GRAVITY SYSTEM DESCRIPTION

The gravity framing system of the restaurants, Southeast building offices, and residential sections of the building site will consist of almost entirely timber framing. The grocery, parking, and Northern building offices will consist of concrete construction due to span lengths and wall heights.

The floor system for the residential areas will consist of a thin layer of concrete sitting on plywood sheathing atop 11 3/4" TJs that feed into bearing walls (Picture A). These deeper joists will allow for extra insulation to be placed inside the diaphragm and allow for added thermal and acoustic insulation between space uses.

The roof system of the Western building will house multiple planters as well as solar panels. In order to support these additional weights a higher grade of TJ (360) will be required.

The roof system of the Northern Structure that houses the multi story residences above the parking garage will also be built up of engineered joists feeding into glulams that are carried down via timber bearing walls and columns to the structural two way slab that covers the parking and offices.

The roof system of the Southeast structure that houses the offices and restaurants consist of an exposed 2x6 plank system that is supported by glulam beams (Picture B). These beams feed into larger glulam girders that are held up by either columns or bearing walls.

The automated parking garage's gravity system will consist of cast in place concrete shear/bearing walls (Picture C) that support the two way slab above. Seeing as there is no human occupancy in the area, aesthetics were not as important as acoustic insulation and vibration prevention. Being that most of the bearing walls will be below grade to hide the automated parking, the walls will have to be relatively thick and thus will supply sufficient acoustic insulation to the sides.

The grocery's and parking's gravity system will consist of a two-way slab (Pictures D& E) in order to better resist the irregular bearing wall placements of the floors above.

PHOTO SOURCES: (A) WWW.NACHI.ORG (B) WWW.APAWOOD.ORG (C) WWW.BASEMENTEXPO.CO.UK (D) WWW.STUDYBLUE.COM (E) WWW.EVSTUDIO.COM
The lateral systems of the building site combine two different systems: concrete shear walls (Picture B), and timber shear walls (Picture A). The structures on the North and West borders of the site will feature a hybrid system of timber construction on the upper floors, and concrete into the lower floors. The Southeastern corner structure however will feature a solely timber shear wall system.

The timber shear wall lateral system will be made up of a diaphragm consisting of engineered joists, glulam beams for longer spans and collectors, and plywood sheathing. This is a typical wooden framed diaphragm system that will feature continuity ties and sufficient lateral connection hardware to create a complete load path to the timber shear walls. The residential units of the North and Western buildings will feature sufficient wall lengths to resist all found lateral forces. In the Northern building that features apartments with multiple levels, additional shear walls will be required to support the sub diaphragms created.

The Northern and Western Buildings will feature shear walls with plywood sheathing located primarily on the exterior of individual housing units to take advantage of the long straight walls void of openings. For interior walls separating living spaces there are thicker walls featuring two rows of 2x4's with a 3/4" airspace to provide an acoustic barrier. This means the shear walls will have sheathing on the exterior of both these rows. Once the lateral loads have been resisted by the timber shear walls, they need to be brought down to the ground. For the Northern and Western buildings the transition needs to be made into a concrete structural system. In order for this transition to happen the timber shear walls must be sufficiently attached to a two way slab (Picture C). This slab must be thick enough to take all of the forces from the above stories and transfer those into the concrete shear walls below.

For the Southeastern building the loads will be relatively light and the building will feature numerous walls that will be sufficient for resisting all the necessary forces. The main difference of this structure compared to the rest of the site is that roof diaphragm will be made up of plywood sheathing attached to 2x6 planks laid flat on glulams spanning the full roof.
The foundation system will be relatively challenging as there will be several height changes as well as structural material changes throughout the site.

Northern Building: The Northern Building will feature the most complicated foundation on the entire site. This structure will house the automated parking system about 2 stories below grade, several offices, and residences on the upper levels. For the area that houses the parking structure that is the northern most part of the site, a specialized foundation system has been defined by the parking system manufacturer, Automotion. However, due to poor soil conditions, it is possible that the suggested foundation dimensions will need to be overhauled and redesigned to span a wider area and possibly deeper. Being that this foundation steps so far down from the adjacent foundation, a step foundation will have to be installed to prevent differential settlement problems. Another provision that will be taken is the mat foundation for the southern half of the Northern Building will have to be connected to the retaining wall of the parking structure in order to prevent any sort of pounding damage that may occur.

Western Building
The Western Building will utilize a simple mat foundation. The mat will not change heights and will be 16" thick and will be the simplest of the three.

Southeastern Building
The Southeastern Building will also be a mat foundation but will step up at different sections of the structure. The further North the building is, the higher the foundation goes to better match the slope of the site. However, each of the separate foundations will be 12"
The system: The automated parking system for the site will utilize the LPM Parking System by Automotion Parking (TM). This system utilizes 3 below grade rows (Picture C) and 1 above grade row to house and store 48 cars safely and out of sight.

How the system works: Patrons will drive onto the on ramp from Broad St. into an entry area. When prompted, they will drive into the car receptacle, remove all necessary items and walk out. Once activated, the car will rotate 180 degrees (Picture B) and the platform is lowered into the storage area. The car will be transferred onto a center track system which will find an empty space and slide the car into that space. When the car is needed again, the patron will activate the system to retrieve the car. The platform is then picked up again by the center track system and lifted back up into the car receptacle.

How it will be supported: The system will be encased in a reinforced concrete structure. This system will not only fully support the impeding horizontal forces from the soil on both sides, but will assist in preventing vibration and noise pollution into the adjacent buildings. The actual parking system will need to be supported by a mat foundation as specified by the manufacturer Automotion. Due to poor soil conditions a mat foundation with additional support may be required.

Features of the system:
Single entry access point
Mostly below grade
Saves space
Hides unsightly system and allows for architectural facade.
48 Spaces
GRAVITY SYSTEM SELECTION

The selection of the gravity system is the result of a collaboration of many different facets and considerations that have guided the project.

Building Program

Of these deciding factors none is more important than the building program. The goal of the site is to create a mixed use collaborative live, work, shop, and dine complex that will cater to the Railroad District of San Luis Obispo. In doing so the building materials should reflect its goals as well as its surroundings.

The layout of the different building uses have guided the materials used for the structures. For the residential areas the shorter building spans allow for timber framing to be used as the numerous intermediate walls will supply sufficient support. For the grocery store in the Western building, higher ceilings and longer spans will require a different building material than timber, therefore a concrete two way slab will be used to meet these requirements.

The concrete slabs that encompass the parking structure serve as not only flooring

Aesthetics

For the Southeastern building the architect has requested an exposed timber ceiling that will employ an industrial aesthetic. Because of this a plank and beam system will be used. The rest of the site will utilize designed wall and ceiling coverings such as gypsum board.

The flat concrete slab over the Northern Building offices and the grocery will allow for a consistently higher floor to ceiling height which is considered to be more aesthetically pleasing.

Fire Resistance

When there are many different building occupancies adjoined together, proper fire resistance will be required. For primary fire protection of the structural components, the entire building will utilize a sprinkler system. This will allow for lower hour partitions to be required for the structure.

All flooring systems in the multi story buildings will feature at least a thin layer of non combustible concrete which will assist in preventing the spreading of fire from floor to floor.

Sustainability

Timber framing has become more and more sustainable with the introduction of engineered lumber. The use of TJI's means the wood being used will be more structurally efficient than typical dimensional lumber. Trussjoist also manufactures many different grades of TJI that will allow for different strengths to be used for similar sized members. The concrete two way slabs use significantly less formwork and will therefore use less resources to construct than a typical beam and slab system.

Constructibility

A driving concern of any project is how well and efficient and cheap the actual project will actually be built. Some of the benefits of having a concrete and timber hybrid sight is that there are only 2 professions need to be hired to build the complex, and they can be building in tandem. The concrete workers can come in first to lay the foundations and retaining walls for the parking system. Then, while the parking system is installed the foundations can be laid for the rest of the site.

The surrounding neighborhood will be a tight fit for most construction equipment so having the individual material contractors work one at a time will be necessary, and this design inhibits this.

Cost

An additional benefit to timber construction is also that it is significantly cheaper than a full concrete or steel construction building. Engineered lumber proves to be a great way to get the most strength for the amount of money used.

The concrete two way slabs may use more concrete than its beam and girder counterpart, but the form work needed for the construction costs so much less that it is actually a cheaper solution.

Summary

A hybrid timber and concrete structure will best meet the building program. This system gives the architect a lot of freedom to create an ever developing design before construction begins with sufficient flexibility.
LATERAL SYSTEM SELECTION

When selecting the lateral system of a structure the most prominent deciding factor of which system to use is the building material itself.

Building Program

The building program works in favor of a timber concrete hybrid system very greatly. The lower levels of the Northern and Western Buildings will supply more than enough exterior walls to meet the lateral requirements of the site. Only 10' of concrete walls are needed for the Western Building and only 15' of concrete shear walls are required for the Northern Building. This will allow the architect more flexibility in wall placement when a final design iteration will occur. As for the timber shear wall residential areas in the multi story buildings, as well as the Southeastern Buildings, many partition walls will be supplied to provide nearly double the necessary wall lengths. Again, because of this, wall openings will have more flexibility while the design develops.

Seismic Performance

According to ASCE-7-10 the buildings on this site have certain requirements when the site is of seismic design category D. Being that the desired height is 42' the seismic force-resisting system have to be checked for code compliance. Being that timber shear walls under seismic codesign category D can only reach 65', the timber shear wall system is more than sufficient. The concrete shear wall system is required to be made of special reinforced concrete shear walls as no other concrete walls will meet ASCE 7-10 Table 12.2-1 compliance.

Compatibility with Gravity System

For the majority of the building that is of timber construction the clear choice is to have the lateral force resisting system consist of timber shear walls. Seeing as the floor to floor heights are fairly typical and not 20 to 30 feet high, utilizing heavy timber framing with braced frames would be an unnecessarily costly method. However, timber shear walls will not satisfy the entirety of the site as the two areas that a concrete two way slab will make up the gravity system for will require stronger support in that of concrete shear walls.

Cost

Shear walls are considered one of the cheaper options when it comes to choosing between braced frames and moment frames. Being that braced frames and moment frames are not able to be built of timber and adding another material to the project would lead to more issues, timber shear walls would be the correct choice.

For the concrete lateral system, shear walls are a better choice than moment frames due to how much cheaper it would be as well as sufficient lengths of exterior walls.

Summary

The lateral force resisting systems should be made entirely of shear walls due to the building program supplying sufficient wall lengths in every direction needed to be a code compliant lateral system.
FOUNDATION SYSTEM SELECTION

Primary Foundation
The primary foundation system of the site will be a mat foundation. The reason for this is mainly to compensate for the poor soil conditions. The site is made up of a very expansive clay which would require significant soil replacement to require a less excessive foundation system.

Parking Foundation
The foundation for the automated parking system is a customized mat footing that will conform to Automotion's specifications. In addition, a step foundation (Picture A) will be necessary to connect the very deep foundation to the surface. Due to such an excessive dramatic drop in height, diagonal and straight braces will be needed to be placed in between the sides of the excavation during construction.

Excavation
The site will require a lot of soil to be excavated, and most likely with further calculations new soil will need to be replaced to improve bearing capacity. The site sits on incredibly expansive soil with a high water table running through it so a mat foundation is a great way to assist with preventing of differential settlements.

The excavation for the Northern building will require a pile and lagging temporary retaining wall in order to take out 20+ feet of soil from such a narrow area. A similar excavation would probably also be required for the northern half of the Western Building.

Environment
The site is located in a very quiet residential/retail area. The introduction of a deep foundation system will most likely cause a lot of noise, vibration, and utilize large, noisy machinery that would disturb the neighbors. In order to prevent these disturbances that would cause locals to contest the construction of the complex, which would also hurt the architect's bid to push the height limit of the site.

Summary
A mat foundation will be used for the entirety of the site due to poor soil conditions. However, the parking structure will require a specialized foundation to support the automated parking that is at the specs of manufacturer.
GRAVITY SYSTEM CONFIGURATION

Level 0

Level 1

Level 2

Level 3

Height Limit

Level 4

Timber Bearing Wall
Concrete Bearing Wall
Concrete Column
Timber Column
Disclaimer: Due to unfinished design, the lines on these diagrams simply state where the shear walls can be placed, after wall openings are designed.
FOUNDATION SYSTEM CONFIGURATION

12" Thick @ 10'-0"

12" Thick @ 8'-0"

12" Thick @ 7'-6"

12" Thick @ 6'-0"

See Parking Manufacturer @ -7'-0"

16" Thick @ 0'-0"

12" Thick @ 0'-0"

12" Thick @ 7'-6"

12" Thick @ 6'-0"
The Mechanical Parking will feature an Automotion LPM System that will house 48 cars. Drivers will enter from Broad Street and enter the platform. The platform will rotate the car and place it into the parking system below for storage. When the car is queued to leave the parking system will pick up the platform and send it back into the turntable.

Additional parking for the site will be located across Broad Street as a park share with the bank.
GRAVITY SYSTEM CALCULATIONS

Western Building Weights
<table>
<thead>
<tr>
<th>Roof Weights</th>
<th>Square Footage (ft²)</th>
<th>4200</th>
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<tbody>
<tr>
<td>Green Roof</td>
<td>Weight (psf)</td>
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<tr>
<td>Typical Dead Load</td>
<td>Wall Length (ft)</td>
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<td>Total Roof Weight (k)</td>
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Third Floor Weights
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<th>Roof Weights</th>
<th>Square Footage (ft²)</th>
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<tbody>
<tr>
<td>Layer</td>
<td>Weight (psf)</td>
<td>11.5</td>
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</tbody>
</table>

Typical Dead Load
| Total       | Wall Weight (lb)     | 84180 |
| Live Load   | 3rd Floor (lb)       | 84000 |
|             | Total Roof Weight (k) | 368.98|

Second Floor Weights
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<td>Layer</td>
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<td>Live Load</td>
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Concrete Two Way Slab Design

Main Trusses 32' 6" 6" - usable rough 32' 6"
Length 60" = 21 1/2" (Assume 12" for conservatism)

TONGUE AND GROOVE ROOF DECKING

<table>
<thead>
<tr>
<th>Nominal Thickness</th>
<th>Allowable Roof Limit by Bending</th>
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<tbody>
<tr>
<td>2&quot;</td>
<td>8000 lb/ft²</td>
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Southern Building Weights
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<td>Tributary Height (ft)</td>
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<tr>
<td>Typical Dead Load</td>
<td>Wall Weight (psf)</td>
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</tr>
<tr>
<td>Total</td>
<td>Roof Weight (lb)</td>
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<td>Live Load</td>
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Northern Building Weights
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<td>Typical Dead Load</td>
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Third Floor Weights
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<td>3rd Floor (lb)</td>
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<td>Live Load</td>
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<td>Total Roof Weight (k)</td>
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Second Floor Weights
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<td>Timber Walls</td>
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<td>Typ. Dead Load</td>
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<td>Total</td>
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<td>Total Roof Weight (k)</td>
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Guadalupe Calls

Length 20' 3" Width 20' 3"
Length 50' 45 Pcs

® = (50' 45') x (50')² / 8
= 2600 ft²
= 216F-28
= 4500 lbs
= 2600 lbs
= 225 lbs
Use 1 1/2" 5/8 216F-28

South Eastern Building Trusses And Steel Plate System
8" Span, Assume Single Span Configuration
Dead Load = 25 psf
Live Load = 20 psf
From ASD Table 2, Bending Steel Required 1000 psf Assume 1000 needed
Use Steel M-212-10-112 Metal Web & Better

Use 1/2" 5/8 216F-28
**LATERAL SYSTEM CALCULATIONS**

### Northern Building
- **Weights**
  - Floor: Weight (k) Sds 0.70
  - Roof: 162.60 R 6.00
  - 3rd Floor: 164.10 le 1.00
  - 2nd Floor: 1175.34 Cs 0.12
  - Total: 1506.12 V (k) 175.97
- **Shear Strength (k/ft)**
  - Roof: 5365.8 33
  - 3rd Floor: 3868.14 23
  - 2nd Floor: 11753.4 10
  - Total: 20987.34

### Western Building
- **Shear Force Sum**
  - Roof: 44.99 44.99 Timber 0.49
  - 3rd Floor: 11.34 22.42 Concrete 20.028
  - 2nd Floor: 98.54 175.97
  - Total: 175.97

### Southeastern Building
- **Weighs Supplied**
  - Western Building
  - Floor: N/s 25.60 25.60
  - 3rd Floor: 25.80 25.80
  - 2nd Floor: 25.60 25.60

**Concrete Shear Wall Strength**

\[
V_c = \frac{3.3}{\sqrt[6]{0.5}} \times 8'' \times \frac{1000}{3} = 1669 \text{ ft/ft} = 20.036 \text{ ksf}
\]
Punching Shear Calls

*Western Building*

\[ V_0 = 4 \cdot \sqrt{3} \cdot b \cdot t \]
\[ b_0 = 4 \cdot \text{diam} + 4 \cdot d = 4 \cdot 12 + 4 \cdot 4 = 64 \]
\[ V_{\text{max}} = 150 \% \]
\[ 150 \cdot 64 = 4 \cdot \sqrt{4000} \cdot 9d + 2d^2 \]

\[ d = 9'' + 3'' \text{ cover} + 4'' \text{ assumption} = 16'' \text{ thick} \]

Punching Shear will be considerably less for the Southern half of the Northern building and the Southeastern building. A 12'' slab is used as an estimation point to provide wiggle room as the project develops.