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Structural Option
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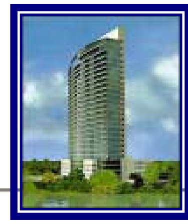


Thesis Proposal

December 5, 2003

Executive Summary

The Miranova Condominiums Building in Columbus, Ohio is a 28 story luxury condominiums building with 4 stories of parking for residents and visitors. The structure of the building consists almost entirely of an 8" post-tensioned flat plate slab for resisting gravity loads and a complex arrangement of concrete shear walls for resisting lateral loads. The mechanical system is composed of separate heating and cooling equipment. The residential spaces are heated by electric baseboard heaters placed around the perimeter of the building while separate water-cooled air conditioning units for each condominium accomplish the cooling. The building is clad in a blue tinted glass curtain wall system on the North face and 6" precast concrete panels on the remaining sides. The cladding allows the building to be very open to the city of Columbus to the North of the building and closed off from Interstate highway directly behind the building. This feature of the building causes the building to act as a "book end to the city."

The proposed solution to the problem of the limited ability for a resident to expand their living spaces horizontally or vertically by purchasing an adjacent unit and combining them is to convert the structure of the building from a concrete system to a steel system. By replacing a majority of the shear walls with steel braced frames, the ability to create door openings between condominium units will be much easier. Although the actual locations of openings will be limited because of the braces, there will still be more capability of expansion than with the existing shear walls. The existing post-tensioned concrete floor system will be replaced with a system that combines a 10" long span steel deck in one direction with a concrete slab on form deck in the other direction. This type of system was originally developed and studied by Thomas Murray in the late 1980's and early 1990's. The loads from the combination of decks will be carried by W10 beams and girders. The 10" deck will be placed within the depth of the beams creating a total floor depth of approximately 13". Not only will this system create a greater capability for vertical expansion between condominium units, it will limit the overall height increase of the building compared to other typical steel systems.

The use of a very deep steel deck may also create savings in cost and time for the mechanical system. The proposed thesis will also investigate the possible use of the open spaces in the deck ribs to be used as ducts; therefore, reducing the amount of required ductwork. The thesis will also investigate the use of electric reheat coils in lieu of baseboard heating. The proposed changes will not only affect the structural and mechanical systems, but will also affect the schedule of the project. Although steel takes longer to fabricate, it can usually be erected faster than forming and placing the concrete. Time may also be saved by reducing the amount of mechanical equipment. A study of the required schedule for the new system will be compared with the schedule of the existing system for any possible advantages or disadvantages

Background

The Miranova Condominiums Building is a $52 million, 27 story luxury condominiums building located in Columbus Ohio. The total height of the building is approximately 295’ and a total building area of approximately 450,000 square feet. The building consists of two main functional components, the first of which is a four story (240 space) parking garage/mixed use area and the second is a 23-story tower, containing condominiums (approximately 150 units), that extends up from the lower portion of the building. Of the first four stories, the basement is visitor parking, the ground level is mixed use, and levels 2-4 are resident parking. The first four stories of this building, plus the basement, is a rectangular shaped box with an area of approximately 30,800 sf each. The approximate dimensions of the lower portion are 250’ x 120’ The tower raises up over only the north half of the building, the south half stops at a roof located at the height of level 5. The tower is approximately 250’ x 60’ with an approximate area of 15,100 sf per story. One of the most unique features of the architecture is the cladding. There were two very different types used on this building. The East, West, and South sides of the building is clad with a 6” precast concrete panel with only a few small windows, while the North side is clad entirely in a blue tinted glass curtain wall. The architect of the building described it as a “Book end to the City of Columbus.”

Figure 1: North Face of Building

Figure 2: South Side of Building

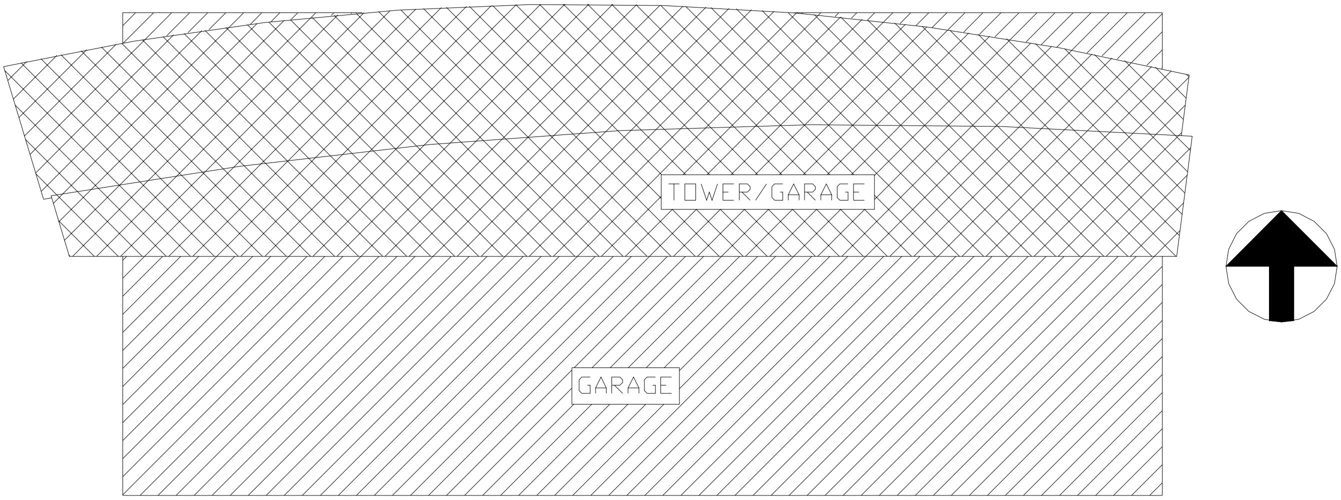


Figure 3: Functional Space Layout

The structure of the building is constructed entirely of cast-in-place concrete with compressive strengths of either 4,000 or 5,000 psi. The building column and shear wall loads are transferred to the ground by a concrete mat foundation. The thickness of the mat ranges from 5'-3" to 5'-9" under the tower and 2'-9" to 3'-3" under the five story portion of the building. The concrete mat is constructed of 4,000 psi normal weight concrete and is placed on a 2" mud slab. The mat must distribute typical column loads in the range of 1300k to 3000k for tower columns and 200k to 750k for columns under the five-story portion. Typical reinforcing for the mat is #11 bars @ 12" O.C. each way, top and bottom under the tower and #8 bars @ 12" O.C. each way, top and bottom under the five story portion of the building. This is the minimum temperature and shrinkage reinforcement required by the code. Additional reinforcement is located in areas where it is required for additional strength. The basement foundation walls are typically 12" thick and are also 4,000 psi, normal weight concrete. The typical reinforcing is #6 @ 12" O.C., with a 3" cover, on the exterior face of the wall and #5 @ 12" O.C. on the interior face.

The basic super structure of the Miranova Condominiums Building is a two-way flat plate concrete slab spanning between concrete columns. The lateral force resisting system consists of a complex arrangement of concrete shear walls in both directions. All concrete in the super structure is 5,000 psi; normal weight concrete and all reinforcing has a yield strength of 60 ksi. The typical columns sizes for the first five stories are 24" x 40" in the tower and 18" x 30" in the remainder of the building. There are both round and square columns in the residential portion of the tower, stories 5 – roof. The round columns can be found along the north side of the building just behind the glass curtain wall. The round shape is an architectural feature and was used because these columns occur in living spaces. The round columns are either 26" or 32" in diameter. The remaining columns in the tower are typically 18" x 36". Another interesting feature is that there are two columns that shift from one gridline to another so their load can be transferred through a shear wall to the ground between levels three and five.

The ground level floor slab is a 12" two-way flat plate. The slab typically spans 25'-6" to 27'-6" in each direction. Typical reinforcing consists of #5 @ 12" O.C. each way top and bottom. Due to the many different uses on the ground floor, additional reinforcing is required in column and middle strips for certain bays. Shear reinforcement is required at a few columns and consists of #4 stirrups. There are also a few beams and girders that frame the larger openings on the ground floor. Typical sizes are 12" x 24". The floor slab for all remaining levels is an 8" post-tensioned flat plate slab. The spans for these slabs are the same as those for the ground level slab because the columns locations are constant throughout the height of the building. All post-tensioning strands have an ultimate tensile strength of 270ksi and a modulus of elasticity of 28,000ksi. The concrete for the garage level slabs contain a DCI-corrosion inhibiting admixture. The profile of the tendons follows a parabolic shape. The post-tensioning tendons are placed in 6' bands centered over the column lines in the east/west direction and are uniformly spaced across the building in the north/south direction. Effective pre-stressing forces for banded tendons range from 175k – 585k and 12 – 27 k/ft for uniformly spaced tendons. The is also additional reinforcing placed in these slabs. Additional reinforcing is shown on plans were it is needed. Like the ground floor, the same shear reinforcing is required at certain columns. A few beams are also used to frame the large slab openings and to carry the heavy cladding on the southern façade.

The structural system used to resist the lateral wind and seismic loads in this building consists of a complex arrangement of concrete shear walls. The concrete used in these wall has a compressive strength of 5000 psi. There are three walls in the five-story portion of the building that extend only to the level 5 roof. All other shear walls extend up to the 22nd floor. The shear walls surrounding the two building cores further extend to the roof. The shear walls are typically 18" thick from the base up to level 6 where most are reduced to 12" thick. The walls range in width from 5' wide to 44'-5" wide. Most of the walls in the building are rectangular and constant throughout the height and can be treated as cantilevered beams. A few of the walls are much more complicated because of openings and shifts at different levels.

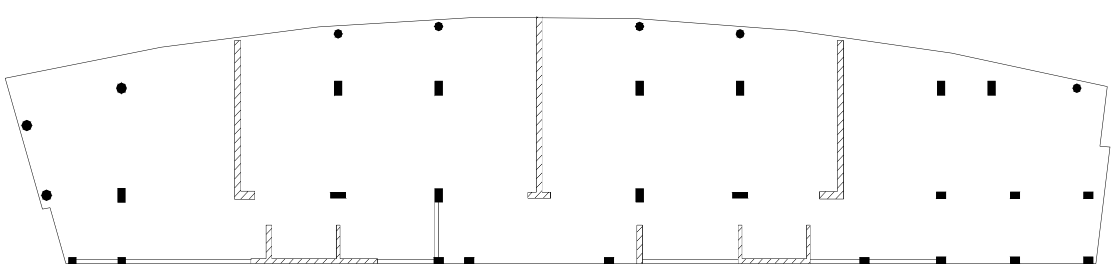


Figure 4: Typical Tower Level Framing Plan

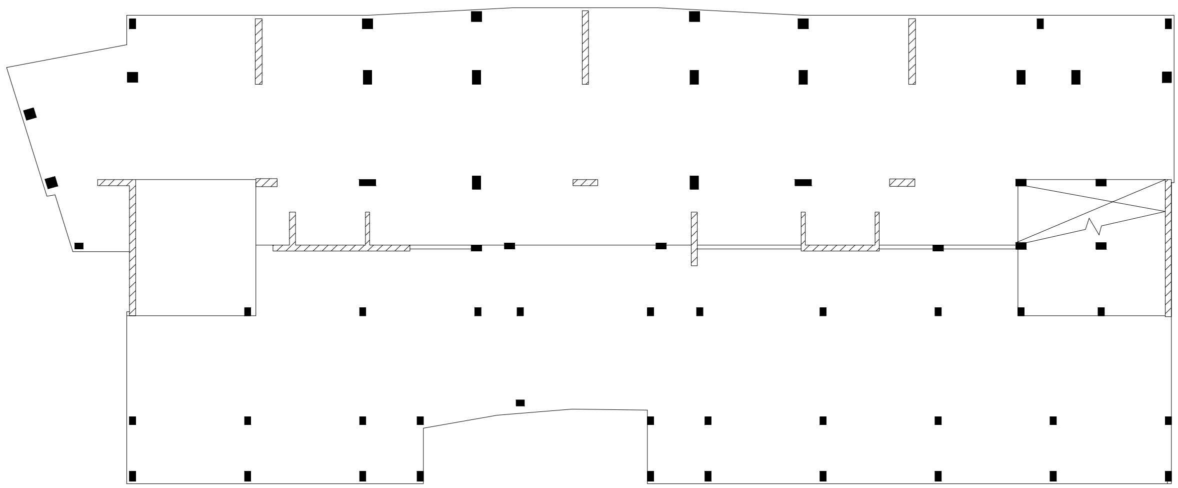


Figure 5: Typical Garage Level Framing Plan

The mechanical system of the building consists mainly of two separate parts. The buildings' heating system consists almost entirely of electric heating in the form of baseboard heating around the perimeter of the building. The individual condominium units are cooled each by a water-cooled air conditioning unit with the water being cooled by two roof top cooling towers and two heat exchangers.

Problem Statement

The current structural system of the building would make it very difficult and expensive to make future renovations and remodeling of the condominium units possible. The possibility exists that in the future, a tenant may want to purchase an adjoining unit, either on the same level, directly above, or directly below their current residence, and connect the two to form a much larger living space. The very large shear walls make if very difficult, if not impossible to connect most of the units to an adjacent one. The post tensioning strands in the floor slabs make it very expensive and difficult to expand a unit vertical. To do this, x-ray equipment would be required to determine the exact location of each tendon and then they must individually be revealed, clamped, and cut off. Additional reinforcing must then be added to support the slab opening. The current mechanical consists of many individual units throughout the building, and therefore, requires many slab openings. The system also requires a longer amount of time to construct due to the placement of all of the equipment.

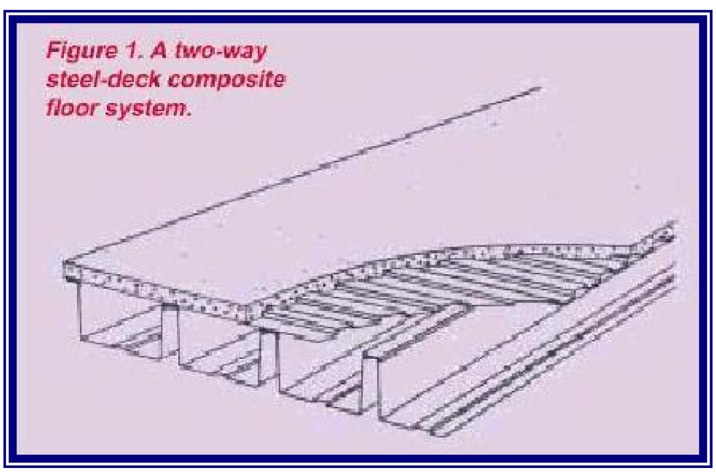
A new floor system must be designed the residential levels that would allow for a much cheaper and easier vertical expansion between condominium units. The floor system would be required to resist a live load of 40 psf, per 2002 Ohio Building Code. The superimposed dead load that the system must resist is 40 psf, as determined for technical assignment #1. The new floor system must also control vibrations problems. Finally, the floor ceiling assembly depth must not increase a great deal over the existing system so that cladding costs will not be increased.

A new lateral system must be designed to allow for future expansion horizontally between condominium units. The system must also be able to resist the wind and seismic loads determined from the 2002 Ohio Building Code. Finally, the lateral system must not drift more than the industry standard of L/400 for wind loads and must meet the code restrictions for drift under seismic loads.

A mechanical system must be designed to limit the amount of individual pieces of equipment. This will help to reduce the construction time and may reduce the total cost of the building. The mechanical system must also minimize the number and size of slab openings, especially if an alternative steel system is to be used.

Proposed Solutions

The alternative solution to the stated problem above will consist of a long span steel deck/composite slab very similar to the one studied in Technical Assignment #2. A 10" deep long span deck will span between W10 wide flange beams. The long span deck will carry a form deck with a 2 ½" slab running in the opposite direction. Self-tapping screws that may enable the slab and form deck to act compositely with the long span deck will connect the two decks. W12 or W14 columns will carry the floor system. The existing column grid will be used with only slight modifications, if necessary. The lateral system will utilize the existing shear walls that surround the two building cores in conjunction with steel braced frames used in place of the other existing shear walls. Moment frames will also be used in the East/West direction of the building where braces could not be used due to the architecture. A preliminary study of alternative foundation systems will be done to determine if a more efficient system could be used. If warranted, a new foundation system will also be designed. This type of floor system was initially developed and studied by Thomas M. Murray and John R. Hillman in the late 1980's and early 1990's.



(Image taken from Murray's Paper in the 1990 Proceedings of the AISC National Steel Construction Conference)

Figure 6: Proposed Alternative Floor System

Modifications to the mechanical system will be studied to find a system the will solve the problems stated above. The first modification that will be studied will be to use reheat coils as part of the AHU to eliminate the need for electric baseboard heating. The possibility of using the space in the deck ribs to be used as ducts will also be studied. This could reduce or even eliminate the need for ductwork, which would save time and cost to the project. This could also possibly help reduce the number of slab openings by using the rib spaces as exhaust ducts. The use of a single AHU per floor, or multiple floors, will also be studied. This will reduce the total number of pieces of equipment that must be placed.

The change of the lateral system from shear walls to braced frames or moment frames will require an acoustical analysis to be performed to design the infill wall system placed in the new braces and frames. These new walls will also need to meet the required fire ratings.

Solution Method

The design of this alternative steel structural system will be based on the AISC's 3rd edition LRFD. The design and check of the existing shear walls to be used will be based on ACI 318-02. The design of the gravity beams and lateral system will be done by using RAM along with another analysis program. Initial member sizes for the lateral elements will be input into RAM and an initial check performed. Models of the lateral elements will then be set up in another analysis program in order to check the elements for torsional loading. This will be required because the available version of RAM does not include the effects of torsion. There is currently no available 10" deep long span deck available. A deck will be designed using the most currently available Cold Formed Steel Specifications. A few variations of the beam and deck layouts will be studied to determine the most efficient design not only for structural purposes, but also the most efficient layout for the mechanical system.

Tasks and Tools

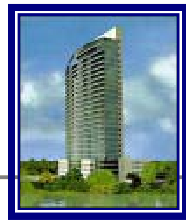
1. Structure

Task 1: Determine initial framing layout alternatives

a) Layout columns with only minimal modifications to existing column grid
b) Layout beams and girders
c) Layout braces types

Task 2: Determine floor loads

a) Determine dead loads of structural members
b) Determine superimposed dead loads from architectural plans
c) Determine live loads based on the 2002 Ohio Building Code



Task 3: Input Model into RAM

a) Input initial layouts into RAM
b) Run analysis to determine gravity load sizes
c) Input these initial sizes into RAM Frame model and check them with the addition of lateral loads

Task 4: Input lateral elements into analysis program

a) Use properties of the frame as calculated by RAM to create models
b) Determine torsional loading
c) Check lateral elements for total loads

Task 5: Design long span steel deck

a) Research the Cold Formed Steel Specifications
b) Using loads previously determined, design the deck
c) Investigate possibility of using screws to allow the 2 decks to act compositely to increase strength
d) Check vibration issues

Task 6: Foundation Investigation

a) Determine possible alternatives
b) Compare alternatives
c) Choose best option
d) Redesign foundation if another option may be more efficient

2. Breadth Work

Task 7: Mechanical system investigation

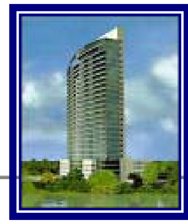
a) Investigate alternative of using electric reheat coils instead of electric baseboard heaters
b) Investigate using deck ribs as ducts to eliminate the need for actual ducts
c) Investigate alternative of using a multi-zone system to reduce the number of units

Task 8: Acoustical and Fire Rating Analysis

a) Select initial assembly to meet fire rating
b) Determine appropriate acoustical criteria
c) Calculate acoustical properties of assembly
d) Compare results with initial criteria

Task 9: Schedule Impact of new design

a) Estimate the duration of the new structure, including the lead-time for steel
b) Compare the required construction time with the actual construction time to see if this system has any schedule benefits



Schedule

January

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11	12	13	14	15	16	17
18	19	20	21	22	23	24
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February

S	M	T	W	Th	F	S
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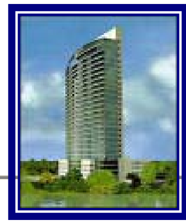

March

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April

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11	12	13	14	15	16	17
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	Task 1
	Task 2
	Task 3
	Task 4
	Task 5
	Task 6
	Task 7
	Task 8
	Task 9
	Spring Break
	Presentations