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Cementing Property Evaluation Of Recycled Fine Aggregate

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ABSTRACT: *Cement is getting expensive day by day. Finding the replacement of cement is now a crucial issue of the world. Recycling of cement can be the better alternative of the fresh cement. The focus of this research is to find out the cementing property of the recycled fine aggregate. The research work is divided into two parts; firstly, finding the material properties of recycled fine aggregate and secondly, examining the compressive strength of the recycled fine (RF) mortar at different proportion. Compressive strength is tested for the fine sand (inert) in case of different proportion as well. Then a comparison is drawn in between the cementing property of recycled fine aggregate and the fine sand to find out the feasibility of using recycled fine aggregate in the construction industry. Results of the experiments clearly show that the recycled fine aggregate has the considerable amount of cementing property.*

Keywords - *Cementing property, Recycled fine aggregate, Fine sand and Compressive strength.*

I. Introduction

Concrete is made from a properly proportioned mixture of cement, water, fine and coarse aggregates, and sometimes, chemical or mineral admixtures. The most common hydraulic cement used in construction today is composite cement. This cement is sometimes very costly. For finding the better replacement of cement, cementing property of recycled fine aggregate is tested. Recycled fine aggregate is a fine aggregate collected from the concrete during crushing. Two types of recycled fine aggregates are taken as the test specimen;

1. Recycled fine aggregate of stone (RFS)
2. Recycled fine aggregate of brick (RFB)

First of all, the material properties like; fineness modulus, bulk specific gravity, absorption capacity, unit weight are determined. Then the compressive strength of recycled fine (stone and brick) aggregate after mixing it with cement at different proportion is found out. On the other hand, the compressive strength of the fine sand (FS) is determined after mixing it with the cement following the same proportion. The fine sand of filling sand is considered as the inert material because it is used only for the filling purpose. More compressive strength in the recycled fine indicates the cementing property in recycled fine.

II. Recycled Fine Aggregate

2.1 General

The first question comes to our mind is that why did we consider the recycled fine as the probable replacement? To get the answer of this question, we need to know the characteristics of cement. The "hydration" property of cement is very important property in this case. During manufacture of cement, chemical analysis is made frequently to ensure a uniformed high-quality product. Four mineral phases make up to 95% of Composite cement clinker in mass are strongly influencing the chemical properties and behavior of all cements. These mineral phases, their approximate chemical formula and common abbreviation are:

1. Tri-calcium silicate ($3CaO\ SiO_2$) : C_3S
2. Di-calcium silicate ($2CaO\ SiO_2$) : C_2S
3. Tri-calcium aluminate ($3CaO\ Al_2O_3$) : C_3A
4. Tetra-calcium aluminoferrite ($4CaO\ Al_2O_3\ Fe_2O_3$) : C_4AF

The characteristics of hydration of cement compounds are shown in Table 1.

Table 1. Characteristics of hydration of cement compounds

Compound	Reaction rate	Strength attained	Liberation of heat, cal/g at 7 days
C3S	Moderate	High	High (1.10)
C2S	Slow	Low at first, high later	Low (0.20)
C3A	Fast	Low	Very high (1.95)
C4AF	Moderate	Low	Moderate (0.50)

So it is clear that the hydration of cement is varied with the time. At the initial stage the outer edge of the concrete hydrated first. The hydration procedure is a continuous process for a long time. The outer surface is hydrated first because of the air contact. In the inner part the hydration continues slowly because of the lack of air contact. So after a long time, if we test the inner part of the concrete then definitely we will find the unhydrated part of cement. The clear representation can be achieved from the **Fig. 1**. It is possible to get this type of unhydrated part of cement from the demolished concrete. The old buildings are replaced by the new buildings frequently to modernize the infrastructures. So it is required to demolish the old buildings. The concrete part of the demolished building could be a large source of unhydrated cement. For this research, recycled fine from concrete slab of the demolished buildings and the concrete cylinders after the compressive strength test in the lab was taken as the specimen for the experiment.

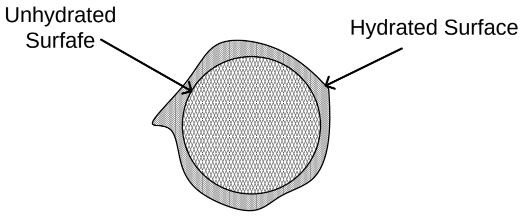


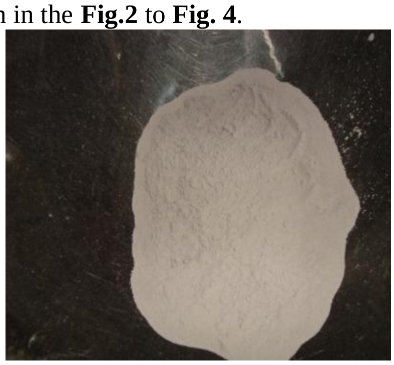
Fig. 1. Cement particle after demolish of concrete

2.2 Collection of the recycled fine aggregate

During the crushing of concrete in the crusher, the recycled fine aggregate (stone and brick) was collected .This recycled fine aggregate is the inner part of the concrete. After collecting the recycled fine aggregate it was preserved into non-air entrained condition. The purpose of keeping those recycled fine into the non-air entrained condition is to avoid the air contact with the recycled fine aggregate. The air contact may cause the hydration in the unhydrated part of the cement.

Before preparing cement mortar, recycled fine aggregate was sieved through #200 sieve to get the cement like powder. The same sieving procedure is done for the fine sand (inert) as well. The recycled fine (stone and brick) aggregate and the fine sand after sieving is shown in the **Fig.2** to **Fig. 4**.

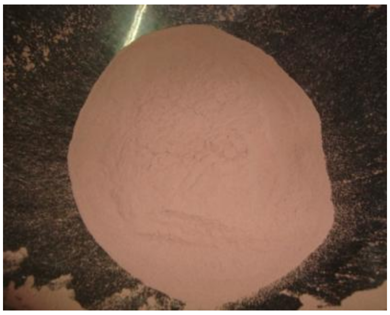
a. RFS (Before sieving)



b. RFS (After sieving)

Fig. 2. Recycled fine aggregate of stone

a. RFB (Before sieving)



b. RFB (After sieving)

Fig. 3. Recycled fine aggregate of brick

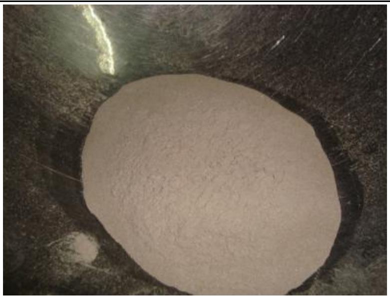


Fig. 4. Fine Sand

After collecting the sieved recycled fine aggregate, we use this material for preparing cube for cement mortar test to determine the cementing properties of recycled fine as a substitute of cement in various percentages which is shown in **Fig. 5**. Then we compare it with fine sand which has no cementing property. After comparing the result we got that the recycled fine has some cementing property which is our major finding from recycled fine aggregate test.

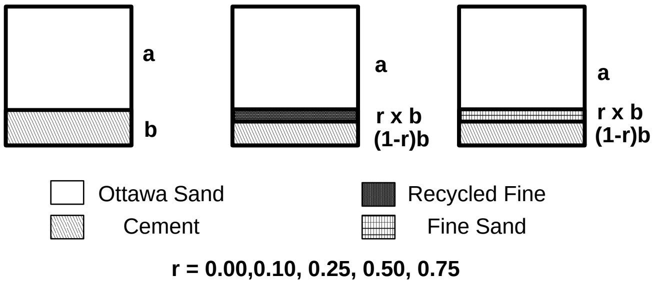


Fig. 5. Addition of recycled fine aggregate and fine sand with cement in different proportion

III. TEST RESULT

3.1 Material Properties

In this part of research, the material properties of recycled fine (stone and brick) aggregate and the fine sand is determined. Table 2 shows the material properties material properties of the recycled fine and fine sand in a tabular form.

Table 2. Average value of material properties of the fine aggregate

Material	Bulk specific gravity		Absorption capacity (%)	Unit weight (Kg/m^3)	
	OD	SSD		OD	SSD
Recycled fine of stone	2.36	2.56	8.4	1389	1506
Recycled fine of brick	1.82	2.12	16.4	1271	1480
Fine sand	2.45	2.42	3.4	1599	1657

3.2 Compressive strength test

Cement mortar test method was followed to get the compressive strength of the recycled fine aggregate. After preparing the cement mortar cubes, the cubes were tested in the hydraulic compressive strength testing machine which is shown in **Fig. 6**.

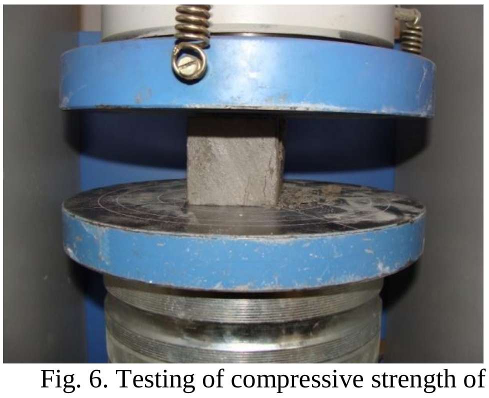


Fig. 6. Testing of compressive strength of cube

The experiment for the compressive strength test was divided into five batches. The summarized average values of the compressive strength are given in the Table 3 to Table 7. The graphical comparison of recycled fine (stone and brick) and fine sand is given in the **Fig. 7** and **Fig. 8**.

Table 3. Average Compressive strength of mortar replacing cement with different percentage of RFS & FS content (Batch-I)

Material ID	Strength in psi(MPa) (3 Days)	Strength in psi(MPa) (7 Days)	Strength in psi(MPa) (28 Days)
100%C	2506 (17.3)	3215 (22.2)	4458 (30.7)
75%C+25%RFS	1454 (10.1)	1872 (12.9)	2452 (16.9)
75%C+25%FS	1313 (9.1)	1753 (12.1)	2260 (15.6)
50%C+50%RFS	626 (4.3)	784 (5.4)	1148 (7.9)
50%C+50%FS	541 (3.7)	684 (4.7)	971 (6.7)
25%C+75%RFS	137 (0.94)	171 (1.2)	244 (1.7)
25%C+75%FS	130 (0.9)	165 (1.1)	210 (1.4)

Table 4. Average Compressive strength of mortar replacing cement with different percentage of RFS & FS content (Batch-II)

Material ID	Strength in psi (MPa) (3 Days)	Strength in psi (MPa) (7 Days)	Strength in psi (MPa) (28 Days)
100%C	-	3215 (22.2)	4458 (30.7)
80%C+20%RFS	-	2057 (14.2)	3115 (21.5)
80%C+20%FS	-	1980 (13.7)	2461 (17.0)
60%C+40%RFS	-	1166 (8.1)	1665 (11.5)
60%C+40%FS	-	969 (6.7)	1549 (10.7)
40%C+60%RFS	-	492 (3.4)	795 (5.5)
40%C+60%FS	-	431 (3.0)	638 (4.4)

Table 5. Average Compressive strength of mortar replacing cement with different percentage of RFS , RFB & FS content (Batch-III)

Material ID	Strength in psi(MPa) (3 Days)	Strength in psi (MPa) (7 Days)	Strength in psi (MPa) (28 Days)
100%C	2614 (18.02)	3625 (25)	4493 (30.98)
90%C+10%RFS	2558 (17.64)	2979 (20.54)	3644 (25.13)
90%C+10%RFB	2718 (18.74)	3202 (22.08)	3921 (27.04)
90%C+10%FS	2281 (15.73)	2657 (18.32)	3398 (23.43)
75%C+25%RFS	1694 (11.68)	1749 (12.06)	2632 (18.15)
75%C+25%RFB	1848 (12.74)	1899 (13.09)	1882 (19.87)
75%C+25%FS	1682 (11.60)	1759 (12.13)	2563 (17.67)
50%C+50%RFS	575 (3.96)	866 (5.97)	1246 (8.59)
50%C+50%RFB	873 (6.02)	1321 (9.11)	1540 (10.62)
50%C+50%FS	791 (5.45)	1163 (8.02)	1749 (12.06)
25%C+75%RFS	295 (2.03)	376 (2.59)	528 (3.64)
25%C+75%RFB	373 (2.57)	457 (3.15)	763 (5.26)
25%C+75%FS	134 (0.92)	264 (1.81)	300 (2.07)

Table 6. Average Compressive strength of mortar replacing cement with different percentage of RFS, RFB & FS content (Batch-IV)

Material ID	Strength in psi (MPa) (3 Days)	Strength in psi (MPa) (7 Days)	Strength in psi (MPa) (28 Days)
100%C	2614 (18.02)	3625 (25)	4493 (30.98)
90%C+10%RFS	2558 (17.64)	2979 (20.54)	3644 (25.13)
90%C+10%RFB	2718 (18.74)	3202 (22.08)	3921 (27.04)
90%C+10%FS	2281 (15.73)	2657 (18.32)	3398 (23.43)
75%C+25%RFS	1694 (11.68)	1749 (12.06)	2632 (18.15)
75%C+25%RFB	1848 (12.74)	1899 (13.09)	1882 (19.87)
75%C+25%FS	1682 (11.60)	1759 (12.13)	2563 (17.67)
50%C+50%RFS	575 (3.96)	866 (5.97)	1246 (8.59)
50%C+50%RFB	873 (6.02)	1321 (9.11)	1540 (10.62)
50%C+50%FS	791 (5.45)	1163 (8.02)	1749 (12.06)
25%C+75%RFS	295 (2.03)	376 (2.59)	528 (3.64)

Table 7. Average Compressive strength of mortar replacing cement with different percentage of RFS,RFB & FS content(Batch-V)

Material ID	Strength in psi (MPa) (3 Days)	Strength in psi (MPa) (7 Days)	Strength in psi (MPa) (28 Days)
100%C	2614 (18.02)	3625 (25)	4493 (30.98)
90%C+10%RFS	2339 (16.13)	2728 (19.81)	3476 (23.97)
90%C+10%RFB	2641 (18.21)	3016 (20.80)	4348 (29.98)
90%C+10%FS	2281 (15.73)	2657 (18.32)	3398 (23.43)
75%C+25%RFS	1822 (12.56)	2000 (13.79)	2621 (18.07)
75%C+25%RFB	1999 (13.09)	2093 (14.43)	2734 (18.85)
75%C+25%FS	1682 (11.60)	1759 (12.13)	2563 (17.67)
50%C+50%RFS	831 (5.73)	1243 (8.57)	1379 (9.51)
50%C+50%RFB	1290 (8.89)	1336 (9.21)	1629 (11.23)
50%C+50%FS	791 (5.45)	1163 (8.02)	1749 (12.06)
25%C+75%RFS	292 (2.01)	331(2.28)	511 (3.52)
25%C+75%RFB	404 (2.78)	563 (3.88)	635 (4.38)
25%C+75%FS	134 (0.92)	264 (1.81)	300 (2.07)

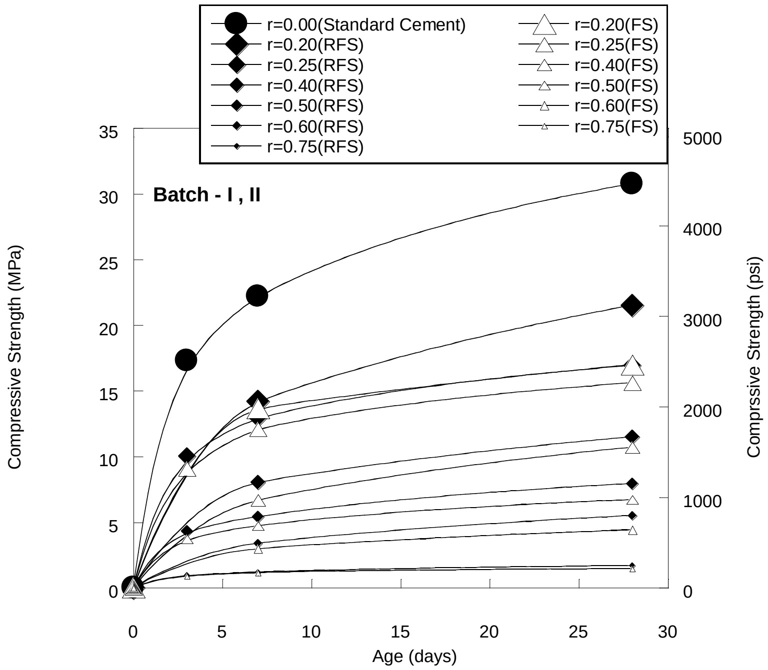


Fig. 7. Compressive strength vs. age graph for Batch- I, II

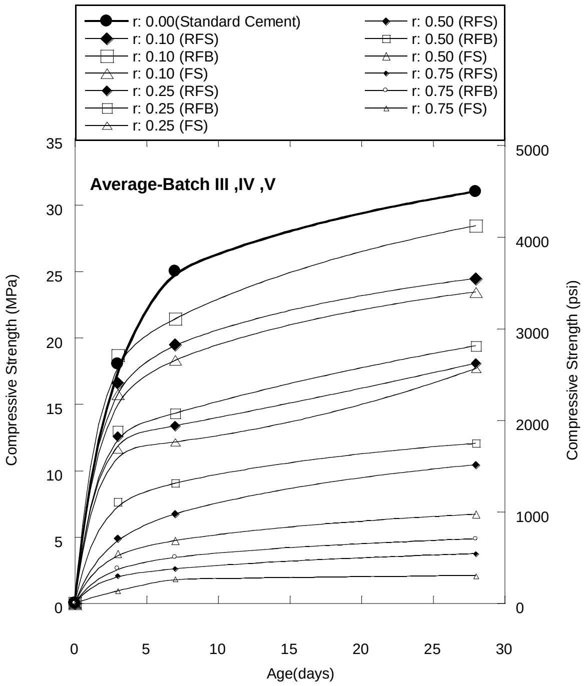


Fig. 8. Average compressive strength vs. age graph for Batch- III, IV, V

IV. Conclusion

Based on the result of the experiment, it can be concluded that there is some unreacted cement in the concrete. The given graph and table show the proof of the cementing property in the recycled fine aggregate. So the following conclusion can be drawn;

1. Recycled fine aggregates contain moderate level of cementing property.
2. It will not be wise to use recycled fine in the structural member of the building but in case of rigid pavement construction recycled fine can be effective as a binding material.
3. We cannot use recycled fine as 100% replacement of cement but it can be 15%-20% replacement of the fresh cement which is cost effective.
4. The most effective scope to use the recycled fine (before sieving) is as the replacement of sand in the concrete mix. In that case some additional cementing strength can be gained from the cementing property of recycled fine.

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