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EXPERIMENTAL INVESTIGATION ON PERMEABLE PAVEMENT USING CELLULOSE POLYMER

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Abstract - *The scope of our project is to reduce the stormwater runoff on the surfaces and increase the ground water level. In nature, the concrete pavements restrict the flow of water from the surfaces which will lead to stormwater runoff during rainy seasons. It will lead to drainage issues and external drainage structures are required to drain the water from the surfaces. In order to reduce these problems permeable pavements are extensively used. Permeable paving is a method of paving vehicle and pedestrain pathways to enable infiltration of stormwater runoff through the porous. Permeable pavements are generally constructed by using pervious concrete for the infiltration of water. The strength of permeable pavement is less compared to other types of pavements due to the presence of voids. In order to increase its strength without affecting permeability of concrete, we are going to use cellulose polymer at the percentage of 2 - 3% of cement. Cellulose is an organic polymer on the earth which gives strength to the cell wall of plants. Since it is a long chain polymer and the chains are firmly holding together it has high tensile strength. It is also hydrophilic in nature so it absorbs the water from the surfaces, this will increase the rate of percolation. From the results it is observed that the addition of cellulose polymer increases the strength of the pavement as well as the rate of percolation.*

Key Words: Cellulose Polymer, Permeable Pavement, Pervious Concrete, Permeability, Compressive Strength.

1. INTRODUCTION

Permeable paving is a method of paving vehicle and pedestrain pathways to enable infiltration of stormwater runoff through the porous. In addition to reducing surface runoff, permeable pavements can trap the suspended solids, thereby filtering pollutants from stormwater. It has less strength compared with the other type of pavements due to the presence of voids. Permeable pavements are generally constructed by using pervious concrete (mixture of cement and coarse aggregates) for the infiltration of water. In order to increase the strength of the pavement we are going to use cellulose polymer which provides additional strength to the pavements.

1.1 Objectives

- To reduce the stormwater runoff on the surfaces.
- To increase the ground water level and reduce the water scarcity problems.
- To reduce the damages due to floods.
- To reduce the usages of drainage structures.
- To increase the strength of the pavement.

1.2 Cellulose Polymer

Cellulose is an organic polymer which gives strength to the cell wall of the plants. Cellulose is a long chain polymer with the formula $(C_6H_{10}O_5)_n$, It consists of linear chain of several hundreds to thousands of $\beta(1\rightarrow4)$ linked D-Glucose units. It has high tensile strength due to the chains are holding firmly to each other.

Fig. 1 Cellulose Polymer

1.3 Properties of Cellulose

- Cellulose has no taste, is odorless, is hydrophilic with the contact angle of 20–30 degree, it is insoluble in water.
- Cellulose is a straight chain polymer.
- Holding the chains firmly together which increases the tensile strength.
- The mechanical role of cellulose fibers in the wood matrix is it gives strong structural resistance.
- Compared to starch, cellulose is much more crystalline.

1.4 CELLULOSE CEMENT COMPOSITES

- Cellulose Fiber
- Microcrystalline Cellulose (MCC)
- Cellulose microfibrils (CMFs)
- Cellulose nanofibrils (CNFs)
- Cellulose nanocrystals (CNCs)
- Bacterial Cellulose (BC).

2. PREPARATION OF CONCRETE

2.1 MIX DESIGN

The following mix proportioning helps to attain the required amount of void content of freshly mixed pervious concrete. The mix design of pervious concrete according to ACI method as follows,

1. Void content of aggregates,

$$\% \text{ of voids} = \frac{(G \times W) - M}{G \times W} \times 100$$

Specific gravity of aggregates (G) = 2.75

Bulk Density of aggregates (M) = 1520 kg/m^3

Unit weight of water (W) = 1000 kg/m^3

$$\% \text{ of voids} = \frac{(2.75 \times 1000) - 1520}{2.75 \times 1000} \times 100 = 44.72\ \%$$

2. Percentage of paste volume,
V_p (%) = (Aggregate void content + Compaction index – Design void content)
The value of Compaction Index (CI) can be varied based on the anticipated consolidation to be used in the field.
For greater consolidation Compaction index
= 1 to 2%
For lighter consolidation Compaction index
= 7 to 8%
The average value of 5% to get similar values between measured fresh pervious concrete void content and design void content.

Compaction index = 5 %
Design void content = 30 %
Percentage of paste volume
= 44.72 + 5 – 30
V_p (%) = 19.72 %

3. Paste Volume, V_p = 27 x (19.72 / 100) = 5.324 ft^3
= 0.15 m^3
4. Water to cement ratio, W/C = 0.3
5. Absolute volume of cement,

$$V_c = \frac{V_P}{1 + [W/C \times RD_C]}$$

Specific gravity of cement,
RD_c = 3.15
Absolute volume of cement,

$$V_c = \frac{5.324}{1 + [0.3 \times 3.15]}$$

= 2.73 ft^3
V_c = 0.079 m^3

6. Volume of water,
$V_w = V_p – V_c$
= 5.32 – 2.73
= 2.59 ft^3
Volume of water, V_w = 0.073 m^3

7. Volume of aggregates,
$V_{agg} = 27 \times (V_p + V_{void})$
= 27 x (49.72) /100
= 13.42 ft^3
V_{agg} = 0.38 m^3

8. Conversion of Volume to weight
Weight of cement
$W_c = V_c \times RD_c \times 62.4 \times 0.593$
= 2.73 x 3.15 x 62.4 x 0.593
= 316.21 kg/m^3
Weight of water
$W_w = V_w \times 62.4 \times 0.593$
= 2.58 x 62.4 x 0.593
= 95.47 kg/m^3
Weight of aggregates
$W_{agg} = V_{agg} \times RD_{agg} \times 62.4 \times 0.59$
= 13.42 x 2.75 x 62.4 x 0.59
= 1365.6 kg/m^3

Mix Proportion = 1 : 4.32

2.2 Mixing of Raw Materials

The cement and aggregates are mixed with a mix ratio of 1 : 4.32 (One parts cement and 4.32 parts of aggregates) with a water to cement ratio of 0.3. The cellulose is added to the cement with the percentage of 2%, 2.5% and 3% respectively.

2.3 Moulding

Moulding is the process of shaping the liquid or flexible raw material using a rigid frame called a mould. The standard mould of size of 150mm x 150mm x 150mm is used for the moulding.

Fig. 2 Mixing of Raw Materials

Fig. 3 Moulding of Concrete

Fig. 4 Demoulding of Concrete

2.4 Demoulding

Demoulding is the process of removing the shaped material from the mould. Usually the demoulding is done after the initial setting time of the concrete. The initial setting time of concrete is about 24 hours.

3. TESTS ON PERVIOUS CONCRETE

3.1 Compressive Strength Test

The compression strength of concrete is the ability of the concrete to resist the compression loads which acts upon it. It is measured by crushing cubical concrete specimens in compression testing machine. The following procedure is used to find out the compressive strength of the hardened concrete,

1. Calculate the mix proportion of concrete and mix the raw materials as per the mix design.
2. Apply the oil on the sides of the mould and pour the fresh concrete into the mould.
3. Fill the mould with the concrete in three layers and compact each layer by 25 times using tamping rod. Remove the concrete from the mould after the initial setting time of 24 hours.
4. The concrete is cured in the water for 7 days, 14 days and 28 days respectively. Place the concrete in the compression testing machine. The load is gradually increased until the specimen fails.
5. Note down the value of failure load. Repeat the procedure for various proportion of concrete and compare their results with conventional concrete.

3.2 Permeability Test

To find out the amount of water percolated per unit time the permeability test is carried out in pervious concrete. The test procedure for the determination of rate of percolation are as follows,

1. The cube size of 150mm x 150mm x 150mm is taken for the permeability test, the sides of the cube is sealed to prevent the side drains of the water.
2. The water is allowed on the top surface of the concrete cube only by placing the concrete cube in the constant flow of tap
3. water.
4. The water is allowed through the concrete for a certain time and the percolated water is collected in the bucket which is placed below the concrete.
5. The time taken is also noted and the rate of percolation is calculated by,

$$\text{Rate of percolation} = \frac{\text{Amount of Water Collected}}{\text{Percolation Time}}$$

6. Repeat the procedure for various concrete samples and compare the values with conventional concrete.

3.3. TEST RESULTS

3.3.1 Compressive Strength

Table -1: Compressive Strength of Concrete

S.No	Properties	Curing Period	Conventional Concrete	Cement + 2 % of cellulose	Cement + 2.5 % of cellulose	Cement + 3 % of cellulose
1.	Load at Failure (kN)	7 Days	218 kN	226 kN	238 kN	253 kN
		14 Days	327 kN	336 kN	350 kN	362 kN
		28 Days	369 kN	385 kN	392 kN	405 kN
2.	Compressive Strength (MPa)	7 Days	9.7 MPa	10.04 MPa	10.57 MPa	11.26 MPa
		14 Days	14.53 MPa	14.93 MPa	15.54 MPa	16.09 MPa
		28 Days	16.4 MPa	17.1 MPa	17.42 MPa	18.02 MPa

3.3.2 Rate of Percolation

Table -2: Rate of Percolation of Concrete

S.No	Properties	Conventional Concrete	Cement + 2 % of cellulose	Cement + 2.5 % of cellulose	Cement + 3 % of cellulose
1.	Percolation Time	19 sec	18 sec	19 sec	19 sec
2.	Amount of water collected (ml)	2300 ml	2600 ml	2800 ml	2970 ml
3.	Rate of percolation (l/sec)	0.12	0.14	0.147	0.156

3.4. COMPARISON OF RESULTS

3.4.1 Compressive Strength

The addition of cellulose will also increase the compressive strength. It is a long chain polymer which are closely holding together so it has high tensile strength which increases the strength of the pavement.

The graph is plotted between the concentration of cellulose (%) and the compressive strength of the concrete (MPa). The graph is plotted for curing period of 7 days, 14 days and 28 days separately for the comparison of compressive strength of concrete of various proportions with conventional concrete.

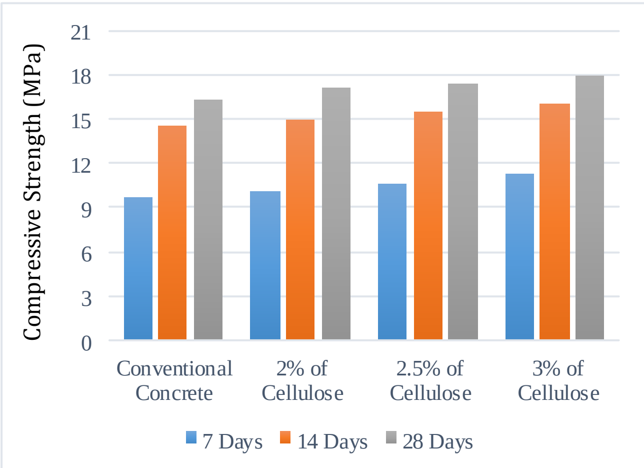

Chart -1: Comparison of Compressive strength of Concrete

3.4.2. Rate of Percolation

From the results obtained from permeability test of allowing water through the concrete specimen the increase in cellulose content will also increases the rate of percolation of concrete. The cellulose is hydrophilic in nature hence it absorbs certain amount of water which increases the permeability of the pavement.

The graph is plotted between the concentration of cellulose (%) and the Rate of percolation (l/sec) for the comparison of various proportions with conventional concrete. The graph clearly shows that the rate of percolation is increased with increase in cellulose content.

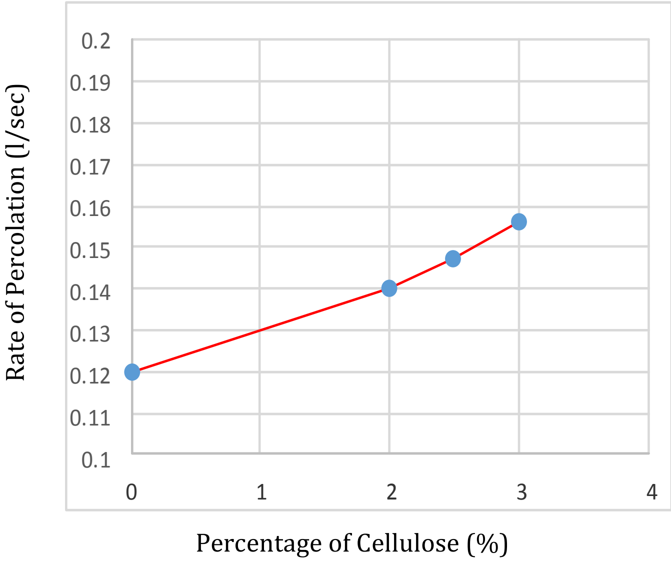

Chart – 2: Comparison of Rate of Percolation of Concrete

4. CONCLUSION

The permeable paving is an effective method to drain the stormwater from the surfaces during rainy seasons. The permeable pavements are constructed by using pervious concrete which has less strength compared with the other types of pavement due to the presence of voids. In order to increase its strength, we are using cellulose polymer at the percentage of 2 - 3% of cement. From the results, it is observed that the addition of 3% of cellulose content increases the rate of percolation and compressive strength of the concrete. The excess amount of cellulose content increases the water absorption of concrete which reduces the strength of the concrete. The mix design of pervious concrete was done by using ACI method. The cement and aggregates are mixed with the mix proportion of 1:4.32 as per the mix design at the water to cement ratio of 0.3. The permeability test and compressive strength test was carried out on the concrete to find out its rate of percolation and compressive strength. The compressive strength test was carried out for the curing period of 7 days, 14 days and 28 days respectively and the results are compared with the conventional concrete results.

REFERENCES

[1] A.M.Admute, S.S.Adsul, A.V.Gandhi, G.S.Bhor (2017) "Permeable Pavement : New techniques for construction of roads in India"

[2] Alalea Kia, Hong S. Wong, Christopher R. Cheeseman (2019) "High strength Clogging Resistant Permeable Pavement"

[3] Arjun R, Ravindran K, Mohammed Abbas (2017) "Study on compressive strength of pervious concrete for utilization as pavement"

[4] Ashutosh, Vrushabh, Sairaj, Dnyaneshwar, Manthan (2019) "A Review On Smart Permeable Pavement"

[5] Isam Alyaseri, Jianpeng Zhou (2016) "Stormwater volume reduction in combined sewer using permeable pavement"

[6] Jan Stovring, Torben Dam & Marina Bergen Jensen (2017) "Surface sedimentation at permeable pavement systems: implications for planning and design"

[7] Kiran Tota-Maharaj and Miklas Scholz (2016) "Efficiency of Permeable Pavement Systems for the Removal of Urban Runoff Pollutants Under Varying Environmental Conditions"

[8] Laura Moretti , Paola Di Mascio and Ciro Fusco (2019) "Porous Concrete For Pedestrian Pavements"

[9] M.Marchioni & G. Becciu (2015) "Experimental Results on permeable pavements in urban areas: A synthetic review"

[10] Matteo Brugin, Mariana Marchioni, Gianfranco Becciu, Filippo Giustozzi, Emanuele Toraldo & Valerio Carlos Andr -Valeri (2017) "Clogging potential evaluation of porous mixture surfaces used in permeable pavement systems"

[11] Miklas Scholz, Piotr Grabowiecki (2016) "Review of permeable pavement systems"

[12] Mohammed Sonebi, Mohammed Bassuoni, Ammar Yahia (2016) "Pervious Concrete : Mix design, Properties and Applications"