BEHAVIOR OF PERVIOUS CONCRETE USING MARBLE WASTE AS COARSE AGGREGATE

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ABSTARCT

Normal or conventional concrete, which is a combination of cement, sand, coarse aggregate and water, forms a hard surface. The fast urbanization and infrastructure developments cause compactly constructed buildings. Depletion of ground water is a major problem today due to the lack of percolation of rain water into the soil. The impermeable nature of conventional concrete restricts the flow of rainwater into the ground. Pervious concrete is one solution to this problem. Pervious concrete is also called enhanced porosity concrete, which is used widely nowadays due to its higher infiltrating ability. Pervious concrete is made up of cement paste, coarse aggregate with little or no fine aggregate. The paste binds the aggregate particles together to develop a system of interconnected and highly permeable voids that encourage the quick drainage of water. Generally, it is used in parking areas, areas with light traffic, residential streets, pedestrian roads and drain covers. On the other hand, many new methods and materials are being introduced for production of concrete to meet the increasing demand. The cost of production of aggregate is increasing at a shocking rate and there is a depletion of the natural resources which give the raw material for its manufacture. The use of waste material as a replacement of coarse aggregate in concrete has become the thrust area for construction industry. It can be used as partial replacement of aggregate in concrete, without compromising on its desired strength. The present research work is focused on pervious concrete made with black marble stone waste aggregate. In the present study, marble waste is used for the pervious concrete in the proportions of 0, 20, 40, 60, 80, 100% in place of natural coarse aggregate. To know the behavior of the above proposed Pervious concrete, an experimental investigation is done to evaluate different properties.

Keywords: Concrete, marble waste, coarse aggregate

1. INTRODUCTION

1.1 General

Concrete is a composite material consisting of cement, sand, coarse aggregate and water and is the most commonly used material in construction globally. It is a brittle material with higher compressive strength. There has been continuous development in the manufacturing of concrete since the time of invention. Initially, materials like gypsum or limestone were burnt and used as crude cement. Later, these cements are mixed with sand and water to form mortar, which was a binding material used to fix stones to each other. Over the years, there was an improvement in the combination of materials which further led to present day concrete. Concrete has gained importance due to its inherent properties and wide range of applications. As there is a huge requirement for concrete production in society, the materials and process of manufacturing of concrete must be very carefully carried out to produce good quality concrete. The constituents of concrete influence the quality of concrete and the life of the structure.

To improve the strength characteristics in any type of concrete, mineral constituents play a vital role in the ingredients of concrete. Many Works has been carried out to improve the performance of the concrete. To prevent the extinction of natural resources in the environment, the usage of new materials in concrete is also increasing day by day without compromising the required properties of concrete to meet the increasing demand in the industry. Concrete is a hard, impervious material in general. There are different types of concrete developed from time to time, such as fiber reinforced concrete, self-compacting concrete, light weight concrete, high density concrete etc to meet the various applications.

1.2 Pervious Concrete

During the rainy season in urban areas, increased runoff to drainage systems is observed in paved areas. This will increase flooding in built up areas and cause overburden on the drainage systems. Huge rain water is being wasted falling on solid surfaces such as driveways, sidewalks, parking lots and streets rather than soaking into the soil. The main reason for this is the use of normal concrete, which is impervious in nature. This creates an ecological imbalance in the environment and leads to various problems like soil erosion, floods, ground water depletion.

On the other hand, the government of India is working hard to safe guard the water sources in the country. There is a need to store this storm water effectively, which is being wasted. Many initiatives have been taken to increase the infiltration of water and thus increase the ground water. In recent years, the government and other organizations joined hands together and implemented many programs like digging of farm ponds, infiltration tanks etc. in all the areas to collect the rain water and improve ground water storage. Telangana has historically been prone to drought conditions especially in Ranga Reddy, Mahbubnagar and Nalgonda districts. Climate is projected to increase drought occurrence in the districts like Nalgonda and Mahbubnagar which would impact not only water resources but also have a cascading effect on other dependent sectors.

Especially in drought areas, Ranga Reddy district being a severely affected district in the state with low rainfall. Based on this scarcity of water, improving water use efficiency is of the utmost priority in the Ranga Reddy District. Many rain water harvesting techniques like Water Conservation schemes (Neeru Pragathi, Check dams, farm ponds, percolation tanks, bore well recharge etc.) have been developed to collect rain water and infiltrate into the soil. By these techniques, only a small quantity of water can be stored and a major quantity of the rain water is wasted as runoff. The runoff on the paved areas can be reduced, if the concrete is able to permeate the flow. The effective solution and most appropriate decision to these problems is switching to pervious concrete rather than using normal concrete.

Pervious concrete is a type of concrete that allows water to percolate through it and recharge the ground water level. Pervious concrete is also called with different names, such as enhanced porosity concrete, no fine concrete, gap graded aggregate concrete etc. According to the National Ready Mixed Concrete Association (NRMCA), "Pervious concrete is a special type of concrete with a high porosity used for concrete flatwork applications that allows water from precipitation and other sources to pass-through it, thereby reducing the runoff from a site and recharging ground water-levels." This concrete is an environmentally friendly building material and is identified as a Best Management Practice for storm water management by the Environmental Protection Agency (EPA). The porosity of the concrete can be increased by removing the fine aggregates from the mix in a higher percentage. Pervious concrete is a blend of cement, coarse aggregate, water and with little or no sand.

Black marble stone waste is used usually for flooring, counters, home decorative items and in many utilities. Black marble stone waste is also extracted and used in laying roadbeds, construction and cement manufacturing.

The Black marble stone waste is also used for various applications such as:

- Wall Cladding
- Vanity Tops
- Furniture
- Refining metals, blackboard and chalk.

The industries use the black marble stone for the manufacture of flooring slabs and for other purposes. After cutting and polishing of the black marble stone, the left residue material is transferred and dumped in the low lying areas of the town. The waste dumped in this area is used as alternative aggregate in this research. The waste is collected and crushed to the required aggregate sizes and used as replacement for coarse aggregate in the present study. The photographs of the collection of waste from the dumping yards and crushed aggregates are shown in Fig, 1.2 and 1.3.

2. LITERATURE SURVEY

2.1 Introduction

Pervious concrete has diversity of names such as porous concrete, no fines concrete and permeable concrete. This type of concrete consists of high permeability rate with porosity and is used for different applications. To recharge the ground water level and to reduce the surface flow, this concrete allows penetration of water directly through it. This type of concrete is in parking areas, areas with light traffic, residential street roads, pedestrian road, swimming pool edges etc. The focus on the usage of pervious concrete is increasing now a days and the research done on pervious concrete is limited. The information relating to pervious concrete is limited to some applications only. The following sections give a brief review on fabrication, properties and application of no-fines concrete or pervious concrete.

2.1.1 Compressive Strength

Hatice Oznuroz (2018) used the acidic pumice aggregate in pervious concrete. By replacing the acidic pumice with the crushed stone at different proportions by total aggregate volume, the variations in the strength characteristics were studied. Fan Yu Daquan et. al (2019) done research to identify the pores characteristics in pervious concrete by 2D/3D CT images and developed a relationship between pores characteristics and permeability. It is observed that permeability is sensitive to content of small pores and as the aggregate size increases, the number of seepage flow lines increases and the seepage flow paths become thicker, which contribute to water permeation. Avizo software is used for simulation. Mohsen and Farid (2019), aimed the feasibility of applications of pervious concrete. They collected rainfall data and studied the compressive strength and permeability. Barnali Debnath et. al (2020) presented the compressive strength, split, flexural, porosity, permeability tests and the prediction equations were developed. The results showed that the equations are fitted well and were in good agreement with calculated values.

2.1.2 Permeability

Xiaodan Chen et. al (2019), studied the environmental impact of pervious concrete with fly ash and slag. The hydraulic conductivity was found slightly higher due to the larger void content.

Maurizio Ziccarelli and Calogere Valore (2019) conducted experiment to identify the composition and properties of pervious concrete to meet the adequate hydraulic conductivity and shear strength. Special attention has been paid to the hydraulic conductivity and the strength and to their relationship to the water/cement and the aggregate/cement ratios.

Jian-XinLu et. al (2019), designed an eco friendly pervious concrete (PC) using waste glass cullet (WGC) and recycled concrete aggregate (RCA). Reduction in compressive strength and the water permeability of the PCs was improved for the PCs prepared with WGC. Satisfactory strength and permeability are achieved by comprising 50% WGC as the fine aggregate and 50% RCA as the coarse aggregates. Rita et.al (2020), presented different methods of measuring infiltration rate and gave a comparative study. Permeability was measured using constant head, falling head and modified ASTH C1707 test for cylinders and it was found that infiltration rate depended non-linearly on head level.

3. OBJECTIVES AND METHODOLOGY

3.1 Introduction

In recent years, pervious concrete is used as an effective storm water management tool. It is different from the conventional concrete and it possesses many voids which are purposely created in conventional concrete and therefore its physical characteristics are varied significantly. This concrete is used for specific applications such as pavements, sidewalks, parking lots, drain covers etc. From the previous chapter, it is understood that many works on pervious/porous concrete were done with different coarse and fine aggregates. But limited research work was done with waste stone produced from stone polishing industries. Hence here in, it is planned to study the stone waste in pervious concrete. From the last few years, the stone polishing industries have grown in a tremendous way. These industries produce huge quantity of black marble stone waste, which has become a problem for their dumping. In this concern, black marble stone waste aggregate is considered as an alternate material for coarse aggregate in concrete.

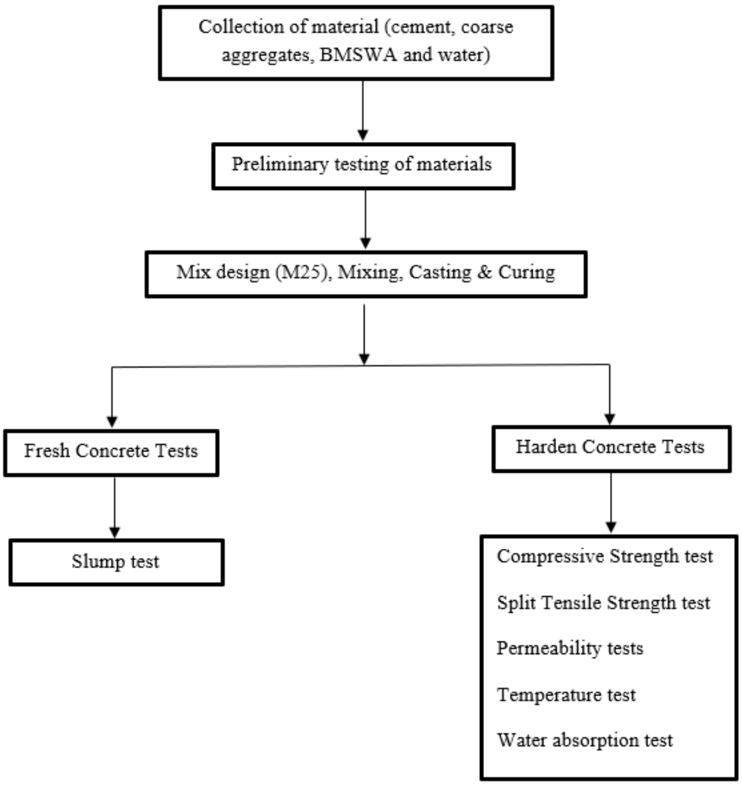
3.2 Aim of the study

The Government of India and some states in India are emphasing to develop rain water harvesting arrangements for each house, very particularly in drought areas. In view of this, it is required to develop few arrangements to infiltrate the rain water or unwanted water, so as to enhance the water table. Many works have been carried out on pervious concrete to study the strength, porosity, permeability characteristics by replacing cement, sand and coarse aggregate with alternate materials. Need for reuse of alternate materials in construction is important for construction industry due to lack of availability of good construction materials (coarse or fine aggregate).In the present study black marble stone waste is used as replacement for natural coarse aggregate in the proportion of 0, 20, 40, 60, 80 and 100%.

3.3 Objective of the study

The present work is mainly to be focused on the development of normal strength M25 grade concrete using black marble stone waste as replacement of natural aggregate in the proportions of 0, 20, 40, 60, 80 and 100%.

- To study the fresh concrete properties (slump).
- To study the hardened properties like Compressive strength and split tensile strength.
- To study the durability properties like permeability by constant head method, Temperature test and water absorption test.



3.4 Experimental program

To achieve the specified objectives (section 3.3) the following test program was planned and presented in the table 3.1. The number of specimens allotted for each test was included in the same table.

Table 3.1: Experimental Program

Type of test to be conducted	Behavior to be identified	Specimen	Size	No
Slump cone test	Fresh concrete properties	-	-	
Compression test	Compressive strength	Cube	150 X 150 X 150 mm	54
Temperature test	Residual Compressive strength	Cube	150 X 150 X 150 mm	54
Water absorption test	Water absorption	Cube	150 X 150 X 150 mm	18
Permeability test	Permeability	disc	100 X 50 mm	18

4. MATERIALS AND MIX DESIGN

4.1 General

Good quality concrete is obtained by proper portioning of ingredients in concrete mix such as cement, fine and coarse aggregates. The appropriate proportion of materials provides homogenous mixture thus achieves designed strength and serves the service life. The nominal mix designs used for adequate strength are based on the fixed cement - aggregate ratio. This is not suitable for all grades of concrete. The estimation of essential quantities of materials in an optimum and economical way to achieve the target strength of concrete is considered as mix design. From the mix design, the suitable quantities of cement, fine aggregate, coarse aggregates and water are obtained. The mix design further depends on the properties of materials used. Material properties such as type of material, consistency, specific gravity, size, shape, texture, density, water absorption and gradation or particle size of aggregate greatly influence the mix design. Hence, in this chapter the basic properties of all materials used in the work are studied. By using these material properties, a suitable concrete mix was designed and the procedure involved is also discussed in this chapter.

4.2 Materials

The physical properties of cement, coarse aggregate and water used in the investigation are presented in this chapter. The standard experimental procedures laid down in IS codes, which were adopted for the determination of normal consistency, initial and final setting times, specific gravity, bulk density, impact strength. The materials used in the experimental investigation include. 1. Cement 2. Coarse aggregate 3. Water The properties of these materials are given in the following sub-sections.

4.2.1 Cement

Cement is anhydrous material with no reaction when it is in dry condition. The oxide form of silica, lime alumina reacts to form complex compounds. It has ability to bind the materials such as aggregates to maintain homogeneity of the mixture. On continuous reaction with water, it imparts strength and durability in hardened stage. When the cement mixed with water, reaction takes place and is called Hydration. The hydration process of cement with the compounds shows the strength of cement. Further, during this process, heat is liberated. Each compound produces different products when it hydrates. The strength of the hardened concrete gets affected, if the consistency of the cement paste is either extremely harsh or wet.

Initial experiments like initial setting time, final setting time, specific gravity and compressive strength test on mortar cubes were conducted on cement with regard to various water quality parameters. Ordinary Portland Cement (OPC) 53 grade was used in the present investigation corresponding to IS 12269 (1987). The used cement is shown in Fig. 4.1. The summary of physical properties and various tests conducted on cement are presented in the Table 4.1.

Table 4.1 Physical Properties of Cement

Physical properties	Test result	Requirement as per IS 12269 (1987)
Specific gravity	3.14	-
Fineness (%)	3	Max 10%
Normal consistency	31%	-
Initial setting time (min)	92	Min. 30 min
Final setting time (min)	325	Max. 600 min

4.2.2 Coarse aggregate

Crushed Granite stone aggregate of maximum size 20 mm, confirming to IS 383-1970 was used. The specific gravity and fineness modulus were found to be 2.7 and 3.28 respectively. Grading analysis is presented in table 4.2. Different properties of the granite coarse aggregate used in this experimental work are given in Table 4.3.

Table 4.2 Grading analysis for coarse aggregate – Sample - 5000gms

S.No	IS Sieve size (mm)	Weight of retained (gms)	Cumulative weight retained (gms)	Cumulative % retained	% Passing
1	80	-	-	-	100
2	40	-	-	-	100
3	20	2940	2940	58.8	41.20
4	10	1040	3980	79.6	20.40
5	6.3	530	4510	90.2	9.80
6	4.75	490	5000	100	-
	total	5000		328.6	271.4

Fineness Modulus=328.60/100 = 3.28

4.2.3 Black Marble Stone Waste Aggregate (BMSWA)

Crushed Black Marble stone waste aggregate of maximum size 20 mm, confirming to IS 383-1970 was used. The specific gravity and fineness modulus were found to be 2.75 and 3.49 respectively. Grading analysis is presented in table 4.4. Different properties of the BMSWA used in this experimental work are given in Table 4.5.

Table 4.4 Grading analysis for BMSWA – Sample - 5000gms

S.No	IS Sieve size (mm)	Weight of retained (gms)	Cumulative weight retained (gms)	Cumulative % retained	% Passing
1	80	-	-	-	100
2	40	-	-	-	100
3	20	2930	2930	58.6	42.4
4	10	1620	4550	91	9
5	6.3	450	5000	100	-
6	4.75	-	-	100	-
	total	5000		349.6	251.4

Fineness Modulus=349.60/100 = 3.49

4.2.4 Water

Potable water has been used for mixing as well as curing of concrete in the present investigation.

4.3 Mix design

The proper proportioning of concrete materials is the prime factor for obtaining better fresh and hardened properties. All the materials are tested for physical properties. The data for mix design is obtained from the tests done on materials required for concrete is shown in below.

Concrete Grade	: M25
Type of Cement	: OPC 53
Type of aggregate	: 20mm Sub rounded
Exposure Condition	: Severe
Specific Gravity Of Cement	: 3.14
Specific Gravity Of Coarse Aggregate	: 2.83
Zone Provision	: Zone II
Workability	: 100 mm (slump)
Cement content	: (350 kg/m3 to 450 kg/m3)
Max w/c ratio	: 0.5

Step 1: Calculation of Target Mean Strength

$\mathbf{f'_{ck}} = \mathbf{f_{ck}} + 1.65$ s

Where s = standard deviation

f_{ck} = Characteristic compressive strength at 28 days

f'_{ck} = Target mean compressive strength at 28 days

Standard deviation value for M25 grade concrete = 4.0 N/mm2

Therefore $f'_{ck} = 25 + 1.65 \times 4$

= 31.6 N/mm2

Step 2: Selection of W/C Ratio

From IS 10262- 2019, Figure.1, for OPC 53 grade, f'_{ck} = 31.6 N/mm2 the W/C is 0.54.

(0.54 > 0.5) – not ok

We are assuming 0.45 (0.45 < 0.5) – hence ok

Hence W/C ratio of 0.45 is taken as a value satisfying both the conditions.

Step 3: Calculation of Water Content

The average nominal size of aggregate taken is 20mm and the water content given in table 8 for 20mm aggregate is 186 lit/m3 (this is for 50mm slump). (Our assumed slump 100mm we need to revised the water content. For 25mm slump → increase 6% water).

Water content: 186 + 6% of 186 = 186 (1+ 0.06) = 197.16 litr/m3.

Therefore, water content obtained is 197.16 lit/m3.

Step 4: Calculation of Cement Content

Cement content = $\frac{\text{water content}}{\text{water−cement ratio}}$

=$\frac{197.16}{0.45}$

= 438 kg/m3

Step 5: Mix Calculations

Volume of Concrete	= 1 m3
Volume of Cement	= $\frac{\text{weight of cement}}{\text{specific gravity of cement}}$ x $\frac{1}{1000}$
	= $\frac{438}{3.14}$ x $\frac{1}{1000}$
	= 0.1395 m3
Volume of Water	=0.197 m3
% Air content	= 1% = 0.01
Total Volume of Aggregates	= 1- (0.1395 + 0.01+ 0.197)
	= 0.6535 m3
Volume Of CA	= 1 x 0.6535
	= 0.6535 m3
Weight Of CA	= Volume of CA x Specific gravity of CA x 1000
	= 0.6535 x 2.83 x 1000
	= 1850 kg

5. EXPERIMENTAL INVESTIGATION

5.1 General

Generally, the fresh, mechanical and durability properties are the indicators of the performance of concrete. In the present experimental work, Pervious concrete is prepared with natural aggregate and Black Marble Aggregate in different proportions (0, 20, 40, 60, 80 and 100%). Various specimens were cast according to standard provisions and cured. Various tests are conducted to determine

ii) Slump cone test (workability)

ii) Compressive strength

iii) Permeability test by constant head method

iv) Temperature test and

v) Water absorption test

The mixing, casting and curing of the specimens and the experimental procedures of tests are explained in the following sub sections.

5.2 Mixing

All the required quantities of cement and coarse aggregates weighed separately and mixed in dry condition. The obtained proportion of water is added to the composite mixture and mix thoroughly until a uniform mixture is formed. The same procedure is repeated for different mixes which includes the replacement of coarse aggregate with black marble stone waste aggregate. The complete mixing is done by hand mixing. After the concrete is mixed, the fresh concrete tests are to be carried out to measure the workability. The detailed explanation of the slump test is reported below.

5.2.1 Slump test

Slump cone test is most simple and common test conducted to determine the workability of concrete mix. According to the IS 1199-1959, Slump test is carried out for every batch of mix. The apparatus is shown in the Table 5.1 and Fig.5.2.

Table 5.1 Apparatus for slump test

S.No	Name of the apparatus	Size of the apparatus
1	Slump cone – Frustum	h = 30 cm, Bottom dia = 20 cm and top dia= 10 cm.
2	Tamping rod with one end round	16 mm dia and 60cm long

Fig. 5.2: Slump cone apparatus

A sample of prepared concrete mix is taken for the test. The internal surface of the frustum of cone is cleaned and greased to avoid the adhesion of concrete. A non-porous base plate is placed on a uniform surface and the slump cone mould is fixed on it. Concrete mix is filled in three equal layers in the mould. The excess concrete is removed and leveled. Now, the cone is lifted in upward direction and the concrete slumps down. The slump (Vertical settlement) is measured in mm.

5.2 Casting and Curing

In the present work cubes and disc specimens were cast to conduct various tests.

5.2.1 Casting of cubes

Totally 90 cubes were cast for conducting various tests. Among them 54 cubes for compressive strength test, 18 cubes for water absorption test, 18 cubes for elevated temperature test. For the preparation of cube specimens, the mixed concrete is poured into the cube moulds made of steel of dimensions of 150 X 150 X 150mm. The moulds are cleaned and greased to avoid sticking of concrete to the moulds and tighten the bolts to prevent leakage of concrete.

The concrete is put in layers into the moulds till the surface and leveled. The specimens are allowed to dry up for 24hrs.

5.2.2 Casting of discs

Total 18 number of disc specimens were cast for different tests. 18 disc specimens for permeability test. The specimens are prepared by pouring the mixed concrete in the moulds of 100mm X 50 mm. The specimens are de-moulded after 24hrs.

5.2.3 Curing

The next stage is curing of the specimens. It is an important phase as the water for hydration is to be maintained in the specimens. Proper curing gives good strength to the concrete. So, after removing from the moulds the specimens are transferred to the curing tank containing water free from impurities and cured for 28 days. The specimens in the curing tank are shown in the Fig 5.4.

Fig. 5.4 Specimens in Curing Tank

5.3 Experimental Procedure

In this section, the test setup and experimental procedure for conducting various tests are discussed.

5.3.1 Compressive strength test (IS 516-1989)

Compressive strength of concrete is the most important characteristic and it is an indexing property as concrete is designed to carry compressive loads. For this experimental study, 54 no. of cube specimens were cast in which 9 specimens are of 100% Natural Aggregate, 9 specimens are of 80% Natural Aggregate + 20% BMSWA, 9 specimens are of 60% Natural Aggregate + 40% BMSWA, 9 specimens are of 40% Natural Aggregate + 60% BMSWA, 9 specimens are of 20% Natural Aggregate + 80% BMSWA and 9 specimens are of 100% BMSWA. The number of specimens cast for each mix is shown in the table 5.2.

Table 5.2 No. of specimens for different mixes for Compressive strength test

S.No	Replacement of Natural Aggregate with MW(%)	Curing		
		7 days	14 days	28 days
1	0	3	3	3
2	20	3	3	3
3	40	3	3	3
4	60	3	3	3
5	80	3	3	3
6	100	3	3	3

This test is conducted to determine the variation of strength of the specimens with varying ratios of coarse aggregate and reduction in fine aggregate content. Compressive strength test machine (CTM) with 2000KN capacity is used to conduct the test on cubes. After placing the cube between the plates in the CTM, load is applied until the crack is observed on the specimen. The load at the point of cracking is considered as failure load and it is noted. The compressive strength is calculated by

Compressive Strength (σ) = Failure load / Cross sectional area of specimen

The testing of the specimen is shown in Fig. 5.5.

Fig 5.5 Testing of cube specimen

5.3.2 Permeability test by constant head method (IS 2720-17 -1986)

Permeability is one of the important hydraulic properties used to assess the draining capacity of pervious concrete and it was measured by constant head permeability method. For this experimental study, 3 specimens are of 100% Natural Aggregate, 3 specimens are of 80% Natural Aggregate + 20% BMSWA, 3 specimens are of 60% Natural Aggregate + 40% BMSWA, 3 specimens are of 40% Natural Aggregate + 60% BMSWA, 3 specimens are of 20% Natural Aggregate + 80% BMSWA and 3 specimens are of 100% BMSWA. The above 3 specimens of each mix proportions for 28 days of curing.

The number of specimens cast for each mix is shown in the table 5.3.

Table 5.3: No. of specimens for different mixes for Permeability test

S.No	Replacement of Natural Aggregate with MW(%)	28days curing
1	0	3
2	20	3
3	40	3
4	60	3
5	80	3
6	100	3

The constant head permeability test involves the passing of water through a cylindrical column of concrete under a constant head. The apparatus consists of concrete disc specimen attached to a cylindrical pipe and a stand. Specimen was saturated prior to the test. Water was allowed into the specimen to obtain a steady state flow. The time in seconds (t) required for the water in the tube (Q) to drop from the top to bottom was recorded. The coefficient of water permeability (k) was calculated using Darcy's Law as shown in Equation:

$k = QL/ A (\Delta H)$

The test setup and testing of the permeability is shown in Fig. 5.4.

Fig. 5.4 Test setup of Permeability

5.3.3 Effect of elevated temperature

Usually, the temperature changes in the environment do not affect the concrete structures severely. But in some special cases like industries with large furnaces, chemical industries and nuclear power plants, concrete structures may be exposed to much higher temperatures when fire breaks out. At high temperatures, the concrete behavior is affected by several factors. Exposure of concrete to elevated temperature affects its strength characteristics. For this experimental study, 54 no. of test cube specimens were cast in which 9 specimens are of 100% Natural Aggregate, 9 specimens are of 80% Natural Aggregate + 20% BMSWA, 9 specimens are of 60% Natural Aggregate + 40% BMSWA, 9 specimens are of 40% Natural Aggregate + 60% BMSWA, 9 specimens are of 20% Natural Aggregate + 80% BMSWA and 9 specimens are of 100% BMSWA..

To study the effect of thermal shock on compressive strength of concrete, the cubes were kept in oven for 4 hours duration subjected to 300oC and 600oC temperature respectively so that there is uniform of supply of heat to the specimens. After that, specimens are removed from the oven and allowed to cool and tested for residual compressive strength. The obtained residual compressive strengths at 300oC and 600oC temperature are compared with the initial compressive strength of cube at 28 days curing period at room temperature 32oC. The percentage loss of compressive strength is found out.

5.3.4 Water Absorption test (BS 1881-122: 2011)

Absorption testing is a popular method of determining the water-tightness of concrete. A water absorption test, such as BS 1881-122: 2011 Testing Concrete: Method for Determination of Water Absorption, measures the amount of water that penetrates into concrete samples when submersed. The lower the absorption, the better the result; however, as do many durability tests, there are limitations:

- It doesn’t account for any type of reactive process that ties up water;
- The assumption that all the weight gain is due to water; and
- There is only a short duration of submersion compared to what might happen in long term conditions.

For this experimental study, 3 specimens are of 100% Natural Aggregate, 3 specimens are of 80% Natural Aggregate + 20% BMSWA, 3 specimens are of 60% Natural Aggregate + 40% BMSWA, 3 specimens are of 40% Natural Aggregate + 60% BMSWA, 3 specimens are of 20% Natural Aggregate + 80% BMSWA and 3 specimens are of 100% BMSWA. The above 3 specimens of each mix proportions for 28 days of curing. The absorption tests will improve over time – as the concrete is saturated and crystals continue to grow. Therefore, when testing durability of concrete, the absorption at later stages will give more realistic results. To acquire the most accurate results, test the concrete at 56 or 90 days, rather than the early stage of 28 days. To study the effect of water absorption of concrete, the cubes were kept in water tank for 28 days curing period. The percentage of absorption is found out.

Water Absorption (%) = ((B-A) / B) *100

Where;

A is the mass of cube sample in air.

B is the mass of the sample after 28 days immersion in water with a dry surface.

6. RESULTS AND DISCUSSIONS

The results of the experimental investigation for the various tests are discussed in this chapter.

6.1 Slump cone test

The slump Values of the concrete for replacement of natural aggregate with BMSWA by 0, 20, 40, 60, 80 and 100 % are graphically represented in Fig 6.1

It is observed that there is increase in the workability of the concrete when the natural aggregate is replaced with BMSWA. The percentage increase of slump values for 20% to 100% replacement of natural aggregate with BMSWA are 12.08 % to 42.85 % respectively. Based on the observations, all of the slump values are in the medium to high workability range.

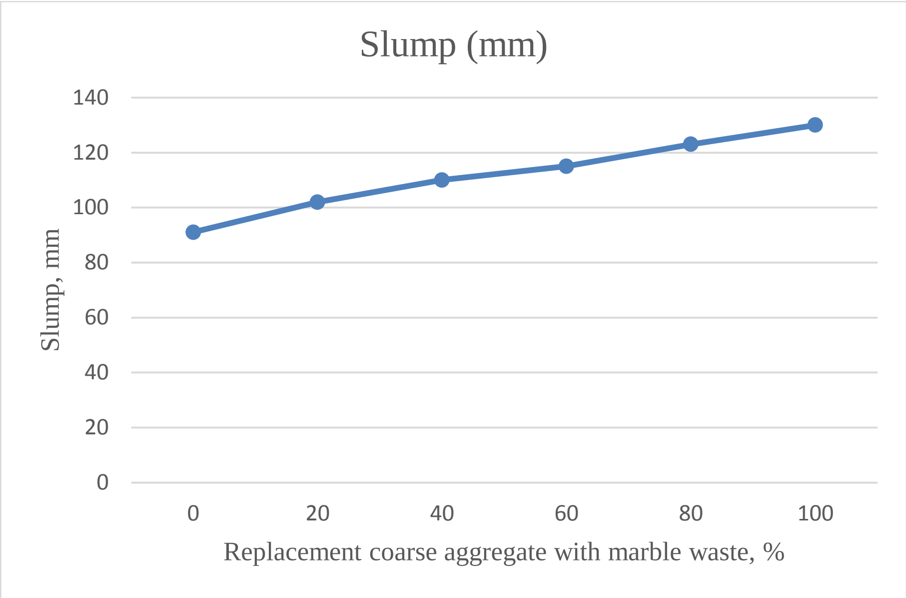


Fig 6.1 Slump Values Vs % replacement coarse aggregate with marble waste

6.2 Compressive strength test

The compressive strength values of the concrete for replacement of natural aggregate with BMSWA by 0, 20, 40, 60, 80 and 100 % are graphically represented in Fig 6.2. Subba reddy et.al (2017) recommended that BMSWA may be used upto 50% replacement for concrete works. K.Obla (2010) conducted experiments on pervious concrete and compressive strength varies from 3 to 17 Mpa. It is observed that there is increase in the compressive strength of the concrete when the natural aggregate is replaced with BMSWA. The percentage increase of compressive strength values for 20%, 40%, 60%, 80% and 100% replacement of natural aggregate with BMSWA are 5.03%, 15.45%, 14.21%, 11.73%, 6.41% respectively. Based on the observations, all of the compressive strength values are higher for BMSWA replacement. The optimum dosage of BMSWA replacement in natural coarse aggregates is 40%.

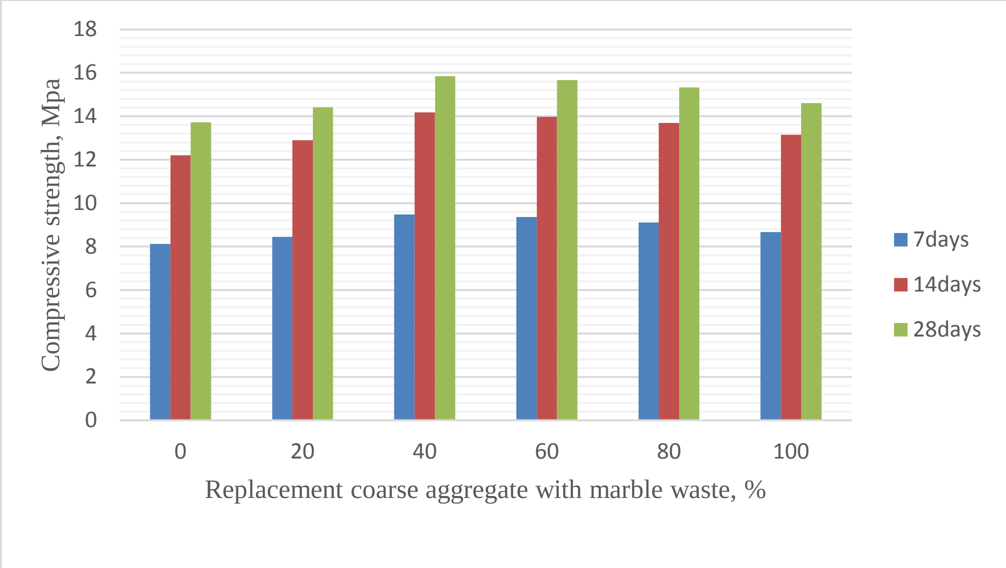


Fig 6.2 Compressive strength Values Vs % replacement coarse aggregate with marble waste

6.3 Permeability test

The Permeability of the concrete by constant head method for replacement of natural aggregate with BMSWA by 0, 20, 40, 60, 80 and 100% for 28 days of curing was done. The Permeability values are graphically represented in Fig 6.3. Rama et.al (2016) conducted constant head permeability test on pervious concrete with two different w/c ratios and value ranges from 0.86 mm/s to 2.21mm/s.

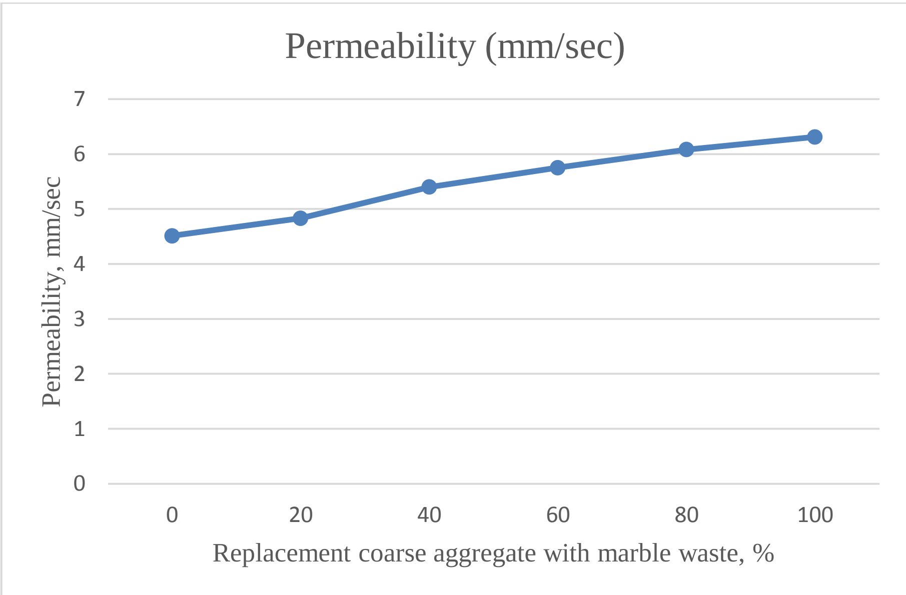


Fig 6.3 Permeability Values Vs % replacement coarse aggregate with marble waste

It is also observed that there is increase in the Permeability of the concrete when the natural aggregate is replaced with BMSWA. The percentage increase in permeability values for 20%, 40%, 60%, 80% and 100% replacement of natural aggregate with BMSWA are 7.09%, 19.73%, 27.49%, 34.81%, 39.91% respectively. Based on the observations, all of the Permeability of the concrete values are higher for BMSWA replacement.

From the results, it is observed that as the natural aggregate is replaced with BMSWA is increases, the pore space in the specimen increases, reducing the flow time and therefore increasing permeability.

6.4 Effect of elevated temperature

The compressive strength results of cubes exposed to temperature of 300oC and 600oC for replacement of natural aggregate with BMSWA by 0, 20, 40, 60, 80 and 100 % are graphically represented in Fig 6.4. H.A.M Bishar (2008) conducted experiment and concluded that compressive strength of concrete at elevated temperatures decreases with increase in temperature and residual compressive strength was 50% of original strength. Rama et.al (2016) conducted temperature test and concluded that there is less reduction in compressive strength for pervious concrete. It is observed that the compressive strengths are decreasing by increasing the temperature and as the percentage reduction in natural aggregate increases, the strengths are also decreasing.

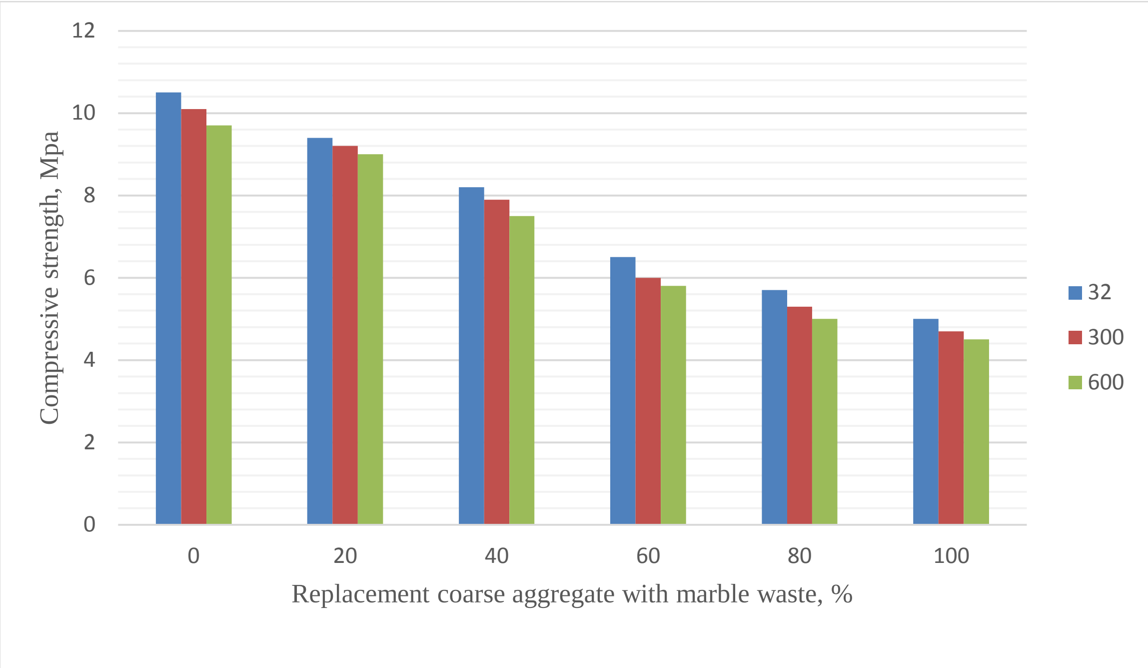


Fig 6.4 Compressive strength Values for elevated temperature Vs % replacement coarse aggregate with marble waste

6.5 Water Absorption test

The Water absorption values of the concrete for replacement of natural aggregate with BMSWA by 0, 20, 40, 60, 80 and 100 % are graphically represented in Fig 6.5. It is observed that there is decrease in the water absorption value of the concrete when the natural aggregate is replaced with BMSWA. The percentage decrement of water absorption values for 20%, 40%, 60%, 80% and 100% replacement of natural aggregate with BMSWA are 15.56%, 20.75%, 36.02%, 47.83%, 91.46% respectively. Based on the observations, all of the water absorption values are lesser for BMSWA replacement.

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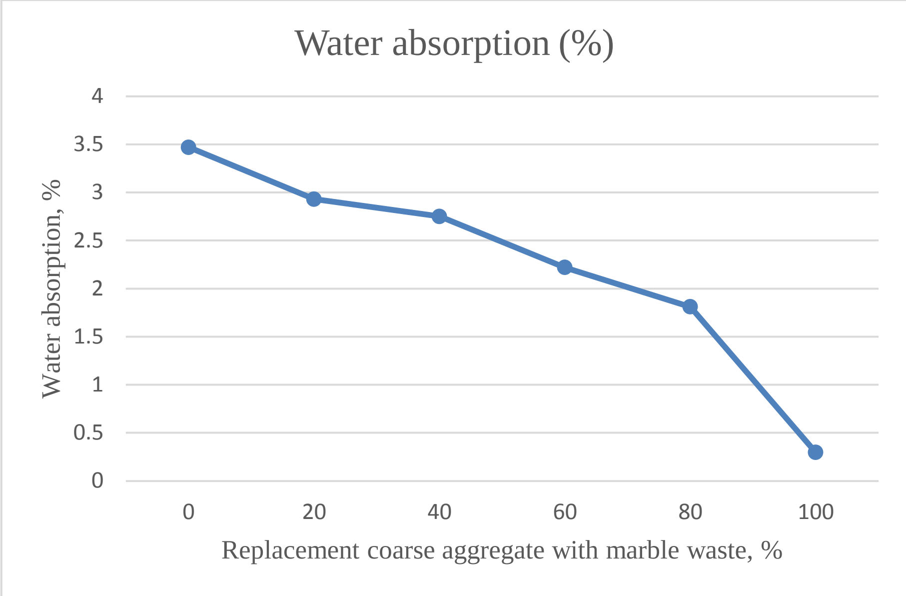

Fig 6.5 Water absorption Values Vs % replacement coarse aggregate with marble waste

7. CONCLUSIONS AND FUTURE SCOPE

7.1 Conclusions

The main objective of this investigation is to study the performance of the Pervious concrete made with reduction of natural aggregate with BMSWA at 0, 20, 40, 60, 80 and 100%. The performance is studied with respect to the mechanical properties namely compression and durability properties namely Permeability using constant head method, Temperature and water absorption. The following conclusions were drawn based on the experimental investigations and statistical analysis on mechanical and durability properties of pervious concrete.

- The workability of the Pervious concrete is increased for replacement of natural aggregate with BMSWA may be due to smooth surface of the aggregate.
- The compressive strengths were decreased with increase of percentage replacement of BMSWA in the concrete mix. This decrease in strength may be due to less aggregate crushing strength as well as less aggregate impact value. The maximum compressive strength was gain for 40% replacement natural coarse aggregate with BMSWA.
- The permeability increases as the natural aggregate is replaced with BMSWA is increases, the pore space in the specimen increases, reducing the flow time and therefore increasing permeability.
- The compressive strengths are decreasing by increasing the temperature and as the percentage reduction in natural aggregate increases, the strengths are also decreasing.
- The Water absorption of concrete are decreasing by increasing the natural aggregate is replaced with BMSWA. The water absorption value for 100% replacement of natural aggregate with BMSWA was approximately zero.

7.2 Recommendations for Future Work

The Present work represents basic properties of pervious concrete by replacing the natural aggregate with BMSWA. The following areas are recommended for future research based on current research findings and literature reviews.

- Experiments with different additives can be done to study the mechanical properties without affecting the draining ability.
- The influence of chemical admixtures and fibres in the mixes can be studied.
- Long-term studies can be conducted to understand the characteristics of the concrete over a period of time.

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