8.0 BREADTH STUDIES

The post-tension concrete design of Gateway Plaza will have an impact on all of the systems in the building, including the construction of the project. In particular, this report will focus on how supply air ducts, part of the mechanical system, can be designed according to ASHRAE Standard 62.1 and how the project can be scheduled efficiently.

8.1 Mechanical Study

The main goal of the mechanical study is to design supply and return air ducts in a typical floor in Gateway Plaza. To keep with the objective of the structural design, minimizing floor depth, these ducts will be designed to minimize their depth. Since the building is for tenant fit-out, there is no existing duct plan to compare. However, the riser on each floor has a main supply duct with a depth of 26”. To handle air return, the ceiling will be used as a plenum for collecting return air, a system that works well when drop ceilings are used. The mechanical room is equipped with two 90”x32” grilles to pull in air from the plenum, and the room has a louver to exhaust air outside.

8.1.1 Indoor Air Quality

Before ducts could be laid out, it is necessary to check that the building is receiving the required amount of outdoor air for proper ventilation. The layout for the new structural system was designed according to *ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality* using the Ventilation Rate Procedure laid out in section 6.2. This procedure “determines outdoor air intake rates based on space type, occupancy level, and floor area.” The actual amount of outdoor air supplied by the mechanical equipment has been compared to the minimum amount of outdoor air intake typical of the office floor (shown on the next page) as determined by the above procedure.

Since the building is for tenant fit-out, a basic design was established where the typical office floor was subdivided into five separate offices, seen in the diagram below. To estimate the occupancy of each office, it was assumed that each person occupied a 10’x10’ cubicle, or 100 ft^2, including hallway circulation space.

Office	A_z (ft^2)
1	2911
2	3738
3	3513
4	2137
5	2600
6	2592

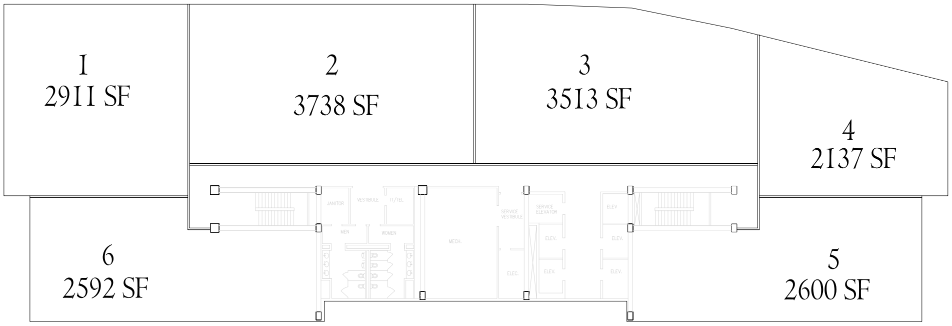

Figure 34-Typical layout of offices, with square footage, for tenant fit-out.

The ventilation rate procedure has been outlined below for the office type 1.

Step 1: Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_a A_z \qquad \text{(Eq. 6-1)}$$

- $R_p = 5cfm$ (Table 6-1)
- $R_a = 0.06cfm/sf$

$$V_{bz} = 5cfm(30\,people) + 0.06cfm/sf\,(2911sf) = 325cfm$$

Step 2: Zone Outdoor Airflow

$$V_{oz} = \frac{V_{bz}}{E_z} \qquad \text{(Eq. 6-2)}$$

- $E_z = 1.0$ (From Table 6-2 for ceiling supply of cool air.)

$$V_{oz} = \frac{325cfm}{1.0} = 325cfm$$

Step 3: Multiple-Zone Recirculation System

- Primary Outdoor Air Fraction

  $$Z_p = \frac{V_{oz}}{V_{pz}} \qquad \text{(Eq. 6-5)}$$

  $$Z_p = \frac{325cfm}{\frac{2911sf}{17{,}491sf}(22{,}725sf)} = .0859cfm$$ where V_{pz} is taken to be the ratio of the area of the office being supplied to the total area of all of the offices multiplied by the total area of the typical floor.

- Uncorrected Outdoor Air Intake

  $$V_{ou} = D\Sigma_{allzones} R_p P_z + D\Sigma_{allzones} R_a A_z \qquad \text{(Eq. 6-6)}$$

  - The occupancy diversity is taken to be 1.0, which is conservative, because each office is being designed as having the same occupancy requirements.

$V_{ou} = 325 cfm$

- Outdoor Air Intake

$$V_{ot} = \frac{V_{ou}}{E_v}$$

  - Ventilation Efficiency: $E_v = 1.0$ because $Z_p < 0.15$.

$V_{ot} = 325 cfm$

Step 4: Outdoor Air Comparison

After all of the spaces have been calculated, the total amount of outdoor air that must be supplied to office space #1 is found to be 1942 cfm (see *Appendix D.1 Mechanical* for calculation of all spaces). This value is greatly less than the 4545 cfm that is supplied to the area by the existing equipment. Therefore, the typical office floor is capable of handling the ventilation requirements. This oversize is to be expected for a tenant fit-out space where space requirements are unknown.

8.1.2 Diffuser Layout

Since the requirements for each office space have been found according to ASHRAE Standard 62.1, the ducts can be laid out to achieve the necessary supply loads. Assuming that each supply diffuser will have a throw range of a 6’-16’ radius, the diffusers can be laid out for each office space, taking care to cover the entire area. The diffusers specified by the architect are 24”x24” so that they will fit into the 24”x48” acoustic ceiling grid. See the diagram below for the preliminary diffuser lay-out and the throw area.

Return grills have been laid out in such a manner to create a natural circulation of air. The returns, about three supplies to each return, have been positioned between rows of supply diffusers. While the air will be supplied to the offices through forced air, ceiling plenum return will bring air back to the mechanical room.

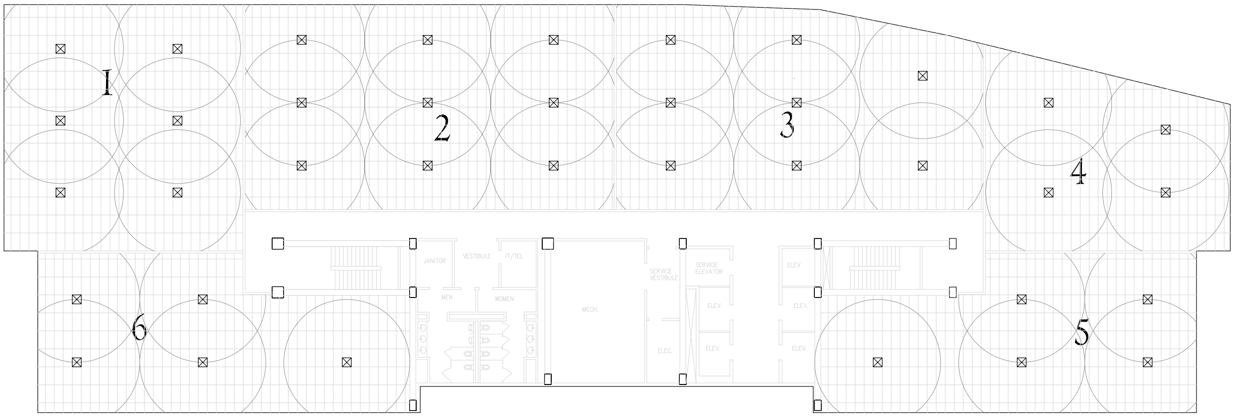

Figure 35-Diffuser layout and ranges of throw.

8.1.3 Duct Layout

The diffusers were connected using the shortest run of ducts from the riser originating in the mechanical room in each floor. The only obstacle that needed to be avoided was the shearwalls flanking the mechanical room and stairwells. Therefore, the runs to the ducts in office spaces 5 and 6 were unusually long. The ducts originated in the mechanical room at a size of 96x26 and eventually branched off to a size of 10x10 at their smallest. To size the ducts, the Duct Designer (duct-o-lator) supplied from the Loren Cook Company was used. A friction loss of 0.08" of water per 100' of duct was assumed.

As was previously mentioned, air will be returned to the mechanical room through the ceiling plenum. To better direct the air in such a large ceiling plenum, duct stubs will be connected to the return grilles to direct the air to the mechanical room.

The plan below shows the layout of ductwork, both supply and return, to each office.

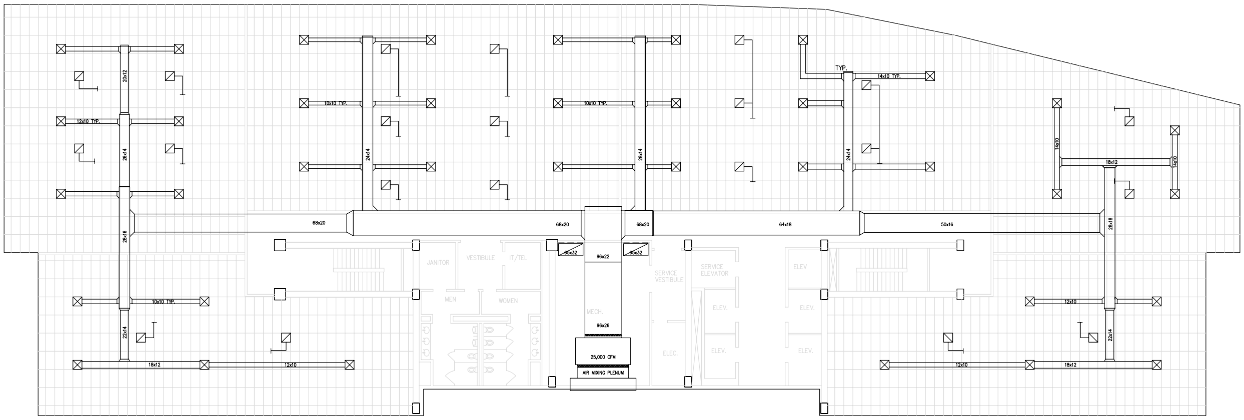

Figure 36-Duct layout.

8.2 Construction Study

8.2.1 Scheduling Impact

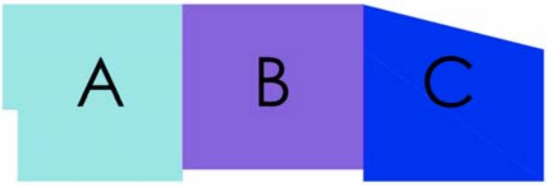

Figure 37-Lifts in the construction sequence.

There is a significant difference in tasks and sequence of tasks that take place when building a concrete structure and building a composite steel structure. There are more trades on site with concrete construction due to the necessary formwork, reinforcement, post-tensioning, and placing of concrete. This leads to the necessity of coordinating these trades to minimize down-time and preventing trades from interfering with one another.

Since there is virtually no lead time for concrete, compared to steel, a post-tensioned concrete floor can be produced from start to finish in around 5 days, so the structure can be erected quickly.

Due to the large size of the elevated slabs, approximately 24,000 ft^2 and 640 cubic yards of concrete per floor, and the limited capacity of concrete trucks, about 10 cubic yards per truck, tasks will be completed in the 3 sections. The diagram below depicts the three sections the building has been divided into: column lines B-E, E-H, and H-L. The areas of these sections are more manageable for crews and for delivery coordination: A=7650ft^2, B=7400 ft^2, C=7000 ft^2.

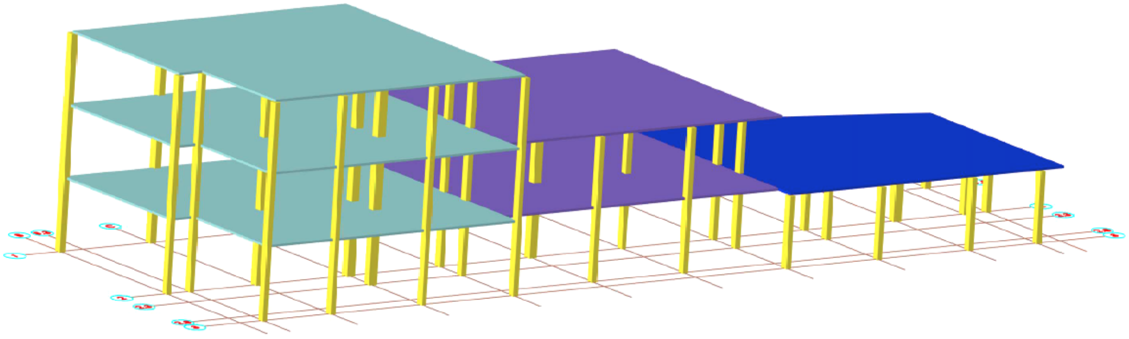

Figure 38-Schematic of how construction will take place with lift sequencing.

The following events and their durations, on a floor by floor and section by section basis, were considered when scheduling this project:

- Columns (F/R/P): 2 days
    - Forming

  - Tying Reinforcement
  - Pouring and curing
- Construct/Erect shoring and formwork: 3 days
- Tie reinforcement for slab and beams: 1 day
- Rough-in for MEP: 1 day
- Concrete (for each section):
  - Pour and finish: 1 day
  - Cure: 2 days
- Strip formwork and install reshoring: 2 days
- Jack the post-tensioning tendons: 1 day

The previous tasks were scheduled using Primavera project management software and compared to the Primavera schedule obtained from the Gilbane Construction Manager for the composite steel structure. For the full schedule, refer to *AppendixD.2: Construction*. The composite steel construction lasted 140 days while the post-tensioned concrete construction lasted 156 days. Though these construction times are comparable, it does not include the lead time needed to obtain and fabricate steel.

8.2.2 Cost Analysis

Structural Framing Costs: The following cost comparisons take into consideration only the structural systems including: slabs, beams, columns, and lateral elements, and do not include foundation costs. Estimates for both systems were compiled using material takeoffs for a typical floor and finding unit prices for each material in RS Means 2005. Although, this is not the year when the project was bid, the estimates are both done using RS Means 2005, so they are in direct comparison. See *Appendix D.2: Construction*.

Cost Comparison		
	Cost/Floor	cost/sf
Concrete	$ 654,702	$ 27.98
Steel	$ 616,892	$ 26.36

Table 7-Cost comparison between post-tensioned concrete structure and composite steel structure.

As evidence by the cost comparison for the two systems, the post-tensioned concrete system is more expensive by $1.62/ft^2 and approximately $626,940 for the whole project. This is a 7% increase over the existing composite steel structure.

Foundations Costs: Since the foundations were changed as part of the post-tensioned concrete design, the change needs to be accounted for when considering project feasibility. Again, material takeoffs, available in *Appendix D.2: Construction*, were compiled and then assembly costs were taken from RS Means 2005. Caissons proved to be much more expensive than the existing concrete filled steel piles. The price for caissons is over $4 million where the price for the piles was only $700,000.

The charts below accurately illustrate differences in price, duration, and foundation costs between the composite steel and post-tensioned concrete systems.

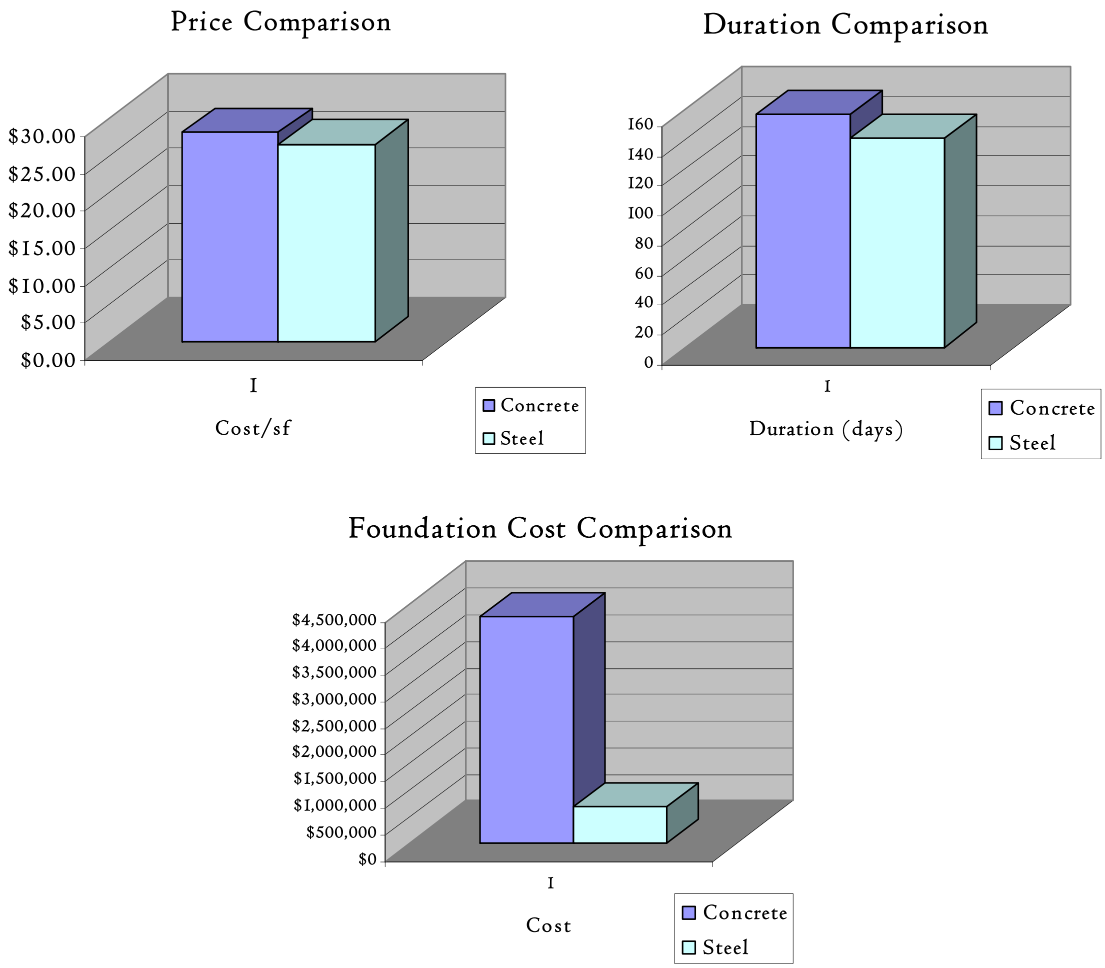

Figure 40-Comparison charts.