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A Comparative Investigation of Self-Repairing Concrete Incorporating Penetron Admix with Ordinary Concrete

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Abstract

Self-repairing concrete is gaining popularity as a viable method for increasing the durability and lifetime of concrete constructions. Self-healing processes are initiated whenever fractures appear by incorporating healing substances into the concrete mixture, resulting in the autonomous restoration of the cracks. A unique self-healing concrete substance called Penetron admix improves concrete's capacity to repair cracks. This study compares self-healing concrete made using Penetron admix against regular concrete to see how well it performs. This research involves analysing and contrasting the above two types of concrete's performance in terms of slump, compressive strength, and the healing of fractures. The results of this study offer insightful information on how self-repairing concrete utilizing Penetron admix performs when compared with traditional concrete. The findings add to the pool of information on self-treatment concrete methods and can aid researchers and building specialists in making material choices that will increase the longevity and preservation of concrete structures.

Keywords: self-repairing concrete, durability, crystalline admixture, Penetron, cracks, compressive strength.

1 Introduction

Concrete is a prominent and well-known building material because of its inherent capacity for self-repairing [1-3]. Since the 1990s, there have been several attempts to produce autonomously self-repairing concrete [1,4]. Around the year 2006, Henk Jonkers, a microbiologist scientist from Delft University of Technology in the Netherlands, created self-repairing concrete, a completely new type of concrete [1, 5].

Self-healing concrete has a distinct process that is often alluded to as the capability of concrete to regenerate itself following fracture. This building material is also known as self-repairing concrete [6,7]. Self-repairing imitates the way the human body's natural ability to heal itself by releasing a particular kind of fluid [8,9]. Concrete is mixed with certain additives (such as fibres, crystalline additives, and capsule) containing healing products with the aim to contribute to concrete's self-repairing. Splits cause the chemicals to come into operation, react, or instantly release solution to close the opening [1].

Due to the comparatively low tensile strength of concrete constructions, cracks in concrete structures are commonly seen [10,11]. Cracks allow potentially dangerous substances to pass through, reducing the durability of the structures periodically [2]. In addition to the damage caused by hazardous liquids seeping through the construction material, reinforcing steel may also be harmed by the microscopic fissures in concrete, which can accelerate its degeneration [4]. As a result, those cracks should be treated as quickly as possible to prevent them from deteriorating further. The tendency of concrete structures to repair themselves from cracks may boost their durability, sustainability, and reliability over time [9].

As a result, there appears to be an increase in interest in self-repairing materials, particularly those with self-healing qualities in ecologically friendly and sustainable construction materials, with a focus on diverse approaches offered by several scientists internationally over the last 20 years. It is difficult to choose the most effective testing technique since each investigation uses a different set of testing procedures to gauge how well the repairs work. Given its capacity for recovery, self-repairing concrete eliminates the need for external aid in identifying and fixing internal flaws (such as gaps). As a consequence, costs are decreased, durability is increased, and corrosion of the reinforcing steel and concrete is also limited.

The purpose of the present research is to evaluate the effectiveness of Penetron-admix self-repairing concrete in comparison with traditional concrete. This study intends to shed light on how self-healing concrete containing Penetron admix performs when compared to traditional concrete through laboratory examination and evaluation of the slump test, compressive strength test, and crack-repairing capacity. The results of this research will add to our understanding of self-repairing concrete products and give scientists and other building specialists useful guidance when making material choices that will boost the longevity and upkeep of concrete constructions.

2 Methods

The purpose of this investigation is the comparison of self-repairing concrete to regular concrete. For this investigation, two unique mixes—a standard mix and a self-healing mix composed with 1% Penetron admix—will be created as shown in Table 1. Measurements of the width of cracks will also be used to gauge the mixes' ability to self-heal. The performance of each mix will additionally be assessed utilizing slump and compressive strength tests.

In this study, the binder is the conventional OPC CEM I 42.5 N, and the mixing medium is potable water. Every computation is performed by hand and double-checked in MS Excel.

Composition $(^{kg}/_{m^3})$	Mix 01 (Ordinary concrete)	Mix 02 (Self-repairing concrete)
Cement	360.00	360.00
F.A (0-4 mm)	725.00	725.00
C.A (4-8 mm)	484.00	484.00
C.A (8-16 mm)	641.00	641.00
Penetron Admix	No	3.60
Water	176.40	176.40

Table 1: Mix design summary.

Figure 1: (a) Concrete casting (b) Curing of specimens.

In this investigation, the slump measurements were taken a total of 03 times for every mixture of concrete while it was still fresh, and an average value was determined. Furthermore, each concrete mixture encountered three 15 cm cubes, which were cast and given 4 weeks to cure as presented in Figure 1. These samples were extensively examined for compressive strength tests after the curing time. The concrete cubes went through destructive compression examination once the 4-week curing phase was over to ascertain their strength properties. The resultant widths of cracks for every sample were subsequently determined. The samples were then immersed in water for a final 2 weeks to speed up their recovery. The samples were once more withdrawn following the 2-week submerged duration, and the last crack width readings were taken. These readings were then evaluated to see how well the concrete mixes could repair themselves.

Figure 2: (a) Slump test (b) Compressive strength (c) Crack width measurements.

This investigation used a variety of measures and experiments to assess the slump, compressive strength, and crack-healing capacity of self-repairing concrete that utilized Penetron admixture in contrast with traditional concrete as shown in Figure 2. The results of this research will offer useful information about the functionality and acceptability of self-repairing concrete for real-world use in the building sector.

3 Results

This section presents the results and analyses from experiments conducted on both concrete mixes. In comparison with traditional concrete, self-repairing concrete demonstrated greater mean slump values. Self-repairing concrete had a mean slump of 167 millimetres while traditional concrete had a mean slump of 143 millimetres as presented in Table 2. It suggests that the self-repairing concrete enhanced workability as well as enhanced consistency, which makes it simpler to manoeuvre and place throughout building construction.

Mix	Slump type	Slump 01 (mm)	Slump 02 (mm)	Slump 03 (mm)	Mean slump (mm)
Mix 01	True	137	141	152	143
Mix 02	True	172	162	168	167

Table 2: Slump test results.

According to the findings of the compressive strength test, self-repairing concrete with Penetron admixture displayed marginally greater strength numbers than regular concrete. The self-repairing concrete's mean compressive strength was established to be 31.41 MPa, compared to the traditional concrete's mean compressive strength, which was 28.82 MPa as shown in Table 3. It suggests that the process of self-repairing triggered using Penetron admixture didn't impact the integrity of reinforced concrete structures and elevated their total strength.

Mix	Compressive strength f_{c1} (MPa)	Compressive strength f_{c2} (MPa)	Compressive strength f_{c3} (MPa)	Mean strength (MPa)	Percentage Increase (%)
Mix 01	25.16	31.70	29.68	28.82	-
Mix 02	28.56	30.05	35.61	31.41	9.00%

Table 3: Compressive strength test results.

The evaluation of the crack-restoration capacity of self-repairing concrete incorporating Penetron admixture and ordinary concrete revealed appreciable variations. Following the destructive testing, the self-repairing concrete showed a mean crack size of 0.69 millimetres, compared to 0.88 millimetres for the traditional concrete (Table 4). The 14 days of submersion in water to speed up the recovery procedure was followed by the acquisition of the last crack size readings. The mean final crack size of 0.63 millimetres showed a significant boost in the self-repairing concrete's ability to repair cracks. The standard concrete, on the other hand, exhibited barely any recovery, with a mean final crack size of 0.88 millimetres. These findings show the use of Penetron admix-infused self-repairing concrete has a greater capacity for fracture repair and recovery, increasing the resilience and lifetime of the buildings made from concrete.

Mix	Mean crack width-I (mm)	Mean crack width-F (mm)	Mean crack healing (mm)	Mean crack healing (%)
Mix 01	0.88	0.88	0.00	0.00
Mix 02	0.69	0.63	0.06	8.69

Table 4: Crack width results.

4 Conclusions and Recommendations

This study compared the slump test, compressive strength test, and crack recovery capacity of self-repairing concrete made using Penetron admix to ordinary concrete to see which performed better. The Penetron additive effectively initiated the self-repairing process, extending the durability and longevity of the concrete structures. Numerous significant insights have been drawn from the experimental investigation and examination of the data.

According to the findings of the slump test, self-repairing concrete displayed slightly greater figures than regular concrete. This suggests that adding Penetron admixture can make new concrete relatively easy to work with and deploy by increasing its workability and consistency. Additionally, the results of the compressive strength test displayed that self-repairing concrete yielded relatively better strength readings than regular concrete. This implies that the self-repairing action provided by Penetron admixture doesn't threaten the integrity of the concrete structures and could possibly add to its structural strength as a whole. Furthermore, it was determined that self-repairing concrete had greater crack sealing and repairing as opposed to traditional concrete in tests of crack repair capacity.

In light of this research, it can be said that self-repairing concrete made with Penetron admixture has benefits against traditional concrete, including enhanced workability and marginally greater compressive strength numbers, in addition to its ability to repair cracks.

The following suggestions for more investigation and real-world use are given considering the results and main findings of this study:

It is important to undertake more studies to better understand the durability and long-term performance of self-healing concrete. Extended evaluation and surveillance under diverse environmental circumstances will give researchers important information about the material's performance throughout its lifespan.

The real-world use alongside field evaluation of self-repairing concrete needs to be promoted in building projects where durability and resistance to cracks are crucial. This can support the validity of the outcomes of the laboratory and offer conclusive proof of its efficacy.

The building sector may take use of the advantages of self-repairing concrete by putting these suggestions into practice. This will aid in building infrastructure that is more resilient and long-lasting.

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References

[1] M. Amran et al., "Self-Healing Concrete as a Prospective Construction Material: A Review," Materials, vol. 15, no. 9. MDPI, May 01, 2022. doi: 10.3390/ma15093214.

[2] M. Rajczakowska, K. Habermehl-Cwirzen, H. Hedlund, and A. Cwirzen, "Self-Healing Potential of Geopolymer Concrete," Proceedings 2019, Vol. 34, Page 6, vol. 34, no. 1, p. 6, Nov. 2019, doi: 10.3390/PROCEEDINGS2019034006.

[3] B. Zehra, A. Salem, S. Senesavath, S. Kashkash, Z. Orban, Sustainable design of concrete using industrial additives and wastes. Pollack 16, 19–24, 2021. https://doi.org/10.1556/606.2020.00250

[4] C. Dry, "Matrix cracking repair and filling using active and passive modes for smart timed release of chemicals from fibers into cement matrices," Smart Mater Struct, vol. 3, no. 2, p. 118, Jun. 1994, doi: 10.1088/0964-1726/3/2/006.

[5] H. M. Jonkers, "Self Healing Concrete: A Biological Approach," Springer Series in Materials Science, vol. 100, pp. 195–204, 2007, doi: 10.1007/978-1-4020-6250-6_9/COVER.

[6] "Smart Nanoconcretes and Cement-Based Materials: Properties, Modelling and ... - Google Books." https://books.google.hu/books?hl=en&lr=&id=oaq-DwAAQBAJ&oi=fnd&pg=PP1&ots=F3WHwYW-Kw&sig=6Wb-_3Ve2loWSnwxBWYs-RvBr_4&redir_esc=y#v=onepage&q&f=false (accessed Apr. 26, 2023).

[7] B. Šavija and E. Schlangen, "Autogeneous healing and chloride ingress in cracked concrete," vol. 61, no. 1, 2016.

[8] V. Lesovik, R. Fediuk, M. Amran, N. Vatin, and R. Timokhin, "Self-Healing Construction Materials: The Geomimetic Approach," Sustainability 2021, Vol. 13, Page 9033, vol. 13, no. 16, p. 9033, Aug. 2021, doi: 10.3390/SU13169033.

[9] K. Van Tittelboom and N. De Belie, "Self-Healing in Cementitious Materials—A Review," Materials 2013, Vol. 6, Pages 2182-2217, vol. 6, no. 6, pp. 2182–2217, May 2013, doi: 10.3390/MA6062182.

[10] A. Sumathi et al., "Development of Bacterium for Crack Healing and Improving Properties of Concrete under Wet–Dry and Full-Wet Curing," Sustainability 2020, Vol. 12, Page 10346, vol. 12, no. 24, p. 10346, Dec. 2020, doi: 10.3390/SU122410346.

[11] B. Han, X. Yu, J. Ou, “Self-Sensing Concrete in Smart Structures, Butterworth-Heinemann,2014. https://doi.org/10.1016/C2013-0-14456-X (accessed Apr. 26, 2023).