COMBINED EFFECT OF CRUSHED CLAY BRICKS AND FLYASH ON THE STRENGTH CHARECTERISTICS OF RECYCLED CONCRETE

DISSERTATION II

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SOHAIB SHAFQAT MARAZI

11616719

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Under the Guidance of

Er. Sristi Gupta

Assistant Professor

DEPARTMENT OF CIVIL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

DECLARATION

I, SOHAIB SHAFQAT MARAZI (11616719), hereby declare that this thesis report entitled **"COMBINED EFFECT OF CRUSHED CLAY BRICKS AND ADMIXTURES ON THE STRENGTH CHARECTERISTICS OF RECYCLED CONCRETE"** submitted in the partial fulfilment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: **SOHAIB SHAFQAT MARAZI**

Place:

CERTIFICATE

Certified that this project report entitled "COMBINED EFFECT OF CRUSHED CLAY BRICKS AND FLYASH ON THE STRENGTH CHARECTERISTICS OF RECYCLED CONCRETE" submitted by "**SOHAIB SHAFQAT MARAZI"** registration number 11616719 of Civil Engineering Department, Lovely Professional University, Phagwara, Punjab who carried out this project work under my supervision.

This report has not been submitted to any other university or institution for the award of any degree.

Er. Sristi Gupta
Assistant Professor
Department of Civil Engineering

Head of Department

Structural engineering

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ABSTRACT

Population increase, urbanization and overall development of human civilization led to the innovation of high-rise buildings now a day in many countries low rise and weak structures are demolished to give way for the building of high rise buildings. Concrete is the most extensively used material in construction it is so because of its properties like durability ,versatility ,compressive strength and easily alterable properties .construction industry is among industries having huge impact on environment as concrete production requires large amount of natural resources and energy and produces large quantity of wastes. Concrete is considered a potential consumer of wastes because of its composite nature and extensive use. By doing this a large quantity of wastes particularly construction and demolition wastes (CDW) would be recycled. This would lead to proper use of CDW otherwise being used as landfill and leading to environmental pollution because of its non-biodegradable nature. Extensive research has been done in the field of processing and utilization of CDW particularly recycled aggregate concrete (RCA) or concrete rubble and crushed clay bricks (CCB) in concrete. This paper would provide an account of characteristic features of RCA and CCB and their effects on the properties of concrete due to their individual and combined inclusion in concrete, after extensive study of more than 20 research papers on related topics .Thus can be valuable for chalking out the design methodology and provides an idea about the research done in this field. Many methods have been developed for effective removal, treatment and utilization of construction and demolition wastes .amongst the different construction wastes the use of recycled concrete aggregate is more popular and promising in terms of end concrete produced. In real practice RCA is enviably mixed with other wastes most importantly CCB thus effecting the physical and mechanical properties of concrete. The separation of CCB from RCA is practically very difficult and uneconomical, thus it is important to study the effects of CCB on the fresh and hardened properties of recycled concrete to improve our knowledge on this matter. And thus pave the way for effective and economical production of sustainable concrete. The aim of my study is to study

the effect of CCB on recycled concrete at different inclusion level and at different w/c and sand to aggregate ratio on the fresh and hardened properties of recycled concrete.

KEY WORDS : Recycled concrete aggregate, crushed clay bricks, workability, compressive strength, tensile strength, flexural strength, permeability

ABBREVIATIONS:

RCA………recycled concrete aggregate,

CCB………crushed clay bricks

RP………...replacement percentage

RCRA…….recycled crushed rock aggregate

RPA………recycled pebble aggregate

RCRC…….recycled crushed rock concrete

RPC……… recycled pebble concrete

W/C……….Water-cement ratio

SWA………sanitary waste aggregate

WCA………waste concrete aggregate

FRA……… fine recycled aggregate

CBA……… crushed brick aggregate.

CHAPTER 1

INTRODUCTION

India alone produces 10-12 million tons of construction wastes. More than 50 % of this construction and demolition wastes comprises of concrete and masonry wastes. Growing environmental concerns over the disposal of the wastes and the depletion of natural reserves of aggregates have pushed us to find a sustainable solution to this problem one of which is to use this waste, in concrete, after proper grading and treatment . Hence it is imperative to study the effect of these materials on the properties of concrete to develop an effective method of incorporating these materials in concrete.it has been found that RCA can be used satisfactorily to replace 25-35% of coarse aggregate but the replacement of CCB has to be limited to 15% for coarse aggregate and 30% for fine aggregate without causing significant decrease in concrete properties. In my study I intend to study the effect of CCB at different replacement levels on the fresh and hardened properties of recycled concrete. And also study the effect of admixture on different levels of replacement of CCB in recycled concrete.

CHAPTER 2

2.1 LITERATURE REVIEW

Jian Yang , Qiang Du , Yiwang Bao(2010) Concrete with recycled concrete aggregate and crushed clay bricks.

They aimed at studying the effects of inclusion of crushed concrete bricks in the concrete produced by using recycled concrete aggregate as coarse aggregate at different replacement percentage (0%,20%,50%)to mimic the real life situation faced while recycling construction and demolition wastes .they used four samples of different mix proportion as below.

Table 1. proportions of CCB and RCA used

SAMPLES AND THEIR PROPORTIONS OF RCA & CCB		
Sample name	CCB	RCA
NA-100	0%	0%
RCB-80	20%	80%
RCB-50	50%	50%
RC-100	0%	100%

OPC and natural sand was used in all the mixes pre-wetting was done for all recycled aggregates. The target strength for all concretes was taken as 40Mpa and w/c was taken as 0.47.different tests were performed on the aggregates and to determine the effect of different replacements on the fresh and hardened properties of concrete. it was found that the recycled aggregates have lower density and higher water absorption .Tests performed on fresh concretes revealed that the slump value decreased replacement percentages of recycled aggregates increased this trend seemed to be more pronounced for higher inclusion levels of crushed clay brick slump value was found to be lowest for RCB 50. Similar trends were found for the compressive strength values it was found that the compressive strength values for RC 100 were comparable to that made with natural aggregate .the loss on tensile strength followed similar trend the decrease was higher after 7day flexural strength of recycled concrete aggregate is generally low but it was found just higher than that of natural aggregate concrete for RCB 80 the reason for this was given that due to low young's modulus of elasticity of crushed clay brick the stress at matrix aggregate interface was lower more over it was found that effect of permeability on compressive and tensile strength was more pronounced than on flexural strength .Concrete mix with 20%crushed clay brick was found to be very good in terms of protective quality and the one with 50% crushed clay brick was of good quality level.

Chunheng Zhou , Zongping Chen (2016)Mechanical properties of recycled concrete made with different types of coarse aggregate

They aimed at investigating the properties of recycling aggregates produced by using different types of aggregates .they used recycled concrete aggregate obtained from concretes made with crushed rock aggregates and pebble rock aggregates they named them "RCRA" and "RPA" they used opc-42.5mpa(28day strength),natural aggregates they employed pre saturation of recycled concrete aggregate to maintain w/c 22different mixes were prepared out of those 10 were for replacement of natural coarse rock aggregate by recycled crushed rock aggregate at replacement percentages 10,20,30,40,50,60,70,80,90,100 at cement content of 398 kg/m^3 and w/c 0.49 similarly for recycled pebble aggregate for cement content 404 and w/c 0.47 different test were performed it was found that w/c ratio in general was higher but that of recycled crushed rock aggregate was higher than that of recycled pebble aggregate from compressive failure pattern it was found that cracks existed in the mortar aggregate interface also the stress strain curve for recycled crushed rock concrete had higher peak than that of recycled pebble concrete .compressive and flexural strength increased with increase in replacement percentages reason for this was concluded that the water absorption of recycled aggregates leads to improved bond strength .elastic modulus decreases with increase in replacement percentages due to lower density and stiffness of recycled concrete aggregate this reduction was higher in concrete made with recycled pebble aggregate due its shape and surface features.

M. Chakradhara Rao, Ramnarayan(2016) Effect of the Quality of Recycled Aggregate on Compressive Strength of Recycled Aggregate Concrete.

They investigated the quality of concrete made with RCA obtained from different parent concretes .recycled aggregates were procured from M20 M25 M30 M40grade concretes and named R20 R25 R30 R40. After determining the physical and mechanical properties of RCA two grades of recycled aggregate concrete MR20 andMR30 of target strength 20 and 30Mpa were produced using R20 and R25 and R30 andR40 thus forming 4 separate mixes namely MR20RA20,MR20RA25,MR30RA30,MR30RA40.during grading recycled aggregates were found to possess more finer portion due to the adhered mortar which breaks of while crushing they were also of lower density and possessed high water absorption ,flakiness and impact value was also found to be higher for recycled aggregates, furthermore it was found that density of mixes obtained from recycled aggregates of higher grade was lower than those made from lower graded recycled aggregates and they also possessed higher water absorption this trend was attributed to more mortar being adhered to recycled aggregate obtained from higher graded concrete .After performing compressive strength test it was found that the samples made with recycled aggregates of grade same as that of its own the compressive strength values were low but for samples made with recycled aggregates obtained from concrete of grade higher than that of sample the values were higher thus it is possible to produce concrete with strength comparable qualities to those of natural aggregate concrete by using recycled aggregates obtained from concrete of higher grade than that of the concrete to be produced.

Cheng-Chih Fan , Ran Huang , Howard Hwang , Sao-Jeng Chao(2016) Properties of concrete incorporating fine recycled aggregates from crushed concrete wastes

They aimed to study the effects of replacing natural fine aggregates with recycled fine aggregates .recycled fine aggregates were produced by two methods first one produced both coarse as well as fine aggregates they were represented by symbol R1 second one produced only fine aggregates they were represented by R2.R2 were found to be of superior qualityR1 were rougher and of angular shapes .two types of mixes were produced for study and in both the types replacement was done at 25,50,100%.one type was designed for constant w/c of 0.35 and the other at w/c of 0.55 former required addition of superplasticisers 1% of the cement content to maintain the workability .FRA(fine recycled aggregates)were of lower density and higher water absorption but R1had even lower density and higher water absorption than that of R2 and R1has more cement paste than R2 workability generally decreases for FRA but that of R2 is even lower than that of R2 concrete and had higher density than that of R1. Water absorption was higher for higher replacement percentages but that of R1 was higher than that of R2.compressive strength values were lower for R2 concrete than that of R1 reason was given that R1 is more porous than R2 initial surface absorption was found to be decreasing with time and dropped sharply in 30minutes and slowed very much after one hour water absorption was found to be higher for higher replacement percentages concrete with R1had higher initial surface absorption as R1aggregat had higher water absorption conclusions drawn from this were that fine recycled aggregates can be used for replacement of fine natural aggregate for concrete production but the quality of resulting concrete depends on the source and quality of the recycled aggregate this can be clearly deduced from the fact that R1 concrete had lower slump density and compressive strength and had higher water absorption than that produced by R2.this difference in the quality of resulting concrete was due to the fact that R2 was of better quality than R1

Farid Debieb , Said Kenai(2006), The use of coarse and fine crushed bricks as aggregate in concrete

They aimed at studying the effect on the properties of concrete on replacing both coarse and fine aggregate with crushed clay bricks Natural sand , coarse aggregate and both were replaced at 0,25,50,75,100% mixes were proportioned to maintain a constant slump of 60-80mm it was found that entrained air increase with increase replacement level. Segregation was noticed at 100%rp Compressive strength decreased upto 35% for coarse 30% for fine and 40% for both. Flexural strength decrease for 15 to 40% for both Modulus of elasticity decrease upto 30% ,40% and 50% for coarse ,fine and both replacement respectively Water absorption was found to be lowest at 25% and 50% for coarse and fine respectively Optimal utilization 25% for coarse and 50% for fine.

Chi Sun Poon , Dixon Chan(2005)Paving blocks made with recycled concrete aggregate and crushed clay brick.

They studied the possibility of using recycled concrete aggregate and crushed clay bricks in paving blocks they replaced both coarse and fine aggregates with recycled concrete aggregate and crushed clay bricks made 2 series of mixes series 1 and series 2. Series 1 contained crushed bricks at replacement levels 0,25,50and 75%same was done in series 2 only difference being that fly ash was used to replace coarse and fine aggregate by 15% by weight in the end a mix using only fine aggregate ,cement and fly ash was made at 25% replacement level of CCB.

Compressive as well as tensile strength of paving blocks reduced with increase in CCB replacement percentage .fly ash addition improved the strength of concrete at same replacement level of CCB water absorption increased with increase in CCB replacement percentage. Paving block prepared at 25% CCB replacement level were of better quality and those made with 50% CCB were acceptable . Replacing only fine aggregates(<5mm) increased splitting strength but reduced density

Mohammed Tarek Uddin, Aziz Hasan Mahmood, Md. Rubayetm Ibna Kamal,S.M. Yashin,Zia Uddin Ahmed Zihan(2016)Effect of maximum size of brick aggregate on properties of concrete

They investigated the effect of aggregate size in the properties of concrete with different sand to aggregate ratio and different water to cement ratio they made a total of 52 mixes they found that the workability increases with increase in size they attributed this to decrease in internal friction they found the compressive strength values for lower cement content increased with increase in aggregate size up to 37.5mm because of reduction of interfacial transition zone but started to decrease possibly due to heterogeneity of interfacial transition zone but for higher cement content compressive strength simply decreased with increase in aggregate size also with increase in w/c there was a decrease in compressive strength irrespective of cement content moreover there is an increase in compressive strength with increase in s/a ratio from 0.4to 0.45.the split tensile strength dropped with increase in size irrespective of s/a. the young's modulus of elasticity increased with increase in size for low cement content and low w/c but for high cement content it decreased with increase in size. From image analysis performed on the samples it was revealed that the perimeter of interfacial transition zone around the aggregates decreases with increase in size thus lower cement content was required to improve the interfacial transition zone and the effect of cement content is more prominent for smaller size aggregates.

Paulo B. Cachim (2008) Mechanical properties of brick aggregate concrete

They used CCB obtained from 2 sources brick A and brick B CCB was incorporated used at 30% and 15% replacement percentages of natural coarse aggregate of recycled concrete with w/c ratio 0.5 and 0.45(pre saturation) cement content 400kg/m3

Workability was found to be constant for both series of samples(w/c0.45=5cm w/c0.5=15cm).

Density decreased with increase in replacement percentage (lower for w/c=0.5) Compressive strength generally decreased with increase in replacement percentage(15% replacement percentage brick B no significant reduction but for 30% replacement percentage 10% reduction, w/c =0.45 closer to control).Similar results were found for tensile strength.

Fathei Ramadan salehlamein, Mochamad .Solikin , Ir.sriSunarjono(2015)
Effect of recycled coarse aggregate on properties of concrete.

They aimed at studying the effect of recycled aggregate on concrete properties (fresh and mechanical) they created 2series of samples with different grading water content cement content and aggregate volume but same target strength ie M-30.

Table 2 mix proportions used.

	Volume	Weight	Water	Cement(kg)	Fine agg(kg)	Coarse agg (kg)
Batch 1	1 m^3	2350	190	355	545	1270
Batch 2	1 m^3	2340	230	430	535	1240

They found that for both the batches the slump decreased with increase in replacement percentage. Flexural strength and modulus of elasticity decreased with increase on replacement percentage. Similar trend was followed in case of compressive strength but it was noted that at lower replacement percentages batch 1(particle size 20mm)showed better results than batch 2(particle size 10mm)

2.2Literature summary:-

2.2.1 Properties of RCA.

Waste concrete structural elements are simply crushed to convert them into RCA this can also be done by employing methods like heating and rubbing ,eccentric shaft rotation method and mechanical grinding method. Scientific research in the properties of RCA was started by

Gulzhge in Russia[7]. RCA thus obtained is inevitably mixed with material like bricks, tiles, metals etc termed as impurities .RCA is adhered mortar containing of natural aggregate at its core ,this adhered mortar dictates most of the properties of RCA.[8] found that the amount of adhered mortar decreases with the increases in nominal size of RCA. For nominal sizes 4-8mm,8-16mm and 16-32mm adhered mortar volume percentage was 60% ,40% and 35% respectively. [8] showed that the water absorption of RCA is more than that of virgin aggregate this is attributed to the porosity of adhered mortar. Some researchers found water absorption of RCA to be 2.3 to 4.6 times higher than that of natural aggregate. [9]Some researchers reported increases in water absorption with the increase in aggregate size. Wet density of concrete was noted to decrease with the increase in RCA inclusion level.

Mechanical and chemical properties of aggregate tend to have a substantial impact on the properties of resulting concrete. [10]Studies have shown that the mechanical strength ,resistance to fragmentation and durability in terms of freeze-thaw resistance of RCA is lower than that of the natural aggregate. However some researchers[11] found compressive strength of RAC higher than normal concrete. Durability of aggregate if measured by the freeze-thaw resistance was found to decrease with increase in RCA, which, with higher water absorption were found to be less resistant to freeze-thaw .[12] observed a noticeable decreases in compressive strength ,flexural strength ,elastic modulus and freeze-thaw durability with increase in crushing index of RCA ,rate of strength loss was higher when crushing index of RCA was higher than 24%.

2.2.2 Effect of RCA on the properties of concrete.

Workability of concrete was found to decrease with increase in inclusion level of RCA this was attributed to the higher water absorption of RCA [9] noted that workability decreased as the nominal size of aggregate increases ,the slump value decreased from 50 mm to 40mm when nominal size was increased from 5mm to 37.5mm. Inclusion of FRA also led to decrease of slump values[13] attributed this to greater angularity of FRA which resulted in increased friction among the particles.[14] found that addition of super plasticizers resulted in increased slump for same water cement ratio .Addition of RCA results in decrease in wet-density of the concrete[15] ,this can be attributed to lower density of RCA itself.

Compressive strength is the one of the most notable properties of hardened concrete. Addition of RCA results in reduction of compressive strength of concrete .[2,3] found that with the increase in inclusion level of RCA compressive strength of resultant concrete keeps on decreasing ,however some researchers[14] noticed that up to inclusion level of 20% for RCA reduction on compressive strength was not significant.[15] found that compressive strength of concrete prepared using SSD RCA was found to be less than the compressive strength of concrete prepared by air dried RCA this was attributed to bleeding of absorbed water in SSD RCA.[13] C.-C. Fan et al also found decrease in compressive strength with increase in FRA content however it was stated that for concrete with target strength up to 20.68Mpa all replacement ratios except the one with 100% replacement would be acceptable.[9] noted that compressive strength increased with increase in mean aggregate size. Highest compressive strength was recorded for nominal size of 20mm ,however it was also noted that 10 mm size was optimum in terms of both compressive and split tensile strength the reason for this was attributed to its rate of water absorption which was lowest compared to higher size aggregates.

Tensile strength is also an important property of concrete. Concrete is weak in tension [9] reported decrease in tensile strength with increase in inclusion level of RCA .On the other hand [16] reported tensile strength remained constant or surpassed the tensile strength of concrete made with natural aggregate this anomalous behavior can be attributed to high water absorption of RCA.

Flexural strength of concrete kept on decreasing with the increase in inclusion level of RCA[3] this can be attributed to weak interfacial transition zone due to weak bond formation between old cement mortar in RCA and new cement paste.

[3] Addition of RCA results in reduction of modulus of elasticity of concrete. Results appeared to follow the same pattern as that of compressive strength.[13] Similar results were obtained for FRA ,it was also noted mix with lower w/c ratio showed better results.

[17] found that strength of concrete was enhanced by the use of two stage mixing approach (TSMA).[18] found that coating aggregate surface with pozzolanic materials (fly ash, silica fume etc) enhanced the strength of recycled aggregate concrete.

Researcher found that addition or RCA reduces the resistance to chloride ion penetration , but noted that chloride ion penetration reduced by soaking RCA in water for 24 hours prior to use also resistance to freeze thaw and carbonation reduces as the inclusion level of RAC increases in concrete[25].

2.2.3 Properties of CCB.

CCB is produced from the brick portion of the concrete structure. It is considered as the impurity when found mixed with RCA used for production of recycled aggregate concrete. Use of CCB in concrete was first done in Germany for the reconstruction after World War II . studies on CCB have shown that CCB has lower compressive strength ,higher water absorption and lower density as compared to natural aggregate concrete. Properties of CCB largely depend on properties of parent brick from which it is obtained. Under normal conditions only a limited quantity of CCB can replace the natural aggregate. [19] reported that in order to produce concrete of satisfactory quality the amount of CCB should be lower than 25% and 50% for coarse and fine aggregate respectively while [4] observed in order to produce concrete without any reduction in its properties replacement should be limited to 15% and with reduction up to 20% replacement should be limited to 30%.

2.2.4 Effect of CCB on the properties of concrete.

[22] Workability of concrete decreases with increase in inclusion level of CCB ,however [21] noted that even though overall workability decreased with increase in CCB inclusion level but concretes made with larger size aggregate and higher w/c ratio turned to have slightly better workability than the rest this was attributed to decrease in lower sized aggregate which results in lower internal friction among aggregates. 5% and 6% Reduction in wet density of concrete was noted by [4] that for concrete mixes with w/c 0.45 and 0.5 respectively.[19] noted segregation in concrete with 100% of both fine and coarse aggregate replacement.

[19] found a notable decrease in compressive strength as the inclusion level of CCB was increased in concrete. It was noted that decrease in compressive strength was 10%-35% for only coarse aggregate replacement ,strength reduction of about 30%was noted for only fine aggregate replacement and strength reduction of 40% when both fine and coarse aggregate were replaced.

[4] observed reduction pattern in tensile strength similar to that in case of compressive strength and mix with 0.45 w/c ratio showed better results than mix with 0.5w/c ratio. Researchers noted a decrease in modulus of elasticity with increase in CCB inclusion level .[19]observed a reduction of 30% ,40% and 50% in modulus of elasticity when coarse ,fine and both coarse and fine aggregates were replaced by recycled brick aggregates.[20] studying the properties of high strength concrete made by replacing natural coarse aggregate with crushed clay bricks observed that the relation between compressive strength reduction and increase in w/c ratio can be predicted by this relation.

$$Fc' = 73517(\mathbf{w/c})^2 - 68347(w/c) + 20432$$

M.T.Uddin et al[21]reported that for lower cement content up to MAS(mean aggregate size) 37.5mm corresponding compressive strength and modulus of elasticity also increased but for higher cement content increase in MAS resulted in reduction in both compressive strength and modulus of elasticity.

2.2.5 Effect of CCB on the properties of RAC

Workability of recycled aggregate concrete(RAC) is lower as compared to normal concrete but it is further reduced if the level of CCB inclusion is increased[7] attributed this to increase in amount of small sized particles produced due to breakage of CCB during mixing and lower relative density of recycled aggregate which led to increase in aggregate volume because the mix proportions used were based on natural aggregate .[7] also noted that concrete having higher quantity of CCB posed difficulty during compaction and surface finishing .[24] studied the properties of paving blocks made of recycled aggregate and crushed clay bricks and found a notable decrease in density of recycled aggregate concrete with increase in inclusion level of CCB attributing this to the lower density of CCB.

[7] observed a significant reduction in compressive strength at higher inclusion level of CCB in RAC. It was also noticed that cracking was mostly at 45 to the axis near the end .Poon and Chang [24] noticed that strength reduction due to increase in CCB inclusion level was not significant after 50% replacement and difference between different compressive strength diminished after 28 days of casting. A significant increase in compressive strength was noticed

due to replacement of 15% aggregate by weight with fly ash. [7] noticed a reduction in splitting tensile strength with the increase in inclusion level of CCB in RAC and in cases of high CCB inclusion level tensile failure was found to occur within CCB particles this phenomenon was attributed to low tensile strength of CCB. [24] noticed a significant increase in tensile splitting strength for mix having 25% inclusion level in both coarse and fine aggregate and 15% of total aggregate content replaced by fly ash this was attributed to the use of 10 mm size aggregate which led to increase in bonding area between cement paste and aggregate. [7] noticed that RAC with higher CCB inclusion had flexural strength at par with concretes made with natural aggregate and in some cases even exceeded the flexural strength of normal concrete. This was attributed to low Young's modulus of CCB due to which the concentration of stress along matrix aggregate interface is relieved. Increase in CCB inclusion level in RAC increased the permeability but it was observed that RAC with up to 20% CCB inclusion level produced concrete with very good protective quality and RAC with 50% inclusion level produced concrete with good protective quality against permeability.

2.2.6 EFFECT OF FLY ASH ON CONCRETE PROPERTIES

2.2.6.1 On fresh concrete.

The use of fly ash as an alternate for cement or its use in addition to cement comes with the requirement more water for the same slump because fly ash is finer than the cement. Use of fly ash particularly as an admixture as oppose to replacement of cement reduces segregation and bleeding. For coarser sand addition of fly ash produces better results and for fine sands its use may increase the water needed for a required workability.

2.2.5.2 On hardened concrete

Addition of fly ash results in lower strength at early curing days but the strength tends to increases in later ages. Modulus of elasticity is lower at early ages and higher at later ages. Coarse fly ashes or the ones having higher carbon increases drying shrinkage as oppose to finer fly ashes .The permeability of concrete decreases with increase in fly ash content. At start fly ash concrete can be more permeable but the permeability keeps on decreasing as the age of the concrete increases.

Fly ash increases sulphate attack resistance of concrete to. Fly ash decreases the heat of hydration in concrete. Addition of Fly ash decreases quantity of air entraining agent required. Addition of fly ash results in increase in initial setting time .

2.2.7 CONCLUSION

- Both RCA and CCB result in reduction in workability of concrete water absorption of CCB is higher than that of RCA but with efficient pre wetting and mixing techniques effective w/c ratio can be control so can be the workability of concrete.
- Both RCA and CCB reduce the density of concrete but the loss is more in case of CCB as the density of CCB is lower than that of RCA.
- Compressive strength and tensile strength decrease with increase in inclusion level of both RCA and CCB. While using CCB in RCA inclusion level of CCB should be kept lesser than 20% for good compressive strength.
- Flexural strength of CCB incorporating concrete is at par and sometimes higher than that of normal concrete while flexural strength of RCA incorporating concrete is lower than that of normal concrete hence RAC with higher inclusion level of CCB tends to have higher flexural strength.
- Addition of pozzolanic material leads to higher strength and lower permeability of RAC incorporating CCB but in some cases reduction in density was noticed for addition of fly ash in recycled aggregate concrete.
- Durability of RAC is lower than that of the normal concrete but concrete incorporating CCB has higher resistance to freeze-thaw cycles but both the types of concrete showed lower resistance to chloride penetration compared to normal concrete.

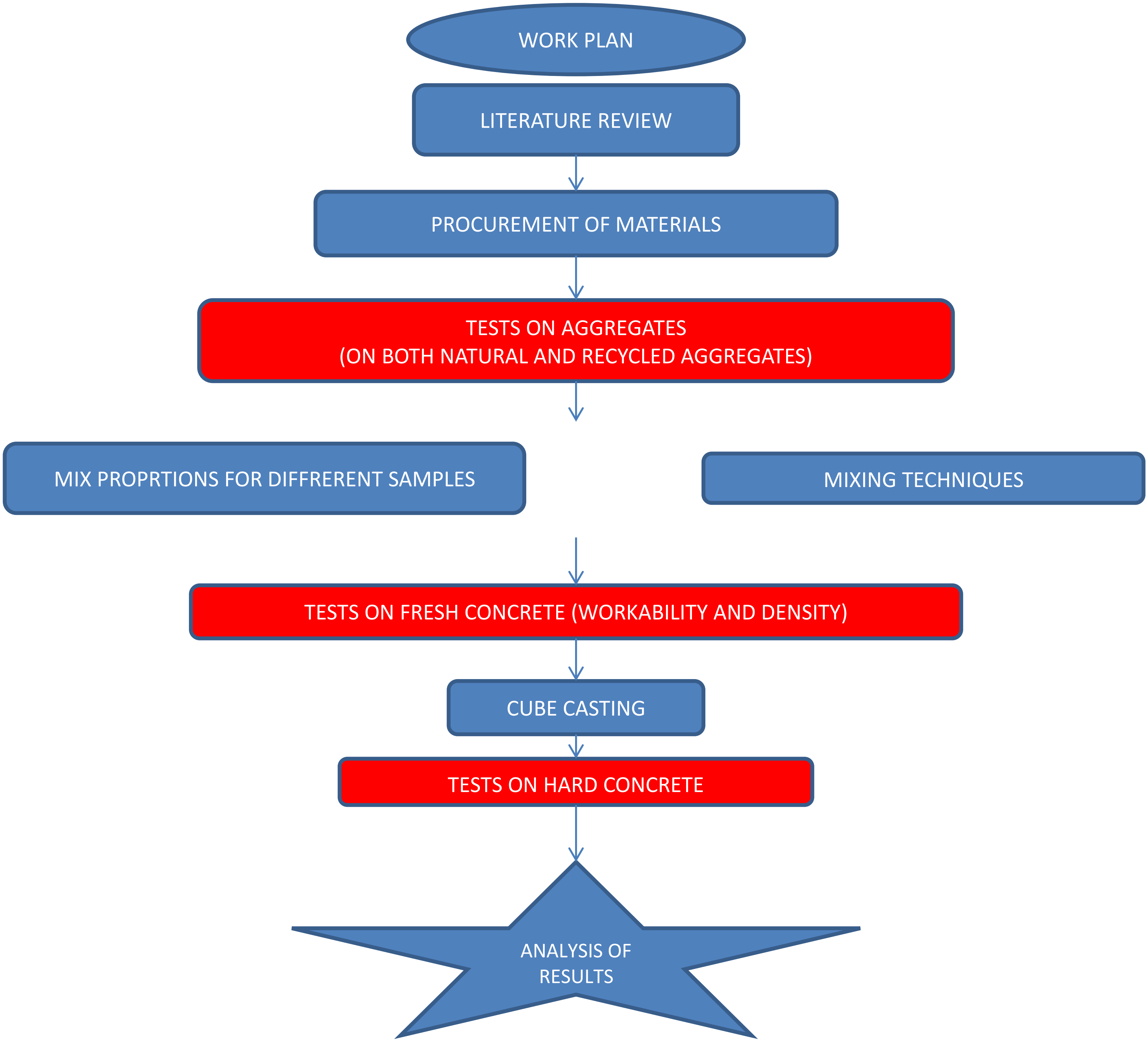
2.3 OBJECTIVE

The object of my project is to study the effects of adding crushed clay bricks on the properties of concrete made with recycled concrete aggregate. The findings of my research will lead to development of efficient techniques to produce recycled concrete using recycled concrete aggregate and crushed clay bricks. It will reduce the depletion of reserves of natural aggregate. It will reduce the environmental pollution caused by ineffective disposal of concrete wastes as well as brick wastes. The findings of my study will help in testing the accuracy of the previous research findings.

Though a lot of research has been done in this field there is still room for more to be found in the aspect of combined effect of CCB and different admixtures on the properties of RCA concrete. Results of past research combined with those of upcoming research in this field will provide insights in the field of using RCA and CCB in non-structural concrete which could not have been perceived before.

CHAPTER 3

METHODOLOGY



3.1 Methodology

First step in this regard will be to procure materials . RCA and CCB were collected from the rubble piled up around in the compound of BH4 hostel LPU. Cementing materials(OPC and fly ash) to be used were bought from the ACC plant near LPU. In order to simulate the conditions generally faced on any given construction site the procured materials were not graded on the bases of the grade of the parent concrete, though the materials after being cursed using a hand held hammer were subjected to grading on size. The fine aggregate used in this project was the simple sand it was graded and analyzed on the bases of particle size. The code followed for grading of coarse and fine aggregate was IS 456 2000

Figure 1: RCA and CCB

3.2.Tests to be run on materials

3.2.1 Tests on cementing materials:

3.2.1.1Consistency

standard consistency is defined as one which will allow Vicat plunger to penetrate up to depth of 5 to 7 from the bottom of the mold. Consistency gives an idea about the amount of water needed to form a paste of cement. To determine standard consistence take 200 g of dry cement and keep on increasing the percentage of water to be added to make the cement paste till the standard consistency is reached i.e. the height of plunger from top of the mold is between 33mm and 35mm

3.2.1.2 Soundness test

Soundness is determined by finding the expansion of cement by boiling the hardened cement for a predetermined time. Make a paste by adding 0.78% of water needed for standard consistency. Cover the mold on both sides with glass sheet and submerge it in water at normal temperature(27^{o}c).Measure the distance between indicator points.Then submerge the mould in water at boiling point and keep it there for 3 hours.Remove it from the water allow it to cool down and measure the distance between the indicators again.Now the difference between these two readings gives the soundness of the cement..

Initial setting time :

Initial setting time is the time till which cement can be moulded without a loss in strength

3.2.1.4 Final setting time:

Final setting time is the time when the cement loses its plasticity and gains its full strength

3.2.1.5 Fineness of cement

Fineness of cement is found by sieving the cement through a standardized sieve size (90 micron) then the weight of cement retained on the sieve is used to determine the fineness of cement.

3.2.1.6 Specific gravity test for cement

Specific gravity of a material means the ratio of its weight to the weight of equal volume of water. Kerosene/ diesel is used for finding the specific gravity of cement

3.2.2 Tests on coarse and fine aggregates:

3.2.2.1 Sieve analysis for coarse and fine aggregates

Is an empirical method of expressing average particle size in the aggregate. It is done by grading coarse aggregate by sieving it through the standardized sieves.

3.2.2.2 specific gravity and water absorption of coarse and fine aggregates.

Sieve analysis ,water absorption and specific gravity is found as per IS-456

3.3 Mix proportions

Mix proportions to be used in this project will be obtained from is code since all the coarse aggregates are to be used in saturated surface dried condition, thus saving us the trouble of making adjustment for it later down the project for water absorbed during the mixing operation. In addition to it the two stage mixing technique was employed during the mixing thus making the mixing operation more efficient .Since the specific gravity of RCA is lower than that of the normal coarse aggregate the resulting concrete is expected to have lower workability than the normal concrete.

Two groups of recycled concrete mixes are to be prepared both incorporating CCB at replacement levels of 15% ,25% and 50% in addition to one mix having 0% CCB ,the only difference being that one group will have 15% of OPC replaced by fly ash thus adding up to 8 individual mixes.

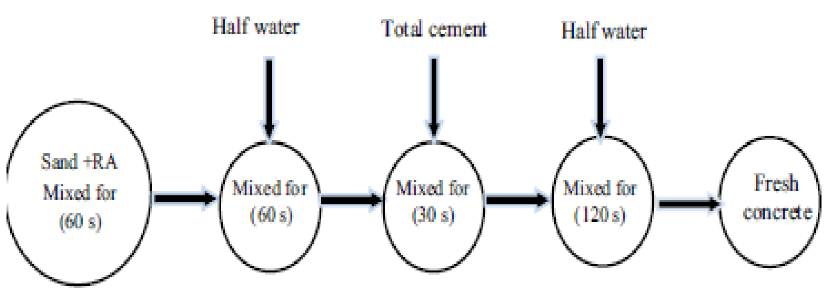


Figure 2: Two stage mixing approach

Table 3: proportions of CCB and RCA to be used in different mix samples

(a) Series I

Proportion of RCA and CCB in recycled concrete without fly ash	
Name of the mix	RCA : CCB
RCA100	1 : 0
RCB 15	0.85 : 0.15
RCB 25	0.75 : 0.25
RCB 50	0.5 : 0.5

(b) Series II

Proportion of RCA and CCB in recycled concrete with 15 %fly ash	
Name of the mix	RCA:CCB
FRCA100	1 : 0
FRCB 15	0.85 : 0.15
FRCB 25	0.75 : 0.25
FRCB 50	0.5 : 0.5

3.4 Tests to be run on fresh concrete:

3.4.1 Wet density of concrete

Density found dividing the weight by the known volume of the container . This gives the idea of the weight of concrete in general.

3.4.2 Test for workability of fresh concrete.

Workability is the measure of ease with which concrete can be mixed, worked with and finished

3.4.3 Tests to be run on hardened concrete:

Compressive strength test, Splitting tensile strength test and test for Determination of modulus of elasticity are to be done as per IS-456 2000

CHAPTER 4

4.1Tests on cement:

4.1.1 Consistency test

Procedure: standard consistency is defined as one which will allow Vicat plunger to penetrate up to depth of 5 to 7 from the bottom of the mold. Consistency gives an idea about the amount of water needed to form a paste of cement. Take 200 g of dry cement and keep on increasing the percentage of water to be added to make the cement paste till the standard consistency is reached i.e. the height of plunger from bottom of the mold is between 33mm and 35mm

Apparatus required:-Vicat apparatus, Balance, measuring cylinder, tray, glass plate.

Note: temperature should be between 25^0c and 27^0c

Figure 3:Vicat apparatus

Empirically consistency is given by formula ; $P = \frac{w}{c} \times 100$

Table 4: Consistency

	Weight of cement used	Percentage of water	Height of plunger from bottom
1	200	25	41 mm
2	200	27	30 mm
3	200	29	11 mm
4	200	30.5	7 mm
5	200	32.5	5 mm
6	200	34.5	4 mm

Therefore consistency turns out to be: 30%

4.1.2Soundness of cement

Apparatus: le-chatelier apparatus, weighing machine, measuring scale, water bath at 100^{o}c and water at normal temperature.

Procedure: soundness is determined by finding the expansion of cement by boiling the hardened cement for a predetermined time.Make a paste by adding 0.78% of water needed for standard consistency. Cover the mold on both sides with glass sheet and submerge it in water at normal temperature(27^{o}c).Measure the distance between indicator points.Then submerge the mould in water at boiling point and keep it there for 3 hours.Remove it from the water allow it to cool down and measure the distance between the indicators again.Now the difference between these two readings gives the soundness of the cement.

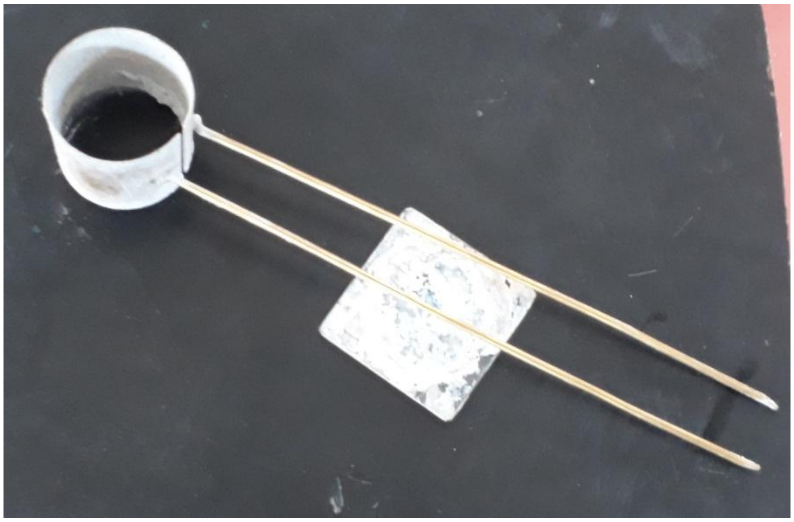


Figure 4: le-chateliers test apparatus.

Conditions of experiment: temperature between 25 and 27

Calculation :

L1 is the distance between the indicator points submerged in water at normal temperature for 24 hours

L2 is the distance between the indicator points submerged in water at 100^0c for 3 hours

Table 5: Soundness

	L1(mm)	L2(mm)	Soundness L2-L1
SAMPLE 1	1.5	3.5	2.0
SAMPLE 2	1.5	3.4	1.9
SAMPLE 3	1.5	3.3	1.8

For ordinary Portland cement the standard value is less than 10 mm

The result of the experiment was that the soundness of the OPC being used is 1.9 mm.

4.1.3 Initial setting time of cement.

Initial setting time: time till which cement can be moulded without a loss in strength

Final setting time: Time when the cement loses its plasticity and gains its full strength

Figure 5: Vicat apparatus

Apparatus : vicat apparatus, weighing balance, trowel, stopwatch.

Procedure: Take 200 grams of dry cement of predetermined consistency. Add the 0.85 times required amount of water to the cement to achieve the standard consistency. Place it in the mould and let the plunger drop this time the plunger touches the bottom of the mould. Repeat the experiment again and again till the stops at 5mm from the bottom of the mould. The time passed from mixing the cement till that time is the initial setting time.

Final setting time is when the cement paste reaches its full strength.

Percentage of Water required=

$$0.85 \times 30 = 25.5$$

volume of water added= $25.5 \times \left(\frac{200}{100}\right) = 51ml$

Table 6: Initial setting time

Sample	T_1	T_2	Setting time (T_2-T_1)
Sample a	10:15	12:18	123
Sample b	11:05	1:12	127
Sample c	12:00	2:10	130

The initial setting is calculated by taking the average of the three reading and is found to be 127 minutes

The final setting time was found to be 220 minutes. (as per IS 8112-1989 initial setting time is supposed to be more than 30 minutes and final setting time is supposed to be lower than 600 minutes)

4.1.4 Fineness of cement

Apparatus: 90 micron sieve, lid, weighing machine, pan and dry cement.

Procedure : fineness of cement is found by sieving the cement through a standardized sieve size (90 micron) then the weight of cement retained on the sieve is used to determine the fineness of cement.

Take 100 g of dry cement sieve it through the 90 micron sieve the weight of residue x is recorded.

Table 7: Fineness

	Weight of cement	**X**	**Fineness=$\frac{x}{100}\times 100$**
Sample 1	100	7.6	7.6
Sample 2	100	7.5	7.5
Sample 3	100	7.3	7.3

Fineness of cement is taken as the average of that of the three samples and is 7.46%

This is within the limits of IS 8112-1989 as per which it supposed to be below 10mm.

4.1.5 Specific gravity test

Specific gravity of cement:

Specific gravity of a material means the ratio of its weight to the weight of equal volume of water. Kerosene/ diesel is used for finding the specific gravity of cement.

Apparatus : le chateliers flask, dry cement , diesel and weighing balance.

Procedure:

Fill the dried out flask with kerosene/diesel till the level reaches zero mark. This gives the initial reading.

Now put pre weighed quantity of cement in the flask. Take care that the cement doesn't adhere to the sides of the flask . roll it gently on an inclined position till all the gas is expelled from the cement. Note the level of liquid this gives the final reading.

Empirically specific gravity is given by formula

Cement's Specific gravity=$\frac{w}{v2-v1}$

W is the weight of cement used

V1 is the initial reading on the flask

V2 is the final reading on the flask

Figure 6: Le-Chatelier's flask

W=50 g

V1= 0 ml

V2= 15.38 ml

Specifc gravity of cement = 3.25

4.2 Tests performed on the coarse aggregates and fine aggregates.

4.2.1 Sieve analysis of coarse aggregates and fine aggregates.

Sieve analysis of coarse aggregate:

Is an empirical method of expressing average particle size in the aggregate. It is done by grading coarse aggregate by sieving it through the standardized sieves.

Apparatus: different sieves of sizes 80mm,40mm,20mm,10mm,4.75mm and 2.3mm and weighing balance.

Weight of coarse aggregate used= 5 kg.

Table 8: Fineness modulus of coarse aggregates.

Sieve size (mm)	Weight retained (kg)	% weight retained	Cumulative % retained(X)	Cumulative % passing
80	0	0	0	100
40	0	0	0	100
20	0.400	8	8	92
10	2.850	58	64	34
4.75	1.480	30	94	6
2.36	0.270	6	100	0
1.18	0	0	100	0
0.6	0	0	100	0
0.3	0	0	100	0
0.15	0	0	100	0
Total	5	100	666	

Hence fineness modulus of coarse aggregate= $\frac{X}{100} = \frac{666}{100} = 6.6$

4.2.2 Specific gravity and water absorption of coarse aggregate(RCA).

Apparatus used: weighing machine, oven, non reactive non absorbant vessel sample etc

Procedure:

Put 1 kg of material in the vessel and fill it completely with water and weigh it let w1 be its weight, Empty the vessel and dry off the aggregate and fill it with water and weigh it again w2. Then weigh the dried off aggregate w3. Then dry the aggregate in oven and weigh it again w4

Table9: specific gravity and water absorption of CA

SAMPLE	W_1 (kg)	W_2 (kg)	W_3 (kg)	W_4 (kg)
Sample 1	3.3	2.8	1.4	0.98
Sample 2	3.1	2.6	1.3	0.97
Sample 3	3.05	2.65	1.1	0.99
Average	3.1	2.75	1.1	0.982

Average specific gravity= =$\frac{\boldsymbol{w4}}{\boldsymbol{w3}-(\boldsymbol{w1}-\boldsymbol{w2})} = \frac{\mathbf{0.982}}{\mathbf{1.1}-(\mathbf{3.1}-\mathbf{2.75})} = \mathbf{2.1}$

Water absorption percentage= $\frac{\boldsymbol{w3}-\boldsymbol{w4}}{\boldsymbol{w4}} \times \mathbf{100} = \frac{\mathbf{1.1}-\mathbf{0.982}}{\mathbf{0.983}} = \mathbf{12}\%$

4.2.2.1. Determination of sieve analysis for fine aggregates.

Fineness modulus is an empirical method of expressing average particle size in the aggregate. It is done by grading coarse aggregate by sieving it through the standardized sieves.

Weight of fine aggregate used = 1kg

Table 10:Fineness modulus of fine aggregates

Sieve size	Weight retained (kg)	Percentage retained	Cumulative percentage	% weight passing (kg)
4.75 mm	0.05	5	5	95
2.36mm	0.03	3	8	92
1.18mm	0.1	10	18	82
600 µm	0.2	20	38	62
300 µm	0.5	50	88	12
150 µm	0.112	11.2	99.2	0.8
Pan	0.008	0.8	100	0
Total	1 kg		X=374.2	

Fineness modulus of fine aggregate=$\frac{x}{100} = \frac{374.2}{100} = 3.7$

4.2.2.2 Specific gravity and water absorption of fine aggregates:

Apparatus used: pycnometer , measuring cylinder, oven, filter paper, weighing balance.

Procedure: Put 1 kg of material in the pycnometer and fill it completely with water and weigh it let “w1” be its weight,Empty the pycnometer and dry off the aggregate and fill the pycnometer with water and weigh it again “w2”. Then weigh the dried off aggregate “w3”. Then dry the aggregate in oven and weigh it again “w4”

Figure 7 : Pycnometer.

Table 11: specific gravity of fine aggregate

	Weight in grams
Weight of dry aggregates (W)	500
Weight of pycnometer, sample and water (W_1)	1890
Weight of pycnometer and water (W_2)	1590
Weight of saturated surface dried aggregate(W_3)	498
Weight of oven dry sample (W_4)	494

Specific gravity = $\frac{w4}{w3-(w1-w2)} \times 100 = \frac{494}{498-(1890-1590)} = 2.6$

Water absorption =$\frac{w3-w4}{w4} \times 100 = \frac{500-494}{494} \times 100 = 0.8\%$

CHAPTER 5

5.1 MIX DESIGN

Design mix is done as per IS:10262-2009.

1. Target strength for mix design

STEP I

Target strength is given by

Fm=fck + ts

=20+1.65*4.6=27.59

STEP II

W/C ratio from graph=0.46

STEP III

CORRECTION FACTOR

	water content	sand content
For increase or decrease In Compaction factor	**+3**	**--**
For increase or decrease In w/c ratio	**0**	**-2.6**

STEP IV

Water content for nominal size=20mm

186 kg/m3

Corrected water content= 186+186*3/100=191.58kg/m3

Hence, cement content=191.58/0.47=407.617kg/m3

Volume of sand=35-2.6=32.4

Therefore ρ=0.324

From equation $v = \left[w + \frac{c}{s_c} + \frac{1}{\rho} * \frac{fa}{s_{fa}}\right]$ **we get fa=570.97kg/m3**

And from equation

$$v = (w + \frac{c}{sc} + \frac{1}{p} \times \frac{ca}{Sca}) \times \frac{1}{1000}$$

we get ca=1146.918kg/m3

Water content=191.58kg/m3

Cement content=407.617kg/m3

Fine aggregate=570.97kg/m3

Table no. 12: proportion for mix

Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (kg/m^3)
407.617	570.97	1146.918	191.58
1	1.4	2.8	0.47

Therefore ratio of mix = 1 : 1.4 :2.8.

5.2 Complete volumetric mix proportions for different mixes for every 1 kg of the mix

Table 13: volumetric proportion of different ingredients

(a) Series I

Mix	Cement	Fine aggregate	Coarse aggregate		Water/cement
			RCA	CCB	
RCA100	0.19	0.27	0.54	0	0.46
RCB 15	0.19	0.27	0.46	0.08	0.46
RCB 25	0.19	0.27	0.41	0.13	0.46
RCB 50	0.19	0.27	0.27	0.27	0.46

(b)

Mix	Cement	Fly ash	Fine aggregate	Coarse aggregate		Water/cement
				RCA	CCB	
FRCA 100	0.16	0.03	0.27	0.54	0	0.46
FRCB 15	0.16	0.03	0.27	0.46	0.08	0.46
FRCB 25	0.16	0.03	0.27	0.41	0.13	0.46
FRCB 50	0.16	0.03	0.27	0.27	0.27	0.46

CHAPTER 6

6.1Tests and results

6.1.1 Wet density and yield of concrete

Apparatus :

- cylindrical container
- tamping rod.

Procedure: fill the cylindrical container in 5cm thick levels deliver about 60 strokes for every 10 liter concrete continue till the container is full strike off the extra material to leave behind a smooth surface.

Density : is found simply by dividing the weight by the volume of the container

Procedure: take a cylindrical container of hieight 320 mm and internal diameter 200mm weigh it “w1” then completely filled with fresh concrete in 3 layers with 25 tamps uniformly over the concrete then weigh it again “w2” density “d” is given by formula d=(w2-w1)/0.01

Table 14: wet density of fresh concrete (a)

Wet density values for mixes without fly ash (kg/m^3)			
	Trial 1	Trial 2	Average
RCA100	1702	1700	1700
RCB 15	1691	1702	1696.3
RCB 25	1674.3	1685.5	1680
RCB 50	1647.7	1652.2	1650

(b)

Wet density value of mixes with fly ash (kg/m^3)			
	Trial 1	Trial 2	Average
FRCA 100	1742	1740	1740
FRCB 15	1722.5	1727.4	1724.8
FRCB 25	1701	1707.5	1705
FRCB 50	1662	1671	1668

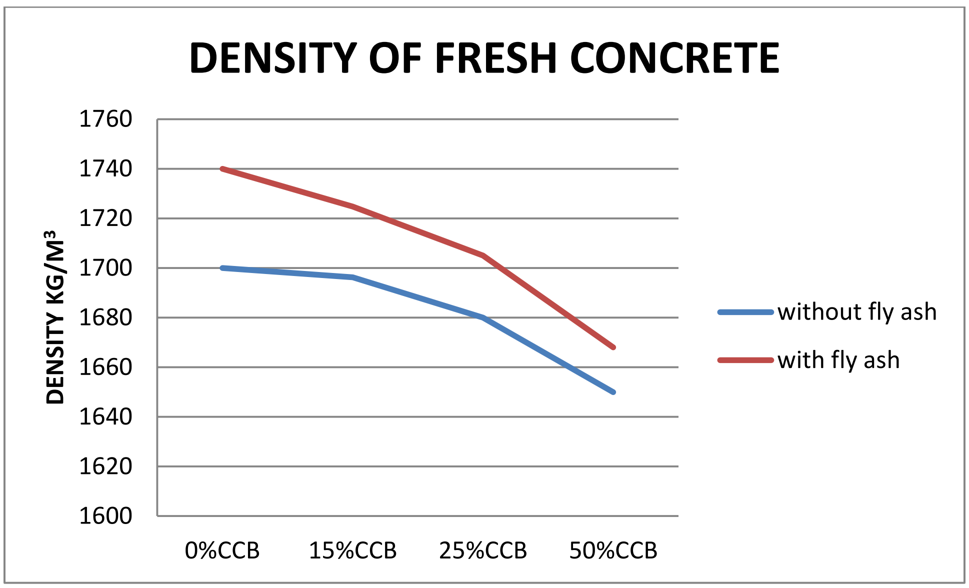


Figure 8:

Density is found to decrease with increase in CCB content this is attributed to the low density of the CCB compared to the RCA. Mixes incorporating fly ash were found to have higher density compared to the mixes with out fly ash.

6.1.2 Workability test(slump):

Objective: to find the workability of fresh concrete

Apparatus required:

- Slump cone(height 30cm, bottom dia 20cm, top dia 10cm)
- Tamping rod
- Non absorbent smooth surface

Procedure : Place the cone on the smooth surface. Then pour concrete in the cone in approximately 4 layers and compact each newly filled layer by 25 blows with the tamping rod until completely filled. Remove the mold by lifting it quickly in vertical direction and let the concrete subside under its own weight when the concrete is completely settled take the measurements.

Figure 8: slump test

Table 15: slump values of fresh concrete

Slump values for mixes without fly ash			
	Trial 1	Trial 2	Average
RCA100	30mm	30mm	30mm
RCB 15	27mm	28mm	27.5mm
RCB 25	25mm	27mm	26mm
RCB 50	15mm	14mm	14.5mm

Slump value of mixes with fly ash			
	Trial 1	Trial 2	Average
FRCA 100	20mm	23mm	21.5mm
FRCB 15	15mm	16mm	15.5mm
FRCB 25	14mm	13mm	13.5mm
FRCB 50	9mm	10mm	9.5mm

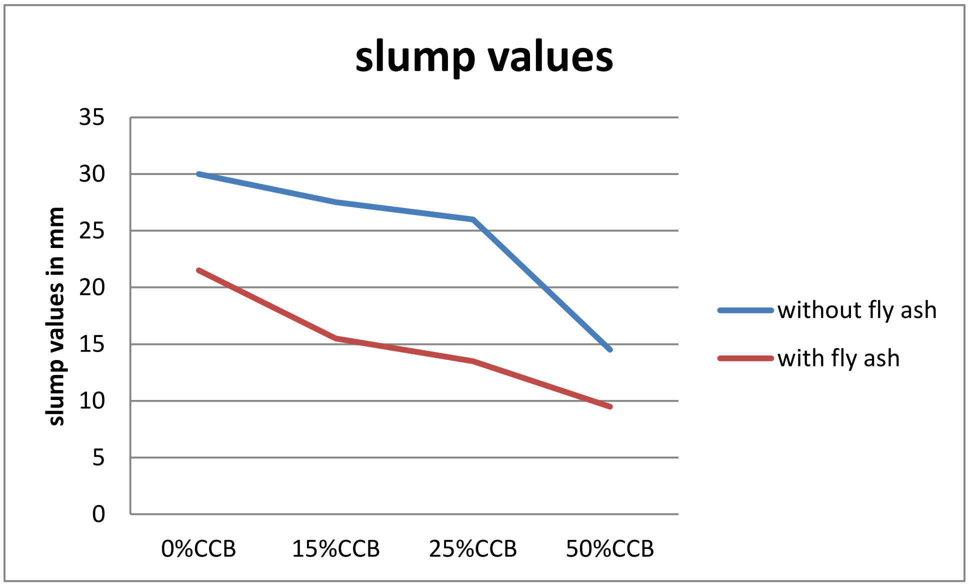


Figure 9:graph plot of slump values

Slump was observed to decrease with increase in CCB replacement level this can be because of either of these two reasons firstly the mix design used was originally for natural aggregates due to this there may have been some unbalance in the amount of different aggregates secondly the CCB particles tend to break during mixing thus increasing the amount of fines and in turn decreasing the slump value.

Addition of fly ash resulted in decrease of slump value this is attributed to the higher surface area of fly ash which increases the water requirement for hydration

6.2. Tests on hardened concrete:

6.2.1Compressive strength test

Compressive strength is the maximum load a concrete cube can bear. Tests of specimens were done after curing. Specimen sizes were measured before testing. Clean and surface dried. After placing the cube on the lower plate the upper plate was lowered until touched the top face of the cube. The load was increased gradually and maximum load until failure was noted.

Cubes of size 10mm×10mm×10mm were used for finding compressive strength of concrete. Manual compression testing machine was used to determine the compressive strength of the concrete.

Figure 10: compressive strength tests

Table 16: compressive strength values (a)

Compressive strength of mixes without fly ash(N/mm^2)												
	7 days			14 days			28 days			56 days		
	sample 1	sample 2	Avg	sample 1	sample 2	Avg	sample 1	sample 2	Avg	sample 1	sample 2	avg
RCA100	18.4	21.4	19.9	20.5	22.05	21.3						
RCB 15	19.25	17.75	18.5	18.37	20.04	19.2						
RCB 25	17.05	17.75	17.4	18.83	19.475	18.5						
RCB 50	14.85	15.75	15.3	18.16	17.26	17.7						

(b)

Compressive strength of mixes with fly ash(N/mm^2)												
	7 days			14 days			28 days			56 days		
	sample 1	sample 2	avg	sample 1	sample 2	Avg	sample 1	sample 2	Avg	sample 1	sample 2	Avg
FRCA 100	20.14	20.65	20.4	28.2	22.3	22.6						
FRCB 15	18.4	19.35	18.9	20.23	20.84	20.8						
FRCB 25	18.3	17.7	18.01	18.54	19.64	18.8						
FRCB 50	16.7	16.26	16.5	19.05	17.35	18.2						

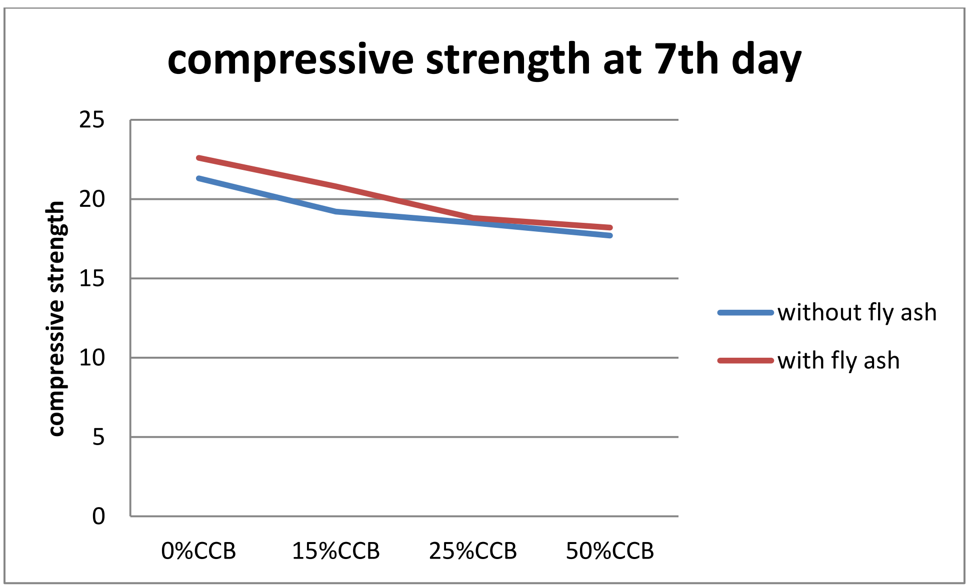


Figure 11: compressive strength at 7th day of curing

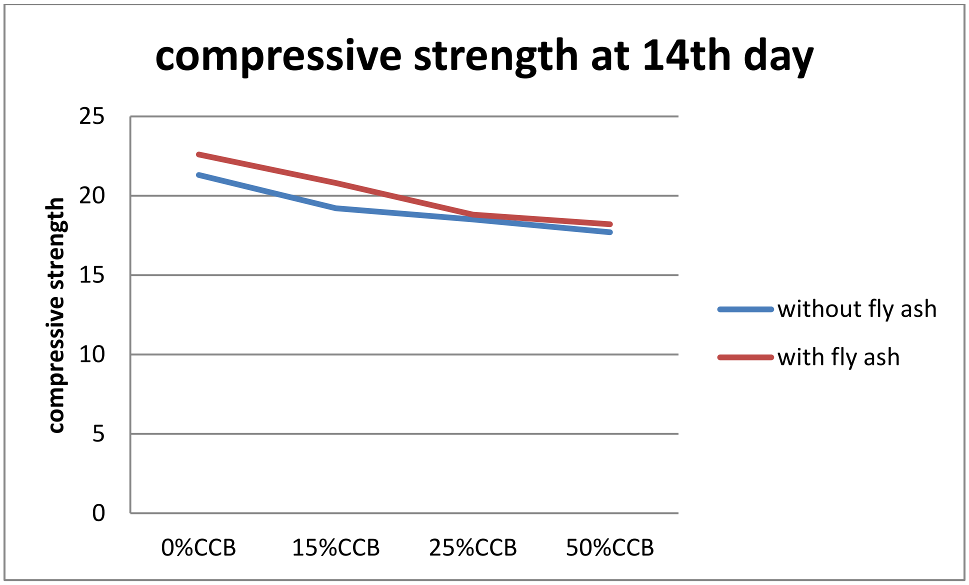


Figure12 :Compressive strength at 14th day of curing

It was observed that the CCB particles broke right through in most of the samples but in case of RCA-100 the failure was in the interfacial zone pointing out the weak interfacial bond between the RCA and the new concrete mortar this must be due to the weak interfacial bond between RCA particles' already adhered mortar and the new mortar but the compressive strength decreases with increase in CCB replacement level this is attributed to the lower compressive strength of CCB particles.

Addition of fly ash resulted in increased strength at all levels of CCB replacement in recycled concrete.

6.2.2 Splitting tensile strength

Concrete is weak in tension hence it is imperative to find the tensile strength of concrete to get an idea of the amount of load it can with stand without breaking. Tensile strength tests are to be conducted on 14th and 28th days. Two packing plywood strips are needed to keep the cylinder in position during the test.

Figure13: splitting tensile strength test

Table 17: splitting tensile strength(N/mm^2)

(a)

	7 Days	28 days
RCA100	3.07	
RCB 15	3.05	
RCB 25	2.64	
RCB 50	2.87	

(b)

	7 days	28 days
FRCA 100	2.87	
FRCB 15	2.65	
FRCB 25	2.50	
FRCB 50	2.90	

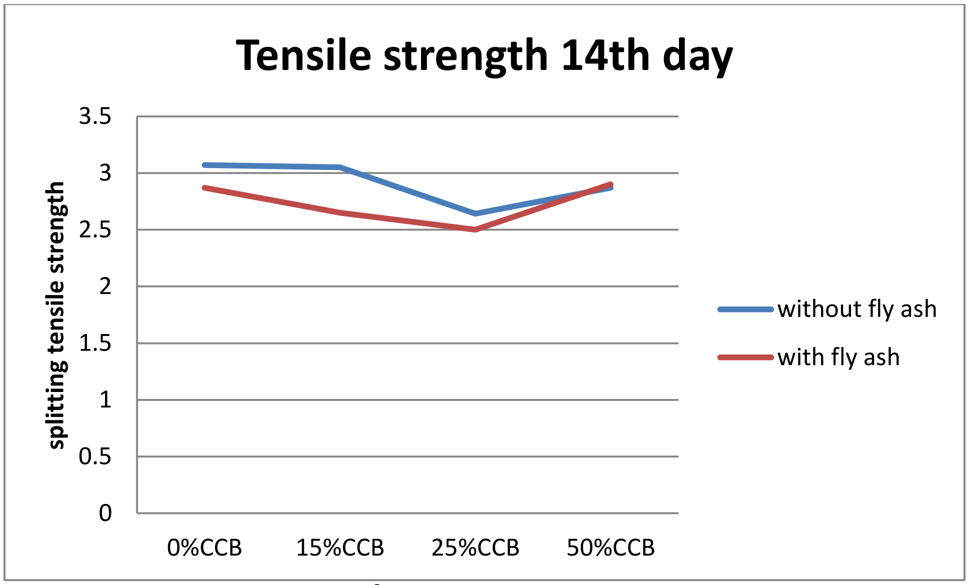


Figure 14:14th daySplitting tensile strength

Tensile strength followed the same pattern as the compressive strength. Increase in CCB resulted in decrease in tensile strength this was attributed to low tensile strength of CCB particles and like in case of compression failure the failure surface passes through the CCB particles pointing out the low tensile strength of CCB as well as the strong interfacial bond between the CCB surface and cement mortar. It was noted that decrease in tensile strength was more pronounced at lower inclusion level of CCB in recycled concrete. This may be due to the water absorbed by CCB particles during the saturation. The weak interfacial bond between the RCA surface and cement mortar resulted in the failure of this interfacial bond.

Addition of fly ash decreased the tensile strength at early curing stages

CONCLUSIONS BASED ON AVAILABLE RESULTS:

It was observed that the replacement of RCA with CCB in recycled concrete reduces the slump value of the mix. The reasons for this is attributed to the mix design which was designed originally for natural aggregates and the breaking of CCB particles during mixing which increases the level of fines in the mix. The loss of slump or workability was more pronounced when we replaced a part (15%) of cement with fly ash. This was attributed to the increase in surface area to be hydrated due to the small particle size of fly ash.

It was observed that the wet density of recycled concrete decreased with increase in CCB replacement level. This is attributed to the low density of CCB as compared to the RCA. Wet density was noted to increase by partially replacing cement with fly ash. The reason for this is attributed to the lower particle size of fly ash due to which it was able to get into the pores and thus made the concrete denser.

The compressive strength keeps on decreasing with the increase in CCB level in recycled concrete. This is attributed to the low compressive strength of CCB in itself. It was noted from observing the inner side of the failure cracks that the CCB particles were broken across this is the evidence of strong interfacial bond between the CCB particles and the concrete mortar which in turn is attributed to the saturated surface dried condition the CCB particles were in which provided water for hydration in early and later stages of curing and thus lead to strong interfacial bonds being formed. The addition of fly ash didn't have significant improving effects on compressive strength on the early stages but the improvement was more evident in the later stages of curing this is attributed to time taken to begin the hydration of fly ash particles the effect on the compressive strength of mixes having level of CCB replacement was more notable. Thus it can be concluded that fly has improving effect on compressive strength of CCB incorporating recycled concrete.

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