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Assessing Water Foot-print of Building Materials in Indian Context: The Case of Concrete Masonry Units

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Abstract: In the context of the booming building and real estate industry in the rapidly urbanizing countries, the environmental resources are being consumed unsustainably with signs of this skewed development showing in the degraded ecosystems and climate change calamities, causing loss of lives as well as compromised qualities of living. In this backdrop as well as the United Nation's watchword for 2015 Environment Day 'Sustainable production and consumption', this paper reports the results of a study that investigated the water consumption pattern of a widely used building material in the Indian construction industry – the Concrete Masonry Units (CMUs), commonly referred to as concrete blocks – through primary survey of a manufacturing unit located in West Bengal, India. Since this material has emerged as a popular substitute of the conventional burnt clay brick for use in walls, it becomes pertinent to check its environmental imprint with respect to water in comparison to bricks to ensure a more sustainable construction. The study finds the water foot-print of hollow concrete blocks to be 0.119 kL/Cu m and the solid concrete blocks to be 0.416 kL/Cu m against that of the common clay bricks as 0.71 kL/Cu m.

Keywords: Water foot-print, embodied water coefficient, concrete blocks, sustainability.

I. INTRODUCTION

Water is one of the most important natural resources consumed in building construction without much accountability and scanty database on the consumption pattern. Similarly, information on embodied water of building constituent materials is also known for limited availability. Out of one of the few umbrella studies, United Nations Environment Program (UNEP) has indicated that over an entire life-cycle, a building consumes a global average of 30% of fresh water and generates 30% of world's effluents [1]. In India, Manual on water supply and treatment [2] mentions the water embedded in steel and it is, thus, the only building material having a recorded water foot-print. Other major building materials like bricks, cement, aluminium, glass etc. use considerable quantity of water in their manufacturing process through extraction and processing, though data on their water-foot print is not readily available, especially in the Indian context. It is more so when upcoming and alternative materials are concerned. Concrete Masonry Units or CMU.s, also commonly referred as concrete blocks, both hollow and solid, have been introduced in the market and these have successfully replaced the clay bricks in the Indian construction industry. Apart from the regular components of cement, sand and stone-chips, these may also have industrial wastes e.g. fly ash and gypsum along-with certain chemicals. These blocks have long service life, low maintenance and have been reported to be cost effective [3]. These blocks have also been testified to possess distinct structural advantages over the conventional clay bricks. In general, the concrete mixture used for blocks has a higher percentage of sand and a lower percentage of coarse aggregate and water than the concrete mixtures used for general construction purposes. The dry stiff mixture retaining its shape after removal from the mould is possible only with mechanised compaction and vibration that gives it high quality in spite of the lean mix [3]. However, the environmental foot-print of these blocks have not yet been widely studied. While the energy and waste impacts of the different manufacturing processes of these also need to be conclusively established, this paper focuses on the water consumption of the CMU.s and presents the water foot-print results in terms of their Embodied Water Coefficient (EWC) i.e. amount of water per unit volume of the blocks. The same may also be termed as virtual water content of the blocks.

II. SCOPE & METHODOLOGY

Based on product types, concrete masonry units may be classified as solid, hollow and cellular blocks and based on the manufacturing process, it may be either semi-mechanized or fully mechanized [3]. The types of system that produce concrete elements are mainly machines using hydraulic compression and extraction. This is the most common method used to form the product shapes required by the building industry. The scope of the study is to ascertain the embodied water coefficient of solid and hollow concrete blocks manufactured by the semi-automated process in small-scale production units that use concrete mixes for placing into steel moulds, followed by vibration and compaction, and finally by de-moulding and curing.

For the purpose of the study, primary field survey was conducted at a concrete block manufacturing unit located in 24 Parganas (North) in the eastern State of West

Bengal, India. A simple ready to fill-in format was prepared for obtaining data from the manufacturers to have first hand information of the water consumption pattern in the production process. This was followed by actual field visits, survey and documentation. Water is used during preparation of the raw materials. After screening, the mix is prepared thoroughly with appropriate quantities of water, lime, fly ash, sand, cement and stone chips of 1.4 mm size. Concrete mixer machine is used for mixing water and the mixture is placed in the moulds of hydraulic / vibro press of the egg-laying concrete hollow block making machine. The concrete blocks thus prepared were of lower density due to usage of fly ash.

III. MAPPING THE CMU PRODUCTION PROCESS

Quantity of water used in the process was documented by both top-down and bottom-up approaches:

A. *Top-down method*

The top-down approach involved recording of the total amount of water used by the unit daily while the bottom-up approach takes into account the actual volume of water used for production of the blocks. The source of water was found to be ground-water and withdrawal of this ground water takes place with the help of two water pumps. Thus, the total water quantity consumed daily by the plant could be given by the product of the yields of these pumps and hours of their respective operations per day. This was found to be 21 kL per day, as presented in Table I.

B. *Bottom-up method*

The bottom-up method considers the quantity of water used in the actual block manufacturing process. In the surveyed unit, it was found that blocks are prepared in batches of 14 numbers. The quantity of fresh water used for daily production of hollow blocks was found to be 1.1 kL per day.

IV. WATER FOOT-PRINT ASSESSMENT

A. *Top-down assessment*

The study began with mapping of the water consumption pattern of the plant by collecting data on the number of bore wells, their yields and hours of their operation. The finding is tabulated in the table below:

TABLE I: WATER CONSUMPTION IN CMU PRODUCTION

Sl	Item	Qtty	Unit
1	No. of construction bore wells constructed	2	nos.
2	Yield of the bore wells	1500	Litres/ hour
3	Hours of pump operation	7	Hours/day

The plant produces CMU.s of several sizes, though the current study mapped the water consumption for solid and hollow blocks of size 400 x 200 x 75 only, this being the most commonly produced unit by the plant. The daily production of this unit is 1540 pieces. Water foot-print of the CMU.s of such size, assessed from the information given in the above table through top-down approach comes to 2.26 kL/ Cum of the blocks, both solid and hollow. However, these values have been ignored for the purpose of this research, as it was not possible to assert with an acceptable degree of certainty that this amount of water was used solely for concrete block production and not for any other unrelated purpose.

B. *Bottom-up assessment*

Thus, the bottom-up method was considered to give more accurate results as it focuses on the water used by the production process only. The basic information collected about the CMU manufacturing towards this intent was:

- 10 liters of water was used for 14 pieces of hollow concrete blocks of size 400 x 200 x 75.
- 10 liters of water was used for 4 pieces of solid concrete blocks of size 400 x 200 x 75.
- The mixer machine is run for 110 times per day to produce 110 x 14 = 1540 nos. of hollow concrete blocks.
- The waste water is stored in two reservoirs, which is re-used for curing of the blocks before dispatch.

Assessment of embodied water in the blocks was obtained in terms of volume of water per unit volume of the blocks and expressed as kilo-litres/Cum – termed as Embodied Water Coefficient (EWC) of the material. The volume of both solid and hollow blocks were assessed to be 0.006 Cum. Considering 10 litres of water used for 14 nos. blocks, each hollow block uses (10/14*0.006) litres/ Cu m = 119 litres/Cu m or the EWC of hollow concrete block was 0.119 kL/Cu m. Similarly, each solid block uses (10/4*0.006) litres/ Cu m = 416 litres/Cu m or the EWC of solid block was 0.416 kL/Cu m.

Fig. 1. Production process of the blocks in the surveyed unit

Fig. 2. Moulding of the blocks for vibration and compaction

V. COMPARISON WITH BURNT CLAY BRICKS

Burnt or fired clay brick production in India is still widely dependent on the traditional small scale production methods using the rich clayey soil of the river banks as the raw material producing about 150 billion bricks a year [3]. In terms of EWC, bricks would have to have higher water foot-print as these need to be worked well with water for their moulding, which can generally be classified into four categories based on the water content of the raw mix. These are soft-mud or hand moulded bricks, extruded bricks, semi-dry/dust pressed bricks and dry pressed bricks. Out of these, the hand moulding process that is most commonly practised in India for soft mud brickworks has 25-35% of water content. This means about 0.3 kL of water present in one Cum of brick notwithstanding the indirect water that had been used to prepare the homogeneous and plastic clay mass. This finds corroboration in a technical note of Brick Industries' Association [4] that mentions water requirement as 20-30% of clay amount, which matches with the above figure. A previous study had estimated the water foot-print of clay bricks as 0.71 kL/ Cum [5] that appears reasonably acceptable considering half of this amount is already embedded in the body of the brick. Further, the report of Green Construction Board, UK [6] refers to the water foot-print value for soft mud brickworks as 0.563 m^3/tonne of brick production that almost exactly corresponds with the aforementioned figure. This means concrete blocks are much more water efficient than the clay bricks – the hollow blocks being about six times more and the solid block about 1.7 times more.

A comparative chart of the embodied water coefficients of the concrete masonry units versus the burnt clay bricks has been presented in figure 3.

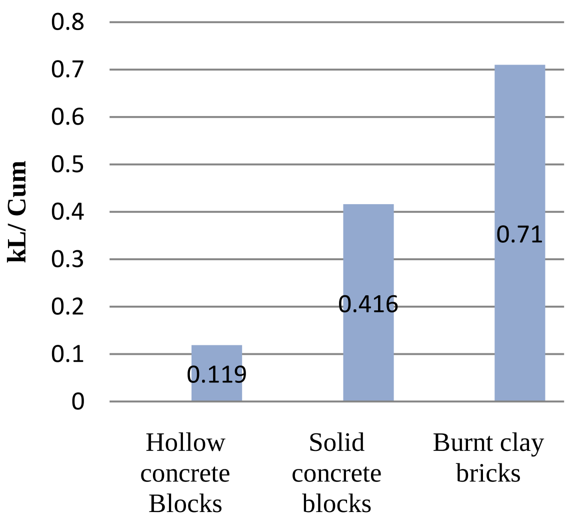

Fig. 3. Comparative EWC.s of the studied building materials

VI. CONCLUSION

This paper presents a study on assessment of the Embodied Water Coefficient (EWC) or water foot-print of Concrete Masonry Units (CMU) or concrete blocks that are being used widely in the building and construction industry in India. Since these concrete blocks are commonly used in the building envelope as walls and have gained popularity over conventional burnt clay bricks, this study compared the EWC of the two materials to check their respective water efficiencies. The study finds the water foot-print of hollow CMU blocks to be 0.119 kL/Cu m and that of solid CMU blocks to be 0.416 kL/Cu m. On the contrary, clay bricks were previously assessed to have a EWC of 0.71 kL/ Cum. Thus, it may be concluded that concrete blocks are almost 2-6 times more water efficient than the traditional bricks and therefore, can contribute to a more water-wise and sustainable construction.

Considering the production process of these two building materials, the results are quite rational and understandable. However, it may also be important to mention here that the EWC of concrete blocks deduced from this single primary survey need to be validated further with additional case studies to substantiate the findings. Since concrete block manufacturing has become a good business option these days for small scale producers due to low capital costs as well as potential of being a local sourcing point for the building industry, such units may be encouraged with better water audit and monitoring to favour sustainable production practices and good water governance in the construction sector. Only then the UN's agenda of 'Sustainable production and consumption' may be able to achieve its goal.

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