ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2025, 10 (2): 108-116 doi: 10.28978/nesciences.1698437

Experimental Study on the Structural Behavior of RC Beams contains Pharmaceutical Waste

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Abstract

The recycling and disposal of trash have garnered heightened attention. This report presents the results of testing and examination of beams made of reinforced concrete, including pharmaceutical blister waste particles, as an exchange for sand in the concrete. Recycling pharmaceutical blister trash is often challenging and may require substantial energy expenditure. This research included grinding leftover pharmaceutical blisters and using them as a substitute for sand at replacement scales of 5%, 10%, 15%, 20%, 25%, and 30% by the amount of sand in a cubic meter of concrete. The beams were minimally fortified with steel rebar and engineered to collapse under shear. Test findings indicated that using shredded particles from pharmaceutical blister waste as a sand replacement in concrete leads to a decrease in ultimate failure load by around 7.4%. The stiffness characteristics and failure modes of recycled pharmaceutical waste-reinforced concrete are almost equivalent to conventional beams. The maximum capacity for the load was substantially altered, and the load-deflection response exhibited modest changes due to the incorporation of pharmaceutical waste particles up to 18.8%. Comparing the test results, it revealed that the predictions of moment capacity are precise. The disparity between the moment derived from testing and that derived from computed compressive strength was deemed insignificant. It is determined that a maximum of 25% well-graded pharmaceutical waste may be included safely to manufacture this sort of recycled reinforced concrete beams for structural purposes. Consequently, the study's results advocate for the suggested technique of recycling discarded pharmaceutical blisters in concrete.

Keywords:

Shear, strength, beams, waste, pharmaceutical.

Article history:

Received: 04/03/2025, Revised: 18/05/2025, Accepted: 23/06/2025, Available online: 30/08/2025

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Introduction

The use of pharmaceuticals resulted in heightened pharmaceutical manufacturing and an increased creation of trash from pharmaceutical blisters, which mainly contain the drugs. Pharmaceutics has significantly evolved in recent decades concerning pharmaceutical administration and safeguarding; however, vesicles remain essential as primary packaging initial packing for most tablets and specific capsule formulations. The heightened consumption of medications by patients, the trend of self-treatment with prescription drugs, and the growing request seeking widespread exemption-boosting products have led to an increase in trash from pharmaceutical packings, such as blistering packages and containers, from both medical facilities and residences. Nevertheless, little progress has been made regarding blister sustainability, necessitating attention to environmental considerations. To safeguard pharmaceuticals, blister packs are constructed from a complicated amalgamation of challenging-to-use items, such as plastic and aluminum foil, which are unfortunately not acknowledged by most recycling programs. Most blisters include plastic and aluminum, necessitating a chemical and/or physical procedure for layer separation and recycling, a step often neglected by recycling businesses. Recycling alone does not ensure sustainability since separating aluminum from plastic might require significant energy expenditure. Applying biological liquids or substances that corrode agents necessitates a comprehensive assessment of ecological impacts (Rahal & Elsayed, 2021).

Due to the persistent bonding of plastic and metal layers in waste pharmaceutical blisters, the mechanical separation of these components is almost difficult (Özkılıç et al., 2023). The authors have endeavored to identify a sustainable method for repurposing discarded pharmaceutical blisters, either crushing them into a powder or using them in concrete as a partial relief for sand. It fulfills the dual function of recycling pharmaceutical blister trash and conserving aggregates from nature. Concrete is a combination of different substances. Consisting of cement and aggregates formulated in proportions according to the mixture composition. Coarse aggregates furnish bulk and fortitude, whereas sand occupies unenforceable and somewhat enhances strength (Baldeón et al., 2024). Cement serves as a binding agent that unites the various components of concrete while also providing strength under compressive pressure. Water is essential for the hydration procedure to occur inside the mixture. The reaction involving chemicals occurs ultimately by mixing both water and cement. While aggregates remain inert. Consequently, researchers often substitute sand with alternative materials for long-term viability. Contemporary research involves substituting sand with materials such as ferronickel slag, iron ore tailings, coir pith, white crystal stones, glass powder waste, treated oil sand waste, waste marble dust, recycled tire aggregates, plastic box waste, polyethylene terephthalate waste, ferrochrome slag, alum sludge, recycled plastics, pretreated glass particles, waste glass, plastic waste, recycled brick, pulverized termite mounds, epoxy-coated polylactic acid, treated sawdust, glass powder, and waste glass sand, among others (Salih et al., 2024; Sabzi et al., 2024; Orhorhoro et al., 2016). Medical trash, especially pharmaceutical prescription blisters, has typically been banned from recycling in the building sector because to concerns over its potential hazards to human health. This investigation included the substitution of sand with waste pharmaceutical blister fine particles, subjected to solar dealings with at dosages of 5%, 10%, 15%, 20%, 25%, and 30% (Shahjalal et al., 2021) (Gerges et al., 2023). Initially, all materials were distinguished, subsequently leading to the suitable design of tests. Three criterion mixtures with varying water-cement ratios were prepared to achieve a goal strength of 25 N/mm^2 in accordance with the conventional coding. Its mechanical integrity with retention of moisture properties of the samples was then assessed using specific techniques outlined in the code (Karthikeyini & Palanisamy, 2015).

Materials and Methods

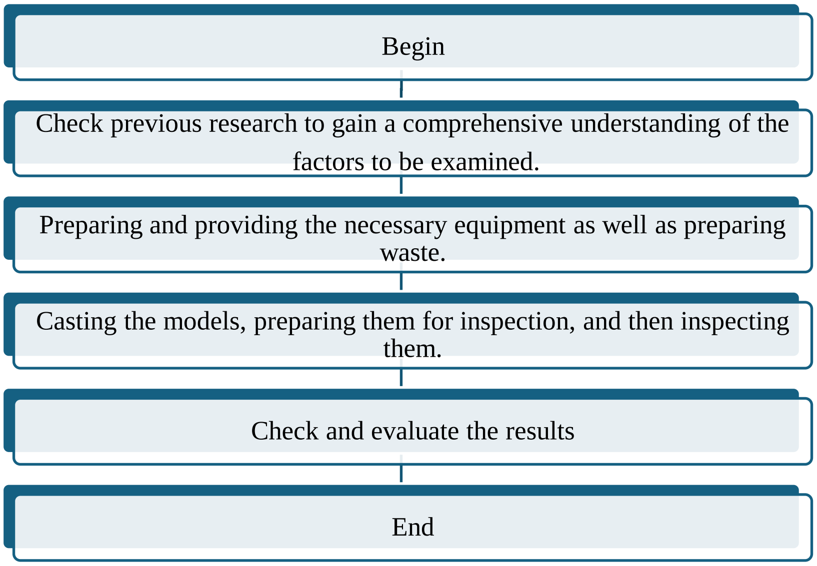

Figure 1. Methodology Diagram

Figure 1 illustrates the methods used to conduct the current investigation.

Preparation of Mixes

Empty pharmaceutical blister packs were gathered from a local drugstore. The empty drug blister packets were either returned by consumers or obtained from expired medications. Illustration 2. They were thereafter exposed to intense sunshine for twelve days in July, when temperatures in Kerbala City, Iraq, normally range from 45 °C to 50 °C, for a minimum of 8 hours each day for disinfection purposes. Subsequently, they were pulverized into a powder. The powder was sieved prior to its incorporation into concrete to achieve particle sizes between 10 mm and 0.15 mm, closely aligning with the sand's gradation. The materials used in the production of pharmaceutical blister waste mostly include Polyvinyl Chloride (PVC) (C_2H_3Cl) n, Polyvinylidene Chloride $(C_2H_2Cl_2)$ n, Polychlorotrifluoroethylene (C_2ClF_3) n, Aluminum foil (Al), and Cyclic The material The substances (Dalal et al., 2022; Ecemis et al., 2024). Experimental Design: A goal compressive strength of 30 N/mm² was selected for the investigation since it represents the predominant concrete type used in the area. It is often used for minor construction projects and modest residential structures. Ordinary Portland Cement (OPC) The greatest measurement of coarse aggregates used was 20 mm, along with fine aggregates. Research indicates that substituting aggregates often reduces the strength, feasibility, and resilience of composite materials made from cement, whereas the use of superplasticizers is beneficial. Sulfonated Naphthalene. The research used formaldehyde superplasticizer, an effective dispersion agent and strength booster. The dose of plasticizer was 4 ml per kilogram of cement, which was utilized by combining it with water. The mix design is shown in Table 1, and the sand replacement % is indicated in Table 2.

Figure 2. Pharmaceutical waste used in this study

Table 1. Concrete mix used in a study

Cement(kg)	Sand(kg)	Coarse aggregate(kg)	Water
400	700	1170	160

Table 2. Sand replacement percentage

Mix ID	Replacement
Mix no.1	0%
Mix no.2	5%
Mix no.3	10%
Mix no.4	15%
Mix no.5	20%
Mix no.6	25%
Mix no.7	30%

Specimens Information

Seven reinforced concrete beams with identical size and reinforcement are subjected to gradual static loading tests (Aksoylu et al., 2023). The beams are 150 mm in width, 250 mm in height, and 1200 mm in length (Kalaiselvi & Kumar, 2024). The specimens are engineered to exhibit shear weakness by omitting the stirrups that were included in the design while maintaining flexural strength (Mohammed & Hama, 2023). Figure 3 illustrates the size and reinforcement of the specimens. Two primary bottom reinforcement bars with a diameter of 16 mm and two top longitudinal bars with a diameter of 10 mm serve as the principal reinforcement A transverse reinforcing stirrup is placed at both ends. the stirrups from the blueprint of the beam to secure the longitudinal reinforcement (Ali M. Taher, 2024; Nieminen et al., 2020). The seven specimens include control specimens and three RC specimens, including varying amounts of pharmaceutical blister waste (5%, 10%, 15%, 20%, 25%, and 30%) (Ibrahim et al., 2022). An incremental monotonic loading test examines the shear conduct of seven reinforced RCs constructed with varying amounts of pharmaceutical blister debris. The specimens are held at both ends, as seen in Figure 4. The loads are incrementally applied by a hydraulic jack at a rate of 2 kN /min, maintaining a separation of 350 mm between the loads and the support, as seen in Figure 4. The load is transferred to the face of the beam by using rigid plates. As seen in Figure 4, Linear Variable Displacement Transducers detect upward beam deflection halfway (Aksoylu et al., 2022).

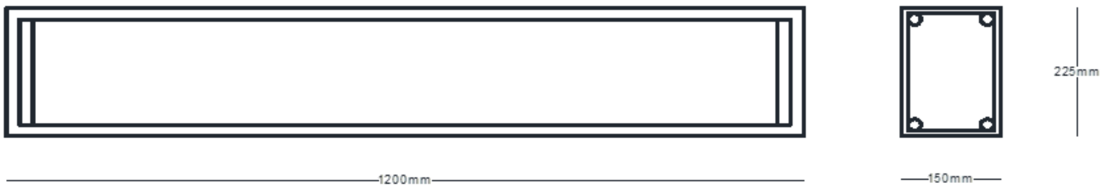

Figure 3. Beams Details

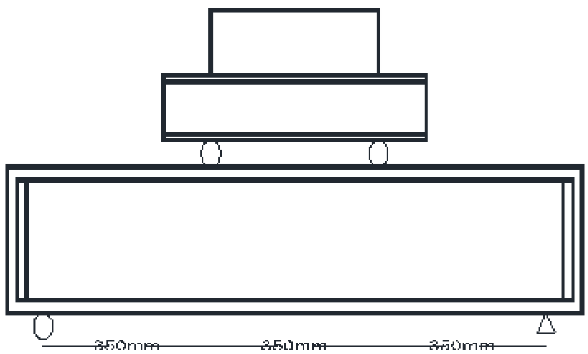

Figure 4. Test setup

Table 3. Beams indications

Beam ID	Replacement
Control BeamB0	0%
BeamB1	5%
BeamB2	10%
BeamB3	15%
BeamB4	20%
BeamB5	25%
BeamB6	30%

Test Results and Discussions

Provided are loading displacement arcs, starting cracking load, peak load, failure mechanisms, and cracking layouts.

Load Deflection Curve Characteristics

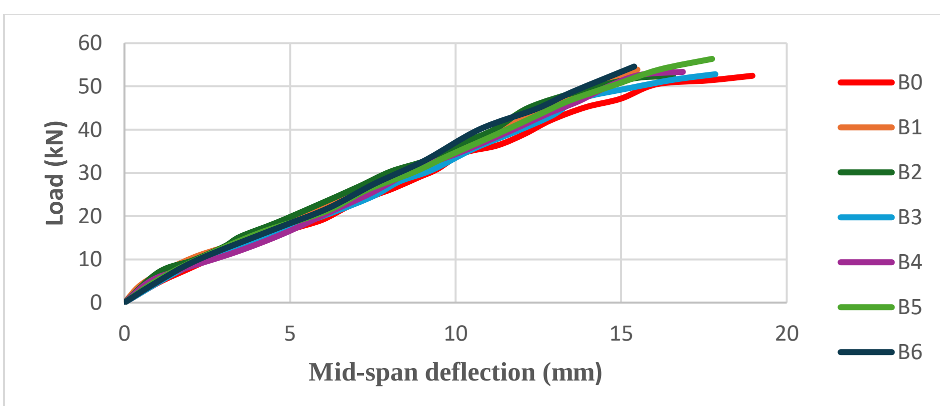

Figure 5. Curve of Load-deflection

Figure 5 illustrates the mid-span deflection underload for the seven beams. Table 3 and Figure 8 provide the initial cracking load, crack width, maximum load, and mid-span deflection at the maximum load for all beams.

Table 4. Beams load details

Symbol of a Beam	The initial cracking load (kN)	The failure load(kN)	Mid-span deflection mm)
B0	3.61	52.455	18.963
B1	3.89	53.873	15.490
B2	4.18	52.278	16.568
B3	3.78	52.281	17.843
B4	4.52	53.341	16.862
B5	3.85	56.354	17.745
B6	3.24	54.582	15.392

Table 4 shows that beam B0 failed at a load of 52.4 kN less than beams B2, B4, B5, and B6 by 2.7% ,1.7%,7.4%and 4.1%, respectively.

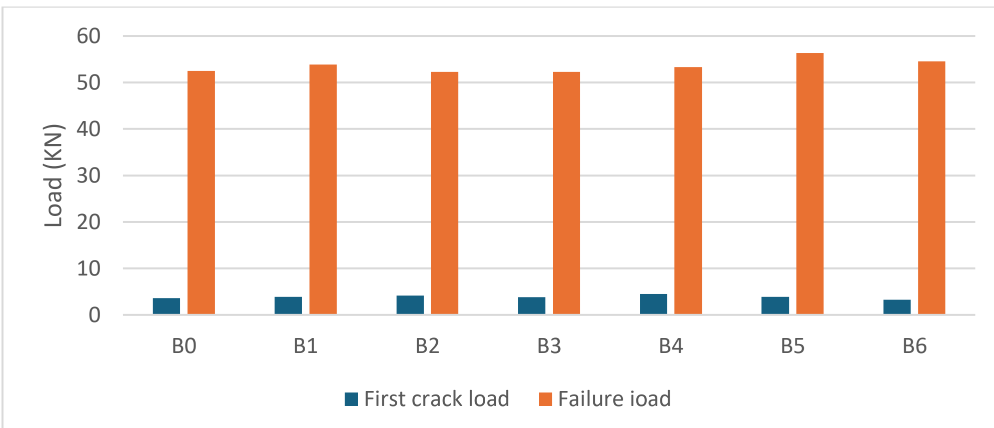

Figure 6. Utmost loads and first cracking loads

The use of distinct proportions of waste did not affect the shape of the deflection curve much because it did not come in the form of cracks and did not change, but it changed the amount of deflection and reduced it. adoption between all values of load cracking is shown in Figure 6.

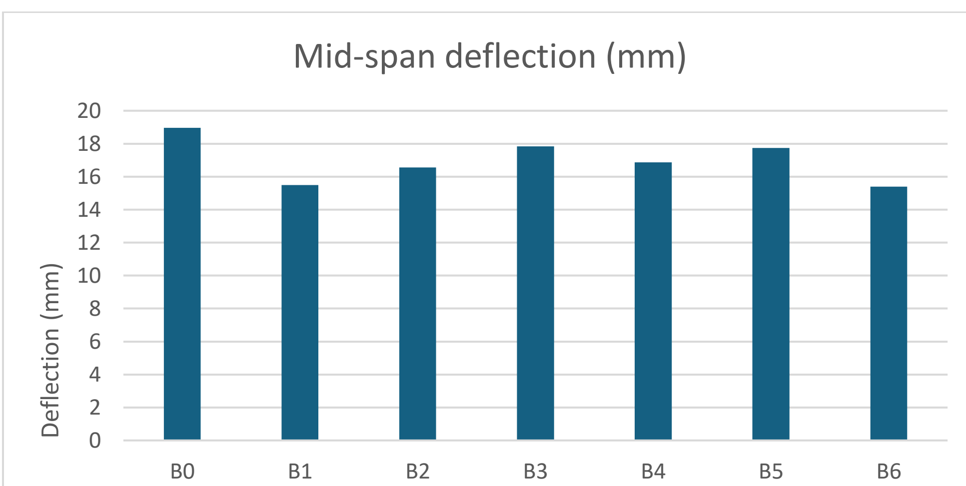

Figure 7. Mid-span deflection at failure loads

The reduction in mid-span deflection for B1, B2, B3, B4, B5, and B6 is 18.3%,12.6%,5.9%,11%,6% and 18.8% respectively. As shown in figure 7.

Cracking Pattern

Figure 8. Cracking Pattern

The shape of the cracks was similar among all thresholds, but small cracks decreased when high percentages of pharmaceutical waste powder were used. Most of the cracks were inclined at 45 degrees. The rise in stress caused the fractures to enlarge and spread, which resulted in failure due to shear. as seen in figure 8.

Conclusions

This experimental investigation examined the shear and fracture characteristics of several RCBs composed of pharmaceutical blister debris. Seven experimental beams were chosen as reference specimens for testing, devoid of any pharmaceutical blister debris. The other components comprised 5%, 10%, 15%, 20%, 25%, and 30% of pharmaceutical blister waste. From this empirical investigation, we derive the following conclusions:

- We notice that the crack pattern of the slit starts from the support upwards, which is inclined at a 45-degree angle in all models, whether they contain pharmaceutical waste.
- By comparing the deviation in all models, we notice a decrease in the deflection value with an increase in the percentage of waste used. The maximum reduction in mid-span deflection is 18.8 when using 30% of pharmaceutical waste.
- The first cracks were delayed in all models when using pharmaceutical waste compared to the standard beam.
- The maximum shear failure load found with the beam contains 25% of pharmaceutical waste used. In general, the failure loads are similar for all models with the model.

Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

All authors' contributions are equal for the preparation of research in the manuscript.

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