Experimental Investigation on Field and Laboratory Curing of Natural and Recycled Aggregate Concrete

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Abstract
The present investigation aims to obtain strength characteristics of field and laboratory type concrete for M20, M30, M40, M50, and M60 grades. Extensive series of tests were carried out results in strength properties, such as cube compressive strength, modulus of rupture and Young's modulus of elasticity which are known as destructive testes. And further from non-destructive tests, ultrasonic pulse velocity (UPV) was examined. To maintain good quality in concrete, super plasticizer Sp-430 was used. In the present investigation these above five grades of concrete of the natural and recycled aggregates in two different curing environments were considered, namely lab-curing and field curing. Comparison in different strength properties which represent the quality control for concrete made using natural aggregate and concrete using recycled aggregate as well as curing in the lab (water tank curing) and curing in the field were considered. The investigation reported the loss in hardened concrete properties for field curing and using of recycled coarse aggregate concrete are in the limit of 1 to 10% for the grades of concrete M20 and M30 comparing with laboratory curing and use of natural aggregate, but the loss are up to 15% and above in high grades of concrete M40, M50 and M60 which is slightly inferior properties. Results are encouraging and quite interesting.

Keywords: Strength characteristics, lab curing and field curing, natural aggregate, recycled aggregate and high grades.

1. Introduction

In order for the inspector to be effective as a leader of quality concrete construction, that person must know the reasons for the many field tests and observations that are continually made during the concrete construction process. Using proper and consistent test procedures is vital to achieving high quality concrete structures. The inspector must also make detail observations, knowing when to ask questions and when to give direction. All too often the contractor and the inspector view each other as enemies. The inspector believes the contractor will do anything to cut costs. The contractor sees the inspector as an obstructionist only interested in getting something for nothing. Nobody wins in such situations. The owner is usually has to defend excessive claims, late completion, and the contractor loses profit and the inspector's career may be at a dead end.

1.1 Definition of the Quality in Construction

Quality in construction is defined as meeting or exceeding the requirement of client/owners. In construction industry, quality is used in different every than the product industry. In the product industry, quality of some product is better than the other, but we cannot say that one grade of concrete. Quality in construction is employed with conformity with which specifications are met.

1.2 Source and Production of Recycled Aggregate

Waste concrete can be produced from a number of different sources, many structures like bridges, reinforced concrete structures, plain concrete structures, concrete pavements & precast concrete units etc., which are discarded or demolished are the basic sources of recycled aggregates. Apart from this masonry rubble, especially brick rubble is another source of recycled aggregates. After the demolition of concrete elements, they are screened to remove foreign matter such as steel, wood, hardware plastics, lumber, dirt etc.

1.3 Need for the Work

Quality control of the concrete means rational use of resources. Quality control of the concrete is a procedure to implement appropriate mixing, proper compaction, correct placement and adequate curing. Quality control of the concrete ensures strict monitoring of every stage of concrete production and rectification of faults. Quality control of the concrete reduces maintenance costs.

1.4 Aims and Objectives

To determine mix proportions and strength of the grades of concrete fromM20, M30, M40, M50, and M60 using Natural aggregate and Recycled aggregate cured in field and laboratory.

To produce a concrete of the required strength and compare lab curing and field curing for M20 – M60 grades of concrete.

1.5 Scope of Work

For five grades of concrete that is M20-M60, the specimens considered are cubes, cylinders and prisms and for laboratory 90 specimens and field curing 90 specimens are considered.

2. Literature Review

HansenT.C and Narud [1] reported that densities of coarse recycled aggregates in saturated surface dry conditions ranging from 2340kg/m3 (for 4-8 mm material), to 2490 kg/m (for 16-32 mm material), independent of the quality of controlled concrete. Weshe K and Schulz R [2] found that recycled aggregate concrete consistently 10% lower compressive strength than controlled concrete made with natural aggregate.Kakizaki M Harada M [3] reported that the elastic modulus of recycled aggregate concrete to be 25% to 40% lower than controlled concrete. Gerardu JJA and Hendriks C.F. [4] report says a maximum of 15% lower modulus of elasticity of recycled aggregate concrete made with coarse recycled aggregate and natural sand.Seyed-Hassan Bagheri-Zadeh1; Hyoungkwan Kim2; Scott Hounsell3; Charles R. Wood4; Hamid Soleymani5; and Michael King6 (2007) [5] in their paper titled "Field Study of Concrete Maturity Methodology in Cold Weather", they reached to conclusions that, the concrete maturity method has been available for more than50 years, but its actual application in the construction industry has been quite slow.Al-Feel J R1 and Al-Saffar N S2 (2008) [6] in their paper titled "Properties of Self Compacting Concrete at Different Curing Condition and their Comparison with properties of Normal Concrete", concluded that;1) The compressive and tensile strength of Self-compacting concrete were higher than those of ordinary concrete at all considered ages and for all curing condition The SCC gave high early strength (before 28-days).S. Newbolds1, J. Olek2, (2001) [7] in their research titled "The Influence of Curing Conditions on Strength Properties and Maturity Development of Concrete", concluded that, based on the research results presented in this document.

Ronald G. Burg,(1996) [8] in his paper titled "The Influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete", Concluded that based on the results of this laboratory program, 1) As concrete mix temperature is increased from23°C (73"F), slump will decrease approximately 20mm for each 10°C increase in temperature (0.8 in. slump decrease for each 20"F temperature increase).

Manuel Celaya1, Soheil Nazarian2 and Deren Yuan3, (2009) □9□ their research titled "Comparison of Field and Laboratory Strengths of Concrete Slabs", they concluded that the differences between the strengths from lab-cured specimens and those measured on in-place slabs are discussed here.

3. Experimental Programme

3.1 Procurement of Materials and its Testing

Main constituents of the concrete viz., fine aggregate, cement and natural coarse aggregate have been procured from outside. Recycled aggregate is procured by breaking the cubes, cylinders etc. manually and crushed in a jaw crusher and required size of recycled aggregate is produced for the experimental programme and stacked separately to avoid contamination.

3.2Cement

Locally available ordinary Portland standard cement of 53 grade had procured, conforming to BIS: 269 (1976) and stored separately, where there is no ventilation, and the following tests have been carried out according to IS: 12269-197

3.3 Fine Aggregate

Fine aggregate i.e. natural sand conforming to grading zone -ii of table 4, of IS: 383 - 1970[25].was used as fine aggregate. Tests have been carried out as per the procedure given in IS: 383- (1970) . The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm; properties of the fine aggregate used in the experimental work are typically fineness modulus 3.5, moisture content 1% ,specific gravity 2.56, zone II sand,bulk density loose and compacted are 15.5 &16.94 kN/m3 respectively.

3.4 Natural Coarse Aggregate

Available coarse aggregates having the maximum size of 20 mm and 10mm were used in the present work. Testing of coarse aggregates was done as per IS: 383-1970 . The 10mm aggregates used were first sieved through 10mm sieve and then through 4.75 mm sieve and 20mm aggregates were firstly sieved through 20mm sieve.

3.5 Recycled Coarse Aggregate

The recycled coarse aggregate was obtained by crushing randomly selected laboratory tested samples like cubes, cylinders. These specimens are broken by hand first and then crushed in laboratory type special Jaw Crusher, wherein special sieve was attached to it to get different fractions like 0-6mm, 6-12mm, 12-20mm. All the tests to evaluate physical and mechanical properties as mentioned above (for natural aggregate) are also carried for recycled aggregate.

3.6 Water

Potable tap water was used in this experimental programme for the concrete mixing preparation and curing of specimens.

Table 1Properties of natural and recycled coarse aggregate

Property	Natural coarse aggregate	Recycled coarse aggregate
Specific gravity	2.69	2.52
Bulk density **a) Loose** **b) Compacted**	 13.87kN/m^3 15.34kN/m^3	 12.34kN/m^3 14.20kN/m^3
Voids **a) Compacted** **b) Loose**	 41.00 46.65	 38.79 46.81
Water absorption (%)	1 .00	4.60
Flakiness Index (%)	14.22	5.78
Elongation Index (%)	21.33	15.31
Crushing Value (%)	29.50	32.71
Impact Value (%)	18.32	32.09

Table 2 Mix proportion of concrete.

Grades		**M20**	**M30**	**M40**	**M50**	**M60**
NCA	C	363	429	530	562	631
	F	640	598	392	378	482
	CA	1204	1183	1318	1254	1149
	W	182	189	185	185	189
	SP in ml	-	-	208	220	248
RCA	C	363	429	530	562	631
	F	640	598	392	378	482
	CA	1204	1183	1318	1254	1149
	W	182	189	185	185	189
	SP in ml	-	84	208	220	248

3.7 Super Plasticizer

Complast SP-430 is concrete Super plasticizer based on SulphonatedNapthalene Polymers and supplied as a brown liquid instantly dispersible in water. Conplast SP-430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability. Complast - SP 430 saves cement up to 5-8% or more and it is non-toxic.

3.8 Curing Procedure

After the casting of cubes, cylinders and prisms the moulds are kept for air curing for one day and the specimens were removed from the moulds after 24 hours period of moulding of concrete. Marking has been done on the specimens to identify the grade of concrete, type of aggregate. To maintain the constant moisture on the surface of the specimens. Three specimens from each cubes, cylinders and prisms were placed in water tank for the lab curing, and the next three specimens were placed out site the lab for field curing and that was carried out, daily sprinkling water 3 to 4 times a day on the field specimens for 28 days.

3.9 Hardened Properties of Concrete

This is the most common property of concrete, because desirable characteristics of concrete are quantitatively related to compressive strength. The compressive strength of recycled aggregate concrete is compared with that of natural aggregate in different and similar environments of curing with respect to different grades of concrete.

M20, M30, M40, M50 and M60 Grades of Concrete, concrete specimens, which are prepared by using natural aggregate as coarse aggregate and recycled aggregate as coarse aggregate and cured for the age of 28 days in different and similar environments gained the cube compressive strength, are given the in tables: which show the variation of compressive strength of natural coarse aggregate concrete in the different environments of curing and recycled coarse aggregate concrete in different environments of curing and variation of compressive strength of similar grade of natural coarse aggregate concrete and recycled coarse aggregate in similar environments of curing respectively.

3.10 Ultrasonic Pulse Velocity Tests

M20, M30, M40, M50 and M60 Grades of Concrete, concrete specimens, which are prepared by using natural aggregate as coarse aggregate and recycled aggregate as coarse aggregate and cured for the age of 28 days in different and similar environments gained the cube ultrasonic pulse velocity tests , are given in the following tables: which show the variation of UPV tests of natural coarse aggregate concrete in the different environments of curing and recycled coarse aggregate concrete in different environments of curing and variation of UPV test with similar grade of natural coarse aggregate concrete and recycled coarse aggregate in similar environments of curing respectively.M20, M30, M40, M50 and M60 Grades of Concrete, concrete specimens, which are prepared by using natural aggregate as coarse aggregate and recycled aggregate as coarse aggregate and cured for the age of 28 days in different and similar environments gained the cube ultrasonic pulse velocity tests , are given in the tables:, which show the variation of UPV tests of natural coarse aggregate concrete in the different environments of curing and recycled coarse aggregate concrete in different environments of curing and variation of UPV test with similar grade of natural coarse aggregate concrete and recycled coarse aggregate in similar environments of curing respectively.

Table 3. Cube Compressive Strength of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	Compressive Strength @28days (MPa)					
	Natural Aggregate			Recycled Aggregate		
	Lab Curing	Field Curing	%Diff lab curing	Lab Curing	Field Curing	%Diff lab curing
M20	37.78	34.67	-8.23	35.70	33.48	-6.22
M30	42.23	37.93	-10.18	39.00	36.44	-6.56
M40	57.19	50.00	-12.57	48.89	44.30	-9.39
M50	60.74	51.30	-15.54	51.54	44.38	-13.89
M60	65.48	54.20	-17.23	54.86	45.64	-16.81

Table 4. Cube Compressive Strength of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	Compressive Strength @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	37.78	35.70	-5.51	34.67	33.48	-3.43
M30	42.23	39.00	-7.65	37.93	36.44	-3.93
M40	57.19	48.89	-14.51	50.00	44.30	-11.40
M50	60.74	51.54	-15.15	51.30	44.38	-13.49
M60	65.48	54.86	-16.22	54.20	45.64	-15.79

Table 5. Cube Ultrasonic Pulse Velocity of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	UPV @28days (MPa)					
	Natural Aggregate			Recycled Aggregate		
	Lab Curing	Field Curing	%Diff over Lab	Lab Curing	Field Curing	%Diff over Lab
M20	4.53	4.41	-2.65	4.32	4.28	-0.93
M30	4.57	4.44	-2.84	4.33	4.26	-1.62
M40	4.62	4.45	-3.68	4.35	4.26	-2.07
M50	4.65	4.46	-4.09	4.36	4.22	-3.21
M60	4.68	4.48	-4.27	4.28	4.08	-4.67

Table 6. Cube Ultrasonic Pulse Velocity of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	UPV @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	4.53	4.32	-4.64	4.41	4.28	-2.95
M30	4.57	4.33	-5.25	4.44	4.26	-4.05
M40	4.62	4.35	-5.84	4.45	4.26	-4.27
M50	4.65	4.36	-6.24	4.46	4.22	-5.38
M60	4.68	4.28	-8.55	4.48	4.08	-8.93

Table 7. Cylindrical Ultrasonic Pulse Velocity of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	UPV @28days (MPa)					
	Natural Aggregate			Recycled Aggregate		
	Lab Curing	Field Curing	%Diff over Lab	Lab Curing	Field Curing	%Diff over Lab
M20	4.51	4.40	-2.44	4.30	4.23	-1.63
M30	4.65	4.51	-3.01	4.42	4.32	-2.26
M40	4.70	4.55	-3.19	4.45	4.34	-2.47
M50	4.76	4.54	-4.62	4.47	4.30	-3.80
M60	4.91	4.65	-5.30	4.58	4.37	-4.59

Table 8. Cylindrical Ultrasonic Pulse Velocity of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	UPV @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	4.51	4.30	-4.66	4.40	4.23	-3.86
M30	4.65	4.42	-4.95	4.51	4.32	-4.21
M40	4.70	4.45	-5.32	4.55	4.34	-4.62
M50	4.76	4.47	-6.09	4.54	4.30	-5.29
M60	4.91	4.58	-6.72	4.65	4.37	-6.02

Table 9. Prisms Modulus of Rupture of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	UPV @28days (MPa)					
	Natural Aggregate			Recycled Aggregate		
	Lab Curing	Field Curing	%Diff over Lab	Lab Curing	Field Curing	%Diff over Lab
M20	3.56	3.29	-7.58	3.26	3.22	-1.23
M30	4.49	4.07	-9.35	4.08	3.93	-3.68
M40	5.46	4.90	-10.26	4.85	4.62	-4.74
M50	5.98	5.32	-11.04	5.26	4.98	-5.32
M60	6.75	5.50	-18.52	5.82	5.00	-14.09

Table 10. Prism Modulus of Rupture of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	UPV @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	3.56	3.26	-8.43	3.29	3.22	-2.13
M30	4.49	4.08	-9.13	4.07	3.93	-3.44
M40	5.46	4.85	-11.17	4.90	4.62	-5.71
M50	5.98	5.26	-12.04	5.32	4.98	-6.39
M60	6.75	5.82	-13.78	5.50	5.00	-9.09

Table 11. Cylindrical Modulus of Elasticity of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	UPV @28days (MPa)					
	Natural Aggregate			Recycled Aggregate		
	Lab Curing	Field Curing	%Diff over Lab	Lab Curing	Field Curing	%Diff over Lab
M20	27.4	2.57	-6.20	25.6	24.8	-3.13
M30	31.5	29.5	-6.35	29.2	28.2	-3.42
M40	38.6	35.7	-7.51	35.7	33.8	-5.32
M50	4.58	42.2	-7.86	41.7	37.9	-9.11
M60	47.4	43.6	-8.02	43.1	38.5	-10.67

Table 12.Cylindrical Modulus of Elasticity of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	UPV @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	27.4	25.6	-6.57	25.7	24.8	-3.50
M30	31.5	29.2	-7.30	29.5	28.2	-4.41
M40	38.6	35.7	-7.51	35.7	33.8	-5.32
M50	45.8	41.7	-8.95	42.2	37.9	-10.19
M60	47.4	43.1	-9.07	43.6	38.5	-11.70

Table 13. Cylindrical Compressive strength of Natural and Recycled Aggregates Concrete Cured in Different Environments

Grades	UPV @28days (MPa)	
	Natural Aggregate	Recycled Aggregate

	Lab Curing	Field Curing	%Diff over Lab	Lab Curing	Field Curing	%Diff over Lab
M20	19.00	17.77	-6.47	18.50	17.53	-5.24
M30	19.76	18.12	-8.30	18.97	17.86	-5.85
M40	22.34	19.43	-13.03	20.82	18.65	-10.42
M50	24.86	21.46	-13.68	22.58	18.95	-16.08
M60	25.65	21.98	-14.31	23.00	19.25	-16.30

Table 14. Cylindrical Compressive Strength of Natural and Recycled Aggregates Concrete Cured in Similar Environments

Grades	UPV @28days (MPa)					
	Lab Curing			Field Curing		
	Natural Agg	Recycled Agg	%Diff over Natural	Natural Agg	Recycled Agg	%Diff over Natural
M20	19.00	18.50	-2.63	17.77	17.53	-1.35
M30	19.76	18.97	-4.00	18.12	17.86	-1.43
M40	22.34	20.82	-6.80	19.43	18.65	-4.01
M50	24.86	22.58	-9.17	21.46	18.95	-11.70
M60	25.65	23.00	-10.33	21.98	19.25	-12.42

4. Discussions

4.1 Workability of the Concrete

The workability of recycled aggregate concrete made with recycled coarse aggregate for M20, M30, M40, M50, and M60 are less by 17.33%, 25%, 62.5%, 40%, and 0% respectively when compared with the workability of natural aggregate concrete. And compaction factors for recycled coarse aggregate concrete also for m10, m20, m30, m40, m50, and m60 are less by 2.17%, 4.45%, 14.77%, 14.46% and 22.50% respectively when compared with the compaction factors of natural aggregate concrete. This probably can resolve by enough soaking of recycled coarse aggregate with water. Thus workability of recycled aggregate concrete in terms of its mobility and place ability is satisfactory and hence it possess no problem during construction. All the test results are presented in Tables 1-14**.**

Compressive Strength of Concrete (NACvs RAC field and lab)

The compressive strength of natural aggregate concrete and recycled aggregate for different grades of concrete in similar and different environments of curing were compared and discussed below, M20, M30, M40, M50 and M60 Natural Grades of Concrete Cured in the Lab vs. natural aggregate cured in the lab attained the cube compressive strength (37.78, 42.23, 57.19, 60.74 and 65.48) MPa at 28 days of curing respectively. The corresponding cube compressive strength attained by natural aggregate cured in the field are (34.67, 37.93, 50.00, 51.30 and 54.20) MPa at 28 days of curing respectively. this indicates that cube compressive strength of natural aggregate cured in the field are 92%, 90%, 88%, 85% and 83% of that corresponding cube compressive strength of natural aggregate cured in the lab, in other word, loss of cube compressive strength in respect of field curing are of the order of 8%, 10%, 12%,15% and 17%.M20, M30, M40, M50 and M60 Recycled Grades of Concrete Cured in the Lab vs.

Field,Naturalaggregate cured in the lab attained UPV tests, (4.51, 4.65, 4.70, 4.76 and 4.91) km/s at 28 days of curing respectively.

The corresponding cylindrical UPV test attained by natural aggregate cured in the field are (4.40, 4.51, 4.55, 4.54 and 4.65) km/s, at 28 days of curing respectively. this indicates that UPV test of natural aggregate cured in the field are 97%, 97%, 97%, 95% and 95% of that corresponding cylindrical UPV tests of natural aggregate cured in the lab,. In other word, loss of cylindrical UPV tests, in respect of field curing is of the order of 3%, 3%, 3%, 5% and 5%.

5. CONCLUSIONS

1. Recycled coarse aggregate indicated high water absorption when compared to natural coarse aggregate, which is soaking of recycled coarse aggregate before mixing is necessary.
2. Slump test indicate that workability of recycled aggregate concrete made with recycled coarse aggregate is lower by 17%, 25%, 62%, 40%, and 0% respectively when compared to the workability of natural aggregate concrete.
3. Cube compressive strength of natural coarse aggregate cured in the field for grades, M20, M30, M40, M50 and M60, are found less by 8%, 10%, 12%, 15% and 17% respectively for similar natural coarse aggregate cured in the lab.
4. Cube ultrasonic pulse velocity test of natural coarse aggregate cured in the field for grates, M20, M30, M40, M50 and M60, are found less by 3%, 3%, 4%, 4% and 4% respectively for similar natural coarse aggregate cured in the lab. And cube ultrasonic pulse velocity test of recycled coarse aggregate cured in the field for grades, M20, M30, M40, M50 and M60, are found less by 1%, 2%, 2%, 3% and 5% respectively for similar recycled coarse aggregate cured in the lab.
5. Cube ultrasonic pulse velocity test of recycled coarse aggregate cured in the lab for grades, M20, M30, M40, M50 and M60, are found less by 5%, 5%, 6%, 6% and 8% respectively for natural coarse aggregate cured in the lab.
6. Flexural strength of natural coarse aggregate cured in the field for grades, M20, M30, M40, M50 and M60, are found less by 8%, 9%, 10%, 11% and 8% respectively for similar natural coarse aggregate cured in the lab. And prisms flexural strength of recycled coarse aggregate cured in the field for grades, M20, M30, M40, M50 and M60, are found less by 1%, 4%, 5%, 5% and 14% respectively for similar recycled coarse aggregate cured in the lab.
7. Cylindrical compressive strength of recycled coarse aggregate cured in the lab for grades, M20, M30, M40, M50 and M60, are found less by 3%, 4%, 7%, 9% and 10% respectively for natural coarse aggregate cured in the lab. And cylindrical compressive strength of recycled coarse aggregate cured in the field for grades, M20, M30, M40, M50 and M60, are found less by 1%, 2%, 4%, 12% and 13% respectively for natural coarse aggregate cured in the field.
8. The study investigated that the loss in properties of field curing and using of recycled coarse aggregate is in the limit of 1 to 10% for the grades of concrete up to M30, but the losses are up to 15% or above in high grades of concrete from M40 and above which is slightly inferior properties.

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