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Investigating the Effect of Green SMA Materials on the Construction of Concrete Tanks in Fiber-Reinforced Concrete Mixtures Using Finite Element Analysis

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Abstract

The use of additives in concrete has become increasingly common to improve desirable properties such as strength. One of the most notable types of concrete is fiber-reinforced concrete (FRC), which offers lightweight materials that reduce the weight of concrete. FRC is essentially a composite material that incorporates reinforcing fibers into the concrete mixture, enhancing tensile strength and cohesion. This composite combination increases the overall strength and provides the ability to produce curved, resistant surfaces. FRC also exhibits high energy absorption capabilities and does not easily disintegrate under impact loads. Historically, this technology can be traced back to the use of straw and mud in construction. In fact, FRC is an advanced version of this technology, where natural and synthetic fibers replace straw, and cement replaces mud. FRC possesses excellent properties such as high ductility, exceptional strength, energy absorption, and crack resistance, making it suitable for various applications. In this study, the innovative use of green SMA materials in FRC mixtures is explored, and the results indicate that the inclusion of green materials improves the mechanical behavior of FRC.

Keywords: Concrete Tanks, Green Materials, SMA, Fiber-Reinforced Concrete.

Introduction

The use of additives in concrete has become increasingly common to improve desirable properties such as strength. One of the most notable types of concrete is fiber-reinforced concrete (FRC), which offers lightweight materials that reduce the weight of concrete. FRC is essentially a composite material that incorporates reinforcing fibers into the concrete mixture, enhancing tensile strength and cohesion. This composite combination increases the overall strength and provides the ability to produce curved, resistant surfaces. FRC also exhibits high energy absorption capabilities and does not easily disintegrate under impact loads. Historically, this technology can be traced back to the use of straw and mud in construction. In fact, FRC is an advanced version of this technology, where natural and synthetic fibers replace straw, and cement replaces mud. FRC possesses excellent properties such as high ductility, exceptional strength, energy absorption, and crack resistance, making it suitable for various applications.

Figure 1-2: Schematic of the structure of fiber-reinforced concrete and conventional concrete.

As seen in the study of "The Performance of Fiber-Reinforced Concrete Under Applied Forces," the use of various fibers (such as glass, carbon, steel, polypropylene, nylon, etc.) in concrete mixtures increases its energy absorption and resistance to impact, sudden shocks, and increased loads. Compared to conventional concrete, FRC is less prone to cracking and failure. The energy absorption and impact resistance make FRC an ideal choice for specific structures such as airport runways, industrial floors, explosive storage facilities, and shelters for protection against aerial attacks. In addition to these advantages, FRC offers benefits such as ease and speed of installation, as well as sound and thermal insulation. The fibers used in FRC vary in material, and the choice of FRC for a structure depends on the location, design, and required tensile and abrasion resistance. The fibers used in FRC range in size from 3 mm to 2 cm, with smaller fibers providing more uniform distribution of forces within the concrete volume. FRC is typically used in prefabricated panels for construction, but it can also be cast on-site.

Figure 2-2: Schematic of fiber-reinforced concrete.

Today, sprayed FRC is used to enhance pre-constructed structures such as tunnels, providing increased strength and durability. The addition of fibers to FRC serves as a good alternative to reinforcement bars, as it increases compressive strength while reducing brittleness and surface cracking. The goal of this study is to investigate the mechanical behavior of FRC under impact loading using finite element analysis. Given the novelty of impact loading compared to static loading and the complexity of the equations involved, research centers and universities are still extensively studying this topic. Cracks in concrete, particularly in the transition zone between cement paste and coarse aggregates, make it vulnerable to impact loads. One solution to this problem is the use of steel, polypropylene, and nylon fibers, which prevent crack propagation and increase the ductility of concrete.

To answer the question of how green materials, affect concrete, it is important to note that concrete made with recycled materials (which are environmentally friendly) is called green concrete. Another definition of green concrete is the reduction of environmental impact by minimizing the use of natural resources. In recent years, due to continuous mining of aggregates, resource storage issues have emerged. Today, green concrete is considered a viable solution. Green concrete is not related to color; it is more cost-effective than conventional concrete because waste products are used as substitutes for cement, reducing energy consumption in production and increasing durability. Green concrete, also known as eco-concrete, is similar in appearance to conventional concrete but is made using environmentally friendly materials. The use of eco-concrete is increasing due to its lower cost and faster strength gain compared to conventional concrete. Structures made with eco-concrete have higher resistance to heat and corrosion, making them suitable for high-temperature environments (up to 2400°F). Green concrete also has higher resistance to corrosion, which is significant given the environmental impact of pollution. Instead of using 100% Portland cement, green concrete uses up to 25% fly ash, a byproduct of coal combustion, collected from industrial power plants.

RESEARCH METHODOLOGY

In this study, the effect of green SMA materials on the construction of concrete tanks in fiber-reinforced concrete mixtures was investigated using finite element analysis. A geometric model was used for numerical modeling, with the specifications shown in Figure 2.

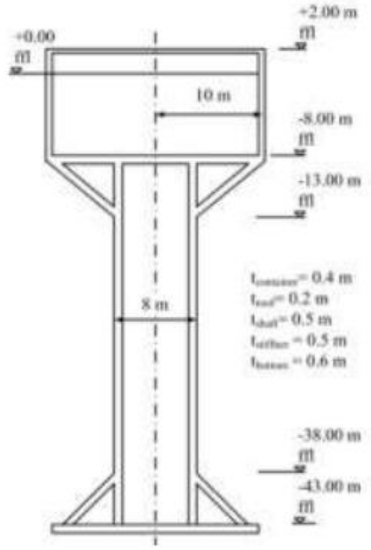

Figure 3-2: Geometric details of the concrete tank.

The parameters studied for the concrete tank include FRC with and without green SMA materials, which were modeled and analyzed.

Table 2-1: Impact of Study Parameters

Parameter	Model
Without Green Materials	Geometric Model
With Green SMA Materials	Geometric Model with SMA

To validate the software model, experimental studies by Bageri et al. (2018) were used. After modeling the experimental sample in Abaqus software, the displacement history curves of the two samples were compared, showing a negligible difference of about 2%, as shown in the figure below.

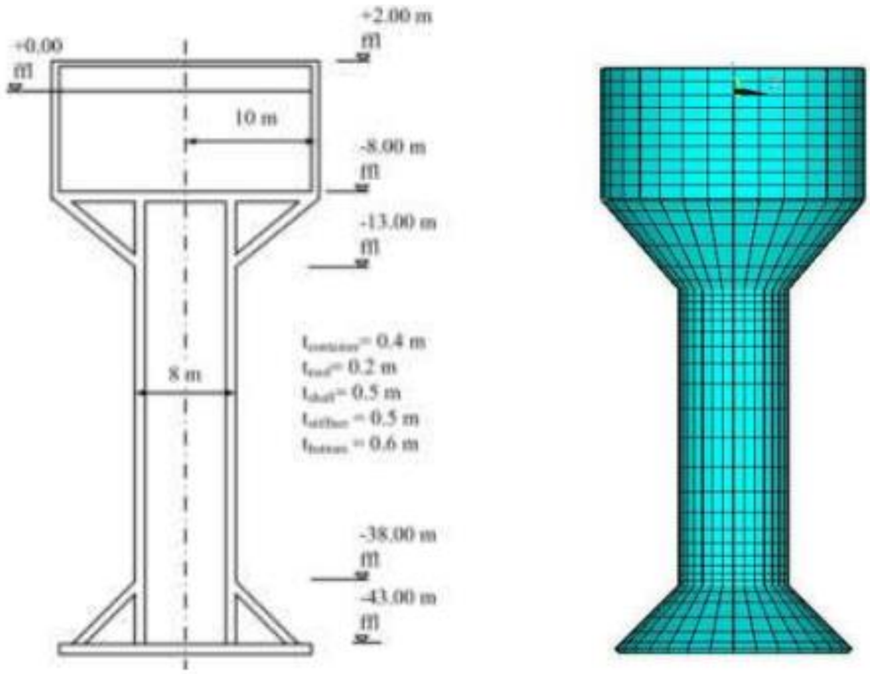

Figure 4-2: Validation of the software model and experimental model by Bageri et al.

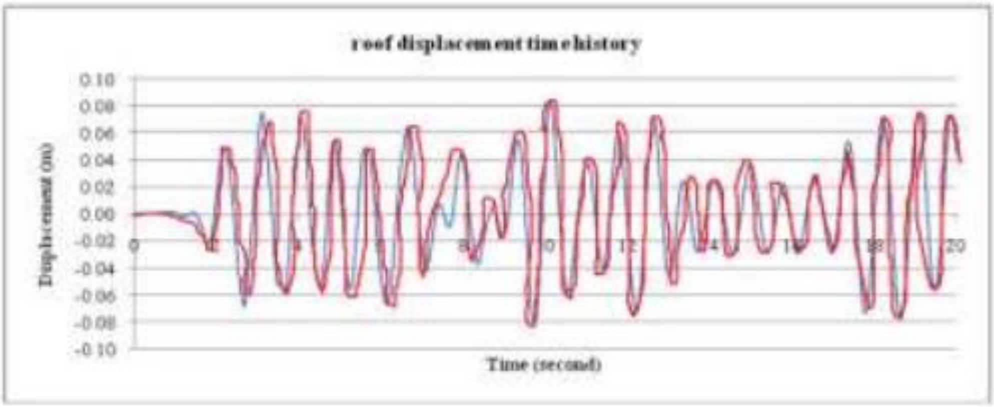

Figure 5-2: Comparison of the validated experimental study by Bageri et al.

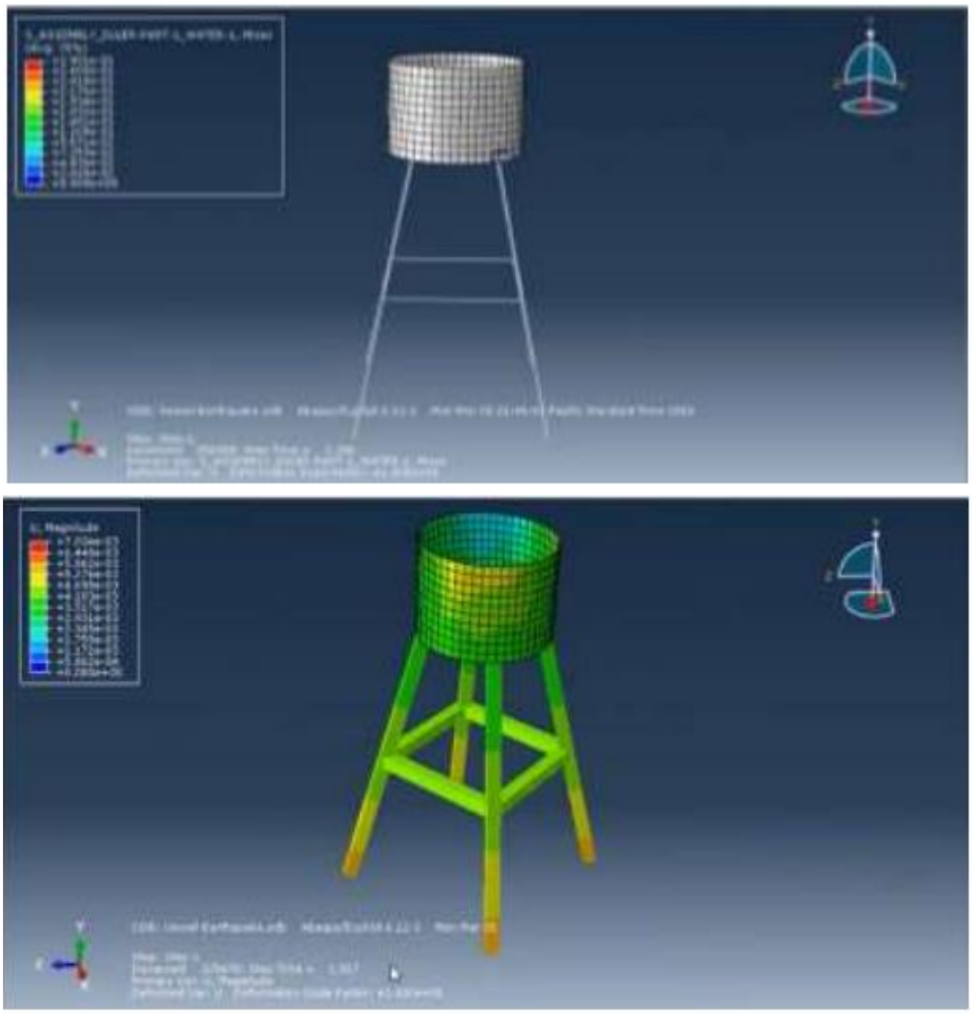

Figure 6-2: Contour of displacement stress in the concrete tank body.

ANALYSIS RESULTS

In this stage, the effect of SMA materials on the potential behavior of the concrete tank structure was investigated using finite element analysis. After modeling and analyzing the samples in Abaqus, the results showed that the capacity of the concrete tank structure decreased by approximately 26.37% when SMA materials were used. This reduction indicates improved mechanical behavior and increased ductility of the concrete.

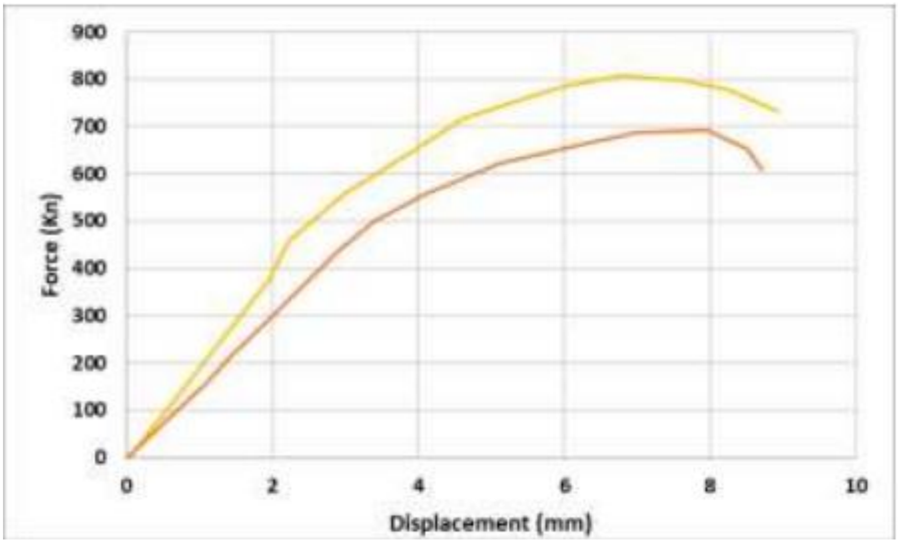

Figure 7-2: Capacity curve of the concrete tank structure (FRC without SMA materials and FRC with SMA materials).

After performing finite element analysis, the compressive stress in the tank body was observed. The results showed that the compressive stress in the tank body decreased by approximately 24.62% when SMA materials were used.

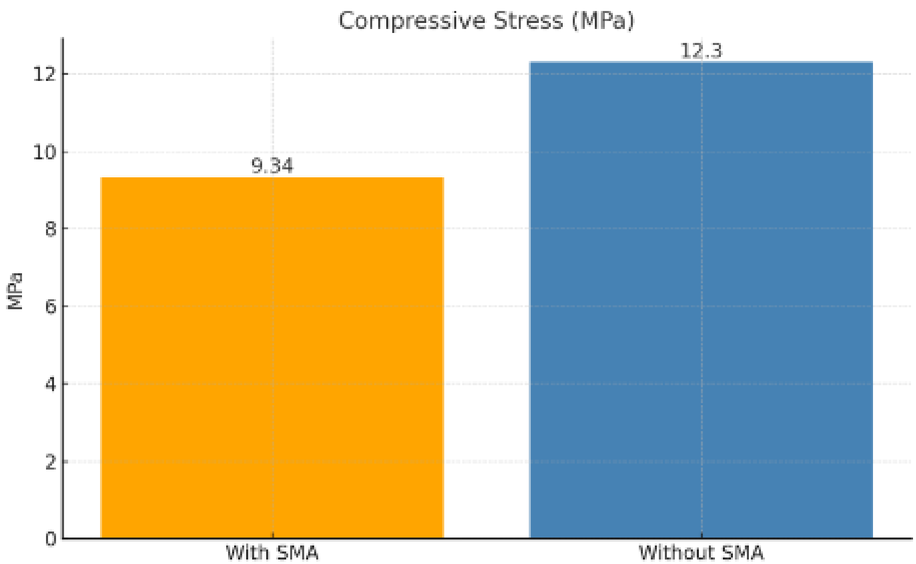

Figure 8-2: Compressive stress curve of the concrete tank model (FRC without SMA materials and FRC with SMA materials).

After performing finite element analysis, the shear stress in the model was observed. The results showed that the shear stress decreased by approximately 21.62% when SMA materials were used.

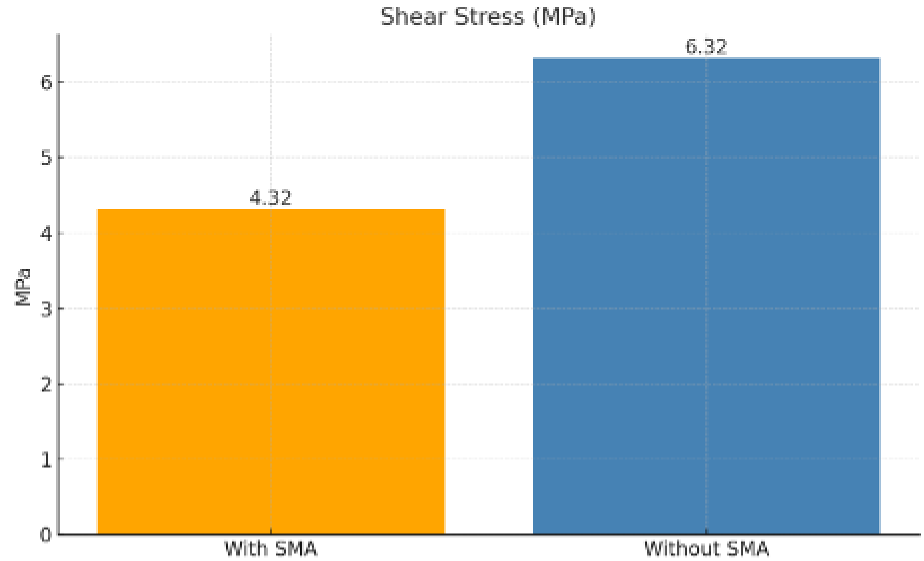

Figure 9-2: Shear stress curve of the concrete tank model (FRC without SMA materials and FRC with SMA materials).

After performing finite element analysis, the shear strain in the model was observed. The results showed that the shear strain in FRC decreased by approximately 24.92% when SMA materials were used.

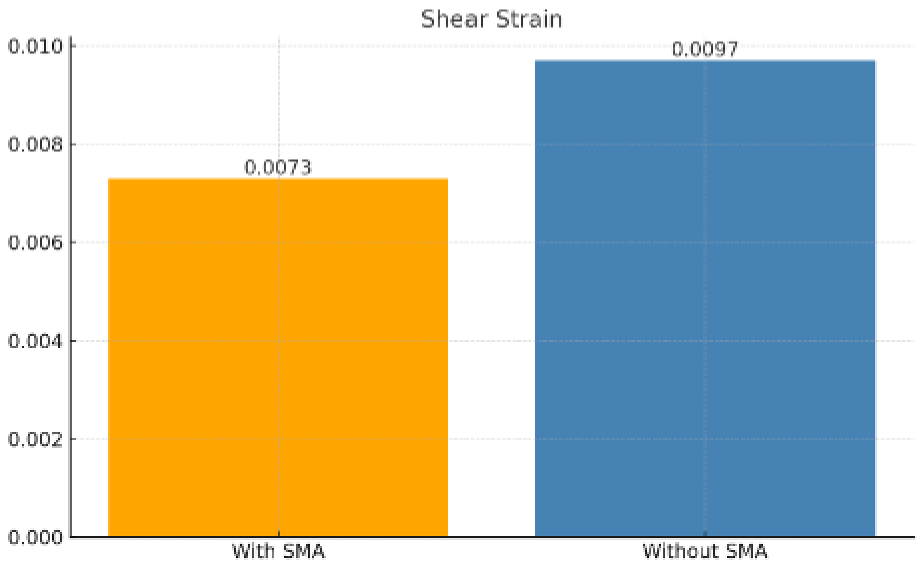

Figure 10-2: Shear strain curve of the concrete tank model (FRC without SMA materials and FRC with SMA materials).

In this section, the behavior of the concrete tank model under seismic loading was also investigated. The results showed that the displacement history of the tank structure decreased by approximately 26.76% when SMA materials were used.

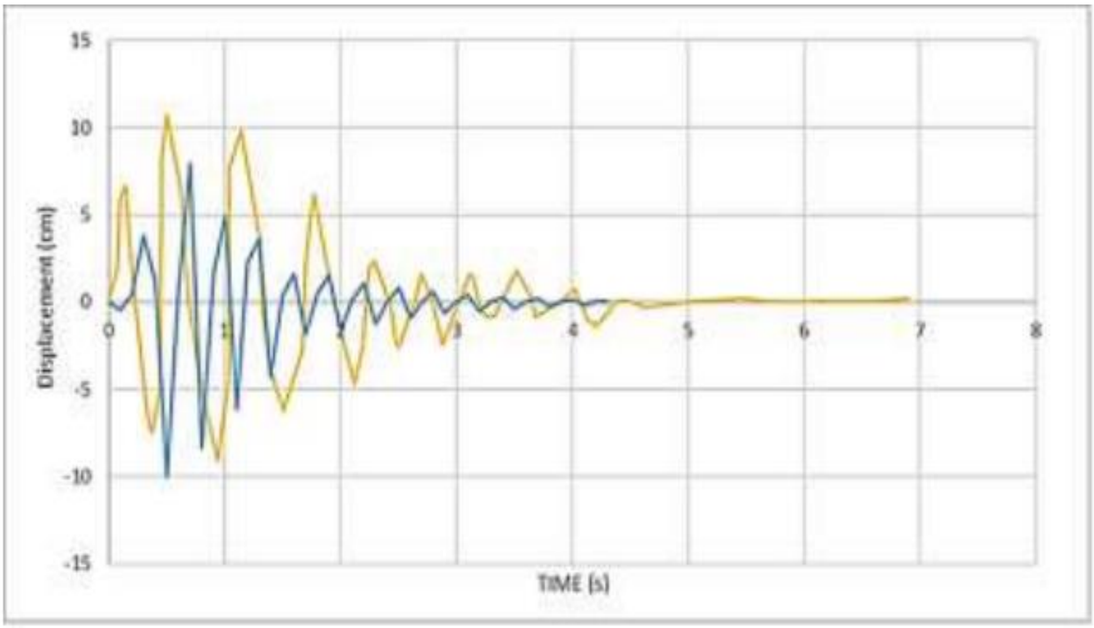

Figure 11-2: Average displacement history curve of the concrete tank model with and without SMA materials.

CONCLUSION

After modeling and performing finite element analysis, the following results were obtained:

-The compressive stress in the concrete tank body decreased by approximately 24.62% when SMA materials were used.

-The shear stress decreased by approximately 21.62% when SMA materials were used.

-The shear strain in FRC decreased by approximately 24.92% when SMA materials were used.

-The capacity of the concrete tank structure decreased by approximately 26.37% when SMA materials were used.

-The displacement history of the tank structure decreased by approximately 26.76% when SMA materials were used.

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