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Review Article

The Influence of Natural Additives on Mechanical Properties of Concrete Specimens: A Review

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Abstract

Concrete can be assumed as the most regular constructional material in the world, which has a lot of advantages as well as disadvantages that attracted the attention of researchers. Adding natural materials including silica fume, fly ash, rice husk ash, metakaolin, and natural fibers and animal waste to concrete can improve the fresh and hardened properties of concrete such as slump, strength, water absorption, and durability, and at the same time reduce the environmental effects. On the other hand, adding too many natural additives can cause adverse effects on concrete, such as reducing efficiency and increasing curing time, which can be compensated by adding different kinds of fibers to the concrete mixture. In order to add natural additives to concrete, several experimental and field tests were performed, in which the effects of natural additives on the properties of concrete and their long-term performance were evaluated. Reducing the carbon footprint, and increasing resistance to cracking and corrosion are among the advantages of natural additives. In this paper, a review was conducted to evaluate the influence of natural additives on the mechanical properties of concrete specimens including compressive strength, flexural strength, and water absorption. The overall effects of utilizing natural additives on concrete properties were reviewed and listed accordingly.

Keywords:

Natural additives; Rice husk ash; Natural fibers; Animal waste; Blast furnace slag; Curing time.

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1. Introduction

Concrete is one of the widely used materials in the construction industry, which is made by mixing water and aggregates, such as sand or gravel, in specific proportions (Zaid et al., 2021). Concrete has several advantages, including compressive strength and average durability compared to other construction materials (Khatib et al., 2022), which makes more affordable. On the other hand, concrete has inherent properties such as tensile strength and low formability (i.e. brittleness), which to overcome these shortcomings, researchers investigated adding natural materials to concrete that can improve the properties of concrete and at the same time reduce its environmental effects (Youssf et al., 2019). Some of the most promising natural additives include rice husk ash (Habeeb et al., 2010; Kang et al., 2019; Nair et al., 2008; Onyelowe et al., 2021; Parveen et al., 2019), bamboo fiber (Ede et al., 2020), and green tea ash (Castel & Foster, 2015; González et al., 2009; Onyelowe, Kontoni, et al., 2022a; Ravina & Mehta, 1986; Roshani et al., 2021). These natural additives can improve the strength and durability of concrete and resistance to increase cracking and corrosion and reduce carbon dioxide footprint (Collins, 2010; Iswarya & Beulah, 2021; Tashima et al., 2004).

To investigate the effectiveness of natural additives, several different tests are usually performed to evaluate the properties of concrete several times. Since natural additives are added to improve the properties of concrete and eliminate the shortcomings of concrete and are obtained from natural materials, they can have a wide range of effects on the properties of concrete (Federico & Chidiac, 2009; Pellegrino & Gaddo, 2009). Some natural additives are effective and durable. They improve concrete while others improve its environmental stability and beauty, in addition, these natural additives can affect the thermal performance, fire resistance, acoustic properties, and biodiversity of concrete (Dabbaghi, Nasrollahpour, et al., 2021; Lippiatt & Ahmad, 2004; Nematzadeh et al., 2021; Soleymani & Esfahani, 2019; Stolz et al., 2018; Yavuz Bayraktar et al., 2021). As a result, natural admixtures in concrete can have many advantages over chemical admixtures, for example, natural admixtures are often more environmentally sustainable and can be produced and used with fewer resources than their chemical counterparts. Another advantage of natural additives is that they can be sourced locally and reduce transportation costs and environmental impacts. In addition, natural additives can often have unique benefits that are not available in chemical additives such as improving biodiversity or increasing fire resistance (Han et al., 2020; Khan & Alhozaimy, 2011; Shahmansouri et al., 2020).

One of the key advantages of natural additives is their ability to improve the thermal performance of concrete (<i>*Effect of Natural Additives on Concrete Mechanical Properties*, n.d.). By adding natural additives such as wood fibers or rice husk, the thermal conductivity of concrete can be reduced and as a result, insulation and energy efficiency can be improved (Demirboğa & Gül, 2003; Harwalkar & Awanti, 2014; Onyelowe et al., 2022; Onyelowe, Kontoni, et al., 2022b; Sukontasukkul, 2009). In addition, natural additives can increase the resistance of concrete against fire by reducing its flammability and increasing its resistance to high temperatures. By adding one natural additive such as coconut or hemp, it is possible to absorb sound and insulation (Syed et al., 2020). improved and as a result created a calmer and more comfortable work or life environment. Another advantage of natural additives is to increase the aesthetic properties of the concrete material, for example, natural additives such

as color pigments or aggregates can be added to concrete to create a unique and visually appealing appearance which can be especially useful in architectural applications and make the structure beautiful (Salas et al., 2009). Fig. 1 showed the various advantages of utilizing natural additives in the concrete mixture.

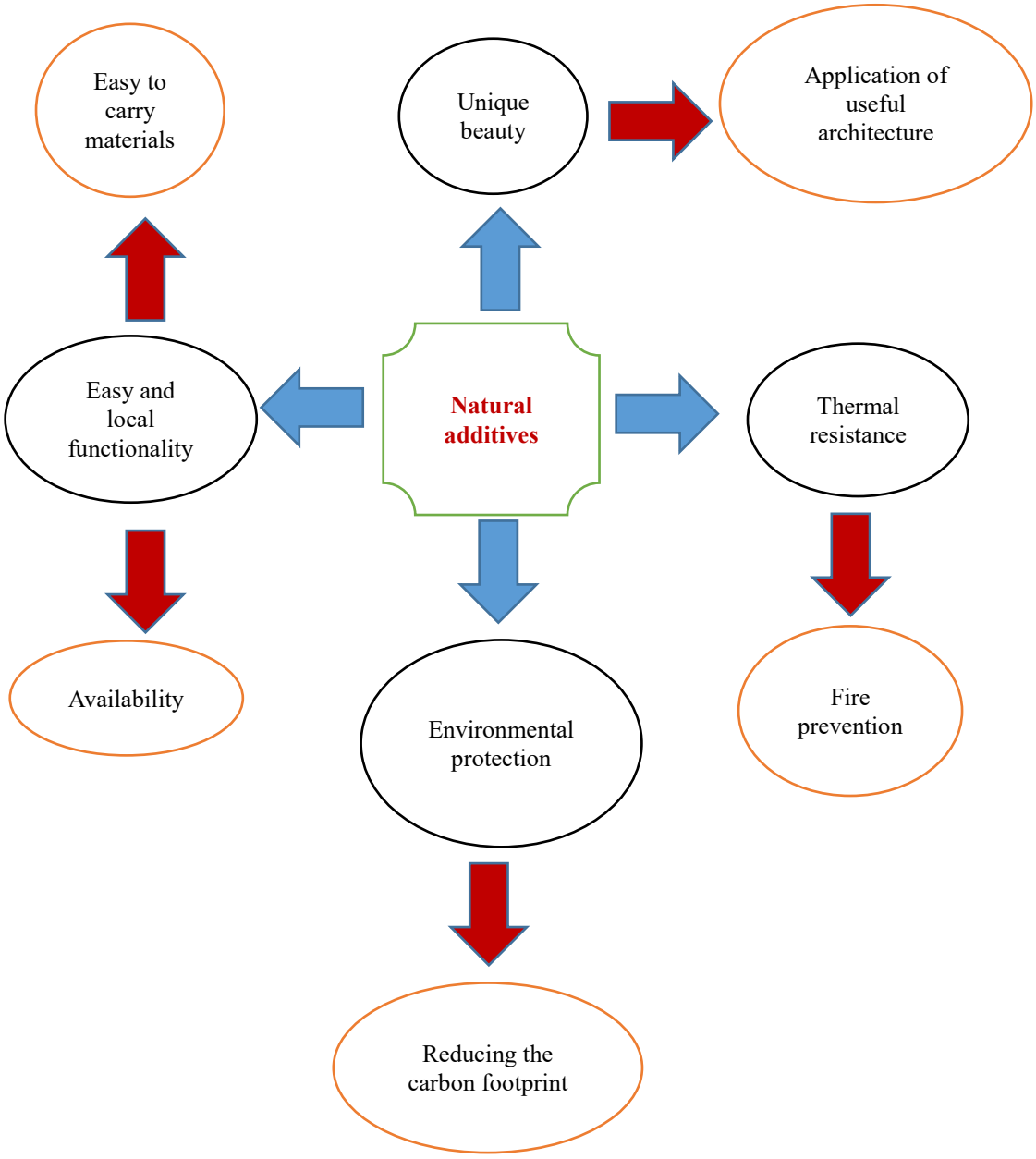

Fig. 1. Various advantages of utilizing natural additives in the concrete mixture.

2. Experimental tests for concrete materials

Adding natural additives to concrete is a way to improve the properties and characteristics of concrete, which has both advantages and disadvantages. To test the effectiveness of these natural additives, several different experimental tests are usually performed, some of the common tests include compressive strength (Madandoust et al., 2012), flexural strength (Banthia & Soleimani, 2005), water absorption (Padmini et al., 2002), durability (Zhang et al., 2018), and abrasion tests (Thomas et al., 2016), some of the most important ones were listed and explained below.

2.1. Compressive strength tests

The compressive strength test of concrete is a common test that is performed on concrete samples to determine the maximum force that can be applied to the concrete before breaking (ASTMC39/C39M, 2020). This test is usually performed on cylindrical samples that are filled with a cylindrical mold with fresh concrete and allowed for a certain period of time to be ready for curing (Zainal Abidin et al., 2014). After finishing the curing time, the concrete sample is removed from the curing space and placed in the pressure testing machine. It enters the sample at a constant speed until it stops working. This is where the compressive strength of concrete is determined, because the compressive strength of concrete is the same force that is applied to it before failure, and as a result, its numerical value is recorded. The concrete compressive strength test is a very important test to determine the quality of concrete and to ensure concrete for a specific project (Mohseni et al., 2019). As a result, many previous research works were designated to obtain the compressive strength of concrete mixtures with different properties and including various natural additives (Ashrafian et al., 2018; Kewalramani & Gupta, 2006; Murad et al., 2019; Onyelowe et al., 2022; Wang et al., 2018).

2.2. Flexural strength tests

The flexural strength test of concrete is generally summarized and performed in 5 stages (ASTMC293-07, 2007).

a) At first, a concrete sample is prepared according to the required specifications, usually a rectangular beam with specified dimensions is used which is in accordance with the standard.
b) The sample is placed horizontally on two points of the support that are far apart, and this distance is equal to three times the depth of the beam.
c) The sample is loaded at the middle point by a loading device that applies an incremental load to the sample in such a way that bending stress is gradually applied to it and this stress increases slowly.
d) The test takes place until the concrete under the machine is no longer effective and the bending stress number is fixed.
e) The number obtained after the device is fixed is called the bending strength value of the desired concrete.

It is important to mention that the flexural strength test of concrete is performed to evaluate the performance of concrete under bending stress and is usually used in applications such as construction, bridge, and tunnel construction. Many researchers studied the flexural behavior of various concrete mixtures in which natural additives were utilized as a cement alternative (Banthia & Soleimani, 2005; Dabbaghi, Rashidi, et al., 2021; Onyelowe et al., 2022). To ensure that the flexural strength test gives accurate results, the material used must have good thermal and electrical properties. In addition, the dimensions of the experimental sample must be placed within the framework provided by the testing device and must be properly designed to check whether the test was performed correctly or not. After completing the test, the results of the bending strength test can be used to check the material's load-bearing characteristics in terms of its strength and deformation. In most cases, the test results should show that the material has good strength and deformation, which is a sign that the material is suitable for use. In addition, these results may be used to determine the maximum capacity of materials and the best design for load-bearing structures. In addition, the results of the flexural strength

test can be used to optimize the design of the concrete structure and improve its strength-to-weight ratio. Moreover, this method can be used to determine the strength and behavior of concrete under different loads. Finally, the test results can be used to study the effect of environmental conditions on the strength of concrete components.

The literature review of the flexural behavior of concrete mixture showed that in most cases, utilizing natural additives caused a decrease in the flexural strength of concrete which can be compensated by adding some amount of fibers (Banthia & Soleimani, 2005; da Silva et al., 2020).

2.3. Water absorption tests

To conduct a water absorption test, first, a dry concrete sample should be selected and weighed accurately, then the sample will be soaked in water for a specified period, which is usually 24 hours, after the soaking period, the sample should be removed from the water and its surface should be excessed with a wet cloth, after removing the sample from the water, it will be weighed to determine the increase in weight due to water absorption, and as a result, the water absorption can be calculated by dividing the dry weight by the initial dry weight of the sample (Shoaib et al., 2022). It is worth mentioning that the concrete water absorption test is an important test to evaluate the durability and quality of concrete. In addition to experimental tests, researchers have also conducted field tests of concrete structures with natural admixtures to evaluate their long-term fresh and hardened performances (Sanjeev & Sai Nitesh, 2020; Sharifi et al., 2016; Topçu & Şengel, 2004).

3. Results and discussions

In general, adding natural additives to concrete is a promising way to improve its properties and at the same time reduce its environmental effects. However, using the right amount of natural additives to achieve the desired improvements without affecting the overall quality of concrete. It is important.

Complete investigations of natural additives to concrete show that they increase the quality of concrete by improving hardness and stability. In addition, they contribute to an optimal value proportional to the technical desirability of the materials used. This increase in quality can make the construction or reconstruction of structures easier and lead to a greater variety of projects that can be done. Therefore, in principle, the use of natural materials can have a positive effect on the quality of concrete in addition to the overall quality of concrete. It is useful, the use of natural additives also improves its tensile, compressive strength, and flexural strength (*Effect of Natural Additives on Concrete Mechanical Properties*, n.d.).

In general, it is clear that the tensile, compressive, and flexural strength tests of concrete is an important measurements for evaluating the properties of concrete and optimizing its design. In addition, it is also useful in improving the reliability of materials used in various applications. Therefore, regularly performing these tests and recording the obtained results are important to ensure the quality of the structure and its components. In addition, it is important to follow the changes made in the mixing plan and learn about the benefits of different additives on concrete resistance. By doing this, a suitable concrete mix can be created for different applications, and the maximum number of items used in this process.

4. Conclusions

In general, by paying attention to natural additives and their addition to concrete, realize that natural additives have many positive effects on concrete. These effects can be summarized below:

1. Natural additives can improve the efficiency and plasticity of concrete and make it easier to work and shape during construction. This is especially important for large-scale projects where concrete must be transported over long distances and poured in various forms.
2. Natural additives can increase the durability and strength of concrete and increase its resistance to cracking, weathering, and chemical damage. These materials can increase the lifespan of concrete structures and the duration of repairs and maintenance.
3. Natural additives can also be beneficial for the environment, because most natural additives are a branch of renewable resources that reduce the carbon footprint of concrete produced, this is because the construction industry is looking for a more sustainable and compatible method.
4. Natural additives in concrete can also improve the thermal performance of the material and make it more energy efficient. This is because some natural additives, such as rice husk ash or cotton, have insulating properties that can help reduce heat loss and improve comfort levels indoors.
5. The use of natural additives can help reduce the amount of waste produced by the construction industry. For example, some natural additives, such as ground glass or fly ash, are by-products of other industrial processes and can be used as substitutes for traditional cement compositions.

In general, the use of natural additives in concrete can be a promising development that can have significant benefits for the construction industry and the environment, however, to fully understand the effects of different types of natural additives and how they can be more research is needed to mix them in the best way to make concrete. The use of natural additives in concrete has the potential to increase the performance, stability, and aesthetics of the material. As research in this area continues to progress, it will be interesting to see how natural additives are incorporated into concrete mixes and what new possibilities they open up for the construction industry. The use of natural additives has more positive effects on the structure than chemical additives, which increases the quality of life and raises the level of the environment.

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