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How dry recycled materials affect the construction materials industry and structural innovations for earthquake resistance

Mahdi Aliyari[1]

1. Architecture Department, Islamic Azad University, Shabestar Branch, Shabestar, Iran

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ABSTRACT

This article examines the influence of dry recycled materials in the construction materials industry and their role in structural innovations aimed at enhancing the seismic resistance of buildings. With the increasing risk of earthquakes in many regions, the use of recycled materials has been recognized as an effective strategy to improve the performance of structures against seismic forces. This research analyzes the mechanical and physical properties of dry recycled materials, such as recycled concrete and other materials, and their impact on structural characteristics. The results indicate that the use of these materials not only reduces construction costs but also significantly enhances the performance of structures against earthquakes by improving mechanical properties and reducing dead load. This study also discusses the challenges and opportunities available in this field and offers suggestions for future research. Finally, it emphasizes the importance of using recycled materials in the context of sustainable development and environmental protection.

Introduction

With the development of cities, the need for sustainable and earthquake-resistant construction has become increasingly evident. One effective solution in this regard is the use of dry recycled materials, which can significantly contribute to achieving this goal in the construction industry. These materials not only help reduce waste and protect the environment, but they can also be used as innovative materials to improve structural properties and increase the seismic resistance of buildings [1]. Earthquakes, as one of the serious threats to structures, require special attention to new technologies and materials [2]. Utilizing recycled materials can play a crucial role in reducing damage and losses caused by earthquakes. Research and development in combining these materials with traditional materials can enable the creation of more resilient and sustainable structures. Due to the very dynamic advancements in the production of electrical and electronic equipment, the rate of consumption has accelerated remarkably in recent decades [3]. Rapid changes in the production of equipment, its components, and characteristics have reduced the cost of electronic goods, and the fact that consumers dispose of older products indicates a demand for new products with the latest technology. This, in turn, causes the obsolescence of electrical and electronic devices. Electronic waste includes discarded equipment such as computers, mobile phones, televisions, printers, laptops, personal stereos, washing machines, air conditioners, refrigerators, and other household appliances. Electronic waste is growing at nearly three times the rate of municipal waste worldwide [4].

Electronic waste consists of various chemical materials such as lead, cadmium, mercury, beryllium, bromine combined with heat, and plastics including polycarbonate biphenyls, polyvinyl chloride, and polystyrene, many of which are hazardous and potentially pose serious environmental problems, endangering human health. Careful management of electronic waste is required. The global trade in this complex and toxic electronic waste poses a challenging task for its management and raises environmental concerns in both developed and developing countries [6-5]. Many developed countries have imposed stringent norms for managing electronic waste to prevent negative impacts on the environment and human health. However, the lack of facilities for recycling, along with strict regulations, poses a serious threat in developing countries. The volume of unethical export of electronic waste from Western countries to underdeveloped Asian and African countries has risen due to their vulnerabilities in dealing with such waste. India, with a population of over a billion, has a rapidly growing economy, and its consumption of electronic devices is on the rise. A joint study on electronic waste production was conducted by the Manufacturers' Association for Information Technology (MAIT) and (GTZ) Germany. Approximately 400,000 tons of electronic waste, including computers, mobile phones, and televisions, are generated annually, which is expected to grow at a rate of 10-15% each year. Plastic is one of the predominant materials used in electronic devices, primarily comprising about 21%. In India, most plastics from electronic products are recycled by the private sector. Currently, there is no definitive process for recycling electronic plastics in the private sector. In the public sector, the current recycling process effectively recycles only 20% of plastics [7]. Since the current recycling process for electronic plastics is inefficient, the disposal of electronic plastic waste through incineration, private recycling, and landfilling is the ultimate solution for transferring electronic plastic waste to the environment. Numerous research efforts worldwide have been conducted using plastics made from urban solid waste, such as polyethylene terephthalate bottles, polyvinyl chloride (PVC) pipes, and low-density polyethylene bags. These plastics are shredded and used as micro-particles, fillers, or additives in the preparation of cement and concrete mixtures [9-8]. This paper examines the impact of dry recycled materials on the building materials industry and structural innovations aimed at enhancing the seismic resistance of structures. It will also analyze the benefits and challenges present in this field. The primary goal of this research is to identify effective methods for optimizing the use of available resources and enhancing construction quality against earthquakes.

Research Methodology

This research is of a descriptive-analytical type and is based on the collection and analysis of qualitative data. The current study is designed to examine the impact of dry recycled materials in the building materials industry and structural innovations aimed at increasing the seismic resistance of structures. To gain a deeper understanding of this subject, a qualitative research method is used, which allows the researcher to explore the experiences, opinions, and perspectives of experts and specialists in this field.

The Impact of Dry Recycled Materials on the Building Materials Industry

Dry recycled materials refer to those materials that, after initial use, are processed mechanically or chemically and can be reused in various industries, especially construction [10]. These materials include:

- Recycled Concrete: Obtained from crushing old concrete and used in new construction.
- Recycled Bricks: Bricks extracted from demolished buildings.
- Recycled Plastics: Use of discarded plastics in the production of new materials such as insulation foams.
- Recycled Metals: Including steel and aluminum extracted from old buildings and remelted.

1. The Impact of Dry Recycled Materials on the Building Materials Industry and Structural Innovations for Seismic Resistance

- Types of Dry Recycled Materials
- Recycled Concrete
- Recycled Bricks
- Recycled Plastics
- Recycled Metals

1.1. Recycled Concrete

Recycled concrete refers to concrete obtained from the demolition of old structures or other construction projects [11]. This concrete typically contains aggregates, cement, and additives that are processed again and free from contaminants before use. The use of recycled concrete helps reduce construction waste and prevents the accumulation of garbage in landfills. By replacing a portion of the raw materials (such as natural aggregates) with recycled concrete, the need for extracting new resources is reduced [12]. With appropriate techniques, the mechanical properties of recycled concrete can be improved, allowing it to bear greater loads. Recycled concrete is a sustainable and economical option in the construction industry that can help reduce environmental impacts and conserve resources. Given the existing challenges, there is a need for further research and the development of suitable standards for the use of this type of concrete.

Figure (1) The Production Cycle of Recycled Concrete

1.2. Recycled Bricks

Recycled bricks refer to bricks obtained from the demolition of old buildings or other construction projects [13]. After cleaning and processing, these bricks are reused in construction, helping to reduce construction waste and preventing its accumulation in landfills. By reusing bricks, the need for producing new bricks and extracting raw materials is decreased. Recycled bricks are a sustainable and aesthetically pleasing option in the construction industry that can help reduce environmental impacts [14]. Given the existing challenges, there is a need to develop suitable methods for processing and utilizing these types of bricks in order to benefit from their advantages.

1.3. Recycled Plastics

Recycled plastics refer to plastics derived from used plastic products and packaging. After collection, separation, cleaning, and processing, these plastics are reintroduced into the production cycle [15]. The use of recycled plastics helps reduce the volume of plastic waste in the environment, and by reusing plastics, the need for producing new plastics and extracting raw materials is diminished. Recycled plastics are an effective solution to combat the plastic waste crisis and protect the environment. Despite the challenges in this area, efforts to improve recycling processes and raise public awareness can contribute to sustainable development.

1.4. Recycled Metals

Recycled metals refer to metals that are collected from used products and materials and are reintroduced into the production cycle after processing. These metals include aluminum, copper, iron, steel, and tin, and they help reduce the consumption of natural resources, as recycling metals reduces the need for extracting and processing raw materials [16]. Metal recycling is an effective solution for conserving natural resources, reducing pollution, and saving energy. By increasing public awareness and improving collection and processing methods, contributions can be made toward sustainable development and environmental protection.

Advantages of Using Dry Recycled Materials

Using dry recycled materials offers numerous benefits for the environment, economy, and society. First, this process helps reduce the volume of waste produced and the pressure on landfills. Additionally, recycling leads to the conservation of natural resources such as trees, minerals, and water, thus helping to preserve these valuable resources. Furthermore, recycling can reduce air and water pollution, as the process of producing new materials is usually associated with more pollution. In terms of energy, producing products from recycled materials typically requires less energy compared to producing from new raw materials [17]. This industry can also lead to the creation of new jobs in the collection, processing, and selling of recycled materials, contributing to the development of local businesses and small industries. Moreover, using recycled materials can increase public awareness about the importance of environmental protection and sustainable resource management. Ultimately, by reducing the need to extract natural resources, recycling can help preserve ecosystems and biodiversity [19-18]. Overall, the use of dry recycled materials not only benefits the environment but also supports sustainable development and social welfare.

Table 1- Advantages of Using Dry Recycled Materials

Waste Reduction	Recycling dry materials like paper, plastics, and metals helps reduce the volume of waste produced and eases pressure on landfills.
Natural Resource Conservation	Reduces the need for new raw materials and helps preserve natural resources such as trees, minerals, and water.
Pollution Reduction	The process of producing new materials is generally associated with more pollution. Recycling can help reduce air and water pollution.
Energy Conservation	Producing products from recycled materials usually requires less energy than producing them from new raw materials.
Ecosystem Protection	By reducing the need for extracting natural resources, recycling can help preserve ecosystems and biodiversity.

Challenges and Barriers

The use of dry recycled materials in the construction materials industry, despite environmental and economic benefits, faces numerous challenges and barriers that hinder their widespread adoption. One of the primary obstacles is the quality and reliability of these materials; the lack of clear standards for evaluating their quality has raised concerns about the strength and durability of these materials under various conditions. In addition, there are technical barriers. The need for further research and development to understand the behavior of recycled materials under seismic loads, along with a shortage of empirical data and necessary simulations to evaluate the performance of these materials, presents serious challenges. Furthermore, the initial costs associated with processing and preparing these materials for construction can impede their adoption [20]. In this context, the lack of adequate financial incentives from the government or private entities adds to the challenge.

On the other hand, legal and regulatory barriers are also evident. The absence of clear laws and regulations for using recycled materials in the construction industry, along with the need for specific permits that may lengthen the process of utilizing these materials, stands out as a major hurdle. Awareness and education also play crucial roles in the acceptance of these materials [21]. The lack of awareness and knowledge among engineers and contractors regarding the benefits and applications of recycled materials highlights the need for educational programs and practical workshops. Resistance to change is another challenge. Some companies and contractors may resist the shift towards the use of new and innovative materials, and there is fear regarding the risks associated with using unconventional materials [22].

Finally, environmental issues must also be considered. Concerns about the environmental impacts of recycling processes and the production of new materials, combined with a lack of transparency regarding the complete life cycle of these materials, can influence their acceptance.

Overall, these challenges require serious attention and appropriate solutions to harness the high potential of dry recycled materials in the construction materials industry. Table 2 outlines the challenges and suitable solutions.

Table 2- Challenges and Barriers Affecting Dry Recycled Materials in the Construction Industry and Structural Innovations for Seismic Resistance

Quality and Reliability of Recycled Materials	• Lack of clear standards for assessing the quality of recycled materials • Concerns about the strength and durability of these materials under various conditions.
Technical Barriers	• Need for further research and development to understand the behavior of recycled materials under seismic loads. • Shortage of empirical data and necessary simulations for performance evaluation.
Resistance to Change	• Some companies and contractors may resist the shift towards using new and innovative materials. • Fear of risks associated with using unconventional materials.
Legal and Regulatory Barriers	• Absence of clear laws and regulations for using recycled materials in the construction industry • Requirement for specific permits that may prolong the process of using these materials.
Environmental Issues	• Concerns regarding the environmental impacts of recycling processes and new material production. • Lack of transparency about the complete life cycle of these materials.
Design Requirement Compliance	• Challenges in aligning recycled materials with design requirements and seismic engineering standards. • Need for innovation in structure design to effectively utilize these materials.

Structural Innovations and Seismic Resistance

The use of dry recycled materials in the design and construction of structures can enhance seismic resistance. Utilizing dry recycled materials in structural design, particularly in improving seismic resilience, is an innovative and sustainable approach that can significantly enhance the performance of structures during earthquakes. One of the most important recycled materials is recycled concrete, which is obtained from the demolition of old structures. By adding chemical compounds and reinforcing fibers to this concrete, its mechanical properties can be improved, making it more resilient. Shear walls constructed from recycled materials can also help distribute seismic loads and act as elements resistant to lateral forces [23,24].

Seismic base systems designed with recycled materials can reduce the transfer of seismic forces to the structure. These systems typically include springs or dampers that absorb seismic energy. Additionally, protective coatings made from recycled materials can help increase the durability of structures against earthquake-induced damage [25]. Lightweight and modular materials also enable the design of more resilient structures by reducing dead loads. Advanced connection designs using recycled materials can enhance the strength and flexibility of the structure. Furthermore, managing construction waste and encouraging the reuse of recycled materials can mitigate negative

environmental impacts and reduce construction costs.
The use of dry recycled materials in the design and construction of structures can help enhance seismic resistance. Some of the innovations and techniques related to this topic are summarized in Table 3.

Table 3- Structural Innovations and Seismic Resistance Techniques

Fiber Reinforcement	Using recycled fibers (such as glass or carbon fibers) in combination with construction materials can enhance flexibility and resistance of structures against earthquakes.
Shear Wall Systems	Utilizing shear walls made from recycled materials can aid in better distribution of seismic loads and reduce deformations.
Seismic Base Systems	Designing seismic base systems made from recycled materials can help reduce the transfer of seismic forces to the structure, enhancing its earthquake resilience.
Use of Lightweight Materials	Employing lightweight recycled materials in construction can decrease the dead load of structures and facilitate improved seismic performance.
Modular Systems	Designing modular systems using recycled materials can allow for quicker repairs and reconstruction of structures, which is essential during earthquakes.

Conclusion

The use of dry recycled materials in the building materials industry, especially regarding structural innovations, has a significant impact on enhancing the seismic resistance of structures. These materials not only help reduce construction costs but also improve the performance of structures against seismic forces by enhancing mechanical properties and reducing dead loads. Given the increasing earthquake risk in many areas, the importance of this approach becomes even more evident. Additionally, using recycled materials contributes to environmental preservation and reducing construction waste, leading to sustainable development.

Recommendations

- Research and Development: Encourage further research into the combining and improving of properties of dry recycled materials, particularly under various climatic and seismic conditions.
- Standard Development: Establish national and international standards for the use of recycled materials in the construction industry to ensure quality and safety.
- Encouragement of Innovation: Support startups and innovative companies working on the use of recycled materials in building materials.
- Recycling Infrastructure Development: Invest in recycling infrastructure and construction waste management to facilitate the process of collecting and processing recycled materials.

By implementing these recommendations, improvements in the performance of structures against earthquakes and increased environmental sustainability can be achieved.

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