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A REVIEW PAPER ON NO FINES CONCRETE

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ABSTRACT

Considerable research has been conducted on environmentally sustainabledevelopment. This has lead to the use of no-fines concrete in place ofconventional concrete and asphalt surfaces. This material dramatically reducesenvironmental degradation and the negative effects associated with urban sprawl.No-fines concrete has been used as an effective method for treating and reducingnegative environmental impacts.This thesis analyses the effectiveness of no-fines concrete in pavementapplications. This was achieved by analysing the properties and characteristics ofno-fines concrete. The performance of no-fines concrete was compared with aconcrete sample that is comparable to the material used for the construction of conventional concrete road pavement.

Keywords: *Nofines concrete, Compressive strength test, Tensile strength test.*

I. INTRODUCTION

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 and porous concrete.

No-Fines concrete consists of an agglomeration of coarse single sized aggregate covered with a thin layer of cement paste approximately 1.3 mm thick (Neville 1997). This form of concrete has the ability to allow water to permeate the material which reduces the environmental problems associated with asphalt and conventional concrete pavements. The most common application of no-fines concrete is in low traffic volume areas, for example: parking lots, residential roads, driveways and footpaths.

The force exerted on the foundations by no-fines concrete is approximately one third of that produced by the same structure constructed from conventional concrete. This difference may be of critical importance when considering structures on ground with a low bearing capacity (Fulton 1977).

No-fines concrete has been predominantly used in non-pavements applications, with only a limited use in pavements applications. The purpose of this project is to assess the suitability for no-fines concrete to be used for the construction of road pavements. This assessment will include investigating current literature on the topic and conducting some mix designs and standard concrete testing on conventional concrete and no-fines concrete to determine and compare their properties. From the tested data a conclusion as to the usefulness of no-fines concrete pavements will be drawn and it may be determined that further testing is required.

II. LITERATURE REVIEW

The initial use of no-fines concrete was in the United Kingdom in 1852 with the construction of two residential houses and a sea groyne. It was a further 70 years before any further recorded use of no-fines concrete occurred when it was reintroduced into the United Kingdom in 1923 from Holland. The use of no-fines concrete became more important after the conclusion of World War II with the associated material shortages (Malhotra 1976).

Malhotra : (1976) found that the density of no-fines concrete is generally about 70 percent of conventional concrete when made with similar constituents. The density of no-fines concrete using conventional aggregates varies from 1602 to 1922 kg/m3. A clinker aggregate was trailed and the no-fines concrete produced a density of 961 kg/m3.

Adequate vibration is imperative for strength of conventional concrete. The use of no-fines concrete is different and is a self-packing product. Malhotra (1976) suggests that the use of mechanical vibrators and ramming is not recommended with no-fines concrete. A light rodding should be adequate and used to ensure that the concrete reaches all sections of the formwork. This is not a problem with conventional concrete since it has greater flow ability than no-fines concrete. The light rodding ensures that the concrete has penetrated all the areas impeded by reinforcing steel.

Malhotra (1976) stresses that in situations where normal conditions are not achieved during placement and curing, the formwork should not be removed after 24 hours as with conventional concrete. No-fines concrete has very low cohesiveness and formwork should remain until the cement paste has hardened sufficiently to hold the aggregate particles together. However, this is more of a consideration in low temperature conditions and when used in non-pavement applications where the concrete is not sufficiently supported by the ground or other means.

Ghafoori [et al] :- (1995) Undertook a considerable amount of laboratory investigation to determine the effectiveness of no-fines concrete as a paving material. The curing types were investigated to determine if there was any difference between wet and sealed curing. There appeared to be only a negligible difference in strength between the different curing methods. It was clear from the test results that the strength development of no-fines concrete was not dependent upon the curing conditions.
The indirect tensile test conducted by Ghafoori (1995) found that the sample tests varied between 1.22 and 2.83 MPa. The greater tensile strength was achieved with a lower aggregate-cement ratio. Ghafoori et al (1995) explained the more favourable properties obtained by the lower aggregate-cement ratio by an improved mechanical interlocking behaviour between the aggregate particles.

Abadjieva[et al] :- Determined that the compressive strength of no-fines concrete increases with age at a similar rate to conventional concrete. The no-fines concrete specimens tested had aggregate-cement ratios varying from 6:1 to 10:1. The 28 day compressive strength obtained by these mixes ranged from 1.1 and 8.2 MPa, with the aggregate-cement ratio of 6:1 being the strongest. He concluded that the most plausible explanation for the reduced strength was caused by the increased porosity of the concrete samples. This strength is sufficient for structural load bearing walls and associated applications. Ghafoori et al (1995) produced no-fines concrete with a compressive strength in excess of 20 MPa when using an aggregate-cement ratio of 4:1.
Abadjieva et al investigated the influence of the aggregate-cement ratio on the tensile and flexural strength of no-fines concrete. This study only assessed aggregate-cement ratios ranging from 6:1 to 10:1. The highest strengths were obtained with an aggregate-cement ratio of 7:1 and the strength decreased with an increasing aggregate-cement ratio. He found that the tensile and flexural strengths of no-fines concrete were considerably lower than those obtained from conventional concrete, but he could not explain why the sample with the highest strength had a ratio of 7:1.

Krishna Raju :- A study conducted by Krishna Raju(1975) focused on the optimum water content for no-fines concrete. It was determined that for the particular aggregate-cement ratio there is a narrow range for optimum water-cement ratio. This water-cement ratio was imperative to gain the maximum possible compressive strength. A higher than ideal water-cement ratio would cause the cement paste to drain from the aggregate particles. Alternatively, a water-cement ratio too low would stop the cement paste from adhering sufficiently to the aggregate. When the optimum water-cement ratio was not obtained, sufficient compaction could not be achieved, further compounding the loss of compressive strength.

The large air voids in no-fines concrete does not allow water to penetrate using capillary action. Malhtora (1976) noted that the depth of penetration in no-fines concrete by this method under conditions of high humidity and no air movement is generally no greater than two or three times the largest aggregate diameter. The penetration of moisture was higher in no-fines concrete made from conventional aggregates than clinker aggregate.

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III. METHODOLOGY

Test Methodology

This project is focused predominantly on the use of no-fines concrete as a road pavement material. As this is a comparison between no-fines concrete pavements and conventional concrete pavements, there is a requirement that the tests being conducted can occur on both samples.

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. With the mix ratio known, the 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 under water for 28 days before testing occurred. The samples were tested using standard hardened concrete tests. The same workability and hardened concrete tests were undertaken on M20 grade of concrete. With both sets of data, a comparison of the properties of the no-fines concrete could be assessed and conclusions relating to its usefulness reached.

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 and compacting factor tests on the wet concrete sample.

The hardened concrete tests proposed for the project were compressive strength, indirect tensile test and modulus of rupture.

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 two mixes were designed. The mixes were determined from previous literature and particular mixes. There are only three constituents of no-fines concrete that can be considered and varied: aggregate, cement and water content.

Conventional Concrete

There was no mix design undertaken for conventional concrete, since the strength of certain mixes is readily known. This meant that no trials were required to be carried out. When conducting the tests to determine the properties of a conventional concrete, a M20 grade of concrete was used.

No Fines Concrete

The mix designs for no-fines concrete were obtained from printed articles. There were a large number of different mixes that are currently being used for a whole range of applications. For this reason two different mixes were selected. The aggregate-cement-water ratio mixes were:

Table No.1 – Mix Proportions Used for No Fines Concrete Mixes

Aggregate	**Cement**	**Water**
6	1	0.4
4.5	1	0.4

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

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IV. TEST ON FRESH CONCRETE

Introduction

This chapter includes the workability tests on no-fines concrete mix. The workability tests include the slump and compacting factor tests. These tests were chosen as they will provide a clear indication of the workability and fresh concrete characteristics.

No-fines concrete is said to have self compacting properties. This will be tested with the compacting factor test. The slump test is not good for testing no-fines concrete due to the low cohesion between the aggregate particles.

Slump Test

The slump test is a method of testing the fresh concrete for particular characteristics including workability. It is a simple method of determining if different batches of concrete are the same. This is determined if the same constituents in the same proportions do not vary the characteristics of the concrete sample.

The slump is determined by filling a slump cone with fresh concrete in three layers. Each layer is compacted 25 times. The slump cone is removed and the vertical subsidence of the fresh concrete sample is measured. No-fines concrete has very little cohesion due to its structure and may collapse on removal of the cone resulting in a poor result with little or no value. The values obtained from the slump test were compared with results obtained by compressive strengths and other related tests in an attempt to be able to describe the characteristics of the concrete. This is a simple test that can be performed simply in the field without requiring any special training.

Apparatus

1. Slump Mould – manufactured from galvanised steel sheet with a wall thickness of 1.5 mm and internal dimensions as follows: bottom diameter = 200 mm, top diameter = 100 mm and vertical height = 300 mm.
2. Rod – constructed of 16 mm diameter metal rod approximately 600 mm long with a tapered and spherical end with a radius of 5 mm.
3. Base Plate – smooth, rigid and non-absorbent.
4. Ruler – an appropriate steel ruler.

Figure No. 01 – Equipment Required to Conduct a Slump Test

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Procedure

1. Make sure the internal surface of the slump cone is free from hard concrete.
2. Wet the internal surface with a damp cloth before commencing test.
3. Place the mould on the base plate and hold in place by standing on the foot pieces provided during the filling procedure.
4. Fill the mould in three equal layers and tamp each layer 25 times. The tamping must occur uniformly over the entire cross section of the concrete.
5. Ensure that the top layer of the concrete is in line with the top of the mould on completion of the filling and tamping procedures.
6. Carefully remove the slump mould without disturbing the concrete sample.
7. Measure the slump by determining the difference in height between the mould and the average height of the top surface of the concrete.

Result of Slump Test

This test was undertaken on each sample of concrete used for the hardened concrete tests. The slumps obtained on the concrete samples are as follows:

Table No. 2 – Result of Slump Test

Type of Concrete	Slump (mm)
No Fines Concrete (6:1)	170
No Fines Concrete (4.5:1)	155
Conventional Concrete (M20)	75

Compacting Factor Test

The compacting factor test is used to determine the extent with which the fresh concrete compacts itself when allowed to fall without the application of any external compaction. The compaction obtained from the free falling is compared with the same sample under standard compaction practices (that is 3 layers, each tamped 25 times). The sample falls from the initial cone and is captured in a second cone. It is then allowed to fall into a test cylinder with a diameter of 150 mm and height of 300 mm.

This test is another test for consistency of a fresh concrete sample and as with the other tests it should not vary considerably for different batches with the same mix proportions. This is probably the most appropriate method for testing the consistency of no-fines concrete as it is considered to be a self compacting material and can be dropped from height without affecting its properties.

Apparatus

1. Compacting Factor Apparatus – consists of 2 conical hoppers mounted above a cylinder.
2. Trowel – requires the use of two trowels.
3. Rod – constructed of 16 mm diameter metal rod approximately 600 mm long with a tapered and spherical end with a radius of 5 mm.
4. Balance – capable of measuring to an accuracy of 0.1 percent.

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FigureNo.02 – Apparatus Used to Conduct the Compacting Factor Test

Procedure

1. Ensure the internal surfaces of the hoppers and cylinders are free from hardened concrete.
2. Moisten all the internal surfaces with a damp cloth before commencing each test.
3. Gently fill the upper hopper with concrete using the trowel, then immediately open the trapdoors to allow the concrete to fall into the second hopper.
4. Immediately after the concrete has come to rest, open the lower trapdoor allowing the concrete to fall into the cylinder.
5. Level the top of the cylinder and wipe clean any concrete on the mould.
6. Determine the mass of the concrete in the cylinder to the nearest 10 grams. This mass is known as the 'mass of the partially compacted concrete (m1)'.
7. Empty the cylinder and fill with a new sample of concrete and compact by tamping the concrete in three layers. Carefully strike off the top surface and clean the outside of the cylinder.
8. Determine the mass of the concrete in the cylinder to the nearest 10 grams. This mass is known as the 'mass of fully compacted concrete (m2)'.
9. Calculate the compacting factor with the following equation:

$$\text{Compacting Factor} = \frac{(m_1)}{(m_2)}$$

Result of Compacting Factor Test

The results from the compacting factor test conducted on the concrete samples are found in table 3.

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Table No. 03 – Result of Compacting Factor Test

Type of Concrete	Partially Compacted (m_1)	Fully Compacted (m_2)	Compacting Factor
No Fines Concrete (6:1)	10.925	11.435	0.96
No Fines Concrete(4.5:1)	10.245	11.435	0.90
Conventional Concrete (M20)	13.095	13.565	0.97

V. TESTING ON HARD CONCRETE

Compressive Strength

The compressive strength tests are conducted to ensure a minimum strength is achieved by the particular mix. Cylinder and cube testing are methods of determining the compressive strength. The cylinder testing is an Australian Standard for testing compressive strength, while cube testing is a British Standard.

The cube test, due to the method by which it is implemented, should give a more stable test specimen than the cylinders. This test will determine the strength of the sample along the entire length of the sample and eliminate problems encountered with the edge aggregate dislodging and failing. The cube method usually determines a concrete strength increased by 10 and 40 percent in comparison to the equivalent cylinder test.

Apparatus

1. Testing Machine – complying with the appropriate requirements.
2. Bearing Strips – require two tempered grade hardboard, 5 mm thick.

Testing Procedure

1. The measuring and testing of test specimens was undertaken as soon as possible after being removed from the water.
2. All specimens were tested in a wet condition and excess water removed from the surface.
3. The dimensions of the test specimens were measured and recorded.
4. The platens were cleaned when necessary to ensure no obstruction from small particles or grit.
5. It was ensured there was no trace of lubricant on the bearing surfaces.
6. The 150 by 150 mm plate was placed on top and bottom of the specimen directly opposite each other.
7. The specimens were centered on the bottom platen of the testing machine.
8. The upper platen was lowered until uniform pressure was provided on the specimen.
9. A force was applied at the required rate shown by the rotating disc on the testing machine.
10. The maximum force applied to the cylinder was recorded and the compressive strength calculated:

$$pressure = \frac{Force}{Area}$$

Results of Compression Strength

The maximum force determined in the cube tests and the associated compressive strength is shown in Table 4

Table No.04 – Compressive Strength of Concrete Cubes for 3 Days

Sr. No.	Specimen Type	Force (kN)	Cross Sectional Area (mm^2)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
1	No Fines (6:1)	113	22500	5.02	5.11
2	No Fines (6:1)	117	22500	5.18	
3	No Fines (6:1)	115	22500	5.13	
4	No Fines (4.5:1)	135	22500	6.00	6.42
5	No Fines (4.5:1)	154	22500	6.81	
6	No Fines (4.5:1)	145	22500	6.45	
7	Conventional (M20)	343	22500	15.24	15.98
8	Conventional (M20)	358	22500	15.9	
9	Conventional (M20)	378	22500	16.8	

Table No.05 – Compressive Strength of Concrete Cubes for 7 Days

Sr. No.	Specimen Type	Force (kN)	Cross Sectional Area (mm^2)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
1	No Fines (6:1)	142	22500	6.30	4.67
2	No Fines (6:1)	67	22500	2.98	
3	No Fines (6:1)	106	22500	4.73	
4	No Fines (4.5:1)	182	22500	8.10	8.67
5	No Fines (4.5:1)	198	22500	8.80	
6	No Fines (4.5:1)	205	22500	9.11	
7	Conventional (M20)	493	22500	21.91	22.20
8	Conventional (M20)	461	22500	20.49	
9	Conventional (M20)	544	22500	24.2	

Table No.06 – Compressive Strength of Concrete Cubes for 28 Days

Sr. No.	Specimen Type	Force (kN)	Cross Sectional Area (mm^2)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
1	No Fines (6:1)	330	22500	14.69	12.71
2	No Fines (6:1)	219	22500	9.73	
3	No Fines (6:1)	308	22500	13.71	
4	No Fines (4.5:1)	305	22500	13.58	12.38
5	No Fines (4.5:1)	229	22500	10.18	
6	No Fines (4.5:1)	301	22500	13.38	
7	Conventional (M20)	717	22500	31.87	38.80
8	Conventional (M20)	916	22500	40.73	
9	Conventional (M20)	986	22500	43.8	

Indirect Tensile Strength Test

The tensile strength of concrete cannot be measured directly. This leads to the need to determine the tensile strength through indirect methods. The indirect tensile test is also referred to as the 'Brazil' or splitting test, where a cylinder is placed on its side and broken in the compression machine. This test can also be used to determine the modulus of elasticity of the concrete sample.

Apparatus

1. Testing Machine – complying with the appropriate requirements.
2. Bearing Strips – require two tempered grade hardboard, 5 mm thick.

Testing Procedure

1. The diameter of specimen in the plane in which it is being tested as well as the lengths where the bearing strips are in contact were determined.
2. The bearing strips between the testing jig and the test specimen were aligned.
3. The testing jig was centered in the compression machine and the top platen was lowered.
4. The force was at the required rate without shock (shown on inner disc of machine).
5. The maximum force applied to the concrete before failure was recorded.
6. The fracture type and appearance of concrete was also recorded.
7. The indirect tensile strength of the specimen was calculated using the following equation:

$$T = \frac{2P}{\pi L D}$$

Results of Indirect Tensile Strength Test

The results from the indirect tensile test are shown in Table 7.

Table No.07 – The Results of Indirect Tensile Strength Test on Concrete Cylinders of Different Mixes

Sr. No.	Specimen Type	Force, P (kN)	Length, L (mm)	Diameter, D (mm)	Indirect Tensile Strength, T (MPa)	Average Tensile Strength (MPa)
1	No Fines (6:1)	74	300	150	1.05	1.13
2	No Fines (6:1)	80	300	150	1.13	
3	No Fines (6:1)	85	300	150	1.21	
4	No Fines (4.5:1)	120	300	150	1.70	1.88
5	No Fines (4.5:1)	131	300	150	1.85	
6	No Fines (4.5:1)	147	300	150	2.09	
7	Conventional (M20)	148	300	150	2.10	2.25
8	Conventional (M20)	162	300	150	2.29	
9	Conventional (M20)	166	300	150	2.36	

VI. CONCLUSION

The strength of No fines concrete is lower, then also this concrete is used for road pavement.The compressive strength of No fines concrete is 68.09 % smaller than the conventional concrete at 28 days. The Indirect tensile strength of strength of No fines concrete is 16.44 % smaller than the conventional concrete at 28 days. The workability of No fines concrete is lower than conventional concrete. The cost of No fines concrete is less than conventional concrete,because of omitting the fine aggregate from concrete.No fines concrete is environmental friendly due to absence of river sand. No-fines concrete does not suffer from these inadequacies of Standing water, since a large volume of water will be stored instantly within the pavement.

Recommendations For Further Studies

There are an unlimited number of possible topics for further studies but there are a small number that would be particularly useful. Investigation of these may affect the future design and specifications of no-fines concrete pavements. The most critical element that should be investigated relates to the flakiness of the aggregate particles used. It was found during this project that a small change in flakiness can have a dramatic affect on the compressive strength of the no-fines concrete. The no-fines concrete gained 6 to 8 MPa with a drop in flaky particles of about 2 percent.This could be taken further by investigating different aggregates like ridge gravels which would have close to no flaky particles, or to investigate the use of recycled aggregates. Alternative materials that can be readily used in no-fines concrete applications could reduce costs and make it more environmentally friendly. Another line of investigation could entail finding the optimum aggregate size that will provide the greatest strength while not affecting the permeability of the concrete. However, this may be difficult to establish because different applications require different water management capabilities.

Methods of reducing or even eliminating the ravelling that occurs on the surface of no-fines concrete pavements should be investigated. This is one of the major drawbacks associated with the use of no-fines concrete. It is of critical importance that a solution is found that can be readily implemented. As no-fines concrete pavements are designed by rule of thumb, it may be appropriate to create a design tool to determine the required depth of the different components that make up the pavement. A design graph similar to what is used for the design of asphalt pavements would be effective in reducing problems associated with a lack of knowledge.

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Lack of Experience

The lack of experience existing with the use of no-fines concrete pavement stems from it being a relatively new product. The difference between the properties of no-fines concrete and conventional concrete requires it to be placed and compacted in a different manner. The low workability and self-compacting nature of the no-fines concrete results in only a minimal amount of rodding and compaction and no vibrating.

The different placement and compaction methods required are not widely understood. When these important procedures are not correctly undertaken it can have a detrimental affect on the strength, appearance and effectiveness of the pavement. This can affect the water permeating capacity of the pavement, reducing the environmental benefits associated with its use.

Lack of Public Awareness

Before a product is accepted and implemented by the public, there must be an awareness of its benefits. The environmental and economic benefits of the no-fines concrete are not yet widely recognised. In terms of the environment, this product can potentially eliminate the negative impacts to the environment associated with the use of conventional concrete. No-fines concrete has the ability to make driving conditions safer by eliminating standing water and the problems associated with the lack of grip on roads. In economic terms, the lack of need of extensive earthworks and the upgrade of existing sewer systems means saving time and money but this benefit is not widely recognised.

This lack of public awareness is limiting the use of no-fines concrete in pavement applications in Australia. This is because it is a recently developed material that has not been widely used in Australia. Developers and homeowners would more readily use this product if its benefits were publicised. In a society with an emphasis on supporting the environment, greener products should be encouraged and possibly enforced by the government in an attempt to reduce the negative impacts associated with urban sprawl.

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