An Analysis on Bacterial Growth on Vinyl and Polished Concrete

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Abstract

Utilizing flooring with minimal permeability is imperative to maintain human safety by preventing bacterial spread and growth. Harmful bacteria can cause dangerous, and even deadly, Symptoms, to those exposed. Vinyl, epoxy, and polished concrete are frequently used in grocery stores, restaurants, schools, hospitals, and retail stores due to their durability with high foot traffic. The ability for these surfaces to maintain safe levels of bacteria in conjunction with regular cleaning is dependent on the porosity and permeability of the material. The more permeable the surface is, the more moisture and therefore bacteria can penetrate through the floor and continue to grow and thrive. The goal of this study was to analyze the permeability and bacterial growth in various polished concretes and vinyl flooring. For this project, ASTM C 1585 was performed to determine the permeability of vinyl, 200 grit, 400 grit, 800 grit, and float concrete samples. Additionally, a controlled bacterial growth environment was simulated, and an area fraction analysis was performed on the samples to determine the amount of bacterial growth on each sample. It was found through testing that vinyl flooring is less permeable and therefore optimally prevents bacteria from saturating through the body of the material.

Introduction

Bacteria growth is a common problem in grocery stores, restaurants, schools, hospitals, and retail stores due to exposure to contaminated food, settlement of airborne bacteria, contact by shoes, and pathogens from spilled/dripped human fluids (Lemmen, Hafner, & Lutticken, 2004). These bacteria include E. coli, salmonella, listeria, staphylococcus aureus, and more. Human exposure to the harmful bacterial strains can cause severe food poisoning in humans resulting in nausea, vomiting, and dehydration. Death can even occur in humans with lowered immune Systems to include the elderly and young children (Mayo Clinic). Studies where surfaces of groceries stores have been swabbed for bacteria have determined the presence of harmful bacteria in all stores tested, to include fecal bacteria (Morris, 2010). Additionally studies have found that 40% of E. coli and similar bacteria strains are transferred from surfaces to fingertips when touched (Rusin, Maxwell, & Gerba, 2002).

Vinyl, ceramic, and polished concrete are frequently used in these environments due to their durability with high foot traffic. The ability for these surfaces to maintain safe levels of bacteria in conjunction with regular cleaning is dependent on the porosity and permeability of the material. The more permeable the surface is, the more moisture and therefore bacteria can penetrate through the floor and continue to grow and thrive. Porosity is a measure of the volume of voids in concrete (American Concrete Institute, n.d.). Permeability is the rate of flow of moisture through concrete under a pressure gradient (American Concrete Institute, n.d.). Voids through which moisture can move must be interconnected and of a certain size. Discontinuous pores and pores with narrow entrances retard the flow of moisture. Therefore, concrete that is more porous tends to be more permeable. This is important for evaluating various materials as more porous materials will be more susceptible to moisture and contaminant absorption.

Vinyl is less porous than concrete and subsequently less permeable. This reduces the capacity for the surface to absorb and then store bacteria or the nutrients that feed the bacteria. It is also commonly thought that polishing the concrete at increasing grits reduces the porosity of the concrete, however this has not been demonstrated in a laboratory or field setting. The purpose of this paper is to evaluate the capacity of vinyl covered concrete flooring and varying grades/grits of polished concrete floor to resist short and long term bacteria growth.

Materials and Methods

Sample Preparation

- A Type I/II Portland cement with a Blaine fineness (surface area, m2/g) of 0.345 m2/g was used as the primary cementitious material for experimentation. The cement composite and concrete samples were made using Portland cement with a chemical composition of: SiO_2, 19.9%; CaO, 63.9%; Al_2O_3, 4.8%; Fe_2O_3, 3.2%; C_3S, 57%; C_2S, 13%; and C_3A, 7%. An ASTM C 33 alluvial aggregate with a maximum aggregate size of 25.4 mm (1.00 inches) was used for the coarse aggregate. An ASTM C 33 graded concrete sand was used with a specific gravity of 2.62 and absorption of 1.00% (ASTM C 33-13, 2013).
- Concrete samples, Table 1, were mixed and cast per ASTM C 192 and cut to 2-inch length to model a petri-dish shape. This concrete mix design was used to conform to conventional concrete used in the flooring industry for polished concrete floors. Standard fresh and hardened properties to include ASTM C 143, C 1064, C 231, and C 39 were measured to validate the concrete mixture. Twelve experimental samples, Table 2, were created to compare the permeability differences and subsequent bacterial growth in polished concrete and vinyl samples as well as bacterial growth compared to reference petri dishes.

TABLE 1-CONCRETE MIX DESIGN

Material	pcy (fl oz per cwt)
ASTM C 150, Type I-II Portland Cement	540
ASTM C 33, 57/67 Coarse Aggregate	1652
ASTM C 33, Fine Aggregate (Sand)	1443
Mid-Range Water Reducer	(5.0)
Water	259

TABLE 2-REFERENCE AND EXPERIMENTAL MIXTURES

ID	No. of Samples
Reference (Petri Dish)	2
Vinyl – Covered Concrete	2
Floated Finish Concrete	2
Polished Concrete 1 – 200 grit	2
Polished Concrete 2 – 400 grit	2
Polished Concrete 3 – 800 grit	2

After mixing and cutting, the samples were cleaned and oven dried. A 2-inch by 2-inch square was marked on the surface of each sample as an indicator for the area of focus during the bacterial growth analysis portion of this project. Samples were then cured for 28-days before being polished and epoxied. The polished samples were polished according to the specified grit for each sample. The vinyl surfaces were epoxied to the concrete for the two vinyl samples. All samples were epoxied around the 2-inch by 2-inch square, Figure 1.

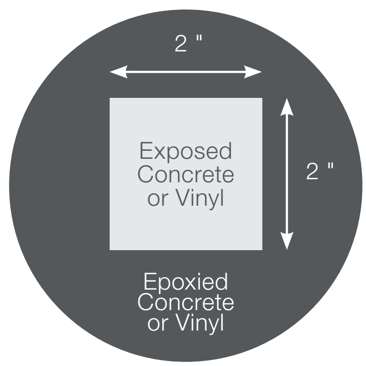


Figure 1 - Rudimentary drawing of sample preparation

ASTM C 1585 Set-up

Two concrete samples at 3-inch diameter by 2-inch tall were from the concrete mix design in Table 1 and prepared based on the layout in Table 2. The concrete samples were subjected to a low pressure water environment for a period of 7-days. During this seven days, concrete samples exhibited primary and secondary absorption to varying degrees. These absorptions were calculated based on weight gain measurements of the concrete samples from the absorbed water. Both the primary and secondary absorption are dependent upon the permeability and percolation of the concrete, polished concrete, and vinyl covered concrete.

Bacterial Growth Set-up

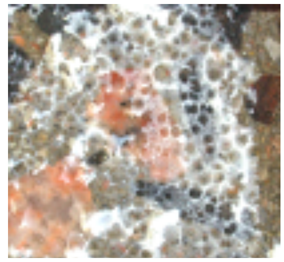
For the reference, petri dish samples agar was prepared by heating the bottle for 30 seconds, stirring, and continuing to heat in 15 second intervals until the agar became liquid. The agar was then poured into the petri dishes until the bottom of the surface was completely covered. The agar was left to sit for an hour until it took a gelatin-like form. 1-2 mL of milk was then poured onto the hardened agar surface.

For the experimental mixtures, samples surfaces were coated with agar and the entire sample was soaked in milk for five days to completely saturate the sample and simulate the environment that is present with chronic exposure to fluids, flood, etc. in real-world situations. This was done by placing the samples in individual ventilated containers with a salt water solution to create 75% relative humidity environment in the container. Skim milk was poured into the container until the samples were completely covered with milk. A heater was placed three feet away from the samples at a temperature of 85 degrees F to accelerate bacterial growth.

After five days, samples were removed from the containers and cleaned by spraying the surface and wiping the remaining portions of the sample with water. The samples were then propped on approximately one millimeter stilts with the surface of the sample facing the bottom of the container, similar to the ASTM C 1585 set-up. The containers were then filled with 10-12 millimeters of the sugar water solution. The containers were sealed and placed three feet from the heaters at 85 degrees for 42 hours.

After 42 hours, the sugar water was removed from the containers. The samples were again propped, with the surface facing down, and milk was poured so that 2-3 millimeters of the concrete surface were covered with milk. The containers were sealed and placed three feet from the heaters at 85 degrees for 24 hours. Images were captured of the samples to be used for area fraction analysis, Figure 2.

Area fraction analysis is a method used to determine the percent of a sample surface area containing specific constituents. In this case, the area fraction for each sample is the amount of the surface consumed by bacterial growth divided by the entire top surface area. This provides a percent of surface that contains bacterial growth.



Float 1

Vinyl 1

Figure 2 – Example float and vinyl samples used for area fraction analysis

Experimental Results

The fresh and hardened properties for the concrete mix are listed in Table 3 and Table 4.

TABLE 3-COMPRESSIVE STRENGTH OF CONCRETE MIXTURE

Compressive Strength (psi)	
7 - Day	4895
28 - Day	5385

TABLE 4 – FRESH PROPERTIES OF CONCRETE MIXTURE

Fresh Properties	
Unit Weight (lb)	37.15
Slump (in)	2.25
Temperature (F)	72.0

The ASTM C 1585 results showed a significant decrease in average absorption when comparing the vinyl sample to the float and polished concrete, Figure 3. The 200 grit samples experienced the most absorption followed by the float samples, 800 grit samples, and 400 grit samples. This reduction in absorption observed in the vinyl samples shows that the vinyl surface best prevented moisture that can contain harmful bacteria from permeating through the surface. This moisture prevention in vinyl surfaces also decreases the amount of nutrients present that bacteria can consume to spread and thrive. Concrete's permeability allows for the penetration of bacteria and bacterial nutrients through the surface through the concrete matrix, thus promoting bacterial growth.

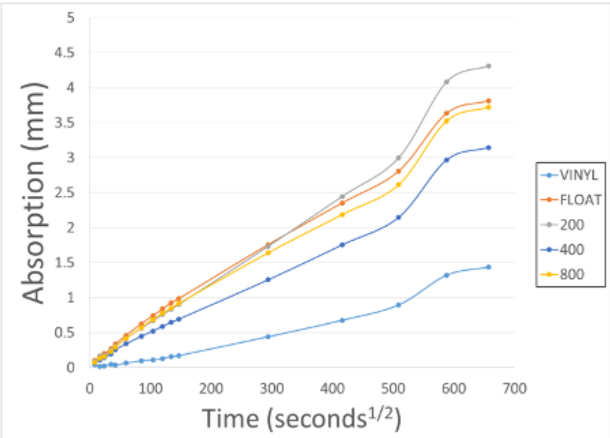


Figure 3 – Averaged absorption

The area fraction analysis showed a significant decrease in bacteria grow th for the vinyl samples when compared to the polished and float concrete samples, Table 5.

TABLE 5 – RESULTS OF AREA FRACTION ANALYSIS

Sample	Average Area Fraction (%)
200 grit	11.25
400 grit	4.83
800 grit	9.84
Float	27.89
Vinyl	1.03

Discussion

Bacteria growth in flooring of hospitals, grocery stores, warehouses, etc. is extremely dangerous for human health. A more permeable surface is a result of a porous material that is more susceptible to this harmful bacterial growth. To further understand the effects that polishing of concrete and vinyl has on the permeability of the floor, laboratory tests were performed on 200 grit, 400 grit, 800 grit, float, and vinyl samples.

The ASTM C 1585 results showed a significant reduction in absorption of water with the vinyl samples as compared to the float and various grit samples. When compared to the float, 200 grit, 400 grit, and 800 grit samples, vinyl reduced absorption by 62%, 67%, 54%, and 61%, respectively. Additionally, the 400 grit experienced less absorption than the 800 grit or 200 grit samples indicating that there is not a linear correlation between the polishing grade and resulting permeability of the concrete.

The area fraction analysis showed that the vinyl samples displayed the smallest percent of area fraction followed by the 200 grit, 400 grit, 800 grit, and finally float sample. This shows that the vinyl samples experienced the least amount of bacterial growth on the surface.

By analyzing the area fraction analysis in conjunction with the ASTM C 1585 results, it is apparent that the vinyl samples prevent bacteria growth at the surface and subsequent penetration through the sample.

Conclusion

In order to maintain human safety in stores and hospitals, it is imperative to minimize bacterial spread and growth. This is done by utilizing flooring with minimal permeability. This research sought to analyze the permeability and bacteria growth in various polished concretes versus vinyl flooring. It was found through testing that vinyl flooring is less permeable and therefore optimally prevents bacteria from saturating through the body of the material. This was shown through the absorption of moisture through the body of the sample as well as the bacterial growth found at the surface. Further, it was found that the grit at which concrete is polished does not have a correlated impact on absorption or bacterial growth. Therefore, it was found that vinyl floorings systems are more resistant to bacterial growth than concrete flooring.

References

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