Improvement of Recycled Brick Aggregate

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Declaration of Candidate

It is hereby declared that this thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma (except for publication).

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Abstract

A study was conducted to improve the quality of recycled brick aggregate (RBA) for use in concrete as coarse aggregates. For this, demolished concrete blocks were collected and crushed into pieces (5 mm to 25 mm). For the improvement of RBA, three types of coatings were used, such as cement paste coating, fly ash plus hydrated lime coating, and slag plus hydrated lime coating. Both single layer coating and double layer coating were applied on the RBA. The properties of recycled aggregates and coated aggregates, such as specific gravity, absorption capacity, and abrasion loss were investigated. Cylindrical concrete specimens (diameter 100 mm and height 200 mm) were made with W/C of 0.45 and 0.55, cement content of 340 kg/m^3, and sand to aggregate volume ratio of 0.44. As a control case, virgin brick aggregate was also investigated. A separate mixing method of concrete was also investigated by considering mixing of RBA with cement paste before adding other ingredients of concrete. In addition to the cylindrical concrete specimens, mortar specimens were also made by screening concrete with a #4 sieve (opening 4.75 mm). After mixing concrete, slump test was conducted for fresh concrete. Concrete specimens were tested after 7, 14, and 28 days for compressive strength, tensile strength, and Ultrasonic Pulse Velocity (UPV). Rapid chloride migration test (RCMT) was also conducted after 28 days. Moreover, interfaces of aggregate were also investigated using a Scanning Electron Microscope (SEM) at 28 days.

The abrasion of coated RBA is reduced and also coated RBA showed higher specific gravity. The compressive strength of concrete is increased for the coated RBA, especially for the cases with double layer coating with cement or slag plus hydrated lime coating. Mixing of RBA with cement paste before adding other ingredients of concrete in the mixture also showed better performance.

Keywords: Cement, Coating, Compressive Strength, Concrete, Recycled Brick Aggregate, Hydrated Lime, Slag, UPV.

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Chapter 1 Introduction

Concrete is utilized to give strength, durability, and adaptability to a structure. Because of these useful qualities, concrete has become a dependable and durable material for both commercial and residential construction works[1]. Production and transportation of cement and concrete is responsible for 8% annual carbon emission.[2] So cement production should be kept to an extent which will ensure limited carbon footprint. Alongside that maximum use of produced concrete needs to be ensured to prevent unnecessary production of cement.

Moreover, 1.8 million tons of CO_2 is emitted annually by brick kilns in Dhaka only.[3] The mass extraction natural stone aggregates are reducing its availability and the mining work required for its extraction is playing a considerable role in global carbon emission.

Recycled brick aggregates can play a major role in ensuring sustainable construction activities. If NBA (Natural Brick Aggregates) or natural stone aggregates are replaced with RBA (Recycled Brick Aggregates) the overall carbon emission caused by the production of coarse aggregates can be reduced to a significant extent. Also using crushed concrete as RBA ensures the reusing or recycling of concrete which is beneficial for the environment. The significance of employing recycled resources, particularly recycled aggregate, cannot be overlooked given the rising emphasis on environmental preservation and resource efficiency. Recycling decreases waste and energy use, making the construction industry more environmentally friendly[4]. Crushing and processing of previously used concrete structural components is the major source of RCA. In addition to crushed concrete, RBA also includes other mixed elements such lime, fly ash, cement paste & slag[5].

Chapter 2 Literature Review

2.1 Properties of Recycled Brick Aggregates

2.1.1 The Absorption Capacity of RBA

The mortar of RBA (Recycled Brick Aggregate) raises RBA's capacity to absorb water or liquid as compared to NBA (Natural Brick Aggregate) which is caused by the porosity of the adhered mortar. Absorption capacity of NBA ranges between 0.34% to 3.00% while RBA ranges between 5.00% to 14.75%.[6]

2.1.2 L. A. Abrasion Loss

Los Angeles Abrasion test is conducted to measure the degree of degradation aggregates subjected to frequent impact loadings. The test setup includes the rotating steel drum filled with a selected number of steel balls. It is a popular test procedure for determining aggregate toughness and abrasion properties is the Los Angeles (L.A.) abrasion test.[7] The L. A. abrasion test result shows a higher percentage of loss in the case of RBA than NBA. The reason for this is the higher porosity of RBA than compared to NBA.[6]

2.1.3 Specific Gravity

The specific gravity of NBA is more than that of RBA. The denser micro-structure of NBA causes the specific gravity to be higher than RBA as the adhered mortar of RBA is more porous than the original aggregate. RBA has a specific gravity between 1.91 and 2.7 whereas, NBA ranges between 2.4 to 2.89.[6]

2.2 Properties of Concrete Produced with RBA

2.2.1 Workability

The workability of RAC (Recycled Aggregate Concrete) is found to be lower than NAC (Natural Aggregate Concrete). The reason for such behavior is the higher void percentage and lower density of RBA than compared to NBA. In order to obtain similar workability for both RAC and NAC 5%-15% more water in weight is required.[8]

2.2.2 Compressive Strength

After testing the compressive strength of RAC for different replacement percentage of natural aggregates with RBA the strength of concrete was found to be reducing with the increase of RBA content (%). 86% of compressive strength found for 100% NBA was obtained in case of complete replacement by RBA.[8] The strength development rate is found to be higher in case RAC as compared to NAC. The reason for this is the additional mortar content in the RAC. [6] After 28 days of curing the compressive strength found for RAC is 10% to 35% lower than NAC.[9]

2.2.3 Flexural Strength

The flexural strength shown by RAC is 10% lower than that of NAC.[10]

2.2.4 Tensile Strength

The tensile strength of the concrete is found to have reduced by 10% in a study in case of RAC compared to NAC.[11]

2.2.5 Shrinkage

As the percentage of RBA rises, the shrinkage values rise as well. The curves tend to settle by the conclusion of the test period for RBA percentages up to 50%. However, the shrinkage values continue to rise with time at increasing percentages (more than 50%). This is because a significant amount of water has been held in the RBA's pores. When the proportion of RBA rises by 10%, shrinkage rises between 35 and 45 mm/m. These findings are consistent with those of other authors who demonstrate that the shrinkage increase occurs in the lower part of this interval when only the fine fraction or only the coarse fraction is substituted, whereas the shrinkage occurs in the upper part of the interval when both fractions are substituted.[12]

2.3 Possible Ways of Performance Enhancement and their Impacts

2.3.1 Replacing a part of Ordinary Portland Cement by Fly Ash

If 20% of OPC is replaced by FA in the mix, the compressive strength increases by more than 10% for 50% RBA content and 5% for 100% RBA content.[13] The workability of fresh concrete is observed to have increased after taking this approach.[14] Fly ash reduces the absorption capacity of concrete. Replacing a portion of OPC by FA causes the RAC to be more resistive against shrinkage.[13]

2.3.2 Two Step Mixing Process

In two step mixing process, the water used to mix the concrete was split into two parts and added to the mixture at two different times. This method of mixing calls for combining all the aggregates for 60 seconds, followed by adding the first quantity of water, and mixing again for another 60 seconds. After mixing the aggregates with the first part of water for 60 seconds, cement is added, and mixing continues for another 30 seconds. Later, the second amount of water is added, and mixing continues for an additional 120 seconds. This technique is developed by Tam et al. (2005) and Tam and Tam (2007). This technique is observed to have improved the ITZs of the RAC. The approach is observed to have caused the cement slurry to gel up the RBA inside and form a stronger ITZ by filling the cracks and pores.[15]

2.3.3 Coating RBA with Pozzolanic Powders

RBA was coated with slurry of a mixture of pozzolanic powders (FA, SF, Slag) in the initial stage of the concrete mixing. After the coating the remaining items were added to produce fresh concrete. This technique is reported to have improved the compressive strength of the concrete as well as increased the workability of fresh RAC.[16]

2.3.4 Impregnating RBA with a 10% Silica Fume Solution

The compressive strength increased by 23-33% and 15%, respectively, after the silica fume treatment at ages 7 and 28 days. The process begins with dissolving 1kg of Silica Fume in 10L water and super plasticizer (1% by weight of SF) in a Hobart Mixer. RBA were soaked in the solution for 24h after keeping in the oven for 48h. The RBA were then dried in the oven for the second time to ensure proper penetration of SF into the RBA.[17]

Chapter 3 Experimental Methods

3.1 Aggregates

Crushed blocks of concrete were collected from structural members of demolished concrete building. The blocks were then broken into three pieces of three types of sizes as 25 mm to 20 mm, 20 mm to 10 mm, 10 mm to 5 mm. The pieces were shaken with sieve of required opening to ensure proper gradation. After separating three different sizes of aggregates, 5% of the aggregate were mixed from 5 to 10 mm, 57.5% were mixed from 10 to 20 mm, 37.5% were mixed from 20 to 25 mm. Few properties were also tested of this recycled brick aggregates (RBA) which are specific gravity according to ASTM C-127, absorption capacity according to ASTM C-128-03 and abrasion loss according to ASTM C131-03. Same properties were tested for natural brick aggregates (NBA) which were procured from local suppliers. We also measured the specific gravity of cement, sand, fly ash and slag with respect to both water and kerosine.

3.2 Procedure of coating

The prime objective of this research was to improve the properties of recycled brick aggregate (RBA). To achieve this purpose, several treatment methods were attempted. Applying coating layer on the surface of the aggregate was our main treatment method. The objectives of coating the surface of the aggregates were filling up the pores on the aggregates and reducing the absorption capacity which can improve its properties and increase the strength of concrete made with these aggregates. Three types of coating were applied which are cement coating, fly ash and hydrated lime coating, slag and hydrated lime coating. To determine the optimum mixture proportions of these materials, trial and error method was followed. After conducting several trials, a mixture proportion which produced the most smooth and strong coating layer covering the entire surface of the aggregate was finalized. Both single and double layer of coating were applied to each type of coating. The amount of coating materials was determined for 1000g of aggregates. The mixture proportions of the coating materials for 1000g of aggregates are shown below:

Table 1: Coating Materials for Fly Ash and Lime coating

Fly Ash and Lime coating	
FA	80g
Lime	20g
Water	30g
Admixture	1g

Table 2: Coating Materials for Slag and Lime coating

Slag and Lime coating	
Slag	80g
Lime	20g
Water	35g
Admixture	1g

Table 3: Coating Materials for Cement coating

Cement coating	
Cement	100g
Water	30g
Admixture	1g

The amount of water required for slag and lime coating was slightly higher compared to other types of coating because it kept producing a rough layer on the surface of the aggregate and was taking more time to react with the water. As a solution, the amount of water was increased to 35g from 30g. In case of double coating, same amount of coating materials was applied on the single layer of coating for per 1000g aggregate after the single coating is fully hydrated. The whole coating procedure was conducted by concrete mixer machine. Initially, we poured the coating materials inside the mixer machine and let it mix for some time. Then we added the water and again mixed for some time which produced a slurry. Finally, the aggregates were added to let the surface to be coated by coating materials by mixing for sufficient time. Once the coating procedure was finished, it was spread over a large polythene in the open atmosphere to facilitate the hydration process. The aggregates were separated maintaining a distance between those so that those cannot create bonds between those during the hydration process. After that, all the aggregates were covered with another large polythene to ensure that the moisture is preserved. The aggregates were kept in this condition for a duration of one day. The next day, covering polythene was removed and all the aggregates were collected. The aggregates which were entangled with one another were detached manually by hand. After collecting the aggregates, those were stored in some buckets. The buckets ere sealed properly to prevent any moisture leakage. The aggregates were cured frequently by spraying water in a regular interval. Properties such as specific gravity (ASTM C127), absorption capacity (ASTM C128-03) and abrasion loss (ASTM C131-03) were determined for each type of coated aggregate too.

Figure 1: Coated aggregates spread over polythene

Figure 2: Coated aggregates covered with polythene

Figure 3: Coated aggregates stored in buckets

Figure 4: Cement single coating

Figure 5: Cement double coating

Figure 6: Fly ash and lime single coating

Figure 7: Fly ash and lime double coating

Figure 8: Slag and lime single coating

Figure 9: Slag and lime double coating

3.3 Cases

Two types of w/c ratio were considered for casting cylindrical concrete specimens in this research which are 0.45 and 0.55. Apart from the single and double coated aggregates, 100% natural brick aggregate (NBA), 100% recycled brick aggregate (RBA), a mixing variation method was also considered for making concrete specimens. Combining all these cases, there were total of 18 cases in this research. Breakdown of all the cases is shown below:

1. 100% Natural Brick Aggregate (NBA) for W/C = 0.45 in concrete
2. 100% Natural Brick Aggregate (NBA) for W/C = 0.55 in concrete
3. 100% Recycled Brick Aggregate (RBA) for W/C = 0.45 in concrete
4. 100% Recycled Brick Aggregate (RBA) for W/C = 0.55 in concrete
5. Cement Single Coating on the surface of aggregate for W/C = 0.45 in concrete
6. Cement Single Coating on the surface of aggregate for W/C = 0.55 in concrete
7. Cement Double Coating on the surface of aggregate for W/C = 0.45 in concrete
8. Cement Double Coating on the surface of aggregate for W/C = 0.55 in concrete

9. Fly ash + Hydrated lime Single Coating on aggregates for W/C = 0.45 in concrete
10. Fly ash + Hydrated lime Single Coating on aggregates for W/C = 0.55 in concrete
11. Fly ash + Hydrated lime Double Coating on aggregates for W/C = 0.45 in concrete
12. Fly ash + Hydrated lime Double Coating on aggregates for W/C = 0.55 in concrete
13. Slag + Hydrated lime Single Coating on aggregates for W/C = 0.45 in concrete
14. Slag + Hydrated lime Single Coating on aggregates for W/C = 0.55 in concrete
15. Slag + Hydrated lime Double Coating on aggregates for W/C = 0.45 in concrete
16. Slag + Hydrated lime Double Coating on aggregates for W/C = 0.45 in concrete
17. Mixing Variation for W/C = 0.45 in concrete
18. Mixing Variation for W/C = 0.55 in concrete

3.4 Mixing Procedure

Regarding normal mixing procedure, initially full cement and sand was poured inside mixer machine simultaneously and mixed for some time. Then water was added and mixed for some time to form the mortar. Finally aggregate was added and mixed for some time which produced fresh concrete. In case of mixing variation, a slight change was executed in mixing procedure. Firstly, half cement and half water were added and mixed for 1.5 minutes. Then, recycled brick aggregate (RBA) was added and again mixed it for 2 minutes. Finally, full sand was added along with remaining cement and water which produced fresh concrete.

3.5 Specimen Breakdown

A total of 12-cylinder specimens of 4 inch diameter and 8 inch height were allotted for casting for each case. 3 for compressive strength at 7 days, 3 for compressive strength at 14 days, 2 for compressive strength at 28 days, 2 for tensile strength test at 28 days, 1 for Rapid Chloride

Migration Test (RCMT), 1 for carbonation test. Therefore, total of 216 cylindrical concrete specimen were casted consisting of all 18 cases.

3.6 Mix Design of Concrete

Ordinary Portland Cement (SEM Type-I) was used for casting the concrete specimens. For mix design, cement content was taken 340 kg/m^3. Typical river sand and normal tap water was used for casting as well. High Range Water Reducing Admixture (HRWRA) was used in cases of w/c = 0.45 to improve the workability. 0.8 ml admixture was added for per kg cement. The amount of materials required for making 1 m^3 of concrete in the mix design for all the cases is listed in the chart below:

Table 4: Concrete mix design for all cases

Sl no.	Case Designation	Cement (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	CA (kg/m^3)
1	NBA 0.45	340	153	817.71	789.40
2	NBA 0.55	340	187	771.98	744.41
3	RBA 0.45	340	153	736.30	937.11
4	RBA 0.55	340	187	701.49	892.80
5	CSC 0.45	340	153	816.28	865.75
6	CSC 0.55	340	187	777.68	824.81
7	CDC 0.45	340	153	816.29	853.67
8	CDC 0.55	340	187	777.69	813.31
9	FLSC 0.45	340	153	816.28	863.74
10	FLSC 0.55	340	187	777.68	822.9
11	FLDC 0.45	340	153	816.28	871.80
12	FLDC 0.55	340	187	777.68	830.57
13	SLSC 0.45	340	153	816.28	869.78
14	SLSC 0.55	340	187	777.68	828.66
15	SLDC 0.45	340	153	816.28	875.82
16	SLDC 0.55	340	187	777.68	834.41
17	MV 0.45	340	153	736.30	937.11
18	MV 0.55	340	187	701.49	892.80

*NBA = Natural Brick Aggregate

*RBA = Recycled Brick Aggregate

*CSC = Cement Single Coating

*CDC = Cement Double Coating

*FLSC = Fly Ash and Lime Single Coating

*FLDC = Fly Ash and Lime Double Coating

*SLSC = Slag and Lime Single Coating

*SLDC = Slag and Lime Double Coating

*MV = Mixing Variation

0.45 and 0.55 in the case designation denotes the w/c ratio.

3.7 Casting and Curing

Before casting, aggregates were kept in Saturated Surface Dry (SSD) condition for almost 24 hours by submerging under water or spraying water. Sand is also converted to SSD condition just before casting by pouring required amount of water followed by mixing thoroughly. Sand was filtered by sieve to remove impurities and finer particles. Cylindrical molds of 4 inch diameter and 8 inch height were tightened and oiled before casting as well. After successfully preparing all the materials, mixing was initiated in the mixer machine. Mixing procedure was conducted the way explained previously. Materials for 1 case combined of 12 cylindrical molds was mixed at a time. After mixing for sufficient time, the fresh concrete was discharged on the ground from the mixer machine. Immediately, slump value was measured to determine the workability according to ASTM C143. Cylindrical molds were filled with the fresh concrete dividing it into two layers one by one by tamping each layer for 25 times, scaling the outer surface and hammering the metal surface of the mold properly so that no void is left inside the concrete. 3 cubical mortar specimens of 2 inch dimension were also made from the remaining mortar paste of the fresh concrete regardless the w/c ratio. Therefore, mortar of 9 cases were made consisting of 27 cubical specimens. To make a plain top surface all the specimens were capped by cement mortar after a few hours of casting. After capping, all the molds were covered by polythene for one day. The next day, all the cylindrical and cubical molds were demolded and concrete and mortar specimens were removed from the molds. Then the specimens were submerged under water in chambers for curing purpose.

Figure 10: Slump test

Figure 11: Casted cylindrical specimens

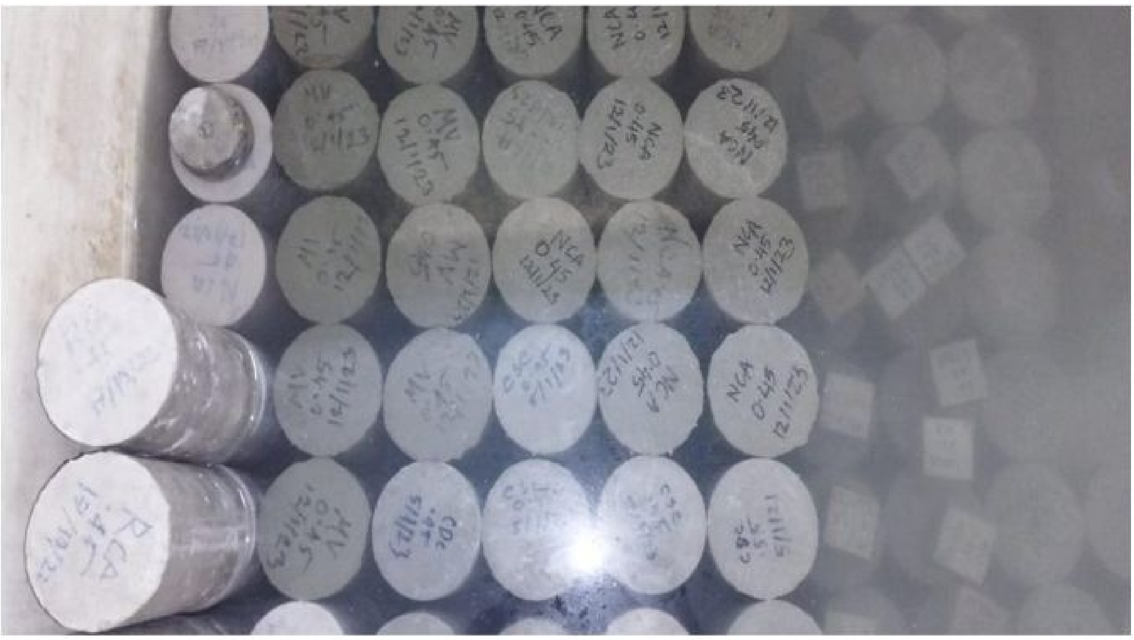

Figure 12: Underwater curing of concrete specimens in chamber

3.8 Performed Tests

Specified specimens were picked up after particular days of curing to conduct different tests. Compressive strength test according to ASTM C39 and Ultrasonic Pulse Velocity (UPV) according to ASTM C597 were performed after 7, 14 and 28 days of curing. Strain was also measured of specimens tested for compressive strength at 28 days by putting it inside the dial gauge. Tensile strength test was performed only after 28 days of curing by splitting the specimens according to ASTM C496. Scanning Electronic Microscope (SEM) test was also conducted of all types of coated and uncoated aggregates and crushed concrete specimens to measure the coating thickness as well as analyze the microstructure of concrete.

Figure 13: Crushed concrete specimens

Figure 14: Concrete specimens reserved for SEM

Figure 15: Strain measurement using dial gauge

Chapter 4 Results and Discussion

4.1 Properties of Aggregate

The properties of coated aggregates such as cement coated aggregates; Fly ash plus hydrated lime coated aggregates and slag plus hydrated lime coated aggregates that are investigated are summarized in table 3. Both single and double coated aggregated were investigated. For comparison, recycled brick aggregates and virgin aggregates were also investigated. Recycled brick aggregates were collected from demolished building and crushed into pieces (5mm to 25mm) to use as coarse aggregate. In all of the cases coated RBA shows higher specific gravity. The absorption capacity also reduced for some of the cases and some of the cases shows that the absorption capacity is close to RBA. The abrasion values for coated aggregates also reduced.

Table 5: Results of aggregates properties

Type	Specific gravity	Absorption	Abrasion (%)
NBA	1.95	18.7	51.05
RBA	2.15	13.16	43.77
CSC	2.15	13.65	38.96
CDC	2.12	11.18	38.77
FLSC	2.15	14.01	42.71
FLDC	2.17	13.7	40.52
SLSC	2.16	13.44	43.33
SLDC	2.17	13.04	42.77

4.2 Workability of Concrete

The workability of concrete as slump (in cm) is shown in fig. 2 for W/C = 0.55 and 0.45. It is found that the workability has increased for all of the coated aggregate concrete. And in W/C = 0.45 the workability has also increased for most of the cases except for FLSC and FLDC. Also RBA has showed slightly higher workability compared to the virgin aggregate concrete. The reason is that the coating fills the void in the recycle aggregate and made its surface smoother. That's why it has achieved more workability.

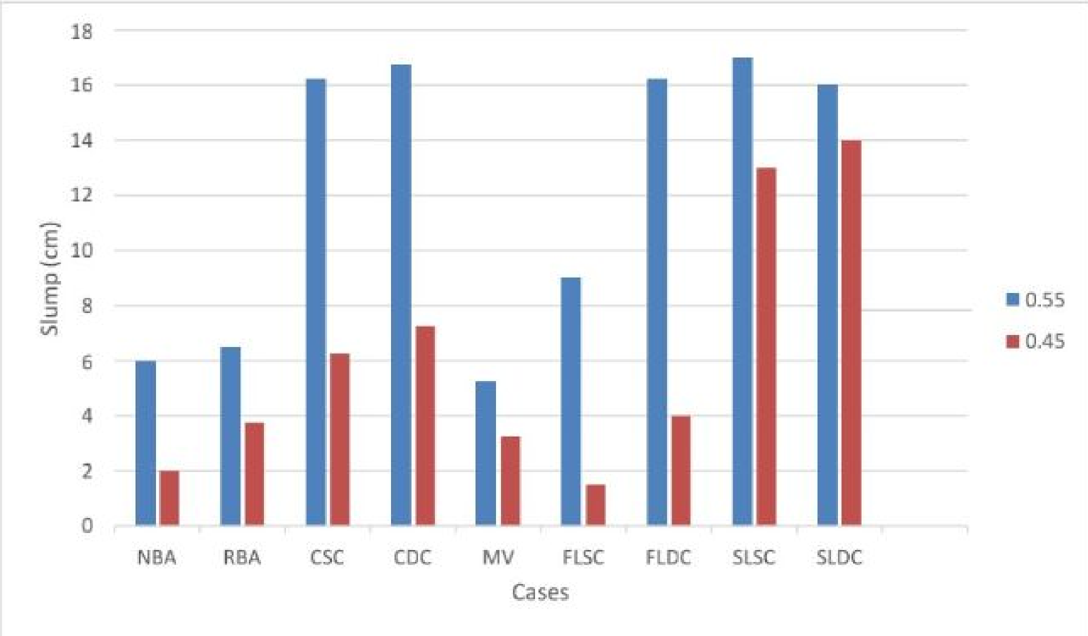

Figure 16: Slump results

4.3 Compressive Strength of Concrete

The compressive strength of concrete at 7, 14, 28 days is shown in figure 3 for W/C=0.55. In most of the cases the concrete with coated aggregate shows higher compressive strength compared to RBA expect fly ash plus hydrated lime double coating, which shows slightly less strength compared to RBA. The coated aggregates also shows higher strength compared to concrete made with virgin aggregate except FLDC.

For W/C = 0.45 the coated aggregate shows higher compressive strength compared to the RBA concrete except SLSC and SLDC. In comparison with the virgin aggregate the coated aggregates shows better result except SLSC and SLDC. The reason is that may be the ITZ of aggregate is improved with the application of coating. In case of SLSC 0.45 and SLDC 0.45 as slag is more water absorbent, may be slag is unable to fill the internal void to gain the desired knowledge. Further investigation is necessary.

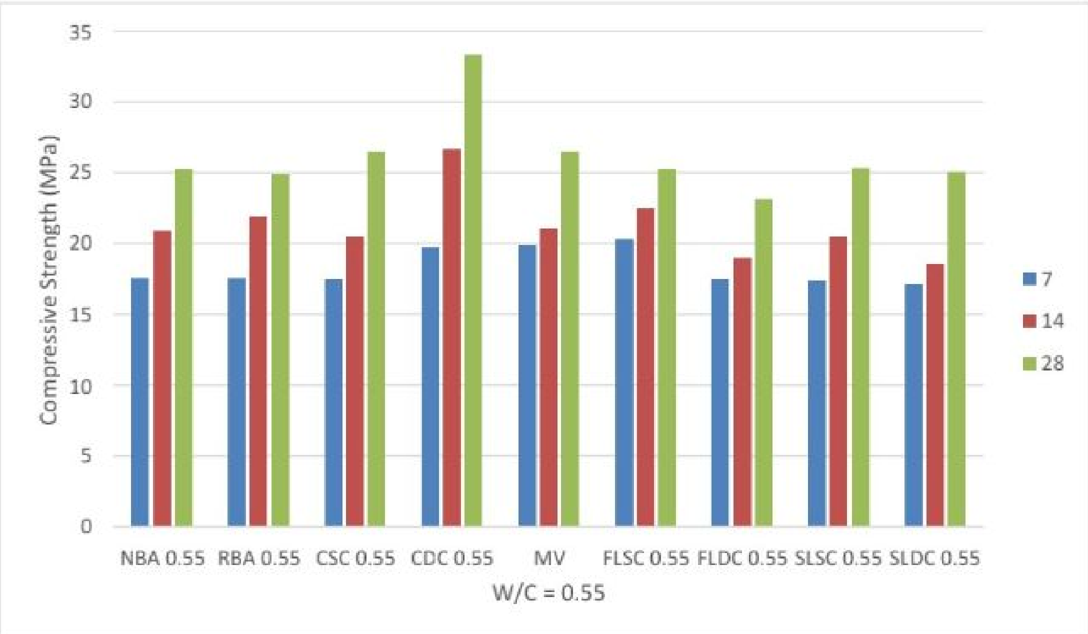

Figure 17: Compressive strength results for w/c = 0.55

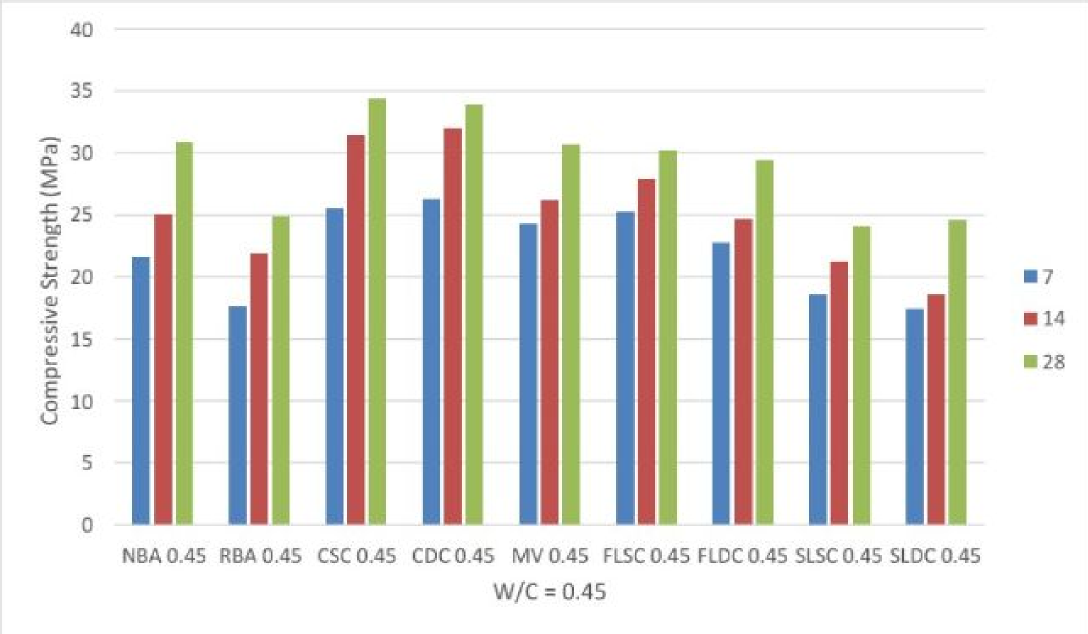

Figure 18: Compressive strength results for w/c = 0.45

4.4 Tensile Strength of Concrete

The tensile strength of concrete at 28 days made with coated aggregate with W/C = 0.55 and W/C = 0.45 is shown in figure. Also, the results were compared with NBA and RBA. The tensile strength has increased for most of the cases in W/C=0.55 but no significant results are found in W/C=0.45. The reason is as explained before.

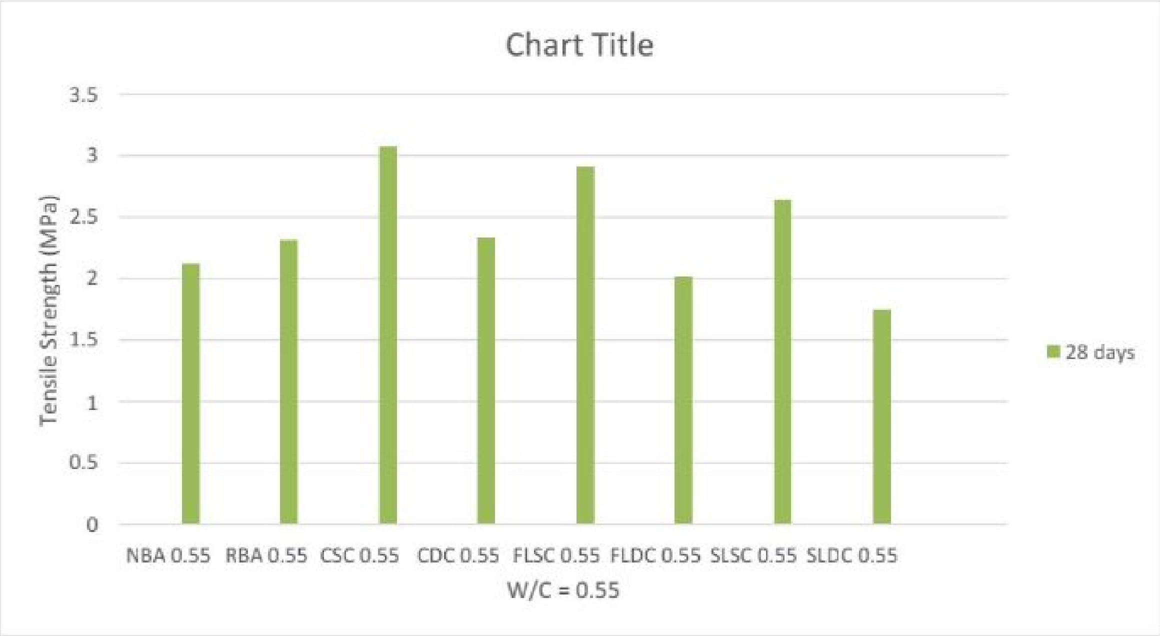

Figure 19: Tensile strength results for w/c = 0.55

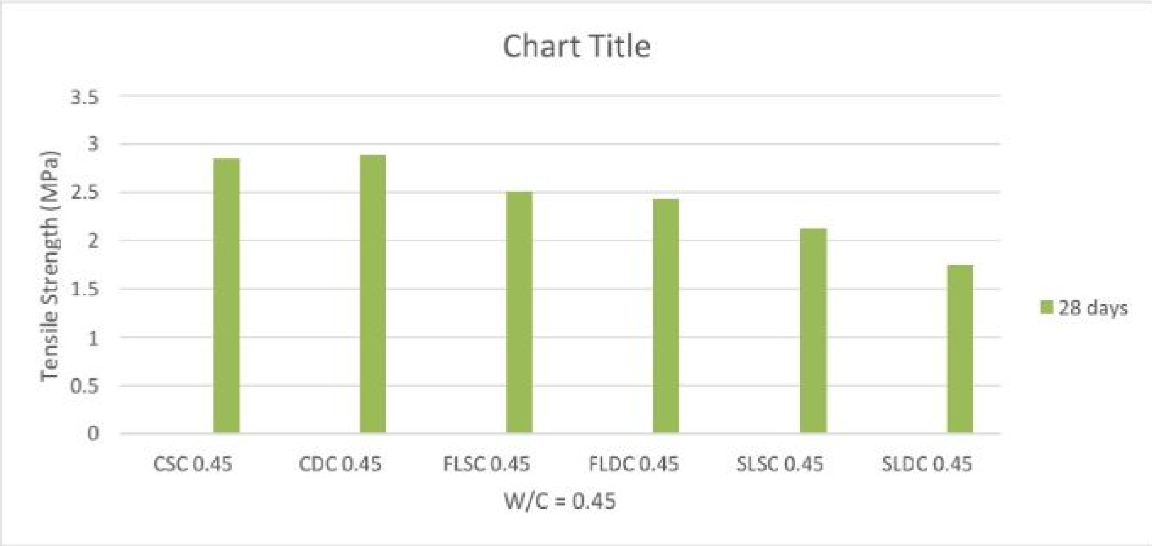

Figure 20: Tensile strength results for w/c = 0.45

4.5 Ultrasonic Pulse Velocity

The variation of UPV of the coated aggregate of 7,14 and 28 days concrete are shown in fig. The lowest UPV is found in RBA and the UPV of the coated aggregate concrete has increased. Coarse aggregate with high absorption capacity contains a lot of pores. These pores reduce UPV as it tries to pass through the concrete specimens. It is understood that aggregate with higher absorption capacity and less unit weight contributes to lesser UPV in concrete.

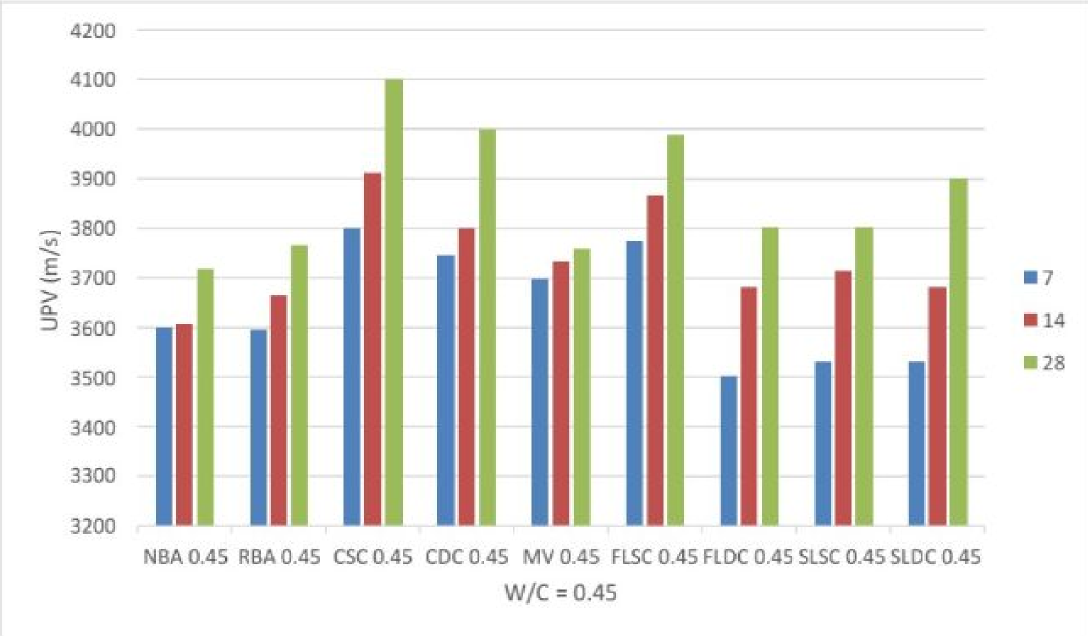

Figure 21: UPV results for w/c = 0.45

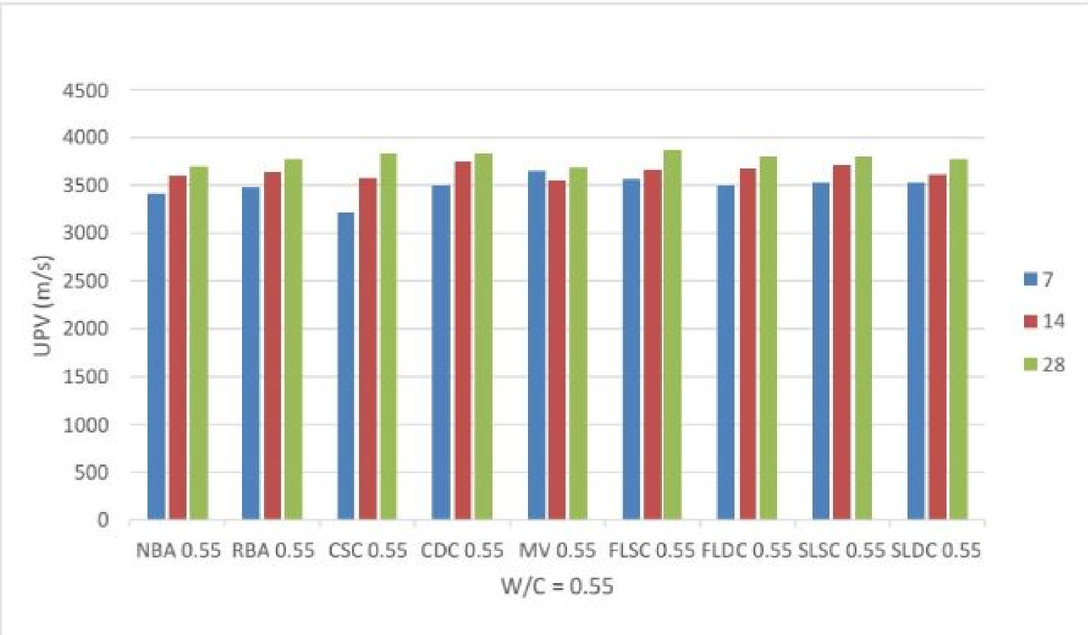

Figure 22: UPV results for w/c = 0.55

4.6 Scanning Electronic Microscope (SEM)

Here are some photos of coated aggregates generated through SEM analysis.

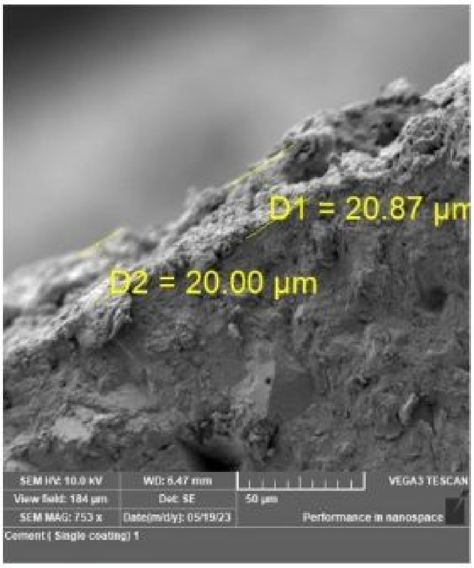

Figure 23: Cement single coating; thickness = 21 micron

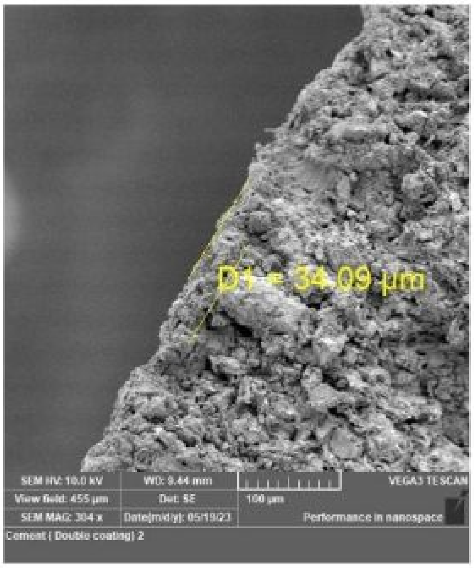

Figure 24: Cement double coating; thickness = 34 micron

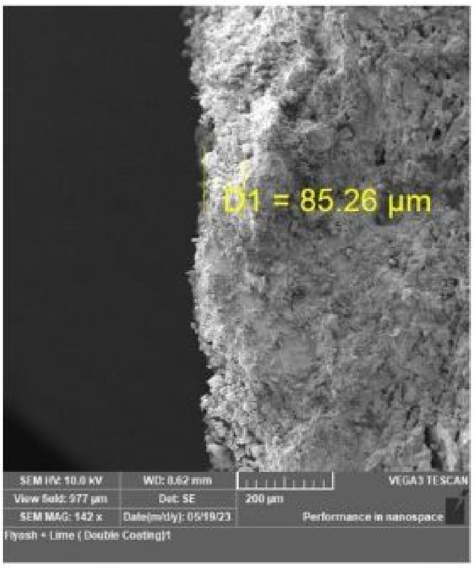

Figure 25: Fly ash and hydrated lime double coating; thickness = 85 micron

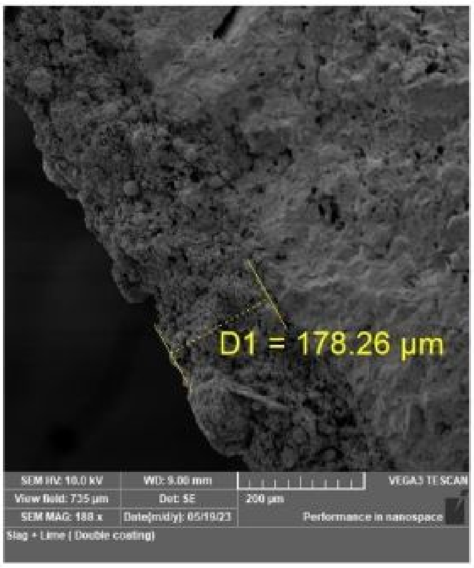

Figure 26: Slag and hydrated lime double coating; thickness = 178 micron

4.7 Compressive strength of mortar specimen

Compressive strength of mortar specimen made by screening concrete with a #4 sieve (opening 4.75 mm) were tested at 28 days. Coated aggregates enhanced the compressive strength or mortar compared to the mortar prepared from screening from RBA 0.45. Most of the cases showed almost same values except cement coating mortar. Perhaps the cement paste with cement coating aggregate has higher percentage of concrete that's why It has gained more strength in W/C = 0.55.

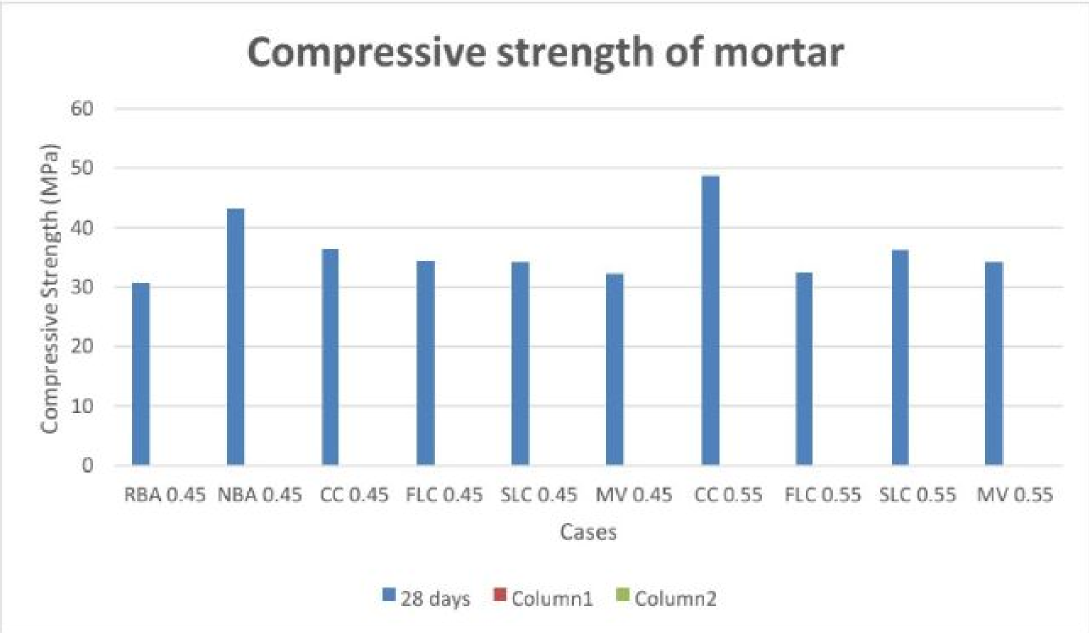

Figure 27: Compresive strength results of mortar specimens

4.8 UPV of mortar

Ultrasonic pulse velocity of mortar specimen at 28 days were investigated. In W/C = 0.55 the upv has shown better results than the cases in W/C= 0.45. In W/C = 0.55 due to high water content the concrete paste has higher workability, that's why it fills the void during the casting of mortar, and it increases the UPV. Less dense or void in the mortar shows less UPV.

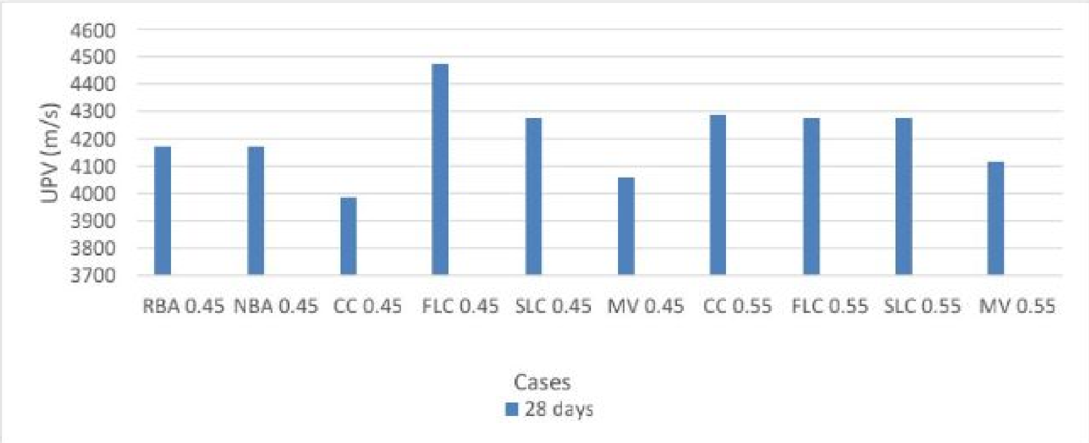

Figure 28: UPV results of mortar specimens

Chapter 5 Conclusion

After observing the test results the following conclusions can be drawn,

1. Aggregates coated with double layer cement paste shows improvement in resistance to abrasion. The abrasion loss of cement double layer coated aggregates is 5% less than the uncoated RBA.
2. Cement paste double layer coated aggregates show significant reduction of water absorption capacity compared to the other cases.
3. For W/C = 0.55 fresh concrete produced using cement paste double coated aggregates and slag plus lime single coated aggregates show almost similar values in slump test. Concrete produced with slag plus lime single coated aggregates and W/C = 0.55 has the highest workability among all the cases. Least workability is found for the mixing variation case which is equal to 5.25 cm.
4. For W/C = 0.45 fresh concrete produced with slag plus lime double coated aggregates show a slump of 14 cm which is the highest value for W/C = 0.45. The least workable concrete in this case is observed to be produced with fly ash plus lime single layer coated aggregates which is below 2 cm.
5. In case of the compressive strength, concrete produced with double layer cement paste coated aggregates show the highest 28-days strength for W/C = 0.55. Compressive strength of this case is observed to be 38.67% higher than the compressive strength of concrete produced with uncoated RBA for W/C = 0.55.
6. For W/C = 0.45 the compressive strength of concrete produced with cement paste single layer coated aggregates show the highest value. Concrete produced with cement paste double layer coated aggregates shows almost similar compressive strength with a difference of only 0.4 MPa.

7. The UPV of concrete for all the cases of W/C = 0.55 and 0.45 ranges between 3500 to 4000 m/s after 28 days of curing.

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