AFFORDABLE HOUSING UNIT UTILIZING NELPLAST ECOBLOCKS

INSTRUCTIONAL MANUAL

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NOT APPROVED FOR CONSTRUCTION

STUDENT PROJECT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

TABLE OF CONTENTS

1. Foreword
2. Required Materials
3. Grading
4. Excavation
5. Footings and Foundation
6. Steel Reinforcement Layout
    a. Steel Reinforcement Layout at Columns
7. First floor:
    a. Floor Slab
    b. Superstructure (columns)
    c. EcoBlock Masonry Walls
    d. Over-Door Lintels
    e. Over-Window Lintels
    f. EcoBlock Masonry Walls
    g. EcoBlock Column & Wall Joint Connection
8. Second floor:
    a. Floor Slab
    b. Superstructure (columns)
    c. EcoBlock Masonry Walls
9. Roof structure
10. Electrical & Plumbing
11. Exterior Finishes
12. Roof & Terrace Finishes
13. Interior Finishes
14. Conclusion

FOREWORD

This instructional manual is an academic deliverable for a student project in partial fulfillment of the requirements for the degree of Bachelor of Science at Worcester Polytechnic Institute. This is not an approved document for construction.

This manual will utilize United States customary units for all measurements, mainly feet and inches. A single apostrophe (‘) denotes feet, while a double apostrophe (“) denotes inches.

This instructional manual aims to provide instructions for creating consistent and reliable housing units for teachers and nurses in the town of Akyem Dwenase utilizing the EcoBrick product produced by Nelplast Eco, Gh Ltd. The following documents are designed for, but are not limited to Akyem Dwenase and rural Ghanian townships.

This housing unit has 5 bedrooms, 5 bathrooms, 5 living room/kitchens, and 5 outdoor verandas.

Akyem Dwenase in southern Ghana has a tropical climate with temperatures averaging 76.2°F to 88°F year-round. There is little to no seismic activity in southern Ghana of concern to our design. These geographic characteristics informed design choices and are not applicable to all areas.

This building was designed not to be mechanically conditioned, therefore ventilated naturally.

Due to the lack of boring logs and soil testing, the soil conditions in Akyem Dwenase were assumed to be low-activity clay with high base saturation. The most conservative clay soil-bearing capacity of 1500 psf was assumed based on the 2021 International Building Code (IBC). This assumption guided the sizing of footings.

Concrete beams and columns were designed assuming the compressive strength of concrete is equal to 3,000 psi and the yield strength of steel reinforcement bar is equal to 40,000 psi. U.S. standard steel reinforcement bar sizes were used in the design.

REQUIRED MATERIALS

1. Excavation equipment
2. Concrete (approx. 40 cubic yards)
3. EcoBlocks (approximately 13,170 blocks)
4. #4 steel rebar (approximately 2,040 feet)
5. Windows (following specified sizes on construction documents)
6. Doors (following specified sizes on construction documents)
7. Wooden Roof Rafters (approximately 110 16-foot long 2x8's)
8. Corrugated Aluminum sheets
9. Electrical support equipment
10. Kitchen Fixture for 5 kitchens
11. Bathroom Fixtures for 5 bathrooms
12. Appropriately sized stair stringers (2 sets)
13. Lightweight wood to construct 2 sets of stairs, railings, and landings

NOTE: The quantity of materials specified is an estimate and will require further research.

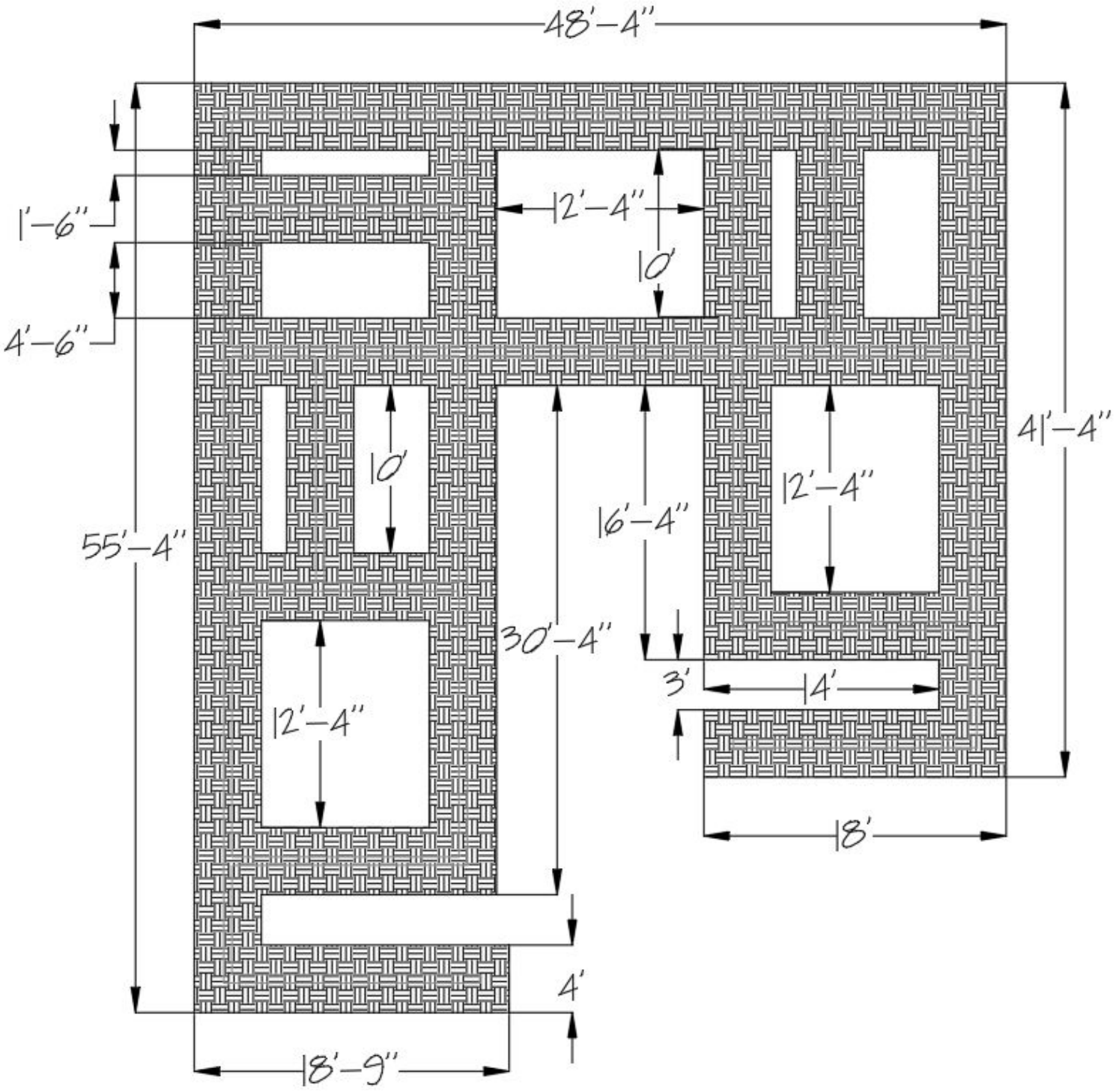
GRADING

The area identified as the site of construction must be graded prior to other construction activities. Grading involves removing trees, rocks, bushes, or anything else that might be on the site and creating a consistent slope away from the future structure. Grading ensures that any rainfall will be lead away from the structure's foundation. Then the foundation site must be leveled before excavation. Leveling involves ensuring that the ground surface is at a consistent level without significant differences in soil height or uneven surfaces. Grading and leveling require equipment capable of removing large amounts of soil and debris. Common tools such as shovels and metal rakes are helpful in achieving this goal.

Proposed site in Akyem Dwenase, Ghana

EXCAVATION

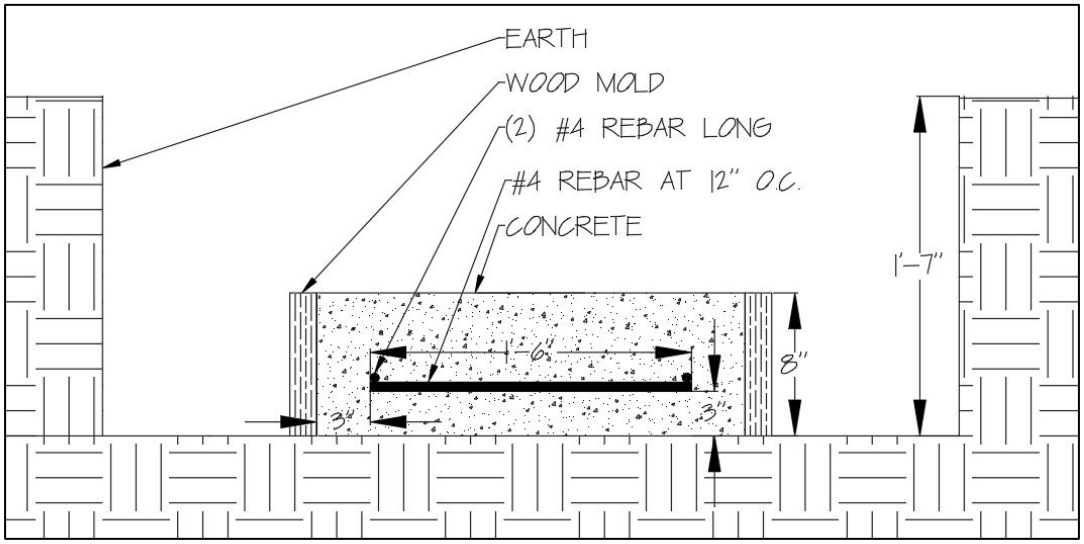
Soil must be removed to prepare for 2-foot wide poured concrete footings. A depth of 1’-7” deep should be dug in the areas denoted below:



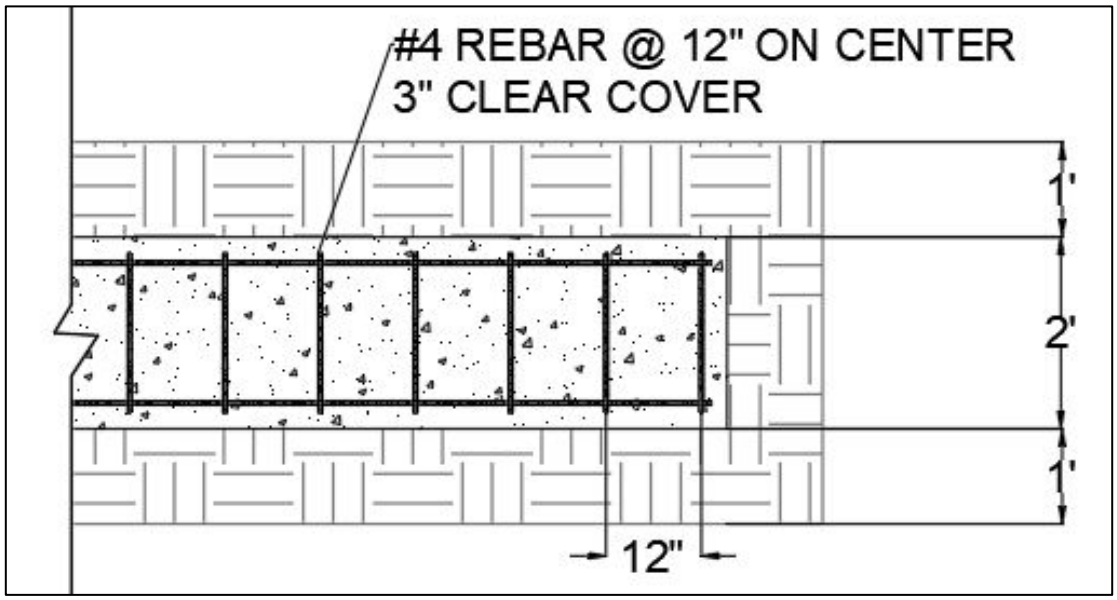
Shaded region denotes areas to be excavated to a depth of 2-feet

FOOTINGS AND FOUNDATION

A wooden mold should be constructed to hold rebar and concrete as it sets. #4 rebar will run both vertically and horizontally through the footing, 3-inches above the bottom of the mold (Figure 3). Running perpendicularly to each wall will be #4 rebar spaced 12-inches apart on center. Two #4 rebars will be running the length of the walls. These should be held in place in the wooden mold, then concrete poured in the mold to the depth of 8-inches (Figure 4).

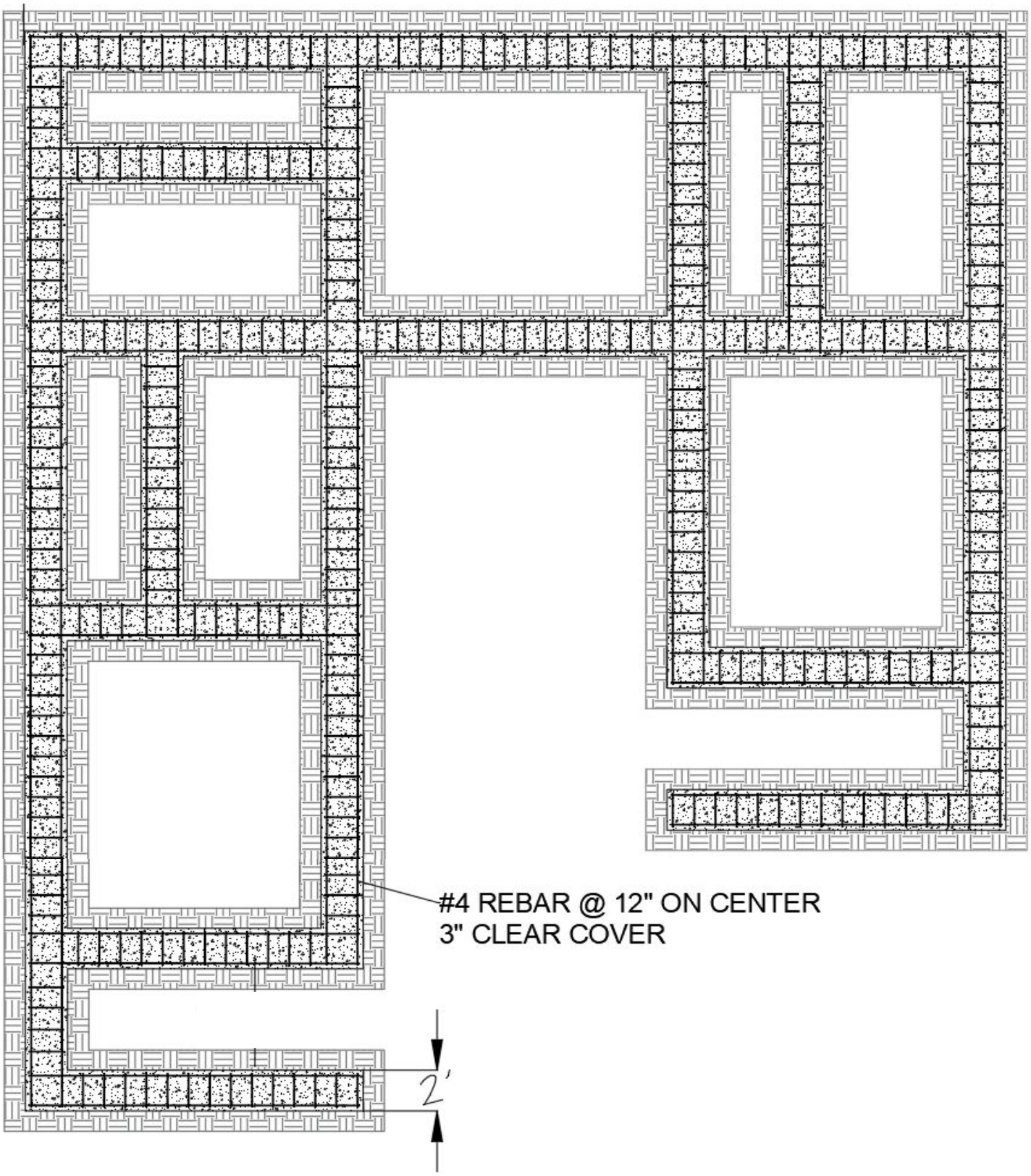


Section view of footings, wooden molds, and excavated earth



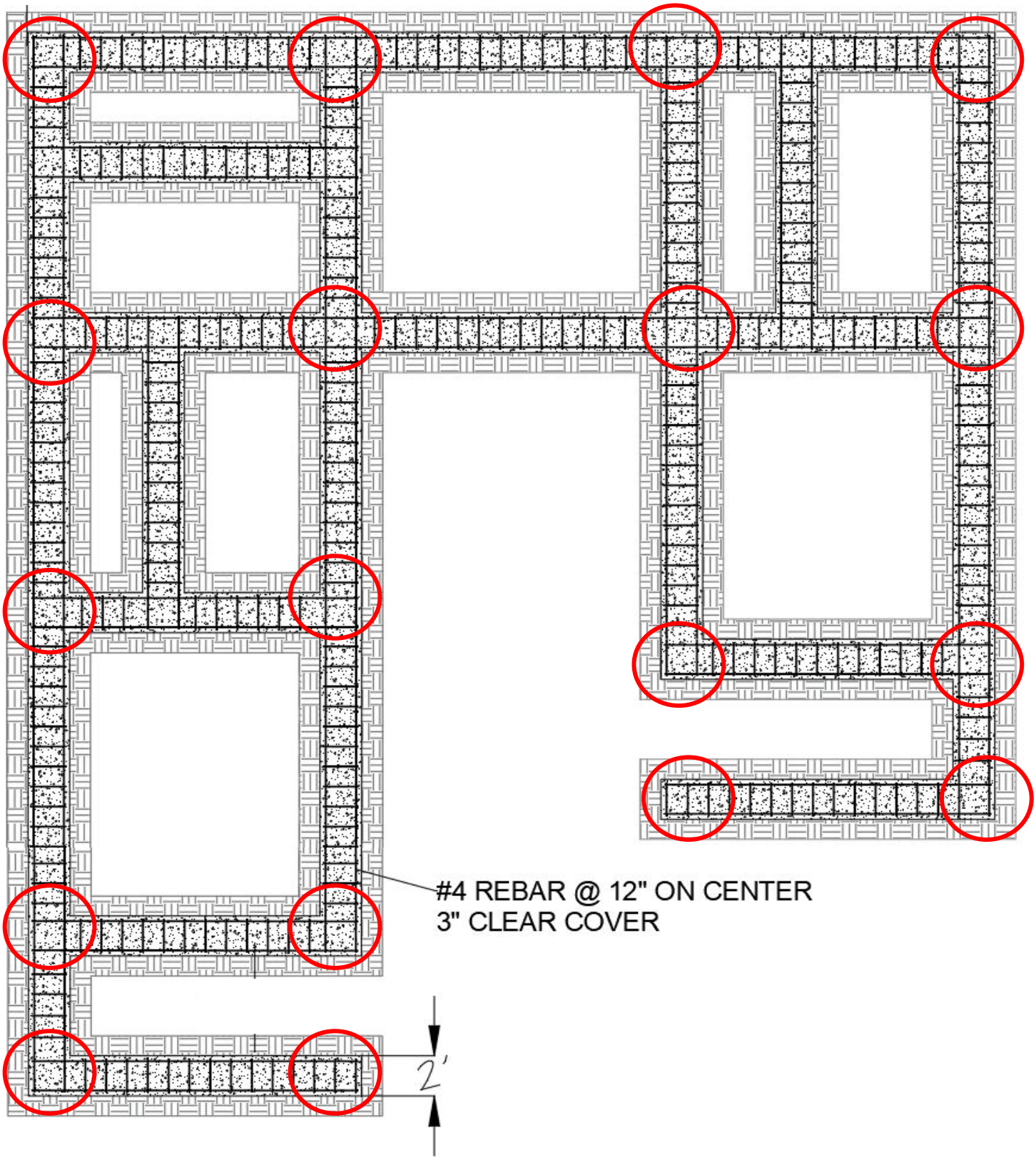
Layout of steel reinforcements located 3-inches above the Earth and 3-inches from the wooden mold

STEEL REINFORCEMENT LAYOUT



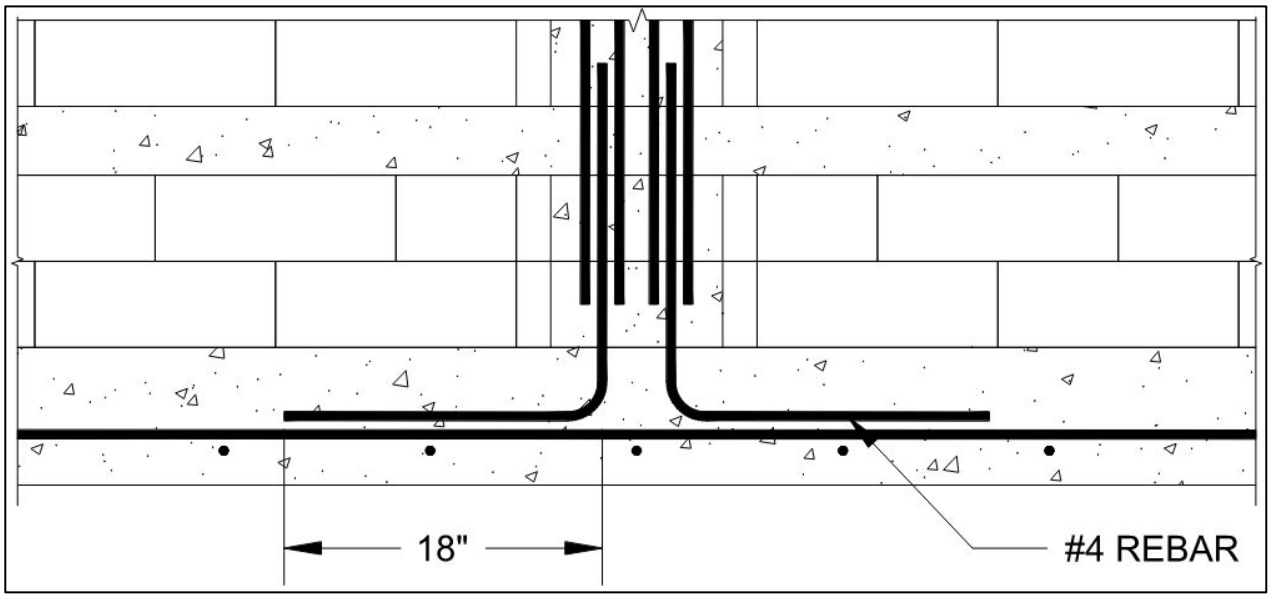
Layout of #4 steel reinforcements to install before concrete footings are poured.

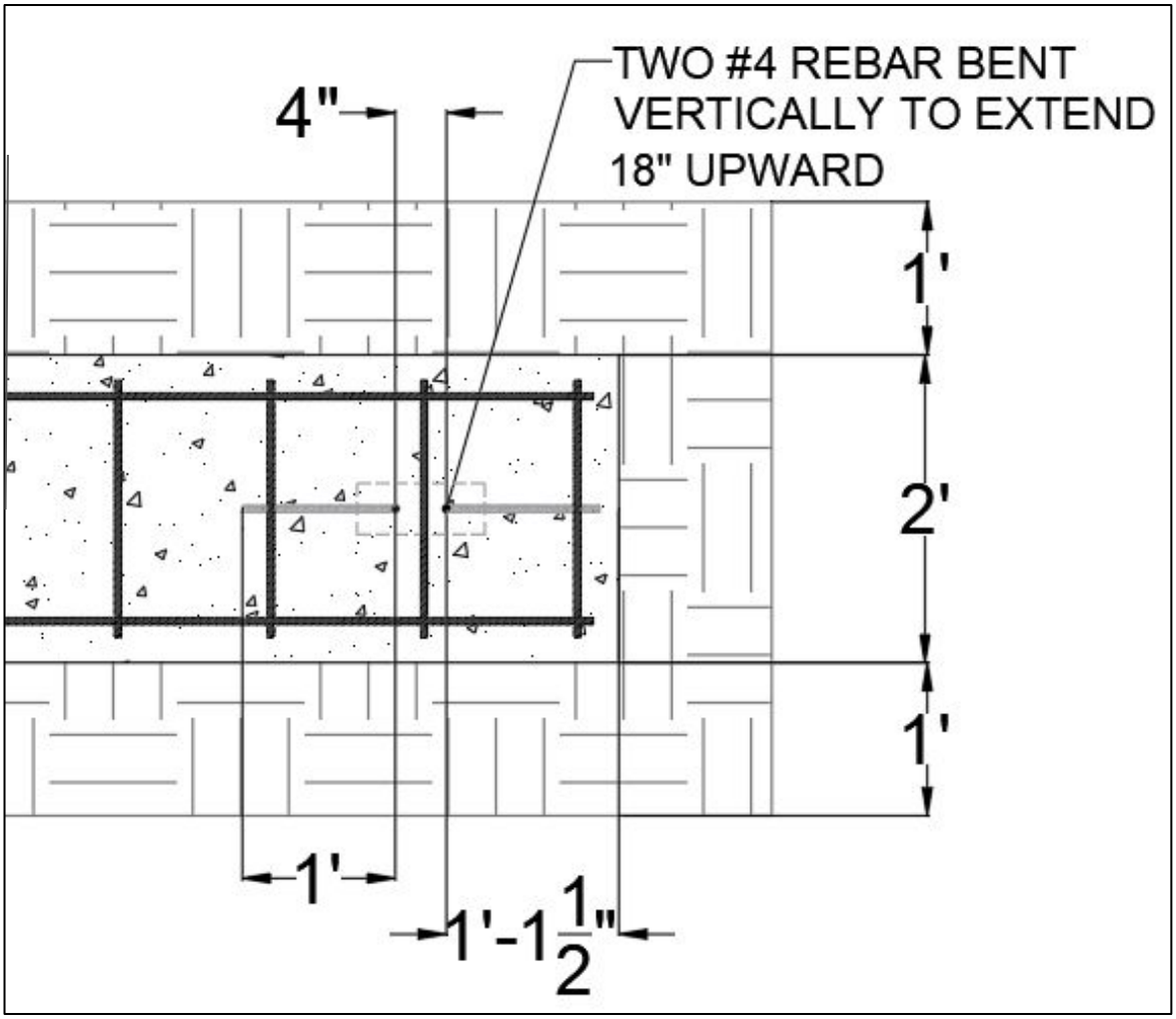
STEEL REINFORCEMENT LAYOUT CONTD.



Column locations where steel reinforcements tie-in from foundation to columns.

STEEL REINFORCEMENT LAYOUT AT COLUMNS





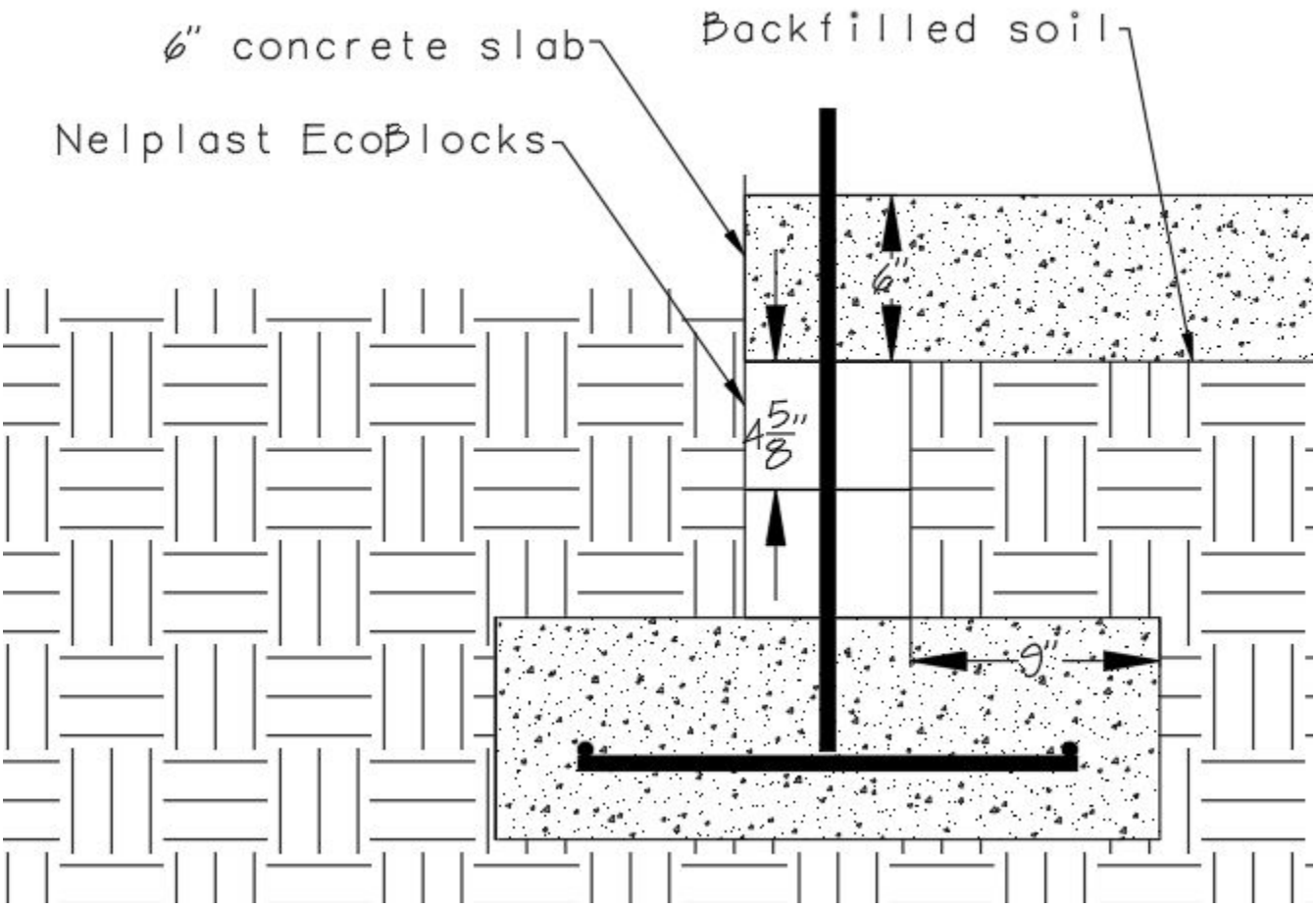
Layout of #4 steel reinforcements to install before concrete footings are poured at column locations.

FIRST FLOOR

FIRST FLOOR: FLOOR SLAB

Concrete footings should be untouched and allowed to cure per manufacturer's specifications. Then, mortar should be used to secure a row of EcoBlocks to the center of the footing. This mortar must also cure. While the mortar is setting, the wood molds should be removed from the footings. After 14 days, two more rows of EcoBlocks should be added. A 6-inch slab will rest on the EcoBlocks and packed earth as is shown in Figure 9. To accomplish this, the excavated area should be re-packed tightly, then a wood mold constructed to contain the 6" concrete slab as it cures.

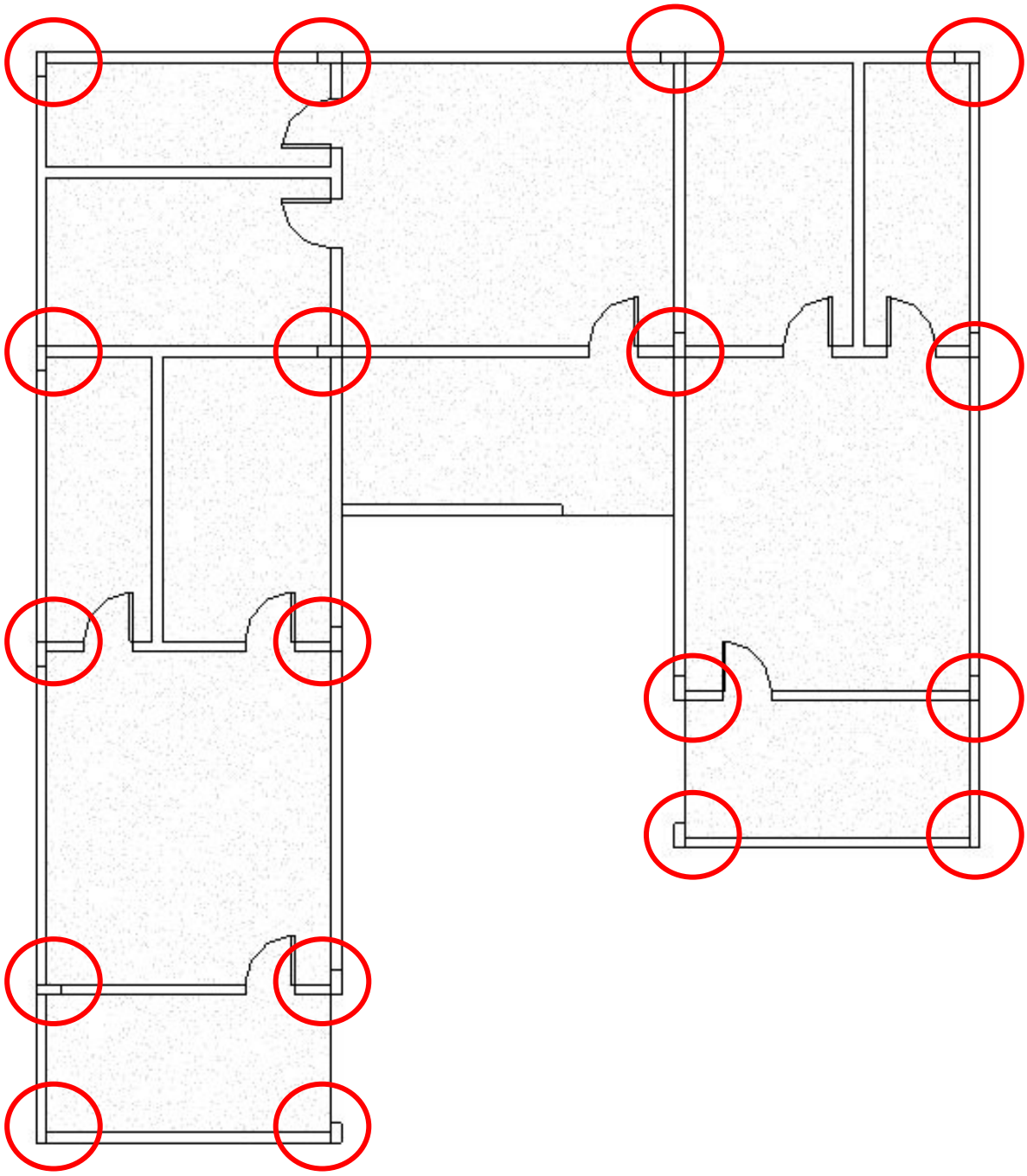
The following diagram shows a section view of the slab setup.



Section view of Footing to Slab Detail

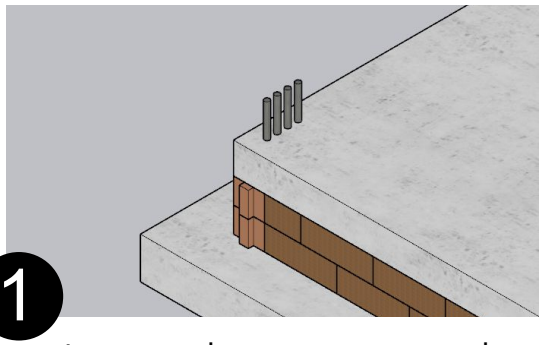
FIRST FLOOR: SUPERSTRUCTURE (COLUMNS)

Corner column blocks will be utilized in the following locations shown in Figure 10.



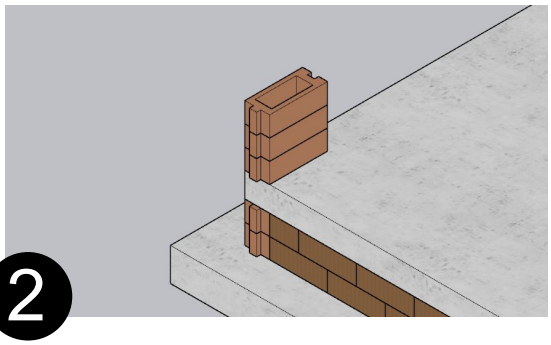
Column locations where steel reinforcements tie-in from foundation to columns.

FIRST FLOOR: SUPERSTRUCTURE (COLUMNS) CONTD.



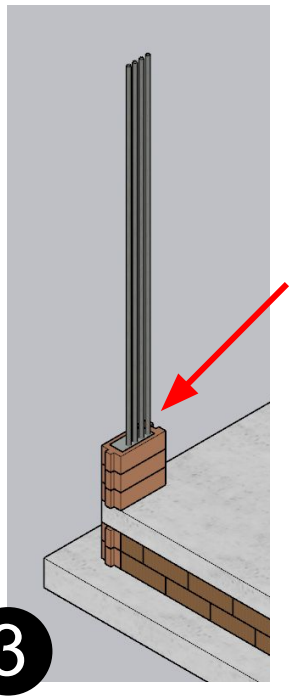
1

Locate the corner on the bottom left of the structure (based on the construction drawing set)



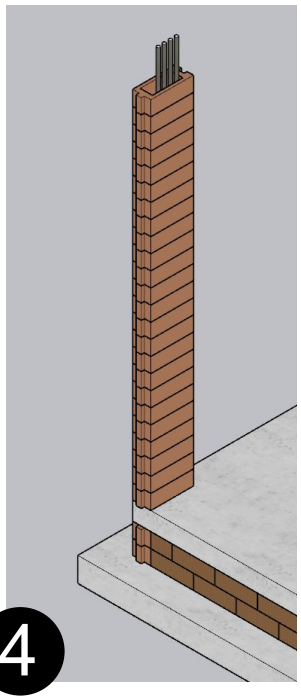
2

Stack three column blocks with the extruded end facing outwards



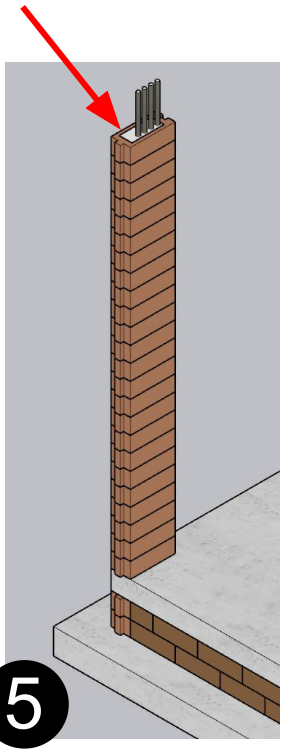
3

Place four 10’-9” pieces of #4 rebar inside of the center of the blocks (spaced 2 inches on center) and fill the remaining space with concrete



4

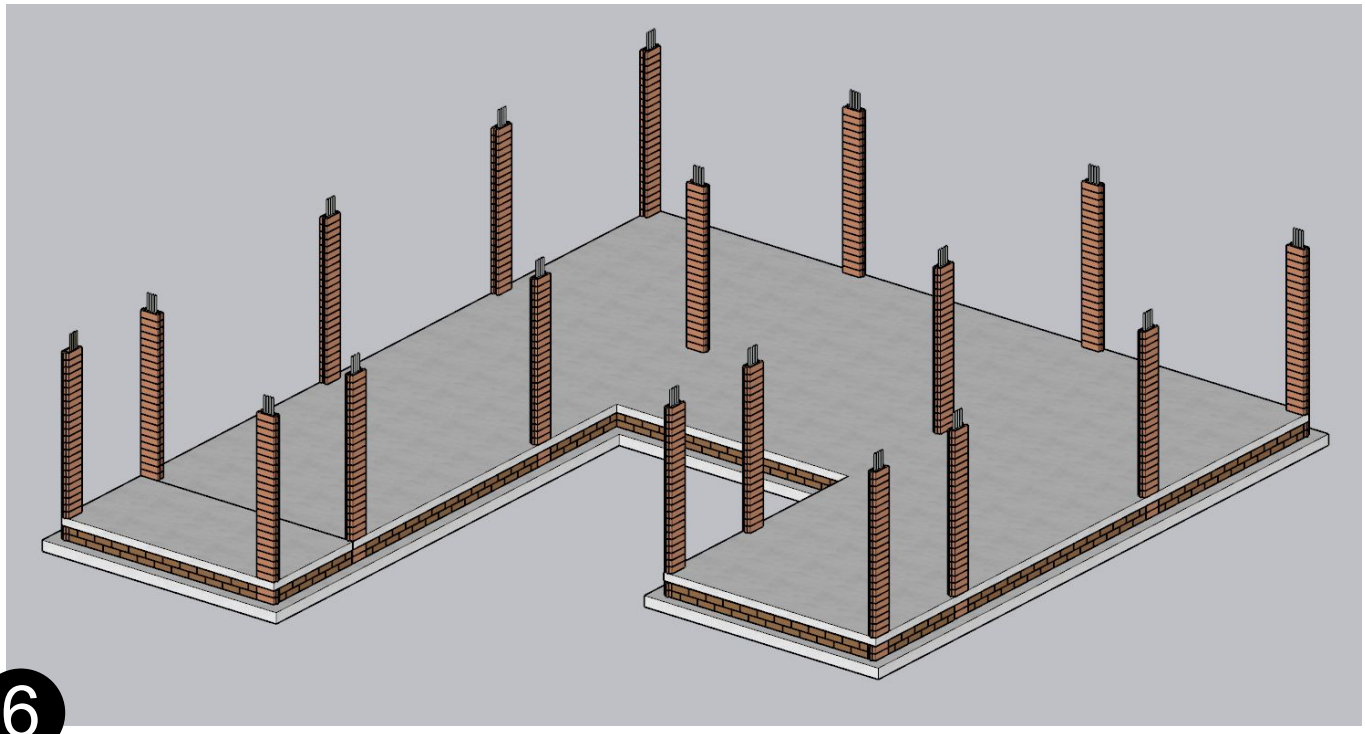
Once the concrete is set, continue stacking the rest of the 24 column blocks on top of one another



5

Fill the remaining space inside of the column blocks with concrete and let it cure per manufacturer's specifications

FIRST FLOOR: SUPERSTRUCTURE (COLUMNS) CONTD.

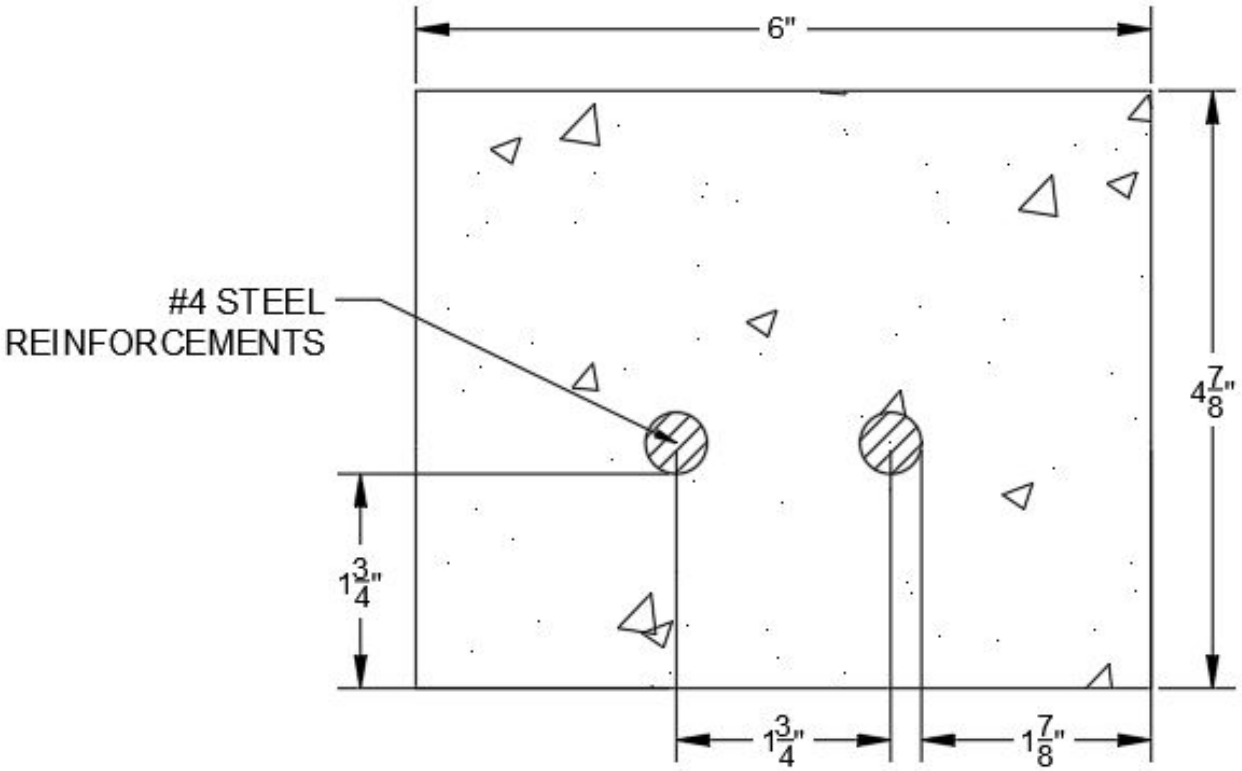


6

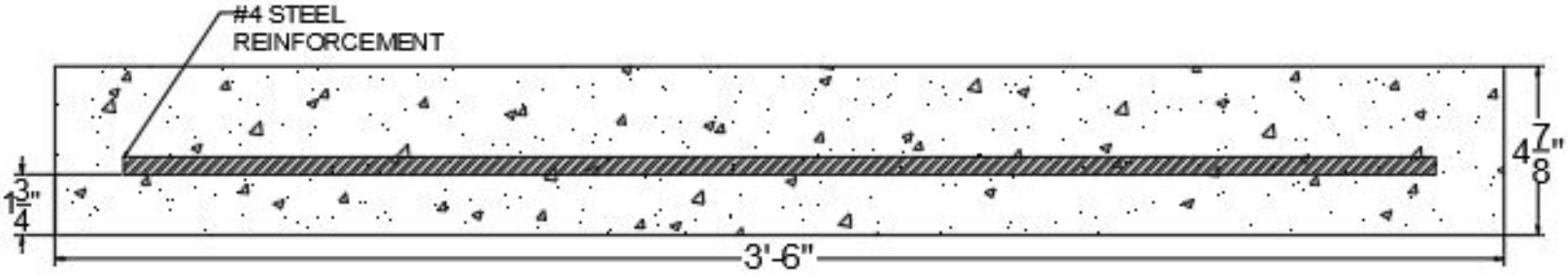
Repeat steps 1-5 for every column location (18 in total)

FIRST FLOOR: OVER-DOOR LINTELS

To make a lintel for doorways, create a rectangular wooden mold 3’ 6” long, 6” wide, and 4 ⅞” tall. Pour concrete into mold and install #4 steel reinforcements as shown in Figures 11 & 12. Allow reinforced concrete lintels to cure entirely before installing into the final structure. All top of windows are directly below a 6” steel reinforced concrete slab and do not require separate lintels.



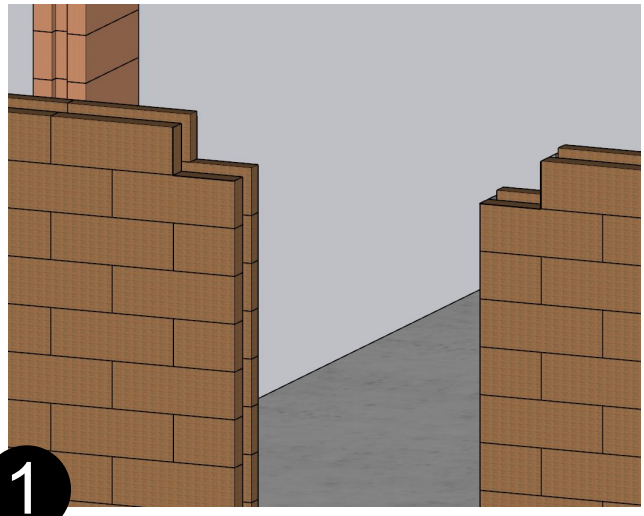
Transverse cross-section view of doorway lintel.



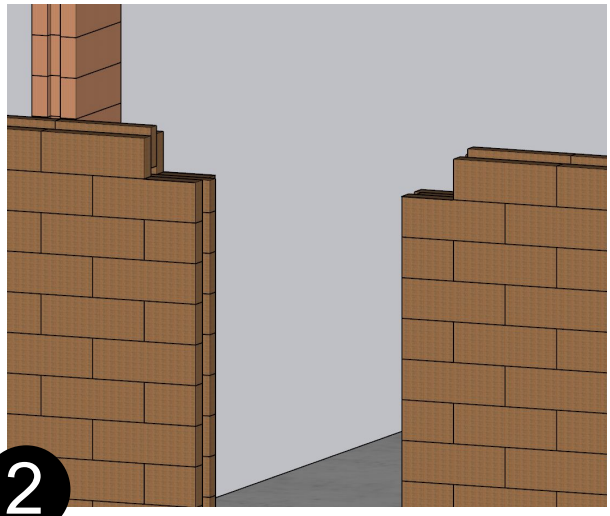
Longitudinal cross-section view of doorway lintel.

FIRST FLOOR: OVER-DOOR LINTELS CONTD.

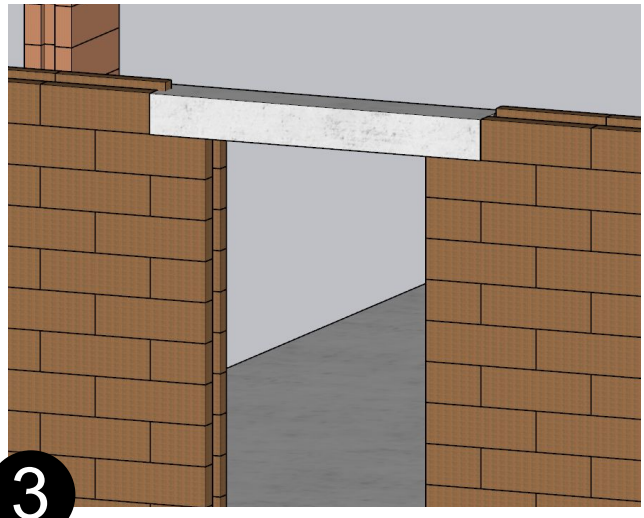
The following steps detail the installation of the precast reinforced concrete lintels above doorways:



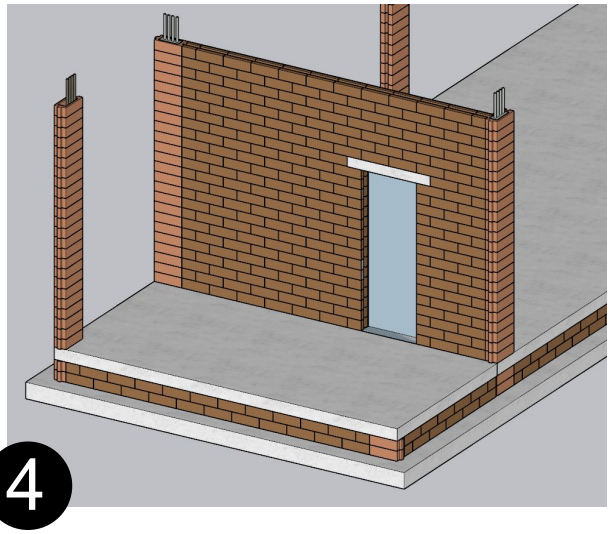
1 Build the EcoBlock wall with allocated space for a 28” by 80” door frame.



2 Remove notches in EcoBlock to make room for lintel.



3 Place precast reinforced concrete lintel above door frame.

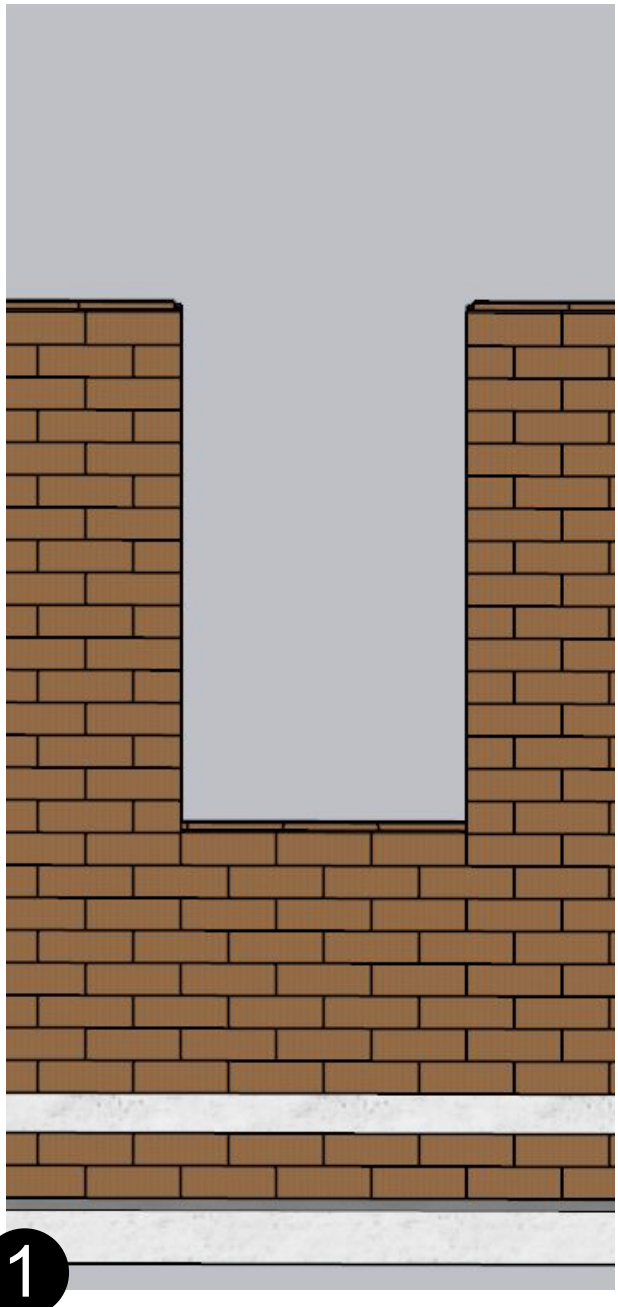


4 Finish the wall by stacking blocks above lintel.

NOTE: Precast window lintels are not required. This is applicable to both the first and second floors.

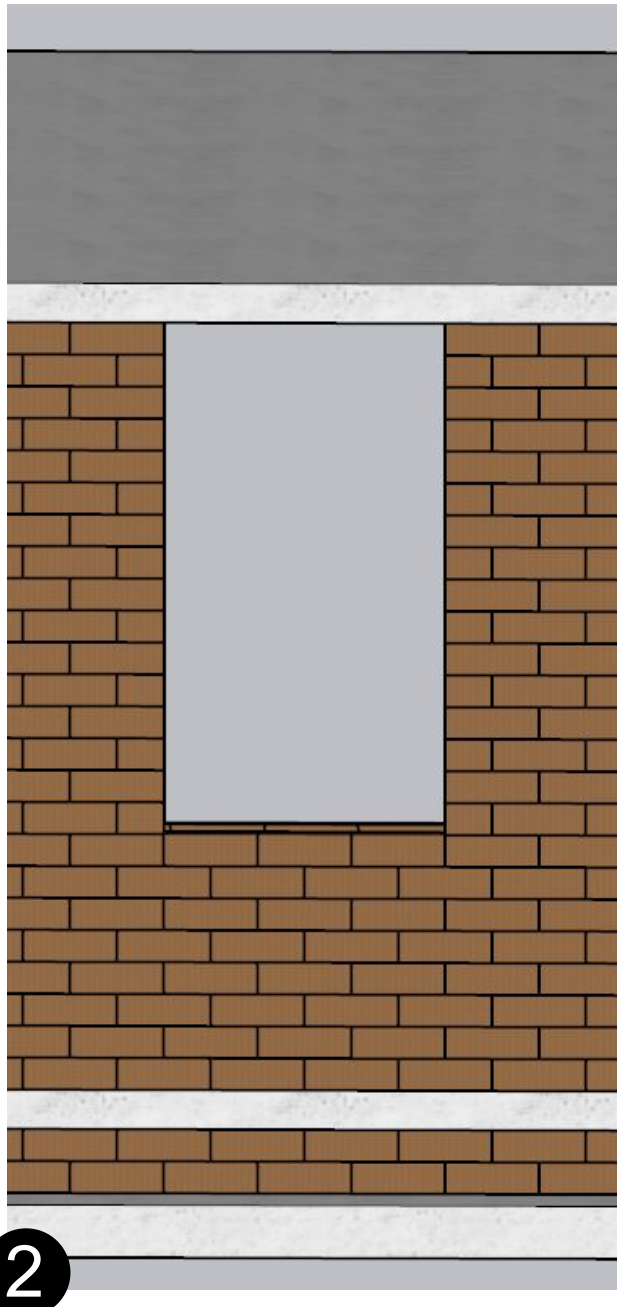
FIRST FLOOR: OVER-WINDOW LINTELS

The following steps detail the top of window support:



1

Build the EcoBlock wall with allocated space for a 42” by 72” window frame.



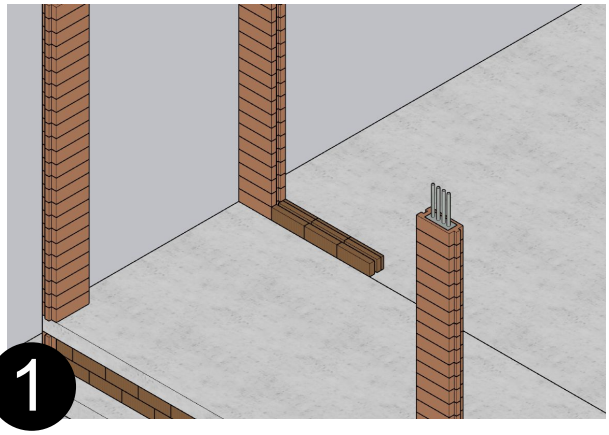
2

Frame and pour a 6” reinforced concrete slab..

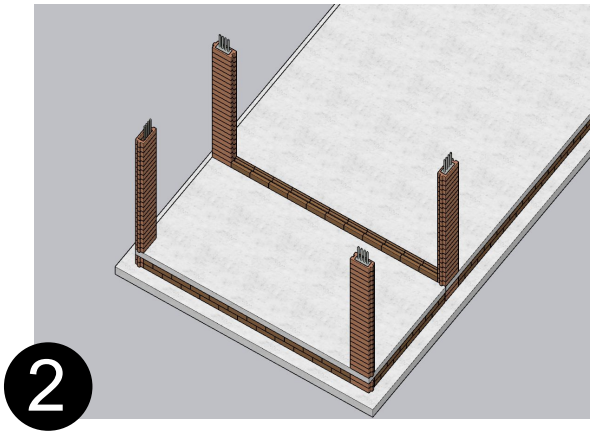
NOTE: Precast window lintels are not required. This is applicable to both the first and second floors.

FIRST FLOOR: ECOBLOCK MASONRY WALLS

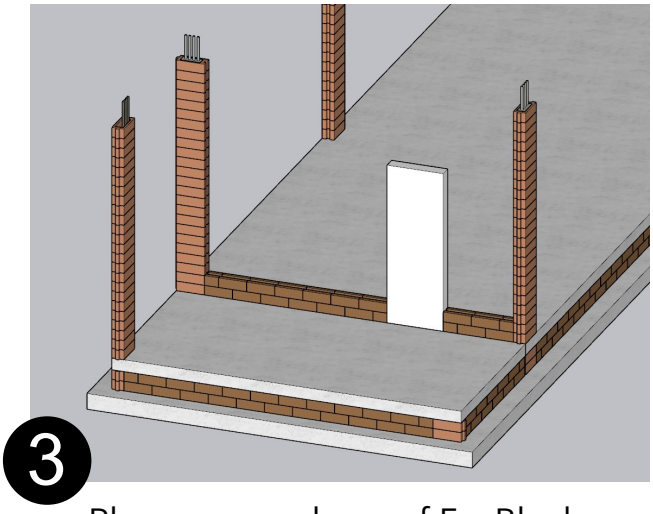
EcoBlocks are provided with notches and tabs that should be hammered together as tightly as possible. Blocks should connect with column block tabs whenever possible.



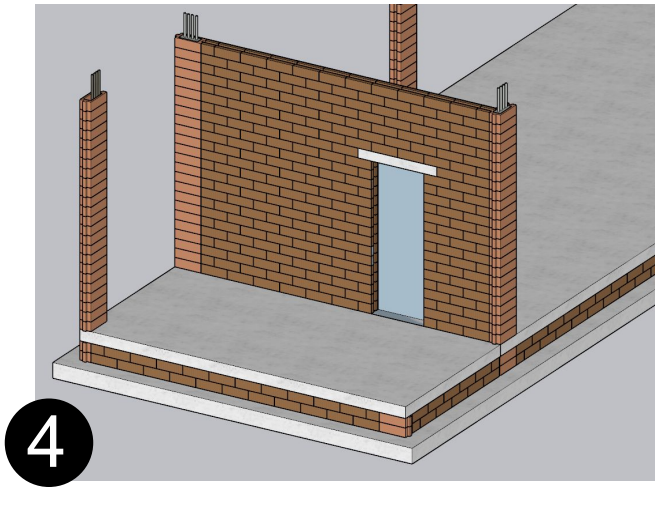
Locate the corner on the bottom left of the structure (based on the construction drawing set) and begin placing EcoBlocks against the column.



Continue to complete the row of blocks. See drawing set to know where spaces must be left to accommodate windows and doors.

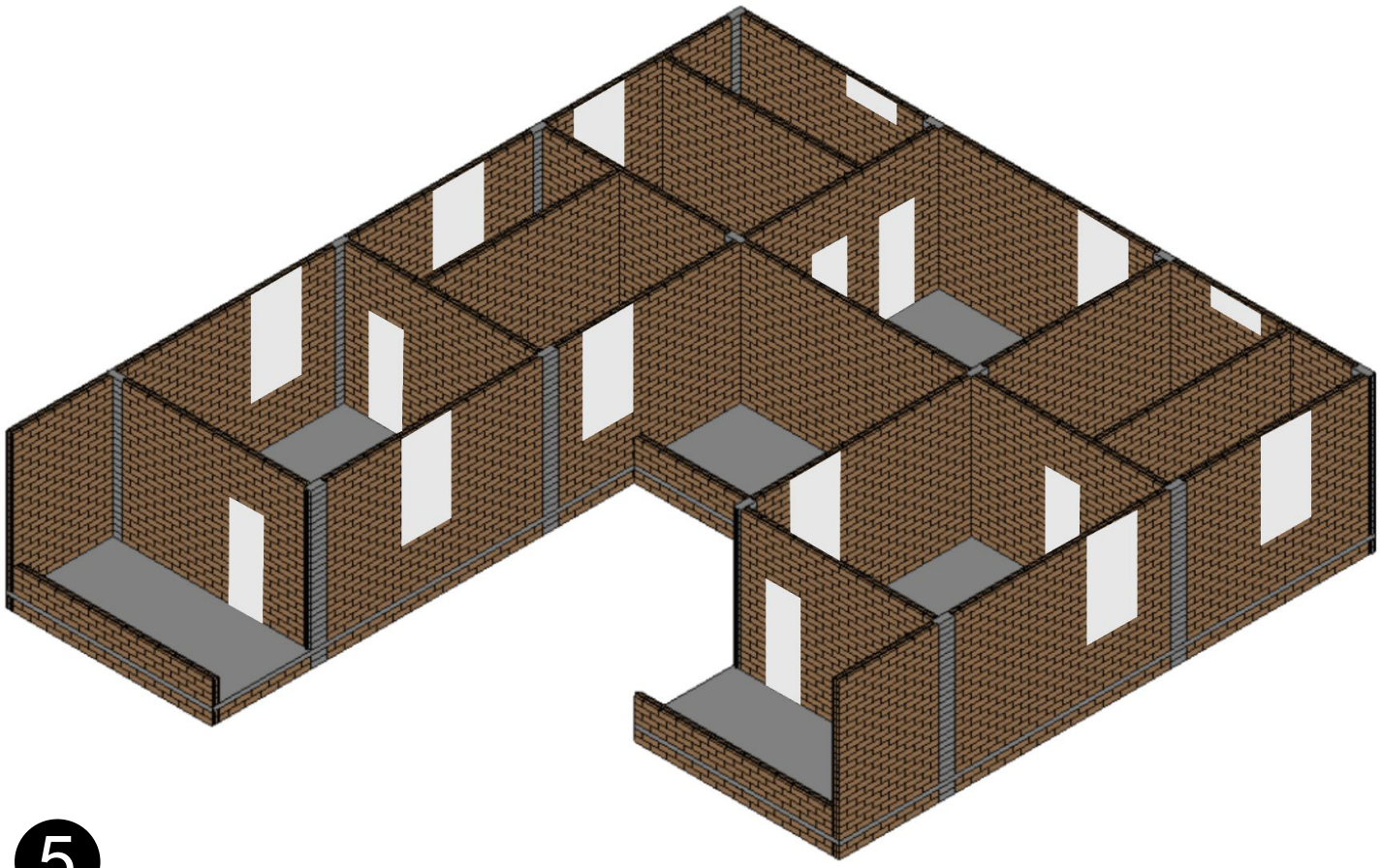


Place a second row of EcoBlocks on top of the first, offsetting the blocks by half of the block width.



Continue stacking EcoBlocks until the wall has reached the height of the column, incorporating the lintel detailed previously.

FIRST FLOOR: ECOBLOCK MASONRY WALLS CONTD.



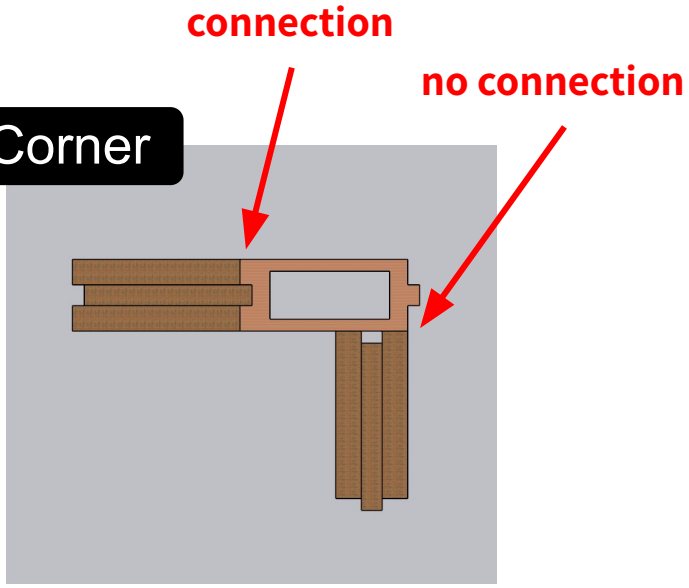
5

Repeat steps 1-4 for every wall location (27 in total) that are shown above. Accurate dimensions and spacing is shown in the drawing set. The half-wall provided on the porch is 3-feet tall.

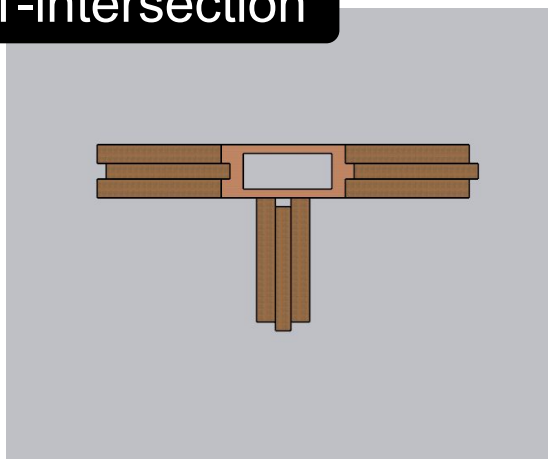
FIRST FLOOR: ECOBLOCK COLUMN & WALL JOINT CONNECTION

NOTE: Due to the shape of the Nelplast Column EcoBlocks, connections with the wall are only possible on two sides.

Corner

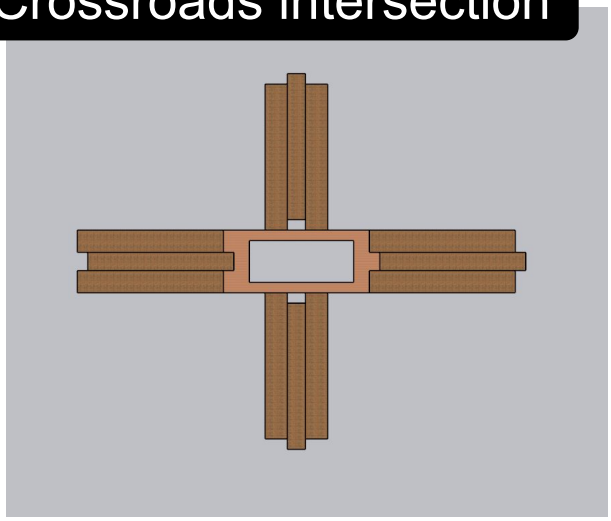


T-intersection



Therefore, some of the walls will interlock with the columns, while others will only align with them.

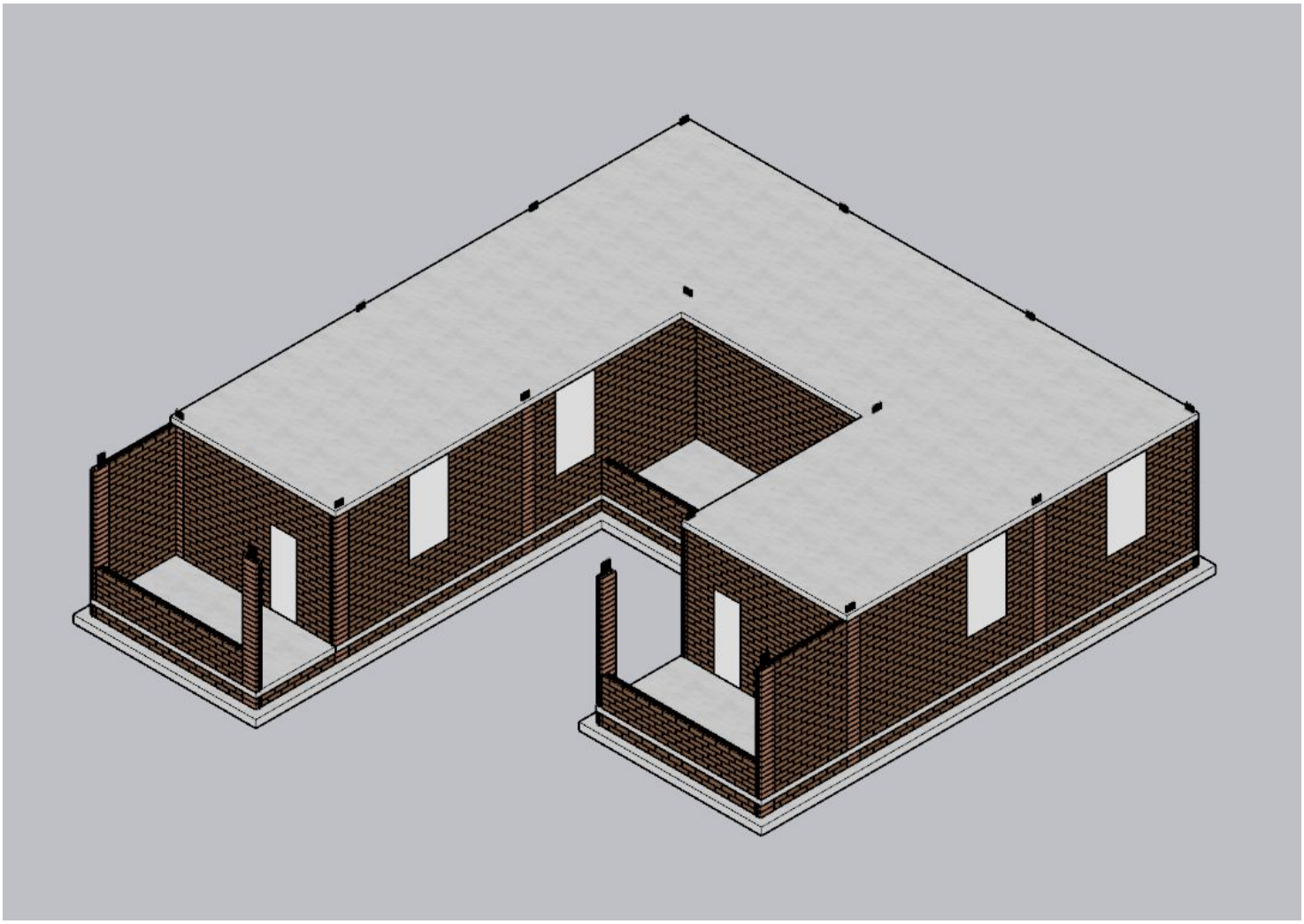
Crossroads intersection



SECOND FLOOR

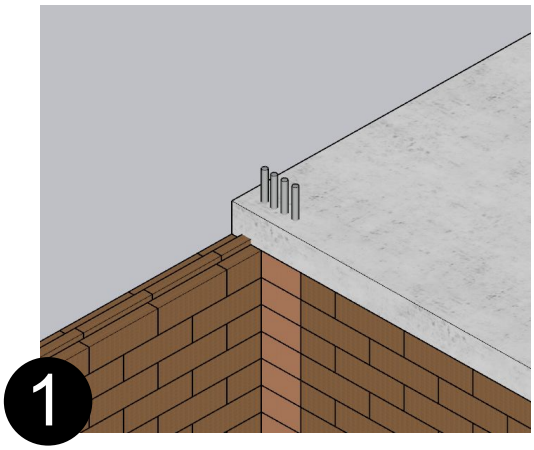
SECOND FLOOR: FLOOR SLAB

Figure X below indicates the floor plate of the second floor. This steel reinforced, one-way concrete slab is 6-inches thick and will need to be supported by wooden framing while it cures per manufacturer's specifications.

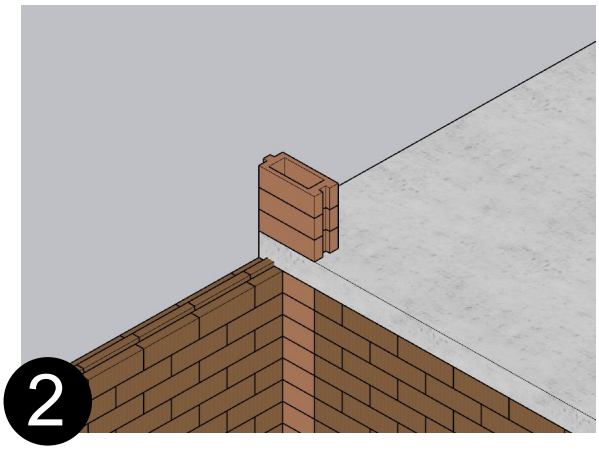


Second floor steel reinforced, one-way slab design.

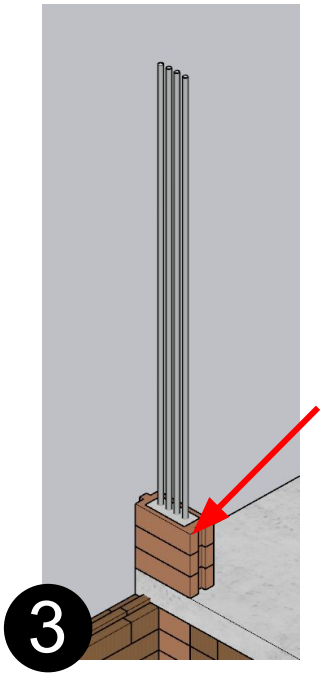
SECOND FLOOR: SUPERSTRUCTURE (COLUMNS)



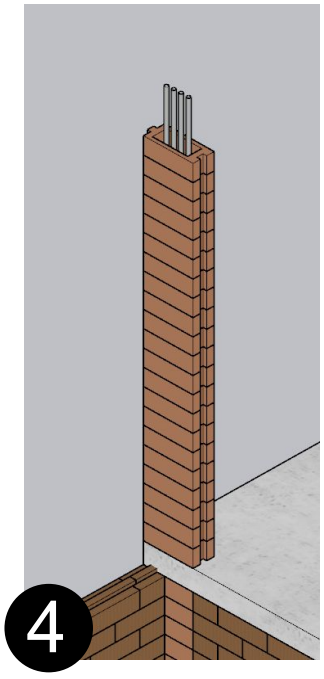
Locate the corner on the bottom left of the structure (based on the construction drawing set)



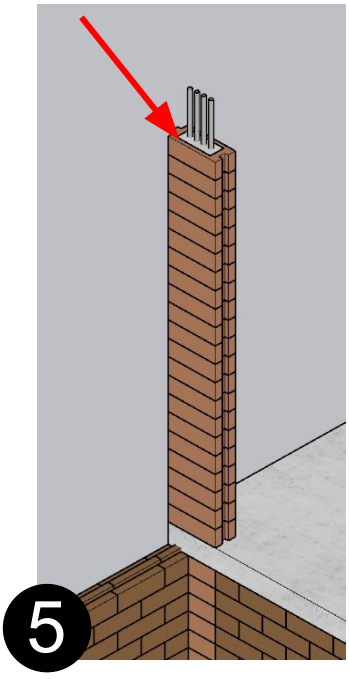
Stack three column blocks with the extruded end facing outwards



Place four 10’-9” pieces of #4 rebar inside of the center of the blocks (spaced 2 inches on center) and fill the remaining space with concrete

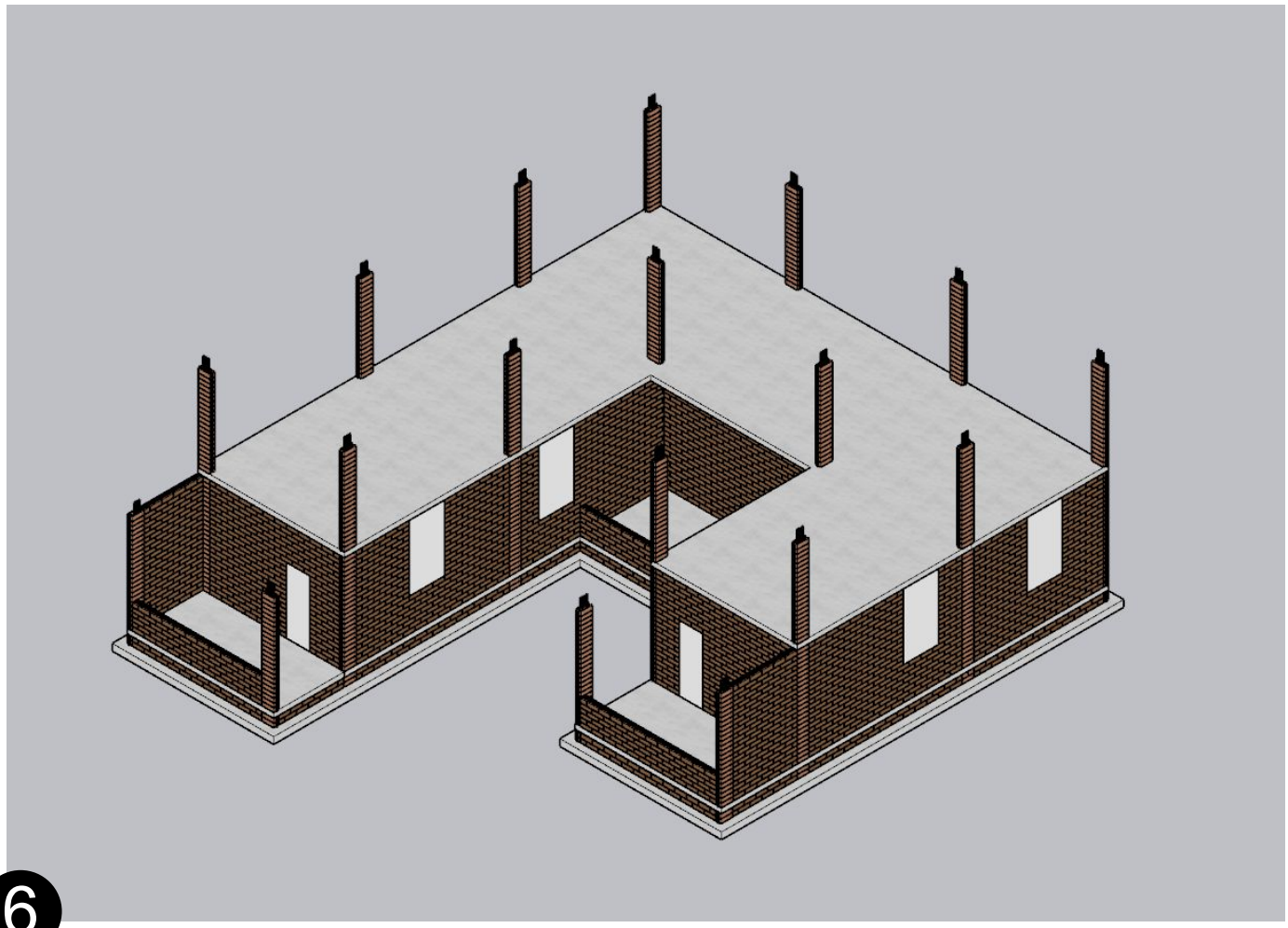


Once the concrete is set, continue stacking the rest of the 24 column blocks on top of one another



Fill the remaining space inside of the column blocks with concrete and let it cure per manufacturer's specifications

SECOND FLOOR: SUPERSTRUCTURE (COLUMNS) CONTD.

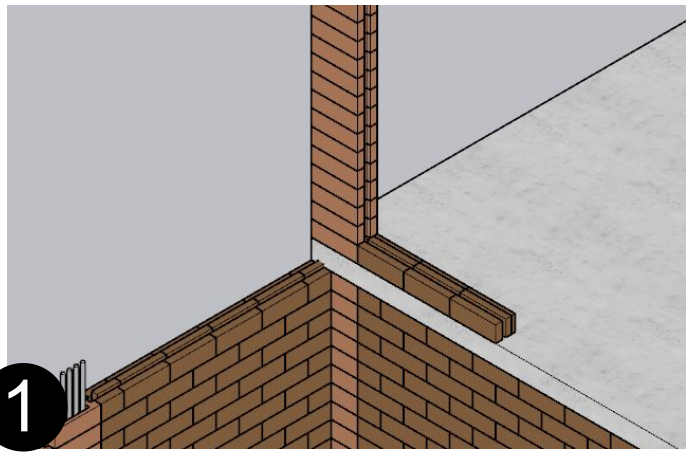


6

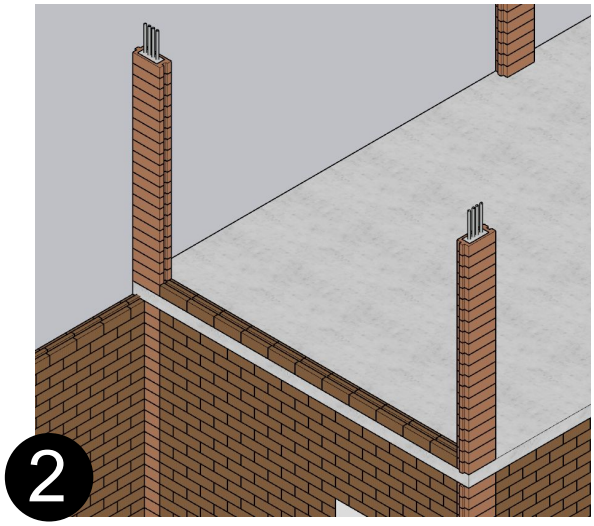
Repeat steps 1-5 for every column location (18 in total).

SECOND FLOOR: ECOBLOCK MASONRY WALLS

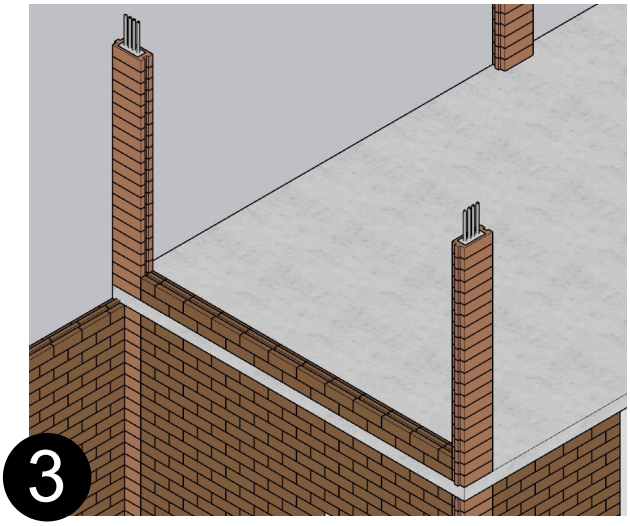
EcoBlocks are provided with notches and tabs that should be hammered together as tightly as possible. Blocks should connect with column block tabs whenever possible.



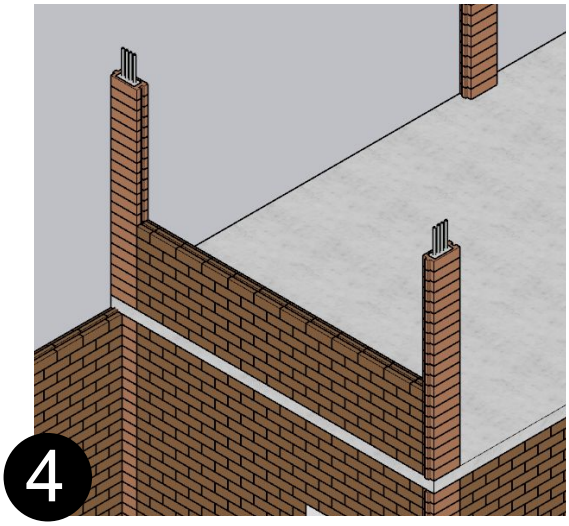
Locate the corner on the bottom left of the second floor slab(based on the construction drawing set) and begin placing EcoBlocks against the column.



Continue to complete the row of blocks. See drawing set to know where spaces must be left to accommodate windows and doors.

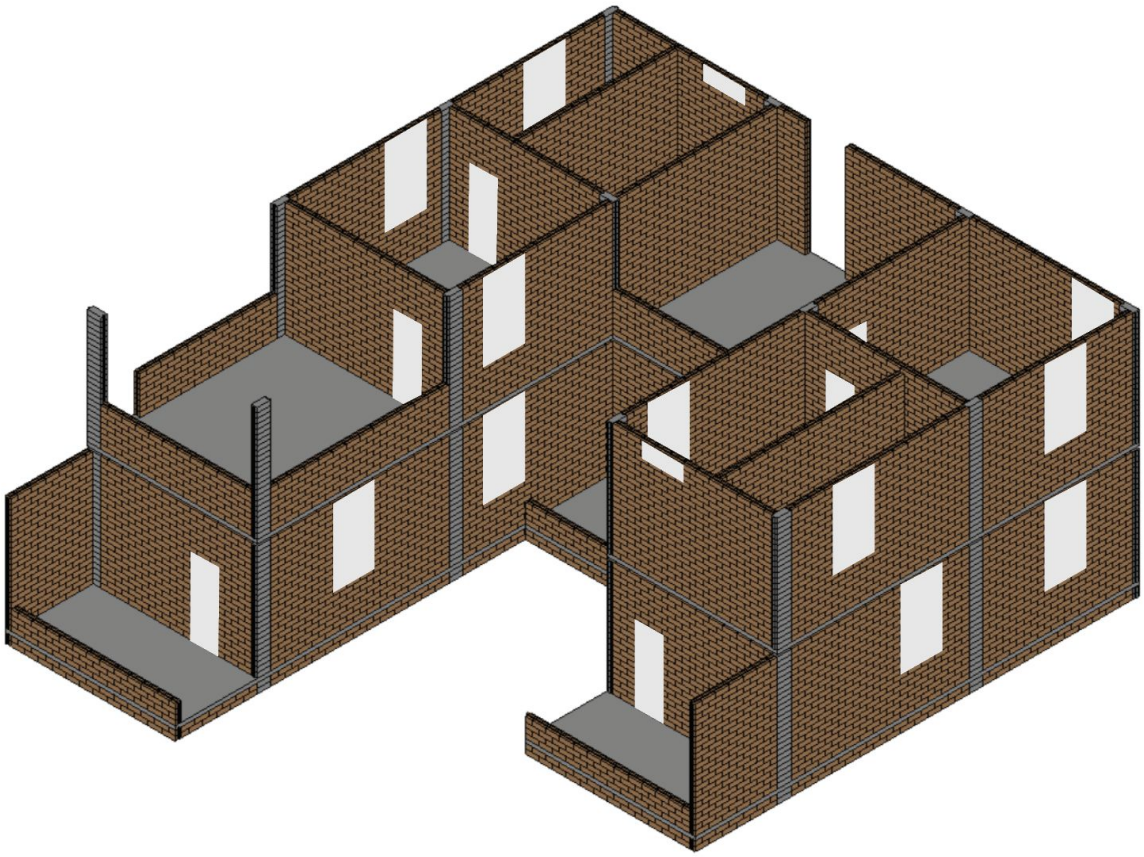


Place a second row of EcoBlocks on top of the first, offsetting the blocks by half of the block width.



Continue stacking EcoBlocks until the wall has reached the height of the column, incorporating the lintel detailed previously.

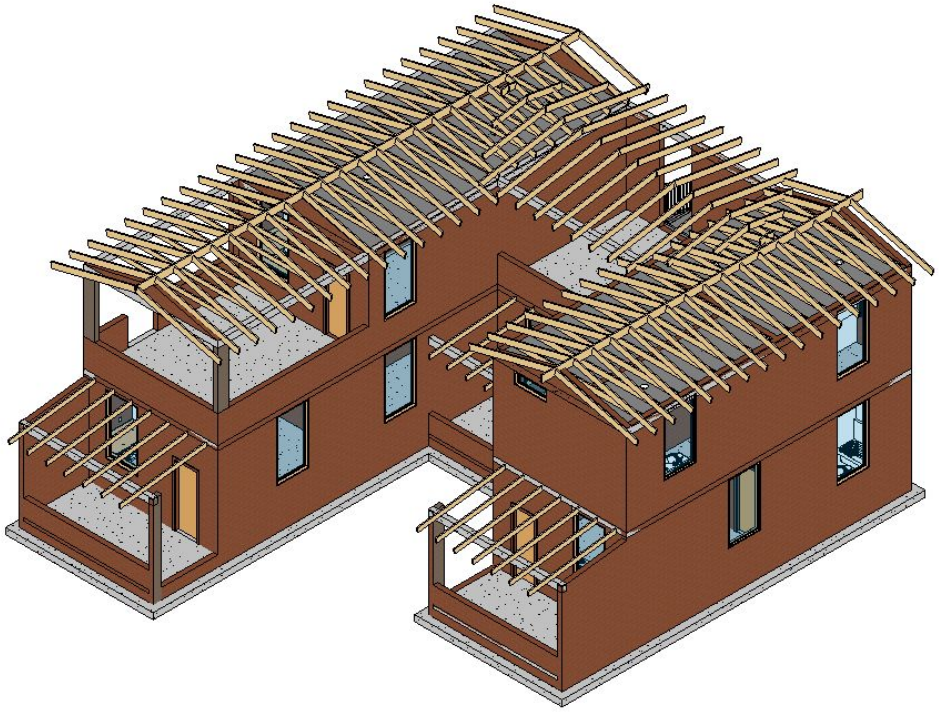
SECOND FLOOR: ECOBLOCK MASONRY WALLS CONTD.



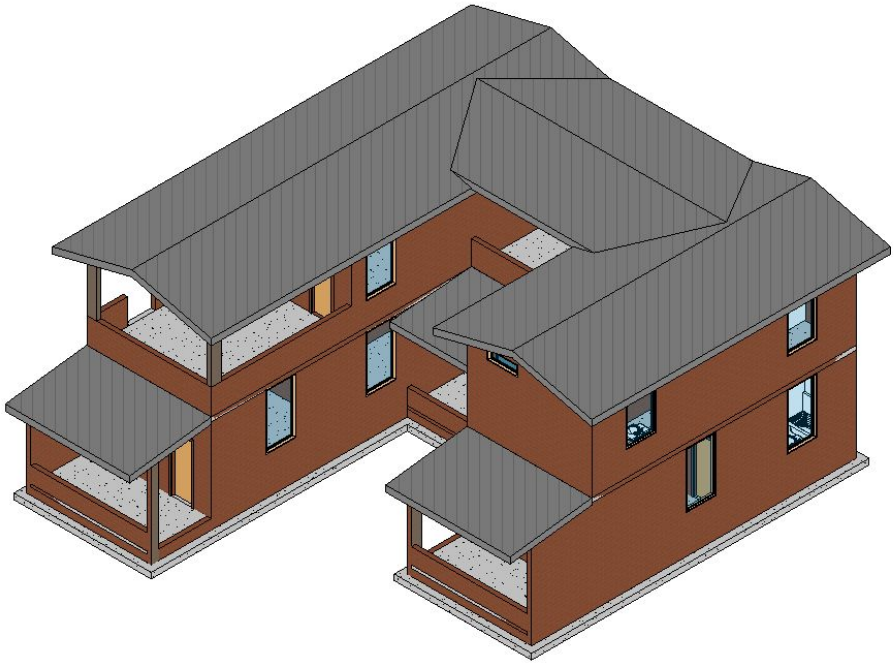
5

Repeat steps 1-4 for every wall location that are shown above. Accurate dimensions and spacing is shown in the drawing set. The half-wall provided on the porch is 3-feet tall.

ROOF STRUCTURE

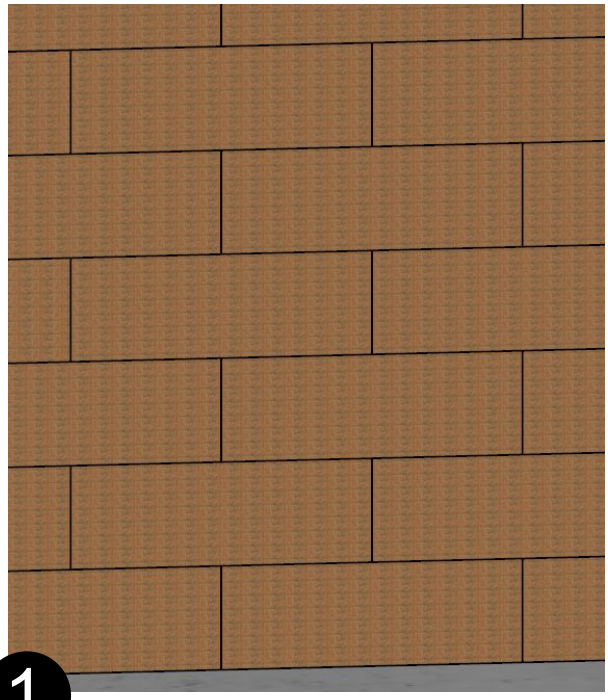


1. Frame a gable roofing system using 2” by 8” rafters at 24” on center, 2” by 6” ceiling joist, and 2” by 10” non-structural rafter.

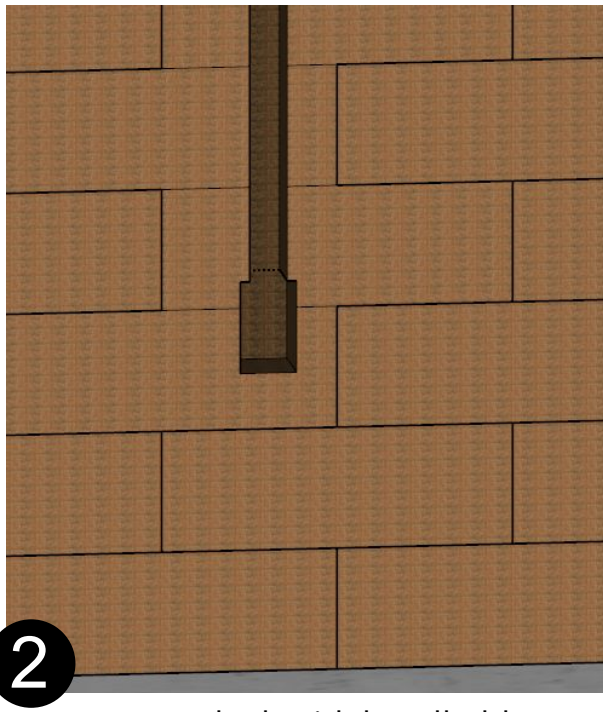


2. Place and secure corrugated metal panels to wood framing, ensuring 2’ of overhang.

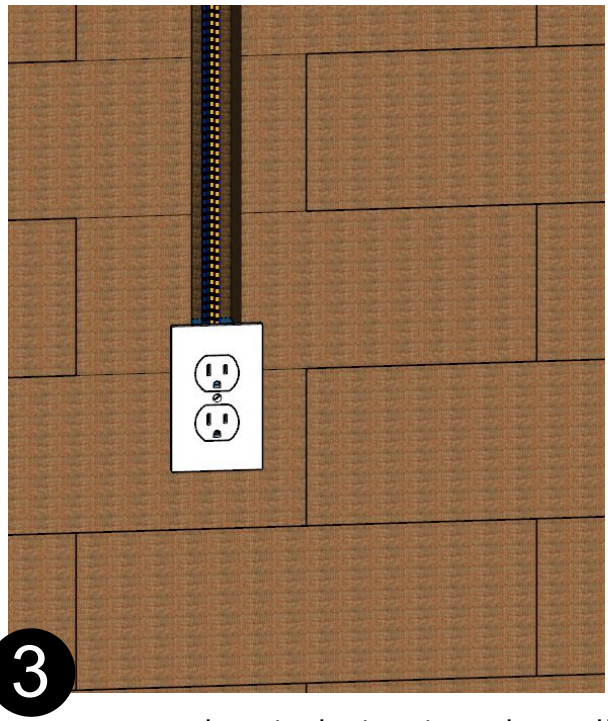
ELECTRICAL & PLUMBING



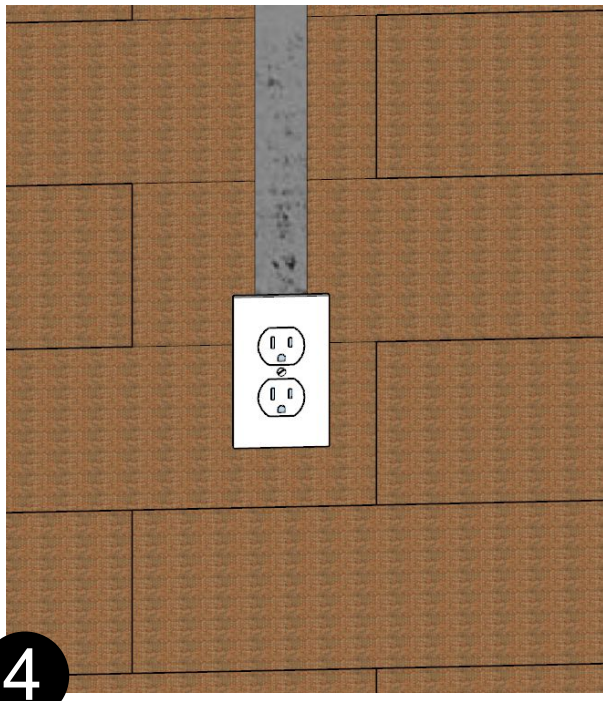
1 Identify locations for outlets and other electrical connections based on electrical plans.



2 Cut EcoBlock with handheld or circular saw to create space for electrical components.



3 Insert electrical wires into the wall.

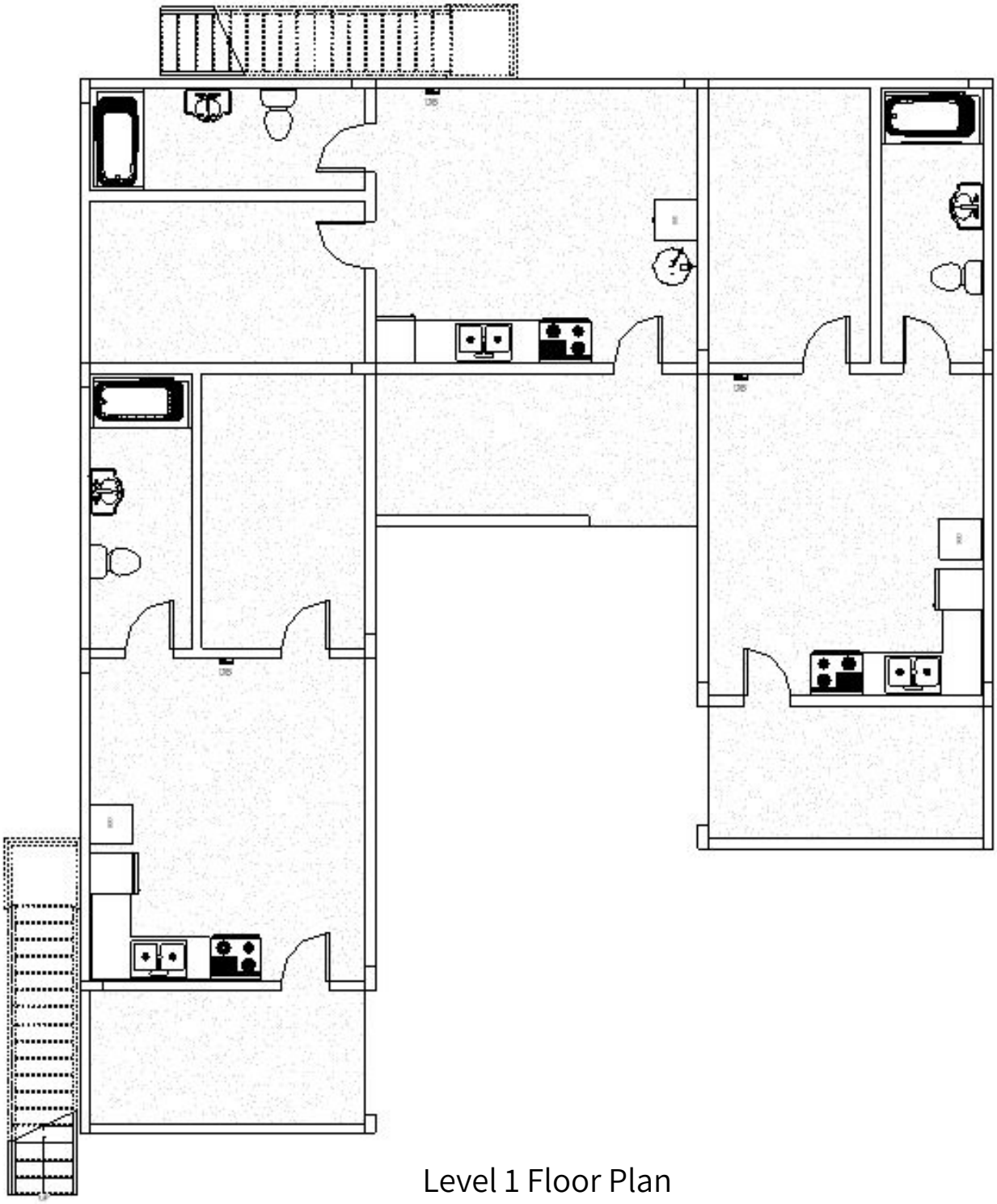


4 Fill in the wall with POP cement and smooth level with block wall.

NOTE: This technique is applicable to both electrical and plumbing systems. See attached plans for exact electrical and plumbing design.

INTERIOR FINISHES

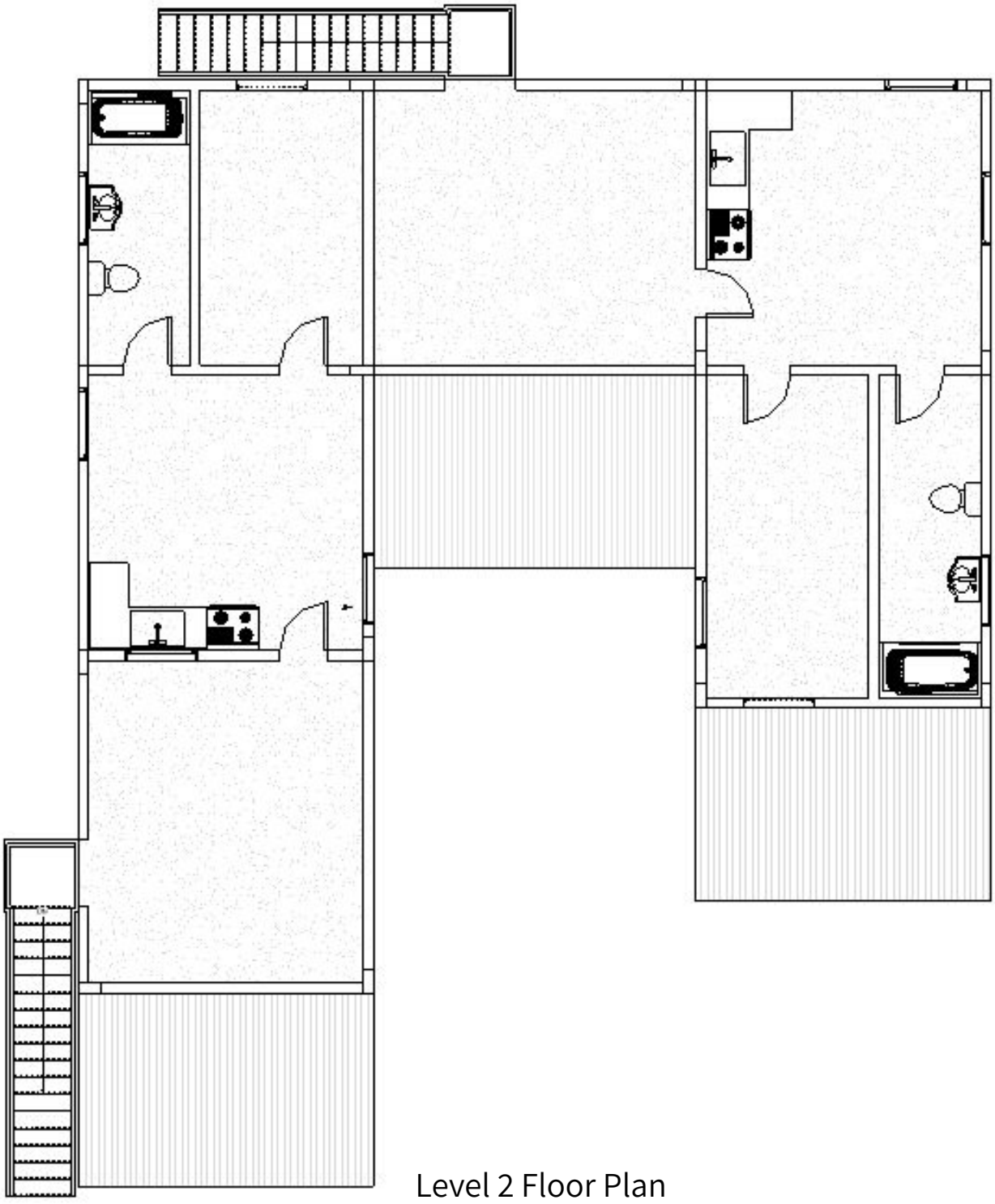
Locate the interior appliances and fixtures as they are located in the floor plans. For the kitchens, this includes a refrigerator, stove, sink, and counters/cabinets. For the bathrooms, this includes a shower/bathtub, sink, and toilet.



Level 1 Floor Plan

INTERIOR FINISHES

Locate the interior appliances and fixtures as they are located in the floor plans. For the kitchens, this includes a refrigerator, stove, sink, and counters/cabinets. For the bathrooms, this includes a shower/bathtub, sink, and toilet.



Level 2 Floor Plan

CONCLUSION

This manual acts as a guide to construct the proposed housing design. It should be noted that the images used to depict construction methods neglect to consider the realistic tendencies of the materials used.

Each of these steps are logical suggestions that would help to complete this project in the most efficient, cost-effective, and timely manner. However, logical alternate decisions can be made in the field.

Following these instructions will result in the creation of an affordable and sustainable housing structure, but there are several elements of building systems that fall outside of the scope of this manual. A septic system will be required to support the 5 toilets of these homes. It is assumed by the team that this system is provided by a company that is able to supplement its installation, and was therefore not in the scope of this project. Attachment to the town water line will also be required. The location of the closest access point and the procedure for adding residences to this line will require further coordination with town officials and was therefore not in the scope of this project.