Beneficial Use Potential of Mineral Wool Waste

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Introduction

Mineral wool is a construction material with a matted wool textured material that is made using inorganic materials. They are categorized by their source material and are usually either rock wool, which comes from volcanic rocks like basalt, or slag wool, which comes from iron ore waste or slag, or glass wool, which is made from glass.

Certain properties such as superior firestopping, thermal insulation, sound dampening, moisture resistance, and especially its ability to create an energy efficient envelope for apartments making it desirable as insulation material for buildings, especially high-rises, that must follow the strict New York City building codes. The high demand for mineral wool is present in any city; this high demand causes a lot of mineral wool to be imported into the city every year.

Mineral wool waste is created when an apartment or building gets demolished or renovated. The process of demolition causes many other construction debris to mix in with the mineral wool; this causes its chemical composition to change. Currently, a majority of the mineral wool waste from demolition is dumped into landfills as that is the cheapest method for many companies. However, due to the low density of the mineral wool waste their high-volume takes up a lot of space in the landfills. There is also a problem that is caused by the leaching of binders that are used in the mineral wool, this leaching can be toxic and cause contamination in the soil. Although mineral wool waste is recyclable, there are many difficulties with preparing the material for reuse. Some of these include the highly variable chemical composition from demolition, toxic byproducts released while heating and processing the waste, and etc. It has grown increasingly important to find beneficial use pathways due to the increased demand of mineral wool and in turn an increased production of mineral wool waste and the shrinking space available in landfills.

There are regulations that differentiate between the types of mineral wool waste such as if they are hazardous or not, whether it's been recycled or not, etc. There are different regulations for different types that have been set by the state and the city in order to decide the best method of discarding the mineral wool waste. According to Open House New York there is approximately 6 million tons of C&D waste annually with no specific percentage or amount of that 6 million being mineral wool waste (*Getting to Zero NYC*, n.d.).

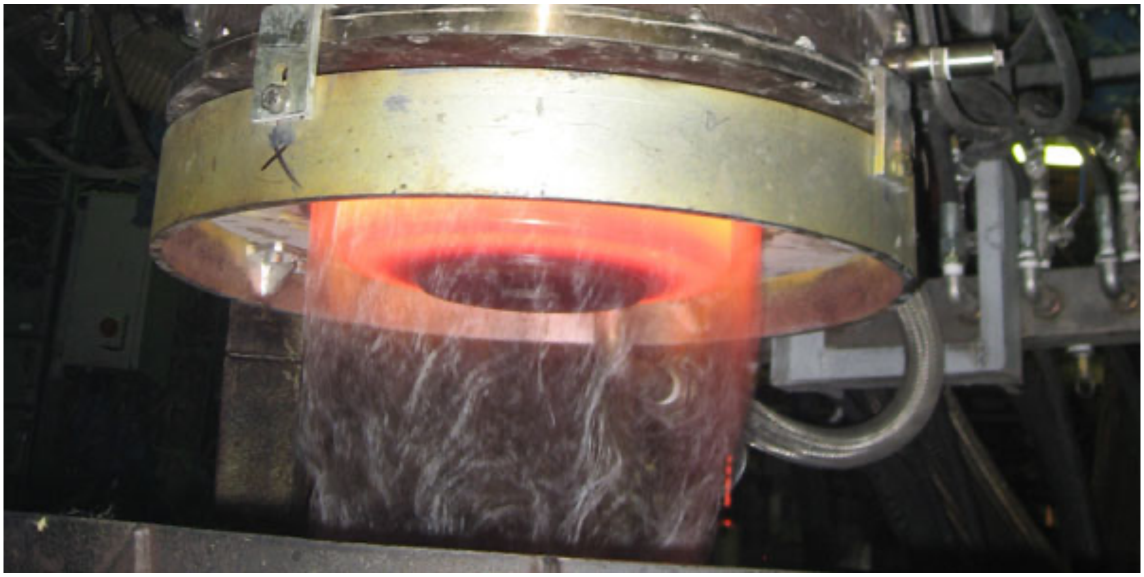
Material Properties

It is imperative to have a background of the chemical and physical properties of mineral wool insulation to better understand the different pathways of reuse. A study on characterizing mineral wool focused on two main types, glass wool and stone wool, which differ in composition due to their respective manufacturing processes. These manufacturing processes introduce raw materials, fiberizations and organic resins that influence different properties. The study analyzed 15 glass wool and 12 stone wool samples retrieved from pre-demolition audits, demolition sites, landfills, waste management stations and production sites (Yliniemi et al., 2021). The samples were found in various conditions such as prolonged exposure to weather or among debris with samples of dust.

The process for manufacturing glass wool starts by melting raw materials such as sand, limestone, soda and borax (Yliniemi et al., 2021). The melted mix is fiberized by a spinning machine with more than 2,000 small holes creating very fine wool. In the case of stone wool, it is created mainly by melting basalt and diabase that is spun through a spinner wheel (Yliniemi et al., 2021). Fiber dimension is important because it directly affects the material property, fiber respirability and fiber clearance. Smaller fibers will create denser structures and improve mechanical strength. The last step is to add organic resin binders to help the fibers keep their shape which include phenolic resin, polyesters, melamine-urea-formaldehyde, polyamides, furan-based resin, and sugar-based resin (Yliniemi et al., 2021) that range from 1-10% composition by weight (Milat et al., 2025).

Figure 1.

Spinning Machine for Glass Wool Production



Note. The melted glass is pulled through the fiberizer using compressed air and fiber is produced from the perforated disc openings. From Gamma Meccanica. (n.d.). Fiberizer, spinning machine. Retrieved December 29, 2025, from https://www.gamma-meccanica.it/en/mineral-wool-production-lines/glass-wool/fiberizer-spinning-machine/#next.

Chemical Composition

The result of the chosen raw materials for glass wool forms a chemical composition by weight of primarily 7.6-9.9% CaO, 59.2-64.2% SiO_2, 1.4-5.9% Al_2O_3, 0.3-2.1% Fe_2O_3, 15.0-17.7% Na_2O, and 1.8-3.3% MgO, through XRF and TGA analysis of the 15 samples (Yliniemi et al., 2021). Additionally, stone wool's chemical composition by weight consists primarily of 14.4-

22.6% CaO, 39.1-42.9% SiO_2, 14.0-17.7% Al_2O_3, 5.5-8.8% Fe_2O_3, 1.4-3.0% Na_2O, 7.7-14.2% MgO and 1.0-3.3% TiO_2 from the 12 samples (Yliniemi et al., 2021). The abundance of calcium, silicate, aluminum and iron can explain the potence of using mineral wool insulation as a supplementary material as typical Portland cement concrete is primarily composed of the above-mentioned elements. However, the chemical compositions outline potentially toxic elements such as Cr, Ba, and Ni that are present in low concentration but are there, nonetheless. All factors of risk should be weighed before deciding its suitability for repurposing.

Table 1.

Chemical Composition of Glass Wool

Glass wool compositions in this study (N=15)				Glass wool compositions in the literature (N=18)			
	Median	Min	Max		Median	Min	Max
CaO	8.19	7.61	9.90	CaO	7.41	3.00	8.50
SiO_2	62.70	59.20	64.15	SiO_2	63.60	57.50	68.30
Al_2O_3	1.86	1.36	4.90	Al_2O_3	3.50	1.30	5.80
Fe_2O_3*	0.48	0.27	2.06	Fe_2O_3	0.21	0.00	0.59
Na_2O	16.93	14.95	17.68	FeO	0.10	0.00	0.40
K_2O	0.56	0.41	0.91	Na_2O	15.34	10.10	15.85
MgO	2.48	1.77	3.29	K_2O	1.23	0.00	2.90
P_2O_5	0.14	0.02	0.56	MgO	3.00	0.21	4.13
TiO_2	0.07	0.03	0.61	P_2O_5	0.00	0.00	0.00
SO_3	0.41	0.11	1.83	TiO_2	0.06	0.00	0.20
MnO	0.31	0.02	0.56	SO_3	0.17	0.00	0.33
Cr_2O_3	0.05	0.03	0.18	B_2O_3	4.90	4.10	10.70
ZrO_2	0.01	0.00	0.03	MnO	0.01	0.00	0.80
SrO	0.02	0.00	0.04	Cr_2O_3	0.00	0.00	0.00
BaO	0.00	0.00	0.23	ZrO_2	0.01	0.00	0.03
NiO	0.02	0.01	0.07	SrO	0.08	0.08	0.08
CuO	0.01	0.01	0.09				
ZnO	0.01	0.01	0.16	F	0.00	0.00	0.83
PbO	0.01	0.00	0.33				
Cl	0.09	0.00	0.12				
Bi_2O_3	0.00	0.00	0.01				
LOI 525°C	7.95	0.60	11.90				

Note. *Chemical composition of retrieved glass mineral wool waste compared with literature values of glass wool composition. From Yliniemi, J., Ramaswamy, R., Luukkonen, T., Laitinen, O., de Sousa, Á. N., Huuhtanen, M., & Illikainen, M. (2021). Characterization of mineral wool waste chemical composition, organic resin content and fiber dimensions: Aspects for valorization. Waste Management, 131, 323–330.* https://doi.org/10.1016/j.wasman.2021.06.022.

Table 2.

Chemical Composition of Rock Wool

Stone wool compositions in this study (N=12)				Stone wool compositions in literature (N=43)			
	Median	Min	Max		Median	Min	Max
CaO	17.96	14.43	22.58	CaO	17.89	10.04	40.10
SiO_2	40.55	39.05	42.90	SiO_2	44.00	39.80	54.00
Al_2O_3	16.36	14.01	17.70	Al_2O_3	16.00	7.00	24.00
Fe_2O_3	7.11	5.48	8.78	Fe_2O_3	7.00	n.a	13.22
Na_2O	2.25	1.38	2.95	FeO	4.66	n.a	8.20
K_2O	0.71	0.41	1.15	Na_2O	2.40	0.13	6.20
MgO	9.73	7.70	14.19	K_2O	1.10	0.30	3.80
P_2O_5	0.28	0.07	0.52	MgO	9.25	2.00	13.00
TiO_2	2.02	0.98	3.33	P_2O_5	0.30	0.00	0.80
SO_3	0.21	0.06	1.69	TiO_2	1.70	0.50	3.06
MnO	0.22	0.14	0.40	SO_3	0.23	0.15	0.23
Cr_2O_3	0.07	0.05	0.10	S	0.10	0.00	0.50
ZrO_2	0.03	0.00	0.07	B_2O_3	0.00	0.00	0.10
SrO	0.10	0.00	0.13	MnO	0.20	0.00	1.10
BaO	0.04	0.00	1.66	Cr_2O_3	0.10	0.00	0.40
NiO	0.03	0.02	0.04	ZrO_2	0.02	0.00	0.03
CuO	0.02	0.01	0.04	SrO	0.10	0.00	0.10
ZnO	0.01	0.00	0.03	BaO	0.10	0.00	1.00
Cl	0.09	0.04	0.19	Others	0.40	0.40	0.40
Nb_2O_5	0.01	0.00	0.01				
Y_2O_3	0.00	0.00	0.01				
Ga_2O_3	0.00	0.00	0.01				
Co_3O_4	0.00	0.00	0.04				
PbO	0.00	0.00	0.01				
Bi_2O_3	0.00	0.00	0.01				
LOI 525°C	2.85	1.40	7.40				
LOI 950°C	1.70	1.00	3.20				

Note. *Chemical composition of retrieved stone mineral wool waste compared with literature values of stone wool composition. From Yliniemi, J., Ramaswamy, R., Luukkonen, T., Laitinen, O., de Sousa, Á. N., Huuhtanen, M., & Illikainen, M. (2021). Characterization of mineral wool waste chemical composition, organic resin content and fiber dimensions: Aspects for valorization. Waste Management, 131, 323–330.* https://doi.org/10.1016/j.wasman.2021.06.022.

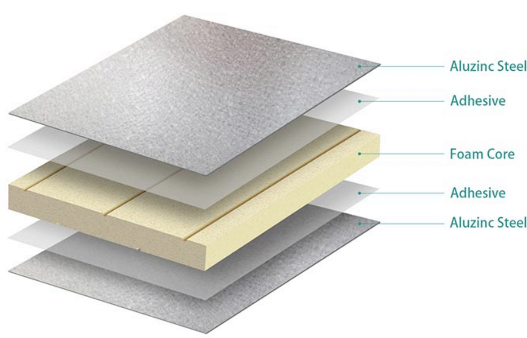
Physical Properties

Physical properties of mineral wool insulation include low thermal conductivity, low density, high porosity, fire resistant and soundproof. The material performs extremely well as insulation due to the low density and high porosity trapping air and impeding heat transfer with a thermal conductivity of 0.037 W/(m·K) (Milat et al., 2025). For rock wool with a density of 80 kg/m^3, study has shown that thermal conductivity rose from 0.036 to 0.148 W/(m°C) as moisture rose from 0 to 13 percent indicating that reused mineral wool must be lower than 2% moisture to be acceptable in terms of performance (Gusyachkin et al., 2019). The property of fire resistance makes mineral wool very useful in applications such as fire containment due to mineral wool having a specific heat of 850 J(kg·K) (Pozorski et al., 2023). Under testing, mineral wool was heated from 21°C to 750°C and its temperature was discovered to increase significantly after reaching 200°C due to the burning of the binder found from production (Pozorski et al., 2023).

A common use case for mineral wool is in the construction industry as sandwich panels consisting of two thin metal sheets sandwiching an insulating core, in this case, mineral wool.

Figure 2.

General Structure of Sandwich Panels



Note. Adhesives are present between the steel plates and foam core which is referred to as the binder in the heating test. In the scope of this report, the foam core is mineral wool. From GTeek. (n.d.). Stainless Steel Sandwich Panels. Retrieved December 29, 2025, from https://www.gteek.com/Stainless-Steel-Sandwich-Panels.

Standards and regulations for sandwich panels include EN 14509 which specifies the types of insulating core that can be used, EN 13501-1 classifies fire performance of construction materials, EN 1364-1 specifies procedures for fire resistance testing of non-loadbearing construction elements and EN 1365-2 for fire resistance testing of load bearing construction elements (Pozorski et al., 2023). These regulations are important as specific types of insulation core can provide thermal resistance and improve fire safety while other insulation cores may melt and spread fires quicker (Pozorski et al., 2023).

Additional mineral wool product regulations were found within ROCKWOOL's specification guide for mineral wool insulation under various applications (ROCKWOOL, 2010). Surface burning characteristics are tested with ASTM E84. Corrosion resistance is tested with ASTM C665 and ASTM C795. Moisture resistance is tested with ASTM C1104. Fungi resistance is tested with ASTM C1338. All products include an Environmental Product Declaration (EPD) stating the material must be included on a UL Certified EPD, which tracks the product's environmental impact. All products are also both DECLARE and INTEREK certified, signifying their safety to human and environmental health by complying with safety standards. Different ASTM standards provide guidelines for different required characteristics while different certifications improve the safety rating and reliability of the product. Specific ASTM standards are used depending on the reuse potential of mineral wool and the desired application so not every ASTM standard will need to be met in practice.

Environmental and Health Considerations

It is important to understand the risks associated with reuse of mineral wool waste such that personal and environmental health are protected. These risks are primarily attributed to the material composition of mineral wool such as its fiber morphology, organic binder content and demolition debris.

During fiberization, the raw material for mineral wool is formed into small fibers. This introduces a health concern as smaller fiber diameters and longer lengths can circulate into a person's lungs to cause inflammation and disease. A possible solution is to increase fiber width during production to decrease the content of fibers with a width less than 3 micrometers and length longer than 5 micrometers (Yliniemi et al., 2021). During take-back of mineral wool waste, the required cutting, dismantling and handling from construction sites will cause contact with the fibers and lead to irritation of the skin, eye and lungs. Dust and debris will also be prominent at deconstruction sites which can cause physical injuries and respiratory diseases. Thus, it is important to handle mineral waste with proper personal protective equipment such as gloves, protective clothing and masks.

Additionally, organic resin binders are introduced during production. These include phenolic resin, polyesters, melamine-urea-formaldehyde, polyamides, furan-based resin, and sugar-based resin (Yliniemi et al., 2021) that range from 1-10% composition by weight (Milat et al., 2025). The presence of these binders introduces risk in reactions when used as a supplementary cementitious material as typically inert supplementary cementitious materials are desired. Furthermore, these binders may vaporize under heat and chemical treatment in a typical reuse process to release toxic compounds including ammonia, phenol and formaldehyde. Pre-treatment methods will be required to neutralize the compounds (Milat et al., 2025). These emissions will be particularly relevant in thermal and chemical preprocessing treatment methods where proper ventilation to capture the emitted gases should be utilized to mitigate risks of inhalation or spread of fumes to the outside environment.

Overall, these risks can be mitigated by proper planning and administration. Administrators should enforce the use of proper personal protective equipment during handling and processing. Preprocessing facilities should be equipped with proper ventilation systems to neutralize the toxic fumes from the organic resin binders. Proper sampling and contamination testing of mineral wool waste from source sites will have to be conducted to adhere to environmental and safety standards.

Material Properties Impact on Reuse Pathways

The following table summarizes the important properties of mineral wool and how they affect its reuse pathways. There are 5 reuse pathways discussed in this report being reuse as supplementary cementitious material (SCM), raw material for silica aerogels, ROCKWOOL's Rockcycle take-back program, fiber addition for mortars and recycling for thermal insulation.

Property / Condition	Why It Matters	Affected Reuse Options
Binder content	Organic binders can influence chemical reactivity and release emissions during heat treatment. This can interfere with cement hydration and release toxic fumes.	This affects mineral wool waste's reuse as SCM, fiber addition for mortars, and raw material for silica aerogel.
Fiber dimensions	Thin and long fibers will improve mechanical strength of mineral wool but introduce respirable fiber health risks. It can also affect workability of cement due to interlock.	This affects mineral wool waste's reuse as SCM, fiber addition for mortars, and recycling for thermal insulation.

Sensitivity to moisture	Increased moisture content significantly increases thermal conductivity and reduces compressive strength. The moisture content should be kept to under 2% otherwise it limits the insulation potential of mineral wool waste.	This affects mineral wool waste's reuse as recycled thermal insulation such as in the case of sandwich panels and take-back programs like Rockcycle.
Chemical composition	There is an abundance of calcium, silicate, aluminum and iron which are the primary elements of Portland cement concrete. This supports mineral wool waste as a supplementary cementitious material. Furthermore, the abundance in silica for both glass and rock wool supports using mineral wool waste as a raw material for silica aerogel.	This affects mineral wool waste's reuse as SCM and raw material for silica aerogel.
Contaminants	The chemical compositions outline toxic elements such as Cr, Ba, and Ni that are present in low concentration. The presence of chloride will also accelerate corrosion of steel rebars in reinforced concrete.	This affects mineral wool waste's reuse as SCM and fiber additive for mortars.
Demolition debris	Mineral wool waste is often found in demolition debris covered in dust or	This affects mineral wool waste's reuse as SCM,

	exposed to prolonged weathering. As a result, mineral wool waste is required to undergo preprocessing before reusing.	fiber additive for mortars and insulation reuse programs such as Rockcycle.

Table 3. Properties and conditions of mineral wool and the subsequent reuse pathways affected.

Beneficial Use Options

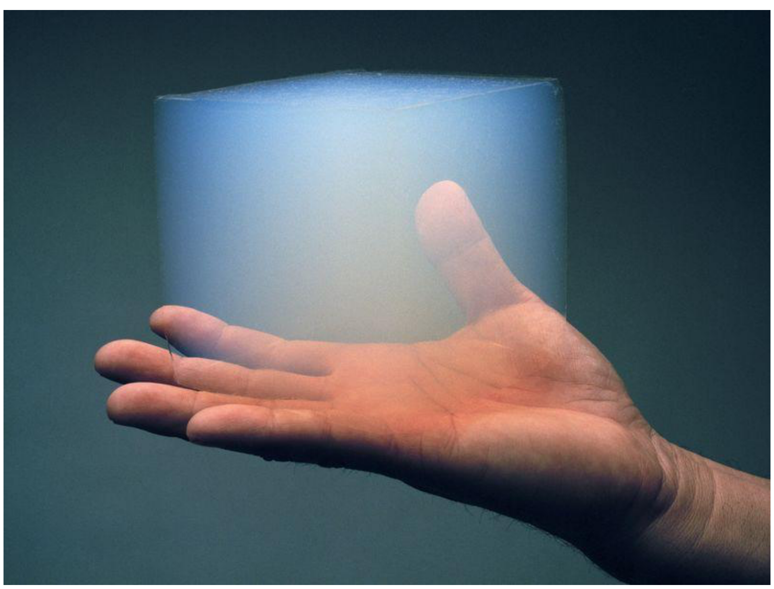
Raw Material for Silica Aerogel

Purpose

A promising reuse strategy for mineral wool waste lies in its high amorphous silica content making it a source of raw material for silica aerogel (Borzova et al., 2025). The upscaling of mineral wool waste into silica aerogel is conducted by the ambient pressure drying method.

Figure 3.

Silica Aerogel Held in Hand



Note. Silica aerogel is composed of 95% air resulting in the highest known thermal insulation properties. From SAIREM. (2020). Drying of insulating aerogel. https://www.sairem.com/drying-of-insulating-silica-aerogel/.

Aerogels are also a great insulation material with low thermal conductivity and fire retardancy. However, the use of aerogels is hindered by their high cost of implementation which can be attributed to the cost of production. Recycled mineral wool waste into a source of raw material will aid in reducing the high cost. Silica aerogel price is reported at approximately 200 euros per square meter while mineral wool only costs about 23 euros per square meter (Borzova et al., 2025). This implies that having recycled mineral wool supplement as raw material for silica aerogel at a fraction of the price will provide a great cost reduction.

Preprocessing and Testing

The research delves into the extraction of silica from both raw and waste mineral wool collected from samples contaminated with demolition debris. The different samples of waste mineral wool underwent several acid treatments to extract pure silica and then dried. The research also investigated which acid would be the most efficient for silica extraction from stone wool, with results indicating hydrochloric acid being the most effective at dissolving contaminants (Borzova et al., 2025).

Benefits

The thermal conductivity of produced aerogels ranged from 21.4 to 26.9 mW/mK being slightly higher than commercial aerogels at 18.9 mW/mK (Borzova et al., 2025). The aerogels were also hydrophobic with water contact angle of 147-149 degrees, high specific area of 603-676 m^2/g, high porosity of 94.4-97.1% and a density of 86-136 kg/m^3 (Borzova et al., 2025). As such, the recycling of mineral wool waste for the synthesis of silica aerogels can create effective insulators.

Limitations

Limitations of this method include the cost of preprocessing and chemical extraction associated with procuring reagents. Additionally, mineral wool is manufactured with organic binders that can release ammonia, phenol and formaldehyde during treatment so additional safety measures will need to be taken when conducted on a large scale. Currently, NYSDEC grants Beneficial Use Determinations (BUDs) by application forms to reclassify waste material from solid waste (NYSDEC, 2025). Mineral wool waste is not clearly outlined as part of any of the currently approved materials that are no longer considered solid waste when used. However, projects using mineral wool waste as raw material substitute for silica aerogel would have to follow the case-specific BUDs pathway as this applies to waste materials used as substitutes for a component material in the manufacture of a product (NYSDEC, 2025).

Case Study of ROCKWOOL's Rockcycle

Purpose

A less direct alternative method to repurposing mineral wool waste is observed in the case of ROCKWOOL Group, a leading manufacturer of stone wool insulation. ROCKWOOL has published sustainability reports documenting their resource use, recycling and efforts towards a circular economy throughout the years. ROCKWOOL's report offers insight into their sustainability strategy which is to support circularity in construction by producing products from recyclable stone wool. This is carried out by their most notable group policy, Rockcycle, a global strategy designed to reclaim end-of-life stone wool from markets back to ROCKWOOL factories for reprocessing for use as raw materials.

Figure 4.

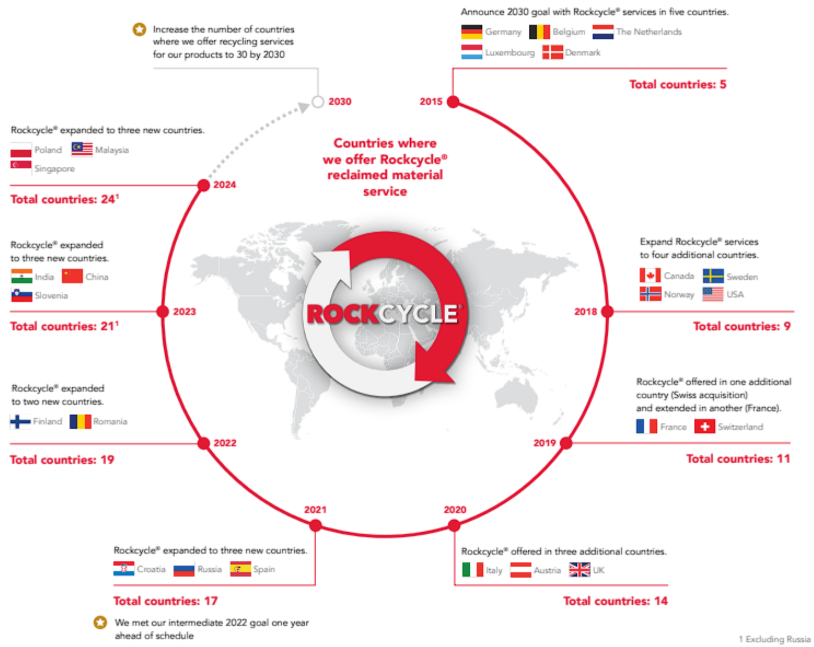
ROCKWOOL's 2024 Sustainability Highlights

Note. *Progress is measured using 2015 as a baseline time while the achievement goal is set by 2030 except for the goal for greenhouse gas emissions to be achieved by 2034. From ROCKWOOL Group. (2025). Annual Report 2024. https://www.rockwool.com/siteassets/investors/financial-reports/2024/annual-report-2024.pdf.*

They utilize reclaimed material from the market and secondary materials from other industries to avoid these materials from being landfilled. ROCKWOOL currently offers recycling services in 24 countries with this initiative having started in 2015 (ROCKWOOL Group, 2024). They have shown steady growth with the goal being to hit 30 countries by 2030. Rockwool policies promote deconstruction over demolition, introduce landfill bans for recyclable materials, and regulate the transport of stone wool waste (ROCKWOOL Group, 2024).

Figure 5.

Expansion of Countries with Rockcycle Services by Year



Note. *Rockcycle is a service offered by ROCKWOOL in which they reclaim stone wool waste from global markets. From ROCKWOOL Group. (2025). Annual Report 2024. https://www.rockwool.com/siteassets/investors/financial-reports/2024/annual-report-2024.pdf.*

Preprocessing and Testing

The reclaimed stone wool waste from global markets will act as raw material varieties that include basalt and gabbro and are used to make ROCKWOOL products. The manufacturing process will then follow the typical manufacturing processes for rock wool. In the report, decarbonization efforts are high and seen as a top priority where recent advancements have been made in this aspect. ROCKWOOL is building new electric-melting production lines in various countries including Romania, United States, and Sweden (ROCKWOOL Group, 2024). The currently existing electrified factory is in Flums, Switzerland which is hydro powered to supply renewable energy. Reportedly, CO_2 emissions at the factory has decreased by 75 percent which is equivalent to 25,000 tonnes of CO_2 a year (ROCKWOOL Group, 2024). The change in the methodology of processing facilities show that renewability needs to be focused not only on the preprocessing step but also on the processing step to greatly reduce environmental impacts.

Benefits

From their 2024 sustainability highlights, landfill waste in tonnes has been reduced by 40% since 2015 with a goal to hit 85% by 2030 (ROCKWOOL Group, 2024). This percentage translates to a reduction in 37 kilotonnes of landfill waste reduced from stone wool production. This is an effective strategy that companies who manufacture mineral wool products should employ. Rockwool's sustainability report offers great insight into the policies promoted by a company with sustainability as the foundation of their principles. They can be used as a model for how construction or manufacturing companies should act to mirror Rockwool's success in reducing landfill waste from stone wool production.

Limitations

However, this does not go without its share of limitations. Smaller scale companies cannot participate in large scale extraction of end-of-life mineral wool waste from global markets and as a result fail to procure supply. They would need to have locations in many countries around the world to effectively transport waste to their regional facilities. ROCKWOOL's Rockcycle program is a company led circular economy initiative and not a state approved BUD, so the program itself is not found in the approved public listings. Its direct implementation in a New York City context would require approval from NYS BUD program under case specific determinations for waste material as substitutes in commercial products (NYSDEC, 2025).

Furthermore, the Rockcycle would need to comply with NYSDEC and NYC solid waste handling regulations due to its nature being a recycling program. From a NYC feasibility standpoint, implementing a Rockcycle class program would require collection and preprocessing hubs that should be located near industrial zones for ease of access to heavy construction and demolition. The recovered materials will often be contaminated with dust and moisture from demolition or weathering so sorting and quality testing will be necessary in these preprocessing hubs. Moisture levels should be a main criterion of testing as the properties of mineral wool show that moisture levels over 2% will greatly increase thermal conductivity and reducing its potential as an insulator (Gusyachkin et al., 2019).

Fiber Addition for Mortars

Purpose

A beneficial reuse for mineral wool insulation is the reuse of it into a sustainable reinforcement material in cement mortar and concrete for the purpose of either improving or displaying passable strength and durability while simultaneously diverting insulation waste from disposal pathways.

Preprocessing and Testing

An experiment compared 5 different mortar mixes, with one of the mortars being a control. The other four mortars were reinforced with 1% or 1.5% respectively of mineral wool or coconut fibers, with the goal of observing differences in mechanical strength, durability, and the microstructures that are formed by these mixes. There was an additional need for preprocessing and treatment, as the fibers required alkaline (NaOH) treatment in order to improve the fibers bonding and overall performance.

Benefits

Some benefits were discovered in this testing period. The best result for overall strength came from the mortar infused with 1.5% mineral wool, as the flexural strength had increased by 47% in comparison to the control mortar. In terms of compressive strength, the best result was yielded by the mortar with 1% mineral wool. Mineral wool reduces water absorption and void formation, which leads to increased bulk density and improved microstructural bonding in the cement matrix.

Limitations

However, some limitations persist. All mineral-wool-reinforced mixes showed signs of lower compressive strength than the control, and after a 28-day (about 4 week) period, the compressive strength of the mortars decreased anywhere from 12 to 32 percent for mineral wool contents of 1-1.5%. This was attributed to fiber overlap and void formation, which created failure pathways when loads were placed onto the mortars. However, 1 to 1.5 percent fiber content remained the best performing percent range, as higher contents increased voids, which hurt the workability and compressive strength.

Further limiting the potential reuse of mineral wool is the lack of approval from NYSDEC part 360. The reuse of mineral wool in cement mortar would need a Beneficial Use Determination (BUD) under 6 NYCRR Part 360. The lack of standardized applications for this materials waste in mortar reuse would mean regulatory approval is not automatic and would further require supporting evidence and testing done to make sure the material can be used in this manner.

The preprocessing treatment also brought about challenges to consider, as preprocessing further adds cost, handling considerations, and more complexity to the idea of integrating materials such as mineral wool insulation into sustainable reinforcement materials. Due to these factors, mineral-wool-reinforced mortar is concluded to not be suitable as a primary means for structural application (Awoyera et al., 2022).

Overall, the key result of the experiment was that the dosage window for optimal strength was narrow, sitting round 1% and 1.5%, as 1.5% yielded the best flexural strength yield, while 1% yielded the best compressive strength performance. Despite flexural gains, all the miner-wool infused mixes showed lower compressive strength than the control, as shown by the measure of compressive strength throughout 28 days. Given the compressive strength decline and sensitivity to fiber dispersion, mineral wool infused cement mortars would not be suitable for primary structural elements within NYC. However, the use of cement mortars infused with mineral wool could see use in applications such as interior panels, the repair or patching of mortars, or use as thin overlays and durability-focused renders. NYC-specific quality control would need to be implemented, such as strict regulation of fiber dosage, pretreatment verification to ensure bond quality, testing, and use-specific specifications.

Supplementary Cementitious Material (SCM)

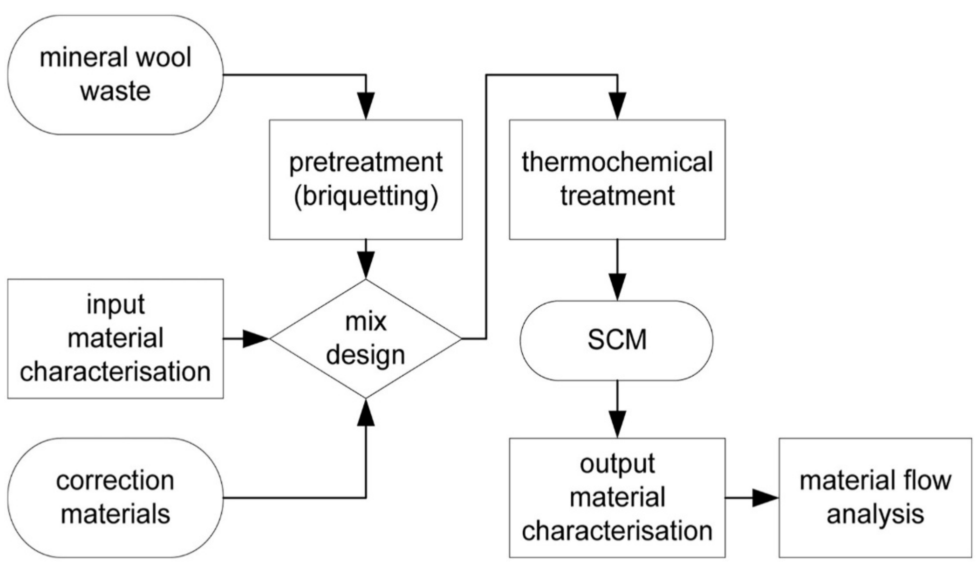
Purpose

A potential beneficial use option for mineral wool waste is a supplementary cementitious material. Supplementary cementitious materials or SCMs are materials that are added to a cement in order to obtain a desirable physical or chemical property as well as to reduce cost in most cases.

Preprocessing and Testing

Before mineral wool waste is able to be used as an SCM it must go through testing and certain preprocessing treatments in order to ensure some uniformity and quality. These tests include a purity and contamination identification, chemical composition testing, contamination testing for chlorides and a physical analysis test (Yap et al., 2021). The purity and contamination identification and physical analysis testing are used to categorize the current quality of the mineral wool waste, the type of mineral wool, whether there is high contamination from dust and other construction debris, how it was used prior to being waste, and its physical condition. Chemical composition testing is needed to determine the chemical composition of the mineral wool which affects the chemical reactions that the cement has with its environment. The contamination testing for chlorides is especially important for SCMs as chloride can cause the steel rebar within concrete to rust and ultimately weaken the structure. All of these tests are used to determine what kind of pretreatment the mineral wool waste will undergo to prepare it for use as an SCM.

The pretreatment process that mineral wool waste must go through include, grinding or milling, washing, and heating or thermal treatment before they can be used as SCMs (Yap et al., 2021). The grinding down the mineral wool waste allows for homogeneity of the mixture and easier blending with the mixture. Washing is especially crucial as it



refers to washing any chloride out of the mineral wool waste that could cause corrosion of steel if steel is used to reinforce a concrete structure. Then there is thermal treatment in which burns off any organic material that could have been left by other construction debris.

Benefits

There are several benefits to using mineral wool waste as a SCM. Some studies have reported increases in concrete strength when mineral wool waste is used as a SCM, primarily due to its high silica content (SiO_2 ~ 70%) and calcium oxide content (CaO ~ 20%) (Yap et al., 2021). The high SiO_2 content contributes to pozzolanic activity, where the SiO_2 reacts with calcium hydroxide produced during cement hydration to form additional calcium-silicate-hydrate or C-S-H, leading to a denser microstructure and improved strength. The CaO content also contributes to the latent hydraulic behavior by further enhancing strength development under appropriate curing conditions. In addition to mechanical performance, studies have observed improvements in durability-related properties, including increased resistance to chloride-ion penetration and abrasion, properties that are associated with pore refinement and reduced permeability. However, the effect of mineral wool waste on strength is highly dependent on the replacement level and processing method. At higher replacement levels starting at approximately 50%, some studies have reported a reduction in compressive strength, while flexural strength increases, indicating a change in fracture behavior and stress distribution within the concrete matrix. Overall, the use of mineral wool waste as an SCM promotes the development of alternative cementitious materials derived from recycled resources, reducing reliance on virgin raw materials and diverting mineral wool waste from landfills.

Limitations

Despite the extensive amount of benefits to using mineral wool waste as an SCM there are some drawbacks. Mineral wool waste was found to have inconsistent strength growth at ages 7 days and 28 days when 0.5% mineral wool waste was added to the cement mortar (Awoyera et al., 2022). This makes the material unpredictable as it could be unstable at certain curing times. Sometimes mineral wool waste was not found to have any hydration benefits and instead caused unpredictable hydration.

Mineral wool waste has been tested too sparsely to be regularly used as an SCM and needs to be tested more as well as find a way to enforce a stricter code in how they can be made. If more mineral wool is made in such a way that limits variability between different brands of mineral wool, then more uniform results can be achieved.

Recycling Mineral Wool for Insulation

Purpose

Mineral wool waste can be recycled and reused as thermal insulation after reprocessing. Thermal insulation is used in buildings and houses that keeps the building or room at a constant temperature. They also create very energy efficient buildings due to less energy being needed to maintain the temperature in a room. This makes thermal insulation necessary in places such as New York City which has strict building codes.

Preprocessing and Testing

To determine whether certain mineral wool waste can be recycled into new thermal insulation it must go through tests to make sure that the quality is good enough. Some of these tests include physical tests, hygrothermal performance tests, and mechanical performance tests (Acar et al., 2024). The physical tests are a thickness measurement and a density measurement.

The thickness test was meant to determine if too many layers of the mineral wool were contaminated and therefore could not be used. The density measurement is used as an indicator of the compressive strength of the mineral wool. The hygrothermal performance tests are a short-term water absorption test and long-term water absorption test. The short-term water absorption test is used to evaluate the hydrophobic behavior of the insulation while the long-term water absorption test is used to evaluate the moisture uptake over long exposure and how well it will hold up in the long term. The mechanical performance tests are to ensure that the mineral wool is able to handle different loads specified for roofing.

The process that mineral wool waste must go through before it is able to be reused is dismantling, inspection, cutting, and conditioning (Acar et al., 2024). The dismantling is to maintain the shape of the panels of mineral wool. Inspection is to ensure the top layer of the mineral wool panels are still intact and for any residual adhesive that may be on the top layer. Cutting and conditioning are to proportion the mineral wool waste so it can be reused and then dried to be put under performance testing.

In practice, the forms of mineral wool most realistically suitable for reuse are intact insulation boards that can be recovered during controlled deconstruction. These panels typically preserve their original fiber structure, density, and thermal resistance. In contrast, loose-fill material or heavily fragmented mineral wool is far less suitable for direct reuse, as it is more susceptible to contamination, moisture uptake, and loss of mechanical integrity during removal and handling.

The study done by Acar, Steemen and Bossche indicated that mineral wool insulation bonded with adhesives, bitumen, or roofing membranes can still be reused provided that contamination is limited and can be mechanically removed without damaging the fiber structure.

However, insulation exposed to excessive moisture, biological growth, or embedded debris is generally not suited for reuse as moisture absorption degrades thermal performance and compressive strength.

Reuse would most likely occur through selective deconstruction practices rather than conventional demolition. Roofing replacements projects, and interior renovations offer opportunities to recover intact mineral wool panels. However, space constraints on NYC construction sites may present challenges. Reuse would require off-site staging and conditioning facilities, where recovered insulation can be dried, cleaned, inspected and stored before redistribution.

Benefits

There are many benefits for reusing mineral wool waste as thermal insulation. These benefits include the maintaining of thermal performance and it prevents mineral wool from being wasted when it can be reused for decades. After 28 years of being used there was no degradation in the thermal conductivity value (Acar et al., 2024). Along with that, density was found to remain the same even after dismantling. Due to these lasting properties mineral wool waste is a good option for reuse that limits that amount that would be dumped into landfills.

Limitations

However, there are also many limitations when it comes to reusing mineral wool waste for new thermal insulation. It was measured that a majority of the mineral wool waste that was to be recycled failed a moisture absorption test’s current standards and needs vapor barriers in order to be successfully implemented and reused (Acar et al., 2024). There was also found to be lower compressive strength in the reused mineral wool waste, approximately 43% of the samples failed to meet compressive strength requirements.

The primary bottlenecks to reuse are moisture damage and compressive strength degradation. The durability assessment shows that while thermal conductivity may remain stable, prolonged moisture exposure can lead to reduction in compressive strength limiting its use as a load bearing or roof applicable material. Leading to it may be better used in non-structural insulation applications.

Although it may seem that reusing mineral wool waste for new thermal insulation may seem like an easy idea that can be implemented, it is not necessarily the only implementation that can be used as the demands for new thermal insulation may not be enough to reuse all the mineral wool waste that is generated.

Feasibility of Each Reuse Option Compared

The 5 reuse options for mineral wool waste presented have promising potential but are also limited in the context of NYC implementation. Feasibility is dependent on recovered material condition, cost of facilities for take-back and preprocessing hubs, and approval from regulations such as NYSDEC BUDS. The potential of each reuse option is summarized in the following table where they are compared against each other for their feasibility.

Reuse Option	Preprocessing	Benefits	Limitations	NYC Feasibility	Part 360/BUDs Status
Raw material for silica aerogel	Requires waste sorting, drying, chemical treatment with acid to remove binders and thermal treatment.	Produces silica aerogel with thermal conductivity 21.4–26.9 mW/(m·K) and porosity greater than 94%.	Cost of preprocessing as chemical treatment can be expensive. During treatment, can	This reuse pathway has a moderate feasibility of implementation in NYC. The required facilities	Not pre-approved and will require case-specific BUDs.

		Silica aerogel price is approximately 200 euros per square meter while mineral wool is only about 23 euros per square meter.	release ammonia, phenol and formaldehyde depending on the binder present.	will be a long-term project and will be costly. However, the cost difference and thermal properties produced makes mineral wool a great alternative raw material.	
Mineral wool waste take-back (ROCKWOOL's Rockcycle)	Requires sorting from global markets, contamination control and moisture control. The processed waste will then undergo regular manufacturing by electric-melting production lines.	ROCKWOOL has achieved 40% landfill waste reduction from their production. This amounts to 37 kilotonnes removed. Additionally, their move to electric-melting production lines has reduced CO_2 emissions by 25,000 tonnes per year.	Requires large-scale participation from manufacturers to cooperate with the take-back program. Transportation of waste will contribute to a large cost unless facilities are set up nearby.	This reuse pathway has a moderate feasibility of implementation in NYC. Hubs will have to be setup for take-back and preprocessing near industrial zones.	Not a pre-approved BUD. Will need to comply with NYSDEC and NYC solid waste management regulations.
Fiber addition for mortars	Requires Alkaline (NaOH) treatment to improve fiber-cement bonding.	Flexural strength increases by up to 47%, reduced water absorption and improved fiber-matrix bonding, and diverts insulation waste from disposal routes.	Compressive strength decrease, fiber overlap and entrained voids form causing preferential failure pathways.	Not feasible structurally, viable from non-structural applications. Requires tight dosage control, however.	Not a pre-approved BUD. Will require use-specific and site-specific BUD from NYSDEC.

			Introduction of higher fiber contents reduce workability and increase porosity. Chemical pretreatment increases costs and handling.		
Supplementary cementitious material	Purity and contamination identification, chemical composition testing, contamination testing for chlorides and a physical analysis test	Increased compressive strength, denser microstructures, chloride-ion and abrasion resistance	High chemical composition variability between brands, not enough research done to be confidently implemented	This reuse pathway has a moderate feasibility of implementation in NYC. More research would need to be done to ensure structural integrity of the structures being made.	Not a preapproved BUD.
Recycling for reuse as thermal insulation	Physical tests, hygrothermal performance tests, and mechanical performance tests	The thermal conductivity of the mineral wool did not decrease by a significant amount over a long period of time.	Many of the mineral wool waste failed the moisture absorption test, causing the need for vapor barriers	This reuse pathway has a high feasibility for implementation in NYC. Best used as non-structural insulation.	Not a preapproved BUD.

Table 4. Comparison of Mineral Wool Beneficial Reuse Options.

NYC Specific Context

New York City's standards for mineral wool insulation are a precise combination of safety regulation, housing specifications, waste management, and circular construction policies. Due to New York City's nature as a very dense population, recycling and building safety are all growing concerns that need to be addressed. The powerful characteristics of mineral wool have led to increased importance of the material being integrated into NYC construction, as mineral wool is an effective material in its safety aspect and its ability to be recycled post-use.

The New York City Department of Housing Preservation and Development, or the HPD, established a detailed list of requirements that insulation materials must follow when used in residential or newly constructed facilities and buildings. In section 7A of the HPD's report on insulation specifications back in 2004, mineral wool was listed as one of the accepted materials for use in apartment walls and penetrations. This was due to mineral wool passing the multitude of ASTM standards and meeting requirements for fire safety, which included the limit of flame-spread and smoke development. Mineral wool matched the needs of NYC construction well, reflecting the city's emphasis on safety properties, protecting residents from potential fire-related disasters that could be further compounded by the already dense population. Mineral wools classification as a non-combustible, along with its establishment as a strong material in terms of safety, made mineral wool more desirable for builders and the NYC construction industry as a whole (NYC HPD, 2004). Although Title 27 is no longer the primary governing building code used in NYC, Title 27 still stands as a legacy code, with its regulations still in play in existing buildings, and the regulations from the code are still relevant today as modern NYC code still contains the same requirements for mineral wool and the material is still the preferred insulation material in buildings. The continued use of mineral wool for insulation is seen in the 2022 New York City Building Code, particularly in relation to multi-family and high-rise buildings. The

2022 NYC Code lists “batts or blankets of mineral wool and mineral fiber” as permitted fire blocking materials. This confirms the continued use and importance of mineral wool within the NYC construction ecosystem (NYC DOB, 2022).

While mineral wool safety is up to standard, the question that remains is the materials’ end-of-life implications. This question is answered by waste management data in the city. The New York City Department of Sanitation’s 2023 Waste Characterization Study gives insight into the construction and demolition (C&D) debris that is generated across the city. The DSNY Waste Characterization Study reflects material collected through DSNY-managed residential and select industrial wastes streams (meaning the study does not reflect majority of privately hauled C&D debris in NYC). The report lists mineral wool and other insulation materials as “other C&D debris”. A study shows that from 2017 to 2023, C&D aggregate debris declined from 4.5% to 3.3%, supporting the continual decline of 5.2% in 2005. This is also accurately reflected in pounds per household (Lb/HH) from 87 Lb/HH to 60.9 Lb/HH from 2017 to 2023. Categorically, both unclassified and treated/contaminated wood debris have been reduced in Lb/HH over the years. These unclassified "other" debris include insulation material which as a group has decreased from 41.9 Lb/HH to 35.8 Lb/HH. However, the results of the study show a positive trend in terms of the debris being created over the years. The insulation-related debris decreased significantly, indicating that mineral wool is being used more efficiently during construction or there is reduced disposal volumes. Further clarification states that mineral wool insulation is primarily regulated at the contractor level, meaning that mineral wool insulation waste is handled primarily through disposal channels and private hauling (DSNY, 2023).

As NYC continues to further optimize mineral wool use, another key player that continues to emerge is the idea of circulating construction and embodied carbon goals. The New

York City Economic Development Corporation's Circular Construction Guidelines state that through the efforts of material reuse, improved material management, and a better understanding of the lifecycle of materials like mineral wool, carbon emissions have been reduced by nearly 50%. Mineral wool itself is a primary reuse material; however, insulation materials are considered when discussing carbon strategies to better reach climate goals set by the state.

The NYCEDC outlines the lifecycle method for materials, from the design phase to the end-of-life deconstruction phase, and how to get the material back into the design phase. The essence of circular construction is the continued cycle of life for materials, not the death of a material after a single lifespan. Within this framework, mineral wool properties, such as durability and long-life align well with the goals of circular construction, as these properties reduce replacement frequency and long-term material waste (NYCEDC, 2024). More methods to use materials such as mineral wool are being developed daily, and as circular construction continues to grow, the reuse opportunities for mineral wool also expand within the city.

At present, there's no widely documented NYC-specific pilot projects that are exclusively working on finding solutions for mineral wool insulation reuse. However, this does not mean that there will not be any in the future. Mineral wool falls within the section of C&D material recovery efforts that are promoted by the NYCDEC for circular construction programs. However, reuse of mineral wool has proven difficult due to the constraint of on-site storage capacity and the dense construction sites that are part of NYC. Furthermore, reuse pathways require NYSDEC Part 360 Beneficial Use Determinations, which have added permitting constraints on top of the difficulty in generating mineral wool waste in the first place (due to mineral wool insulation waste being generated in small quantities during demolition/renovation processes).

Conclusion

Each strategy should be considered carefully to deem its viability in the context of NYC such that the city can minimize the amount of mineral wool waste that is being dumped into landfills. Among the five strategies presented, the most applicable in the near future would be the direct recycling of mineral wool waste for insulation. This has been demonstrated by ROCKWOOL in their Rockcycle program to be very effective at reducing landfill waste and their sustainability reports grant applicable data. This promising strategy is further supported by the study on reusing thermal insulation materials by Acar et al., (2024) which proved that mineral wool insulation retains its thermal conductivity even after 28 years. This strategy should be combined with repurposed mineral wool waste as a pozzolanic SCM because it is another strategy proven to give beneficial results with low cost of implementation. On the other hand, strategies such as raw material for silica aerogel are less manageable due to the high processing costs associated with reagents, safe chemical handling, and the need for approval from NYSDEC for case specific BUD.

The main challenges are the limited research on mineral wool waste, contamination and the different recipes that different companies use to create mineral wool. With more research into mineral wool other options could be thought of and older methods can be improved upon. Mineral wool waste is found in different conditions such as from debris, prolonged exposure to weather or from ceilings and walls. The need for chemical treatment to remove impurities introduces a large cost and the thermal conductivity of mineral wool decreases as moisture level increases. The differing recipes between companies is especially a problem as it causes high variability in different samples of mineral wool waste which causes different properties in each mineral wool.

Material properties and conditions play an extremely important role in determining which beneficial use potential option is best suited for the specific piece. The high silicate and calcium oxide content in mineral wool waste makes it a valid option to be used as an SCM as both silicate and calcium oxide improve the strength of cement. These could also be limiting factors as seen in the differing conditions of mineral wool waste, each condition has a different chemical composition making the properties that it can provide highly variable. Extensive testing and pretreating which may not be economically worth it would prevent mineral wool waste from being reused.

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