

Comparative Analysis of Concrete Mix Design Methods: SNI 03-2834-2000 vs. SNI 7656:2012

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Abstract Concrete mix design is a critical facet of construction, determining the composition of concrete for optimal performance and durability. This research paper presents a comprehensive comparative analysis of concrete mix designs based on two prominent Indonesian standards: SNI 03-2834-2000 and SNI 7656:2012. The study evaluates these standards in terms of technical accuracy and economic viability, shedding light on their effectiveness in producing efficient and sustainable concrete mixtures. The analysis encompasses various parameters, including slump value, aggregate sizes, water-cement ratio, and aggregate content. Notably, the research delves into the weight-based method and the absolute volume method as specified in the standards. Detailed calculations and considerations are undertaken to explore the differences and convergences in mix designs under the two standards. The study's findings reveal intriguing insights. The alignment of concrete masses obtained from both standards underscores their reliability and compatibility. Similarly, the agreement in water-cement ratios emphasizes the fundamental principles shared by these standards. However, the research unveils nuanced variations in the aggregate content between the weight-based and absolute volume methods, opening discussions on their distinct abilities to capture aggregate intricacies. Incorporating an economic analysis based on standard unit prices, the research highlights the financial implications of the different mix designs. The cost-effectiveness of SNI 7656:2012, which entails reduced cement usage while producing heavier concrete, introduces a sustainable perspective by minimizing

material consumption. The synthesis of technical precision and economic feasibility forms the crux of this study's insights. As the construction industry seeks optimal mix designs that balance performance, durability, and sustainability, this research offers guidance to engineers and practitioners. In an era of evolving construction practices, where resource efficiency is paramount, this study contributes to the discourse on concrete mix design, enriching decision-making for resilient and cost-effective construction practices.

Keywords Concrete Mix, Concrete Material, Building Material, Sustainable Construction

1. Introduction

The construction industry relies on the steadfast backbone of concrete, a material that epitomizes the strength, versatility, and longevity demanded by the modern built environment [1]–[4]. Modern architecture emphasizes sustainability, and concrete is a key material in green building practices. The choice of concrete mix design can influence the environmental impact, energy efficiency, and overall sustainability of a construction project, aligning with contemporary architectural principles. The structural integrity of skyscrapers, bridges, and foundational structures hinges on the quality of concrete, making it an irreplaceable cornerstone. Yet, beneath its surface, the art and science of crafting an ideal

concrete mix design intricately governs its performance.

Concrete mix design, a foundational discipline within civil engineering, determines the proportions of constituent materials in concrete [5], [6]. This seemingly intricate dance between cement, aggregates, water, and additives is far from arbitrary; rather, it forms the blueprint for concrete's mechanical attributes, durability, and, ultimately, the safety of constructed marvels [7], [8]. Unravelling the intricacies of concrete mix design brings to light its pivotal role in the realization of architectural visions.

Within this context, the focus of this research paper transcends the ordinary, delving into a comparative study of two pivotal methodologies, SNI 03-2834-2000 [9] and SNI 7656:2012 [10], widely employed in Indonesia. As integral players in the realm of concrete mix design, these methodologies guide the intricate symphony of material ratios that give life to concrete's structural prowess.

The need for an effective concrete mix design cannot be overstated. Beyond meeting structural demands, the mix design is a key influencer in a myriad of concrete properties – be it the compressive strength that guards against collapses, the workability that eases construction, or the durability that safeguards against environmental stresses [11].

From aggregate sizes dictating the workability and mechanical properties of the mix to the delicate balance of water-cement ratios that marry strength with durability, every parameter in concrete mix design weaves an intricate narrative. Achieving the optimal blend of these elements requires a holistic understanding of their interplay.

Moreover, the journey into concrete mix design is enriched by the multifaceted considerations in materials, construction context, and even environmental factors. Aggregate sizes shape the mix's mechanical properties, the water-cement ratio orchestrates the balance between strength and workability, and overall mix workability ensures ease of placement and compaction. These facets come together in a harmonious interplay, guided by the principles of SNI 03-2834-2000 and SNI 7656:2012 methodologies.

As this research unravels the nuances of concrete mix design, it endeavours to illuminate the importance of a well-structured mix, shedding light on how different methodologies respond to varying design parameters. By examining both methodologies through the lens of shared aggregate data and an identical compressive strength benchmark, this research strives to unveil a deeper understanding of how these methods address the diverse challenges posed by the dynamic world of construction.

Ultimately, this research seeks to empower scholars, practitioners, and students of civil engineering with a comprehensive understanding of concrete mix design science. As construction ventures grow in complexity, the ability to craft tailored mix designs ensures structures that

endure both the rigors of time and the demands of dynamic environmental conditions.

2. Methodology

2.1. SNI 03-2834-2000 vs. SNI 7656:2012

This research delves into a comparative study of two distinct concrete mix design methodologies: SNI 03 - 2834 - 2000 and SNI 7656:2012. These methodologies represent established frameworks for crafting concrete mixes in Indonesia and are adapted from international standards, showcasing the convergence of global best practices with local construction demands.

The investigation commences by scrutinizing the concrete mix design method outlined in SNI 03 - 2834 - 2000. Originating from The British Mix Design Method (DOE) of 1975 [12], this methodology has held a preeminent position in Indonesia's construction industry for decades. This study will elucidate the foundational tenets of this method, encompassing its theoretical underpinnings and pragmatic application in actual concrete mix design.

A parallel trajectory within this research involves an in-depth exploration of the concrete mix design approach stipulated in SNI 7656:2012. Derived from the American Concrete Institute's ACI 211.1-91 [13], this method offers an alternative perspective, accommodating diverse parameters to orchestrate optimal concrete mix performance. This research will rigorously probe the intricacies of SNI 7656:2012, unveiling its unique attributes and application nuances.

Both SNI 03 - 2834 - 2000 and SNI 7656:2012 are characterized by their individual strengths and limitations, tailored to specific contextual scenarios. In a bid to illuminate the salient features of each method, this research rigorously compares their outcomes. This comparative analysis transcends mere theoretical juxtaposition, shedding light on the practical implications of employing either method in real-world construction scenarios.

2.2. Case Study

A pivotal dimension of this study involves real construction project case studies. These case studies serve as conduits to bridge theoretical discourse with practical reality. By scrutinizing instances where both methodologies are deployed, this research aspires to decode how the principles distilled from SNI 03 - 2834 - 2000 and SNI 7656:2012 reverberate in the realm of tangible construction, acknowledging the nuances that manifest when theory encounters the complexities of actual implementation.

Central to this research is the utilization of consistent aggregate data within both methodologies. Aggregates,

serving as elemental components of concrete mixtures, exert a profound influence on the resultant concrete's characteristics and performance. Detailed data pertaining to the physical properties of fine and coarse aggregates, meticulously outlined in Table 1, will form the bedrock of the ensuing concrete mix planning endeavours.

Table 1. Aggregate properties

Properties	Fine	Coarse
Density (kg/m ³)	2.2	2.6
Water absorption (%)	1.36	2.95
Water content (%)	7.49	2.17

Critical to comprehending aggregate suitability is a granular analysis of their gradation. Of paramount significance, the fineness modulus of the fine aggregate stands at 2.64, ascertained by dividing the cumulative percent retained between sieve sizes 38 mm and 0.15 mm by 100, in adherence with ASTM C33-03 [14]. This calculated value serves as a key parameter in comprehending the aggregate's profound influence on concrete properties. Additionally, the modulus of the coarse aggregate is calculated to be 7.13. This modulus, derived through a similar methodology, substantiates the pivotal role of coarse aggregates in shaping concrete mix characteristics.

Moreover, the congruence in compressive strength is pivotal to our study's validity, as both methods are juxtaposed against a common benchmark – a compressive strength of 35 MPa.

3. Design Mix Results

3.1. SNI 03-2834-2000

This subsection elucidates the concrete mix design process by employing the SNI 03 - 2834 - 2000 method. The methodology encompasses a series of sequential steps aimed at achieving the desired concrete properties. The first pivotal step involves establishing the targeted compressive strength (f_{cr}), which is determined to be no less than 47 MPa. This parameter lays the cornerstone for subsequent mix design decisions.

Material selection assumes critical importance in this process. Specific attention is devoted to the choice of cement type, coarse aggregates, and fine aggregates. For the cement component, Portland Cement Type II or V is favoured. Coarse aggregates are carefully chosen as crushed stone, while fine aggregates take the form of meticulously selected sand.

The water-cement ratio, a key determinant of concrete performance, is carefully prescribed. A ratio of 0.40 is selected, factoring in requisites for sulphate resistance and seawater exposure resilience. For practicality and ease of handling, a slump value of 100 mm is assumed, steering

the mix towards optimal pourability and levelness.

The maximum aggregate size, an influential factor in determining the concrete's structural characteristics, is established at 37.5 mm. The free water content, meticulously calculated at 205 kg/m³, assumes a pivotal role in ensuring optimal workability and effective hydration. The calculated cement content (K_s) is ascertained to be 512.5 kg/m³, constituting a fundamental component within the mix composition.

A core aspect of the mix design process pertains to the particle size distribution of fine aggregates. Compliance with prescribed gradation standards ensures consistency and quality within the mix. Similarly, meticulous attention is paid to the composition of coarse aggregates, which adheres to specified gradation criteria, thereby enhancing the structural integrity of the mix. The selection of a 30% fine aggregate percentage is grounded in considerations of mix performance and intended characteristics. The calculation of the relative density of aggregates, leading to a value of 2.47, establishes a crucial link between aggregates and their contribution to the overall mix. The resultant concrete density, confirming at 2250 kg/m³, assumes significance in terms of assessing volume proportions accurately. Moreover, the total aggregate content, determined at 1532.5 kg/m³, encapsulates the comprehensive contribution of aggregates within the mix.

Fine aggregate's specific content, termed as fine aggregate content (K_{ah}), is deduced to be 459.75 kg/m³, thereby contributing to the holistic composition of the mix. Similarly, coarse aggregate content (K_{ak}), quantified at 1072.75 kg/m³, underscores the structural robustness inherent within the mix. Further refinement involves correction factors, addressing the mix's susceptibility to water content adjustments due to aggregate porosity. These adjustments ensure proportionality within the mix, aligning with intended performance objectives. The ultimate final concrete weight, ascertained at 2250 kg/m³, assumes a significant role in guiding the overall mix design process.

In summary, the concrete mix proportion for 1 m³ of concrete, utilizing the SNI 03 - 2834 - 2000 method, encompasses: Water: 185.18 kg, Cement: 512.5 kg, Fine Aggregate: 487.93 kg, Coarse Aggregate: 1064.38 kg. This methodological framework furnishes a systematic approach towards achieving the specified compressive strength and intended performance characteristics inherent within the concrete mix.

3.2. SNI 7656:2012

The process of concrete mix design, in accordance with SNI 7656:2012, encompasses a systematic sequence of steps aimed at determining an optimal composition that ensures the desired strength, workability, and durability of concrete structures. This section elucidates each step in detail.

The initial step entails the selection of a representative

slump value to characterize the workability of the concrete mixture. In the case under examination, a slump value of 100 mm is chosen to establish the required plasticity of the concrete. The choice of maximum size for coarse aggregates assumes paramount importance, influencing not only workability but also economic considerations. Adhering to SNI guidelines, the nominal maximum size is set at one-fifth of the smallest dimension of the mould, translating to a size of 37.5 mm.

The quantification of the mixing water and air content constitutes a pivotal facet. By recourse to pertinent tables and considering the specified parameters, the water content is calculated as 181 kg/m³ and the air content is determined to be 1% to ensure the appropriate degree of entrained air. The selection of the water-cement ratio assumes significance in influencing the strength characteristics of the concrete. Deliberating on the prescribed strength requisites and accounting for the constraints imposed by preceding steps, a water-cement ratio of 0.40 is opted for to achieve the desired structural robustness.

Employing the elected water-cement ratio, the requisite cement content is deduced. In the instance at hand, the calculated cement content stands at 452.5 kg/m³, reflecting the proportion necessary to achieve the stipulated properties.

The estimation of coarse aggregate content hinges upon factors such as the maximum aggregate size and the fineness modulus. By interpolation, the volume ratio of coarse aggregate to the total concrete volume is determined to be 0.726, resulting in a coarse aggregate content of 864 kg/m³. Two distinct methods are employed to gauge the fine aggregate content. The weight-based approach, which considers the weights of other constituents, yields an estimate of 912.5 kg/m³. Conversely, the absolute volume method, predicated on volume calculations, yields a value of 754.6 kg/m³.

In light of the inherent porosity of aggregates, a moisture adjustment is introduced to ensure proportionality in the mix. This corrective step accounts for the propensity of aggregates to absorb moisture and maintains accuracy in the composition. Integrating all corrections and adjustments, the final weight of the concrete mix is ascertained. For the weight-based and absolute volume methods, the finalized weights stand at 2410 kg and 2252.1 kg, respectively, encapsulating the culmination of the concrete mix design process.

This comprehensive and meticulous methodology of concrete mix design, aligned with the guidelines stipulated by SNI 7656:2012, assures a meticulously calibrated composition that harmonizes structural demands with the attributes of the aggregates and the prevailing environmental considerations.

4. Discussions

The comparative analysis of concrete mix designs

between the standards SNI 03-2834-2000 and SNI 7656:2012 as shown in Table 2 presents insightful findings regarding material proportions and economic considerations. This discussion further delves into the scientific implications of the observed differences and their practical significance.

Table 2. Concrete design mix comparison

Material	SNI 03 – 2834 – 2000	SNI 7656:2012	
		Weight	Volume
Water (Kg/m ³)	185.18	131.8	141.8
Cement (Kg/m ³)	512.5	452.5	452.5
Fine aggregate (Kg/m ³)	487.93	968.44	800.86
Coarse aggregate (Kg/m ³)	1064.38	857.26	857.26
Total (Kg/m ³)	2250	2410	2252.1

The observed convergence in final concrete weights between the two standards, SNI 03-2834-2000 and SNI 7656:2012 (using the absolute volume method), underscores the suitability of both methods in yielding comparable concrete masses. This agreement suggests that the methods effectively accommodate variations in aggregate characteristics and their volume contributions, ultimately leading to analogous final concrete densities.

The congruence in water-cement ratios across the methods provides further support for their coherence. This alignment reinforces the fundamental principle that the water-cement ratio profoundly influences the workability and strength development of concrete. The convergence in this crucial parameter between the standards indicates their consistency in maintaining suitable water-cement ratios for optimum concrete performance.

The distinction in fine and coarse aggregate volumes, particularly the higher volume of fine aggregate as determined by the weight method in SNI 7656:2012, introduces an interesting point for consideration. The discrepancy between these two aggregates' volumes signifies that the weight-based approach might better capture the intricate interplay between aggregate characteristics, such as their gradation and specific gravities. This variance from the tabulated values in SNI 7656:2012 warrants attention, as it could potentially lead to refined mix designs that better address real-world aggregate attributes.

Notably, the calculated aggregate weights obtained using the weight method with equations closely mirror those derived through the absolute volume method. This finding provides empirical evidence that, within the context of the considered mix designs, the use of equations in conjunction with the weight method can yield results akin to the absolute volume method. This concurrence contributes to the practicality of employing either method, offering engineers greater flexibility in selecting the most

appropriate approach based on the specific project requirements and available data.

Turning to the economic dimension, the evaluation of unit prices of materials based on the Jakarta 2022 standard unit price as shown in Table 3 facilitates a comprehensive comparison of the three methods. This economic analysis introduces a pragmatic aspect to the concrete mix selection process, where the financial implications of various material compositions can significantly impact project feasibility and budgetary considerations.

Table 3. Material cost comparison (per m³ in Rupiah)

Material	SNI 03 – 2834 – 2000	SNI 7656:2012	
		Weight	Volume
Water	1,296.26	922.60	992.60
Cement	1,060,875.00	936,675.00	936,675.00
Fine aggregate	79,710.02	158,207.88	130,831.40
Coarse aggregate	120,718.43	97,227.57	97,227.57
Total	1,262,599.71	1,193,033.05	1,165,726.57

The reduced material costs associated with SNI 7656:2012 bear substantial implications. Despite the higher final concrete weight yielded by SNI 7656:2012, its cost-effectiveness stems from a judicious reduction in cement usage. Cement, being a pivotal ingredient in concrete production, commands a substantial portion of the material costs. The method's ability to achieve comparable concrete performance with lower cement content manifests its potential to contribute to sustainable construction practices by reducing material consumption and associated environmental impacts.

In conclusion, the comparative analysis of concrete mix designs in SNI 03-2834-2000 and SNI 7656:2012 spans both technical and economic domains. The observed alignments, discrepancies, and cost considerations provide valuable insights for engineers and practitioners in selecting appropriate mix design methods. This discussion underscores the importance of evaluating mix designs from a holistic perspective, encompassing both technical efficacy and economic feasibility, to drive informed decision-making in concrete construction.

5. Conclusions

The comparison and analysis of concrete mix designs between SNI 03-2834-2000 and SNI 7656:2012 have yielded multifaceted insights into the realm of concrete mixture optimization. This study has emphasized the significance of both technical precision and economic feasibility in the decision-making process for concrete mix designs.

The congruence observed in final concrete weights

between the two standards underscores their compatibility and their ability to produce comparable concrete masses. This concordance serves as a testament to the robustness of both the absolute volume method and the weight method, highlighting their adaptability to diverse aggregate characteristics.

Furthermore, the convergence in water-cement ratios across the methods reaffirms their alignment in terms of mix design fundamentals. The consistency in this crucial parameter underscores the enduring importance of maintaining an optimal water-cement ratio to achieve desired concrete performance.

The discrepancy in fine and coarse aggregate volumes, particularly the higher volume of fine aggregate as determined by the weight method in SNI 7656:2012, introduces a nuanced perspective on aggregate interplay. This variance prompts consideration of the weight-based method's potential in capturing the intricate relationships between aggregate characteristics, leading to refined mix designs that more closely mirror real-world conditions.

Incorporating an economic analysis based on the Jakarta 2022 standard unit prices, this study underscores the financial implications of various mix designs. The cost-effectiveness of SNI 7656:2012, despite yielding heavier concrete, highlights the pragmatic reduction in cement usage. This aspect has far-reaching sustainability implications, as it aligns with the growing emphasis on minimizing material consumption and its associated environmental impact.

Collectively, the comparative study illuminates the interplay between technical precision and economic viability in concrete mix design. The findings emphasize the importance of a holistic approach to decision-making, where both technical excellence and financial practicality are considered. As the construction industry continually seeks to balance performance and sustainability, this study contributes to the evolving discourse on optimal concrete mix design, guiding engineers and architects towards more informed and sustainable choices.

In essence, while this study offers valuable insights into concrete mix design, it is essential to recognize that certain aspects, such as concrete rheology and the limitations of the slump test, remain as areas for future investigation. By addressing these limitations and expanding the scope of research, the concrete industry can continue to refine its mix design practices and enhance concrete performance.

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