

# Comparative Evaluation of Concrete Spacer Systems for Reinforced Concrete Structures in Tropical Environments

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**Abstract-** Concrete spacers play a critical role in maintaining the required concrete cover and ensuring the durability of reinforced concrete structures, particularly in tropical environments characterized by high humidity, elevated temperatures, and chloride exposure. This study presents a comparative evaluation of three commonly used concrete spacer systems: cement-based spacers, stone or brick spacers, and polymer-coated spacers. A qualitative, non-experimental research design was employed using data synthesized from established engineering literature, technical standards, and previous studies related to reinforced concrete durability and spacer performance. The evaluation was conducted through a Multi-Criteria Decision Analysis (MCDA) framework using eight performance criteria, namely compressive strength, water absorption, chloride penetration resistance, durability, bond compatibility, ease of installation, stability during concreting, and cost efficiency. Each criterion was assigned a corresponding weight based on its relevance to structural serviceability and durability in tropical conditions. Results of the weighted decision matrix indicated that cement-based spacers achieved the highest overall score of 4.655 due to their material compatibility with surrounding concrete, superior bond performance, and long-term durability. Polymer-coated spacers obtained a score of 3.655, demonstrating strong resistance to moisture penetration but exhibiting potential interfacial limitations under thermal and mechanical stresses. Stone or brick spacers recorded the lowest score of 1.750 because of their high porosity, irregular geometry, and poor durability performance. The findings suggest that cement-based spacers provide the most reliable overall performance for reinforced concrete structures exposed to aggressive tropical environmental conditions. This study highlights the importance of selecting appropriate spacer systems to enhance structural durability, minimize reinforcement corrosion, and improve long-term serviceability in tropical construction environments.

**Index Terms-** Bond Compatibility, Concrete spacers, Multi-Criteria Decision Analysis (MCDA), Reinforcement Corrosion, Tropical environments.

## I. INTRODUCTION

Concrete spacers play a crucial role in reinforced concrete construction by ensuring the correct positioning of reinforcement and maintaining the specified concrete cover during casting. In tropical environments, high humidity, and chloride exposure accelerate deterioration mechanisms such as moisture ingress and reinforcement corrosion.

One of the critical components influencing the effectiveness of concrete cover protection is the concrete spacer system. Concrete spacers are temporary or permanent construction accessories used to maintain the required spacing between reinforcing steel and framework during concreting operations. Proper reinforcing position ensures that the designed concrete cover thickness is achieved, thereby protecting reinforcement against corrosion and environmental attack. Although spacers are relatively small compared to other structural components, their material composition and durability characteristics significantly influence the long-term behavior or reinforced concrete structures.

Different spacer systems are commonly utilized in construction practice, including cement-based spacers, polymer-coated spacers, and improvised stone or brick spacers. Cement-based spacers are manufactured using cementitious materials similar to the surrounding concrete, allowing them to develop compatible mechanical and chemical bonding with the concrete matrix. Polymer-coated spacers are produced using synthetic materials or polymer coatings designed to resist moisture penetration and improve handling efficiency during construction. In contrast, stone or brick spacers are often improvised from construction debris or site materials because of their

low cost and availability. However, these improvised materials frequently possess irregular geometry, high porosity, inconsistent strength, and poor compatibility with surrounding concrete.

The performance of spacers systems is closely associated with the behavior of the Interfacial Transition Zone (ITZ) which refers to the microscopic region between the spacer material and surrounding concrete the ITZ is widely recognized as one of the weakest regions in concrete composites because it often contains higher porosity, microcracks, and discontinuities compared to the bulk cement matrix. Under tropical environments exposure, the ITZ may become a preferential pathway for moisture migration, chloride penetration, and chemical attack. Weak interfacial bonding between the spacer and surrounding concrete may increase permeability and accelerate reinforcement corrosion, the material composition and surface characteristics of spacers directly influence the durability and protective performance of reinforced concrete structures.

Several previous studies have examined the durability of reinforced concrete and the influence of concrete cover on corrosion resistance. Existing literature also discusses the behavior of individual spacer materials and their effect on reinforcement positioning during construction. However, limited comparative research has been conducted regarding the performance of different concrete spacer systems under tropical environmental conditions, particularly in relation to Interfacial Transition Zone (ITZ) behavior, chloride penetration resistance, moisture migration, and long-term durability. Furthermore, many construction projects continue to treat spacers as minor accessories despite their significant influence on structural serviceability and reinforcement protection.

This study addresses these research gaps by conducting a comparative evaluation of cement-based spacers, polymer-coated spacers, and stone or brick spacers using a Multi-Criteria Decision Analysis (MCDA) framework. The study specifically evaluates the engineering performance of each spacer system in terms of compressive strength, water absorption, chloride penetration resistance, durability, bond compatibility, ease of installation, stability during concreting, and cost efficiency under tropical

environmental exposure. The findings of this research aim to provide engineers, researchers, contractors, and developers with a technically grounded basis for selecting suitable spacer systems capable of improving reinforcement protection, minimizing corrosion risk, and enhancing the long-term durability of reinforced concrete structures in tropical regions.

The study is limited to the comparative assessment of three commonly utilized spacer systems based on synthesized engineering literature, published technical references, and established durability principles. The research does not include laboratory experimentation, field testing, or numerical simulation. The evaluation focuses only on reinforced concrete structures exposed to tropical environmental conditions characterized by high humidity and chloride exposure.

The primary objective of this study is to evaluate the performance of cement-based, polymer-coated, and stone/brick spacers in tropical environments. Specifically, this study aims to:

1. Assess the mechanical properties and durability characteristics of different spacer system using synthesized engineering data.
2. Evaluate the engineering performance of each spacer system in terms of compressive strength, water absorption, chloride penetration resistance, durability, bond compatibility, ease of installation, stability during concreting, and cost efficiency.
3. Analyze the influence of material composition on the Interfacial Transition Zone (ITZ) to identify potential weak points for moisture migration.
4. Provide a technically grounded recommendation for selecting the most reliable spacer system to minimize reinforcement corrosion in high-humidity and saline regions.

## II. METHODS

This study employed a qualitative, non-experimental comparative research design to evaluate the performance of different concrete spacer systems used in reinforced concrete structures exposed to tropical environmental conditions. The research focused on three commonly utilized spacer types: cement-based spacers, stone or brick spacers, and polymer-coated concrete spacers. The evaluation emphasized the influence of spacer materials on the durability,

serviceability, and long-term protection of reinforced concrete members subjected to high humidity, elevated temperatures, frequent wetting and drying cycles, and chloride exposure commonly experienced in tropical regions such as the Philippines.

The study utilized a literature-based analytical approach wherein data and technical information were synthesized from published engineering journals, international standards, textbooks, technical reports, and previous studies related to reinforced concrete durability, reinforcement corrosion, spacer performance, and interfacial transition zone (ITZ) behavior. Major references included publications from recognized engineering databases and institutions such as MDPI, Springer, Elsevier, the American Concrete Institute (ACI), and the British Standards Institution (BSI). The collected literature served as the basis for evaluating the engineering performance of each spacer system according to established material behavior and durability characteristics.

To systematically compare the spacer systems, the study adopted a Multi-Criteria Decision Analysis (MCDA) framework. MCDA was selected because it allows the integration of multiple engineering criteria affecting structural performance and durability into a single comparative evaluation model. Eight evaluation criteria were identified based on their relevance to reinforced concrete performance in tropical environments. These criteria included compressive strength, water absorption, chloride penetration resistance, durability, bond compatibility, ease of installation, stability during concreting, and cost efficiency.

Each criterion was evaluated using a five-point rating scale ranging from 1 to 5, where higher values indicated more favorable engineering performance. The rating scales were developed from synthesized findings in related literature and existing engineering standards concerning reinforced concrete durability and construction practices. The interpretation of the rating system is presented below:

- 5 – Excellent / Highly Favorable Performance
- 4 – Good Performance
- 3 – Acceptable or Moderate Performance
- 2 – Poor Performance
- 1 – Unsatisfactory Performance

The compressive strength criterion evaluated the spacer's load-bearing capacity and resistance to crushing during reinforcement placement and concreting operations. Water absorption assessed the permeability characteristics and susceptibility of the spacer material to moisture ingress. Chloride penetration resistance examined the ability of the spacer system to prevent chloride ion migration that may initiate reinforcement corrosion. Durability evaluated the long-term resistance of the spacer material to environmental deterioration, thermal variation, and chemical attack. Bond compatibility focused on the quality of adhesion and material integration between the spacer and surrounding concrete, particularly at the Interfacial Transition Zone (ITZ). Ease of installation considered labor efficiency, handling convenience, and practical field application. Stability during concreting evaluated the spacer's ability to maintain reinforcement positioning during pouring and vibration activities. Cost efficiency assessed the balance between initial material cost and long-term maintenance implications.

To reflect the relative importance of each criterion under tropical exposure conditions, corresponding weights were assigned within the MCDA framework. Higher weights were allocated to chloride penetration resistance and bond compatibility due to their direct influence on reinforcement protection and structural durability. Durability was also assigned a significant weight because of its importance in ensuring long-term serviceability under aggressive environmental conditions. The remaining criteria were distributed proportionally to incorporate both structural and practical construction considerations. The assigned criterion weights are shown in Table 9.

The weighted score for each spacer system was calculated using the Weighted Decision Matrix method. Individual criterion ratings were multiplied by their assigned weights, and the resulting values were summed to determine the total performance score of each spacer type. The spacer system with the highest cumulative weighted score was considered the most suitable for reinforced concrete structures in tropical environments.

To improve the reliability of the evaluation, the scoring and weighting process was guided by

documented engineering principles, durability requirements, and published research findings related to concrete cover protection and reinforcement corrosion prevention. The study did not involve laboratory experimentation; therefore, conclusions were limited to the comparative evaluation of synthesized literature and established engineering data. Despite this limitation, the methodology provides a structured and technically grounded framework for assessing the suitability of concrete spacer systems in tropical reinforced concrete construction.

### III. RESULT AND FINDINGS

The comparative evaluation of the three concrete spacer systems revealed significant differences in their mechanical performance, durability characteristics, and long-term suitability for reinforced concrete structures exposed to tropical environmental conditions. Using the Multi-Criteria Decision Analysis (MCDA) framework, the study assessed the overall effectiveness of cement-based spacers, polymer-coated spacers, and stone or brick spacers based on eight engineering performance criteria. The findings indicate that the material composition and interfacial behavior of spacers substantially influence the protective capability of the concrete cover and the long-term durability of reinforced concrete members.

Table 1: Compressive Strength Rating of Concrete Spacer Systems

Spacer type	Mechanical Capacity	Rating
Cement Based	Very High	5
Polymer-Coated	Moderate	3
Stone/Bricks	Very Low	1

Cement-based spacers achieved the highest rating (5) because they are materially identical to the surrounding concrete, allowing for a chemical and mechanical bond that creates a monolithic cover. Polymer-coated spacers (3) introduce a mechanical slip-plane due to their smooth coating. Stone and brick spacers (1) are highly porous or inert inclusions that offer no chemical bond and can lead to localized weakness.

Table 2: Water Absorption Rating of Concrete Spacer Systems

Evaluation Criteria	Cement-Based	Polymer-Coated	Stone or Brick
Water Absorption rate	4	5	1
Capillary Suction Resistance	4	5	1
Interfacial Porosity Risk	3	5	1
Composite Score	3.7	5	1

Polymer-coated spacers ranked highest in absorption resistance (5) due to their non-porous barrier. Cement-based spacers (3.7) show standard performance but carry the risk of micro-cracking at the ITZ. Stone and brick spacers (1) act as sponges, wicking moisture directly to the reinforcement.

Table 3: Chloride Penetration Resistance Rating of Concrete Spacer System

Evaluation Criteria	Cement-Based	Polymer-Coated	Stone/Brick
Chloride Ion Diffusion Resistance	4	5	1
Interface Impermeability (ITZ)	3	5	1
Chemical Passivity Support	5	1	1
Composite Score	4.0	3.7	1.0

Cement-based spacers (4.0) maintain a high alkalinity (pH > 12.5), supporting the passive layer around the steel. While polymer coatings (3.7) hinder chloride migration through the spacer body, ions can often travel around the spacer via the ITZ. Stone and brick (1.0) provide virtually zero defense.

Table 4: Durability Rating of Concrete Spacer Systems

Evaluation Criteria	Cement-Based	Polymer-Coated	Stone/Brick
Sulphate & Acid resistance	4	5	1
Interfacial Stability	5	2	1
Service Life Predictability	5	4	1
Composite Score	4.7	3.7	1.0

The durability score reflects the material's ability to withstand tropical stressors over a 50-year design life. Cement-based spacers received a high score (4.7) because their coefficient of thermal expansion is identical to the surrounding concrete, preventing micro-gaps during the extreme temperature shifts common in tropical afternoons. Polymer-coated spacers (3.7) provide an excellent chemical barrier, but the risk of "differential thermal expansion" at the interface can lead to debonding over time. Stone and brick (1.0) failed this criterion as they introduce non-standardized minerals into the structure that may react poorly with the cement paste.

Table 5: Bond Compatibility of Concrete Spacers in Tropical Region

Spacer type	Bond Compatibility	Rating
Cement Based	Very High	5.0
Polymer-Coated	Low	2.0
Stone/Bricks	Low	2.0

Cement-based spacers are the "gold standard" for bond compatibility (5.0), providing a seamless, monolithic bond with the structures. Polymer-coated and stone/brick spacers (2.0) exhibit weak interface characteristics that can trigger micro-cracking and increased permeability.

Table 6: Ease of Installation of different Spacers

Evaluation Criteria	Cement-Based	Polymer-Coated	Stone/Brick
Handling and Weight	3	5	2
Placement Speed	4	5	2
Composite Score	3.5	5	2

Practicality on the construction site is essential for ensuring the spacers are actually used correctly. Polymer-coated spacers scored highest (5.0) here due to their lightweight nature and often integrated "snap-on" clips that allow for rapid attachment to rebar. Cement-based spacers (3.5) are heavier and require tie-wires, which increases labor time. Stone and brick (2.0) are difficult to install consistently as they lack any attachment mechanism and must be manually wedged into place, often leading to incorrect positioning.

Table 7: Stability during concreting of different types of concrete spacer system

Evaluation Criteria	Cement-Based	Polymer-Coated	Stone/Brick
Load-Bearing capacity	5	3	3
Movement During Vibration	4	3	2
Shape Uniformly	4	5	1
Composite Score	4.3	3.6	2.0

Stability refers to the spacer's ability to remain in place during the high-pressure pouring and vibration of wet concrete. Cement-based spacers (4.3) are typically heavy and stable, resisting displacement. Polymer-coated spacers (3.6) can sometimes shift or "float" if not clipped tightly. Stone and brick (2.0) scored the lowest; field observations show they frequently shift during vibration, leading to "rebar touching the formwork," which results in immediate exposure and future structural failure.

Table 8: Cost Efficiency of Concrete Spacers

Spacer type	Initial Cost	Rating
Cement Based	Very High	5
Polymer-Coated	Moderate	3
Stone/Bricks	High	4

While Stone and Brick are the cheapest (often considered "zero-cost" site debris), they scored poorly (1.0) in true cost-efficiency because they lead to expensive repairs and shortened structural life. Cement-based spacers (5.0) represent the best value-for-money, balancing a moderate purchase price with long-term maintenance savings. Polymer-coated spacers (3.0) are the most expensive option, often requiring importation or specialized manufacturing, which may not be feasible for all local projects in the Philippines.

Table 9: Weighted Decision Matrix of Concrete Spacer Systems

Criterion	Weight	Cement-Based	Polymer-Coated	Stone/Bricks
Compressive Strength (Mechanical Capacity)	0.10	0.50	0.30	0.10
Water Absorption/ Porosity	0.10	0.37	0.50	0.10
Chloride Penetration Resistance	0.20	0.80	0.74	0.20
Durability	0.15	0.705	0.555	0.15
Bond Compatibility	0.20	1.00	0.40	0.40
Ease of Installation	0.10	0.35	0.50	0.20
Stability During Concreting	0.10	0.43	0.36	0.20
Cost Efficiency	0.10	0.50	0.30	0.40
Total	1.00	4.655	3.655	1.75

The overall evaluation shows that the cement-based spacers obtained the highest total score of 4.655, followed by the polymer-coated spacer with a score of 3.655, while the stone/Bricks spacers recorded the lowest score of 1.75. These results indicate a clear

difference in performance among three spacer systems when all criteria are considered collectively.

#### IV. CONCLUSION

This study presented a comparative evaluation of cement-based spacers, polymer-coated spacers, and stone or brick spacers used in reinforced concrete structures exposed to tropical environmental conditions. Using a Multi-Criteria Decision Analysis (MCDA) framework, the spacer systems were assessed according to eight engineering performance criteria, including compressive strength, water absorption, chloride penetration resistance, durability, bond compatibility, ease of installation, stability during concreting, and cost efficiency.

The findings revealed that cement-based spacers achieved the highest overall weighted score of 4.655, indicating superior overall performance among the evaluated systems. Their material compatibility with surrounding concrete allowed the formation of a monolithic bond that minimized interfacial weaknesses and improved long-term durability. Cement-based spacers also demonstrated strong resistance to chloride penetration, stable mechanical behavior, and improved structural integration under tropical exposure conditions.

Polymer-coated spacers demonstrated satisfactory overall performance, particularly in terms of water resistance, low permeability, and ease of installation. Their non-porous characteristics provide effective protection against direct moisture penetration. However, the study identified potential limitations associated with interfacial bonding and differential thermal expansion, which may contribute to long-term debonding and reduced durability under severe environmental exposure.

While stone or brick spacers obtained the lowest overall performance rating among the evaluated systems. Their high porosity, irregular geometry, inconsistent material characteristics, and weak interfacial compatibility may increase the risk of moisture migration, chloride penetration, reinforcement corrosion, and premature concrete deterioration. Although these materials are commonly used because of their low initial cost and availability,

the findings indicate that their application may compromise the long-term durability and serviceability of reinforced concrete structures.

The study demonstrates that the selection of appropriate concrete spacer systems significantly influences the durability and protective performance of reinforced concrete members exposed to aggressive tropical environments. The findings provide a technically grounded basis for improving reinforcement protection, reducing maintenance-related deterioration, and enhancing the long-term serviceability of reinforced concrete infrastructure in tropical construction practice.

## V. RECOMMENDATION

In conclusion of the comparative evaluation of concrete spacer systems, the following recommendations are proposed to enhance the durability and serviceability of reinforced concrete structures in tropical environment.

1. Developers should prioritize Cement-Based spacers, it is highly recommended to utilize it for all primary structural members, as they achieved the highest performance score (4.655) due to their material compatibility and superior bond performance.
2. The use of stone or brick fragments as spacers should be strictly prohibited in professional construction. As these materials recorded the lowest score (1.750) and act as "sponges" that wick moisture directly to the reinforcement.
3. While polymer-coated spacers offer excellent moisture resistance (5.0), they should be reserved for applications where ease of installation is the primary concern and where thermal fluctuations are minimal to avoid interfacial debonding.
4. Future researchers should transition from this qualitative framework (4.655 for cement-based) to experimental laboratory testing, including accelerated chloride diffusion and pull-out tests to quantify bond strength.
5. A detailed life-cycle cost analysis should be conducted to demonstrate how the "Very High" initial rating of cement-based spacers (5.0) translates into significant long-term maintenance savings compared to cheaper alternatives.

## REFERENCES

- [1] A. M. Neville, *Properties of Concrete*, 5th ed. London, UK: Pearson Education, 2011. (The fundamental source for concrete material science).
- [2] S. Alzyoud, H. S. Wong, and N. R. Buenfeld, "Improving the spacer-concrete interface for bond strength and durability," *Purdue University e-Pubs*, 2016. (Directly supports your discussion on Bond Compatibility and the ITZ).
- [3] P. K. Mehta and P. J. M. Monteiro, *Concrete: Microstructure, Properties, and Materials*, 4th ed. New York: McGraw-Hill Education, 2014. (Essential for explaining chloride penetration and reinforcement corrosion).
- [4] British Standards Institution, *BS 7973-1:2001 - Spacers and chairs for steel reinforcement and their specification: Product specifications*, 2001. (The primary industry standard for spacer performance).
- [5] A. Seneviratne and S. Ganeshan, "Performance of polymer-based materials in concrete durability under aggressive environments," 2020. (Provides the scientific basis for your evaluation of polymer-coated spacers).
- [6] American Concrete Institute, *ACI 318-19: Building Code Requirements for Structural Concrete and Commentary*, 2019. (Justifies your nominal cover thickness requirements).
- [7] I. Lapiro, R. Eid, and K. Kovler, "Degradation of RC columns under combined exposure to chloride-induced corrosion and axial loading," *Materials*, vol. 17, no. 5, 2024. (Relevant for your focus on column degradation in tropical zones).
- [8] F. Muslim, H. S. Wong, and N. R. Buenfeld, "The Interfacial Transition Zone between concrete and various spacer materials," *Magazine of Concrete Research*, 2017. (Crucial for your "Interfacial Adhesion" results).
- [9] D. Wilson, "Quality concrete surfaces mean a longer life asset," in *Tailor Made Concrete Structures*, J. C. Walraven and D. Stoelhorst, Eds., CRC Press, 2008, p. 116. (Links spacer stability to long-term surface durability).

- [10] J. Wang et al., "Weathering resistance of novel sustainable prefabricated thermal insulation wall," *Frontiers in Materials*, vol. 11, 2024. (Supports your findings on thermal stability and environmental stressors).
- [11] A. Gojević et al., "Resistance of concrete with crystalline hydrophilic additives to chloride penetration," *Applied Sciences*, vol. 14, 2024. (Supports your results on chloride resistance).
- [12] Swiss Re, "Building resilience to climate events: Devastating storms and extreme precipitation," 2023. (Contextualizes the extreme weather stressors in tropical environments).