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Experimental Study On Compressive Strength And Permeability Of Pervious Concrete Using Polypropylene Fibers

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Abstract

The main focus of the research is to study strength characteristics of pervious concrete and its permeability. Pervious concrete's high porosity often leads to a honeycomb structure, which can compromise its strength compared to conventional concrete. Pervious concrete is a special kind of concrete which allows water to flow through it because of its high porosity and therefore high permeability. Therefore the pervious concrete can be used as solutions to many problems such as drainage problems, ground water table recharge, sustainable development. In pervious no fine aggregates are used or sometimes fine aggregates are used to very little extent. There are various application of pervious concrete. It can be used in basement drainage, pedestrian walkways, local streets, low traffic highway, parking lots.

Keywords: Pervious Concrete, Porous Concrete, Permeability, No-fine Concrete.

1.0 INTRODUCTION

In recent times, urbanization has led to a significant increase in concrete development, leaving little land available. Due to excessive concreting, floods are occurring more frequently due to which 5000 citizens of Nagpur on August 9, 2024, filed petition against cement concrete roads [1]. The group has also organized a protest rally on same day. There have been observations about depletion of water table due to reduced infiltration area availability. The reduction in available infiltration area is due to the construction of various kinds of infrastructure. One of the most important infrastructure on this are the concrete pavement. About 80% of precipitation is directed yielded as surface run off in case of concrete pavement. Permeable concrete, sometimes referred to as pervious concrete, is free of particles. Concrete is porous, meaning that water can pass through it. Its spaces are what make it porous. Aggregate grading can be used to control these voids. The ground water table will rise as a result of the increased infiltration area provided by permeable concrete pavement. In addition to resolving the ground water table issue, pervious concrete application has numerous other advantages. By using pervious concrete, drainage issues will be resolved because no water will remain on the pavement's surface. Drains can be eliminated, which will save money by reducing the amount of land required. Even in situations where large levels of precipitation are feasible due to local topography, pervious concrete can be built to create the necessary voids and, consequently, the necessary coefficient of permeability to achieve efficient drainage. It efficiently controls runoff from paved surfaces, avoids contamination in runoff water, replenishes aquifers, regulates pollutants in groundwater recharge, absorbs less heat than conventional concrete and asphalt, and lowers the demand for air conditioning as compared to impervious concrete. By using it, detention ponds and other conventional storm water management systems that are required by federal requirements for commercial locations larger than one acre are frequently eliminated. By enabling the early installation of stone recharge beds, pervious concrete can expedite construction timelines while lowering ambient air temperatures and lowering energy expenditures for cooling buildings. Pervious concrete provides many benefits over regular concrete, while having a lower compressive strength and more permeability (about 70% of its weight). But it also has drawbacks that need to be taken into account while making plans. When more permeability and lower strength are required, the link between aggregate size variation and strength/permeability needs to be investigated.

LITERATURE REVIEW

The primary goal of the project is to compare the mechanical characteristics of conventional and porous concrete. The project's M20 and M25 grade mix design is taken into account. Nine 150 x 150 x 150 mm cubes of porous and regular concrete were created using the mix design proportions of coarse aggregate, cement, fine aggregate, and water. Cubes were put through 7, 14, and 28 days of compression strength testing. Although pervious concrete is a unique kind of concrete with a high porosity, it is not as strong as regular concrete.

Therefore, it can be used for low-load flat works applications that permit water to pass through, but it is not suitable for heavy-load buildings. [2]

Because of its favorable environmental effects, pervious concrete has become more popular as a pavement material for low-volume road applications in recent years. The state-of-the-art and advancements relevant to pervious concrete research and techniques are reviewed in this work. Numerous research' examinations of the mechanical, hydrological, and durability characteristics of pervious concrete have been evaluated. Pervious concrete has been shown to be an effective storm water filtration system. There has been discussion of the field studies of a few test sections and existing pervious concrete pavements. Rehabilitating pervious concrete pavements to improve their hydraulic efficiency has been reviewed. The life cycle cost analysis of pervious concrete has been brought up. Because pervious concrete is being used more often, because of its many advantages, the pavement sector has a lot of room for more study to better understand the material, which will make it a potential sustainable roadway material in the future. [3]

It has been discovered that pervious concrete, also known as no-fines, porous, gapgraded, permeable, and enhanced porosity concrete, is a dependable storm water management technique. The field of pervious concrete is the subject of extensive research. Because of its voids and porosity, pervious concrete has a lower compressive strength than conventional concrete. The water to cementitious material ratio in pervious concrete is typically between 0.28 and 0.45. The mixture has little to no fine aggregates and is made up of cementitious ingredients, water, and coarse aggregates. Our project's primary goal is to increase the M40 grade pervious concrete's strength properties. However, it is frequently seen that with Pervious concrete's permeability will decrease as its strength increases. Since permeability is the attribute that fulfills its function, strength development shouldn't have an impact on it. [4]

Compressive strength decreases as the proportion of recycled aggregate replacement increases. On the other hand, compressive strength increases as the mix's water/cement ratio is reduced. For 30% to 40% of RCA replacement, the required compressive strength (40 MPa) can be attained by lowering the water cement ratio and modifying the mix's additive amount. [5]

By letting water from precipitation and other sources flow through, pervious concrete—a special kind of high porosity concrete used for flatwork applications—has been shown to lower runoff from a site and restore ground water levels. Its void content is between 18 and 35%, and its compressive strengths range from 28 to 281 kg/cm². For the pervious concrete, it will be between 80 and 720 per minute per square meter. In order to coat the coarse aggregate particles and preserve the interconnectivity of the void, pervious concrete often contains very little or no fine aggregate and just enough cementitious paste. [6]

Examine the infiltration rate of pervious concrete in addition to reducing the fine aggregate from zero to 100% in order to assess the compressive strength of no-fine concrete. Pervious concrete's compressive

strength showed that a higher percentage of sand decreases compressive strength. The reduction in 100% sand from the design mix resulted in a 50% reduction in compressive strength.

Conversely, the 28-day infiltration rate demonstrates a direct correlation with a sand reduction of over 40%, reaching a maximum of 273% when all sand is reduced by the design mix. Concrete with a 90% reduced sand content has a significant compressive strength of 2150 Psi and an infiltration rate of 165.79 inches per hour, making it appropriate for parking and pedestrian area pavements.[7]

MATERIALS AND METHODOLOGY

Concrete is made using cement, aggregate, water and admixture.

Cement: Ordinary Portland Cement of grade 53.

Aggregate: Aggregate of size 10mm and 20mm are used. Physical properties of coarse aggregate.

Admixture: In this project polypropylene fibers are used as admixtures

Water: Portable water is used as per clause 5.4 of IS 456:2000 for casting and curing of blocks.

MIX DESIGN FOR M20

Ratio - 1:1.5:3

$$\begin{aligned}\text{Volume of mold} &= (150 \times 150 \times 150) \text{ mm}^3 \\ &= (0.15 \times 0.15 \times 0.15) \text{ m}^3 \\ &= 3.375 \times 10^{-3} \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Dry Volume} &= 3.375 \times 10^{-3} \times 1.54 \\ &= 5.1975 \times 10^{-3} \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Volume of cement} &= 1/5 \times 5.1975 \times 10^{-3} \\ &= 945 \times 10^{-6} \text{ m}^3\end{aligned}$$

$$\text{Cement} = 945 \times 10^{-6} \times 1440 = 1.36 \text{ kg}$$

$$\begin{aligned}\text{Volume of sand} &= 1.5/5.5 \times 5.1975 \times 10^{-3} \times 35.3147 \\ &= 50.05 \times 10^{-3} \text{ m}^3\end{aligned}$$

$$\text{Sand in kg} = 1.5/5.5 \times 945 \times 10^{-3} \times 1600$$

$$=2.268 \text{ kg}$$

$$\text{Volume of Aggregate} = 3/5.5 \times 5.1975 \times 10^{-3}$$

$$= 2.835 \times 10^{-3}$$

$$\text{Aggregate in kg} = 3/5.5 \times 5.1975 \times 10^{-3} \times 1500$$

$$=4.25 \text{ kg}$$

$$\text{Water required} = 0.5 \times 1.36 = 0.68 \text{ lit}$$

$$10\% \text{ reduction of sand} = 2.04 \text{ kg}$$

$$20\% \text{ reduction of sand} = 1.81 \text{ kg}$$

RESULT AND DISCUSSION

COMPRESSION TEST

Description	Mix proportion	Comp. strength after 7 days (N/mm ²)	Comp. strength after 14 days (N/mm ²)	Comp. strength after 28 days (N/mm ²)
Conventional Mix (M20)	1:1.5:3	11.64	18.15	21.36
Cube 1	1:6	6.18	8.49	9.44
Cube 2 (M20)	10% reduction	10.3	14.45	16.06
	20% reduction	7.52	10.39	11.95
Trial 3 M20 (Added with polypropylene fibres)	10% reduction	11.84	16.71	18.51
	20% reduction	8.72	11.63	13.15
Trial 4 (1:6) Added with 10% PP vol.		7.11	9.63	11.03

PERMEABILITY TESTS

Permeability tests were carried out with the apparatus based on Darcy's law. Following are the results obtained in the test performed.

$$k = \frac{a \cdot L}{A \cdot t} \ln \frac{h_0}{h_t}$$

K= coefficient of discharge

$a = \text{area of discharge hole} = (\pi / 4) * 12 = 3.14 \text{ cm}^2$

$A = \text{area of sample} = 15 * 15 = 225 \text{ cm}^2$

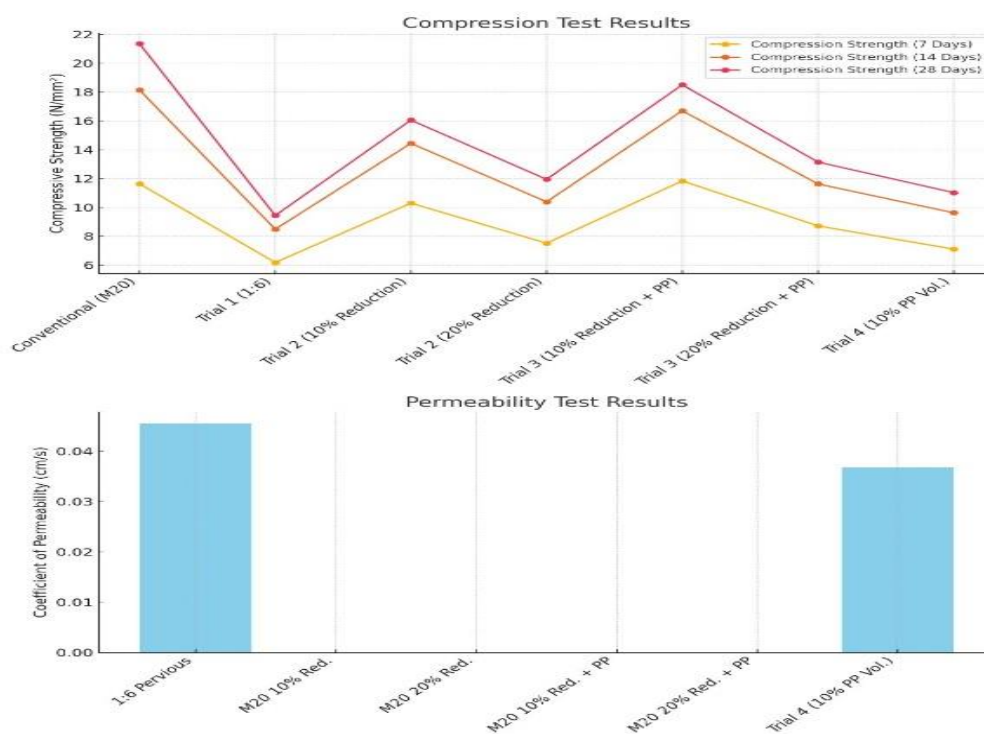
$L = \text{length of sample} = 15 \text{ cm}$

$t = \text{time in seconds}$

$H_1 = \text{initial head in cm}$

$H_2 = \text{final head in cm}$

Description	H1 in cm	H2 in cm	Time in seconds	coefficient of discharge cm/s
1:6 pervious concrete	60	2.3	15	0.0455
M20 10% reduction	60	51.4	3600	9.63×10^{-7}
M20 20% reduction	60	17.8	3600	7.9×10^{-6}
M20 10% reduction with polypropylene	60	52.7	3600	8.1×10^{-7}
M20 20% reduction with polypropylene	60	21.9	3600	6.3×10^{-6}
Trial 4 (1:6) Added with 10% PP vol.	60	4.2	15	0.0368



CONCLUSION

Following conclusions are drawn from the research study.

1. After performing compression test on concrete, it is observed that strength slightly reduces after 10% reduction in sand content. Reduction in strength is not that appreciable, might be due to a very limited honeycombing.
2. After 20% sand reduction drastic reduction in strength is observed, which is due to reduction in effective cross-sectional area taking the stress.
3. After the addition of polypropylene fibres strength increases by 10 to 18% but coefficient of permeability reduces by 15 to 22%
4. Workability of concrete is slightly reduced when added with polypropylene fibers in test performed. But this reduction can be mitigated by optimizing gradation. In spite of this drawback, appreciable improvement is seen in strength when polypropylene fibers are used.

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