International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 2, Issue 1, pp: (58-65), Month: April 2014 - September 2014, Available at: www.researchpublish.com

Low Energy Green Materials by Embodied Energy Analysis

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Abstract: **In Building construction, the requirement of energy is large. It is in various forms. Materials which are required for construction, there manufacturing, transportation, actual use in construction and after construction, large amount of energy utilized. That form of energy is called as Embodied Energy. Secondly, there is good trend to use various green building materials in building construction. It will definitely helpful to make our building as Green Building. Production of Green material generally involves these types of material which are conventional, recyclable, waste products. Researchers are always trying to produce new building material, keeping various mix proportions, various conventional and non conventional in gradients and taking all appropriate tests on them and conclude that this material suitable for construction work. But no one is tried to calculate their embodied energy along with all tests. So this paper is focused on Embodied Energy Calculations of various Building materials which given by various researchers along with their research paper.**

Keywords: **Materials, Green Building, Embodied Energy, Mix Proportions**

1. INTRODUCTION

Buildings have a significant and continuously increasing impact on the environment since they are responsible for a large portion of carbon emissions and also uses considerable number of resources[1]. Buildings account for one-sixth of the world's fresh water withdrawals, one quarter of its wood harvest, and two-fifths of its material and energy flows[2]. The construction sector consumes considerable amount of energy from the production of basic building materials, its transportation and assembling called embodied energy. Energy conscious and eco-friendly development hold the key potential to significantly reduce thermal loads and electricity use in commercial buildings. Low embodied energy materials conserve energy and limit Green House Gases (GHG) emissions thus limiting the impact on the environment.[3] The energy in buildings may be looked from two different perspectives. Firstly the energy that goes into the construction of the building using a variety of materials. Secondly the energy that is required to create a comfortable environment within the building during its lifetime. [4]

2. EMBODIED ENERGY

Embodied Energy is the sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself. The concept can be useful in determining the effectiveness of energy-producing or energy-saving devices, or the "real" replacement cost of a building, and, because energy-inputs usually entail greenhouse gas emissions, in deciding whether a product contributes to or mitigates global warming. One fundamental purpose for measuring this quantity is to compare the amount of energy produced or saved by the product in question to the amount of energy consumed in producing it.

Embodied energy is an accounting method which aims to find the sum total of the energy necessary for an entire product life-cycle. Determining what constitutes this life-cycle includes assessing the relevance and extent of energy into raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition as well as human and secondary resources. Different methodologies produce different understandings of the scale and scope of application and the type of energy embodied

Embodied energy analysis is interested in what energy goes to supporting a consumer, and so all energy depreciation is assigned to the final demand of consumer. Different methodologies use different scales of data to calculate energy embodied in products and services of nature and human civilization. International consensus on the appropriateness of data scales and methodologies is pending. This difficulty can give a wide range in embodied energy values for any given material. In the absence of a comprehensive global embodied energy public dynamic database, embodied energy calculations may omit important data on, for example, the rural road/highway construction and maintenance needed to move a product, human marketing, advertising, catering services, non-human services and the like. Such omissions can be a source of significant methodological error in embodied energy estimations [5].

Here are values of Embodied Energy of various materials,

TABLE I: MATERIAL AND THERE EMBODIED ENERGY VALUE

Sr. No.	Material	Energy MJ/kg	Sr. No.	Material	Energy MJ/kg
1	Aggregate	0.083	**23**	Slate	0.1–1.0
2	Concrete (1:1.5:3)	1.11	**24**	Clay tile	6.5
3	Bricks (common)	3	**25**	Aluminium (general & incl 33% recycled)	155
4	Concrete block (Medium density)	0.67	**26**	Bitumen (general)	51
5	Aerated block	3.5	**27**	Medium-density fibreboard	11
6	Limestone block	0.85	**28**	Plywood	15
7	Marble	2	**29**	Plasterboard	6.75
8	Cement mortar (1:3)	1.33	**30**	Gypsum plaster	1.8
9	Steel (general, av. recycled content)	20.1	**31**	Glass	15
10	Stainless steel	56.7	**32**	PVC (general)	77.2
11	Timber (general, excludes sequestration)	8.5	**33**	Vinyl flooring	65.64
12	Glue laminated timber	12	**34**	Terrazzo tiles	1.4
13	Cellulose insulation (loose fill)	0.94–3.3	**35**	Ceramic tiles	12
14	Cork insulation	26	**36**	Wool carpet	106
15	Glass fibre insulation (glass wool)	28	**37**	Wallpaper	36.4
16	Flax insulation	39.5	**38**	Vitrified clay pipe (DN 500)	7.9
17	Rockwool (slab)	16.8	**39**	Iron (general)	25
18	Expanded Polystyrene insulation	88.6	**40**	Copper (average incl. 37% recycled)	42
19	Polyurethane insulation (rigid foam)	101.5	**41**	Lead (incl 61% recycled)	25.21
20	Wool (recycled) insulation	20.9	**42**	Ceramic sanitary ware	29
21	Straw bale	0.91	**43**	Paint - Water-borne	59
22	Mineral fibre roofing tile	37	**44**	Paint - Solvent-borne	97

3. LITERATURE SURVEY

A. "Comparative Analysis for Embodied Energy Rates for walling elements in India" [6]

This paper is focus on the computation of Embodied Energy Rate of selected alternative walling elements and comparing the rates to identify most suitable option. Here the total study is limited to walling elements of single brick or block thickness and plastering work has been excluded from the computations. In their analysis, they prove that traditional bricks which are widely used in India prove to be the worst choice with respect to the energy input involved.

B. "Embodied Energy Computations in Building" [7]

This paper is focus to cover the issues and problems with the current materials and techniques used in the building industry at present. The choice of appropriate materials and technology considering their embodied energy utilizing during construction will also have to be considered for producing energy efficient and environment friendly houses. In this paper, they considered total four types of case studies for the computation of Energy. Also contribution of human labor and equipment energy for the construction is not considered.

C. "A material life cycle assessment of a net zero energy building" [8]

In this paper, the life cycle environment impacts of material phase of a net zero energy building is analyzed. Also they prove that concrete and steel which is used in foundation and structural work of building, represent the highest environmental impact. Also they suggests that, it is important to identify those materials within the building system that have the greatest effect on a building's environmental impacts in order to target specific areas for minimizing environmental impact in future construction.

D. "Indexing of building materials with Embodied operational Energy and Environmental Sustainability with reference to Green Building" [3]

This paper focus on to develop quantified index energy and environment index based on energy consumption both in building materials and buildings usages as well as the related environmental emissions and conserve finite natural resources. The paper focuses upon comparison of two types of structures using fire clay bricks and ash blocks structure. Though ash blocks are 3 times costlier than fire clay bricks but the use of ash blocks has considerably reduced the size of air conditioning system, total usage of energy and finally the total cost of building due to its light weight and insulating nature. Finally they conclude that, use of ash blocks has helped in conserving the natural resources, energy and environment.

E. "Life Cycle Energy Analysis of a Multifamily Residential House: A case study in Indian Context" [9]

The paper presents life cycle energy analysis of a multifamily residential house situated in Allahabad (U.P), India. The study covers energy for construction, operation, maintenance and demolition phases of the building. The selected building is a 4-storey concrete structured multifamily residential house comprising 44 apartments with usable floor area of 2960 m2. This paper shows that while the operating phase of building is very significant (89%), the manufacturing phase is also not negligible (11%). Energy for on site construction and demolition of the building is minute (1%) and can be ignored in evaluation of LCE building. Steel, Cement and bricks are most significant materials in terms of contribution to the initial embodied energy profile of the building.

F. "Optimization of Embodied Energy of Building with alternative materials: A case study" [1]

In this paper an educational building is selected. Then cost estimate and energy estimate is prepared. After that, considering conventional and there alternative material and their energy calculations are done. After all these, best option is selected.

4. METHODOLOGY

In this paper, various research articles, research papers, conference paper those are related with production of a building material which have these parameters such as eco friendly, use of non conventional in gradients, waste materials etc. All papers are studied properly. Each paper has some samples which are prepared by keeping change in mix proportions. Papers are related with various types of concrete and bricks. Now main question is why these two material's research paper are considered? Because either you made a general building or energy efficient or eco friendly building these two materials have large amount use in construction. Considering their results, which are already compared with IS, trying to calculate their embodied Energy and then put best product for further construction. For reference the table no 1 values are considered for all calculations in this paper.

For calculation of Embodied Energy this formula is used
Embodied Energy of Material (MJ) = Weight of Material in kg X Value of Embodied
Energy in MJ/kg

5. GREENER CONCRETE

In this paper, the possible roles of post consumer products namely used tyre, plastics and glass in the manufacturing of greener concrete. Tyre chips have been used in experimental concrete in laboratory over past several years as a partial replacement of aggregates. Several researchers have invested the effect of aggregates substitution by tyre chips and crumb rubber on the slump, workability and unit weight of Portland cement. When we use plastic in concrete, the mechanical properties such as compressive strength, modulus of elasticity, tensile strength etc of concrete containing plastic aggregate derived from post consumer plastic wastes decreases with increase in aggregate content. Fine aggregate PET waste may be used for the development of light weight aggregate concrete, the composite strength of such concrete may reduce by 5% to 30% depending upon it quantity in the concrete mixture.
Post consumer glasses which are directly used in concrete. Post consumer glass after crushing can be used as partial replacement of aggregate[11]. There are following details for the replacement of sand with crushed glass and then we have calculate their Embodied Energy of each sample. (Ref. Table II)
After calculation of embodied energy for each mix proportion and comparing the results of compressive strength and splitting tensile strength we can easily get which proportion is economical and greener. In these mix proportion, Mix no B1 superior then other.

TABLE II: MIX PROPORTIONS OF CONCRETE AND EMBODIED ENERGY

Sr. No.	Mix No.	Quantities in kg/m3					Embodied Energy in MJ for 1 m^3 Concrete
		Cement	Fly Ash	Sand	Glass	Stone	
1	A0	429	0	720	0	1079	2658.967
2	A1	427	0	611	99	1073	4211.822
3	A2	426	0	499	197	1071	5754.71
4	A3	421	0	389	292	1059	7225.834
5	B0	362	79	677	0	1073	2447.02
6	B1	361	79	574	98	1071	3990.655
7	B2	361	79	477	196	1071	5540.804
8	B3	359	79	375	295	1067	7094.406
9	C0	298	160	642	0	1069	2258.113
10	C1	296	160	548	97	1064	3780.496
11	C2	298	160	444	195	1070	5342.262
12	C3	298	161	346	293	1072	6894.824
13	D0	234	240	607	0	1073	2067.54
14	D1	232	237	507	97	1064	3582.103
15	D2	232	237	406	193	1064	5100.12
16	D3	231	236	304	291	1059	6641.259

6. UTILIZATION OF RECYCLED WASTE AS IN-GRADIENTS IN CONCRETE MIX

In this paper, Laboratory experimentation was carried out to analyze the performance of M25 concrete made by partially replacing aggregates with waste materials like construction debris, PVC scrap and leather waste. The resultant concrete was tested for parameters like weight, compressive strength, slump and workability and compared with conventional plain cement concrete. It has been observed that the use of waste materials results in the formation of light weight concrete. There is a considerable increase in the compressive strength of concrete when the coarse aggregates are fully or partially replaced with construction debris. However a minor reduction in workability of the concrete mix was observed. When the coarse aggregates were replaced with PVC scrap in small percentage by weight, the resultant concrete shows fair value of compressive strength and the workability. But with the partial introduction of leather waste in place of sand in concrete, the concrete passed workability test but it failed completely in compressive strength test and gave almost zero strength. Hence, except leather waste other materials like construction debris and PVC scrap performed well as full or partial replacement for concrete aggregates and can find suitable application in construction industry as alternative to conventional materials. Uses of such waste materials will not only cut down the cost of construction, but will also contribute in safe disposal of waste materials. Apart from the environmental benefits, the addition of such wastes, also improves certain properties of resultant concrete. [12]

In table, the mix proportions are considered for further tests. We have calculated their embodied energy for each mix and try to find out best mix proportion for green building material. (Ref Table III)

After calculating the embodied energy for each mix, we can consider that mix no 4 have less embodied energy compare with other. And remaining results which are given in research paper shows that mi no 4 is superior to other.

TABLE III: IN-GRADIENTS OF CONCRETE AND THEIR EMBODIED ENERGY

Sr. No.	Type of Mix	In-gradients in kg					Embodied Energy in MJ/ m^3 of concrete
		Cement	Sand	Coarse Aggregate	Debris	PVC	
1	PCC	554.5	627.55	1222.5	0	0	3397.38
2	100% Debris as Coarse Aggregate	554.5	627.55	0	1222.5	0	4652.89
3	50% debris + 50% Coarse Aggregate	554.5	627.55	611.25	611.25	0	4025.13
4	25% debris + 75% Coarse Aggregate	554.5	627.55	916.88	305.63	0	3711.26
5	5% PVC + 95% Coarse Aggregate	554.5	627.55	1161.38	0	61.13	8111.54
6	10% PVC + 90% Coarse Aggregate	554.5	627.55	1100.25	0	122.25	12824.93

7. EXPERIMENTAL STUDIES ON LIME SOIL FLY ASH BRICKS

Fly ash is generated in large quantities especially by thermal power plants. A lot of research has been carried out for effective utilization of fly ash in building industry. Use of fly ash in manufacturing brick is one such subject which is being studied by researchers. The aim of the present study is to investigate the strength and water absorption characteristic of fly ash bricks made of lime (L), local soil (S) and fly ash (FA). The experiments were conducted both on Hand molded and Pressure molded fly ash bricks. It was observed that none of the L-S-FA bricks satisfy all the requirements of standard codes. While some of the bricks satisfy the provisions in respect of strength only the L-FA (40: 60) bricks satisfy the requirement of Indian Standard Code in respect of strength as well as water absorption characteristics [13].

TABLE IV: LIME SOIL FLY ASH BRICK AND EMBODIED ENERGY CALCULATION

Sr. No.	Sample No	% of Lime	% of Soil	% of Fly Ash	Weight in kg			Embodied Energy MJ/brick
					Lime	Soil	Fly Ash	
1	1	15	5	80	0.44	0.15	2.32	2.50
2	2	10	10	80	0.29	0.29	2.32	1.66
3	3	25	5	70	0.73	0.15	2.03	4.13
4	4	20	10	70	0.58	0.29	2.03	3.29
5	5	35	5	60	1.02	0.15	1.74	5.76
6	6	30	10	60	0.87	0.29	1.74	4.92
7	7	20	0	80	0.58	0	2.32	3.29
8	8	30	0	70	0.87	0	2.03	4.92
9	9	40	0	60	1.16	0	1.74	6.55

If we see the embodied energy values of each mixes, the value of sample no 9 is maximum. But as per result discussed in this paper, only sample no 9 passes all tests as per IS.

8. COMPARATIVE STUDY ON JUTE FIBER AND BANANA FIBER IN FLY ASH BRICKS

Increasing concern about the global warming, primarily due to deforestation has led to the ban on use of clay brick by government in buildings construction. Subsequently, a large action plan for the development use of fly ash bricks substitute has resulted in creation of more awareness about the use of fly ash based building materials. In the past one decade or so the joint efforts by R & D organizations, private industries and funding agencies provided the much needed thrust for the actual transfer of technical know-how and product to the end users. Most of the developing countries are very rich in agricultural and natural fiber. Except a few exceptions, a large part of agricultural waste is being used as a fuel. India alone produces more than 400 million tonnes of agricultural waste annually. It has got a very large percentage of the total world production of rice husk, jute, stalk, jute fiber, banana fiber and coconut fiber. All these natural fibers have excellent physical and mechanical properties and can be utilized more effectively in the development of building materials (Inclusion in fly ash bricks) for various building applications. So in this paper, various samples are considered which have mix of jute and banana. There all tests are taken and results derived [14].

TABLE IV: JUTE AND BANANA FIBER IN FLY ASH BRICK AND EMBODIED ENERGY CALCULATIONS

Sr. No.	Sample	% of Material						Weight in kg				Embodied Energy MJ/brick
		Fly Ash	Sand	Lime	Cement	Jute	Banana	Fly Ash	Sand	Lime	Cement	
1	Fly Ash	60	20	15	5	0	0	1.95	0.65	0.49	0.16	3.77
2	JF 1	60	20	15	4.5	0.5	0	1.95	0.65	0.49	0.15	3.71
3	JF 2	60	20	15	4	1	0	1.95	0.65	0.49	0.13	3.59
4	JF 3	60	20	15	3.5	1.5	0	1.95	0.65	0.49	0.11	3.48
5	JF 4	60	20	15	3	2	0	1.95	0.65	0.49	0.09	3.36
6	JF 5	60	20	15	2.5	2.5	0	1.95	0.65	0.49	0.08	3.30
7	BF 1	60	20	15	4.5	0	0.5	1.95	0.65	0.49	0.15	3.71
8	BF 2	60	20	15	4	0	1	1.95	0.65	0.49	0.13	3.59
9	BF 3	60	20	15	3.5	0	1.5	1.95	0.65	0.49	0.11	3.48
10	BF 4	60	20	15	3	0	2	1.95	0.65	0.49	0.09	3.36
11	BF 5	60	20	15	2.5	0	2.5	1.95	0.65	0.49	0.08	3.30

In the calculation of Embodied energy of all samples, there is minor difference. As per the conclusion of this paper, the sample of fly ash, JF 1 and BF 1 can satisfy all criteria as per IS. And there embodied energy values are almost same.

9. RESULT AND DISCUSSION

In this paper, total four research papers are considered. First two papers are based on production of concrete using waste materials. In Green Concrete, there is discussion on use of plastic and rubber in concrete and mix proportions related with use of crushed glass. Total 16 different mixes are considered. Changes are in percentage of fly ash and crushed glass. Fly ash replaces cement and crushed glass replace sand. In calculation, the embodied energy of fly ash is less as compare with cement. But if we compare embodied energy of crushed glass with sand, there is a huge difference. So when we use crushed glass in formation of concrete, the embodied energy of that concrete get increased and the testing results of use of crushed glass are not so good. We can conclude that crushed glass is not a proper material which replaces the sand. But fly ash is a good option to replace cement in concrete. In second paper, there is a try to replace coarse aggregate by construction debris and PVC waste. Embodied value of debris is low as compare with PVC. And test results of PVC mix does not satisfy IS code. But 25% replacement of coarse aggregate by debris is feasible. Because it passed in all test and that mix have lowest Embodied Energy value comparing other mixes.

In remaining two papers, Fly Ash bricks are considered. In third paper, Lime Fly Ash bricks are considered. Here some mixes has only 2 in-gradient i.e. Lime and Fly Ash. Keeping various mix proportions of Fly Ash and lime, there are total 3 mix proportions. In remaining 6 mix proportions, lime is replaced by soil. In all these 6 mix proportions the embodied energy value is low comparing with Fly ash lime mixes. But all samples of Fly ash, lime and soil doesn't satisfy provisions of IS code. Only one mix satisfy the IS code but that mix have maximum Embodied Energy value.In fourth paper, Fly ash-Lime bricks are considered. Here sand and cement is also mixed. In 5 mix proportions cement is partially replaced by banana fiber and in remaining 5 mix proportions cement is partially replaced by jute fiber. Also one mix is considered without any type of fiber. After calculating the embodied energy of all mix proportions, the values have small differences. But as per testing done in this paper on all mixes, only three mixes can satisfy the IS provisions and there Embodied Energy values are quite same.

10. CONCLUSION

Generally, researchers are always trying to find out new building material which relates with recycle of material, use of waste material as in-gradients etc. In this paper also we have seen total 4 papers which related with production of building material. Some product can succeed in IS criteria and some are not. This paper helps to determine embodied energy for material. After calculations we see that when we increase the quantity of cement in concrete then automatically Embodied energy value gets increased. In higher strength concrete, use of cement is large and in that comparison the embodied energy value also gets increased. In production of bricks, we have to increase more use of fly ash. In brick production, when brick is in burning process, the un-burnt carbon gets utilized and remaining fly ash have low content of embodied energy. So we can conclude that, if we increase use of fly ash in bricks then we get lower embodied value of our whole structure.

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