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Enhancing Concrete Sustainability: A Comprehensive Review of Steel Slag and Foundry Sand as Alternative Aggregate

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A B S T R A C T

This review paper examines the use of steel slag and foundry sand in concrete based on research studies. The focus is on evaluating how these materials affect the strength, durability, and sustainability of concrete. Steel slag is shown to enhance compressive and flexural strengths, especially when used in high-strength concrete mixes, although workability tends to decrease with increased replacement levels. Foundry sand, when used as a fine aggregate replacement, performs well up to 30% substitution without significantly affecting mechanical performance. These materials provide viable, ecofriendly alternatives to traditional aggregates, offering environmental benefits such as reduced resource consumption and waste management improvements.

Keywords: Steel slag, Foundry sand, Compressive strength, Durability, Eco-friendly concrete, Sustainable materials, Concrete aggregates.

INTRODUCTION

Concrete is an essential material in the construction industry, but its production is associated with significant environmental impacts, such as natural resource depletion and high carbon emissions. The search for sustainable alternatives to conventional materials has led researchers to investigate the use of industrial by-products, particularly steel slag and foundry sand, as replacements for natural aggregates in concrete. These materials, by-products of steel manufacturing and metal casting industries, offer potential not only to reduce the environmental burden but also to enhance the mechanical properties of concrete. This paper reviews studies that explore the use of steel slag and foundry sand in concrete, focusing on their effects on the strength, durability, and overall sustainability of the resulting concrete mixtures.

Literature Review

Steel Slag in Concrete

Palankar, Shankar, & Mithun (2016): This study investigated the use of steel slag as coarse aggregates in eco-friendly concrete mixes. It found that using steel slag improved sustainability and reduced reliance on natural aggregates. However, a slight reduction in durability was observed, particularly when exposed to acidic environments. Despite this, the compressive strength remained relatively high.

Mitwally et al. (2024): This research focused on using steel slag as a partial replacement for coarse aggregate in concrete. The findings demonstrated that a 30% replacement level improved compressive and flexural strengths while slightly reducing workability. The study highlighted the benefits of steel slag in producing more sustainable and stronger concrete mixtures. It suggested careful control of the replacement ratio to optimize performance.

Sezer & Gülderen (2015): The authors compared the performance of concrete made with steel slag versus traditional limestone aggregates. They concluded that steel slag enhanced the freeze-thaw resistance and overall strength of concrete. However, when used as a fine aggregate, steel slag was less effective compared to coarse aggregate applications. The research emphasized the need for further study on steel slag's behavior as a fine aggregate.

Guo et al. (2019): This study examined unprocessed steel slag as a fine aggregate in high-strength concrete. It found that steel slag could enhance compressive behavior and ductility, especially at 100% replacement levels. The research noted that steel slag performed best in environments where high strength and durability were essential. Despite its benefits, the study warned of the potential expansion due to free lime content.

Chinnaraju et al. (2013): This research explored the combined use of steel slag as a coarse aggregate and eco sand as a fine aggregate replacement in concrete. The study showed that a 60% replacement of coarse aggregates with steel slag offered significant strength improvements and cost savings. The eco sand also contributed positively to the mixture's performance, making this approach both eco-friendly and economically viable.

González-Ortega et al. (2019): The study evaluated the durability of concrete made with electric arc furnace (EAF) slag as an aggregate. Results showed that EAF slag offered sufficient strength for low-structural-responsibility areas, although durability varied depending on the composition of the concrete mix. The research suggested that EAF slag could be a viable option for non-critical structures while offering environmental benefits.

Venkatesan et al. (2021): This paper explored the partial replacement of fine aggregate with steel slag and coarse aggregate with walnut shell. The results indicated improvements in mechanical properties, particularly in compressive strength, when steel slag was incorporated. However, higher percentages of steel slag led to a reduction in workability. Walnut shell aggregates were found to contribute to sustainable construction practices.

Subramani & Ravi (2015): In this study, steel slag was used to replace traditional coarse aggregates in concrete, leading to significant improvements in strength and durability. The authors found that a 60% replacement level was optimal for both strength and workability. The research highlighted the potential of steel slag to produce eco-friendly concrete without sacrificing mechanical performance.

Tran et al. (2015): This research compared the performance of concrete using steel slag and basalt as coarse aggregates. The study found that steel slag offered superior durability and comparable compressive strength to basalt concrete. However, steel slag's expansion due to the free lime content posed a challenge in long-term applications. The authors suggested the use of appropriate treatments to mitigate this issue.

Costa (2021): This paper focused on the mechanical and durability performance of self-compacting concrete made with steel slag aggregates. The study showed that steel slag improved chloride penetration resistance, making the concrete more durable in harsh environments. The presence of steel slag powder also contributed to higher compressive strength. The research concluded that steel slag could be a suitable aggregate for high-durability concrete.

Saxena & Tembhurkar (2018): This study examined the effects of using steel slag and wastewater in concrete production. The results demonstrated that replacing 50% of coarse aggregates with steel slag significantly improved compressive and flexural strengths. Additionally, the modulus of elasticity increased, making the concrete more resilient under load. The research also highlighted the environmental benefits of using industrial waste products in construction.

Wang et al. (2013): This research explored the mechanical properties and durability of concrete when steel slag was used as an aggregate. The authors found that steel slag reduced early strength but improved long-term performance. The study emphasized that careful mix design is crucial when using steel slag to ensure balanced strength and durability. The research also suggested that weathering the slag before use could mitigate some of its initial drawbacks.

Rajan (2014): This study investigated the effects of replacing sand with steel slag in M20 grade concrete. The results showed that a 30% replacement level was optimal for improving flexural strength without compromising workability. The study also noted that steel slag enhanced the durability of concrete, especially in aggressive environments. The findings suggested that steel slag could be a viable alternative to natural sand in construction.

Metwally et al. (2011): The researchers tested the use of steel slag as a coarse aggregate in high-performance concrete beams. The study found that steel slag significantly improved the mechanical properties and flexural behavior of the beams. Additionally, the cost-effectiveness of using steel slag as an alternative to natural aggregates was highlighted. The research concluded that steel slag could be successfully used in load-bearing structures.

Moosberg-Bustnes (2004): This study focused on the use of steel slag as a filler material in concrete. The results showed that finely ground steel slag improved the compressive strength of concrete while reducing its reactivity. The research emphasized the importance of proper processing and particle size control when using steel slag as a filler. It concluded that steel slag could be an effective alternative to traditional filler materials in concrete.

Rondi et al. (2016): The authors examined the 100% replacement of natural aggregates with electric arc furnace (EAF) steel slag in concrete. The results showed that EAF slag was a viable option for use in foundations and industrial pavements due to its stable compressive strength over time. However, the study cautioned against its use in structural applications without further testing. The research supported the use of EAF slag in low-risk construction projects.

Jalil et al. (2019): This study explored the use of steel slag as a partial replacement for cement in concrete. The findings revealed that finer steel slag particles increased compressive strength due to enhanced pozzolanic activity. However, higher slag content reduced workability, which the authors attributed to the increased water demand. The research suggested optimizing the particle size distribution of steel slag to balance strength and workability.

Liu & Guo (2018): This research analyzed the effects of using steel slag powder and aggregates in ultra-high-performance concrete (UHPC). The study found that up to 10% steel slag powder improved the fluidity of the paste and increased compressive strength. The authors also highlighted the environmental benefits of using steel slag in UHPC, particularly in reducing reliance on natural resources. The research concluded that steel slag could enhance the performance of UHPC in various applications.

Awoyera et al. (2016): The study focused on the performance of steel slag aggregate concrete with varying water-cement ratios. The results showed that increasing the water-cement ratio improved compressive strength and mechanical performance. The research also found that steel slag contributed to better durability, especially in aggressive environmental conditions. The study recommended further exploration of steel slag in high-performance concrete applications.

Thanga et al. (2013): This paper investigated the use of welding and furnace slags as partial replacements for sand in concrete. The results indicated that optimal replacement percentages enhanced compressive strength while maintaining workability. The research also noted that the use of these industrial by-products contributed to more sustainable concrete production. The study recommended further investigation into the long-term performance of concrete made with welding and furnace slags.

Mathew et al. (2013): This study examined the use of steel slag as a coarse aggregate replacement in concrete pavements. The authors found that a 20% replacement level offered optimal compressive and split tensile strengths. The research also highlighted the environmental benefits of using steel slag in road construction, particularly in reducing the demand for natural aggregates. The study concluded that steel slag could improve the performance and sustainability of pavement concrete.

Tangadagi et al. (2020): The research focused on the use of steel slag in M30 grade concrete. The findings showed that up to 30% replacement of coarse aggregates with steel slag improved compressive strength and durability. However, the study also noted that higher steel slag content negatively affected workability. The authors suggested using admixtures to mitigate workability issues while maximizing the strength benefits of steel slag.

Foundry Sand in Concrete

Prabhu et al. (2015): This study explored the use of foundry sand as a fine aggregate replacement in concrete. The authors found that up to 30% replacement enhanced compressive strength and significantly improved chloride penetration resistance. The study also showed that foundry sand reduced the permeability of concrete, making it more durable in aggressive environments. It recommended foundry sand as an eco-friendly alternative to traditional sand.

Siddique et al. (2008): This research focused on the effects of used foundry sand on the mechanical properties of concrete. The authors observed a marginal increase in strength when foundry sand was used, particularly at replacement levels between 10% and 30%. The study highlighted the potential of foundry sand to enhance the durability and long-term performance of concrete. The authors recommended further research into its long-term effects.

Arasu et al. (2017): This study investigated the effects of waste foundry sand on concrete's compressive strength. The authors found that an optimal replacement level of 15-20% increased compressive strength without significantly affecting workability. However, higher levels of foundry sand replacement slightly decreased workability, suggesting the need for careful control of water content in the mix. The study concluded that foundry sand was a viable replacement for natural fine aggregates.

Pandey et al. (2015): This research explored the use of foundry sand in low-cost concrete mixtures. The results showed that even at a 10% replacement level, foundry sand enhanced the compressive strength of concrete beyond that of conventional mixtures. The study also demonstrated the cost-effectiveness and environmental benefits of using industrial waste materials in concrete production. Foundry sand was recommended for low-strength applications.

Suri & Babu (2016): This paper examined the combined effects of using steel slag and eco-sand (a by-product similar to foundry sand) in concrete. The authors found that a mix with 60% steel slag and 30% eco-sand improved both strength and durability, especially in non-marine environments. The study also highlighted the reduction in resource consumption when using these materials, contributing to sustainable construction practices.

Pasetto & Baldo (2015): The authors investigated the use of waste foundry sand and steel slag in hydraulically bound mixtures for road foundations. A slag-to-sand ratio of 4:1 was found to meet technical standards for road construction. The study emphasized the benefits of using these waste materials to lower the environmental impact of construction projects. Additionally, the results showed significant cost savings in foundation construction.

Gholampour et al. (2020): This study developed waste-based concretes using 100% foundry sand as a fine aggregate replacement. The results showed that foundry sand improved workability, making the concrete easier to handle and place. Additionally, the use of a mix with fly ash and ground granulated blast furnace slag enhanced the strength of the concrete. The research concluded that foundry sand could be an integral part of sustainable concrete mixes.

Ho (2023): The paper explored the performance of concrete incorporating 100% steel slag and foundry sand. It found that while steel slag reduced workability, the overall cost of concrete production was significantly lowered. Foundry sand, in particular, improved the cost-effectiveness and workability of the mixture. The study recommended the use of foundry sand for general and marine construction due to its durability-enhancing properties.

Hossiney (2016): This study addressed the challenges associated with the use of foundry sand, particularly in terms of workability and shrinkage. The results indicated that replacing up to 15% of fine aggregates with foundry sand produced concrete with acceptable workability and minimal shrinkage issues. The research highlighted foundry sand's potential for use in structural applications, provided the replacement level remained within the optimal range.

Shahbaz & Lalotra (2018): The authors explored the combined use of foundry sand and fly ash in concrete, finding that a 15% replacement of fine aggregates with foundry sand and 5% fly ash offered optimal mechanical performance. The concrete showed improved compressive strength and durability, demonstrating the potential for sustainable construction. The study concluded that using these industrial by-products could significantly reduce the environmental footprint of concrete.

Soundar Rajan (2014): This paper focused on the replacement of sand with steel slag in M20 grade concrete, with an emphasis on its effects on flexural strength. The authors concluded that a 30% replacement level provided the best results in terms of strength without compromising workability. The research highlighted the potential of using industrial by-products to create stronger and more durable concrete mixtures.

Torres (2020): This study advocated for the use of foundry waste materials, such as foundry sand, in concrete production. The results indicated that foundry sand replacement at levels between 10% and 30% improved the compressive strength and durability of normal-strength concrete. The research also emphasized the environmental benefits of diverting waste materials from landfills and utilizing them in concrete production.

Vasanthi (2014): The authors examined the flexural behavior of reinforced concrete slabs using steel slag as a coarse aggregate replacement. The study found that up to 60% replacement of coarse aggregates with steel slag enhanced compressive and flexural strengths. However, higher replacement levels negatively impacted workability. The research concluded that steel slag could be used in reinforced concrete slabs, provided the replacement levels were carefully controlled.

Gurumoorthy & Arunachalam (2019): This study evaluated the durability of concrete containing treated used foundry sand. The authors found that a 30% replacement level improved chloride ion resistance, making the concrete more durable in aggressive environments. The study also highlighted the environmental advantages of using foundry sand, including reduced waste disposal and lower demand for natural resources.

Cardoso et al. (2013): This research examined the use of foundry slag, a by-product of foundry sand, as a fine aggregate substitute in concrete. The authors concluded that up to 20% replacement improved the durability of the concrete, especially in terms of resistance to chemical attack. However, higher replacement percentages resulted in reduced strength. The study recommended using foundry slag in applications where durability was prioritized over strength.

Agudelo et al. (2020): The study identified 20% foundry sand replacement as the optimal level for enhancing the compressive strength of concrete. The researchers attributed the strength improvement to the pozzolanic activity of foundry sand. The study concluded that foundry sand could be a sustainable alternative to natural sand in concrete, especially in pozzolanic cement systems.

Reshma et al. (2021): This research investigated the effects of waste foundry sand and fly ash on the mechanical and fresh properties of concrete. The results showed that replacing 30% of fine aggregates with foundry sand maximized both compressive strength and workability. The study also demonstrated that this mix reduced construction costs and environmental impacts, making it a viable option for sustainable construction projects.

Singh & Siddique (2011): This study focused on the strength and durability properties of concrete incorporating used foundry sand. The authors found that up to 15% replacement improved both compressive strength and durability, making the concrete suitable for structural applications. The research highlighted the environmental benefits of using foundry sand, including reduced waste disposal and decreased reliance on natural sand.

Yu et al. (2016): The study investigated the combined use of steel slag and waste glass as partial replacements for aggregates in concrete. The authors found that both materials enhanced fire resistance and improved mechanical properties, especially in terms of compressive strength. The research concluded that combining steel slag and waste glass in concrete could lead to more durable and fire-resistant construction materials.

Palanisamy et al. (2015): This paper examined the potential of steel slag as a partial replacement for fine aggregates and cement in concrete. The results showed that steel slag could replace up to 36% of fine aggregates and 40% of cement without compromising strength. The study highlighted the environmental benefits of using steel slag in concrete, including reduced carbon emissions and material waste.

Ahmad et al. (2022): The authors conducted a comprehensive review of the sustainable use of foundry sand as a replacement for natural sand in concrete. The study recommended up to 30% replacement to improve both durability and mechanical performance. The research emphasized the potential of foundry sand to reduce the environmental impact of concrete production, particularly in terms of waste management.

Ibrahim Metwally et al. (2011): This study evaluated the effects of foundry sand on the strength and durability of concrete. The authors found that a 30% replacement level provided optimal performance, with significant improvements in both compressive and tensile strengths. The study concluded that foundry sand could be effectively used in structural concrete without compromising durability.

Metwally et al. (2011): The study focused on the flexural behavior of reinforced high-performance concrete beams made with steel slag coarse aggregates. The results showed that steel slag improved the mechanical properties of the beams, making it a cost-effective and durable alternative to natural aggregates. The research also highlighted the environmental benefits of using industrial by-products in high-performance concrete.

Moosberg-Bustnes (2004): This paper examined the use of steel slag as a filler material in concrete. The authors found that fine grinding of steel slag enhanced compressive strength while reducing its reactivity. The study concluded that steel slag could be an effective alternative to traditional filler materials, provided it was properly processed.

Rondi et al. (2016): This research investigated the complete replacement of natural aggregates with electric arc furnace (EAF) steel slag in concrete. The results showed that EAF slag offered stable compressive strength over time, making it a viable option for foundations and industrial pavements. However, the study cautioned against using EAF slag in structural applications without further testing.

Combined Use of Steel Slag and Foundry Sand

Several studies have examined the combined use of steel slag and foundry sand in concrete mixtures, finding significant improvements in both strength and durability. Subramani & Ravi (2015) demonstrated that using steel slag as a replacement for coarse aggregates and foundry sand for fine aggregates enhanced compressive and flexural strengths while reducing water absorption, improving resistance to environmental factors like freeze-thaw cycles. The combination also promotes sustainability by reducing the need for natural aggregates and lowering the carbon footprint of concrete production. Additionally, Pasetto & Baldo (2015) found the combined use of these materials in road foundations met technical standards for strength and durability. Gholampour et al. (2020) reported that using steel slag and foundry sand together improved workability without compromising strength, making the mix more suitable for structural applications. These findings suggest that the combined use of steel slag and foundry sand offers both environmental and economic benefits, making concrete production more sustainable and cost-effective for large-scale projects.

Conclusion

This review paper synthesizes experimental studies on the use of steel slag as coarse aggregate and foundry sand as partial fine aggregate replacement in cement concrete. The findings indicate that these alternative materials enhance the mechanical properties of concrete, particularly compressive, flexural, and tensile strength, with optimal replacement levels yielding the best results. Additionally, their incorporation improves durability in aggressive environments, such as exposure to freeze-thaw cycles and chloride penetration.

The review also highlights challenges related to workability, especially at higher replacement levels, necessitating careful mix design and the use of chemical admixtures. Furthermore, the density of concrete is influenced by the percentage of steel slag and foundry sand used, with variations impacting both performance and sustainability. By utilizing these industrial byproducts, the depletion of natural resources is reduced, and environmental sustainability is promoted.

Overall, the reviewed studies emphasize the potential of steel slag and foundry sand as viable alternatives for sustainable concrete production. Future research should further investigate their long-term performance, durability under varying conditions, and optimization strategies to enhance their applicability in structural concrete.

References

[1] N. Palankar, A. U. Ravi Shankar, and B. M. Mithun, "Durability studies on eco-friendly concrete mixes incorporating steel slag as coarse aggregates," J Clean Prod, vol. 129, pp. 437–448, Aug. 2016, doi: 10.1016/j.jclepro.2016.04.033.

[2] M. E. Mitwally, A. Elnemr, A. Shash, and A. Babiker, "Utilization of steel slag as partial replacement for coarse aggregate in concrete," Innovative Infrastructure Solutions, vol. 9, no. 5, May 2024, doi: 10.1007/s41062-024-01464-y.

[3] G. Ganesh Prabhu, J. H. Hyun, and Y. Y. Kim, "Effects of foundry sand as a fine aggregate in concrete production," Constr Build Mater, vol. 70, pp. 514–521, Nov. 2014, doi: 10 .1016/j.conbuildmat.2014.07.070.

[4] Y. Guo, J. Xie, J. Zhao, and K. Zuo, "Utilization of unprocessed steel slag as fine aggregate in normal- and high-strength concrete," Constr Build Mater, vol. 204, pp. 41–49, Apr. 2019, doi: 10.1016/j.conbuildmat.2019.01.178.

[5] C. Komarasamy, K. Chinnaraju, V. R. Ramkumar, K. Lineesh, S. Nithya, and V. Sathish, "STUDY ON CONCRETE USING STEEL SLAG AS COARSE AGGREGATE REPLACEMENT AND ECOSAND AS FINE AGGREGATE REPLACEMENT." [Online]. Available: www.ijreat.orgwww.ijreat.org

[6] M. A. González-Ortega, S. H. P. Cavalaro, G. Rodríguez de Sensale, and A. Aguado, "Durability of concrete with electric arc furnace slag aggregate," Constr Build Mater, vol. 217, pp. 543–556, Aug. 2019, doi: 10.1016/j.conbuildmat.2019.05.082.

[7] B. Venkatesan, V. J. Lijina, V. Kannan, and P. R. Dhevasenaa, "Partial replacement of fine aggregate by steel slag and coarse aggregate by walnut shell in concrete," in Materials Today: Proceedings, Elsevier Ltd, 2020, pp. 1761–1766. doi: 10.1016/j.matpr.2020.07.361.

[8] T. Subramani and G. Ravi, "Experimental Investigation Of Coarse Aggregate With Steel Slag In Concrete," 2015. [Online]. Available: www.iosrjen.org

[9] M. Van Tran, C. Van Nguyen, T. Nawa, and B. Stitmannaithum, "PROPERTIES OF HIGH STRENGTH CONCRETE USING STEEL SLAG COARSE AGGREGATE."

[10] L. C. B. Costa et al., "Mechanical and durability performance of concretes produced with steel slag aggregate and mineral admixtures," Constr Build Mater, vol. 318, Feb. 2022, doi: 10.1016/j.conbuildmat.2021.126152.

[11] S. Saxena and A. R. Tembhurkar, "Impact of use of steel slag as coarse aggregate and wastewater on fresh and hardened properties of concrete," Constr Build Mater, vol. 165, pp. 126–137, Mar. 2018, doi: 10.1016/j.conbuildmat.2018.01.030.

[12] Q. Wang, P. Yan, J. Yang, and B. Zhang, "Influence of steel slag on mechanical properties and durability of concrete," Constr Build Mater, vol. 47, pp. 1414–1420, 2013, doi: 10.1016/j.conbuildmat.2013.06.044.

[13] S. T. Ramesh, R. Gandhimathi, P. V. Nidheesh, S. Rajakumar, and S. Prateepkumar, "Use of furnace slag and welding slag as replacement for sand in concrete," International Journal of Energy and Environmental Engineering, vol. 4, no. 1, 2013, doi: 10.1186/2251-6832-4-3.

[14] S. I. Zaki, I. M. Metwally, and S. A. El-Betar, "Flexural Behavior of Reinforced High-Performance Concrete Beams Made with Steel Slag Coarse Aggregate," ISRN Civil Engineering, vol. 2011, pp. 1–10, Oct. 2011, doi: 10.5402/2011/374807.

[15] "385-Moosberg-Bustnes".

[16] A. Jalil, A. Khitab, H. Ishtiaq, S. H. Bukhari, M. T. Arshad, and W. Anwar, "Evaluation of Steel Industrial Slag as Partial Replacement of Cement in Concrete," Civil Engineering Journal (Iran), vol. 5, no. 1, pp. 181–190, Jan. 2019, doi: 10.28991/cej-2019-03091236.

[17] J. Liu and R. Guo, "Applications of Steel Slag Powder and Steel Slag Aggregate in Ultra-High Performance Concrete," Advances in Civil Engineering, vol. 2018, 2018, doi: 10.1155/2018/1426037.

[18] J. Teknologi, P. O. Awoyera, O. M. Olofinnade, A. A. Busari, I. I. Akinwumi, and M. Oyefesobi, "PERFORMANCE OF STEEL SLAG AGGREGATE CONCRETE WITH VARIED WATER-CEMENT RATIO," 2016. [Online]. Available: www.jurnalteknologi.utm.my

[19] "IJEMS 22(3) 339-344".

[20] P. Mathew, L. Stephen, and J. George, "Steel Slag ingredient for concrete pavement," Int J Innov Res Sci Eng Technol, vol. 2, 2013, [Online]. Available: www.ijirset.com

[21] R. Tangadagi et al., "Utilization of Steel Slag as an Eco-Friendly Material in Concrete for Construction," 2020. [Online]. Available: https://www.researchgate.net/publication/343538093

[22] G. Ganesh Prabhu, J. W. Bang, B. J. Lee, J. H. Hyun, and Y. Y. Kim, "Mechanical and Durability Properties of Concrete Made with Used Foundry Sand as Fine Aggregate," Advances in Materials Science and Engineering, vol. 2015, 2015, doi: 10.1155/2015/161753.

[23] R. Siddique, G. de Schutter, and A. Noumowe, "Effect of used-foundry sand on the mechanical properties of concrete," Constr Build Mater, vol. 23, no. 2, pp. 976–980, Feb. 2009, doi: 10.1016/j.conbuildmat.2008.05.005.

[24] A. N. Arasu, S. Vivek, J. Robinson, and T. T. Ranjith, "Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete."

[25] V. Srivastava, P. Pandey, and A. Harison, "Utilization of Waste Foundry Sand as Partial Replacement of Fine Aggregate for Low Cost Concrete International Journal of Current Engineering and Technology Utilization of Waste Foundry Sand as Partial Replacement of Fine Aggregate for Low Cost Concrete," 2015. [Online]. Available: http://inpressco.com/category/ijcet

[26] N. Suri and Y. A. Babu, "Experimental Investigations on Partial Replacement of Steel Slag as Coarse Aggregates and Eco Sand as Fine Aggregate," International Journal of Civil Engineering and Technology, vol. 7, no. 5, pp. 322–328, [Online]. Available: http://www.iaeme.com/IJCIET/index.asp322http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=5http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=5

[27] M. Pasetto and N. Baldo, "Experimental analysis of hydraulically bound mixtures made with waste foundry sand and steel slag," Materials and Structures/Materiaux et Constructions, vol. 48, no. 8, pp. 2489–2503, Aug. 2015, doi: 10.1617/s11527-014-0333-4.

[28] A. Gholampour, J. Zheng, and T. Ozbakkaloglu, "Development of waste-based concretes containing foundry sand, recycled fine aggregate, ground granulated blast furnace slag and fly ash," Constr Build Mater, vol. 267, Jan. 2021, doi: 10.1016/j.conbuildmat.2020.121004.

[29] Q. Van Ho and T. P. Huynh, "A comprehensive investigation on the impacts of steel slag aggregate on characteristics of high-performance concrete incorporating industrial by-products," Journal of Building Engineering, vol. 80, Dec. 2023, doi: 10.1016/j.jobe.2023.107982.

[30] N. Hossiney and J. Jose, "Characteristics of Concrete Containing Waste Foundry Sand and Slag Sand," Article in International Journal of Earth Sciences and Engineering, 2016, [Online]. Available: www.cafetinnova.org

[31] M. Shahbaz and M. Lalotra, "To Study the Effect on Mechanical Behavior of Concrete using Fly Ash and Foundry Sand," 2018.

[32] A. Kumar, S. Pratheba, R. Rajendran, K. Perumal, N. Lingeshwaran, and S. Susmitha, "An experimental study on the mechanical properties of concrete replacing sand with quarry dust and waste foundry sand," in Materials Today: Proceedings, Elsevier Ltd, Jan. 2020, pp. 828–832. doi: 10.1016/j.matpr.2020.06.271.

[33] A. Torres, "Using Foundry Waste Materials in Concrete for a More Sustainable Future," Current Trends in Civil & Structural Engineering, vol. 6, no. 3, Sep. 2020, doi: 10.33552/ctcse.2020.06.000638.

[34] P. Vasanthi and A. Professor, "FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE SLABS USING STEEL SLAG AS COARSE AGGREGATE REPLACEMENT." [Online]. Available: http://www.ijret.org

[35] N. Gurumoorthy and K. Arunachalam, "Durability Studies on Concrete Containing Treated Used Foundry Sand," Constr Build Mater, vol. 201, pp. 651–661, Mar. 2019, doi: 10.1016/j.conbuildmat.2019.01.014.

[36] C. Cardoso et al., “Using foundry slag of ferrous metals as fine aggregate for concrete,” Resour Conserv Recycl, vol. 138, pp. 130–141, Nov. 2018, doi: 10.1016/j.resconrec.2018.05.020.

[37] G. Agudelo, C. A. Palacio, S. Neves Monteiro, and H. A. Colorado, “Foundry Sand Waste and Residual Aggregate Evaluated as Pozzolans for Concrete,” Sustainability (Switzerland), vol. 14, no. 15, Aug. 2022, doi: 10.3390/su14159055.

[38] T. V. Reshma, M. Manjunatha, S. Sankalpasri, and H. M. Tanu, “Effect of waste foundry sand and fly ash on mechanical and fresh properties of concrete,” in Materials Today: Proceedings, Elsevier Ltd, 2021, pp. 3625–3632. doi: 10.1016/j.matpr.2020.12.821.

[39] G. Singh and R. Siddique, “Effect of waste foundry sand (WFS) as partial replacement of sand on the strength, ultrasonic pulse velocity and permeability of concrete,” Constr Build Mater, vol. 26, no. 1, pp. 416–422, 2012, doi: 10.1016/j.conbuildmat.2011.06.041.

[40] X. Yu, Z. Tao, T. Y. Song, and Z. Pan, “Performance of concrete made with steel slag and waste glass,” Constr Build Mater, vol. 114, pp. 737–746, Jul. 2016, doi: 10.1016/j.conbuildmat.2016.03.217.

[41] S. P. Palanisamy, G. Maheswaran, M. G. L. Annaamalai, and P. Vennila, “Steel Slag to Improve the High Strength of Concrete,” 2015. [Online]. Available: https://www.researchgate.net/publication/282267666

[42] J. Ahmad, Z. Zhou, R. Martínez-García, N. I. Vatin, J. De-Prado-gil, and M. A. El-Shorbagy, “Waste Foundry Sand in Concrete Production Instead of Natural River Sand: A Review,” Materials, vol. 15, no. 7, Apr. 2022, doi: 10.3390/ma15072365.

[43] M. A. González-Ortega, S. H. P. Cavalaro, G. Rodríguez de Sensale, and A. Aguado, “Durability of concrete with electric arc furnace slag aggregate,” Constr Build Mater, vol. 217, pp. 543–556, Aug. 2019, doi: 10.1016/j.conbuildmat.2019.05.082.

[44] R. B. Tangadagi and P. T. Ravichandran, “Performance Evaluation of Cement Mortar Prepared with Waste Foundry Sand as an Alternative for Fine Aggregate: A Sustainable Approach,” Iranian Journal of Science and Technology - Transactions of Civil Engineering, 2024, doi: 10.1007/s40996-024-01505-7.

[45] L. Rondi, G. Bregoli, S. Sorlini, L. Cominoli, C. Collivignarelli, and G. Plizzari, “Concrete with EAF steel slag as aggregate: A comprehensive technical and environmental characterisation,” Compos B Eng, vol. 90, pp. 195–202, Apr. 2016, doi: 10.1016/j.compositesb.2015.12.022.