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Original Article

Framework Towards Achieving Sustainable Strategies for Water Usage and Wastage in Building Construction

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Abstract *- Water usage and wastage management in the construction industry is the key to achieving active water efficiency. It is essential to use water conservation practices in the process of building construction as there is a huge amount of water being wasted and not recycled or reused. This study aims to evaluate the various criteria affecting water usage and wastage during the construction work of buildings, to identify sources of water wastage during building construction work, to evaluate water wastage quantity in residential building construction projects, and to suggest the methodology for the selection of the alternative methods, measures, and strategies to reduce water wastage. The research objective further enlightened the data collection and survey parameters to derive the results and discuss the measures that can be incorporated to cater to the issue's solution. The results derived from the questionnaire survey also helped to understand the existing ongoing practices of building construction in Mumbai City and derived the Mean Score Index (MSI) of the questionnaires along with the ranking of weightage of questions which then later helped in developing the measures and strategies of water management which can help to conserve water in building construction practice. Water management tools and techniques must be incorporated into various activities involved in the construction industry and other industries where water consumption and utilization are significantly higher. With ongoing concerns of Mumbai city for water-related issues, it is mandatory and very important to understand the usage and wastage of water in building construction in Mumbai City and derive the measures and strategies for the conservation of the same.*

Keywords *- Construction water efficiency, urban water supply, Construction management strategies, Sustainable use of water.*

1. Introduction

Water usage in building construction practice is essential, and it plays and key important role in the development of infrastructure [1-5]. Water is essential in the preparation of Reinforced Concrete (RC) members as it governs the overall durability, strength of concrete, and hydration of cement [6-8]. Also, water is used in various other construction factors, and many factors determine the wastage of water in building construction. On the other hand, a modern building has a substantially greater water footprint since the materials used in its construction are typically highly processed and need a lot of water [9,10]. Additionally, a building requires a constant water supply to suit a variety of functions (e.g., drinking, washing, waste disposal, cooling, and swimming). The roof, driveway, and connected roads of a contemporary structure all produce a significant amount of stormwater runoff that can contaminate our waterways [11]. For daily operation, building construction activities require a considerable volume of water.

Additionally, significant water contamination issues are caused by wastewater, stormwater runoff, and water from dewatering operations. For instance, groundwater supplies nearby can get contaminated by arsenic from mine tailing. Similarly, due to chromium's high solubility in water, chromium from mine tailings flow may have disastrous impacts on the ecosystem and local public health [12]. Water use occurs both directly and indirectly in a typical building construction project. The water utilized directly comprises worker consumption, water needed to wash aggregates, prepare raw concrete, cure concrete, suppress dust, and wash equipment and hard surfaces[6,13,8]. Embodied water utilized in manufacturing building materials is related to indirect use [14]. Water is also needed for a typical building's operation, such as drinking water, washing, gardening, toilet flushing, and activities for recreation and cooling; at the planning stage, essential steps should be taken to limit this sort of water use [15]. Wastewater from construction sites must be collected and cleaned before being dumped in open water bodies. In addition, other industries, such as mining activities, utilize a substantial amount of water, both for operational needs and in relation to wastewater and stormwater runoff produced at the construction site. This makes mining a key element of water management [33].

However, over the past 20 years, several approaches and tools have been presented for reducing water use in infrastructure operations, mining operations, and construction sites in response to the call for sustainably managed water use and policy formulation [17-20]. Buildings should be designed by engineers, town planners, and architects to protect the environment better, i.e., to use the least amount of energy and water possible to reduce greenhouse gas emissions. The life cycle evaluation, which can determine the cost and impact of specific building components, may accomplish this [17]. Mumbai is experiencing a severe "water crisis" that calls for an action plan to manage water usage and wastage. Such discourses obscure the urban water supply from urban slum communities, while the amount of water wasted by wealthy elites and their chosen urban utilities continues to be enormous.

The literature shows that fresh and clean water is a limited resource and is wasted at the construction site and for building consumption. However, the same water is also needed for human and other living species consumption along with agriculture for food consumption. There is a need to develop appropriate strategies, reduce water consumption, and take a major step towards sustainable water wastage and conservation in building construction. Also, Mumbai has always faced a water crisis, leading to water wars in the city. So, it clearly states that it is required to conserve and save water during the construction process as it is already a limited resource, and the city is facing a crisis for the same. The primary aim of this study is to evaluate the various criteria affecting water wastage during the construction work of buildings, to identify sources of water wastage during building construction work, to understand the water wastage quantification and evaluate the selection of the alternative methods to reduce water wastage. The need of this study is to understand the water wastage in components of activities building construction and identify the parameters of water conservation in building construction to achieve sustainable strategies in water management of building construction by technologies, ideologies, strategies, and methodology statements which can be followed throughout in building construction.

2. Methodology

The methodology of the present study aims to fill the gaps identified during the literature survey and to understand the usage and water wastage in the building construction industry. To accomplish this, first, the literature review was conducted to understand the critical review of the existing knowledge. This helped to understand the problem statement and the motivation to develop further research in the line work of the selected topic and identify the gap in the subject, which further enhanced the formulation of the research objective. Fig. 1 shows the flowchart of the methodology used to derive the strategies and measures to minimize water usage and wastage. The flow chart (Fig. 1) explains the methodology of the research study, where literature review and study of the existing research studies helped analyze the problem statement and motivation to carry out further research of the subject and identify the gap in it and formulate the research objective. The objectives aimed to evaluate various components affecting water usage and wastage during building construction. The identification of aspects and components will be made based on a questionary survey, which will help select the alternative method to reduce water wastage in building construction. Statistical Package analyzes the quantification of water analysis based on a questionary survey for the Social Sciences (SPSS) software. The performance indicators such as Mean, Standard Error, Median, Mode, Standard Deviation, Variation, and Mean Score Index (MSI) are used in deriving the results, and they have their significant for analyzing the data. Then, the derivation for strategies and measures to minimize usage and conserve water in building construction. Then, the research study summarized and concluded along with the scope and limitations of the study.

Identifying sources of water wastage in building construction is based on a questionnaire survey conducted by professionals related to the construction industry at various sites of residential building construction projects in Mumbai City. Questionnaire respondents were asked to fill out the questionnaire, which is evaluated to understand sources, usage, wastage and strategic measures that can be used for water efficiency during design, construction and operation stages.

Then the questionnaires are evaluated on a Likert scale that varies between scales (1 to 5; 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree).

The performance indicators that are used to analyze the questionnaire are given below as follows:

The Mean Score Index (MSI) was computed using the following equation;

$$Mean\ Score\ Index\ (MCI) = \frac{\Sigma W}{(A\ X\ N)} \tag{2.1}$$

Where,
W is the respondents' weighting of each element
A is the highest weight
N is the respondent's number
The Standard Error (SE) was computed employing the following equation;

$$Standard\ Error\ (SE) = \frac{\sigma}{\sqrt{n}} \tag{2.2}$$

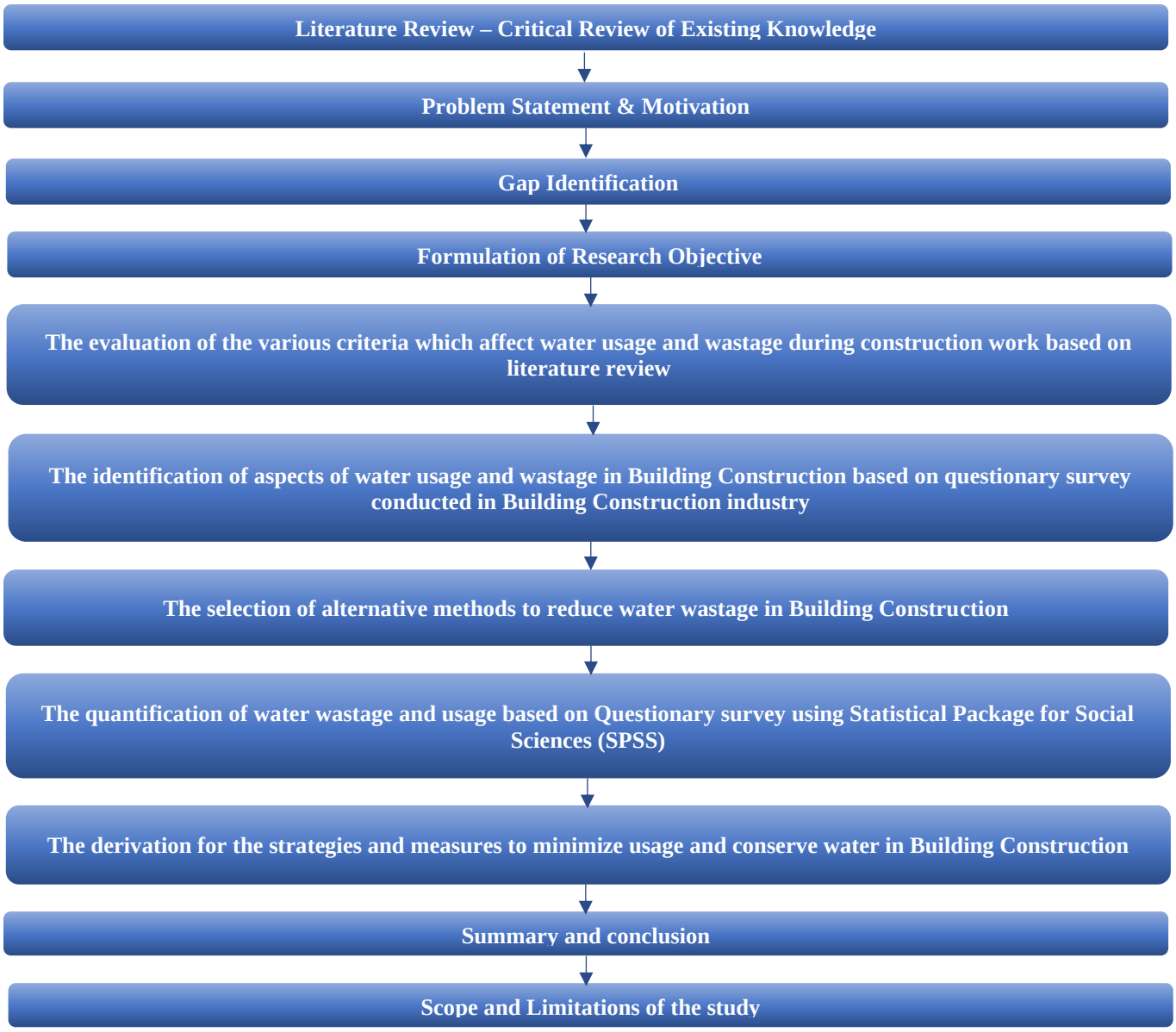

Fig. 1 Flowchart of the methodology used to derive the strategies and measures to minimize water usage and wastage

Where,
σ is the standard deviation
n is the sample numbers
The Standard Deviation (σ) was computed employing the following equation;

$$Standard\ Deviation\ (\sigma) = \sqrt{\frac{\Sigma\ (X-\mu)}{N}} \qquad (2.3)$$

Where,
X is the dataset distribution value
μ is the population mean
N refers to total observations numbers

3. Results and Discussion

Table 1, as shown below, shows the analysis of the responses received from the respondent, which were analyzed based on the Linkert scale in the questionnaire survey. Respondents were asked to fill the 29 questions to evaluate on a Likert scale (1–5) which has the potential to understand the sources, usage, wastage, and strategic measures that can be used for water efficiency during design, construction and operation stages (5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree). Table 1 shows the data collected from respondents with its framework, including the data statistics in the form of performance indicators such as standard deviation, mode, median, mean, standard error of the mean, variation, ranges, minimum and maximum of the respondents to the survey.

Table 1. Statistics of data collected from respondents with performance indicators as mean, standard error of the mean, median, mode, standard deviation, variation, range, minimum and maximum

Sr. No.	Water usage and wastage factor in the form of questions	Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Variance	Range
1	Is water one of the important natural resources used in Building Construction?	4.62	0.10.	5.00	5.00	0.73	0.53	4.00
2	With the current proportions of freshwater usage, will there be a crisis/scarcity or water availability in the future?	4.63	0.11	4.50	5.00	0.75	0.56	3.00
3	Are the proportions of fresh water usage high during the Construction of the Building?	4.25	0.13	4.50	5.00	0.93	0.86	4.00
4	Is there a need for a water monitoring system to monitor the usage and wastage of water during the Construction of the Building?	4.64	0.07	5.00	5.00	0.53	0.28	2.00
5	Is there a need to develop water-saving strategies for Building Construction?	4.74	0.08	5.00	5.00	0.53	0.28	2.00
6	Do you think there is a need for tools and techniques for water management in Building Construction?	4.56	0.08	5.00	5.00	0.58	0.33	2.00
7	Is there a scope for water conservation in the process of Building Construction?	4.56	0.09	5.00	5.00	0.64	0.42	3.00
8	Should sustainable strategies for water conservation in Building Construction be adopted?	4.46	0.10	5.00	5.00	0.73	0.54	3.00
9	Do the water usage and wastage are very high during the mixing and curing of Concrete for Building Construction?	4.30	0.10	4.00	4.00	0.71	0.50	3.00
10	Does the Ponding and immersion method of curing help in the conservation of water during Building Construction?	3.38	0.09	3.00	3.00	0.67	0.44	3.00
11	Does Fogging and spraying method of curing help in water conservation during Building Construction?	4.02	0.09	4.00	4.00	0.62	0.99	3.00
12	Does the Saturated Wet Covering method of curing help in the conservation of water during Building Construction?	4.10	0.08	4.00	4.00	0.58	0.34	2.00
13	Will the drip curing method as an alternative method of curing help in water conservation during Building Construction?	4.14	0.08	4.00	4.00	0.57	0.33	3.00
14	Will using admixtures reduce water usage and improve workability because of the minimization of the water-cement ratio and provide better durability and strength in construction projects?	4.14	0.09	4.00	4.00	0.64	0.41	3.00
15	Can groundwater be used instead of surface water for the curing of concrete?	3.84	0.12	4.00	4.00	0.87	0.75	3.00
16	Curing and mortar preparation requires the maximum amount of water. Utilization of dry mortar effectively reduces the water demand as the use of wet mortar can be reduced. Furthermore, dry mortar use totally eliminates the required curing. Therefore, helpful for massive water conservation in the construction phases.	4.16	0.11	4.00	4.00	0.79	0.63	3.00
17	Do covering concrete with impervious paper or plastic sheets helps in the reduction of loss of water during Building Construction?	3.98	0.13	4.00	4.00	0.94	0.88	3.00
18	Does applying membrane-forming curing compounds help accelerate Concrete Strength gain during Building Construction?	4.16	0.10	4.00	4.00	0.74	0.55	2.00
19	Are heating coils usually used as embedded elements that help accelerate concrete strength gain during Building Construction?	4.16	0.12	4.00	5.00	0.82	0.69	2.00

20	Does live steam and high-pressure steam help accelerate Concrete strength gain during Building Construction?	4.08	0.12	4.00	4.00	0.83	0.69	3.00
21	Will concrete produced using fly ash proportion in place of cement help reduce water usage while using concrete during Building Construction?	3.34	0.18	4.00	4.00	1.29	1.66	4.00
22	Do water usage and wastage are very high during cleaning equipment in Building Construction?	4.08	0.13	4.00	4.00	0.92	0.85	3.00
23	Is water wastage very high during water distribution because of leakage in the pipeline of Building Construction?	3.76	0.16	4.00	4.00	1.10	1.21	3.00
24	Can water harvested or recycled be utilized for tasks other than mixing cement, such as cleaning the work area and equipment?	4.30	0.10	4.00	4.00	0.68	0.46	3.00
25	Can utilizing water-saving devices and fixtures save water usage by up to 30% to 40%.?	4.38	0.09	4.00	4.00	0.67	0.44	3.00
26	Does a change in design layouts or efficient development of layouts help in the reduction of water wastage in Building Construction?	3.24	0.18	3.00	2.00	1.27	1.62	4.00
27	Is seasonal fluctuation in water usage important in Building Construction?	3.28	0.12	3.00	3.00	0.83	0.70	4.00
28	Can the usage of smart appliances and sensors be helpful for the reduction of water conservation and wastage in Building Construction?	4.18	0.13	4.00	4.00	0.90	0.80	4.00
29	Does water should be reused, recycled and reduced in Building Construction?	4.64	0.10	5.00	5.00	0.69	0.48	4.00

Tables 2, 3, and 4 and Figures 1, 2 and 3 shows example of the descriptive frequencies, percentage, valid percentage, and cumulative percentage of responses on individual questionnaires based on the Likert scale.

Table 2. Descriptive Frequencies of responses on "Water is one of the important natural resources used in Building Construction?" based on the Likert scale.

Sr.	Likert Scale	Frequency	%	Valid %	Cumulative %
1	Strongly Disagree	1	2.0	2.0	2.0
2	Neutral	1	2.0	2.0	4.0
3	Agree	13	26.0	26.0	30.0
4	Strongly Agree	35	70.0	70.0	100.0
5	Total	50	100.0	100.0	

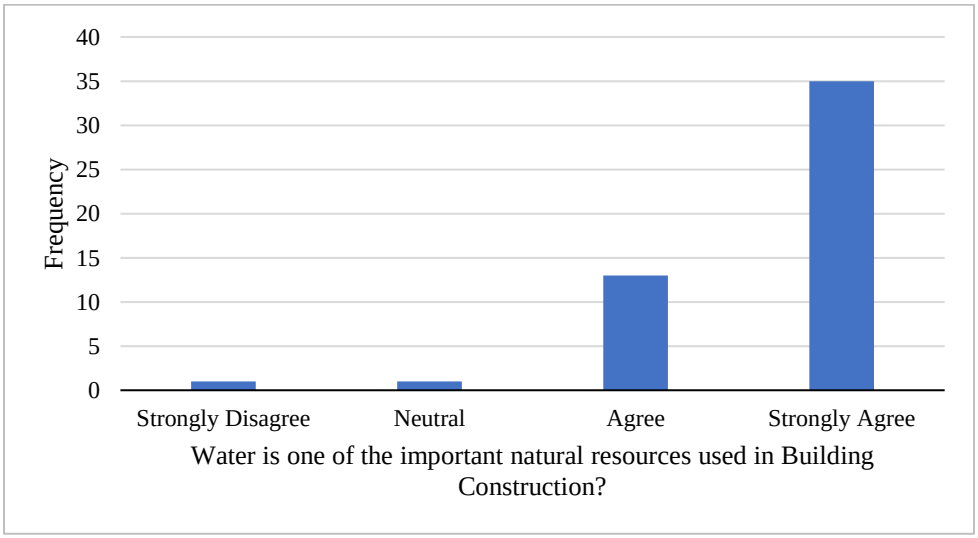

Fig. 2 Descriptive frequencies of responses on each of the questionnaires based on the Likert scale.

Table 3. Descriptive Frequencies of responses on "With current proportions of usage of fresh water, there will be crisis/scarcity or availability of water in future?" based on the Likert scale.

Sr. No.	Likert Scale	Frequency	%	Valid %	Cumulative %
1	Disagree	1	2.0	2.0	2.0
2	Neutral	5	10.0	10.0	12.0
3	Agree	19	38.0	38.0	50.0
4	Strongly Agree	25	50.0	50.0	100.0
5	Total	50	100.0	100.0	

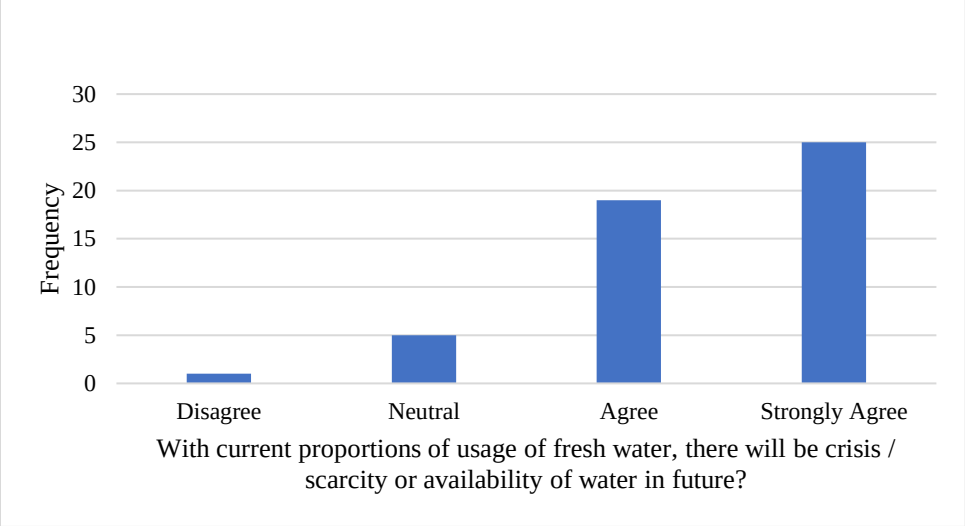

Fig. 3 Descriptive frequencies of responses on each of the questionnaires based on the Likert scale.

Table 4. Descriptive Frequencies of responses on "The proportions of usage of fresh water are high during Construction of Building?" based on the Likert scale.

Sr. No.	Likert Scale	Frequency	%	Valid %	Cumulative %
1	Strongly Disagree	1	2.0	2.0	2.0
2	Disagree	2	4.0	4.0	6.0
3	Neutral	4	8.0	8.0	14.0
4	Agree	18	36.0	36.0	50.0
5	Strongly Agree	25	50.0	50.0	100.0
6	Total	50	100.0	100.0	

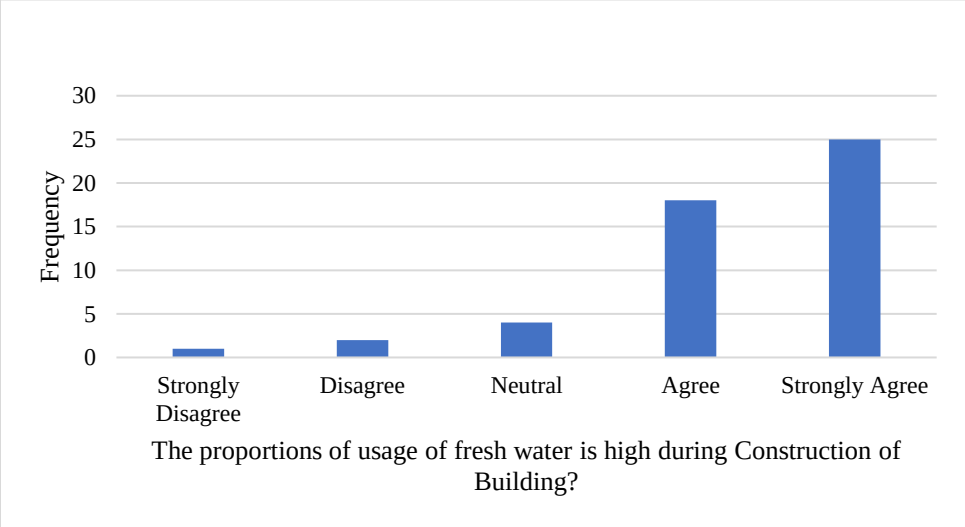

Fig. 4 Descriptive frequencies of responses on each of the questionnaires based on the Likert scale.

Table 5. Ranking of questionnaire responses based on the Relative Importance Index.

Sr. No	Particulars	Mean Score Index (MSI)	Ranking
1	Is there a need to come up with water-saving strategies for Building Construction?	0.948	1
2	Is there a need for a water monitoring system to monitor the usage and wastage of water during the Construction of the Building?	0.928	2
3	Water should be reused, recycled and reduced in Building Construction?	0.928	3
4	Is water one of the important natural resources used in Building Construction?	0.924	4
5	Do you think there is a need for tools and techniques for water management in Building Construction?	0.912	5
6	Is there a scope for water conservation in the process of Building Construction?	0.912	6
7	Should sustainable strategies for water conservation in Building Construction be adopted?	0.892	7
8	Water usage may decrease by up to 30% to 40% using water-saving fixtures and devices.	0.876	8
9	With the current proportions of freshwater usage, will there be a crisis/scarcity or water availability in the future?	0.872	9
10	Are water usage and wastage very high during the mixing and curing of Concrete for Building Construction?	0.860	10
11	The water saved from harvesting or recycling may undoubtedly be used for tasks other than mixing cement, such as cleaning the work area, cleaning the equipment, etc.	0.860	11
12	Are the proportions of usage of fresh water high during the construction of the building?	0.856	12
13	Does the usage of smart appliances and sensors helpful for the reduction of water conservation and wastage in Building Construction?	0.836	13
14	Curing and mortar preparation requires the maximum amount of water. Utilization of dry mortar effectively decreases the water demand as the use of wet mortar can be reduced. Furthermore, dry mortar use eliminates the required curing. Therefore, helpful for massive water conservation in the construction phases.	0.832	14
15	Does apply membrane-forming curing compounds helps accelerate Concrete Strength gain during Building Construction?	0.832	15
16	Are heating coils usually used as embedded elements that help accelerate concrete strength gain during Building Construction?	0.832	16
17	Could the drip curing method as an alternative method of curing help in water conservation during Building Construction?	0.828	17
18	Will using admixtures reduce water usage and improve workability because of the minimization of the water-cement ratio and provide better durability and strength in construction projects?	0.828	18
19	Does the Saturated Wet Covering method of curing help in the conservation of water during Building Construction?	0.820	19
20	Does live steam and high-pressure steam help accelerate concrete strength gain during Building Construction?	0.816	20
21	Are water usage and wastage very high during cleaning of equipment's Building Construction?	0.816	21
22	Does Fogging and spraying method of curing help in water conservation during Building Construction?	0.804	22
23	Do covering concrete with impervious paper or plastic sheets helps in the reduction of loss of water during Building Construction?	0.796	23
24	Can groundwater be used instead of surface water for curing concrete?	0.768	24
25	Do water wastage very high during water distribution because of leakage in the pipeline of Building Construction?	0.752	25
26	Does the Ponding and immersion method of curing help in the conservation of water during Building Construction?	0.676	26
27	Will concrete substitutes fly ash for cement help reduce water usage while using concrete during Building Construction?	0.668	27
28	Is seasonal fluctuation in water usage important in Building Construction?	0.656	28
29	Does a change in design layouts or efficient development of layouts help in the reduction of water wastage in Building Construction?	0.648	29

The Table 5 shows the particulars and ranking of questionnaire responses based on the Mean Score Index (MSI).

3.1. Suggested Measures and Strategies

Various measures and strategies are effectively implemented to decrease the usage of water used on building construction sites. The following measures and strategies are suggested, which can be implemented to reduce the usage and wastage of water used on construction sites and for the new RC building construction.

3.1.1. Steel structure vs R.C.C structure buildings

In comparison between the R.C.C Structure and the steel structure, the steel structure saves a huge quantity of water. So, it is always advised to construct steel structures and composite steel structures as it saves around 32 % water compared to the R.C.C. structure. The only constraint is that the cost of the composite steel structure is about 41% higher than the R.C.C structure, and the cost of the steel structure is about 38 % higher than R.C.C Structure. Moreover, steel construction proved to have no effect from climatic and soil conditions.

3.1.2. Reduce the Water Quantity Consumed at a Facility

These techniques generally include water reuse and recycling systems, water conservation measures, and system optimization (i.e., repair, leak detection and efficient water systems). Moreover, a wide range of measures and techniques can be considered within each of these strategies for energy consumption and saving water. A few of them are water recycling or reuse measures and water-efficient plumbing fixtures [21].

3.1.3. Water Management Hierarchy (WMH)

The WMH is a hierarchy of water conservation goals [22]. It includes eliminating sources, source reduction, external water sourcing or direct reuse, regeneration reuse, and freshwater [23,24]. Elimination, reduction, outsourcing/reuse, and regeneration are the hierarchy levels in order of importance for water conservation. Elimination is preferable over both reducing water consumption and eliminating it altogether. Direct reuse/recycling and outsourcing water using techniques like rainwater gathering are therefore favored. Following this, wastewater is regenerated or treated before being reused. Freshwater will only be utilized after every possible water-saving measure has been tried. The WMH has been utilized as an efficient screening tool as it is a cost-effectively reduced water network methodology to increase the water-saving limits than those approachable using traditional methods.

3.1.4. Water Pinch Analysis (WPA)

WPA is a system-based technique to reduce water usage and wastewater generation using integrated water-efficient processes and activities [34]. Because of these reasons, WPA is widely utilized as a tool for water conservation in industrial process plants [26,27]. Moreover, recently the WPA [13] and other modern water-saving and management techniques [29-31] have been utilized and proved efficient for water resource management and building construction projects.

4. Conclusion

With regards to the study, it analyzes water usage and wastage management strategies as water is a very limited resource. The analysis conducted through the literature reviews and questionnaire survey shows that strategies should be adopted to reduce water consumption in building construction. It is concluded that fresh and clean water is a limited resource, and the proportions of wastewater consumption on building construction sites are very high. Thus, it is important to use strategies and reduce water consumption and take a major step towards water management in building construction. Water management tools and techniques must be incorporated into various activities involved in the construction industry and other industries where water consumption and utilization are significantly higher. The water crisis is a global challenge not only in India the whole world is in trouble which can become a giant in the near future if suitable planning and implementation are not performed in time with adequate management and monitoring models, tools and techniques for this problem. Steps need to be taken at the Government level, and policies formed for this problem in the legislature are insufficient to tackle such a severe problem. The implementation and regulation of a prepared framework for the policies and laws are essential to achieve the desired result and target, and the most important cooperation and contribution of people as an individual as well as in groups is also very essential to resolve the problem related to the discretionary use of water. The main benefit of water reduction in the building construction process can be achieved when water conservation ingrains into a construction project from the planning phase. Engineers and architects can employ various water usage and waste management strategies to lower water use and make the structures more sustainable. The construction of green and sustainable buildings will increase building efficiency by adopting water usage and water wastage management strategies.

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