RELATIONSHIP BETWEEN ULTRASONIC PULSE VELOCITY AND COMPRESSIVE STRENGTH OF CONCRETE MADE WITH RECYCLED BRICK AGGREGATE

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PROJECT REPORT APPROVAL

The thesis titled “Relationship between Ultrasonic Pulse Velocity and Compressive Strength of Concrete for Recycle Brick Aggregates Available in Bangladesh” submitted by RASHIK IHSRAQ, TOUFIK HASSAN and ANJUM SUBHAN CHOWDHURY St. No. 135436, 135440 and 125411 has been found as satisfactory and accepted as partial fulfillment of the requirement for the Degree Bachelor of Science in Civil Engineering.

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DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Professor Dr. Tarek Uddin and this work has not been submitted elsewhere for any purpose (except for publication).

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DEDICATION

We dedicate our thesis work to our family. A special feeling of gratitude to our loving parents. We also dedicate this thesis to our many friends who have supported us throughout the process. We will always appreciate all they have done.

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"*In the name of Allah, Most Gracious, Most Merciful*"

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CONTENTS

ABSTRACT

Keywords: *Ultrasonic Pulse Velocity, compressive strength, coarse aggregate, sand to aggregate ratio, virgin brick aggregate, recycle brick aggregate, etc.*

For quite a few years, many attempts are made in order to find a suitable relationship between ultrasonic pulse velocity (UPV) and compressive strength of concrete. Such relations, if properly established, can promote a sustainable structural health monitoring system. Therefore, in this study, recycle brick aggregates that are commonly available in Bangladesh are tested in order to find a working relationship between UPV and compressive strength of concrete. Tests have been carried out on 28 days. Three volumetric sand to total aggregate ratios (s/a) 0.36, 0.40, 0.44 are considered to study the effect of variation of s/a. And, three W/C ratio are chosen as 0.45, 0.50, and 0.55. The cement paste occupies 32% of the total concrete volume (V_{Paste} =32%).

Here, the compressive strength of concrete is related with UPV on the basis of s/a ratio variation. Some relationships are proposed between UPV and compressive strength. Some comparison is also done between recycle brick aggregates and virgin brick aggregates for UPV and Compressive Strength. Finally, an elaborate and comprehensive analysis is made in order to compare between concrete made with recycle brick aggregates to have a final view about the relationship between ultrasonic pulse velocity (UPV) and compressive strength of concrete

LIST OF SYMBOLS

V_p	Pulse velocity of concrete
S	Compressive strength of concrete
V_p-S	Relationship between ultrasonic pulse velocity and compressive strength of concrete
W/C	Water to Cement ratio
s/a	Sand to total aggregate volumetric ratio
Vpaste, %	Volumetric cement paste content
f'_c	Compressive strength of concrete

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Chapter 1: Introduction

1.1 General

The compressive strength of concrete has always been considered as one of the most important properties of concrete. In structures, its primary application is to resist compressive stress. Its strength, however, is defined as its resistance to rupture and can be measured from its strength in compression, in tension or in shear or flexure. Hence, to design for a structure, determination of compressive strength is crucial. A number of methods are widely used to determine the strength of concrete.

The goal of all these methods is to find out the most effective strength for design purpose. There are theoretical and practical methods. Theoretical methods like the classic law of Abram's [2004] or Powers and Brownyard [2005] relationship can give the compressive strength just by considering W/C ratio, volume of cement or specific volume of cement and some other strength regarding factors. This way, the strength determination does not get time consuming and also good for 28 day's strength if the concrete is fully compacted. Although in practical situation, the compressive strength is found out to be much lower than theoretically estimated.

This is because of the consideration of concrete to be a homogenous and fully solid mass. In actual scenario, there are always flaws present in the concrete structures. They can be like voids due to less degree of compaction, bleeding channels or ruptures due to drying and temperature shrinkage. Griffith's theory explains that, due to presence of flaws, concrete undergoes a considerable reduction in its strength. Mostly because of the intense stress concentration in or around the voids. So, the practical methods are carried out in order to determine the actual strength of concrete.

The compressive strength of concrete is usually determined by testing cylinders or cubes made in laboratory. These tests are referred as destructive tests as the concrete will be crushed and no longer usable. The drawbacks of these methods are, they generate a lot of rubbish and also cannot ensure the quality of concrete in actual structures. Destructive tests are also cannot be held to inspect the structural health in any instance thus limiting the scope for continuous monitoring the state of the structure. Hence the use of non-destructive methods can be adopted. Non-destructive tests are the methods to find out the compressive strength of concrete without crushing any concrete build. Concrete in service is exposed to a wide variety of environment and due its physical and chemical nature it may deteriorate inside [3]. Non-destructive tests response to the extent of impairment. Furthermore, in order to assess current adequacy and future performance, routine evaluation of structural health is a primary concern [4]. In these regard, non-destructive tests are capable of assessing structures and call for remedial measures if necessary.

Among the non-destructive tests, four are usually performed:

1. Impact-echo method
2. Ultrasonic pulse velocity method
3. Impact elastic wave method
4. Thermographic method (used to find flaws in concrete)

In the construction industry of Bangladesh, brick aggregates are widely used as coarse aggregate in concrete because of the scarcity of natural sources of stone aggregates. But the production process of brick blocks in brick fields is not environment-friendly. Brick industry in Dhaka city produces around 15,500 tons of SO_2, 302,000 tons of CO, 6,000 tons of black carbon, and 1.8 million tons of CO_2 per year. (Guttikunda et al. 2013).

INTRODUCTION

Utilization of recycled aggregate collected from sites of demolished concrete structures can help to reduce the consumption of brick aggregates to some extent.

In this study, an experimental investigation has been carried to understand the influence of recycled brick aggregate on Ultrasonic Pulse Velocity (UPV) and compressive strength of concrete for different mix parameters.

The compressive strength and UPV results of recycled brick aggregate concrete have also been compared with the properties of virgin brick aggregate concrete found in the literature.

1.2 Literature Review

Previous researches conducted numerous studies to address the influence of

Demirboğa (et al. 2004): used Ultrasonic pulse velocity to evaluate the compressive strength of concrete with mineral admixtures. In addition, the relationship between ultrasonic pulse velocity and compressive strength of concrete are evaluated.

Mohammed (et al. 2017): studied Effects of different chemical admixtures on fresh and hardened properties of prolonged mixed concrete and their cost-effectiveness were investigated. Influence of sand to aggregate volume ratio (s/a), cement content (C) was studied.

Mohammed and Mahmood (2016): Tests have been carried out on 28 days. Three volumetric sand to total aggregate ratios (s/a) 0.36, 0.40, 0.44 are considered to study the effect of variation of s/a. And, three W/C ratio are chosen as 0.45, 0.50, and 0.55. The cement paste occupies 32% of the total concrete volume (V_{Paste} =32%). For some cases, volumetric mix ratios of 1:1.5:3 and 1:2:4 were also prepared in order to relate to the common field practice.

Kaplan (1959), (Ben-Zeitun 1986) etc: Experiments have been made on concretes with varying aggregate/cement and water/cement ratios, with the main object of ascertaining the effects of changes in age and water/cement ratio upon the relation between ultrasonic pulse velocity and the compressive strength of concrete.

On UPV through concrete. Very few literatures investigated the influence of different types of aggregate on UPV through concrete (Trtnik 2009, Mohammed and Rahman 2016.

However, none of these studies investigated the influence of using recycled brick aggregate on UPV through concrete.

Therefore, this study aims to investigate the influence of recycled brick aggregate on UPV through concrete.

1.2.1 Water Content (W/C)

Water content plays a vital role in the context of gaining strength and pulse velocity. W/C and age of concrete can be can considered as ruling parameter to find out V_p-S =relationship as done in a study led by I. Lawson et al (2011) [5]. In that study, the ranges of W/C considered were 0.35, 0.40, 0.50, and 0.55. Based on these four different W/C, UPV measurement and compressive strength tests were carried out at the age of 28 days. Pulse velocity at the age of 28-days for W/C of 0.40 and 0.55 were around 4000 m/s and 3800m/s respectively.

So, it was observed that with higher W/C the pulse velocity of concrete gets lower. Similar trend was observed to be followed by the strength of concrete with W/C. Compressive strength at the age of 28-days for W/C of 0.40 and 0.55were around 25 MPa and 22 MPa respectively. So, it was concluded that higher W/C creates more voids and less mass. Velocity can only get higher if there are more solid mass present. Lower W/C creates dense concrete so velocity and strength both were supposedly found higher for 28-day measurement.

Researchers in this study prepared mix proportions considering five different W/C. In the study they examined the cement paste and concrete side by side. They showed that from higher to lower W/C, both the cement pastes and concrete gain strength and pulse velocity. But it was also observed that both the cement pastes and concrete have compressive strength around 3000 psi. Cement paste had far less UPV than concrete. The reason behind was explained as the strength of concrete is as good as the strength of the cement paste. For a particular W/C concrete and

cement paste must reach the same strength. Adding aggregate may increase the UPV of concrete but it has less significance upon its strength.

1.2.2 Aggregate & Mix Proportion

Aggregates have a serious effect on pulse velocity. For recycle brick aggregate and mix proportions pulse velocity changes a lot and thus needed to be specified. Their mix proportion was 1:2:4 and for each W/C they used 17 Kg of cement, 45 Kg of sand and 42 Kg of CA. Highest V_p was found out to be 4132 m\s. And the result includes high determination for predicting strength indicating quality of concrete in terms of density, homogeneity and uniformity was good.

Y. Lin et al (2007) [2006] showed that aggregate could be a key factor to predict compressive strength of concrete. They considered detail specification and measurement for materials including cement, fine aggregate (FA), course aggregate and water. Upon completing sieve analysis fine aggregates were found to be uniformly graded and course aggregate to be well graded. Mixture content were prepared for the test. Several UPV values were found for nine cases and their response time was different from each other.

1.3 Objectives of the study

The objectives of the thesis can be enlisted as-

1. To determine the UPV and compressive strength of concrete made with recycled brick aggregate for varying sand to aggregate ratio (s/a) and water to cement ratio (W/C).

2. To compare the compressive strength and UPV results of recycled brick aggregate concrete with the properties of virgin brick aggregate concrete found in the literature.

3. To study the influence of s/a ratio on recycled brick aggregate concrete.

1.4 Scope of the study

The scope of the study involves-

1. Experimenting the effect of variation in strength controlling parameters of concrete in compressive strength of concrete.

2. Studying the relative variation in pulse velocity of concrete with change in compressive strength.

3. Establishing standard velocity-strength relationship by relating compressive strength of concrete with pulse velocity

Chapter 2 Materials

2.1 General

To carry out the experiment, different materials were used to gain distinct prospect on the study. These materials are chosen to have, not only a broad view on the overall scenario of the materials available in Bangladesh, but also to study their properties as a strength giving element for concrete mixture. Different codes of ASTM were followed regarding the tests of the materials in order find out their properties, mix designs, and compatibility.

Setting up a structural health monitoring system via non-destructive test such as ultra-sonic pulse velocity technique, needs to test for all types of commonly used material that are used in preparing concrete mixtures. It is because, for every types of materials used, their property for conductance of high frequency ultra-sonic pulse is different. In this thesis, recycle brick aggregates are used which are commonly available in Bangladesh. These aggregates are tested for their properties and later on for their strength giving ability with their high frequency conductance property. In this chapter properties of materials that are used to make the concrete specimens are thoroughly described. The results from these tests are also described materials.

2.2 Binding Materials

As binding material, Portland composite cement (PCC) has been used. It has strength class of 42.5N; meaning, compressive strength of concrete at 28 days must exceed 30 N/mm² (i.e. higher than class C25/30 according to NBN B 15-001). These cements are also suitable for use at lower temperatures. In this thesis, CEM type-II/A-M is selected to carry out the experiments. This cement has about 80-94% of its contents as clinker and 6-20% of its contents as minerals. Specific gravity of cement was found out to be 2.9 by test carried according to ASTM specification C 188-14

2.3 Coarse Aggregates

As the thesis is entitled, recycle brick aggregates available in Bangladesh are used in the experiment. These aggregates were tested prior to use in preparing concrete mixture.

2.4 Fine Aggregate

Fine aggregate used in this thesis is Sylhet sand. Sylhet sand is tested for specific gravity and %absorption value according to ASTM C128. Also sieve analysis of fine aggregate was performed according to C136.

Table 2.1: Different Properties of Coarse Aggregates and Fine aggregate

Type of aggregates	Specific gravity	Absorption capacity (%)	SSD Unit Weight (kg/m^3)	Abrasion	FM
Fine	2.46	3	1574	2.05	2.582
Coarse	2.05	17	1155	46	Controlled as per ASTM 33

2.5 Gradation of Coarse Aggregate

Gradation of all the coarse aggregate in this thesis is guided by ASTM C33. From the gradation chart, 20mm (3/4th down) maximum size of aggregates, size-6 is chosen. Sizes are chosen in between 20mm to 9.5mm.

Table 2.2: Fineness Modulus of Coarse Aggregate

Sieve Size (mm)	% Retained	% Cumulative Retained	% Finer
25	0.00	0.00	100
20	5	5	95
12.5	65	70	30
9.5	30	100	0
4.75	0	100	0
2.36	0	100	0
1.18	0	100	0
0.6	0	100	0
0.3	0	100	0
0.15	0	100	0
Pan	-	-	
Total	100.00	675	
Fineness Modulus = 6.75			

2.6 Conclusions

The material properties obtained are used later to address the reason behind various findings of the study. In this chapter, materials properties are addressed to quantify the nature and anticipate the likely behavior for recycle brick aggregates under many possible circumstances. The values not only a give a comprehensive understanding but also gives a brief idea about the suitability to many potential applications.

Chapter 3 Methodology

3.1 General

As the study has a wide insight on a variety of aspects, different methods were adopted in order to achieve the objective of this study properly. And by implementing these methods, a direct approach has been set out to fulfill the scope of the study. In this chapter, the methods adopted and implemented are discussed thoroughly. This involves the selection of key parameters for mixture proportions, the mix design, the testing parameters etc.

3.2 Cases Investigated

For proper insight of the study, different key parameters for mixture proportion are considered in the experiment. All of the cases that selected to carry out are performed with a weight based mix design approach. Although, keeping in mind the general practice in Bangladesh, some volume based mix ratios are also considered to relate to the actual field scanner.

3.2.1 Mixture Proportion

As the study involves recycle brick aggregates available in Bangladesh, the mix design is adopted in such a way that the comparative analysis of these aggregates is possible. With recycle brick aggregates, concrete is to be made and hence the main approach is to build a relationship between their compressive strength and ultrasonic pulse velocity (UPV).

3.2.2 Weight Based Mix Proportion

In weight based mix design approach; some considerations are made in order make the analysis with UPV more accurate. These considerations are-

Volumetric content (m3) of cement paste, fine and coarse aggregate should be constant. Similar weight based content (Kg/m3) for cement and fine aggregate needs to be adopted for recycle brick aggregates. Volumetric content (m3) of materials should be constant irrespective to their type.

And as for the key parameters of the weight based approach, following considerations are adopted in this study-

	W	= Water
a) W/C – 0.45, 0.50, 0.55	C	= Cement
b) s/a – 0.36, 0.40, 0.44	s	= Sand
c) Cement – 395 Kg/m3, 372 Kg/m3, 351 Kg/m3	s/a	= Sand to total
Aggregate		Volumetric ratio

For the propagation of the ultrasonic pulse, it is very important to make sure that the interfaces through which the pulse will be pass, be constant in terms of cement paste and aggregate distribution. Although this cannot be completely brought under control, it is possible to make it as constant by approaching the volumetric content (m3) to be constant. This way, the constant paste content (%) and a constant volumetric content (m3) of fine and coarse aggregates, irrespective of the type can give a constant distribution of these materials.

Table 3.1: Mix Design for concrete to be made with Recycle brick_aggregate

Mix Proportion Designation	W/C	s/a (%)	V-Paste (%)	Mixture Proportion, Kg/m^3			
				Cement	Water	Fine Aggregate	Coarse Aggregate
RBA-45-36-395	0.45	36	32	395	178	588	874
RBA-50-36-372	0.50			372	186		
RBA-55-36-351	0.55			351	193		
RBA-45-40-395	0.45	40		395	178	652	819
RBA-50-40-372	0.50			372	186		
RBA-55-40-351	0.55			351	193		
RBA-45-44-395	0.45	44		395	178	718	765
RBA-50-44-372	0.50			372	186		
RBA-55-44-351	0.55			351	193		
The first two digits indicate W/C, the second two digits indicate sand to aggregate volume ratio in %, and the last three digits indicate cement content in kg/m^3.							

3.2.3 Concrete Specimens

For testing purpose of this study, standard 100mm×200mm (4”×8”) size cylindrical shaped molds are used for making concrete specimens. Concrete specimens made with recycle brick aggregates are casted accordingly to enable testing at 28 days. For each of the cases 4 cylindrical specimens are casted. So, for recycle brick aggregates for 9 cases 4x9=36 specimens were casted.

3.3 Casting of Specimens

3.3.1 Casting Procedure

For the casting of concrete of specimens, ASTM C33 is followed for standard procedure. Coarse aggregates and fine aggregates were brought up to surface saturated dry (SSD) condition before casting. All necessary precautions are taken as-

a) Prevention of drying of the bed on which casting is to be done.

b) Dampening of the sheet on which slump is to be taken is also prevented.

c) To prevent mortar attack and mixing, the sheets and wall of mixing machine are washed every time before a batch is mixed and casted.

d) Made sure that grease is applied to the wall of all cylindrical molds.

e) Made sure that proper distribution of paste and aggregate is done in casting all specimens.

f) The top surface of specimens must have a smooth surface, if that is not possible during casting, then capping with a thick mortar after half an hour of casting is provided.

It is mandatory to cast a specimen with a proper distribution of materials, such as, the top must get as much aggregate as the middle or bottom part of the specimen

3.3.2 Slump

The concrete slump test is used for the measurement of a property of fresh concrete. The test is an empirical test that measures the workability of fresh concrete. More specifically, it measures consistency between batches. The slump cone has a base of 200mm (8”), a smaller opening at top of 100mm (4”) and a height of 300mm (12”). While performing the slump test, all three types of slumps are noticed. For collapse slump and true slump one reading is taken and for shear slump average reading is taken. To carry out the slump test, standard procedure is adopted from ASTM C143.

3.3.3 Curing

For the curing of specimens, a preliminary curing is done and followed by underwater curing. After casting, unmolding is to be done within 20±4 hours. Within this time range, the cylinder can often get dried and it is necessary to wrap its top surface with moist cloth to prevent that. It is done till unmolding and called preliminary curing. After unmolding, specimens are brought underwater and cured till performing the crushing tests.

3.4 Testing of Specimens

3.4.1 Measuring of Ultrasonic Pulse Velocity (UPV)

For measuring the ultrasonic pulse velocity, a pulse velocity instrument is needed. It has a transducer and receiver. The transducer generates pulse where the receiver receives the pulse. A coupling media (gel) is applied to the ends of a cylindrical specimen in order to provide a proper condition for transducing and receiving. The frequency of the pulse is kept at 54 kHz. The transducer and receiver are held at both ends of the specimens. The pulse is generated and time elapsed between pulse generation and receiving at the other end is recorded. By dividing the length of cylinder to the time we get the pulse velocity. The standards are adopted from ASTM C597 to carry out the test.

3.4.2 Compressive Strength

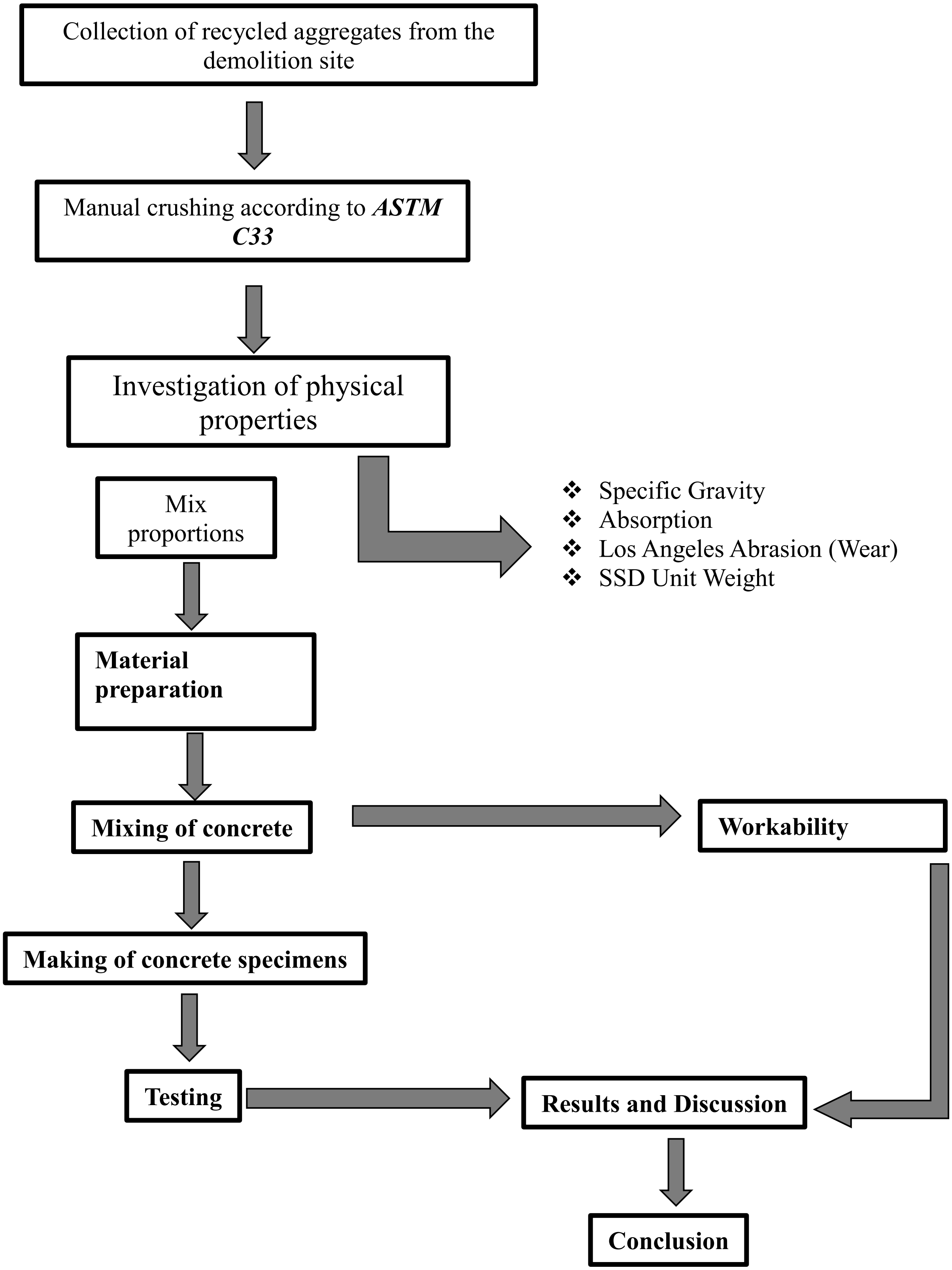
Compressive strength tests are performed as the cases are planned to investigate in 28 days. Crushing test is done in the semi-auto crushing machine. As per the procedure of the test, ASTM C33 standard is followed. Following precautions are adopted-

a) The top surface must be smooth, if not, capping is provided.

b) A base plate and top plate is applied to ensure uniform load distribution.

c) Load rate adopted from the standard (0.023MPa/s) is to be maintained throughout the crushing. After each test the base plate of the machine is to be wiped for crushed particles.

3.4.3 TEST PROCEDURE:



100mm X 200mm

3.5 Conclusion

In this chapter, different methods adopted to achieve the objectives of the study are thoroughly discussed. Different testing parameters are explained in order to relate it to the study result. Experimental method is important in order to set out the scope the study. So, the methodology is followed by result and discussion in the next chapter.

Chapter 4: Results and Discussion

4.1 General

In order to establish the relationship between ultrasonic pulse velocity (UPV) and compressive strength of concrete, different cases are investigated in this study. Recycle brick aggregates are tested for establishing the relationship so that structural health monitoring system can be introduced. Although extensive investigations on different strength regarding parameters are needed, in this study a preliminary approach is taken to relate UPV with different strength regarding parameters. By relating to these parameters, it is possible to investigate thoroughly the nature and behavior of UPV in concrete, to know exactly what can be achieved adopting this non-destructive technique and its shortcomings.

As from the previous chapter of *Methodology*, the study has fixed some definite key parameters to run a thorough investigation. Different s/a ratios, W/C ratios, cement content variations and all constant volumetric content (m^3) for materials irrespective of their types are considered to have a broad insight into the study. So, in order to state the results and findings of the study and to discuss them, it is necessary to fix some key parameters.

In this chapter, the results of the study conducted will be quantified. It will be discussed elaborately in order to establish the relationship and analyze different aspects of UPV.

Variations in slump values, effect for water content variations, effect for cement content variations, effect for different s/a ratios, effect of curing period. is discussed in this chapter. Finally, some relationships are proposed regarding the different mixing parameters and type of materials being used.

These relationships can be used to measure the strength of concrete up to a certain degree of accuracy. Different aspects of these relationships will be discussed and also the degree of accuracy will also be determined and discussed at the end of this chapter

4.2 Workability

The slump test is done for same w/c ratio which is 0.45 of three cases.

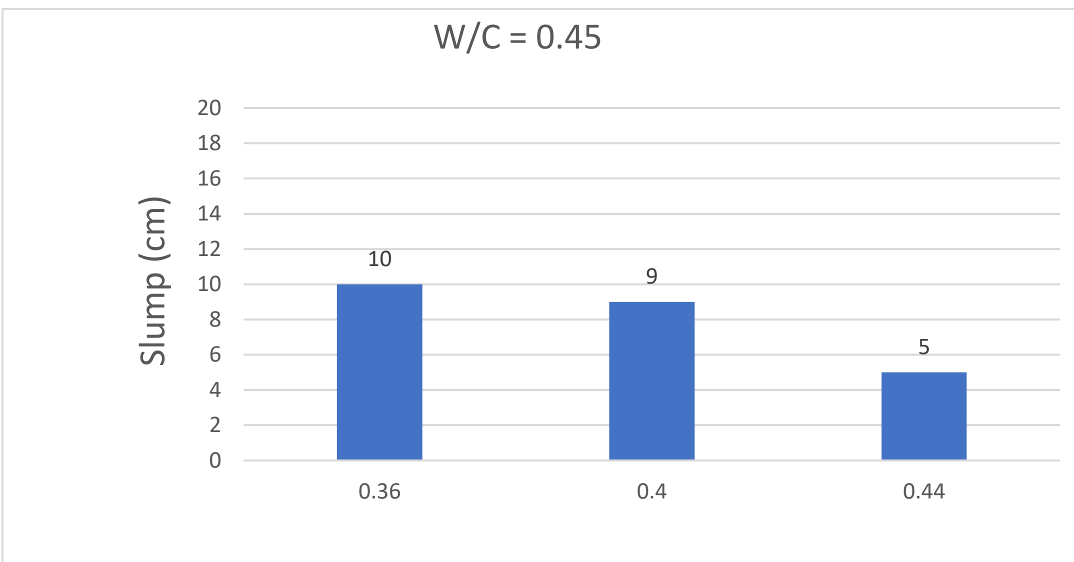


Figure: 4-1 Workability of concrete

For other three cases slump test is done for w/c=0.50 ratio

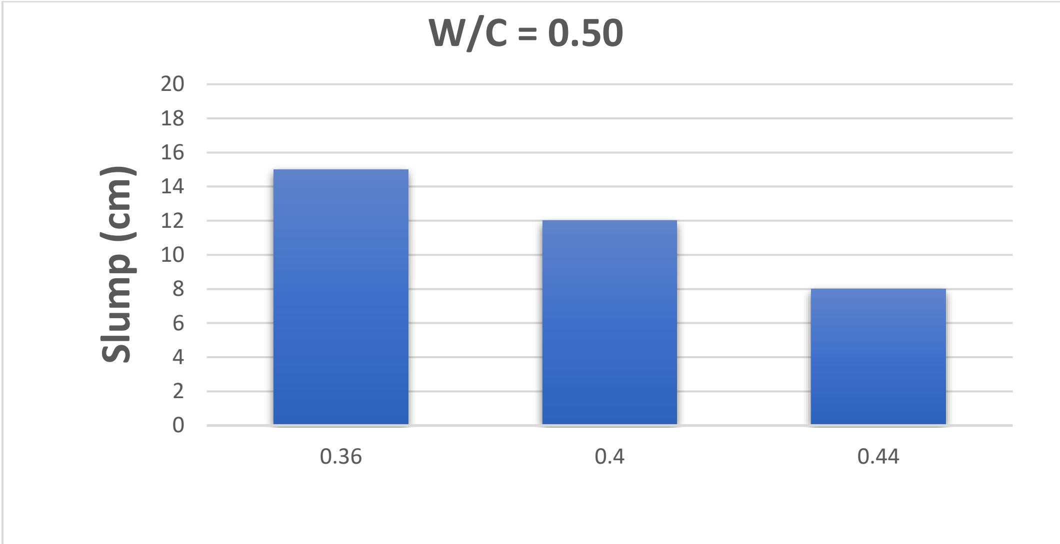


Figure: 4-2 Workability of concrete

And for the final three cases slump test is done for w/c= 0.55

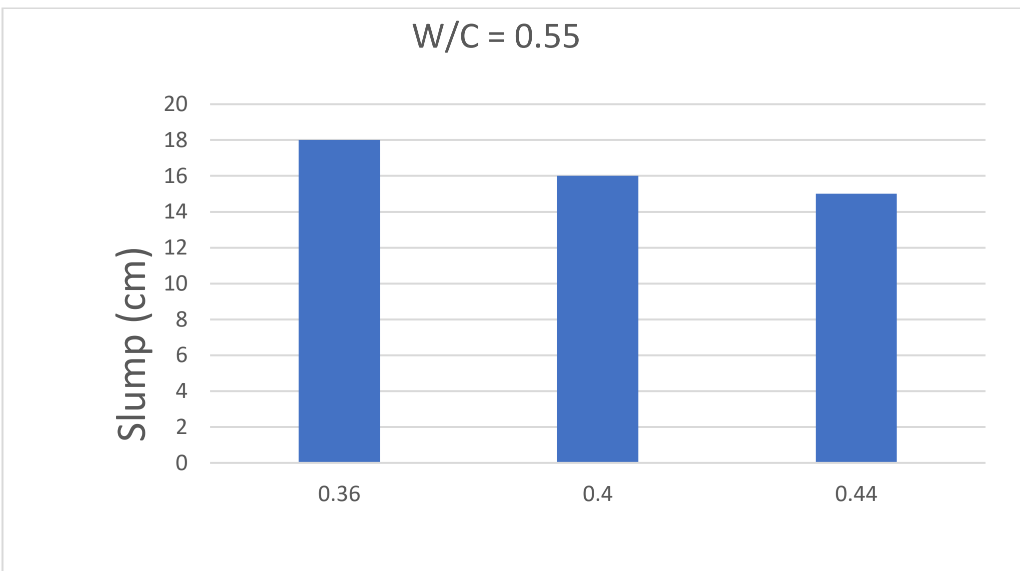


Figure: 4-3 Workability of concrete

4.3 Unit Weight

The unit weight of concrete for recycle brick aggregates are shown in the following figures (Fig. 4-6, 4-7, 4-8, 4-9). Unit weight variations in terms of curing period can also be observed from the plots. Variations in unit weights are mainly because of greater specific gravity of one aggregate than the others. Highest variation in unit weight of similar concrete for aggregate to aggregate variation is observed in 28 days when the concrete ted to achieve almost 80%-85% of its strength indicating most of the hydration is done within this time (28 days).

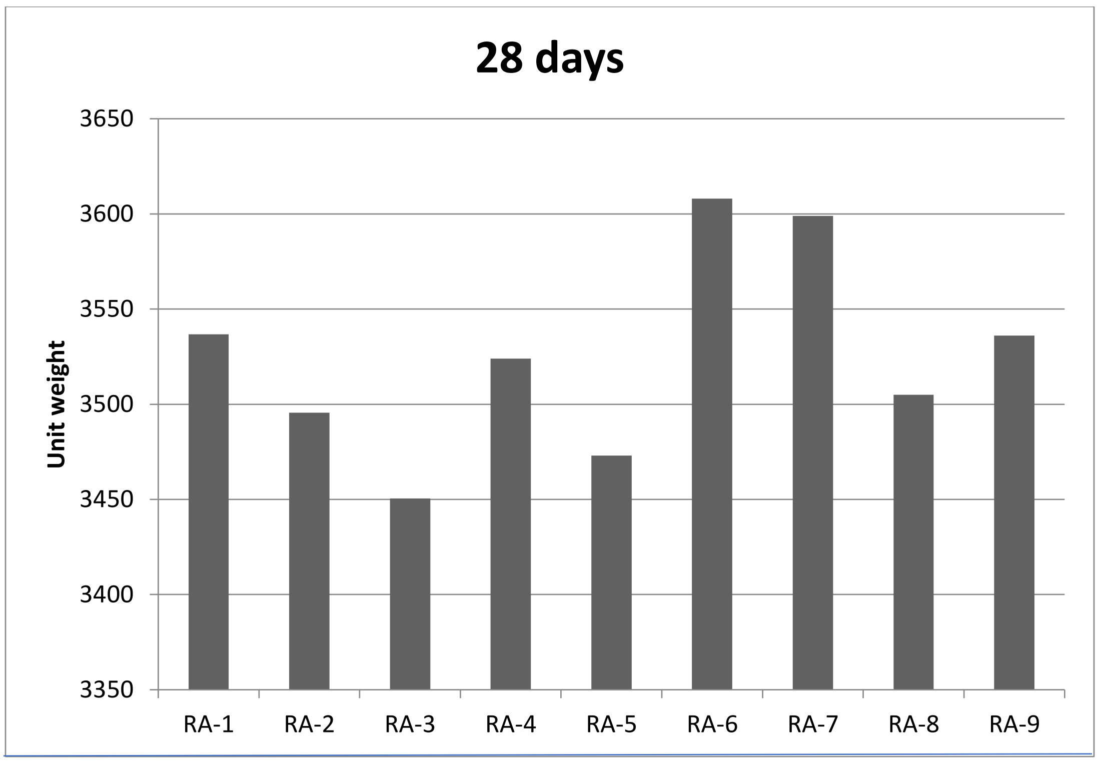


Figure: 4-4 Unit weight of recycle brick aggregate

4.4 UPV through concretes made with RA and virgin brick aggregates.

The tests that have done for different cases of recycle brick aggregates is compared with the results of virgin brick aggregates from the literature that was done before by Nafiur Rahman before. In this section UPV is compared between recycle brick aggregates and virgin brick aggregates.

First table shows the result of UPV where w/c= 0.45 and s/a = 0.36

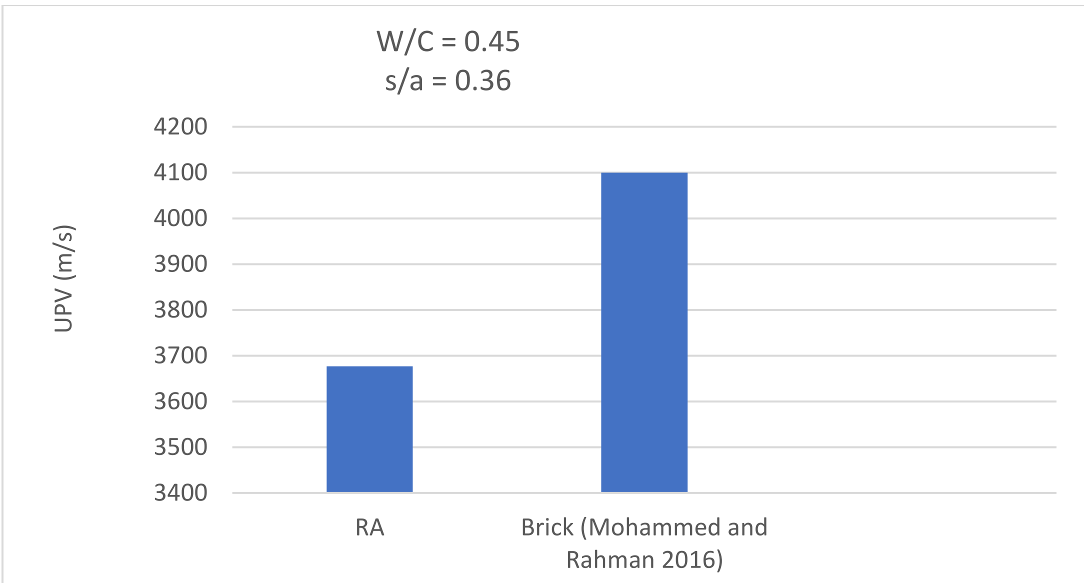


Figure: 4-5 UPV result of RA and VBA

This table shows the result of UPV where w/c = 0.50 and s/a = 0.36

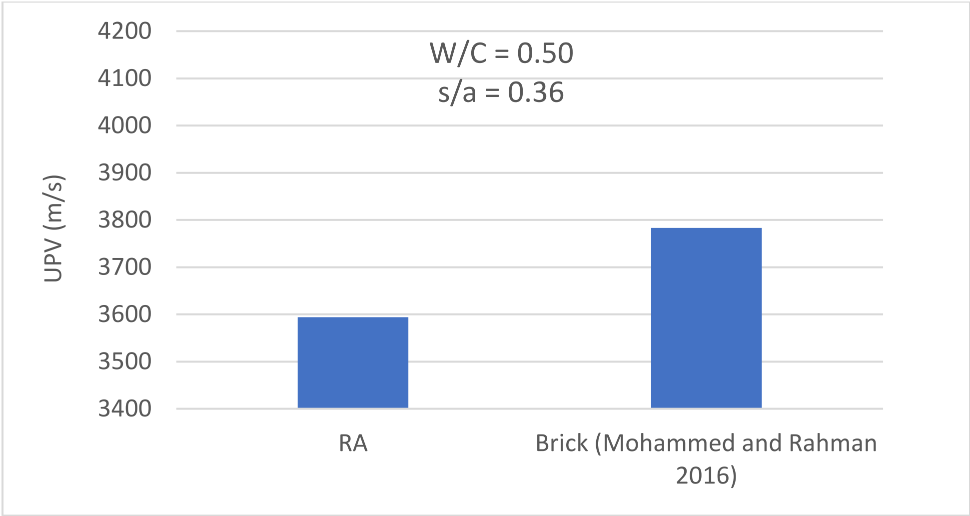


Figure: 4-6 UPV result of RA and VBA

This table shows the result where w/c = 0.55 and s/a = 0.36

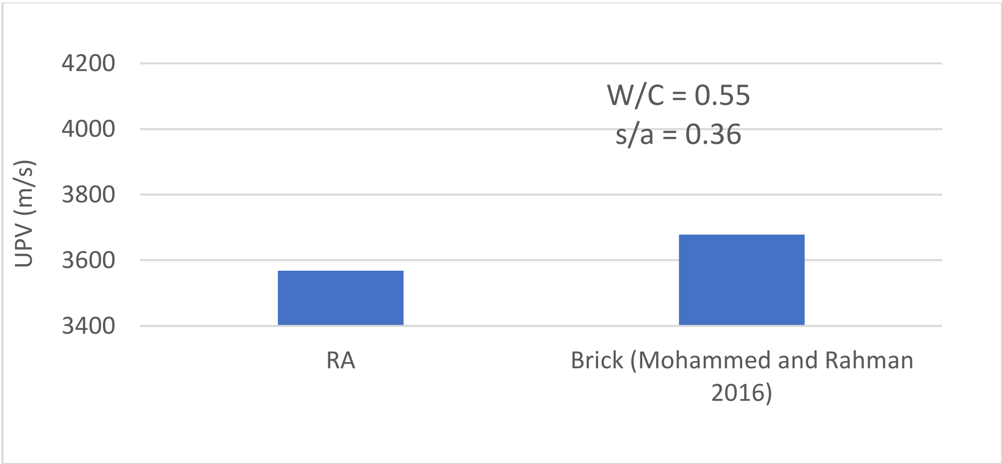


Figure: 4-7 UPV result of RA and VBA

This table shows the result where w/c = 0.45 s/a = 0.40

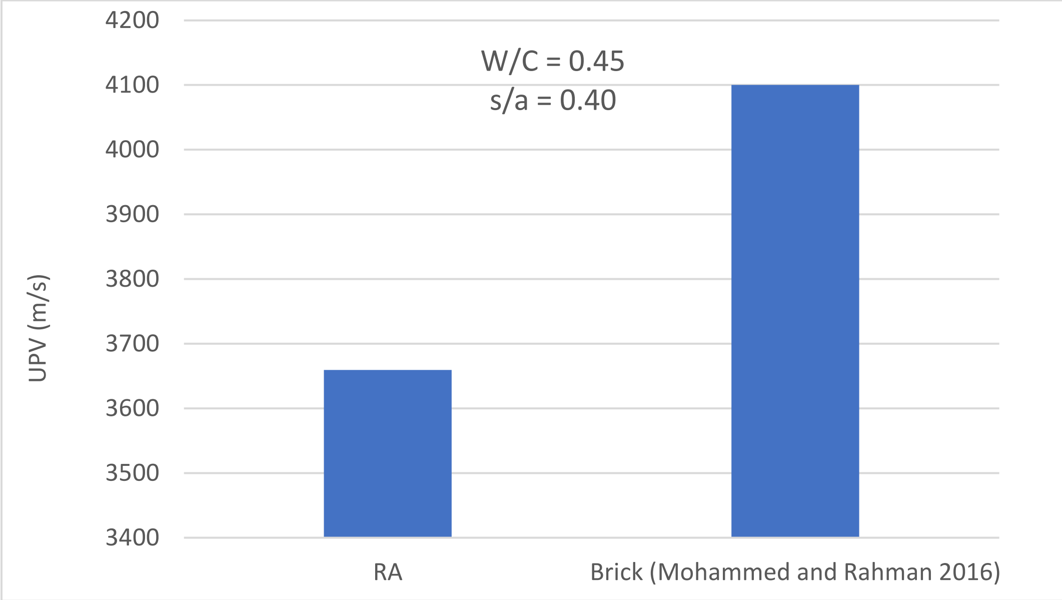


Figure: 4-8 UPV result of RA and VBA

This table shows the result where w/c = 0.50 s/a = 0.40

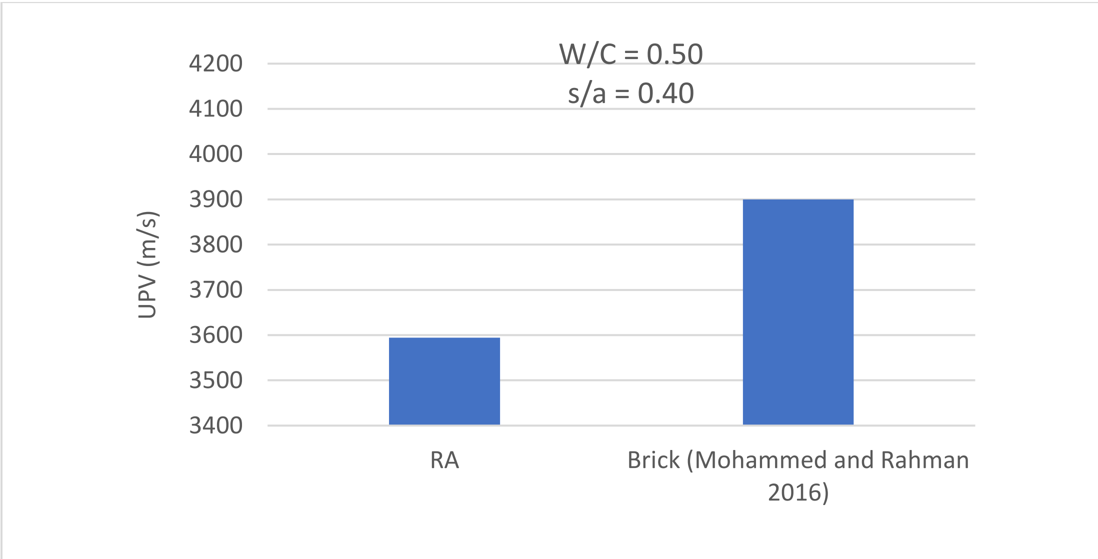


Figure: 4-9 UPV result of RA and VBA

This table shows the result where w/c = 0.55 s/a = 0.40

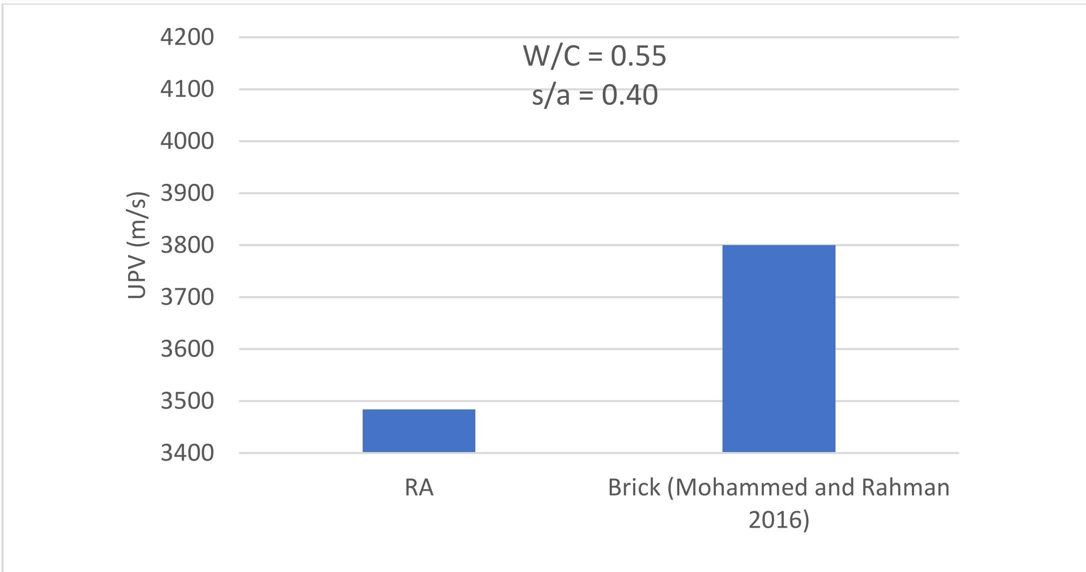


Figure: 4-10 UPV result of RA and VBA

From the above tables we see that the UPV result of recycle brick aggregates are much lower that the virgin brick aggregates. When we use recycle brick aggregates the Interfacial Transition Zone (ITZ) volume of concrete increased. That's why the UPV faced more challenge in recycle brick aggregates in comparison to virgin brick aggregates.

4.5 Compressive strength of concretes made with RA and virgin brick aggregates.

The tests that have done for different cases of recycle brick aggregates is compared with the results of virgin brick aggregates from the literature that was done before by Nafiur Rahman before. In this section compressive strength is compared between recycle brick aggregates and virgin brick aggregates.

This table shows the result where w/c = 0.45 s/a = 0.36

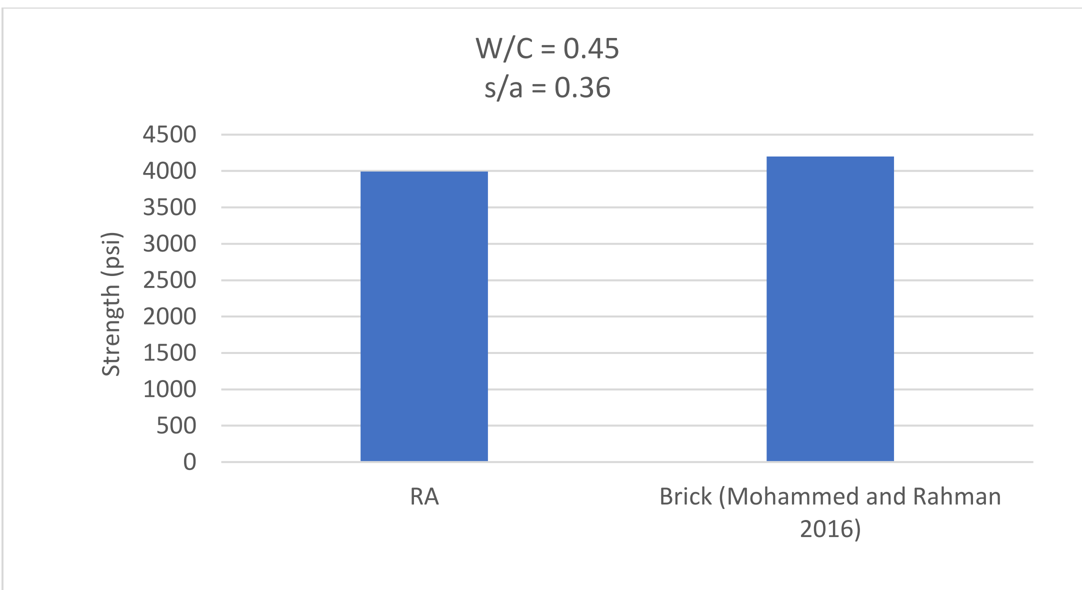


Figure: 4-11 Compressive strength result of RA and VBA

This table shows the result where w/c = 0.50 s/a = 0.36

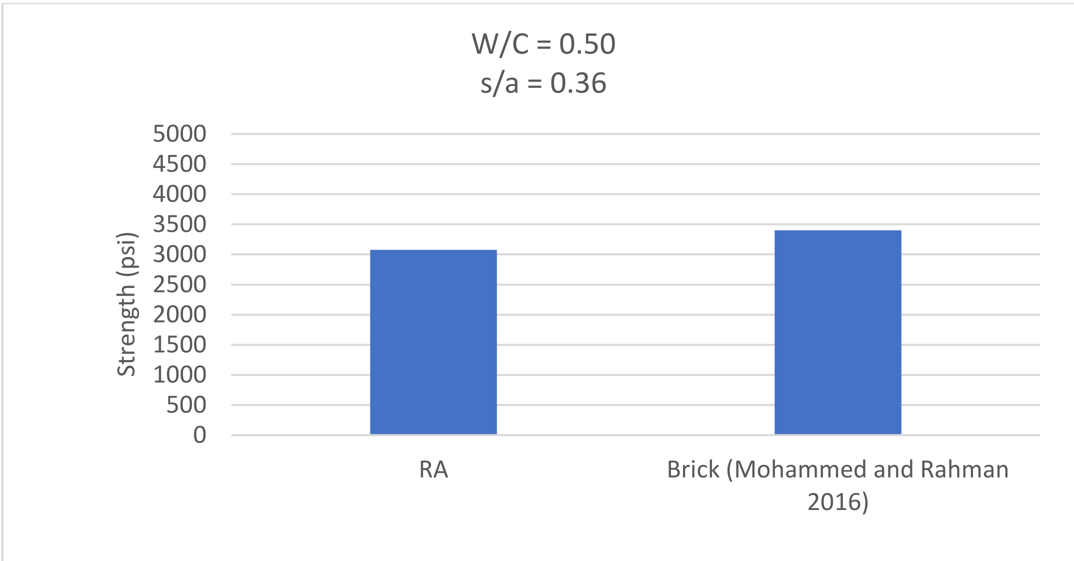


Figure: 4-12 Compressive strength result of RA and VBA

This table shows the result where w/c =0.55 s/a= 0.36

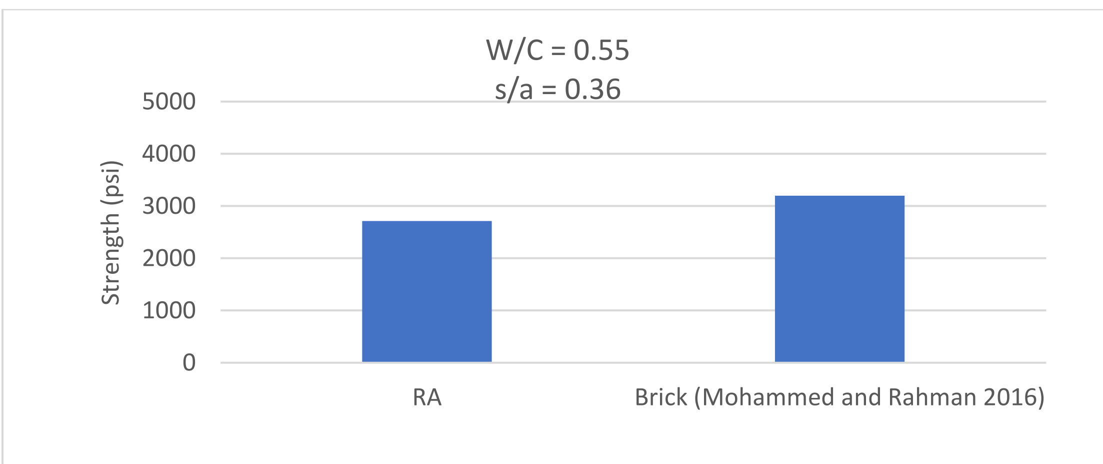


Figure: 4-13 Compressive strength result of RA and VBA

This table shows the result where w/c = 0.45 s/a = 0.40

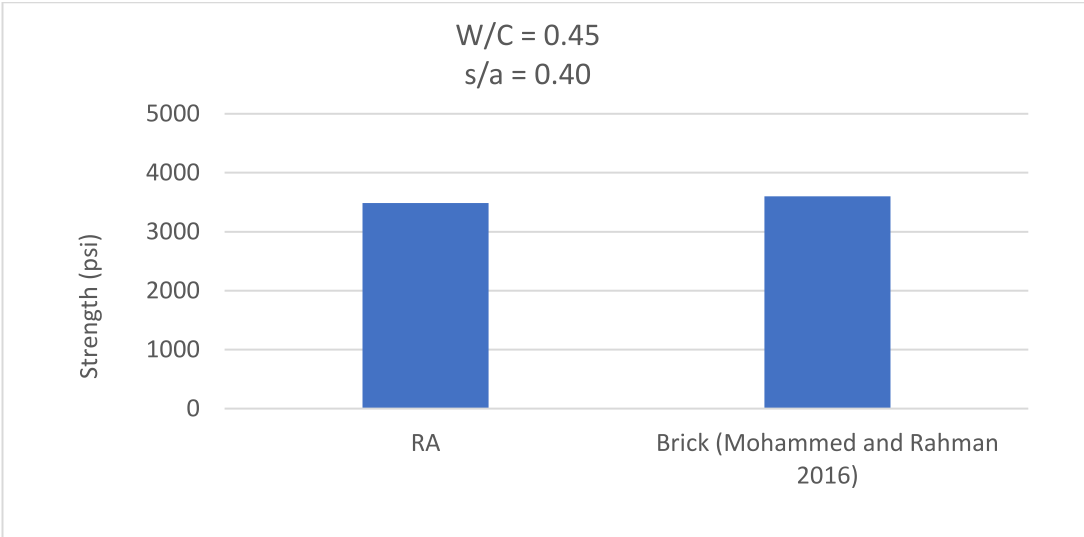


Figure: 4-14 Compressive strength result of RA and VBA

This table shows the result where w/c = 0.50 s/a = 0.40

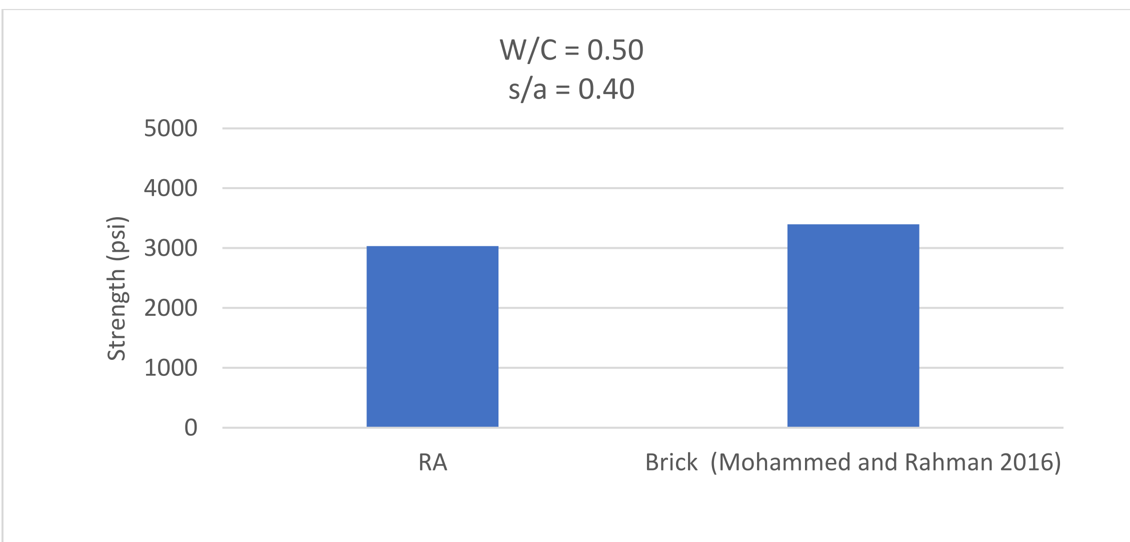


Figure: 4-15 Compressive strength result of RA and VBA

This table shows the result where w/c = 0.55 s/a = 0.40

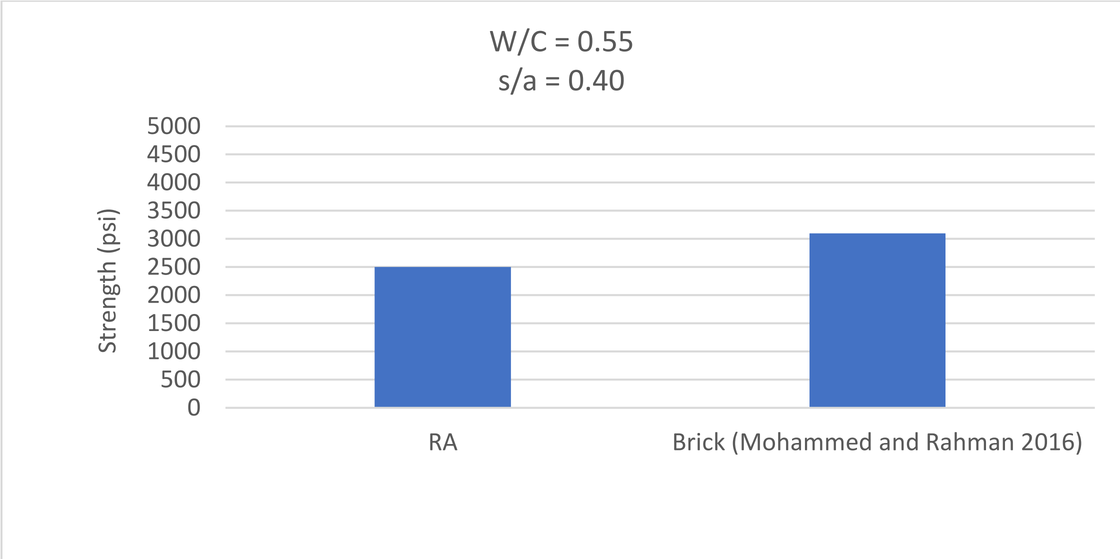


Figure: 4-16 Compressive strength result of RA and VBA

From the tables we see that the compressive strength of recycle brick aggregates are muck closer to virgin brick aggregates. As the virgin brick aggregates are used all over the world for construction purpose we can also use recycle brick aggregates as alternatives. Because recycle brick aggregates can take as much load and stress like the virgin brick aggregates. It will reduce the harm of environment. As making of virgin brick aggregates causes a lot of CO2 and other harmful gases.

4.6 Effect of s/a ratio on UPV through recycled aggregate concrete

Normally for s/a value UPV changes. For the recycle brick aggregates the UPV value varies a lot. In this section the changes will be shown.

This figure will show for a fixed w/c = 0.50 the value of UPV changes with s/a ratio.

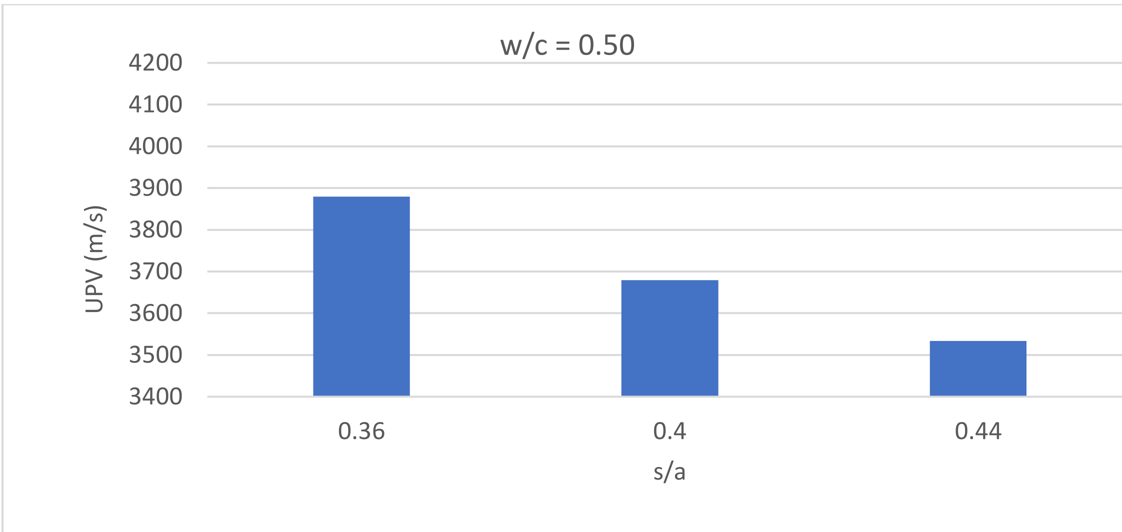


Figure: 4-17 UPV result for different s/a ratio

From the figure we can see that with the increase of s/a ratio the UPV value decreases for recycle brick aggregates.

4.7 Effect of s/a ratio on compressive strength of recycled aggregate concrete.

The compressive strength of recycle brick aggregates varies with the s/a ratio. In this section it will be shown.

This figure will show for a fixed w/c = 0.50 the value of compressive strength changes with s/a ratio.

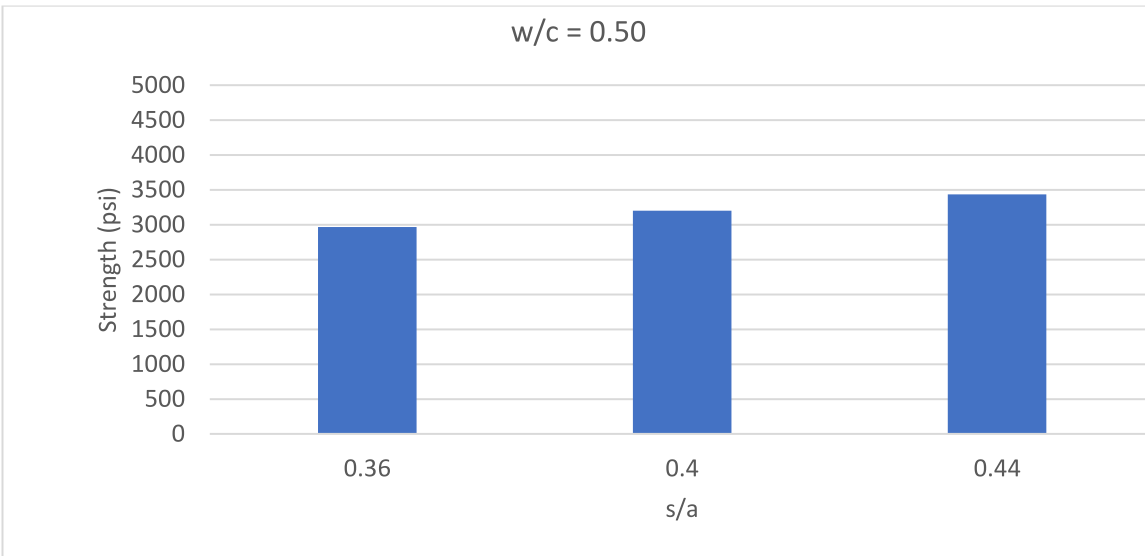


Figure: 4-18 Compressive strength result for different s/a ratio

From the figure we can see that with the increase of s/a ratio the value of compressive strength increases for recycle bricks aggregates.

4.8 Conclusion

The primary goal of this study was to find out and establish relationship between ultrasonic pulse velocity and compressive strength of concrete. Also, brief analysis with an attempt to establish link between different properties of concrete and UPV was also done. Comprehensive study among concrete made with recycle brick aggregates are made in order to have a better understanding.

Chapter 5: Conclusions

5.1 Reviews on Completed Research Work

As per the objective and scope of the study to find out a suitable relationship between compressive strength of concrete and UPV, different relationships are found out on the basis of the sand to total aggregate volumetric ratios. Also different options are explored to find out possible relationship between UPV and other properties of recycle brick aggregates and virgin brick aggregates.

In this chapter the findings of these tests will be mentioned in a short way to highlight the main points related to the study.

5.2 Summary and Conclusion

- Ultrasonic pulse velocity through recycled brick aggregate concrete is lower compared to virgin brick aggregate concrete.
- Compressive strength through recycled brick aggregate concrete is slightly lower than concrete made with virgin brick aggregate.
- Ultrasonic pulse velocity through concrete decreases with the increase of s/a ratio.
- Compressive strength of concrete increases with the increase of s/a ratio.

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