Executive Summary:

Lexington II is a residential tower located in the Historical Penn Quarter of Washington D.C. To maintain the architectural significance of important buildings throughout our nation's capital, restrictive zoning requirements are imposed on this unique area. In order to comply with the strict height requirement of 130' in this district, the current structural system is two-way flat plate slab.

The structural system of Lexington II allows for this 12 story building to stand at 125', just 5' below the maximum height limit. This was achieved by designing Lexington II with the smallest possible floor sandwiches made possible by the use of 2-way flat plate slab and the smallest bays possible. The irregular column grid allows columns to fit unobtrusively within patron walls while keeping bay sizes to approximately 13' x 16.5'. A core of shear walls located around a centrally placed elevator shaft allows lateral forces to be resisted with no effect on the gravity floor system. By moving MEP ducts into soffits along the interior partition walls, Lexington II was able to keep floor sandwiches to a mere 8" of slab with no additional depth.

With height as the structural design's controlling criteria, it is possible that a more economical solution was overlooked.

I propose to compare the current structural system of Lexington II with two other systems which may have been possible had there been a lesser height restriction. The building will first be analyzed and redesigned using a one-way joist floor system. A one-way joist system will maintain a relatively small floor sandwich while providing other benefits; such as additional stiffness, a more uniform column grid, and ease of formwork during construction.

The second system to be analyzed will be a composite floor system with steel framing. By analyzing a composite deck system, the entire building structure can be redesigned as steel. This completely steel redesign will include a comparison of steel lateral systems, as both moment and braced frames will be investigated.

The proposed systems will be compared to the current system in Lexington II. Criteria for this comparison include material availability, costs (material and labor), scheduling and erection time, and other issues of feasibility.

Background:

Lexington II is a residential tower located in Washington D.C. as part of the Market Square North building complex. Standing 125 feet high, Lexington II is comprised of 3 below grade parking and retail levels and 12 above grade residential levels containing a total 72,000 square feet.

Developed by Gould Property Company and Boston Properties, Lexington II is an elegant and spacious apartment building located in the Historical Penn Quarter of Washington D.C. The zoning of such a well known and desirable downtown district has a strict height requirement restricting buildings to 130'.

Compling with zoning while maintaining 12 residential stories was the most important criteria used in designing Lexington II's structural system. The selected system used to reduce floor sandwich heights and thus stay below the building's height requirements was 2-way flat plate slab with no edge beams along internal bays.

The two-way plate flat plate slab system in place has a total depth of 8" on the residential levels and, with the exception of a finished floor and sprayed acoustical sealant, these 8" are the entirety of the floor sandwich depth. In order to achieve such a small depth without the use of beams, long spans were avoided by small bay sizes running in both directions of the building. The column grid restricts the average bay size to 16.5' by 13'. To avoid disrupting the architectural plans of Lexington II and the open space provided in the apartment units, many columns are slightly offset and turned as to fit within partition walls. (Figure 1 shows the column grid).

All columns travel the entire height of Lexington II but are decreased in size on the upper levels. The base of the columns rests on Lexington II's MAT foundation. The MAT foundation design is 3'-6" deep. A MAT foundation was chosen to resist the punching shear of the columns. Due to the columns' close spacing, a MAT foundation is a logical choice rather then pouring each column its own footing in such close proximity to the next. The MAT foundation rests on undisturbed soil and 14 x 89 HP piles to avoid undermining a preexisting building.

Although comprised of a monolithically poured concrete frame, the lateral force resisting system of Lexington II is entirely comprised of concrete shear walls. These shear walls form a small core located around the centrally placed elevators of Lexington II. (Shear walls are denoted on Figure 1).

Another way the floor sandwiches were maintained at an 8" shallow depth was by running the building MEP systems through the partition walls of each apartment unit. The mechanical ducts are concealed in drywall soffits along the interior partitions of Lexington II and therefore do not add to either the ceiling or floor depths. The only above grade level of Lexington II with a deepened floor sandwich is the top story where a suspended ceiling is used to conceal fresh air and plumbing distribution.

Other features of Lexington II include a non-load bearing brick cavity wall featuring pre-cast trim and punched windows.

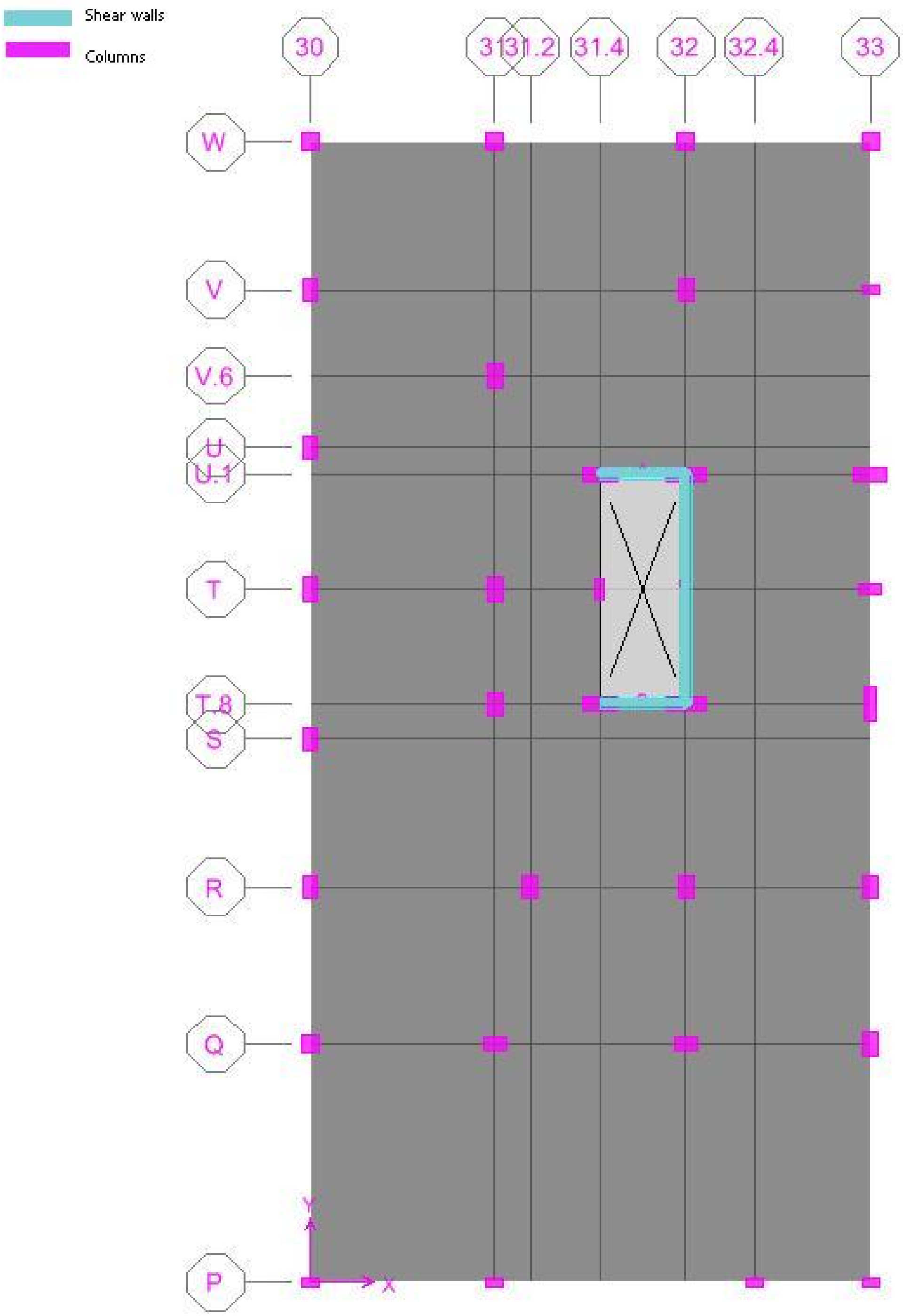

Figure 1.
Column gird and shear wall plan of Lexington II

Statement of the Problem:

Zoning height restrictions in Washington D.C. greatly limit the number of feasible structural systems that can be considered when designing a high rise building for that area. When height limitations are the controlling criteria for designing a building, more economical but deeper structural systems are not always possible. Had Lexington II been located outside of the central Washington D.C. area, other systems which employ the use of beams and the creation of a deeper floor sandwich would have been investigated in greater depth. Another structural system may have proved to have been a more time and cost efficient design for Lexington II.

Proposal:

As an investigation into other structural systems suitable for Lexington II; I propose to analysis two alternative structural systems without imposing a height restriction. These systems are then to be compared to the current structural system of Lexington II by economy of the systems based on time and cost.

Proposed Solutions of the Problem:

The proposed alternative systems to be analyzed for Lexington II are one-way joist floor and composite deck with steel framing.

As discovered in a previous analysis, technical report 2, the above mentioned systems are the two which prove to be the best solutions while maintaining a reasonably shallow floor sandwich. By analyzing the two systems which continue to limit the height imposed on Lexington II by the structural system, it is my hope that had one of these designs been utilized in the actual design, a zoning variance could have been obtained.

For either solution, the column grid, lateral load resisting system, and foundation will also be redesigned. The current short spans of the building prove to be inefficient for most other floor systems and will therefore be altered by eliminating rows of columns. The newly created longer spans will allow for the use of one-way floor systems instead of the current two way system. By removing the height criteria, beams may be added along these spans if needed.

Preliminary studies show that one-way joist system is the most feasible concrete alternative to the current two-way system. A one-way joist system adds the least amount of depth to the floor sandwich. One-way joist system also reduces the slab self-weight and adds stiffness to the floors. Another benefit to one-way joist floor is the easy in which its form work can be erected.

The other system to be analyzed is a system of composite floor decking and steel framing. In the preliminary analysis, this system was found to be the lightest analyzed and also one of the more shallow systems. Benefits of a composite system also include the elimination of shoring during erection. Opposition to a composite system includes the additional cost of fireproofing and shear studs.

The biggest change in using this composite system will be in redesigning the current concrete columns to steel columns. By changing the system to steel columns, a general comparison of concrete to steel systems may be assessed.

Although shear walls are possible in any building system, it may prove to no longer be the most economical. The column redesign will include a redesign of the lateral system. After the elimination of vertical concrete elements, shear walls will be reevaluated and compared to braced and moment frames.

The foundation will be redesigned as necessary to accommodate the changes made in the building structure. The greatest changes to the foundation design are likely to be due to either the decreased self-weight of the structural system, or an increased punching shear caused by the elimination of columns.

Breadth:

A change in the building materials and structure will have an impact on all other systems throughout Lexington II. As breadth work, two other aspects of the building will be investigated and examined for compatibility with the newly chosen structural system.

The first system that will be investigated is Lexington II’s mechanical systems, including HVAC and plumbing. The current systems are run throughout Lexington II by way of ducts concealed in soffits along interior partition walls. With the creation of larger floor sandwiches it will be possible to redirect the MEP systems through the floor sandwiches and conceal them using a suspended ceiling which would be in place to conceal the structural floor beams as well. A major consideration of changing materials and duct layouts will be acoustics and vibrations and the method in which they are transmitted through Lexington II.

The second issue that will be looked at is the construction management involved with a steel system versus the current concrete system. Changes in construction management will include a variety of issues ranging from crane placement to the time and cost to erect a steel structural system. Other specific items to be investigated are the advantage of prefabricating steel elements offsite and the addition of fireproofing to the structure as well as the creation of a new construction schedule and cost analysis.

Solution Method:

In order to perform the proposed analyses, several methods will be employed. For both proposed systems, one-way joist floors and composite floors, the use of design aids as well as manual calculations will be utilized. Loads will be determined in compliance with ASCE 7-02.

The design of the one-way joist system will be in compliance with the ACI 318-05 and all concrete elements will meet the prescribed code. Initial member sizing will be chosen after consulting the CRSI handbook. All chosen sizes will be checked with hand calculations and best system will be chosen based on easy of construction and application to the designated space.

Several possible composite floor systems will be chosen from decking catalogs and once again evaluated by hand calculations to determine the most efficient. All systems will be analyzed to the steel standards set in the LRFD code. The chosen system will then be entered into RAM, and RAM will be used to design both the beams and the vertical elements. Spot checks and hand calculations will be used to verify the results given from RAM.

RAM will also be the primary method used to evaluate lateral force resisting systems. Both moment and braced frames will be analyzed, and designed in RAM as needed. The results verified by hand calculated spot checks and deflection checks.

The final solution will be decided by a feasibility, cost, and time analysis. The cost analysis will include criteria such as material cost and construction cost. Comparison between systems based on time will include the total erection time needed for the building construction taking into consideration which items may be fabricated off site. Feasibility will look at any additional issues which may arise with constructing a particular system.

Tasks and Tools:

Gravity Systems

a) Determine gravity loads based on ASCE-7.
b) Investigate most plausible alternative column spacing.

1. One-way Joist System
   a) Choose trial sizes from the CRSI handbook
   b) Evaluate floor sizes to find logical choice to continue analysis with. Include analysis of beam sizes needed to support floor system.
   c) Re-evaluate joist system with self-weight included. Adjust column layout as needed. Run deflection check.
2. Composite Slab System
   a) Choose trial sizes and fire rated assembly from decking catalog.

b) Design beams in accordance with LRFD and decking catalogs. Adjust floor decking and column layout as needed.
c) Verify results using deflections checks and including self weight.

Lateral Force Resisting System

1. Shear Wall
   a) Determine through analysis if current shear wall system is adequate.
1. Moment Frame
   a) Determine through brief hand calculations if a moment frame system is feasible.
   b) Model column outlay as determined for gravity load in RAM. Design connections as moment connections.
   c) Apply lateral loads and run RAM analysis using LRFD standards. Adjust moment frames and connections as needed until a reasonable solution is found.
   d) Verify results by hand calculations, deflections checks and overturning checks.
2. Braced Frame
   a) Determine if braced frame system is feasible and which frames will be most probable solution as braced.
   b) Model column outlay as determined for gravity load in RAM. Design braced frames as determined in step a.
   c) Apply lateral loads and run RAM analysis using LRFD standards. Adjust braced frames as needed until a reasonable solution is found.

Breadth Work

1. Mechanical
   a) Redesign MEP ducts and layout to fit in ceiling sandwich if possible.
   b) Determine critical locations of MEP noise and vibration as well as other areas of critical importance.
   c) Analyze chosen structural system for acoustical and vibrational soundness.
   d) Apply other means of acoustical and vibration damping if needed. Recalculate.
2. Construction Management
   a) Arrange site plan including field offices, crane placement, lay down area, etc.
   b) Material cost analysis; determine amount of materials needed and average cost.
   c) Labor Cost; RS means to determine worker payment.
   d) Determine construction schedule including excavation, erection, fireproofing, finishes. Study of offsite element fabrication where possible.

Final Tasks

a) Organize and Compile all material and calculations used in thesis research.
b) Write final thesis report.
c) Prepare presentation.

Concluding Remarks:

In conclusion, a study has been proposed to investigate alternative structural systems for Lexington II. This study will include an analysis of one-way joist floor systems, the best alternative to the current system. An analysis of Lexington II with composite floor decking will also be performed. This second analysis will include the structural redesign of Lexington II to a completely steel system. An in-depth comparison of moment to braced frames will also be provided as part of the steel redesign. Mechanical differences between the systems and their affects on acoustics and vibration will also be considered. Additional issues such as fireproofing and prefabrication off site will also be considered. The final comparison of the systems will be based on ease of construction, cost (material and labor), and time for erection.

Timetable:

January:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9 Semester Starts	10	11 Gravity Load Analysis	12 Gravity Load Analysis	13 Gravity Load Analysis	14
15	16 No Class	17 Investigate Column Layouts	18 Investigate Column Layouts	19 Investigate Column Layouts	20 Investigate Column Layouts	21
22	23 Joist System Analysis	24 Joist System Analysis	25 Joist System Analysis	26 Joist System Analysis	27 Joist System Analysis	28
29	30 Composite Floor Analysis	31 Composite Floor Analysis				

February

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Composite Floor Analysis	2 Composite Floor Analysis	3 Composite Floor Analysis	4
5	6 Catch-up, misc.	7 Catch-up, misc.	8 Catch-up, misc.	9 Catch-up, misc.	10 Catch-up, misc.	11
12	13 Moment Frame Analysis	14 Moment Frame Analysis	15 Moment Frame Analysis	16 Moment Frame Analysis	17 Moment Frame Analysis	18
19	20 Braced Frame Analysis	21 Braced Frame Analysis	22 Braced Frame Analysis	23 Braced Frame Analysis	24 Braced Frame Analysis	25
26	27 Catch-up, misc.	28 Catch-up, misc.				

March

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Catch-up, misc.	2 Catch-up, misc.	3 Catch-up, misc.	4
5	6 Spring Break	7 Spring Break	8 Spring Break	9 Spring Break	10 Spring Break	11
12	13 Mech. Breadth	14 Mech. Breadth	15 Mech. Breadth	16 Mech. Breadth	17 Mech. Breadth	18
19	20 C.M. Breadth	21 C.M. Breadth	22 C.M. Breadth	23 C.M. Breadth	24 C.M. Breadth	25
26	27 Catch-up, misc.	28 Catch-up, misc.	29 Catch-up, misc.	30 Write Paper.	31 Write Paper	

April

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1 Write Paper/ Presentation
2 Write Paper/ Presentation	3 Write Paper/ Presentation	4 Write Paper/ Presentation	5 Thesis Paper Due!	6 Work on Presentation	7 Work on Presentation	8 Work on Presentation
9 Work on Presentation	10 Presentations	11 Presentations	12 Presentations	13 Presentations	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						