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Therapeutic Landscape Stepping Stone Using Recycled Plastic, Glass Waste and Coconut Shell Waste

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Abstract

Solid waste is not merely a disposal problem; it is an untapped resource that can be transformed into value. The Therapeutic Landscape Stepping Stone introduces a Waste-to-Value innovation that repurposes plastic PET waste, waste glass and coconut shell waste into sustainable landscape products. Unlike conventional stepping stones that rely on conventional construction materials, this innovation explores waste materials as alternative resources while supporting waste reduction and circular economy principles. Three stepping stone samples were developed separately and evaluated after 28 days of curing to assess performance and suitability for non-structural landscape applications. The results demonstrated promising performance, with the plastic waste sample achieving the highest compressive strength of 23.1 MPa at 5% replacement, followed by 15.3 MPa at 10%. Waste glass achieved 14.7 MPa at 10% and 13.2 MPa at 20%, while coconut shell achieved 5.4 MPa at 10% and 10.9 MPa at 20% replacement. These findings demonstrate the potential of waste materials to produce functional landscape products with measurable engineering performance. More than a stepping stone, the innovation creates a bridge between waste management, sustainable construction and community well-being. Its textured surface suggests potential applications in gardens, recreational spaces, community areas, wellness facilities and therapeutic landscapes. Potential deployment settings include Sabak Bernam landscape facilities, subject to subsequent safety and usability evaluation. Overall, the innovation transforms waste into a value-added product while reducing dependence on conventional resources and supporting a circular economy. It demonstrates a practical pathway from waste to resource, resource to product, and product to community value, supporting sustainable construction, circular economy and greener communities.

Keywords: Therapeutic Landscape; Waste-to-Value; Waste Plastic; Waste Glass; Coconut Shell Waste; Circular Economy.

Introduction

The construction industry is one of the major sectors that consumes large amounts of natural resources, particularly materials such as cement, sand and aggregates. The increasing demand for construction activities has contributed to the consumption of natural resources and has created a need to explore more sustainable alternative materials. At the same time, solid waste management has become an environmental challenge, particularly when potentially recyclable materials are disposed of through conventional disposal methods. Therefore, the utilization of waste materials as alternative materials in construction products is considered a potential approach towards more sustainable development and a circular economy (Munaro et al., 2020).

According to Gupta et al. (2020), various waste materials such as plastic, glass and coconut shells have been investigated for their potential use in concrete and other construction materials that can potentially reduce dependence on conventional raw materials while providing alternative approaches for waste management.

For plastic waste, recent studies have reported that recycled plastic can be incorporated into cement-based materials as an alternative aggregate or filler. However, increasing the proportion of plastic waste may affect the mechanical properties, particularly compressive strength, depending on the type, size and replacement level of the plastic (Bahij et al., 2020). This indicates that the use of recycled plastic requires appropriate selection of replacement levels to achieve suitable performance.

For glass waste, recycled waste glass has been investigated as an alternative material in concrete because of its potential to reduce waste disposal and dependence on natural aggregates. Its influence on concrete performance depends on factors such as particle size, replacement percentage and mixture composition (Qaidi et al., 2022).

Coconut shell is another type of waste material that has potential for utilization in the construction sector. Coconut shell can be used as a partial replacement for conventional aggregate in concrete-based materials, especially in lightweight concrete applications (Janani et al., 2022). The physical characteristics of coconut shells, including its lightweight and porous nature, may influence the mechanical properties of the resulting concrete product (Daud & Mokhtar, 2022).

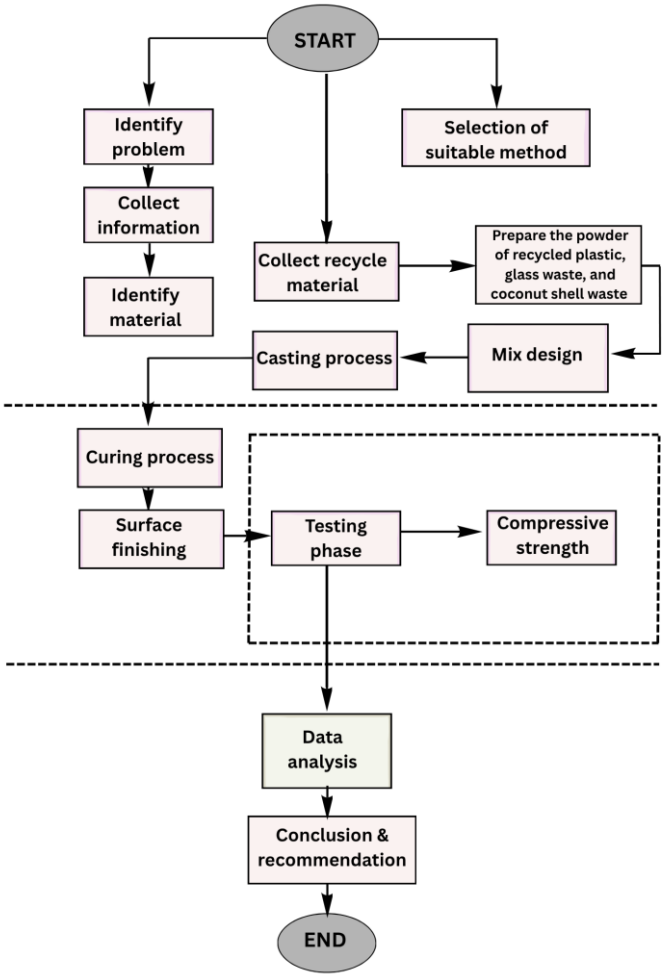
Mokhtar et al. (2021) further highlighted the potential of coconut shells as a partial replacement material in concrete products. The utilization of coconut shells may contribute to the development of more sustainable construction materials and reduce dependence on conventional aggregates. However, the replacement level needs to be considered carefully because changes in coconut shell content may influence the physical and mechanical properties of the final product.

Based on the potential of these three waste materials, this study proposes the development of Therapeutic Landscape Stepping Stone using separate formulations incorporating waste plastic, waste glass and

coconut shell. The proposed product is intended to function as a landscape element while providing additional value through the reuse of waste materials. The utilization of these three types of waste materials in separate product formulations provides a comparative approach to waste management in small-scale construction applications.

The concept of therapeutic landscape emphasizes the development of environments that can provide positive physical and psychological experiences to users (Taheri et al., 2021). In this study, this stepping stone is proposed for use in landscape areas such as gardens, recreational spaces and therapeutic environments. The incorporation of recycled waste materials into the product combines functionality, environmental sustainability and aesthetic value within a single innovation. Therefore, the development of a therapeutic landscape stepping stone using waste plastic, waste glass and coconut shell has potential as an innovative approach to waste utilization. This study focuses on producing a prototype stepping stone and evaluating its compressive strength to determine its suitability for non-structural landscape applications.

Methodology



The project was designed to develop a non-structural therapeutic landscape stepping stone using three selected waste materials such as PET plastic waste, glass waste and coconut shell waste. Each waste material was prepared and incorporated separately into the stepping stone mixture rather than combining all three materials into a single mixture.

The preparation process involved the collection, cleaning, processing and preparation of the selected waste materials before mixing. A total of six mixture combinations were prepared using three different waste materials, namely PET plastic waste (5% and 10%), glass waste (10% and 20%) and coconut shell waste (10% and 20%). Each waste material was incorporated separately into the stepping stone mixture at the selected replacement percentages. The prepared mixtures contained cement and fine aggregate according to the selected replacement percentages. The mixtures were then placed into the stepping stone mould, compacted and finished to obtain the required shape.

The completed samples were cured for 28 days before undergoing compressive strength testing. The reported compressive strength values (one value per mixture in the supplied results table, without replication

statistics) were then compared according to the different waste materials and replacement percentages to evaluate their mechanical performance for potential non-structural landscape applications.

Results and Discussion

The results show differences in compressive strength among six mixtures incorporating PET plastic, glass or coconut shell waste separately. Each waste material was evaluated at two different replacement percentages after 28 days of curing. The results were compared to compare performance by waste material and replacement percentage on the mechanical performance of developed stepping stones.



Figure 1. Three Sample Stepping Stones Using Waste Materials

Table 1.

Waste Materials	Replacement (%)	28 days Compressive Strength Test (MPa)
Coconut Shell Waste	10	5.4
	20	10.9
Glass Waste	10	14.7
	20	13.2
PET plastic waste	5	23.1
	10	15.3

Compressive Strength of Stepping Stone Samples at 28 Days

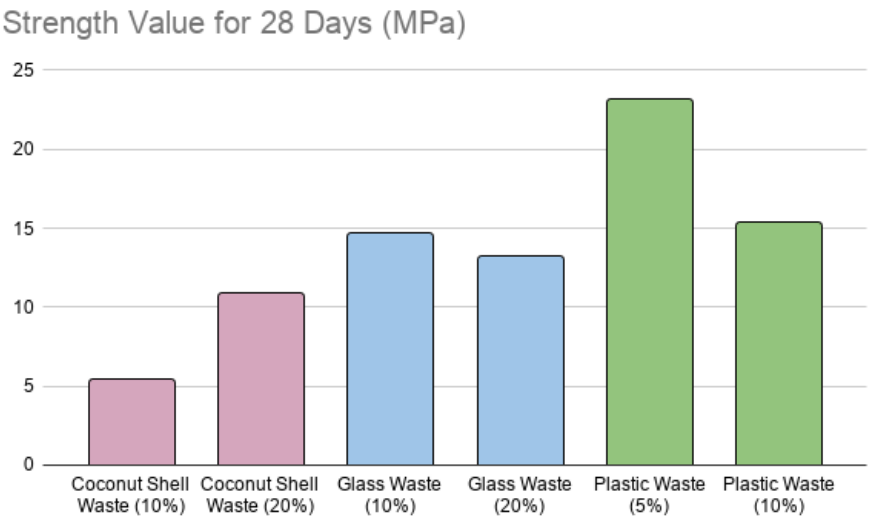


Figure 2. Compressive Strength Test

- **PET Plastic Waste**

  The PET plastic waste samples recorded the highest compressive strength among the three waste materials. The 5% replacement mixture achieved a compressive strength of 23.1 MPa, while the 10% replacement mixture achieved 15.3 MPa after 28 days. The reduction in compressive strength at the higher replacement level indicates that increasing the amount of plastic did not improve the mechanical performance of the stepping stone.

  This trend is consistent with previous research indicating that recycled plastic aggregate can affect compressive strength because of differences in particle characteristics and bonding between plastic particles and the cement matrix. Almeshal et al. (2020) reported that the properties of cementitious composites containing recycled plastic are influenced by factors such as plastic type, particle characteristics and replacement level. Bahij et al. (2020) also reported that increasing plastic waste content can negatively affect the mechanical properties of concrete. Therefore, the 5% PET plastic replacement demonstrated better compressive strength than the 10% replacement in this study.

- **Glass Waste**

  The glass waste samples achieved compressive strengths of 14.7 MPa at 10% replacement and 13.2 MPa at 20% replacement. The reduction in compressive strength at 20% replacement indicates that increasing the glass waste content did not continuously improve the mechanical performance of the stepping stone.

  The result is consistent with findings from recent reviews, which indicate that the mechanical performance of concrete containing recycled glass can vary depending on particle size, replacement ratio, glass characteristics, mixing and curing conditions (Hamada et al., 2022). The particle characteristics of recycled glass may also influence the bond between the glass particles and cement matrix. In this study, the 10% glass replacement provided higher 28-day compressive strength than the 20% replacement. Therefore, the lower replacement level demonstrated better mechanical performance for the glass waste sample.

- **Coconut Shell Waste**

  The coconut shell waste sample achieved a compressive strength of 5.4 MPa at 10% replacement and 10.9 MPa at 20% replacement. Unlike the PET and glass samples, the compressive strength of the coconut shell sample increased when the replacement level increased from 10% to 20%.

  The results indicate that the performance of coconut shells in cement-based products can vary according to replacement level and mixture characteristics. Daud and Mokhtar (2022) reported that coconut shell replacement can influence compressive strength, workability and water absorption. Janani et al. (2022) also highlighted the potential of coconut shells as an alternative aggregate in concrete.

  The relatively lower compressive strength obtained from the coconut shell samples compared with the PET and glass samples may be associated with the physical characteristics of coconut shell, particularly its lightweight and porous nature.

- **Overall Comparison**

  Overall, the results demonstrate that the type and replacement level of waste material influenced the compressive strength of the developed stepping stones. Among the six mixture combinations, PET plastic waste at 5% replacement recorded the highest compressive strength of 23.1 MPa, followed by PET plastic waste at 10% replacement with 15.3 MPa. Glass waste at 10% replacement achieved 14.7 MPa, while glass waste at 20% replacement achieved 13.2 MPa. Coconut shell waste recorded the lowest strength at 10% replacement with 5.4 MPa but increased to 10.9 MPa at 20% replacement.

  The findings demonstrate that there was no single replacement level that produced the highest strength for all three waste materials. Instead, the performance depended on the characteristics of each waste material and its replacement percentage. This observation is consistent with recent literature showing that recycled materials can influence concrete performance differently depending on their physical characteristics, particle properties and proportion in the mixture (Almeshal et al., 2020).

  Although the highest compressive strength obtained was 23.1 MPa, the result remained below the targeted strength of 30 MPa, representing a difference of 6.9 MPa. Therefore, the developed stepping stone did not achieve the initial 30 MPa strength target. Further optimization of the mixture proportions and additional performance testing are recommended before wider application.

Conclusion

In conclusion, the Therapeutic Landscape Stepping Stone using recycled PET plastic, glass waste and coconut shell waste was successfully developed and evaluated based on its 28-day compressive strength. The results showed that PET plastic waste at 5% replacement achieved the highest compressive strength of 23.1 MPa, followed by PET plastic waste at 10% with 15.3 MPa, glass waste at 10% with 14.7 MPa, glass waste at 20% with 13.2 MPa, coconut shell waste at 20% with 10.9 MPa and coconut shell waste at 10% with 5.4 MPa. These results demonstrate that the selected waste materials have potential to be incorporated into cement-based landscape products, although the optimum replacement level differs according to the type of waste material (Daud & Mokhtar, 2022).

The findings demonstrate that the reported prototype development and compressive-strength evaluation objectives were addressed through the development of separate stepping stone samples and evaluation of their compressive strength. The innovation provides a practical approach to converting waste materials into value-added products while reducing dependence on conventional resources. This approach is consistent with the principles of sustainable construction and circular economy, where waste materials can be recovered and reused as resources in new products.

Furthermore, the proposed stepping stone has potential for use in gardens, recreational spaces, community areas and therapeutic landscape environments. The combination of waste utilisation and landscape design suggests a possible application in therapeutic settings; effects on users' well-being were not evaluated. The concept is also supported by research highlighting the importance of therapeutic landscape in creating environments that can contribute to users' well-being (Taheri et al., 2021).

However, the study was limited mainly to compressive strength evaluation and a limited number of replacement percentages. Future research should investigate water absorption, durability, surface safety, different replacement percentages and long-term performance. Further optimization of the mixture design may also improve the mechanical performance of the stepping stone. Overall, the findings demonstrate that recycled waste materials, particularly PET plastic waste at 5% replacement, have promising potential for producing sustainable and functional non-structural landscape stepping stones.

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