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Computing the Pre-operational Embodied Water of a Multistoried Residential Complex in Gurgaon, India

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Abstract : ***The pre-operational embodied water of an upcoming multi-storied residential complex in Gurgaon, India was quantified at 24.0705 kl/m^2 of floor area by computing the water embedded in materials of construction and water used during construction. This translated to 66.21% of the operational water of the complex considering a 50 year life cycle.***

Keywords :Pre-operational embodied water, virtual water, multi-storied residential complex, inherent water, induced water.

I. Introduction

Professor John Anthony Allan [i] from Kings College, London, was the creator of the virtual water concept which measures how water is embedded in the production and trade of food and consumer products. Hoekstra and Chapagain [ii] have defined the virtual water content of a product (a commodity, good or service) as "the volume of fresh water used to produce the product, measured at the place where the product was actually produced." Virtual water is also known as embodied water or embedded water. The concept and study of embodied water akin to embodied energy has been mostly centring on agricultural products and food products. The volume of fresh water used to produce a building has hardly been studied.

According to Jacob Tompkins [iii], director of Waterwise, "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."

Although some work has been carried out in Australia, UK, China and India, very little is reported in terms of pre-operational embodied water of residential buildings.

McCormack et al [iv] had estimated that the embodied water of a typical Australian house equals to about 15 years' worth of operational water. Crawford [v] carried out life cycle water analysis of an Australian residential building and computed the embodied water and operational water as 31.4 kl/m^2 and 31.6 kl/m^2 of floor area respectively, concluding that the embodied water was as much as the operational water.

Brathwaite [vi] in his paper evaluated the significance of the water embodied within the Kingspan Offsite Lighthouse, UK's first zero carbon home. Summary of his findings indicate the total embodied water at 818 kl/m^2 of floor area with steel contributing the highest i.e. 67% of this.

So far as embodied water of residential buildings in India is concerned, there are two reported publications, both for multi-storied residential buildings in the city of Kolkata, West Bengal. The first by Bardhan [vii] computes the embodied water as 27.604 kl/m^2 of floor area. The second by Bardhan [viii] computes the embodied water as 26.8102 kl/m^2 of floor area.

According to Paul Shaffer [iii], associate at the 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." It is therefore necessary to explore the concept of pre-operational embodied water of buildings and quantify the same by computing the water embedded in the materials of construction that may be termed as inherent water along with the water used during construction that may be termed as induced water.

The paper attempts to compute the embodied water of a sample multi-storied residential complex in the city of Gurgaon in India to corroborate the results with existing ones and arriving at a better understanding of its significance.

II. Methodology

An upcoming multi-storied residential complex in the city of Gurgaon, in the northern state of Haryana in India was studied by computing the water embodied in the major materials of construction (inherent embodied water) and the water use during construction (induced embodied water). The inherent embodied water and induced embodied water was then summed up to arrive at the quantum of pre-operational embodied water. A comparative of the total pre-operational embodied water was then carried out to arrive at conclusive results. Operational water demand for the case study was also computed considering a 50 year life cycle and water demand of 150 litres per capita per day with a family size of 5 members per dwelling as per IS 1172: 1993[ix]. Since every dwelling unit had an attached servants room, an additional 3 persons per room was considered for calculating the operational water demand. The pre-operational embodied water was then compared with the operational water to establish its significance. A brief description of the project that was studied is indicated in Table 1.

Table 1. Basic Project Data

Number of floors	3 Towers of Basement + Ground + 20 Floors 3 Towers of Basement + Ground + 26 Floors
Number of dwelling units	275 nos with attached servants' room
Total floor area	165668.22 m^2
Project duration	49 months
Project completion	Targeted September 2017
Type of structure	RCC framed with shear walls and raft foundation for residential towers and isolated footings for common amenities

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To compute the inherent embodied water i.e. the water embodied in the materials of construction, 5 major materials which are brick, cement, steel, aluminium and glass were considered. The embodied water coefficient for brick was considered as 0.71 kl/m^3 based on Bardhan [vii], cement was considered as 1 kl/metric ton based on the Comprehensive Industry Document on Vertical Shaft Kiln Based Mini Cement Plants [x], steel as 200 kl/metric ton based on the Manual on Water Supply and Treatment [xi], aluminium as 0.088 kl/kg based on McCormack et al [iv] and glass as 3.42 kl/m^2 as per Crawford [v]. 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 data on water use during construction i.e. the induced embodied water component was based on information shared by the project team.

III. Results

A summary of the inherent embodied water contributed by each of the materials for the case study with the total are indicated in Table 2.

The inherent embodied water indicates that the contribution of steel is the maximum amounting to 92.39% of the total inherent water. It was observed that the contribution of all other materials put together is much less significant when compared to steel. Steel is followed by glass as the second largest contributor. It must be understood that for double glazed units the area of glass is doubled for calculating the quantum of glass. The results corroborate with those by McCormack et al [iv] and Crawford et al [v] in Australia, Brathwaite in UK [vi] and Bardhan [vii] [viii] in India which also concluded steel as the largest contributor. The inherent embodied water works out to 23.1289 kl/m^2 of constructed floor area which closely resembles the earlier findings by Bardhan [vii] at 25.604 kl/m^2 and Bardhan [viii] at 25.3897 kl/m^2.

Table 2. Inherent embodied water due to materials

Material	Inherent embodied water	
A	B	C
	kl/$m^2$of floor area	% of total
Bricks	0.0436	00.19
Cement	0.2807	01.21
Steel	21.3680	92.39
Aluminium	0.1381	00.60
Glass	1.2985	05.61
Total	23.1289	100%

Induced embodied water calculated for the case study worked out to 0.9416 kl/m^2 of floor area. The study by Bardhan [vii] and Bardhan [viii] in Kolkata had computed the induced embodied water at 2 kl/m^2 and 1.42 kl/m^2 respectively. The results of the present study is on the lower side which could be attributed to the fact that Gurgaon being a part of a water stressed region, the water use is much on the conservative side. The results of total embodied water are indicated in Table 3.

Table 3. Total embodied water

Inherent embodied water		Induced embodied water		Total embodied water
kl/m^2	% of total	kl/m^2	% of total	kl/m^2
D	E	F	G	H = D + F
23.1289	96.09	0.9416	3.91	24.0705

The total embodied water worked out to 24.0705 kl/m^2. The results of the study are slightly on the lower side as compared to the earlier findings of both Australia and India. It is also evident that the inherent embodied water has the highest contribution of 96.01% of the total embodied water thereby conforming to earlier findings by Bardhan [vii] [viii] in Kolkata.

The quantum of embodied water translates to 66.21% of the operational water of the project when a 50 year life cycle is considered, assuming a water demand of 150 litres per person per day and a family size of five per dwelling unit and three per servants' room.. The quantum of embodied water could also be expressed as the water requirement of 14567 families for one whole year, considering a standard family size of 5 members.

IV. Conclusion

A significant amount of fresh water is consumed by multi-storied residential buildings in terms of its pre-operational embodied water that goes unnoticed. There is therefore an urgent need to address this issue. This overlooked aspect of buildings demand serious considerations in sustainable design practices for saving our fresh water reserves.

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