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No Fines Concrete (As Road Pavement)

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***Abstract*-In today's world pavements play an important role in the development of the Country Permeable paving is a range of sustainable materials and techniques for permeable pavements with a base and sub base that allow the movement of storm water through the surface. In addition to reducing runoff, this effectively traps suspended solids and filters pollutants from the water. Examples include roads, paths, lawns and lots that are subject to light vehicular traffic, such as car/parking lots, cycle-paths, service or emergency access lanes, road and airport shoulders, and residential sidewalks and driveways. Although some porous paving materials appear nearly indistinguishable from nonporous materials, their environmental effects are qualitatively different. Whether pervious concrete, porous asphalt, paving stones or concrete or plastic-based pavers, all these pervious materials allow storm water to percolate and infiltrate the surface areas, traditionally impervious to the soil below. The goal is to control storm water at the source, reduce runoff and improve water quality by filtering pollutants in the substrata layers. The analysis was undertaken by conducting a number of tests on no-fines concrete samples. The tests included both fresh and hardened concrete tests to obtain a complete picture of its properties during the construction and working phase. The tests conducted to determine the fresh concrete properties were the slump, VEBE and compacting factor tests. These were complimented by hardened concrete tests including the following: compressive strength, indirect tensile strength and skid resistance. It was found that no-fines concrete pavements possess some positive features like increased skid resistance and high permeability but lacks the high strength required for highly trafficked areas. No-fines concrete has proven to have properties suitable for use in low volume traffic areas. The properties found may change depending on the aggregate particle chosen, however this aspect requires further investigation. Nonetheless, if no-fines concrete pavements can be implemented, it will have numerous positive effects on the environment.**

***Index Terms*-slump, VEBE, compacting factor tests no-fine concrete, modulus of rupture and elasticity, skid resistance test.**

METHODOLOGY & PRELIMINARY MIX DESIGN

No-fines concrete : No-Fines concrete is a mixture of cement, water and a single sized coarse aggregate combined to produce a porous structural material. It has a high volume of voids, which is the factor responsible for the lower strength and its lightweight nature. No-fines concrete has many different names including zero-fines concrete, pervious concrete.

The following sections of this research describes in detail the testing that follows and the methodology used to produce the results to be analysed. A discussion of the preliminary mix design that was conducted during the early stages of this research follows. To provide uniform results and conformity with the concrete testing, an aggregate sample was chosen to be used for the remainder of the project. 20 mm crushed basalt was chosen as it appeared to be the most spherical aggregate available.

Test methodology: This research is focused predominantly on the use of no-fines concrete as a road pavement material. The test procedure included the initial steps of deciding on the tests to be conducted and choosing a number of aggregate-cement ratios for the no-fines concrete. This was followed by conducting the preliminary mix design and compressive strength tests on these samples to determine the mix that performed most successfully, with the mix ratio known, the remaining testing began. This included determining the properties of the aggregate being used with a sieve analysis and a flakiness index test. After mixing, the workability testing was conducted on the wet concrete before the test specimens were constructed. The no-fines concrete samples were placed for 28 days before testing occurred. The samples were tested using standard hardened concrete tests.

Concrete tests: The tests that were conducted had to provide a complete picture of all the characteristics of the concrete in both the wet and hardened state. For this reason, it was proposed that the testing incorporate aggregate testing to determine the potential effect of the aggregate shape on the performance of the no-fines concrete. This was followed by conducting workability tests like the slump, VEBE and compacting factor tests on the wet concrete sample. The hardened concrete tests proposed for the project were compressive strength and indirect tensile tests, modulus of rupture and elasticity and the skid resistance test. This testing includes determining the void ratio and assessing the permeability of the no-fines concrete.

Mix design: The mix design in this case was the determination of the ratio of aggregate, cement and water that possessed the most favourable properties. For this particular situation four trial mixes were designed. The mixes were determined from previous literature and particular mixes used by some companies. There are only three constituents of no-fines concrete that can be considered and varied: aggregate, cement and water content.

No-fines concrete: The mix designs for no-fines concrete were obtained from AMBUJA CEMENT COMPANY. There are a large number of different mixes that are currently being used for a whole range of applications. For this reason different mixes were trialed according to the design specifications by AMBUJA CEMENT COMPANY.

Aggregate	Cement	Water
8	1	0.4
6	1	0.4
4.5	1	0.4
4.8	1	0.36

Table - Mix Proportions used for No-fines Trial

Mixes

These different mixes will test the effect of increasing the fly ash content for the same amount of aggregate.

Trial mix: The trial mixes were used to determine the most suitable mixture for the analysis. The four different samples were mixed and tested for compressive strength and indirect tensile strength at 14 days. From these results, the most appropriate mix was determined and used for the remainder of the analysis. The 28 day strength was tested later to ensure that the chosen concrete mix possessed the highest ultimate compressive strength of the concrete mixes.

Apparatus: Concrete mixer - capable of resisting chemical attack from the cement and of sufficient size to allow mechanical mixing. Shovel - capable of resisting chemical attack and abrasion during the mixing process. Balance - capable of weighing the required mass with an accuracy of 0.1 g.

Mixing process:

1. Weigh aggregate, cement, fly ash, super plasticizer and water for the mix.
2. Moisten the working surface of the mixer to prevent the materials from sticking to the sides.
3. Add the aggregate to the mixer and add approximately half the water and mix until all the aggregate is wet.
4. Spread the cement, fly ash, super plasticizer and water uniformly over the surface of the aggregate.
5. Mix the concrete until the aggregate is evenly covered with cement paste.

Figure Mixing

Compacting and curing: Rodding was adopted for the compaction of no-fines concrete. The concrete samples were tamped 25 times and split into three layers. This procedure ensures sufficient compaction has been produced. The curing process starts with the moulds being left in place for 2 or 3 days, to allow sufficient bonding between the aggregate particles. After the specimens were removed from the mould they were placed in the water until the time of testing.

This process was used to ensure that optimum curing was achieved.

Results and analysis : Half the specimens were tested for compressive strength and indirect tensile strength at 14 days. The remaining small and large specimens were tested for 28 day compressive strength. The results of those tests can be found in the table below.

Aggregate-cement-water ratio	14 day Compressive strength(MPa)	28 day Compressive strength(MPa)
8:1:0.4	4.33	3.06
	4.33	3.82
6:1:0.4	5.60	7.51
	8.02	7.64
4.5:1:0.4	7.77	11.20
	7.89	12.99
4.8:1:0.36	7.89	6.37
	7.26	6.24

Table: Compressive strength of different proportions

From the 14 day testing, the aggregate-cement-water ratio of 4.5:1:0.4 was chosen as the most suitable mix since it produced the highest average compressive strength and possessed the greatest indirect tensile strength. The rest of the analysis will be completed using this mix design.

The large variation in the values obtained was caused predominantly by the inability to adequately seat the specimens. Metal capping was used to try and overcome this problem but the aggregate size made providing a smooth surface hard to achieve.

The specimens tended to fail slightly and then regain strength before failing again. This process continued until the ultimate failure occurred. At times this failure was catastrophic and can be seen in the figure below, which shows the failure of the specimens on completion of 28 day compression testing. This anomaly can be explained by the poor bonding of the top aggregate particles and should be eliminated by sulphur capping, as it will strengthen the bond of these particles. The failure shown in the previous two figures vary from slight shear failure with only small amounts of the concrete missing from the edges, to nearly complete disintegration with only small fragments still visible. A compressive test was undertaken on the large specimens at 28 day strength to assess if the same repeated failing and strengthening occurred. The tested samples appeared to exert the same failure characteristics but did not fail in a catastrophic manner like some of the smaller samples. All the edges in contact with the moulds provided a reasonably smooth surface.

The problem of failure with this form of compressive testing lead to the consideration that cube strength testing may more accurately determine the true compressive strength of no-fines concrete. The cube testing does not rely on providing a smooth surface on the top as the sample is tested on its side. This method of testing should provide a better result as it will test the strength along the entire length of the sample. The shape of the sample should reduce the problem of the tested sample leaning and falling before failure.

PROPERTIES AND TESTING OF AGGREGATE

This research investigates the properties of the aggregate used to make the no-fines concrete test samples. A sieve analysis, flakiness index, impact test, abrasion test of the aggregate sample was determined, so the characteristics of the aggregate could be assessed.

The results of these tests will help explain any differences that occurred during the testing phase. These results are useful when trying to explain differences in the compressive strength of the no-fines concrete when a different aggregate sample of the same size is used.

Sieve analysis : Sieve analysis is a method of determining the grading of a particular aggregate or a mixture of aggregates. The sieve analysis is carried out in a mechanical sieving machine to provide a more consistent result and achieve much greater accuracy. The sieves used vary in size but consecutive sieves used are smaller in aperture as you move down the stack. There are three different methods for undertaking a sieve analysis. Two wet analysis methods can be used, one with alcohol and the other with water. The third method is dry analysis, which can only be used for granular particleslargerthan125m. The aggregate was dry sieved due to the large particle size. Before sieving began the aggregate particles were air dried to ensure that no lumps or small particles contaminated the larger sieves and to prevent the smaller sieves from becoming clogged. The test sample was reduced from a large quantity by the method of 'sample reduction'.

The aggregate was riffled and collected in boxes at the bottom of the chutes. Half was discharged and the other half was riffled again. This process was continued until the specifications for sampling were met and an adequate quantity of material collected for the sieve analysis.

Apparatus : The following apparatus complying with the appropriate Indian Standards were used in all cases. Drying Oven - capable of maintaining a temperature of 110 ± 5ºC and complies with IS460 Part 1:1985.

Balance - capable of weighing the required mass with an accuracy of 0.1 g and complies IS460 Part 1:1985…

Sample Divider - capable of handling the size aggregate to be passed, usually the slot width is 10% wider than the aggregate and complies with IS460 Part 1:1985.

Test Sieves - a certified set of sieves with a lid and collection pan to comply with IS 460 Part 1:1985.

Brush - capable of removing all aggregate from the sieves, without damaging the sieves.

Shaking Device - a machine capable of providing lateral and vertical movement that ensures the continuous movement of the aggregate over the sieves.

Figure - The shaking device and stack of sieves used to conduct the sieve analysis

Procedure

A brief outline of the procedure, which complies with IS : 460 – 1962 follows:

1. The mass of the dry sample obtained from thereafter was measured with an accuracy of 0.1 g.
2. Dry, clean sieves were stacked in order with the largest sieve on the top and collection pan on the bottom.
3. The sample was placed on the top sieve, the lid replaced and the nest of sieves positioned on the shaking device which was operated for 10 minutes.
4. The contents of each sieve were removed separately and the mass of aggregate retained by each sieve weighed.

RESULT OF SIEVE ANALYSIS

Sieve Size (mm)	Mass Retained (g)	Sum mass Retained (g)	Percentage Retained (%)	Percentage Passing (%)
19	160.2	160.2	3.56	96.44
16	855	1015.2	22.59	77.41
9.5	3235.4	4250.6	94.56	5.44
6.7	153.1	4403.7	97.97	2.03
4.75	38.2	4441.9	98.82	1.18
<4.75	53.1	4495	100.00	0.00
Total	4495			

Table - Results of the Sieve Analysis

The results of the sieve analysis show that this 20 mm aggregate sample is not completely single sized but reasonably close.Almost 95 percent of the aggregate was retained on or above the 9.5 mm sieve.There were small amounts of fines and small aggregate, which should not affect the strength of the no-fines concrete but could affect the void ratio.

A sieve analysis was also undertaken on the second sample of 20 mm aggregate obtained to make the no-fines concrete samples.This second sieve analysis was conducted as there was a large variation in the strength of the two concrete samples.Both aggregate samples appeared to be a single-sized aggregate.

Flakiness index: The purpose of determining the Flakiness Index is to find the quantity of flaky or thin aggregate particles. The flakiness of the aggregate particles is of critical importance to the strength of no-fines concrete. The flaky particles can crush under load causing premature failure of the concrete. A flaky particle is defined as an aggregate particle with its least dimension less than 0.6 times its mean dimension (determined by sieving). The Flakiness Index gives the amount of flaky particles expressed as a percentage of the total sample.

Apparatus

The following apparatus used in testing complies with the appropriate Australian Standards.

Drying Oven - capable of maintaining a temperature of 110 ± 5ºC and complies with IS 2386 Part 1.

Balance - capable of weighing the required mass with an accuracy of 0.1 g and complies with IS 2386 Part 1.

Sample Divider - capable of handling the size aggregate to be passed, usually the slot width is 10% wider than the aggregate and complies with IS 2386 Part 1.

Slotted Gauge - capable of withstanding abrasion from aggregate particles and having slots with a width of 0.6 times the sieve sizes.

Figure 5.2 - Shows the slotted gauge used to determine the Flakiness of the aggregate particles

Procedure

1. The mass of the sample retained on each sieve was weighed separately and the test fraction recorded to the nearest gram (m1).
2. With the test fraction and corresponding slotted gauge, attempt to pass the particles through the gauge. Determine the mass of the particles passing through the slotted gauge to the nearest gram and record as (m2).
3. Calculate the flakiness index (FI) from the following equation:

$$FI = \frac{\sum m2}{\sum m1} \times 100$$

Where,

m2 = sum of the masses of selected entire size fractions passing the slotted gauge, in grams

m1 = sum of the masses of selected entire size fractions in grams.

4 Report the flakiness index obtained from the pre.vious calculation to the nearest whole number.

Result of flakiness index The Flakiness Index obtained from testing the aggregate sample is shown in Table 5.2.

Aggregate size(mm)	m_1	m_2
19	160	22
16	855	115
9.5	616	70
6.7	153	33
4.75	59	13
Total	1843	253
Flakiness Index	13.73	

Table - Data collected from the Flakiness Index test

The aggregate sample has a Flakiness Index of 13.73 percent by weight. This means that the amount of flaky particles in the sample is 13.73 percent. Flaky particles are not wanted when making no-fines concrete as it initiates aggregate crushing and promotes poor contact between particles. This amount of flaky particles will slightly reduce the ultimate strength of the no fines concrete. A spherical aggregate shape is most desirable for no-fines concrete applications. The flakiness index from the second aggregate sample is 10.97, which is different to the previous sample. It can be deduced from this that the flakiness of the aggregate particles affects the compressive strength of no-fines concrete, as the concrete made from this sample was considerably stronger.

Aggregate impact value

For determination of the aggregate impact value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.

Reference Standards

IS: 2386(Part IV)-1963 Methods of test for aggregate for concrete Part IV Mechanical Properties.

Equipment & Apparatus

1.Aggregate Impact Test Machine
2.Sieves (12.5mm,10mm)
3.Cylindrical metal measure
4.Tamping Rod
5.Balance (0-10kg)
6.Oven(300^0c)

Figure - Shows the aggregate impact test machine

Preparation of Test Sample

Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve. The aggregate to be tested is dried in oven for a period of not less than 4hours.

Procedure

1. The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
2. The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
3. The cup is fixed firmly in position on the base of the machine and the whole of the test sample is placed in it and compacted by a single tamping of 25 strokes of tamping rod.
4. The hammer is raised until its lower face is 380 mm. above the upper surface of the aggregate in the cup, and allowed to fall freely onto the aggregate 15 times, each being delivered at an interval of not less than one second.
5. The crushed aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
6. The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

Calculation

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as apercentage, to the first decimal place.

Aggregate impact Value = $(W_B / W_A) \times 100$

Precautions

1. Use hand gloves while removing containers from oven after switching offtheoven.
2. To wear safety shoes &goggles at the time of testing.
3. Before testing, machine should be properly checked.
4. Special care should be taken that no outer air enters when using the balance.
5. After test clean the sieve by a smooth brush.

- Keep all the exposed metal parts greased.
- Keep the guide rods firmly fixed to the base & top plate.
- Equipment should be clean thoroughly before testing & after testing.

Description	Sample 1	Sample 2	Sample 3
Total weight of dry sample taken Wa (gm)	352	347	337
Weight of portion passing 2.36 mm sieve wb (gm)	51.5	44.5	44.5
A.I.V= (WB /WA) × 100	14.6%	12.82%	14.6%

Table 5.3 - Data collected from the aggregate impact value

Aggregate impact value is used to classify the stones in respect of their toughness property as indicated below

Aggregate impact value	Classification
< 10%	Exceptionally strong
10-20 %	Strong
20-30 %	Satisfactory for road surfacing
>35%	Weak for road surfacing

CONCLUSION

The sample aggregate is strong with aggregate impact value of 14.6%.The aggregate can be used for bituminous carpet concrete, bituminous penetration macadam and cement concrete wearing course.

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