

# Sustainable Utilisation of Expired Calcium-Based Medicines in Concrete as Cement Replacement

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**Abstract:** *The growing accumulation of expired pharmaceutical products and the increasing environmental impact of cement production have created a need for sustainable waste utilisation strategies in the construction industry. This study investigates the feasibility of using expired calcium-based medicine powder as a partial replacement for Ordinary Portland Cement (OPC) in concrete. The expired medicines were collected, processed into a fine powder, and incorporated into concrete mixes at 5%, 10%, and 15% by weight of cement. A control mix without medicine powder was also prepared for comparison. The experimental investigation evaluated the effects of incorporating medicated powder on the properties of fresh and hardened concrete, including workability, setting time, soundness, compressive strength, flexural strength, and split tensile strength.*

*The results showed that workability gradually declined as the replacement percentage increased, due to the finer particle size and larger surface area of the medicine powder. Both setting time and soundness values increased moderately with higher replacement levels, but all mixes stayed within acceptable limits up to 15% replacement. Mechanical performance was notably affected by the replacement percentage. The 5% replacement mix delivered the best overall results, with a 28-day compressive strength of 42 MPa, compared to 40 MPa for the control. Flexural and split tensile strengths also improved at 5% replacement, reflecting better particle packing and hydration within the concrete. Beyond this level, strength properties gradually decreased. These findings indicate that incorporating a limited amount of expired calcium-based medicine powder can be a sustainable way to enhance concrete, supporting environmentally responsible pharmaceutical waste management and reducing cement use.*

**Keywords:** Sustainable concrete, Expired medicines, Cement replacement, Pharmaceutical waste utilization, Calcium-based medicine powder, Supplementary cementitious material, Mechanical properties, Green construction, Sustainable waste management, Concrete technology.

## I. INTRODUCTION

Concrete remains one of the most widely used construction materials worldwide because of its strength, durability, adaptability, and economic feasibility. Ordinary Portland Cement (OPC), the primary binding material in concrete, plays a crucial role in achieving the required structural performance. Despite its advantages, cement manufacturing is associated with high energy consumption and significant carbon dioxide emissions, making it a major contributor to environmental pollution. With the increasing demand for infrastructure development, the construction industry is under growing pressure to adopt sustainable alternatives that reduce cement consumption without adversely affecting concrete performance [1,2]. The use of supplementary materials in concrete has therefore gained considerable attention as part of sustainable and environmentally responsible construction practices [3].

At the same time, the disposal of expired pharmaceutical products has become a serious environmental concern. Large quantities of expired medicines are generated every year by the pharmaceutical industry, hospitals, medical stores, and other healthcare facilities. Among these wastes, calcium-based medicines constitute a considerable portion due to their widespread medical use. Improper disposal methods, including dumping in landfills or drainage systems, can result in soil and groundwater contamination and may negatively affect both aquatic and terrestrial ecosystems [4,5].



Conventional disposal methods such as incineration and chemical treatment are often costly and may themselves create secondary environmental problems. As a result, there is an increasing need to identify sustainable approaches that convert pharmaceutical waste into useful engineering materials rather than treating it solely as waste [6].

In recent years, several industrial and agricultural by-products, such as fly ash, silica fume, rice husk ash, and ground granulated blast furnace slag, have been successfully used as partial cement replacements in concrete. These materials have improved workability, durability, and long-term strength while reducing the environmental burden associated with cement production [7]. Such approaches contribute to waste minimization, conservation of natural resources, and reduced greenhouse gas emissions [8].

Expired calcium-based medicines contain calcium-rich compounds that may participate in cement hydration reactions or act as fillers within the concrete matrix. This suggests the possibility of utilising such pharmaceutical waste as a partial replacement for cement in concrete production. However, research on the direct use of expired calcium-based medicines in concrete remains limited. Therefore, the present study investigates the feasibility of incorporating powdered expired calcium-based medicines as a partial replacement for Ordinary Portland Cement and evaluates their influence on the mechanical performance and overall behaviour of concrete.

The rapid expansion of the pharmaceutical sector has resulted in a continual buildup of expired medicines, many of which are disposed of in environmentally harmful ways like landfilling and open dumping. Calcium-based medications make up a large portion of this pharmaceutical waste because of their widespread medical use. Incorrect disposal of these substances can cause soil and groundwater pollution, bioaccumulation of toxic compounds, and harm to both aquatic

and terrestrial ecosystems. Traditional disposal methods, such as incineration and chemical treatment, tend to be costly, require a lot of energy, and can lead to additional environmental pollution.

The cement industry remains a significant source of global carbon dioxide emissions due to the energy-intensive nature of cement production. Growing demand for concrete in infrastructure projects has increased the need for sustainable alternatives that can reduce cement use without compromising concrete quality. In this context, this study explores the potential of using expired calcium-based medicine powder as a partial substitute for Ordinary Portland Cement (OPC) in concrete. It also assesses how powdered medicine affects the mechanical properties of concrete, thereby supporting sustainable building practices and environmentally sound pharmaceutical waste management.

## II. LITERATURE SURVEY

Several researchers have explored the use of waste-derived and supplementary materials as partial replacements for cement in order to improve sustainability and reduce the environmental impact of concrete production.

Alaa A. Abdul Hamead (2020) investigated the use of recycled pharmaceutical waste materials in cement mortar coatings. The study incorporated eight types of expired medicines, including omeprazole, warfarin, acetaminophen, diclofenac, and cephalexin, as partial cement replacements at a dosage of 1 wt%. The medicines were finely ground before use, and the resulting mortar samples were evaluated for density, compressive strength, microstructural characteristics, weathering resistance, and antimicrobial properties. The findings indicated minor improvements in density along with enhanced formation of calcium-silicate-hydrate (C-S-H) compounds, demonstrating the potential of pharmaceutical waste in cement-based applications.

Kubilay Kaptan, Sandra Cunha, and José Aguiar (2024) provided an in-depth review of using recycled concrete powder as a supplementary cementitious material. Their analysis covered the physicochemical properties of the recycled powder, such as particle size distribution, specific surface area, mineral composition, and hydration characteristics. The study also explored various activation methods, including mechanical grinding, thermal treatment, carbonation activation, and nano-modification, to boost the reactivity of recycled powder. The review emphasized that proper material processing and activation are crucial for improving the performance of recycled cementitious materials.

Purushottam Narayan Singh, Pushpendra Kumar Kushwaha, and Mithun Kumar Rana (2024) studied the performance of concrete containing metakaolin as a partial replacement for cement. The researchers reported that metakaolin significantly improved hydration reactions, refined the microstructure, reduced permeability, and enhanced compressive strength and durability characteristics. The study further concluded that replacement levels between 5% and 15%



produced noticeable improvements in concrete performance and resistance to chemical attack. The existing literature shows that supplementary cementitious materials and recycled waste can effectively lower cement use and enhance some engineering properties of concrete. However, there is relatively little research on using expired calcium-based pharmaceutical waste in concrete. This gap emphasizes the need for further studies to explore the feasibility and performance of expired calcium-based medicines as an alternative to traditional cement. Previous studies have demonstrated that supplementary cementitious materials and recycled waste products can significantly improve the sustainability and performance of cement-based composites. Industrial by-products such as fly ash, silica fume, metakaolin, and recycled concrete powder have shown considerable potential in reducing cement consumption while enhancing durability, microstructural densification, and long-term mechanical performance. Similarly, limited investigations involving pharmaceutical waste materials have indicated that finely processed expired medicines may contribute to hydration reactions and influence the formation of calcium-silicate-hydrate (C-S-H) compounds within the cement matrix. However, most existing studies have focused either on conventional industrial waste materials or on low-percentage incorporation of pharmaceutical residues in mortar systems. Comparatively little research has been carried out on the direct utilization of expired calcium-based medicines as a partial replacement for cement in concrete applications. In addition, the influence of such materials on compressive strength, workability, and overall concrete performance at varying replacement levels remains insufficiently explored. Therefore, further experimental investigation is necessary to evaluate the feasibility of incorporating expired calcium-based medicine powder in concrete and to identify suitable replacement levels for sustainable construction applications.

### III. MATERIALS AND METHODOLOGY

Ordinary Portland Cement (OPC) conforming to IS 12269 specifications was used as the primary binding material for preparing concrete mixes. Expired calcium-based medicines collected from local medical stores and healthcare facilities were selected for the study. The collected medicines were carefully segregated to remove external packaging materials and unwanted impurities before processing. The medicines were then crushed and ground into a fine powder using a grinding machine to achieve a particle size comparable to cement.

Table 2: Physical Properties of OPC and Medicine Powder

Property	OPC	Medicine Powder
Color	Grey	Off-white
Specific Gravity	3.15	2.23
Fineness	92.3%	96.3%
Particle Size	75 $\mu\text{m}$	65 $\mu\text{m}$

Preliminary characterisation of the processed medicinal powder was conducted to assess its suitability as a supplementary cementitious material. The physical properties considered in the investigation included standard consistency, setting time, and soundness. The results indicated that water demand increased gradually with higher replacement levels, while setting time decreased because of the calcium-rich nature of the medicine powder. Soundness values also increased with increasing replacement percentage; however, mixes up to 15% replacement remained within acceptable limits, whereas the 20% replacement level showed excessive expansion and was considered unsuitable for concrete applications.

#### 3.1 Concrete Mix Design

The concrete mix design adopted in this study was developed in accordance with standard concrete mix proportioning procedures to achieve the desired strength and workability characteristics. Ordinary Portland Cement (OPC) was partially replaced with finely ground expired calcium-based medicine powder at replacement levels of 5%, 10%, and 15% by weight of cement. A control mix without medicine powder was also prepared for comparison. The total cementitious material content was maintained at 400 kg/m<sup>3</sup> for all mixes, while a constant water-cement ratio of 0.45 was used throughout the experimental program to ensure consistency in performance evaluation. Natural fine aggregate and crushed coarse aggregate conforming to standard grading requirements were used in all concrete mixtures. The medicine powder replacement quantities were fixed at 20 kg/m<sup>3</sup>, 40 kg/m<sup>3</sup>, and 60 kg/m<sup>3</sup> for 5%, 10%, and 15%



replacement levels, respectively. The concrete ingredients were thoroughly mixed to obtain a homogeneous mixture before casting. Fresh concrete properties were evaluated using slump tests, and hardened concrete specimens were tested after 7 and 28 days of curing. The adopted mix proportions enabled a comparative assessment of the influence of medicine powder incorporation on the mechanical and workability properties of concrete.

Table 3 Concrete Mix Proportions

Mix ID	Cement (%)	Medicine Powder (%)	Cement (kg/m <sup>3</sup> )	Medicine (kg/m <sup>3</sup> )	Powder Water-Cement Ratio
M0	100	0	400	0	0.45
M1	95	5	380	20	0.45
M2	90	10	360	40	0.45
M3	85	15	340	60	0.45

### 3.2 Experimental Procedure

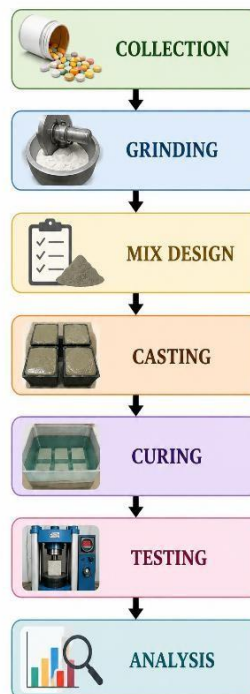


Figure 1 Experimental Procedure Adopted in the Present Study

The flowchart in Figure 1 outlines the experimental methodology for testing the use of expired calcium-based medicine powder as a partial replacement for cement in concrete. It started with collecting medicines from stores, crushing them into fine powder, and then preparing concrete mixes with different replacement levels. The mixes were cast into molds, compacted, and cured under standard conditions. The specimens underwent mechanical tests, including compressive, flexural, and split tensile strength tests. Results were compared to control mixes to assess the influence of medicine powder on concrete's properties.

### 3.3 Fresh Concrete Properties

The properties of fresh concrete were notably affected by adding expired calcium-based medicine powder as a partial cement replacement. Results showed a slow, steady rise in both initial and final setting times as the replacement percentage increased. The control mix had an initial setting time of 45 minutes and a final time of 600 minutes. In comparison, the 15% replacement mix had setting times of 60 and 667 minutes, respectively. This extension in setting



time likely results from changes in hydration behavior caused by the presence of the medicine powder in the cement matrix. Soundness values also increased gradually with higher replacement levels, but all mixes remained within acceptable limits, confirming that the blended cement maintained sufficient dimensional stability.

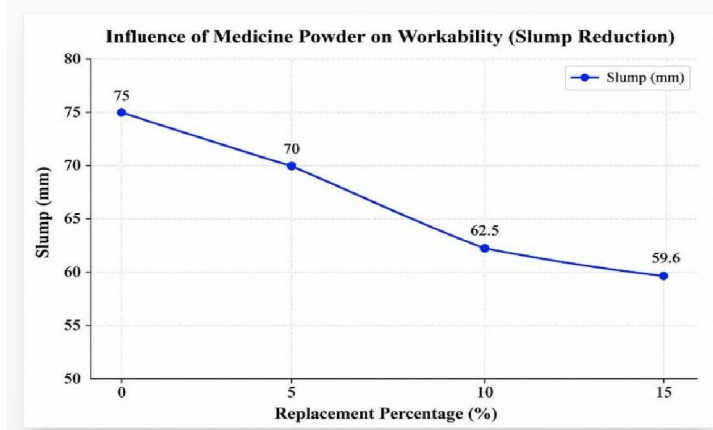


Figure 2: Influence of medicine powder on workability

Workability, measured by the slump test, decreased with increasing medicine powder content, from 75 mm in the control to 59.6 mm at 15% replacement. This decrease is due to the powder's finer particles and increased water demand. Compressive strength remained satisfactory at lower replacement levels but decreased at higher replacement levels. Overall, small amounts of expired calcium medicine powder can be used without greatly affecting the concrete's properties and performance.

Table 4. Fresh Concrete and Cement–Medicine Blend Properties

Replacement Level	Setting Time (minutes)	Soundness (Le Chatelier Expansion, mm)	Workability (Slump, mm)	Remarks
0% (Control)	Initial: 45 Final: 600	1.0	75	Reference mix with conventional cement properties
5%	Initial: 50 Final: 620	1.2	70	Slight increase in setting time and soundness with acceptable strength
10%	Initial: 60 Final: 640	1.5	62.5	Moderate reduction in strength and workability observed
15%	Initial: 60 Final: 667	2.0	59.6	Increased expansion and reduced workability require careful monitoring



**IV. RESULTS AND DISCUSSION**

Comparative Analysis of Mechanical Properties

Table 5. Mechanical Properties of Concrete Mixes

Mix ID	Replacement Level (%)	7-Day Strength (MPa)	28-Day Strength (MPa)	Flexural Strength (MPa)	Split Tensile Strength (MPa)
M0	0	28	40	4.8	3.9
M1	5	30	42	5.2	4.2
M2	10	27	38	4.5	3.6
M3	15	23	32	3.8	3.0

**Effect of Medicine Powder Replacement on Mechanical Performance of Concrete**

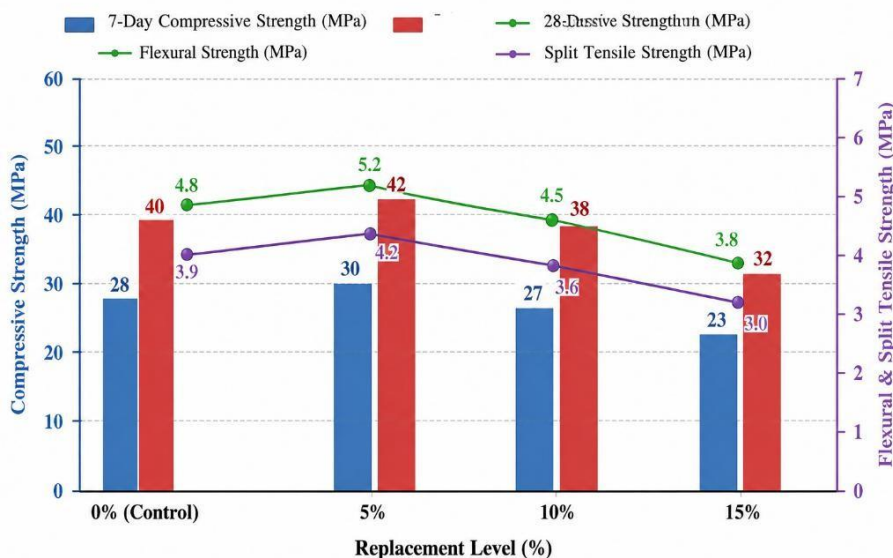


Figure 3: Effect of medicine powder replacement on the mechanical performance of concrete

The mechanical properties of concrete were significantly influenced by incorporating expired calcium-based medicine powder as a partial cement replacement. The results in Table 4 indicate that the 5% replacement mix (M1) exhibited the best overall mechanical performance among all mixes investigated. At 7 days, the compressive strength increased from 28 MPa for the control mix (M0) to 30 MPa for M1, while the 28-day compressive strength improved from 40 MPa to 42 MPa. Similarly, flexural and split tensile strengths increased from 4.8 MPa and 3.9 MPa in the control mix to 5.2 MPa and 4.2 MPa, respectively. This improvement may be attributed to the filler effect of the finely ground medicine powder and the presence of calcium-rich compounds, which may have enhanced hydration and resulted in a denser concrete matrix. However, further increases in the replacement percentage led to a gradual reduction in strength properties. The 10% replacement mix (M2) showed a slight decrease in compressive, flexural, and split tensile strengths compared with the control mix, although the values remained within acceptable limits for non-structural applications. At 15% replacement (M3), a more pronounced reduction in mechanical performance was observed, with the 28-day compressive strength decreasing to 32 MPa. The reduction in strength at higher replacement levels may be due to the lower availability of cementitious compounds and weaker bonding within the concrete matrix caused by excessive cement replacement.





Fig 4: Concrete Test Cubes

Overall, the comparative analysis demonstrates that limited incorporation of expired calcium-based medicine powder can improve concrete performance, whereas excessive replacement adversely affects the mechanical characteristics of concrete. Among all the mixes studied, the 5% replacement level was identified as the optimum dosage for achieving improved strength and satisfactory overall performance.

## V. CONCLUSION

The present study investigated the feasibility of utilising expired calcium-based medicine powder as a partial replacement for Ordinary Portland Cement in concrete. Based on the experimental investigation and comparative analysis, the following conclusions were drawn:

- The incorporation of expired calcium-based medicine powder influenced both the fresh and hardened properties of concrete, with the extent of variation depending on the replacement percentage.
- Workability decreased progressively with increasing medicine powder content. The slump value reduced from 75 mm for the control mix to 59.6 mm at 15% replacement due to the finer particle size and increased water demand of the medicine powder.
- Initial and final setting times increased gradually with higher replacement levels, indicating modifications in the hydration characteristics of the blended cement system.
- Soundness values also increased with increasing replacement percentage; however, all mixes up to 15% replacement remained within acceptable limits, demonstrating satisfactory dimensional stability.
- Among all the mixes investigated, the 5% replacement mix exhibited the best overall mechanical performance. The 28-day compressive strength increased from 40 MPa in the control mix to 42 MPa with a 5% replacement. Similarly, flexural and split tensile strengths increased from 4.8 MPa and 3.9 MPa to 5.2 MPa and 4.2 MPa, respectively.
- The improvement observed at lower replacement levels may be attributed to the filler effect of the finely ground medicine powder and the presence of calcium-rich compounds that contributed to better particle packing and enhanced hydration reactions.
- Further increase in replacement percentage beyond 5% resulted in gradual reductions in compressive, flexural, and split tensile strengths because of the reduced availability of cementitious compounds and weaker bonding within the concrete matrix.
- The 10% replacement mix maintained acceptable mechanical properties for non-structural applications, whereas the 15% replacement level showed a more noticeable decline in performance and workability.
- Overall, the experimental findings demonstrate that expired calcium-based medicine powder can be effectively utilised as a sustainable supplementary material in concrete at lower replacement levels.
- Based on the comparative performance evaluation, 5% replacement of cement with expired calcium-based medicine powder was identified as the optimum replacement level for achieving improved strength and satisfactory overall



concrete performance while also contributing to environmentally responsible pharmaceutical waste management and reduction in cement consumption.

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