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Assessment of Embodied Water of Construction: Case Study of a Four Star Rated Hotel in New Delhi, India

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ABSTRACT

Hotels typically consume a lot of water in terms of its daily requirements of drinking, food preparation, washing, cleaning, etc. Contemporary hotels therefore look at various measures to conserve this 'blue gold' as part of sustainable practices. What goes overlooked is the quantum of fresh water that is embedded in the construction materials and that consumed during its construction. This has hardly been studied or quantified. An attempt has been made to assess this embodied or virtual water of construction, through a case study of a star rated hotel in New Delhi, India. The methodology included the indirect water embodied in major materials of construction, and the water used during construction. Results indicated that the embodied water was to the tune of 20.94 kl/m^2. When compared to the operational water demand of the hotel it was found that the embodied water could work out to 31.65% of the operational water demand considering a 50 year life cycle, clearly indicating the significance that it holds.

Keywords: Embodied water, virtual water, inherent water, induced water, hotels, sustainability

INTRODUCTION

Hotels typically consume a lot of water in terms of its daily requirements of drinking, food preparation, washing, cleaning, laundry, etc. Contemporary hotel designs therefore look at various measures to conserve this water as part of sustainable practices. What goes overlooked is the water embodied in the building itself, which is nothing but the embodied water or the virtual water. The quantum of fresh water that is embodied in the construction materials used in the hotel and the fresh water that may have been consumed during its construction have hardly been studied or quantified or given any consideration.

According to Jacob Tompkins [1], director of Water wise, a UK NGO focused on decreasing water consumption, "The construction industry is very water dependent, directly via material and processes such as water of concrete, water for dust suppression, water for cutting, water for mortars etc. and, indirectly, with embedded water in all construction products." According to Paul Shaffer [1], associate at the Construction Industry Research and Information Association, CIRIA "Embedded water will become an important factor in construction in the near future and we need to collect evidence to see how much of a problem it will be."

With this backdrop and the current issues of sustainability, the concept of embodied water also known as virtual water and research in this area assumes great proportions. The present study attempts to take a holistic look at the embodied water of hotels in India by analyzing the embodied water that is inherent in the materials of construction along with the embodied water that is induced during construction, of a four star rated hotel in the city of New Delhi, the capital of India, and arriving at a better understanding of the subject and establishing its significance.

EXISTING RESEARCH

Very little research has been reported in the field of embodied water of buildings. A brief of the important findings of the existing research published at the time of writing this paper are indicated in the subsequent paragraphs. Although none of the published works relate to the hotel industry, the same have been considered for drawing analogies in the absence of substantive work in this field of research.

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McCormack et al [2] looked at 17 non-residential case studies and found that the embodied water could be as much as 20.1 kl / m^2 of gross floor area. Crawford et al [3] quantified embodied water of a commercial building to 54.1 kl/m^2 of constructed area with steel contributing to the maximum i.e. 17% and the direct water requirement during construction at only 0.7% of the total embodied water. Another study carried out by McCormack et al [4] estimated that the embodied water of a typical Australian house equals to about 15 years' worth of operational water. Results of an independent study carried out by Crawford [5] studied the embodied energy and water of 21 standard construction assemblies of residential, commercial and industrial type of buildings in Australia and found that energy and water embodied in replacement materials can represent as much as 50 per cent of the life cycle energy and water requirements. Results of another study carried out by Crawford [6] on life cycle water analysis of an Australian residential building and its occupants computed the embodied water and operational water as 31.4 kl/m^2 and 31.6 kl/m^2 of constructed floor area respectively.

Brathwaite [7] evaluated the water embodied within the construction of materials and the construction process of the King span Offsite Lighthouse, the UK's first zero carbon home and found it to be 818 kl/m^2 of constructed floor area with steel contributing the highest i.e. 67% of this.

Meng et al [8] considered 6 office buildings in E-town, Beijing, China and computed the embodied water at 20.83 m^3 per m^2 of floor area.

In India, there are two published data available with regard to embodied water of materials consumed by the construction industry. The Comprehensive Industry Document [9] indicates an average embodied water of 1.00 kl/metric ton of cement produced, and the embodied water of steel as indicated in the Manual on Water Supply and Treatment [10] is indicated as 200 to 250 kl/metric ton of steel produced.

So far as computation of embodied water specific to building construction in India is concerned, there are two reported publication. The first publication by Bardhan [11] considered a multi-storied residential building in Kolkata and calculated the embodied water as 27.604 kl/m^2 of floor area. The second publication also by Bardhan [12] considers another multistoried residential building in Kolkata and calculates the embodied water as 26.8102 kl/m^2 of floor area.

METHODOLOGY

A four star rated hotel in New Delhi, the capital of India was considered for the study as a representative sample. A brief description of the hotel project is indicated in Table 1. The name and photographs of the hotel have not been included on request.

Table1. *Basic Project Data of Hotel Case Study in New Delhi*

Location	Aero City, Mahipalpur
Number of floors	4 Basement + Ground + Service Floor + 5 Floors
Number of rooms	261 nos
Total floor area	25908.77 m^2
Project duration	51 months
Project completion	April 2014
Type of structure	RCC framed with brick walls and basement with raft foundation

To compute the inherent embodied water i.e. the water embodied in the materials of construction, five major materials which are bricks, cement, steel, aluminium and glass were considered. The embodied water coefficient for brick was considered as 0.71 kl/m^2 as per Bardhan [11], cement as 1 kl/metric ton based on the Comprehensive Industry Document [9], steel as 200 kl/metric ton based on the Manual on Water Supply and Treatment [10], aluminium as 0.088 kl/kg based on McCormack et al [4] and glass as 3.42 kl/m^2 as per Crawford [6]. It should be noted that while the embodied water of glass at 3.42 kl/m^2 is for clear float glass. However in the absence of any other published data, the same was considered for the present study. The Bill of Quantities was used for collection of data on quantities of materials of construction. These quantities were then multiplied by the embodied water coefficients of the materials and translated to per m^2 of floor area to arrive at the inherent embodied water component. The quantities of double glazed units used in the hotel were doubled to arrive at the quantum of inherent water for glass.

To compute the induced embodied water, the average water use per day was estimated and translated to per m^2 of floor area for the entire project duration. The project used water tankers for supply of water. The induced embodied water was calculated on the basis of the average number of tanker supplies per day and the total project duration.

The inherent and induced embodied water was then summed up to arrive at the total embodied water for each case study. A comparative of the total embodied water was then carried out to arrive at conclusive results. Operational water demand for the case studies was also computed considering a 50 year life cycle. Water demand was based on the number of beds as per IS 1172: 1993[13]. The embodied water was then compared with the operational water to establish its significance.

RESULTS

Total Embodied Water

A summary of the total embodied water with the breakup of inherent embodied water and induced embodied water for the hotel case study is indicated in Table 2.

Table2. *Total Embodied Water of Hotel Case Study in New Delhi*

Inherent embodied water		Induced embodied water		Total embodied water
kl/m^2 of floor area	% of total	kl/m^2 of floor area	% of total	kl/m^2 of floor area
A	B	C	D	E = A + C
18.9795	90.60%	1.9684	9.40%	20.9480

The total embodied water worked out to 20.9480 kl/m^2 of constructed floor area. This is lower than the embodied water of residential buildings studied by Bardhan in Kolkata [11] [12] and the residential study by Crawford [6] in Australia. However, when compared to non-residential case studies, the similarities are remarkable. McCormack et al [2] in Australia had computed the embodied water of non-residential buildings at 20.1 kl/m^2 of floor area and Meng et al [9] who had considered 6 office buildings in E-town, Beijing, China had computed the embodied water at 20.83 m^3 per m^2 of floor area. The results of the present study thus corroborates with non-residential case studies of Australia and China.

It is also evident that the inherent embodied water has the highest contribution of 90.60% of the total embodied water. It could therefore be concluded that the inherent embodied water of the materials of construction is far more significant than the induced embodied water. The results conform to earlier findings by McCormack et al [4] in Australia and Bardhan [11] [12] in India.

Comparison of Total Embodied Water to Operational Water

To establish the significance of the total embodied water, the same was compared with the operational water demand of the hotel. Water demand of 180 litres per bed per day based on IS 1172: 1993[13] and a 50 year life cycle was considered for computing the operational water demand. The results are indicated in Table 3.

It was found that the quantum of embodied water could be as high as 31.65% of the operational water demand of hotels for a 50 year life cycle. The quantum of embodied water translates to 15.83 years of operational water. This figure is very close to the findings of McCormack et al [4] were it was estimated that the embodied water of a typical Australian house equals to about 15 years' worth of operational water.

Table3. *Total Embodied Water of Hotel Case Study in New Delhi*

Total embodied water	Total operational water considering a 50 year life cycle	Embodied water as a % of operational water	Embodied water in terms of number of years of operational water
kl	kl	%	No of years
F = E*(floor area)	G = (Operational water demand per day)*(365days)*(50years)	H = F/G %	I = F/(G/50years)
542735.8400	1714770.0000	31.65	15.83

CONCLUSION

If the sample hotel is considered as a representative of similar hotels in India, it could be safely concluded that the average embodied water of hotels in India of four star category could be to the tune of 20.9480 kl/m^2 of floor area. The study also found that the inherent embodied water is much more significant when compared to the induced embodied water for hotel buildings in India. This basically means that the water embodied in the materials of construction is far more significant than the actual water use during construction. The present study considered only five materials of construction and it would be needless to state that if more materials are considered the quantum of inherent embodied water would be even higher.

It can also be concluded that the embodied water when compared to the operational water is quite significant in case of hotels in India. The case study indicates an average embodied water of 31.65% of the operational water considering a 50 year life cycle. This translates to 15.83 years of operational water, which is a significant amount of fresh water that is embodied in the hotel buildings that goes unnoticed.

There is therefore an urgent need to address the issue of embodied water of hotel buildings per se or any building in general and carry forward this field of research to fill in the missing links in collaboration with the manufacturing industry and the building industry. It is of utmost significance that we target embodied water for a better understanding of water use patterns during the buildings' production stage. With a better understanding of the embodied water of buildings, a more holistic approach towards conservation of water may be adopted. With the growing demand of fresh water it is important to consider embodied water of materials while selecting the same, as is presently the practice for embodied energy. This overlooked aspect of buildings demand serious considerations if one is really concerned of saving our fresh water reserves through sustainable design practices.

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