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Experimental on Improving Thermal Comfort of Building using Locally Available Biomass Wastes

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Abstract: Buildings require energy and most energy consumed is for thermal comfort of its inner space. It also provokes global warming due to more energy demand arising due to increases of buildings, climate change etc. More insightful techniques and materials are developed to improve the thermal comfort thy reducing the energy consumption. Of the various materials used for reducing the thermal conductivity of roofs, using natural materials lead to sustainable development. And also will benefit in waste management. About 70 – 80% of organic waste is produced in Asian countries, and is a boon for using natural materials for construction. However, implementation is not much successful in countries like India, due to rural population. In this work, locally available materials such as RHA from downdraft gasifier, jute and coir are used in reinforced concrete as construction material up to 20%. Compressive test and thermal conductivity tests are done and found to be promising in terms of strength and thermal comfort. The thermal conductivity is low for coir and RHA combination and it can be used for improving thermal comfort of the building. The results are also validated using Deep learning neural network.

Keywords: Wastes from downdraft gasifier, RHA, coir, jute, thermal comfort, insulation materials, Deep learning neural network.

I. INTRODUCTION

Buildings are major energy demander in all countries [1]. It consumes 40% of global energy consumption and emits about 30% of CO_2, among the consumption more energy is spent for thermal comfort in buildings [2]. Solar heat absorption in summer and heat lost in winter are importantly considered during design for the thermal comfort which lead towards energy efficient buildings [3]. For reducing energy consumption in buildings considering thermal comfort, the modern design concepts used are, position and orientation for building and windows, geometry shading to accompany more light without heat gain, using wall envelops to reduce heat conductivity, internal heat source occupancy etc [4]. However, roofs enclose 50-70% of the total building and it gains most solar heat [5]. Hence, thermo physical properties can be modified by using envelops or insulating materials to maintain the indoor air temperature within the thermal comfort range [6].

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The use of insulations thus reduces the required air conditioning systems thereby reduces the total energy cost [1].

Insulation materials can be classified as two main group inorganic or mineral and organic insulation materials [5]. Insulation with a low thermal conductivity can contribute much for new or retrofitting buildings when energy efficiency is prominence [7]. Roof coatings is a passive technique which reflects the solar radiation to be observed, thus 18-93 % cooling load is reduced and 11-27 % of the peak cooling load is reduced in air-conditioned spaces. This could be an immediate possible solution for non insulated buildings [8]. By paving natural stones along the building envelop, 62% of the solar radiation is reflected back achieving better thermal performance by reducing wall surface temperature [9]. To improve the Turkey's economy by reducing energy consumption in buildings, glass and rock wools available in local market was suggested as insulation materials [10]. Mixture of PCM and eutectic enclosed in polyethylene of raised temperature resistance pipe is used in building roofs with cool materials, thus influence of surrounding outer environment is neglected to achieve energy saving. In can also cut away the urban heat island [11]. Various other insulation products used are wool products, polymeric foams, aero gel materials, application of PCM etc [5].

Moreover, increasing the use of natural materials for insulation in buildings will serve additional benefits such as environmental score for sustainable development [12]. A new material transparent wood as material offers many advantages, of that it is found to be a good thermal insulator with thermal conductivity of 0.32 W/mK [13]. The composition of natural cement, sand and (DPF) date palm fibers (for 0 to 30% weight concentrations) are used to form a new material, concluded that 5-15% fiber content can be used to have the strength and thermal conductivity compared with other composites [14]. Cotton stack fiberboard (sustainable material) is manufactured using high frequency hot pressing technique and the resulting thermal conductivity is in the range of 0.0585 to 0.0815 W/mK [15]. Woven fabric waste for insulation material is studied experimentally, and a 56% of increase in thermal behavior was determined. Its thermal conductivity was compared with the other materials and found to be similar [16]. In the combination of soil, sand and straw, wheat straw, barley straw and wood shavings are the reinforcement. Increasing the percentage of straw fibers decreases the thermal conductivity [17]. The combination of cement, sand and fibre waste of coconut could benefit in lightweight and low thermal conductivity material. From the basic experiments (compressive test) the new material matches the basic requirement of construction materials as wall or roof [18].

The wastes from the water treatment plants and the wood wastes in Brazil is used combining with concrete and 11.1 MPa compressive strength is achieved which can be successfully used for construction [19].
Rice husk ashes (RHA) is classified based on the sizes were studied in combination with Portland cement and the mortar with one specific size of RHA results in good strength and porosity [20]. Rice husk is combusted in controlled environment to reduce the direct burning and from the derived ash concrete mixtures are manufactured. The compressive strengths are greater than the concrete mixtures when using RHA [21]. RHA is used to improve the microstructure of high-performance concrete. Some general experiments when RHA is blended with Portland cement concrete reveals that blending percentage of RHA is an important parameter [22]. The sawdust is replaced for sand in light weight concrete in the percentage of 0, 25 up to 100%. The compressive strength is also close to the minimum requirement for light weight concrete [23]. Managing solid wastes without dumping to landfills can benefit in environmental protection and using it for construction materials could benefit in reducing disposal issues. Wood ash is suggested for making structural grade concrete [24]. The acceptable sawdust particle in the concrete mixture for the substitution to aggregates for residential concretes in terms of thermal insulation is studied [25]. The fibre waste from India is used to increase the compressive strength with the addition of jute, coir and bamboo is studied. And the other improved properties are ductility, impact toughness and fracture toughness [26].

Burning of wastes, ground water pollution due to waste are the serious environmental issues faced by developing countries like India [27]. When it comes to rural area, the village sustainability and quality of life could be improved considering the solid waste management [28]. Asian countries produce 70-80% organic matter as solid waste. Moreover, reducing these wastes are carried out by composting in agricultural lands and disposed to landfills [29]. Hence, because of the increasing importance of conserving energy and using natural materials, locally available materials for concrete structure could benefit in reducing environmental impacts, thermal conductivity of the roof structure and possibly weight. In this work, combination of jute, coir combined with rice husk ash from the biomass gasified is used for reinforced cement concrete structure. And the compressible strength, ductility and the deflection are tested for the specimen manufactured.

II. MATERIALS AND METHODS

2.1. Material collection

Jute, coir and rice husk ash are the materials chosen for the study. The natural materials like jute, coir and rice husk ash is available in plenty are collected. The region were the raw materials are collected was southern part of TamilNadu named Kanyakumari in India. RHA is the base proportion for the mix to be studied. Since, RHA with its amorphous form contributes better strength when mixed with concrete; which can be achieved by slow burning. Hence, RHA from the gasifier is collected from the available nearby industries. About three industries in our region consist of gasifier. Since water separates the ash from the gasifier it consists of high moisture. The RHA is requires drying if it has to be stored for long days. In that case a day drying is required with frequent mixing. Jute bags with no chance for reusing (damaged) are collected from the market. And it was cut into required pieces with proper size using the available cutters. Coir is abundantly available, because the region is mostly cultivated with coconut trees. Coir is the waste covering the coconut shell. It is available in industries which process coir for compositing as well as producing ropes.

Thus the combination of RHA and jute, RHA and coir with reinforced concrete are planned for the study. The collected samples are shown in figure 1 and the physical properties of the natural fibers are listed in table 1.

Table 1. Physical properties of fibre

No	Fibre type	Fibre length
1	Jute	108 – 250mm
2	Coir	50 – 250 mm
3	RHA	1 – 1.5mm

Figure 1. Jute, RHA and coir

From the literature, using these types of fibre in concrete resulted in good improvement in terms of insulation (reduction in thermal conductivity) as well as strength. Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly. The tensile and impact strength can be increased due to the addition of jute fibers were reported in literature [30]. Coir is a natural fibre extracted from the husk of coconut. Its addition in concrete will increase or decrease the compressive strength [31]. RHA is the ash after the burning of Rice husk. The RHA concrete exhibits higher compressive strength was reported [32]. Hence, using these locally available natural resources could help toward sustainable development,

2.2. Material preparation

The composites are formed based on 10% and 20% according to the literature. Totally six specimens were made, with 10 and 20% of natural material combination.
The mixing proportions of concrete, sand, and the proposed natural materials is of 1:2, and the water cement proportion of 0.4 with the steel bar of 6mm dia. Traditional mixing was preferred for mixing concrete. Thus based on the proportions the materials are to be mixed with the concrete, and the planned six specimens denoted as specimen 1, specimen 2, specimen 3 and specimen 4 listed in table 2.

Table 2. Percentage of fibers in each specimen

Materials	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Jute	10	-	5	-
Coir	-	10	-	5
RHA	10	10	15	15
Concrete	80	80	80	80

2.3. Experimental procedure and setup

Aggregates and materials (cement, proposed natural materials) are added in correct proportions by weighting, and fed into the drum mixer in dry form for some minutes. And water is added after some minutes. Proper homogeneous mixing of all the fibers is critical for improving the mechanical properties of the reinforced concrete slab. Finally, mixed concrete are added until consistent mixing is achieved. The concrete is poured to the pattern of size 1 x 1 x 0.04 m. The concrete is allowed to cure for a day. After that the pattern is removed and allowed for drying at room temperature. The concrete specimens are shown in the figure 2. The tests are conducted for 7, 14 and 28 days after the sample preparation and the conducted test are for determining compressive strength, ductility and deflection.

Figure 2. Slabs manufactured for test

The compressive tests are conducted using the equipments available in the lab. Compressive strength is determined using vibrating table (AIM 365, AMIL Ltd., India) of vibration frequency 3.6 kHz. All the specimens are tested to measure the compressive strength. Guarded hot plate apparatus is used to determine the thermal conductivity of the materials. The hot and cold end plated will maintain the temperature. The hot and cold plate is in perfect thermal contact. It can able to measure the thermal conductivity, thermal resistance of the specimens. The hot plate apparatus (K-Meter EP 500) is used for testing the thermal conductivity for the planned test temperature. It can maintain the temperature conditions of the specimen and can adjust the test temperature. It can complete up to three tests continuously at different temperatures (30-60). The data were extracted from the data logger and the conductivity is predicted using the software associated with the device.

2.4 Modeling and optimization

The prediction analysis of reinforced concrete slab with added fibers is modeled by using deep learning algorithms. Deep learning (otherwise called deep organized learning or various leveled learning) is a division of a more extensive group of Artificial Intelligence strategies dependent on learning information portrayals, instead of the task - explicit techniques.

The other techniques that are used for the optimizations are reported. Replacing concrete with conventional saw dust ash and its compressive strength is predicted based on Scheffes's simplex method [33]. Optimizing the strength of concrete with sedimentary rock as aggregates of 8-16 mm size is studied using Scheffes's simplex method and the compressive strength is found to be 11.78 N/mm2 [34]. Generalized reduced gradient (GRG) algorithm is developed for minimizing the cost and eight of the reinforced and high strength concrete [35]. The optimum concrete mixtures were chosen for replacing with natural aggregate with bricks and tiles based on the Box-Behnken design [36].

Radial Basis Function: This proposed technique uses RBF neural network model is considered for the prediction investigation of reinforced concrete slab. In this model, the node is portrayed by its middle, which is a vector with measurement equivalent to the number of contributions to the node. The connection between info vector and the RBF node center is assessed by the Euclidean distance equation

$$Dis(PQ) = |P_{lk} - Q_{lk}| = \sum_{l=1}^{L} (P_{lk} - Q_{lk})^2 \quad (1)$$

Where the parameter P and Q are explained as: $P_l = P_1, P_2, P_3 \ldots P_L$ is the input vector, $Q_k = Q_1, Q_2, Q_3 \ldots Q_K$ indicates the center of k[th] node.

Initialization: For examining the structure behavior (like deflection, ductility, and compressive strength) of the FRP-strengthened RC slab, ODLN structure initializes the input parameters as:the type of FRPs, width and thickness of FRPs and load as S1, S2, S3 and S4. The initialization is given by equation (2)

$$S = \{S_1, S_2, S_3, and\, S_4\} \ldots\ldots\ldots (2)$$

Objective Function of RBF: The target work is to accomplish optimal results of forecast examination by the assessment of the minimum error rate. This will be achieved by the training process of RBF structure; for best, we present the Levenberg-Marquardt (LM) algorithm where the network weights are trained at every emphasis procedure.

Training Process of RBF: LM training algorithm is introduced in the RBF network, to train the test data attained from the experimental analysis.

LM Training Algorithm:The LM curve fitting technique is a blend of two minimization strategies: the gradient descent strategy and the Gauss-Newton technique. In the first strategy, the entirety of the squared errors is diminished by refreshing the parameters in the steepest-descent course.

In the second technique, the sum of the squared errors is decreased by expecting the least squares function is locally quadratic, and finding the base of the quadratic. Simple steepest descent method to minimize the following error function:

$$R = \sum_{t=1}^{l} (S_t - C_t) \quad \text{..........} (3)$$

Where, S represents the target,C represents the actual output for the t-the pattern of the neuron, R is the error function, l is the total number of training patterns.

The weight update vector ∇ W is calculated as

$$\nabla W = [J^T(W) * J(W) + \varepsilon I]^{-1} J^T(W) R \quad \text{..........} (4)$$

Underneath J^T(w) J(w) is alluded to as the Hessian lattice. Relating to µ = 0 the algorithm utilizes the Gauss-Newton approach. Relating to extremely extensive µthe LM algorithm utilizes the steepest great or maybe the error backpropagation algorithm. The parameter is routinely changed at each emphasis to defend intermingling. The LM algorithm includes computation on the Jacobian J (w) lattice at every single cycle activity just as the reversal related with JT (w)J(w) square matrix and the R is a vector of size.

Based on the various studies the physical properties of fibers are modified for jute and coir. And the concrete slab is formed based on the above procedure. Finally the slabs are tested for compressive strength, deflection and thermal conductivity to prove the strength and thermal resistance of using these fibers. The utilization of deep learning optimization structure is to predict the values and parameters associated with the addition of fibre.

III. RESULTS AND DISCUSSION

The combination of fibers used in reinforced concrete would result in increase of compressive strength and decrement of thermal conductivity of the material. Thus the study concerning the local fibers used in the concrete mixture for the five specimens are reported. A total three series of tests are conducted for the validation of the result. The experimental results are also compared with the results obtained from the deep learning network optimization. Thus for the tested weight percentages the results are presented in this session.

3.1. Compressive strength

The compressive strength determined for the number of test conducted is given in table 4. The curing days of 14, 28 and 56 are considered for the analysis. In the 14th day test all the natural fibre specimen exhibits less compressive strength. The days for proper curing are more, and compressive strength also increases after. The higher value of the compressive strengths is obtained for the jute, RHA and concrete combination i.e. for specimen 1 and 3. The compressive strength of specimen 2 and 4 is less than the strength of 1and 3. Hence, RHA results in improvement of compressive strength of the slab. However, the compressive strength of coir, RHA and concrete is less than the RHA, jute combination. The compressive strength is observed to be highly depending on RHA and remaining based on the fibre combination. The results are in well agreement with the literature [19]. The compressive strength of the predicted deep learning algorithm is shown in table 3. The predicted value is close to the experimental results obtained (table 4).

Table 3. Predicted compressive strength of specimens

Samples	DLN predicted values for compressive strength		
	14 days	*28 days*	*56 days*
S1	21.5	48.6	63.45
S2	19.5	47.2	61.5
S3	23.2	51.64	65.43
S4	24.85	54.72	70.25

Table 4. Compressive strength of the specimens

		Compressive strength			
Test no	No of curing days	Specimen 1	Specimen 2	Specimen 3	Specimen 4
	14	22.8	21.4	24.6	23.9
1	28	49.4	48.1	53.4	52.6
	56	65.6	62.8	67.4	63.5
	14	22.6	21.2	24.1	23.6
2	28	50.1	48.3	52.9	51.8
	56	65.0	62.3	67.1	63.1
	14	23.1	22.7	24.3	24.6
3	28	49.6	48.6	53.5	52.3
	56	65.2	62.1	67.9	63.6

3.2. Deflection test

Bending tests were done on the five specimens of rectangular concrete slabs with jute, coir and RHA as additives. The deflection of normal concrete slab is considered for comparison. The tested slabs are measured based on the applied load and mid-span deflection. The objective of this test is to find the performance of the added natural materials in concrete slab for bending up to failure. The values of deflection test are shown in the table 5.

Table 5. Deflection test of the specimens

Specimen	Initial Cracking load (kN)	Deflection at first load (mm)	Ultimate load (kN)	Deflection at ultimate load (mm)
1	0.63	0.6	0.9	19.9
2	0.73	0.55	1.6	23.1
3	0.5	0.55	2.1	20.1
4	0.63	0.6	3	23.6

The ultimate load increases with the increase in the RHA percentage. The lower ultimate load capacity is because of the lower fractions of RHA than the other natural fibers. It is observed that, all the specimens undergo deflection hardening irrespective of the percentage of fibre contents.

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The ratio between peak load and first crack load is low for specimen 1 and high for specimen 4. The low value indicates the lower deflection hardening behavior than the other specimens.

In the specimens considered, the deflections at peak loads are 19.9 to 23.6 mm. During experiments, the number of multiple cracks is increased as the weight percentage of the natural fibers increases. The initial cracking and the associated load of the concrete slab specimens are shown in figure 3.

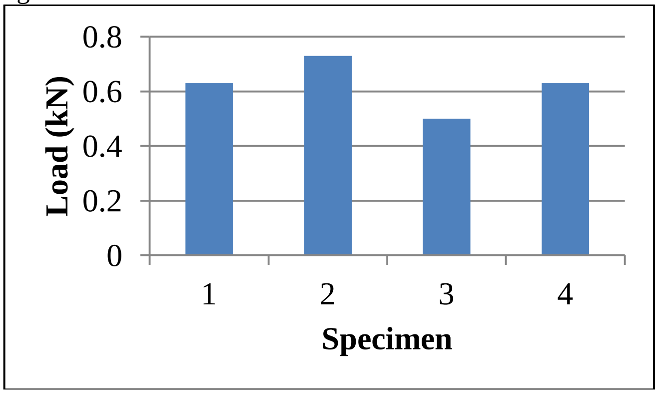

Figure 3. Initial cracking load

Load versus deflection graph of the four specimens of different fibre proportions of jute coir and RHA is shown in figure 5. All slabs exhibits deflection hardening behavior rather being based on the volume percentage of the natural fibers. The slab behaved linearly until crack occurs. When comparing the specimens 1, 2, 3 and 4, increasing RHA decreases the deflection after cracking. The ultimate loads of the specimen slabs are shown in the figure 6. The ultimate load increases as the RHA increases. However, the influence of fibre also contributes a little, i.e., even though the RHA percentage remains same for specimen 1, 3, and 2, 4. The all load-deflection of the tested reinforced concrete slab with different fibre ratios are shown in table 5. The slab behaved linearly until crack occurs. Comparing the specimens 1, 2, 3 and 4 increasing RHA decreases the deflection after cracking is shown in figure 5. The crack occurred during the compressive test is shown in the Figure 4. The predicted deflection and actual experimental values are tabulated in table 7. From the values it is observed that the predicted value is in close agreement with experimental values.

Figure 4. Crack occurred during compressive test

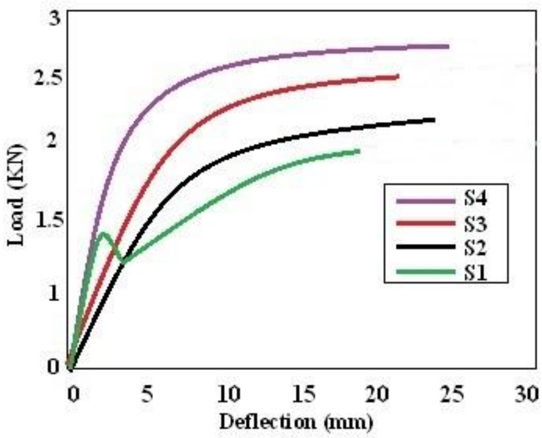

Figure 5. Load Vs deflection

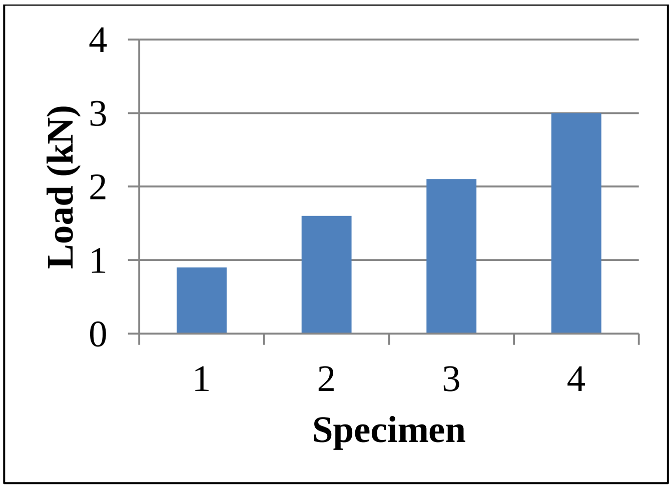

Figure 6. Ultimate load of the specimens

Table. 7. Predicted deflection result of DLNN

	Deflection							
	S1		*S2*		*S3*		*S4*	
Load	***Actual***	***DLN***	***Actual***	***DLN***	***Actual***	***DLN***	***Actual***	***DLN***
0	0	0	0	0	0	0	0	0
0.5	0.6	0.71	0.55	0.63	0.55	0.61	0.6	0.7
1	2	2.2	3	2.9	3	2.8	4	3.7
1.5	5	4.9	9	8.7	6	5.8	8	7.6
2	10	9.75	15	14.21	10	9.5	16	15.7
2.5	15	14.6	23.1	22.2	15	14.6	23.6	22.4
3	19.9	20.2	-	23.4	20.1	21.2	-	24.3

3.3. Thermal Conductivity

Thermal conductivity determines the amount of heat transfer through the thickness of the wall. It directly depends on the temperature. From figure 6 it is observed that thermal conductivity increases as temperature increases. The temperature associated with the region where the work was conducted is within 30 – 50 ºC in summer, and experiments are conducted for this temperature range. From the figure the thermal conductivity of the specimens for the temperatures 30, 40 and 50ºC is illustrated.

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The thermal conductivity of specimen 1 is higher compared to other specimens. Since this work is aimed for the thermal comfort of buildings the coir and RHA is most preferred due to its low thermal conductivity.

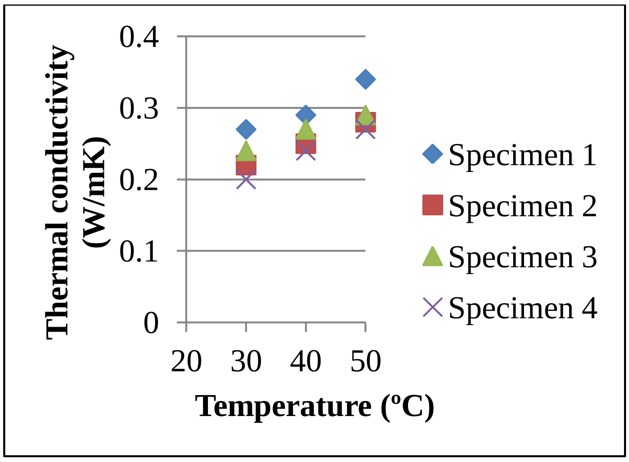

Figure 6. Thermal conductivity of the specimens

IV. CONCLUSION

The locally available RHA, coir and jute is added with reinforced concrete is studied for its strength and thermal properties. Based on the studies the following are the conclusion derived.

- The compressive strength of all the specimens is up to the standard of concrete slabs. Hence these combinations can be used as construction materials.
- The thermal conductivity of the slab is less due to the addition of these fibers. Hence thermal comfort of the building can be improved using these fibers.
- These fibers are available easily on economic basis, so using these fibers could lead to reducing the construction cost as well as energy cost of the building.
- However, the limitation of using these fibers is water absorption capacity. This can be overcome by using reflective paints is suggested as future research scope.

The anticipated result based on the literature studied is proved through the experiments conducted. Therefore these combinations of biomass can be used successfully as construction material to reduce the thermal loads of building in rural areas.

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