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Behaviour of pervious concrete under Abrasion

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ABSTRACT

Pervious concrete has been increasingly used in concrete pavements during recent years, because of its environmental benefits. In addition to strength and permeability, abrasion resistance is an important durability property of pervious concrete. In this project work, abrasion resistance test of pervious concrete was conducted using rotating-cutter method according to American Society of Testing and Materials (ASTM C944). The test set up was fabricated with studded wheels which are used to increase wheel load on the specimen in order to exhibit sensitivity and sufficient repeatability. In this test, different sizes of coarse aggregates were used such as passing through 9.5 mm and retained on 4.75 mm sieve, passing through 12.5 mm and retained on 9.5 mm sieve and passing through 16 mm and retained on 12.5 mm sieve. Totally are nine number of slab specimens of size of 30 cm length, 30 cm breath, 5 cm depth were casted with different aggregate sizes which were casted to conduct abrasion resistance of pervious concrete.

Key words: Pervious concrete, abrasion, ASTM C944, rotating-cutter.

I Introduction

Concrete is a construction material composed of cement, commonly Portland cement as well as other cementations materials such as fly ash and slag cement, coarse aggregate, fine aggregate such as sand, water, and chemical admixtures. Porous concrete is concrete, which is designed to have many voids to trap water and allow it to penetrate through the concrete to the ground below. In this concrete fine aggregate is not be used in the mixture. Hence it has more voids than conventional concrete. The materials used in pervious concrete are coarse aggregates, cements and water as shown in fig 1.1. There are a number of alternate names for porous concrete including permeable concrete, porous concrete, and pervious concrete. Porous concrete is a form of concrete, which is permeable. Porous concrete is made by mixing coarse aggregate material with mortar, creating lots of voids in the cast concrete. When water lands on the concrete, it flows through the voids and to reach the ground below.

Pervious concrete consists of a mixture of coarse aggregate, Portland cement and water that allow for rapid infiltration of water and overlays a stone aggregate reservoir. It is a unique and effective mean to address important environmental issues and support sustainable growth. Porous concrete has been developing as an environmental friendly material in Japan since1980s. Since then it has been widely used in various application. The water -permeating, water-draining water-retaining performances of this porous concrete have been utilized in road pavement, sidewalks, parks and building extension, as well as for plant bedding and permeable gutters.

Porous concrete pavement can potentially infiltrate storm water at source, which will allow the oils from cars and trucks to biodegrade safely, improve driving safety, reduce traffic noise and also reduce urban temperatures. There had been numerous studies throughout others country on porous concrete and their application like road pavement, fishing bank and for sidewalks. Many researchers were

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conducted to design materials based on requirements within the aspect of economical, availability, recyclability, energy use, cost and environmental considerations. Therefore before the new material can be widely used as a building material, the properties of the material and methods to improve the material are to be studied carefully. The good thing about porous concrete is it very suitable for people who are concerned about the environment because porous concrete traps water, rather than allowing it to drain uselessly into the ocean.

Porous concrete can help route storm runoff and rain directly into the soil where it can nourish gardens and flow down into the water table. It also can be made with recycled materials including recycled concrete rubble and recycling aggregates. This flexibility and potential for recycling makes it an ecologically friendly and aesthetically pleasing building material.

Fig 1.1 Pervious concrete

1.1 Water Draining Performance

The water-permeating, water-draining and water-retaining performances of porous concrete have been utilized as road pavements, sidewalks, park and building exteriors, as well as for plant bedding and gutters as shown in fig 1.2. Particularly for road pavement, the porous concrete has been used since 1985, which are of permeable full-depth type. Water-draining composite types have been used for middle and heavy traffic roads. For tollgates on heavy traffic expressways, the porous concrete give advantages by having high rutting resistance, abrasion resistance and oil resistance as well as drainage function.

1.2 Water Purifying Performance

Pollution of urban lakes, rivers and wetlands and enclosed coastal waters near large cities has been serious in recent years due to runoffs containing wastewater from homes and plants, posing problems of environmental disruption. Water purification by porous concrete is a sort of inter- gravel contact oxidation, in which the biota formed on the internal surfaces of continuous voids provides an additional bio-purification function. It is therefore anticipate that the porous concrete applied to revetment and coastal areas would contribute to water purification by the biota consisting of various organisms including microbes.

Fig 1.2 Water permeating capacity of pervious concrete

1.3 Applications of Pervious concrete

It may reduce or eliminate the need for subterranean storm sewer drains. Pervious concrete not only eliminates much of the runoff from pavements, but may also catch the runoff from roofs and return it to the aquifer. Trees are great tools in fighting the greenhouse effect. Unlike impervious pavements, Pervious Concrete lets water and oxygen enter the soil below. This allows tree roots to perform their tasks efficiently. Those tasks include cooling the surrounding air by the evaporation of the captured

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ground water. This helps reduce air conditioning costs.

Pervious Concrete because of its solar standard Reflectivity Index, it absorbs much less heat than asphalt and with its water retention it reduces the load on air conditioning. Finally for the developer or engineer, it makes possible maximum land use for parking lots, roads, and structures. With certified engineering it can reduce the size of retention areas. Storm drains may be eliminated some curbing also. For watershed and estuary areas it is an environmental tool to keep these waters clean and cooler. These are ecological as well as dollars and cents issues. Trees thrive as Pervious Concrete allows rain water to reach their roots. As the water is drawn up to the leaves or blades of grass the miracle of transpiration converts it back to vapor which helps create more rain while cooling surrounding air.

There are many advantages of using porous concrete which have caused it to become a popular option for things like sidewalks, driveways, and parking lots. It is especially popular with ecologically sound construction companies, since it helps to manage water runoff in a sustainable way. From the point of view of a contractor, porous concrete has some distinct water management advantages. Instead of allowing water to pool, porous concrete sucks up water and drain it below. It also makes it safer for people driving, walking, and biking on the concrete, since they do not have pools of water. While extremely wet conditions will eventually overwhelm the absorption capacity of porous concrete. The ability of porous concrete to filter deleterious materials dramatically can reduces the effects of damaging chemicals, such as gas and oils, to the environment. This can be done by trapped the dangerous chemical in the concrete and biological activity will breaks these materials down into their natural harmless form. Also, porous concrete can reduces the amount of local erosion being caused by runoff from conventional concrete structures.

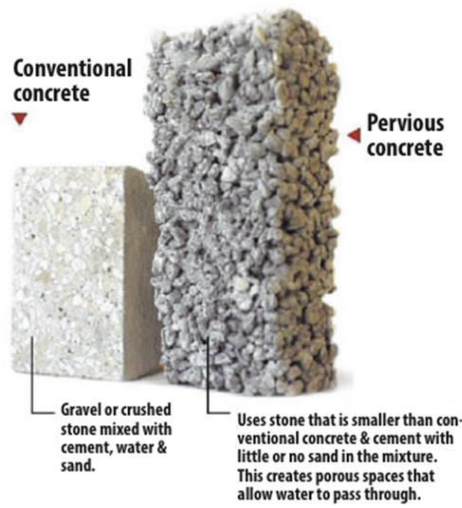

Fig 1.3 Comparison of Conventional concrete & pervious concrete

Fig 1.4 Parking area of pervious concrete

1.4 Advantages of Pervious concrete

- ✓ Water budget retention and pollution removal
- ✓ Residential roads, alleys and driveways
- ✓ Low-volume pavements
- ✓ Sidewalks and pathways
- ✓ Parking areas
- ✓ Tennis courts
- ✓ Sub base for conventional concrete pavements

- ✓ Well linings
- ✓ Swimming pool decks
- ✓ Noise barriers
- ✓ Less need for Storm Sewer
- ✓ Green Building alternative suitable for many application
- ✓ Natural run-off allows rainwater to drain directly to sub-base
- ✓ Reduced construction requirements for drainage structures
- ✓ Recharge to Local Aquifer

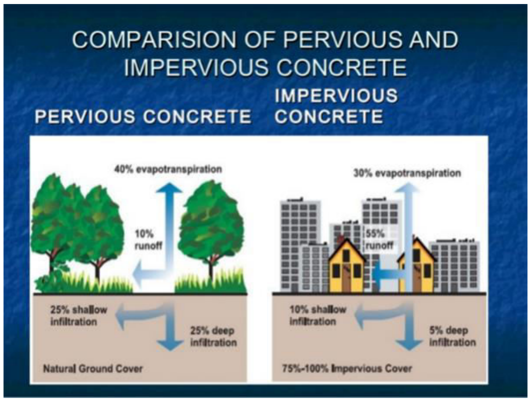

Fig 1.5 Comparison of pervious and impervious concrete

1.6 Research Significance

As our planet is faced with an environmentally uncertain future, a focus on green, sustainable development has become a necessity. Innovative concepts to our present infrastructure are currently being implemented, where pervious concrete is one of the important among them. Operating on a "rain and drain" philosophy, pervious concrete is able to collect the first-flush rainfall and allows it to drain immediately into the ground to recharge the water table.

The primary aim of the study was to test abrasion resistance of pervious concrete with good workability. To achieve this goal the appropriate amount of mix consist of different aggregate to cement ratio 4:1 and the various aggregate sizes of 9.5mm-4.75mm, 12.5mm-9.5mm, 16mm-12.5mm were used.

MATERIAL PROPERTIES

2.1 General

The various strength properties of pervious concrete are dependent on cementitious content, water-cementitious material ratio (w/c), compaction level and aggregate gradations and quality.

2.2 Materials

2.2.1 Cement

Ordinary Portland (OPC) is far the most important type of cement. It was used in casting the specimens. It is a fine powder produced by grinding Portland cement clinker and small amount of gypsum is added to increase the setting time of cement. Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates (3 $CaO{\cdot}SiO_2$ and 2 $CaO{\cdot}SiO_2$), the remainder consisting of aluminum and iron-containing clinker phases and other compounds. The ratio of CaO to SiO shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0% by mass. The OPC was classified into three grades, namely 33 grade cement, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. The Fineness of cement, Specific Gravity, Initial setting time and Consistency of the cement were tested.

2.2.2 Coarse aggregate

All natural aggregate materials originate from bed rocks. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic. These classifications are based on the mode of formation of rocks. Aggregates are divided into two categories from the considerations of size (i) Coarse aggregate and (ii) Fine aggregate. Hard granite broken stones of three different sizes such as 4.75mm – 9.5mm, 9.5mm – 12.5mm, 12.5mm –16mm were used as coarse aggregate. The Specific Gravity, Sieve analysis and Bulk density of the coarse aggregate were tested.

2.3 PROPERTIES OF MATERIALS

2.3.1 Properties of cement

2.3.1.1 Fineness of Cement

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The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offersa greater surface area for hydration and hence faster the development of strength. Fineness of cement is tested in two ways:

(a) By sieving
(b) By determination of specific surface by air-permeability apparatus

2.3.1.2 Sieve Test

Weigh correctly 100 grams of cement and take it on a standard IS Sieve No. 9 (90 microns). Break down the air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes. Mechanical sieving devices may also be used. Weigh the residue left on the sieve. This weight shall not exceed 10% for ordinary cement.

2.3.1.3 Specific Gravity of Cement

The density bottle was used to determine the specific gravity of cement. The bottle was cleaned and dried. The weight of empty bottle with brass cap and washer W_1 was taken. Then bottle was filled by 50 to 100g of dry cement and weighed as W_2.The bottle was filled with kerosene and stirred thoroughly for removing the entrapped air which was weighed as W_3.It was emptied, cleaned well, filled with kerosene and weighed as W_4

$$\text{Specific gravity (G)} = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

Where,

W_1 = Weight of empty density bottle with brass cap and washer in kg.

W_2 = Mass of the density bottle & cement in kg.

W_3 = Mass of the density bottle, cement & kerosene in kg.

W_4 = Mass of the density bottle filled with kerosene in kg.

2.3.1.4 Standard Consistency of Cement

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. The objective of conducting this test is to find out the amount of water to be added to the cement to get a paste of normal consistency. 500 grams of cement wastaken and made into a paste with a weighed quantity of water (% by weight of cement) for the first trial. The paste was prepared in a standard manner and filled into the Vicat mould plunger, 10mm diameter, 50mm long and was attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight. The depth of penetration of the plunger was noted. Similarly trials were conducted with higher water cement ratios till such time the plunger penetrates for a depth of 33-35mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35mm from the top is known as the percentage of water required to produce a cement paste of standard consistency.


Fig. Vicat apparatus & Sieve analysis

2.3.1.5 Initial setting time of cement

The initial setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. The needle of the Vicat apparatus was lowed gently and brought in contact with the surface of the test block and quickly released. It was allowed to penetrate into the test block. In the beginning, the needle completely pierced through the test block. But after sometime when the paste starts losing its plasticity, the needle penetrated only to a depth of 33-35mm from the top. The period elapsing between the time when water is added to the cement and thetime at which the needle penetrates the test block to a depth equal to 33-35mm from the top was taken as the initial setting time.

2.3.2 PROPERTI OF COARSE AGGREGATES

2.3.2.1 Sieve Analysis

The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 mm etc. The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm are termed as coarse aggregate and those fraction from 4.75 mm to 150 micron are termed as fine aggregate. Grading pattern of a sample of Coarse aggregate or fine aggregate. It is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve inquestion and finer than the sieve above. Sieving can be done either manually or mechanically.

2.3.2.2 Specific Gravity

A Pycnometer was used to find out the specific gravity of coarse aggregate. The empty dry Pycnometer was weighed and taken as W_1. Then the Pycnometer is filled with 2/3 of coarse aggregate and it was weighed as W_2. Then the Pycnometer was filled with part of coarse aggregate and water and it weighed as W_3. The Pycnometer was filled up to the top of the bottle with water and weighed it as W_4.

$$\text{Specific gravity (G)} = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

W_1 = Mass of empty Pycnometer in kg.

W_2 = Mass of Pycnometer& coarse aggregates in kg.

W_3 = Mass of the Pycnometer, coarse aggregate & water in kg.

W_4 = Mass of the Pycnometer filled with water in kg.

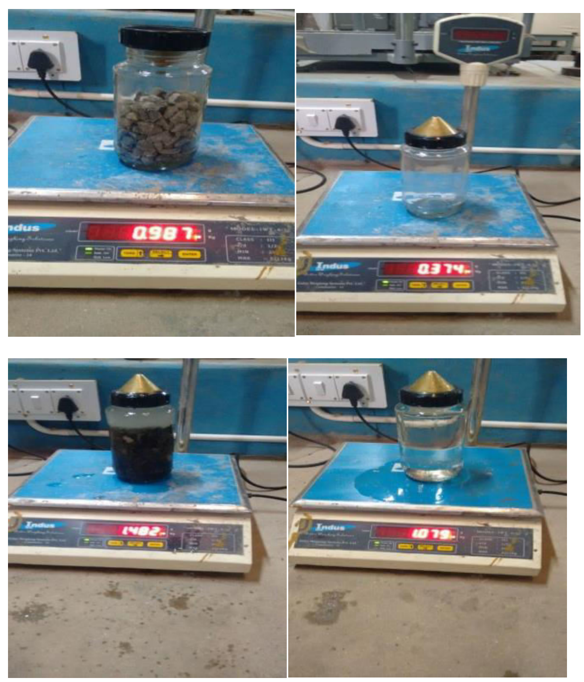

Fig. Specific gravity test

2.3.2.3 Bulk density

The bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of the aggregate. The bulk density of aggregate is

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measured by filling a container of known volume in a standard manner and weighing it. It is expressed in kg/m^3. A cylinder with measurement of nominal diameter 170mm and height 205 mm was used. The cylindrical measure was filled about 1/3 each time with thoroughly mixed aggregate and tampered with 25strokes. The measure was carefully struck off level using tamping rod as straight edge. The net weight of aggregate in the measure was determined. Bulk density was calculated as follows.

Bulk density = Net weight of coarse aggregate in kg/Volume

2.4 MIX DESIGN (based on ACI 522R)

Mix design is the process of selecting suitable ingredients of concrete and determining their relative proportion with the object of producing concrete of certain minimum strength and durability as economically as possible. The following data are required for mix proportioning of a particular grade of concrete.

2.4.1 TRIAL MIX RATIO

The given materials, the four variable factors to be considered in connection with specifying a concrete mix are: Water-Cement ratio, Cement Content or cement-aggregate ratio and Gradation of the aggregates.

The slab specimens were casted with aggregate size range 9.5mm-4.75mm for aggregate cement ratio 4:1. Sample calculation for Aggregate/cement ratio 4:1 for aggregate size 9.5mm-4.75mm.

Bulk density of the aggregate = 1644.30 kg/m^3

Bulk density of cement = 1440 kg/m^3

Quantity of materials:

Water cement ratio as 0.33

Total ratio= 1 + 4 +0.33 = 5.33

$$\text{Cement quantity} = \frac{1}{\text{total ratio}} \times \text{bulk density of cement}$$

$$= \frac{1}{5.33}$$

=270.16 kg/m^3

$$\text{Aggregate quantity} = \frac{1}{\text{total ratio}} \times 4 \times \text{bulk density of aggregates}$$

$$= \frac{1}{5.33} \times 4 \times 1644.30$$

=1233.96 kg/m^3

Water cement ratio kept constant as 0.33

A1S1- A1 represents first specimen of aggregate size S1 9.5mm-4.75mm.

B1S2- B1 represents first specimen of aggregate size S2 12.5mm-9.5mm.

C1S3- C1 represent first specimen of aggregate size S3 16mm-12.5mm.

2.4.2 MIX PROPORTION

Aggregate Size	Aggregate to cement ratio	Mix ID	Cement (Kg/m^3)	Coarse aggregate (kg/m^3)	w/c ratio	Water (ltr/m^3)
9.5 mm – 4.75 mm	4 : 1	A1S1 A2S1 A3S1	270.16	1233.96	0.33	89.15
12.5 mm – 9.5 mm	4 : 1	B1S2 B2S2 B3S2	270.16	1219.46	0.33	89.15
16 mm – 12.5 mm	4 : 1	C1S3 C2S3 C3S3	270.16	1214.45	0.33	89.15

2.5 EXPERIMENTAL INVESTIGATION

2.5.1 Introduction

Production of good quality concrete requires meticulous care exercised at every stage of manufacture of concrete. If meticulous care is not exercised and good rules are not followed, the resultant concrete is going to be of bad quality. With the same material if intense care to be taken and control at every stage then it will be a good concrete. Three different sizes of aggregates are used for the test program. Gradation 1 consists of aggregates size of passing through sieve 9.5mm and retained on 4.75mm, gradation 2 consists of aggregates size of passing through sieve 12.5mm and retained on 9.5mm and gradation 3 consists of aggregates of size of passing through sieve 16mm and retained on 12.5mm.

2.5.2TEST RESULTS OF MATERIAL PROPORTIES

2.5.2.1 Coarseaggregate

Bulk density results of coarse aggregate

Sl. No.	Aggregate size	Bulk Density (kg/m^3)	Reference
1	9.5mm-4.75mm	1644.30	IS 383-1970
2	12.5mm-9.5mm	1624.94	
3	16mm-12.5mm	1618.25	

Specific gravity results of coarse aggregate

Sl. No.	Aggregate size	Specific gravity	Reference
1	9.5mm-4.75mm	2.96	IS 383-1970
2	12.5mm-9.5mm	2.92	
3	16mm-12.5mm	2.61	

3.1 Casting of test specimens

3.1.1 Preparation of the mould

The Abrasion resistance of the pervious concrete was determined using the slab specimen of size 300mmx300mmx50mm as shown in fig 4.1. The Moulds are prepared by using Ply wood sheets to the standard required dimensions.

Fig 3.1 Ply wood mould

3.1.2 Demoulding

The specimens are demoulded after 24 hours from the process of moulding. If the concrete has not achieved sufficient strength to enable demoulding the specimens, then the process must be delayed for another 24 hours care should be taken not to damage the specimen during the process because, if any damage is caused, the strength of the concrete may get reduced. After demoulding, specimen was marked with a legible identification, on the faces by using paint. Various trials conducted at the laboratory, it was found that the optimized potential of the mix can be obtained by exposing the specimens to thermal regime. The curing cycle followed for the specimens in the study are as follows. The specimens after demoulding are kept in water for 28 days in order to achieve strength during were hydration process.

Casted specimen details

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Fig 3.2 Slab specimens

3.2 Tests on fresh concrete

Fresh concrete or plastic concrete is a freely mixed material which can be moulded into any shape. The relative quantities of cement, aggregates and water mixed together, to control the properties of cement in wet and the hardened state.

3.2.1 Slump test

Slump test is the most commonly used method of measuring workability of concrete. The apparatus for testing of slump consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as follows

Bottom Diameter : 20 cm

Top Diameter : 10 cm

Height : 30 cm

The mould was filled with concrete in four layers. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section. The mould was removed from the concrete by raising it slowly and carefully in a vertical direction. The difference in level between the height of the mould and height of subsided concrete is noted and it is taken as slump value.

3.3 TESTS ON HARDENDED CONCRETE

3.3.1 Abrasion resistance of pervious concrete

Concrete durability is the ability to resist weathering action, chemical attack, and abrasion while maintaining desired engineering properties for the expected service life of the structure. This section presents the standardization of abrasion test or test method for abrasion resistance of concrete surface subjected to the various uses. The test methods that are employed world over to evaluate the abrasion resistance of concrete have attempted with various success to reproduce the typical forces detrimental to concrete surfaces. Currently, there are four standard ASTM test methods at International level and one standard Indian Code method for evaluating the resistance of concrete subjected to various types of abrasive actions. ASTM C 418 presents a test method to evaluate the abrasion resistance of concrete by sand blasting technique. ASTM C 944 test method measures the abrasion resistance of concrete by rotating-cutter machine. ASTM C 779 method evaluates the abrasion resistance of horizontal concrete surface by either revolving disc machine or by ball bearing machine and ASTM C 1138 method evaluates the resistance of concrete surfaces subjected to abrasive action of water borne particles on hydraulic structures.

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3.3.2Rotating-cutter method (ASTM C944/C944M-12)

This test method gives an indication of the relativewearresistance pervious concrete based on testing of fabricated specimens. A rotating cutter shallbeusedinwhich22 numbers of 37.5mm[1.5in.]diameter dressing wheels and 24 numbers of 25.4 to 31.75 mm [1 to1.25in.]diameterwashersaremounted.Thewashersasr eceivedshall be stacked and locked on a bolt for the purposeofreducing their diameter to the specified range to avoidrestricting abrasion of the concrete by the washers. Cutterassembly,including washers, shall be locked onto horizontal rodssuchthat individual dressing wheels are free to turnindependently as shown fig 4.5.

The overall diameter of the cutter or the diameter ofthecircular area abraded is 82.5 mm [3 1⁄4 in.].Care shall betakento achieve constant contact between the rotating cutter andtheentiretestsurfaceofthesample.Thiscanbebettera ccom-plished if the cutters have a swivel connection allowingsomeverticalmovement.Ifthedressingwheelsh aveoneroundededge, they shall be mounted with the rounded edge toward theverticalshaft. Theindividualgrindingwheeldressersonthehorizontal shaft of the cutter shall be repositioned wheneverachange in the diameter of the outer cutters becomesapparent.

This is accomplished by reversing each set of dressingwheelsto bring the smaller diameter cutters toward the vertical shaft. Themachine consists essentially of a frame that supports thedrivemotor, stepped pulley, and spindle. A clamping device toholdthe specimen is built into the base. In making a test, the rotating cutter is held in araisedposition by means of the rod provided, the specimenclampedsecurely in position, and motor started. The rotating cutteristhenloweredintocontactwiththespecimenforas pecifiedtime, after which the cutter is raised. Asetofdressingwheelsshallbereplacedperiodically,pre ferably after each 90 min of use. The washers maybeground or replaced to maintain the proper diameter.

The test is performed for two minutes and after that time the loss of weight for each sample is reported. The setup was properly built in order to obtain a rotation speed of 100 rpm, in accordance with ASTM C944/C944M-12. Abrasion test simulates wear on concrete pavement surface.

Fig 4.5 Rotating Cutter

Fig 3.3 Abrasion resistance test setup

4 RESULTS AND DISCUSSION

4.1 Tests on fresh concrete

Slump test results

Sl. No.	Aggregate size	Aggregate to cement ratio	Mix ID	W/c ratio	Slump Value (mm)

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1	9.5mm – 4.75mm	4:1	A1S1	0.33	30
			A2S1	0.33	35
			A3S1	0.33	40
2	12.5mm – 9.5mm	4:1	B1S2	0.33	20
			B2S2	0.33	30
			B3S2	0.33	35
3	16mm – 12.5mm	4:1	C1S3	0.33	10
			C2S3	0.33	15
			C3S3	0.33	10

4.2 TESTS ON HARDENDED CONCRETE

4.2.1Calculation:

Abrasion Loss (%)

$$\text{Abrasion Loss (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 – represents initial weight of specimen (kg).

W_2 – represents final weight of specimen (kg).

Mass Loss rate (%)

$$\text{Mass loss rate } (\Delta m_i) = \frac{m_0 - m_i}{m_0} \times \frac{300 \times 300}{60 \times 82.7} \times 100$$

Where,

Δm_i – represents mass loss rate (%)

m_0 – represents original mass of concrete (kg).

m_i – represents final mass of concrete (kg).

Abrasion Speed index

$$\text{Abrasion speed index } (k_i) = \frac{\Delta m_i - \Delta m_{i-1}}{n} \times 1000$$

Where,

k_i –represents abrasion speed index

Δm_i –represents i^{th} measured mass of concrete

Δm_{i-1} –represents previous measured mass of concrete

n –represents the abrasion frequency between two neighboring measures

Coefficient of Variation

$$\text{Coefficient of Variation} = \frac{\sigma}{\mu} \times 100$$

$$\sigma = \sqrt{\frac{\sum(x - \overline{x})^2}{n}}$$

Where,

σ – represents standard deviation

4.2 ABRASION RESISTANCE TEST RESULTS

Abrasion resistance of 9.5mm-4.75mm aggregates (A1S1) Initial mass: 7.812 kg

Sl. No.	At end each cycles change in Depth (cm)	At end each cycles change in mass (kg)	Abrasion Loss (%)	Mass loss Rate (%)	Abrasion Speed Index
1	8.6	7.792	0.26	4.64	23.21
2	8.4	7.768	0.56	10.21	27.85
3	8.3	7.752	0.77	13.92	18.57
4	8.1	7.730	1.05	19.03	25.53
5	8.0	7.700	1.43	25.99	34.81
6	7.8	7.686	1.61	29.24	16.25
7	7.8	7.662	1.92	34.81	27.85
8	7.7	7.644	2.15	38.99	26.89
9	7.7	7.632	2.30	41.77	13.92
10	7.6	7.624	2.14	43.63	9.28

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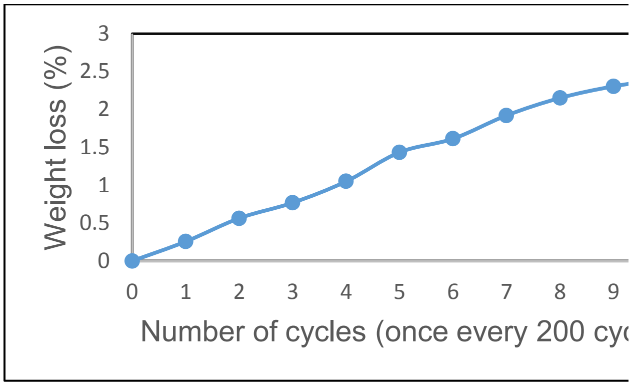
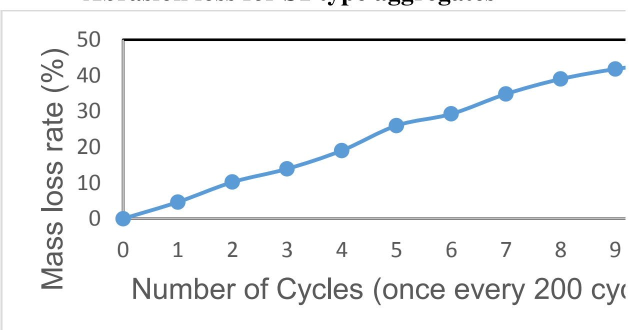
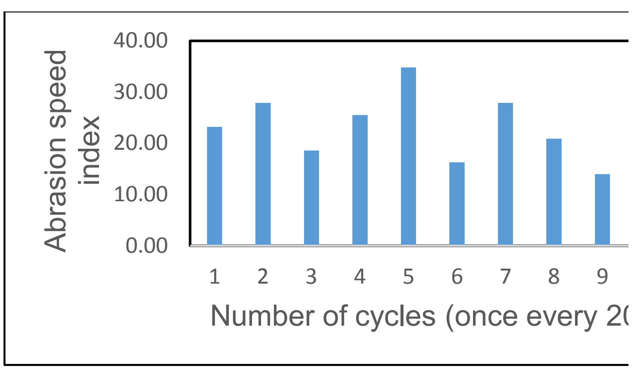


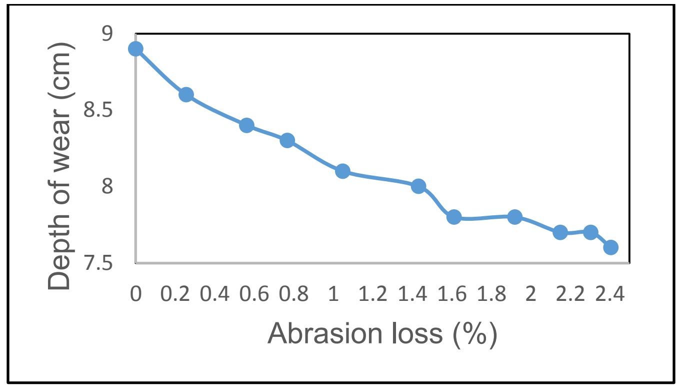
Abrasion loss for S1 type aggregates



Mass loss rate for S1 type aggregates



Abrasion Speed Index for S1 type aggregates



Abrasion losses Vs. Depth of wear

From the above obtained results & graphs, it is inferred that the maximum weight loss is 2.4 %, and the mass loss rate is 43 % at the end of 10 cycles of each 200 rpm for aggregate size of 9.5mm-4.75mm. Whereas the abrasion speed index is non-uniformly varies for each cycles. The maximum variation in depth is 12 % for aggregate size of 9.5mm-4.75mm after 10 cycles of abrasion test.

Abrasion resistance of 12.5mm-9.5mm aggregates

Sl. No.	At end each cycles change in Depth (cm)	At end each cycles change in mass (kg)	Abrasion Loss (%)	Mass loss Rate (%)	Abrasion Speed Index
1	8.5	7.150	0.86	15.59	77.92
2	8.4	7.142	0.97	17.60	10.06
3	8.4	7.142	0.97	17.60	0.00
4	8.4	7.138	1.03	18.60	5.03
5	8.3	7.136	1.05	19.11	2.51
6	8.3	7.134	1.08	19.61	2.51
7	8.3	7.132	1.11	20.11	2.51
8	8.2	7.130	1.14	20.61	2.51
9	8.2	7.128	1.16	21.12	2.51
10	8.0	7.122	1.25	22.62	7.54

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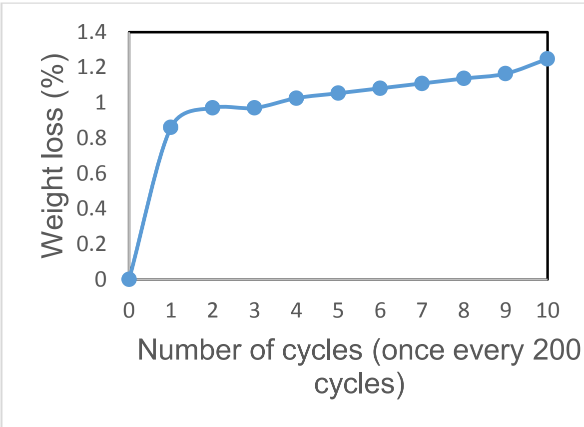
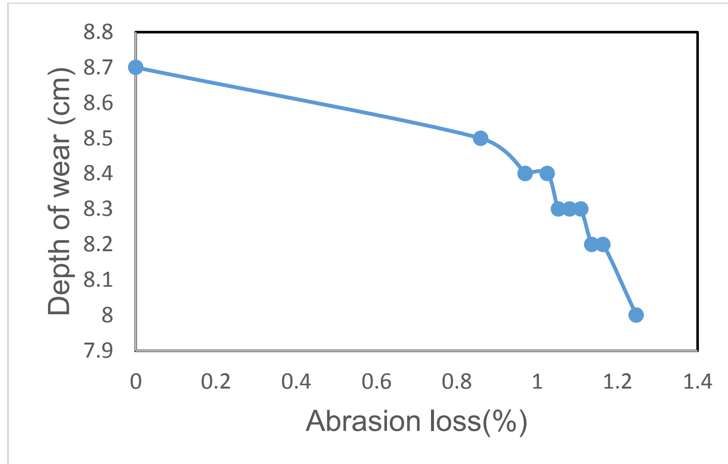
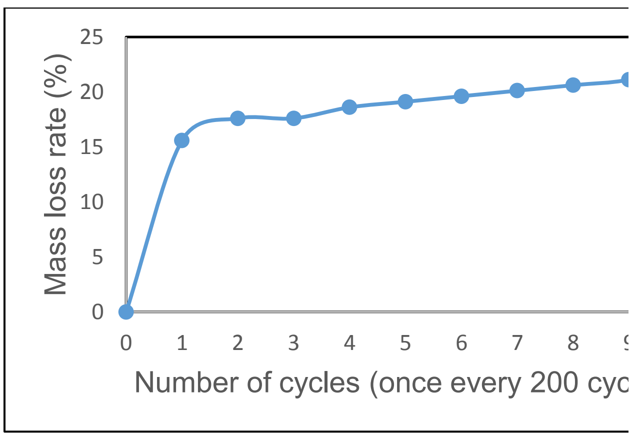


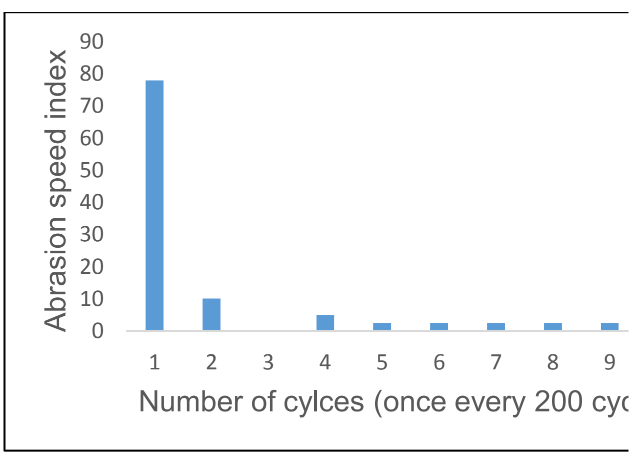
Abrasion Loss for S2 type aggregates



Abrasion losses Vs. Depth of wear



Mass loss rate for S2 type aggregates



Abrasion Speed Index for S2 type aggregates

From the above obtained results &graphs, for aggregate size of 12.5mm-9.5mm, the maximum weight loss is 1.25 %, and the mass loss rate is 22.62% at the end of 10 cycles of each 200 rpm for aggregate size of 12.5mm-9.5mm. Whereas the abrasion speed index is uniformly varies for all other cycles except first cycle. . The maximum variation in depth is 6 % for aggregate size of 12.5mm-9.5mm after 10 cycles of abrasion test.

Abrasion resistance of 16mm-12.5mm aggregates

Sl. No.	**At end each cycles change in Depth (cm)**	**At end each cycles change in mass (kg)**	**Abrasion Loss (%)**	**Mass loss Rate (%)**	**Abrasion Speed Index**
1	8.5	7.684	0.13	2.36	11.80
2	8.4	7.674	0.18	3.30	4.72
3	8.3	7.670	0.23	4.25	4.72
4	8.3	7.66	0.34	6.13	9.44
5	8.2	7.658	0.47	8.49	11.80
6	8.1	7.648	0.55	9.91	7.08
7	8.0	7.642	0.65	11.80	9.44
8	8.0	7.634	0.75	13.68	9.44

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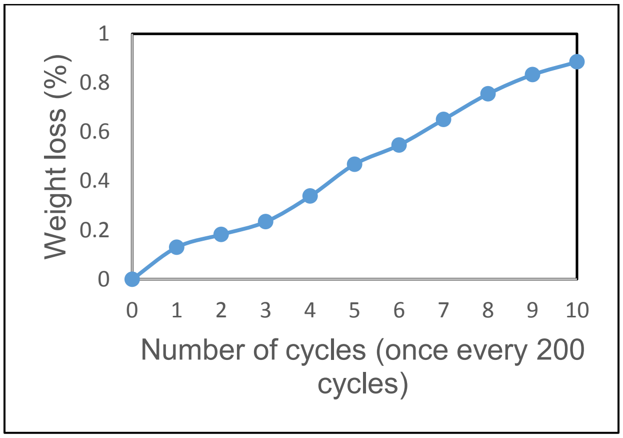
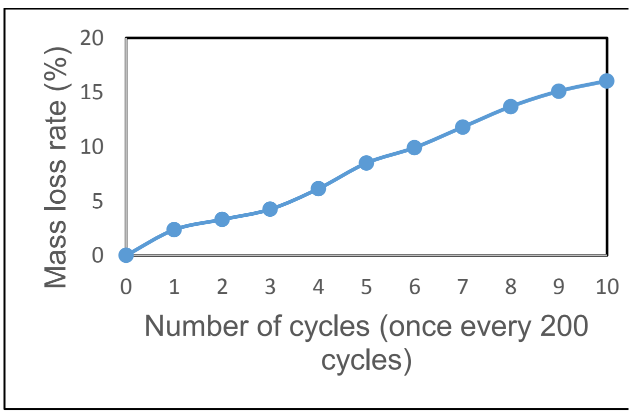
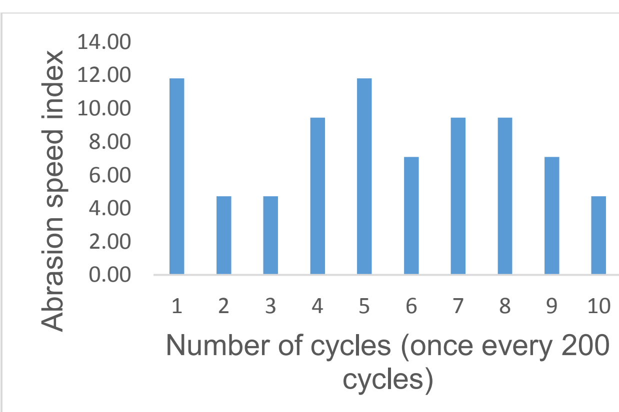
9	7.9	7.626	0.83	15.10	7.08
10	7.9	7.620	0.88	16.04	4.72



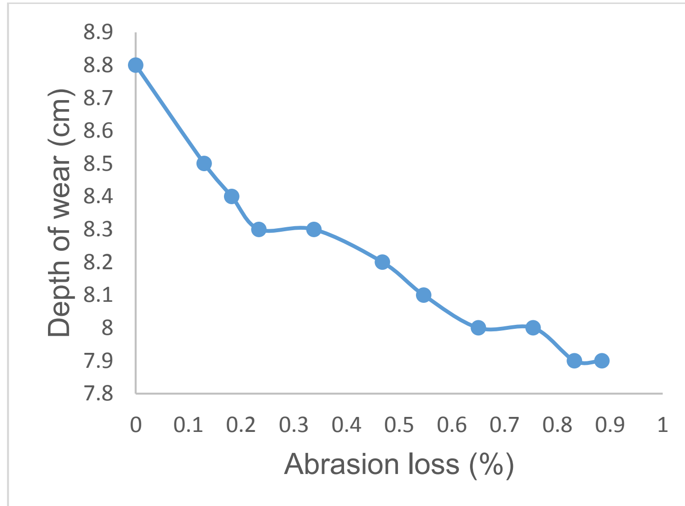
Abrasion Loss for S3 type aggregates



Mass loss rate for S3 type aggregates

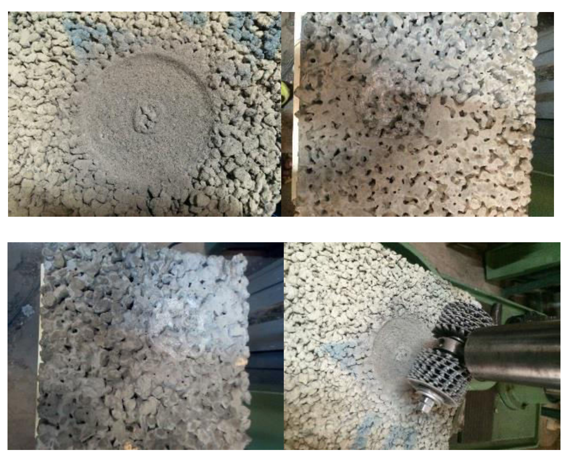


Abrasion Speed Index for S3 type aggregates



Abrasion losses Vs. Depth of wear

From the above obtained results & graphs, it is inferred that the maximum weight loss is 0.88 %, and the mass loss rate is 16 % at the end of 10 cycles of each 200 rpm for aggregate size of 16mm-12.5mm. Whereas the abrasion speed index is non-uniformly varies for each number of cycles. The maximum variation in depth is 7 % for aggregate size of 16mm-12.5mm after 10 cycles of abrasion test.



Abrasion tested specimens

Conclusions

In this project work the fresh and hardened concrete properties of pervious concrete were investigated. The abrasion resistance test set up for pervious concrete was fabricated and test was conducted on pervious concrete containing different mix ratio and aggregate sizes. The following conclusions are drawn:

- ✓ The maximum abrasion loss is 2.41% for aggregate size of 9.5mm-4.75mm, 1.25% for aggregate size of 12.5mm-9.5mm, and 0.88 % for aggregate size 16mm-12.5mm at the end of 10 cycles of each 200 rpm.
- ✓ The maximum mass loss rate is 43.63% for aggregate size of 9.5mm-4.75mm, 22.62% for aggregate size of 12.5mm-9.5mm, and 16.04% aggregate size of 16mm-12.5mm at the end of 10 cycles of each 200 rpm.
- ✓ The maximum abrasion speed index 34.81 for aggregate size of 9.5mm-4.75mm, 10.05 for aggregate size of 12.5mm-9.5mm, and 11.80 for aggregate size of 16mm-12.5mm at the end of 10 cycles of each 200 rpm.
- ✓ The maximum variation in depth is 12% for 9.5mm-4.75mm, 6% for 12.5mm-9.5mm and 7% for 16mm-12.5mm after 10 cycles of abrasion test. The smaller size aggregate shows greater changes in variation of depth at the end of each cycles.
- ✓ The overall coefficient variation is 30% for all type of aggregates.

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