Megan Kohut
Kettler Capitals Iceplex
Arlington, Virginia

Structural Option
Dr. Linda Hanagan
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PROPOSAL

EXECUTIVE SUMMARY

The Kettler Capitals Iceplex is the practice facility for the NHL franchise, Washington Capitals. It is located in Arlington, Virginia just outside Washington D.C. The Iceplex was constructed on top of the existing parking structure for the Ballston Mall in Arlington. The original parking structure consists of concrete two-way slabs and post-tensioned concrete on levels one through 7. The Iceplex was constructed using a composite steel system on levels eight and nine.

When the Iceplex was constructed on top of the existing parking structure, the gravity system, the lateral system, and the foundation system all needed to be reinforced. This was proven to be the most complicated part of the design.

A solution to this problem would have been to tear down the parking structure and construct the new building from scratch. This proposal outlines the steps that will determine if this is indeed a feasible solution. The Iceplex and parking structure will be completely redesigned. The two ice rinks will be moved to the first level on a slab-on-grade, which will help limit deflections. The parking structure will then be designed as a separate structure constructed of a two-way slab with beams and will span over the ice rinks. This will create the need for a large transfer system.

In addition to the complete structural redesign of the Iceplex and parking garage, two breadth topics will be considered. First, an architectural/civil site breadth will examine the most efficient way of laying out the building on the site and will account for any changes in architecture layout. Second, a construction management breadth will compare the cost and schedule of the proposed design to the actual design. Based on the structural redesign and the two breadth topics, it will be concluded whether demolishing the parking garage and building from scratch is a feasible and economical solution.

A list of tasks to be completed and a calendar of these tasks are also included in this proposal.

TABLE OF CONTENTS

INTRODUCTION

The Kettler Capitals Iceplex is the practice facility for the National Hockey League team, Washington Capitals. It is located at the Ballston Common Mall in Arlington, Virginia at the intersection of Glebe Road and Randolph Street. This 137,000 square foot facility was built on top an existing parking structure and houses two regulation sized ice rinks, corporate offices, a training facility, and a pro shop. At 60 ft. above street level, the Kettler Capitals Iceplex is the home of the highest ice rink above street level in the United States.

Design for the Iceplex began in 2000; however, this was the third time the Ballston parking garage has been expanded. The original facility, which dates back to the 1950s, was a five story cast-in-place concrete structure reinforced with mild steel. Then in the 1980s, the parking garage was expanded two more times. In 1981, a five story L-shaped addition was constructed of cast-in-place post-tensioned concrete. Then in 1986, the existing five level structure was topped with two more levels, one post-tensioned concrete and the other composite steel. See Figure 1 for a schematic phasing diagram of these additions.

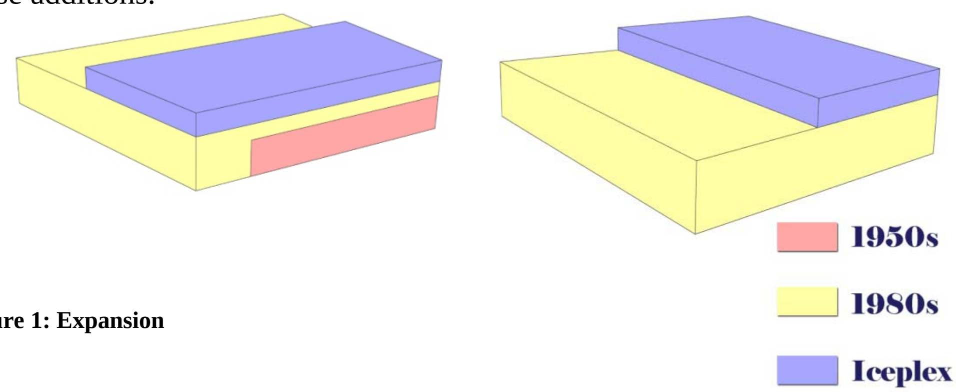


Figure 1: Expansion

There were several challenges when designing the Iceplex. The initial challenge was figuring out how to safely build an ice rink and roof weighing a total of 235 psf dead load plus 130 psf live load over an existing structure that was designed for a total expansion of 60 psf dead load and 50 psf live load. Another challenge was controlling deflection over the long 200 ft. span of each ice rink. A consultant recommended that the deflection be as close to zero as possible in order to prevent the ice from cracking. The need for large column-free spaces limited the locations where lateral members could be placed.

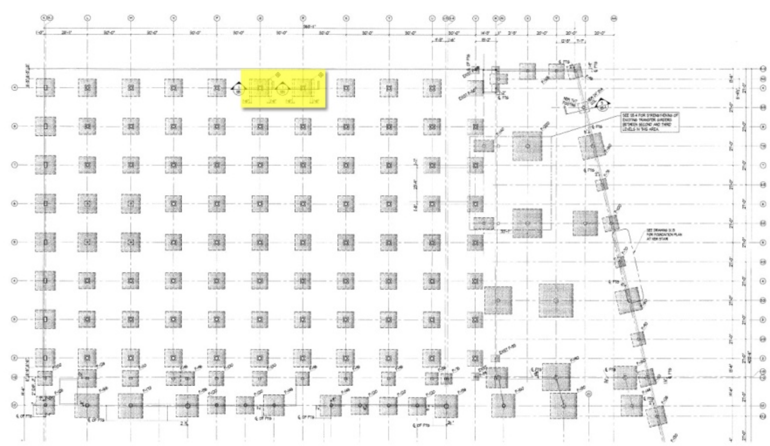
REINFORCING EXISTING PARKING STRUCTURE

As previously mentioned, the actual load of the new Iceplex was about three and a half times that of the allowable expansion load of the existing parking structure. Inevitably, the existing parking structure needed to be reinforced before constructing the new addition.

Foundation

The structural engineer of record, Rathgeber/Goss Associates of Rockville, MD, recommended testing the soil as a first step in the reinforcing process. Engineering Consulting Services, Ltd. was hired to complete the testing. Test results showed that the allowable bearing pressure of the soil was 10,000 psf which was significantly higher than the 6,000 psf used in the original construction. Based on this information and the column loads from the new construction, it was concluded that only two footings needed to be expanded. These footings, along column line 9 (see Figure 2), were expanded 3'-0" in one direction. No increase in footing depth was necessary.

Figure 2: Footing Expansion Locations



Columns

It was also recommended by Rathgeber/Goss that the existing concrete columns be core tested in order to analyze their compressive strength. Engineering Consulting Services, Ltd. was hired to perform these tests as well. However, due to the high density of reinforcing steel in the columns, testable cores were unobtainable. Therefore, a series of Windsor Probe tests were performed throughout the structure in lieu of the originally proposed concrete coring.

A total of nine Windsor Probe tests were performed throughout the existing parking structure. Five tests were located on the first floor, four on the fourth floor, and two on the sixth floor. ECS attempted to concentrate these tests primarily in locations where column loads would increase the greatest with the vertical expansion. After completing the tests, it was recommended that a compressive strength of 5,000 psi be assumed for the existing concrete columns. Since the original concrete strength was assumed to be 3,000 psi, this showed that the concrete had gained significant strength over time. Please see the appendix for the tabulated results.

Based on these results, the columns needing additional reinforcement were determined. A total of 11 columns on levels 3, 4, 5, and 6 were wrapped in carbon fiber reinforcing. These columns are shown in red in Figure 3. Gardner James Engineering, Inc. was commissioned to design this additional reinforcement. GJ chose a product called Aquawrap from Structural Composites, Inc. for the carbon fiber reinforcing. This allowed the ultimate axial load in the columns to be greater than the nominal capacity by a factor of 1.2.

In addition to the carbon fiber reinforcement, all existing steel columns in the parking structure (levels 5 and 6) were encased in concrete in order to provide the additional required capacity. All columns shaded in blue in Figure 3 were reinforced. See Figure 4 for a bolstering detail.

Figure 3: Column Reinforcing Locations

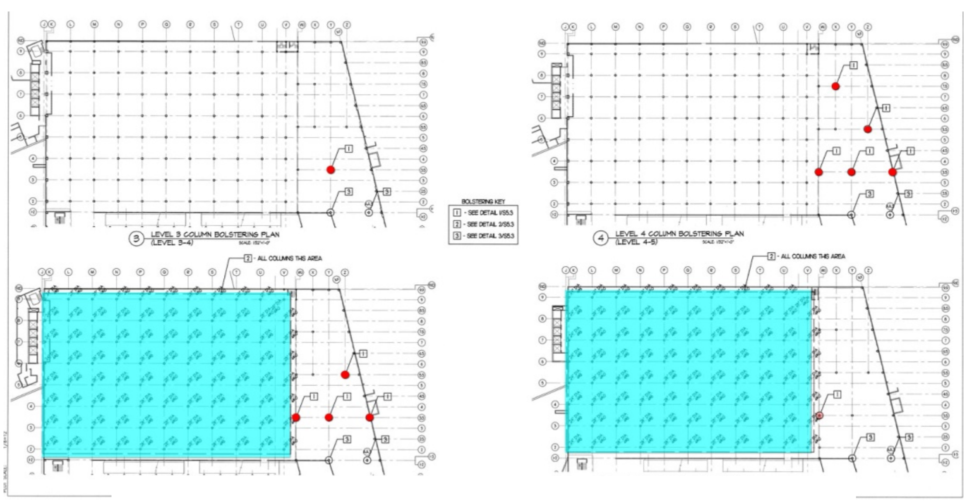
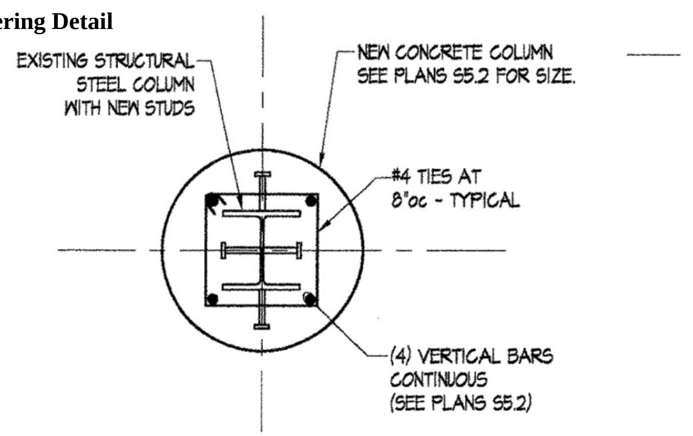


Figure 4: Column Bolstering Detail



GRAVITY FRAMING SYSTEM

There were two expansion joints used in the construction of the new Iceplex, one running in the north-south direction and the other in the east-west direction. Please see Figure 5 for the locations of these joints. Expansion joint A, running north-south, separates the 8th floor parking structure from the 8th floor of the Iceplex. Expansion Joint B, running east-west, separates the ice rinks from team facility including the team offices and locker rooms. Both these joints span vertically the entire height of the building.

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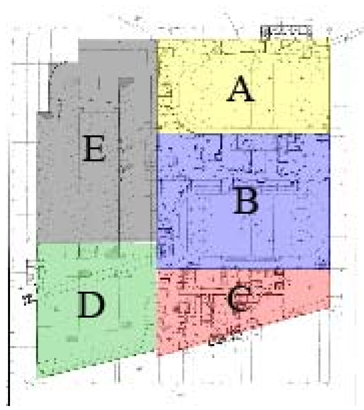
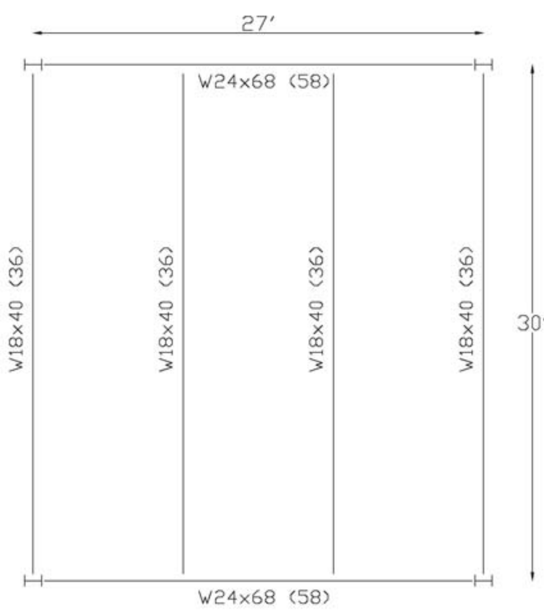


Figure 5: Location of Expansion Joints **Keyplean**

The first five levels of Areas A and B are constructed of mildly reinforced cast-in-place concrete consisting of 26"-28" diameter columns. The two-way slab is 10½" thick with 5¼ " drop panels and column capitals. Levels six and seven are constructed of 27'-0" x 30'-0" composite steel bays with W16x26s spanning the 27' direction and W24x55s spanning the 30' direction. Levels eight and nine of the Iceplex also consist of composite steel framing with the same 27'-0" x 30'-0" bay. Figure 6 shows a typical bay framing of level eight supporting the ice rinks.

Figure 6: Enlarged Framing Plan



LATERAL FRAMING SYSTEM

The lateral system of Areas A and B is somewhat complicated due to the several expansions the structure has encountered over the years and the various materials that were used.

The first five levels of concrete were cast monolithically creating continuous concrete moment frames in each direction throughout the building footprint. In general, this lateral system has proven very stiff and efficient for resisting lateral loads but creates potential problems in seismic regions because of its heavy weight.

When the structure was expanded both horizontally and vertically in the 1980s, reinforcement of the lateral system was needed. The original lateral system is shown in yellow in Figure 7. Areas A and B on levels 7 and 8 were framed using composite steel with moment connections. There are ten moment frames spanning the east-west direction along the exterior of the building. Two frames spanning the north-south direction run the entire width of the building at both sides of the structure.

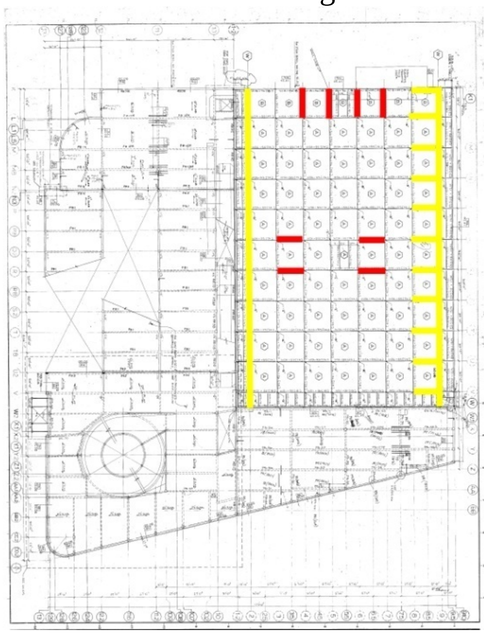


Figure 7: 7th Floor Lateral System

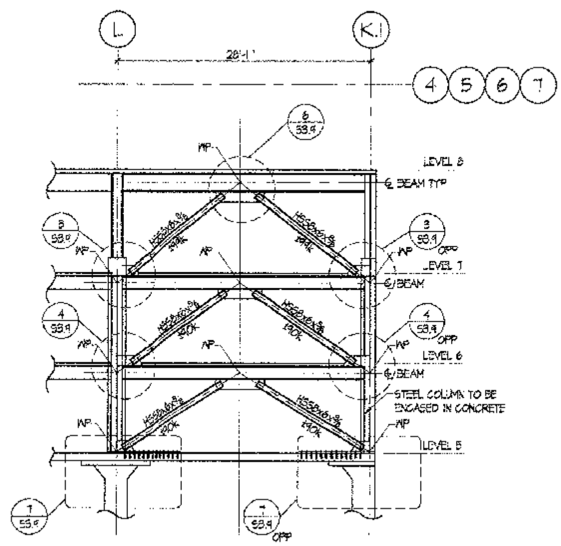


Figure 7A: Braced Frame Detail

Finally, when the Iceplex was added onto the parking structure, a mix of braced frames and moment connections was used. Eight braced frames were constructed on the 7th level reinforcing the existing structure for additional lateral forces. HSS8x6x3/8 tubes were used for all cross bracing. These frames are shown in red in Figure 4 and a detail of these braced frames is shown in Figure 7A. On the 8th level, there are a total of eight braced frames, four in each direction. These frames use the same tube sections and are shown in blue in Figure 5. Eight moment frames were constructed and were spaced evenly throughout with the exception of the voided areas from the ice rinks. These are shown in green in Figure 8.

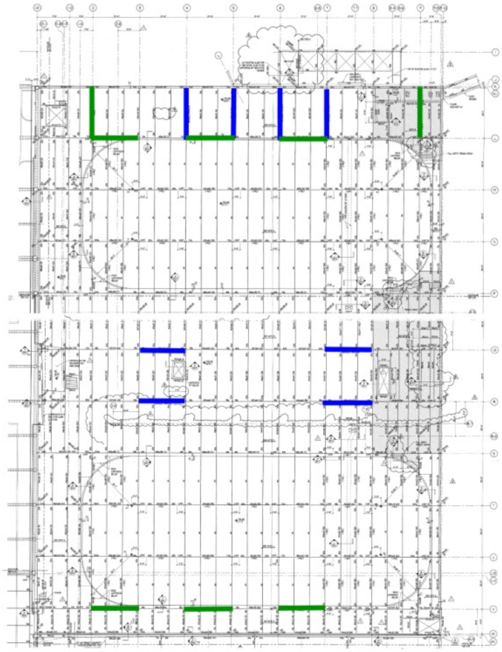


Figure 8: 8th Floor Lateral System

All lateral resisting members on the 9th level in this area are located in Area 9B. Seven moment frames span the north-south direction and four span the east-west direction. W24s and W33s are typical of the moment frames on the 9th level. Figure 9 shows the location of all lateral resisting frames in Area 9B.

Figure 9: 9th Floor Lateral System

The lateral resisting system of Areas A and B may be difficult to understand in 2-dimensions. Figure 10 shows the entire lateral system in 3D which may help to explain how the various systems work together to resist wind and seismic loads.

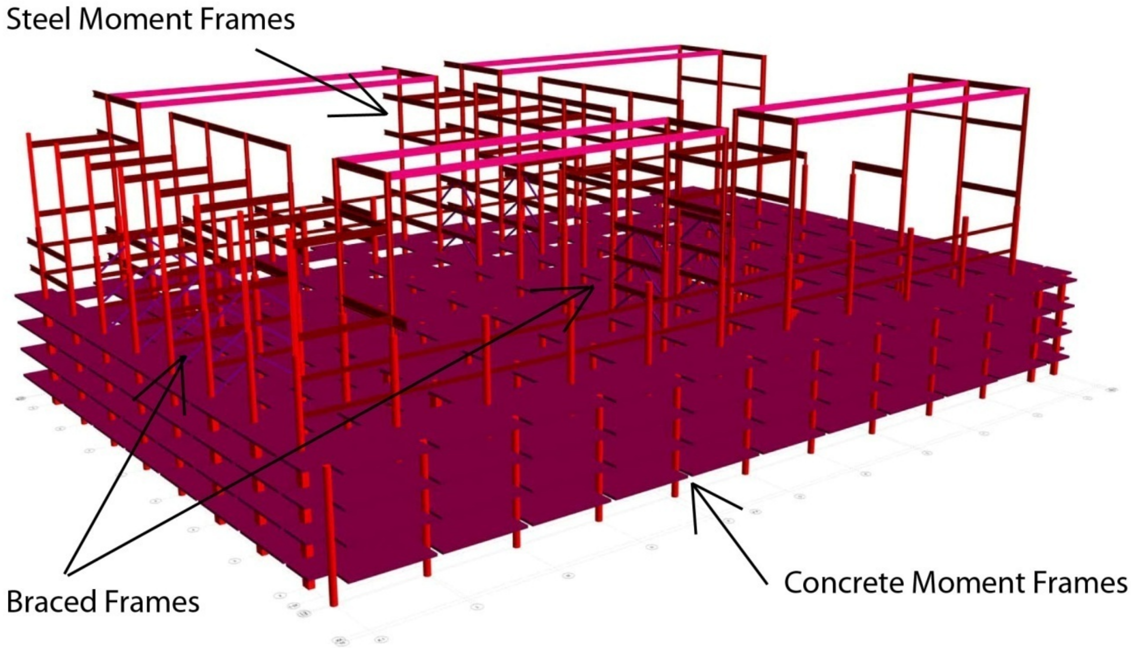


Figure 10: 3D Lateral Resisting System

PROBLEM STATEMENT AND PROPOSED SOLUTION

As previously stated, when the Iceplex was added onto the existing Ballston Mall parking garage, reinforcing the structure was required. Two footings were expanded, most columns were strengthened, and the lateral system needed to be reinforced in order to resist increased lateral loads. This proved to be the most complex part of the design. Also, minimizing deflection was crucial for the ice rinks which are located over 60 feet above grade.

There is a possibility that reinforcing the existing structure was not the most efficient and economical solution to the expansion. Instead, demolishing the existing parking garage and constructing the Iceplex from scratch may have simplified the project. This would eliminate the need for reinforcement and would simplify the lateral framing system. Redesigning the Iceplex and parking structure would allow the two ice rinks to be relocated to the first floor. The rinks could then be supported using a slab-on-grade, therefore minimizing deflection issues.

TASK 1: ARCHITECTURAL/CIVIL SITE BREADTH

Proposed Idea

The architectural/civil site breadth will start off by analyzing the site for vehicular and pedestrian traffic. Since the parking structure and Iceplex are going to be designed from scratch, it should be determined whether a more efficient site layout is possible. Currently, the parking garage has only one entrance and one exit off a main street. Changing the entrance/exit layout and location should be evaluated.

If vehicular and pedestrian access is changed, so will the architecture of the building. Building entrances may need to be relocated to account for new site access locations. This will have an impact on the layout of the building. For instance, team locker rooms and corporate offices may be rearranged in order to make the architectural design more efficient. The layout of the parking garage and the number of parking stalls should also be considered. Currently, the garage uses a circular ramp for vertical transportation. A more conventional layout, such as that off the East Parking Deck on Penn State's University Park campus, should be evaluated. If at all possible, the vehicle capacity of the parking garage should not be decreased. Another thing to be considered in this breadth topic is the location of shear walls. Ideal locations for the lateral system should be determined based on the new building architecture.

Tasks to be Completed

I. Evaluate vehicular flow for nearby streets, Glebe Rd. and Randolph St.
   a. Obtain traffic counts from Virginia DOT website
   b. Correspond with a civil engineer about the data
   c. Make a conclusion regarding the number of garage entrances and exits and their best locations

II. Determine new architecture layout of the building
   a. Determine most efficient entrance location to ice rinks and Capitals corporate offices based on parking garage entrances and exits
   b. Design any changes to the room layout of the Iceplex and its facilities
      i. Decide whether or not to move all facilities to the first level or to keep the offices one level above the ice rinks as in the existing design
   c. Determine the best location for a mechanical room
   d. Determine where lateral members can be placed
      i. Use shear walls wherever possible

III. Redesign the parking structure
   a. Count the number of parking stalls currently in the building
   b. Determine if a more efficient vertical transportation route is possible
      i. Two-way center ramp vs. helical down ramp (existing route)
   c. Determine number of parking stalls available with new layout

TASK 2: STRUCTURAL DEPTH

Proposed Idea

The proposed thesis will redesign the Iceplex and parking garage as if it is to be built from scratch on the existing site. This means that the existing structure is to be completely demolished. The two ice rinks will be relocated to the first floor and supported using a slab-on-grade. As a result, the deflection issues will be minimized. The parking garage is to be built as a separate structure above the Iceplex creating the need for large transfer girders or trusses. Either a Vierendeel Truss or a staggered truss framing system using AISC Design Guide 14 will be used to support the parking structure and span above the rinks. The garage will be framed using a cast-in-place reinforced two-way slab with beams system. The lateral system will consist of shear walls and/or concrete moment frames.

Gravity and lateral loads will be taken from ASCE7-05 and IBC 2006. Steel design will use AISC Steel Construction Manual 13th Edition, LRFD. Concrete design will use ACI 318-05.

Tasks to be Completed

I. Design two-way mildly reinforced concrete structure with beams for the parking garage
   a. Determine trial bay size per architecture/civil site breadth
   b. Determine trial slab thickness per ACI 318-05 Table 9.5a
   c. Determine trial column and beam sizes per CRSI Design Handbook
   d. Use pcaSlab to design concrete slab system
      i. Input representative slab runs (longitudinal and transverse directions) into program
      ii. Consider punching shear
   e. Use Direct Design Method to spot check program output

II. Build structure model using ETABS or RAM
   a. Investigate and determine which program will work more efficiently
      i. ETABS is better for lateral loads
      ii. RAM is more user friendly and better for building gravity model
   b. Determine new building loads and superimposed loads to by analyzed
   c. Set up gridlines in modeling program per architectural/civil site breadth
   d. Model entire structural framing system
   e. Apply loads to model
   f. Run gravity analysis to determine column loads
   g. Perform load takedown calculations by hand to spot check program output
   h. Input wind and seismic parameters into computer software to generate lateral loads
   i. Perform wind and seismic analysis by hand to determine story forces

j. Compare story forces/story shears from computer generated loads and hand calculations. Verify computer output.
k. Compare drift values to industry standard. Make any necessary adjustments.

III. Design columns using pcaColumn
   a. Choose a group of representative columns to design based on loading
   b. Input trail column size and trial reinforcement based on CRSI Design Handbook
   c. Apply gravity and lateral loads from verified model output
   d. Run analysis and check interaction diagram.
   e. Make any necessary changes to column reinforcement to optimize design

IV. Design Shear Walls
   a. Using computer model, determine how much load each wall will take
   b. Using existing spreadsheet for designing concrete shear walls, design reinforcement for all walls based on these loads
   c. Check to make sure existing spreadsheet uses newest code

V. Design transfer system to span over ice rinks
   a. Research Vierendeel Truss and a staggered truss framing system to determine best option
   b. If Vierendeel option is chosen, design using SAP
      i. Based on research, chose and insert trial sizes of members
      ii. Input loads from computer model. For example, column loads from above will act as point loads on truss.
      iii. Run analysis and check member stresses
      iv. Make adjustments to sizes as needed
   c. If a staggered truss framing system is chosen, design using AISC Design Guide 14
      i. Follow design steps as laid out in design guide
      ii. Verify stresses are within limits
   d. Design columns to support transfer system using SAP
      i. Based on architecture and orientation of truss supports, determine if concrete or steel columns would work best
      ii. Chose trial column size
      iii. Input truss shear as axial load on column
      iv. Analyze and check stresses
      v. Make adjustments to column design as necessary

VI. Design slab-on-grade
   a. Research how to efficiently design a SOG for the increased loads of the ice rinks
   b. Limit deflection to L/400 per ice consultant's recommendations

VII. Design foundation system
   a. Try to find allowable bearing capacity of soil based on Arlington, VA area map of soil conditions. The original geotechnical report did not determine allowable bearing capacity but recommended using 3000 psi.
   b. Obtain column loads from takedowns and building model

c. Use existing spreadsheet to design footings
d. Check that existing spreadsheet uses newest code
e. Spot check spreadsheet design using f = P/A + M/S

TASK 3: CONSTRUCTION MANAGEMENT BREADTH

Proposed Idea

The construction management breadth will cover two topics: a cost comparison and scheduling impacts. First, the cost of demolishing the existing structure and building from scratch will be compared to the actual cost of reinforcing the existing structure for the addition of the Iceplex. A detailed cost analysis must be completed using RS Means. A detailed list of actual costs must also be obtained from the contractor of the project. Based on this cost comparison, it can be concluded whether or not the demolition and reconstruction of the Iceplex is a better solution compared to reinforcing the existing structure. The schedule of the proposed solution will also have a major impact on the conclusion of this thesis. If the existing parking structure is demolished, the Ballston Mall will be without parking. It is important to consider how this will impact the mall and surrounding area. The exact amount of time the parking structure will be out of service and its monetary value to the mall must be determined. Combining the cost analysis and scheduling impact, a conclusion can finally be made. Is demolishing and starting from scratch worth it?

Tasks to be Completed

I. Obtain cost and scheduling information from general contractor as soon as possible
II. Obtain information on design fees charged by the architect and structural engineer
III. Determine the cost of the proposed solution
  a. Use RS Means to estimate the cost of demolition and new construction
  b. Correspond with project architect and structural engineer about how long it would take to redesign the Iceplex and the associated fees
IV. Determine scheduling information of the proposed solution
  a. Determine how long will the parking structure be out of service
  b. Determine if there is any temporary parking for the mall
  c. Research how much money the mall would lose if no parking is available
  d. Determine complete construction time
V. Make conclusion
  a. Compare cost and scheduling issues and make conclusion
    i. Is it better to tear down the existing parking structure and rebuild rather than reinforcing the existing structure?

SCHEDULE OF COMPLETING TASKS

JANUARY

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1 WINTER BREAK & INTERVIEWS	2	3	4	5
6	7	8	9	10	11	12
13	14 Contact contractor to get cost & scheduling info	15 Research vehicular flow and determine locations of parking garage entrances and exits	16	17 Determine new vertical route for parking garage	18	19
20	21	22 Determine new archtectural layout (Entrances, Room Layout, Mechanical Room, Shear Walls)	23	24	25	26
27	28	29	30	31		

FEBRUARY

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3 Design Two-Way Slab with Beams for Parking Garage	4	5	6	7 Build Computer Model	8	9
10	11	12	13	14	15	16
17 Analyze Drift and Make Necessary Changes to Design	18	19	20 Perform Column Takedowns to Spot-Check	21	22	23
24	25 Design Concrete Columns, Shear Walls, and Slab-on-Grade	26	27	28	29	

MARCH

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3 Design Transfer System	4	5	6	7 Design Foundation System	8
9	10	11	12 SPRING BREAK	13	14	15
16	17	18	19 Week for Catch-Up	20	21	22
23	24	25 Complete Cost Estimate	26	27	28	29
30 Complete Project Schedule	31					

APRIL

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3 Complete Project Schedule	4	5
6	7	8 Finalize Report and Presentation	9	10	11	12
13	14	15	16 FINAL PRESENTATIONS	17	18	19 PARTY!!!
20	21	22	23	24	25	26
27	28	29	30			