Team Squared

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Engineering 215

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Contents

List of Figures

List of Tables

1. Problem Formulation

1.1. Introduction

The problem definition section of this document introduces the project team members, background on the project, and the objective statement, which defines the necessity for the project.

1.2. Background

Team Squared, whose members include; Ailynn Andersen, Jesse Bobrow, Julian Sicaud and Catherine Carbajal, is tasked with reconstructing a footpath at Zane Middle School in Eureka, Ca, using water permeable materials. The team will be replacing a failed attempt to construct a permeable pathway, which entails a path that is made of a permeable cement to allow water to percolate through it.

1.3. Objective

Team Squared's goal is to redesign a section of Zane Middle School's campus, and implement a permeable footpath, along with any other landscaping elements required to control and channel water, which should make the campus a more accessible, eco-conscious, and beautiful place. The black box model in figure

1.4. Black Box Model

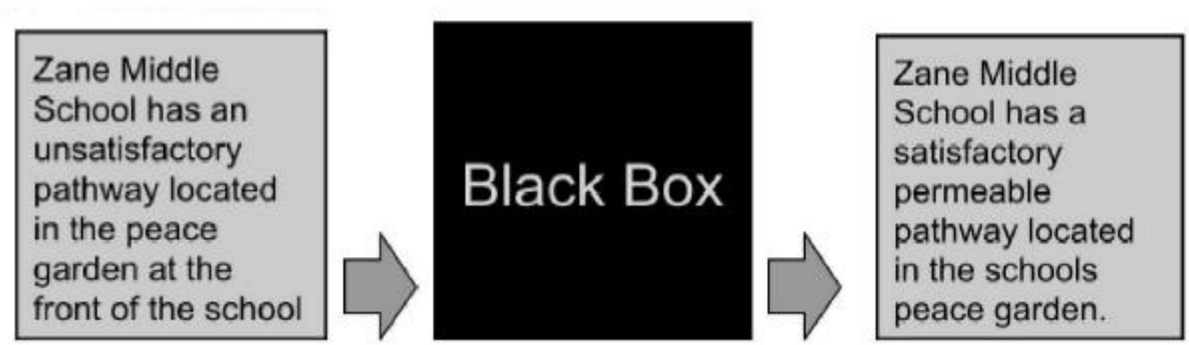

Figure 11 Black Box Model depicting the problem and solution for this project.

2. Problem Analysis and Literature Review

2.1. Introduction to Problem Analysis

The purpose of a problem analysis is to identify the criteria of the project regarding the client and address the constraints of each criterion. Included in the problem analysis are specifications, considerations, criteria, production volume, and usage.

2.1.1. Specifications

The specifications of this project are factors that must be implemented in the design process. The following specifications will be considered during the design process: The path must be permeable, design must provide a long-term pathway, tools and materials required for constructing a permeable pathway, landscaping must be easily maintained.

2.1.2. Considerations

The considerations of this project are relevant facts that may influence the design of this project. The considerations for this project are that the path is durable, permeable, and in some way educational.

2.1.3. Criteria

The criteria of this project, such as durability, permeability, maintenance, functionality, cost, educational value, are necessary qualities this project must have, as requested by the client. Table 2-1 below shows the criteria presented by Trevor Hammons, and their respective constraints.

Criteria	Constraints	Weights
Durability	The path must be able to withstand the weather and multitude of students that will be using it. It must not fall apart, as the previous path did.	10
Permeability	Water needs to be able to percolate completely through the path to avoid issues with runoff.	10
Maintenance	Must be easy to take care of, both the path and landscaping. Landscaping should be no taller than 2ft to avoid students hiding in the shrubbery.	7
Functionality	The path must be level, and easy for students to walk on.	8
Cost	Must have a cost of no more than 400$.	6
Educational Value	Students must be able to learn and understand how the permeable pavement works. They should also understand why permeable pavement is more environmentally friendly compared to other pavement options.	5

Table 1-1 Table of Client Criteria

2.1.4. Usage

The permeable path will be used by students as a way to and from the school. Students will use the path before and after school to safely get to and from the parking lot after being dropped off or before being picked up. It can also be used as an educational tool to instruct students about permeable paths and their benefits to the environment.

2.1.5. Production Volume

There is only a need for one path that runs along the memorial garden at the front of Zane Middle School.

2.2. Literature Review

The literature review will provide background information on our project which will a foundation for the design process of our permeable path. The following topics will be discussed: permeable paths, materials, costs, client criteria, landscaping, soil and surveying.

2.2.1. Permeable Paths

Permeable paths are pathways that consist of a pervious pavement, porous surface or porous material that allows water to percolate through it. The website Paths for All states that permeable pavements are, "Any material that allows water to pass through. The surface can be permeable or porous. Typical surfaces are porous asphalt, gravel paving, grass paving, resin bound paving and geotextiles". The materials stated in Paths for All's definition will be considered for the path being redone at Zane Middle School.

2.2.2. Background on Project Area

The path way at the front of Zane Middle school will be rebuilt to fit the client's criteria. The existing path is falling apart and in poor condition. The figures included in this section depict the state of the path that will be rebuilt, and the path that has met the client's previous criteria.

Figure 21 Successful Path

Figure 22 Path that needed to be redone

2.2.3. Why Permeable Paths Are an Environmentally Positive Choice

Permeable materials are an environmentally positive choice for pathways because they allow water to percolate through them, which is “instrumental in recharging groundwater, reducing storm water runoff, and meeting U.S. Environmental Protection Agency (EPA) storm water regulations”. As the figure demonstrates the pervious pavement allows water to easily percolate through it, rather than running off the surface.

Figure 23 Example of Permeable Pavement

http://www.washingtonconcrete.org/pervious-concret

2.2.4. Benefits of Pervious Pavements

All of the pros are stated by the article *Permeable Pavement: The Pros and Cons You Need to Know* written on GreenBlue Urban.

- Pervious pavements do not create islands- an area of pavement that is much hotter than the surrounding area.
- It can be made by using upcycled materials, rather than just putting pressure on the environment to produce new materials.
- Water can seep through the pavement, therefore ice cannot form providing safer surface for the students to walk on. It will also prevent issues with flooding.
- The pavement will stay cooler warmer temperatures due to the circulations of precipitation

2.2.5. Drawbacks of Pervious Pavements

All of the cons are stated by the article *Permeable Pavement: The Pros and Cons You Need to Know* written on GreenBlue Urban.

- Can be more expensive to install compared to traditional pavements
- Maintenance for permeable paths is challenging compared to traditional pavements. Permeable pavements can clog if the reservoir doesn't drain properly or if sand and small particles buildup. If the clogs are not taken care of properly water may not percolate, defeating the purpose of the permeable pavement.
- Pervious pavements aren't as strong as traditional or asphalt pavements. If too much force is applied, such as the weight of heavy vehicles, structures can collapse.

2.3. Pervious Concrete

Pervious concrete is a concrete mix that allows water to percolate through the cement structure. This type of concrete differs from traditional concrete because it does not use fine aggregates, only one size aggregate (Dellatte, 207). Fine aggregates add more support to the concrete; however, it also closes any gaps that might form in the mix. The uniform aggregate structure of pervious concrete creates gaps in the concrete that allow water and air through. Because of the gaps in the structure, pervious concrete is not as durable as traditional concrete. Which limits the use of pervious concrete because it may not be suitable for applications that require high durability. Pervious pavement is often applied to walkways because they do not require high durability.

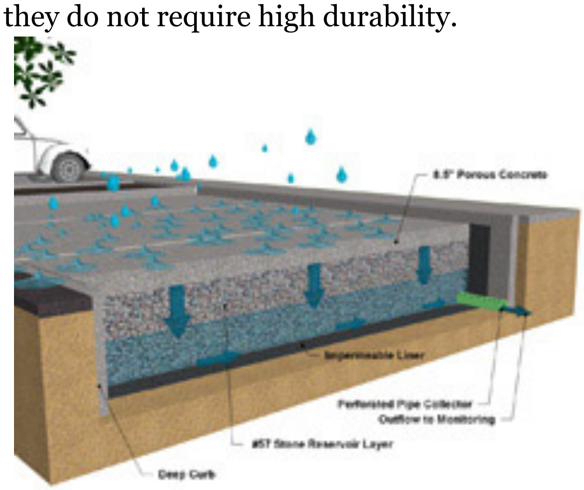

Figure 24 Example of how Permeable Pavement works

http://www.floodcontrol.co.riverside.ca.us/LID.aspx#link

2.3.1.Materials

The main materials needed for pervious concrete are Portland cement and small sized aggregates (perviouspavement.org). Portland cement is a mix that is used to make concrete. The concrete is made by adding sand, fine aggregate, and rocks, small aggregate, to the Portland cement (cement.org). For pervious concrete the Portland cement is used without fine aggregate to bind small aggregate together. The small aggregate act as the basic structure of the concrete and give it rigidness and durability. Many varied sizes of aggregate can be used depending on the application. An example of aggregate that can be used is pea gravel due to its smooth texture. A visual example of this system is provided in figure 2-3.

2.3.2.Costs

The average Portland cement costs $113 per metric ton, as of 2017 (statista.com). However, for the typical consumer Portland cement is purchased by the bag which is approximately $10 dollars for 47lbs (acehardware.com). Aggregate varies in price depending on the type of material the aggregate is made of. A usual price is about $30-35 per cubic yard and $50-75 per cubic yard for colored rock (homeadvisor.com)

2.4.Permeable Paver System

Permeable paver systems are systems that collect rainwater and slowly disperse it back into the groundwater. These systems are often used for driveways and walkways. Paver systems allow for aesthetically pleasing textural geometries while providing a durable pathway (Pilliod). Pavers are much more durable the pervious concrete and are easier to install (www.icpi.org). Another benefit of a paver system is that pavers can be reused and replaced with ease and they do not have to be destroyed to be removed, this makes pavers a much better long term permeable system.

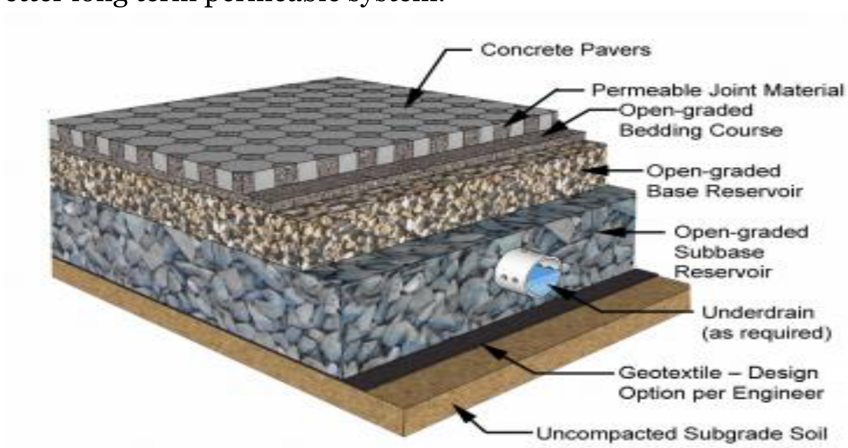

Figure 25 Example of how Concrete Pavers

http://blog.southviewdesign.com/sustainable-landscaping/permeable-paver-systems

2.4.1. Materials

Permeable paver systems typically have eight total layers: pavers, joint material, base layer, subbase layer, drain, geotextile, and uncompacted soil layer. Pavers are the top layer and they provide a durable and flat path/driveway. The spaces between pavers are filled with joint material which allows water to flow into the system. Under the pavers there is a layer of base material which adds support to the pavers. The subbase material acts as a reservoir for the water coming into the system. The drain under the subbase is required to remove excess water from the system in event of a heavy rain fall. Geotextile helps hold the water in the reservoir and slowly releases into the soil. The bottom layer of soil, or subgrade, absorbs the water (Pilliod).

2.4.2. Costs

Costs for permeable paver systems can vary tremendously depending on many factors such as: cost of installation, soil type, size of overall system, and paver type. The average cost per square foot of permeable paver system is around $10-11.35 (remodelingexpense.com).

2.5. Landscaping

This section will lay out what kind of landscaping could be implemented along with the path. Along with research of diverse types of plants that are ideal for easy upkeep and will survive easily in the environment where the school is located.

2.5.1. Materials

Some tools that may be needed in our landscaping include: long handled shears, hoes, gardening gloves, trowels, pruners, shovels and a wheelbarrow. Long handed shears can be used for trimming plants or bushes that can be used in landscaping. Hoes may be needed to take out any possible weeds growing around in the area, since the landscaping should look as nice as possible this would be a great tool to have and not have to pick out the weeds by hand. This also means gardening gloves may be needed. The trowels would be used to do the actual gardening of the plants but can also be done with shovels. The wheelbarrow would also be essential to carry heavy supplies. There are also a lot of other minor supplies such as stirring sticks, or paint mix holders for our concrete samples we will be trying out.

2.5.2. Plants to be Considered

Plants that could be considered for use in this project include flowers, bushes and edible plants. Some possible flowers are: witch hazel, snowdrops or hellebores. Witch hazel flowers are known for being able to handle cold weather and even bloom in late winter. Hellebores are known for being minimal maintenance but do not like being overwatered which may be an issue since the Humboldt county is known for being very rainy. The bushes in consideration are the, Hosta brother Stefan, Hosta shadowland waterslide, ferns, and even edible black berry bushes. Ferns would be an excellent choice for comfort since there is naturally many ferns in this area. But it would also be very cool to add Hosta strains because they are very durable in the Humboldt county weather and beautiful for a low cost. Black berry bushes are another possibility but can come with some issues like thorns or more maintenance.

Figure 26 Example of Location Where Plants can be Purchased

http://madrivergardens.com/plants

2.5.3. Costs

The price of tools can vary anywhere from $10 to $80. The price of plants can also add up very quick, some bushes vary from $10 each to $30 each. Flowers can be bought for a dozen from $15 to $45, aesthetics are important to have a comfortable. There are more economically friendly options to make an area look nice, such as a bench or large rocks, would be a great alternative to purchasing expensive foliage.

2.6. Land Surveying

Surveying is process of measuring and evaluating changes in an area of land by triangulating and plotting the distances and respective angles between disparate points. These plotted points can help engineers and/or surveyors with tasks such as; determining topographical locations, making topographical maps, determining land boundaries, measuring changes in existing features or structures, and determining soil hydrology. Land Surveying is useful in planning landscapes or installations of permeable paths because it can help determine the movement of water, especially during high volumes of precipitaion.

2.6.1. Theodolite and Total Stations

The theodolite is an essential land surveying tool that is used to measure horizontal and vertical angles. Many modern forms are now digital, but the original design was from 16th century mathematician Leonard Digges. Theodolites are mounted on a tripod at eye level and then leveled so that measurements are accurate. Modern Theodolites consist of a telescope mounted in a vertically mounted bracket mounted on a rotating platform allowing movement vertically and horizontally. Many modern Theodolites also have an Electronic Distance Measurement (EDM) to read distances as well as angles. These theodolites with distance measurement capabilities are generally known as "Total Stations." An EDM works by firing a laser and measuring the time it takes for light to reach the target point and reflect to the tool.

Figure 27 Example of a Theodolite

https://www.turbosquid.com/3d-models/3d-theodolite-tripod-base-model/723198

2.6.2.Leveling Rods

Leveling rods are used to measure the vertical distance from a point on the ground and a point that is viewed through a theodolite, which may be level. Also known as self-reading rods, they come in diverse types depending on types of elevations that are being measured. They are graduated rods, usually constructed of wood or aluminum. Rods that come in sections are sometimes called “Philadelphia Rods”.

Figure 28 Example of a Leveling Rod

https://www.google.com/search?q=about+leveling+rods&rlz=1C1CHBF_enUS781US781&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj7x939z7fZAhUGWq0KHVgBA0gQ_AUICygC&biw=958&bih=880#imgrc=bvoyys95S8TZjM:

2.6.3.Measuring Tape and Plumb Bobs

If the instrument used does not have an Electronic Distance Measurement or EDM then measuring tape can be used to measure distances. Although other methods of measuring distance exist, such as pacing, an odometer, or maps, tape is the more accurate and approachable method. The usual length for tape is 100 ft but can range as long as 500. Using the tape to measure distances should be as easy as aligning it, pulling it taught, and taking a measurement, but that does not account for any elevation change. If the distance measured needs to be level with the theodolite but the land slopes up or down the length measurements need to be broken into segments. Vertical displacements need to be calculated before resuming horizontal measuring. In order to achieve true vertical displacement, surveyors use plumb bobs. A plumb bob is a weight attached to a line which hangs down and represents the true vertical line, or "plumb." Once the horizontal measurements are displaced vertically to a comfortable elevation, the horizontal measurements can continue.

Figure 29 Example of a Plumb bob

https://www.google.com/search?rlz=1C1CHBF_enUS781US781&biw=958&bih=929&tbm=isch&sa=1&ei=DjGOWtX5FYWitQWQypr4BQ&q=plumb+bob+&oq=plumb+bob+&gs_l=psy-ab.3...17202.17202.0.18023.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.psy-ab..0.0.0....0.Wdh2ne6ItTg#imgrc=41BbHEfVLVjTwM:

Figure 210 Example of a Measuring Tape

https://www.google.com/search?rlz=1C1CHBF_enUS781US781&biw=958&bih=929&tbm=isch&sa=1&ei=ITGOWvCKE8yWtQWygZmQDA&q=surveying+tape&oq=surveying+tape&gs_l=psy-ab.3...27590.32041.0.32552.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.psy-ab..0.0.0....0.ZojKQXRiK1Q#imgrc=huK4o5Mu315zMM:

2.7. Soil

Considering that the goal of a permeable surface is to reduce runoff by allowing water to permeate into the soil below, the characteristics of the soil below should be considered as well. The USDA has a classification of four general types of soils; A, B, C, and D. The hydrologic soil groups A and B are better suited for proper water absorption and percolation. Groups C and D soils usually require an underdrain in the subgrade to move the excess of water in case the percolation is too slow, or the soil is already saturated. The D3385 and the D5093 Standard Tests from ASTM international can be used if more rigorous tests are needed

Hydrologic soil group	Infiltration rate (inches/ hour)	Infiltration rate (centimeters/ hour)	Soil textures	Corresponding Unified Soil Classification
A	1.63[a]	4.14	gravel sandy gravel silty gravels	GW - well-graded gravels, sandy gravels GP - gap-graded or uniform gravels, sandy gravels GM - silty gravels, silty sandy gravels SW - well-graded gravelly sands
	0.8	2.03	sand loamy sand sandy loam	SP - gap-graded or uniform sands, gravelly sands
B	0.45	1.14		SM - silty sands, silty gravelly sands
	0.3	0.76	loam, silt loam	MH - micaceous silts, diatomaceous silts, volcanic ash
C	0.2	0.51	Sandy clay loam	ML - silts, very fine sands, silty or clayey fine sands
D	0.06	0.15	clay loam silty clay loam sandy clay silty clay clay	GC - clayey gravels, clayey sandy gravels SC - clayey sands, clayey gravelly sands CL - low plasticity clays, sandy or silty clays OL - organic silts and clays of low plasticity CH - highly plastic clays and sandy clays OH - organic silts and clays of high plasticity

Table 2-1 (modified from https://stormwater.pca.state.mn.us/index.php?title=Design_infiltration_rates)

2.7.1. Other Soil Considerations

Permeable paths should not be built on sites containing non-compacted backfill, which can be unstable when saturated with water. On the other hand, over-compacting the soil subgrade may compress the soil and reduce permeability. The slope of the soil subgrade should also be as flat as possible to reduce runoff away from the permeable site. Some designs include a geotextile, or landscaping cloth, along the sides and bottom of the subbase to prevent soil and root growth from "clogging" the subbase.

2.7.2. Underdrains and French Drains

An underdrain is installed below the graded surface and allows the movement of percolated water into a conduit that drains horizontally. A French drain is a simple type of underdrain that is popular in landscaping design. A French drain is installed in the subgrade below the permeable path and subbase. First a trench is dug in the subgrade using a trenching shovel, then the trench is lined with landscaping or weed fabric to prevent roots from encroaching. The trench should go from a point of high saturation to one that is considerably dryer. The trench is then back filled slightly with loose gravel. A Perforated drain tube is placed in the trench before completely back filling with gravel, burying the tube. This system will then be covered by the sub-base.

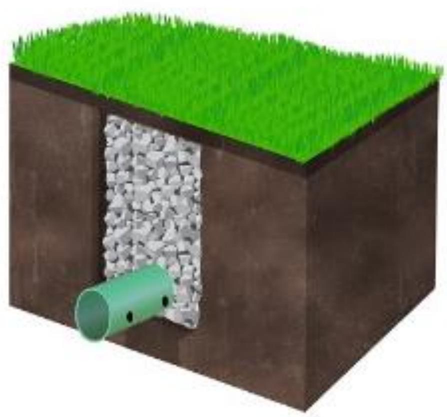

Figure 211 Example of a French Drain

https://www.google.com/search?rlz=1C1CHBF_enUS781US781&biw=958&bih=929&tbm=isch&sa=1&ei=fAGOWr3bO8eWtQXMiqWoCQ&q=french+drain+diagram&oq=french+drain+diagram&gs_l=psy-ab.3...37838.38723.0.38890.0.0.0.0.0.0.0.0..0.0....0...1c.1.64.psy-ab..0.0.0....0.RNprSzKGlTc#imgdii=8ptN0mf9Te2UWM:&imgrc=ZCem-raLgMP1lM:

3. Alternative Solutions

3.1. Introduction

Brainstorming sessions were utilized to develop alternative solutions of design for a previous path. Each of the alternative solutions satisfies the objective statement and the client criteria, offering suitable options for a pervious pathway. A total of five alternative solutions were designs were developed during one brainstorming session.

3.2. Brainstorming

One brainstorming session was held, and during the session a white board was utilized in a classroom. The purpose of the brainstorm was to develop ideas, for the given task, and build off of them to see which ones would be feasible for the project. Many different pervious systems were discussed for the pathway as seen below. Some of the solutions discussed are reclaimed concrete, rubber/ reclaimed tires, brick pavers, decomposed granite, and pervious concrete.

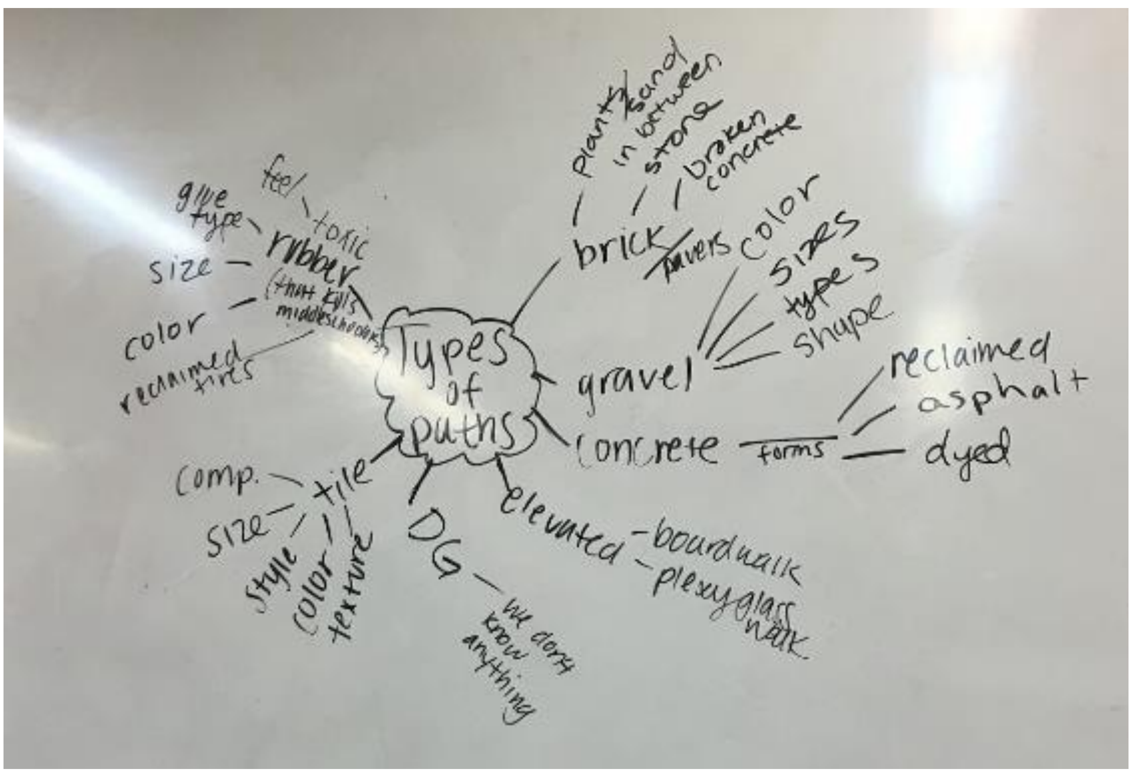

Figure 31 Brainstorm, Picture taken by Ailynn Andersen

3.3. Alternative Solutions

The following is a detailed list of five alternative solutions that were developed during a brainstorming session. Once developed each alternative was described in detail and depicted in a detailed sketch as a visual aid. Each alternative, Rocky Road, Rubberway, Fancy Gravel, Follow the Red and Yellow Brick Road, and Coolcrete Street, will be evaluated and weighted against each other. The one that best fits the criteria will be chosen for the final design.

3.3.1. Rocky Road

The Rocky Road solution consists of reclaimed concrete material which is sometimes referred to as recycled concrete pavement, or crushed concrete. It consists of high-quality, well-graded aggregates (usually mineral aggregates), bonded by a hardened cementitious paste. Normally this concrete is taken from demolition sites, or it is what is left over from someone's house or garden. Reclaimed concrete can be used to create a stepping stone type of pathway that will allow water to absorb into the soil, or filler between the pieces, rather than running off into large puddles. This solution covers a good portion of the client criteria, such as, durability, functionality, maintenance, and cost. A reclaimed concrete path will last for a prolonged period, and it will be able to withstand a constant amount of people using it from day to day. The maintenance is very minimal, and the cost of concrete slabs is just as minimal. Overall Rocky Road would be an acceptable design because it is easy and convers most of the client criteria.

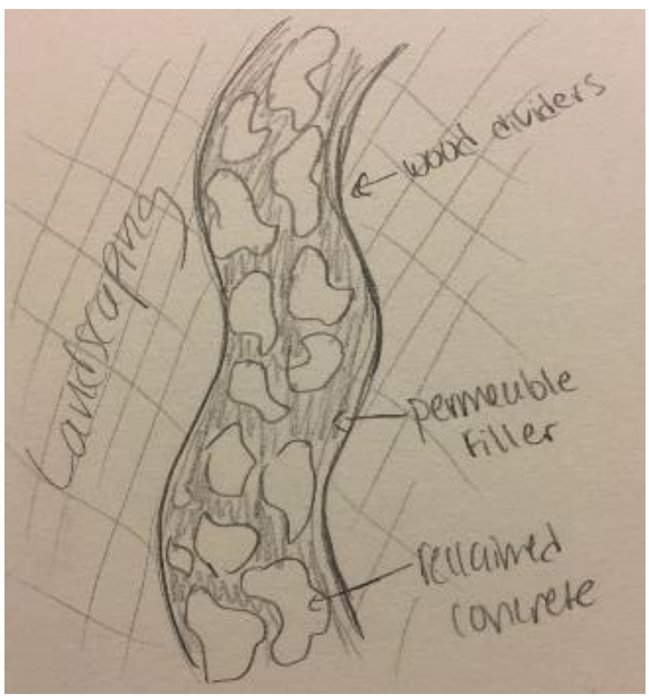

Figure 32 Example of a Reclaimed Concrete Path. Drawing by Ailynn Andersen

3.3.2.Rubberway

The idea of using toxic old rubber tires seems like an innovative idea until you think about the fact that it is toxic. There are ways to test and clean the material from toxins, such as benzene, mercury, styrene-butadiene, polycyclic aromatic hydrocarbons, and arsenic. However, sometimes it is hard to predict what will happen once the material goes through different weathers and uses. Although this can happen with any material, it is a lot more common in using recycled tires. There is natural rubber that is a suitable alternative to the recycled tires, but that alternative is not very ecofriendly. The first characteristic that would need to be cleared would be too make sure it was free of toxins. Some distinctive characteristics should be considered as well, such as the feel, color, and size. Research would have to be done and maybe even take a survey of which types of rubber are most enjoyable to walk on. Other factors that need to be considered are durability, the material's erosion, and weathering characteristics. The color would could not be an eye sore and preferably would not stain anything that it touched. This would be a great alternative for possibly fixing any minor issues that could come along when making the path. Many companies use a rubber mix to fill in cracked concrete because it is easy to apply and can look more natural than applying new cement on old cement if the color is matched correctly. Below is an example of how a recycled tire path could be implemented.

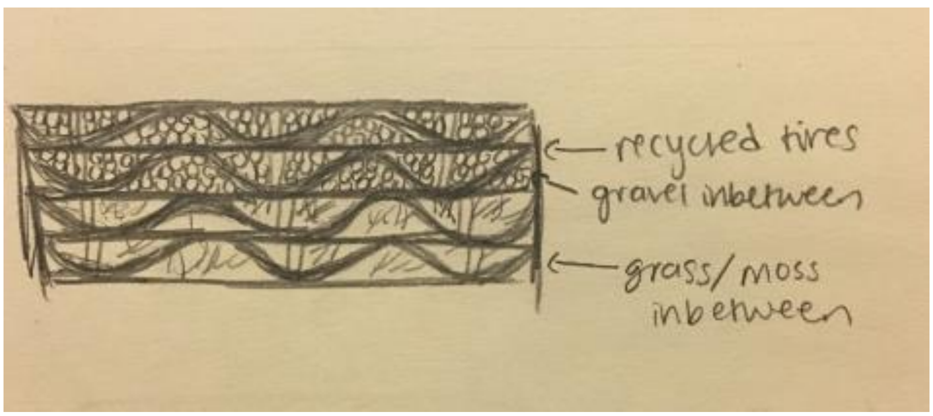

Figure 33 Example of a Section of a Rubber Path. Drawing by Ailynn Andersen

3.3.3. Fancy Gravel

Decomposed granite, or DG, is composed of miniscule aggregates that are byproducts of weathered granite. The aggregate size ranges from a quarter of an inch to sand sized. DG is a natural and “rustic” alternative for outdoor surfaces and happens to be one of the cheapest materials as well. The price of DG can be as low as $1-$3 per square foot. The color of the product depends of the composition of the parent rock or material but generally ranges from almost white to a muddy brown. There are three methods for preparing DG for use in outdoor surfaces. The first is simply compacting additive-free DG. This is the cheapest method but also the most susceptible to erosion, degradation and damage. It is not recommended to install compacted DG in climates with heavy or frequent precipitation. Another disadvantage to DG is the loose aggregates which can be spread by shoes to indoor locations and potentially damage indoor surfaces. Compacted DG surfaces may also need periodic reapplications of DG as the material erodes away. The second method for preparing DG is mixing an additive called a stabilizer. Stabilizer additives bind the DG aggregates together, ideally without decreasing pore space in between aggregates. This binding effect increases the strength of the material and reduces the erosion factor. Stabilizers can also be designed to be slightly springy or flexible which can make for a softer surface experience. This method is slightly more expensive than loose DG because of the additive. The last and generally most expensive method of preparing DG is mixing it with a binding resin, which creates a surface that is similar to asphalt or concrete. This method yields DG surfaces high in strength and durability but can significantly decrease the permeability of the surface.

Figure 34 Example of a Decomposed Granit Driveway

3.3.4.Follow the Red and Yellow Brick Road

Pavers are rectangular shaped blocks of concrete, brick, or rock that are laid out on a walkway, patio, or road to provide a stable surface. Pavers were originally stone laid in mortar, such as a cobblestone surface, or a Roman road, while brick is historically known as any rectangular block of clay that has been fired in a kiln for increased durability (www.gopavers.com). Modern Pavers are usually manufactured by pouring concrete, sometimes with color dyes, into molds. Pavers manufactured with interlocking edges that allow them to be nestled next to one another or pavers that are bound together with concrete, grout, or mortar generally hinder the permeability of the paver surface. There are many paver designs, but only some design methods ensure permeability. One of these design methods, called dry-laid paving, is laying pavers onto a permeable surface with spacing in between adjacent pavers. These spaces can be kept empty or filled with porous materials such as sand, mulch, gravel, plants, mosses, and ground covers. Dry-land pavers could be separated even further apart, such as flagstone steps set in sand or mulch. Another method is to modify the design of the paver itself and not the space in between adjacent pavers. Grass pavers are “hollow”, designed with an open cell allowing them to be filled with aggregates, soil, and plants. Most grass pavers are planted with hardy grasses and groundcovers as they may be stepped on.

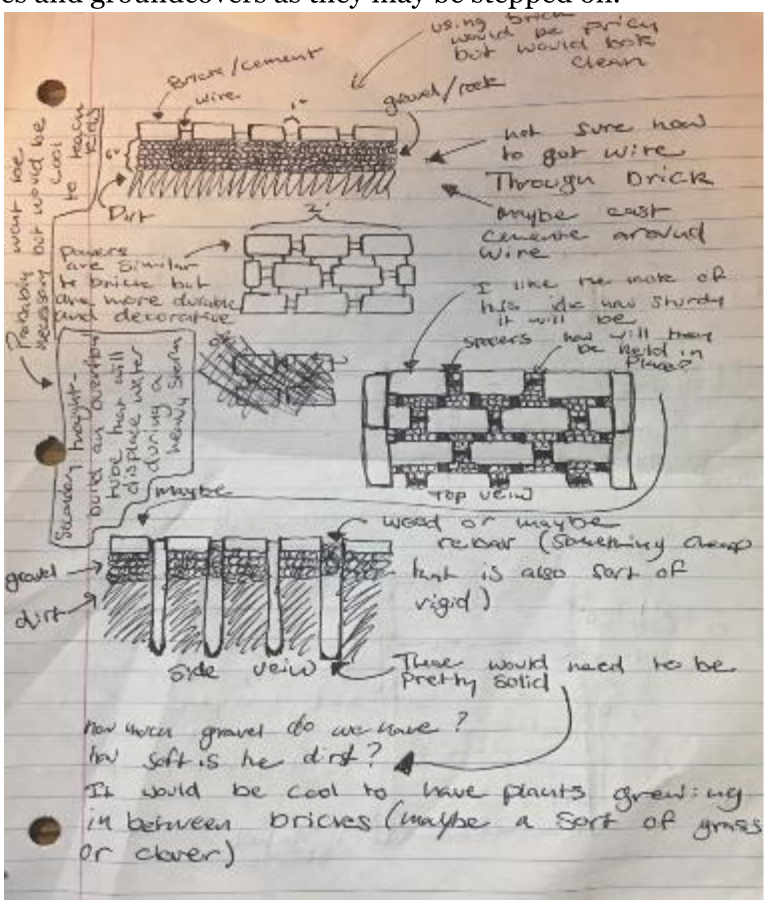

Figure 35 Example of a Path made of Brick Pavers. Drawing done by Jesse Bobrow

3.3.5.Coolcrete Street

Pervious concrete allows for a relatively cheap and durable permeable path. These pathways allow water to pass through the cement and into the ground. This is done by using larger aggregate and less sand in the concrete mix. Once the concrete is ready to poor it is slightly compacted and allowed to dry. Once It is fully dry (after about one week) the water can pass through gaps in the concrete. This pathway option can also be many assorted styles and textures. These types of pathways have a similar texture to gravel however they are more durable and will not get thrown around or stuck in shoes. A downside to this option would be the fact that the pathway can get clogged by small aggregate, however, this can be prevented by proper maintenance as well as proper location. Pervious concrete must be swept 1-2 times a year to be properly maintained. Location is also important because they must be place in a spot that is not surrounded by sand or other small aggregates.

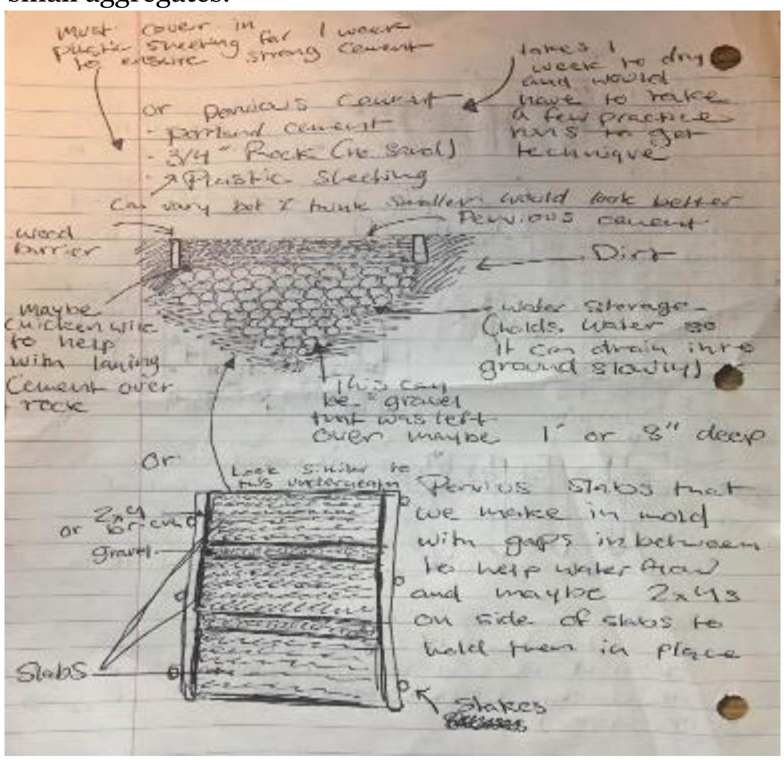

Figure 36 Example of a Permeable Concrete Path. Drawing by Jesse Bobrow.

4. Decision Process

4.1. Introduction

The Decision is the process through which a suitable solution is chosen from the alternative solutions in section 3.3. A suitable solution will be chosen from the alternative solutions, such as Rocky Road, Rubberway, Fancy Gravel, Follow the Red and Yellow Brick Road, and Coolcrete Street, by using the Delphi Method. The Delphi Method will utilize the criteria given in section 2.1.3, to produce a solution that best fits said criteria.

4.2. Criteria

The following criteria were established in section 2.1.3 and will be utilized to determine the best option out of the alternative solutions described in section 3.3.

Durability - The path must be able to withstand the weather and multitude of students that will be using it. It must not fall apart into aggregates, as the previous path did.

Permeability - Water needs to be able to percolate completely through the path into the soil below.

Maintenance - Both the path and landscaping must be easy to take care of. Landscaping should be no taller than 2ft to avoid students hiding in the shrubbery.

Functionality - The path must be raised to the height of the existing sidewalk and be as flat the land will allow.

Cost - Must have a cost of no more than $400.

Educational Value - Students must be able to learn and understand how the permeable pavement works. They should also understand why permeable pavement is environmentally beneficial compared to other pavement options.

4.3. Solutions

The alternative solutions are depicted in section three with descriptions of each. There is a total of five solutions:

1. Rocky Road
2. Rubberway
3. Fancy Gravel
4. Follow the Red and Yellow Brick Road
5. Coolcrete Street

4.4. Decision Process

The decision matrix technique known as the Delphi Method was used to determine the best solution out of the design alternatives. The first step of this matrix is to assign a weight to each of the criteria mentioned in section two. Each criterion was rated on a scale of 1-10 based on importance, with 10 being the highest as seen in table 4-1. The group came to a consensus on the weight of importance for each criterion, giving examples for why one should be of more importance than another. The second step in this process is to assign a rating on a scale of 0-50 for each alternative solution shown in table 4-2. A 50 is given to s solution that best fits the criterion. Again, a group consensus was made for the scoring of each alternative solution, with explanations for each score given to the solutions. The last step in this process is to multiply each alternative solution rating by the criteria ratings; the sum of the multiplied scores are added and used to determine a final solution. The solution with the highest weighted sum is the one that best fits each criterion based on the ratings assigned.

Criteria	Weight (0 - 10high)
Durability	10
Permeability	10
Maintenance	7
Functionality	8
Cost	6
Educational Value	5

Table 4-1 Table of Weighted Criteria

Criteria	Weight	Alternative Solutions (0 - 50high)				
	(0 - 10high)	Rocky Road	Rubberway	Fancy Gravel	Folw R&Y Brick Rd.	Coolcrete Street
Durability	10	40 / 400	45 / 450	20 / 200	50 / 500	50 / 500
Permeability	10	35 / 350	30 / 300	40 / 400	45 / 450	50 / 500
Maintenance	7	25 / 175	30 / 210	10 / 70	35 / 245	40 / 280
Functionality	8	40 / 320	40 / 320	10 / 80	35 / 280	35 / 280
Cost	6	20 / 120	10 / 60	5 / 30	25 / 150	30 / 180
Educational Value	5	10 / 50	15 / 75	5 / 25	10 / 50	20 / 100
	Total	1415	1415	805	1675	1840

Table 3-2 Delphi Method

4.5. Final Decision Justification

The Delphi Method concluded that the design Coolcrete Street was best fit for a long term permeable path at Zane Middle School. Coolcrete Street best fits each of the criteria given and will be easy to reproduce if the school were to implement another permeable path. The process for Coolcrete Street has a reasonable cost and will be easy to implement in the space given for the project.

5. Specifications

5.1. Introduction

Section 5 of this document includes a detailed description of the final solution chosen in the previous section. Multiple views of the solution will be depicted here to help specify details. A table of costs detailing the number of hours spent on this solution along with the amount of money spent of materials. Estimates of material costs will also be included in the cost of materials table. This section will also include how to implement the chosen solution and the documented results after implementation.

5.2. Description of Solution

Coolcrete Street will be around the same length, width, and thickness of the path a previous group implemented in the same area. The path will be 62 feet long, 3 feet wide, and 3 inches thick. The standard measurements for the path are depicted bellow in figure.

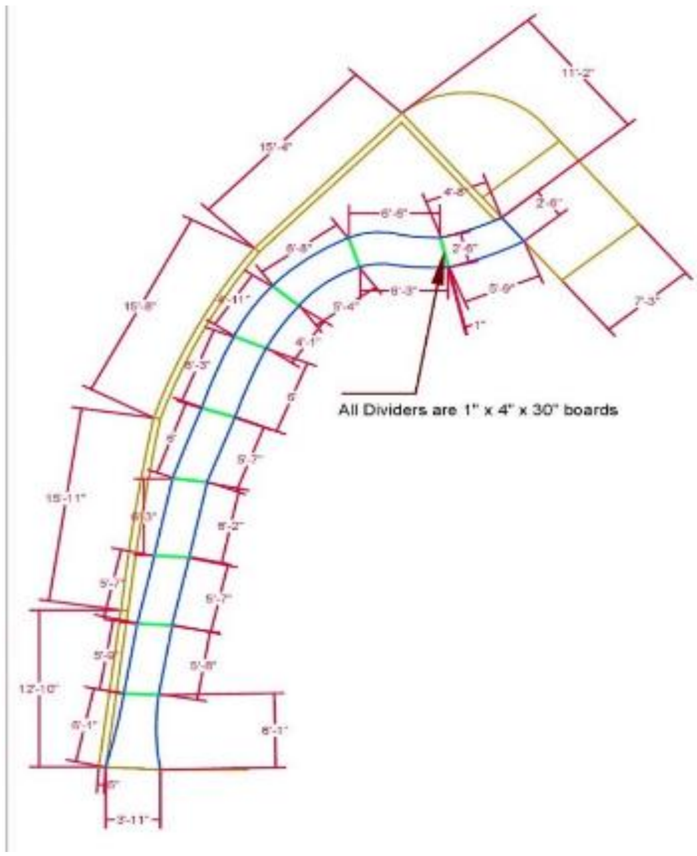

Figure 51 AutoCAD Layout of the Path by Julian Sicaud

5.2.1.Path way

As stated before the path will be approximately 62 feet long, 3 feet wide, and 3 inches thick. A standard section of the permeable path way will be 6 feet long, 3 feet wide, and 3 inches thick as depicted below in figure 5-2. The path will follow along the road to provide students with a safe place to walk, rather than having them walk in the street. Figure 5-3 depicts the location of the path and the way it will follow along the road.

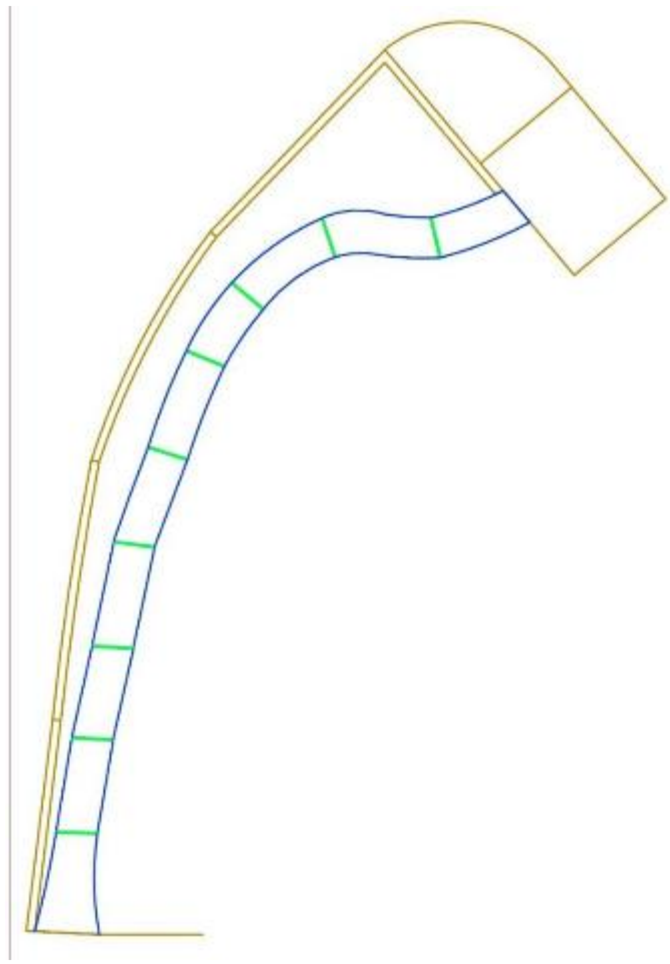

Figure 52 AutoCAD Layout of path without measurements by Julian Sicaud

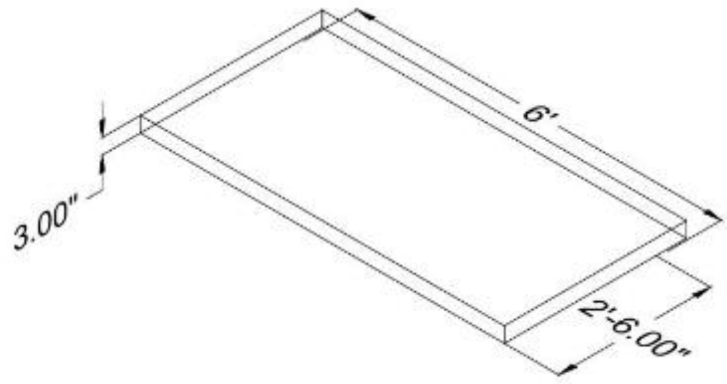

Figure 53 AutoCAD Representation of a typical cell of permeable cement by Ailynn Andersen

5.3. Costs

The costs of the design can be considered in terms of hours spent cultivating and perfecting the solution, along with the physical cost of materials needed for the solution. The following sections detail these costs.

5.3.1. Design Costs

The costs in hours spent developing, designing, and executing the solution, Coolcrete Street, were distributed amongst five categories. Those categories being: Problem Formulation, Problem Analysis/ Literature Review, Alternative Solutions, Final Decision, Decision Specification/ Implementation.

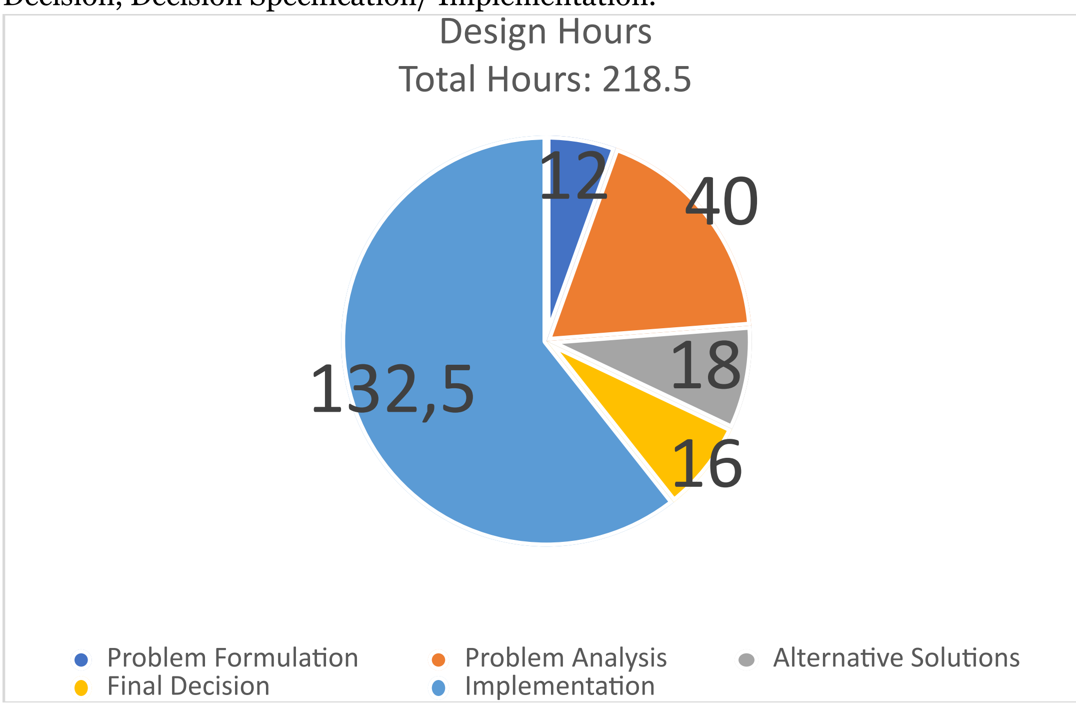

Figure 54 Chart of Design Hours

5.3.2. Implementation Costs

The costs for this project was mostly covered by group members and partly by donations from Zane middle school and a few Eureka hardware stores. Our group spent a total of $198, which is $200 underbudget and significantly lower than our retail price.

Materials	Source	Quantity	Unit	Retail Price per unit ($)	Total Retail($)	Expenses ($)
3/8" Washed Pea Gravel	Mercer-Fraser	2	Cubic Yard	60	120	Donated
3/8" Washed Pea Gravel	Hensell Materials	2	5 gallon bucket	4	4.5	Donated
Weed Cloth	Zane Middle School	1.2	100 feet	68.99	68.99	Donated
Mixing Wheelbarrow	Larry Nichols/Zane	2		150	300	Donated
5 Gal. Bucket	Julian Sicaud	4		4.99	4.99	Donated
1 Foot Wooden Stakes	Zane Middle School	1	100 Stakes	17.5	17.5	Donated
Bender Board	Zane Middle School	6	20 Feet	19.99	120	Donated
Fill Dirt	Zane Middle School	2	Cubic Yard	7.99	15.99	Donated
Portland Cement	Piersons Hardware	5	97 lb bag	16.99	84.95	Donated
Tarp	Julian Sicaud	2		15.99	31.98	Donated
8in Square Tamp	Julian Sicaud	1		21.99	21.99	Donated
Rake	Julian Sicaud	1		19.99	19.99	Donated
Shovel	Julian Sicaud	2		23.86	23.86	Donated
Portland Cement	Hensell Materials	1	47 lb bag	6.07	6.77	6.77
Portland Cement	Shafer's Hardware	1	47 lb bag	9.99	10.84	10.84
Line Level	Piersons Hardware	1		3.69	4.00	4.00
Shovel	Piersons Hardware	1		21.99	23.86	23.86
Garden Hoe	Shafers Hardware	2		16.99	16.99	16.99
Hose Valve Key	Shafers Hardware	1		1.79	1.79	1.79
#9 x 2-1/2" Deck Screws	Hensel's Hardware	1	50 screws	9.78	9.78	9.78
Wood	Almquist	14	Feet	1.09	16.44	16.44
1" x 4" pine	Piersons Hardware	30	Feet	0.69	20.42	20.42
Wheel barrow Tube	Miller Farms	2		9.64	19.28	19.28
Caulking Gun	Harbor Freight Tools	1		2.99	2.99	2.99
Silicone caulk	Harbor Freight Tools	2	Tube	3.99	7.98	7.98
Balloons	Dollar Tree	5	Bag of 25	1	5.43	5.43
Caution Tape	Shafers Hardware	1	Roll	7.59	7.59	7.59
Gloves	Tools	5	pair	7.99	7.99	7.99
Push Broom	Shafers Hardware	1		7.99	7.99	7.99
Plastic Sheeting	Piersons Hardware	1	9 x 400 Feet	24.99	27.11	27.11
				Totals:	1031.99	197.25

Table 4-1 Table of Costs

5.4. Instructions for Implementation

In order to implement the permeable pathway, the old path had to be taken out and disposed of. Once that was finished the path need to be graded so that it no longer had a slope, along with implementing new bordering to create a mold for the new path. After this process is finished the process of laying the pervious path can begin. To create the pervious cement mix water, cement, and pee gravel in a 3:1 ratio, such that you have a mixture of three parts pee gravel to one-part Portland cement. The amount of water added can vary, continue to add water until the mixture, when compacted into a ball in your hand, can hold the shape. Once the mixture is ready it can be poured into the mold and covered with plastic sheeting to dry and cure for a whole week. The path must cure for a week to insure the strength of the path. Images along with instructions are included in the table 6-1 bellow.

How to Install a Permeable Concrete Pathway	
Image	**Step**
	**Step 1:** If needed, remove undesired path or trail, or dig to depth of concrete layer.
	**Step 2:** Prepare sub-grade by leveling and compacting dirt to the depth of porous concrete level. Define concrete blocks with benderboard and 1x4 wood dividers. cover dirt with weed cloth.
	**Step 3:** Mix Porous concrete in wheelbarrow or mixer then pour into path sections, level and immediately cover with plastic to cure for a week.

Table 5-1 Instructions for Installing a Permeable Path

5.5. Results

The results of this project are a wonderful and environmentally friendly permeable pathway that also provides a safe walkway for students before and after school. Because the path is pervious it will prevent students from dragging mud around campus and it will prevent the area from flooding. The path also provides a safe area for students to walk to and from the parking lot before and after school. The finished pathway can be seen below in figures 5-5 and 5-6.

Figure 55 The Finished Pathway, Picture Taken by Julian Sicaud

Figure 56 The Finished Pathway, Picture by Julian Sicaud

6. Appendices

6.1. References

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