Performance evaluation of concrete using Prosopis juliflora as partial replacement of coarse aggregate

GShyamala¹ and ANSwaminathan² and I Rajasri Reddy³

¹Department of Civil Engineering, S R University, Warangal, India
²Department of Civil Engineering, Sree Sakthi Engineering College, Coimbatore, India
³Sumathi Reddy Institute of Technology for Women, Warangal, India.

E-mail: civilshyamala@gmail.com

Abstract. The aim of the work is to study the suitability of Prosopis juliflora as a partial replacement of coarse aggregate. Concrete mix is made with varying proportions of Prosopis juliflora stem replacing the coarse aggregate up to 2.5%, 5%, 7.5%, 10% and 12.5% to the concrete percentage and results to increase in the compressive strength of the concrete cube up to 10% was noted. Water absorption is up to 0.9% and maximum value of flexural strength achieved at 3Mpa. Maximum strength of 34Mpa Compressive strength was achieved. Concrete with Light weight and less thermal conductivity was achieved by using Prosopis juliflora wood as partial replacement for coarse aggregate.

1. Introduction

Construction is known for utilization of huge volume of non-renewable source of energy[1], which is generated from the earth crust leaving carbon footprint[2]. Concrete is most widely used construction material in the world due to its ability to get cast in any form and shape[3]. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients[4]. Huge number of studies are carried out to find the possible replacement of coarse and fine aggregate by waste material thereby finding the solution to improve the strength and durability characteristics of concrete[5]. In the twentieth century usage of mineral admixture and crushed stone is increased by the construction industry[6]. Illegal mining was done in some parts of the country as the result of overexploitation of the stone. Due to this scenario sustainable manufacturing of concrete in the construction industry is expected from the researchers[7]. Some of the material used in the replacement of coarse aggregate is crump rubber[8], coconut shell[9], ceramic[10], recycled aggregate[11], brick waste[12], e-waste[13], fly ash[14] etc.. Wood in different forms in construction industry such as shuttering, windows, doors, truss, interior decoration etc.,[15] Sound insulation property of the wood is considered and is been utilized for recording theatre[16]. In numerous quantities of waste material generated in the world, wood waste is one of the eco-friendly materials, which can be utilized in the concrete to produce timberCret[17].

Replacement of natural aggregate by other material paves way for manufacturing light weight concrete[18]. Light weight concrete is preferred in construction industry as it reduces dead load and reduces the impact of seismic load[19]. Ibrahim replaced coarse aggregate with 80% of pumice stone to make it a light weight concrete. High surface area and irregular shape lowered the workability of the concrete and its improved by increasing water cement ratio[20]. Nehla replaced coarse aggregate with...
crushed walnut shell in the ratio of 5% to 25%, dry density and adsorption ratio increase with slight decrease in compressive strength was observed[21]. Natural coarse aggregate was replaced by 30% to 100% of recycled aggregate and tested for UPV, split tensile strength, compressive strength and mass loss by elevating the temperature up to 600°C[22]. It was identified that there was no fragmentation of spalling of specimen while testing[23]. Discarded rubber tyre was tried as the coarse aggregate in the ratio of 5%, 7.5% and 10% and examined for durability and mechanical test which shows good performance as compared to conventional concrete[24]. The properties of light weight in concrete is influenced by the presence of wood granules added in the mix. Wood concrete provides less thermal conductivity and hence it can be used as insulation material[25].

Anastasia fitted the sigmoidal curve for compressive strength in relation with curing as a function and found that it fitted well[26]. Khelifa’s exploratory work shows that the mechanical properties like modulus of rupture and elasticity can be recognized by bending tests, and the proportion among flexural and compressive quality is 47%. Water absorption was found to be 30%, absorption and swelling tests show that the low density of wood in total cement materials, which make them to classify as a lightweight concrete[27]. As the wood waste content increase in the concrete the compressive strength reduced slightly. But the target strength was achieved with age due to pozzolanic activity[28].

Prosopis juliflora is an invasive species that creates many negative impacts to biodiversity and inhabitants and it is to be removed[29]. Prosopis juliflora reduces soil fertility by limiting the biological nitrogen fixation and depletes water table through deep penetrating roots, it can draw water from deeper layers. Durai Murugan used Prosopis juliflora ash for the partial replacement of cement, and optimum flexural properties was found in the replacement of 30%[30]. This project involves the experimental investigation of strength properties of concrete by partial replacement of Prosopis juliflora stem with coarse aggregate. With the partial replacement of Prosopis juliflora in place of coarse aggregate helps in achieving the target strength in very short time. Prosopis juliflora stem can be easily used as partial replacement material for the construction of tall buildings. Thus, helps in disposing Prosopis juliflora which does not allow the practice of agriculture. With the use of Prosopis juliflora stem in concrete technology, it ultimately helps in improving soil fertility and increasing the yield of the crops. In addition to this, use of Prosopis juliflora stem as construction material helps to minimize the construction cost. As compared to the cost of coarse aggregate, the cost of Prosopis juliflora is very less[31]. Thus, it emphasis on sustainable development, the major concern of today’s world. Prosopis juliflora can be partially replaced by 2.5%, 5% and 7.5% in place of coarse aggregate to obtain higher compressive strength than the conventional concrete.

2. Experimental program
Materials Used: Grade 53 ordinary Portland cement (IS: 12269-1987) was used with the specific gravity of 3.15.1.82 fineness modulus, initial and final setting time of 32 and 570 min respectively. The fine aggregate confirming to zone II according to IS 383 – 1970 was used. The fine aggregate is M-sand was obtained from Karur. The M-sand is almost used for construction purpose, due to non-availability of sand in Tamil Nadu. So, the M-sand is mostly probable[32]. The specific gravity of M-sand is found to be 2.67. The coarse aggregate used is a load crushing unit having a 20mm nominal size. Well graded aggregate according to IS 383 is used in this investigation[33]. The coarse aggregate used was obtained from Venkateshwara blue metals. Coarse aggregates are a construction component made of rock quarried from ground deposits. Examples of these kinds of ground deposits include river gravel, crushed stone from rock quarries, and previously used concrete. Coarse aggregate are generally categorized as rock larger than a standard No. The scientific Name of the wood bark which is used for coarse aggregate replacement is Prosopis Juliflora. Generally, the size of the tree trunk is 50 to 65 ft tall, and of 4 ft trunk diameter. The average dried weight of the wood is 800 kg/m3 with the moisture content of 12%. Charcoal of Prosopis juliflora contains volatile matter of 63%. Ash content 8.2%. Calorific value of 4120 (kcal/kg) and Fixed carbon 25.5%. The Modulus of rupture is found to be 115 Mpa. Elastic modulus is 12.13 Gpa with the crushing strength of 67.3Mpa. The shrinkage in the Radial is 4.6%, Tangential is 8.1%, and volumetric is 12.6%, T/R ratio 1.8. The chemical composition of Prosopis Juliflora wood is found to be CaO 44%, MgO 6.5%, SiO2 4.5% and Sulphur 0.21%.
Prosopic juliflora wood has high calorific value, low moisture content and high fixed carbon content which is suitable for utilization in the alternative of coarse aggregate. Superplasticizer Conplast SP – 430 was used to increase the workability of concrete.

3. Mix Proportion
Code IS 10262:2009 permits the usage of alternative material in concrete respective to increase strength and durability characteristics. Concrete mix design of M30 was used by following the procedure of IS code. The bark is shredded into small pieces of size 12.5 mm to 20 mm and it is sieved to grade the aggregate. The wooden barks are immersed in the six-mix proportion from 2.5 % to 12.5 % addition of wood as replacement for aggregate. To find the workability of concrete for different water cement ratio, superplasticizer Conplast SP -430 was used. The slump cone test was done with the slump of 85 mm. For concrete of each mix (M20) wood aggregate is added in concrete ingredients, precalculated amount of water is added. Cube specimen of 150 X150 mm is casted. Curing was done for 7, 14 and 21 days. The test specimen without wood aggregate is also casted and tested for all the curing days. Cross section of wood, converting it in to pieces, Proportioning and mixing is shown in Figure 1.

![Figure 1a](image1a.png) ![Cross section of wood](image1b.png) ![wood pieces](image1c.png) ![Proportioning](image1d.png) ![mixing](image1e.png)

**Figure 1a.** Cross section of wood 1b. wood pieces 1c. Proportioning 1d. mixing

The most common indicator of determining the strength of concrete which is associated with design mix and the additive used is compressive strength of concrete. The quantity of the concrete ingredients is taken as a weigh batching. The measurement of concrete ingredients is shown in Table 1. The materials are mixed by hand mixing in the order of coarse aggregate, wood fine aggregate, water and super plasticizer. According to the code three specimens for each mix is casted. The sample casted with partial replacement of aggregate with wood is tested after the curing period of 7, 14 and 28 days. Parallel and perpendicular lines are drawn on the concrete cube to analyze the crack pattern in the cube during failure ads shown in figure 2. The chart shows the variation in strength which is due to the usage of 1% of Conplast SP–430 and 2.5%, 5%, 7.5% of Prosopis juliflora to the concrete, the strength
got increased as compared to the conventional concrete. After 7 days of curing results, increases in the strength of the concrete tested for cube and cylinder specimen.

Table 1. Mix proportioning

| Cement       | Coarse aggregate | Fine aggregate | Water      | Prosopis juliflora | Conplast – SP |
|--------------|------------------|----------------|------------|--------------------|---------------|
| 450.74 kg/m³ | 1261.85 kg/m³    | 709.61 kg/m³  | 157.76 lit/m³ | 31.55 kg/m³     | 2.36 g/m³    |

4. Experimental investigation

In order to understand the composition and production of concrete by replacing Prosopis juliflora in various percentages is done. After 7, 14, 28 days of curing tests were taken. Three samples were casted in each proportions and average of this were considered.

4.1 Compressive strength test

Detailed compressive strength results were presented in the figure 3 a. It is observed that the compressive strength increased with the replacement of wood up to 10 %, after which it starts decreasing. All the mix achieved the target strength of 20 MPa. Reduction of compressive strength above 10 % addition of Prosopis juliflora may be due to the reduction in pozzolanic activity and bonding strength reduction. The drawback of using Prosopis juliflora as replacement of aggregate is water absorption characteristics. The best replacement percentage is identified at 10 %. The 7-day compressive strength varied between 22 MPa to 32 MPa as shown in Figure 3a. The maximum strength of 34 MPa was achieved at 28 days with 10 % replacement of wood aggregate. Non-destructive test is carried out using rebound number and it was found to be moderately higher than compressive strength value shown in Figure 4a.
4.2 Split Tensile Strength
Load is provided diagonally to the cylindrical specimen to find the split tensile strength. Tests were conducted at the 28 days curing period. Results varied from 1.81Mpa to 2.12Mpa. The highest strength of 2.12Mpa was achieved at 7.5% replacement of wood aggregate and it is shown in the Figure 3.b.

4.3 Flexure Test
Prisms were casted in the size of 100 mm × 100 mm × 500 mm. Two-point loading were provided to test the flexure of the specimen. Maximum flexural strength of 3Mpa was recorded at the replacement of 10% wood coarse aggregate is shown in Figure 3 b.

4.4 Water absorption
Figure shows the impact of wood replacement and water absorption. The drawback in usage of replacing wood in concrete is high water absorption, but it is noticed that the strength gain is in later stage of curing. The moisture content of the wood waste selected also influence the water absorption characteristics. Selection of size of the wooden bark have the impact on waster absorption characteristics. If the size of the wooden bark is less the surface area increases, increasing the water absorption. If the size of the wood pieces reduced in the concrete the water absorption decreased gradually. Water absorption is found up to 0.9% with 12.5 replacement of aggregate. Variation in water absorption is shown in Figure 4.b.

5. Conclusions
Sustainability in the construction industry is achieved by replacement of renewable source of material, in which the usage of Prosopis juliflora for coarse aggregate replacement proved to be a best
alternative to produce concrete of light weight and less thermal conductivity. Based on the experimental investigation the slump flow test value is found to be 100 mm. So, it shows good degree of workability. With the use of Prosopis juliflora stem in place of coarse aggregate along with 1% of Conplast SP-430 as super plasticizer. There was an increase in compressive strength with increase in percentage of replacement i.e. 2.5%, 5%, 7.5% 10 % and 12.5 %, shows optimum replacement at 10 %. The bonding and pozzalonic activity decrease if the replacement rate is higher. Weight of the concrete is reduced up to 40 % in replacing the wood aggregate.

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