Strengthening of Subgrade Soil by using Crushed Concrete

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Abstract: ***Recycled aggregates consist of crushed, graded inorganic particles processed from the material that have been used in the constructions and demolition debris. The target of the present paper work is to determine the strength characteristic of recycled aggregates for the application in concrete pavement construction. The scope of the paper is to determine and compare the compressive strength, flexural strength and sulphate resistance of concrete by using different percentages of recycled aggregates. The investigation was carried out by using workability test, compressive strength test, flexural strength test and sulphate resistance test. A total of five mixes with replacement of coarse aggregates with 0%, 10%, 20%, 30% and 40% recycled coarse aggregates were studied. The water cement ratio was kept constant at 0.38. It was observed that workability of concrete was decreased with the increase in recycled aggregates in concrete. For the strength characteristics, the results showed that the strengths of recycled aggregate concrete was comparable to the strengths of natural aggregates concrete.***

Keywords: compressive strength, flexural strength, sulphate Resistance, Concrete

1. Introduction

Concrete has been the leading building material since it was discovered and found viable for future due to its durability, easy maintenance, wide range of properties and adaptability to any shape and size. Concrete is the composite mix of cement, aggregates, sand and water. Concrete gets hardened like stone on mixing water with cement and aggregates. Concrete have two type ingredients namely active and inactive. The active group consists of water and cement. The inactive part consists of sand and coarse aggregates. Concrete have high compressive strength and low tensile strength. To overcome this shortcoming, steel reinforcements are used along with the concrete. This type of concrete is called reinforced cement concrete (RCC).

Concrete structures that are designed to have service lives of at least 50 years have to be Crushed after 20 or 30 years because of deterioration caused by many agents. Old buildings require maintenance for better and higher economics gains. The rate of demolition has increased and there is a shortage in dumping space and also increase in cost of dumping. Instead of dumping this Crushed concrete, use of Crushed as recycled concrete would not only reduce the cost but also will conserve the non renewable energy sources. The use of Crushed concrete will further result in reduction in use of natural aggregates. The usage of natural aggregates is causing damage to natural resources resulting in imbalance in environment. Recycled aggregates consist of crushed, graded inorganic particles obtained from the materials that have been used in constructions. Recycled aggregates are generally obtained from buildings, roads and bridges which are Crushed due to completion of life, wars and earthquake.

Earthquakes and bombarding in wars causes a lot of destruction of buildings and roads causing generation of a lot of concrete waste. In Second World War, bombardment caused demolition of buildings and roads. Transportations and reconstruction were the restrains in economy. At the same time, disposal of concrete waste was also a big problem. The idea of reusing Crushed concrete as aggregates gave a solution to this problem and hence was justified as alternative material source in 1976.

Worldwide aggregate use is estimated to be ten to eleven billion tonnes each year. Of this, approximately eight billion tonnes of aggregate (sand, gravel, and crushed rock) is being used in Portland cement concrete (PCC) every year [Naik 2005, Mehta 2001]. Also there is a critical reduction of natural aggregate and an increasing amount of Crushed concrete [Hansen 1984]. It is estimated that 150 million ton of concrete waste is produced in the United States annually [Salem 2003]. In 2005, the American Society of Civil Engineers reported US infrastructure in poor condition with an estimated repair cost of $1.6 trillion over five years.

2. Objective of Study

The study on use of Crushed concrete in pavement construction consists of conducting laboratory investigations on cement concrete prepared by using Crushed concrete to estimate its suitability for pavement construction. The main objectives of study are:

1) To prepare mix design for M40 concrete with varying proportions of recycled aggregates.
2) To determine the compressive strength of the samples at the end of 7, 28, 56 and 90 days.
3) To determine the flexural strength of the samples at the end of 7,28, and 90 days
4) To determine the sulphate resistance strength of samples at the end of 7, 28 and 56 days.

The purpose of this research was to study the behavior of recycled coarse aggregates when it was included in Plain Cement Concrete. Slump test was performed on freshly mixed concrete, and compression test was performed on hardened concrete. 135 samples of concrete were prepared with RCA and natural aggregate, changing their mixture design parameters, including coarse aggregate proportion.

3. Literature Review

Recycled aggregates have been used as concrete kerb and gutter mix in Australia [Shing Chai NGO, 2004]. In the project of Lenthall Street in Sydney, 10 mm recycled aggregates and blended recycled sand are used for concrete kerb and gutter mix.

In road construction recycled aggregates are used as granular base course. They have proved better than the natural aggregates when used as granular base course. In case of wet sub grade areas, recycled aggregates stabilize the base and provide an improved working surface for pavement structure construction. Recycled aggregates are used as base, sub base course and sometimes for foundation purpose also. In USA, the use of recycling technology in a number of full scale pavement rehabilitation projects has been accomplished since 1976 [Kumar,Satish,2002].

Market development study for recycled aggregates products [Shing Chai NGO,2004] stated that recycled aggregates can be used in embankment fill. The embankment site is on the wet sub grade areas, recycled aggregates can stabilize the base and provide an improved working surface for the remaining work. In Hongkong they are used as paving blocks. Norwegian Building Research Institute mentioned that RCA can be used as backfill materials in pipe zones.

In Lowa [Kumar,Satish,2002] recycled concrete was first used in 1976 for the production of new concrete where a 41 years old pavement was crushed and Crushed concrete was used for the construction of 1 mile long and 22.5 cm thick highway pavement. In other construction of 17 mile long and 20 cm thick highway pavement, crushed concrete was used in Lowa in 1978. The Minnesota department of transportation recycled 16 mile long plain concrete pavement into a new concrete pavement on trunk highway in 1980. In Netherland, recycled aggregates are used for partition walls in apartments. After the damage caused in Second World War, countries like Germany, England, Netherland and other European countries have tried to use recycled concrete in new construction and made a lot of investigations over it. Some countries have developed code of practice for the use of recycled aggregates. In India recycled aggregates are not much used, but its future seems bright and one can predict remarkable contribution of recycled aggregates.

The compressive strength is most affected by the w/c ratio [Lin 2004]. Other influential parameters include fine recycled aggregate content, cleanness of aggregate, interaction between fine recycled aggregate content and crushed brick content, and interaction between w/c ratio and coarse RCA content [Lin 2004]. At a constant w/c ratio, air-dried RCA containing concrete had the highest compressive strength compared to oven-dried and saturated surface dry RCA [Poon 2003]. Particularly at lower w/c ratios, unwashed RCA reduces compressive strength. Compressive strength is 60% of virgin concrete at 0.38 w/c and 75% at 0.6 w/c [Chen 2003].

4. Experimental Programme

Testing of strengths of concrete was carried out as per Indian Standard code IS: 516- 1959. Concrete mix design guidelines were as per IS: 10262-2009. The main objectives of the study were to find out the compressive strength, flexural strength and sulfate resistance of the concrete made with Crushed concrete. It was estimated that whether RCA concrete was usable in pavement construction. Mix design is done to select the mix material and their required proportions. The motive of mix design is to determine the proportion in which concrete ingredients like cement, water, fine aggregates and coarse aggregates should be mixed to provide specified strength, workability, durability and other specified requirements as listed in standards such as IS: 456-2000.

Material Properties

The physical and mechanical properties of all ingredients like sand, natural coarse aggregates, cement and Crushed coarse aggregates are per IS: 2386-1963 were determined.

Cement

OPC (Ordinary Portland Cement) of grade 43 was used which conformed to IS: 8112-1989. Testing of cement was done as per IS: 4031-1968.

Natural Fine Aggregates

Natural coarse sand was used as fine aggregate. The sand conformed to zone II as per IS: 383-1970.

Natural Coarse Aggregate

Coarse aggregates of size 10mm and 20mm were used.

Water

Properties of water used were as per clause no. 5.4 of IS 456-2000. It was free from deleterious materials. Water was used for mixing and curing of concrete. Portable water is generally taken for mixing and curing of concrete.

Mix Proportion

As per design of concrete mix M40, the ratio of cement, fine aggregate and coarse aggregate was taken as 1:1.23:2.52 respectively.

Casting of Specimens

Five batches of mixes were prepared as per the mix design of M40. First mix named m0 was taken as control mix. The ratio is 1:1.23:2.52 for cement, fine aggregates and coarse aggregates respectively.

Mixing and Compaction

Power driven mixer was used for mixing the materials. All the mixing water was added to mixing drum before introducing the solid materials. Half of the coarse aggregate was added to drum, and then fine aggregate was added following the addition of cement and at the last remaining coarse aggregate was added to drum.

Properties of Fresh concrete (Workability)

There are a lot of methods of for measuring workability of concrete. Each method measures only a specified aspect of it and there is really no method which measures the workability of concrete in its totality. Two tests were performed to find workability i.e Slump Test and Compaction Factor Test.

Removal of moulds and curing of specimens

Moulds were opened after 24 hours and cleaned. Samples were kept in clean and fresh water for curing in water tanks.

Testing Procedure

Following tests were performed.

1) Compressive strength of cubes at the age of 7, 28, 56 and 90 days.
2) Flexural strength of beams at the age of 7, 28 and 90 days.
3) Sulphate resistance of cubes at the age of 7, 28 and 56 days.

Compressive Strength

The dried cubes were tested at the age of 7, 28, 56 and 90 days. The cubes were tested on compression testing machine (CTM) after drying at room temperature as per IS: 516-1959. The load was applied at rate of 350MPa/minute in a uniform and continuous manner. Impacts were prevented during the application of load. Application of load was kept continued until the sample failed and maximum load carried by the sample was recorded. Three samples for each test reading were tested. Final value of test is taken as an average of three samples.

Flexural Strength

The dried beams were tested on flexural testing machine using two points loading. The transverse bending test was employed. Flexural strength was calculated as per equation given belowfor a rectangular sample under a load in a two-point bending setup where the loading span was one-third of the support span:

$$\sigma = \frac{FL}{bd^2}$$

- F is the load (force) at the fracture point in MPa
- L is the length of the support (outer) span in mm
- b is width in mm
- d is thickness in mm

Sulphate Resistance

Test cubes were cured in water for 28 days before submerging to sulphate solution ($MgSO_4$). Cubes were tested in CTM machine after 7,28 and 56 days for checking the compressive strength. 2 samples were tested for each final value of compressive strength.

5. Results

Testing of sample was done at 7, 28, 56 and 90 days for compressive strength. For flexural strength testing of samples was done at 7, 28 and 90 days. Testing for sulphate resistance was done at 7, 28 and 56 days. Results of these tests are discussed along with the results of workability.

Variation of Compressive Strength with Age

Table 5.1 gives the test results of compressive strength at 7, 28, 56 and 90 days. Water cement ratio was kept as 0.38 for all mixes. Super plasticizer used was 0.6% of cement. Table 5.2 gives the percentage reduction in compressive strength for all mixes at different number of days

Table 5.1: Test Results for Compressive Strength

S.No.	Mix	W/C	Compressive strength (MPa)			
			7 Days	28Days	56 Days	90 Days
1.	m0	0.38	42.43	50.06	51.20	51.8
2.	m1	0.38	42.47	50.36	50.89	51.23
3.	m2	0.38	41.84	50.20	50.68	50.80
4.	m3	0.38	42.60	49.11	50.68	51.4
5.	m4	0.38	40.27	52.36	53.24	53.26

Table 5.2: Percentage Reduction in Compressive Strength at Different Ages

S.No.	Mix	Age (in days)	%age Reduction in Compressive Strength				
			m0	m1	m2	m3	m4
1.	1:1.23:2.52	7	-	100.1	98.6	100.4	95
2.	1:1.23:2.52	28	-	100.5	100.3	98.1	104.5
3.	1:1.23:2.52	56	-	99.4	98.8	98.9	106
4.	1:1.23:2.52	90	-	98.8	98	99.2	104

Variation of Flexural Strength with Age

Table 5.3 gives the test results of flexural strength at 7, 28, and 90 days. The results of flexural strength are the average of 3 beams. Table 5.4 shows the percentage reduction in flexural strength for all mixes at different ages. Figure 5.8 shows the comparison of flexural strength at ages of 7,28 and 90 days.

Table 5.3: Results of Flexural Strength

S.No.	Mix	W/C	Flexural strength (MPa)		
			7 Days	28Days	90 days
1.	m0	0.38	4.20	5.32	5.64
2.	m1	0.38	4.31	5.60	5.67
3.	m2	0.38	4.10	5.40	5.8
4.	m3	0.38	4.12	5.38	5.62
5.	m4	0.38	4.22	5.40	5.58

Sulphate Resistance of RCA Concrete

The effect of sulphate solution on compressive strength of RCA concrete was investigated. Concrete cubes were kept in $MgSO_4$ (magnesium sulfate) solution for 7, 28 and 56 days after normal curing for 28- days. Compressive strength of cubes was checked by using CTM. Table 5.5 gives the test results at age of specified number of days. Table 5.6 gives the details of percentage reduction in compressive strength at the age of specified number of days.

Table 5.5: Test Results for Sulphate Resistance

S.No.	Mix	Type Of Solution	Compressive Strength(MPa)		
			7 Days	28 Days	56 Days
1.	m0	5%of $MgSO_4$	41.75	48.74	48.3
2.	m1	5%of $MgSO_4$	41.79	49.05	49.23
3.	m2	5%of $MgSO_4$	38.8	48.26	47.62
4.	m3	5%of $MgSO_4$	41.8	45.6	49.03
5.	m4	5%of $MgSO_4$	39.53	50.73	49.38

Table 5.6: Percentage Reduction of Compressive Strength Due To Sulphate Attack

S.No.	Mix	Type of solution	% age reduction in compressive strength		
			7 Days	28 Days	56 Days
1.	m0	5%of $MgSO_4$	98.42	97.38	94.3
2.	m1	5%of $MgSO_4$	98.4	97.4	96.08
3.	m2	5%of $MgSO_4$	92.73	96.13	93.96
4.	m3	5%of $MgSO_4$	98.2	92.85	95.4
5.	m4	5%of $MgSO_4$	98.17	96.9	92.75

6. Conclusion

Following conclusions can be drawn from results and discussion of results from the study:

1. The compressive strength of all mixes exceeded at the age of 28 days. Compressive strength of control mix i.e. of m0 is 50.05 MPa which is greater than the target strength of 48.25 for M40 concrete. Compressive strength of m1 is slightly increased to 50.36. So the compressive strength increases by 0.5%. For m2, compressive strength is increased to 50.20 MPa, it also showed an increase in compressive strength by 0.3%. Compressive strength of m3 is decreased to 49.11 MPa that showed a decrease in compressive strength by 1.9%. But in case of m4, there is sudden increase in compressive strength that raises the compressive strength to 52.36 MPa. Compressive strength is increased by 4.5%. So the results of test show that compressive strength does not follow a regular trend from m0 to m4. But from the results it is also concluded that compressive strength never went below the target strength for 28 days. This indicates that RCA can be used as replacement aggregates for compressive strength.

2. Flexural strength also followed the same pattern as of compressive strength. Flexural strength of control mix is 5.32MPa at age of 28 days. Flexural strength of mix m1 increased to 5.60 MPa. It shows that the increase in flexural strength is 5% for m1. For m2 flexural strength at age of 28 days is 5.40MPa, which shows an increase in flexural strength by 1.5%. Flexural strength of mix m3 is 5.38 and the flexural strength increased by 1 %. For the mix m4, flexural strength is 5.40 MPa. It shows that the flexural strength increased by 1.5 % at the age of 28 days. From the results and discussion of the results it is found that the flexural strength of RCA concrete is comparable to the natural aggregate concrete which is a positive point. So the RCA concrete can be used for flexural strength by adjusting W/C ratio.

3. Use of 5% of $MgSO_4$ solution caused the reduction in compressive strength. The compressive strength of RCA mixed concrete reduced upto 7%. Effect of sulphate solution increased when quantity of Crushed concrete aggregate increased. This study showed that the strength of m4 at 56 days was most affected. So with increase in sulphate caused reduction in compressive strength of concrete.

4. It was found that the RCA concrete have relatively lower bulk density, specific gravity and high water absorption as compared to natural concrete. This was due to the presence of mortar in present on recycled coarse aggregates.

5. Trial castings were done to arrive at water content and desired workability. So it was advisable to carry out trial castings with Crushed concrete aggregate proposed to be used in order to arrive at the water content and its proportion to match the workability levels and strengths requirements respectively.

6. It was observed that the Crushed concrete was viable source for construction of concrete pavements. Economical and environmental pressures justify suitability of RCA concrete as alternative to the natural concrete. Where there is non-availability of natural aggregate from new rocks RCA can be a good or viable replacement option for natural coarse aggregate in pavement construction.

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