alfabuild

Review Article

ISSN 2658-5553

Received: September 10, 2025 Accepted: November 28, 2025 Published: December 01, 2025

Potential of genetically engineered strains to enhance concrete strength: A Review

Berezov, Rodion Viacheslavovich[1]
Manukhov, Mikhail Ilyich[2]
Bazhenov, Sergey Vladimirovich[1]
Vatin, Nikolai Ivanovich[3]
Chistyakov, Vladimir Anatolievich[3]
Allilueva, Ekaterina Vladislavovna[3]
Manukhov, Ilya Vladimirovich[1*]

[1] Moscow Institute of Physics and Technology, Moscow Region, Dolgoprudny, Russian Federation; berezov.rodion.2001@gmail.com (B.R.V.); Bazhenov1994@gmail.com (B.S.V.); manukhovi@mail.ru (M.I.V.)
[2] Geh Teplostroyproekt JSC, Moscow, 105066, Russian Federation; mishamanukhov@mail.ru
[3] Peter the Great St.Petersburg Polytechnic University, St. Petersburg, Russian Federation; vatin@mail.ru (V.N.I); vladimirchi@yandex.ru (C.V.A.); katherine_bio@mail.ru (A.E.V)

Keywords:

Bio Concrete, Calcium Carbonate, Urease, Urea Amidolyase, Carbonic anhydrase, Bacillus subtilis

Abstract

The strength and durability of concrete are limited by the progressive development of microcracks, which lead to a decline in operational properties, including water impermeability, frost resistance, and strength. One promising approach to reducing micro-crack formation is the use of spore-forming bacteria that precipitate calcium carbonate in situ. When water penetrates concrete cracks, bacterial spores germinate and initiate mineralization, thereby partially restoring the material's structure. The first experiments on producing bio-concrete were carried out in the mid-2000s and demonstrated that bacteria can form calcite particles up to 100 µm and seal micro-cracks. Concrete possesses an inherent but limited self-healing capacity via atmospheric carbonation, in which CO_2 reacts with calcium hydroxide to form calcite; however, this process is slow and unpredictable. In most biotechnological systems, $CaCO_3$ precipitation is enhanced by urea hydrolysis catalysed by urease. Alongside the urease pathway, alternative mechanisms for urea degradation that lead to carbonate formation are known. For example, the urea amidolyase pathway converts urea into allophanate, which is then hydrolysed by allophanate hydrolase into ammonia and bicarbonate. Moreover, in conditions of elevated CO_2 concentration within micro-cracks, carbonates can also be produced by the action of carbonic anhydrase. Although this approach appears infeasible in the surface layers of concrete exposed to open air due to the reverse reaction of dehydration of carbonates, producing CO_2 that would escape into the atmosphere. The combination of urease (whose reaction product is CO_2) with carbonic anhydrase, which fixes CO_2 into bicarbonates, should theoretically yield superior results for concrete stabilization. The development of new genetically engineered strains carrying genes encoding enzymatic systems based on these pathways could enhance mineralization efficiency and improve the operational properties of bio-concrete.

1 Introduction

Berezov, R.; Manukhov, M.; Bazhenov, S.; Vatin, N.; Chistyakov, V.; Allilueva, E.; Manukhov, I.
Potential of genetically engineered strains to enhance concrete strength: A Review;
2025; AlfaBuild; 36 Article No 3601. doi: 10.57728/ALF.36.1

Funding:

This research was supported by a grant from the Russian Science Foundation No.24-44-20012 https://rscf.ru/project/24-44-20012/.

ARTICLE IN PRESS