MECHANICAL BEHAVIOR

OF

POROUS LIGHTWEIGHT CONCRETE

A Thesis

Submitted in Partial Fulfilment of Requirement for the Degree of

MASTER OF TECHNOLOGY

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With Specialization in

Construction Management

By

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CERTIFICATE

This is to certify that the work which is being presented in the project title ***"Mechanical Behavior of Porous Lightweight Concrete Incorporating Natural Waste"*** in fulfillment of the requirements for the award of the degree of Master of Technology in civil engineering with specialization in **Construction Management** and submitted to Civil Engineering Department, Jayvee University of Information Technology, Waknaghat is an authentic record of work carried out by **Gaurav Gupta (162601)** during a period from August 2017 to June 2018 under the supervision of **Dr. Gyani Jail Singh**, Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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(Gaurav Gupta)

CONTENTS

ABSTRACT

Concrete is widely used binding material for the construction purposes. It is material produced by mixing cement, sand and gravels in the given proportion. Porous concrete is special type of concrete that has low water cement ratio and contains little amount of sand thereby having open cell like structure which allows air and water to pass through it. Porous concrete is made by using large aggregate with little amount of fine aggregate and lightweight concrete is mixture made with cement and lightweight aggregate. It can be further classified into lightweight aggregate concrete, foamed concrete and autoclaved aerated concrete.

The target of this analysis was to work out the mechanical behavior of porous lightweight concrete incorporating natural wastes such as saw wood cuts. This paper represents the properties of porous concrete with ideal amount of replace coarse aggregate (RCA). Five diverse types of porous concrete combine resembling M-15 grade of concrete consisting 0%, 20%, 30%, 40% and 50% of WA are get made to determine the compressive strength and also the split tensile strength. The compressive strength of the porous concrete with optimal alteration of coarse aggregate (CA) by 30% of Wood aggregate (WA) is attained close to regarding 100% of compressive strength of the M-15 grade of concrete.

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is most commonly used binding material in the world. The word concrete is get derived from the Latin word 'concretus' which means compact or condensed. It is made up of cement, sand and aggregate mixed together in the certain defined ratio. Concrete have high compressive strength and low tensile strength so it can be converted into any shape. It is durable, energy efficient and fire resistant material.

Porous concrete is form of concrete with high permeability that permits water to pass through it therefore reducing runoff from location and permitting groundwater recharge. It had been first used in 1800s in Europe as pavement surfacing and load bearing walls. It became popular again in 1920s for two storey homes in Scotland and England. In India it became popular in 2000. It consists of cement, course aggregate, water with little amount of fine aggregate. It has water-cement ratio of 0.28 to .40 percent and void content of 15 to 25 percent.

Lightweight concrete is made up of cement and lightweight course aggregate. It can be further classified into:-

1. Lightweight aggregate concrete:-It can be get produced from various types of lightweight aggregate which comes from natural materials like bamboo cut, saw wood cut, thermal

treatment of naturally raw material like clay, slate or Leca. It conjointly get created from industrial wastes like fly ash and from dispensation of industrial wastes such as Pellite.

2. Foamed concrete: - It is highly workable and low density material which includes 50% of entrained air. It is made up of 20% of foam entered into plastic mortar. It has self levelling and self-compacting properties. It also has good thermal insulation properties.
3. Autoclaved aerated concrete: - It is lightweight precast building material which was get invented in mid 1920s. It is the type of concrete that provide structure insulation as well as fire and mold resistance at same time. It is made up of cement, sand, calcined gypsum and aluminum powder as 0.05%-0.08% by volume. In some countries like India and China, Fly ash generated from coal fire power plants that having 50%-65% silica content is used as aggregate.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The various research papers were get studied about porous lightweight concrete and the various tests were get performed to determine the mechanical behavior of porous lightweight concrete on the basis of literature studies stated below.

2.2 LITERATURE REVIEW

Teo et al. (2005) about the structural bond performance of lightweight concrete using Oil Palm Shells (OPS) as aggregate. Various tests such as slump test, air content test, density test, compressive strength test and pull-out bond properties test were conducted on OPS concrete. Within the pull-out test, each plain and distorted bars of ten, twelve and sixteen millimeter diameters were used. The twenty eighth-day air-dry density obtained is inside the limit of lightweight concrete and also the developed twenty eighth-day compressive strength was more than 28 MPa. The obtained pull-out results were beyond the desired values as per normal.

Rizvi et al. (2009) studied about the behavior of adding Recycled Concrete Aggregate (RCA) in

Porous Concrete which shows that that porous concrete with an optimum RCA content has different amount of strengths, permeability and voids. Concrete with 15% of RCA had similar amount of void content and permeability as that of concrete without RCA however concrete with

30%, 50% and 100% RCA shows significant increase in void content and permeability from concrete without RCA.

Ramli and Dawood (2010) studied regarding the behavior of lightweight crushed brick concrete consisting palm fiber of numerous volume of segments and results shows that the utilization of this fiber rather increases the density of lightweight concrete and the results also shows that the utilization of palm fiber with lightweight crushed brick concrete improves the mechanical properties of the concrete.

Nasir (2011) studied about the behavior of lightweight porous concrete as wall insulation in which he made a wall using porous lightweight concrete and studied its physical and mechanical properties.

Hossian et al. (2011) studied about the behavior of porous concrete using brick chips as course aggregate. The various properties such as strength, permeability and void ratio were tested. The results shows that porous concrete made of brick chips performs well in respect of permeability; however the strength of this concrete is lower than that of the stone aggregate concrete.

Sharma et al. (2012) studied about the mechanical properties of porous concrete and verifies that most compressive strength of porous concrete was achieved by the 20mm sized aggregate and 1:4 cement: total aggregate ratio. The most cube compressive strength obtained at seventh and twenty eighth day was 17.91 N/mm2 and 27.1 N/mm2 respectively Most water perviousness of order 3.39 X10 -4 cm/sec was attained that was about 3.4 times additional penetrable than high porousness concrete.

Awang et al. (2012) studied about the effects of additives on lightweight foamed concrete (LFC). LFC using three totally dissimilar densities of 600, 1000 and 1400 kg/m3 were molded and get tested. Fly ash, lime and plastic fiber were diverse with the LFC at completely dissimilar amounts. Compressive, flexural and drying shrinkage tests were conducted up to one hundred and eighty days to work out the mechanical behavior and Results shows that the density of LFC is measured by the permeability where lesser density LFC means higher penetrability hence thermal conductivity get modified with the perviousness of LFC.

Ealies et al. (2014) studied about the enhancement of strength of concrete by fractional alteration of course aggregate with coconut shell and coir fibers. Numerous checks like test for compressive strength, split tensile strength, temperature opposition, water immersion, electrical opposition, chemical opposition and pH scale check of sample were conducted and results were worthy as estimated that shows that use of coconut shell and coir fibers may be get suggested for low price construction.

Bogas and Gomes (2015) studied about the mechanical and Toughness Behavior of Structural Lightweight Concrete made with Volcanic Slag. Various properties such as compressive and split tensile strength, modules of elasticity, contraction, capillary absorption, carbonation and chloride resistance were verified. The results shows that almost all economical-lightweight concrete with slag mixture can attain compressive strength closed to 35 MPa.

Chindaprasirt et al. (2015) studied about the effects of fine sand and fly ash on Lightweight porous concrete. The results shows that lightweight porous concrete has low density and low thermal conductivity coefficient and also improve the compressive strength, flexural strength and aberration resistance while total void ratio and water permeability seems to reduce.

Hamdulay and John (2015) studied about the impact of adhesive density on the properties of

Hardened concrete by adding various admixtures such as fly ash and Ground granulated blast-

Furnace slag (GGBS) in porous concrete and results shows that paste density obtain for fly ash was very low than Ordinary Portland Cement (OPC) and GGBS.

Carbajo et al. (2015) studied about the auditory properties of permeable concrete made of light weight arlite and vermiculite aggregates. The results concluded that these combined materials produce a comparative high sound immersion and then will develop a tolerable substitute to other normally used materials.

Ghosh et al. (2015) studied about the performance of porous concrete using waste materials and concluded that compressive strength of porous concrete is improved by adding fly ash, chamber scum, rice husk ash, silica fume, and solid waste whereas compressive strength is reduced by addition of rubberized materials. Perviousness is improving with chamber scum, ceramic waste however glass powder, silica fume has no impact on perviousness. Rubberized materials decreases the split tensile and compressive strength of porous concrete whereas it will increase the abrasion resistance & freezing–thawing resistance. Partial addition of rice husk ash, chamber scum, silica fume, glass powder also improves split tensile strength of porous concrete as well.

Khankhaje and Rafieizonooz (2016) studied about the properties of porous lightweight concrete consisting of palm oil kernel shell as course aggregate. The various properties like

Fresh and hardened density and void content, compressive and split tensile strength, perviousness

were get tested and conclusion is made that it's potential to produce porous lightweight concrete using light-weight leftover from palm oil production.

Haji et al. (2016) studied about the properties of porous concrete containing fly ash and silica fume as admixture. In this study, fly ash and silica fume has been replaced by cement from 0% to 25% and water permeability as well as compressive strength of pervious concrete has been tested.

Results showed that Replacement of Fly ash from 5% to 25% shows decrement in strength from 4% to 28%. And permeability also decreased with increment of fly ash mix up to 30% than normal pervious concrete as well as in silica fume, replacement from 5% to 25% shows that with 5% replacement of cement with silica fume increased strength up to 24% higher than normal pervious concrete. But with further increment of this admixture with replaced to cement showed strength loss of 44% then normal pervious concrete.

Sriravindrarajah et al. (2012) considered about the mix design of porous Recycled mixture concrete. The results shows that the compressive strength of porous concrete get improved with reduction in the full aggregate size from twenty to thirteen millimeter. The correlation between twenty eighth day compressive strength and permeability for porous concrete was badly affected with the utilization of recycled concrete aggregate rather than natural mixture.

Zheng et al. (2012) studied about the mix design method for permeable base of porous concrete and the results displays that a new material should be used for designing the porous concrete to maintain the porosity and structural strength of concrete.

Patel et al. (2013) studied about durability of high performance concrete with Alccofine and Fly Ash. Result show that concrete consisting Alccofine and fly ash have larger compressive strength and Alccofine increase durability in the concretes and decrease the chloride diffusion.

Shah and Pitroda (2014) studied about properties of porous concrete such as durability and water absorption. Results shows that porous concrete created by 1:6 combination has a lot of toughness and fewer water absorption and porous concrete created by 1:10 combination has lot of water absorption and fewer toughness that’s why toughness and water absorption are in reverse to every alternative.

Neamitha and Muthadhi (2016) studied about the behavior of porous concrete with industrial waste as course aggregate in which they compares about various types of materials used for producing porous concrete and compare their various properties such as compressive strength, flexural strength, permeability, durability etc.

Kumar and Prakash (2015) studied about the properties of structural lightweight concrete by Mixing Cinder & LECA. The light weight aggregates such as Cinder and Leca were mixed in various ratios as defined 0:100, 10:90, 20:80; 30:70; 40:60, 50:50 and vice-versa by volume of concrete to make light weight concrete. The properties like compressive strength, split tensile strength and density are studied by casting thirty three no. of plain cube samples of size 150 x150 x150mm and cylindrical samples of 150x300mm. M30 grade light weight concrete with 60% Cinder and 40% Leca had a mean compressive strength of 36.52N/mm2 and split tensile strength of 2.5N/mm2.In addition to that Ground Granulated Blast Furnace Slag (GGBFS) is used by exchanging 20% of cement which increases the compressive strength to 39.20N/mm2.

Bandala et al. (2015) studied about the Static and Mechanical Properties of Lightweight Concrete Blocks with Expanded Phenyl-ethylene Foam. The results shows that lightweight concrete blocks with expanded phenyl-ethylene foam with a denseness of 1,441.3 to 1978.6 kg/m3 and a compressive strength of 11–21.6 MPa may be created by partially exchanging coarse aggregate from the normal concrete with MEPS.

Reddy et al. (2013) studied about the durability Aspects of standard concrete. The results shows that the maximum percentage loss in weight and percentage reduction in compressive strength due to Acids for M40 grade concrete are 1.25%,16% with replacement of 10% Metakaoline and the minimum percentage loss in weight and strength are 1.18%, 14.9% with replacement of 20% Fly ash. There is considerable variation in loss of weight and strength only with Silica Fume replacement.

Patidhar and Yadav (2017) studied about the properties of pervious concrete with polypropylene fiber. The results shows that by using 0.30 W/C ratio and mix (50%) aggregates for pervious concrete gives better result. Mix void content 36.58 % was found and Increase in compressive strength of pervious concrete leading by increased density that was observed. It also shows that compressive strength of pervious concrete reduced by larger size of aggregate. Better compressive strength given by mixing of smaller and bigger size of aggregate instead of single size of aggregate.

Patil and Mumal (2014) studied about the various properties of pervious concrete and it is observed that the compressive strength get improved as the w/c ratio is get reduced up to peak level of water cement ratio and with rise in volume of cement. It is observed that cement can be successfully swapped by fly ash that will reduce the cost of porous concrete.

Khan et al. (2017) studied about the Porous concrete with Course Aggregate and Fine aggregate Mix Proportions. They perform various tests such as compressive strength, split tensile strength, Permeability test and concluded that usage of pervious concrete has increased in last several years as it is eco-friendly and sustainable product and conventional concrete are not generally applicable to porous concrete.

Karthik H. Obla (2010) gives review paper about pervious concrete in which the various properties such as void content, infiltration rate, compressive strength, flexural strength, and infiltration rate etc. which should be considered as standard for porous concrete.

2.3 OBJECTIVE

The objective of the thesis is as:

1. To produce porous lightweight concrete using saw-wood cuts.
2. To study the mechanical behavior of porous lightweight concrete.

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 GENERAL

The material used in the present study were cement, sand (10% of cementetious material), aggregate and wood aggregate as in the form of M15 grate of concrete and coarse aggregate was get replaced with wood aggregate with 20%,30%,40% and 50% respectably.

3.2 METHODOLOGY

Wood aggregates (WA) is usually a lot of permeable in nature than the coarse aggregates (CA). The key property of porous concrete is its perviousness, therefore the portion of fine aggregate may be decreased and also the portion of natural aggregate may be swapped with alternative material that can be used as aggregate to boost the perviousness while not much disturbing the strength of the concrete. The materials used for creation of porous concrete are cement, primary coarse aggregates (CA), Wood aggregate (WA) and water and in this type of concrete saw wood cuts were used for replacing course aggregate by volume in which CA is replaced by 20%, 30%,40% and 50% by volume of WA for making porous lightweight concrete.

Porous lightweight concrete is made up of cement, sand (10% by weight of cementetious material used) and course aggregate. M15 grade of concrete is get used.

In this we have follow the following phases

1. Determining the physical properties of CA
2. Preparation of WA
3. Replacement of WA by CA
4. Establishing the mixing properties of porous concrete
5. Determining the physical properties of porous concrete

In this paper, the physical properties of WA which are get determined as specific gravity, water immersion, compressive strength and split tensile strength. Aggregate is get replaced by different proportions to work out the properties like compressive strength and tensile strength. The different mixes are than compared with the referral mix to determine the optimum percentage of WA in the concrete.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 GENERAL

The various properties of porous lightweight concrete such as compressive strength and split tensile strength of the porous concrete were get conducted and the results were get analyzed.

4.2 RESULT AND DISCUSSION

Preparation of WA

1) Stepwise preparation of WA is stated as below:-
    1. Rejected samples of saw wood cuts are collected from workshop.
    2. Collected samples are than cutted into small pieces and then get passed through 20 mm and get retained on 16 mm sieve.
2) Properties of Aggregate

   Various properties of the replaced concrete aggregates are get measured as per IS standards [10-11] therefore to equate them with the properties of primary aggregates and also for the evaluation of their fitness for the fractional replacement of primary aggregate in porous concrete. Table 1 shows the specific gravity and water absorption of FA, CA and WA. Specific gravity is found a lot for CA in comparison to the WA. Water absorption is found fewer for CA in comparison to the WA.

Table 1. Specific gravity and water absorption of aggregate

S. No.	Aggregate	Max Size	Specific Gravity	Water absorption
1	CA	20 mm	2.60	2.5%
2	WA	20 mm	0.63	25%
3	FA	0.75mm	2.80	1.65%

Lesser specific gravity and better water absorption values of switched concrete aggregate states that Wood aggregates are extra permeable as compared to primary aggregates. Essentially specific gravity is associated as parameter of strength of the aggregates and hence it indicates that the Wood aggregates have lower strength in comparison with primary aggregate.

3) Partial Replacement of CA with WA:-

   In the study 20%, 30%, 40%, 50% of primary course aggregate are replaced with Replace Course aggregate to prepare the different mixes of porous aggregate

Table 2. Details of the various mixes having different percentages of WA

Mix	Cement (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	20 mm CA (kg/m^3)	20 mm WA (kg/m^3)
RC00	1250	500	125	4120	0
RC20	1250	500	125	3296	198
RC30	1250	500	125	2884	297
RC40	1250	500	125	2472	396
RC50	1250	500	125	2060	495

Table 2 represents the particulars of the different mixtures consisting of different proportions of WA. The mix consisting of 20% replaced aggregate is named as RC20. Likewise, the term RC30, RC40, RC50 are get allotted, standard concrete with only CA is named as RC. The various mixes are get sewed-up to explore the ability of CA and to measure the impact of replacement of CA by WA.

4) Porous concrete mix design:-

There is no such regular code of practices for the mix design of porous concrete. So, it is vital to create the sample mixes according to the literature study on porous concrete design. The testing of porous concrete is applied as per IS standards. Various properties of various adapted mixes are conducted using different laboratory tests. The mix design is confirmed once the strengths of the mixes attain the lowest specified standards. The amount of materials, shown in Table 3, are concluded for making porous concrete, set according to literature study and on the idea of trial mixes. The accepted water-cement ratio (by weight) is 0.4, different cubes of 15x15x15 cm are being casted with the ratio of cement, sand and coarse aggregate (by volume) is 1:0.1:4 for the preparation of low density porous concrete mix.

Table 3. Materials of Mix Design

S. No.	Material	Quantity (kg/m^3)
1.	Cement	1250
2.	Sand	125
3.	CA	4120
4.	Water	500

4.3 PROPERTIES OF POROUS CONCRETE

Concrete consisting of zero percent substituted aggregates is taken into account as the standard and then this mix is get compared with the one having Wood aggregates. According to the test results, an ideal proportion of replaced concrete aggregate is get suggested.

Figures below displays the samples of porous concrete ready within the laboratory for the determination of the compressive strength and split tensile strength.

Cube samples Cylindrical samples

Fig. 1. Prepared samples of porous concrete without any replacement

Cube samples Cylindrical Samples

Fig 2. Prepared samples of porous concrete consisting of 20% replacement.

Cube Samples Cylindrical Samples

Fig 3. Prepared samples of porous concrete consisting of 30% replacement.

Cube Samples Cylindrical Samples

Fig 4. Prepared samples of porous concrete consisting of 40% replacement.

Cube Samples Cylindrical Samples

Fig 5. Prepared samples of porous concrete consisting of 50% replacement

The properties of various mixes of porous concrete at the time of twenty eight days is shown in Table 4. Restoration of primary coarse aggregates by saw wood cut ends up in reduction in strength of the porous concrete. for 20% replacement mix and then leads to slight escalation in strength for 30% replacement and then reduction in strength for 40% and 50% mixes.

Table 4. Properties of porous light weight concrete

Sample	% Replacement	Density (Kg/m^3)	% Decrement in density	28 Days compressive strength (MPa)	28 Days Split tensile strength (MPa)
RC00	0	2020	-	19.58	1.68
RC20	20	1840	8.9	11.11	0.92
RC30	30	1739	13.9	14.6	1.21
RC40	40	1623	19.6	10.01	0.84
RC50	50	1484	26.5	9.34	0.78

Table 4 also shows the variation of different samples of porous concrete as the density of porous concrete lies between ***1600-2000 kg/m^3*** [Karthik 2010] and density of various above samples lies in this range so this concrete is considered as porous concrete.

Figure 6 also shows the difference of compressive strength at twenty eight days of curing for different percentage substitution of CA. It gets witnessed that by increasing the proportion replacement of CA by WA the compressive strength gets reduced for 20% replacement then it gets increased for 30% and then further decreases for 40% and 50% replacement. It is visibly clear that the combination containing 30% replaced concrete aggregates has compressive strength similar to that of the recommended mix. Compressive strength of the combination holding 30% WA is standardized as this mix has the typical compressive strength of 14.6 MPa which is appropriate for various types of applications.

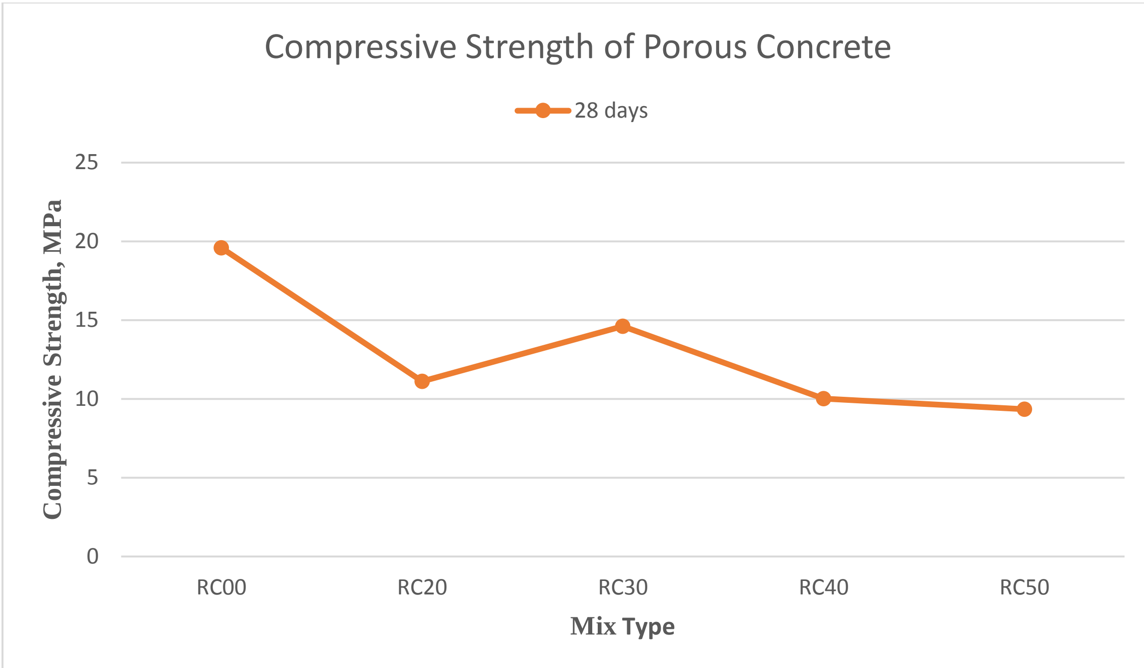

Fig. 6. Compressive strength of porous concrete

Figure 7 shows the variation of split tensile strength at twenty eight days of curing for different percentage substitution of CA. It is observed that with the increase of percentage substitution of CA by WA the split tensile strength gets reduced for 20% replacement then increases for 30% and then further decreases for 40% and 50% replacement. It is visibly clear that the combination consisting 30% replaced concrete aggregates has tensile strength similar to that of the standardized referral mix.

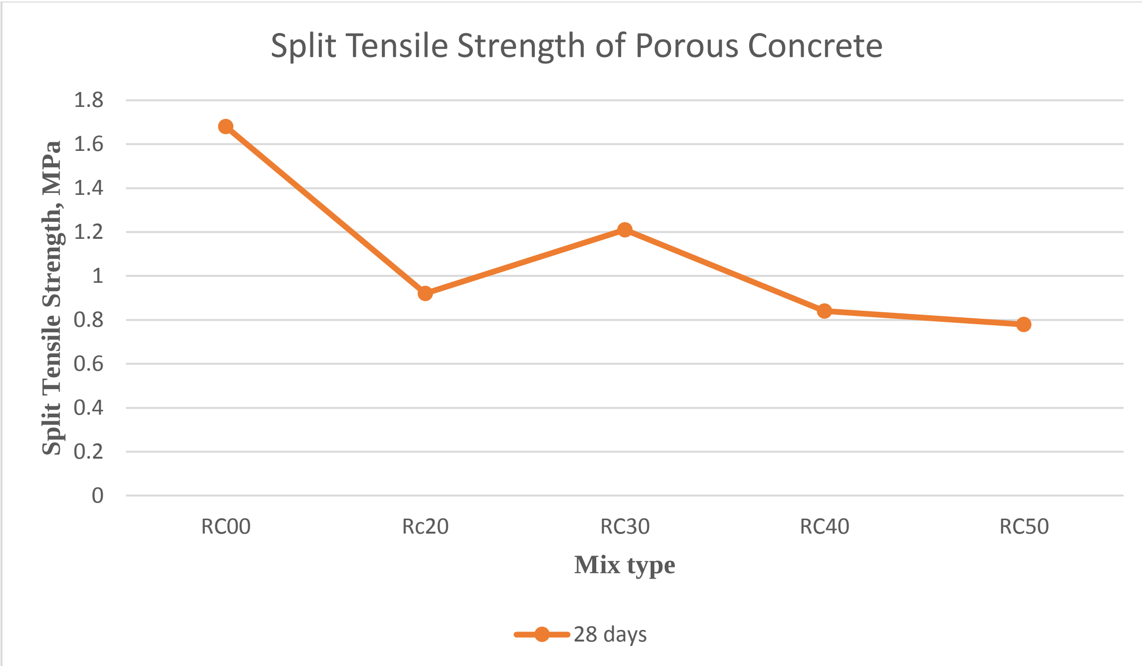

Fig. 7. Split Tensile strength of porous concrete

CHAPTER 5

CONCLUSIONS

5.1 GENERAL

On the basis of the experimental investigation on porous light weight concrete the following conclusions are being concluded as concrete with 30% of replacement with wood aggregate is considered as good replacement as its compressive strength is attained close regarding to M15 grade of concrete.

5.2 CONCLUSION

The persistence of this thesis was to define the mechanical behavior of porous lightweight concrete incorporating natural wastes such as saw wood cuts. Thus the optimum quantity of replaced coarse aggregate (RCA) was determined. Meanwhile five dissimilar kinds of porous concrete mix corresponding to M-15 grade of concrete holding 0%, 20%, 30%, 40% and 50% of WA were prepared to determine the compressive strength and the split tensile strength. The compressive strength of the porous concrete with finest substitution of coarse aggregate (CA) by 30% of Wood Aggregate (WA) is attained close to regarding 100% of compressive strength of the M-15 grade of concrete.

5.3 FUTURE SCOPE

This type of concrete can have good future scope as this can be used an economical for the construction of the porous concrete as wood aggregate are easily available as saw wood waste are easily available which can be easily get converted into saw wood cuts and can get used for the creation of porous lightweight concrete for construction of various structures such as road pavements and various other structure.

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APPENDIX

APPENDIX A

Fig. A1. Saw wood used in the research

Fig. A2. Cubical Moulds used in the research

Fig. A3. Tested sample specimen

Fig. A4. Prepared samples of porous concrete without any replacement

Fig. A5. Prepared samples of porous concrete consisting of 20% replacement

Fig. A6. Prepared samples of porous concrete consisting of 30% replacement

Fig.A7. Prepared samples of porous concrete consisting of 40% replacement

Fig. A8. Prepared samples of porous concrete consisting of 50% replacement