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Review

Mining Waste Materials in Road Construction

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Abstract: Resource depletion and environmental degradation have resulted from the substantial increase in the use of natural aggregates and construction materials brought on by the growing demand for infrastructure development. Road building using mining waste has become a viable substitute that reduces the buildup of industrial waste while providing ecological and economic advantages. In order to assess the appropriateness of several mining waste materials for use in road building, this study investigates their engineering characteristics. These materials include slag, fly ash, tailings, waste rock, and overburden. To ensure long-term performance in pavement constructions, it evaluates their tensile and compressive strength, resistance to abrasion, durability under freeze-thaw cycles, and chemical stability. The review indicate that waste rock and slag have excellent mechanical strength and durability, which makes them suitable alternatives to conventional aggregates for high-traffic roadways. Despite their need for stabilization, fly ash and tailings have important pozzolanic qualities that improve subgrade reinforcement and soil stability. When properly processed, overburden materials can be used again for subbase layers and embankment building. This review also assesses the environmental effects, such as acid production and leachability, to make sure that the use of mining waste complies with legal and sustainable requirements. This review paper helps to reduce landfill disposal, minimize carbon emissions, and promote circular economy concepts in the construction sector by maximizing the use of mining waste in road building. The findings show that mining by-products have the potential to be widely used in infrastructure projects as an economical and ecologically friendly substitute for traditional materials. To enable broad adoption, future studies should concentrate on improving stabilizing methods, long-term field performance tracking, and policy frameworks.

Keywords: mining waste; compressive strength; tensile strength; road construction; sustainable materials; pozzolanic reaction; waste utilization

1. Introduction

The expansive development of infrastructure has led to increased consumption of virgin aggregates in road construction, resulting in significant environmental impacts. High carbon emissions, habitat devastation, and resource depletion are only a few of the negative environmental effects of these materials' extraction and processing [1]. One sustainable solution to these problems is the use of waste mining materials in road construction, which has been investigated by engineers and researchers. Large volumes of waste, such as tailings, waste rock, slag, fly ash, and overburden materials, are produced by mining operations and are frequently dumped in landfills or abandoned sites, which pollute the air, contaminate the land, and depletes water supplies [2]. Reusing these byproducts as building materials rather than disposing of them as waste provides a workable answer to the problems of infrastructure and waste management. In addition to minimizing the environmental impact of mining operations, using mining waste materials for road construction also reduces the need for virgin resource extraction, which lowers prices and advances the ideas of the circular economy. From an economic standpoint, the expenses of acquiring, transporting, and disposing of resources can be greatly decreased by using waste materials in road construction. Infrastructure projects can be cost saving and promote sustainable construction practices by utilizing these mining wastes. And obviously this can lower the carbon footprint as it reduces energy intensive processes. The idea of using mining waste in construction is consistent with the circular economy and

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sustainable development concepts, which place an emphasis on resource efficiency, waste minimization, and environmental preservation [3].

The many forms of mining waste used in road construction are examined in this paper, along with its engineering characteristics, uses, and advantages for the environment and the economy, as well as any drawbacks or restrictions. This study intends to demonstrate the viability of mine waste as a sustainable building material by examining these variables and offering guidance to researchers, engineers, and politicians to encourage its broader use in road infrastructure projects.

2. Types of Mining Waste Used in Road Construction

Many of the waste materials produced by mining activities have engineering qualities that make them appropriate for use in road construction. When appropriately stabilized and processed, these materials can be utilized in different road structural layers, lowering the need for virgin resources and lessening their negative effects on the environment. The basic types of mining waste utilized in road construction involve tailings, waste rock, slag, fly ash and bottom ash, and overburden materials. Each type has its distinct physical, chemical and mechanical properties that influence its suitability for different road construction applications.

2.1. Tailings

When valuable minerals are extracted from ores, the finely powdered residues that remain are known as mining tailings [4]. Typically stored in tailings ponds or impoundments, these materials pose next level environment risks due to their potential to leach heavy metals and other contaminants into surrounding ecosystems. However, tailings can be used again as subbase and base materials for roads if they are stabilized with cementitious binders or geopolymers. Because tailings are fine-grained, they can improve soil stabilization and lessen the requirement for conventional binding agents [5].Tailings that have been appropriately handled have been shown to have great compressive strength and durability, which makes them appropriate for rural road development and low-traffic road applications [6].

2.2 Waste Rock

Waste rock consists of large fragments of rock and soil deleted during mining operations to deposits ore access. This material can be used in place of natural aggregates in road construction because it is usually coarser and more durable than tailings [7]. Waste rock can be used in boarding, subbase layers, and drainage structures due to its high load-bearing capacity and resistance to weathering. Cursed and graded waste rock provides excellent mechanical linking properties, enhancing the stability and longevity of roads. Besides, its use as a substitute for conventional aggregates helps mitigate the environment impact of aggregate quarrying. Although, the existence of sulfide minerals in some waste rock materials needs careful handling to prevent acid mine drainage, which can lead to water and soil contamination. Finally, there are significant financial advantages to employing waste rock. Construction projects can save money for contractors by reducing their reliance on pricey natural aggregates through the reuse of mining leftovers. Furthermore, using waste rock can lessen the environmental impact of conventional mining methods, supporting a circular economy in the building industry and being in line with global sustainability standards.

2.3. Slag

Slag is a byproduct of mining metallurgical processes, especially those that refine metals like copper, steel, and lithium. Slag is frequently used in road building as an alternative to crushed stone aggregates because of its great mechanical strength, longevity, and resistance to chemical weathering [8]. For example, steel slag has been effectively used in road base layers and asphalt pavements, providing better performance in terms of load-bearing capacity and skid resistance. Lithium slag, a

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relatively new waste material, is gaining attention for its pozzolanic properties, making it a potential blinder in road construction. Indeed, it is crucial to test for leachability before utilizing slag in road infrastructure to make sure that no hazardous trace metals are released into the environment. Traces of lead, cadmium, chromium, or arsenic may be present in some types of slag, especially those that come from industrial operations like steelmaking. These metals may be harmful to the environment and human health if they seep into the soil and water. Regulatory agencies frequently demand laboratory testing utilizing techniques such as the Synthetic Precipitation Leaching Procedure (SPLP) or the Toxicity Characteristic Leaching Procedure (TCLP) in order to evaluate leachability. These tests assist in determining if slag satisfies safety requirements for usage in construction. Slag can be altered or treated before being used in infrastructure projects if leachability is an issue.

2.4 Fly Ash and Bottom Ash

Fly ash and bottom ash are combustion residues produced in coal-fired power plants, commonly associated with mining operations in coal-rich regions [9]. A fine, powdery substance with cementitious qualities, fly ash is frequently used to stabilize soil and partially replace Portland cement in concrete road pavements. It lowers the overall carbon footprint of road construction projects while enhancing the concrete's workability, strength, and durability. In embankments, bottom ash, a coarser material, is frequently used as a filler or subbase. These materials solve the issue of power plant ash disposal while also assisting in lowering reliance on traditional cement and aggregates. When using fly ash in road buildings, it is important to closely monitor the levels of unburned carbon and heavy metals like arsenic, lead, and mercury to ensure environmental safety. Unburned carbon can degrade the material's strength and possibly contribute to unwanted emissions when it's being used on roads. On the other hand, heavy metals present serious hazards of leaking into nearby ecosystems and groundwater, particularly when the material is exposed to moisture or harsh weather. To reduce these hazards, strict quality control procedures are necessary, such as routine testing for impurities and the application of binders or stabilizing agents [10].

2.5. Overburden Material

Overburden is the rock or soil layer that needs to be removed in order to access the ore being mined. Overburden is also referred to as spoil or waste. Overburdens are removed from surface mining and do not contain toxic components, unlike tailings, which is another type of underground mining waste. Interburden, a related term, refers to the material that lies between orebodies in subsurface levels [11]. Overburden, which is typically regarded as garbage, can be used for road infrastructure projects such as subgrade improvement, slope stabilization, and embankment building. When packed properly, overburden on a road construction is particularly beneficial in mining regions where the transportation of conventional construction is particularly beneficial in mining regions where the transportation of conventional construction materials is costly. Indeed, geology and mining circumstances can have a substantial impact on the composition of overburden materials. Because of this heterogeneity, site-specific evaluations are essential for determining if they are suitable for road building. To guarantee stability, durability, and environmental safety, variables like moisture content, mineral composition, particle size distribution, and possible pollutants must be examined. The effectiveness of using overburden materials such as subgrade, base, or fill material in road infrastructure is determined by standard tests such as proctor compaction, California Bearing Ratio (CBR), and permeability evaluations. A thorough assessment guarantees peak performance and reduces hazards including erosion, settling, and toxic material leaking [12].

3. Engineering Properties of Mining Waste Materials

The sustainability of mining waste materials used for road construction is determined by its engineering properties. These characteristics affect the permeability, strength, stability, durability, and environmental effect of roads constructed using these kinds of materials. Numerous laboratory

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and field tests are performed to assess the physical, mechanical, and chemical properties of mining waste in order to make sure it satisfies the necessary building requirements. In this section, the main engineering properties of different types of mining waste materials are examined, along with their use in road construction.

3.1. Physical and Mechanical Properties

The physical and mechanical properties of these materials mainly include particle size distribution, density, specific gravity, shear strength, permeability, and durability. These properties are important as it evaluate the strength, stability, and acceptability of mining waste for road building.

3.1.1. Size of Particles

Size of mining waste material effects on the compaction characteristics, permeability and load bearing capacity of constructed road. Mining waste when combined with cement or lime, tailings, which are mostly fine-grained particles (<0.075 mm), can act as a stabilizing agent. But, on the other hand, if they are not treated properly, there may occur problem of excessive dust on mix resulting water retention [13]. Likewise, waste rock is suitable for replacing aggregate used as road bases as it is coarser and contain particles ranging from gravel to boulders. Steel slag aggregates have high angle of internal friction (40° to 45°) that contribute to high stability and well graded particle distribution, thus can be used in pavement works [14]. Similarly, fine-grained materials like fly ash and bottom ash are frequently used to stabilize soil or to replace cement in concrete roadways. In the case of overburden materials, before being applied, they must be screened and graded since their grain sizes range from loose dirt to big rock pieces.

3.1.2. Density and Specific Gravity

Specific gravity and density affect a material's ability to withstand loads and compaction. Slag and waste rock are perfect for road base layers because of their high densities (bulk density ~2.8–3.5 g/cm^3) [6]. Similarly, fly ash is appropriate for soil stabilization and lightweight embankments due to its reduced density (~2.1 g/cm^3) [15]. Before being used in road layers, tailings must be stabilized since their densities vary according to the mineral content. Since overburden materials comprise a mixture of heavy and light particles, grading is necessary to get the ideal density for embankments.

3.1.3. Shear Strength and Bearing Capacity

Because shear strength determines a material's resistance to deformation under stress, it is essential for road materials' stability. Waste rock and slag exhibit high shear strength; thus, those can be excellent alternative for crushed stone, especially favorable for pavement applications [16]. Likewise, when mixed with cementitious materials, fly ash and tailings gain significant compressive and shear strengths that enable their application in stabilized subgrade layers [17]. Compaction is necessary for overburden materials to improve their bearing capacity and shear strength for subbase layers and embankments.

3.1.4. Compaction Characteristics

Proper compaction is crucial for stability, preventing settlement over time. For optimal compaction, greater moisture content is necessary for tailings. For fly ash and bottom ash to reach the appropriate compact levels, lime or cement stabilization is beneficial. High-strength Road layers may be made from slag and waste rock as they compress well under mechanical rolling.

3.1.5. Permeability and Drainage Properties

Drainage and water retention in road layers are impacted by permeability. When utilized in road foundation, tailings limited permeability necessitates drainage layers. Because slag and waste rock

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have high permeability, waterlogging in road constructions is avoided. Additives are needed to enhance the drainage properties of fly ash.

Table 1. Impact of Mining Waste Content on Concrete Compressive Strength.

Types of Mining Waste	Replacement Level (%)	Compressive Strength	Major Finding	Citation
Slag	5%	6.39	Cement and slag increase compressive strength by generating dense microstructures and improving hydration. Five percent replacement produced the best results.	[6]
Fly ash	10%	22.8	Compressive strength is increased when fly ash and cement combine to create more C-S-H (calcium silicate hydrate) gel. But too much replacement might weaken the material.	[18]
Tailing	20%	32.4	Improved early strength but reduced long-term durability.	[19]
Waste rock	25%	45.2	Enhance strength due to its rough/ angular surface	[20]
Overburn	30	29.8	Has weak performance, thus need binding agents	[19]

3.2. Chemical and Environmental Properties

Mining waste materials possess unique chemical and environmental properties that influence their suitability for road construction. The chemical composition of mining waste materials is a major factor in influencing their durability, environmental safety, and binding capacity. For road infrastructure to be free of pollutants, poisons, and instability caused by mining waste, a thorough inspection is essential.

3.2.1. Chemical Composition and Stability

Depending on the kind of ore and the mining technique, mining waste has a different chemical composition. Common components include silica, alumina, iron, calcium, and trace metals. Certain materials are perfect for stabilizing road bottoms because of their cementitious qualities, such as fly ash and slag. The presence of sulfides in some tailings, however, can result in acid mine drainage (AMD) when they encounter water and air [21]. Mining waste is frequently treated with cement or lime to increase stability, which lowers its reactivity and qualifies it for use as road subgrades and embankments [6].

3.2.2. Leachability and Environmental Impact

How quickly pollutants break down and move into soil and water is referred to as leachability. Lead, arsenic, and cadmium are among the heavy metals found in small concentrations in some mining wastes, such as coal fly ash and metal tailings, which can contaminate groundwater [22]. However, studies have also shown that leaching is reduced by compaction, encapsulation, and decreased water infiltration when mining waste is mixed into road layers under controlled settings. Many stabilizing and containment techniques are used to reduce these concerns, such as bitumen or cement encapsulation, which limits the flow of pollutants. Furthermore, neutralizing procedures using lime or other alkaline substances aid in decreasing the solubility of dangerous substances, guaranteeing environmental security [23].

3.2.3. PH and Sulfate Resistance

The chemical reactivity and long-term stability of mining waste materials are greatly influenced by their pH level. Road construction can benefit from alkaline waste products like steel slag, which can stabilize acidic soils. However, certain fly ash and tailings contain extremely acidic qualities that, if left untreated, may destroy the structural integrity of roadways.

Another challenge is sulfate content, which can react with cement and lead to expansion, cracking, and premature failure of road structures.

3.3. Durability and Weathering Resistance

The durability of mining waste materials varies, which impacts how suitable they are for road construction. Slag and waste rock are perfect for roads with heavy traffic and cold climates because of their exceptional resilience to abrasion and freeze-thaw cycles [24]. In contrast, fly ash and tailings require stabilization to prevent moisture-related degradation and improve wear resistance. The permeability and shear strength of tailings are poor, but waste rock is rough and very durable [21]. Fly ash requires a binder for structural stability; however slag has significant pozzolanic qualities that improve binding. Before being used, overburden materials need to be graded and compacted. Natural aggregates can be substituted with slag and waste rock, however fly ash and tailings require treatment to reduce acid production and leachability. Mining waste may improve the sustainability and performance of road construction when properly processed.

Table 2. Impact of Mining Waste Content on Concrete Tensile Strength.

Types of Mining Waste	Replacement Level (%)	Tensile Strength	Major Finding	Citation
Slag	10%	4.5	Improved tensile resistance due to pozzolanic reaction	[25]
Fly ash	15%	3.9	Moderate performance requires fiber reinforcement	[26]
Tailing	20%	3.1	Weak bonding, needs stabilization	[25]
Waste rock	25%	4.8	High tensile strength due to angular particle interlock	[26]
Overburn	30%	2.7	Low performance, needs additional stabilizing agents	[25]

4. Applications of Mining Waste in Road Construction

Mining waste such as we discussed before like tailings, waste rock, slag, fly ash, and overburden are increasingly being utilized in road construction due to their mechanical strength, cost-effectiveness, and environment benefits. Reusing mining waste provides a practical substitute for traditional road construction materials, lowering the need for natural aggregates while minimizing environmental impact considering growing concerns about resource depletion and sustainability

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[27]. These waste materials can be integrated into the subgrade foundation, surface layer, or other layers of a road, depending on their engineering characteristics. The following are the key applications of mining waste in road construction.

4.1. Subgrade and Subbase Layers

The Subgrade forms the foundation of a road, straight supporting all upper layers. If the subgrade is weak, the entire road structure may tolerate from settlement, cracking, or deformation. The subbase layer, which is positioned above the subgrade, improves the road's capacity to disperse loads and withstand deformation [28]. Traditionally, natural soil, crushed stone, or gravel are used to create subgrades and subbases; however, mining waste has become a more affordable option [29].

In subgrade layers, weak or expansive soils can be stabilized with mining waste, such as tailings, waste rock, and overburden materials. Tailings are perfect for roads constructed on clayey or unstable terrain because they can greatly increase soil strength and lessen shrink-swell behavior when combined with cement or lime. Compacted waste rock and overburden, which are typically coarser, can create a robust subbase layer that enhances drainage and prevents settlement. Additionally, the burden of waste storage at mining sites is lessened and land degradation is prevented by employing these materials in subgrades. For example, in Chinese road constructions, clayey subgrades have been stabilized using coal tailings and lime, boosting their bearing capacity by more than 30% [30].

4.2. Road Base Layers

One of the most important structural elements of a pavement system is the road base. Because of its strength, stability, and load-bearing ability, it guarantees that the top layers of the road will hold up under the strain of traffic and the elements. When utilized in road base layers, mining waste materials in particular, fly ash, slag, and waste rock, have demonstrated exceptional performance. For road bases, crushed mine waste rock can be compacted and used in place of natural gravel because it has a high shear strength and durability. Waste rock is especially useful in heavy traffic roads, as it resists rutting and wears better than conventional aggregates. Another high-performance substance utilized in road bases is slag, which is a byproduct of metal extraction procedures. Slag's cementitious qualities can strengthen the link between particles, increasing stiffness and performance over time [31]. The economic and structural advantages of integrating mining waste into base layers were demonstrated by an Indian study that indicated that a 30% fly ash and cement mix in road bases extended pavement lifespan by 25% [32]. Road building projects can significantly reduce costs and advance sustainable infrastructure development by substituting waste mining for natural materials.

5. Environmental and Economic Benefits

Natural resources and the environment are under a lot of strain due to the quick development of urban infrastructure and transportation systems. Traditional road building supplies, mostly natural aggregates like sand, gravel, and crushed stone, are taken out of mines and quarries, which results in overuse of these resources and related environmental damage. Furthermore, the mining sector produces enormous volumes of trash, such as fly ash, slag, tailings, and waste rock, which are usually dumped or kept in sizable garbage piles. However, it is feasible to lessen the impact on the environment, save money, and encourage long-term sustainability by integrating mining waste into road development.

5.1. Reduction in Mining Waste Disposal Issues

Large volumes of waste are produced by mining activities, and these must be stored or disposed of somehow. Large tailing ponds, waste rock piles, or slag heaps are frequently created using traditional disposal techniques, which might present long-term environmental hazards. For instance, poorly managed tailings have the potential to contaminate soil and groundwater by releasing toxic

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substances into the environment. Large garbage mounds can also disturb nearby ecosystems and occupy important land area.

By turning waste into a valuable resource, repurposing mining waste in road construction helps alleviate these disposal concerns. Various stages of road building, including subgrade stabilization and road base materials, can make use of tailings, slag, and waste rock that would otherwise need expensive storage or present environmental hazards. This offers a workable answer to the expanding issue of mining waste management, decreases environmental hazards, and lessens the requirement for sizable disposal sites. By using mining waste in this manner, hazardous waste accumulation is less likely to occur, and improved land use is made possible.

5.2. Cost Savings and Economic Feasibility

The financial savings that come with utilizing mining waste in road construction are among its main benefits. Traditional road construction materials, such as sand, gravel, and crushed stone, are derived from quarries, which need considerable financial inputs in extraction, shipping, and processing. Long-distance transportation of these commodities can also be costly and harmful to the environment because of emissions and fuel usage. On the other hand, mining waste products like fly ash, slag, and tailings are frequently found at or close to mining sites, which lowers the need for substantial processing and transportation expenses. This offers financial incentives for road construction projects as well as the mining sector. Large waste storage spaces are not as necessary, and mining businesses save money on trash disposal. Mining waste provides a cost-effective substitute for natural aggregates in building projects without sacrificing the road's strength or longevity.

Additionally, road development projects can benefit from the use of mining waste. Road strength, load-bearing capacity, and pavement durability can all be improved by the intrinsic qualities of materials like fly ash and steel slag. This lowers the frequency of upkeep and repairs, which improves infrastructure development financially over the long run [33].

5.3. Long-Term Sustainability and Environmental Benefits

By minimizing the environmental impact of extraction operations, preserving natural resources, and lowering the demand for virgin aggregates, the use of mining waste in road construction promotes long-term sustainability. In comparison to traditional quarrying, it reduces habitat destruction, water pollution, and land degradation. Additionally, by replacing Portland cement, which uses a lot of energy, with materials like fly ash and slag, road construction can have a lower carbon footprint. Additionally, roads become more durable, requiring fewer repairs and upkeep. In general, recycling mining waste encourages ecologically conscious behavior and guarantees future infrastructure that is more durable and resilient.

6. Challenges and Limitations

There are financial and environmental advantages to using mining waste materials to build roads, but successful implementation requires addressing several obstacles. Environmental hazards, technical hurdles, and problems with social acceptance and regulations are the main causes of these difficulties. The possible environmental danger, especially with regard to leaching and toxicity, is a major worry when employing mining waste products. Hazardous materials like heavy metals (such as arsenic, lead, and mercury) are frequently present in mining wastes like tailings, slag, and waste rock. If these materials are not adequately stabilized, they can seep into nearby soil and water. Ecosystems and groundwater may become contaminated by this leaching process. Another environmental hazard is acid mine drainage (AMD), which occurs when sulfide minerals combine oxygen and water to generate sulfuric acid, which then releases more hazardous metals into the environment. Stabilization procedures are required for mining waste materials in order to reduce these risks, but they increase the expense and complexity of road construction projects.

Incorporating mining waste materials into road building presents substantial technological challenges. These materials, which include waste rock, fly ash, and slag, frequently differ physically from conventional construction aggregates. For instance, adding fly ash to concrete can increase its strength, but doing so requires careful handling to ensure that durability and strength requirements are met. Despite being robust and long-lasting, slag can have a high angularity, which might impact workability and compaction when combined with asphalt. Furthermore, the type of ore and the mine site can have a significant impact on the composition of mining waste, which might result in inconsistent material quality. Construction projects become more complex as a result of these variances, which call for extensive site-specific testing and quality monitoring [34]. Bring out two major issues with utilizing mining waste to build roads. Regulatory obstacles include stringent laws that label mining waste as dangerous and necessitate thorough testing and approval prior to usage, which can cause delays and raise expenses. Social acceptance refers to the public's worries about the safety of using mining waste, particularly in areas close to mining facilities. Concerns about environmental harm and health hazards are common. To overcome these obstacles and win support and trust for the use of mining waste in construction projects, it is necessary to communicate clearly, be transparent, and involve local population in decision making.

7. Conclusions

Mining waste materials offer a promising alternative to conventional road construction materials, contributing to sustainable infrastructure development. Despite challenges, ongoing research and technological advancements can facilitate the wider adoption of mining waste in road construction. Implementing appropriate guidelines and regulations will further enhance the feasibility and environmental benefits of this approach. Using mining waste materials to build roads is a sustainable way to manage the environment and build infrastructure. Fly ash, slag, and tailings are examples of mining byproducts that can be converted into useful building materials. This promotes the notion of a circular economy while also lessening the demand for natural resources. Mining waste provides an affordable substitute that lessens environmental damage as the need for conventional resources increases. We can minimize the adverse effects on the environment and reduce construction expenses by turning these by-products into useful resources.

1. An environmentally friendly substitute for conventional building materials is the use of mining waste products such as fly ash, slag, and tailings in road construction. The concept creates a circular economy, in which garbage is reused rather than wasted, by converting these waste products into useful assets which promotes sustainable growth and lessens the demand for natural resources.

2. Utilizing mining waste helps preserve the environment by lowering the demand for natural resources. Also, it minimizes ecological harm and its influence on ecosystems. By lowering construction expenses, this approach lowers the cost of developing roads and leads to a decrease in carbon emissions.

3. It promotes effective resource and waste management. There is less demand for raw materials once mining scraps are reused which minimizes the impact on the environment and waste and also improves the sustainability and environmental friendliness of building.

4. Despite there are many advantages to using mining waste in buildings, there are still drawbacks. Regulatory concerns, possible environmental hazards, and material difficulty are a few of them. To tackle these issues, more study is required. In addition to meeting rules, it will help increase material consistency, which will ensure that mining waste may be utilized in building in a safe and efficient manner.

5. There is a lot of potential for improving infrastructure development's sustainability through the long-term use of mining waste in buildings. By reducing demand on conventional materials and promoting the worldwide switch to more sustainable building methods, mining waste may play a significant role in eco-friendly building practices with additional study and technological developments.

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References

1. S. H. A. C. A. S. A. B. T. Y. P. C. A. U. a. K. K. Menglim Hoy, "Innovations in recycled construction materials: paving the way towards sustainable road infrastructure," Frontiers in Built Environment, 2024.
2. S. &. M. M. &. D. M. Satapathy, "Literature Review on Waste Generation from Mines," in Sustainable Waste Management Practices for the Mining Sector Through Recycling of Mining Waste, 2024, pp. 7-14.
3. A. &. H. R. El Machi, "Implementation of Circular Economy Between Mining and Construction Sectors: A Promising Route to Achieve Sustainable Development Goals.," in Sustainable Structures and Buildings, Springer Nature, 2024, pp. 51-63.
4. G. M. Alaa Abbadi, "A review on complex utilization of mine tailings: Recovery of rare earth elements and residue valorization," Journal of Environmental Chemical Engineering, vol. 12, no. 3, 2024.
5. M. D. T. C. a. R. A. d. S. Gabriella Melo de Deus Vieira, "Stabilization of an iron ore tailings by-product with perlite waste geopolymer," Web of Conferences, Brasilia, 2023.
6. P. &. S. A. E. M. &. A. M. &. B. M. Segui, "Mining Wastes as Road Construction Material: A Review.," Minerals, 2023.
7. I. &. A. R. &. S. C. T. M. O. Jacob, "Application of mine tailings sand as construction material – a review.," MATEC Web of Conferences, vol. 364, 2022.
8. T. S. E.J. Kamprath, "LIMING," in Encyclopedia of Soils in the Environment, north coralina state, elsevier, 2005, pp. 350-358.
9. P. K. A. A. G. R. R. C. Majid Ghassemi, "Hazardous Waste from Fossil Fuels," in Encyclopedia of Energy, Boston, Elsevier Science, 2004, pp. 119-131.
10. S. &. P. D. &. S. M. &. N. A. &. M. S. M. A, "Heavy Metals in Fly Ash; Its Impact on Human Health and Environment.," in NICMAR 2nd International Conference On Construction, Real Estate, Infrastructure and Project (CRIP) Management, pune, 2017.
11. "What is Overburden in Mining?," [Online]. Available: https://www.flyability.com/blog/overburden#:~:text=Overburden%20is%20the%20rock%20or,type%20of%20underground%20mining%20waste..
12. V. S. D. S. R. &. R. S. Jagdish Gouda, "Evaluating Overburden Materials for Haul Road Construction with and Without Cellular Confinement: A Comprehensive Study in Indian Context," Mining Metallurgy & Exploration, vol. 41, p. 3395–3408, 2024.
13. L. L. Xiqing Jiang, "Stabilization of iron ore tailing with low-carbon lime/carbide slag-activated ground granulated blast-furnace slag and coal fly ash," in Construction and Building Materials, 2024.
14. T. Z. K. C. J. J. Y. J. T. C. L. E. A. Isaac L. Howard, "Steel Slag as a Paving Aggregate: Properties, Applications, and Comparison to Alternatives," Mississippi State University, Mississippi State, 2019.
15. P. G. &. S. H. Kumar, "Stabilization of expansive subgrade soil by using fly ash.," Materials Today: Proceedings, vol. 45, no. 7, pp. 6558-6562, 2020.
16. Z. Y. X. C. R. Y. D. C. J. C. Shenghua Yin, "Mechanical properties of cemented tailings and waste-rock backfill (CTWB) materials: Laboratory tests and deep learning modeling," Construction and Building Materials, 2023.

17. D. R. A. Z. F. G. S. S. J. K. Z. Zimar, "Application of coal fly ash in pavement subgrade stabilisation: A review," Journal of Environmental Management, 2022.
18. E. M. A. A. A. Dr.Eng. Ali Hussein Mohammed M. Bass, "The Effects of Waste Materials on Cement Mortar Properties [Case Study: Fly Ash and Cement Dust]," IJERT, vol. 13, no. 11, 2024.
19. S. C. a. A. Kubilay Kaptan, "A Review of the Utilization of Recycled Powder from Concrete Waste as a Cement Partial Replacement in Cement-Based Materials: Fundamental Properties and Activation Methods," MDPI, vol. 14, no. 21, 2024.
20. F. S. a. K. Amirreza Kandiri, "Predicting Compressive Strength of Concrete Containing Recycled Aggregate Using Modified ANN with Different Optimization Algorithms," MDPI, vol. 11, no. 2, 2021.
21. M. &. S. J. &. Y. E. Yeheyis, "Long-term evaluation of coal fly ash and mine tailings co-placement: A site-specific study," Journal of Environmental Management, vol. 91, no. 1, pp. 237-244, 2009.
22. Z. P. N. K. S. D. H. s. R. R. K. M. G. Mohsen Moghimi Dehkordi, "Soil, air, and water pollution from mining and industrial activities: Sources of pollution, environmental impacts, and prevention and control methods," Results in Engineering, vol. 23, no. 31, 2024.
23. J. P. M. a. P. d. Plessis, "NEUTRALISATION OF ACIDIC EFFLUENTS WITH LIMESTONE," Division of Water Technology, Pretoria, South Africa, 1993.
24. Y. Z. D. L. &. X. L. Pu Yuan, "Effect of Freeze-Thaw Cycle and Moisture Content on Compressive and Energy Properties of Alkali Slag Ceramsite Concrete," KSCE Journal of Civil Engineering, vol. 28, no. 5, p. 1980–1991, 2024.
25. A. J.-V. I. G.-R. M. M.-d. P. J. G.-G. R. M.-G. P. Jagadesh, "Effect of Design Parameters on Compressive and Split Tensile Strength of Self-Compacting Concrete with Recycled Aggregate: An Overview," MDPI, 2021.
26. A. M. L. U. a. B. Muniter Muresa Muda, "Strength, Porosity and Permeability Properties of Porous Concrete Made from Recycled Concrete Aggregates," MDPI, pp. 81-92, 2022.
27. A. e. M. S. M. A. M. B. Pauline Segui, "Mining Wastes as Road Construction Material: A Review," Scilit, vol. 13, 2023.
28. P. Mazurowski, "Tensar," [Online]. Available: https://www.tensarinternational.com/resources/articles/what-are-the-function-of-layers-in-a-flexible-pavement.
29. E. T. Yuanjie Xiao, "Best Value Granular Material for Road Foundations," Minnesota Department of Transportation, Research Services Section , 2012.
30. D. R. A. Z. F. G. S. S. J. K. Z. Zimar, "Application of coal fly ash in pavement subgrade stabilisation: A review," Journal of Environmental Management, vol. 312, 2022.
31. A. B. G. a. E. P. Marco Pasetto, "The Use of Steel Slags in Asphalt Pavements: A State-of-the-Art Review," MDPI, vol. 15, no. 11, 2023.
32. C. P. Subodh Kumar, "Estimation of resource savings due to fly ash utilization in road construction," Resources, Conservation and Recycling, vol. 48, no. 2, pp. 125-140, 2006.
33. T. N. P. T. R. K. Priyank Patel, "Review on Effect of Steel Slag and Fly Ash in Road Construction," Metszet, vol. 8, no. 8, pp. 153-165, 2023.
34. I. A. A. C. W. LOVELL, "Use of Waste Materials in Highway," TRANSPORTATION RESEARCH RECORD.
35. I. Z. M. F. C. D. L. D. Ø. M. Haoxuan Yu, "Reimagining resources policy: Synergizing mining waste utilization for sustainable construction practices," Journal of Cleaner Production, vol. 464, 2024.