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IMPROVEMENTS OF IBS 3D PRINTIG MIX DESIGN MATERIAL PERFORMANCE WITH KENAF FIBER IN THE BUILDING CONSTRUCTION

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ABSTRACT

The construction industry has experienced a paradigm shift, leading to a growing demand for sustainable construction methods. 3D printing technology has revolutionized the construction industry by allowing for mass-customization of structures, reducing the need for formwork and labor. However, 3D printing has faced challenges due to unstable and low-strength materials, making it an expensive method. This research aims to find a sustainable material for 3D printing technology in the construction industry, ensuring its strength, cost, and handling methods are superior to those of existing materials. The use of natural building materials from plant waste is crucial for reducing the cost of construction using 3D printing technology in each country. This research aims to find a sustainable material that can be used in 3D printing technology that is used in the construction industry, and make sure that its strength, cost, and handling methods are greater to those of the materials that are already used in building construction. In addition to acquiring more precise data, the goal of this research is to investigate the efficacy of the proposed material (kenaf fibre) for use in Machine 3D Printing and to compare the strength of this new study material with those of materials that have been employed in previous studies. This study shall demonstrates that the Kenaf Fiber Mortar has a compressive strength that meets the requirements of the JKR Mortar Grade 20 Standard Specifications.

Keywords: *kenaf, 3D printing, natural fibres, material mix, strength*

INTRODUCTION

In today's world, the construction sector has undergone a paradigm shift, which has implications to structural engineers. The modern society has a growing demand for a construction sector that is more sustainable, which is a call that needs to be responded by every discipline that is engaged in the construction cycle. Over the course for the past many years, new methods have been created, making it possible to create designs that carry and transmit loads in an effective manner. One of these ongoing high-tech breakthroughs in today's construction technology is the printing of concrete structures using three-dimensional (3D) printers. It is obvious to see the benefits, which include a significant increase in the amount of design freedom, rapid construction, reduction of the requirement for formwork, and reduced need for physically demanding labor (Karslıoğlu Kaya et al., 2022; Pandit & Kumari, 2021). Because it does not require every (structural) piece of a structure to be the same, this method makes it possible to mass-customize products. This is advantageous from a speed and cost perspective. In addition, because the printer only prints in the areas that are requested, there is no longer a need for structures that are substantial and large (Karslıoğlu Kaya et al., 2022; Pandit & Kumari, 2021). The development of new structures using 3D printing provides an answer to the demand for a builtenvironment that is more environmentally friendly.

Nevertheless, it is a certainty that any new piece of technology that is developed will confront challenges that will interfere with its operation. The same can be said for the 3D Printing technology, which has been struggling for a long time with the unstable and low strength of materials, which leads the construction of the building to be unplanned (Wolfs, 2015). This technology, known as 3D Printing, is also frequently seen as an expensive method of building because it makes use of synthetic materials, the prices of which are rather high on the market (Hambach & Volkmer, 2017). So, the aim of this research is to find a sustainable material that can be used in the 3D printing technology that is used in the construction industry, and make sure that its strength, cost, and handling methods are greater to those of the materials that are already used in building construction. This innovation is important to ensure that 3D Printing technology in the construction industry can be used more widely in each country. Especially when the cost of construction using this 3D printing decreases due to the use of natural building materials from plant waste.

LITERATURE REVIEW

Since the world entered this era of modernity, this 3D printing technology has received a very encouraging response in numerous industries including the construction industry, and this matter has attracted the attention of researchers around the world to study the effectiveness of this technology in carrying out works that have been carried out entirely by manpower. The application of 3D printing technology in the field of construction has prompted a vast number of questions, the majority according to which focus on the issue of whether or not this technology is capable of producing a sturdy structure comparable to one that is built with human power by itself; whether or not this 3D printing order can carry out construction work continuously and without disruptions; the combination of building materials that need to be used in this order to ensure that the constructed structure can stand firmly; and so The application of this technology in the building industry has also come as a big surprise to organizations that are involved in the construction industry, such as architects, engineers, designers, and so on. This is because the application of this technology is very different from the typical way in which construction was carried out in the past.

3D Printing Technology in Construction

The technique that is now known as 3D printing was initially developed in the 1980s; however, it did not meet with much achievement at the time due to the very high cost that is required to make use of this technology (Karslıoğlu Kaya et al., 2022) . In the year 2000 it started to get quite a good response because the system applied in this technology started to be stable and has caused this 3D technology to develop more widely including the product production sector, design, component and tool manufacture, consumer, electronic, plastic, metalworking, aerospace engineering, dental and medical applications, and footwear (Pandit & Kumari, 2021).

The 3D technology that is used in the construction industry is a technology that was developed so that construction work could be carried out on construction sites without the need for the labour of humans. This technology necessitates the use of computer control technology in order for it to be operated in accordance with the building design that has been programmed into the computer. Because this kind of technology is now available in the building and construction industries, intricate architectural plans can be realised with relative ease in a significantly shorter amount of time (Pandit & Kumari, 2021). There have been advancements made in the technology of additive manufacture, which involves layering cement and a variety of other materials. Utilizing the benefits of both shotcrete and self-compacting concrete, this technology was developed as a result of collaborative efforts involving research in the fields of materials science, robotic coding, and architectural design. When it comes to this kind of printing, the capacity to pump, the constructability, and the workability of new concrete, as well as the strength of hardened concrete, are of the utmost importance (Karslıoğlu Kaya et al., 2022).

The application of 3D printing in the construction industry shows great promise. When compared to conventionally constructed buildings, 3D printing of buildings can save between 50 to 75 percent of the cost of labour, 50 to 80 percent of the cost of time, and 30 to 60 percent of the cost of materials, it has been estimated by industry professionals that 3D printing of buildings can cut costs by between 30 and 50 percent overall (Yin et al., 2022).

According to a study conducted by Žujović et al., (2022), there is a trend in the numberof research papers with the title 3D printing in the construction sector that were published beginning ten years ago and continuing until the fourth quarter of 2022. Figure 1 depicts the rate of publication of related research papers on 3D printing in the construction sector from 2013 to the fourth quarter of 2022. 52 (80%) of the 65 papers chosen were published within the last five years. Furthermore, 35 of the 65 papers, or 53.8% of the total number of papers, were published in the previous three years. Previous research indicates a recent trend of rapid growth in the number of publications.

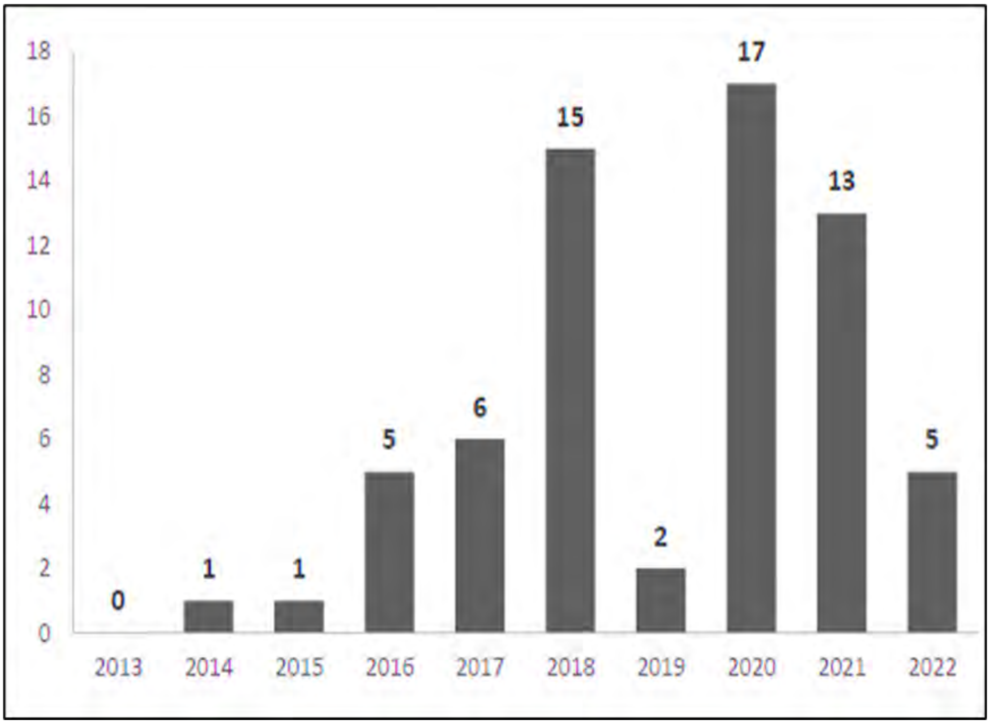


Figure 1: Rate of Publication of Related Research Papers on 3D Printing in The Construction Sector (Source: Žujović et al., 2022)

Concrete Mixture in IBS 3D Printing

The industrialised building system (IBS) 3D Printing construction method is undeniably a form of cutting-edge technology that has the potential to advance the building process nonstop, twenty-four hours a day, seven days a week. With the advent of this 3D Printing machine, it is no longer difficult to accomplish something like this in the field of construction. However, in order to keep the quality and smoothness of the movement of the machine, the building materials that are mixed and manufactured by this machine need to be in the appropriate measure so that there are no arising issues in the future. For successful concrete extrusion, the material should have sufficient flow and workability to provide a continuous easy-flowing paste from the source to the printing nozzle (Zainuri et al., 2020). Once the mate-rial is extruded, the printed layers must have sufficient shear strength to withstand its own weight and the weight of the following layers printed above it (S. Natanzi & Mcnally, 2020). To put it another way, the concrete needs to have a low viscosity and remain fluid while it is inside the pump and the nozzle. After that, it needs to have enough build ability characteristics to lay down correctly, stay in its position, and be solid enough to support the layers that are on top of it without deforming or collapsing, as well as provide a good bond between the layers (S. Natanzi & Mcnally, 2020). In order to prevent cold joints between the layers of a concrete 3D print, the material being used should not immediately harden, in contrast to the printing of metal and plastic. When pumping concrete, the force applied by the pump should be adequate to overcome the material's yield stress, which will cause the material to flow and be extruded out the nozzle. Because of the high yield stress, the material, once it has been extruded, is able to resist flow within the material and avoid deformation (Wolfs, 2015). In addition, the yield stress of the extruded concrete increases with time as a consequence of reversible physical changes in the structure brought about by thixotropy and irreversible chemical and structural changes brought about by the hydration of cement with time(S. Natanzi & Mcnally, 2020). Understanding the relationship between mix design, selection of chemical admixtures and mineral additives, and the time-dependent cement-based paste rheological response (i.e., deformation and flow characteristics) is therefore required for the designing and formulating of effective printing inks. This includes correlating the fluid rheological properties (static and dynamic yield stresses) and hydration kinetics to the evolving plastic viscosity of the fresh cement-based paste under the influence of shrinkage. When it comes to the formulation of cement-based printing inks, one of the most significant issues is meeting the requirements set by the size of the object being constructed, the speed of the robot, and the vertical build rate (Khan et al., 2020). Table 2.1 shows the basic mixture that been used in IBS 3D printing.

Table 1: Basic Material Mixes for 3D Printing Source: (Lediga & Kruger, 2017)

Sand	Binder
3:	2
Maximum 2mm aggregate size	70% Cement
	20% Fly Ash
	10% Silica Fumes
Additionally,	
Water binder ratio	0.26%
Micro polypropylene fibers (length/diameters)	12/0.18%
Super plasticizer (binder weight)	1%
Retarder (binder weight)	0.5%

As can be seen in table 1, the fundamental mixture that goes into 3D printing is a combination of sand and binder at a ratio of 3:2. The binder that is incorporated in the ratio of 2 has the following components: 70% cement, 20% fly ash, and 10% silica fumes. in addition to this, various admixtures were utilized, such as water, micro polypropylene fibres, super plasticizer, and retarder (Lediga & Kruger, 2017).

Fiber Usage in Concrete

The incorporation of fibres into the matrix gives rise to a wide variety of significant effects. Most notable among the improved mechanical characteristics of Fibre Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength, and resistance to fatigue. Improving fatigue performance is one of the primary reasons for the extensive use of Steel Fibre Reinforced Concrete (SFRC) in pavements, bridge decks, offshore structures, and machine foundations, where the composite is subjected to cyclically loading and unloading (Hambach & Volkmer, 2017). Fibre Reinforced Concrete (FRC) is a composite To improve the post-cracking response of the concrete, which means to improve its energy absorption capacity and apparent ductility, as well as to provide crack resistance and crack control, adding steel fibres to the concrete matrix is typically done (Hambach & Volkmer, 2017). The primary reason for this is to improve the post-cracking response of the concrete. Additionally, it contributes to the material's ability to retain its structural integrity and cohesion. The preliminary studies, in conjunction with the extensive amount of follow-up research, have resulted in the development of a wide variety of material compositions that are suitable for use as fibre-reinforced concrete (Zainuri et al., 2020). The high tensile strength, low modulus of elasticity, and high stiffness modulus of steel fibre make it a great choice for use in internal mechanical interlocking. This results in a product that has creased ductility and is user friendly. It may be utilised in applications that include strong impact and fatigue loading without the risk of brittle concrete failure. Therefore, Steel Fibre Reinforce Concrete (SFRC) displays superior performance not only under static and quasi-statically applied loads, but also under fatigue, impact, and impulsive loading conditions (Zainuri et al., 2020).

Kenaf Fiber Production and Properties

The building and construction industry has already researched far too many different kinds of fibers, including natural fibers, synthetic fibers, and organic fibers, in order to utilize them as one of construction elements that can further boost the tensile strength of concrete or mortar (Fajrin et al., 2022). But in recent years, the field of construction has been increasingly interested in the study and application of materials that are renewable and biodegradable in building work materials. Kenaf fibers are one of the natural fibers that are well known for being utilized in a variety of industries, including the construction industry, due to the fact that they are both strong and lightweight.

At first, kenaf fiber was extracted from the Hibiscus Cannabinus plant, as demonstrated in figure 2.4 (Ramesh, 2016; Zainuri et al., 2020). In this plant, the fibers extracted from the bark and the core have been utilized in a variety of industries, including the construction industry. Kenaf fiber is technically capable of replacing the usage of reinforcement in construction, and it is also capable of reducing costs associated with construction due to the fact that the cost to obtain it is very low, and it does not contaminate the environment in any way (Ramesh, 2016).

Kenaf Fiber Usage in 3D Printing as Development Idea

The use of plant fibre (PF) in fibre-reinforced geopolymers offers a broad range of potential development avenues due to its widespread application in nature, plenty of resources, high quality properties, and good development prospects.

It has been stated that kenaf fibre (KF) have a significant capacity to take the place of glass fibres (GF). In contrast to GF, however, KF has not seen nearly as much use for large-scale structural applications(Kong et al., 2021). This is because there is a paucity of knowledge and research pertaining to the effects that KF and GF have on the performance of cement-based composites. As a consequence of this, the goal of this work is to conduct a literature review on the effects that KF have on the characteristics of cementitious composites.

New 3D printing material have been suggested by (Kong et al., 2021), and they are based on waste slag from industrial and agricultural processes, such as FA, GGBS , kenaf straw core, and kenaf fibre. Studying the viscosity evolution, form retention, and cross-section characteristics of various geopolymers allowed for the evaluation of the extrusion and printing qualities of various geopolymers. According to the findings, the viscosity recovery rate and the thickness shape retention rate of the 3D printing mixture that was supplemented with kenaf rod powder and kenaf fibre both rose by 67.63% and 189.19%, respectively, as compared with the group that served as the control (Kong et al., 2021). The dry density dropped from 1749.32 kg/m3 to 1560.60 kg/m3, which makes it very easy to print several layers. In addition, scanning electron microscopy (SEM) was used to confirm, on a microscopic level, both the skeletal action of the kenaf rod and the bridging activity of the kenaf fibre in geopolymer (Kong et al., 2021).

An internal bridging effect was seen when (Kong et al., 2021) inserted 0.2% kenaf fibres to 3d Printing. As shown in figure 2.5 The kenaf fibres linked firmly with the matrix and did not break even after the matrix was mechanically destroyed, demonstrating the existence of this effect. When it came to the bending strength of 3d Printing, kenaf stalks and kenaf fibres had significantly different characteristics. The bending strength of 3d Printing that have been doped with 0.2 weight percent kenaf fibres is increased, and the increased amplitude varies depending on the type of extrusion nozzle used. After curing for 28 days, the compressive test revealed that the compressive strength of the three-layer printing sample produced by 3d Printing with 0.2 weight percent kenaf fibre could reach 8.39 megapascals (MPa) (Hambach & Volkmer, 2017). The yield stress of mortars that had 1 weight percent of microcrystalline cellulose added to them was found to be 190.0% higher than the yield stress of mortars that did not have any microcrystalline cellulose added to them. When compared to mortar that did not contain micro-crystalline cellulose, the compressive strength and flexural strength of mortars that contained 1 weight percent of microcrystalline cellulose improved by 18.6 and 12.5, respectively, after 28 days.

Laboratory Experiment Method

The objective of this laboratory experiment is to collect data that is both more comprehensive and accurate in order to advance the research on material mixes used in 3D printing. In addition to acquiring more precise data, the goal of this experiment is to research the efficacy of the proposed material for use in Machine 3D Printing and to compare the strength of this new study material with the strength of materials used in previous studies. Readings of the material's compressive strength and tensile strength were taken on the 7th and 28th day of this experiment, using two samples of cube and two samples of cylinder respectively.

Materials

- Kenaf Fibre (1.5%)

In this study, Kenaf Fiber was obtained from Tasblock (M) Sdn Bhd in the form of Long Fiber and later cut to no more than 40mm as suggested by Noor Abbas et al., (2023) in his journal. The fiber kenaf, which was cut into short fibers, was then pulled so that it would not stick to each other to make it easier for other materials during the mixing work. 1.5% of the total mixed material that will be used in this experiment will be comprised of kenaf short fiber.

- Cement (31.49%)

In this experiment, the cement used is Ordinary Portland Cement (OPC) ASTM C150-07 with an amount of 31.49% of the total mixture used. Cement is the main binding material in this mix and also makes the mixed mortar achieve the required properties. In the first place, it plugs the spaces left behind by the fine aggregates, which in turn renders the mortar impermeable. With the passage of time and the addition of water to the mixture, it fuses the fine aggregates into a solid mass. After the substance has had a chance to solidify and set, it also gives it strength.

- Silica Fume (4.5%)

It is well known that using silica fume as a partial replacement for cement combined with superplasticizers results in a large improvement in the strength of concrete. This phenomenon has been studied and documented extensively and it is considered that the reduction in the amount of water in fresh concrete and the production of a matrix that is more densely compacted at the interfacial zone are the primary explanations for this improvement in the durability and strength of the material (Toutanji & El-Korchi, 1995). Recent research has established a number of contradicting conclusions regarding the factors that contribute to the improvement in strength. For the purpose of this study, silica fumes were used in the 3D printing mortar mixture at a concentration of up to 4.5%. This was done as an extra material to further reinforce the structure of the sample.

- Super Plasticizer (1.0%)

The addition of superplasticizers, which are water-reducing admixtures, to Ordinary Portland Cement (OPC) concrete helps to reduce the amount of water in the mortar while maintaining its workability (Paul, 2022). This ultimately results in greater concrete strength and durability. Mortar can be fluidized with the use of superplasticizers by maintaining the same level of water content throughout the mixture and his allows the mortar to flow more easily while maintaining its compressive strength (Paul, 2022). The quantity of superplasticizer that was added in the mortar mix throughout this research was 1%. To improve the flowability of the mortar without increasing the amount of water, which would reduce the mix's buildability, it is mixed in as an additive.

- Water (20.42%)

Most attributes of hardened concrete, including strength and durability, are significantly affected by the water-cement ratio. A material's bond strength is measured by its ability to prevent mixing material from being detached from mortar or concrete. Concrete qualities, such as strength and durability, may be affected in the long term when more water is added on purpose to improve workability on the mixture (S.A. Ayanlere, 2023). Thus, determining an appropriate water-cement ratio on the mortar is essential for producing high-quality samples. Therefore, the quantity of water used in mixing this 3D Printing mortar is 20.42%.

- **Fine Aggregate (55%)**

Fine Aggregate function in this mixture is to decreases the amount of shrinkage that the binding substance experiences, which stops cracks from forming as a result. It offers a significant amount of resistance to the mortar so that it can survive the compressive stresses. It does this by separating the paste from the substance that binds it and then spreading it out to create additional surface contact area. The percentage of fine aggregate in this mix is 55%.

Mortar Sample Preparation Procedure

- Mold preparation

Using a brush, thoroughly remove any dust or concrete debris from the inside and outside of two cube molds measuring 100mm x 100mm and two-cylinder mold measuring 200mm in height. This will prevent the remaining dust and concrete residue from clinging to whatever is poured into it.

- Applying oil on mold surface

Make sure that all of the molds are in a tight state without any holes that could cause leaking when mortar is poured into them by making sure that all of the screws and nuts on each mold connector are tightened. Apply oil on each mold surface evenly to ensure that the poured mortar does not stick to the mold surface when the sample is hard and make it easier to dismantle the mold to remove the sample.

- Material Preparation

Prepare all of the components that will be required for the making of the mortar mixture. These components include fine aggregate, cement, silica fume, water, superplasticizer, and short kenaf fibers. All required materials are weighed according to the weight that has been calculated using an electronic scale.

- Mixing Process

Mix binding materials such as cement, fine aggregate and silica fume in the mixing tray and mix until all the ingredients are mixed together. Add water slowly while mixing the mixture using a shovel. After the mortar mixture is mixed well, add the short kenaf fiber into the mixture by shredding it so that it does not stick to each other. Stir the mixture until well combined and finally add the superplasticizer.

- Mold filling

After thoroughly combining all of the materials, the mixture is poured into the molds that have been prepared, which include two molds in the shape of cubes and two molds in the shape of cylinders. Three layers of the sample should be inserted in the mold, with each layer occupying approximately one-third of the mold's height. The use of a tamping rod to compact each layer is highly recommended. A trowel or straightedge can be used to smooth up the concrete's surface. Place the sample in a suitable spot, arrange it there, and then let it sit there for a full day so that the sample mortar can dry out and firm.

- Dismantle mold

After twenty-four hours, the sample of mortar has effectively dried out and hardened. In order to get a sample of the mortar out of the mold, each screw and nut is loosened, and the mold itself is opened. In order to avoid the samples from shattering, the cubes and cylinders are slowly removed. To prevent mortar debris and excess oil from adhering to molds, each and every mold is scrubbed with a brush and dried with a cloth to remove any trace of previous use.

- Curing process

After all of the samples have been removed from the mold, the curing procedure needs to be carried out. This will keep the moisture level in the mortar sample constant, which will both increase the mortar's strength and prevent the mortar to dry in a shorter amount of time, which can lead to cracks. Every sample is first sprayed with water all over its surface, and then it is covered in multiple layers of plastic wrap in order to keep the water from evaporating from the sample while it is being stored. Every sample is stored in a location that maintains standard room temperature and average air humidity.

Testing Methods

The testing carried out in this study is very important to get an accurate reading. The results of the testing conducted will then be analyzed and determined whether the research conducted is suitable for use by the industry or not. Basically, the testing that needs to be carried out in this study is very much. However, due to the lack of testing facilities, the testing carried out in this study was only compressive strength testing and tensile strength testing.

- Compressive strength test

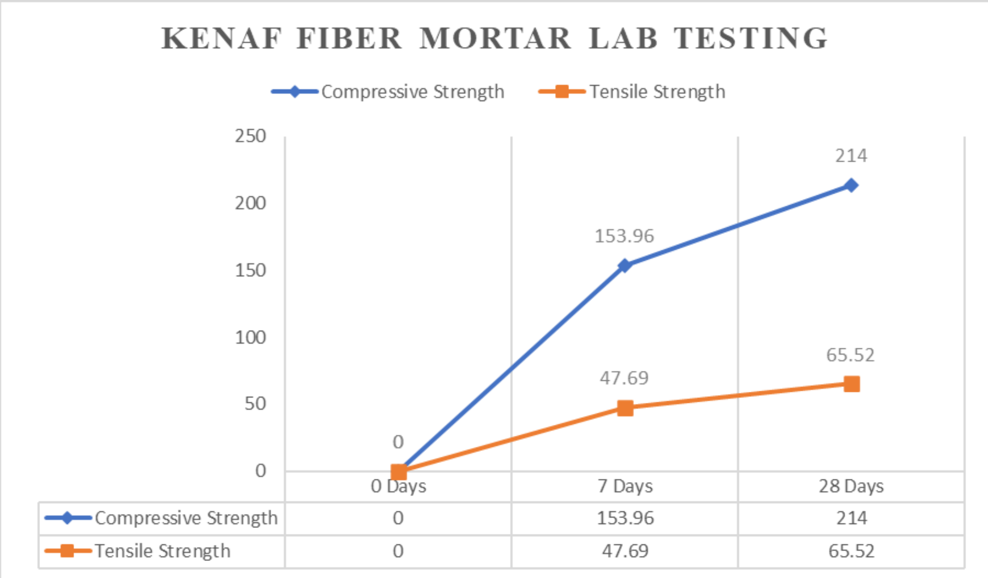
For development reasons, it is crucial to know the compressive strength of each mixture to ensure that the structure can safely support all of the loads placed upon it. The compressive strength of sample is typically tested by applying a compressive force to cylindrical or cubic specimens of uniform size and shape using a hydraulic press machine. The specimen is subjected to increasing loads until it is crushed, at which point the maximum load applied is recorded, along with the specimen's cross-sectional area, to yield the compressive strength. In a wide range of engineering and construction contexts, the compressive strength of mixture is a critical parameter that determines the material's quality, durability, and suitability. In this study, the compressive test was carried out twice using two cube samples that had gone through the curing process for 7 and 28 days to obtain the maximum compressive strength for comparison.

- Tensile Strength Test

The concrete tensile test is a method of determining the tensile strength of concrete. It is a less common test than the concrete compressive test, but it can be useful for assessing the tensile strength of concrete in applications where tensile stresses are present. The concrete tensile strength test is a test used to determine the tensile strength of mixture sample, which is the maximum stress that the mixture can withstand before it begins to fracture. This test is usually performed by preparing cylindrical specimens and then subjecting them to tension through the use of a testing machine, such as a universal testing machine. The tensile strength is typically measured in megapascals (MPa) and is a key indicator of the overall strength and quality of concrete.

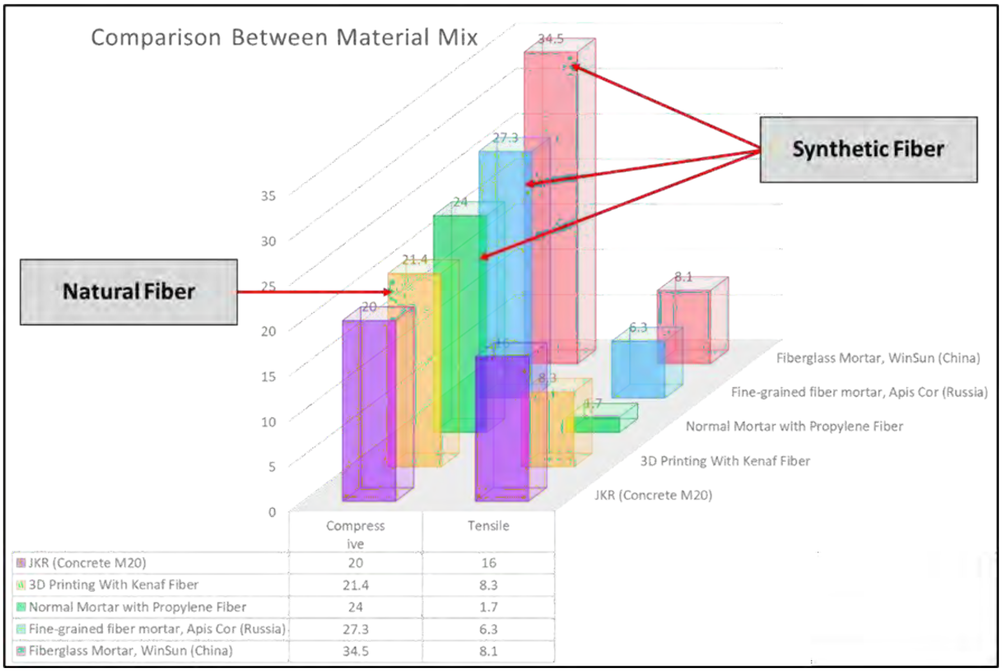
RESULTS

Table 2: Tensile and Compressive Lab Testing Results



Referring to Table 2, it can be seen that on the 7th day of Cube sample conducted the compressive test showed its strength of 153.96mp and on the 28th day increased to 214mp strength on compressive strength. In terms of tensile strength, on day 7, it showed a tensile strength reading of 47.69mp and on the 28th day increased by 65.52mp.

This shows that using the proposed material mix design in this study found that the compressive strength obtained was higher than the tensile strength.



	Compressive	Tensile
JKR (Concrete M20)	20	16
3D Printing With Kenaf Fiber	21.4	8.3
Normal Mortar with Propylene Fiber	24	1.7
Fine-grained fiber mortar, Apis Cor (Russia)	27.3	6.3
Fiberglass Mortar, WinSun (China)	34.5	8.1

Figure 2: Comparison Between Material Mix

As can be seen in Column Chart in figure 4.11 is a comparison between the 3D Printing Mortar used in this study, the mortar mixture used in the existing 3D Printing Company and the concrete strength set by the Malaysian Public Works Department/ Jabatan Kerja Raya Malaysia (JKR).

According to the chart, 3D Printing with Kenaf Fiber has the least amount of compressive strength compared to other mortar mixes, with a value of 21.4 MPa for its Compression Strength. While Normal Mortar with Propylene Fiber may reach a compressive strength of up to 24 MPa, fine-grained fiber mortar like the kind used by Apis Cor in Russia can reach up to 27.3 MPa, and Fiberglass Mortar like the kind used by Winsun 3D Printing Company in China can reach up to 34.5 High. MPA.

It is clear from the results of this research that the kenaf fiber mortar, which was employed in the experiment, possesses a greater strength than the other mortar combinations when measured in terms of tensile strength. It has been demonstrated, and the results are presented in the column chart located above, that the kenaf fiber mortar that was utilized in this investigation possesses a tensile strength that is as high as 8.3Mpa. In the meanwhile, normal mortar made with propylene fiber has a tensile strength of 1.7 MPa, fine-grained fiber mortar like the kind used by Apis Cor in Russia reaches 6.3 MPA, and fiberglass mortar like the kind used by Winsun 3D Printing firm in China has a compressive strength of 8.1 MPA, making it the strongest of its kind.

With the help of the analysis done through the column chart that was displayed, it was discovered that the compressive strength obtained from the Mortar Mixture combined with fiber kenaf is lower than the compressive strength acquired from the other mixture that has been employed by the construction firm using the method of 3D Printing. On the other hand, it can be noted that the strength of the Kenaf Fiber Mortar that was used in this investigation is 1.4Mpa higher when compared to the strength of Concrete Grade 20 JKR. This demonstrates that the Kenaf Fiber Mortar that was researched has a compressive strength that meets the requirements of the JKR Mortar Grade 20 Standard Specifications.

CONCLUSION

The analysis obtained from this study proves that the strength of the mortar that mixed with natural fibers cannot match the mortar which added synthetic fibers into it. This statement can be supported by comparing certain research which shows the physical properties of synthetic fibers and natural fibers. When compared to these two tables together, the majority of the strength of Synthetic Fibers is much higher than the strength of Natural Fibers. However, the strength obtained from the study also found that mortar added with natural fibers such as kenaf fibers can achieve strength equivalent to concrete grade 20 set by JKR. This means, even though the mortar mix that was studied could not overcome the strength of the mortaradded with synthetic fibers but the strength obtained was suitable for building a strongbuilding. As a recommendation to further improve the results of the study in the future, the hybrid method can be used in this 3D printing mortar mixture by mixing syntheticfiber with natural fiber into the same mixture to obtain maximum strength. This is because according to research that has been conducted it has been found that synthetic fiber has a high strength in compressive strength. Meanwhile, natural fiberhas a relatively high strength in tensile strength. So, by mixing these two ingredients,it is highly likely that these two strengths will increase stably.

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