RECYCLED GLASS MIX PHASE III

CENE 476

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Abbreviations

NAU – Northern Arizona University

ASR – Alkali-Silica Reaction

ASTM – American Society for Testing and Materials

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1.0 Project Understanding

1.1 Project Purpose

The purpose of this project is to create a mix design that utilizes recycled glass powder for both pervious pavement and regular concrete. Pervious pavement is designed to have a high void ratio, thus allowing water to pass through concrete quickly. This makes pervious pavement the solution to many engineering problems, for example, water runoff, recharging water tables, and reducing soil erosion. Using recycled glass in concrete applications decreases the amount of waste glass on the market, reduces the amount of glass in landfills and substitutes for expensive aggregates in the concrete mix. Therefore, both concrete products will create more environment friendly designs and structures.

The project team will first need determine various mix design options then obtain the necessary materials required to make pervious pavement and concrete using recycled glass powder. These materials are, but not limited to, recycle glass powder, cement, and aggregate [1]. The next step is to produce samples using mix designs, and then testing the samples, for slump, density, thermal expansion, compressive strength, tensile strength and, porosity. Lastly a machine that will be used to simulate freeze-thaw cycles to see whether or not the concrete samples will survive in Northern Arizona's climate.

1.2 Project Background

This project is for Northern Arizona University (NAU) and in general, all of northern Arizona and anywhere there is a problem with high temperature fluctuation. A map of the Arizona (Figure 1.1) shows the general worldwide location of this project while Figure 1.2 narrows the project site down to the City of Flagstaff and has NAU's location represented.

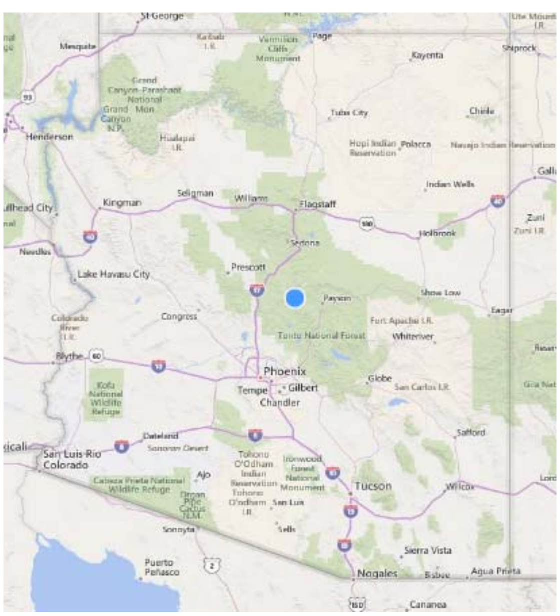

Figure 1.1. Map of the Arizona. Bing Maps [2]

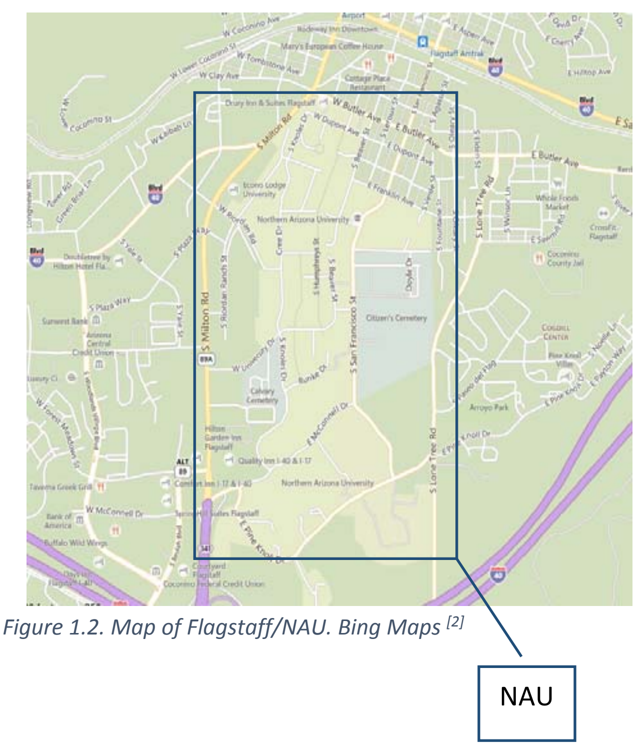

Figure 1.2. Map of Flagstaff/NAU. Bing Maps [2]

Creating concrete mix designs for northern Arizona requires special attention because of the large temperature fluctuations that can occur. As seen in Figure 1.3, seven months out of the year Flagstaff's temperature falls below freezing, during these seven months Flagstaff has higher precipitation (Figure 1.4) than those months where the average temperature is above freezing. This illustrates that the concrete will be exposed many freeze-thaw cycles. The project requires engineers to produce two separate mix designs, one design is for pervious pavement, and the other is for a more generic type of regular concrete. Both mix designs must incorporate recycled glass powder. NAU has already developed a mix design for pervious pavement, however, the design will be slightly altered so that it includes recycled glass powder. The regular concrete's mix design has not yet been developed to any degree, it will be up to the engineers to develop a design, and test the product, to achieve the goal.

1.3 Technical Considerations

Recycled glass concrete can be made by replacing a portion of Portland cement with recycled glass powder. The purpose of introducing recycled glass powder into the mix design is to create a more environmentally friendly product. Adding glass powder into the concrete mix may cause undesired effects on the strength, thermal expansion and void ratio of the concrete. This issue can be managed by adding silica fume or fiber materials. Silica fume is a powder like substance that is used to increase the strength of concrete [4]. Recycled glass becomes a reactive aggregate that is prone to a situation known as alkali-silica reaction (ASR). To reduce the possibility of ASR, engineers use pozzolan, and engineers will replace 5-30 percent of Portland cement with pozzolan [4]. Pozzolan is usually derived from waste glass products [5]. ASR can cause concrete to expand and crack, but ASR is not solely found it concrete made using glass, it happens in all concrete applications, concrete made using glass has a higher probability of being affected by ASR.

1.3.1 Mix Materials

The materials required to produce recycled glass concrete, and pervious concrete with recycled glass are pozzolan, cement, aggregate, water, chemical admixtures, and even fiber additives which are; air-entraining, hydration-controlling, internal curing, mid-range water-reducing, rheology-controlling, and viscosity-modifying [5]. These mix materials are what give the concrete its strength and functionality.

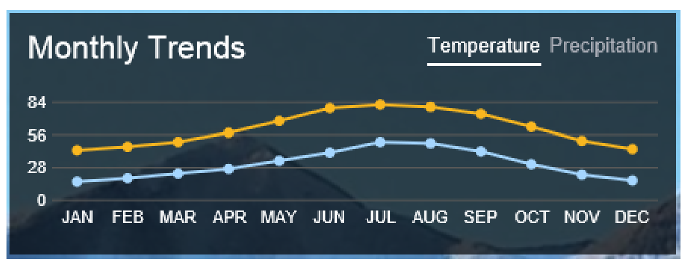

Figure 1.3 Flagstaff, AZ Monthly Temperature Trends. Yahoo Weather [3]

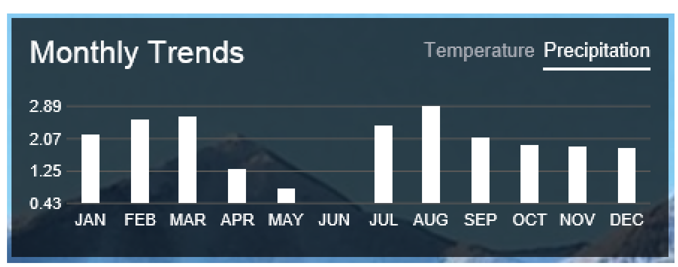

Figure 1.4 Flagstaff, AZ Monthly Precipitation Trends. Yahoo Weather [3]

1.3.1.1 Cement

Cement is a substance that bonds materials together. Portland cement is the most common cement for concrete production. Cement is classified by the American Society for Testing and Materials (ASTM). The ASTM uses three categories to allocate cement types, Portland cement (ASTM C150), blended hydraulic cement (ASTM C595), and performance-based specifications (ASTM C1157) [6]. Each blend is used for a specific purpose. The following table shows cements types and the corresponding purposes:

Cement Type	Description
Type I	Normal
Type II	Moderate Sulfate Resistance
Type II(MH)	Moderate Heat of Hydration
Type III	High Early Strength
Type IV	Low Heat Hydration
Type V	High Sulfate Resistance

Table 1.1 Cement types and Description [12]

Cementation materials contribute for a vast amount of properties for regular concrete. Common cementation materials are slag cement, fly ash and silica fume. Slag cement is made by burning slag in the oven. Slag cement is hydraulic and can be added to the mixture as an SCM. Fly ash is a secondary product of thermal power generating stations and it is the most commonly used in concrete.

1.3.1.2 Aggregate

There are two major components used in the production of concrete, coarse aggregate and fine aggregate. Aggregate accounts for 60 to 75 percent of the total volume in concrete. The shape and size of aggregate affect the performance and properties of concrete. Porosity is important when developing pervious pavement. Porosity is dependent on the shape and size of aggregates used. Angular particulates that are poorly graded tend to increase the amount of voids within concrete, while, well graded particles decrease porosity. NAU has previously researched which aggregates are best to use when producing pervious pavement [7], the best particulates are ones that pass a #4 sieve and, ⅜”, ½”, and ¾” size aggregate.

1.3.1.3 Additives

Admixtures are added in concrete mix designs to advance the performance properties of concrete. Chemical admixtures are any ingredients other than common base materials such as water, Portland cement, and aggregate [8]. Chemical admixtures can affect concrete by influencing its ingredients, by either changing the amounts needed or by reducing time needed or temperature required for curing. Silica fume is an admixture that has form of a solid powder that is used to improve compressive strength. Fiber can also be added to the design mix to improve strength, permeability, and increase freeze-thaw durability.

1.3.2 Mix Testing

The project design team is required to test for several properties for both pervious concrete and regular concrete. Pervious concrete will need to be specifically tested for flow rate, to make sure fluid flows through at the desired rate. Each concrete design will be subjected to a compressive strength test and a freeze-thaw test. The compressive strength test is to ensure the products are strong enough to pass ASTM standards. The freeze-thaw test is used to determine whether the concrete will thrive in locations where there is a high amount of freeze-thaw cycles.

1.3.2.1 Flow Rate (Pervious Concrete)
The flow rate through pervious concrete depends on its materials, and how the concrete is mixed. A typical flow rate through pervious concrete is anywhere between 3 to 8 gal/ft^2/min [10]. The design team will use the void ratio test when testing for getting the porosity in this project. The design team will be using the ASTM C127 procedure to test void ratio.

1.3.2.2 Compressive Strength
The compressive strength test is used to find the capacity that a specimen can withstand load. For this test, the shape of the specimen needs to be a cylinder. The specimens will be placed in a machine that continuously adds pressure until the specimen fails. The testing apparatus displays at what pressure the specimen failed, and from the failing pressure an actual load can be calculated [9].

1.3.2.3 Freeze-Thaw
Most existing structures and surfaces are constructed using concrete. In all these structures, there is a possibility of deterioration from process known as freeze-thaw. The freeze-thaw process occurs in cycles where water is inside the pores of the concrete and freezes then thaws continuously on and off during a cold season. Water expands and contracts during freeze-thaw cycles. Freeze-thaw cycles can heavily affect both pervious concrete and regular concrete. Durability for both pervious concrete and regular concrete is closely related to the porosity, or void space within the concrete [10], porosity varies depending on the design mix. Pervious concrete however is made so that water can easily flow through the concrete and retaining its strength. Considering pervious concrete is made with large pores, freeze-thaw cycles may cause many issues in areas where temperatures can fluctuate heavily.

1.4 Potential Challenges
Using recycled glass presents several challenges. One challenge being how to attain the materials required to produce adequate testing samples. Companies that have the materials will be contacted, and ask to donate their materials for research. Another complication is the team must be able to use all the testing hardware and equipment to replicate field conditions expected in northern Arizona. The freeze-thaw cycle is critical to concrete design, and having adequate time to optimize the mix will be a challenge. Accurately measuring the concrete samples for slump, strength, density and thermal expansion will require time and expertise. Testing the samples for freeze thaw cycle, compression strength and the void ratio is a time challenge because, the freeze thaw cycle test needs enough time to reach the desired amount cycles. The other tests do not require much time and can be finished quickly.

1.5 Stakeholders
The goal is to produce adequate mix designs utilizing recycled glass powder that will eventually become the standard concrete design used in Northern Arizona. Northern Arizona University (NAU) and all of northern Arizona are the two primary stakeholders for this project, but could be used for all locations where high temperature fluctuations cause concrete structural problems. Final mix designs may be used to produce products that are not only strong, durable, and green, but also aesthetically pleasing [11]. For this project, the stakeholders could be either interested in specifically the mix designs of our project or the environmental effects. Pervious concrete has a connection between the upper surface of earth and the water table underground.

2.0 Scope Tasks

2.1 Research

Research is the primary resource needed when creating and discovering new mix designs. Allowing already known mix design failures to be thrown out, while, possibly finding productive valuable resources that have promising mix designs and then utilizing those ideas and improving them to create a mix that could be the best solution to the proposed problem.

2.1.1 Pervious Pavement Design

Pervious concrete mix design research starts by finding resources that have produced mix designs that can be used as a base reference for a high freeze-thaw cycle location such as Northern Arizona.

2.1.2 Concrete Design

Finding quality mix formulas for regular concrete is necessary because having a good starting point is key when trying to find a new mix designs.

2.1.3 Recycled Glass Additive

Adding glass to both designs causes reactions to form in each type of mix design, this means research is required on how to accommodate both mixes with glass powder, and use correct admixtures to help avoid undesired chemical reactions.

2.2 Standards and Codes

Standards and Codes are provided through ASTM. This section will be discussed in details in CENE 486 for developing new mixtures and recipes for concrete designs. Phase 3 will meet and adhere to ASTM codes and standards for both pervious concrete and regular concrete with added glass. Another organization for material testing is Intertek.

2.3 Acquire Materials

For this project there are many materials and additives needed besides the typical concrete materials. This project will seek sponsors to donate certain materials for research periods.

2.3.1 Typical Concrete Materials

NAU provides all typical materials needed to produce both pervious concrete and regular concrete. The materials noted as “typical” are the primary ingredients for any type of concrete, they are: cement, aggregate, and water.

2.3.2 Recycled Glass Powder

Phase III of the concrete mix designs required recycled glass to be added with concrete aggregates. Results will be performed on recycled glass concrete and regular mix concrete. Samples will be ordered from companies with recycled glass production.

2.3.3 Concrete Support Materials

Extra additives are needed in the concrete to increase strength, these additives will be attained through sponsor donation.

2.4 Design

2.4.1 Pervious Concrete with Recycled Glass

Design the pervious concrete with recycled glass. The design will base on the all needed materials and will meet all ASTM standards and codes, taking flow rate and compressive strength into account.

2.4.2 Regular Concrete with Recycled Glass

Design regular concrete using recycled glass. The design will use all necessary materials and meet all ASTM standards and codes. Formulas will be developed to optimize the effectiveness of the concrete whilst having recycled glass powder incorporated into the mix.

2.5 Mix Procedure

The mix procedure is for both types of concrete. All concrete will be mixed using their respected design formula that was determined earlier. Specimens will be created for many concrete mixing formulas to have a large comparison range between concrete mixtures.

2.6 Test Procedure

The compressive strength testing device is used to find the compressive strength. The Gilson Specific Gravity Bench is used to test the void ratio. The Gilson HM-120 Automatic freeze-thaw apparatus is used to test how the specimens react to extreme temperature fluctuations. After all specimens are tested there is a possibility that some will fail and not meet ASTM standards. If a specimen results in failure, the design will be recreated from step 2.4.

2.7 Project Management

2.7.1 Project Schedule

A complete schedule of the project is provided with start and end dates for each scope task. The client is able to check on the order of the task and when each task is to be completed.

2.7.2 50% Design Report

50% of the report will be provided to the client in order to check that the project is being completed to the client’s standards.

2.7.3 Final Design Report

A final design report focused on pervious concrete and regular concrete using recycled glass is to be provided during the 2nd semester of capstone. An alternate plan for this project is to work on phase II design with additions to improve it.

2.7.4 Final Presentation

The final presentation will be in May.

2.7.5 Website

A home page and a document page are created and populated for this semester. The rest of the website will be finished in conjunction with the final report.

3.0 Schedule

The schedule includes all the dates including starting and ending dates for each task. The total time needed the project is 216 work days. The project starts on January 20, 2015 and ends on December 17, 2015. The critical path for this project is shown in the schedule.

The schedule is attached (last page).

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4.0 Cost of Engineering Services

The required participants for this project are noted in Table 4.1. The table below is a list of staff titles, codes, and hourly rates. All senior members must have 5 or more years of experience, good intercommunication skills, leadership skills, must be able to manage others and have prior experience in similar aspect projects. This design project only has need of one senior member, a Senior Engineer.

Code	Classification	Rate$/hour
SENG	Senior Engineer	114
ENG	Engineer	58
LAB	Lab Technician	44
INT	Engineering Intern	21
AA	Administrative Assistant	38

Table 4.1 Staff Titles and Hourly Rate

The cost of materials and equipment can be seen below in Table 4.2. Each machine or material is crucial in order to produce the concrete molds and also in the testing of each mold.

Total Cost of Materials			
Description	Unit Cost	Quantity	Total Cost
Sieve Machine/ Sieves	700	1	700.00
Mixer	170	1	170.00
Compressive Strength Machine	$60 /hr	8	480.00
Void Ratio Machine	$20 /hr	7	140.00
Freeze-Thaw Machine	$100 /day	20	2,000.00
Molds	$80.95 /36 molds	2	161.90
Cement	$9.45 /bag	3	28.35
Aggregate	$60 /cubic yard	1.5	90.00
Sand	$4.17 /bag	2	8.34
Recycled Glass	$4.98 /bag	2	9.96
Total			$3,788.55

Table 4.2 Total Material Cost

The total project price is a combination of total labor cost and total equipment cost, a project contingency is added to make sure all miscellaneous purchases or hours are covered. The cost of materials and equipment can be seen below in Table 4.3. Each machine or material is crucial in order to produce the concrete molds, and also, in the testing of each mold.

Task	Hours				
	SENG	ENG	LAB	INT	AA
1.1 Pervious Pavement Design	2	2	0	10	5
1.2 Concrete Design	2	2	0	10	5
1.3 Recycle glass additive	2	2	0	10	5
2.0 Review Documentation	5	5	0	5	5
3.1 Basic Materials	0	0	2	10	0
3.2 Recycled Glass Powder	0	0	2	10	0
3.3 Extra Additive	0	0	2	10	0
4.1 Perivous Pavement with Recycled Glass	10	15	0	0	0
4.2 Regular Concrete wth Recycled Glass	10	10	0	0	0
5.1 Mix Procedure	0	2	20	2	0
5.2 Test Phase 1	0	2	30	30	0
5.3 Test Failure 1	0	2	6	1	0
5.4 Test Phase 2	0	2	30	30	0
5.5 Test Failure 2	0	2	6	1	0
6.1 Project Schedule	15	10	0	0	0
6.2 50% Design Report	20	30	0	0	30
6.3 Final Design Report	20	30	0	0	30
6.4 Final Presentation	0	5	0	0	0
6.5 Website	0	0	0	20	20
Hours per Worker	86	121	98	149	100
Rate$/hour	148	75	57	27	50
Cost for each type of engineer	12728	9075	5586	4023	5000
Total Labor Cost	**$36,412**				
Total Equipment Cost	**$3,727.35**				
Project Contigency @ 15%	**$6,020.90**				
Total Project Price	**$46,160.25**				

Table 4.3 Total Project Cost

5.0 References

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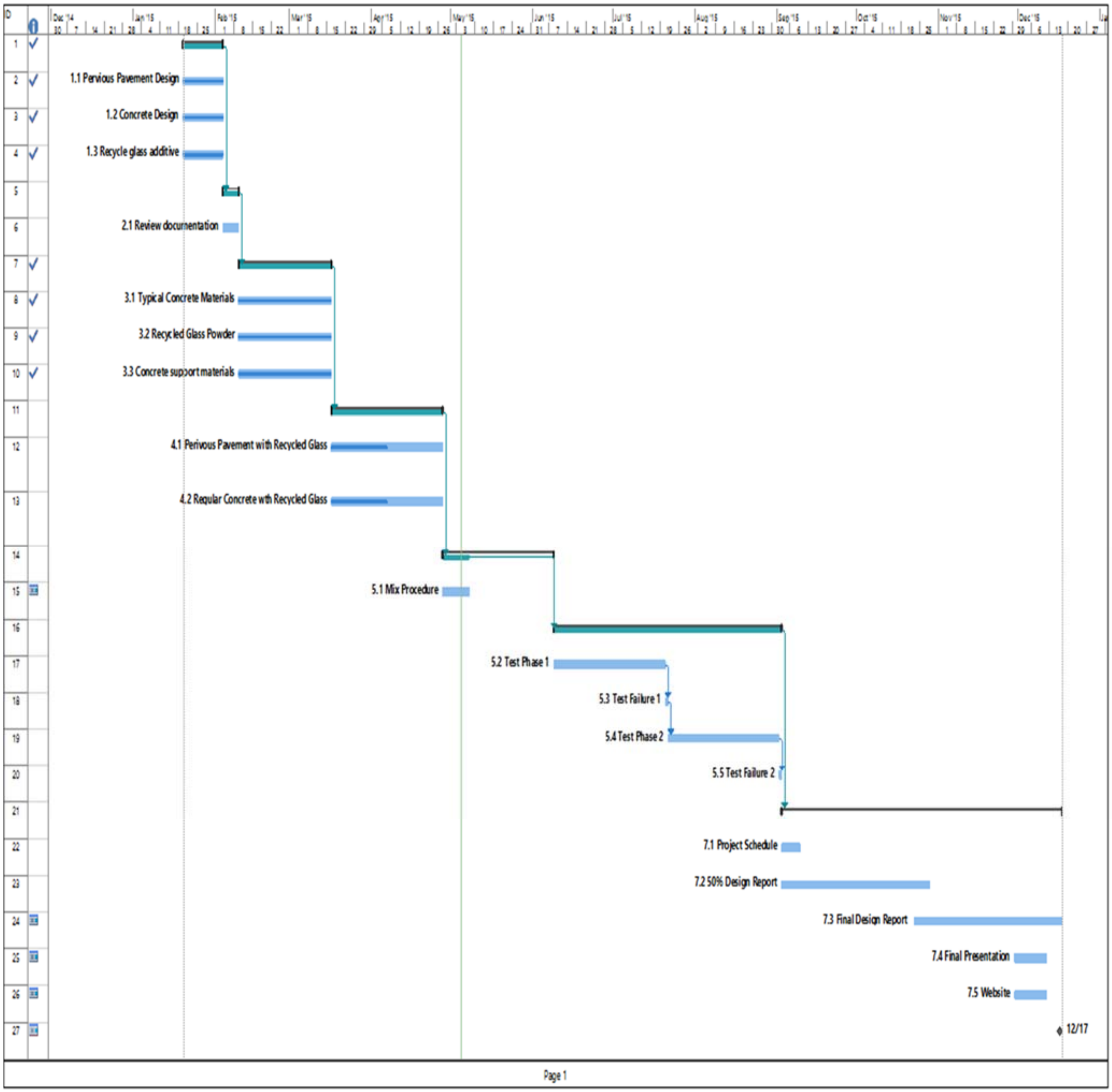
1.1 Pervious Pavement Design
1.2 Concrete Design
1.3 Recycle glass additive
2.1 Review documentation
3.1 Typical Concrete Materials
3.2 Recycled Glass Powder
3.3 Concrete support materials
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