

ANALYSIS 2: GREEN ROOF

Introduction

Problem Statement

Above the commercial space in the Palmerton, is a large standard flat roof with three air handling units on it. This is a potential eye sore to buildings in close proximity that would look down onto it, along with the students in the above apartments. This roof can also be seen by pedestrians walking up the street. This area, as it is now, will be looked over as if it was negative space, the hope is that people will focus more on the apartments above than the roof below them.

This roof has the potential to be something more. It could be one of the defining characteristic of the building. This roof might cost more, but, hopefully it will add enough value to the building to be able to pay for itself over time.

Goal

The implementation of an intensive green roof on this space can provide a positive architectural image and usable space that could bring money in for the owner if implemented correctly. There are three main things to make this possible, first, **Breadth 1**, analyze the existing structure and redesign it when necessary, due to the added weight of the saturated soil, plants, and the increased live load. Second, design the layout and the access to the roof. Third, look at ways to have this space make money for the owner to offset the cost.

Expected Outcomes

The addition of this intensive green roof should allow The Palmerton to grow in popularity and makes this building a hot spot to live, which can potentially allow the owner increase rent.

Background

What is a Green Roof

A green roof is a roof that utilizes vegetation and a growing media as the outmost layer of the roof. This acts as the protective component of the roof. There are two different types of green roofs. The first is an extensive green roof which is a simpler lighter version, consisting of typically 3"-6" of growing media weighing 16-35 psf when it is fully saturated. The second type is an intensive green roof, which requires a deeper growing media, usually 8" or more. This requires a more complicated drainage system and sometimes an irrigation system. These spaces are typically used for public access and can vary greatly in weight.

Advantages

Typical roofs take all the rain that hits them, adds pollutants, and then transports the water directly to a drain toward a sewer. These sewers dump this polluted water directly to our streams which is then used for drinking water where we take out the pollutants through a fairly expensive and energy intensive procedure. Before we, as humans, disrupted this system, rain would hit soil and plants. As the water traveled through the soil the plants pulled out the impurities and fed off of them. This naturally filtered water then seeps down to underground streams which then emerge as spring water. Green roofs can help restore this process by retaining this water to grow plants providing oxygen and potential habitat. If there is an excess of rain, the water would still be able to run off through a drainage system.



Figure 3: Water Runoff

Green roofs also can help save energy by keeping the roof cooler in the summer. As the sun hits the plants, the plants go through photosynthesis and help keep the building cool. This process helps maintain the roof temperature. See [Figure 4](#). Typically 40% of cities impervious area is roofs; this can cause a great deal of heat island effect.

Green roofs also have a much longer life span than typical roofs. Typical roofs have a life span of and green roofs have a life span of. Green roofs also have the potential to reduce some upfront costs of drains, HVAC, and water management.

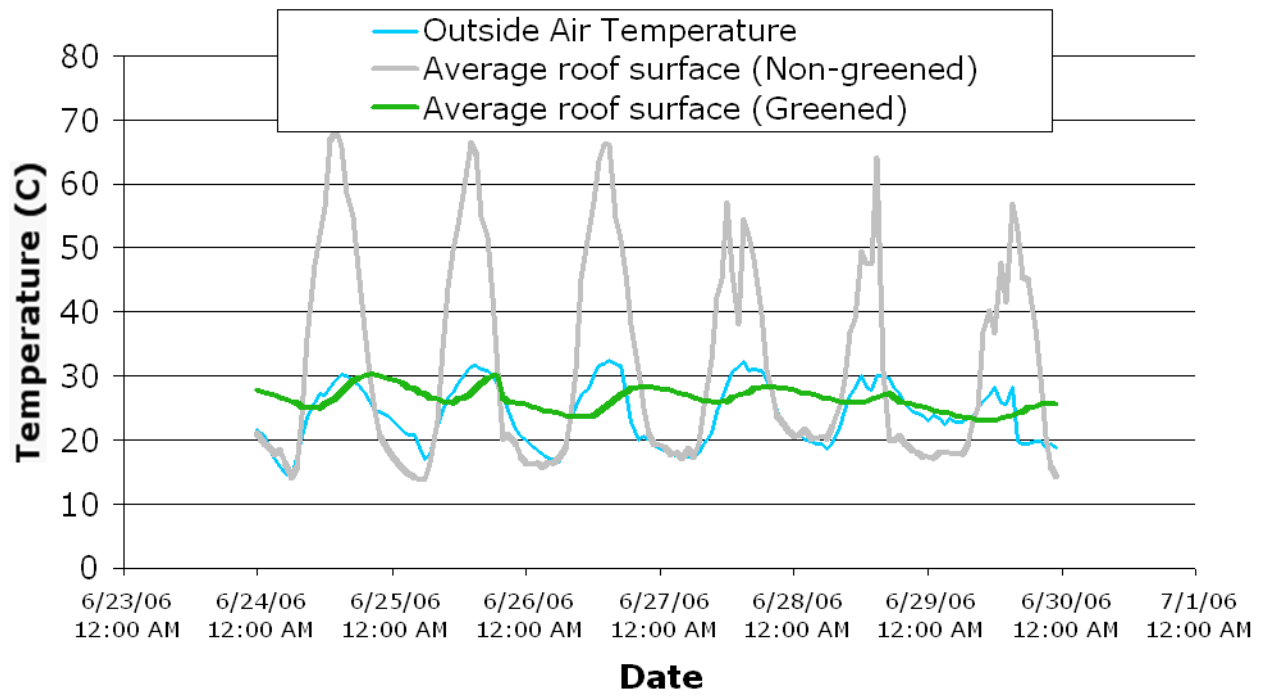
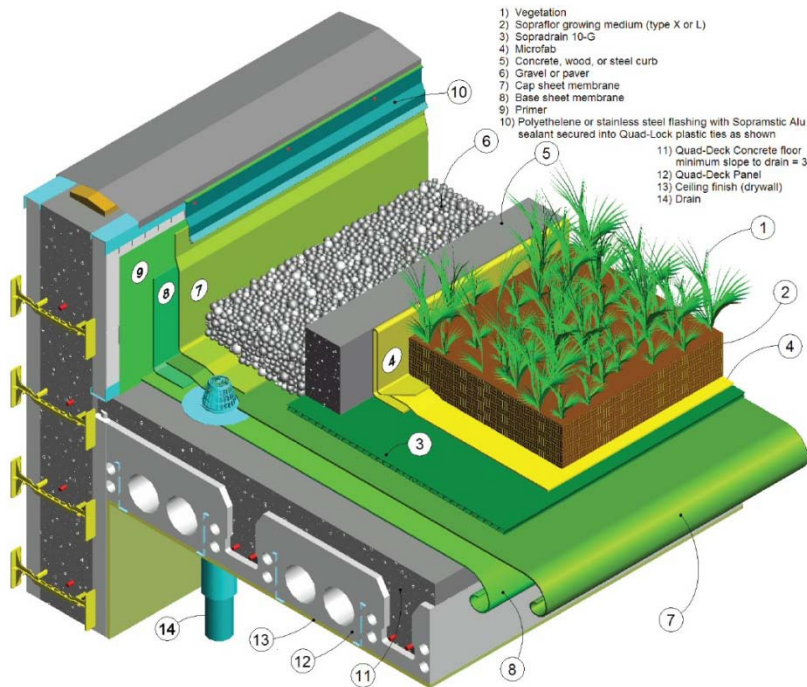


Figure 4: Average Roof Temperature

Green Roof Composition

Green Roofs have several different components in them. Starting from the bottom is the structure. After this is the insulation and then the water proof membrane. From this point the roof is pretty standard; the roof would normally have some kind of gravel above this. With a



green roof there are a couple additional layers, a root barrier, so the roots can't grow into the building, a drainage layer, for irrigation and runoff for downpours, filter fabric, growing media, and the vegetation.

Figure 5: Green Roof Composition

Green Roof Uses

There is approximately 6,500 SF of roof above the commercial space. This is split into 2 different areas. The northern part and the southern part which drops down about 12" in areas where the building steps back. As of now there are 3 air handling units and some other small equipment on this roof. In order for this roof to work as a potential occupied space these would need to be moved. There is space under the commercial area and behind it where a unit could fit. This will go further in depth in [Analysis 3: Mechanical Redesign](#).

This space could be a great area for relaxation in a hectic stressful college lifestyle. If residents were granted private access to this space they could use it as a place to study and relax. It could be a place to sun tan or just a place to hang out with friends, maybe have a picnic.

This space could also be used as a seating area for a café or restaurant that is renting in the space below. If the seating area was surrounded by greenery, this could turn into a major hot spot to eat and draw a lot of attraction.

This space could be a valuable asset to the owner of the building. This space adds valuable space and increases the value of the building. The owner could charge more money for rent for the residents to use this space. More detail can be found in the **Green Roof Survey** section. The owner could also charge the tenant in the commercial space for utilizing the roof as a sitting area. Typically in State College, rates for indoor space are typically \$16 - \$18 per square foot per month. Typically for outdoor seating on sidewalk, realtors let their tenants use it for free. For a green space on the roof, the rates would be in the vicinity of \$2 - \$4 per square foot per month. This works out to be \$5,000 - \$10,000 a month for approximately 2,500 SF, that's \$60,000 - \$120,000 a year. This will help pay off the initial investment of the green roof.

Green Roof Design

This space wants to be private while still making it beautiful from the street and from the roof. The best way to do this esthetically is to use tall plants. This becomes a problem because the depth of the soil would have to increase to support the taller plants. This adds weight, meaning more material, more cost, more time to construct. The building would also need some major design changes. The challenge was to create the same amount of privacy without impacting the structure significantly.

It was important that the schedule of residential part of the building was not impacted much by addition of the green roof and that it would continue on as originally scheduled. In order to do this effectively while using conservative structural numbers the depth of the soil was decreased to 4". This means that many taller plants could not grow in this soil. Therefore 12" of soil, contained in a planter box, was used around the edge of the green roof directly above the columns below. This way the hollow planks could be kept light otherwise some other kind of structure would ne to be used such as double t beams.

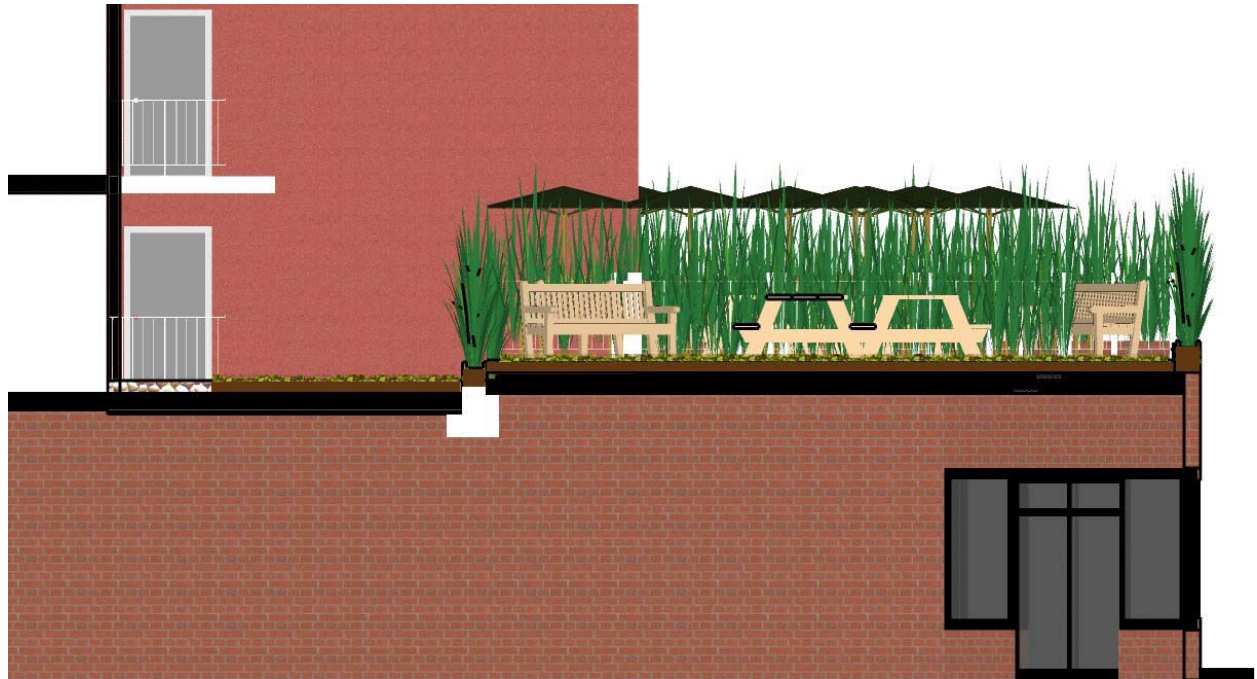


Figure 6: Green Roof Section

Plant Selection

Vegetation needs to be chosen carefully. The plants need to withstand the harsh winter, people walking on them, as well as surviving in the shade. The coral carpet is extremely durable and can withstand people walking on it. The big bluestem can be used as the barrier and be the planting on the edge of the roof. The others can be dispersed throughout.



Figure 7: Big Bluestem, Little Bluestem, Ostrich Fern, Coral Carpet

Green Roof Survey

A survey was performed in an attempt to quantify what Penn State students would pay for a green roof that was accessible to them. The survey was presented as follows. "You are a student at Penn State, living in downtown State College. There are 2 buildings that you are looking at living in." They were shown the pictures below on an 11X17 sheet of paper. "The picture on the bottom middle is the one building; the other is shown in the center. The other views show what the building and roof would look like from different spaces. The building with the proposed green roof would be accessible to you, as a resident, for studying, hanging out, parties, whatever you would like. How much more would you be willing to pay a month to live in the building with the green roof?" Some asked how much would they already be paying and they were told \$550 a month per person and everything except parking is included in this rate.

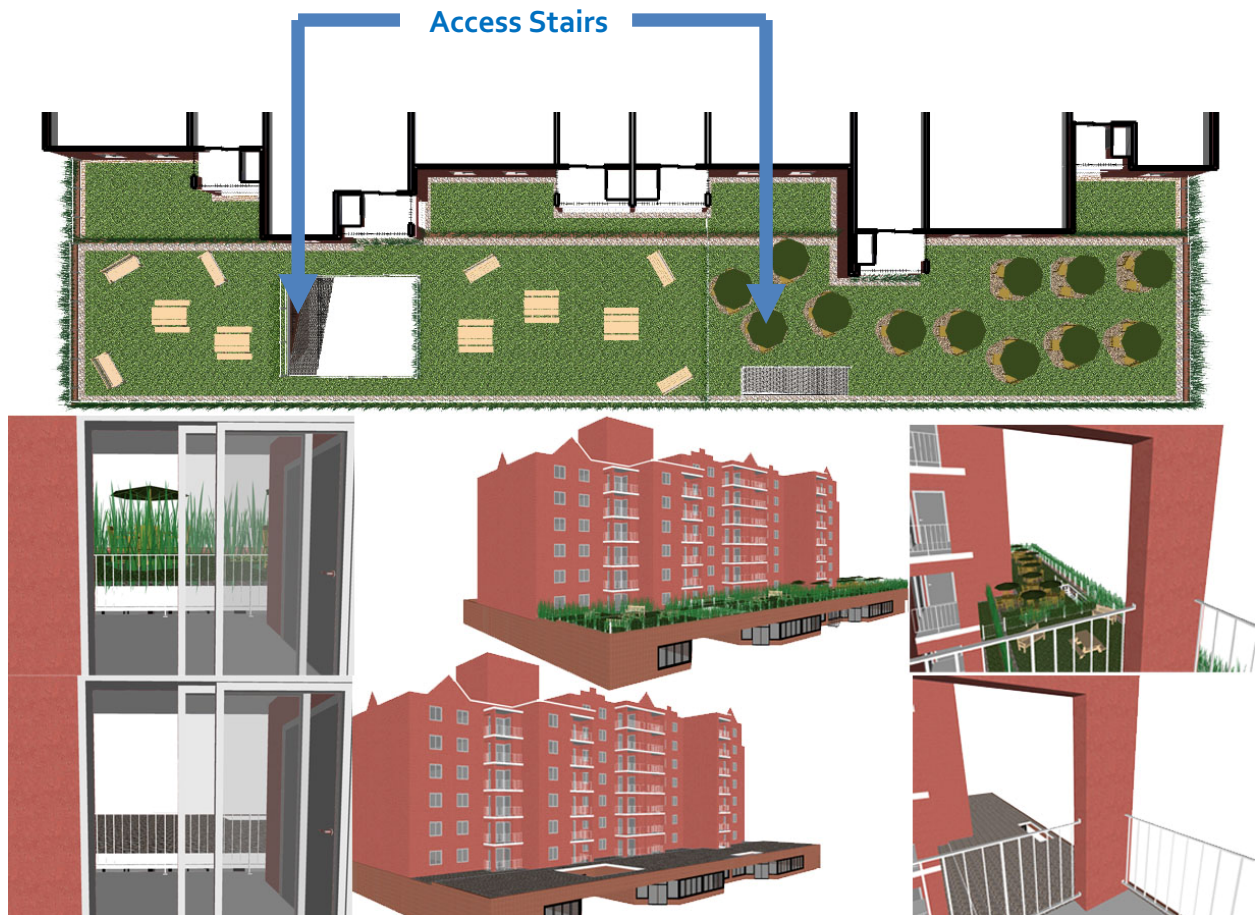


Figure 8: Existing Roof Compared to the Proposed Green Roof

Table 4: Survey Analysis

| | Rate Per Month |
|------|----------------|
| 1 | \$ 20.00 |
| 2 | \$ 75.00 |
| 3 | \$ - |
| 4 | \$ 15.00 |
| 5 | \$ 50.00 |
| 6 | \$ 50.00 |
| 7 | \$ 25.00 |
| 8 | \$ 50.00 |
| 9 | \$ 50.00 |
| 10 | \$ 50.00 |
| 11 | \$ 20.00 |
| 12 | \$ 20.00 |
| 13 | \$ 20.00 |
| 14 | \$ 100.00 |
| 15 | \$ 110.00 |
| 16 | \$ 25.00 |
| 17 | \$ 50.00 |
| 18 | \$ 100.00 |
| 19 | \$ 75.00 |
| 20 | \$ 100.00 |
| 21 | \$ 50.00 |
| 22 | \$ 50.00 |
| 23 | \$ 10.00 |
| 24 | \$ - |
| 25 | \$ 20.00 |
| 26 | \$ 50.00 |
| 27 | \$ 25.00 |
| 28 | \$ 50.00 |
| 29 | \$ 10.00 |
| 30 | \$ 50.00 |
| 31 | \$ 30.00 |
| 32 | \$ 25.00 |
| 33 | \$ 50.00 |
| 34 | \$ 50.00 |
| Avg. | \$ 43.38 |
| Mean | \$ 50.00 |
| Min | \$ - |
| Max | \$ 110.00 |

Survey Results

Once the cost of rent was revealed, most students were overwhelmed with the number. Knowing this many said that they would never live here. This altered to survey somewhat, but at the same time could have made it realistic, because now they know they have something to base their answer off of. Even though the students said they would not pay for the apartment. Due to the fact that The Palmerton has been booked for quite some time, some students are willing to pay this and would probably pay a little more anyways just because of the high demand for nice housing downtown.

The most common response was \$50 a month, with the lowest being \$0 a month and the highest at \$110 a month.

This data may be a little skewed due to the student base being a great deal of architectural engineers. However, the ones that were not gave similar numbers and sometimes a little higher. Therefore if this data was skewed it may even be a little low. This may be due the architectural engineers knowing about green roofs and are more familiar with them. This means that students that do not know a lot about green roofs may be more intrigued and think of them as more rare; in turn they are likely to pay a little more.

Another factor that may decrease the numbers in the survey is that only half of the students would be living on the green roof side. This fact was not known to the students who took part in the survey.

Even with this smaller data base this data shows that students are willing to pay more a great deal more for an accessible green roof and most had similar numbers. Assuming the owner charges \$40, this green roof will make\$9,600 a month, that’s \$115,200 a year from the residents alone.

This survey got different results then the Student Apartment Survey, the main reason is probably due to seeing the space. Most students from the first survey might not be able to picture what a large difference a green space can make.

Green Roof Structural Redesign, Breadth 1

Refer to the Structural Calculations in [Appendix G: Structural Calculations](#).

Green Roof Schedule

This roof was designed completely with schedule in mind. There are minimal changes in the residential side of the building with relatively no impact on schedule. The only major change is the roof and planting. This can be done while the majority of the work is going on inside. There is no major equipment needed at this point. A telescoping boom fork lift can take care of all the lifting required to the 1 story roof. Refer to [Appendix A1: Proposed Project Schedule](#).

The beams on the south side of the roof, where the roof lowers, are 1617% faster to erect than the existing design, due to them being precast. The cast in place takes 219.144 hours to form and pour, where the precast beams take 18 hours to erect. This will allow that part of the building to speed up by a week, which allows the rest of the structure, which may take a little while longer, to finish on schedule.

Green Roof Estimate

Table 5: Green Roof Comparison shows the difference in cost of the existing system compared to the first system. The proposed green roof costs about twice as much. However, the additional income from the green roof is substantial. Renting the space out to a café or restaurant below can bring in \$5,000 - \$10,000 a month. According to the green roof survey will bring in \$9,600 a month if residents pay \$40 additionally a month. Assuming the lower value of commercial rent and a 1 year payback. The owner would charge the residents \$21.00 a month, half the amount students said they would pay.

| Item | Size | Type | Unit | Mat | Lab | total | # | Total | |
|---------------------------------------|-------|------------------|------|-------------|-------------|-------------|------|---------------|----------------------|
| Table 5: Green Roof Comparison | | | | | | | | | |
| Existing | | | | | | | | | |
| Spread Footer | 8" | 3000 PSI | SF | \$ 241.00 | \$ 297.00 | \$ 538.00 | 8 | \$ 4,304.00 | |
| Steel Column | 8x8 | HSS8x8 | EA | \$ 555.00 | \$ 43.50 | \$ 598.50 | 8 | \$ 4,788.00 | |
| Steel Beam | 12x8 | HSS12x8x5/8 | LF | \$ 37.30 | \$ 13.80 | \$ 51.10 | 190 | \$ 9,709.00 | |
| | 12x35 | W12x35 | LF | \$ 36.39 | \$ 2.66 | \$ 39.05 | 24 | \$ 937.20 | |
| Concrete Beam | 32 | Cast in Place | CY | \$ 298.00 | \$ 385.00 | \$ 683.00 | 27 | \$ 18,441.00 | |
| Screens for AHU | 60" | Ruskin Screen | LF | \$ 20.00 | \$ 20.00 | \$ 40.00 | 68 | \$ 2,720.00 | |
| Hollow Core | 8" | 15 strand | SF | \$ 8.15 | \$ 4.61 | \$ 12.76 | 6487 | \$ 82,774.12 | |
| Roof | | 4 plies & gravel | SF | \$ 1.49 | \$ 1.62 | \$ 3.11 | 6487 | \$ 20,174.57 | |
| Total | | | | | | | | | \$ 143,847.89 |
| Proposed With Green Roof | | | | | | | | | |
| Spread Footer | 8" | 3000 PSI | LF | \$ 460.00 | \$ 500.00 | \$ 960.00 | 8 | \$ 7,680.00 | |
| Steel Column | 10x5 | HSS10x5x3/8 | EA | \$ 555.00 | \$ 43.50 | \$ 598.50 | 8 | \$ 4,788.00 | |
| Steel Beam | 14x10 | HSS14x10x5/8 | LF | \$ 45.62 | \$ 14.80 | \$ 60.42 | 190 | \$ 11,479.61 | |
| | 12x72 | W12x72 | LF | \$ 75.00 | \$ 3.40 | \$ 78.40 | 24 | \$ 1,881.60 | |
| Concrete Beam | 24' | Precast T 12x32 | EA | \$ 193.00 | \$ 12.88 | \$ 205.88 | 9 | \$ 1,852.92 | |
| Planter Box | 1' | Brick with 2x4 | SF | \$ 6.65 | \$ 12.65 | \$ 19.30 | 840 | \$ 16,212.00 | |
| | | Soil and Plants | | \$ 25.00 | \$ 1.51 | \$ 26.51 | 840 | \$ 22,268.40 | |
| Railing | 4' | Simple Metal | LF | \$ 11.30 | \$ 6.10 | \$ 17.40 | 280 | \$ 4,872.00 | |
| Hollow Core | 10" | 15 strand | SF | \$ 8.80 | \$ 4.28 | \$ 13.08 | 6287 | \$ 82,233.96 | |
| Stairs | 10' | Metal 16 Risers | EA | \$ 7,775.00 | \$ 1,825.00 | \$ 9,600.00 | 2 | \$ 19,200.00 | |
| Roof | | 4 plies | SF | \$ 1.02 | \$ 1.70 | \$ 2.72 | 6287 | \$ 17,100.64 | |
| Green Roof | 4" | | SF | \$ 20.00 | \$ 1.51 | \$ 21.51 | 6287 | \$ 135,233.37 | |
| Total | | | | | | | | | \$ 324,802.50 |

Assumptions

The beams on the south side in each estimate are assumed to be the same all the across the building. In each design this beam would be the most significant in cost, schedule and bearing capacity. The screens to hide the 3 AHUs were estimated based on a couple different types of fences.

Green Roof Summary

The addition of this green roof can add major interest to the building. Pedestrians, whether they are students or not will be able to see this roof and know right away what it is and if they do not, they will probably want to find out. This can provide a great image for the owner and more importantly for the building itself. Imagine students asking, "Where do you live?" "I live the building with the green roof." It could become what defines the building instead of just the name or the location. Because of this, the roof could become an invaluable investment.

This aside, the addition of this green roof will cost about \$180,000 more than the existing, due to a small increase in structure and the cost of the green roof itself. Renting this space to a café or a restaurant would bring in \$5,000 - \$10,000 a month. This alone makes the payback period 1.5 to 3.0 years. With the commercial paying for this alone, the roof is definitely a worthwhile investment. Including the residents paying, it can cut the payback time practically in half. Assuming residents will pay as much as they said they would the payback is in 9 months. Even if they pay half or a quarter of that, the green roof is a no brainer.