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A REVIEW OF ASSESSMENT OF EMBODIED ENERGY OF BUILDINGS AND APPLICATION OF ARTIFICIAL NEURAL NETWORK

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Abstract: ***Whenever we think about living, house is the first thought. The construction process involves lot of operations. Modern day construction has evolved radically in recent years. State of art machines, frameworks and infrastructure with modern engineering have become an essential and integral part of the construction. Usage of embodied energy on large scale has emerged as one of the major part of the construction. Embodied energy calculations prior to construction can give us a clearer picture of environmental effect and help us make better material choices. The environment friendly materials can reduce energy cost in long run and help us reduce the environmental degradation. The paper makes an attempt to reviews the previous research to reduce and calculate embodied energy with the use of artificial neural network or otherwise. The use of artificial neural network to find optimum solution for buildings has also been studied. Since construction has become imperative part of world which in turns is causing global pollution, making better and sustainable choices in material selection may lead to a greener future.***

Keywords: Embodied energy, Artificial neural network, Environmental impact

I. INTRODUCTION

Every construction material involves embodied energy. To design and develop infrastructure for sustainability it is imperative to use materials wisely and vigilantly. In order to select material on the basis of sustainability embodied energy is a big factor. So embodied energy calculation is very important. Construction is the process to make building/ infrastructure a distinct reality. Construction is different from manufacturing because manufacturing generally includes the mass production of similar products without specifying the buyer, while the building is generally located at a known location of the customer [1].The project manager is usually responsible for managing the construction work [2]. Architects are primarily responsible for planning and designing the building. Construction managers, design engineers, construction engineers or architects are responsible for supervising the construction sites. The personnel involved in the design and implementation must consider the zoning requirements, impact of the work environment, schedule, budget, and construction site safety, availability of construction and transportation materials, logistics, construction delays and public inconvenience caused by bid. Large-scale construction projects are sometimes called large projects [3].The Building starts with excavating ground to lay down the foundation. The time and process of excavation depends upon the type of super structure to be build. Once foundation is laid, the extruded columns serves as the basic blocks to lay down slabs and beams, Meanwhile Sewer, Electrical, Water, Gas fittings are put in position. Windows, Weather Resistant Barrier, Rain Screen etc are done once the brickwork and plaster starts.[4].

II. ARTIFICIAL NEURAL NETWORK (ANN)

Machine learning algorithms help in decision making, while ANN classify decision making in groups. Artificial neural networks consist of simple elements that operate in parallel. Artificial neural networks basically work with weights. When an ANN initially presents a pattern, it randomly 'guesses what it might be. Then it will see how far its answer is from the actual answer, and adjust the weight of the connection appropriately [5].

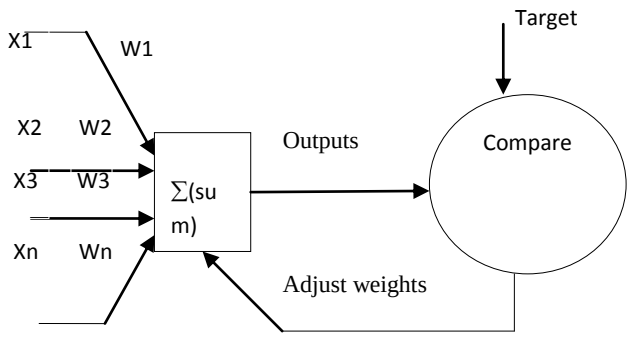

Figure 1 Artificial neural network

- **Activation function**

The ANN can be trained to perform specific functions by adjusting the values of the weights between the units. The artificial network function is determined by the connection between elements. This function is used to generate related output based on the weighted sum of inputs. The output is compared to the target; if the generated output is compatible with the actual output, the input is correct, otherwise the output will be adjusted based on weight [6].

- **Sigmoid function**

It is a real value and differentiable, with negative and positive first derivatives, a local minimum, and a local maximum. It produces an 'S' curve.

$$sig(a) = \frac{1}{1 + e^{-a}}$$

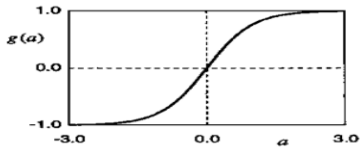

Figure 3 Sigmoid function

In the proposed research work, the sigmoid function is utilized as an activation function to generate output. It is used in ANN to add nonlinearities in the architecture. The ANN calculates a linear combination of its input (I/P) signals and a sigmoid function is applied to the output. It satisfies the characteristics among the derivative of the function and itself, so it become simple to compute. Its derivatives are utilized for learning scheme [7].

2.1 Training ANN

ANN's training requirements are based on certain learning processes. Using learning methods, the network is forced to produce specific responses to specific inputs. When the information about the input is unknown or incomplete, it becomes necessary.

i. Supervised learning

In this system, we assume that at each moment when the input is applied, the desired response of the system is obtained. It tries to predict the result of a known example. Such systems compare their predictions with known results and learn from mistakes.

ii. Unsupervised learning

In unsupervised learning process no feedback algorithm is used. Hence in this system the neuron itself find the pattern and characteristics from the i/p data and the relationship among the i/p and o/p data [8].

III. Previous research

Wall et al. [8, 2018] proposed a technique named, 'Life cycle assessment (LCA)', which has been utilized to determine the environmental load of building throughout their life. Comparison of different building materials such as wood, concrete building has been made. For experiment, 30m*30m concrete slab that consist of two stories has been taken into consideration. It has been concluded that the experiment results on less operational and embodied energy in case of steel building.**Koezjakov et al. [9, 2018]** studied the relationship between demand of heat and embodied energy by considering the Dutch residential building. The performance of experiment has been analyzed by using "Center for climate change and sustainable energy policy high effective building". At last floor area has been design with the HEB model. It has been analyzed that pre-cast concrete is the main contributor to the embodied energy with 27% of an average energy. Reinforced concrete and wood are the second and third construction material responsible for embodied energy. **Dixit and M. K. [10, 2017]** Proposed an enhance input- output hybrid technique to calculate the operational as well as embodied energy of the construction sites. I/p o/p is a top down method to calculate the embodied energy by deriving the coefficient directly from the economic i/p o/p framework. Using direct coefficient the direct energy value required by the construction environment has been calculated.

The above figure represents the direct and indirect inputs related with different phases.

$$indirect\ requirement = total\ requirement - direct\ requirement$$

The total requirement has been determined by using PSA9 Power series approximation approach. From the experiment it has been studied that the energy intensity of wool, lumber material is less as compare to bricks, clay wall, lime, steel and aluminum. **Dixit and M. K. [11, 2017]** presented the relationship between embodied energy and the cost of building. The experiment has been done on 21 types of construction materials. After experiment, positive relationship between embodied energy and cost of materials has been determined. The material used by the author is named as metal, polymers, ceramics etc. The results are analyzed on the basis of mechanical. Power, lights, plumbing and relation has been determined between cost and embodied energy. The zero energy building and energy efficiency cost is high. If LCA has been used then the cost can be reduced. **Weiler et al. [12, 2017]** Presented a comparison between different schemes used for determining the LC (Life cycle) of individual building. Initially, the embodied energy, greenhouse –gases, their requirement and the energy that utilized or exposed during the constriction process have been calculated.

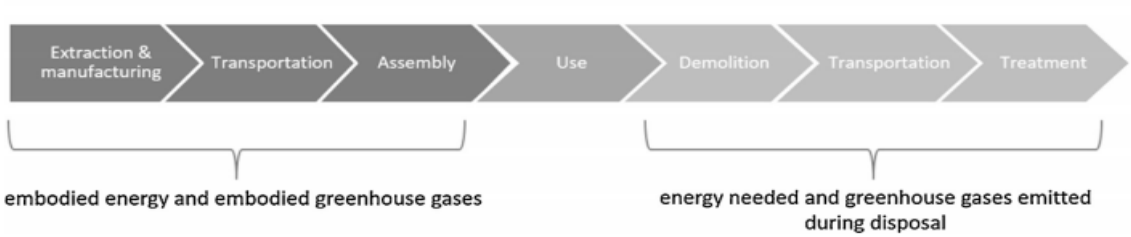

Figure 6 Substages of life cycle

The life cycle has been subdivided into seven number of sub-phases. Initially the raw materials extraction and , manufacturing of building materials has been considered. The transportation and assembly of building materials comes under production stage. **Cellura et al. [13, 2017]** proposed combination of building LCA and simulation by using the TRNSYS tool. TRNSYS system includes an engine, which reads and processed input information and rapidly solves the problem by using equations.**Buratti et al. [14, 2014]** investigated a number of residential buildings to know the performance and energy consumption level. The temperature characteristics along with the outdoor climate and indoor climate have been observed for the available accommodation for 1 week. The data collected from these observations have led to the neural network architecture for creating database so that the performance of the building can be observed.**Xia et al. [15, 2013]** examined the household and international green building-evolution process as per the previous research and developed a green building along with the LCA (Life cycle assessment) and "Artificial neural Network". In this paper, authors used LCA along with ANN to make green building. **Kumar et al. [16, 2013]** presented ANN (Artificial neural network) to explore the total heat and carbon emission of 6 -storey building. The energy performance of a building is affected by a number of factors including surrounding weather conditions, the structure and characteristics of the building, the operation of the lighting, HVAC system and other secondary components, occupancy along with their behavior. Thus it becomes difficult to know the energy consumed during construction. The total load measured by the authors is 2.09 million KW/year. It has been observed that during total heat load (heating load and cooling load) the data is most suitable for the 'regression coefficient of 0.99812 along with validation value of 1312.5202. **González, M. J., & Navarro, J. G. [17,2006]** declare that construction materials with high embodied energy emit high Co_2 compared to the martial with less embodied energy**. Nielsen and C. V. [18, 2008]** used method to calculate CO_2 emission also the requirement of full life cycle has been implemented. It has been observed that concrete during the production stage increases the 'embodied CO_2. The major cause of the carbon footprint is the concrete carbon footprint is the process of cement production. The process of transportation affects the CO_2 very little. It becomes necessary to use high temperature mass of concrete so that energy performance of building can be increased. Building material along with heavy thermal mass indicates small energy consumption over the whole year. After the end of concrete life, the concrete should be removed and crushed into small part which can be used for road construction, backfill materials, and many more. This reduces the need for landfills and the demand for natural aggregates. **Gustavsson et al. [19, 2006]** studied and compared the emission of CO_2 from the building that uses concrete material and wood material. The analysis has been performed in the Sweden and Finland that uses wood frames and concrete building construction. It has been observed that the building made up from wood material have low embodied energy and also emit small carbon dioxide to the environment as compared to the concrete made building. The calculate lifecycle emission variation between wood frames and concrete made building lies from 30 kg C per m2 of floor area to 130 kg C per m2 of floor area. Thus, one can say that a total reduction of Carbon dioxide emission has been obtained by using the wood based building than concrete building. **Scheuer et al. [20, 2003]** conducted a LCA "life cycle assessment" over six storey building having area of 7300 square meter for 75 year time span. The building is situated in the "University of Michigan campus". In the building, ground floor, 1st floor and 2nd floor are used as classroom and the above three floors are used for hotel. Material replacement has been conducted to cover the building along with the utility and clean unit. An automatic system has been used to know the energy consumption during heating, cooling, lightning, and water consumption process. **Thormark and C. [21, 2002]** presented embodied energy values, along with the energy required for working and recycling potential of apartments in Sweden. It has been observed that 45 % of embodied energy observed over 50 years of spam. The recycling spam lies between 35 % and 40 % of the total embodied energy. The results have been measured per square meter of the residential floor per apartment. The parameters such as production energy, operational energy along with recycling energy have been measured. The recycling potential observed for the

existing work observed is about 35 %. **Alcorn et al. [22, 2002]** utilized three techniques for the energy analysis along with some hybrid technique. The three methods named as statistical analysis, input output analysis and process analysis have been used. In hybrid methods the advantages of all three analysis techniques have been integrated. The hybrid technique has been used to generate embodied energy coefficient for the utilization of construction materials in New Zealand construction industry.

IV. ADVANTAGES OF NEURAL NETWORK

Neural networks has the edge over all other methods to find and compare the embodied energy as in this approach neurons are developed and connected through each other to pass and train the data. the embodied energy can not only be calculated but predicted as well for various applications. It has a easy and objective approach towards finding future solutions. With the environment being degraded at a rapid pace the technologies can make construction industry and users more vigilant.

4.1 Application of ANN in civil engineering

Artificial neural network has a huge number of applications in civil engineering domain. **Engineering hydrology:** ANN has been used in forecasting water levels, rainfall frequency, discharge of reservoirs, evapo-transpiration rates, draught analysis, soil water storage, classification of river basins [23].**Structural design:** The application of ANN in structural designing work is growing by leaps and bounds. Mukherjee et al[24] have applied ANN in modeling an initial design process. While Chen et al[25] developed an back propagation neural controller for active control of structure under dynamic loading. There is also a neuro floor[26] developed to help the designer in steel bar joist flooring systems. Saxena et al[27] used 24 different loading condition data from STAAD for warren truss and developed an ANN for the same.**Material engineering:** Yeh I.C[28] explained as how the compressive strength of high performance concrete can be predicted by ANN. Other research work also displayed as how the compressive strength of concrete for ultrasonic pulse velocity (NDT) test results[29] may be predicted by ANN. **Structure management and servicing:** Using back propagation technique Young Sang Cho et.al[30] studied 10 member truss structure and projected a saving method for the same. While Morcous[31] created an ANN for bridge management system which helped rehabilitation and replacement work.

V. CONCLUSION

Different researches indicate that making informed choices for the betterment of environment have to be first priority. Based on the review of literature on embodied energy calculation, it can be concluded that many have worked upon LCA of materials but there is scope for cradle to grave embodied energy calculation. To achieve the goal more efficiently neural network may be a reliable option because of its scope in developing, improving and predicting properties. However there is scope for other ways to be more helpful when it comes to decision making based on circumstances. All the research based results suggest, using Neural network is for less faulty, cumbersome and optimal use of material.ANN has found application in all the sub- streams of civil engineering and may be used in developing reliable machine suggestions.

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