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Study on Physical and Mechanical Properties of Porous Concrete using Recycled Concrete Aggregate

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Abstract. While porous concrete has a poor compressive strength because of its porous structure, concrete will lead to failure when the load applied is high. With recycled concrete aggregate and PVA fibre, an attempt was made to improve porous concrete's physical and mechanical properties. The features of ingredients such as recycled concrete aggregate, cement, Polyvinyl alcohol fibre, and water were first discovered, and then the mix was created and cast. After proper curing, the mechanical properties of concrete were determined by conducting the following tests: compression strength, split tensile strength, and flexural strength, along with physical factors such as permeability. The findings reveal that using the aggregate size of 1012mm improves mechanical characteristics. Permeability was also excellent. On the other hand, strength increased as the percentage of PVA fibre grew and at a certain point strength as well as porosity decreased. The maximum strength was attained at an incorporation % of 1. The mechanical characteristics of the aggregate declined when the size increased, as the surface area available for the cement to bind them together shrank.

Introduction

General

Porous concrete plays an important role in groundwater recharge and stormwater runoff reduction by absorbing and draining rainwater into the ground [10]. It's constructed with cement, coarse particles, and water, much like regular concrete. It is free of sand, resulting in a porous amorphous structure that allows water to flow freely [3]. It can absorb 3 to 5 gpm per sqft of surface area of stormwater which can surpass those required to avoid runoff during typical rainstorms [2].

From 2012 to 2014, the building and demolition industry generated over 370 million tons of concrete trash, according to the US Environmental Protection Agency [4]. If current trends continue, more than 4300 lakh tonnes of concrete debris could be produced in a year by the end of the decade. Despite the fact that concrete waste recycling is becoming more popular, much of it is still dumped in landfills [5]. Furthermore, replacing natural aggregates with recycled aggregates has the potential to cut 15%–20% of CO2 emissions while also protecting a major percentage of limestone resources all around the world. Replacement ratios of two have been found to be effective in studies.[1]

Up to 75% of a city's surface area is impermeable pavement, which prevents groundwater recharge, contributes to abrasion and flooding, transports pollution to adjacent waters, and increases the complexity and cost of storm water treatment [6]. Parking and access spaces benefit from pervious pavement with a compressive strength of up to 4000 psi [7]. Summer ambient

temperature can be reduced by 2–4 degrees [8]. This study looked at the research on porous concrete made from recycled concrete aggregate, as well as its physical and mechanical qualities and ways to improve its performance [9].

Scope of our project

- Reducing the use of natural aggregate in concrete and consuming recycled concrete aggregate.
- Reduction of concrete waste and its impact on environment
- Accelerating the ground water table level by reducing the storm water runoff and stagnation of water

Objective

- To make a systematic study on porosity and mechanical properties of porous concrete using recycled concrete aggregates.
- To achieve maximum strength by using poly vinyl alcohol with required porous parameters.
- To give exact conclusion based on tests and observations.

Methodology

Initially the project started with identification and collection of materials, followed by specimen casting for different incorporation's and two types of tests were preferred namely destructive tests and non-destructive tests. Destructive tests include compressive, split tensile and flexural tests. Non-destructive tests include ultrasonic pulse velocity, permeability, porosity tests. The test results were analysed and conclusion was arrived.

Materials

- Cement OPC Grade 43
- Recycled concrete aggregate
- Water
- Poly vinyl alcohol

Cement

Cement is a substance that holds things together. Cement comes in a variety of forms that are utilized in building. Based on its composition, each variety of cement has different features, uses, and advantages. This experiment used Ordinary Portland Cement (OPC) 43 Grade cement. Various tests were done to find the property of cement that we utilized.

Figure.1. Cement(binder)

Coarse aggregate

As the major coarse aggregate, we employ recycled concrete aggregates that pass a 20mm screen and are retained at 10mm. Crushed cement concrete or asphalt pavement from construction detritus that is reused in other building projects is referred to as recycled aggregates. The utilisation of recycled materials in construction is a long-term strategy in the business. It has a number of advantages, including minimising the requirement for fresh aggregates, lowering energy use, reducing landfill trash, and lowering emissions. These recycled aggregates can be used in the construction of bicycle lanes, pavement shoulders, and many other parts of construction once they have been gathered and processed.

Table.1. Properties of RCA

Specific gravity	2.54
Water absorption	3.44
Impact test	33%
Fineness modulus	7.90

Figure.2. RCA

Polyvinyl alcohol fibre

Polyvinyl alcohol is the full name for PVA. Polyvinyl alcohol is a synthetic or manmade polymer. Vinyl and alcohol groups are present in the PVA polymer molecule. PVA is adsorbed onto cement and moistened goods when a little amount is introduced. The properties of PVA fibre are tabulated below.

Table.2. Characteristics of PVA

Elastic modulus(GPa)	45
Density(g/mm^3)	1.26
Fibre length(mm)	6
Tensile strength(MPa)	1600

Experimental programmes

To determine the strength of permeable concrete, compressive, split tensile, and flexural strength tests were done with 0, .5, 1, 1.5, 2 percent polyvinyl alcohol added to the cement mass. The mix proportion for M30 grade is designed using IS 10262 – 2009[12]. Cube, cylinder and beam were casted and tested for strengths and porous property using the compression testing machine, Flexural testing machine, Ultrasonic pulse velocity etc.

Results

Compressive strength

The cubes were tested by Compression Testing Machine. Compressive strength of the concrete cubes for five types of mixes (one is adding polyvinyl alcohol in the concrete and other is the reference concrete) for 28 days are found. Table 3 shows the results obtained.

Table.3. Compressive strength test

Mix	Fibre incorporation (%)	Compressive strength(N/mm^2)
P0	0%	10
P1	0.5%	12
P2	1%	13.5
P3	1.5%	14
P4	2%	15

Split Tensile strength

The cylinders were tested by Compression Testing Machine. The concrete cylinders' tensile strength was evaluated after 28 days and the findings were tabulated in table 4.

Table.4. Split tensile strength test

Mix	**Fibre incorporation (%)**	**Tensile strength**
P0	0%	2.5
P1	0.5%	3.2
P2	1%	3.3
P3	1.5%	3.6
P4	2%	3.8

An increase in strength of 52% was observed for the highest incorporation (2%) from the reference concrete with 0% incorporation.

Flexural strength

The Beams were tested by Flexural Testing Machine (FTM). The Flexural strength of concrete beams for 28-day mixes was discovered. Table 5 shows the outcomes achieved.

Table.5 Flexural strength test

Mix	**Fibre incorporation (%)**	**Flexural strength**
P0	0%	1.5
P1	0.5%	1.8
P2	1%	2.1
P3	1.5%	2.3
P4	2%	2.5

Flexural strength for pavements must be between 1 to 4 MPa. Hence These values (between 1.5 and 2.7 MPa) are well within the limit and can be proceeded. Further an increase of strength about

66% was observed for the highest percentage of incorporation (2%) from the reference concrete P0.

Ultrasonic pulse velocity test

The cubes are tested by ultrasonic pulse velocity tester. The ultrasonic values for cubes at 28 days were found out and tabulated in table.

Table.6. Ultrasonic pulse velocity

Mix	Fibre incorporation (%)	Values (km/sec)
P0	0%	3.3
P1	0.5%	3.4
P2	1%	3.6
P3	1.5%	3.8
P4	2%	3.9

Values more than 4.5 are considered as excellent. Values between 3.5 to 4.5 are considered good. They are considered as medium when their values range between 3.0 to 3.5 doubtful when they are below 3. Our test result shown a range of 3.3 to 3.9 which are considered as good.

Permeability

Table.7. Permeability

Mix	Fibre incorporation (%)	Permeability(cm/s)
P0	0%	3.1
P1	0.5%	2.7
P2	1%	2.9
P3	1.5%	2.6
P4	2%	2.4

From the results of permeability tests, it is known that the permeability of the material has decreased, as a result of the increased inclusion of PVA Fibre and decreased gradually and the permeability values are good enough to be used in construction of porous concrete.

Porosity

Porous concrete has a porosity of 15 to 35 percent is considered as nominal in sites. Results from figure 9 shown a range from 25 to 26%. Which is high enough to be considered to be a permeable concrete.

Table.8. Porosity Table

Mix	Fibre incorporation (%)	Porosity (%)
P0	0	25.9
P1	0.5	25.5
P2	1	25.7
P3	1.5	25.4
P4	2%	25.2

Porous concrete has a porosity of 15 to 35 percent is considered as nominal in sites. Result from table 8 shown a range of 25.2%. Which is high enough to be considered to be a permeable concrete.

Conclusion

We specifically conclude from the results of the experiments conducted that

- The optimum range of PVA fibres is at 1%, where all the test results are at the good satisfiable value.
- The mechanical qualities of porous concrete grew in strength as the amount of fibre incorporated rose, however the porosity property declined for the most part as the amount of fibre incorporated increased.
- Because of improved surface porosity, A greater bonding between recycled aggregate and cement paste resulted in increased strength and abrasion resistance.
- The use of recycled concrete generally aggregates specifically showed actually good result in all segments which ensures that it can specifically be used as a substitute for virgin aggregate.
- Incorporation of fibre resulted a 50%, 52%, 66% increase in the property of compressive, tensile and flexural strength respectively from the reference concrete with 0% incorporation of fibre to the highest value of incorporation that is 2%.
- For a better result an incorporation of 1% of PVA fibre is basically recommended for achieving sufficient strength and permeable property of porous definitely concrete at the same time in a subtle way.

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