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Formulating Concrete Mix Design Process via MCDM Methodology for Sustainable Quality Management of Concrete

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Sustainable quality of the concrete refers to a systematic process to ensure sustainability in terms of environmental, societal and economic objectives while maintaining the highest quality. Existing methods of concrete inspection improvements include implementing green building certification, incorporating environmentally friendly construction methods. Current methodologies to sustainable quality management of concrete may have limitations such as standardization and consensus on sustainability standards , problems and gaps in determining the sustainability of concrete mix systems, and incorporating challenge chains into conventional concrete production considerations, including supply. The methodology section describes a systematic approach for selecting and evaluating solid mix designs using a multicriteria decision-making (MCDM) model, an analytical hierarchy process (AHP), and order prioritization by similarity of model solutions (TOPSIS); which makes it easier to decide for concrete construction of long-term quality. According to the MCDM model and the proposed TOPSIS analysis, water/cement ratio and density are important parameters in concrete quality stability. It is determined that the Design of Experiment (DOE) method is more suitable for concrete quality control which will last longer, since its objectives -there are quality-properties, analysis of concrete-mix components. These results are in accordance with the current literature and theoretical framework, demonstrating the advantages of the proposed method in applications of materials sustainability in concrete construction.

Keywords: Quality Management of Concrete, Concrete Production, Multicriteria Decision-Making, Analytic Hierarchy Process, Design of Experiments.

1. Introduction

A necessary need of society as a result of rapid urbanization and growing populations is the improvement of infrastructure. The building industry has a strong connection to construction of infrastructure and utilizes approximately 44% of the planet's natural resources. Concrete is often regarded as a multipurpose/all-around material and the primary source of energy for infrastructure building. Concrete, which is like other heterogeneous materials, makes use of a variety of natural resources [1] [2]. As a result, there is an increasing need to research and develop innovative approaches for optimizing concrete mix design, reducing natural resource consumption, minimizing waste, and making the concrete design and construction process more efficient [3] [4]. Concrete is a flexible mixture of water, cement, and other fine and coarse substances in certain quantities used in construction. Concrete mixture variables and the proportion of water to cement impact flexibility, durability, and stability. Concrete composition is also impacted by the ratios of coarse aggregate to cement and fine material compared to overall aggregate [5] [6]. Concrete quality is influenced by a variety of factors, including cement type, cement durability, aggregate types and sizes, aggregate grading, coarse aggregate-to-cement ratio, green or concrete with a hardening process characteristic, and expenses [7].

Throughout the years, researchers have attempted to make cost-effective, low-thermal transmission strong mechanical properties in the concrete. Over years, scientists have been interested in economic issues and mechanical qualities. As people become more conscious of change in climate sustainable practices is growing in the building sector [8] [9]. It is the moment to take strong steps towards improving mix design while considering its impact on the environment in order to avoid wasteful usage of natural resources. In over the last few years, it seems to be an increasing awareness of the building industry's negative impact on the environment. Construction enterprise, like the building material sector, directly threatens the ecosystem through the decreasing supply of natural raw materials, the production and release of greenhouse emissions required for the extraction process, shipping, building, functioning, repairs, and deconstruction. The construction sector also contributes significantly to the release of greenhouse gases in the European Union and other nations (5-40%) [10]. In 2009, the construction accounting for 23% of worldwide economic activity [11]. Construction innovators increasingly agree that worldwide growth should coincide with the use of techniques, technologies, and projects that are less resource intensive and environmentally destructive while still profitable.

The consumption of the initial supplies rises when concrete is employed in the building industry, which exacerbates the depletion of resources from the environment. Since a significant amount of carbon dioxide is released during the synthesis of essential components for concrete, especially during cement manufacturing processes, it has an adverse effect on the environment [12]. The basic components, specifically limestone utilized for the manufacturing of concrete cement, account for approximately 65% of CO2 emissions [13]. Increased development and building efforts in developing nations have resulted in a 4% yearly growth rate in cement output [14]. Approximately 5-8 percent of the overall carbon dioxide emissions in the environment originate from the cement industry. The melting of limestone and the ensuing combustion of the powder allow the carbon dioxide to permeate the ecosystem as a whole. Global warming, which is a serious threat to both humanity and the environment, is the result of such circumstances. Elevated the amount of carbon dioxide act as a thermal barrier, retaining heat in the atmosphere and raising the temperature. A study was also conducted on determining concrete materials for desired durability and lowered global warming capability.

Existing approaches to sustainable concrete quality management frequently include the incorporation of alternative resources, such as industrial and municipal waste, into concrete mixes in order to limit environmental effect and depletion [15]. However, these approaches have several disadvantages. One prevalent issue is a lack of thorough decision-making frameworks for assessing and optimizing concrete mix designs for sustainability. Traditional approaches prioritize capacity and sustainable development alongside other important factors including environmental, cost and social aspects [16] [17]. The unpredictability of different materials and properties makes reproducibility and consistency of line construction difficult. As is the difficulty of balancing the multiple dimensions of a concrete mix systematic, such as technical requirements, environmental objectives, and economic considerations make it difficult to achieve optimal results may delay the extensive quality control methods [18] [19]. Thus these obstacles highlight the need for rigorous policy approaches to effectively address the challenges of sustainable concrete production and quality control.

The objective of the proposed study is to develop a concrete mix design process that uses a multi-criteria decision making approach to improve the long-term quality management of concrete. The study looks at other characteristics that affect sustainability and resilience, such as environmental impact, affordability and social factors. The study uses the Integrated Analytical Hierarchy Process and the TOPSIS methodology to structurally analyze and rank hybrid systems according to their overall performance in terms of sustainability. This approach will enable the construction of high-quality concrete mix systems with minimal environmental impact while addressing technical and economic constraints. The study aims to address the shortcomings of current methods, such as the lack of appropriate decision-making processes and established methods for environmental performance analysis. The aim of the proposed methodology is it will encourage the use of sustainable concrete methods in the construction industry. The study’s key contributions are as follows:

1) Application of MCDM model for concrete mix design selection is greatly helped by incorporating various criteria such as environmental impact, cost effectiveness, sustainability and resource efficiency This approach assure that the chosen mix design meets sustainability objectives while maintaining high standards.

2) The combination of AHP and TOPSIS methods provides a robust framework for evaluating concrete mix designs. This integration improves decision-making by combining pairwise comparisons of criterion weights and preference ranking system

3) The weighting of the AHP-based evaluation ensures that the importance of each criterion is strategically considered, contributing to the transparency and fairness of the decision-making process.

4) TOPSIS preference ranking enables the systematic assessment of alternative mix designs based on their performance against ideal solutions, making it easier to select the best option for long-term quality concrete manufacturing.

The remaining section of this study is structured as follows. Section 2 contains significant previous research on the work scheduling problems utilizing various efficiency methodologies. Section 3 addressed the problematic statement. Section 4 addressed the proposed approach. Section 5 describes the experimental setup, results, and discussion of findings. Section 6 presents the conclusion of the study.

solid particles.

2. Related Works:

Frost et al. [20] proposed a methodological approach known as the Holistic Quality Model to facilitate processes of decision-making in building projects. This paper provides a comprehensive review of HQM applications, using a sealed concrete slab as a case study. The study highlights the advantages of precast concrete over conventional methods, especially in terms of environmental performance. HQM not only allows priority choices that consider the entire life cycle, but also highlights the interdependence of technological, environmental, and quality of life standards. The study acknowledges limitations due to data accessibility and analytical limitations, particularly in quantifying relationships between parameters. The data shows HQ's effectiveness in guiding design decisions, clarifying business, and improving overall construction performance. Limitations include limitations in data availability and methodological limitations in testing quality relationships. These characteristics limit the validity of the study, and may have an impact on the sustainability of the decision-making processes. While headquarters provides a comprehensive plan, the benefits vary according to the complexity of the construction project and the availability of the necessary information. More research is needed to address these barriers and improve the effectiveness of the HQ in facilitating sustainable policy decision making.

Huseien et al. [21] presented a scientific approach to improve concrete's sustainability by replacing ordinary Portland cement with effective microorganisms and fly ash. Several combinations were examined, and varying amounts of FA and EM replaced OPC. The study investigated the strength and microstructural properties of this modified concrete mix. An adaptive neuro-fuzzy estimation system was created to estimate strength properties by binder mass percentage. Results showed significant mechanical improvements, including a 30% increase in compressive strength, improved microstructures and increased durability of concrete, lower porosity, dry shrinkage and carbonation depth replaced by 10% EM and FA. The study concludes that replacing OPCs with FAs and EMs can reduce carbon dioxide emissions, energy consumption, costs, and enhance sustainable development. Limitations consequences the occurrence of discrepancies is due to factors such as concrete curing conditions, material properties, and environmental factors affecting term performance. The emphasis on strength properties and microstructure can overshadow other important considerations such as durability under extreme conditions or long-term environmental sustainability. The applicability of the findings may be limited by specific geographical or project restrictions, and further research is needed to assess the feasibility and practicality of the suggested concrete mixture in different construction conditions.

Revilla-Cuesta et al. [22] offered a scientific framework for assessing the differences between performance and environmental sustainability in Self-Compacting Concrete by replacing natural raw materials with industrial byproducts. A total of 19 SCC mixtures were analyzed, including recycled concrete, ground granulated blast furnace slag, and sustainable aggregate powders using a multi-criteria decision-making algorithm used to evaluate variables such as flow, energy, carbon footprint, and cost. The findings suggest that while sustainability can be strengthened by incorporating outcomes, innovative and complex practices can suffer. The MCDM analysis found optimal combinations for different values, indicating the importance of balancing performance and sustainability. The study highlights the need to modify SCC policies to reduce the negative impacts of outputs while promoting economic productivity and sustainable development. The study emphasizes lab-scale testing, which may not fully replicate real-world conditions or physical property differences. The carbon footprint and value analysis focused only on the composition of the SCC mix, leaving aside such as the mode of transportation. The value of findings may be limited due to unique project requirements or regional restrictions. The MCDM model used for decision-making is based on predefined criteria and weights, which may leave out other important factors. More research is needed to validate these findings in a practical construction environment and explore new parameters for evaluating the sustainability of SCC connections more efficiently.

Chen, Chow, and Lau [23] suggested a comprehensive evaluation focused on the utilization of urban garbage in concrete to decrease environmental pollution and promote sustainable construction practices. The review investigates the use of numerous urban waste elements in concrete to improve its efficiency and sustainability. It explores the functions of urban garbage in concrete, as well as the associated issues and possible solutions, with a focus on the viability of green concrete production. The assessment focuses on scientific technologies for addressing important concerns and outlines future directions to promote the progressive growth of sustainable concrete. The inclusion of urban waste concrete in the waste management industry is seen as a viable option for environmentally friendly construction materials that effectively manage urban waste. Limitations include necessity that more research is done on technical issues. In the sections may also ignore factors affecting the feasibility and scalability of incorporating municipal waste into concrete on a large scale can the significance of the findings vary depending on local waste procedures and technology. Addressing these limitations is important to maximize the potential of using municipal waste in concrete for sustainable construction practices.

Muthusubramanian et al. [24] presented a method to examine the use of polyethylene carrier bags and PET bottles as fibres in fiber-reinforced aerated concrete, lightweight non-autoclaved plastic, which might potentially replace traditional bricks. The study addressing global plastic pollution and discusses plastic waste, emphasizing the importance of sustainable solutions. Optimal NAPFRAC mixtures are determined using Design-Expert 9.0 optimization tools. The mechanical properties are checked and the wall elements are tested for load carrying capacity compared to conventional bricks. An exploratory study uses NAPFRAC infill panels to analyze architectural aspects of high-rise buildings. Microstructural Evaluation indicates NAPFRAC structure, while energy analysis indicates carbon dioxide incorporation and energy requirements. The study potentially reducing plastic waste and increasing productivity in the field. Limitations and flexibility possibilities in the nature and availability of plastic wastes hinder the reproducibility and scalability of NAPFRAC. The emphasis on the load carrying capacity of the study may overshadow other important considerations such as durability and longevity. The suitability of NAPFRAC under various construction conditions and climatic conditions deserves further investigation. Environmental impacts beyond carbon dioxide emissions, such as toxicity and recyclability, must be considered. The research methodology used in the study cannot fully capture real-world production data or consider regulatory constraints.

The papers presented above suggests new strategies for improving the sustainability of building materials and processes. They look at various approaches, such as the use of industrial wastes in concrete production, the use of a wide range of materials to assess building materials, the incorporation of beneficial microorganisms into concrete mixtures, and cities of waste added to concrete. However, limitations include additional research required to establish long-term reliability and system integrity, address changes in waste characteristics, determine scalability and economic viability. Environmental issues about our environment, the environment beyond carbon emissions, and practical applications are critical to the development of this technology. Addressing these challenges is essential to realizing the potential of sustainable building materials and processes to reduce environmental impact and promote sustainable development.

3. Problem Statement:

The above studies highlight many issues in sustainable concrete production that require innovative solutions. These problems include the need to effectively incorporate industrial and municipal waste materials into concrete mixtures while maintaining long-term reliability and structural integrity. Characteristics other than concrete and changes in waste characteristics is a major obstacle to the reproducibility and sustainable line-making of manufacturing processes. Difficult to combine environmental performance, cost effectiveness, efficiency and durability in concrete mix design requires detailed and systematic planning to ensure long-term quality control of processes. It is important to encourage use and meet environmental objectives in construction projects [19] [21]. Consequently, the proposed research seeks to develop a concrete mix design scheme using the MCDM method to overcome these challenges, allowing the design of environmentally sustainable concrete mixes sustainability, longevity and affordability prioritize while efficient use of industrial and urban waste materials.

4. Proposed MCDM Model for Concrete Mix Design Process for Quality of Sustainable Management of Concrete:

The suggested MCDM framework for concrete mix design systems includes a number of sustainability and quality factors such as environmental impact, cost, durability, flexibility, and material consumption optimization. The model provides a methodology for optimizing concrete mix designs to meet sustainability objectives while maintaining high-quality requirements. Information on concrete configuration combinations at startup for NT Data is collected mouth from the included data set. The parameters are then weighted using the AHP method, based on expert opinion and consistency tests. The TOPSIS method then uses generalized decision matrices to test various hybrid configurations to determine their closeness to the optimal solution. The combination of AHP and TOPSIS results in a comprehensive decision-making process, facilitating the selection of optimal mixture design methods for long-term production quality of concrete. This method provides reliable decision-making is greater and contributes to achieving targeted performance results in concrete construction projects. Fig.1 refers the overall process of the suggested approach.

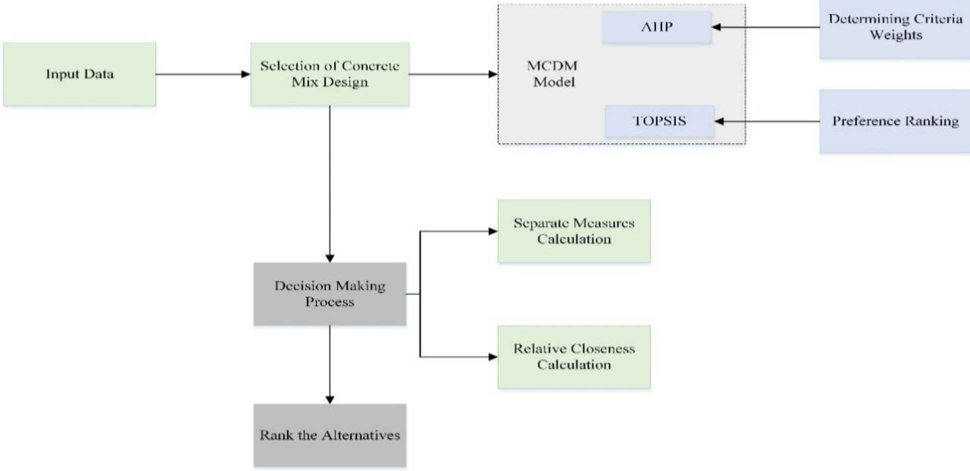

Fig. 1 Block Illustration of the Proposed Approach

4.1 Data Collection

Table.1. Sample Dataset

Course Aggregate (CA)	Fine Aggregate (FA)	Max Size of CA (mm)	Passing 0.6 mm Sieve (%)	Target Mean Strength (N/mm2)	Cement O.P.C (Kg/m3)	W/C Ratio	Water Content (Kg/m3)
Crushed	Natural	40	0	43	365	0.52	225
Crushed	Natural	40	0	CALcrete	365	0.52	225
Crushed	Natural	20	45.6	38	350	0.53	185
Natural	Natural	20	57.9	38	340	0.49	165
Natural	Natural	20	19.5	38	325	0.51	165
Natural	Natural	20	19.5	38	325	0.51	165
Crushed	Natural	20	39.4	38	340	0.56	190
Crushed	Natural	20	39.4	38	340	0.56	190
Crushed	Natural	20	33.4	38	370	0.5	185

The database for this study, originally collected from Kaggle, contains information on approximately 2500 concrete system connections. This record contains information on water-cement (W/C) ratio, water content and chemical admixtures used. This study aims to assess the dynamic development of concrete mix designs in terms of chemistry and materials scientifically and studies the effects of aggregate, cement content, and other factors on compressive strength over a 28-day period to provide practical insights into how to design optimal concrete structures for improved performance and durability [25]. The dataset selection is displayed in Table 1.

4.2 Selection of Concrete Mixture Design Utilizing MCDM Model

The selection of concrete mix design is important to ensure the long-term maintenance of the concrete. A comprehensive approach to sustainability and quality control is applied to the concrete mix design process using the MCDM model includes materials environmental, cost, durability, simplicity, and efficiency all strive to improve the system. In selecting complex mixtures with specific performance objectives, engineers often choose mixture design techniques. These methods assume various mixtures adjusted to the specific requirements determined by the chosen method. Several strategic decision-making methods have been developed to support valuation, goal setting, prioritization, and extreme selection but the selection of the most appropriate method depends on its ability to effectively support decision making and provide confidence in decision making which will turn out to be a useful outcome. The TOPSIS method is selected. This method exploits the characteristics of both AHP and TOPSIS methods, resulting in a comprehensive decision-making process. The proposed two-step AHP-TOPSIS method not only uses hierarchical decision-making processes and measurable weights, but it can also compare model solutions and provide a method for ranking, as it provides intuitive understanding and practical applications in solid mix design optimization. This combined approach is compared with the individual AHP and TOPSIS methods to demonstrate its effectiveness in complex decision making of complex mix designs. The structure for selecting the best combination development technique for the environmentally friendly manufacture of premium concrete is shown in Fig. 2.

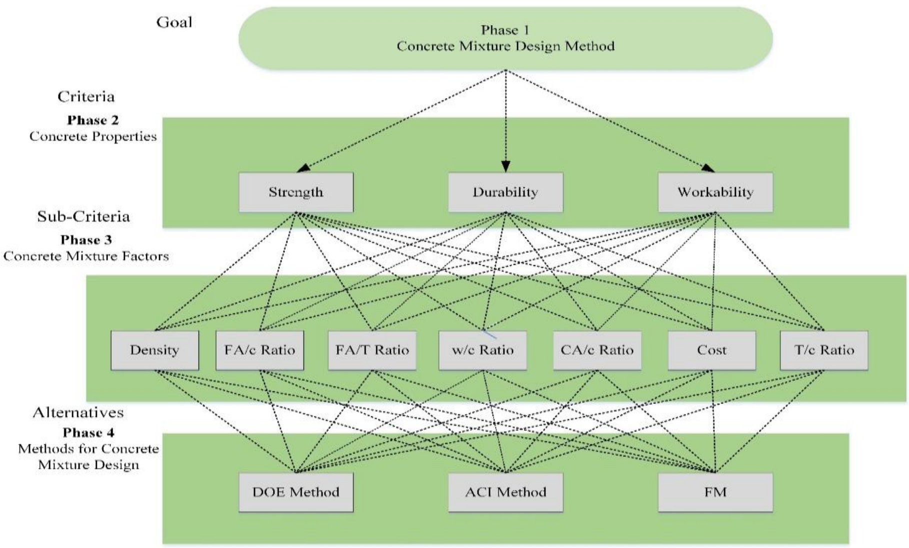

Fig. 2 Framework for Choosing the Optimal Method of Mixture

Design for the Sustainable Production of High-Quality Concrete.

4.3 Evaluation of Concrete Mix Design Using Integrated Analytic Hierarchy Process and TOPSIS Approach

Concrete mix design is evaluated using an incorporated Analytic Hierarchy Procedure and Approach for Order of Preference by Similarities to Ideal Solution approach, which entails systematic evaluation of alternative mix design methodologies and criteria. AHP determines criteria weights by pairwise comparisons, assuring consistency with the Consistency Index and Consistency Ratio. The normalized choice matrices are then analyzed to identify negative ideal and ideal solutions. By calculating the corresponding proximity to the optimal solution, TOPSIS facilitates the process of ranking mix selections for the manufacture of concrete under difficult conditions.

4.3.1. Weighting of Criteria Using AHP

In the process of making decisions, professionals in the sector select any of the nine semantic options on the basic scale for every factor comparison, resulting in personalized questionnaires for each decider. The obtained judgments are used to create an evaluation matrix, with rows and columns representing the relevant criteria. The expert's position (c_ij) in the matrix shows their assessment of the relative distinction between criteria i and j using Saaty's basic scale. It's worth noting that the assessment matrix can also include the scale's reverse values. This inclusion is important as if criteria i is deemed much more important than criterion j, criteria j should also be regarded less important. AHP comparability matrix are always mutually beneficial, so if c_ij=x, c_ij=1/x. The comparison of matrix C is represented by Eqn. (1).

$$\mathbf{C} = (\mathbf{c_{ij}}) = \left(\mathbf{c_{11}}\ \mathbf{c_{21}}\ \vdots\ \mathbf{c_{n1}}\ \ \frac{\mathbf{1}}{\mathbf{c_{21}}}\ \mathbf{c_{22}}\ \vdots\ \mathbf{c_{n2}}\ \ \dots\ \dots\ \ddots\ \dots\ \ \frac{\mathbf{1}}{\mathbf{c_{n1}}}\ \frac{\mathbf{1}}{\mathbf{c_{n2}}}\ \vdots\ \mathbf{c_{nn}} \right) \quad (1)$$

In Eqn. (1), c_ij represents the proportional evaluation of criteria i and j; j=1,2,….m;i=1,2,….m. The AHP approach determines parameter weights (W,c_i) by selecting the component of the eigenvector with the biggest eigenvalue from the comparison matrix. Eqn. (2) calculates the weights for each condition.

$$\mathbf{W}, \mathbf{c_i} = \sum_{\mathbf{j=1}}^{\mathbf{n}} \frac{\frac{\mathbf{c_{ij}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{c_{ij}}}}{\mathbf{n}} \quad (2)$$

To establish statistical authenticity, the matrix used for comparison must be consistent. The Consistency Index (CI) is used to evaluate matrix stability and can be determined using Eqn. (3).

$$\mathbf{CI} = \frac{\mathbf{\Delta_{max} - n}}{\mathbf{n - 1}} \quad (3)$$

The most significant eigenvector is denoted by Δ_max, while the total number of features is represented by n. To assess the reliability of each decision-making, the consistency ratio (CR) has been calculated using the specified approach. When an assessment is 100% consistent, the CR rating is zero. To compensate for errors and inconsistencies in decisions made by humans, a consistency ratio below 0.1 is reasonable for the purposes of this study. Eqn. (4) provides a calculation for determining the CR. The size of the matrix utilized has a significant effect on the Random Index (RI).

$$\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RI}} \quad (4)$$

4.3.1. Preference Ranking Using TOPSIS Approach

The conventional decision-making matrix, represented by y = [y_ij], is formed, with y_ij representing the evaluated value of the i^th alternative on the i^th criterion. The number of choices (i) spans from 1 to n, whereas the number of criteria (j) extends from 1 to m. Using Eqn. (5), the conventional decision-making matrix was normalized.

$$\mathbf{y_{ij}} = \frac{\mathbf{y_{ij}}}{\sqrt{\prod_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{y_{ij}^2}}}, (\mathbf{j = 1, 2, \dots, m; i = 1, 2, \dots, n}) \quad (5)$$

The weighted normalized decision matrix $\mathbf{U} = (\mathbf{u_{ij}})$was created by multiplying the normalized conventional decisions-making matrix and previously gathered weights $[\mathbf{w_j}]$ by Eqn. (6).

$$\mathbf{u_{ij}} = \mathbf{y_{ij}} \times \mathbf{w_j}, (\mathbf{j} = \mathbf{1}, \mathbf{2}, \ldots., \mathbf{m}; \mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots., \mathbf{n}) \quad (6)$$

Eqn. (7) for benefit criteria connected with K and Eqn. (8) for non-benefit criteria linked with K' are used to identify the positive and negative ideal solutions, respectively.

$$(\mathbf{u_1^+}, \ldots., \mathbf{u_n^+}) = [(\mathbf{j}\epsilon\mathbf{k})(\mathbf{j}\epsilon\mathbf{k'})], (\mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots., \mathbf{n}) \quad (7)$$

$$(\mathbf{u_1^-}, \ldots., \mathbf{u_n^-}) = [(\mathbf{j}\epsilon\mathbf{k})(\mathbf{j}\epsilon\mathbf{k'})], (\mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots., \mathbf{n}) \quad (8)$$

Eqns. (9) and (10) are used to compute the separation distances from the positive and negative ideal solutions, respectively.

$$\mathbf{SD_i^+} = \sqrt{\sum_{j=1}^{m} \left(\mathbf{u_{ij}} - \mathbf{u_j^+}\right)^2}, (\mathbf{j} = \mathbf{1}, \mathbf{2}, \ldots.\mathbf{m};\ \mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots.\mathbf{n}) \quad (9)$$

$$\mathbf{SD_i^-} = \sqrt{\sum_{j=1}^{m} (\mathbf{u_{ij}} - \mathbf{u_j^-})^2}, (\mathbf{j} = \mathbf{1}, \mathbf{2}, \ldots.\mathbf{m};\ \mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots.\mathbf{n}) \quad (10)$$

The deviation distances from positive and negative ideal solutions are represented by $\mathbf{SD_i^+}$ and $\mathbf{SD_i^-}$,, respectively. Eqn. (11) calculates the overall performance score for each of the options in the TOPSIS approach. TOPSIS scores vary from 0 to 1, and greater ratings signify superior examination of possibilities.

$$\mathbf{TOPSIS_i} = \frac{\mathbf{SD_i^-}}{\mathbf{SD_i^+} + \mathbf{SD_i^-}}, (\mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots., \mathbf{m}) \quad (11)$$

After getting TOPSIS values for all possibilities, arrange them in a chronological order based on the values they each have. A higher rating on this scale indicates more sustainability for the alternatives.

4.4 Decision Making Process for Sustainable Quality Concrete Production

Normalization is necessary since the variables that determine the best combinations technique might be quantified in various quantities. In this case, standardized TFN values are maintained in [0, 1] by employing the traditional linear scales transformation normalization procedure. If $\underline{\mathbf{r}}$ represents the standardized decision matrix as Eqn. (12)

$$\underline{\mathbf{r}} = \underline{\mathbf{R_{ij}}}_{\mathbf{max'}}, \mathbf{j} = \mathbf{1}, \mathbf{2}, \ldots \ldots, \mathbf{m}; \mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots \ldots, \mathbf{n} \quad (12)$$

Divide each number in the standardized decisions matrices by the significant values of the evaluation parameters to get the calculated standardized decision matrices. Eqn (13) represents its weighted standardized decision matrices and $\underline{\mathbf{y_j}}$ denotes the important weight of criteria $\mathbf{c_j}$ determined by Eqn. (14).

$$\underline{\mathbf{u}} = \underline{\mathbf{u_{ij}}}_{\mathbf{max'}}, \mathbf{j} = \mathbf{1}, \mathbf{2}, \ldots \ldots, \mathbf{m}; \mathbf{i} = \mathbf{1}, \mathbf{2}, \ldots \ldots, \mathbf{n} \quad (13)$$

$$\underline{\mathbf{y_j}} = \frac{\mathbf{1}}{\mathbf{n}}(\underline{\mathbf{y_j^1}} + \underline{\mathbf{y_j^2}} + \cdots. + \underline{\mathbf{y_j^n}}) \quad (14)$$

Where, n is the overall amount of members in an individuals group and $\underline{\mathbf{y}}$ is the fuzzy weight of the $\mathbf{j^{th}}$ criteria examined by the $\mathbf{n^{th}}$ individuals.

Calculating the Closeness Coefficient (CC) identifies all possible alternate ordering, enabling those making decisions to choose the optimum likely course of action. Eqn. (15) provides the proximity coefficient for each possibility.

$$\mathbf{C_i = \frac{e_i^-}{e_i^+ + E_i^-}, i = 1, 2, 3, \ldots \ldots n} \quad (15)$$

Proposed MCDM Approach to Choose the Concrete Mix Design

Input: Concrete Design Combinations Data

Output: Identifying sustainable quality of concrete with concrete mix factors

Step 1: Establish a structure of problem criteria, normalize the decision matrix, then weight it using AHP

Step 2: Employ AHP to ensure consistency in each pairwise comparison matrix

- Calculate CR and CI values for each pairwise comparison matrix and the aggregate matrix

Step 3: Calculate alternative weights based on sub criterion weights

Step 4: Compute TOPSIS by using AHP to normalize the decision matrix

Step 5: Compute separation measures and identify ideal and negative ideal solutions

- Determine the positive and negatives ideal solutions.
- Compute splitting distances from the negative ideal and ideal solutions for each alternative

Step 6: Sort the preferences in order of selection and determine how near the answer is to the ideal one.

- Determine the relative proximity of each option.
- Then, order the options according to their degree of proximity scores.

End

5. Results and Discussion:

The application of Multicriteria Decision-Making approach to concrete mix design produces promising outcomes for long-term quality management. Optimal mix designs are produced by conducting a thorough review of several variables such as environmental impact, cost-effectiveness, and durability. The proposed approach ensures that all critical parameters for sustainable concrete production are considered, resulting in improved concrete structure performance and lifetime. Concrete designers and engineers can use MCDM techniques to effectively balance multiple objectives, resulting in improved concrete mix properties. Reduced environmental impact and increased sustainability. This shows the potential of MCDM to transform change complex projects towards sustainable practices.

5.1 Sensitivity Analysis

Fig.3 examines how changes in criteria weights affect the ranking of alternatives, providing insights into the decision-making process's robustness. It represents a specific criterion weighting variation, while the columns reflect alternative methods (ACI, DOE, FM). Decision makers can understand the stability of their preferences in different situations through the process of fixing weights and recalculating proximity. Sensitivity analysis helps to identify which determinants have the greatest influence on selected final rankings for concrete production Increased confidence in the design process of mixtures.

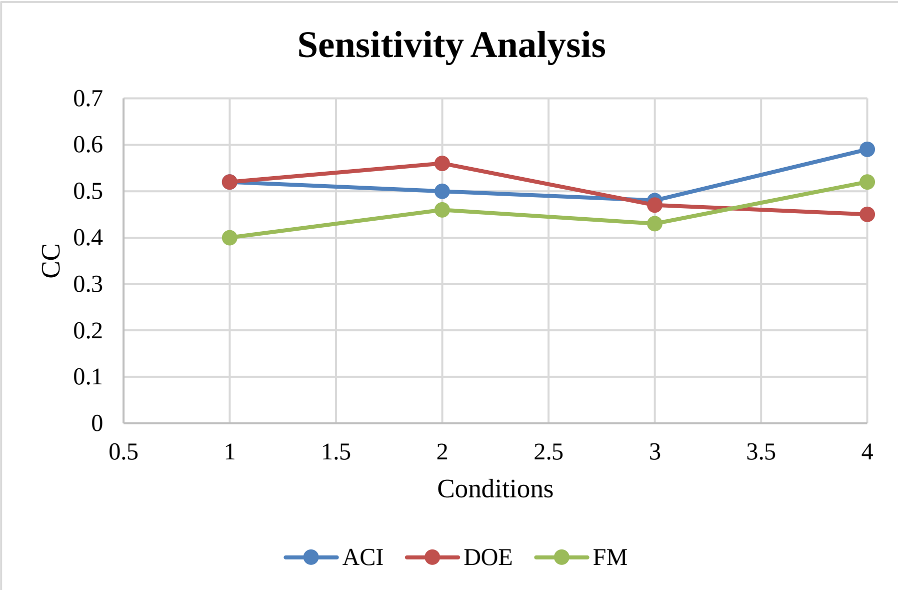

Fig.3 Sensitivity Evaluation

5.2 Ranking of Design Mix Parameters

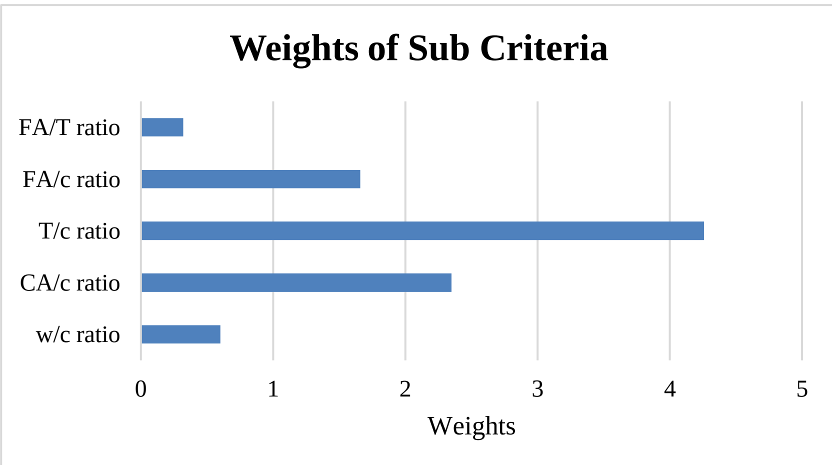

Fig.4. Ranking of Design Mix Parameter

5.3 Discussion

Sensitivity analysis highlights the flexibility of the decision-making process by examining the effect of value weights on new rankings. These successful variables help to understand the stability of preferences under different conditions, identify critical features, and increase confidence in selected options. Ranking design mix parameters provides useful information about the importance of a there is some importance of each parameter for optimal concrete mix design for tight settings. The DOE approach to aggregates is well suited for continuous concrete quality management because it focuses on quantitative characteristics and aggregate properties.

6. Conclusions:

Establishing a concrete mix design program using the MCDM method provides a systematic approach to long-term quality control of the concrete. This approach ensures that the concrete mix design meets development objectives and high standards through characteristics such as biodiversity impact, affordability, adaptability, sustainable development and other factors effectively incorporating the use of AHP for criterion loading, and TOPSIS for analyzing various hybrid designs Creates decision-making processes. This comprehensive approach improve complex strategies for advanced operations and environmental sustainability. MCDM methods improve decision-making in realistic construction efforts, resulting in flexible, sustainable and environmentally friendly buildings. The proposed MCDM model for TOPSIS is consistent with existing research and simulations. The DOE method is more suitable for long-term concrete quality control due to its focus on measurable properties and variable mixtures. Future research in this area should focus on extending the breadth of assumptions addressed by the MCDM model to include sustainability indicators such as carbon footprint, embodied energy, and life cycle analysis added to the. The researcher can explore advanced methods of teaching the machine to provide previously accurate estimates based on construction material mixes and field testing of acclaimed concrete structure mix construction and duration will analyse their own small presentation and constant positioning robust constants improve results-productivity.

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