C.3 Foundation Redesign ~ *Structural Breadth*

Figure 1: Foundation Excavation

The Current Foundation System for the Wellington Condominiums has been analyzed and is broken down as followed:

C.3.1 Problem Statement

With poor subsurface conditions prevalent, can the foundation system be redesigned to possibly reduce cost and time spent without interfering with architects or owner needs?

This problem was identified through the geotechnical reports, change orders, and project manager interviews. A lot of money, time, and energy were spent by the project team having to deal with poor subsurface conditions. An analysis communicating some potential solutions is one study of great interest to many on the Wellington Condominiums Project.

C.3.2 Proposed Solution

A possible solution to the Wellington Condominiums Project is for a structural redesign of the foundation system. A structural breath will be utilized in the analysis of the comparison between the current and proposed systems. The current foundation system makes use of single slab column footings and will be challenged through the redesign of a matt slab foundation. A matt slab foundation system is proposed and will be researched to do the following possibilities:

1. Save time and money by not having to excavate as deep in rock material.
2. If footing depth can be decreased possible savings in the dewatering system could happen.
3. Using a matt slab could reduce the strength needed for foundation concrete and also if designed correctly act as a slab on grade. This could potentially save time and cost to the project.

C.3.3 Analysis Steps

The procedure to investigating if a matt slab foundation system would be more viable than a traditional single slab column footing is as followed:

1. Learn in more detail and have available the single slab column footing's estimate, schedule, design documentation, specifications, and methods of construction.
2. Redesign the foundation system utilizing a matt slab foundation. Figure out how much material, cost, and time would be spent to construct.
3. Compare the two systems and create a matrix chart based on the owner requirements of which system overall is better for the project.

C.3.4 Analysis Result Overview

The matt slab foundation system at first seems to be an ironic system to select rather than pouring single slab column footings. When looking at the following items: cost and time spent to rock excavate by rock hammering, putting in a extensive permanent dewatering system and support equipment, weeks of delays that would push back the façade construction to the winter months, and the structural engineer specifying the use of 6,000 PSI concrete for footings. Once you look at all those variables the cost and ease of simply pouring the entire slab may be a better alternative. Also the analysis can be swayed either way by the owners inputs of the foundation system based on a matrix chart.

C.3.4.1.A Overview of the Current Wellington Condominium's Foundation System

The Wellington Condominium's foundation consists of a large part of the cast in place concrete that was done on the construction site. The type of horizontal and vertical formworks and concrete placement methods of the foundation are described in more detail as followed:

Footings:

- Normal weight concrete with a minimum compressive strength of 3,000 PSI at 28 days (This was value engineered due to the CM questioning the specified 6,000 PSI compressive strength in the contract documents by the engineer of record.)
- Reinforcing will consist of A615, Grade 60
- Average size of column footing 15'L X 15'W X 18"D
- Minimum of 3 feet below finished surface where exposed to frost
- Minimum allowable bearing pressure of 3,500 PSF

Figure 2: Wellington Condominium's Foundation

Slab on Grade:

- 5 inches of normal weight concrete with a minimum compressive strength of 3,000 PSI at 28 days
- Reinforced with 6 X 6 – W2.1 X W2.1 welded wire fabric, over a 14 inch crushed stone sub base and vapor barrier

Foundation Bearing and Shear Wall Construction: (includes exterior and stair and tower walls)

- 8” and 12” normal weight reinforced concrete with a minimum compressive strength of 3,000 PSI at 28 days

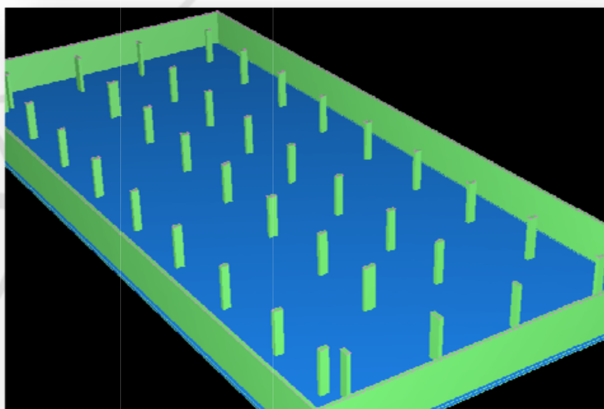


Figure 3: Substructure from RAM Concept

Since the soil at the time had enough cohesion to stay in place, the foundation strip and column footings did not require any horizontal or vertical formwork. The only task left was to situate the footing rebar and place the concrete with a concrete pump at the locations required. Once the footings were to the strength required, the foundation’s exterior walls and columns took form with large gang forms. These large forms took shape very quickly with a 120 ton AmQuip crane tipping up each one into position. The formwork was connected and reinforced into place with lateral bracing. After the formwork was set and properly supported, the rebar was placed in the foundation walls and columns. Following inspection from the project management team, the concrete was placed with a concrete pump and allowed time to gain strength.

C.3.4.1.B Original Estimate and Schedule

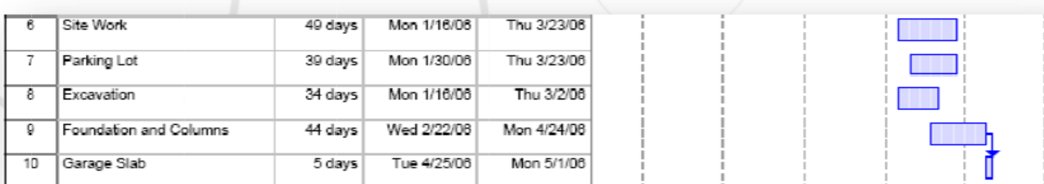
The Wellington Condominium's original foundation system estimate and schedule are detailed as followed:

Original Estimate:

• Single Slab Column Footings:	$104, 374
• Wall Strip Footings:	$13,070
• Foundation Walls:	$133,139
• Foundation Columns:	$33,488
• Slab on Grade:	$73,048
Total:	**$357,119**

~See Attached Appendix for Detailed Structural Takeoff~

Original Schedule:



6	Site Work	49 days	Mon 1/16/06	Thu 3/23/06
7	Parking Lot	39 days	Mon 1/30/06	Thu 3/23/06
8	Excavation	34 days	Mon 1/16/06	Thu 3/2/06
9	Foundation and Columns	44 days	Wed 2/22/06	Mon 4/24/06
10	Garage Slab	5 days	Tue 4/25/06	Mon 5/1/06

Total: **83 Work Days = 17 Weeks**
Mon 1/16/06 – Mon 5/1/06

~See Attached Appendix for Full Schedule~

C.3.4.1.C Geotechnical Report Summary

The Wellington Condominium's project team hired on Earth Engineering, a geotechnical engineer and geologist company located in East Norriton PA, to perform a geotechnical investigation for the site conditions at Wellington Condominiums. Fifteen test borings were completed for the investigation from May 23 through May 25, 2005. The borings were conducted by Main Line Drilling Company of Wayne, PA and were field located to the project team's specifications by the surveyor Hopkins and Scott, Inc. A representative of Earth Engineering supervised and monitored the test boring activities.

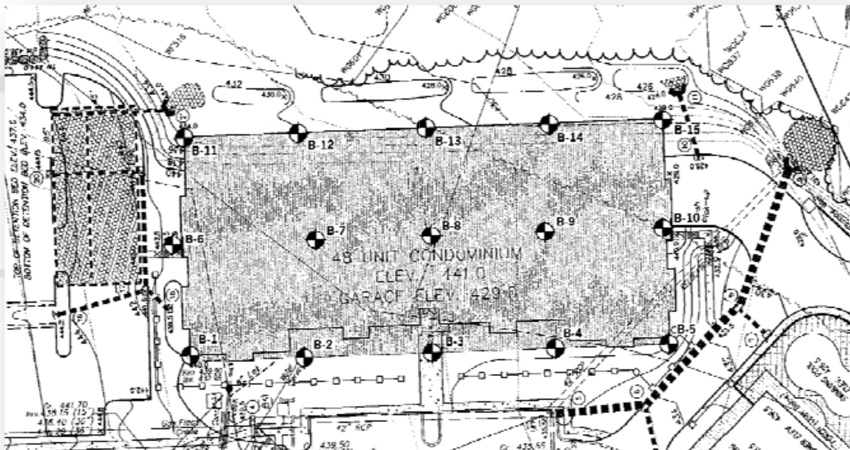


Figure 4: Site Boring Investigation

The laboratory results indicated that the soil classification for a majority of the soil according to ASTM specifications was sandy silt. It has a bearing capacity of 4 KSF and a fair drainability record. Groundwater was encountered at all of the boring locations and as much as 5 feet above the proposed finished floor garage. Earth Engineering recommends raising the finished floor grade or providing permanent waterproofing and drainage system to maintain groundwater levels below the proposed finished floor grade. Substantial soil and rock excavations below the existing grade must be done to achieve the correct soil bearing pressure.

~See Attached Appendix for Test Boring Results~

C.3.4.1.D Foundation Construction

The project team armed with this information knew that soil conditions would be an issue and therefore took the recommendation of Earth Engineering to provide waterproofing and permanent dewatering systems to the foundation system. The architects did not want to raise the finished floor grade due to the parking garage at the foundation level. An increase in elevation would make the parking garage more visible and possibly make the building less architecturally pleasing. During excavation the project team encountered poor subsurface conditions and had to take extra measures through change orders to ensure a proper foundation design. During the course of excavation the following amounts of change orders had to be conducted to correct the poor subsurface conditions:

Change Orders

#	DESCRIPTION	AMOUNT
1	Site plan topography wrong, and poor soils had to be excavated	$20,000
2	Unsuitable soils	$38,487
3	Unsuitable soils	$4,709
4	Unsuitable soils	$12,942
5	Change under slab drainage pipe from SDR35 to SCH40 so it won't get crushed. It wasn't spec'd.	$1,930
6	Unsuitable soils	$35,808
7	Rock Crusher	$43,000
8	Additional cleanouts and floor drains at garage	$1,749
9	Footing over-excavation and lean fill	$12,620
10	Add'l 3" ID binder	$1,391
11	Unsuitable soils	$10,000
12	Waterproofing	$80,000
	TOTAL CHANGES	**$253,159**

Figure 5: Foundation Change Orders

The total amount for change orders was $253,159 and resulted in a total payout of $610,278. This ended up being a 70% increase in the total budget for the foundations. The encounter of poor subsurface conditions led to delaying the project by more than 3 weeks. This created a domino effect to the entire schedule and was one of the major reasons why the façade construction was pushed to the middle of winter.

C.3.4.2.A Overview of the Foundation Redesign

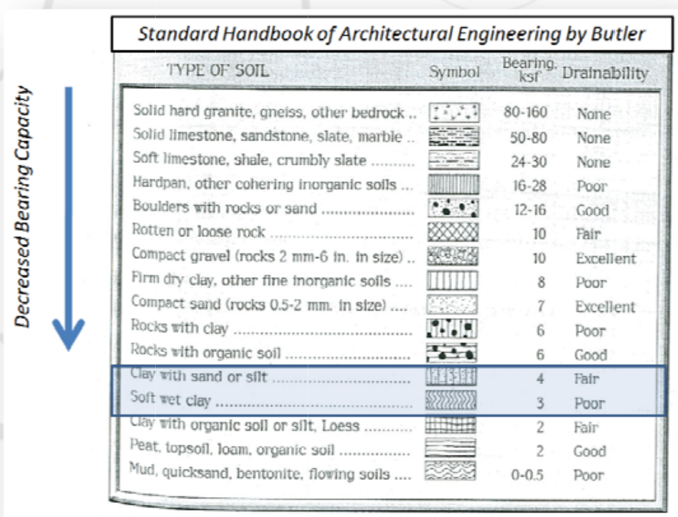
With the encounter of poor subsurface conditions there was an opportunity to investigate whether or not the foundation system should have been changed. It is through this analysis to decide whether or not a redesign of the foundation system would be deemed a viable solution. The selection of a particular foundation was based on a number of factors from the *Building Design and Construction Handbook by Merritt* and is as followed:

1. **Adequate Depth:** Preventing frost damage and undermining by scour.
2. **Bearing Capacity Failure:** Foundation must be safe against failure.
3. **Settlement:** Must not settle to the extent that it damages the structure.
4. **Quality:** Must have adequate quality so that it is not subjected to deterioration.
5. **Adequate Strength:** Must be built to sufficient strength so that it does not fracture or break apart under superstructure loads. The foundation construction must conform to design specifications.
6. **Adverse Soil Changes:** The foundation must be able to resist adverse soil conditions. Expansive soils such as silt and clay could expand or shrink, causing movement of the foundation and damage to the structure.
7. **Seismic Forces:** Foundation must be able to support the structure during an earthquake without excessive settlement or lateral movement.

Footing types other than spread footings are usually used for the following reasons and were used as a guide from the *2007 RS Means Assemblies Data* to the selection of the Wellington Condominiums foundation redesign:

1. Bearing Capacity of soil is very low.
2. Very large footings are required, at a cost disadvantage.
3. Soil under footing is very compressible, with the probability of causing excessive or differential settlement.
4. Good bearing soil is deep.
5. Potential for scour action exists.
6. Varying subsoil conditions within building perimeter.

All these reasons apply to the Wellington Condominium Foundation. The bearing capacity can only be designed to withstand 3500 PSI which is considered fairly low. With varying subsoil conditions within the building perimeter, comes the requirement of utilizing large and deep footings to prevent excessive settlement and have good bearing soil.



Standard Handbook of Architectural Engineering by Butler

TYPE OF SOIL	Symbol	Bearing, ksf	Drainability
Solid hard granite, gneiss, other bedrock ..		80-160	None
Solid limestone, sandstone, slate, marble ..		50-80	None
Soft limestone, shale, crumbly slate		24-30	None
Hardpan, other cohering inorganic soils ...		16-28	Poor
Boulders with rocks or sand		12-16	Good
Rotten or loose rock		10	Fair
Compact gravel (rocks 2 mm-6 in. in size) ..		10	Excellent
Firm dry clay, other fine inorganic soils		8	Poor
Compact sand (rocks 0.5-2 mm. in size)		7	Excellent
Rocks with clay		6	Poor
Rocks with organic soil		6	Good
Clay with sand or silt		4	Fair
Soft wet clay		3	Poor
Clay with organic soil or silt, Loess		2	Fair
Peat, topsoil, loam, organic soil		2	Good
Mud, quicksand, bentonite, flowing soils		0-0.5	Poor

Figure 6: Properties of Soils

From Figure 6, it can be shown that the bearing capacity for the soils at Wellington Condominiums is poor and that the drainability is between the range of fair and poor. Therefore due to the reasons listed above, it was determined to analyze the redesign of the Wellington Condominiums foundation system by utilizing a mat foundation.

C.3.4.2.B Mat Foundation Concept Applied to Wellington Condominiums

According to the *Building Design and Construction Handbook by Merritt,* a mat foundation is defined: as a single combined footing for an entire building unit. It is economical when building loads are relatively heavy and the safe soil pressure is small. Based on economic considerations according to the *Building Design and Construction Handbook by Merritt*, mat foundations are constructed for the following reasons and are judged against the Wellington Condominiums circumstances:

1. **Large Individual Footings:** A mat foundation is often constructed when the sum of individual footing areas exceeds about ½ of the foundation area.

   Wellington Condominiums Calculation:
   - 259’ x 121’ Building Area = 31,339 SQ FT
   - 36 Footings x (20’ x 20’ Max Footing Area) = 14,400 SQ FT
   - (14,400 SQ FT / 31,339 SQ FT) x 100 = 45.95% < 50% SUM

   From the calculation, it can be determined that approximately 46% of the footing area is below the rule of thumb value but is within consideration for mat foundation.
2. **Cavities or Compressible Lenses:** Mat foundation used when subsurface exploration indicates that there will be unequal settlement below the foundation due to small cavities or compressible lenses. A mat foundation would distribute the load more evenly and create better conditions for any possible settlement.

   Wellington Condominiums Analysis Viewpoint:
   - Cavities or Compressible Lenses have not been indicated in the geotechnical reports or have been an issue during construction.
   - Minimal value has been placed on cavities or compressible lenses for this analysis.
3. **Shallow Settlements:** A mat foundation can be recommended when shallow settlements predominate and the mat foundation would minimize differential settlements.

   Wellington Condominiums Analysis Viewpoint:
   - Differential Settlement was identified in the geotechnical report and has been a large concern to the project team.
   - Large consideration has been placed on how the foundation settlements would be with a mat foundation system.
4. **Unequal Distribution of loads:** Large disparity in building loads acting on different areas of the foundation can be subjected to excessive differential settlement with conventional spread footings. Using a mat foundation would tend to distribute the unequal building loads and reduce the differential settlements.

Wellington Condominiums Analysis Viewpoint:

- The column and wall loading varies and therefore different column sizes and spread footings are utilized. The largest spread footings are constructed at the corners and center of the foundation.
- Unequal distribution of loads is something to consider but is not a major focus for the design of the Wellington Condominiums mat foundation redesign analysis. Load distribution will be considered in the analysis for completeness.

5. **Hydrostatic Uplift:** A mat foundation could be used to resist uplift forces due to a high groundwater table.

Wellington Condominiums Analysis Viewpoint:

- Groundwater at the project site is of huge concern to the project team. Extensive groundwater measures had to be in place before construction could ever begin.
- Any reduction in waterproofing or groundwater measures from the utilization of a mat slab would be of great savings in budget and schedule.

C.3.4.2.C Mat Foundation Design Background

The design background for a mat foundation tends to be very complicated and requires extensive knowledge and experience. Being said there are many articles and programs that engineers use when considering the design of a mat foundation system. Some of the design criteria outlined in the *Building Design and Construction Handbook by Merritt* are as followed:

1. Weight of soil excavated for the foundation decreases the pressure on the soil under the mat. If excavated soil weighs more than the building, there is a net decrease in pressure at mat level from that prior to excavation.
2. When the mat is rigid, a uniform distribution of soil pressure can be assumed and the design can be based on a statically determinant structure as shown in the Figure 7 below.
3. If the centroid of the factored loads does not coincide with the centroid of the mat area, the resulting nonuniform soil pressure should be used in the strength design of the mat.
4. Strength-design provisions for flexure, one-way and two-way shear, development length, and serviceability should conform to ACI 318 Building Code Requirements.

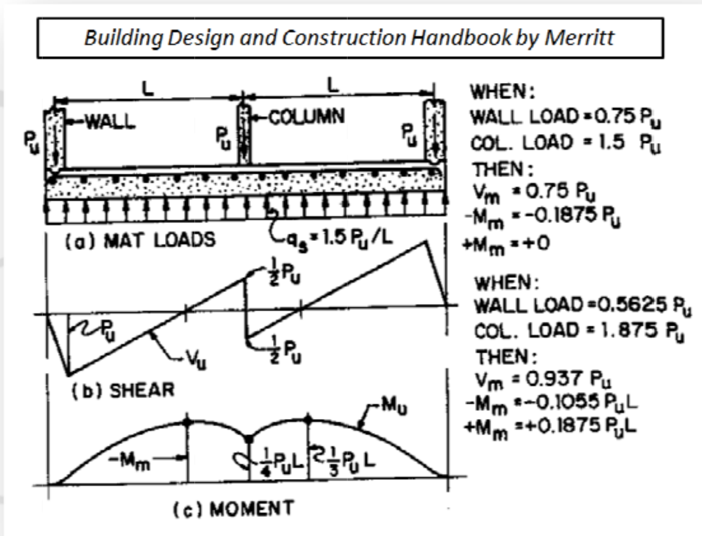


Figure 7: Design Conditions for a Rigid Mat Footing

C.3.4.2.D Mat Foundation Design Input Data and Assumptions

A mat foundation design was created through the utilization of PCA MAT® Software by Structure Point. This software specializes in the complicated design of mat foundations. Before utilizing the software and inputting data, information background about the foundation conditions had to be identified.

- Earth Engineering has assumed and indicated in contract documents that the column loads will not exceed 473 kips, and that the wall loads will not exceed 10 kips per lineal foot. Earth Engineering has assumed that no unbalanced moments or lateral loads are imposed on the columns and walls. Based on these assumptions, Earth Engineering estimated that the total settlement to be less than one inch and the differential settlement to be within tolerable limits.
- Concrete
  - Compression Strength: 3 KSI
  - Unit Weight: 145 PCF
  - Young's Modulus: 3155.92 KSI
  - Poisson's Ratio: 0.15
- Soil
  - Subgrade Modulus: 50 KCF
  - Allowable Pressure: 3.5 KSF
- Steel
  - Yield Strength: 60 KSI

  - Young's Modulus: 29,000 KSI
- Design Parameters
  - Minimum Reinforcing Ratio (% of gross area): 0.18
  - Top and Bottom Reinforcing
    - X-Direction: 3.25 inches
    - Y-Direction: 3.5 inches
- Column Dimensions (from construction documents)
- Slaved Nodes: Rx Degree of Freedom
- Loads and Load Combinations
  - Service
  - Ultimate

C.3.4.2.E Mat Foundation Design

Once the data has been inputted and assigned to elements in the PCA MAT® Software program, results can be quickly attained. The advantage to this software is analyzing how thick a mat slab has to be to properly support the required loads of the structure. Simply changing the thickness in the input data will update the results for the viewer to see. The goal is to get the thickness of the mat foundation as thin as possible due to the controlling cost of concrete and reinforcement. Also by decreasing the depth of the foundation better control over hydrostatic uplift, load distribution, and settlements will occur.

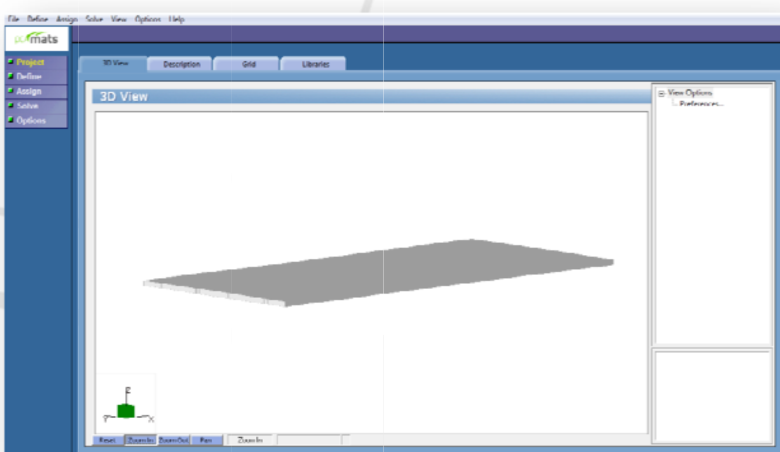


Figure 8: PCA MAT® Software

For the design analysis the following thickness will be looked at to determine the most appropriate for the Wellington Condominiums mat foundation system: 120", 108", 96", 84", 72", 60", 48", 36", 24", and 12". With each thickness the amount of reinforcing, deflection settlement, and moment capacity will be determined. The best combination of

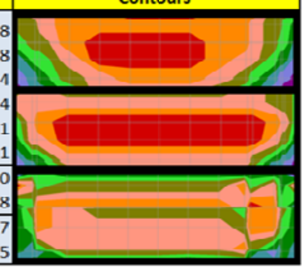
the three will result in the selected mat foundation thickness. The chart below shows the results of the analysis using the PCA MAT® Software.

PCA MAT® Analysis Results Chart

Thickness (in)	Max Deflection (in)	Contours	TYP. AS (sq in/ft)	TYP. Rebar Size #
120	0.306	Good	2.592	18
108	0.316	Good	2.333	18
96	0.328	Good	2.074	14
84	0.343	Good	1.814	14
72	0.361	Good	1.555	11
60	0.382	Okay	1.296	11
48	0.405	Okay	1.037	10
36	0.426	So So	0.778	8
24	0.45	So So	0.518 (mix sizes)	7
12	0.545	Bad	0.259 (mix sizes)	5

Thick
Thin

Contours



From the PCA MAT® Chart, it can be shown that the ideal thickness for the mat foundation lies between 48" and 36". Above the results creates large rebar sizes and thick mat slabs which are unnecessary to carry the structural load. Below the results creates mixed rebar sizes and bad settlement contours. Therefore it is recommended that a 48" mat slab be utilized due to the settlement contours and typical rebar sizes that are commonly found in constructing foundations. This value tends to be on the conservative side of the given results.

~See Attached Appendix for PCA Mat® Contours And Analysis Calculations~

C.3.4.2.F Other Mat Foundation Design Considerations

One of the major concerns addressed on the project site other than poor subsurface conditions was the high water table. As an example in Figure 9, the Boring B-5 Garage Finished Floor Elevation (G.F.F.E.) and groundwater depth is at 429.00 feet and 423.00 feet respectively. With a 4 foot mat foundation there will be an additional 2 feet above the groundwater depth level.

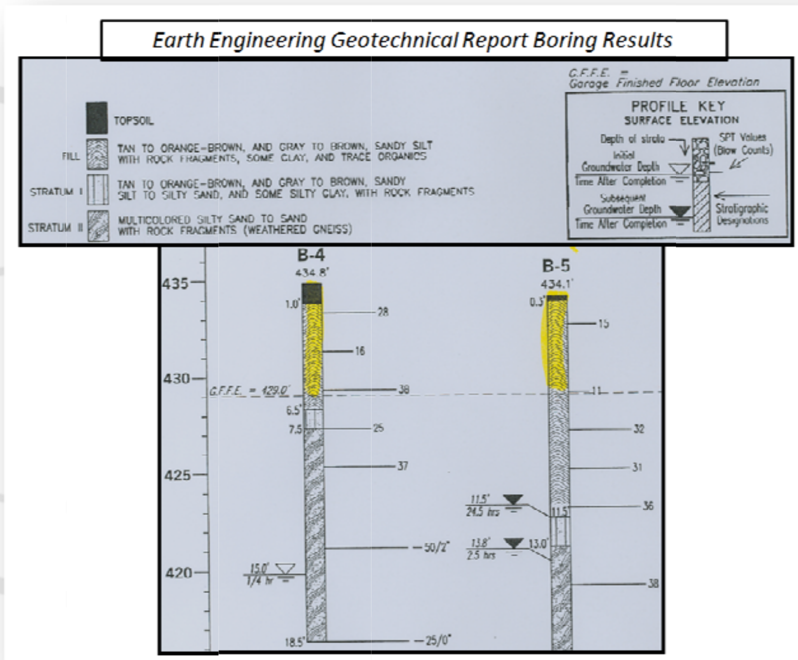


Figure 9: Geotechnical Boring Results from Earth Engineering

More concern by the project team was given for the depth of the groundwater table at B-1, B-6, and B-11. The groundwater table was above the G.F.F.E. and something needed to be done. The project team decided at the beginning of the project to install first the dewatering system and an excellent waterproofing system. This proved to pay dividends when constructing the foundation system. Even though the soil was considered poor, construction workers with the dewatering system were provided a dry area to work in. If the permanent dewatering system was not installed prior to foundation construction, delays and productivity decreases could have resulted. It is in this analysis that the project team did an excellent job concerning waterproofing and the design for the mat foundation concerning groundwater depth should remain the same.

The permanent dewatering system utilizes a gravity flow system with an electrical sump pump backup. The current gravity flow system utilizes a 6” DIA perforated drainage PVC under the 5” slab on grade from a starting elevation of 430.75’ to a gravity outfall of 429.71’. The maximum travel distance is approximately 379’ with a 0.03 in/ft drainage piping slope. The drainage piping currently runs between column and footings and it is recommended that the piping system remain the same but be dropped 4’ to accommodate the mat foundation system. Doing so may result in a greater influx of water and create a greater need for the dewatering and waterproofing system. With this increase in demand

for water removal may create a possible backlog of additional hydrostatic pressure that cannot be forgotten about. With a possibility of increased hydrostatic pressure with the utilization of the same drainage system comes to the responsibility of the designer as to what to do. Through advice of structural engineers and contractors it was recommended that once you start constructing your foundation that the dewatering system must be in effect to reduce the possibility of high hydrostatic pressure on the foundation system. With a permanent dewatering system installed prior to construction, it will alleviate any potential risk during construction of hydrostatic pressure. The following calculation is provided as to give a rule of thumb to the structural load interaction of the Wellington Condominiums Project:

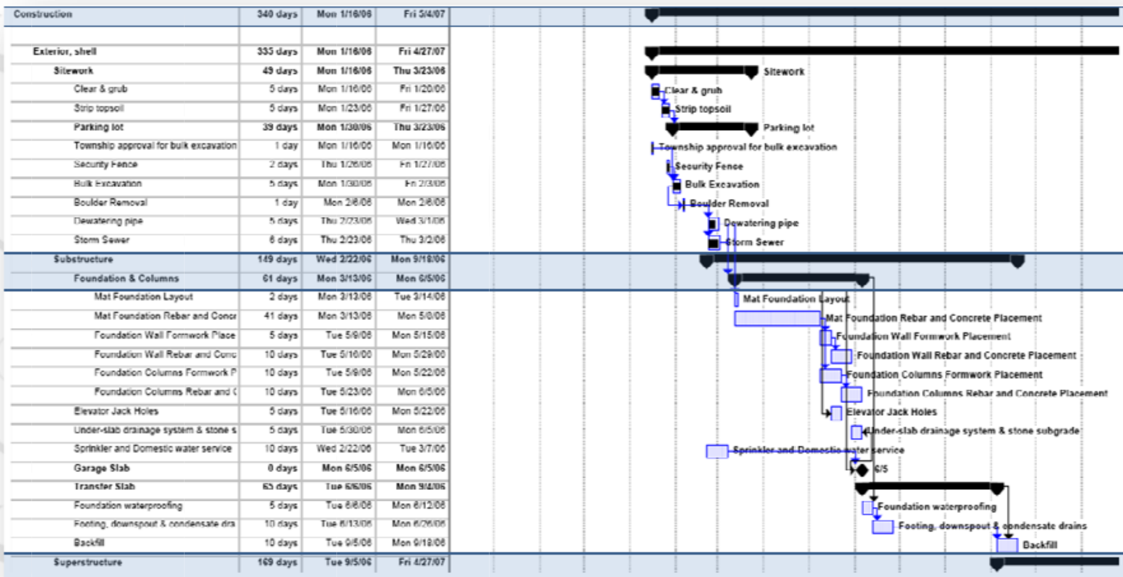
Allowable Bearing Pressure of Soil Conditions:	3.5 KSF
Square footage of Mat Foundation: 259’ x 121’	31,339 SF
Allowable Total Load Transferred to Soil Conditions:	**109,687 K**

Maximum Column Load: 473 K x 36 Columns	17,028 K
Maximum Wall Load: 10 K/FT x 760 FT	7600 K
Total Mat Foundation Load:	**24,628 K**

The mat foundation load is less than the allowable mat foundation load; therefore the foundation has enough strength to allow for the prevalent soil conditions. There is a 4.45 safety factor on this analysis which will allow for any additional hydrostatic pressure and uplift from the soil conditions present. With the permanent dewatering system installed prior to foundation construction and continued throughout the project; there is no additional analysis to consider.

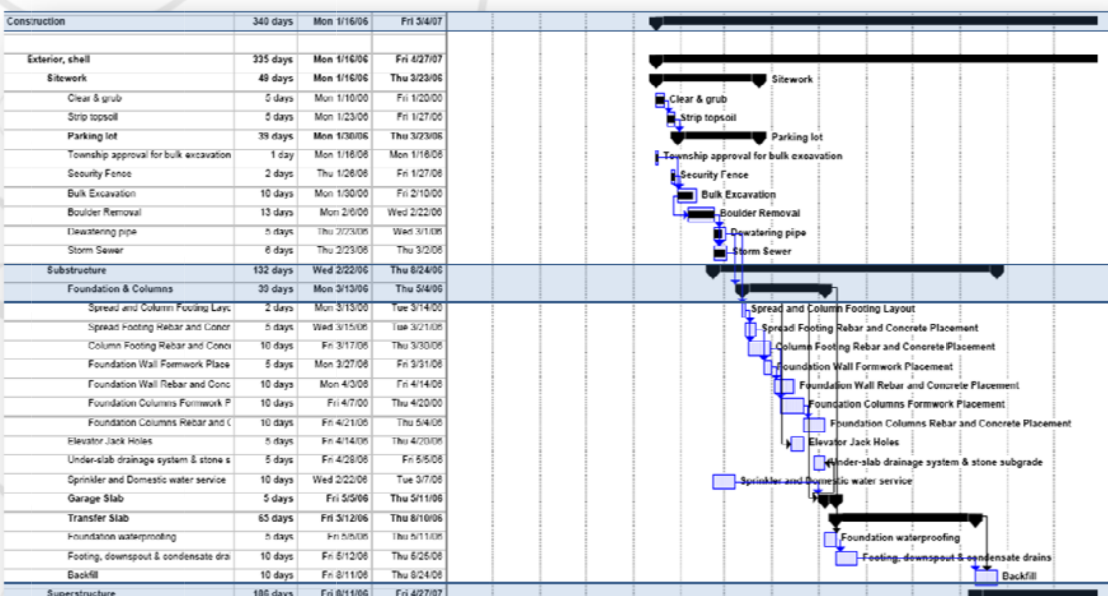
C.3.4.2.G Mat Foundation Schedule Implications

The schedule effect to the implementation of the mat foundation system is shown in Figure 10.A along with the original schedule in Figure 10.B.



Construction	340 days	Mon 1/16/06	Fri 5/4/07
Exterior, shell	335 days	Mon 1/16/06	Fri 4/27/07
Sitework	49 days	Mon 1/16/06	Thu 3/23/06
Clear & grub	5 days	Mon 1/16/06	Fri 1/20/06
Strip topsoil	5 days	Mon 1/23/06	Fri 1/27/06
Parking lot	39 days	Mon 1/30/06	Thu 3/23/06
Township approval for bulk excavation	1 day	Mon 1/16/06	Mon 1/16/06
Security Fence	2 days	Thu 1/26/06	Fri 1/27/06
Bulk Excavation	5 days	Mon 1/30/06	Fri 2/3/06
Boulder Removal	1 day	Mon 2/6/06	Mon 2/6/06
Dewatering pipe	5 days	Thu 2/23/06	Wed 3/1/06
Storm Sewer	6 days	Thu 2/23/06	Thu 3/2/06
Substructure	149 days	Wed 2/22/06	Mon 9/18/06
Foundation & Columns	61 days	Mon 3/13/06	Mon 6/5/06
Mat Foundation Layout	2 days	Mon 3/13/06	Tue 3/14/06
Mat Foundation Rebar and Concr	41 days	Mon 3/13/06	Mon 5/8/06
Foundation Wall Formwork Place	5 days	Tue 5/9/06	Mon 5/15/06
Foundation Wall Rebar and Conc	10 days	Tue 5/16/06	Mon 5/29/06
Foundation Columns Formwork P	10 days	Tue 5/9/06	Mon 5/22/06
Foundation Columns Rebar and C	10 days	Tue 5/23/06	Mon 6/5/06
Elevator Jack Holes	5 days	Tue 5/16/06	Mon 5/22/06
Under-slab drainage system & stone s	5 days	Tue 5/30/06	Mon 6/5/06
Sprinkler and Domestic water service	10 days	Wed 2/22/06	Tue 3/7/06
Garage Slab	0 days	Mon 6/5/06	Mon 6/5/06
Transfer Slab	65 days	Tue 6/6/06	Mon 9/4/06
Foundation waterproofing	5 days	Tue 6/6/06	Mon 6/12/06
Footing, downspout & condensate dra	10 days	Tue 6/13/06	Mon 6/26/06
Backfill	10 days	Tue 9/5/06	Mon 9/18/06
Superstructure	169 days	Tue 9/5/06	Fri 4/27/07

Figure 10.A: Mat Foundation System Schedule



Construction	340 days	Mon 1/16/06	Fri 5/4/07
Exterior, shell	335 days	Mon 1/16/06	Fri 4/27/07
Sitework	49 days	Mon 1/16/06	Thu 3/23/06
Clear & grub	5 days	Mon 1/16/06	Fri 1/20/06
Strip topsoil	5 days	Mon 1/23/06	Fri 1/27/06
Parking lot	39 days	Mon 1/30/06	Thu 3/23/06
Township approval for bulk excavation	1 day	Mon 1/16/06	Mon 1/16/06
Security Fence	2 days	Thu 1/26/06	Fri 1/27/06
Bulk Excavation	10 days	Mon 1/30/06	Fri 2/10/06
Boulder Removal	13 days	Mon 2/6/06	Wed 2/22/06
Dewatering pipe	5 days	Thu 2/23/06	Wed 3/1/06
Storm Sewer	6 days	Thu 2/23/06	Thu 3/2/06
Substructure	132 days	Wed 2/22/06	Thu 8/24/06
Foundation & Columns	39 days	Mon 3/13/06	Thu 5/4/06
Spread and Column Footing Layc	2 days	Mon 3/13/06	Tue 3/14/06
Spread Footing Rebar and Concr	5 days	Wed 3/15/06	Tue 3/21/06
Column Footing Rebar and Conc	10 days	Fri 3/17/06	Thu 3/30/06
Foundation Wall Formwork Place	5 days	Mon 3/27/06	Fri 3/31/06
Foundation Wall Rebar and Conc	10 days	Mon 4/3/06	Fri 4/14/06
Foundation Columns Formwork P	10 days	Fri 4/7/06	Thu 4/20/06
Foundation Columns Rebar and C	10 days	Fri 4/21/06	Thu 5/4/06
Elevator Jack Holes	5 days	Fri 4/14/06	Thu 4/20/06
Under-slab drainage system & stone s	5 days	Fri 4/28/06	Fri 5/5/06
Sprinkler and Domestic water service	10 days	Wed 2/22/06	Tue 3/7/06
Garage Slab	5 days	Fri 5/5/06	Thu 5/11/06
Transfer Slab	65 days	Fri 5/12/06	Thu 8/10/06
Foundation waterproofing	5 days	Fri 5/5/06	Thu 5/11/06
Footing, downspout & condensate drai	10 days	Fri 6/12/06	Thu 6/25/06
Backfill	10 days	Fri 8/11/06	Thu 8/24/06
Superstructure	186 days	Fri 8/11/06	Fri 4/27/07

Figure 10.B: Original Foundation System Schedule

~See Attached Appendix for the Complete Schedule~

From the schedules the important dates to take notice are highlighted in blue and listed as followed for analysis:

Mat Foundation System:

• Construction: 340 Days	Mon 1/16/06 – Fri 5/4/07
• Substructure: 149 Days	Wed 2/22/06 – Mon 9/18/06
• Foundation and Columns: 61 Days	Mon 3/13/06 – Mon 6/5/06
• Superstructure: 169 Days	Tue 9/5/06 – Fri 4/27/07

Original Foundation System:

• Construction: 340 Days	Mon 1/16/06 – Fri 5/4/07
• Substructure: 132 Days	Wed 2/22/06 – Thu 8/24/06
• Foundation and Columns: 39 Days	Mon 3/13/06 – Thu 5/4/06
• Superstructure: 186 Days	Fri 8/11/06 – Fri 4/27/07

Key: Red – Schedule Push Back | Green – Schedule Pull Back

Some interesting results have occurred that are worth noting for the comparison between schedules. The construction of the mat foundation in comparison to the original foundation system will result in as followed:

- Construction: Entire Construction of the project will be the same start and finish date with no increase or decrease in project schedule.
- Substructure: The construction of the substructure will increase by 17 days. The substructure construction will start on the same day but finish at a later time.
- Foundation and Columns: Foundation and Columns will increase by 22 days. The foundation and column construction will start on the same day but finish at a later time.
- Superstructure: The superstructure will decrease in time of construction by 17 days. The start time will be pushed back but will finish on the same day as the original schedule.

What this data is revealing is that there is float within the schedule and the utilization of a mat foundation system will not delay the overall project. There is an increase in parts of the schedule but due to superstructure float was able to take on those extra days of construction and still finish on time. Therefore based on these observations, more analysis must be conducted further as to whether or not to utilize a mat foundation system for the Wellington Condominiums Project.

C.3.4.2.H Mat Foundation Budget Implications

The current budget for the Wellington Condominiums Foundation system is based on the following estimates:

Original Estimate:

• Single Slab Column Footings:	$104, 374
• Wall Strip Footings:	$13,070
• Slab on Grade:	$73,048
• Change Orders	$253,159
Total:	**$443,651**

Mat Foundation Estimate @ 4' Thickness:

- **2007 RS Means Building Construction Data**
- Cubic Yards of Mat Foundation: 259' x 121' x 4' — 4,643 CY
- 2 Crews (C-14C) Totaling:
  - 2 Foreman
  - 12 Carpenters
  - 4 Rodmen (reinf.)
  - 8 Laborers
  - 2 Cement Finishers
  - 2 Gas Engine Vibrators
- Material Cost: $174/CY — $807,882
- Labor Cost: $70/CY/Crew x 2 Crews = $140/CY — $650,020
- Equipment: $0.38/CY/Crew x 2 Crews = $0.76/CY — $3,529

Total: $1,461,431

Mat Foundation Estimate @ 3' Thickness:

- **2007 RS Means Building Construction Data**
- Cubic Yards of Mat Foundation: 259' x 121' x 3' — 3,482 CY
- 2 Crews (C-14C) Totaling:
  - 2 Foreman
  - 12 Carpenters
  - 4 Rodmen (reinf.)
  - 8 Laborers
  - 2 Cement Finishers
  - 2 Gas Engine Vibrators
- Material Cost: $174/CY — $605,868
- Labor Cost: $70/CY/Crew x 2 Crews = $140/CY — $487,480

- Equipment: $0.38/CY/Crew x 2 Crews = $0.76/CY $2,646

Total: $1,095,994

From the estimate analysis, at a minimum 3' mat foundation thickness the cost is 2.5 times over the original foundation estimate. At the preferred 4' mat foundation thickness the cost is 3.3 times over the original foundation estimate. If utilized the 4' mat foundation system, 53% of the total structural system would be put towards the redesign. Also 84% of the original cost would have to be put towards the construction of the mat foundation system.

If the owner were to decide solely on the estimates given here for the project budget as to what system should be utilized. It would not be beneficial to use a mat foundation system based on these estimates.

C.3.4.3 Comparison of the Two Foundation Systems

The comparison of the two foundation systems have been created through a matrix chart based on the owner requirements of which system overall is better for the project.

Compare and Contrast Foundation Systems	Orginal Foundation System					Mat Foundation System				
Categories of Interest	Ratings	Total Weight	Weight	Grade	Comment	Ratings	Total Weight	Weight	Grade	Comment
Material and Equipment	11	3.83	2.87	75.00%	Good	11	3.83	2.49	65.00%	Okay
Change Orders	4	10.83	5.96	55.00%	Poor	4	10.83	7.04	65.00%	Okay
Cost	1	13.83	11.76	85.00%	Great	1	13.83	7.61	55.00%	Poor
Watertable Interaction	3	11.83	7.69	65.00%	Okay	3	11.83	7.69	65.00%	Okay
Schedule	7	7.83	5.09	65.00%	Okay	7	7.83	5.09	65.00%	Okay
Subsurface Interaction	2	12.83	7.06	55.00%	Poor	2	12.83	10.91	85.00%	Great
Load Distribution	6	8.83	5.74	65.00%	Okay	6	8.83	8.39	95.00%	Excellent
Drainage System	5	9.83	7.37	75.00%	Good	5	9.83	6.39	65.00%	Okay
Labor Intensive	8	6.83	4.44	65.00%	Okay	8	6.83	4.44	65.00%	Okay
Installation	10	4.83	3.14	65.00%	Okay	10	4.83	3.14	65.00%	Okay
Versatility	12	2.83	2.12	75.00%	Good	12	2.83	1.84	65.00%	Okay
Quality Control	9	5.83	4.37	75.00%	Good	9	5.83	4.37	75.00%	Good
TOTAL		100.00	**67.6**		**Okay**		100.00	**69.4**		**Okay**
Average				70.00%					72.50%	

The comparison and contrast of the two foundation systems have been created through a matrix chart based on what was most important through the owner's perspective on a scale of 1-12. Each system would be graded on how well it performs in each of the 12 categories. For instance, the cost for the original foundation system was deemed as a reasonable price and was commented as being great advantage to the project budget. The mat foundation was deemed as poor due to the high cost imposed onto the project budget.

The results have indicated that a score of 67.6% and 69.4% for the original and mat foundation system respectively. Both are indicated as an okay system but it is the mat foundation which should be selected by the owner. This provides an interesting perspective in that the mat foundation even though cost was a number one concern and was over three times the original foundation system; the mat foundation should be perused if given the correct amount of funding availability. The advantages of the mat foundation in subsurface interaction and load distribution create just enough of an advantage to spend the extra money on the system. If however other variables were to change; it could give the possibility of the original foundation system being preferred over the mat foundation system. But with the current information provided, if the amount of funding is available, the mat foundation system should be selected for the Wellington Condominiums Project.