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POLYPROPYLENE STUDS ADD COMPRESSIVE AND SPLIT STRENGTH TO ELEVATED TEMPERATURES CONCRETE.

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ABSTRACT-

The effect the surroundings have on the crushing and breaking tensile properties of concrete with exceptional strength was investigated in the current study. Three different types of concrete—Self-consolidating concrete (SCC), High strength concrete (HSC), and Fly ash concrete (FAC)—are regularly evaluated for Specific heat, thermal conductivity, and thermal expansion in the 200–800 ^{O}C temperature range. For our study we are going to test on the 100-200 ^{O}C Only. In order to evaluate the overall durability and fire resistance of concrete buildings, it is essential to understand high temperature thermal properties. The results of a research on the impact of polypropylene (PP) fibers on the thermal properties of HSC are presented in this paper. Concrete may be made using ratios of 0.46, 0.40, and 0.35 of water to Bonding material, polypropylene fibre concentration of 1-3 kg/m3, and replacement amounts of 6% and 10% for rice husk ash. Concretes with PP fibres had greater compressive values in comparison to those without.

Further test findings demonstrate that the HSC's strength characteristics during heating can be significantly improved by the inclusion of 2.1 kg/m^3 or more polypropylene fibers. According to tests, HSC works way better than other High strength concrete like FAC or SCC in terms of specific heat, and thermal expansion, thermal conductivity, in the temperature range of 200-800 ^{O}C. It may not give fine properties like SCC. Concrete needed to be maintaining temperature between 300 and 800 ^{O}C to have greater strength. Additionally, the inclusion of PP fibres improved compressive strength above 200°C. All of the concrete had good mechanical properties at room temperature, but after being exposed to 300°C, there was a definite loss in strength.

Introduction

As we know that since concrete typically possesses excellent fire resistance qualities, it is frequently used in structures like buildings and other structure, where fire safety is in a top priority. Over the past three decades, concrete technology has undergone extensive research and development, and this has resulted in better concrete mixtures known as high-performance concrete (HPC) mixes that have benefits in terms of cost, strength, and durability. They are therefore finding a variety of uses. HSC performs better in harsh environments and has significantly greater mechanical strengths than normal-strength concrete (NSC). Since the 1920s, the behaviour of NSC at high temperatures has been well-known thanks to the findings of a vast amount of study. Various studies have been performed in recently to identify the temperature behaviour variations between HSC and other concrete. The likelihood that HSC will be subjected to high temperatures such as those brought on by unintentional fires or persistently high temperatures increases as HSC is used more frequently. As a result, they are being used in many different ways.

For a fire-resistance study, concrete's mechanical, thermal, deformational, and unique properties induced spalling must be considered. The paper will assess thermal properties such as conductivity, specific heat, diffusion rate, heat expansion, and mass loss. Mechanical and deformation characteristics like strength, deformation, and elastic elasticity have a significant impact on how a structural system reacts to fire. Deformation traits like slip and fire-induced spalling, which can happen in concrete under certain circumstances, are also significant factors that can affect how a reinforced concrete structural structure responds. The proportions of the mix, the type of aggregate, the presence of fibres, and the addition of mineral and chemical admixtures all have an impact on these properties, which all change with temperature. Recent developments and the evolution of concrete have made it possible to choose a particular type of concrete based on the desired properties for a project, making it more essential than ever to understand how fire behaves. Different types of concrete are made based on the material engineer's choice to meet the project requirements. Furthermore, self-consolidating concretes' spalling sensitivity can be fairly anticipated due to their denser matrix, which also allows for self-consolidating concretes to exhibit fire-induced spalling that is similar to HSC even at lower strengths. The reliability of its high-temperature properties must be established, but as the use of HSC in built infrastructure increases, rigorous investigations are required to address its weaknesses under fire circumstances. Data on the fire behaviour of HSC plainly shows that it performs worse at high temperatures than NSC.

This study's primary goal was to look into how temperatures affected the thermal qualities of polypropylene-infused high strength concrete. The high temperatures work greatly expands upon the body of currently available knowledge regarding the behaviour of high strength concrete with fibres. The thermal resistance of concrete may be improved with polypropylene fibers, based on numerous experiments done by various authors. At a temperature of approximately 160–170 °C, the fibres melt, forming routes for expansion. The additional porosity created by the melting of the polypropylene fibers could compromise the residual tensile properties of the concrete. The literature on this topic has conflicting findings. Numerous studies conducted by various authors demonstrate that residual strength decreases in accordance with increased porosity, while other studies show that residual strength increases. The experimental conditions, specimen cure state, and temperature rise can all have an impact on how the results vary.

Studying the addition of steel fibres to concrete that has been exposed to high temperatures demonstrates their significant impact on the mechanical characteristics. Steel fibres enhance the heated concrete's residual mechanical qualities. All writers have demonstrated that the increase in tensile strength was more significant than the increase in compressive strength. As we know that from past study the existence of steel fibres has little impact on the modulus of elasticity's variation with temperature". It observed "that steel fibres made a good mechanical contribution for temperatures below 1000 °C".

The existence of steel fibres may have an impact on the thermal stability. Concrete can be reinforced with steel and polypropylene fibres to lessen spalling and increase leftover strength after heating. There aren't many studies on concrete or cement made with steel and polypropylene fibres that are heated to high temperatures. The outcomes attained by various writers seem incompatible. The research highlights a significant increase in the residual mechanical performance of cocktail fibre concretes over fiber less concretes.

On the other hand, **Suhaendi and Takashi's** findings indicate little change or a decline in the residual mechanical power. The percentage of steel or polyethylene fibers in the fiber blend is an important factor. The data that are currently available in the literature relate to a limited number of fibre combinations that have been tested under various experimental circumstances.

The mass loss, porosity, leftover strengths, and elastic flexibility of high strength concretes that contain a mixture of fibers are also poorly understood. In order to better understand how high strength concrete reinforced with a variety of fibers behaves at high temps, this article presents new experimental results. There are two phases to the study's execution. First, the behavior of high strength concretes made with steel and polyethylene fibers is compared to that of high strength concretes produced without fibers. Two amounts of steel and polypropylene fibres are examined for their effects. Next, it is looked into how high strength alloys composed of steel and polyethylene fibers behave. At different ratios, the proportional volume fractions of the two types of fiber are examined. The effects of each variety of fiber in the fibre cocktail concrete can be determined using this methodical approach, which also helps to clarify how the fiber cocktail impacts the thermo-mechanical behavior of concrete.

Research Review

Song, Chaojie, et al.(2023) report an study on the fire behavior of polypropylene fiber prestressed concrete (PFPC) bridge girders exposed to localized hydrocarbon-fuel fire (mixed diesel and natural gas) and applied structural loading. Throughout the full fire exposure period, the thermal responses, including the temperature of the concrete, the temperature of the prestressing strands, and the temperature inside the container, were monitored and evaluated. The In-depth research was also done on structural responses to the test findings, including mid-span deflection, efficient prestress, spalling brought on by polypropylene (PP) fiber concrete, fire resistance, damage progression, and failure processes. The results of the experiment demonstrate that PP fibre can greatly reduce the pressure of water vapour that builds up inside the high-strength concrete used in PFPC bridge girders, effectively improving the concrete's resistance to spalling at high temperatures. The prestressing strands start to break as the fire exposure hits its maximum, and the effective prestress suddenly decreases. After that, PFPC bridge girders quickly reach a limit state that is contingent on the rate of deflection, displaying a brittle failure characteristic. Reserved prestressing strands can stop this collapse of PFPC bridge girders. Under conditions of exposure to fuel fire, PFPC bridge girders, which are intended as under-reinforced girders at room temperature, are vulnerable to exhibiting the failure characteristics of rare-reinforced girders.

Maged, Tawfik, et,al (2022) Showed By tracking the initiation and spread of cracks, it was discovered that mixing various fibre types into a concrete mixture could enhance the Cementitious matrices' strength characteristics. In order to completely understand the function of hybrid fibers, it is important to consider various aspects, such as fiber variety and content. This study investigated the effects of hybrid steel-polypropylene fibre addition on the mechanical characteristics of the concrete mix. Compressive, tensile, and flexural strengths of hybrid fiber-reinforced high-strength concrete mixes were examined. The test findings demonstrated that adding hybrid fibers to the concrete mixture significantly enhanced the mechanical properties compared to adding just one type of fiber for examples subjected to room temperature. When compared to using only one type of fiber, using hybrid fibers in the concrete mixture improved compressive, tensile, and flexural strength by about 45%, 50%, and 55%, respectively. Results also indicated that the addition of hybrid fibres to the concrete mixture improved the specimens' residual compressive strength when subjected to high temperatures. The control specimens, which lacked fibres and couldn't withstand temps higher than 200 °C, on the other hand, exploded during heating due to thermal spalling.

Moghadam et al. (2020) investigated one of the critical areas of worry in civil engineering: the behavior of a concrete structure at high temperatures. This research demonstrates the effects of steel and glass fibre addition on the high-temperature behaviour of regular concrete. Tests were conducted on the mechanical and durability standards after cooling and at elevated temperatures, respectively. The volume percentage of fibres is 0.25 percent, and measurements are made between 28 °C and 800 °C. According to the findings, adding steel fibres increases the material's compressive, tensile, and shear strengths at high temps by 9–27%, 8–198%, and 1-22%, respectively. Compressive and tensile strength improvements for specimens containing glass fibre vary from 1 to 18% and from 19 to 213%, respectively. Although the tests for durability indicate that high temperatures can harm concrete's durability qualities, the addition of fibres has made up for this harm. In the meantime, it has been noted that tests on the sorptivity and depth of water penetration performed because of capillary properties have comparable outcomes.

Reza Abaeian, et al. (2018) studied how improvements in technology and newer construction materials have increased the output of high-strength concrete (HSC). Due to technical and economic considerations in the building of concrete sections, this material is now used more frequently. Although concrete's tensile strength does not grow as its compressive strength does, it does become more brittle the more compressive strength it has. Compared to normal concrete, HSC has a higher density and lower porosity, making it more susceptible to high temperatures. Researchers have proposed a number of solutions to resolve these HSC flaws, including the incorporation of polypropylene fibers in concrete blend designs. In this study, high performance synthetic macro polypropylene fibers (HPP), a brand-new type of polypropylene fiber, were used at doses of 1, 2, and 3. Compressive strength, tensile strength, and flexural strength tests on hardened concrete are performed at temps of 30, 120, 250, and 300 °C. With the addition of 1 kg of fibers, HSC's compressive strength, tensile strength, and bending strength all increased by up to 14, 17, and 8.5%, respectively. Additionally, the greatest improvement in the mechanical qualities of concrete subjected to high temps was seen when adding 1 kg/m3 of fibers to HSC.

Venkatesh Kodur et al. (2011) research was to better understand how a polypropylene and steel fibre combination affected the behaviour of high strength concretes exposed to high temperatures. In order to study concrete mixtures, steel, polyethylene, and a combination of fibres were added. Different heating-cooling cycles were applied to the concrete examples. The analyzed concrete mixes' initial and enduring mechanical characteristics, porosity, and mass loss were examined. Tests were conducted on different concrete compositions containing varying amounts of steel or polypropylene fibres. The residual mechanical properties of concretes containing the fibre cocktail significantly outperform concretes without fibres, according to experimental findings.

Pliya, P., et al (2010) in circumstances where it might be exposed to high temperatures, high strength concrete has been used. Numerous authors have demonstrated the important role that polypropylene fibre plays in high strength concrete's ability to withstand spalling. The mechanical properties and structure of high strength concrete incorporating polypropylene fibre are examined in this interesting study at high temperatures of up to 200 °C. At 180 °C, high-strength concrete reinforced with polypropylene fiber easily melts and volatilizes, expanding the concrete's porosity and forming minute channels. The highest temperature of the degradation process in the high strength concrete was revealed by DSC and TG measurement. Mechanical tests showed a few minor variations in compressive strength, elastic elasticity, and splitting tensile strength that might be connected to polypropylene fiber melting.

Ali Behnood et al. (2009) published the results of a comprehensive practical study on the crushing and breaking tensile strengths of strong concrete with and without polypropylene (PP) strands. Despite all of the concretes having strong mechanical properties at room temperature, after exposure to 600°C, a significant decline in strength was seen, especially in the silica fume-containing concretes. For concrete to have greater strength, the range of 300-600 1C was more important. Concretes with PP fibres had greater relative compressive strengths than concretes without PP fibres. Compressive strength of concrete is more resistant to heat than breaking tensile strength. Additionally, the inclusion of PP fibers improved compressive strength above 200°C more so than breaking tensile strength.

A. Noumowe et.al. (2005) examined polypropylene fibers to help release the vapour pressure in the high-strength concrete (HSC) microspores in high-temperature environments. However, air entrained HSC can work well in place of polypropylene fiber reinforced HSC in structures that are vulnerable to fire because of its intrinsic porosity. To increase the strength of air-entrained concrete and investigate its efficacy at high temperatures in the 200–800 °C range, an experimental programmed was created. In this research, the mechanical and material characteristics of conventional and air-entrained HSC in the unstressed (hot) state were compared. The air-entrained HSC were put to the test at 4% and 8% air volume variations. The effects of a greater heating rate of 10 °C per minute were investigated with respect to compressive strength, splitting tensile strength, stress-strain response, elastic modulus, spalling, mass loss, and fracture behavior. The results show that air-entrained HSC at high temps has enhanced spalling mitigation and physical properties with superior mechanical property preservation.

Composition of the Materials-

To prepare the concrete examples for this test, Ordinary Portland Cements (OPC) that complied with IS: 8112-1989 was used. To make the RHA concretes a premium industrial **Rice Husk Ash (RHA)** was employed. The coarse limestone aggregate used had a maximum dimension of 12.5-16 mm. The coarse aggregate had a specific gravity of 2.65, a water absorption rate of 0.6%, and it complied with 33 grading criteria for aggregates with sizes varying from 12.5 to 4.75 mm. The fine substance was made of river sand, which has a specific gravity of 2.70 and a water absorption of 0.8%. The modified polycarboxylate ether high-range water-reducing additive, which comprises 45% solid particles and is commonly used, was used to make the concretes. We employed 12 mm-long polypropylene fibrillated threads in the 1, 2, and 3 kg/m^3 densities.

In the project's initial part, experiments were done to investigate how different concretes behaved with w/cm ratios of 0.40, 0.35, and 0.30. The other mixes were made by substituting Rice Husk Ash for a portion of the cement in two separate amounts, 6% and 10%, respectively. The second portion of the study utilized concrete mixtures with fibers, to evaluate how polypropylene fibres affected the properties of concrete, which had a constant w/cm of 0.30.

Preparation of Specimens and Test Procedure

Materials were combined in accordance with IS Code. Prior to turning on the blender, the coarse material and about one-third of the mixing water were added. The remaining Rice Husk Ash, fine sand, cement, water, and other ingredients were gradually added to the running blender. The mixer was then progressively filled with fibres. PP fibre insertion typically takes two minutes. For combinations without fibres, the mixing process went on for another 3 minutes. The final mixing requires 2 minutes after a 3 minute break period. The specimens were layered twice and cast in cylindrical moulds that were 102 mm in diameter and 204 mm height. A vibrating table was used to consolidate each layer.Fresh mixes are sag tested for workability per IS:1060 and to determine unit weight and air capacity usin g IS:1199. Concrete samples are poured, covered with wet jute and polyethylene and left inside the structure a t room temperature for 24 hours according to IS:516. (1959). The deformed specimens were stored in a wet li me water bath until tested. According to IS: 10262, curing were carried out. Previous on evaluation, extra effort was taken to hinder drying out the materials. Testing for compressive strength was done in accordance with IS: 516(1959, and testing for breaking tensile strength was done in accordance with IS: 5816 (1999). Each blend's cylinders were placed in an oven and heated at an average rate of three degrees Celsius per minute (C/min) from ambient temperature 20^{O}C to 100, 200, and 300 ^{O}C. The samples were heated to 600 °C at the same rate as the oven in an electrically fueled furnace. After almost three hours at the correct climate the burner is corrected off and the fragment is allowed to cool to room temperature. During warming grant the moisture in the test item to disappearance calmly.

Test Results and Analysis

Compressive Strength -

All four concrete's relative residual compressive strengths under evaluation. The mixes of concrete labeled respectively, contain 1.1, 2.1, and 3.1 kg/m^3 of PP fibres. Additionally, the control combination without PP fibres is NF concrete. As is evident, adding PP fibres had no appreciable impact on concrete's flexural strength at room temperature. The smooth surface of PP fibres weakens the interfacial bond between them and cements slurry. Furthermore, even at 5% volume percentage, they discovered no strength increase with PP fibres. However, because polypropylene is hydrophobic and chemically inactive, molecular bonding is not feasible. Fibrillation consequently has a big impact on communication. According to Bentur et al., mechanical anchoring and interfacial binding have the biggest effects on how fibres and matrix interact. The development of multi filament structure as a result of insufficient PP fiber dispersion in the concrete mixture should also be recognized as a delicate situation that calls for extra caution.

The proportionate compressive strengths of the NF and WF-I and WF-II Concretes at 100°C were, respectively, 84.5 and 86.7% and 87.1% of the values observed at room temperature, and the compressive strengths of each concrete significantly declined after being heated to this temperatureAfter being exposed to 100 ^{O}C, Concretes with and without PP fibers had approximately equal residual compressive strengths. This outcome was consistent with other studies' findings that the presence of fibres did not substantially affect the permeability of the porous network.

All three concretes' residual compressive strengths were discovered to be slightly higher at 200°C than they were at 100°C. The increase in surface relationships among gel particles brought on by the drop in moisture content accounts for the increase in strength correlated with this temperature increase. When compared to concrete without fibers, the power returns of concrete with fibers made of PP were significantly different. When compared to 100 ^{O}C at 200 ^{O}C, NF and WF-I, WF-II concretes showed the least and most increases, respectively. This may be explained by the quantity of water vapor that can easily exit through the paths created when PP fibers dissolve between 160 and 170 °C.

Furthermore, they asserted that despite the melted PP molecules' big size relative to pore breadth, the cement matrix is capable of absorbing it. The NF, WF-1, and WF-2 concretes had proportional residual compressive values of 68.7, 70.9, and 73.1, correspondingly. Due to their dense structures, which result in high pore vapors pressure, NF concretes in particular experience substantial decreases at 200°C. The linked network of micro cracks can grow and turn into macro cracks in conditions of high atmospheric pressure, causing an abrupt loss in strength. Cement paste also shrinks and aggregates increase when heated. The Different temperature properties of the components can affect the material's leftover compressive strength because concrete may have stress concentrations. The remaining compressive values of the WF concretes were higher at 200 °C compared to that of the NF concrete. It is common knowledge that concrete's porosity has an impact on pore vapour pressure. Because the PP fibers dissolve before the concrete reaches 300°C, the weight of water vapors was reduced by increasing the concrete's porosity and adding more exit pathways. Since PP fibers increase open space and act as thermal absorbers, their removal also reduces the effects of ther mal mismatch between aggregate and slurry. The proportion of remaining compressive forces significantly decreased after exposure to 600°C. Most scientists agree that calcium hydroxide breaks down into lime and water vapors at a temperature of between 500 and 600°C.

When calcium hydroxide is heated in this region, lime and water vapors are produced. As was already mentioned, fiber concretes significantly outperformed NF concretes in terms of water vapour pressure. Concrete strength gains and losses due to some post-cooling behavioral modifications involving lime have been recorded. After being subjected to 100 ^{O}C, Concretes with and without PP fibers had relatively similar leftover compressive strengths. The loss of energy is typically attributed to the rehydration of lime, which is followed by a 45% rise in volume.

According to reports, the major ingredients of the hydrocarbons produced by the breakdown of PP fibres are propylene, pentene, and heptanes'. At various doses and at 100 ^{O}C, it can be inferred that the presence of PP fibers has a negligible impact on the corresponding residual compressive property of concrete, but at greater temperatures, they significantly increase it. Additionally, due to its better performance during heating, it has been determined that lumsum 2.1 kg/m^3 of fibers is the ideal quantity of PP fibers in concretes.

<u>Splitting tensile strength-</u>

The breaking tensile values of the WF-1 and WF-2 concretes at room temperature were, respectively, 9.1% and 11.9% higher than those of the NF concrete. The impact of fibres on how concrete acts when it cracks were explained by Shah. The study cited indicates that the presence of fibres increases the closing pressure as a crack grows. As a result, the combination is more resistant to cracking. As a consequence, higher matrix stresses will be needed before critical fracture propagation begins. After being heated to 100 °C, the breaking tensile force losses for the NF, WF-1, and WF-2 concretes were approximately 19%, 12.1%, and 9.9% of the values at room temperature. PP fibers, which show long-term resilience to 100 ^{O}C, are to blame for these variations in thermal behavior between concretes with and without fibers. These concretes prevent fractures from spreading and from localizing into larger breaches in contrast to

In NF concrete, the cohesion between the internal layers, the surface energy of numbing and the appearace of micro cracks can be reduced. In contrast to concretes having PP fibers, the relative splitting tensile strengths of NF concretes declined at 200 ^{O}C as opposed to 100 ^{O}C, and they were typically steady between 100 and 200 ^{O}C. The spaces left behind when PP fibres disappear between 160 and 170 ^{O}C could provide an explanation. The vacant spaces at the ends of PP fibres have the potential to turn into micro cracks when stresses accumulate there. The outcome is a rapid loss in strength. At 300 ^{O}C, the splitting tensile values of the NF, WF-1, and WF-2 concretes, respectively, dropped by approximately 34.2%, 31.9%, and 30.2%. As was previously mentioned, degradation on physical and chemical level results in extreme strength loses in concrete

The higher permeation of strand concretes at 200°C as well as the grinding effect of high temperature on the pores dimensions transportation, which has been documented in multiple studies, may be accountable for the greater decreases in the splitting tensile advantages of strand concrete materials at this temperature as compared to 100°C. According to a research on the breaking strength of concrete with various PP fibre dosages, increasing the concrete's high temperature resilience by 2-2.1 kg/m3 of PP fibre is possible. The ratio of each concrete's residual tensile strength to compressive strength at various temps is shown. As can be seen, as temperatures increased, the remaining splitting tensile strength to compressive strength ratios usually dropped. The amount of accessible load-bearing area will reduce with each new fracture, but this reduction will raise the stresses at major fissure tips. Additionally, fractures often close off when subjected to compressive loads while opening up when subjected to tensile loads. As a result, crack coalescence affects compressive strength more so than breaking tensile strength. On the other hand, the site of micro fissures into macro cracks is greatly influenced by the increased vaporization of water pressure, breakdown of products of hydration, and temperature behavioral disparity between aggregates and cement paste. Even for fiber concrete, the compressive strength was less susceptible to greater temperatures than the breaking tensile strength. An apparent exception to the earlier result appears to be the properties of fibre concretes at 100°C. Since adding PP fiber to the system increases tensile strength more than compressive strength, the loss in compressive strength at 100 OC is greater than that of tensile strength at 20 OC. It is observed that the addition of 20, 100 and 200 PP fibers increases the ratio of residual tensile strength to compressive strength. It implies that the inclusion of PP fibers usually decreased the compressive strength's greater susceptibility to high temperatures than the splitting tensile strength. The inclusion of 2.1 kg/m3 PP fibers can greatly improve the HSC's remaining mechanical properties during heating. Because there were more declines and/or more voids, correspondingly, lower and greater fiber amounts typically performed less effectively.

Conclusion-

These inferences may be made in light of the findings of this scientific study:

1. Despite all of the concretes having excellent mechanical properties at room temperature, those that contained Rice Husk Ash in particular experienced significant strength losses after being exposed to more temperature Increase. Therefore, the range of more than 200 ^{O}C is more crucial for concrete to have higher strength.
2. The range of implementation of this method at high temps is limited to 300°C, with a tolerance of approximately 70% of the expected values. Concretes with PP fibers had higher percentage residual tension values than concretes without PP fibers.
3. Tests of the material's compressive strength at room temperature are used to calculate the breaking tensile strength in accordance with ACI 363.
4. The tensile strength of concrete is more sensitive to high temperatures than the compressive strength. Additionally, the incorporation of PP fibers increased the compressive strength above 200°C in relation to the tearing tensile strength.

5. The method is limited to 300°C at elevated temperatures with a tolerance of approximately 70% of the expected value.
6. Concrete with PP fibers had higher residual stress percentage values than concrete without PP fibers.
7. The residual compressive strength of the four types of concrete did not change significantly after being heated to 100°C. Concrete containing 1, 2, 3 and more PP kg/m3 fibers exhibited an equivalent loss in ultimate strength of 7.9%, 10.5%, 7.3% more than fibreless concrete.
8. Test results show that the performance of HSC during heating can be significantly improved by including 2.1 kg/m3 of PP fibers. Lower and higher dosage fibers generally exhibit correspondingly lower performance due to greater degradation and/or more voids.

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