Abstract - The evolution of concrete through the years has made many applications that were once unattainable. Common place in construction today. One such application is the use of porous concretes. Porous concrete is so unique because the fact that water can drain through the concrete decreasing the possibility of water runoff on a large pad surface. The water runoff of a standard concrete pad needs a large water drainage plan, But with the invention of concrete that allows water to flow through it and still allow the soil underneath to do the natural job of water drainage; therefore allow projects to get away with a smaller less intense drainage plan and cut costs. Though this additive to concrete is so recent there hasn’t been much research done about the concrete strengths and lifetime. Through hands-on testing and research, I will engage in exploring the testing and analysis aspect behind porous concrete. These results will be able to explain some characteristics and traits of porous concrete that will have a great deal of influence of determining the application needed for a specific job.

Index Terms - Pervious Concrete, Compression Strengths, Freeze Thaw Strengths, Lifespan of Pervious Concrete.

BACKGROUND
American Concrete Institute (ATI) defines the term “pervious concrete" as a typically zero slump material; consisting of portland cement, coarse aggregate, very little to no fine aggregate, admixtures, and water. The reasoning behind pervious concrete was to make concrete eco friendly as well as meet standards of the Clean Water Act.

Pervious concrete has been designed to decrease the amount of storm water runoff of a concrete pad. By allowing what would normally be storm water to seep into the ground it recharges the ground water supply and lessens the dependency on storm water runoff construction. The way this is achieved is through the removal of the small aggregate in the mixture content. This removal of the small aggregate creates a relatively little particle packing, which creates gaps between particles where water may flow by the use of gravity. These gaps are more known as voids, the percentage of voids to the total concrete is extremely important for it to be actually classified as pervious concrete. The void size is typically between 2 to 8 mm, this allows water to pass through easily. [1] The void content can range from 18 to 35%, with typical compressive strengths of 400 to 4000 psi. The drainage rate of pervious concrete will vary with aggregate size and density of the mixture, but will generally fall into the range of 2 to 18 gal./min/ft^2.

Though this is a very simple innovation to an old construction material such as concrete, there are many environmentally beneficial reasons why porous concrete is a great idea. One of the ways this process effects the environment is the fact that the ground water supply is not decreased by a large concrete slab. With porous concrete the rain water will flow strait through the concrete and penetrate the soil evenly underneath the pad. A second environmentally friendly consideration is the decrease in surface flowing water called runoff. There are also many benefits to porous concrete when it comes to LEED certified construction projects.

PERSONAL INTERESTS
This topic interested me right away because it is a great idea. With my experience of soil erosion through living on a family farm, I seen the importance of sub-soil drainage compared to surface drainage. During a 1 inch rain storm a single acre (.000156 square miles) of land accumulates 27,154 gallons of water. With proper subsoil drainage this water will saturate the soil and drain through the natural sub-surface ground water, instead of surface runoff that collects minerals and particles as it over runs the surface.

HYPOTHESIS
My hypothesis that I will be looking to prove wrong is the freeze thaw strength of pervious concrete is much less compared to standard concrete. Due to voids that collect water, when frozen these frozen voids will expand enough to crack the concrete, therefore lowering the lifespan of the concrete.

APPLICATION PROCESS
According to (Concrete Delivers, 2010)[1] there are many precautions and preparations it takes to lay porous concrete. The first preparation is a uniform sub-grade support. Meaning that the surface which the concrete is to be layer on must be smooth and compacted to prevent faults or
problems in the pouring and curing stages. Also before laying of the concrete the sub-base must be moist but without standing water in order to prevent water being removed from the lower portion of the pavement too soon.

When mixing porous concrete, there are tighter acceptable limits because of the special properties the concrete has. For example the water content of porous concrete is a much more precise limit than normal concrete, too much water in the mixture will affect the strength and permeability. Along with the water in the mixture, Aggregate levels should also be closely monitored to ensure that the moisture supplied to the aggregate does not decrease integrity. Since porous concrete has much lower levels of water content, transportation of the material may be troubling. The truck may require special attention from the driver during transportation and placement to assure that the levels of moisture are within tolerance.

When considering the process of laying the concrete it should be obvious that there are special measures to be taken here as well. Prior to laying the concrete each truck should be inspected to ensure that the specifications are met, if they are not in range then don't pour. A step that I said before, the sub-base must be moist without standing water. The next important key is to remember not to shake down the concrete as much as normal. The shaking down of the concrete will create less voids between particles, therefore it would defeat the purpose of the concrete because it wouldn't allow water to pass through it.

**RESEARCH**

The construction industry is consistently looking for innovative ideas to enhance the effectiveness of the building materials within construction projects. Pervious concrete is fast becoming a new marketable idea that can be used in a myriad of different situations. As previously mentioned, the standards for pervious concrete relies heavily on the ability of the concrete to filter water while consistently maintaining a compressive strength. Although pervious concrete is a relative newcomer to the construction industry, much of the testing started back in the late 1970’s. In 2001, the American Concrete Institute formed committee 522 “Pervious Concrete” to develop and maintain standards for this application. The committee referred too many of the case studies that have been developed and carried out in the recent years. In doing so, these case studies have given our research a solid starting point to which carry on. Of course, the research that will be conducted has started but we hope to continue through the year. As we look at the case studies and their results, understand that these were conducted across different parts of the country. The main sticking point for pervious concrete is its inability to hold up to a consistent compressive strength over time based on the thin application of Portland cement and the constant integration of water flow. In order to better understand the dynamics behind our continued research, we investigate those previous case studies to provide direction and control for our freeze-thaw cycles, and the ability of the materials compressive strength to remain constant and above regulations. The weather interpretation for these case studies ranged from mild to severe based on location within the country. The case studies were developed by a host of companies across the nation and the ACI. The compressive strength integrated with each project can be seen in the following graph. Please notice the relationship between the compressive strength and the void ratio, (which is determined before pour).

![Figure 1: Compressive strength vs. Void Ratio](Image)

The relationship between compressive strength and void ratio has been documented by others, such as Schaefer et al. (2006), and is obviously strong.

Over the course of the testing, the freeze-thaw impact on compressive strength was minimal. The Storm water Management Academy at the University of Central Florida performed similar tests on the ability of pervious concrete to sustain compressive strengths with 5 different sites selected in Florida. The results recommended that 4-8 inches of clean aggregate be placed below for permeability to reduce the effect of the freeze-thaw cycle (Delatte, 2004). The different cases that were involved in Florida were reduced to parking lots to determine the sustained permeability and compressive strengths. As permeability increases, the sustained compressive strength will also increase (Delatte, 2004).

Further studies in the Midwest have shown promise for pervious concrete. The National Ready Mixed Concrete Association has been involved with these studies over the past ten years. Locations across the Midwest were selected based on the harshness of the conditions for testing. In Ohio, the results of testing showed that there is a correlation between the sustained compressive strength of the concrete and the tensile strength over time. In the following chart, you can see that as the void ratio is increased, the tensile strength is reduced. This correlation shows that compressive strength is reduced when void or additives are emplaced with the concrete.
While each is strong in application, these cases show that different locations and conditions affect pervious concrete in different ways. Our goal with our research is to conduct a yearlong study of the freeze-thaw cycles with pervious concrete in different applications and mixtures to determine the feasibility of pervious concrete in cold weather locations. The end result of our research will give documentation to the performance of pervious concrete in freeze-thaw environments in order to give guidance on optimum mixture rates, permeability percentages, and compressive strengths in relation to tensile strength and void ratios.

**FUTURE TESTING**

Because my research is a work in progress, it will take future testing and analysis to completely determine the lifespan of this material. There are many factors that contribute to reasons why it may not last as long as standard concrete. The fact that these voids create more surface area of the object that is emitted to the elements may be a leading cause of why its lifespan is shorter. Testing of the strength lost due to missing fine aggregate from mixture may be a leading cause to why the strength is much less compared to standardized concrete. With many more factors to consider, the research is not complete. Therefore, the future plan is to take into consideration all these factors, then with these testing finalize the results in what is to be expected. With reason to believe that not all expectation will be known, pervious concrete is so particular and specific in every aspect. It is not yet accurate enough to determine what a case of pervious concrete would exhibit if not admitted to a general common term. These terms may refer to the time it takes for the concrete to cure, or not quite a perfect blend of mortar mix, etc. With all these special cases, each mix will be different, and each mix may have different properties than the other.

**REFERENCES**


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