Utilization Of Kota Stone Slurry Powder and Recycled Aggregate for Rigid Pavement

[1] Aditya Jakhar, [2] Mahendra Chaudhary

[1] MTech Scholar, Department of Transportation Engineering (Structural Engg.), MBM University, Jodhpur (Rajasthan),

[2] MTech Scholar, Department of Transportation Engineering (Structural Engg.), MBM University, Jodhpur (Rajasthan),

Abstract: This research paper highlights the use of waste materials such as recycled coarse aggregate (RCA) and stone slurry powder (SSP) in the production of concrete, which offers significant environmental and economic benefits. The aim of this study was to investigate the impact of substituting cement with SSP on the consistency, initial and final setting time, and strength properties of concrete, as well as replacing natural coarse aggregate (NCA) with RCA and cement with SSP on the fresh and hardened properties of concrete. The experimental results showed that the substitution of cement with SSP and NCA with RCA improved the compressive strength, split tensile strength, and flexural strength of the concrete. This research contributes to sustainable construction practices by providing an alternative to depleting natural resources and reducing waste generation from stone-cutting activities. The findings of this study suggest that using SSP and RCA in concrete production has the potential to reduce the environmental impact of the construction industry while also providing a cost-effective and sustainable alternative to traditional concrete production methods. However, the use of SSP resulted in a decrease in slump, which may require more water and absorb water from the mix, leading to reduced workability. Therefore, further research is needed to investigate the long-term durability and sustainability of concrete made with SSP and RCA. In conclusion, this study demonstrates the potential for using SSP and RCA as alternative materials in concrete production to achieve stronger, more sustainable, and cost-effective construction.

Keywords: Waste Materials, Recycled Coarse Aggregate, Stone Slurry Powder, Sustainability

1. Introduction

The use of waste materials in construction has gained increasing attention in recent years due to its potential to reduce environmental impact, conserve natural resources, and minimize construction waste. In particular, the use of waste materials such as recycled coarse aggregate (RCA), stone slurry powder (SSP), and recycled concrete aggregates (RCA) has been investigated to replace natural aggregates and cement in concrete production. This paper reviews several studies that have explored the effects of incorporating these waste materials into concrete for pavement construction, investigating the mechanical properties, durability, and environmental benefits of these materials.

Anandaraj et al. examined the use of limestone residue (LP) and fly ash (FA) as partial replacements for ordinary Portland cement (OPC) in self-compacting concrete (SCC), finding that a 10% replacement of cement with LP improved compressive, flexural, and split tensile strengths. Singh and Aggarwal investigated the performance of concrete mixtures containing marble and granite powders as partial replacements for cement and sand, discovering that concrete with 10% marble powder and 25% granite powder had higher strengths than the control mix after 7 and 28 days.

Studies also explored the use of waste materials such as rice husk ash (RHA), waste marble powder (WMP), and steel fibers in concrete. Gencel et al. studied the microstructural, mechanical, and transport properties of foamed concrete exposed to high temperatures and freeze-thaw cycles, using RHA as a cement substitute and WMP as a sand replacement. The optimal blend contained 10% RHA and 50% WMP, exhibiting the highest compressive strength after 90 days. Gupta et al. tested M20 grade concrete containing varying percentages of marble dust and steel fibers, finding that the optimal combination for strength was 15% marble dust and 1% steel fiber as cement substitutes.

In addition to waste materials, the use of recycled aggregates in pavement construction has also been explored. Various studies have investigated the mechanical properties, durability, and environmental benefits of using RCA and coarse recycled aggregates (CRA) as substitutes for natural aggregates in various pavement applications. These studies demonstrate that recycled aggregates show promise in replacing a portion of natural aggregates in pavement construction, while also reducing construction waste.

Overall, the utilization of waste materials and recycled aggregates in concrete production presents a promising avenue for sustainable construction practices. However, further research is necessary to determine the long-term durability and sustainability of these materials in pavement construction.

2. Experimental Program

The following materials were used for the experimental program:

- Cement: Ordinary Portland Cement (OPC) conforming to the requirements of IS: 12269-2013 was used.
- Stone Slurry Powder (SSP): Stone Slurry Powder was used as a partial replacement for cement.
- Natural Coarse Aggregate (NCA): Crushed granite was used as the Natural Coarse Aggregate.
- Recycled Concrete Aggregate (RCA): RCA was used as a partial replacement for NCA.
- Fine Aggregate: River sand was used as fine aggregate.
- Water: Potable water was used for mixing and curing.

2.1 Mix Design and Specimen Preparation

Two concrete grades, M30 and M45, were selected for the experimental program. Cement was replaced by SSP in varying proportions (3%, 6%, 9%, 15%, and 20%), and NCA was substituted by RCA at 50%. The mix design was performed following the guidelines of IS: 10262-2009. The specimens were prepared in the form of cubes, cylinders, and beams for compressive strength, split tensile strength, and flexural strength tests, respectively.

The specimens were cast using a standard vibrating table. After casting, the specimens were covered with a plastic sheet to avoid moisture loss and left undisturbed for 24 hours. The specimens were then de-molded and cured in a water tank for 28 days at a temperature of 27±2°C. Test results of OPC shown in Table 1 and Mix proportion of M30 and M45 Table 2, respectively.

3. Testing Procedure

The nomenclature for the experimental program includes two groups: M30 and M45. Group M30 includes NCA and RCA with 0%, 3%, 6%, 9%, 15%, and 20% substitution of cement by SSP. Group M45 also includes NCA and RCA with the same substitution percentages. The nomenclature is represented by codes such as 30M0, 30M1, 30M2, 30M3, 30M4, 30M5, 30M0R, 30M1R, 30M2R, 30M3R, 30M4R, 30M5R, 45M0, 45M1, 45M2, 45M3, 45M4, 45M5, 45M0R, 45M1R, 45M2R, 45M3R, 45M4R, and 45M5R.

Table 1: Test results of OPC

S. No.	Test Name	Cement
i.	Specific gravity(g/cm^3)	3.15
ii.	IST (minutes)	175
iii.	FST (minutes)	235
iv.	Consistency(%)	31%
v.	Fineness (%)	5

Table 2: Mix proportion of M30 and M45

Materials	**M30**	**M45**
Cement	430.9302	463.25
Fine Aggregate	663.975	653.3753
Coarse aggregate (20mm)	1143.29	1125.039
Water	185.3	185.3

4. Results and Discussion

4.1 Compressive Strength

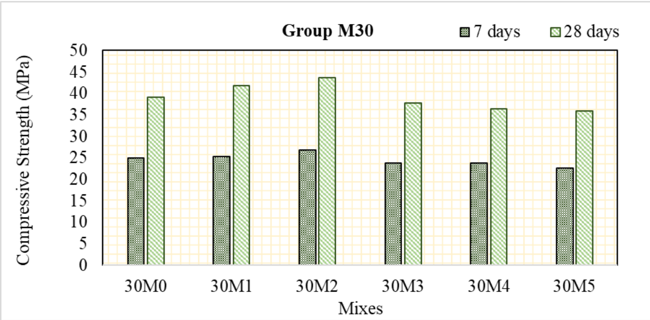

Fig 1: CS of M30 grade with NCA

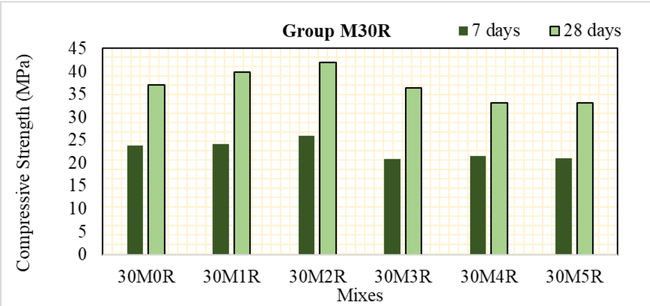

Fig 2: CS of M30 grade with RCA

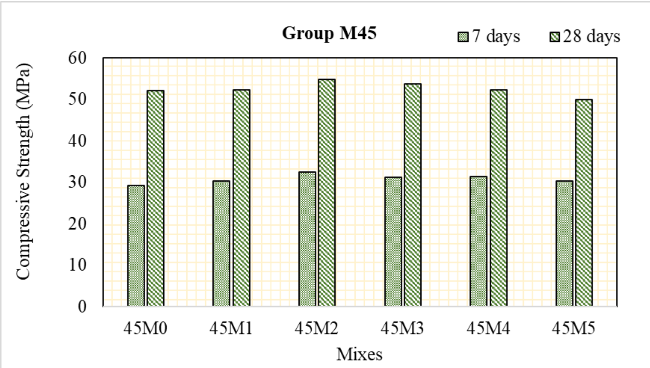

Fig 3: CS of M45 grade with NCA

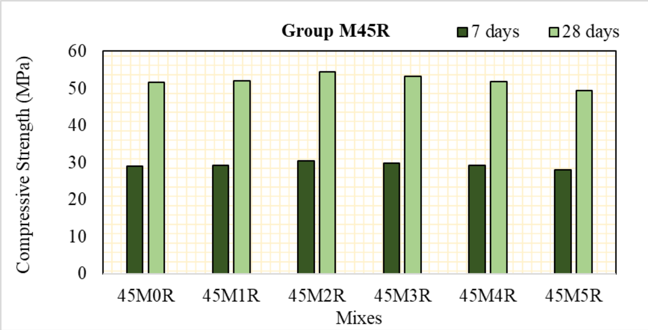

Fig 4: CS of M45 grade with RCA

The compressive strength of concrete mixes containing recycled materials was investigated in this study. Figure 1 showed that 30M2 had the highest compressive strength compared to the control mix (30M0), with an increase of 7.44% and 11.17% at 7 and 28 days, respectively. The same trend was observed in Figure 2, where 30M2R had the highest compressive strength, with an increase of 9.05% and 13.38% at 7 and 28 days, respectively. The use of RCA in place of NCA showed better performance, as demonstrated in Figures 1 to 4. Figure 3 showed that 45M2 had the highest compressive strength, with an increase of 11.11% and 4.98% at 7 and 28 days, respectively, compared to the control mix (45M0). The use of recycled materials, such as RCA and SSP, was found to increase the compressive strength of the concrete. The results also demonstrated the potential for utilizing recycled materials in concrete production, which could make it cost-effective while reducing waste.

4.2 Split Tensile Strength

The split tensile strength test was performed on cylindrical specimens (150mm diameter and 300mm height) according to IS: 5816-1999.

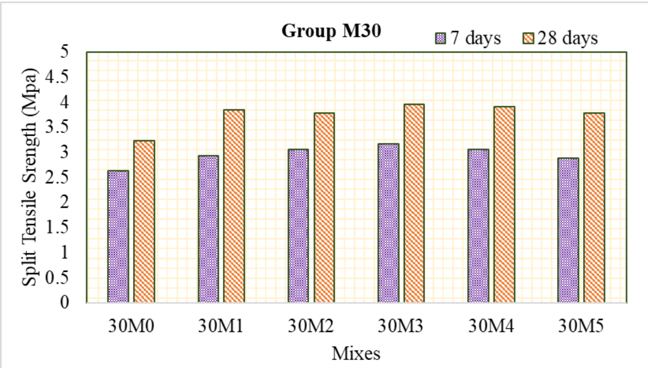

Fig 5: STS of M30 grade with NCA

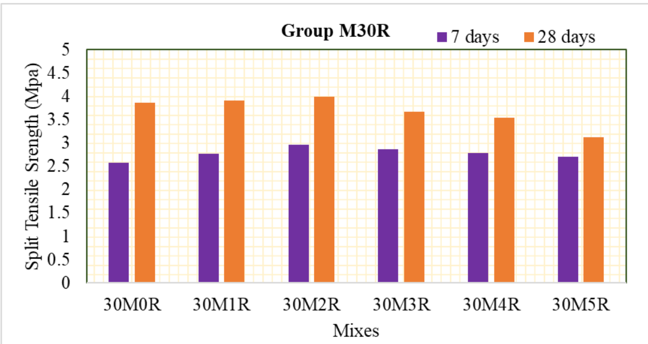

Fig 6: STS of M30 grade with RCA

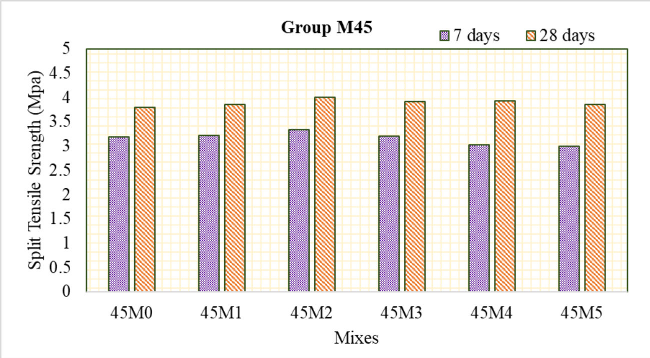

Fig 7: STS of M45 grade with NCA

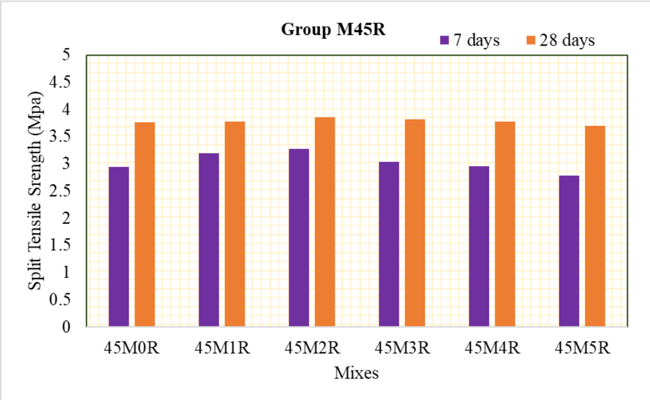

Fig 8: STS of M45 grade with RCA

The research findings indicate that the incorporation of SSP and RCA in concrete mixtures enhances their split tensile strength. Figure 5 and 7 demonstrate the highest split tensile strength attained for 30M2 and 45M2, respectively, relative to their respective control mixes. At 7 and 28 days, the split tensile strength of 30M2 increased by 15.97% and 17.03%, while 45M2 increased by 4.70% and 5.54%. Similarly, Figures 6 and 8 show the highest split tensile strength attained for 30M2R and 45M2R, respectively, relative to their respective control mixes. At 7 and 28 days, the split tensile strength of 30M2R increased by 14.73% and 3.10%, while 45M2R increased by 11.56% and 2.39%. The observed increase in split tensile strength was attributed to the filler effect of the SSP, which fills the small voids, resulting in higher strength.

4.3 Flexural Strength

The flexural strength test was conducted on beam specimens (100mm x 100mm x 500mm) as per IS: 516-1959.

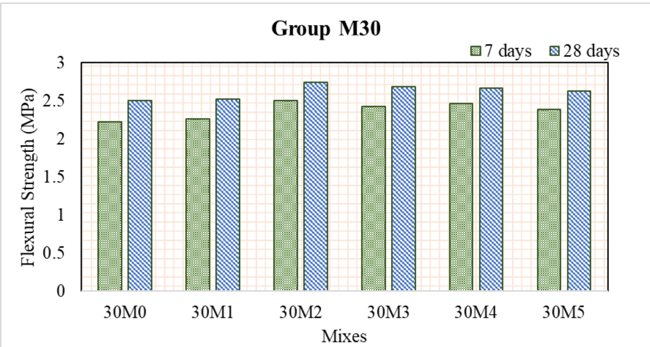

Fig 9: FS of M30 grade with NCA

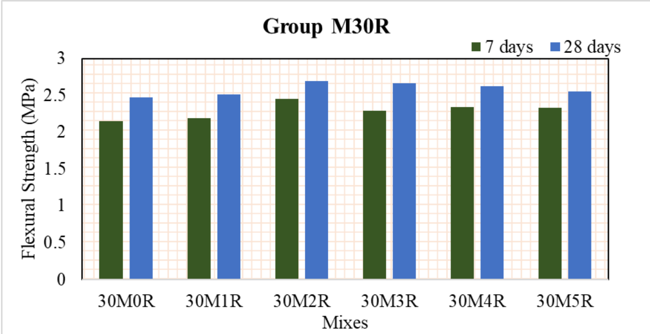

Fig 10: FS of M30 grade with RCA

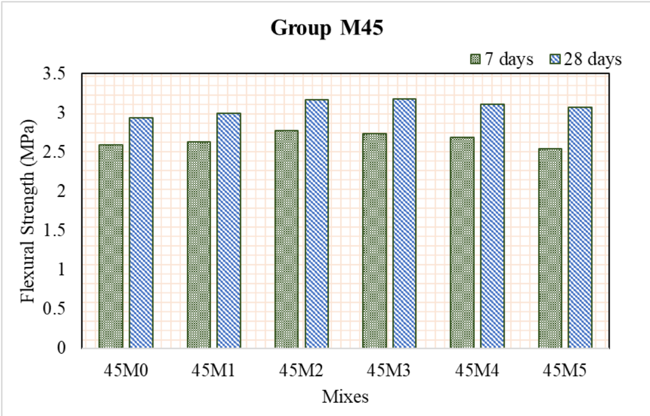

Fig 11: FS of M45 grade with NCA

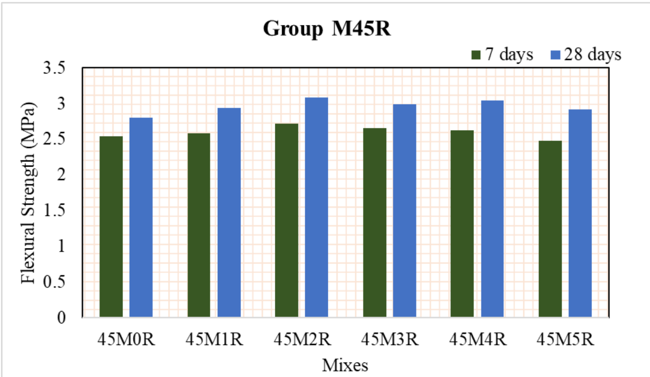

Fig 12: FS of M45 grade with RCA

These four figures 9,10,11 and 12 present the flexural strength results of different concrete mixtures using recycled aggregates and Supplementary Cementitious Materials (SCMs). Figure 9 and Figure 10 demonstrate the highest flexural strength obtained for 30M2 and 30M2R mixtures, respectively. In contrast, the control mixtures (30M0 and 30M0R) show the minimum flexural strength. The increase in flexural strength is attributed to the filler effect of the SCM (SSP), which fills the small voids leading to higher strength. Similarly, Figures 11 and 12 show that the flexural strength of 45M2 and 45M2R is higher than that of their control mixtures (45M0 and 45M0R), respectively. These results indicate that using recycled aggregates and SCMs can improve the flexural strength of concrete.

5. Conclusion

The results of the tests were analyzed to determine the effect of SSP and RCA on the mechanical properties of M30 and M45 grade concrete. Comparisons were made between the control mix and the mixes with varying proportions of SSP and RCA. The optimum percentage of SSP and RCA that yielded the desired properties without significantly affecting the performance of the concrete was identified. The study investigated the effect of partial replacement of cement with Stone Slurry Powder (SSP) and the use of recycled concrete aggregate (RCA) on the properties of concrete. The results showed that increasing the replacement level of cement with SSP resulted in a higher normal consistency of the mixes. Additionally, the initial and final setting times of the mixes increased as the replacement level increased. The slump decreased as the percentage of SSP in the mix increased, with the minimum slump recorded at 20% replacement.

Regarding the mechanical properties, the highest compressive strength was obtained for 30M2 mix, which had a 9% replacement of cement with SSP, and the highest split tensile strength was observed for the 30M2 mix as well. Similarly, the highest flexural strength was achieved for the 30M2 mix. The use of RCA also had a positive impact on the properties of concrete. Mix D, with 50% replacement of coarse RCA, had the highest compressive strength among the RCA mixes, and the maximum compressive strength was obtained for 30M2R mix at 9% replacement and 50% RCA replacement. The highest flexural strength was obtained for the 30M2R mix, while the highest split tensile strength was achieved for 30M2 mix.

In summary, the study demonstrated that partial replacement of cement with SSP and the use of RCA could improve the mechanical properties of concrete. Additionally, the results indicated that a 9% replacement of cement with SSP and a 50% replacement of RCA could be used in the production of cost-effective and sustainable concrete.

Reference

[1] Lopes et al. 2016. "Development of a Semi-Flexible Heavy Duty Pavement Surfacing Incorporating Recycled and Waste Aggregates - Preliminary Study." *Construction and Building Materials* 102: 155–61.

[2] Ali, Babar, Liaqat Ali Qureshi, and Sibghat Ullah Khan. 2020. "Flexural Behavior of Glass Fiber-Reinforced Recycled Aggregate Concrete and Its Impact on the Cost and Carbon Footprint of Concrete Pavement." *Construction and Building Materials* 262: 120820. https://doi.org/10.1016/j.conbuildmat.2020.120820.

[3] Anandaraj, S. et al. 2022. "An Experimental Study on Fly Ash (FA) and Marble Powder in the Properties of Self-Compacting Concrete (SCC)." *Materials Today: Proceedings* 52: 1771–74. https://doi.org/10.1016/j.matpr.2021.11.441.

[4] Anitha Selvasofia, S. D., A. Dinesh, and V. Sarath Babu. 2020. "Investigation of Waste Marble Powder in the Development of Sustainable Concrete." *Materials Today: Proceedings* 44: 4223–26. https://doi.org/10.1016/j.matpr.2020.10.536.

[5] Ashish, Deepankar Kumar. 2018. "Feasibility of Waste Marble Powder in Concrete as Partial Substitution of Cement and Sand Amalgam for Sustainable Growth." *Journal of Building Engineering* 15(September 2017): 236–42. https://doi.org/10.1016/j.jobe.2017.11.024.

[6] Gared, Omprakash, and Arun Gaur. 2020. "Feasibility Study of Jarosite as Cement Replacement in Rigid Pavement." *Materials Today: Proceedings* 44: 4337–41. https://doi.org/10.1016/j.matpr.2020.10.554.

[7] Gencel, Osman et al. 2021. "Effect of Waste Marble Powder and Rice Husk Ash on the Microstructural, Physico-Mechanical and Transport Properties of Foam Concretes Exposed to High Temperatures and Freeze–Thaw Cycles." *Construction and Building Materials* 291: 123374. https://doi.org/10.1016/j.conbuildmat.2021.123374.

[8] Hernández-Olivares, F. et al. 2007. "Fatigue Behaviour of Recycled Tyre Rubber-Filled Concrete and Its Implications in the Design of Rigid Pavements." *Construction and Building Materials* 21(10): 1918–27.

[9] J, Karthik, Prathibha V S, and Anand Kumar G. 2022. “Determination of Properties and Environment Due to the Usage of Flyash and Marble Waste Powder in Concrete.” *Materials Today: Proceedings* 65: 1367–74. https://doi.org/10.1016/j.matpr.2022.04.297.

[10] Karimipour, Arash, Hashem Jahangir, and Danial Rezazadeh Eidgahee. 2021. “A Thorough Study on the Effect of Red Mud, Granite, Limestone and Marble Slurry Powder on the Strengths of Steel Fibres-Reinforced Self-Consolidation Concrete: Experimental and Numerical Prediction.” *Journal of Building Engineering* 44(July): 103398. https://doi.org/10.1016/j.jobe.2021.103398.

[11] Krishna Murthy, H., S. Brijbushan, and P. D. Maneeth. 2019. “An Experimental Research on Partial Replacement of River Sand by Silica Sand and Partial Replacement of Cement by GGBS in Rigid Pavements.” *International Journal of Recent Technology and Engineering* 8(3): 4971–77.

[12] Mikhailenko, Peter et al. 2021. “Durability and Surface Properties of Low-Noise Pavements with Recycled Concrete Aggregates.” *Journal of Cleaner Production* 319: 128788. https://doi.org/10.1016/j.jclepro.2021.128788.

[13] Mohammadinia, Alireza, Mahdi M. Disfani, Guillermo A. Narsilio, and Lu Aye. 2018. “Mechanical Behaviour and Load Bearing Mechanism of High Porosity Permeable Pavements Utilizing Recycled Tire Aggregates.” *Construction and Building Materials* 168: 794–804. https://doi.org/10.1016/j.conbuildmat.2018.02.179.

[14] Muthaiyan, Uma Maguesvari, and Sundararajan Thirumalai. 2017. “Studies on the Properties of Pervious Fly Ash–Cement Concrete as a Pavement Material” ed. Raja Rizwan Hussain. *Cogent Engineering* 4(1): 1318802. https://doi.org/10.1080/23311916.2017.1318802.

[15] Palanisamy, Chandrasekaran et al. 2022. “Experimental Investigation on Self-Compacting Concrete with Waste Marble and Granite as Fine Aggregate.” *Materials Today: Proceedings* 65: 1900–1907. https://doi.org/10.1016/j.matpr.2022.05.159.

[16] Pham, Phuong Ngoc et al. 2019. “Application of Rubberized Cement-Based Composites in Pavements: Suitability and Considerations.” *Construction and Building Materials* 223: 1182–95. https://doi.org/10.1016/j.conbuildmat.2019.08.007.

[17] Poongodi, K., P. Murthi, and P. Revathi. 2022. “Influence of Coir Fibre and Recycled Aggregate on Bond Strength of Pavement Quality Concrete.” *Materials Today: Proceedings* 61: 400–405. https://doi.org/10.1016/j.matpr.2021.10.370.

[18] Rajkumar, R. et al. 2018. “Flexural Behaviour of Reinforced Concrete Beams with Partial Replacements of Metakaolin and Marble Powder.” *Materials Today: Proceedings* 34: 550–55. https://doi.org/10.1016/j.matpr.2020.03.111.

[19] Rashwan, M. A., T. M. Al - Basiony, A. O. Mashaly, and M. M. Khalil. 2020. “Behaviour of Fresh and Hardened Concrete Incorporating Marble and Granite Sludge as Cement Replacement.” *Journal of Building Engineering* 32(May): 101697. https://doi.org/10.1016/j.jobe.2020.101697.

[20] Sadati, Seyedhamed, and Kamal H. Khayat. 2016. “Field Performance of Concrete Pavement Incorporating Recycled Concrete Aggregate.” *Construction and Building Materials* 126: 691–700. http://dx.doi.org/10.1016/j.conbuildmat.2016.09.087.