return system and all apparatuses for a complete hot-water heating system.

Lighting/Electrical

The incoming electrical service for the CFG comes from the existing campus 4800 Volt distribution loop. A 5 kV switchgear was added to allow for primary electric distribution routed across the site via underground ductbank to a new dual primary voltage, 13.2/4.8 kV, pad-mounted transformer located at the north side. Dual secondary feeders will be routed underground in the ductbank to the main switchboard and fire pump service entrance switchboard/disconnect switch.

The new main switchboard provides facility power distribution which includes: 3200 A, 277/480V distribution sections with individually mounted main and feeder circuit breakers, solid-state trip device and ground fault protection, customer metering, digital type and pulse initiator for kW demand, and transient voltage surge suppression.

Floor distribution of power includes two vertical busways fed from the main switchboard for power to each floor (one in each wing). Mechanical distribution of power includes the combination motor controllers and disconnect switches or variable frequency drives in mechanical equipment rooms (for pumps, fans, packaged equipment, etc.).

The generator provides power to the emergency side of each transfer switch and the main switchboard provides power to the normal side of each transfer switch. The load side of each transfer switch feeds the distribution switchboards. The lighting panels on each floor service the wing that they are located in, and the lighting panels serve a dry type transformer, 480 V to 208/120V for incidental 120V life safety power at selected locations. Standby power is provided for legally required mechanical equipment such as smoke control fans. The optional standy distribution provides power to loads determined to meet the needs of the building as directed by the University at Albany.

All lighting is hung from the building structure independently of the ceiling support system. In general, lighting is fluorescent with incandescent used where desired or appropriate.

Fire Protection

The fire protection is designed in accordance with the New York State Uniform Fire Prevention and Building Code, Title 9B, IBC, NFPA 13, 14, 20, and 45, and local regulations. The building construction class is type 2B (noncombustible), however due to use as a research lab and the need to store large amounts of chemicals, (2) hour rated construction for all columns and beams supporting all floors including the roof are provided. The sprinkler design in the laboratory is based upon Ordinary Group 2 hazard classification which requires a design density of 0.20 gpm per square foot over 1500 square feet of design area. Therefore, it requires approximately 300 gpm for sprinkler flow within the building and 250 gpm additional for hose allowance. Mechanical spaces require 0.15 gpm per square foot, and corridors, toilet rooms and offices require 0.10 gpm per square foot. Equipping the structure with an automatic sprinkler system, the area limitation is increased from 23,000 to 69,000, which forms the floor as one fire area. At each stair landing, a 2 ½" fire hose valve with a 2 ½" x 1 ½" reducer with cap and chain is installed. The standpipe system is designed to accommodate 1000 gpm. A four-way fire department connection is located at the front side of the building.

Transportation

The stairwells are located along the southeastern-most wall, the east end of the curtainwall system on the northern side, and against the northwestern corner of the building. 2 elevators are included in the building. The main passenger use elevator has a capacity of 2500 lbs. with a sheet vinyl floor, stainless steel walls, doors and hoistway doors. It is ADA compliant with emergency communications sytem. The large elevator has a capacity of 5000 lbs. with a sheet vinyl floor, stainless steel walls, doors, and hoistway doors. In this elevator, the door is 8'-0" high. Also, it is ADA compliant.

Telecommunications

The incoming service for the new facility comes initially from the existing services in the Administration buliding, or through the education center. These services include voice, data and video over copper, coax and fiber optic media. An underground duct bank connects the Cancer Research Center to an underground telecommunication vault; through this vault duct bank connections are made to the Administration building, the education enter, outside service providers and the rest of the campus. Each standard laboratory contains (1) Category 6 copper cable connecting a wall phone. Each A/V outlet has a wall interface and/or a projector interface. Outlet types and locations are coordinated with the University of Albany's IT staff.

Acknowledgements

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  Dr. Ali Memari
  Robert Holland

A special thanks goes out to my fellow AE 5th year students for the late but enjoyable nights, the Penn State Rugby team for their constant encouragement, and my family for listening to me complain over the past five years.

Existing Typical Floor Plan

The typical floor plan of the Gen*NY*Sis Center for Excellence in Cancer Genomics (CFG) consists of mainly laboratories and offices with an atrium in the center. The hallway was designed to have a minimum clearance of 9’-6” throughout the whole building. Displayed at the right in Figure 1 is the breakdown of the sections of the building used for construction of the project. Figure 2 shows the location of the offices with a view from the curtain wall façade along the North side of the building in sections II and III, while section I contains only one floor for a seminar room and sections IV and V are laboratories, classrooms, conference rooms and storage rooms. The green represents laboratories and classrooms, the blue is offices, red is stairwells and elevators, yellow is corridor space, and gray is mechanical rooms.

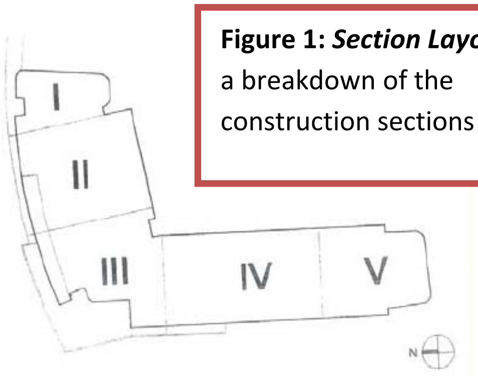


Figure 1: ***Section Layout*** a breakdown of the construction sections

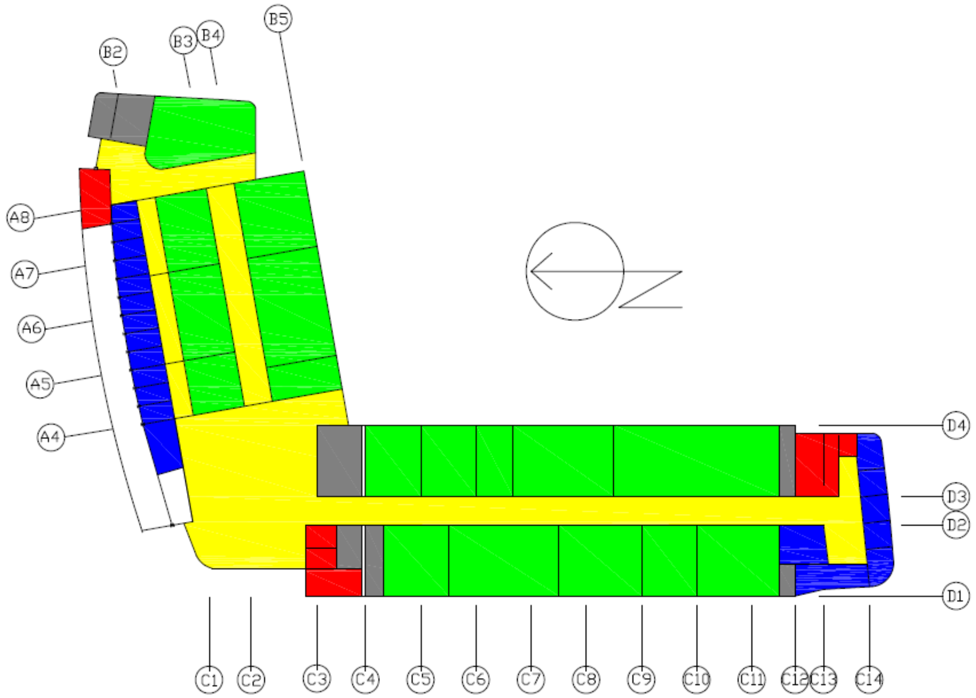
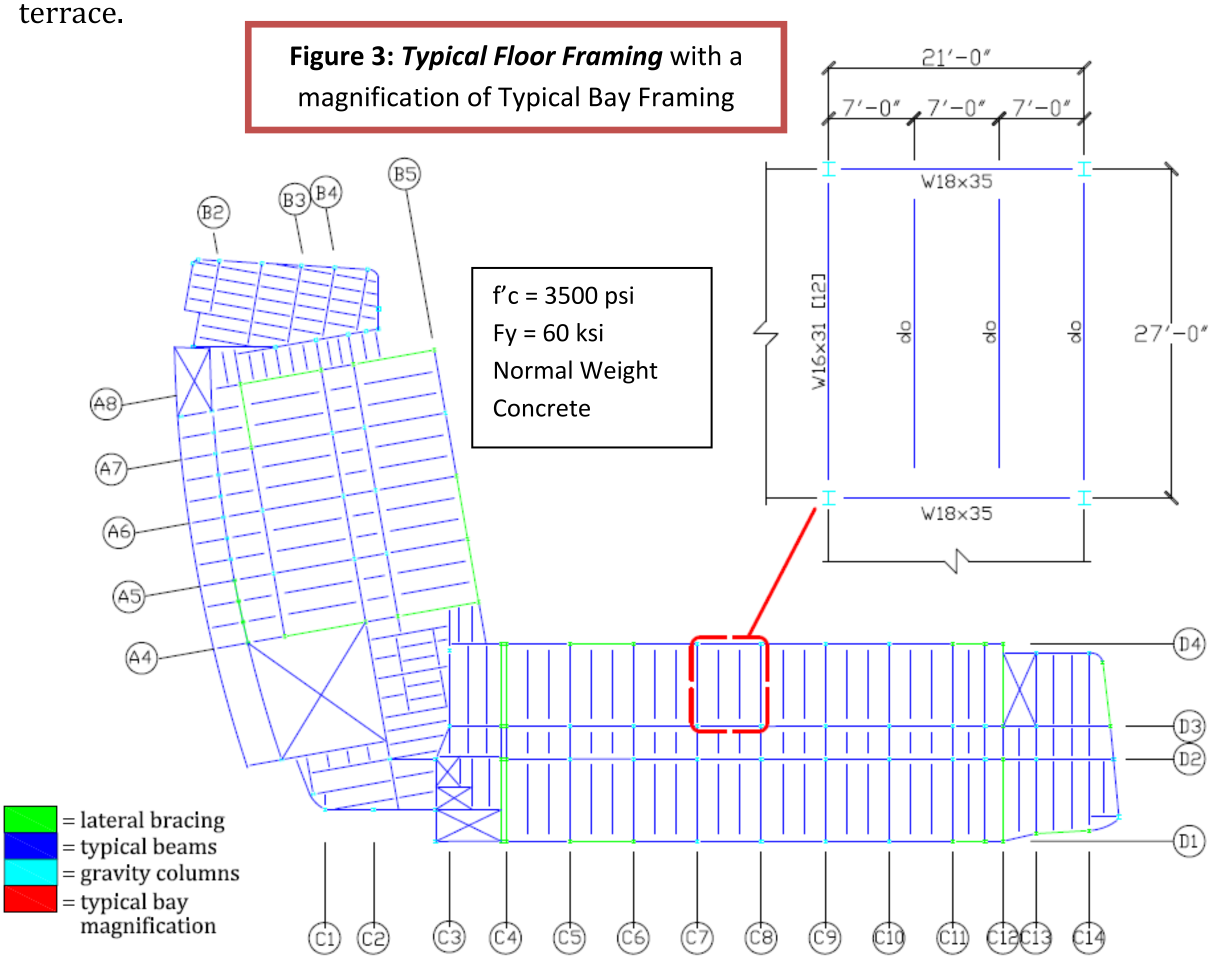


Figure 2: ***Architectural Room Layout*** Green is labs and classrooms, blue is offices, yellow is corridors, red is stairways and elevators, gray is mechanical rooms

Floor Framing

The structural layout is displayed in Figure 3 with typical beams in blue, gravity columns in cyan, and lateral bracing in green. A section of the structural grid is magnified to show a typical bay with dimensions and beam sizes. The typical floor system consists of composite metal decking which spans the north-south direction across sections IV and V and east-west across sections I, II and III. Typical floor framing includes 2-inch, 20-gauge, galvanized composite metal deck with 4½-inches normal weight concrete (total slab thickness of 6½-inches) with 6x6-W2.9xW2.9 wire welded fabric. Normal weight concrete was chosen over lightweight for vibration control. The structural steel used has a weight of 8 psf of floor area. Typical floor beams are W16x31 spaced 7-feet apart with 20 shear connectors. Filler beams across the 10-foot corridor are W10x12 spaced 7-feet apart. Girders along the interior column lines and along the exterior walls are W18x35 with 32 shear connectors. Camber will not be accounted for due to relatively short spans. Atypical framing is located in the lobby and offices along the North wall. Transfer girders are required in the lobby and mechanical rooms along the North wall to maintain column-free areas. Offices along the North wall are cantilevered over columns along the First Floor terrace.

Figure 3: *Typical Floor Framing* with a magnification of Typical Bay Framing



Foundation

The geotechnical report indicates that the allowable bearing capacity is 4000 psf. Typical column footings are 9-feet square and 25-inches deep calling for (11)#9 reinforcing bars each way on the bottom. Typical continuous wall footings are 1-foot deep by 2-feet wide calling for (3)#5 continuous bars and (1)#5 bar at 12-inches on center, transverse. The 20-inch thick basement walls retain 20-feet of soil (see diagram for reinforcement). Typical slab-on-grade is 5-inch thick with steel fiber reinforcement. The mechanical room slabs are 6-inch thick with steel fiber reinforcement. All steel fibers in slab-on-grade are at 30 pounds/cy. Weights for cast-in-place concrete, footings, foundation walls and piers, and slabs on metal deck are 4000 psi, 3000 psi, 4000 psi, and 3500 psi, respectively.

Figure 4: *Typical Column Pier* and foundation layout

Roof

To satisfy the extra HVAC loading on the roof, a concrete slab is set on the metal deck framing that is supported by steel beams. The 6½-inch slab is on 2-inch, 20-gauge, galvanized composite metal deck with 4½-inches of normal weight concrete reinforced with 6x6xW2.9xW2.9 wire welded fabric. Roof framing supports a screen wall set back from the face of the building, extending 15 to 20-feet above the roof slab. Typical roof framing filler beams are W16x31 spaced 7-feet apart with 20 shear connectors. Deeper beams will be required at bearing points of the penthouse posts. Filler beams spanning the corridor bay will be W10x12 spaced 7-feet apart with no shear

Figure 5: *Penthouse Mechanical Screen* with structural tube braces

connectors. Girders along the interior column lines and along the exterior walls will be W18x40 with 32 shear connectors. The structural steel used in the Main Roof framing is 10 psf of roof area. Penthouses on the roof have cross-braced steel-frames supporting steel joists and 1½", 22-gauge, galvanized, wide-rib (type B) roof deck. The structural steel used in the Penthouse Roof framing is 5 psf of penthouse area.

Columns

Typical columns are W12x72 members at the lower tier and W12x53 members at the top tier. Using W12 columns as a minimum size simplifies fabrication of connections of beams framing into the columns and allows the OSHA-required four anchor bolts to fit within the flanges at the base. This minimizes both base plate and pier sizes. A column splice with a bolted web and welded flanges is required 4-feet above the Second Floor for all columns. Perimeter columns will bear on piers 1-foot below the First Floor elevation of 195.0'. Interior columns will bear on footings 1-foot below the Ground Floor elevation of 175.0 feet.

Lateral Force Resisting System

Steel braced frames, shown in Figure 6, will resist wind and seismic lateral loads. An expansion joint at the intersection of the two building wings will isolate the two sections from each other. The expansion joint will require a row of columns along each side of the joint, with the building structures separated by a distance sufficient to provide seismic isolation—approximately 6 to 8-inches. Each building section has braced frames across the ends, and two bays of bracing along the length of each exterior wall. Bracing diagonals are tube-shaped steel members in non-moment-resisting eccentrically braced frames. The building is designed for wind loading drift criteria of H/400, including second order effects.

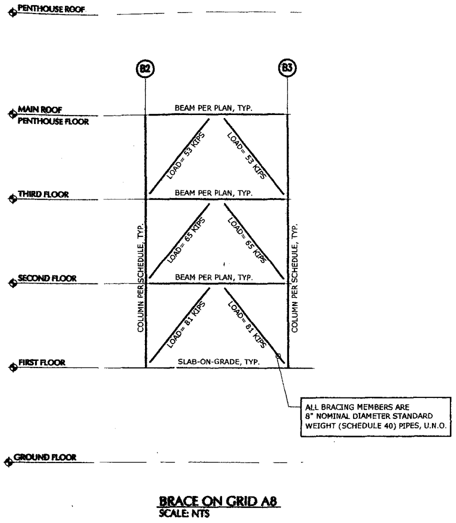


Figure 6: ***Typical Lateral Brace***

Figure 7: ***Floor Elevation*** **of a typical bay size**

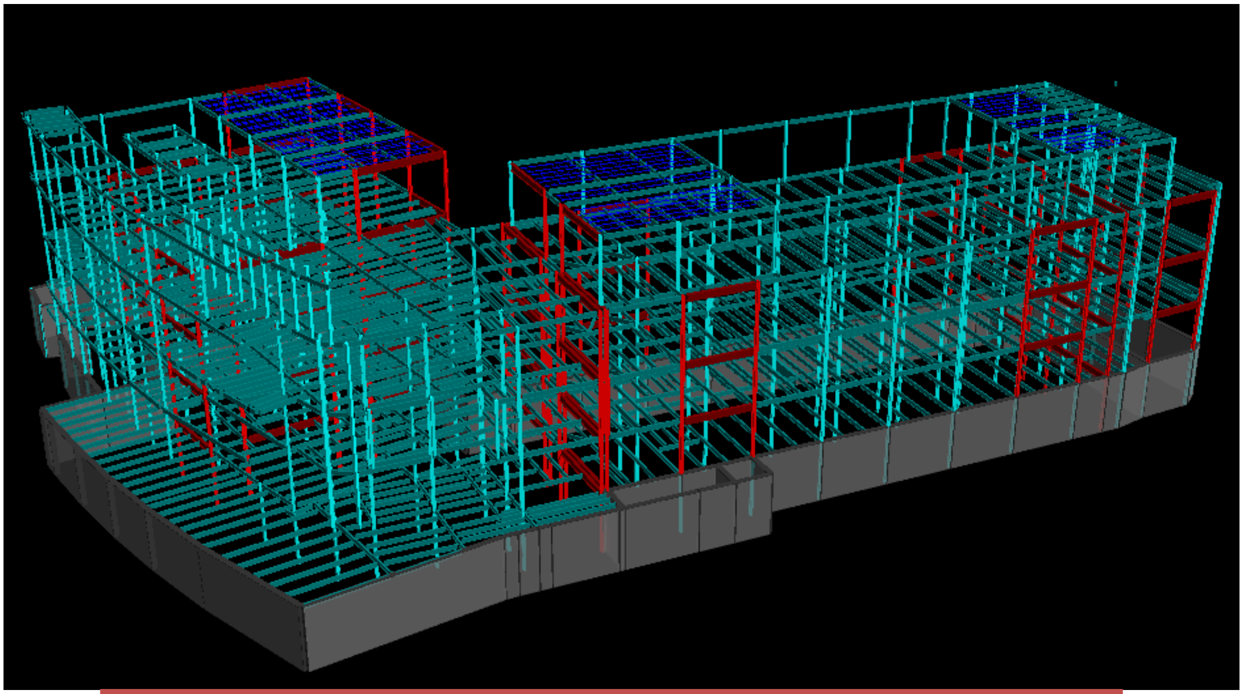


Figure 8: ***RAM 3-D View of Structural System with Lateral Bracing Highlighted* (Northwest corner)**

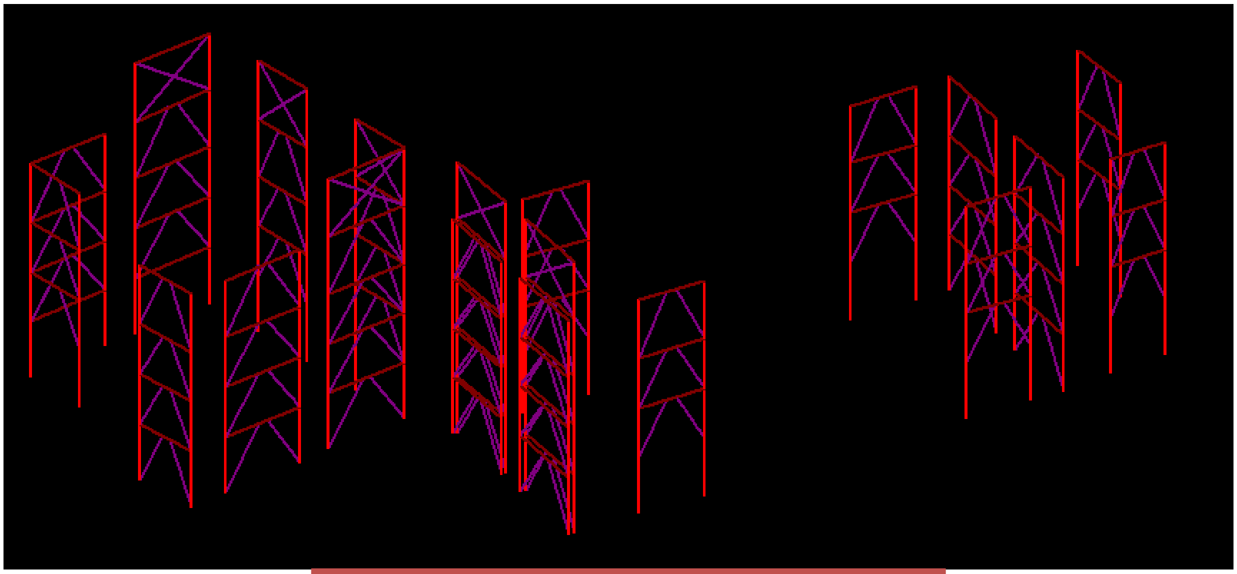


Figure 9: ***RAM 3-D View of Lateral Braces***

LRFD Load Combinations

1.4(Dead)
1.2(Dead) + 1.6(Live) + 0.5(Roof Live or Snow)
1.2(Dead) + 1.6(Roof Live or Snow) + 1.0(Live) or 0.8(Wind)
1.2(Dead) + 1.6(Wind) + 1.0(Live) + 0.5(Roof Live or Snow)
1.2(Dead) + 1.0(Seismic) + 1.0(Live) +0.2 (Snow)
0.9(Dead) + 1.6(Wind)
0.9(Dead) + 1.0(Seismic)

Figure 10: ***Elevation from the South***

Original Design Loads

Construction Dead Load

Concrete	150 pcf
Steel	490 pcf

Dead Load

Partitions	20 psf
M.E.P.	10 psf
Finishes	5 psf
Windows and Framing	20 psf
Roof System without slab	30 psf
Roof System with slab	85 psf
Typical Elevated Floor System	85 psf
Elevated Terrace Floor System	170 psf maximum

Live Loads

Office/Laboratory flexibility	70 psf

Lobbies and first floor corridors	100 psf
Corridors above first floor	80 psf
Stairs and Exits	100 psf
Seminar Room	100 psf
Balcony/Terrace	100 psf
Mechanical Penthouse	200 psf
Roof Live Load/Roof Snow Load	
Ground Snow Load, p_g	65 psf
Flat-roof Snow Load, p_f	50 psf
Snow Exposure Factor, C_e	1.0
Snow Load Importance Factor, I	1.1
Thermal Factor, C_t	1.0
Wind Load	
Basic Wind Speed (3-sec gust), V	90 mph
Building Category	II
Wind Importance Factor, I	1.15
Wind Exposure Category	B
Internal Pressure Coefficient, GCp_i	±0.18
Height and Exposure Adjustment Coefficient, λ	1.16
Component & Cladding Design Wind Pressure	30 psf
Seismic Load	
Seismic Use Group	II
Importance Factor	1.0
Spectral Response Acceleration, S_s	0.220
Spectral Response Acceleration, S_1	0.076
Site Class	C
Site Class Factor, F_a	1.2
Site Class Factor, F_v	1.7
Spectral Response Acceleration, S_{MS}	0.264g
Spectral Response Acceleration, S_{M1}	0.129g
Spectral Response Coefficient, S_{DS}	0.159
Spectral Response Coefficient, S_{D1}	0.073
Seismic Design Category	B
Response Modification Factor, R	7.0
Nonmoment-Resisting Eccentrically Braced Frames	
Seisimc Period Coefficient, Ct	0.03
Seismic Response Coefficient, Cs	0.0251 sec
Period Coefficient, x	0.75

Problem Statement

Receiving a grant in September of 2002, the University at Albany was given $45 million to create the cornerstone to New York State's Gen*NY*Sis (Generating Employment Through New York Science) program, which is an initiative by government and private investors to lure jobs in life science into New York. Given the location of the building near Albany, NY, it makes sense to use a structural steel system. Also, the foundation loads were not able to stand the heavy weight of a concrete system. Furthermore, a fast-track method was desired and a concrete system generates a longer construction period.

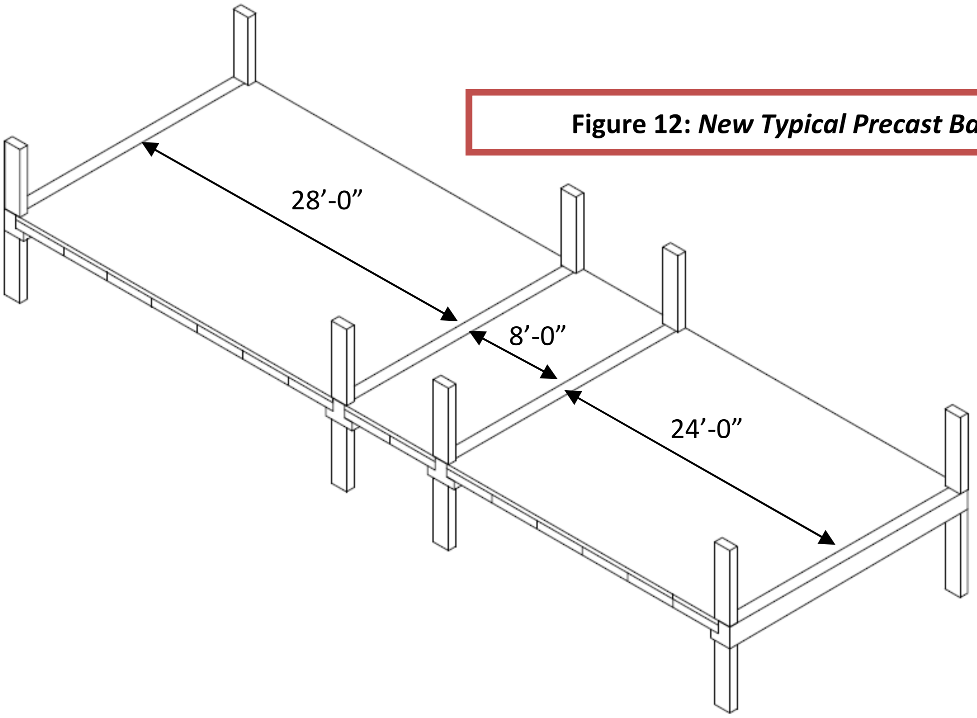
However, steel decking is not always the ideal situation for vibration control, which is important for a laboratory that deals with cell experiments. A concrete system is much more ideal for this type of building. Therefore, a redesign in a new location, at a new site with a different soil bearing capacity might be able to handle such a structure. For the purposes of this research, the building has been moved from Rensselaer, NY to the Penn State University Hershey Medical Center to fulfill different design criteria. In addition, the fast track delivery can still be utilized with the use of precast panels. Because of this elimination of steel, a new lateral design must be employed. Also, to go along with the precast panels, concrete shear walls are a good compliment to resist the building's lateral loads. Furthermore, the effect on the vibration control will be investigated and compared in the original composite steel deck and the precast concrete. Because of the heavier structure, a look into the changes needed in the foundation will be conducted.

Figure 11: *Map of Location Change*

Preliminary Redesign

The redesign with concrete began with a recalculation of the wind loads and the seismic loads to see what condition controls in Hershey, PA. With this recalculation, it was determined that the new wind load controlled, as seen in Appendix D. An addition of an inhabitable green roof made the gravity columns and beam capacities change as well. The new roof load needed to include a roof with assembly live loads, green roof live loads, and the saturated soil weight of the proposed green roof. To further make the penthouse a place of refuge, the original mechanical screen was removed to allow a better view of the surroundings. Also, all staircases and the elevators were extended to 18'-0" above the Main Roof level to provide egress to the roof. The use of lightweight concrete was an option in preliminary design to represent the use of fly ash, which improves the workability of concrete by decreasing its water demand, reducing segregation and bleeding and lowering the heat of hydration. However, it was eliminated based on some more criteria seen later in the vibration section of this report. Once the wind and seismic loads were determined, seen in Appendix D, the PCI Industry Handbook, 6th Edition was used to size hollow-core precast planks. Upon further calculations, it was decided that it would be best to use a hollow-core plank with a 4" topping to further dampen the vibration effects on the laboratory equipment. The edge beams are made up of 20LB24 L-beams and T-beams of 28IT20 which can be seen in Appendix E.

Figure 12: ***New Typical Precast Bay***



The original layout of the CFG has rather small bay sizes most likely due to a better control of the vibration frequencies. In an attempt to minimize the architectural layout changes, the bay sizes were kept close to the original. Since the precast panels are cast in increments of 4'-0" wide, minor changes to the floor plan was necessary. It was necessary to keep the hallway width to at least 60". The hallway was recreated to be 96" wide, which is slightly narrower than the original. Also, the bay sizes changed to 20'-0" by 24'-0" and 20'-0" by 28'-0". The column lengths remained the same with a penthouse level bringing the overall height to 90'-0". In section III, the typical bay size is not used. Part of the grid is laid out at an angle presenting a challenge for how to lay down flooring in a typical size. Therefore, a few unique panels would need to be ordered.

New Design Loads

To begin the new RAM model, the dead loads and live loads were calculated from the roof load first. To try and keep the bay sizes low, the span was set at 21'-0" to stay consistent with the old architectural plan. Once the load and moment of the roof and penthouse were calculated, a hollow-core plank was selected from PCI Industry Handbook, 6th Edition, see Appendix E. Once the planks were chosen, the weight was divided up into tributary areas in the 21'-0" spans and the L-and T- beams were selected to hold up the weight of the slab. Once the appropriate sizes were approximated, the total weight was tabulated and divided up amongst the tributary areas to be loaded through the columns. From there it was determined that an overall use of a 20" x 20" column would be most appropriate. To model the precast in RAM, the Concrete Beam analysis was set to only use #8 to reinforce the slab and beams since those are the sizes that are used in the prestressed strands of the precast planks. With an estimated size for each part at each level, the loads were then carried down and the foundation could be resized. To help carry these loads and to enclose the interior, structural insulating panels were chosen to use as the load bearing wall system. In particular, Murus foam core SIPs not only can take the place of for instance a metal gauge studs and drywall system but they also provide better acoustical and

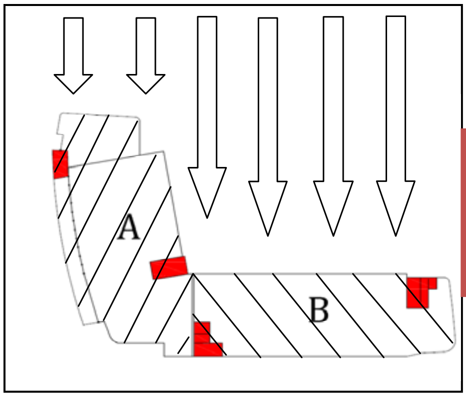


Figure 13: ***Distribution of Lateral Forces to the building frame***

temperature characteristics which could be very helpful for a building full of lab experimenting. See Appendix F for more spec information.

Lateral Framing

Figure 14: ***Allowable and Actual Story Drift***

Floor	Story Height (ft)	Allowable Story Drift (in)	RAM Story Drift (in)		
Penthouse	18.42	0.553	0.134	✓	1
Roof	18.58	0.557	0.121	✓	1
3rd	16	0.480	0.084	✓	1
2nd	16	0.480	0.081	✓	1
1st	18	0.540	0.036	✓	1

To go along with the precast panels, concrete shear walls were designed to take on the new lateral loading and continue with the concrete theme. Since the building location moved from Rensselaer, NY to Hershey, PA, the wind and seismic loads changed. Also, upon further inspection, the building was originally designed so that there is a disconnection between sections III and IV. Therefore, the analysis of the loading was re-calculated with this in mind so that there are two diaphragms with separate loading cases. This was modeled in RAM by laying out two different slabs around Building A and Building B. Also with the new dimensions and variables, the new main roof height was increased to 67'-0" as opposed to the 30'-0" originally used by the engineer. Also, the wind and seismic direction were as displayed in Figure 13. The main differences between the original system and the new system design loads are shown in Appendix D. In the new situation, the wind load controls which was not the case for the original system, which makes drift more of a concentration than before.

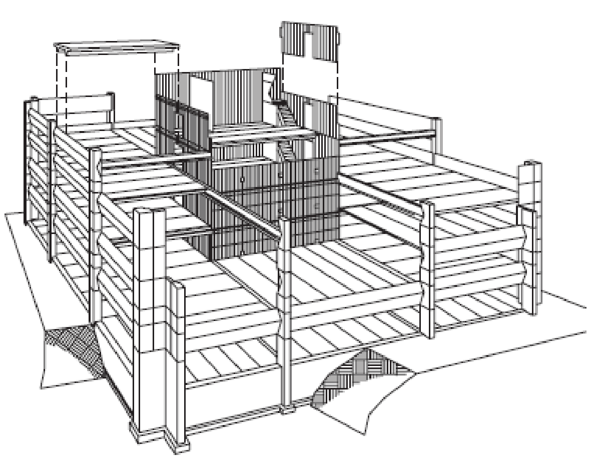


Figure 15: ***Interior Shear Wall System*** as shown and defined by the PCI Handbook, 6th Edition

To firm up the diaphragm it makes sense to use cast-in-place concrete shear walls. Even though it is a slower method, pouring concrete is most likely a faster method than placing a CMU wall. Another method is to use precast load bearing walls for the shear walls, which is also an option that was looked into. However, that was dismissed because it would make the shear wall elements to reliant on the rest of the structure and thus lose the continuity. Since there are already plenty of vertical egress components available, it makes sense to continue them up through the roof and make them the shear wall components. Another stairwell was added as access to the roof for the green roof but also to take on more of the lateral forces. With the addition of the shear walls, the center of rigidity changed relative to each Building Section. However, this data was inputted into RAM as four separate diaphragms at the Penthouse level and then breaks down into the two Building Section diaphragms. Therefore, the center of rigidity is off and the hand calculation was used to size the shear wall. To simplify the shear walls, only the continuous walls were considered to take lateral forces, so there were no wall openings accounted for, and no coupling beams were designed. Each shear wall was designed with a boundary element to increase the amount of shear capacity withheld. Displayed below is the drift of one of the more severe shear walls. For shear wall calculations see Appendix G.

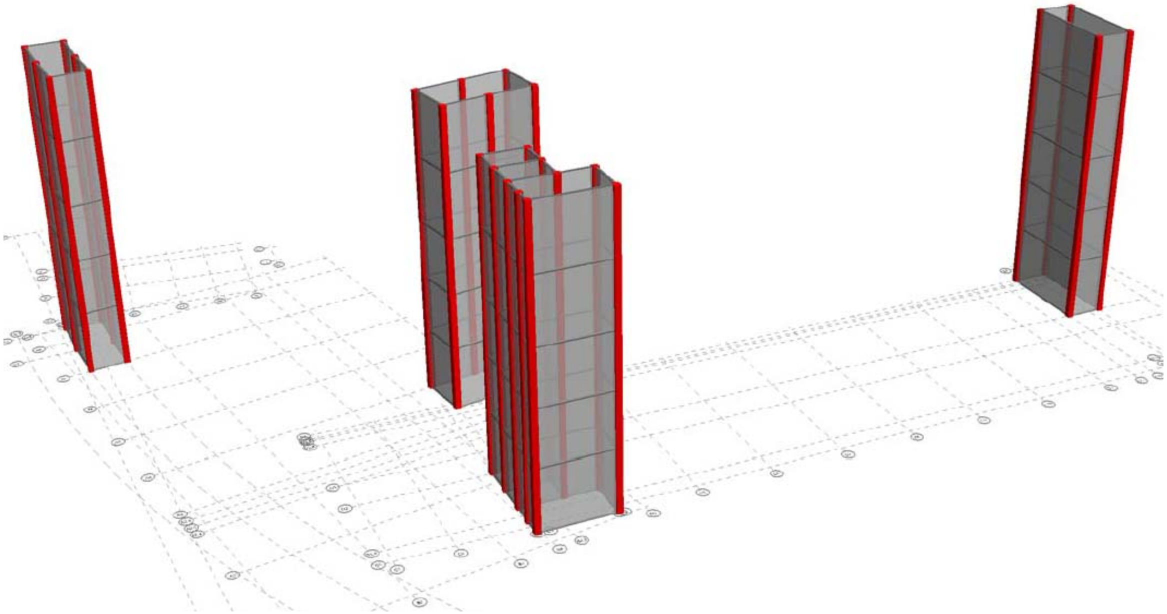


Figure 16: ***RAM 3-D View of Lateral Walls***

Vibration Analysis

Another factor in design was the effect that vibration of the floor. Because this building is used for very precise medical experimentation with sensitive equipment, vibration can be considered as a key piece of design guideline. Concrete is more of solid and dense material so it would make sense that it would have a smaller effect from vibration compared to the original steel design. Unfortunately, there is very little information as for how to calculate vibration in concrete while there is a full steel design guide for the analysis of vibration caused by footsteps. However, a paper entitled "Vibration of Precast

Prestressed Concrete floors" by Robert F. Mast, was also used to help determine the vibration figures to compare with steel. Figure 17 shows the results of this analysis.

		Steel System	Concrete System
	fn	7.85	5.62
Vibration Velocity at:	Fast Walking	8870	5204
(micro in/ sec)	Moderate Walking	1951	1145
	Slow Walking	532	312

Figure 17: ***Comparison of Vibration Analysis***

Looking at the table, it can be seen that actually while the concrete system can withstand the vibrations at one more severe of a level than the original steel system could. The concrete system is able to handle sensitive equipment up to electron microscopes at 30,000x magnification, while the steel system can only safely use bench microscopes up to 400x magnification. This analysis also shows that the best environment for the laboratories is one in which there is predominantly slow walking and absolutely no running. STAAD was also used to analyze this and Figure 18 shows those results of the natural frequency felt amongst continuous spans of the typical bay size. Another option that was investigated was the use of lightweight concrete for purposes of sustainable design. However, it was deemed that lightweight concrete was a little too light and registered a natural frequency that went below 5 Hz, which is the limit to which this vibration analysis can be used with.

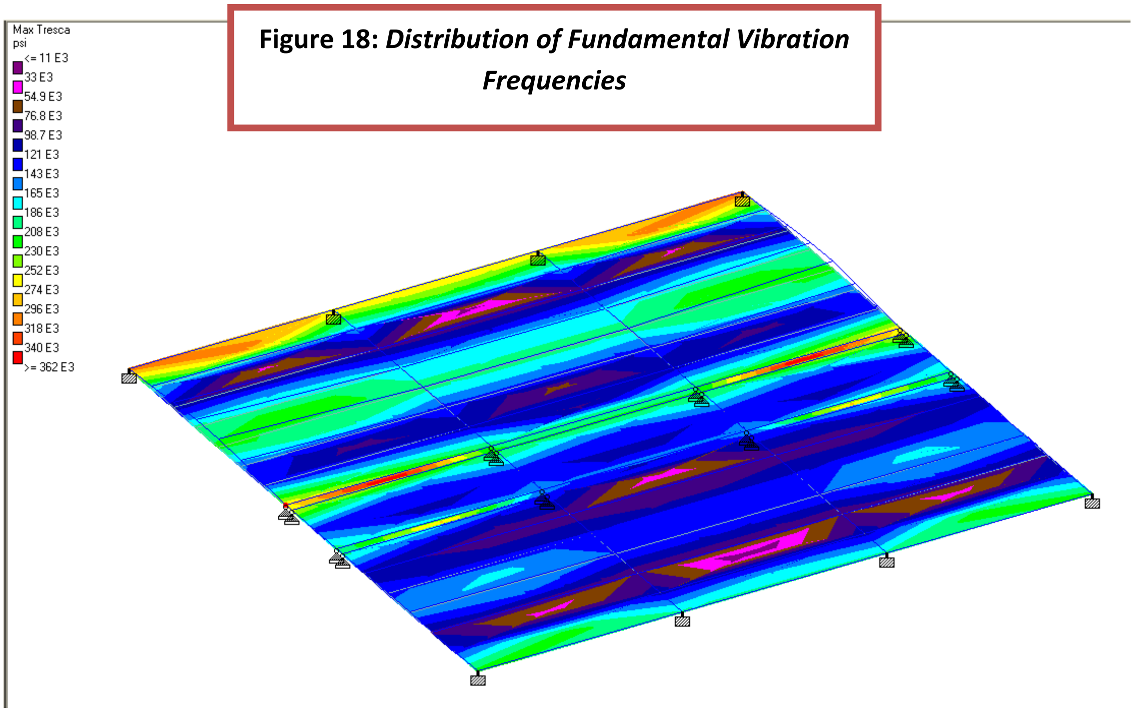


Figure 18: ***Distribution of Fundamental Vibration Frequencies***

Foundation Redesign

Because the overall weight of the system is much heavier with the massive amounts of concrete being added, a foundation redesign was in order. Only the worst case scenario shear wall was recalculated and designed with a footing foundation. The bearing capacity of the soil in Hershey, PA was estimated based on the soil reports on the USDA records available online. It was assumed to be much lower than the bearing capacity available in Albany, NY. Sturdier foundations are needed, and the option of caissons was looked into.

Breadth Topic #1: Cost and Schedule Analysis

While this project was not necessarily a cost-driven one, cost is always a matter in the design of a project. In fact, this project was more reliant on the fast delivery first, which is why a precast concrete system was proposed. Therefore, the purpose of the re-design of the structure is to find the difference in cost and scheduling. Both steel erection and precast erection need lead time so the factories can make the materials and have them all ready to be shipped on-site when the schedule asks for it.

As far as the cost has represented, see Appendix K for CSI form spreadsheet, the cost of the steel is $2,000,000 higher than the cost of the precast superstructure. Even though the floor plan increases slightly with the use of precast panels, it is still a cheaper system. The cost accounted for doesn't even go to include connections or shear studs, but on the same side the concrete side doesn't account for grout. Fire resistance is also an issue since with the concrete system, the fire rating is already met where as the steel members need to be fire proofed as a separate item which adds cost and time to the project. However, the cost for the lateral systems is a little different as seen in Appendix K.

Figure 19: ***On-Site Picture*** of precast columns being erected

		COST	% of Overall System
Shear Wall	$	12,531,148.24	84%
Braced Frames	$	1,493,536.96	9%
Precast Overall	$	14,840,417.98	
Steel Overall	$	16,618,444.75	

Figure 20: ***Comparison Chart*** of pricing of the structural systems

While the steel braced frames are a cheaper lateral system, the overall system is more expensive than the precast and concrete shear wall system together. This means that if less shear walls can be designed, then it could be the overall governing system. Although, it should be kept in mind that none of the shop pricing is involved in these calculations. It can be easier to order steel because the sizes are more of a general size and can be fitted into a design much easier than the precast panel design. Each system still needs a crane on site which can accrue a large expense if kept on site for a long period of time.

The schedule created for the new system demonstrated that it would actually take longer for the precast plank system to go up rather than the steel. This is partly due to the fact that the original project schedule was never issued and just a guideline of six months to place foundations erect all the steel was given and this was a longer period due to the complex curved foundation. According to Appendix J, the precast system took about 284 days to complete which doesn't quite hold up to the steel system's 130 days to completion. However, it would seem that the precast system took a lot longer mainly due to the length of time it takes to let the concrete of the shear walls cure to begin the placement of the next floor. The way this system was sequenced is the same as the original project: by section as detailed in Figure 1. Another sequence that was considered was to start from Section III and build out simultaneously towards Section I and Section V. This was determine to make the site much too congested because two cranes would need to rented as well as multiple pumps trucks. In general, it would make the job site much too hectic and difficult to manage.

Breadth Topic #2: Penn State Sustainability

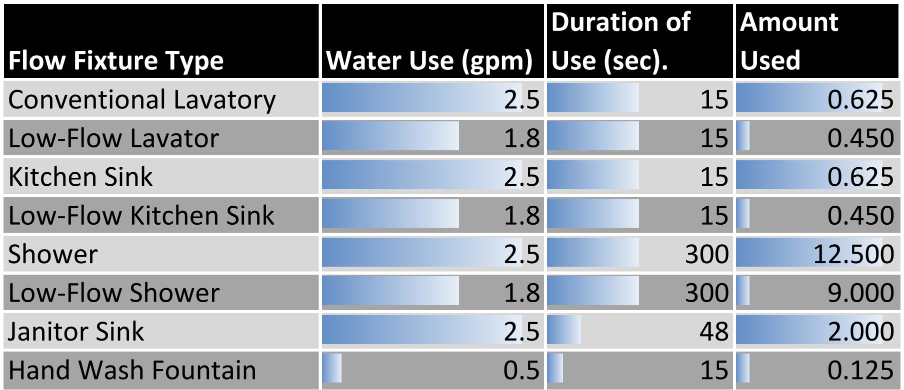
One of the areas that seemed to be slighted in the original design of the Gen*NY*Sis Center for Excellence in Cancer Genomics is that area of sustainable principles. In an effort to encourage green building practices, Penn State University has adopted its own version of the LEED principles, which is why the proposal relocated the building to the Hershey Medical Center. Penn State has issued a checklist to follow for new construction on Main Campus and all branch campuses.

Figure 21 : ***Google Map*** of Hershey Medical Center

Sustainable Sites

As seen in Figure 21, the building has been placed on the Hershey Medical Center Campus mainly to gain from the solar rays that the large windows of the curtain wall can benefit from. Not only does this provide an affect of bringing the outside atmosphere inside, but it helps keep the building heated in the winter. Another benefit of this plot is that it is easily accessible from the road, and as displayed in Figure 21 , the bus route (the red arrows) passes by one of the entrances of the building, encouraging the use of public transportation. To go along with public transportation, bike racks are also a necessity to encourage bicycle traffic rather than automobile traffic. Another application of the LEED principles is the use of bioswales which is can be implemented adjacent to the road or setback off the main building. Building these into the site in the beginning of construction can allow for the creation of a very green atmosphere and view from inside and outside. Another aspect of a sustainable site is avoiding the use of light pollution, which simply means using light fixtures that either focus down in order to not waste energy by sending the lumens up into the sky.

Water Efficiency



Flow Fixture Type	Water Use (gpm)	Duration of Use (sec).	Amount Used
Conventional Lavatory	2.5	15	0.625
Low-Flow Lavator	1.8	15	0.450
Kitchen Sink	2.5	15	0.625
Low-Flow Kitchen Sink	1.8	15	0.450
Shower	2.5	300	12.500
Low-Flow Shower	1.8	300	9.000
Janitor Sink	2.5	48	2.000
Hand Wash Fountain	0.5	15	0.125

Figure 22 : *Comparison Chart* of ordinary vs. water efficient appliances (courtesy of http://www.csemag.com/article/CA504173.html)

This category is one of the LEED categories that could and should be applied to all newly constructed buildings. A couple of solutions include waterless urinals, special reduced water dishwashers, greywater systems, and water filtration equipment. Figure XX shows how much water can actually be saved using the water efficient technology. It is difficult to retroactively fit these kind of systems into a building which is why they need to be implemented during the design period of building construction. In the case of the CFG building, these types of appliances can definitely be used and designed into the architectural and mechanical layout.

Energy and Atmosphere

This section is to promote the use of alternative energy sources as opposed to fossil fuels. One way that the CFG can fulfill this credit is to apply solar shading to the curtain wall system. Sunshades are used to subtly shade from the harsh light of a summer day while still gaining the heat from the sun to heat up the building and save on energy costs. An example that can be applied to the CFG can be seen in Figure 23. While this system takes advantage of solar power, it is also possible to achieve these points by implementing bio-fuel based electrical systems (agricultural crops or waste, landfill gas, animal waste or other organic waste, untreated wood waste), low-impact hydro-

Figure 23: *Metal Mesh Shading* created by Cambridge Architectural (http://www.cambridgearchitectural.com/System.aspx?ID=21#)

electric power systems, or wave and tidal power systems. This is also known as green power.

Materials and Resources

There is a big campaign across the Penn State communities right now to push towards recycling. This criterion requires that the construction waste be collected and removed without question. Of that waste, at least 10% must be recycled by Penn State standards. In order to keep transportation and the use of gasoline to a minimum, LEED points are given if materials are used that are located within a 500 mile radius of the project. In this case, the redesign of the building was done with precast concrete and Nitterhouse is a well-known company for precast concrete materials for the Mid-Atlantic region. In fact, the plant is only about 70 miles away from the Hershey Medical Center.

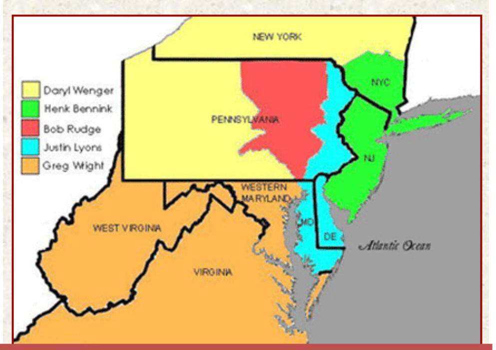


Figure 24: ***Regions Serviced by Nitterhouse***

Indoor Environmental Quality

Because the labs need to be in a controlled environment, the building is mechanically ventilated. In order to satisfy this LEED point, it helps to install carbon dioxide monitors in spaces with 25 people per 1000 sq. ft. or more. Also, outdoor airflow measurement devices help to make sure that the mechanical system is not overworking and wasting energy. Observing these factors should be done during construction and before occupancy just to monitor the well being of building occupants. Another important part of this section is that the materials used in the building are low-emitting materials to keep all occupants safe. As well as safe, there is an order for occupant comfort with lighting and temperature. Part of the occupant comfort for the CFG is the use of daylight and the view that occupants get from the two-story atrium with the curtain wall.

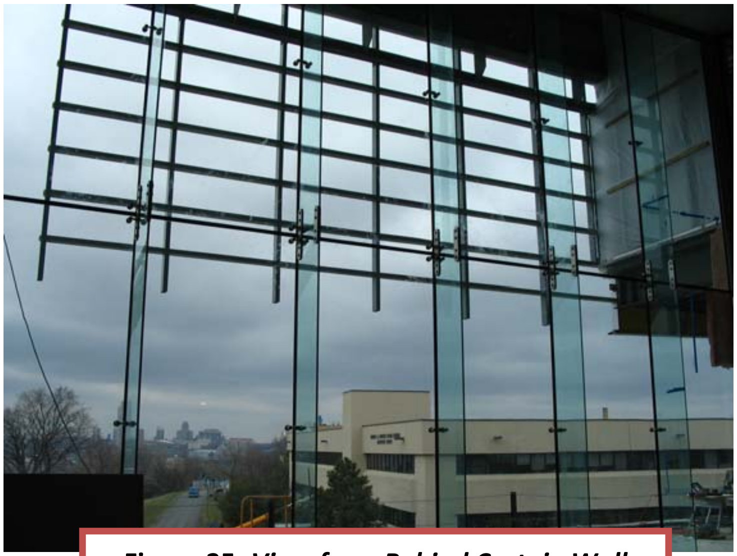


Figure 25: ***View from Behind Curtain Wall***

Conclusion

The redesign of the Gen*NY*Sis Center for Excellence in Cancer Genomics as a precast plank structure with concrete shear walls was a suitable replacement for the original composite steel framed building. However, it is probably not the ideal choice in this situation.

The concrete structure performed decently when it came to vibration sensitivity for the sensitive lab equipment. It performed well for equipment up to 1000 µips, which includes bench microscopes at a magnification greater than 400x. Even though it performed better than the steel structure, it can still be designed even better for the sensitive equipment used in this building.

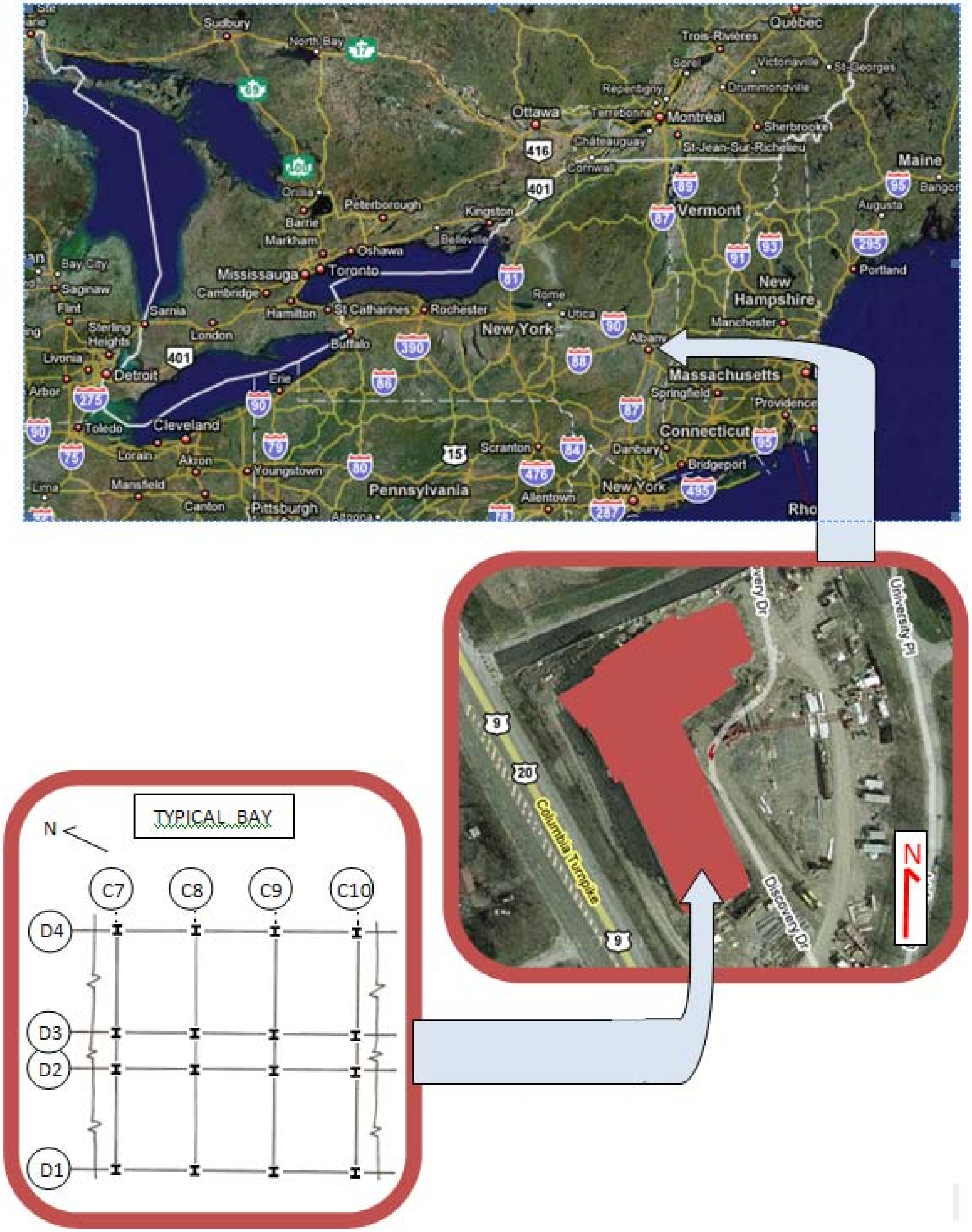
The overall architectural plan minimally changed in typical bay size which slightly changed the overall area of the building. However, the floor sandwich slightly decreased leaving a little bit more overhead space.

The foundation of the precast building needed to be resized and become larger thus more costly.

The resulting cost of was a cheaper overall system but the concrete shear walls were more expensive and longer to produce than that of the steel and lateral braced framing.

Many sustainable elements were able to be added to the building to make it a Penn State LEED approved building which is well on its way to being an official LEED approved building. And it demonstrates how effective planning of a building can allow it to be a truly green building.

Overall this thesis project brought together my five years of learning and also truly challenged me to remember everything I learned so I am now ready for the real world of structural engineering.


Sudbury
North Bay
Québec
Trois-Rivières
Sorel
Victoriaville
St-Georges
Drummondville
Repentigny
Terrebonne
Montréal
Sherbrooke
Ottawa
Châteauguay
St-Jean-Sur-Richelieu
Cornwall
416
401
Maine
Bangor
Augusta
Orillia
Peterborough
Kingston
Barrie
Belleville
Vermont
Markham
Oshawa
Portland
Bay City
Saginaw
Mississauga
Toronto
Cambridge
New Hampshire
Flint
Sarnia
Hamilton
St Catharines
Rochester
Rome
Utica
Manchester
Sterling Heights
London
Buffalo
New York
Albany
Livonia
Detroit
Erie
Massachusetts
Springfield
Providence
Arbor
Toledo
Cleveland
Connecticut
Lorain
Akron
Youngstown
Scranton
Danbury
Bridgeport
Lima
Mansfield
Canton
Pittsburgh
Pennsylvania
Allentown
New York
Rho
Altoona
90
275
75
79
80
86
390
81
88
87
89
91
93
95
295
476
84
495
287
15
Discovery Dr
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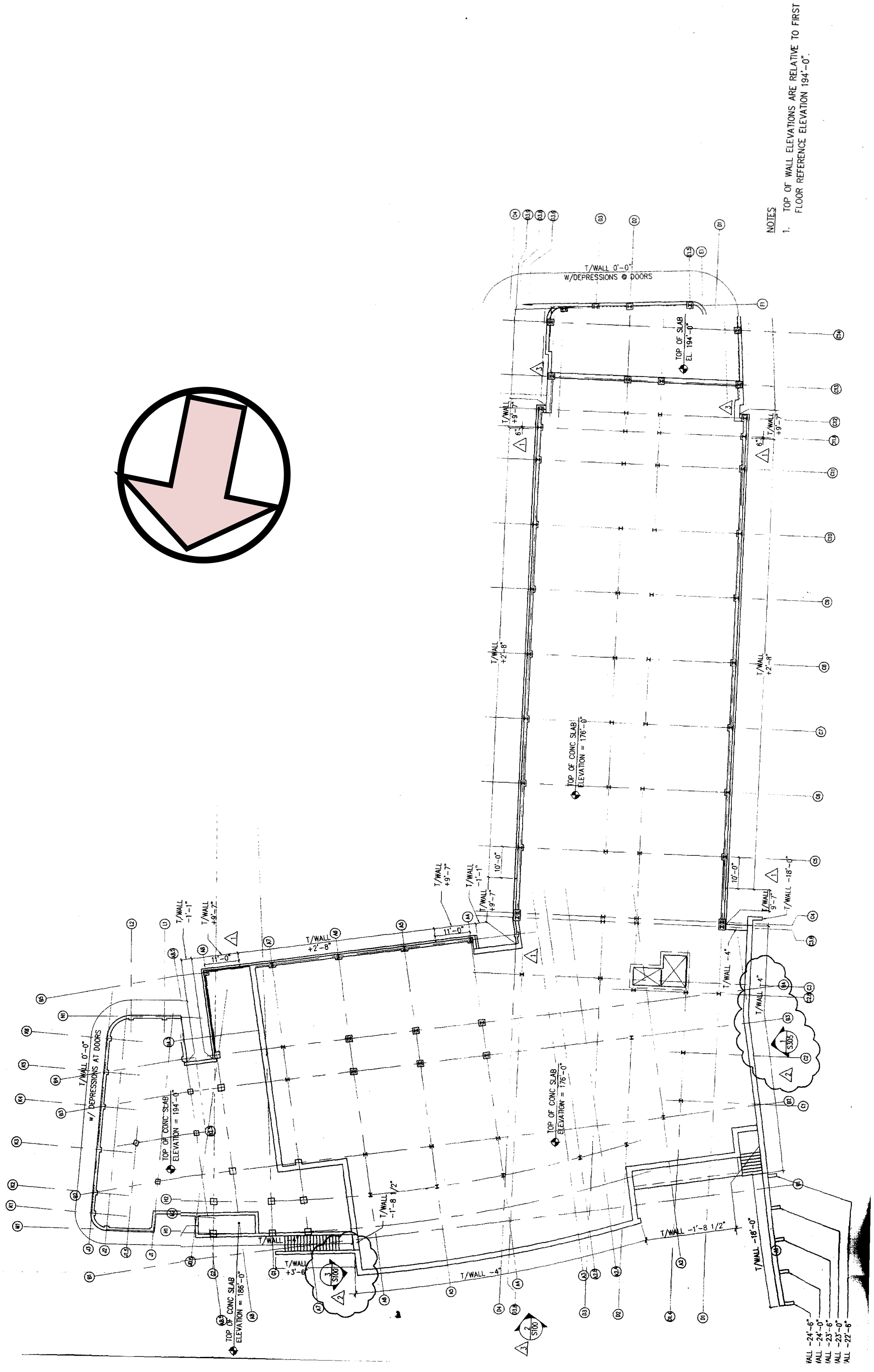
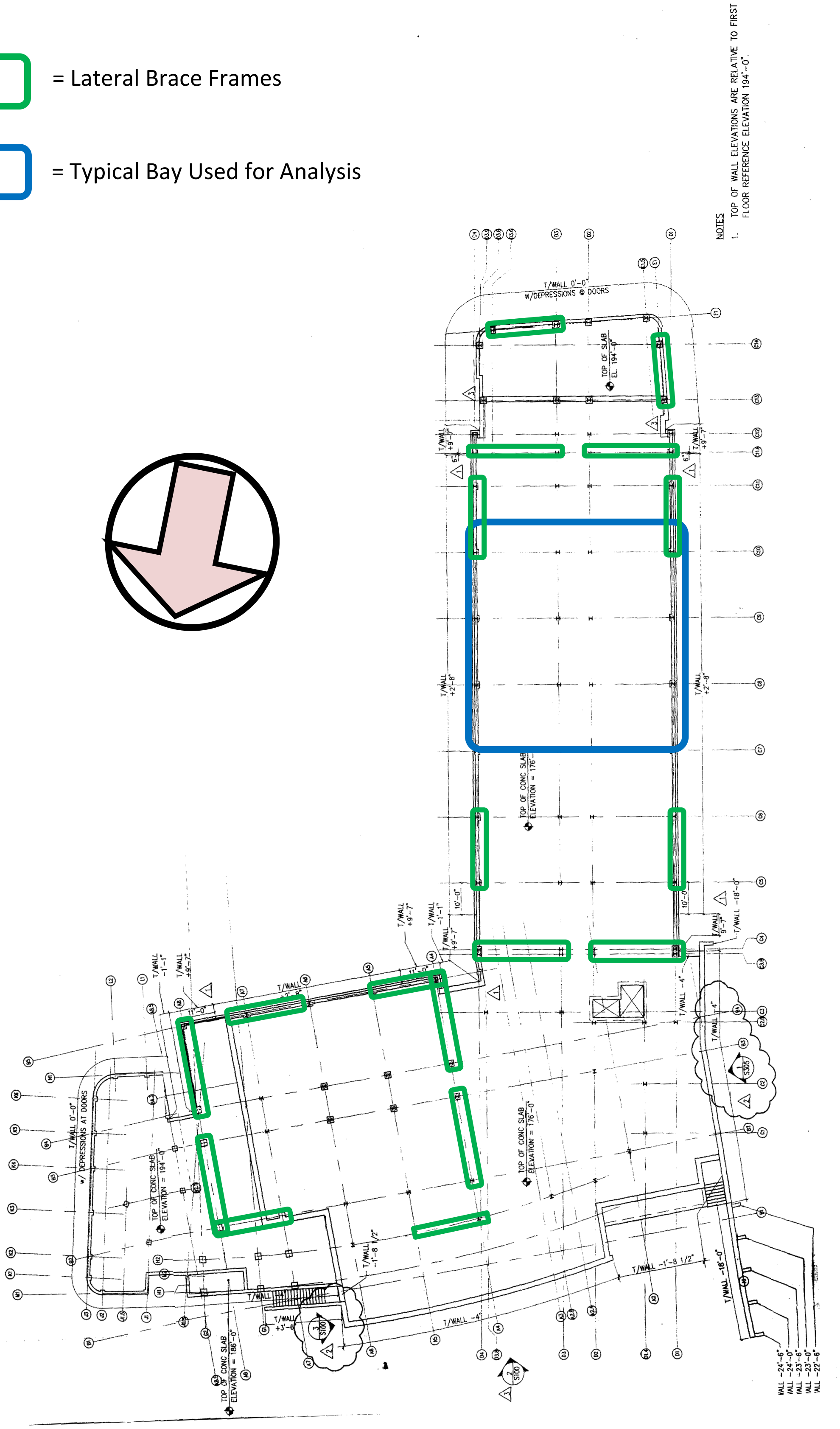

NOTES
1. TOP OF WALL ELEVATIONS ARE RELATIVE TO FIRST FLOOR REFERENCE ELEVATION 194'-0".
T/WALL 0'-0" W/DEPRESSIONS @ DOORS
TOP OF SLAB EL 194'-0"
T/WALL +9'-7"
T/WALL +2'-8"
TOP OF CONC SLAB ELEVATION = 176'-0"
T/WALL -18'-0"
10'-0"
T/WALL -1'-1"
11'-0"
T/WALL -4"
TOP OF CONC SLAB ELEVATION = 194'-0"
TOP OF CONC SLAB ELEVATION = 186'-0"
T/WALL -1'-8 1/2"
T/WALL -16'-0"
T/WALL +3'-6"
S100
S305

🟩 = Lateral Brace Frames

🟦 = Typical Bay Used for Analysis



Breakdown of New Hershey Wind Loads

	Elevation	Height Above Base (ft)	Height Above Ground (ft)	K_1	K_2 (1- (12 /(1.4*40)))	K_3 (e^ -0.0625z)	K_{zt}	K_z	q_z
Penthouse	263'-0"	87.00	78.00	0.119	1.000	0.78	1.19	0.921	19.4
Roof	242'-0"	66.00	54.00	0.119	1.000	0.78	1.19	0.829	17.5
3rd	226'-0"	50.00	38.00	0.119	1.000	0.78	1.19	0.750	15.8
2nd	210'-0"	34.00	22.00	0.119	1.000	0.78	1.19	0.641	13.5
1st	194'-0"	18.00	6.00	0.119	1.000	0.78	1.19	0.442	9.3
Grade	188'-0"	12.00	0.00	0.119	1.000	0.78	1.19	0.570	12.0
Ground	176'-0"	0.00	-12.00	0.119	1.000	0.78	1.19	0.570	12.0
at h			67.20	0.119	1.000	0.78	1.19	0.878	18.5

BLDG SECT A

	Elevation	Height Above Base (ft)	q_z	qGC_p (windward)	q_iGCp_i positive	q_iGCp_i negative	qGC_p (leeward)		Total WW (psf)	Total LW (psf)	Total Wind Load (psf)	Tributary Area (sf)	Load (kips)	Shear (kips)	Moment (ft-kips)
Penthouse	263'-0"	87.00	19.4	13.08	3.49	-3.33	-4.68	0.16	16.57	-8.01	24.58	3868	95.07	0	8271
Roof	242'-0"	66.00	17.5	11.77	3.14	-3.33	-4.68	-0.19	14.92	-8.01	22.92	3868	88.66	95.07	5852
3rd	226'-0"	50.00	15.8	10.65	2.84	-3.33	-4.68	-0.48	13.49	-8.01	21.50	3868	83.17	183.73	4158
2nd	210'-0"	34.00	13.5	9.10	2.43	-3.33	-4.68	-0.90	11.53	-8.01	19.54	3868	75.58	266.89	2570
1st	194'-0"	18.00	9.3	6.28	1.67	-3.33	-4.68	-1.65	7.95	-8.01	15.96	3868	61.73	342.47	1111
BASE	176'-0"	0.00							64.47	-40.03	104.49	19341	404.20	404.20	35166

BLDG SECT B

	Elevation	Height Above Base (ft)	q_z	qGC_p (windward)	q_iGCp_i positive	q_iGCp_i negative	qGC_p (leeward)		Total WW (psf)	Total LW (psf)	Total Wind Load (psf)	Tributary Area (sf)	Load (kips)	Shear (kips)	Moment (ft-kips)
Penthouse	263'-0"	87.00	19.4	12.61	3.49	-3.33	-7.52	0.16	16.10	-10.85	26.95	1197	32.27	0	2807
Roof	242'-0"	66.00	17.5	11.35	3.14	-3.33	-7.52	-0.19	14.49	-10.85	25.34	1197	30.34	32.27	2002
3rd	226'-0"	50.00	15.8	10.27	2.84	-3.33	-7.52	-0.49	13.11	-10.85	23.96	1197	28.69	62.61	1434
2nd	210'-0"	34.00	13.5	8.78	2.43	-3.33	-7.52	-0.90	11.20	-10.85	22.05	1197	26.41	91.29	898
1st	194'-0"	18.00	9.3	6.05	1.67	-3.33	-7.52	-1.66	7.73	-10.85	18.58	1197	22.24	117.70	400
BASE	176'-0"	0.00							62.63	-54.25	116.88	5987	139.94	139.94	12175

New Hershey Seismic Criteria

0.2-Sec Spectral Response Acceleration			
	S_s	0.209	(%) of gravi
1.0-Sec Spectral Response Acceleration			
	S_1	0.055	(%) of gravi
Site Class	C		
Short-Period Site Coefficient			
	F_a	1.2	
Long-Period Site Coefficient			
	F_v	1.7	
	S_{MS}	0.2508	
	S_{M1}	0.094	
	S_{DS}	0.167	
	S_{D1}	0.062	
mic Design Category	B		
ortance Factor	I	1.0	
	R	4.0	
roximate Fundamental Period			
	T_L	6.00	sec
	T_a	0.584	sec
	C_t	0.02	
	x	0.75	
	h_n	90.0	ft
damental Period			
	T	0.993	
	C_u	1.7	
Seismic Response Coefficient			
	C_s	0.0267	
Building Weight	W	12400	kips
mic Design Shear			
	V	331	^{k}

New Hershey Wind Criteria

[redacted]

		Original		New	
		N-S	E-W	A	B
Shear	Wind	263.1	263.7	404.2	140.0
	Seismic	279.0	279.0	331.0	331.0
Moment	Wind	14244.0	14444.0	21962.0	7541.0
	Seismic	15997.0	15997.0	18962.0	18692.0

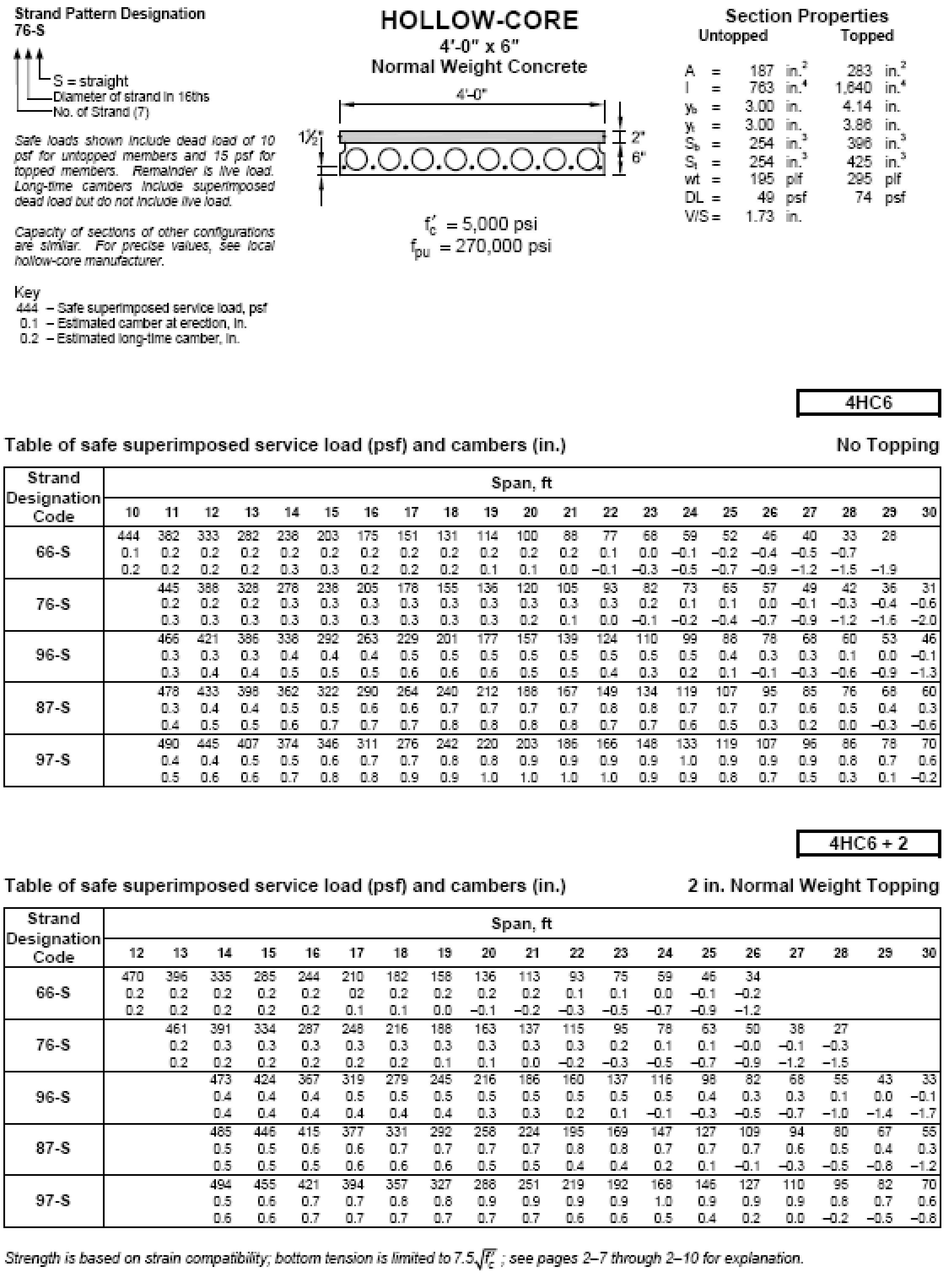
Comparison of New and Old Controlling Loads

		Penthouse	Roof	3rd	2nd	1st	Total
qz	Original	20	18.2	17	14.5	12.1	
	New	19.39	17.45	15.49	13.49	9.3	
Total WW (psf)	Original N-S	17.63	16.37	15.33	13.77	12.09	
	New Bldg A	16.57	14.92	13.49	11.53	7.95	
	Original E-W	10.35	9.1	8.26	6.52	4.84	
	New Bldg B	16.1	14.49	13.11	11.2	7.73	
Total LW (psf)	Original N-S	12.37	12.37	12.37	12.37	12.37	
	New Bldg A	8.01	8.01	8.01	8.01	8.01	
	Original E-W	12.32	12.32	12.32	12.32	12.32	
	New Bldg B	10.85	10.85	10.85	10.85	10.85	
Load (kips)	Original N-S	69.3	50.6	48.8	46	48.4	**263.1**
	New Bldg A	95.07	88.66	83.17	75.58	61.73	**404.21**
	Original E-W	71.4	51.4	49.4	45.2	46.3	**263.7**
	New Bldg B	32.27	30.34	28.69	26.41	22.24	**139.95**
Moment (ft-kips)	Original N-S	6029	3340	2440	1564	871	**14244**
	New Bldg A	8271	5852	4158	2570	1111	**21962**
	Original E-W	6212	3392	2470	1537	833	**14444**
	New Bldg B	2807	2002	1434	898	400	**7541**

Comparison of Albany Wind Loads to Hershey Wind Loads

		Penthouse	Roof	3rd	2nd	1st	Total
w_x (kips)	Original	564	1921	1947	1913	2644	
	New	1022	1921	1947	1913	2644	
$h_x^k w_x$ (ft-kips)	Original	418750	947223	636563	353430	190574	
	New	88914	126786	97350	65042	47592	
C_{vx}	Original	0.164	0.372	0.25	0.139	0.075	
	New	0.209	0.298	0.229	0.153	0.112	
$F_x = C_{vx}V$ (kips)	Original	45.8	103.6	69.6	38.7	20.9	
	New	69.1	98.6	75.7	50.6	37	
V (kips)	Original	0	46	149	219	258	**279**
	New	0	69.1	167.7	243.4	294	**331**
$M = F_x h_x$ (ft-kips)	Original	3984	6840	3482	1315	375	**15997**
	New	6015	6507	3785	1720	666	**18692**

Comparison of Albany Seismic Loads to Hershey Seismic Loads



Strand Pattern Designation
76-S

S = straight
Diameter of strand in 16ths
No. of Strand (7)

Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

Key
444 – Safe superimposed service load, psf
0.1 – Estimated camber at erection, in.
0.2 – Estimated long-time camber, in.

HOLLOW-CORE
4'-0" x 6"
Normal Weight Concrete

f'_c = 5,000 psi
f_{pu} = 270,000 psi

Section Properties

		Untopped		Topped	
A	=	187	$in.^2$	283	$in.^2$
I	=	763	$in.^4$	1,640	$in.^4$
y_b	=	3.00	in.	4.14	in.
y_t	=	3.00	in.	3.86	in.
S_b	=	254	$in.^3$	396	$in.^3$
S_t	=	254	$in.^3$	425	$in.^3$
wt	=	195	plf	295	plf
DL	=	49	psf	74	psf
V/S	=	1.73	in.		

4HC6

Table of safe superimposed service load (psf) and cambers (in.) **No Topping**

Strand Designation Code	Span, ft																				
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
66-S	444	362	333	282	238	203	175	151	131	114	100	88	77	68	59	52	46	40	33	28	
	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.5	−0.7		
	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.3	−0.5	−0.7	−0.9	−1.2	−1.5	−1.9	
76-S		445	386	328	278	238	205	178	155	136	120	105	93	82	73	65	57	49	42	36	31
		0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.0	−0.1	−0.3	−0.4	−0.6
		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.7	−0.9	−1.2	−1.6	−2.0
96-S		466	421	386	338	292	263	229	201	177	157	139	124	110	99	88	78	68	60	53	46
		0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.1	0.0	−0.1
		0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.3	0.2	0.1	−0.1	−0.3	−0.6	−0.9	−1.3
87-S		478	433	398	362	322	290	264	240	212	188	167	149	134	119	107	95	85	76	68	60
		0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.3
		0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.3	0.2	0.0	−0.3	−0.6
97-S		490	445	407	374	346	311	276	242	220	203	186	166	148	133	119	107	96	86	78	70
		0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6
		0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.3	0.1	−0.2

4HC6 + 2

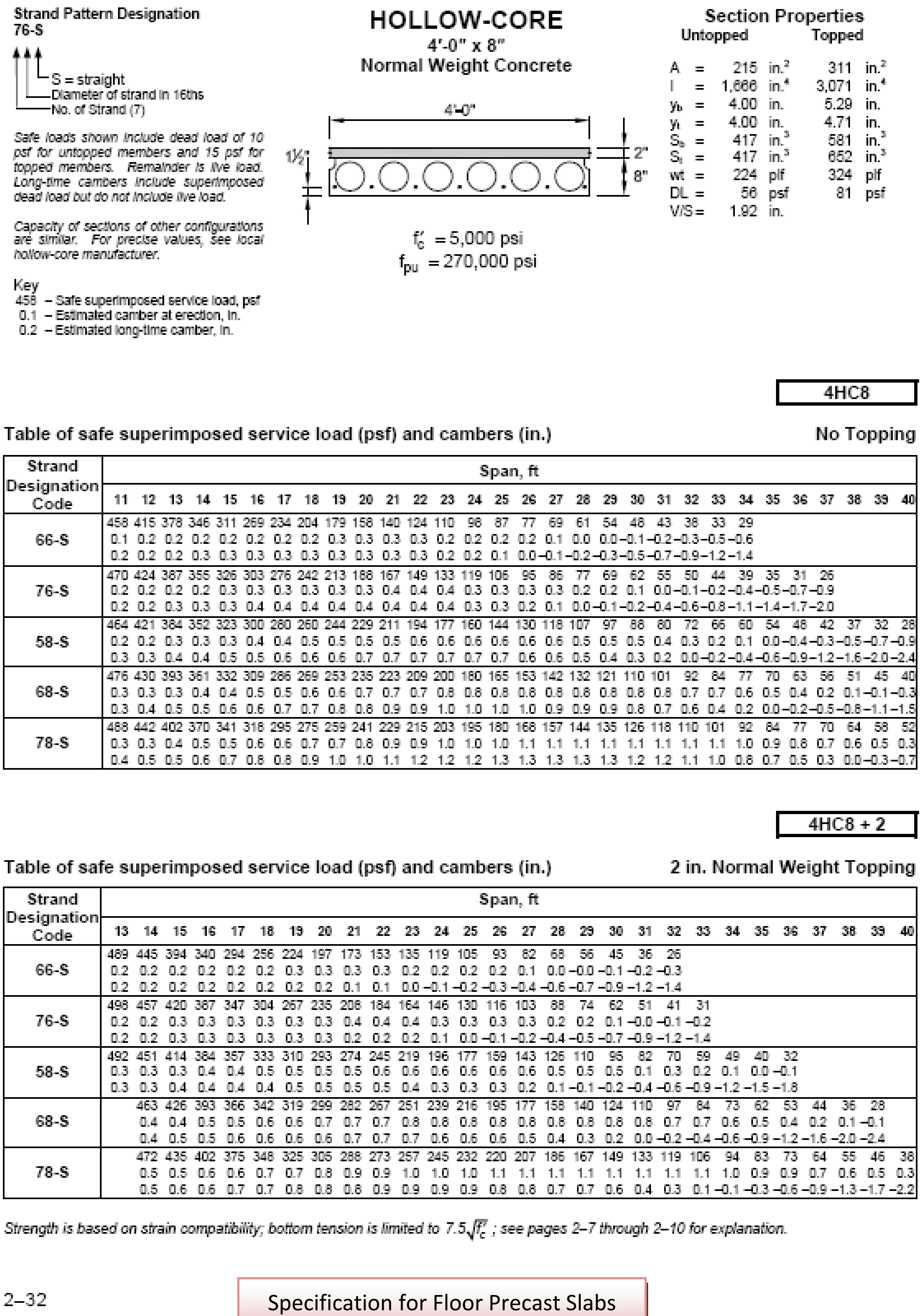
Table of safe superimposed service load (psf) and cambers (in.) **2 in. Normal Weight Topping**

Strand Designation Code	Span, ft																		
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
66-S	470	396	335	285	244	210	182	158	136	113	93	75	59	46	34				
	0.2	0.2	0.2	0.2	0.2	02	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.2				
	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.2	−0.3	−0.5	−0.7	−0.9	−1.2				
76-S		461	391	334	287	248	216	188	163	137	115	95	78	63	50	38	27		
		0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.1	−0.0	−0.1	−0.3		
		0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.2	−0.3	−0.5	−0.7	−0.9	−1.2	−1.5		
96-S			473	424	367	319	279	245	216	186	160	137	116	98	82	68	55	43	33
			0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.1	0.0	−0.1
			0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	−0.1	−0.3	−0.5	−0.7	−1.0	−1.4	−1.7
87-S			485	446	415	377	331	292	258	224	195	169	147	127	109	94	80	67	55
			0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.3
			0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.2	0.1	−0.1	−0.3	−0.5	−0.8	−1.2
97-S			494	455	421	394	357	327	288	251	219	192	168	146	127	110	95	82	70
			0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6
			0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.2	0.0	−0.2	−0.5	−0.8

Strength is based on strain compatibility; bottom tension is limited to $7.5\sqrt{f'_c}$ *; see pages 2–7 through 2–10 for explanation.*

2–31

Specification for Roof Precast Slabs



Strand Pattern Designation
76-S

S = straight
Diameter of strand in 16ths
No. of Strand (7)

Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

Key
458 – Safe superimposed service load, psf
0.1 – Estimated camber at erection, in.
0.2 – Estimated long-time camber, in.

HOLLOW-CORE

4'-0" x 8"
Normal Weight Concrete

f'_c = 5,000 psi
f_{pu} = 270,000 psi

Section Properties

		Untopped		Topped	
A	=	215	in.^{2}	311	in.^{2}
I	=	1,666	in.^{4}	3,071	in.^{4}
y_b	=	4.00	in.	5.29	in.
y_t	=	4.00	in.	4.71	in.
S_b	=	417	in.^{3}	581	in.^{3}
S_t	=	417	in.^{3}	652	in.^{3}
wt	=	224	plf	324	plf
DL	=	56	psf	81	psf
V/S	=	1.92	in.		

4HC8

Table of safe superimposed service load (psf) and cambers (in.) **No Topping**

Strand Designation Code	Span, ft																													
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
66-S	458	415	378	346	311	269	234	204	179	158	140	124	110	96	87	77	69	61	54	48	43	38	33	29						
	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.5	-0.6						
	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.5	-0.7	-0.9	-1.2	-1.4						
76-S	470	424	387	355	326	303	276	242	213	188	167	149	133	119	106	95	86	77	69	62	55	50	44	39	35	31	26			
	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9			
	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7	-2.0			
58-S	464	421	384	352	323	300	280	260	244	229	211	194	177	160	144	130	118	107	97	88	80	72	66	60	54	48	42	37	32	28
	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0.0	-0.4	-0.3	-0.5	-0.7	-0.9
	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.3	0.2	0.0	-0.2	-0.4	-0.6	-0.9	-1.2	-1.6	-2.0	-2.4
68-S	476	430	393	361	332	309	286	269	253	235	223	209	200	180	165	153	142	132	121	110	101	92	84	77	70	63	56	51	45	40
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	-0.1	-0.3
	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.4	0.2	0.0	-0.2	-0.5	-0.8	-1.1	-1.5
78-S	488	442	402	370	341	318	295	275	259	241	229	215	203	195	180	168	157	144	135	126	118	110	101	92	84	77	70	64	58	52
	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.3
	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.8	0.7	0.5	0.3	0.0	-0.3	-0.7

4HC8 + 2

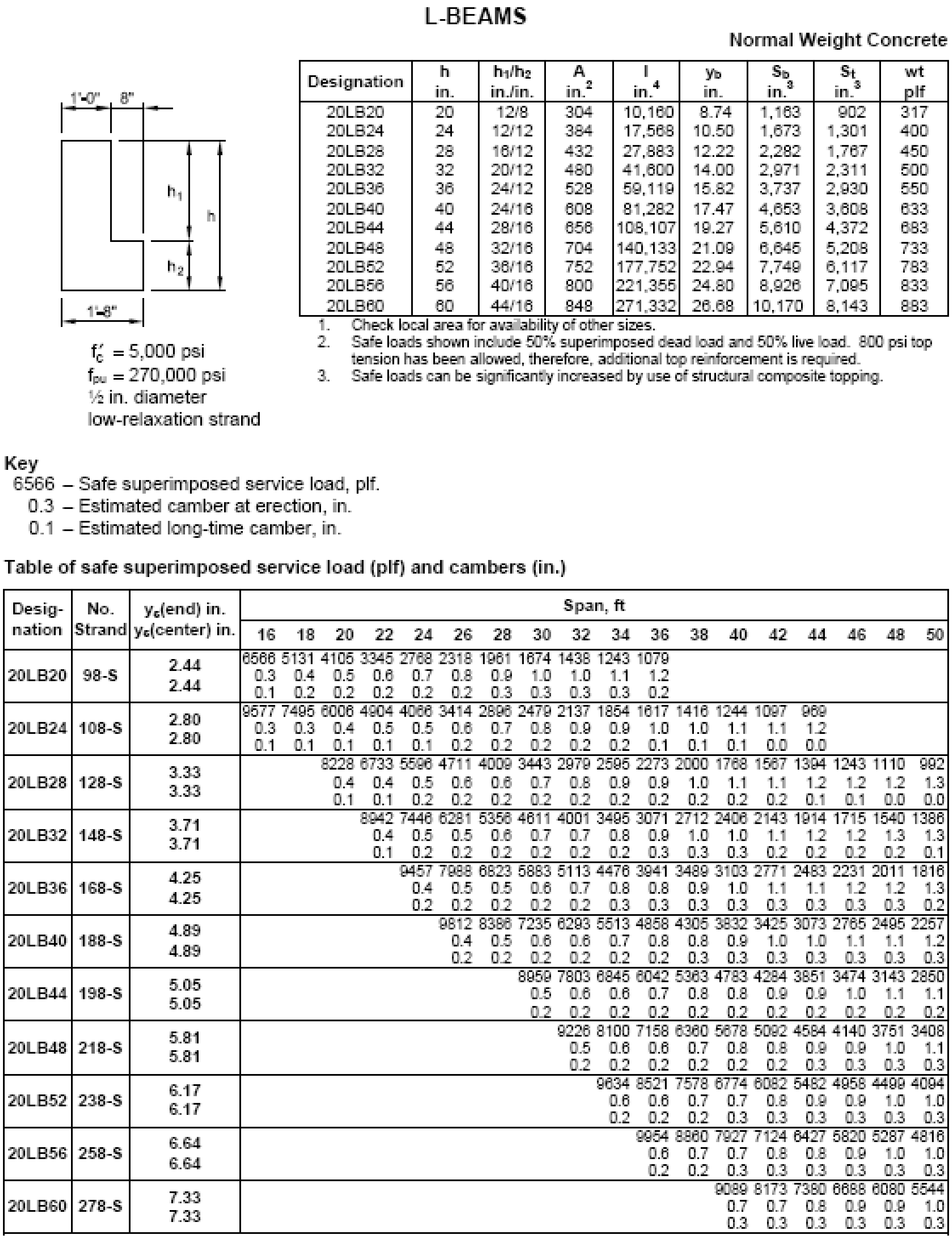
Table of safe superimposed service load (psf) and cambers (in.) **2 in. Normal Weight Topping**

Strand Designation Code	Span, ft																											
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
66-S	489	445	394	340	294	256	224	197	173	153	135	119	105	93	82	68	56	45	36	26								
	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	-0.0	-0.1	-0.2	-0.3								
	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.7	-0.9	-1.2	-1.4								
76-S	498	457	420	387	347	304	267	235	208	184	164	146	130	116	103	88	74	62	51	41	31							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	-0.0	-0.1	-0.2							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.0	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9	-1.2	-1.4							
58-S	492	451	414	384	357	333	310	293	274	245	219	196	177	159	143	126	110	96	82	70	59	49	40	32				
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.1	0.3	0.2	0.1	0.0	-0.1				
	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.1	-0.1	-0.2	-0.4	-0.6	-0.9	-1.2	-1.5	-1.8				
68-S		463	426	393	366	342	319	299	282	267	251	239	216	195	177	158	140	124	110	97	84	73	62	53	44	36	28	
		0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	-0.1	
		0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.0	-0.2	-0.4	-0.6	-0.9	-1.2	-1.6	-2.0	-2.4	
78-S		472	435	402	375	348	325	305	288	273	257	245	232	220	207	186	167	149	133	119	106	94	83	73	64	55	46	38
		0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9	0.7	0.6	0.5	0.3
		0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.4	0.3	0.1	-0.1	-0.3	-0.6	-0.9	-1.3	-1.7	-2.2

Strength is based on strain compatibility; bottom tension is limited to $7.5\sqrt{f'_c}$; see pages 2–7 through 2–10 for explanation.

2–32

Specification for Floor Precast Slabs



L-BEAMS

Normal Weight Concrete

Designation	h in.	h_1/h_2 in./in.	A in.^{2}	I in.^{4}	y_b in.	S_b in.^{3}	S_t in.^{3}	wt plf
20LB20	20	12/8	304	10,160	8.74	1,163	902	317
20LB24	24	12/12	384	17,568	10.50	1,673	1,301	400
20LB28	28	16/12	432	27,883	12.22	2,282	1,767	450
20LB32	32	20/12	480	41,600	14.00	2,971	2,311	500
20LB36	36	24/12	528	59,119	15.82	3,737	2,930	550
20LB40	40	24/16	608	81,282	17.47	4,653	3,608	633
20LB44	44	28/16	656	108,107	19.27	5,610	4,372	683
20LB48	48	32/16	704	140,133	21.09	6,645	5,208	733
20LB52	52	36/16	752	177,752	22.94	7,749	6,117	783
20LB56	56	40/16	800	221,355	24.80	8,926	7,095	833
20LB60	60	44/16	848	271,332	26.68	10,170	8,143	883

1. Check local area for availability of other sizes.
2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore, additional top reinforcement is required.
3. Safe loads can be significantly increased by use of structural composite topping.

f'_c = 5,000 psi
f_{pu} = 270,000 psi
½ in. diameter
low-relaxation strand

Key
6566 – Safe superimposed service load, plf.
0.3 – Estimated camber at erection, in.
0.1 – Estimated long-time camber, in.

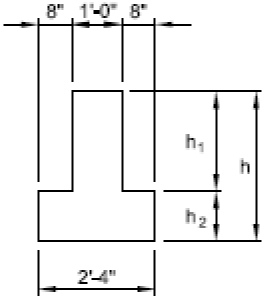
Table of safe superimposed service load (plf) and cambers (in.)

Desig-nation	No. Strand	y_s(end) in. y_s(center) in.	Span, ft																	
			16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
20LB20	98-S	2.44 2.44	6566 0.3 0.1	5131 0.4 0.2	4105 0.5 0.2	3345 0.6 0.2	2768 0.7 0.2	2318 0.8 0.2	1961 0.9 0.3	1674 1.0 0.3	1438 1.0 0.3	1243 1.1 0.3	1079 1.2 0.2							
20LB24	108-S	2.80 2.80	9577 0.3 0.1	7495 0.3 0.1	6006 0.4 0.1	4904 0.5 0.1	4066 0.5 0.1	3414 0.6 0.2	2896 0.7 0.2	2479 0.8 0.2	2137 0.9 0.2	1854 0.9 0.2	1617 1.0 0.1	1416 1.0 0.1	1244 1.1 0.1	1097 1.1 0.0	969 1.2 0.0			
20LB28	128-S	3.33 3.33			8228 0.4 0.1	6733 0.4 0.1	5596 0.5 0.2	4711 0.6 0.2	4009 0.6 0.2	3443 0.7 0.2	2979 0.8 0.2	2595 0.9 0.2	2273 0.9 0.2	2000 1.0 0.2	1768 1.1 0.2	1567 1.1 0.2	1394 1.2 0.1	1243 1.2 0.1	1110 1.2 0.0	992 1.3 0.0
20LB32	148-S	3.71 3.71				8942 0.4 0.1	7446 0.5 0.2	6281 0.5 0.2	5356 0.6 0.2	4611 0.7 0.2	4001 0.7 0.2	3495 0.8 0.2	3071 0.9 0.3	2712 1.0 0.3	2406 1.0 0.3	2143 1.1 0.2	1914 1.2 0.2	1715 1.2 0.2	1540 1.3 0.2	1386 1.3 0.1
20LB36	168-S	4.25 4.25					9457 0.4 0.2	7988 0.5 0.2	6823 0.5 0.2	5883 0.6 0.2	5113 0.7 0.2	4476 0.8 0.3	3941 0.8 0.3	3489 0.9 0.3	3103 1.0 0.3	2771 1.1 0.3	2483 1.1 0.3	2231 1.2 0.3	2011 1.2 0.3	1816 1.3 0.2
20LB40	188-S	4.89 4.89						9812 0.4 0.2	8386 0.5 0.2	7235 0.6 0.2	6293 0.6 0.2	5513 0.7 0.2	4858 0.8 0.2	4305 0.8 0.3	3832 0.9 0.3	3425 1.0 0.3	3073 1.0 0.3	2765 1.1 0.3	2495 1.1 0.3	2257 1.2 0.3
20LB44	198-S	5.05 5.05								8959 0.5 0.2	7803 0.6 0.2	6845 0.6 0.2	6042 0.7 0.2	5363 0.8 0.2	4783 0.8 0.2	4284 0.9 0.2	3851 0.9 0.2	3474 1.0 0.2	3143 1.1 0.2	2850 1.1 0.2
20LB48	218-S	5.81 5.81									9226 0.5 0.2	8100 0.6 0.2	7158 0.6 0.2	6360 0.7 0.2	5678 0.8 0.2	5092 0.8 0.2	4584 0.9 0.3	4140 0.9 0.3	3751 1.0 0.3	3408 1.1 0.3
20LB52	238-S	6.17 6.17										9634 0.6 0.2	8521 0.6 0.2	7578 0.7 0.2	6774 0.7 0.3	6082 0.8 0.3	5482 0.9 0.3	4958 0.9 0.3	4499 1.0 0.3	4094 1.0 0.3
20LB56	258-S	6.64 6.64											9954 0.6 0.2	8860 0.7 0.2	7927 0.7 0.3	7124 0.8 0.3	6427 0.8 0.3	5820 0.9 0.3	5287 1.0 0.3	4816 1.0 0.3
20LB60	278-S	7.33 7.33													9089 0.7 0.3	8173 0.7 0.3	7380 0.8 0.3	6688 0.9 0.3	6080 0.9 0.3	5544 1.0 0.3

Specification for Edge L-Beam Precast Beams

INVERTED TEE BEAMS

Normal Weight Concrete



Section Properties								
Designation	h in.	h_1/h_2 in./in.	A $in.^2$	I $in.^4$	y_b in.	S_b $in.^3$	S_t $in.^3$	wt plf
28IT20	20	12/8	368	11,688	7.91	1,478	967	383
28IT24	24	12/12	480	20,275	9.60	2,112	1,408	500
28IT28	28	16/12	528	32,076	11.09	2,892	1,897	550
28IT32	32	20/12	576	47,872	12.67	3,778	2,477	600
28IT36	36	24/12	624	68,101	14.31	4,759	3,140	650
28IT40	40	24/16	736	93,503	15.83	5,907	3,869	767
28IT44	44	28/16	784	124,437	17.43	7,139	4,683	817
28IT48	48	32/16	832	161,424	19.08	8,460	5,582	867
28IT52	52	36/16	880	204,884	20.76	9,869	6,558	917
28IT56	56	40/16	928	255,229	22.48	11,354	7,614	967
28IT60	60	44/16	976	312,866	24.23	12,912	8,747	1,017

1. Check local area for availability of other sizes.
2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore, additional top reinforcement is required.
3. Safe loads can be significantly increased by use of structural composite topping.

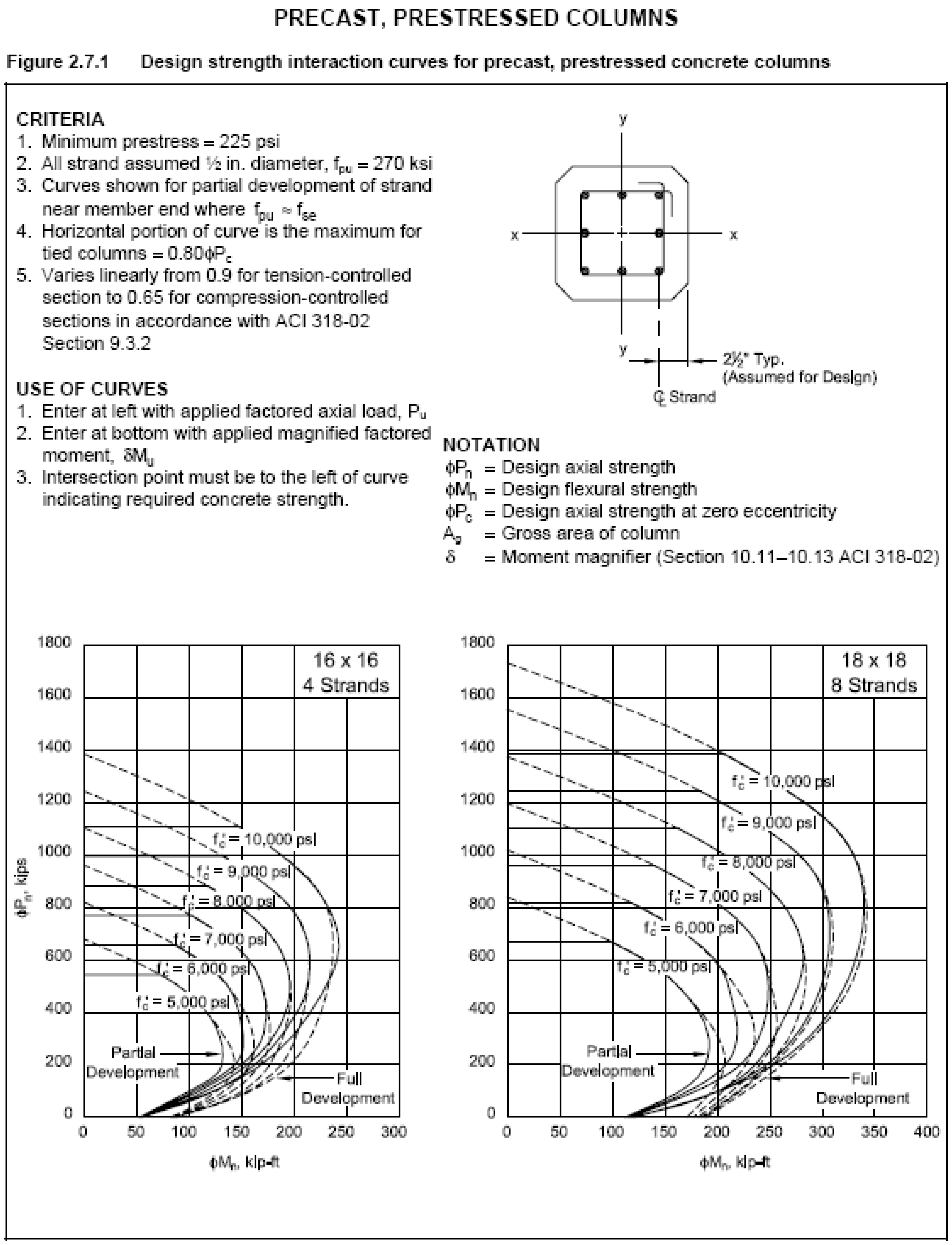
f'_c = 5,000 psi
f_{pu} = 270,000 psi
½ in. diameter
low-relaxation strand

Key
6511 – Safe superimposed service load, plf.
0.2 – Estimated camber at erection, in.
0.1 – Estimated long-time camber, in.

Table of safe superimposed service load (plf) and cambers (in.)

Desig-nation	No. Strand	y_s(end) in. y_s(center) in.	Span, ft																	
			16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
28IT20	98-S	2.44 2.44	6511 0.2 0.1	5076 0.3 0.1	4049 0.4 0.1	3289 0.4 0.1	2711 0.5 0.1	2262 0.5 0.1	1905 0.6 0.0	1617 0.7 0.0	1381 0.7 0.0	1186 0.7 0.0	1022 0.8 –0.1							
28IT24	188-S	2.73 2.73	9612 0.2 0.1	7504 0.3 0.1	5997 0.3 0.1	4882 0.4 0.1	4034 0.4 0.1	3374 0.5 0.1	2850 0.6 0.1	2427 0.6 0.1	2081 0.7 0.1	1795 0.7 0.1	1555 0.7 0.0	1351 0.8 0.0	1178 0.8 –0.1	1029 0.8 –0.2				
28IT28	138-S	3.08 3.08			8353 0.3 0.1	6822 0.3 0.1	5657 0.4 0.1	4750 0.5 0.1	4031 0.5 0.1	3451 0.6 0.1	2976 0.6 0.1	2582 0.7 0.1	2252 0.7 0.1	1973 0.8 0.1	1735 0.8 0.0	1530 0.8 0.0	1352 0.9 –0.1	1197 0.8 –0.2	1061 0.8 –0.2	
28IT32	158-S	3.47 3.47				9049 0.3 0.1	7521 0.4 0.1	5333 0.4 0.1	5389 0.5 0.1	4628 0.5 0.1	4006 0.6 0.1	3490 0.6 0.1	3057 0.7 0.1	2691 0.7 0.1	2379 0.8 0.1	2110 0.8 0.1	1876 0.9 0.0	1673 0.9 0.0	1495 0.9 0.0	1337 0.9 –0.1
28IT36	168-S	3.50 3.50					9832 0.3 0.1	8295 0.4 0.1	7075 0.4 0.1	6092 0.5 0.1	5287 0.5 0.1	4619 0.6 0.1	4060 0.6 0.1	3587 0.7 0.1	3183 0.7 0.1	2835 0.8 0.1	2534 0.8 0.0	2271 0.9 0.0	2040 0.9 0.0	1836 0.9 –0.1
28IT40	198-S	4.21 4.21							8638 0.4 0.1	7440 0.5 0.1	6460 0.5 0.1	5647 0.6 0.1	4966 0.6 0.1	4390 0.7 0.1	3898 0.7 0.1	3474 0.8 0.1	3107 0.8 0.1	2787 0.8 0.1	2506 0.9 0.1	2258 0.9 0.1
28IT44	208-S	4.40 4.40								9186 0.4 0.1	7989 0.5 0.1	6997 0.5 0.1	6165 0.6 0.1	5462 0.6 0.1	4861 0.7 0.1	4344 0.7 0.1	3896 0.7 0.1	3505 0.8 0.1	3162 0.8 0.1	2859 0.8 0.0
28IT48	228-S	4.55 4.55									9719 0.4 0.1	8525 0.5 0.1	7523 0.5 0.1	6676 0.6 0.1	5953 0.6 0.1	5330 0.7 0.1	4791 0.7 0.1	4320 0.8 0.1	3907 0.8 0.1	3542 0.9 0.1
28IT52	248-S	5.17 5.17										9987 0.5 0.1	8823 0.5 0.1	7838 0.6 0.1	6998 0.6 0.1	6274 0.6 0.1	5647 0.7 0.1	4100 0.7 0.1	4619 0.8 0.1	4196 0.8 0.1
28IT56	268-S	5.23 5.23												9307 0.5 0.2	8319 0.6 0.2	7469 0.6 0.2	6731 0.7 0.2	6088 0.7 0.2	5524 0.8 0.2	5026 0.8 0.2
28IT60	288-S	5.57 5.57													9645 0.6 0.2	8668 0.6 0.2	7820 0.7 0.2	7081 0.7 0.2	6432 0.8 0.2	5859 0.8 0.2

Specification for Inverted T Precast Girder



PRECAST, PRESTRESSED COLUMNS

Figure 2.7.1 **Design strength interaction curves for precast, prestressed concrete columns**

CRITERIA

1. Minimum prestress = 225 psi
2. All strand assumed ½ in. diameter, f_{pu} = 270 ksi
3. Curves shown for partial development of strand near member end where $f_{pu} \approx f_{se}$
4. Horizontal portion of curve is the maximum for tied columns = $0.80\phi P_c$
5. Varies linearly from 0.9 for tension-controlled section to 0.65 for compression-controlled sections in accordance with ACI 318-02 Section 9.3.2

USE OF CURVES

1. Enter at left with applied factored axial load, P_u
2. Enter at bottom with applied magnified factored moment, δM_u
3. Intersection point must be to the left of curve indicating required concrete strength.

NOTATION

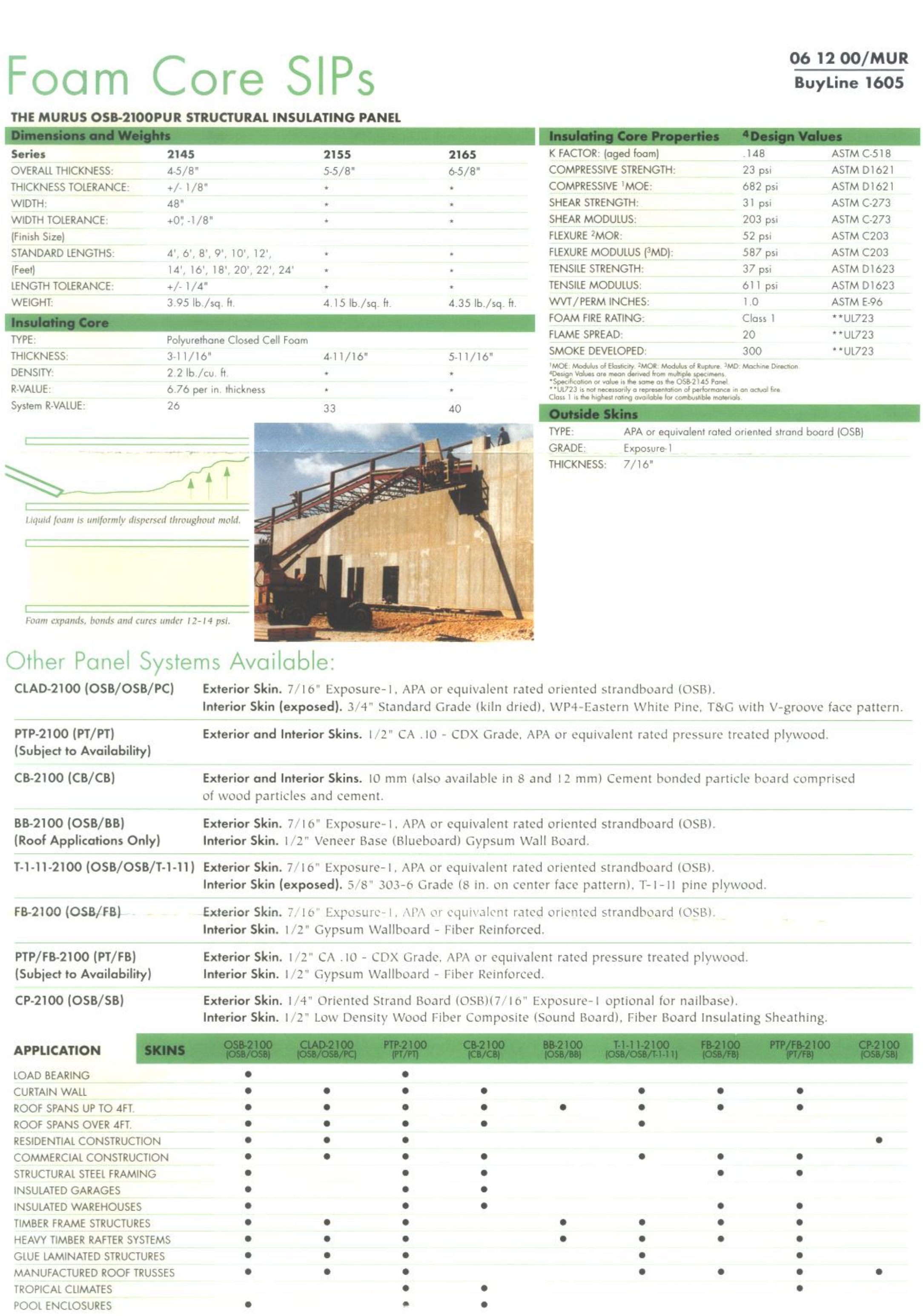
ϕP_n = Design axial strength
ϕM_n = Design flexural strength
ϕP_c = Design axial strength at zero eccentricity
A_g = Gross area of column
δ = Moment magnifier (Section 10.11–10.13 ACI 318-02)

2–48

Specification for Precast Column

Penthouse/Roof							
Mechanical Equipment	160 kips	160	kips				
Roof							
Roof Meadow DL =	70 psf x 14600 sf =	1022	kips				
Roof Garden LL with Assembly	100 psf x 14600 sf =	1460	kips				
1.2DL + 1.6LL =	1.2(160) + 1.6(1460) =	166	psf			<------------------------	Hollow-Core
		22600	sf				8" thick
							NWC
							4HC6 + 2" topping
							96-S
3rd Floor							
Roof Slab	74 psf x 22500 sf	1665	kips				
		2687	kips				
Roof Column DL	145 pcf x 1 ft^2 x 18.58 ft x 86 columns	232	kips				
Lab LL	70 psf x 19000 sf	1330	kips				
Corridor LL	80 psf x 3500 sf	280	kips				
1.2DL + 1.6LL		4852		216	psf	<----------	Hollow-Core
							10" thick
							4HC8 + 2" topping
							58-s
2nd Floor							
Weight from Above		2919	kips				
3rd Floor slab	81 psf x 22500 sf	1823	kips				
		4742	kips				
3rd Column DL	145 pcf x 1ft^2 x 16 ft x 86 columns	200	kips				
Lab LL	70 psf x 19000 sf	1330	kips				
Corridor LL	80 psf x 3500 sf	280	kips				
1.2DL + 1.6LL		5002		222	psf	<----------	Hollow-Core
							10" thick
							4HC8 + 2" topping
							58-s
1st Floor							
Weight from Above		4941	kips				
2nd Floor Slab	81 psf x 22500 sf	1823	kips				
		6764	kips				
2nd Column DL	145 pcf x 1 ft^2 x 16 ft x 103 columns	239	kips				
Lab LL	70 psf x 19000 sf	1330	kips				
Corridor LL	100 psf x 3500 sf	350	kips				
1.2DL + 1.6LL		5162		229	psf	<----------	Hollow-Core
							10" thick
							4HC8 + 2" topping
							58-s
Foundations							
Weight from Above		7002	kips				
1st Floor Slab	81 psf x 22500 sf	1823	kips				
1st Column DL	145 pcf x 1 ft^2 x 18 ft x 103 columns	269	kips				
Weight from SOG	145 pcf x 22600 sf x 6 in	1639	kips				

Precast Slab Loading



Foam Core SIPs

06 12 00/MUR
BuyLine 1605

THE MURUS OSB-2100PUR STRUCTURAL INSULATING PANEL

Dimensions and Weights			
Series	**2145**	**2155**	**2165**
OVERALL THICKNESS:	4-5/8"	5-5/8"	6-5/8"
THICKNESS TOLERANCE:	+/- 1/8"	*	*
WIDTH:	48"	*	*
WIDTH TOLERANCE: (Finish Size)	+0", -1/8"	*	*
STANDARD LENGTHS: (Feet)	4', 6', 8', 9', 10', 12', 14', 16', 18', 20', 22', 24'	* *	* *
LENGTH TOLERANCE:	+/- 1/4"	*	*
WEIGHT:	3.95 lb./sq. ft.	4.15 lb./sq. ft.	4.35 lb./sq. ft.
Insulating Core			
TYPE:	Polyurethane Closed Cell Foam		
THICKNESS:	3-11/16"	4-11/16"	5-11/16"
DENSITY:	2.2 lb./cu. ft.	*	*
R-VALUE:	6.76 per in. thickness	*	*
System R-VALUE:	26	33	40

Insulating Core Properties	[4]Design Values	
K FACTOR: (aged foam)	.148	ASTM C-518
COMPRESSIVE STRENGTH:	23 psi	ASTM D1621
COMPRESSIVE [1]MOE:	682 psi	ASTM D1621
SHEAR STRENGTH:	31 psi	ASTM C-273
SHEAR MODULUS:	203 psi	ASTM C-273
FLEXURE [2]MOR:	52 psi	ASTM C203
FLEXURE MODULUS ([3]MD):	587 psi	ASTM C203
TENSILE STRENGTH:	37 psi	ASTM D1623
TENSILE MODULUS:	611 psi	ASTM D1623
WVT/PERM INCHES:	1.0	ASTM E-96
FOAM FIRE RATING:	Class 1	**UL723
FLAME SPREAD:	20	**UL723
SMOKE DEVELOPED:	300	**UL723

[1]MOE: Modulus of Elasticity. [2]MOR: Modulus of Rupture. [3]MD: Machine Direction.
[4]Design Values are mean derived from multiple specimens.
*Specification or value is the same as the OSB-2145 Panel.
**UL723 is not necessarily a representation of performance in an actual fire.
Class 1 is the highest rating available for combustible materials.

Outside Skins	
TYPE:	APA or equivalent rated oriented strand board (OSB)
GRADE:	Exposure-1
THICKNESS:	7/16"

Liquid foam is uniformly dispersed throughout mold.

Foam expands, bonds and cures under 12-14 psi.

Other Panel Systems Available:

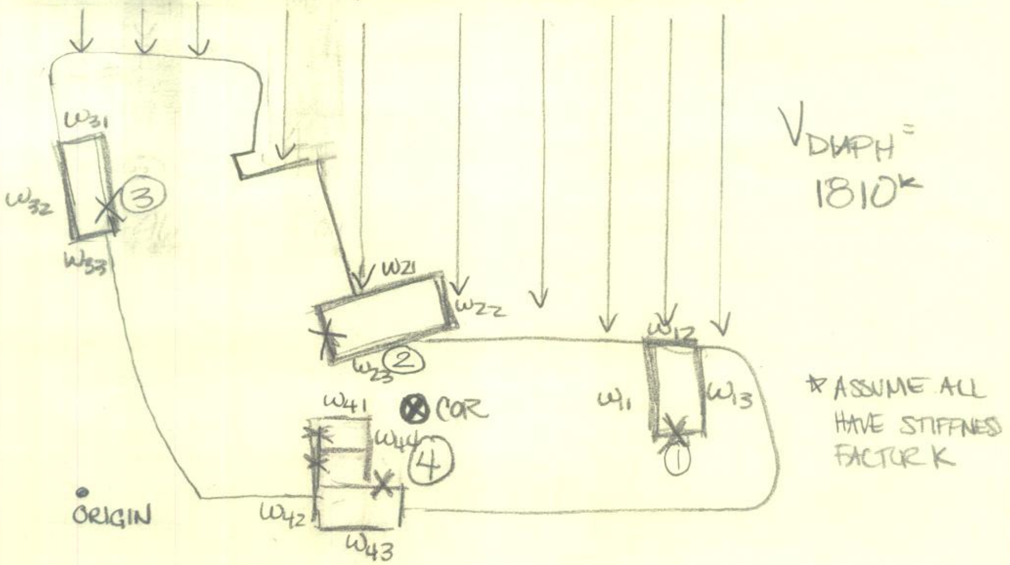
CLAD-2100 (OSB/OSB/PC)	**Exterior Skin.** 7/16" Exposure-1, APA or equivalent rated oriented strandboard (OSB). **Interior Skin (exposed).** 3/4" Standard Grade (kiln dried), WP4-Eastern White Pine, T&G with V-groove face pattern.
PTP-2100 (PT/PT) **(Subject to Availability)**	**Exterior and Interior Skins.** 1/2" CA .10 - CDX Grade, APA or equivalent rated pressure treated plywood.
CB-2100 (CB/CB)	**Exterior and Interior Skins.** 10 mm (also available in 8 and 12 mm) Cement bonded particle board comprised of wood particles and cement.
BB-2100 (OSB/BB) **(Roof Applications Only)**	**Exterior Skin.** 7/16" Exposure-1, APA or equivalent rated oriented strandboard (OSB). **Interior Skin.** 1/2" Veneer Base (Blueboard) Gypsum Wall Board.
T-1-11-2100 (OSB/OSB/T-1-11)	**Exterior Skin.** 7/16" Exposure-1, APA or equivalent rated oriented strandboard (OSB). **Interior Skin (exposed).** 5/8" 303-6 Grade (8 in. on center face pattern), T-1-11 pine plywood.
FB-2100 (OSB/FB)	**Exterior Skin.** 7/16" Exposure-1, APA or equivalent rated oriented strandboard (OSB). **Interior Skin.** 1/2" Gypsum Wallboard - Fiber Reinforced.
PTP/FB-2100 (PT/FB) **(Subject to Availability)**	**Exterior Skin.** 1/2" CA .10 - CDX Grade, APA or equivalent rated pressure treated plywood. **Interior Skin.** 1/2" Gypsum Wallboard - Fiber Reinforced.
CP-2100 (OSB/SB)	**Exterior Skin.** 1/4" Oriented Strand Board (OSB)(7/16" Exposure-1 optional for nailbase). **Interior Skin.** 1/2" Low Density Wood Fiber Composite (Sound Board), Fiber Board Insulating Sheathing.

APPLICATION **SKINS**	OSB-2100 (OSB/OSB)	CLAD-2100 (OSB/OSB/PC)	PTP-2100 (PT/PT)	CB-2100 (CB/CB)	BB-2100 (OSB/BB)	T-1-11-2100 (OSB/OSB/T-1-11)	FB-2100 (OSB/FB)	PTP/FB-2100 (PT/FB)	CP-2100 (OSB/SB)
LOAD BEARING	●		●						
CURTAIN WALL	●	●	●	●		●	●	●	
ROOF SPANS UP TO 4FT.	●	●	●	●	●	●	●	●	
ROOF SPANS OVER 4FT.	●	●	●	●		●			
RESIDENTIAL CONSTRUCTION	●	●	●						●
COMMERCIAL CONSTRUCTION	●	●	●	●		●	●	●	
STRUCTURAL STEEL FRAMING	●		●	●			●	●	
INSULATED GARAGES	●		●	●					
INSULATED WAREHOUSES	●		●	●			●	●	
TIMBER FRAME STRUCTURES	●	●	●		●	●	●	●	
HEAVY TIMBER RAFTER SYSTEMS	●	●	●		●	●	●	●	
GLUE LAMINATED STRUCTURES	●	●	●			●		●	
MANUFACTURED ROOF TRUSSES	●	●	●			●	●	●	●
TROPICAL CLIMATES			●	●				●	
POOL ENCLOSURES	●		●	●					

Specification for SIPs

GEN*NY*SIS | CFG | SHEAR WALLS

BASED ON ASCE 7-05, SEISMIC LOAD CONTROLS



V_{DIAPH} = 1810ᵏ

* ASSUME ALL HAVE STIFFNESS FACTOR K

h = 87.00 ft COR : (90.24, 67.53) → RAM OUTPUT
ORIGIN @ A1.B1

COR

$$\bar{X} : \frac{(-21.16)(30\text{ ft}) + (61.97)(21') + (73.97)(18') + (90.4)(14') + (248.55)(27') + (259.22)(27.5')}{30 + 21 + 18 + 14 + 27.5 + 27.5}$$

$\bar{X}$: 124.84

$$\bar{Y} : \frac{(174.5)(10.5') + (145.5)(10.5') + (16.5)(21.7) + (46.5)(12) + (98.05)(27) + (84.15)(27) + (84.17)(10.7)}{(10.5 + 10.5 + 21.7 + 12 + 27 + 27 + 10.7)}$$

$\bar{Y}$: 84.56

MY CALCULATED COR : (124.84, 84.56)
$\bar{X}$ $\bar{Y}$

ECCENTRICITY

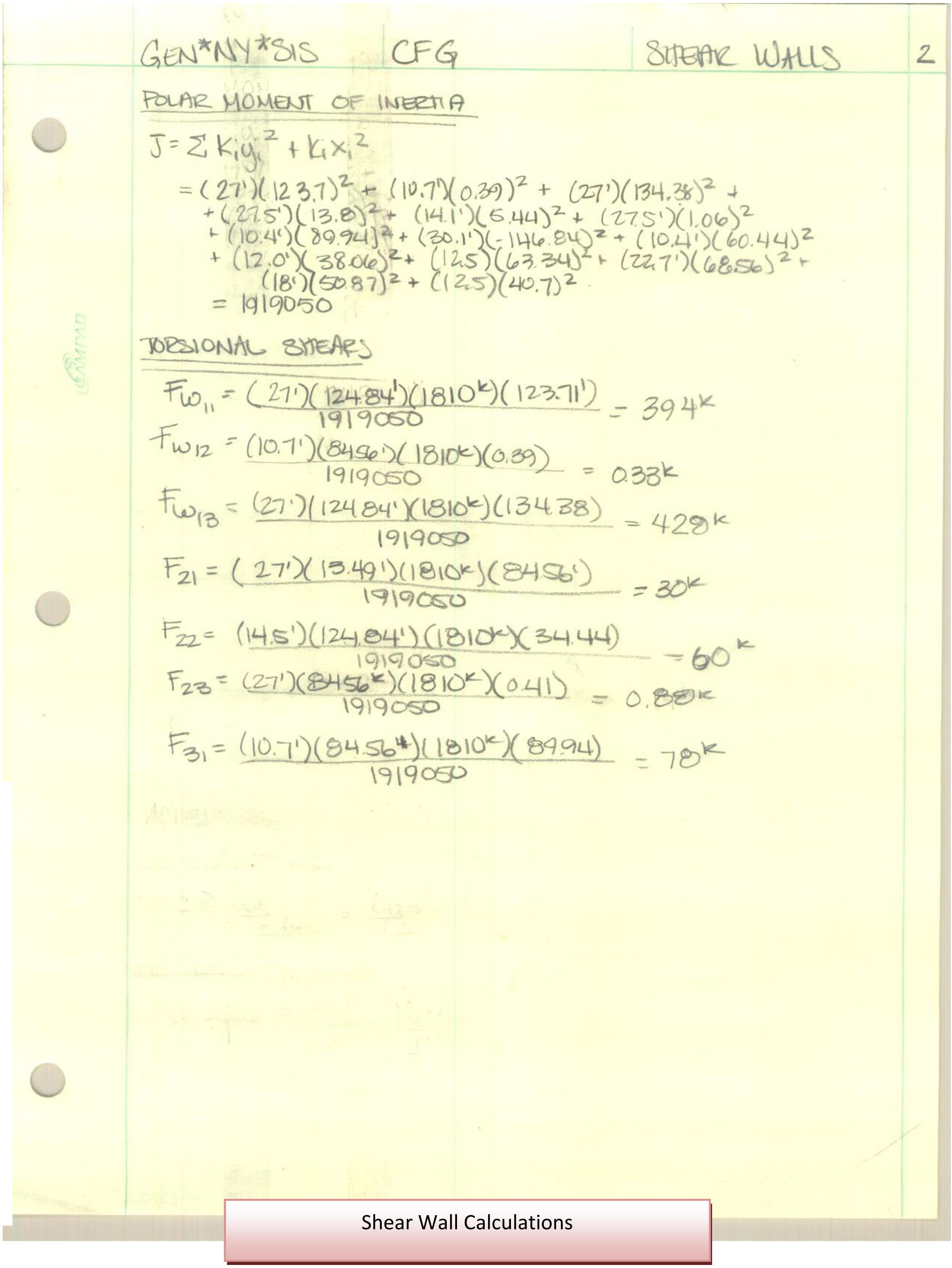
1-1 e(123.71, 0)
1-2 e(0, -0.39)
1-3 e(134.38, 0)

2-1 e(0, 13.49)
2-2 e(-34.44, 0)
2-3 e(0, -0.41)

3-1 e(0, 89.94)
3-2 e(-146, 0)
3-3 e(0, 20.66)

4-1 e(0, -38.06)
4-2 e(-62.87, 0)
4-3 e(0, -68.56)
4-4 e(-56.87, 0)

Shear Wall Calculations



GEN*NY*SIS CFG SHEAR WALLS 2

POLAR MOMENT OF INERTIA

$$J = \Sigma K_i y_i^2 + K_i x_i^2$$

$$= (27')(123.7)^2 + (10.7')(0.39)^2 + (27')(134.38)^2 + + (27.5')(13.8)^2 + (14.1')(6.44)^2 + (27.5')(1.06)^2 + (10.4')(89.94)^2 + (30.1')(-146.84)^2 + (10.4')(60.44)^2 + (12.0')(38.06)^2 + (12.5)(63.34)^2 + (22.7')(68.56)^2 + (18')(50.87)^2 + (12.5)(40.7)^2$$

$$= 1919050$$

TORSIONAL SHEARS

$$F_{w_{11}} = \frac{(27')(124.84')(1810^k)(123.71')}{1919050} = 394^k$$

$$F_{w_{12}} = \frac{(10.7')(8456')(1810^k)(0.39)}{1919050} = 0.33^k$$

$$F_{w_{13}} = \frac{(27')(124.84')(1810^k)(134.38)}{1919050} = 428^k$$

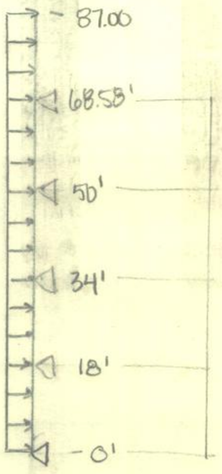
$$F_{21} = \frac{(27')(13.49')(1810^k)(8456')}{1919050} = 30^k$$

$$F_{22} = \frac{(14.5')(124.84')(1810^k)(34.44)}{1919050} = 60^k$$

$$F_{23} = \frac{(27')(8456^k)(1810^k)(0.41)}{1919050} = 0.88^k$$

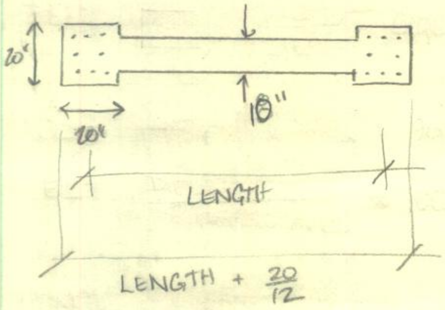
$$F_{31} = \frac{(10.7')(84.56^*)(1810^k)(89.94)}{1919050} = 78^k$$

GEN*NY*SIS | CFG | SHEAR WALLS | 3



ORDINARY CONCRETE SHEAR WALL

$f'c = 5$ ksi
$fy = 60$ ksi



$b_w = 8$ in
$h_w = (20/12 \text{ ft}) + L$
$\underline{A_g} = (10/12 \text{ ft})(20/12 \text{ ft} + L)$
$\underline{I_g} = (1/12)(10/12 \text{ ft})(20/12 + L)^3$

CONFINEMENT REINFORCEMENT

S_{max} | 1/4 (20") = 5"
MIN | 4" ←GOVERNS

ASSUME #5@9" o.c.

SEE EXCEL SPREADSHEET FOR REINFORCEMENT JUSTIFICATION

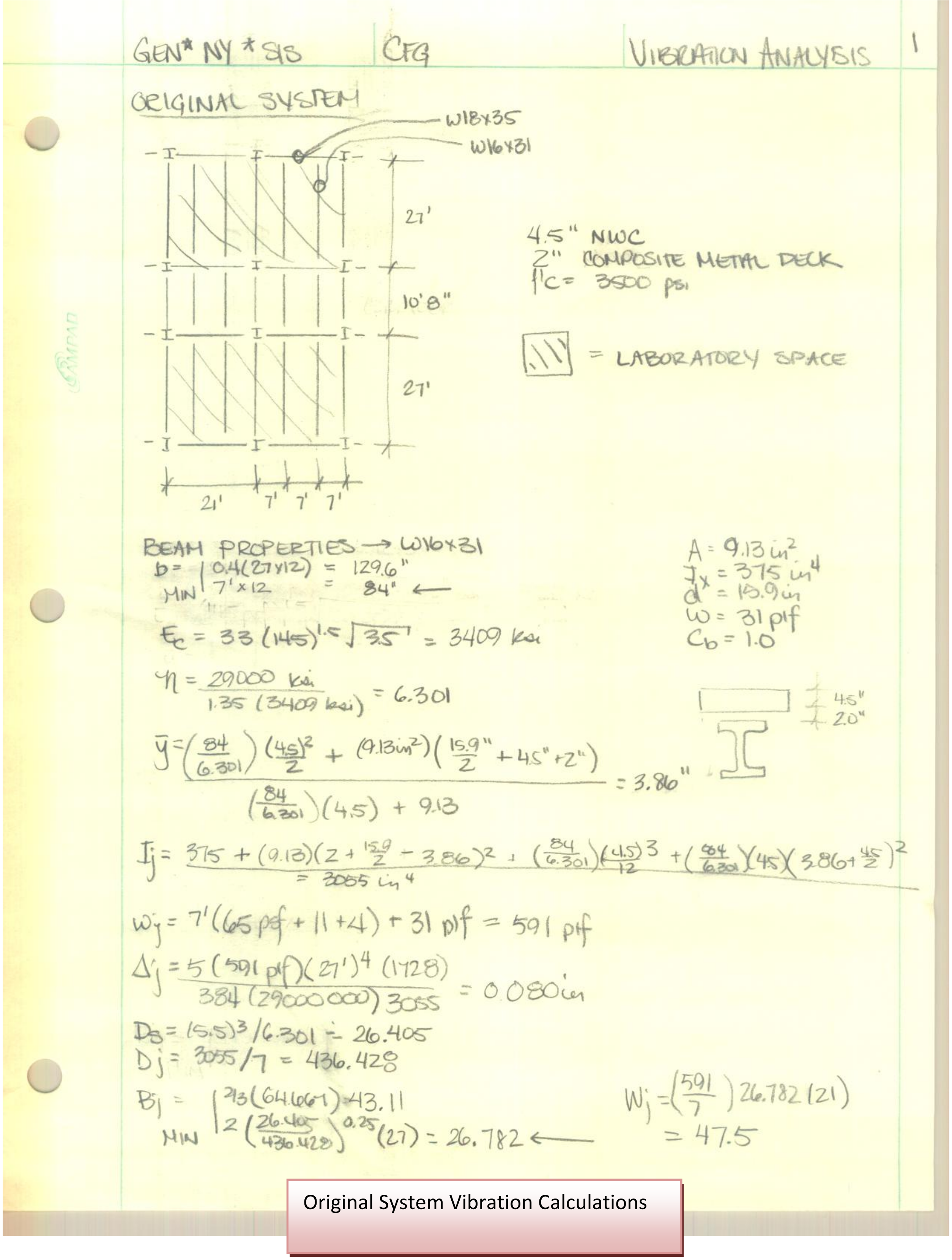
Shear Wall Calculations

	ex	ey	length	Torsional Shear (kips)	Direct Shear, Vu (kips)
wall 1-1	123.71	0	27.00	87.784	85.55
wall 1-2	0	0.39	10.67	0.074	36.01
wall 1-3	134.38	0	27.00	95.356	85.55
wall 2-1	0	13.49	27.00	6.484	91.15
wall 2-2	34.44	0	14.50	13.124	45.95
wall 2-3	0	0.41	27.00	0.197	91.15
wall 3-1	0	89.94	10.67	17.078	36.01
wall 3-2	146	0	29.00	111.276	91.89
wall 3-3	0	20.66	10.67	3.923	36.01
wall 4-1	0	38.06	12.00	8.130	40.51
wall 4-2	62.87	0	12.00	19.828	38.02
wall 4-3	0	68.56	21.67	26.444	73.15
wall 4-4	56.87	0	18.00	26.903	57.04
		Total Lx	119.67		404.00
		Total Ly	127.50		kips
			247.17		

Direct Shear Calculations

	Surface Area (SF)	tw (in)	w (ksf)	Moment (ft-kips)	hw (ft)	Gross Area, Ag (SF)	Ig (ft^4)	fc (ksi)	0.2f'c (ksi)
wall 1-1	2349.00	10.00	0.0364	7443.11	28.67	23.89	1635.95	65.2127	1.0
wall 1-2	927.94	10.00	0.0388	3132.80	12.33	10.28	130.26	148.3032	1.0
wall 1-3	2349.00	10.00	0.0364	7443.11	28.67	23.89	1635.95	65.2127	1.0
wall 2-1	2349.00	10.00	0.0388	7930.39	28.67	23.89	1635.95	69.4820	1.0
wall 2-2	1261.50	10.00	0.0364	3997.22	16.17	13.47	293.43	110.1159	1.0
wall 2-3	2349.00	10.00	0.0388	7930.39	28.67	23.89	1635.95	69.4820	1.0
wall 3-1	927.99	10.00	0.0388	3132.97	12.33	10.28	130.28	148.2972	1.0
wall 3-2	2523.00	10.00	0.0364	7994.45	30.67	25.56	2002.80	61.2051	1.0
wall 3-3	927.99	10.00	0.0388	3132.97	12.33	10.28	130.28	148.2972	1.0
wall 4-1	1044.00	10.00	0.0388	3524.62	13.67	11.39	177.27	135.8686	1.0
wall 4-2	1044.00	10.00	0.0364	3308.05	13.67	11.39	177.27	127.5202	1.0
wall 4-3	1884.99	10.00	0.0388	6363.87	23.33	19.44	882.19	84.1594	1.0
wall 4-4	1566.00	10.00	0.0364	4962.07	19.67	16.39	528.24	92.3706	1.0
	21503.42							Boundary Element Needed	

Acv (ft^2)	Acv (in^2)	2Acv(f'c^0 .5) (kips)	Vu (kips)	Acv (in^2 /ft)	Spacing (in)	Alpha c	rho t	Normal Shear Capactiy (kips)	Phi Vn (kips)	Direct Shear, Vu (kips)	Pu (lbs)	Ast (in^2)
21.250	3060	432.7494	85.55	0.30	12.4	3.03	0.0026	1271	762.9	85.55	275671	6.460
7.638	1100	155.5522	36.01	0.30	12.4	7.05	0.0026	968	580.6	36.01	293718	7.082
21.250	3060	432.7494	85.55	0.30	12.4	3.03	0.0026	1271	762.9	85.55	275671	6.460
21.250	3060	432.7494	91.15	0.30	12.4	3.03	0.0026	1271	762.9	91.15	293718	7.082
10.833	1560	220.6173	45.95	0.30	12.4	5.38	0.0026	1039	623.4	45.95	275671	6.460
21.250	3060	432.7494	91.15	0.30	12.4	3.03	0.0026	1271	762.9	91.15	293718	7.082
7.639	1100	155.5624	36.01	0.30	12.4	7.05	0.0026	968	580.6	36.01	293718	7.082
22.917	3300	466.6905	91.89	0.30	12.4	2.84	0.0026	1309	785.2	91.89	275671	6.460
7.639	1100	155.5624	36.01	0.30	12.4	7.05	0.0026	968	580.6	36.01	293718	7.082
8.750	1260	178.1909	40.51	0.30	12.4	6.37	0.0026	992	595.5	40.51	293718	7.082
8.750	1260	178.1909	38.02	0.30	12.4	6.37	0.0026	992	595.5	38.02	275671	6.460
16.806	2420	342.2386	73.15	0.30	12.4	3.73	0.0026	1172	703.3	73.15	293718	7.082
13.750	1980	280.0143	57.04	0.30	12.4	4.42	0.0026	1104	662.4	57.04	275671	6.460
		CAN USE 1 CURTAIN		ASSUME	2 CURTAINS				8758.282			(9) #8s
				(1) #5	#5 HORIZ							EQ. SPACE
					#5 VERT							
					AT 15" o.c.							



GEN* NY * SIS | CFG | VIBRATION ANALYSIS | 1

ORIGINAL SYSTEM

4.5" NWC
2" COMPOSITE METAL DECK
$f'c = 3500$ psi

▨ = LABORATORY SPACE

BEAM PROPERTIES → W16x31

$$b = \min\left|\begin{array}{l} 0.4(27\times12) = 129.6'' \\ 7'\times12 = 84'' \leftarrow \end{array}\right.$$

$A = 9.13\ in^2$
$I_x = 375\ in^4$
$d = 15.9\ in$
$w = 31\ plf$
$C_b = 1.0$

$$E_c = 33(145)^{1.5}\sqrt{3.5} = 3409\ ksi$$

$$n = \frac{29000\ ksi}{1.35\ (3409\ ksi)} = 6.301$$

$$\bar{y} = \frac{\left(\frac{84}{6.301}\right)\frac{(4.5)^2}{2} + (9.13in^2)\left(\frac{15.9''}{2} + 4.5'' + 2''\right)}{\left(\frac{84}{6.301}\right)(4.5) + 9.13} = 3.86''$$

$$I_j = \underline{375 + (9.13)(2 + \tfrac{15.9}{2} - 3.86)^2 + \left(\tfrac{84}{6.301}\right)\tfrac{(4.5)^3}{12} + \left(\tfrac{84}{6.301}\right)(4.5)\left(3.86 + \tfrac{4.5}{2}\right)^2}$$
$$= 3055\ in^4$$

$$w_j = 7'(65\ psf + 11 + 4) + 31\ plf = 591\ plf$$

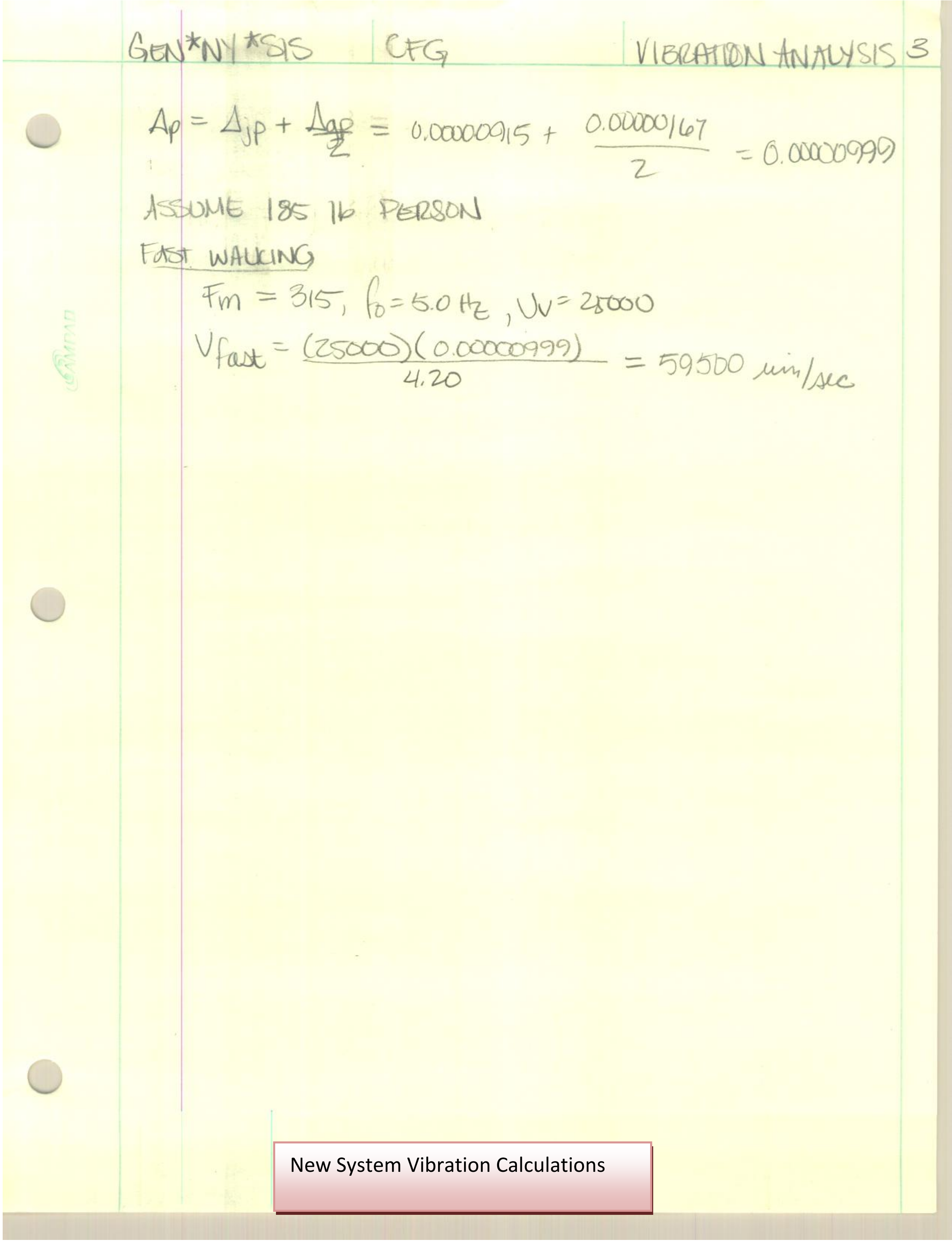
$$\Delta_j = \frac{5(591\ plf)(27')^4(1728)}{384(29000000)3055} = 0.080\ in$$

$$D_s = (5.5)^3/6.301 = 26.405$$
$$D_j = 3055/7 = 436.428$$

$$B_j = \min\left|\begin{array}{l} \frac{2}{3}(64.667) = 43.11 \\ 2\left(\frac{26.405}{436.428}\right)^{0.25}(27) = 26.782 \leftarrow \end{array}\right.$$

$$W_j = \left(\frac{591}{7}\right)26.782(21) = 47.5$$

Original System Vibration Calculations



GEN*NY*SIS CFG VIBRATION ANALYSIS 3

$$A_p = \Delta_{jp} + \frac{\Delta_{gp}}{2} = 0.00000915 + \frac{0.00000167}{2} = 0.00000999$$

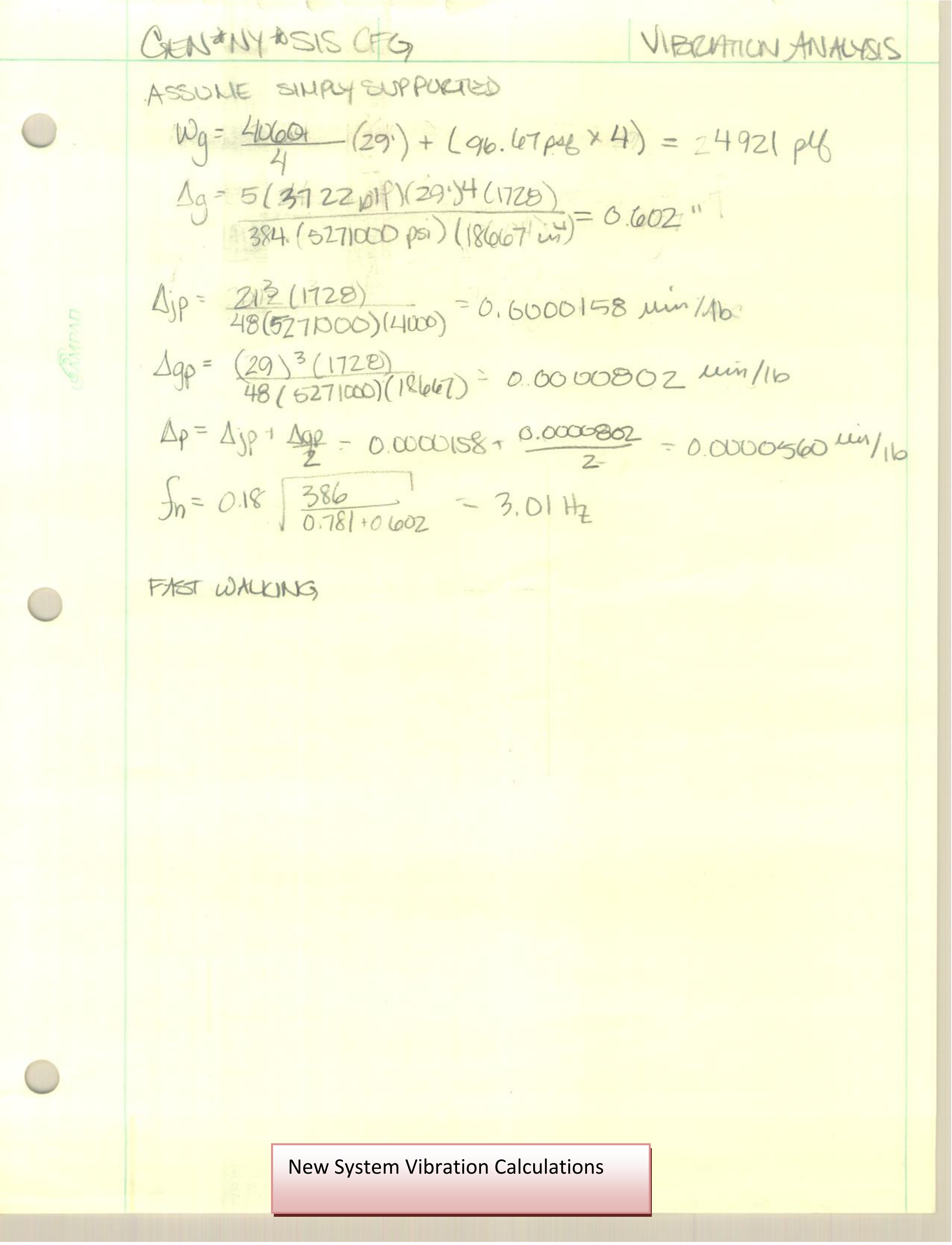
ASSUME 185 lb PERSON

FAST WALKING

$F_m = 315$, $f_o = 5.0$ Hz, $U_v = 25000$

$$V_{fast} = \frac{(25000)(0.00000999)}{4.20} = 59500 \text{ μin/sec}$$

New System Vibration Calculations



GEN*NY*SIS CFG

VIBRATION ANALYSIS

ASSUME SIMPLY SUPPORTED

$$W_g = \frac{40604}{4}(29') + (96.67\,\text{psf} \times 4) = 24921\ \text{plf}$$

$$\Delta_g = \frac{5(3722\,\text{plf})(29')^4(1728)}{384(5271000\,\text{psi})(18667\,\text{in}^4)} = 0.602''$$

$$\Delta_{jp} = \frac{21^3(1728)}{48(5271000)(4000)} = 0.6000158\ \text{in}/\text{lb}$$

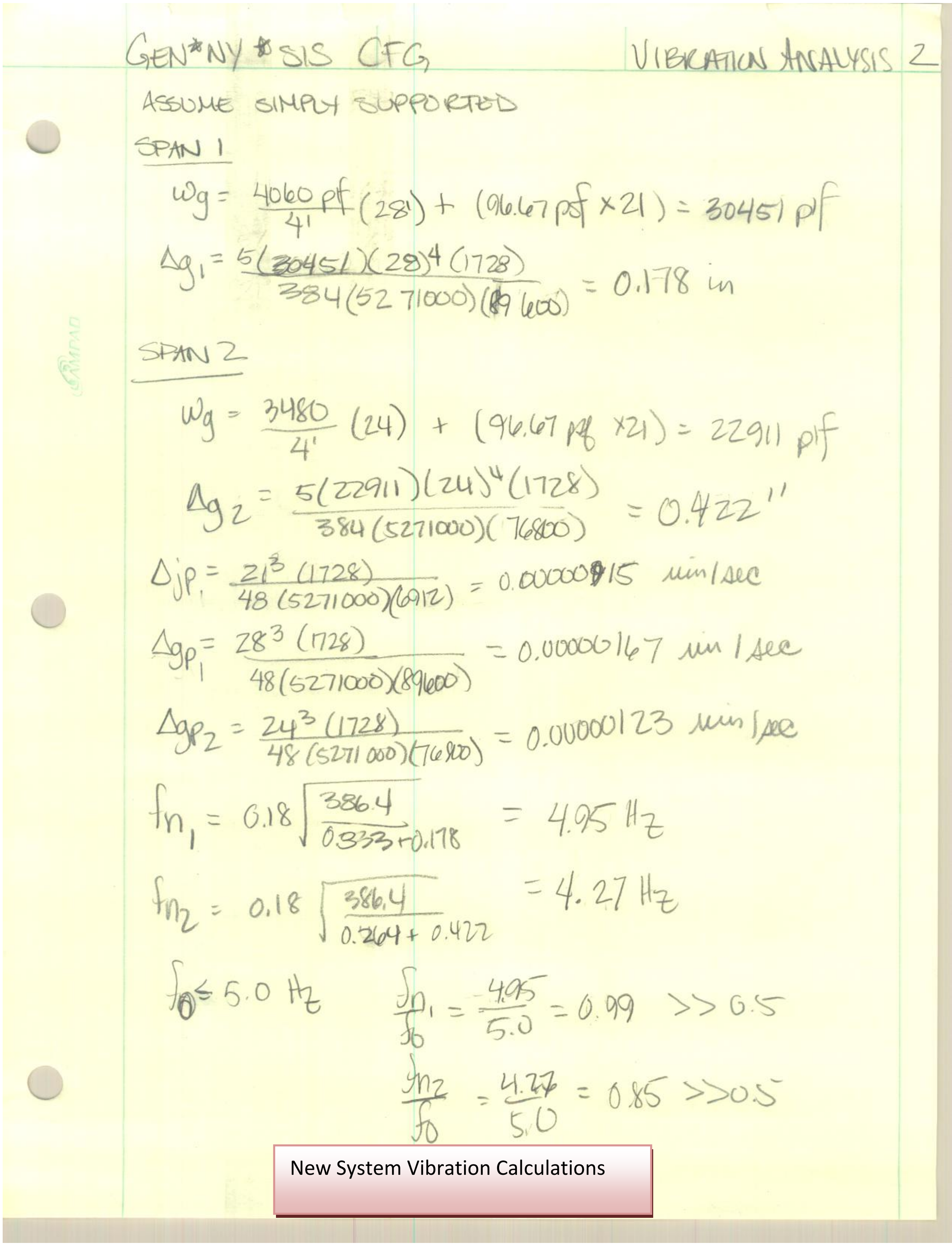
$$\Delta_{gp} = \frac{(29)^3(1728)}{48(5271000)(18667)} = 0.0000802\ \text{in}/\text{lb}$$

$$\Delta_p = \Delta_{jp} + \frac{\Delta_{gp}}{2} = 0.0000158 + \frac{0.0000802}{2} = 0.0000560\ \text{in}/\text{lb}$$

$$f_n = 0.18\sqrt{\frac{386}{0.781 + 0.602}} = 3.01\ \text{Hz}$$

FAST WALKING

New System Vibration Calculations



GEN*NY*SIS CFG — VIBRATION ANALYSIS 2

ASSUME SIMPLY SUPPORTED

SPAN 1

$$w_g = \frac{4060\text{ plf}}{4'}(28') + (96.67\text{ psf} \times 21) = 30451\text{ plf}$$

$$\Delta_{g_1} = \frac{5(30451)(28)^4(1728)}{384(5271000)(89600)} = 0.178\text{ in}$$

SPAN 2

$$w_g = \frac{3480}{4'}(24) + (96.67\text{ plf} \times 21) = 22911\text{ plf}$$

$$\Delta_{g_2} = \frac{5(22911)(24)^4(1728)}{384(5271000)(76800)} = 0.422''$$

$$\Delta_{jp_1} = \frac{21^3(1728)}{48(5271000)(6912)} = 0.00000915\text{ in/sec}$$

$$\Delta_{gp_1} = \frac{28^3(1728)}{48(5271000)(89600)} = 0.00000167\text{ in/sec}$$

$$\Delta_{gp_2} = \frac{24^3(1728)}{48(5271000)(76800)} = 0.00000123\text{ in/sec}$$

$$f_{n_1} = 0.18\sqrt{\frac{386.4}{0.333+0.178}} = 4.95\text{ Hz}$$

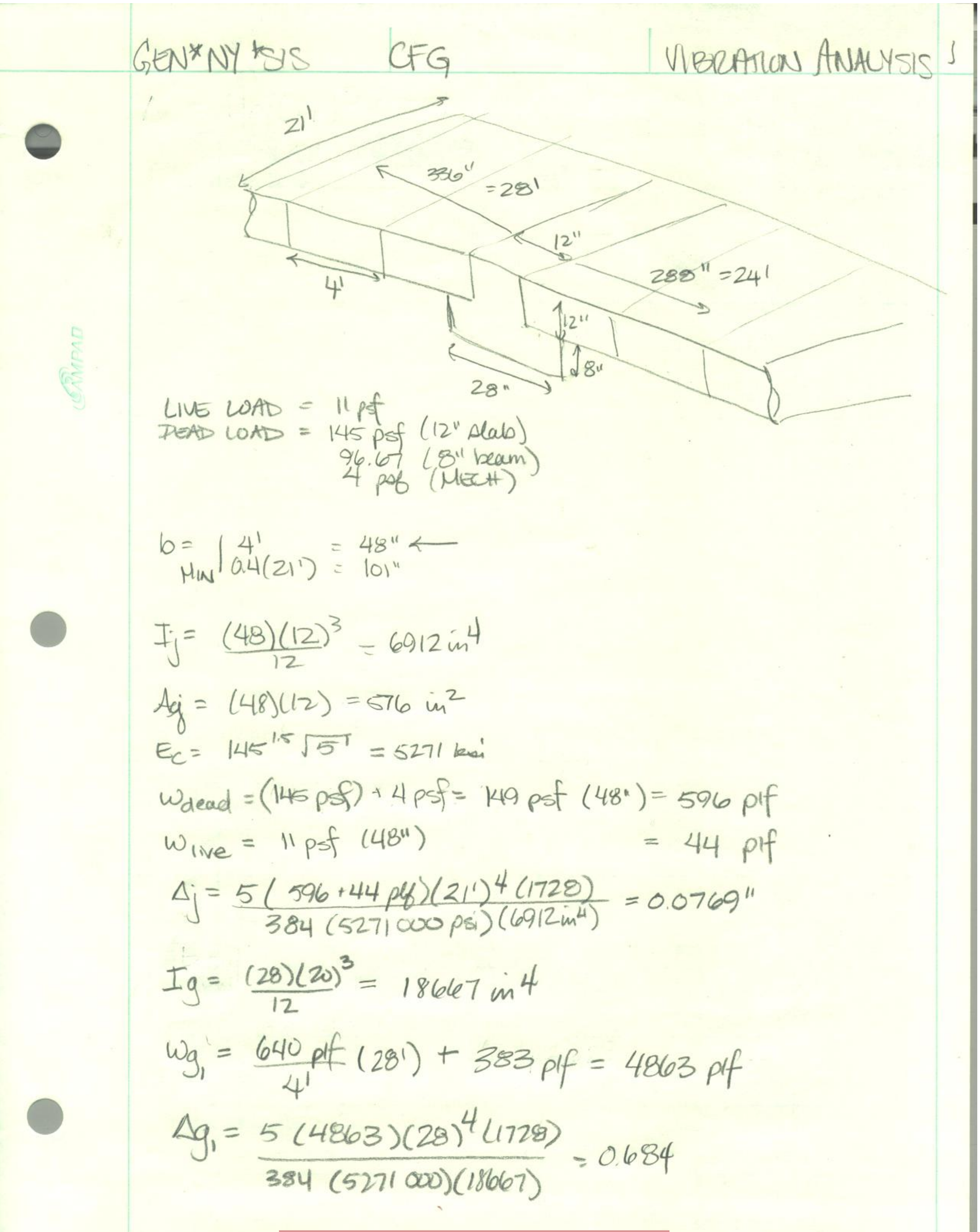
$$f_{n_2} = 0.18\sqrt{\frac{386.4}{0.264+0.422}} = 4.27\text{ Hz}$$

$f_0 \le 5.0$ Hz

$$\frac{f_{n_1}}{f_0} = \frac{4.95}{5.0} = 0.99 >> 0.5$$

$$\frac{f_{n_2}}{f_0} = \frac{4.27}{5.0} = 0.85 >> 0.5$$

New System Vibration Calculations



GEN*NY*SIS CFG VIBRATION ANALYSIS 1

LIVE LOAD = 11 psf
DEAD LOAD = 145 psf (12" slab)
96.67 (8" beam)
4 psf (MECH)

$b_{MIN} = \left| \begin{array}{l} 4' = 48" \leftarrow \\ 0.4(21') = 101" \end{array} \right.$

$I_j = \frac{(48)(12)^3}{12} = 6912 \text{ in}^4$

$A_j = (48)(12) = 576 \text{ in}^2$

$E_c = 145^{1.5}\sqrt{5} = 5271 \text{ ksi}$

$w_{dead} = (145 \text{ psf}) + 4 \text{ psf} = 149 \text{ psf } (48") = 596 \text{ plf}$

$w_{live} = 11 \text{ psf } (48") = 44 \text{ plf}$

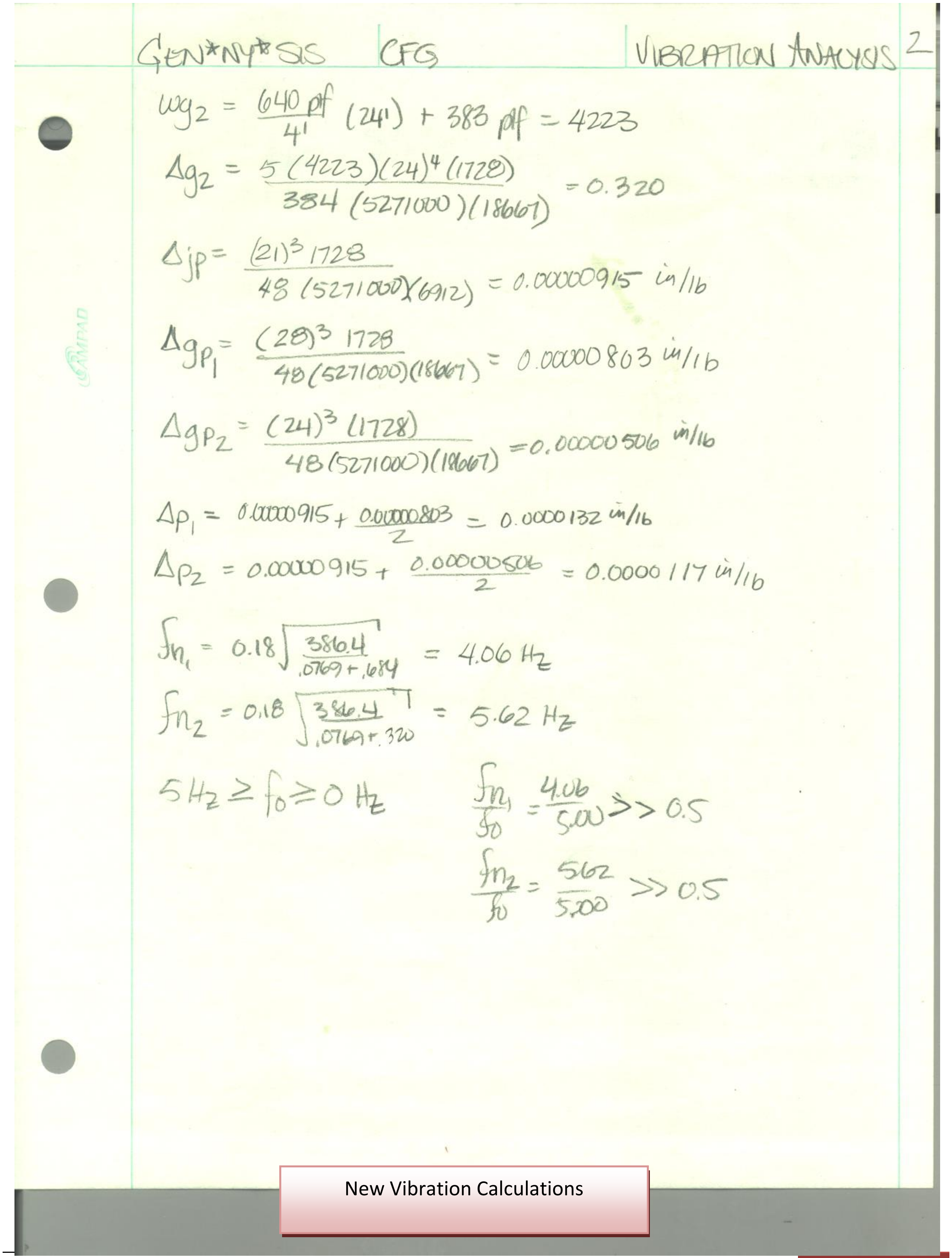
$\Delta_j = \frac{5(596 + 44 \text{ plf})(21')^4(1728)}{384(5271000 \text{ psi})(6912 \text{ in}^4)} = 0.0769"$

$I_g = \frac{(28)(20)^3}{12} = 18667 \text{ in}^4$

$w_{g_1} = \frac{640 \text{ plf}}{4'}(28') + 383 \text{ plf} = 4863 \text{ plf}$

$\Delta_{g_1} = \frac{5(4863)(28)^4(1728)}{384(5271000)(18667)} = 0.684$

New Vibration Calculations



GEN*NY*SIS CFG VIBRATION ANALYSIS 2

$$wg_2 = \frac{640 \text{ plf}}{4'}(24') + 383 \text{ plf} = 4223$$

$$\Delta g_2 = \frac{5(4223)(24)^4(1728)}{384(5271000)(18667)} = 0.320$$

$$\Delta_{jp} = \frac{(21)^3 1728}{48(5271000)(6912)} = 0.00000915 \text{ in/lb}$$

$$\Delta g_{p_1} = \frac{(28)^3 1728}{48(5271000)(18667)} = 0.00000803 \text{ in/lb}$$

$$\Delta g_{p_2} = \frac{(24)^3(1728)}{48(5271000)(18667)} = 0.00000506 \text{ in/lb}$$

$$\Delta p_1 = 0.00000915 + \frac{0.00000803}{2} = 0.0000132 \text{ in/lb}$$

$$\Delta p_2 = 0.00000915 + \frac{0.00000506}{2} = 0.0000117 \text{ in/lb}$$

$$f_{n_1} = 0.18\sqrt{\frac{386.4}{.0769 + .684}} = 4.06 \text{ Hz}$$

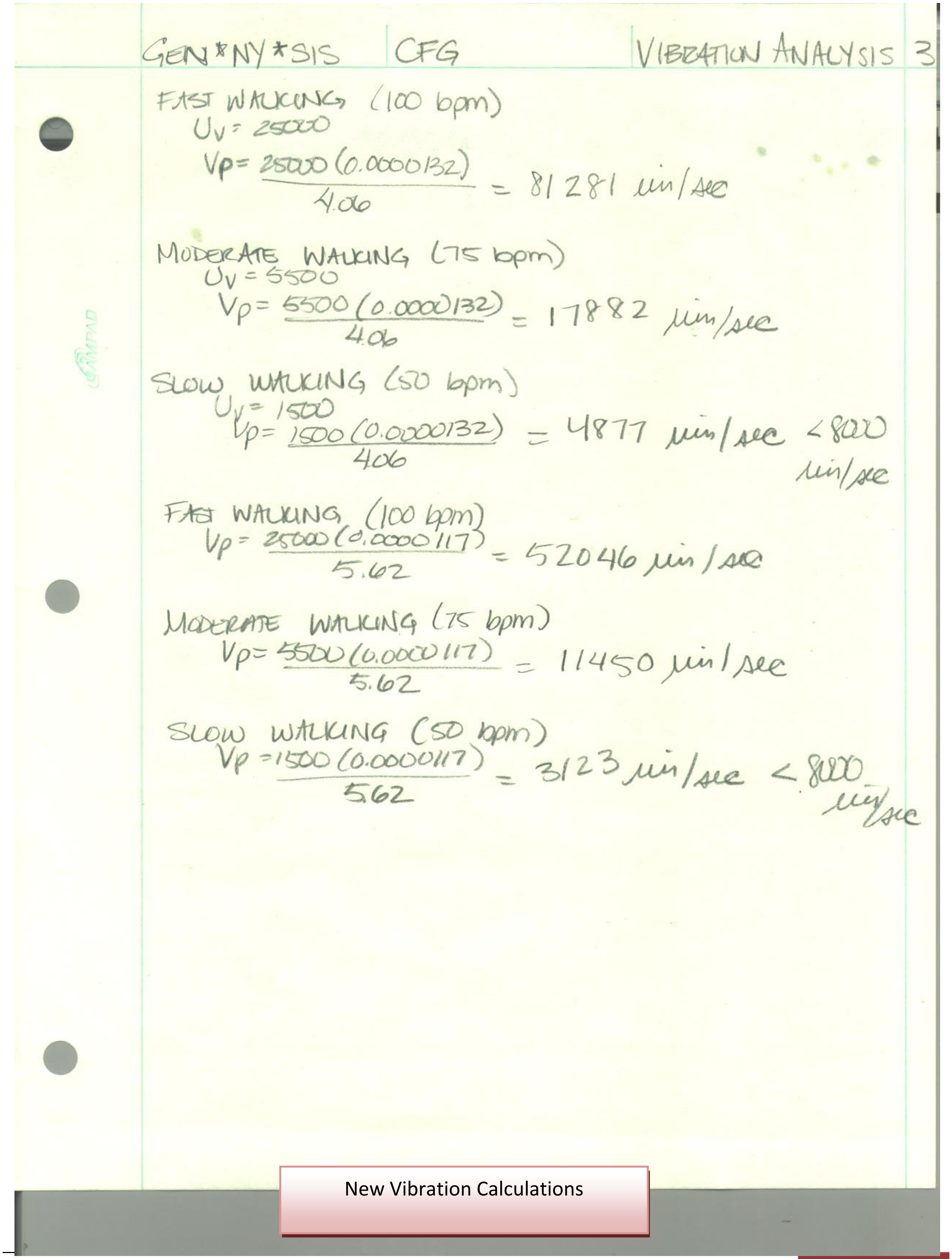
$$f_{n_2} = 0.18\sqrt{\frac{386.4}{.0769 + .320}} = 5.62 \text{ Hz}$$

$$5 \text{ Hz} \geq f_0 \geq 0 \text{ Hz}$$

$$\frac{f_{n_1}}{f_0} = \frac{4.06}{5.00} >> 0.5$$

$$\frac{f_{n_2}}{f_0} = \frac{5.62}{5.00} >> 0.5$$

New Vibration Calculations



GEN*NY*SIS | CFG | VIBRATION ANALYSIS 3

FAST WALKING (100 bpm)

$U_V = 25000$

$$V_p = \frac{25000(0.0000132)}{4.06} = 81281 \ \mu in/sec$$

MODERATE WALKING (75 bpm)

$U_V = 5500$

$$V_p = \frac{5500(0.0000132)}{4.06} = 17882 \ \mu in/sec$$

SLOW WALKING (50 bpm)

$U_V = 1500$

$$V_p = \frac{1500(0.0000132)}{406} = 4877 \ \mu in/sec < 8000 \ \mu in/sec$$

FAST WALKING (100 bpm)

$$V_p = \frac{25000(0.0000117)}{5.62} = 52046 \ \mu in/sec$$

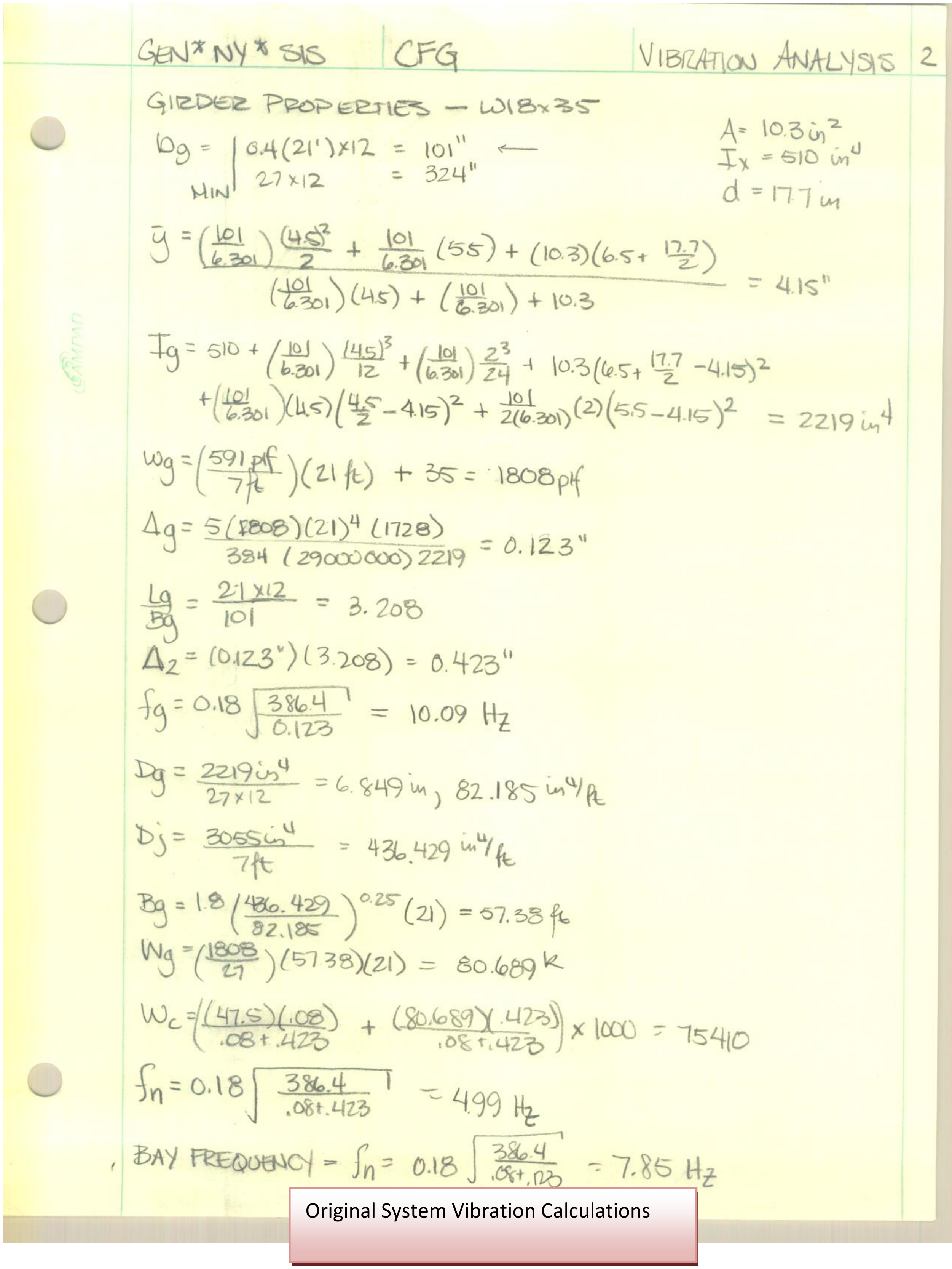
MODERATE WALKING (75 bpm)

$$V_p = \frac{5500(0.0000117)}{5.62} = 11450 \ \mu in/sec$$

SLOW WALKING (50 bpm)

$$V_p = \frac{1500(0.0000117)}{5.62} = 3123 \ \mu in/sec < 8000 \ \mu in/sec$$

New Vibration Calculations



GEN*NY*SIS | CFG | VIBRATION ANALYSIS | 2

GIRDER PROPERTIES — W18x35

$$b_g = \underset{\text{MIN}}{\left|\begin{array}{ll} 0.4(21')\times 12 & = 101'' \leftarrow \\ 27\times 12 & = 324'' \end{array}\right.}$$

$A = 10.3\ in^2$
$I_x = 510\ in^4$
$d = 17.7\ in$

$$\bar{y} = \frac{\left(\frac{101}{6.301}\right)\frac{(4.5)^2}{2} + \frac{101}{6.301}(55) + (10.3)\left(6.5 + \frac{17.7}{2}\right)}{\left(\frac{101}{6.301}\right)(4.5) + \left(\frac{101}{6.301}\right) + 10.3} = 4.15''$$

$$I_g = 510 + \left(\frac{101}{6.301}\right)\frac{(4.5)^3}{12} + \left(\frac{101}{6.301}\right)\frac{2^3}{24} + 10.3\left(6.5 + \frac{17.7}{2} - 4.15\right)^2$$
$$+ \left(\frac{101}{6.301}\right)(4.5)\left(\frac{4.5}{2} - 4.15\right)^2 + \frac{101}{2(6.301)}(2)(5.5 - 4.15)^2 = 2219\ in^4$$

$$w_g = \left(\frac{591\ plf}{7\ ft}\right)(21\ ft) + 35 = 1808\ plf$$

$$\Delta_g = \frac{5(1808)(21)^4(1728)}{384(29000000)2219} = 0.123''$$

$$\frac{L_g}{B_g} = \frac{21\times 12}{101} = 3.208$$

$$\Delta_2 = (0.123'')(3.208) = 0.423''$$

$$f_g = 0.18\sqrt{\frac{386.4}{0.123}} = 10.09\ Hz$$

$$D_g = \frac{2219\ in^4}{27\times 12} = 6.849\ in,\ 82.185\ in^4/ft$$

$$D_j = \frac{3055\ in^4}{7ft} = 436.429\ in^4/ft$$

$$B_g = 1.8\left(\frac{436.429}{82.185}\right)^{0.25}(21) = 57.38\ ft$$

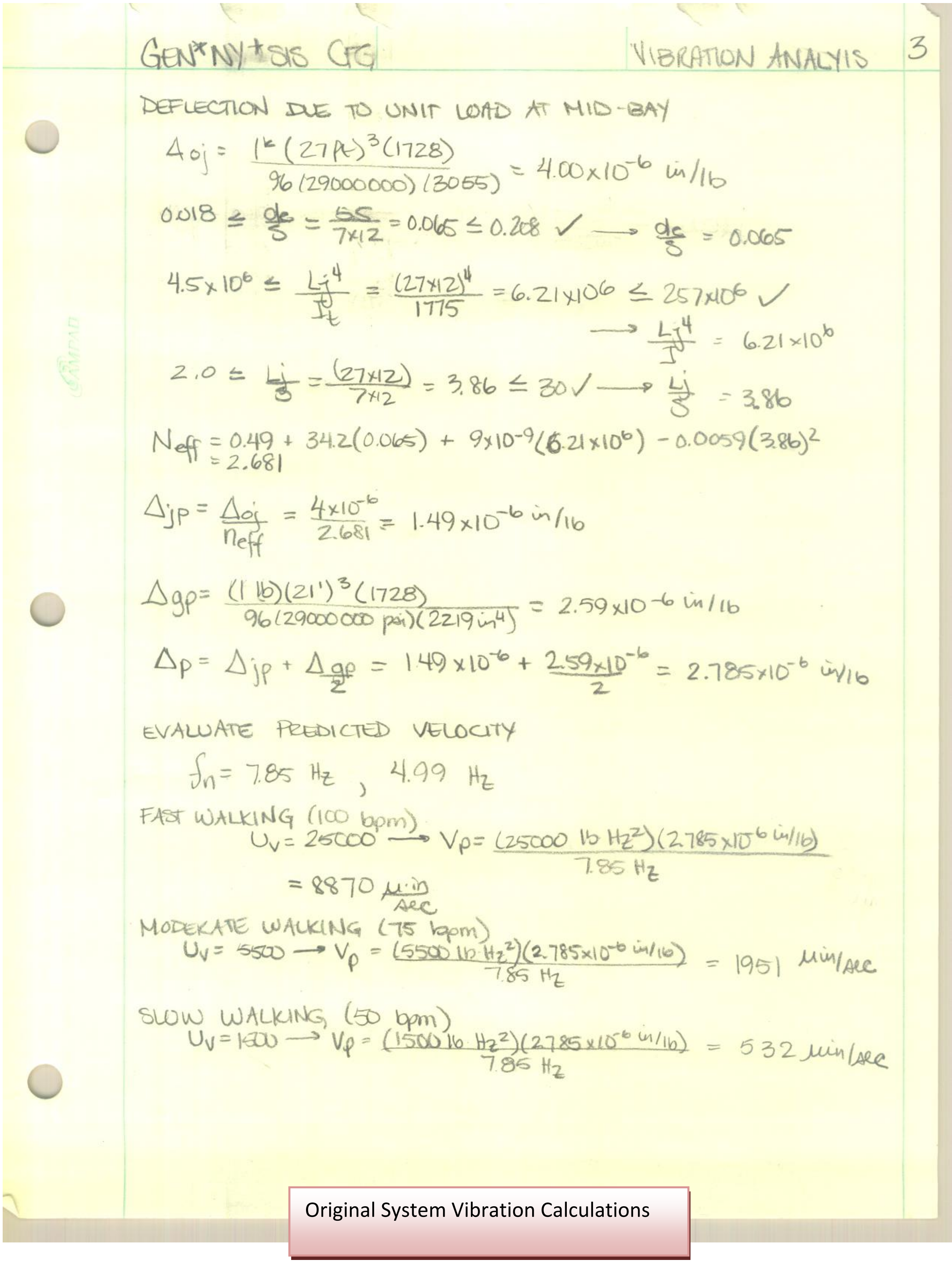
$$W_g = \left(\frac{1808}{27}\right)(57.38)(21) = 80.689^k$$

$$W_c = \left(\frac{(47.5)(.08)}{.08 + .423} + \frac{(80.689)(.423)}{.08 + .423}\right)\times 1000 = 75410$$

$$f_n = 0.18\sqrt{\frac{386.4}{.08 + .423}} = 4.99\ Hz$$

BAY FREQUENCY $= f_n = 0.18\sqrt{\frac{386.4}{.08 + .123}} = 7.85\ Hz$

Original System Vibration Calculations



GEN*NY*SIS CFG | VIBRATION ANALYIS | 3

DEFLECTION DUE TO UNIT LOAD AT MID-BAY

$$\Delta_{oj} = \frac{1^k (27 ft)^3 (1728)}{96(29000000)(3055)} = 4.00 \times 10^{-6} \text{ in/lb}$$

$$0.018 \leq \frac{d_e}{S} = \frac{5.5}{7 \times 12} = 0.065 \leq 0.208 \checkmark \longrightarrow \frac{d_e}{S} = 0.065$$

$$4.5 \times 10^6 \leq \frac{L_j^4}{I_t} = \frac{(27 \times 12)^4}{1775} = 6.21 \times 10^6 \leq 257 \times 10^6 \checkmark$$

$$\longrightarrow \frac{L_j^4}{I} = 6.21 \times 10^6$$

$$2.0 \leq \frac{L_j}{S} = \frac{(27 \times 12)}{7 \times 12} = 3.86 \leq 30 \checkmark \longrightarrow \frac{L_j}{S} = 3.86$$

$$N_{eff} = 0.49 + 34.2(0.065) + 9 \times 10^{-9}(6.21 \times 10^6) - 0.0059(3.86)^2$$
$$= 2.681$$

$$\Delta_{jp} = \frac{\Delta_{oj}}{n_{eff}} = \frac{4 \times 10^{-6}}{2.681} = 1.49 \times 10^{-6} \text{ in/lb}$$

$$\Delta_{gp} = \frac{(1 \text{ lb})(21')^3(1728)}{96(29000000 \text{ psi})(2219 \text{ in}^4)} = 2.59 \times 10^{-6} \text{ in/lb}$$

$$\Delta_p = \Delta_{jp} + \frac{\Delta_{gp}}{2} = 1.49 \times 10^{-6} + \frac{2.59 \times 10^{-6}}{2} = 2.785 \times 10^{-6} \text{ in/lb}$$

EVALUATE PREDICTED VELOCITY

$$f_n = 7.85 \text{ Hz} , \quad 4.99 \text{ Hz}$$

FAST WALKING (100 bpm)

$$U_v = 25000 \longrightarrow V_p = \frac{(25000 \text{ lb Hz}^2)(2.785 \times 10^{-6} \text{ in/lb})}{7.85 \text{ Hz}}$$
$$= 8870 \frac{\mu \cdot \text{in}}{\text{sec}}$$

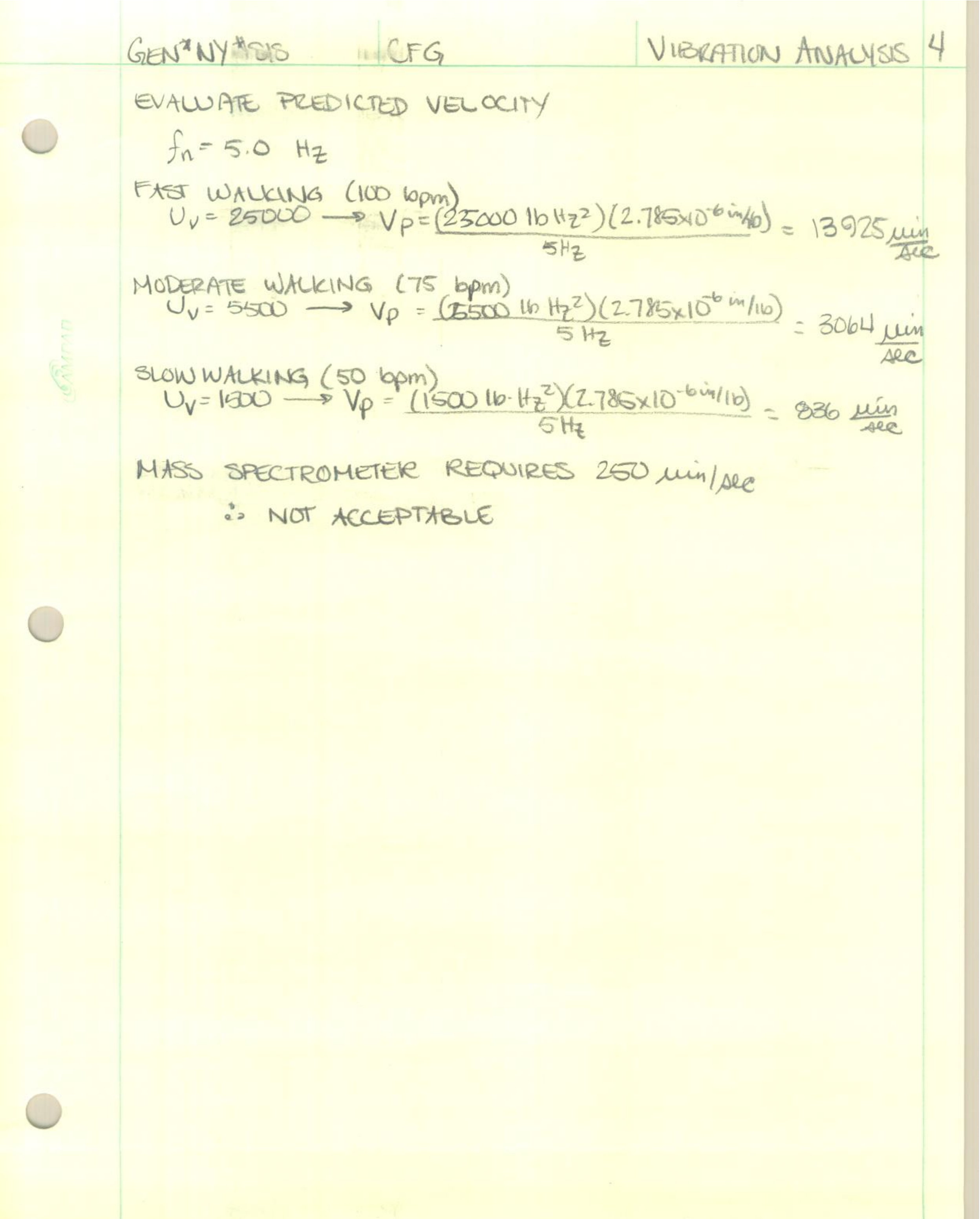
MODERATE WALKING (75 bpm)

$$U_v = 5500 \longrightarrow V_p = \frac{(5500 \text{ lb Hz}^2)(2.785 \times 10^{-6} \text{ in/lb})}{7.85 \text{ Hz}} = 1951 \ \mu\text{in/sec}$$

SLOW WALKING (50 bpm)

$$U_v = 1500 \longrightarrow V_p = \frac{(1500 \text{ lb Hz}^2)(2.785 \times 10^{-6} \text{ in/lb})}{7.85 \text{ Hz}} = 532 \ \mu\text{in/sec}$$

Original System Vibration Calculations



GEN*NY*SIS CFG VIBRATION ANALYSIS 4

EVALUATE PREDICTED VELOCITY

$f_n = 5.0$ Hz

FAST WALKING (100 bpm)

$U_v = 25000 \longrightarrow V_p = \frac{(25000\ \text{lb Hz}^2)(2.785\times10^{-6}\ \text{in/lb})}{5\ \text{Hz}} = 13925\ \frac{\mu\text{in}}{\text{sec}}$

MODERATE WALKING (75 bpm)

$U_v = 5500 \longrightarrow V_p = \frac{(5500\ \text{lb Hz}^2)(2.785\times10^{-6}\ \text{in/lb})}{5\ \text{Hz}} = 3064\ \frac{\mu\text{in}}{\text{sec}}$

SLOW WALKING (50 bpm)

$U_v = 1500 \longrightarrow V_p = \frac{(1500\ \text{lb}\cdot\text{Hz}^2)(2.786\times10^{-6}\ \text{in/lb})}{5\ \text{Hz}} = 836\ \frac{\mu\text{in}}{\text{sec}}$

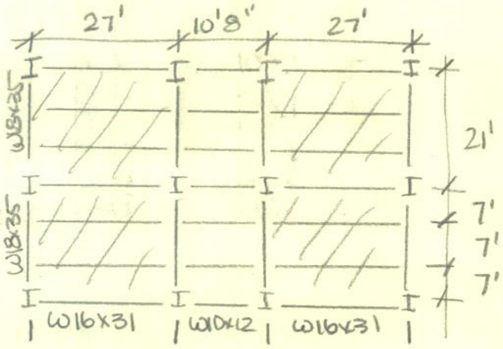
MASS SPECTROMETER REQUIRES 250 μin/sec

$\therefore$ NOT ACCEPTABLE

Original System Vibration Calculations

GEN* NY*SIS CFG VIBRATION ANALYSIS 5

ORIGINAL SYSTEM



4.5" NWC
2" COMP METAL DECK
$f'c = 3500$ psi

▨ = LABORATORY SPACE

DECK PROPERTIES
CONCRETE $w_c = 145$ pcf
$f'c = 3500$ psi
$t_d = 2"$
$t_c = 4.5"$
$d_e = 5.5"$

SLAB + DECK WEIGHT = 72 psf

BEAM PROPERTIES - W16x31
$A = 9.13 \text{ in}^2$
$d = 15.9 \text{ in}$
$I = 375 \text{ in}^4$

W10x12
$A = 3.54 \text{ in}^2$
$d = 9.87 \text{ in}$
$I = 53.8 \text{ in}^4$

GIRDER PROPERTIES - 18x35
$A = 10.3 \text{ in}^2$
$d = 17.7 \text{ in}$
$I = 510 \text{ in}^4$

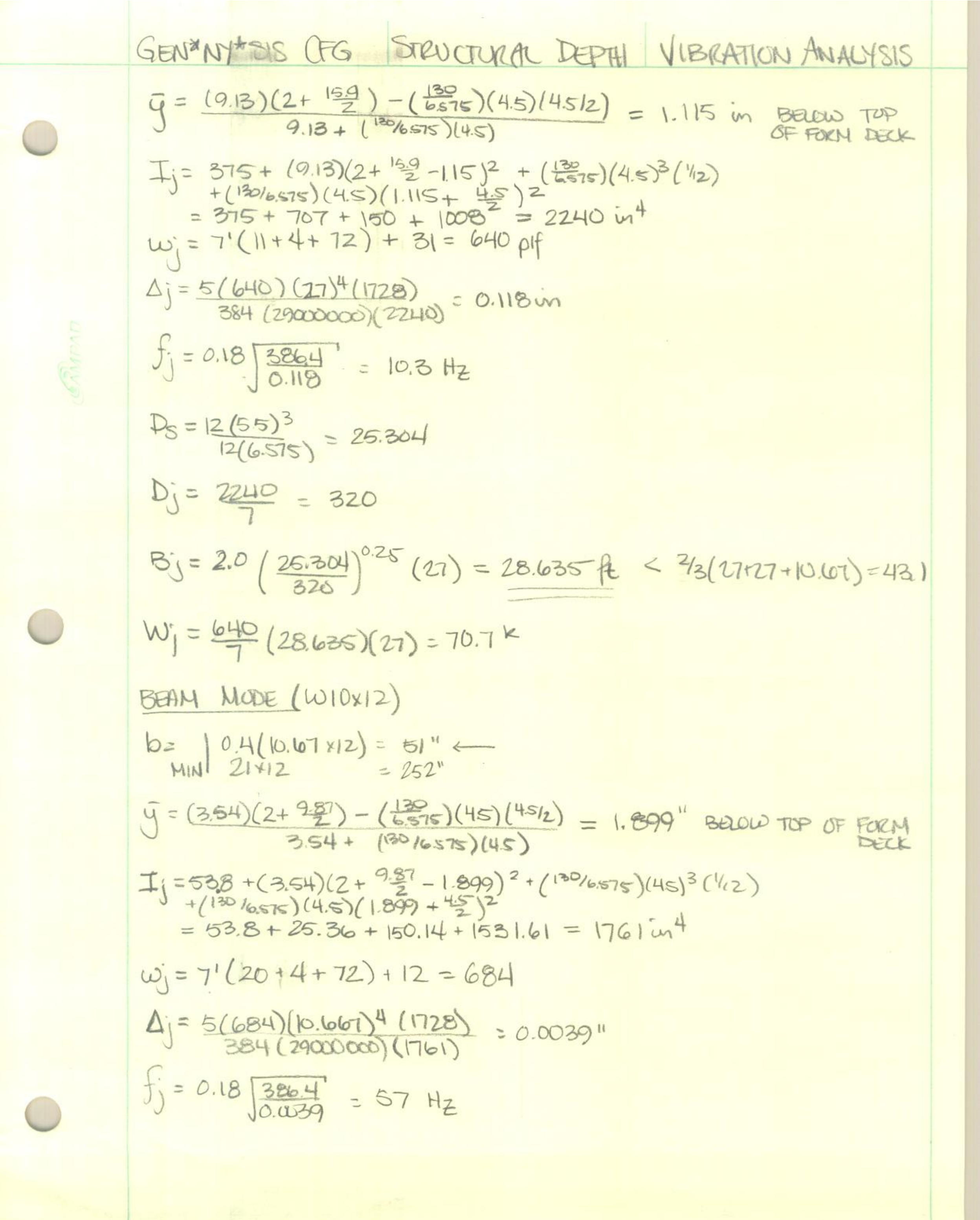
BEAM MODE (W16x31)

$$b = \underset{\text{MIN}}{} \left| \begin{array}{ll} 0.4(27 \times 12) & = 130" \leftarrow \\ 21 \times 12 & = 252" \end{array} \right.$$

$$E_c = (145)^{1.5}\sqrt{3.5} = 3267 \text{ ksi}$$

$$\eta = 29000/(1.35)(3267) = 6.575$$

Original System Vibration Calculations



GEN*NY*SIS CFG | STRUCTURAL DEPTH | VIBRATION ANALYSIS

$$\bar{y} = \frac{(9.13)(2+\frac{15.9}{2}) - (\frac{130}{6.575})(4.5)(4.5/2)}{9.13 + (130/6.575)(4.5)} = 1.115 \text{ in}$$ BELOW TOP OF FORM DECK

$$I_j = 375 + (9.13)(2+\tfrac{15.9}{2} - 1.15)^2 + (\tfrac{130}{6.575})(4.5)^3(1/12) + (130/6.575)(4.5)(1.115 + \tfrac{4.5}{2})^2$$
$$= 375 + 707 + 150 + 1008 = 2240 \text{ in}^4$$

$$w_j = 7'(11+4+72) + 31 = 640 \text{ plf}$$

$$\Delta_j = \frac{5(640)(27)^4(1728)}{384(29000000)(2240)} = 0.118 \text{ in}$$

$$f_j = 0.18\sqrt{\frac{386.4}{0.118}} = 10.3 \text{ Hz}$$

$$D_s = \frac{12(5.5)^3}{12(6.575)} = 25.304$$

$$D_j = \frac{2240}{7} = 320$$

$$B_j = 2.0\left(\frac{25.304}{320}\right)^{0.25}(27) = \underline{\underline{28.635 \text{ ft}}} < 2/3(27+27+10.67) = 43.1$$

$$W_j = \frac{640}{7}(28.635)(27) = 70.7^{k}$$

BEAM MODE (W10x12)

$$b_{MIN} = \left|\begin{matrix} 0.4(10.67 \times 12) = 51'' \leftarrow \\ 21 \times 12 = 252'' \end{matrix}\right.$$

$$\bar{y} = \frac{(3.54)(2+\frac{9.87}{2}) - (\frac{130}{6.575})(45)(4.5/2)}{3.54 + (130/6.575)(4.5)} = 1.899''$$ BELOW TOP OF FORM DECK

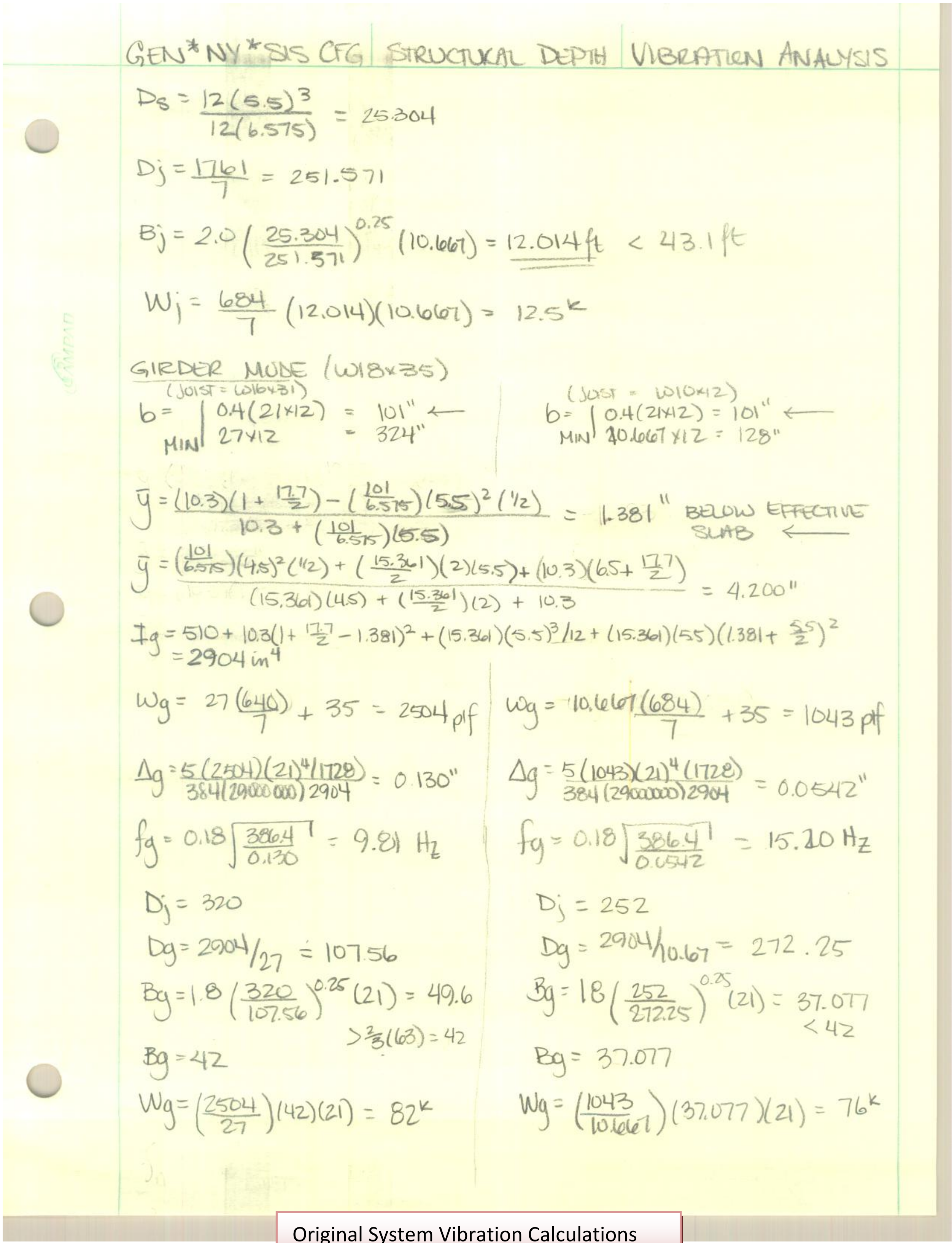
$$I_j = 53.8 + (3.54)(2+\tfrac{9.87}{2} - 1.899)^2 + (130/6.575)(45)^3(1/12) + (130/6.575)(4.5)(1.899 + \tfrac{4.5}{2})^2$$
$$= 53.8 + 25.36 + 150.14 + 1531.61 = 1761 \text{ in}^4$$

$$w_j = 7'(20+4+72) + 12 = 684$$

$$\Delta_j = \frac{5(684)(10.667)^4(1728)}{384(29000000)(1761)} = 0.0039''$$

$$f_j = 0.18\sqrt{\frac{386.4}{0.0039}} = 57 \text{ Hz}$$

Original System Vibration Calculations



GEN*NY*SIS CFG | STRUCTURAL DEPTH | VIBRATION ANALYSIS

$$D_s = \frac{12(5.5)^3}{12(6.575)} = 25.304$$

$$D_j = \frac{1761}{7} = 251.571$$

$$B_j = 2.0\left(\frac{25.304}{251.571}\right)^{0.25}(10.667) = \underline{\underline{12.014\,ft}} < 43.1\,ft$$

$$W_j = \frac{684}{7}(12.014)(10.667) = 12.5^k$$

GIRDER MODE (W18x35)

(JOIST = W16x31)

$$b = \min \left| \begin{array}{ll} 0.4(21 \times 12) & = 101'' \leftarrow \\ 27 \times 12 & = 324'' \end{array} \right.$$

(JOIST = W10x12)

$$b = \min \left| \begin{array}{l} 0.4(21 \times 12) = 101'' \leftarrow \\ 10.667 \times 12 = 128'' \end{array} \right.$$

$$\bar{y} = \frac{(10.3)(1 + \frac{17.7}{2}) - (\frac{101}{6.575})(5.5)^2(\frac{1}{2})}{10.3 + (\frac{101}{6.575})(5.5)} = 1.381'' \text{ BELOW EFFECTIVE SLAB} \leftarrow$$

$$\bar{y} = \frac{(\frac{101}{6.575})(4.5)^2(\frac{1}{2}) + (\frac{15.361}{2})(2)(5.5) + (10.3)(6.5 + \frac{17.7}{2})}{(15.361)(4.5) + (\frac{15.361}{2})(2) + 10.3} = 4.200''$$

$$I_g = 510 + 10.3(1 + \frac{17.7}{2} - 1.381)^2 + (15.361)(5.5)^3/12 + (15.361)(5.5)(1.381 + \frac{5.5}{2})^2$$
$$= 2904\,in^4$$

$$w_g = 27\frac{(640)}{7} + 35 = 2504\,plf$$

$$\Delta_g = \frac{5(2504)(21)^4/1728)}{384(29000000)2904} = 0.130''$$

$$f_g = 0.18\sqrt{\frac{386.4}{0.130}} = 9.81\,Hz$$

$$D_j = 320$$

$$D_g = 2904/27 \doteq 107.56$$

$$B_g = 1.8\left(\frac{320}{107.56}\right)^{0.25}(21) = 49.6$$
$$> \tfrac{2}{3}(63) = 42$$

$$B_g = 42$$

$$W_g = \left(\frac{2504}{27}\right)(42)(21) = 82^k$$

$$w_g = 10.667\frac{(684)}{7} + 35 = 1043\,plf$$

$$\Delta_g = \frac{5(1043)(21)^4(1728)}{384(29000000)2904} = 0.0542''$$

$$f_g = 0.18\sqrt{\frac{386.4}{0.0542}} = 15.20\,Hz$$

$$D_j = 252$$

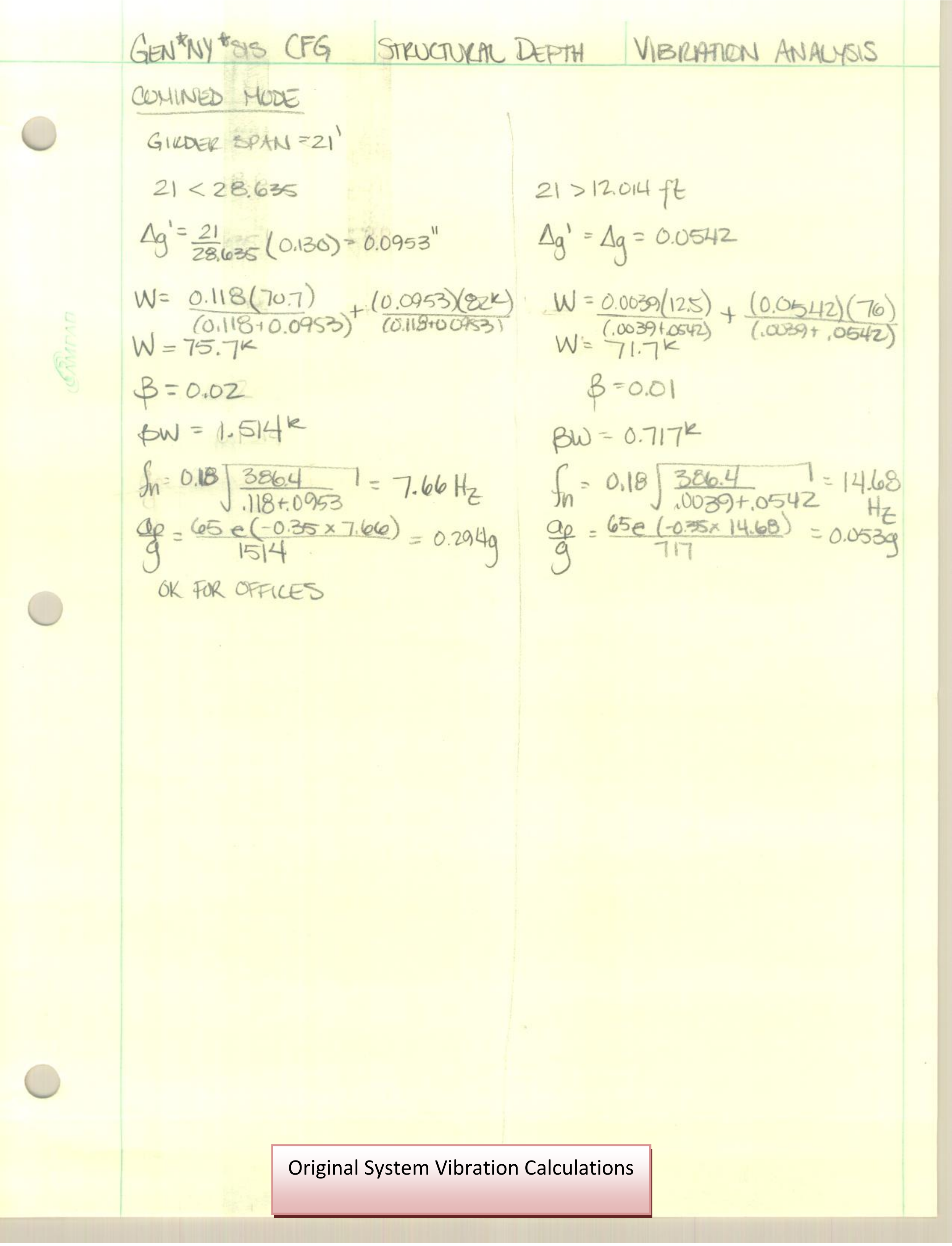
$$D_g = 2904/10.67 = 272.25$$

$$B_g = 18\left(\frac{252}{272.25}\right)^{0.25}(21) = 37.077$$
$$< 42$$

$$B_g = 37.077$$

$$W_g = \left(\frac{1043}{10.667}\right)(37.077)(21) = 76^k$$

Original System Vibration Calculations



GEN*NY*SIS CFG | STRUCTURAL DEPTH | VIBRATION ANALYSIS

COMINED MODE

GIRDER SPAN = 21'

$21 < 28.635$

$\Delta g' = \frac{21}{28.635}(0.130) = 0.0953''$

$W = \frac{0.118(70.7)}{(0.118+0.0953)} + \frac{(0.0953)(82^{k})}{(0.118+0.0953)}$

$W = 75.7^{K}$

$\beta = 0.02$

$\beta W = 1.514^{k}$

$f_n = 0.18\sqrt{\frac{386.4}{.118+.0953}} = 7.66\ Hz$

$\frac{a_p}{g} = \frac{65\ e(-0.35 \times 7.66)}{1514} = 0.294g$

OK FOR OFFICES

$21 > 12.014\ ft$

$\Delta g' = \Delta g = 0.0542$

$W = \frac{0.0039(12.5)}{(.0039+.0542)} + \frac{(0.0542)(76)}{(.0039+.0542)}$

$W = 71.7^{k}$

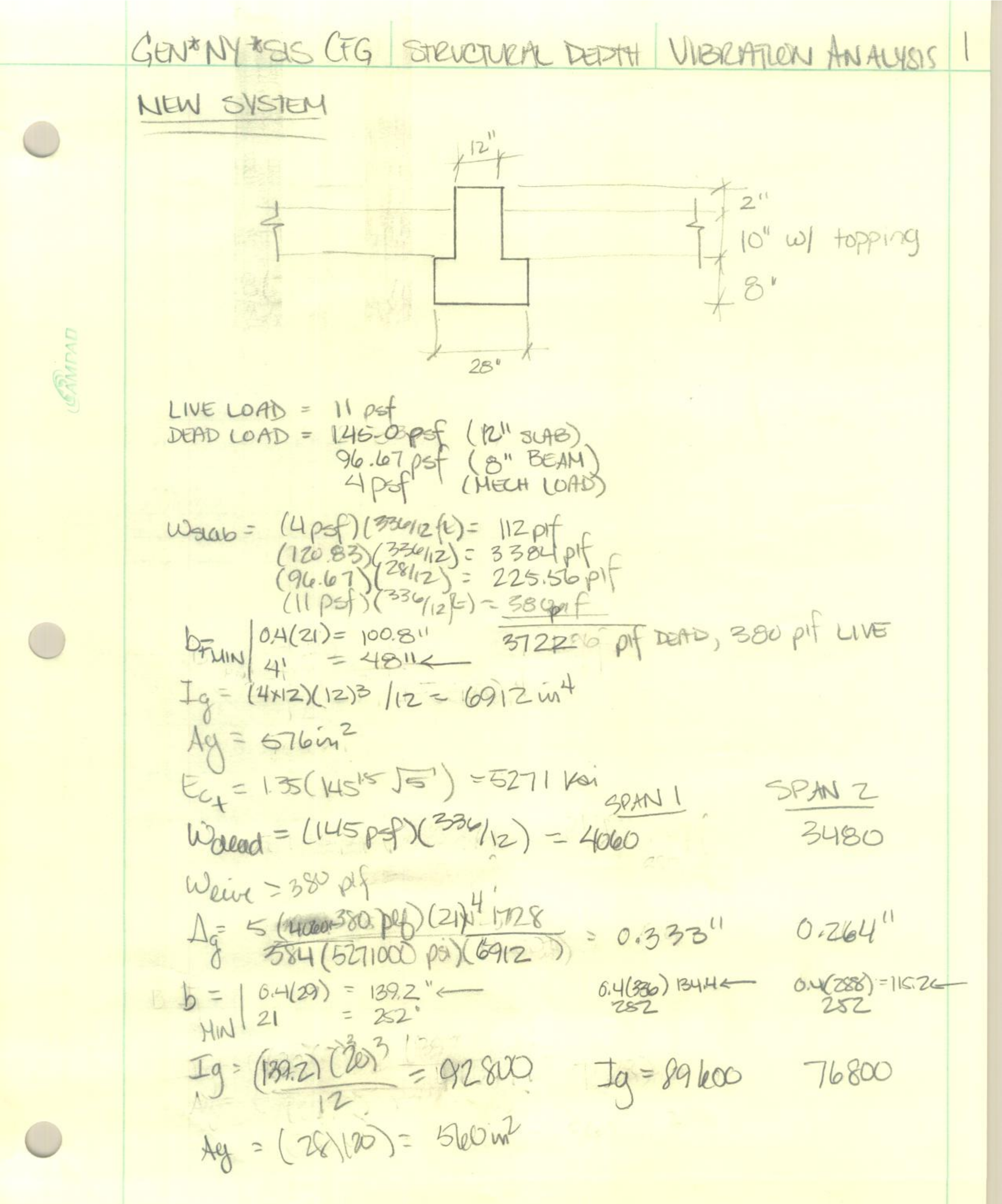
$\beta = 0.01$

$\beta W = 0.717^{k}$

$f_n = 0.18\sqrt{\frac{386.4}{.0039+.0542}} = 14.68\ Hz$

$\frac{a_p}{g} = \frac{65e(-0.35 \times 14.68)}{717} = 0.053g$

Original System Vibration Calculations



GEN*NY*SIS CFG | STRUCTURAL DEPTH | VIBRATION ANALYSIS | 1

NEW SYSTEM

LIVE LOAD = 11 psf

DEAD LOAD = 145.0 psf (12" SLAB)
96.67 psf (8" BEAM)
4 psf (MECH LOAD)

w_{slab} = (4 psf)(336/12 ft) = 112 plf
(120.83)(336/12) = 3384 plf
(96.67)(28/12) = 225.56 plf
(11 psf)(336/12 ft) = 380 plf

3722 plf DEAD, 380 plf LIVE

$b_{f\,MIN}$ | 0.4(21) = 100.8"
4' = 48" ←

$I_g = (4\times12)(12)^3/12 = 6912\ in^4$

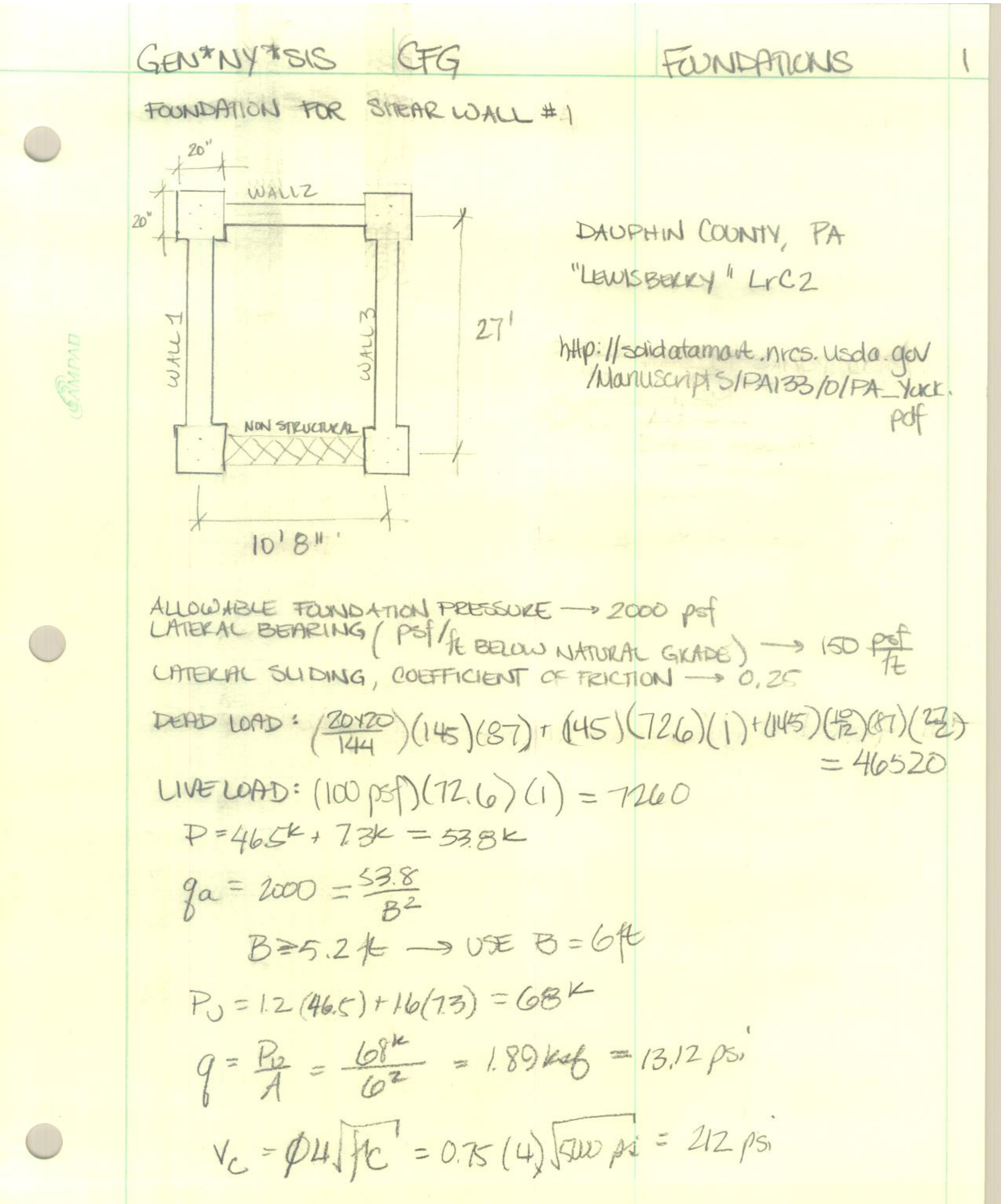
$A_g = 576\ in^2$

$E_{c_t} = 1.35(145^{1.5}\sqrt{5}) = 5271$ ksi

	SPAN 1	SPAN 2
$w_{dead} = (145\ psf)(336/12)$ =	4060	3480
w_{live} = 380 plf		
$\Delta_g = \dfrac{5(380\ plf)(21)^4\ 1728}{384(5271000\ psi)(6912)}$ =	0.333"	0.264"
b_{MIN} = | 0.4(29) = 139.2" ← 21 = 252"	0.4(336) 134.4 ← 252	0.4(288) = 115.2 ← 252
$I_g = \dfrac{(139.2)(20)^3}{12} = 92800$	I_g = 89600	76800

$A_g = (28)(20) = 560\ in^2$

New System Vibration Calculations



GEN*NY*SIS CFG FOUNDATIONS 1

FOUNDATION FOR SHEAR WALL #1

DAUPHIN COUNTY, PA
"LEWISBERRY" LrC2

http://soildatamart.nrcs.usda.gov/Manuscripts/PA133/0/PA_York.pdf

ALLOWABLE FOUNDATION PRESSURE → 2000 psf
LATERAL BEARING (psf/ft BELOW NATURAL GRADE) → 150 $\frac{psf}{ft}$
LATERAL SLIDING, COEFFICIENT OF FRICTION → 0.25

DEAD LOAD: $\left(\frac{20\times20}{144}\right)(145)(87)+(145)(72.6)(1)+(145)\left(\frac{10}{12}\right)(87)\left(\frac{27}{2}\right)$
$= 46520$

LIVE LOAD: $(100\ psf)(72.6)(1) = 7260$

$P = 46.5^k + 7.3^k = 53.8^k$

$q_a = 2000 = \frac{53.8}{B^2}$

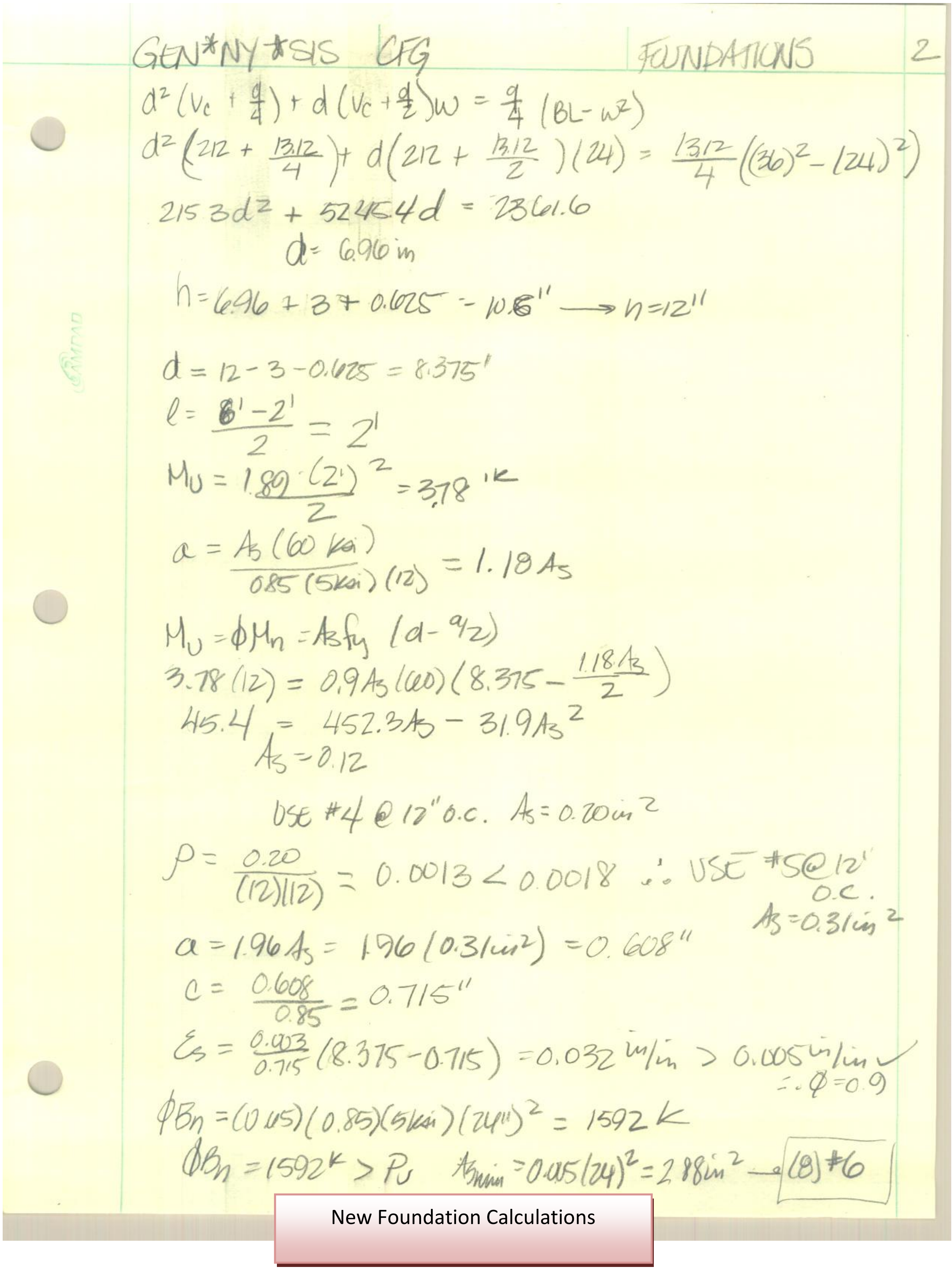
$B \geq 5.2\ ft \rightarrow$ USE $B = 6ft$

$P_u = 1.2(46.5) + 1.6(7.3) = 68^k$

$q = \frac{P_u}{A} = \frac{68^k}{6^2} = 1.89\ ksf = 13.12\ psi$

$V_c = \phi 4\sqrt{f'c} = 0.75(4)\sqrt{5000\ psi} = 212\ psi$

New Foundation Calculations



GEN*NY*SIS CFG FOUNDATIONS 2

$d^2(v_c + \frac{q}{4}) + d(v_c + \frac{q}{2})w = \frac{q}{4}(BL - w^2)$

$d^2(212 + \frac{13.12}{4}) + d(212 + \frac{13.12}{2})(24) = \frac{13.12}{4}((36)^2 - (24)^2)$

$215.3d^2 + 52454d = 2361.6$

$d = 6.96 \text{ in}$

$h = 6.96 + 3 + 0.625 = 10.6'' \longrightarrow h = 12''$

$d = 12 - 3 - 0.625 = 8.375'$

$l = \frac{8' - 2'}{2} = 2'$

$M_U = \frac{1.89(2')^2}{2} = 3.78^{'k}$

$a = \frac{A_s(60 \text{ ksi})}{0.85(5 \text{ ksi})(12)} = 1.18 A_s$

$M_U = \phi M_n = A_s f_y (d - a/2)$

$3.78(12) = 0.9 A_s(60)(8.375 - \frac{1.18 A_s}{2})$

$45.4 = 452.3A_s - 31.9A_s^2$

$A_s = 0.12$

USE #4 @ 12" o.c. $A_s = 0.20 \text{ in}^2$

$\rho = \frac{0.20}{(12)(12)} = 0.0013 < 0.0018$ $\therefore$ USE #5 @ 12' o.c. $A_s = 0.31 \text{ in}^2$

$a = 1.96 A_s = 1.96(0.31 \text{ in}^2) = 0.608''$

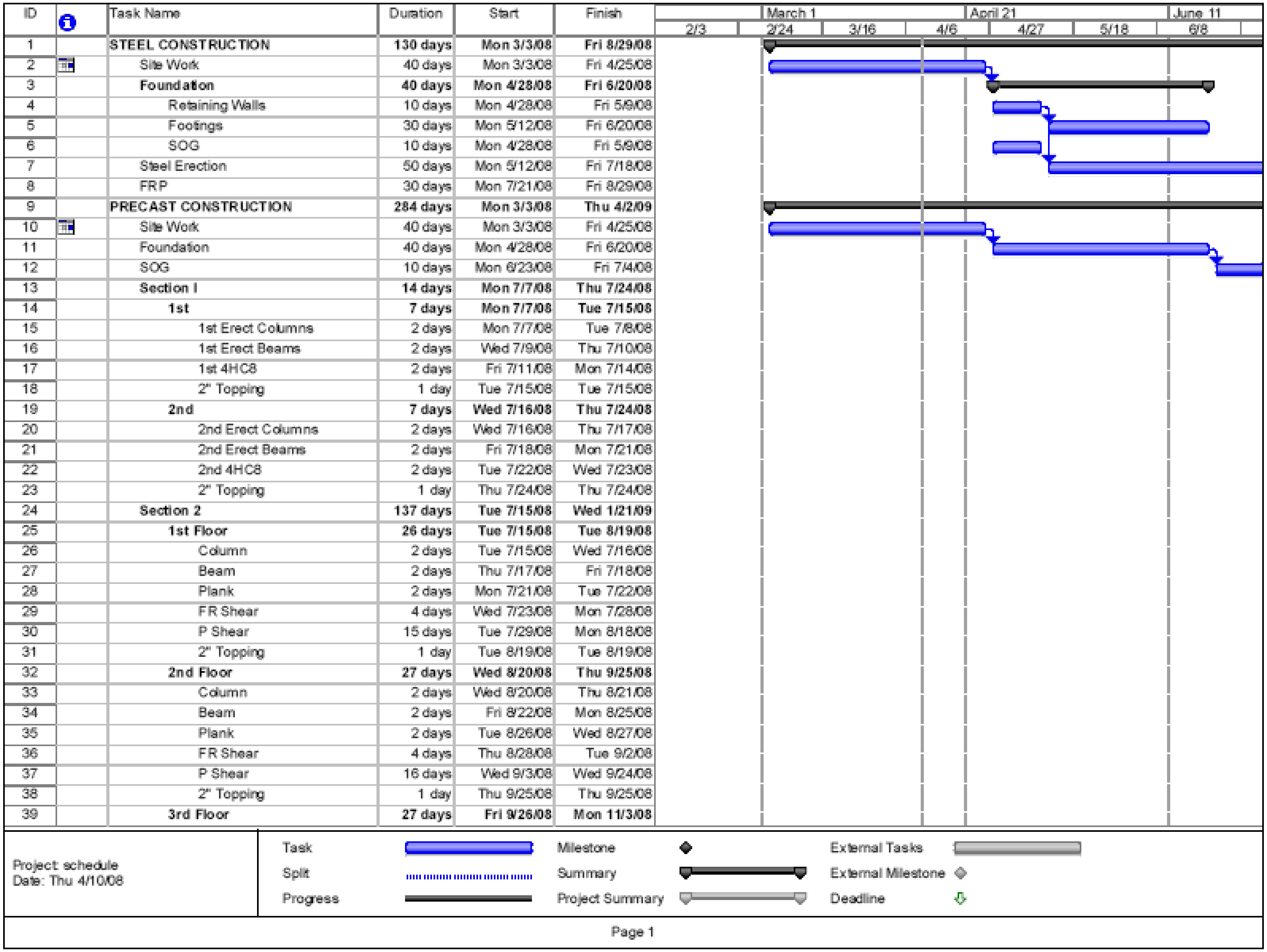
$c = \frac{0.608}{0.85} = 0.715''$

$\varepsilon_s = \frac{0.003}{0.715}(8.375 - 0.715) = 0.032 \text{ in/in} > 0.005 \text{ in/in}$ ✓ $\therefore \phi = 0.9$

$\phi B_n = (0.65)(0.85)(5 \text{ ksi})(24'')^2 = 1592 \text{ K}$

$\phi B_n = 1592^k > P_u$ $A_{s_{min}} = 0.005(24)^2 = 2.88 \text{ in}^2 \rightarrow \boxed{(8)\#6}$

New Foundation Calculations



ID	ℹ	Task Name	Duration	Start	Finish
1		**STEEL CONSTRUCTION**	**130 days**	**Mon 3/3/08**	**Fri 8/29/08**
2	▦	Site Work	40 days	Mon 3/3/08	Fri 4/25/08
3		**Foundation**	**40 days**	**Mon 4/28/08**	**Fri 6/20/08**
4		Retaining Walls	10 days	Mon 4/28/08	Fri 5/9/08
5		Footings	30 days	Mon 5/12/08	Fri 6/20/08
6		SOG	10 days	Mon 4/28/08	Fri 5/9/08
7		Steel Erection	50 days	Mon 5/12/08	Fri 7/18/08
8		FRP	30 days	Mon 7/21/08	Fri 8/29/08
9		**PRECAST CONSTRUCTION**	**284 days**	**Mon 3/3/08**	**Thu 4/2/09**
10	▦	Site Work	40 days	Mon 3/3/08	Fri 4/25/08
11		Foundation	40 days	Mon 4/28/08	Fri 6/20/08
12		SOG	10 days	Mon 6/23/08	Fri 7/4/08
13		**Section I**	**14 days**	**Mon 7/7/08**	**Thu 7/24/08**
14		**1st**	**7 days**	**Mon 7/7/08**	**Tue 7/15/08**
15		1st Erect Columns	2 days	Mon 7/7/08	Tue 7/8/08
16		1st Erect Beams	2 days	Wed 7/9/08	Thu 7/10/08
17		1st 4HC8	2 days	Fri 7/11/08	Mon 7/14/08
18		2" Topping	1 day	Tue 7/15/08	Tue 7/15/08
19		**2nd**	**7 days**	**Wed 7/16/08**	**Thu 7/24/08**
20		2nd Erect Columns	2 days	Wed 7/16/08	Thu 7/17/08
21		2nd Erect Beams	2 days	Fri 7/18/08	Mon 7/21/08
22		2nd 4HC8	2 days	Tue 7/22/08	Wed 7/23/08
23		2" Topping	1 day	Thu 7/24/08	Thu 7/24/08
24		**Section 2**	**137 days**	**Tue 7/15/08**	**Wed 1/21/09**
25		**1st Floor**	**26 days**	**Tue 7/15/08**	**Tue 8/19/08**
26		Column	2 days	Tue 7/15/08	Wed 7/16/08
27		Beam	2 days	Thu 7/17/08	Fri 7/18/08
28		Plank	2 days	Mon 7/21/08	Tue 7/22/08
29		FR Shear	4 days	Wed 7/23/08	Mon 7/28/08
30		P Shear	15 days	Tue 7/29/08	Mon 8/18/08
31		2" Topping	1 day	Tue 8/19/08	Tue 8/19/08
32		**2nd Floor**	**27 days**	**Wed 8/20/08**	**Thu 9/25/08**
33		Column	2 days	Wed 8/20/08	Thu 8/21/08
34		Beam	2 days	Fri 8/22/08	Mon 8/25/08
35		Plank	2 days	Tue 8/26/08	Wed 8/27/08
36		FR Shear	4 days	Thu 8/28/08	Tue 9/2/08
37		P Shear	16 days	Wed 9/3/08	Wed 9/24/08
38		2" Topping	1 day	Thu 9/25/08	Thu 9/25/08
39		**3rd Floor**	**27 days**	**Fri 9/26/08**	**Mon 11/3/08**

Project: schedule
Date: Thu 4/10/08

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ID	ℹ	Task Name	Duration	Start	Finish
40		Columns	2 days	Fri 9/26/08	Mon 9/29/08
41		Beams	2 days	Tue 9/30/08	Wed 10/1/08
42		Plank	2 days	Thu 10/2/08	Fri 10/3/08
43		FR Shear	4 days	Mon 10/6/08	Thu 10/9/08
44		P Shear	16 days	Fri 10/10/08	Fri 10/31/08
45		2" Topping	1 day	Mon 11/3/08	Mon 11/3/08
46		**Roof**	**34 days**	**Tue 11/4/08**	**Fri 12/19/08**
47		Columns	3 days	Tue 11/4/08	Thu 11/6/08
48		Beams	2 days	Fri 11/7/08	Mon 11/10/08
49		Plank	4 days	Tue 11/11/08	Fri 11/14/08
50		FR Shear	4 days	Mon 11/17/08	Thu 11/20/08
51		P Shear	20 days	Fri 11/21/08	Thu 12/18/08
52		2" Topping	1 day	Fri 12/19/08	Fri 12/19/08
53		**Penthouse**	**23 days**	**Mon 12/22/08**	**Wed 1/21/09**
54		FR Shear	2 days	Mon 12/22/08	Tue 12/23/08
55		P Shear	21 days	Wed 12/24/08	Wed 1/21/09
56		**Section 3**	**182 days**	**Wed 7/23/08**	**Thu 4/2/09**
57		**1st**	**37 days**	**Wed 7/23/08**	**Thu 9/11/08**
58		Column	2 days	Wed 7/23/08	Thu 7/24/08
59		Beam	2 days	Fri 7/25/08	Mon 7/28/08
60		Plank	2 days	Tue 7/29/08	Wed 7/30/08
61		FR Shear	4 days	Thu 7/31/08	Tue 8/5/08
62		P Shear	26 days	Wed 8/6/08	Wed 9/10/08
63		Topping	1 day	Thu 9/11/08	Thu 9/11/08
64		**2nd**	**37 days**	**Fri 9/12/08**	**Mon 11/3/08**
65		Columns	2 days	Fri 9/12/08	Mon 9/15/08
66		Beams	2 days	Tue 9/16/08	Wed 9/17/08
67		Plank	2 days	Thu 9/18/08	Fri 9/19/08
68		FR Shear	4 days	Mon 9/22/08	Thu 9/25/08
69		P Shear	26 days	Fri 9/26/08	Fri 10/31/08
70		Topping	1 day	Mon 11/3/08	Mon 11/3/08
71		**3rd**	**37 days**	**Tue 11/4/08**	**Wed 12/24/08**
72		Columns	2 days	Tue 11/4/08	Wed 11/5/08
73		Beams	2 days	Thu 11/6/08	Fri 11/7/08
74		Plank	2 days	Mon 11/10/08	Tue 11/11/08
75		FR Shear	4 days	Wed 11/12/08	Mon 11/17/08
76		P Shear	26 days	Tue 11/18/08	Tue 12/23/08
77		Topping	1 day	Wed 12/24/08	Wed 12/24/08
78		**Roof**	**39 days**	**Thu 12/25/08**	**Tue 2/17/09**

Project: schedule
Date: Thu 4/10/08

Task	▬	Milestone	◆	External Tasks	▬
Split	┅	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

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ID	ℹ	Task Name	Duration	Start	Finish
79		Columns	3 days	Thu 12/25/08	Mon 12/29/08
80		Beams	2 days	Tue 12/30/08	Wed 12/31/08
81		Plank	2 days	Thu 1/1/09	Fri 1/2/09
82		FR Shear	2 days	Mon 1/5/09	Tue 1/6/09
83		P Shear	28 days	Wed 1/7/09	Fri 2/13/09
84		Topping	2 days	Mon 2/16/09	Tue 2/17/09
85		**Penthouse**	**32 days**	**Wed 2/18/09**	**Thu 4/2/09**
86	▦	FR Shear	4 days	Wed 2/18/09	Mon 2/23/09
87		P Shear	28 days	Tue 2/24/09	Thu 4/2/09
88		**Section 4**	**42 days**	**Thu 7/31/08**	**Fri 9/26/08**
89		**1st**	**10 days**	**Thu 7/31/08**	**Wed 8/13/08**
90		Column	3 days	Thu 7/31/08	Mon 8/4/08
91		Beam	2 days	Tue 8/5/08	Wed 8/6/08
92		Plank	3 days	Thu 8/7/08	Mon 8/11/08
93		Topping	2 days	Tue 8/12/08	Wed 8/13/08
94		**2nd**	**10 days**	**Thu 8/14/08**	**Wed 8/27/08**
95		Column	3 days	Thu 8/14/08	Mon 8/18/08
96		Beam	2 days	Tue 8/19/08	Wed 8/20/08
97		Plank	3 days	Thu 8/21/08	Mon 8/25/08
98		Topping	2 days	Tue 8/26/08	Wed 8/27/08
99		**3rd**	**10 days**	**Thu 8/28/08**	**Wed 9/10/08**
100		Column	3 days	Thu 8/28/08	Mon 9/1/08
101		Beam	2 days	Tue 9/2/08	Wed 9/3/08
102		Plank	3 days	Thu 9/4/08	Mon 9/8/08
103		Topping	2 days	Tue 9/9/08	Wed 9/10/08
104		**Roof**	**12 days**	**Thu 9/11/08**	**Fri 9/26/08**
105		Column	3 days	Thu 9/11/08	Mon 9/15/08
106		Beam	2 days	Tue 9/16/08	Wed 9/17/08
107		Plank	5 days	Thu 9/18/08	Wed 9/24/08
108		Topping	2 days	Thu 9/25/08	Fri 9/26/08
109		**Section 5**	**121 days**	**Tue 8/12/08**	**Tue 1/27/09**
110		**1st**	**23 days**	**Tue 8/12/08**	**Thu 9/11/08**
111		Column	2 days	Tue 8/12/08	Wed 8/13/08
112		Beam	2 days	Thu 8/14/08	Fri 8/15/08
113		Plank	2 days	Mon 8/18/08	Tue 8/19/08
114		FR Shear	2 days	Wed 8/20/08	Thu 8/21/08
115		P Shear	14 days	Fri 8/22/08	Wed 9/10/08
116		Topping	1 day	Thu 9/11/08	Thu 9/11/08
117		**2nd**	**25 days**	**Fri 9/12/08**	**Thu 10/16/08**

March 1 | April 21 | June 11
2/3 | 2/24 | 3/16 | 4/6 | 4/27 | 5/18 | 6/8

Project: schedule
Date: Thu 4/10/08

Task
Split
Progress
Milestone ◆
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External Tasks
External Milestone ◆
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ID	ℹ	Task Name	Duration	Start	Finish
118		Column	2 days	Fri 9/12/08	Mon 9/15/08
119		Beam	2 days	Tue 9/16/08	Wed 9/17/08
120		Plank	2 days	Thu 9/18/08	Fri 9/19/08
121		FR Shear	2 days	Mon 9/22/08	Tue 9/23/08
122		P Shear	16 days	Wed 9/24/08	Wed 10/15/08
123		Topping	1 day	Thu 10/16/08	Thu 10/16/08
124		**3rd**	**25 days**	**Fri 10/17/08**	**Thu 11/20/08**
125		Column	2 days	Fri 10/17/08	Mon 10/20/08
126		Beam	2 days	Tue 10/21/08	Wed 10/22/08
127		Plank	2 days	Thu 10/23/08	Fri 10/24/08
128		FR Shear	2 days	Mon 10/27/08	Tue 10/28/08
129		P Shear	16 days	Wed 10/29/08	Wed 11/19/08
130		Topping	1 day	Thu 11/20/08	Thu 11/20/08
131		**Roof**	**27 days**	**Fri 11/21/08**	**Mon 12/29/08**
132		Column	2 days	Fri 11/21/08	Mon 11/24/08
133		Beam	2 days	Tue 11/25/08	Wed 11/26/08
134		Plank	2 days	Thu 11/27/08	Fri 11/28/08
135		FR Shear	2 days	Mon 12/1/08	Tue 12/2/08
136		P Shear	18 days	Wed 12/3/08	Fri 12/26/08
137		Topping	1 day	Mon 12/29/08	Mon 12/29/08
138		**Penthouse**	**21 days**	**Tue 12/30/08**	**Tue 1/27/09**
139		FR Shear	2 days	Tue 12/30/08	Wed 12/31/08
140		P Shear	18 days	Thu 1/1/09	Mon 1/26/09
141		Topping	1 day	Tue 1/27/09	Tue 1/27/09

March 1			April 21			June 11	
2/3	2/24	3/16	4/6	4/27	5/18	6/8	

Project schedule
Date: Thu 4/10/08

Task	▬	Milestone	◆	External Tasks	▬
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

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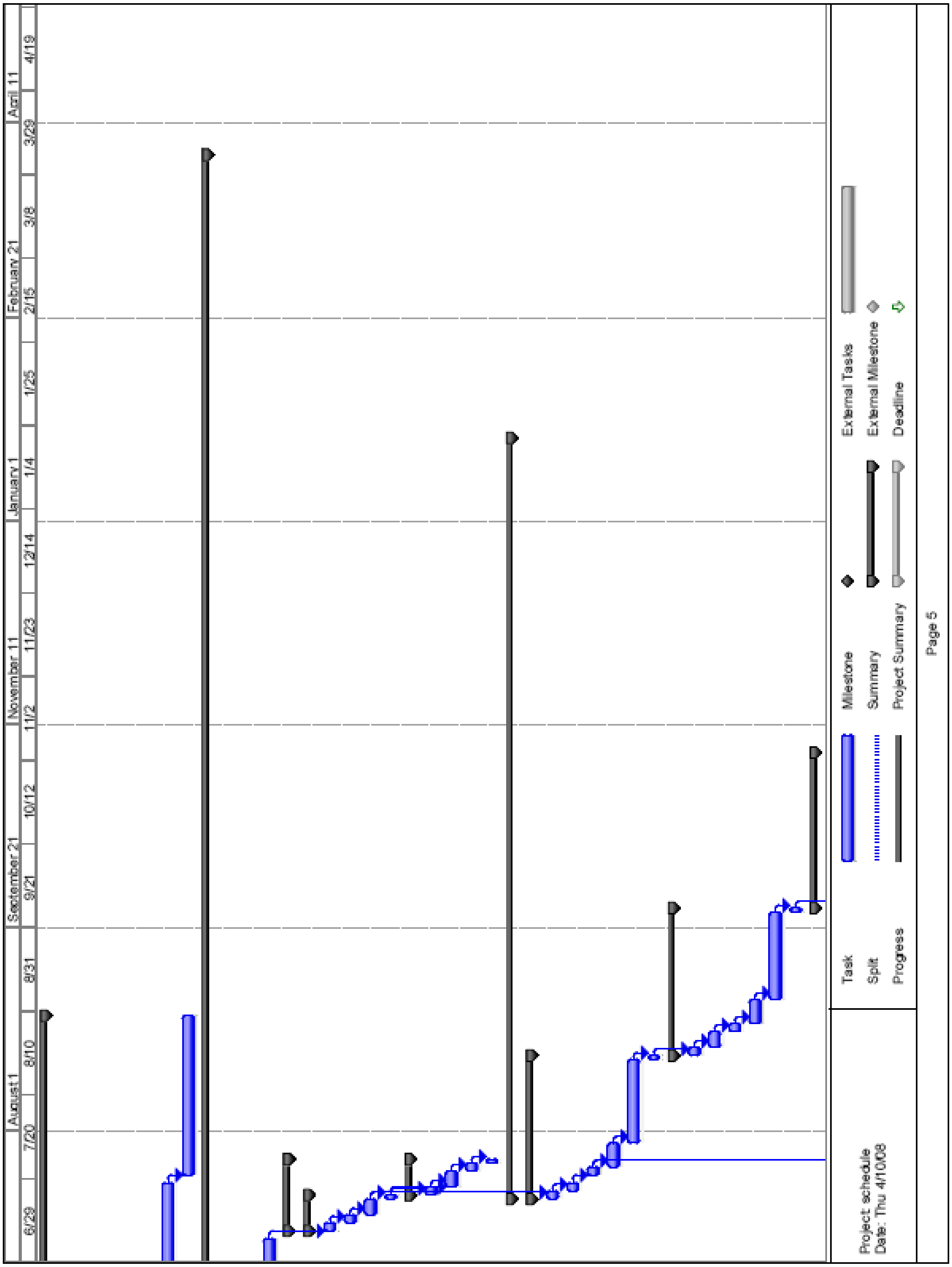
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6/29
7/20
8/10
8/31
September 21
9/21
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November 11
11/2
11/23
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January 1
1/4
1/25
February 21
2/15
3/8
April 11
3/29
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Project: schedule
Date: Thu 4/10/08
Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline
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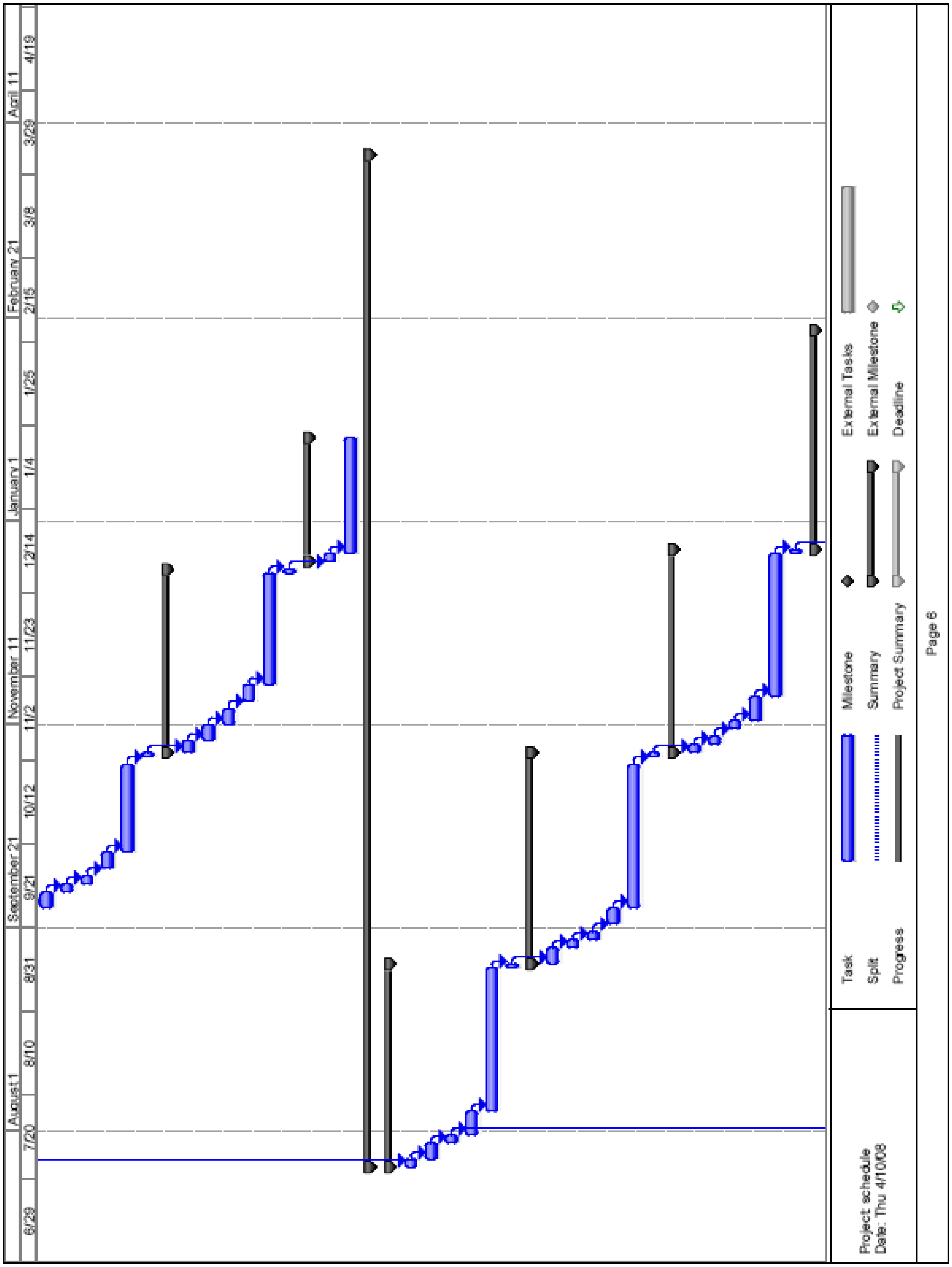
August 1
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November 11
January 1
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Project schedule
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Project Summary
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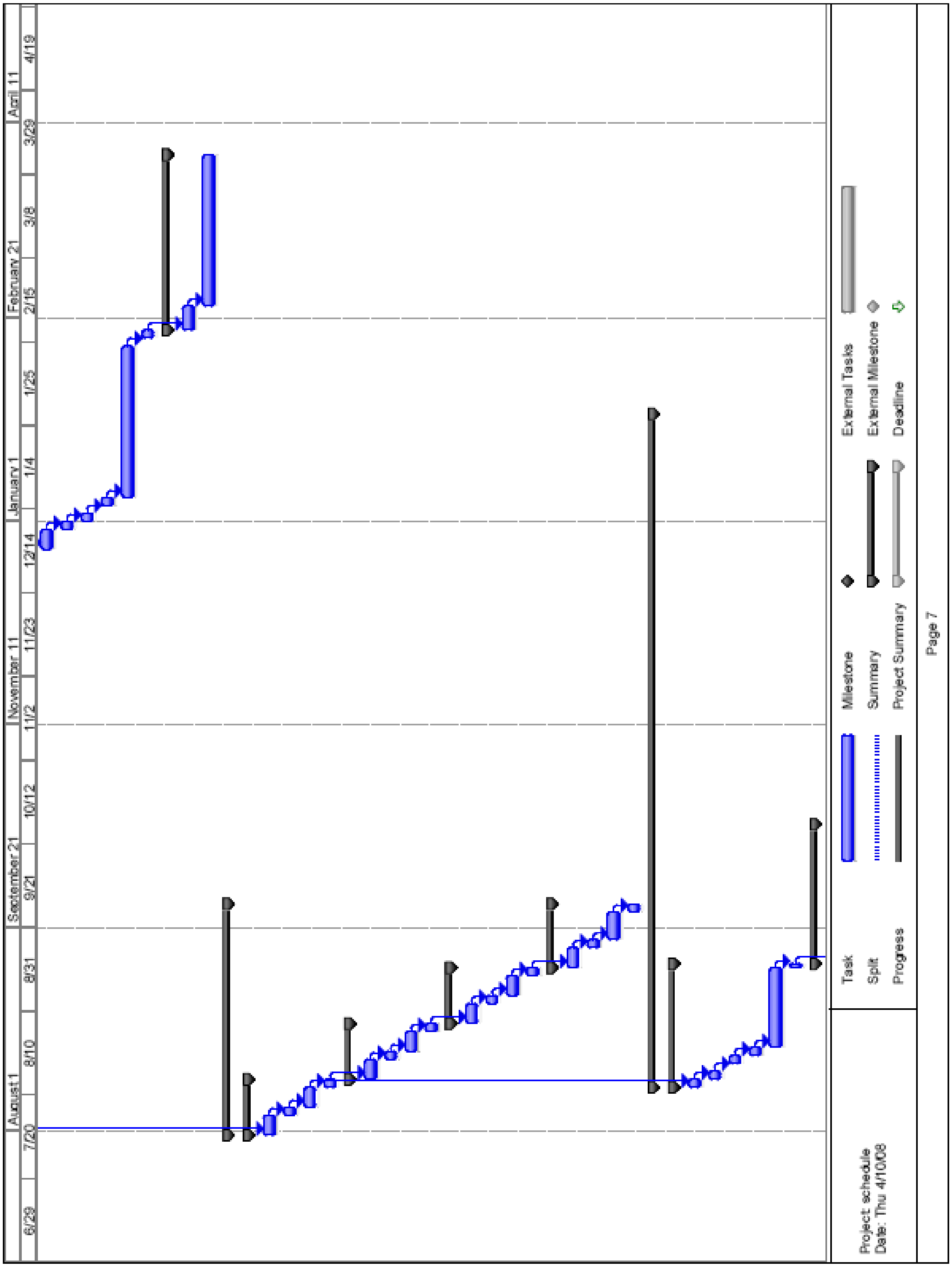
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Project schedule
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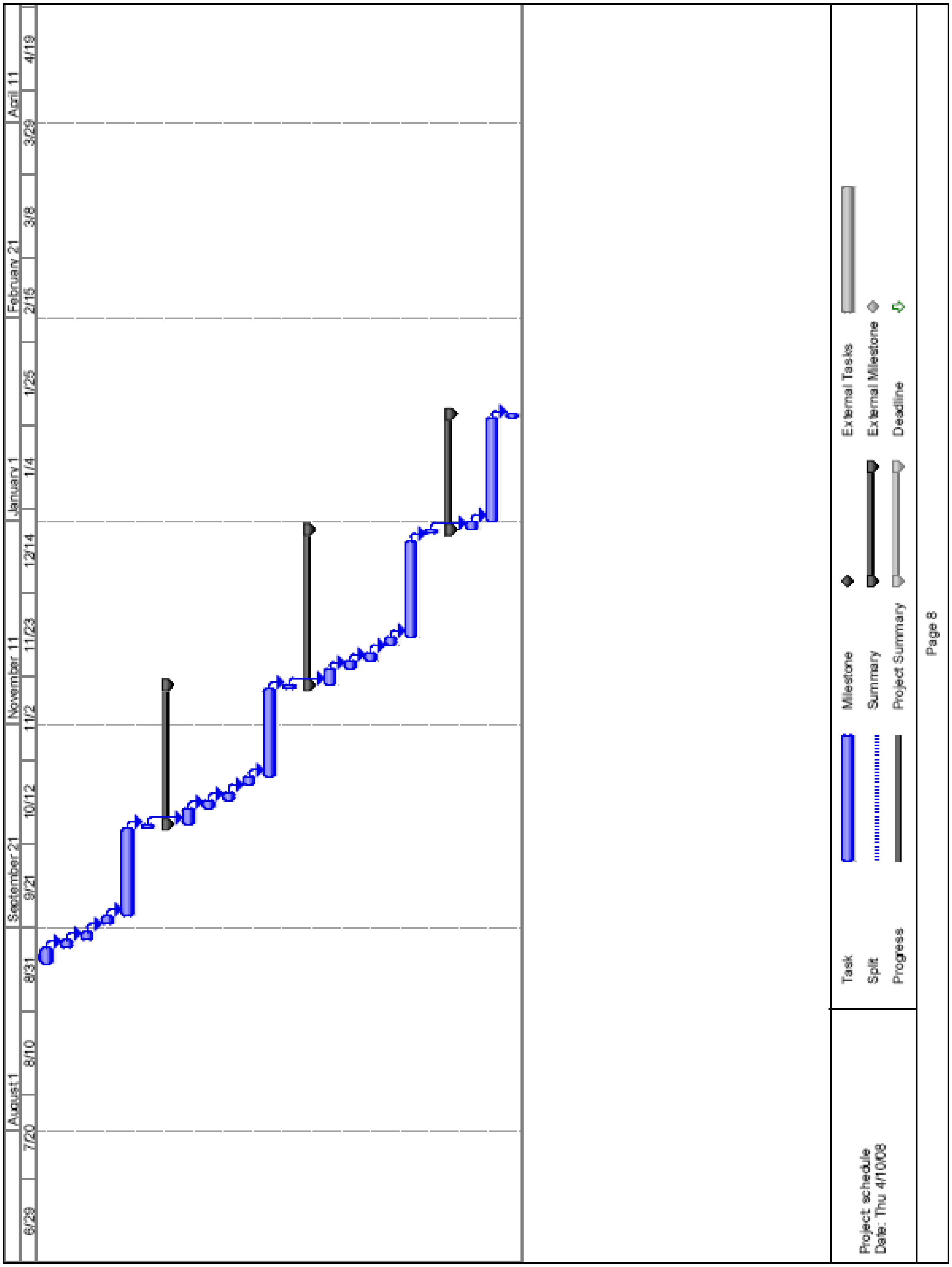
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September 21
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February 21
April 11
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Project schedule
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CSI Division	CSI Subdivision	Description	Crew	Daily Output	Labor-Hours	Unit of Measure	Quantity	Unit Mat'l Cost	Mat'l Cost	Unit Labor Cost	Labor Cost	Unit Equip/Sub Cost	Equip/Sub Cost	Item Cost	Total Item Cost
03310-220		Concrete, ready mix													
	400	Regular weight				C.Y.	190720	$ 77.00	$ 14,685,440.00					$ 77.00	$ 16,153,984.00
05120-260		Columns													
	4550	HSS6x6x1/4"x12'-0"	E-2	54	1.037	Each	34	$ 165.00	$ 5,610.00	$ 34.50	$ 1,173.00	$ 26.50	$ 901.00	$ 226.00	$ 7,684.00
	4600	HSS8x8x3/8"x14'-0"	E-2	50	1.12	Each	34	$ 360.00	$ 12,240.00	$ 37.00	$ 1,258.00	$ 28.50	$ 969.00	$ 425.50	$ 14,467.00
	6850	W8x31	E-2	1080	0.052	L.F.	420	$ 21.00	$ 8,820.00	$ 1.72	$ 722.40	$ 1.32	$ 554.40	$ 24.04	$ 10,096.80
	7150	W12x50	E-2	1032	0.054	L.F.	6245	$ 33.50	$ 209,207.50	$ 1.80	$ 11,241.00	$ 1.38	$ 8,618.10	$ 36.68	$ 229,066.60
	7200	W12x87	E-2	984	0.057	L.F.	50	$ 58.50	$ 2,925.00	$ 1.89	$ 94.50	$ 1.44	$ 72.00	$ 61.83	$ 3,091.50
05120-640		Structural Steel Members													
	600	W10x12	E-2	600	0.093	L.F.	180	$ 8.10	$ 1,458.00	$ 3.10	$ 558.00	$ 2.37	$ 426.60	$ 13.57	$ 2,442.60
	1900	W14x26	E-2	990	0.057	L.F.	120	$ 17.50	$ 2,100.00	$ 1.88	$ 225.60	$ 1.44	$ 172.80	$ 20.82	$ 2,498.40
	2320	W14x43	E-2	810	0.069	L.F.	120	$ 29.00	$ 3,480.00	$ 2.29	$ 274.80	$ 1.75	$ 210.00	$ 33.04	$ 3,964.80
	2700	W16x26	E-2	1000	0.056	L.F.	240	$ 17.50	$ 4,200.00	$ 1.86	$ 446.40	$ 1.42	$ 340.80	$ 20.78	$ 4,987.20
	3300	W18x35	E-5	960	0.083	L.F.	325	$ 23.50	$ 7,637.50	$ 2.81	$ 913.25	$ 1.57	$ 510.25	$ 27.88	$ 9,061.00
	4100	W21x44	E-5	1064	0.075	L.F.	275	$ 29.50	$ 8,112.50	$ 2.53	$ 695.75	$ 1.42	$ 390.50	$ 33.45	$ 9,198.75
	4900	W24x55	E-5	1110	0.072	L.F.	120	$ 37.00	$ 4,440.00	$ 2.43	$ 291.60	$ 1.36	$ 163.20	$ 40.79	$ 4,894.80
05210-600		Open Web Joists													
	2200	18LH04, 12 lb/lf	E-7	1400	0.057	L.F.	225	$ 5.95	$ 1,338.75	$ 1.93	$ 434.25	$ 1.14	$ 256.50	$ 9.02	$ 2,029.50
	2320	28LH60, 16 lb/lf	E-7	1800	0.044	L.F.	490	$ 7.95	$ 3,895.50	$ 1.50	$ 735.00	$ 0.89	$ 436.10	$ 10.34	$ 5,066.60
	2360	32LH08, 17 lb/lf	E-7	1800	0.044	L.F.	380	$ 12.45	$ 4,731.00	$ 1.50	$ 570.00	$ 0.89	$ 338.20	$ 14.84	$ 5,639.20
05310-300		Metal Decking													
	5300	Non-cellular comp deck, galv. 2" deep 20 gauge	E-4	3600	0.009	S.F.	117400	$ 0.95	$ 111,530.00	$ 0.31	$ 36,394.00	$ 0.02	$ 2,348.00	$ 1.28	$ 150,272.00
															$ 16,618,444.75

Original System Cost Analysis

CSI Division	CSI Subdivision	Description	Crew	Daily Output	Labor-Hours	Unit of Measure	Quantity	Unit Mat'l Cost	Mat'l Cost	Unit Labor Cost	Labor Cost	Unit Equip/Sub Cost	Equip/Sub Cost	Item Cost	Total Item Cost
03110-410		Forms In Place, Columns													
	6500	24"x24" columns, 4 use	C-1	238	0.134	SFCA	342	$ 0.63	$ 215.46	$ 3.81	$ 1,303.02			$ 4.44	$ 1,518.48
03110-455		Forms In Place, Walls													
	2850	Over 16' high, 4 use	C-2	330	0.145	SFCA	304	$ 0.69	$ 209.76	$ 4.25	$ 1,292.00			$ 4.94	$ 1,501.76
03210-600		Reinforcing in place A615 Grade 60													
	250	Columns, #8 to 18	4 Rodm	2.3	13.913	Ton	30	$ 550.00	$ 16,500.00	$ 475.00	$ 14,250.00			$ 1,025.00	$ 30,750.00
	700	Walls, #3 to #7	4 Rodm	3	10.667	Ton	75	$ 535.00	$ 40,125.00	$ 365.00	$ 27,375.00			$ 900.00	$ 67,500.00
03310-220		Concrete, ready mix													
	400	Regular weight				C.Y.	161120	$ 77.00	$ 12,406,240.00					$ 77.00	$ 12,406,240.00
03310-700		Placing Concrete													
	650	Columns, 24", crane and bucket	C-7	55	1.309	C.Y.	190			$ 33.50	$ 6,365.00	$ 19.40	$ 3,686.00	$ 52.90	$ 10,051.00
	5200	12" thick, crane and bucket	C-7	90	0.8	C.Y.	420			$ 20.50	$ 8,610.00	$ 11.85	$ 4,977.00	$ 32.35	$ 13,587.00
03410-100		Beams, "L" shaped													
	11	20' span, 12"x20"	C-11	32	2.25	Ea.	240	$ 1,400.00	$ 336,000.00	$ 75.00	$ 18,000.00	$ 53.00	$ 12,720.00	$ 1,528.00	$ 366,720.00
	2200	30' span, 12"x36"	C-11	24	3	Ea.	220	$ 3,750.00	$ 825,000.00	$ 109.00	$ 23,980.00	$ 77.00	$ 16,940.00	$ 3,886.00	$ 854,920.00
03410-210		Rectangular Columns													
	300	24' high, small	C-11	192	0.375	L.F.	6462.12	$ 104.00	$ 672,060.48	$ 12.55	$ 81,099.61	$ 8.80	$ 56,866.66	$ 125.35	$ 810,026.74
03410-620		Prestressed slabs													
	50	6" thick	C-11	1800	0.026	S.F.	22500	$ 4.57	$ 102,825.00	$ 0.86	$ 19,350.00	$ 0.60	$ 13,500.00	$ 6.03	$ 135,675.00
	100	8"thick	C-11	3200	0.023	S.F.	22600	$ 5.00	$ 113,000.00	$ 0.75	$ 16,950.00	$ 0.53	$ 11,978.00	$ 6.28	$ 141,928.00
															$ 14,840,417.98

New System Cost Analysis

CSI Division	CSI Subdivision	Description	Crew	Daily Output	Labor-Hours	Unit of Measure	Quantity	Unit Mat'l Cost	Mat'l Cost	Unit Labor Cost	Labor Cost	Unit Equip/Sub Cost	Equip/Sub Cost	Item Cost	Total Item Cost
05120-260		Columns													
	4600	HSS8x8x3/8	E-2	38	1.12	Each	2803	$ 360.00	$ 1,009,080.00	$ 37.00	$ 103,711.00	$ 28.50	$ 79,885.50	$ 425.50	$ 1,192,676.50
	6850	W8x31	E-2	38	0.052	L.F.	420	$ 21.00	$ 8,820.00	$ 1.72	$ 722.40	$ 1.32	$ 554.40	$ 24.04	$ 10,096.80
	7150	W12x50	E-2	2095.34	0.054	L.F.	6245	$ 33.50	$ 209,207.50	$ 1.80	$ 11,241.00	$ 1.38	$ 8,618.10	$ 36.68	$ 229,066.60
	7200	W12x87	E-2	36	0.057	L.F.	50	$ 58.50	$ 2,925.00	$ 1.89	$ 94.50	$ 1.44	$ 72.00	$ 61.83	$ 3,091.50
05120-640		Structural Steel Members													
	2700	W16x26	E-2	1000	0.056	L.F.	1170	$ 17.50	$ 20,475.00	$ 1.86	$ 2,176.20	$ 1.42	$ 1,661.40	$ 20.78	$ 24,312.60
	3300	W18x35	E-5	960	0.083	L.F.	914	$ 23.50	$ 21,479.00	$ 2.81	$ 2,568.34	$ 1.57	$ 1,434.98	$ 27.88	$ 25,482.32
	4900	W24x55	E-5	1110	0.072	L.F.	216	$ 37.00	$ 7,992.00	$ 2.43	$ 524.88	$ 1.36	$ 293.76	$ 40.79	$ 8,810.64
															$ 1,493,536.96

Lateral Brace Cost Analysis

CSI Division	CSI Subdivision	Description	Crew	Daily Output	Labor-Hours	Unit of Measure	Quantity	Unit Mat'l Cost	Mat'l Cost	Unit Labor Cost	Labor Cost	Unit Equip/Sub Cost	Equip/Sub Cost	Item Cost	Total Item Cost
03110-410		Forms In Place, Columns													
	6500	24"x24" columns, 4 use	C-1	238	0.134	SFCA	342	$ 0.63	$ 215.46	$ 3.81	$ 1,303.02			$ 4.44	$ 1,518.48
03110-455		Forms In Place, Walls													
	2850	Over 16' high, 4 use	C-2	330	0.145	SFCA	304	$ 0.69	$ 209.76	$ 4.25	$ 1,292.00			$ 4.94	$ 1,501.76
03210-600		Reinforcing in place A615 Grade 60													
	250	Columns, #8 to 18	4 Rodm	2.3	13.913	Ton	30	$ 550.00	$ 16,500.00	$ 475.00	$ 14,250.00			$ 1,025.00	$ 30,750.00
	700	Walls, #3 to #7	4 Rodm	3	10.667	Ton	75	$ 535.00	$ 40,125.00	$ 365.00	$ 27,375.00			$ 900.00	$ 67,500.00
03310-220		Concrete, ready mix													
	400	Regular weight				C.Y.	161120	$ 77.00	$ 12,406,240.00					$ 77.00	$ 12,406,240.00
03310-700		Placing Concrete													
	650	Columns, 24", crane and bucket	C-7	55	1.309	C.Y.	190			$ 33.50	$ 6,365.00	$ 19.40	$ 3,686.00	$ 52.90	$ 10,051.00
	5200	12" thick, crane and bucket	C-7	90	0.8	C.Y.	420			$ 20.50	$ 8,610.00	$ 11.85	$ 4,977.00	$ 32.35	$ 13,587.00
															$ 12,531,148.24

Shear Wall Cost Analysis

List of Websites Used for Sustainability Breadth

http://www.greencontractors.us/how/leedguide/LEEDNC2-EAC2.pdf

http://depts.washington.edu/urbhort/html/education/StormwaterChallenges&Solutions.pdf

http://www.archenergy.com/_edr-leed/html-pages/SSpages/LEEDSSc61.htm

http://www.greeninfrastructurewiki.com/page/3Bs:+Bioswale?t=anon

http://www.skykeepers.org/odlight.html

http://www.csemag.com/article/CA504173.html

http://www.cambridgearchitectural.com/System.aspx?ID=21#

http://leedbootcamp.blogspot.com/2006/09/ea-energy-and-atmosphere.html

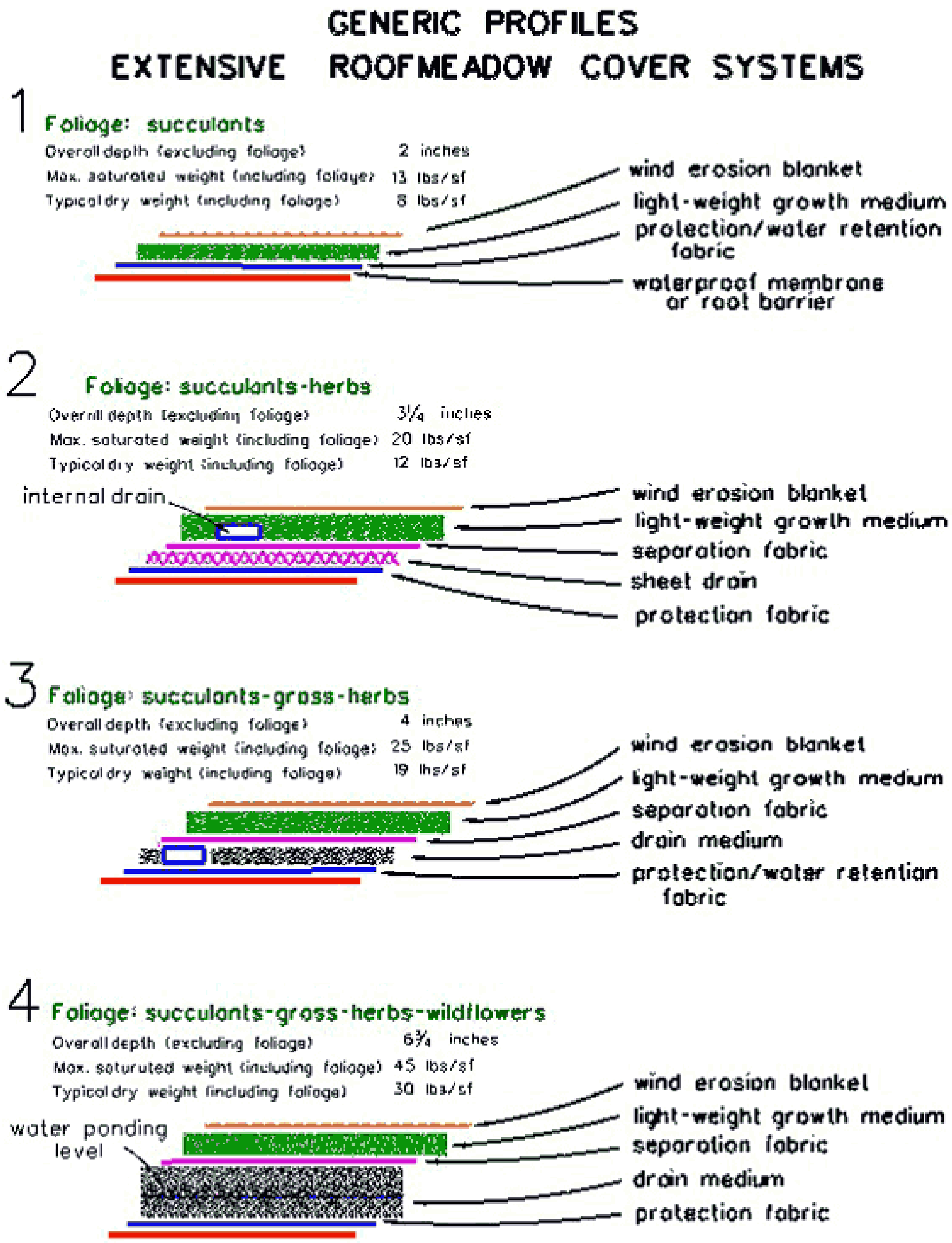
http://www.archenergy.com/_edr-leed/html-pages/EApages/LEEDEAc4.htm

http://www.nitterhouse.com/CompanyInfo/CompanyInfoSub/CompanyInfoOverview.html

http://www.archenergy.com/_edr-leed/html-pages/IEQpages/LEEDIEQc1.htm

http://www.roofmeadow.com/

Sections of Green Roofs



Roofscapes, Inc.
www.roofmeadow.com