Broad Street Plaza Architectural and Structural Design

A Senior Project

Presented to:
Faculty of the Architecture and Architectural Engineering Department
California Polytechnic State University, San Luis Obispo

In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Science

By
Madison Busby and Jenny Nguyen

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LETTER TO CLIENT | EXECUTIVE SUMMARY

4 JENNY NGUYEN | MADISON BUSBY 2115 BROAD STREET | SAN LUIS OBISPO ARCH 453 | ARCE 415 WHITE | NUTALL

DEAR MS. WHITE,

THANK YOU FOR GIVING US THE OPPORTUNITY TO EXPRESS OUR CREATIVITY THROUGH THE DESIGN OF THIS PROJECT. IT HAS BEEN A PLEASURE CREATING A PROJECT FOR THE UNIQUE LITTLE CITY OF SAN LUIS OBISPO THAT WILL BRING THE COMMUNITY TOGETHER AS WELL AS CREATE AN ECLECTIC ENVIRONMENT THAT WILL BORDELINE MULTIPLE DIFFERENT PORTIONS OF THIS CITY.

JEMA ARCHITECTS IS A FIRM CONSISTING OF ONE FOURTH YEAR ARCHITECTURAL ENGINEERING STUDENT AND ONE FOURTH YEAR ARCHITECTURAL STUDENT FROM CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO.

WE ARE HAPPY TO PRESENT THE OUTCOME OF OUR INTEGRATED DESIGN PROCESS PRESENTED WITHIN THIS PROJECT. IN THIS PACKAGE, YOU WILL FIND IMAGES DEPICTING BOTH DESIGNS FOLLOWED BY A BRIEF DESCRIPTION OF OUR INTENT. OUR DESIGN INCLUDES RESIDENTIAL PROGRAMS, COMMERCIAL AREAS, OFFICES, AND A SHARED COMMUNITY CENTER. WE HOPE THESE DESIGNS MEET YOUR EXPECTATIONS; AND IF THEY DO NOT, WE ARE MORE THAN HAPPY TO COLLABORATIVELY RE-DESIGN FOR YOUR BEST INTEREST.

CHEERS!
JEMA ARCHITECTS
{JENNY & MADISON}

THE MAJOR FOCUS OF THIS DESIGN WAS TO CREATE AN ENVIRONMENT THAT WILL BRING THE COMMUNITY TOGETHER WHILE STILL GIVING THE RESIDENTIAL SPACE ITS PRIVACY. THIS WAS ACCOMPLISHED BY CREATING AN OUTLET FOR PEDESTRIANS AND BIKERS THROUGH THE OPEN COURTYARD. WITHIN THIS COURTYARD ARE SHARED OPEN SPACES AND GARDENS. WE ALSO KePT THE RESIDENTIAL UNITS CLOSER TO BRANCH STREET AND TUCKED NORTH ABOVE THE RESTAURANTS ON THE SECOND FLOOR. THESE NATURAL URBAN SPACES ARE INTERTWINED WITH THE PROGRAMS SUCH THAT THEY CREATE A CONNECTED ATMOSPHERE WITH THE BUILDINGS.

OUR PROGRAM PROMOTES HEALTHY LIVING BY PROVIDING BIKE RACKS, EASY ACCESS TO WALKWAYS, LIMITED PARKING, AND ON SITE LOCAL PRODUCE MARKET. ALL PARKING ARE HIDDEN UNDERGROUND AND COMPLETE MECHANICAL.

IN ORDER TO WORK THE SURROUNDINGS, ALL OF OUR BUILDINGS ARE UNDER THE 35’ MAXIMUM CONSTRAINED BY THE CITY CODES. AN UNDULATED FACADE AND WOOD CONSTRUCTION ALLOWS THE APARTMENTS TO BLEND INTO THE REST OF BRANCH STREET. WE DEALT WITH THE SITE SLOPE BY CREATING DIFFERENT STEPS FOR DIFFERENT SITE USES. OUR PROGRAM PUSHES DENSITY, BUT ALL WITHIN REASON.
CLIENT GOALS | DESIGN APPROACH

PROGRAMATIC BREAKDOWN:

[5] ONE BEDROOM
[3] TWO BEDROOM
[3] THREE BEDROOM
[8] STUDIO UNITS
[3] OFFICES
[2] RESTAURANTS
[1] CAFE
[1] MARKET
[1] RESIDENTIAL MECHANICAL PARKING
[1] COMMERCIAL MECHANICAL PARKING

- ALLOW FOR BOTH RESIDENTIAL AND COMMERCIAL PROGRAMS TO COEXIST WITHOUT INTRUDING ONTO ONE ANOTHER (EXCLUDING THE SHARED COURTYARD)

- CREATE A PLACE OF REFUGE WHERE PEDESTRIANS AND BIKERS CAN ESCAPE FROM THE BUSY BROAD STREET TRAFFIC

- INCORPORATE SUSTAINABLE ELEMENTS WITH EACH USE (ROOFTOP GARDEN, LOCAL FARMER’S MARKET)
The site is located within the South Broad Street Area neighborhood, which is bounded by High Street, Union Pacific Railroad, Orcutt Road, and Broad Street on the four cardinal directions, respectively. Located in the center of the city, this neighborhood is adjacent to Highway 101, Downtown San Luis Obispo, the Historic Railroad District, and Little Italy.

Since Broad Street is a main transportation corridor that runs continuously from Downtown SLO down south towards Arroyo Grande, Pismo Beach, and Grover Beach, the area is close to many shopping stores, schools, employment centers, and major transportation facilities like public transit stops, the county regional airport, and Amtrak train stations.

This area currently houses various types of buildings and programs. Along with the mixed-density residential, small scale retail and restaurants, there are plenty of manufacturing and industrial services along the street, including parts that were originally developed in the Imperial Addition (1888). Over time, zoning changed and non-residential uses appeared while most of the old neighborhood was demolished. The few remaining homes from that period is located between Humbert Avenue and Woodbridge Street.

In 2012, the South Broad Street area has been described as a neighborhood in transition with funky, diverse, and/or dilapidated culture due to the mix of older commercial and residential buildings, lack of public facilities, and underutilized properties.
Increase the percentage of all trips made by bicycle within San Luis Obispo. Establish and maintain an integrated system of bikeways and parking facilities that enables safe and convenient bicycling, with an emphasis on travel to employment centers, commercial districts, schools and recreational destinations.

Advocate bicycling as a way of addressing climate change, preserving clean air, reducing traffic congestion and noise, conserving land and energy resources, and promoting good health.

Develop financial partnerships with other organizations when the resultant bicycle facilities or activities provide significant benefits to San Luis Obispo residents.
CLIMATE ANALYSIS
SAN LUIS OBISPO, CA

Most of the wind direction is W - NW throughout the year.
During Fall and Winter the wind also has a E - SE direction.
SLO is sunny most of the year.
Some strategies:
- Passive solar heating
- Entrance of winter light
- Summer shading
- Natural Ventilation

Precipitation in San Luis Obispo is higher during winter and early spring.
Most of the noise comes from Broad Street.
### Site Analysis

**2115 Broad St**

**Land Use Designation**
- Neighborhood Commercial | C-N

**Zoning Regulations**

#### Density

- **Average Cross-Slope**
  - **Maximum Density Allowed (density units per net acre)**
    - Land Use Designation
      - R-1
        - 0-15
        - 16-25
        - 26+
      - R-2, O-C., N, C-T
        - 0-15
        - 16-25
        - 26+
      - R-3
        - 0-15
        - 16-25
        - 26+
      - C-R, C.D., G-C
        - 0-15
        - 16-25
        - 26+
      - C-S, M
        - 0-15
        - 16-25
        - 26+

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<th>R-1</th>
<th>R-2, O-C., N, C-T</th>
<th>R-3</th>
<th>R-4</th>
<th>C-R, C.D., G-C</th>
<th>C-S, M</th>
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<td>24</td>
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<td>16-25</td>
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<td>26+</td>
<td>1</td>
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<td>3</td>
<td>4</td>
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#### Density Bonus
- **(low/moderate-income housing)**
  - Percentage Moderate-Income Units
  - Percentage Density Bonus

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<th>Percentage Moderate-Income Units</th>
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**Development Standards**
- **Maximum Height:** 35 feet
- **Maximum Coverage:** 75%
- **Maximum Floor Area to site ratio:** 2.0

**Occupancy Standards**
- 25 max population density/net acre
- 12 density units/net acre

**Packing**
- 2 spaces per unit

**Bicycle Parking**
- Spaces as a percentage of required auto spaces*
- Minimum short-term bicycle spaces**
- Minimum long-term bicycle spaces***

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<tr>
<td>15%</td>
<td>50%</td>
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* *Requirements apply to uses that require 10 or more vehicle parking spaces. When less than ½ space is calculated, one space is required*
** *“Short-Term” bicycle parking is used by visitors to multi-family housing and by patrons of commercial uses. Bicycle racks are used to satisfy this need*
*** *“Long-Term” bicycle parking is used by employees of commercial uses and by residents. Fully enclosed lockers are used to satisfy this need. Lockable rooms reserved for bicycle storage and secured parking areas managed by attendants are other acceptable forms. Bicycles shall be parked vertically or horizontally with at least the rear tire resting at floor level. Additionally, bicycle lockers or interior space within each dwelling or accessory structure have to be provided for the storage of at least two bicycles per unit*
RESIDENTIAL ROOF GARDEN

JENNY NGUYEN | MADISON BUSBY  2115 BROAD STREET  |  SAN LUIS OBISPO   ARCH 453  |  ARCE 415   WHITE  |  NUTALL

17
MID-LEVEL COURTYARD
STEEL

STEEL FRAMING WILL BE USED FOR COMMERCIAL AND OFFICE SPACE. IT WILL HAVE WIDE FLANGE BEAMS, GIRDERNS, AND COLUMNS WITH BOLTS AND PLATES FOR CONNECTION.

THERE WILL BE VERCO STEEL DECKING TOPPED WITH A 3” LIGHT WEIGHT CONCRETE SLAB WHICH WILL PROVIDE A SOUND/FIRE BARRIER. ALTHOUGH STEEL IS MORE EXPENSIVE AND REQUIRES SPECIAL SKILLS TO INSTALL, IT WILL ONLY BE USED FOR A SMALL PORTION OF THE PROJECT AND IS IMPORTANT FOR ACHIEVING THE DESIRED ARCHITECTURAL STYLE. A LARGE PORTION OF STEEL IS REUSED AFTER A BUILDING IS TORN DOWN, MAKING IT SUSTAINABLE.

CONCRETE

CONCRETE WAS THE OBVIOUS CHOICE IN GRAVITY SYSTEM BECAUSE IT WILL BE UNDERGROUND, AND THE COLUMNS WILL BE HOLDING UP AND HELD UP BY LARGE CONCRETE SLABS. SO CONSTRUCTABILITY AND STRENGTH WISE IT IS THE ONLY MATERIAL THAT MAKES SENSE.

CMU

CMU BEARING WALLS WILL BE PAIRED WITH BOTH WOOD AND STEEL GRAVITY SYSTEMS WHERE THEY ARE ALREADY BEING USED FOR LATERAL SYSTEM.

WOOD

WOOD FRAMING WILL BE USED FOR RESIDENTIAL AND OFFICE SPACE. IT WILL CONSIST OF A LIGHT FRAM WOOD SYSTEM WITH TJI JOISTS. COLLECTORS AND BEAMS (IF NEEDED) WILL BE PSL. BEARING WALLS WILL CARRY THE ROOF AND FLOOR LOADS.

WOOD FRAMING WAS CHOSEN FOR RESIDENTIAL, OFFICES, AND SMALLER COMMERCIAL BUILDINGS BECAUSE IT IS THE MOST COST EFFECTIVE.

ESPECIALLY FOR RESIDENTIAL, WOOD CONSTRUCTION IS ALSO THE ‘WARMEST’ MATERIAL COMPARED TO STEEL AND CONCRETE.

TRELLIS IS ALSO THE BEST MATERIAL CONSTRUCTABILITY WISE. THEREFORE THERE WILL BE PLENTY OF WORKERS CAPABLE OF COMPLETING THIS PORTION OF THE PROJECT WITH LITTLE INSTRUCTION WHILE STILL PRODUCING QUALITY WORK. WOOD CAN ALSO BE REUSED, MAKING IT SUSTAINABLE.

THERE WILL BE VERCO STEEL DECKING TOPPED WITH A 3” LIGHT WEIGHT CONCRETE SLAB WHICH WILL PROVIDE A SOUND/FIRE BARRIER. ALTHOUGH STEEL IS MORE EXPENSIVE AND REQUIRES SPECIAL SKILLS TO INSTALL, IT WILL ONLY BE USED FOR A SMALL PORTION OF THE PROJECT AND IS IMPORTANT FOR ACHIEVING THE DESIRED ARCHITECTURAL STYLE. A LARGE PORTION OF STEEL IS REUSED AFTER A BUILDING IS TORN DOWN, MAKING IT SUSTAINABLE.

CMU BEARING WALLS WILL BE PAIRED WITH BOTH WOOD AND STEEL GRAVITY SYSTEMS WHERE THEY ARE ALREADY BEING USED FOR LATERAL SYSTEM.
Gravity Systems

The gravity systems were configured based on span, potential use of space, and surrounding structure.

For the residential, because the interior areas are so small, bearing walls will be on the exterior of each unit. The TJI joists will span in the shortest direction. For offices, there will need to be a couple columns on the lower floor, which then requires PSL beams in the shorter direction, and TJI joists spanning the longer direction. This is to reduce the ceiling height as much as possible.

The interior columns line up with the bearing walls above to reduce loading on the beams and girders. Again, to reduce ceiling height, beams will span the longer directions while girders in the shorter direction. CMU bearing walls are used where openings are not needed.

Sizing

A typical TJI joist (TJI 230 14") is used for all the residential and office spaces unless noted otherwise. Simpson T5 hangers will support joists. When columns are needed, a HSS 4x4x1/4 steel column will be used.

In the commercial building, steel girders are W14x61 and beams are W14x34 while columns are W8x31.
TIMBER SHEAR WALL [RED]

Wood shear walls include 2x6 studs spaced 16" O.C. with structural plywood sheathing with nailing spaced according to the strength that is needed, still using the same 10D nails. At each end of every shear wall, there will be HDU2 hold downs.

Timber shear walls will be used in all light framed timber buildings that are not in need of large openings. Bearings will be used at the gravity system for most of the wood framed buildings and can double as shear walls. Other options would be masonry shear walls, but when the load is not too high and with smaller openings.

MASONRY SHEAR WALL [BLUE]

Masonry shear walls will work with wood structures to create a more space efficient shear wall. Because they have more strength per foot, we would be able to use less wall and have more openings. It is made up of 8" CMU which is reinforced based on minimum requirements and calculations.

Masonry shear walls will be used when timber shear walls are too large, not strong enough, or a combination of the two. Masonry shear walls have a lot of strength compared to the weight constuction, allowing them to be smaller in width. They also can be aesthetically pleasing, especially in slo area.
CONFIGURATION

THE LATERAL SYSTEM WAS CONFIGURED BASED ON CENTER OF MASS AND RIGIDITY, OPENINGS, ASTHETICS, AND WALL SPANS.

THE WOOD SHEARWALLS WERE PLACED WHERE THE WALL WOULD BE CONTINUOUS HORIZONTALLY AND VERTICALLY TO TRY AND AVOID EXCESS DRAG AND LOAD TRANSFER BEAMS. FOR THE RESIDENTIAL ABOVE THE COMMERCIAL AREA, THE SHEARWALLS LINE UP WITH SYSTEMS BELOW WHEN POSSIBLE. EXTERIOR SHEAR WALLS WILL NEED TO BE ADJUSTED BASED ON FINAL WINDOW AND DOOR PLACEMENTS.

CMU SHEARWALLS ARE PLACED ALONG THE LOWER PORTION OF THE COMMERCIAL AND OFFICE BUILDING IN ORDER TO ALLOW LARGER OPENINGS. WE ARE PLANNING ON HAVING LARGE WINDOWS AND A GARAGE DOOR, AND THE CMU WALLS BEING MORE COMPACT WILL PROVIDE THE SPACE TO ACCOMMODATE THAT.

LATERAL SYSTEM

BLDG 1
NEED 76’ OF WOOD SHEAR WALL IN EACH DIRECTION
NEED 93’ OF MASONRY SHEAR WALL IN EACH DIRECTION

BLDG 2
NEED 56’ OF WOOD SHEAR WALL IN EACH DIRECTION
NEED 44’ OF MASONRY SHEAR WALL IN EACH DIRECTION

BLDG 3
NEED 130’ OF WOOD SHEAR WALL IN EACH DIRECTION
THE PARKING GARAGE WILL BE A REINFORCED TWO WAY CONCRETE STRUCTURE. THE CONCRETE WILL BE REGULAR WEIGHT WITH A STRENGTH OF 4KSI WITH 60KSI REBAR FOR SHEAR AND TENSION REINFORCEMENT. A BASIC REPRESENTATION OF THE STRUTURAL LAYOUT IS SHOWN IN FIGURE 1.

THE PARKING IS UNDERGROUND, MAKING THE WALLS BEARING WALLS THAT WILL NEED TO SUPPORT THE SURROUNDING SOIL.

USERS WILL PARK THEIR CAR INTO A GARAGE LIKE FEATURE ABOVE GRADE. ONCE THEY HAVE ENTERED THEIR INFORMATION, THE CAR WILL BE PARKED COMPLETELY MECHANICALLY. THERE WILL BE TWO ELEVATORS AT EACH ENTRANCE SO PEOPLE CAN ENTER/EXIT WITH EASE. A SMALL STRUCTURE WILL HIDE THE MECHANICAL SYSTEM.

ONE WILL PARK THEIR CAR BY PULLING INTO A STRUCTURE SIMILAR TO FIGURE 2, AND WILL THEN LEAVE THEIR CAR AND RECEIVE A PARKING SLIP. THE CAR WILL THEN BE LOWERED INTO THE SYSTEM SHOWN IN FIGURE 3. ONCE THEY WANT TO RETRIEVE THE CAR, THEY WILL NEED TO RE-ENTER THE SLIP AND THE CAR RETURNS TO THE STRUCTURE IN FIGURE 2.

IN THIS FULLY SELF PARKING SYSTEM, EACH SPOT IS 7'0" by 18'-0" AND TWO LAYERS OF PARKING IS JUST UNDER 14' IN HEIGHT.
The parking system was separated into residential and commercial to try and facilitate traffic and keep the residential feeling more private.

The columns in the commercial parking are 18"x18" and line up with the columns from the steel structure above, and all the other parking columns are spaced to allow the mechanical parking.

Residential parking spots needed: 28
Commercial parking spots needed: 64
Total required: 92

Residential parking spots provided: 48
Commercial parking spots provided: 44
Total provided: 92
FOUNDATION SYSTEM

THE EXPANDING AND CONTRACTING NATURE OF THE CLAY SOIL ON THE SITE REMOVES PAD FOOTINGS AS AN OPTION FOR THE PROJECT. A QUICK CALCULATION CONCLUDED THAT THE PAD FOOTINGS WOULD BE SO LARGE BASED ON THE SITE’S POOR SOIL BEARING STRENGTH, THE PAD FOOTINGS WOULD NEARLY BE A MAT FOOTING.

PILES COULD WORK, BUT THEY WOULD HAVE TO BE PRE-DRILLED BECAUSE DRIVEN PILES CAUSE LOUD NOISES AND HEAVY VIBRATIONS THAT MAY DISRUPT SURROUNDING HOMES AND BUSINESSES.

BECAUSE THE SITE MAY HAVE AN UNDERGROUND WATER TABLE, DRILLING MAY ALSO BE AN ISSUE BECAUSE THE WATER MAY FILL THE HOLE, REQUIRING MORE EQUIPMENT AND LABOR.

THIS LEAVES MAT FOUNDATIONS, WHICH WILL REQUIRE EXCAVATION FOR THE UNDERGROUND PARKING AS WELL AS THE LEVELING OF THE SITE. THE MAT FOUNDATION WILL RESIST WATER PRESSURE IN THE SOIL WHILE ALSO BEING RELATIVELY SIMPLE/CONSISTANT TO INSTALL.

A MAT FOUNDATION IS A FOUNDATION SYSTEM THAT COVERS THE ENTIRE FOOTPRINT OF THE PROJECT RATHER THAN JUST BEING UNDER INDIVIDUAL COLUMNS. THE MAT FOUNDATION WILL HAVE 60 KSI STEEL REINFORCEMENT AND WILL BE AT LEAST ONE FOOT IN DEPTH.

WHERE THERE IS UNDERGROUND PARKING, THE FOUNDATION WILL SERVE AS A FLOOR SLAB FOR THE PARKING GARAGE, AND THE ROOF OF THE GARAGE WILL CONTINUE WITH THE ON-GRADE MAT FOUNDATION.

LIKE THE REST OF THE PARKING SYSTEM, THE FOUNDATION WILL USE 4 KSI REGULAR WEIGHT CONCRETE.

SIMILAR TO A PAD FOOTING, MAT FOUNDATIONS TAKE THE POINT LOADS FROM INDIVIDUAL COLUMNS AND SPREAD THEM OUT IN ORDER TO NOT PUT TOO MUCH PRESSURE ON THE SOIL, AS IN THE DIGRAM BELOW. MAT FOOTINGS CAN BE SEEN AS PAD FOOTINGS THAT HAVE BEEN CONNECTED.

IF THE DEPTH OF THE TOP SLAB IS NOT ENOUGH TO RESIST PUNCHING SHEAR, EXTRA DEPTH AND OR REINFORCEMENT WILL BE ADDED AROUND THE COLUMN TO SLAB CONNECTION.
CONFIGURATION

THE FOUNDATION SYSTEM WAS COMPLICATED BY POOR SOIL BEARING PRESSURE, UNDERGROUND PARKING, AND A SLOPED SITE.


MAT FOUNDATION

THE FOUNDATION THICKNESS IS BASED OFF OF PUNCHING SHEAR FROM THE COLUMNS THAT FRAME INTO IT. TO FIND THIS, I TOOK THE COLUMN WITH THE MOST WEIGHT FROM EACH MAT TO FIND A THICKNESS FOR EACH INDIVIDUAL MAT. THIS WILL HOPEFULLY AVOID HAVING UNNEEDED CONCRETE. THE THICKNESS NEEDED WAS 15”.

PARKING CEILING/SLAB

THE CEILING OF THE PARKING STRUCTURE DOUBLES AT A FLOOR FOR INDOOR AND OUTDOOR SPACES. IT WILL BE A TWO WAT SLAB WITH 18” CONCRETE COLUMNS SPACED AT 21’ SUPPORTING IT. ASSUMING A SLAB OF 12” WILL SUPPORT THE DEAD AND LIVE LOAD FROM THE BUILDINGS ABOVE MEANS I DO NOT NEED TO DO EXTRA CHECKS FOR A-TYPICAL COLUMNS AND BEARING WALLS THAT IT SUPPORTS. THE ROOF SLAB WILL BE 12”.

FOUNDATION SYSTEM
The South Broad Street area has been described as a neighborhood in transition with funky, diverse, and/or dilapidated culture due to the mix of older commercial and residential buildings and underutilized properties. In order to create an environment in which people felt safe from the busy Broad Street traffic as well as belonging to the eclectic environment of San Luis Obispo, residential and commercial uses are connected by a common courtyard that encourages cross circulation between both sides. Outdoor patio dining areas and a small performance stage allows for an opportunity to connect with the site and retain visitors. Ground level market opens into in the courtyard to become a farmer’s market for the restaurants and local residents.
RESIDENTIAL UNITS ARE ALONG BRANCH STREET AND ABOVE RESTAURANTS. OFFICES ARE ABOVE THE MARKETPLACE OVERLOOKING THE OUTDOOR DINING PATIO.
WOOD FRAMING DESCRIPTION

Wood framing will be used for a majority of the site. It will consist of a light frame wood system with joists. Joists will be spaced between 16" and 24" and topped with plywood sheathing diaphragm. Collectors and beams (if needed) will be PSL. Bearing walls will be made up of 2x6 sawn lumber spaced at 16" with plywood sheathing, base p and double top plates. Connections will be made with 10d nails for sheathing and 16d otherwise. Simpson connections for beam to wall.

STEEL FRAMING DESCRIPTION

Steel framing will be used for commercial and office space. It will have wide flange beams, girder columns with bolts and plates for connections. Wide flanges will be A992 50 ksi steel. There will be Verco Steel decking topped with a 3" light weight concrete slab which will provide a sound/fire barrier.

LATERAL

TIMBER SHEAR WALL DESCRIPTION

Wood shear walls will include 2x6 studs spaced 16" o.c. with structural plywood sheathing and 4" nailing, still using the same 10d nails. At each end of every shearwall, there will be HDU2 hold downs.

MASONRY SHEAR WALL DESCRIPTION

Masonry shear walls will work with wood/steel structures to create a more space-efficient shearwall. Because they have more strength per foot, we would be able to use less wall and have more openings than a wood shearwall. It is made up of 8" CMU which is reinforced based on minimum requirements and calculations.
The parking system was separated into residential and commercial to try and facilitate traffic and keep the residential feeling more private.

The driver pulls into a residential garage like structure and leaves the car. They then either take a ticket or enter a pin (for residential) and the car will be lowered and parked mechanically. Once below the ground, the car is led down the middle isle and parked on either side and on one of two levels. The entrances are two cars wide to allow two cars to enter/exit at the same time.

The columns in the commercial parking are spaced to allow two or three spots to be uninterrupted.

The parking is underground, making the walls bearing walls that will need to support the surrounding soil.

### Foundation

A mat foundation is a foundation system that covers the entire footprint of the project rather than just being under individual columns. The mat foundation will have 60 ksi steel reinforcement (similar to Figure 1) and will be at least one foot in depth.

Where there is underground parking, the foundation will serve as a floor slab for the parking garage, and the roof of the garage will continue with the on grade mat foundation.

Like the rest of the parking system, the foundation will use 4 ksi regular weight concrete.

Similar to a pad footing, mat foundations take the point loads from individual columns and spread them out in order to not put too much pressure on the soil, as in the diagram above. Mat footings can be seen as pad footings that have been connected.
BROAD STREET PLAZA
STRUCTURAL DOCUMENTS

ARCHITECTS AND ENGINEERS

MADISON BUSBY + JENNIFER NGUYEN
STEEL

Steel framing will be used for commercial and office space. It will have wide flange beams, girders, and columns with bolts and plates for connections. Wide flanges will be A992 50 ksi steel.

WOOD

Wood framing will be used for residential and office space. It will consist of a light frame wood system with TJI joists. Joists will be spaced between 16" and 24" and topped with a plywood sheathing diaphragm. Collectors and beams (if needed) will be PSL.

Bearings walls made up of 2x6 sawn lumber spaced at 16" with plywood sheathing, base plates, and double top plates. Connections will be made with 10d nails for sheathing and 16d otherwise, and Simpson connections for beam to wall.

CONCRETE

Reinforced concrete will be used for the underground parking and for the foundation of the building.

CMU

CMU bearing walls will be paired with both wood and steel gravity systems where they are already being used for the lateral system.

GREEN - STEEL

YELLOW - WOOD

Steel framing will be used in the larger commercial buildings which require long spans and an architectural desire for a more industrial feel. Steel will also allow for larger and more open indoor to outdoor flow, which is an important component of our courtyard. The beam spans are ~30’, and the girder spans are ~ 25’ which would be possible with wood, but would require a much larger structural system, or possibly wood trusses.

Although steel is more expensive and requires special skills to install, it will only be used for a small portion of the project and is important for achieving the desired architectural style.

Steel is also less flammable, which may benefit the industrial kitchen to residential connection. In addition, a large portion of steel is reused after a building is torn down, making it sustainable.

Wood framing was chosen for residential, offices, and smaller commercial buildings because it is the most cost effective. For an example building (shown below) the cost of structural elements for a steel building were 43% higher than those of a wood framed building.

Especially for residential, wood construction is also the most “warmest” material, unlike the industrial feel of steel and concrete. Some of the wood will be exposed to give this effect.

Timber is also the best material constructability wise. Therefore there will be plenty of workers capable of completing this portion of the project with little instruction while still producing quality work. Wood can also be reused, making it sustainable.

A small amount of heavy/engineered lumber will be used for larger spans/architectural appeal in the residential common area.

Concrete was the obvious choice for the parking gravity system because it will be underground, and the columns will be holding up and held up by large concrete slabs. So constructibility and strength wise it is the only material that makes sense.

Concrete is not very reusable in general, but it can absorb heat during the day and release it at night, possibly being a sustainable heat source.

Concrete also is the most sturdy of the materials, which will help prevent vibrations from the mechanical parking. This is important because it is the foundation of every other building.

<table>
<thead>
<tr>
<th>Component/Trade</th>
<th>Total Material Cost</th>
<th>Total Material Cost from Builder's Invoices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steel House</td>
<td>Wood House</td>
</tr>
<tr>
<td>Framing Materials</td>
<td>$9,618.26</td>
<td>$7,125.51</td>
</tr>
<tr>
<td>Features</td>
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<td>$2,473.02</td>
</tr>
<tr>
<td>Total</td>
<td>$10,580.00</td>
<td>$7,372.53</td>
</tr>
</tbody>
</table>
TIMBER SHEAR WALL (RED)

Wood shear walls will include 2X6 studs spaced 16" o.c. with structural plywood sheathing with nailing spaced according to the strength that is needed, still using the same 10d nails. At each end of every shearwall, there will be HDU2 hold downs.

MASONRY SHEAR WALL (BLUE)

Masonry shear walls will work with wood structures to create a more space-efficient shearwall. Because they have more strength per foot, we would be able to use less wall and have more openings. It is made up of 8" CMU which is reinforced based on minimum requirements and calculations.
TIMBER SHEAR WALL

Timber shear walls will be used in all light framed timber buildings that are not in need of large openings. Bearing walls, which will be used as the gravity system for most of the wood framed buildings, can double as shear walls. The other option would be masonry shear walls, but when the loading is not too high and there are only smaller openings, wood shear walls are the best looking, easiest to build, and the most cost effective. I could have also chosen to use cold formed steel instead of wood, but price and popularity in the area made wood my top choice.

MASONRY SHEAR WALL

Masonry shear walls will be used when timber shear walls are too large, not strong enough, or a combination of the two. Masonry shear walls have a lot of strength compared to the weight of wood construction, allowing them to be smaller in width. They also can be aesthetically pleasing, especially in the area. Masonry shear walls were also chosen for the steel construction in place of braced frames or moment frames because of cost, aesthetics, and continuity through the site.
A mat foundation is a foundation system that covers the entire footprint of the project rather than just being under individual columns. The mat foundation will have 60 ksi steel reinforcement and will be at least one foot in depth.

Where there is underground parking, the foundation will serve as a floor slab for the parking garage, and the roof of the garage will continue with the on grade mat foundation.

Like the rest of the parking system, the foundation will use 4 ksi regular weight concrete.

Similar to a pad footing, mat foundations take the point loads from individual columns and spread them out in order to not put too much pressure on the soil, as in the diagram below. Mat footings can be seen as pad footings that have been connected.

If the depth of the top slab is not enough to resist punching shear, extra depth and or reinforcement will be added around the column to slab connection.
The expanding and contracting nature of the clayey soil on the site removes pad footings as an option for the project. Besides that, a quick calculation concluded that the pad footings would be so large based on the site's poor soil bearing strength, the pad footings would nearly be a mat footing.

Piles could work, but they would have to be pre drilled because driven piles cause loud noises and heavy vibrations that may disrupt surrounding homes and businesses.

Because the site may have an underground water table, drilling may also be an issue because the water may fill the hole, requiring more equipment and labor.

This leaves mat foundations, which will require excavation for the underground parking as well as the leveling of the site. The mat foundation will resist water pressure in the soil while also being relatively simple/consistent to install.
The parking garage will be a reinforced concrete structure with a two way system. The concrete will be regular weight with a strength of 4 ksi with 60 ksi rebar for shear and tension reinforcement. A basic representation of the structural layout is shown in Figure 1.

The parking is underground, making the walls bearing walls that will need to support the surrounding soil.

Users will park their car into a garage-like feature above grade, and once they have entered their information, the car will be parked completely mechanically. There will be two elevators at each entrance so people can enter/exit with ease. A small structure will hide the mechanical system.

One will park their car by pulling into a structure similar to Figure 2, and will then leave their car and receive a parking slip. Their car will then be lowered into the system shown in Figure 3. Once they want to retrieve their car, they re-enter the slip and the car returns to the structure in Figure 2.
The gravity systems were configured based on span, potential use of space, and surrounding structure.

For the residential, because the interior areas are so small, bearing walls will be on the exterior of each unit. The TJI joists will span in whichever direction is the shortest. For the offices, there will need to be a couple columns on the lower floor, which then requires PSL beams in the shorter direction, and TJI joist spanning the longer direction. This is to reduce the ceiling height as much as possible.

For the commercial buildings there are columns spaced ~15’ so that the braced frames are most efficient. The interior columns line up with the bearing walls above to reduce loading on beams and girders. Again, to reduce ceiling height, the beams will span in the longer direction while the girders span the shorter span.

The CMU/concrete is being used only for the elevator, parking structure, and bearing walls.
GRAVITY SYSTEM

RESIDENTIAL FLOOR TOIST
DL: 30 psf
LV: 40 psf
TRIB WIDTH: 10"
W = (30 psf + 40 psf) * 10 = 990 psf
MAX SPAN = 10'
\( M_{\text{max}} = \frac{W^2}{2} = 4950 \) ft
\( V_{\text{max}} = \frac{W}{2} = 495 \) ft
\( T^2 = 260 \) M

\( R = \frac{4950}{2} \) ft
\( V = 2910 \) ft

RESIDENTIAL GARDEN FLOOR TOIST
DL: 20 psf + 40 psf
LV: 40 psf
TRIB WIDTH: 10"
W = (20 psf + 40 psf) * 10 = 1960 psf
MAX SPAN = 10'
\( M_{\text{max}} = \frac{W^2}{2} = 9810 \) ft
\( V_{\text{max}} = \frac{W}{2} = 4905 \) ft
\( T^2 = 210 \) M

\( R = \frac{4905}{2} \) ft
\( V = 1990 \) ft

COMMUNITY CENTER FLOOR TOIST
DL: 30 psf
LV: 40 psf
GENERAL: 15" O.C.
W = (30 psf + 40 psf) * 10 = 700 psf
\( V = \frac{W}{2} = 350 \) ft
\( M_{\text{max}} = \frac{W^2}{2} = 1225 \) ft
\( T^2 = 240 \) M

RESIDENTIAL/ OFFICE COLUMN
DL: 30 psf
LV: 40 psf
TRIB AREA: 16" x 20" = 320 ft²
\( P = (16" x 20") * 320 = 320 \) ft²
USE H99 COLUMN
\( \phi = 0.25 \) max
\( M_{\text{max}} = 925 \) ft

Design Properties (100% Load Bandwidth)

Alternate Design Properties (100% Load Bandwidth)

\( 8" x 8", 6000 \) lb
\( 4" x 4", 3000 \) lb

\( 5" x 5", 2000 \) lb

\( 3" x 3", 1500 \) lb

**COMMERCIAL STEEL BEAM**

**DL**: 90 PSF + 20 PSF (timber)

**LV**: 10 PSF

**TBW**: 1' 1 1/2

**W**: (10 PSF + 40 PSF) 1' 1 1/2 = 50 PSF

**Max Span**: 20'

**M**: \( \frac{W^2}{8} = 170.9 \text{ ft}^3 

**P** = 700 ft

**From Table B-10**

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**COMMERCIAL STEEL COLUMN**

**DL**: 80 PSF + 30 PSF (wood)

**LV**: 40 PSF

**Max **Span**: 30'

**M**: \( \frac{W^2}{8} = 131.3 \text{ ft}^3 

**P** = 700 ft

**From Table B-10**
The lateral system was configured based on center of mass/rigidity, openings, aesthetics, and span of wall.

The wood shearwalls were placed where the wall would be continuous horizontally and vertically to try and avoid excess drag and load transfer beams. For the residential above the commercial area, the shearwalls line up with systems below when possible. Exterior shearwalls will need to be adjusted based on final window/door placement.

CMU shearwalls are placed along the lower portion of the commercial/office building in order to allow for larger openings. We are planning on having large windows and a garage door, and the CMU walls being more compact will provide the space for that.
LATERAL SYSTEM

COMMERCIAL SHEARWALLS

$$V_L = 35.5K$$

$$\phi V_L = \phi (2.25 A_L) \left( \frac{V}{f_{w}} \right) + 0.25 V_L$$

$$\phi = 0.9 A_{L} (91')$$

$$35.5K = 0.9 \left( \frac{V}{f_{w}} \right) + 0.25 (35.5K)$$

$$I = 39'$$

OFFICE SHEARWALLS

WOOD:

$$V_L = 28.3K$$

$$A = 1.1'$$

$$V_L = \frac{28.3K}{1.1'}$$

MASONRY:

Building height = 33'

$$V_L = 30.8K$$

Office Space

130' Wood SW E.W.

Residential Above Commercial

76' Wood SW E.W.

Commercial - Market

56' Wood SW E.W.

Commercial - Restaurant

93' Masonry SW E.W.
The foundation system was complicated by poor soil bearing pressure, underground parking, and a sloped site.

The two parking garages entrances are level with the street, making them 8’ apart in depth. The roof of the garages serves as a foundation for the building above. To try and soften the grade change between buildings on opposite sides of the site, the residential community center (yellow) will be in between the two, along with the landscape in front of it. Where parking can not be the building foundation, a mat foundation will take shape of the footprint of the building (purple and blue). The parking garages will also have their own mat foundations (pink and maroon).
The parking system was separated into residential and commercial to try and facilitate traffic and keep the residential feeling more private.

The parking system is two layers of cars, each 7’ tall and 7’ wide. Because of this sizing, the columns were spaced at either 21’ or 14’ so as not to obstruct any openings.

The parking was meant to line up underneath buildings in order to reduce foundation area (parking ceiling could double as building foundation), but this was compromised in order to push the parking closer to the street to avoid wasting space.

The driver pulls into a residential garage like structure and leaves the car. They then either take a ticket or enter a pin (for residential) and the car will be lowered and parked mechanically. Once below the ground, the car is led down the middle isle and parked on either side and on one of the two levels. The entrances are two cars wide to allow one car to enter/exit at the same time.
The foundation thickness is based off of punching shear from the columns that frame into it. To find this, I took the column with the most weight from each mat to find a thickness for each individual mat. This will hopefully avoid having unnecessary concrete.

PARKING CEILING/SLAB

The ceiling of the parking structure doubles as a floor for indoor and outdoor spaces. It will be a two-way slab with 18” concrete columns spaced at 21’ supporting it. Assuming a slab of 12” will support the dead and live load from the buildings above means I do not need to do extra checks for atypical columns and bearing walls that it supports.