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ORIGINAL CONTRIBUTION

Strength Analysis of Ultra-High-Performance U-H-P Steel Fibre Reinforced Mortar Part of Concrete Using Rice Husk Ash & Nano Silica Fume

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Abstract— **The purpose of this study is to provide Pakistani citizens with Ultra-High-Performance Concrete utilizing locally available resources. In an experimental study, steel fibres are combined with silica fume and rice husk ash when superplasticizers are present. Several different tests were done using completely different volumes and different amounts of ingredients from local supplies and steel fibres to investigate ultra-high-performance concrete. Results show that ultra-high-performance concrete can be produced using locally accessible material. There are differences in the compressive and flexural strengths of the Ultra High-Performance concrete. Every outcome is pleasing. Scanning electron microscopy and X-ray diffraction tests were also used to assess the ultra-high-performance concrete's microstructural analysis. The transition zone between fine aggregates and the cement paste is enhanced by the use of silica, according to X-ray diffraction and scanning electron microscopy test results. Dense packing is one of the main factors influencing concrete strength, and it is achieved by using a low water-to-cement ratio. This observation is gained from Scanning Electron Microscopy and X-ray diffraction tests. The steel fibers in ultra-high-performance concrete inhibited the propagation of cracks in the matrix.**

Index Terms— **Cement, Silica fume, Rice husk ash, compression, flexure, X-ray diffraction, Scanning Electron Microscopy, Ultra High-Performance concrete**

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I. INTRODUCTION

The pozzolanic offerings were profitable, and the manufacturing of UHPC was less complicated than that of the most recent concrete mix.[1, 2, 3, 4, 5] Granulated ground blast furnace slag, flying ash, rice lichen ash, and silica fume are among the materials that are frequently utilized in UHPC buildings. Globally, the expected use of concrete in a year is 12 billion per tonne. It not only makes greater potential, but it also makes water drinkable. This assertion is accurate, given how successful modern advertising is becoming. A breakthrough in the production of cement resulting from the discovery of metals and pure chemistry occurred in the 20th century [6, 7, 8, 9]. The strength, flexibility, and longevity of the cement are all greatly impacted by the way the steel fibres are designed into the cement. The restriction of concrete's compression and its strong elastic resistance and ductility [10, 11, 12, 7, 13]. In the 1950s, even though the strength of concrete and high building height and equipment used in 1980, additional compressive strength of 5,100 Psi at 9500 Psi of pressure was accomplished by increasing the vitality of the earth believes that excessive force. The new knowledge-a-chaos UHP 17500 power results are better than the PSI. This study includes economic analysis, towering buildings, and portions of the company's building structure [14, 15, 16]. The cost of a dream was lowered with UHP water. Massive led ziravîtî is removed from the mass's aftermath. Child Icailika is anticipated to generate UHP-in, which is connected to the adaptability and resources of Amorphous silver content. The silver scrolls' small weight and their 26% pozzolanic content are the outcomes of the tools he utilizes. Silver Cup, Fly to the Sky, and many more are also available at a lower cost. Use the wood ash to see the treasure. Hatim, after examination of the kind and quantity of further particular suggestions that pozzolanic discovered [16, 17, 18].

By preventing cracks, the use of steel fibres in UHPC ultimately increases fracture toughness. Tentatively investigated the mechanical properties of the fume-Fe_2-O_3 and fume-SiO2 bond mortars and found that the crushing quality was significantly better after 7 and 28 days than it was after ordinary concrete. Microstructure analysis shows that the pozzolanic reaction's response resulted in the fume particles topping over voids and reducing measures regarding calcium oxide.

According to some researchers [19, 20], F.A. with a smaller particle size has better pozzolanic qualities than Ordinary Portland Cement, which improves the early-age strength characteristics. Many academics [21, 22], and others [22, 23, 24] also noted that concretes with Fly ash particles at

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a rate of substitution of 5–30% showed higher C.S. According to a study [7], class F fly ash is the most important ingredient for lowering the total amount of chloride penetration of concrete. The effect of Fly Ash content on permeable voids in concretes was investigated by [19, 25]. They showed that permeability voids dramatically reduced up to a 30% Fly Ash replacement; yet, compared with the control specimens, exceeding a 50% Fly Ash exchange showed a greater porous void;

- UHPC blend is achieved by utilizing local materials in Pakistan.
- To achieve ultra-high compressive strength of UHPC different ingredients were used in different ratios. Also, the flexural strength of UHPC should be checked.
- Also, the microscopic study of UHPC will be investigated using SEM and XRD tests.
- The work program goal is summarized as follows: the production of UHPC is very costly, and the materials used for it are not easily available in the local market. The focus is increasingly on how to reduce the composition of binder content and replace it with Supplementary Cementitious Materials (SCMs), which are much cheaper.

II. MATERIALS AND MIXING PROCEDURE

Supplementary cementitious ingredients are utilized in UHP concrete trials to improve the strength characteristics of the material while also reducing the need for sand. Water usage was decreased through the use of mixtures. R-H-A, SiO2, and cement make up the binder components, and the mix's combined constituents include quartz filler and fine aggregates. Superplasticizer is added to the mixture in addition as the water-to-cement ratio decreases to 25%. U-H-P-C is produced using;

- Cement
- Silica Fume
- Fine Sand
- Rice Husk Ash
- Quartz powder
- Superplasticizers

A. Mixing process

1) Initial mixing technique

The mortar was mixed in the Hobart mixture for 3 minutes in dry condition. Water was added into the mix about 75% and further mixed the sample for 2 minutes. When the mixture was fully converted to a wet state. A super plasticizer was added to the mix and mixed the sample for the next 2 minutes. Till the sample changes to a fluid state. The remaining water was added and mixing was continued for a further 2 minutes. For mixing the sample total time is between 9 to 14 minutes.

2) Final mixing technique

Mixing the components for 3 min in a dry state. Water is added to the mixture about 75% and mixing is allowed for 2 minutes. Super plasticizer is added and at last, the remaining water is poured into the mix. Further fibres are added to the blend and the mixing is continued. Normally 9 to 15 minutes are required to mix the sample.

B. Experimental program

1) Mix design

Samples are prepared using Ordinary Portland Cement (OPC), ASTM type 1 cement, silica fume, and RHA. The Cherat Cement Factory produced the OPC that was used. RHA and silica fume were bought locally. Since sand and quartz powder are readily available in the area, they were collected for the creation of concrete mixtures. After the sand was transported to the laboratory, a sieve analysis was done. To keep the water-to-cement ratio low and the blend flowable, S.P. was added to the design mix. In the second phase of the experiment, steel fibres were added, and a final mixture was produced. Steel fibres measuring 13 mm in length and 0.3 mm in thickness.

2) UHPC casting and curing

As per ASTM C-39, the mix is cast into a 2x2x2 in3 mould for compressive strength, and 12x3x3 in3 beams are formed for flexural strength by ASTM C293-1. The samples were extensively tested and cured before being checked out. After a day, samples are removed from the mould and placed in a bucket with spreading H_2O until the test date specified. Samples are cured at room temperature in water.

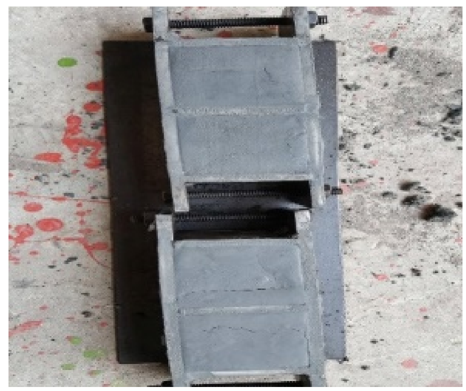

Fig. 1. Casting and curing of cubes used in the trials

3) Workability of concrete

The test of slump was performed to measure the workability of fresh UHPC concrete. This process was performed using ASTM C-143. The process was completed, and the value was evaluated and described as a concrete mini-cone slump. It was done for all the different mixes of UHPC

Fig. 2. Mini slump cone test for fresh concrete in the first phase of the trials

III. RESULTS AND DISCUSSION

Following are the results of the different tests acquired during the investigation. To attain a most suitable mix a series of tests were conducted which was carried out in 2 phases. The compressive test of the cubes and mini flow test were influential tests during the 1st phase.

A. Impact of quartz filler

In the first phase of research work, different trials were made to investigate the achievement of maximum compressive strength of the UHPC mix. For which different percentages of quartz filler ratios concerning 25% percent of water to cement ratio were used. Figure 9 shows that 15% of Quartz filler shows abrupt changes at 7 days as well as 28 days. And shows a direct relation to the compressive strength.

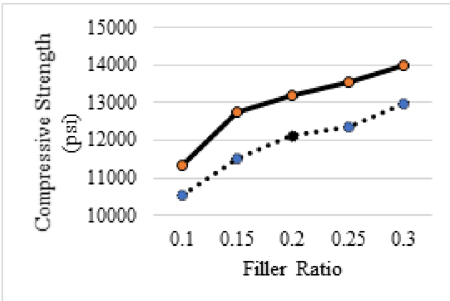

Fig. 3. Variation of the graph between quartz filler and compressive strength at 7 and 28 days with a water-to-cement ratio of 25%

Also, the mini flow test shows the workability of UHPC concrete. Quartz filler shows in direct relation to the mini flow test. Increasing the quartz filler ratio decreases the workability value of the fresh UHPC concrete.

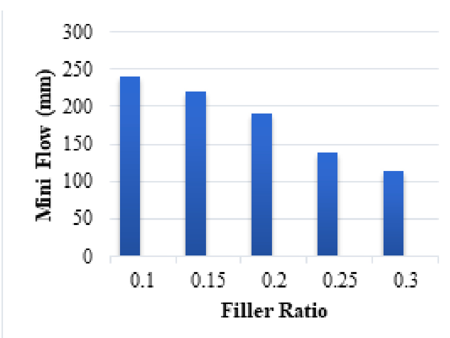

Fig. 4. Variation of the graph between quartz filler and mini cone slump test for fresh concrete with a water-to-cement ratio of 25%

B. Impact of rice husk ash

The impact of rice husk ash is directly related to the compressive strength of UHPC concrete. Increasing the RHA percentage from 5% to 10% shows abrupt changes for 7 days and 28 days.

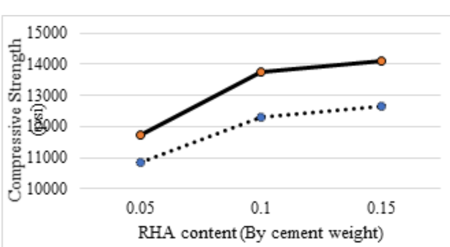

Fig. 5. Variation of the graph between rice husk ash and compressive strength at 7 and 28 days with a water-to-cement ratio of 25%

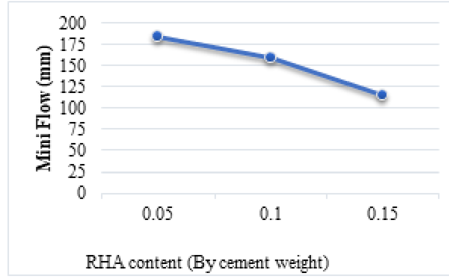

Fig. 6. Variation of the graph between rice husk ash and mini-slump cone test for fresh concrete with a water-to-cement ratio of 25%

C. Impact of silica fume

The use of silica fume also has a direct impact on compressive strength, which increases the ratio of silica fume and the value of compressive strength. On the other hand, silica fume shows an indirect relation to the workability of fresh UHPC concrete. Increasing the ratio of silica fume decreases the value of the workability of the fresh UHPC concrete. Figures 13 and 14 show the compressive strength and workability of concrete, respectively.

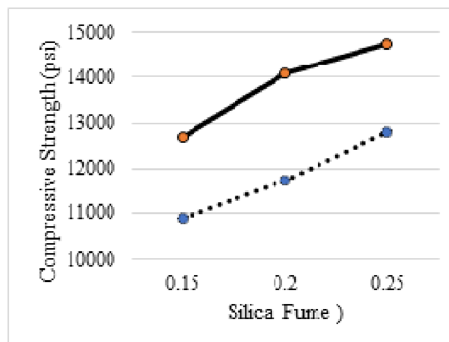

Fig. 7. Variation of the graph between silica fume and compressive strength at 7 and 28 days with a water-to-cement ratio of 25%

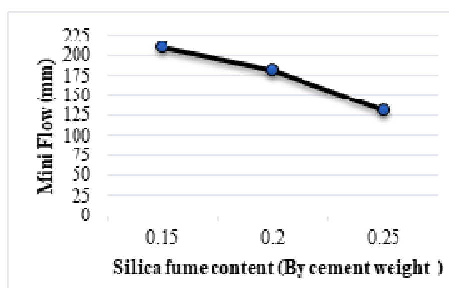

Fig. 8. Variation of the graph between quartz filler and mini-slump cone test for fresh concrete with water-to-cement ratio 25%...

1) Impact of superplasticizer

Superplasticizer is used to make the concrete workable by using the least amount of water. Superplasticizer shows direct relation with mini flow test.

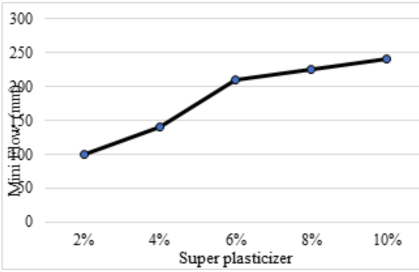

Fig. 9. Variation of the graph between superplasticizer and mini-slump cone test for fresh concrete with a water-to-cement ratio of 25%

Steel fibres were added once the ideal mixture had been reached. Using x-ray diffraction, scan electron microscopy, compressive testing of the cubes, and flexural strength testing of the beams, the highly outstanding properties of the UHPC were assessed in the second phase of the research project.

IV. MIX COMPOSITION OF THE FINAL MIX BY CEMENT WEIGHT

A. Mix design

The final mix design of UHPFRC concrete contains steel fibres. These are referred to as T11 & T22, and their respective cement weight contents of steel fibres are 0.1 and 0.2 per cent. The final mix's ingredients are listed below and displayed in table 1.

TABLE I
BATCH DETAILS USED IN THE FINAL DESIGN MIX

Ingredients	Batch Details	
	T11	T22
Cement	1	1
Sand	85%	85%
Water to Cement Ratio	25%	25%
Quartz Filler	20%	20%
Rice Husk Ash	10%	10%
Silica Fume	20%	20%
Superplasticizer	7%	7%
Steel Fibre	10%	20%

B. Workability of concrete

The same procedure and toolset as previously mentioned were used to assess the concrete's fresh qualities. The workability of the fresh UHPFRC concrete is displayed in Figure 10. As Figure 11 illustrates, it is evident that the addition of steel fibres to the blend has a significant impact on workability. When compared to the design mix without steel fibres, the flow is reduced. The blend's flow is reduced as the fibre content rises. And with the T22 mix design, it is even lower.

Fig. 10. Mini slump cone test for fresh concrete in 2nd phase of trials

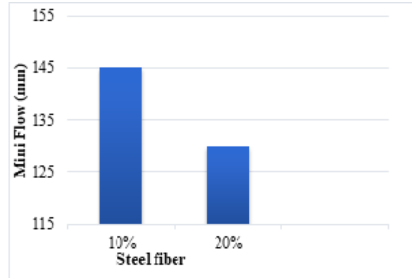

Fig. 11. Variation of the graph between steel fibres and mini-slump cone test for fresh concrete 25%.

C. Compressive strength test

Load is utilized on the sample contained in the UTM, and ASTM C-39 requirements are adopted. The sample is exposed to the maximum load & therefore, the compressive strength is considered on 8in3 cubes. The test was performed for samples of 7 days and 28 days. The maximum load at which the sample failed is considered.

Fig. 12. Performance of the compressive strength tests on concrete cubes

In this study, 7-day and 28-day tests of compressive strengths were performed. The observation is shown in table 2. Maximum strength was achieved by using steel fibres in the final mix design. Graphs are also shown in Figure 13.

TABLE II
VARIATION OF COMPRESSIVE STRENGTH OF UHPFRC

Batch Details	Compressive Strength (psi)	
	7Days	28Days
T11	14230	14985
T22	16330	17225

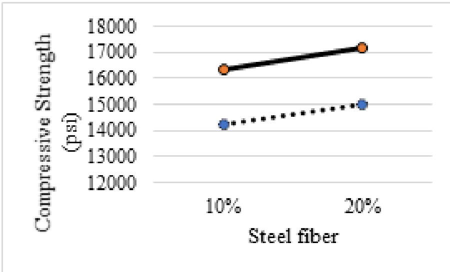

Fig. 13. Performance of the compressive strength tests on concrete cubes

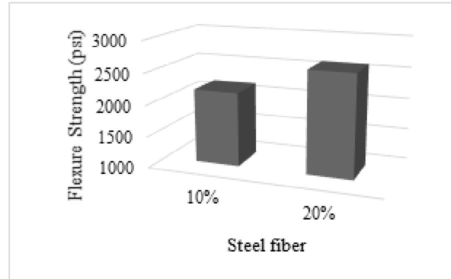

Fig. 15. Variation of Flexural strength of UHPFRC

D. Flexural strength test

Following ASTM C-293-1, samples are exposed to failure to measure the Flexural value. The sample is exposed to most load and thus flexural value is designed. Beams having an area of 108in3 have been cast to consider the flexural strength of UHPFRC.

Fig. 14. Performance of the flexural strength tests on concrete cubes

The flexural strength test was performed by using ASTM C293-1. In this study, a 28-day test of flexural strength was performed. 10% and 20% of steel fibres were used and the result is shown in table 3 and Figure 15.

TABLE III
VARIATION OF COMPRESSIVE STRENGTH OF UHPFRC

Batch Details	Flexural Strength (psi)	
	Loads	28Days
T11	3269.01	2179.1
T22	3936.2	2624.1

E. X-Ray diffraction

At the University of Peshawar, KPK, the Crucial Useful Resource Lab (CRL) hosted X-ray diffraction studies. The specimens on the final design mix were finished. An XRD analysis of a dust sample obtained from the final mix's models has been finished. Model JDX-352 needs the XRD equipment installed at CRL. Angle variation ranges from 00 to 1600. The specimens shown in Figure 21 had undergone examination.

The third sample, following the prescribed pattern, is defined and contains rice husk ash, quartz filler, and silica fume. When comparing the results to previous studies, it was found that the height of 6.230 was indicative of silica fume. Additionally, the presence of rice husk ash was indicated by another minor peak at 20.810. The height of 26.210 indicates the existence of quartz filler within the design because it is in a substance related to silica fume.

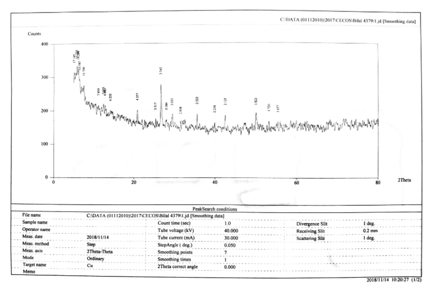

Fig. 16. Variation of the graph shows the composition of the mix in the XRD test

F. Scanning electron microscopy

SEM tests are conducted in NCEG in UOP. The samples were made using the final mix design. Specimens were taken from the inner part of the test sample to avoid possible artefacts caused by thermal effects at the surface. UHPC mixtures examined showed a very dense & Homogenous microstructure B/C of silica fume. Also, it is shown that B/C of very low W/C ratio & B/C of fine filler materials result in very low porosity. When microcracks propagate through the cement paste due to loading, the fibres can bridge the microcracks. The combined effect provided excellent mechanical properties.

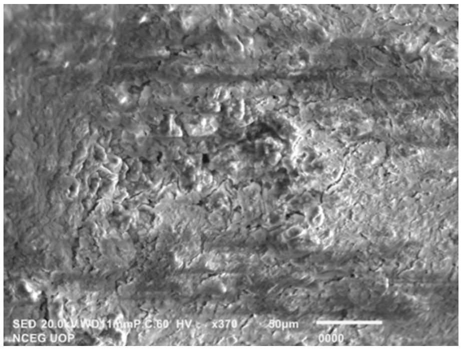

Fig. 17. Variation of the graph shows the composition of the mix in the SEM test

V. CONCLUSION

The main goal of the current analysis was to progress UHPC utilizing locally manufactured components. UHPC was advanced within the initial mix without the usage of steel fibres. The characteristics of every component have been intensively examined within the preliminary tests. The assessments that have been passed out within the preliminary phases have been the mini-slump flow test and compressive strength test. In the second phase, with steel fibres used in the design mix, a mini-slump test, compressive strength test, flexural strength test, x-ray diffraction test, and scanning electron microscope test were carried out. The following decisions are made based on the ideas of the above trials.

A compressive strength of virtually 17004lb/in2 is attained, whereas a flexure energy of 2605lb/in2 is achieved. The mix of various components is diversified to acquire excellent workability and compression value.

Probably, the utmost appropriate proportion of sand to cement is discovered to be 1-1 with a water-to-cement proportion of 25%.

The Utmost fitted contented material of sio2 to cement weight was discovered to be 20%. However, the maximum compression value was attained at 25% of the cement weight. While an extreme flow to the cement weight was noticed at 15%.

Powder of Quartz filler is used as a cement alternative in the analysis. By cement weight, most of the compressive strength was attained at 30%, while most flow by cement weight was noticed at 10%. Probably the utmost appropriate satisfied material of powder quartz filler to cement weights was discovered to be 20%.

Most compression value was noted once the cement weight of 15% of R-H-A was cast off within the blend, where a flowable blend of the cement weights was noticed at 5%. The utmost appropriate satisfied material of the cement weights of R-H-A was probably discovered to be 10%.

According to the findings in this study, the presence of steel fibers improved the strength performance of UHPC. Also, increasing dense packing of UHPC due to the low water-to-binder ratio and the pozzolanic reactivity of S.F., the interfaces between the steel fibers and the matrix were very intense so that the fibers could bridge the cracks very efficiently. Hence, the crack propagation process could be inhibited if the fibers were presented. It has also been discovered that the transition zone between fine aggregates and the cement paste is improved by using silica.

A. Suggestions & recommendations

Suggestions are completed & given below are dependent on the knowledge of the Entire experimental works;

Durability assessments ought to be carried out reminiscent of freezing and thawing, drawing shrinkage, and so forth. To check the durability of UHPFRC.

Lowering the w/c ratio additional also needs to be studied.

Various kinds of fibres are reminiscent of glass fibres, Polypropylene fibres, hook-end steel fibres, and so forth. The completely changed amount of ingredients must be inspected.

Rice husk ash with growing content material ought to be investigated.

B. Limitations and implications

The limited specimen size employed in the investigation could restrict how broadly the outcomes can be applied, which is one of the investigation's article's limitations. Furthermore, some factors that might have an impact on the ultra-high performance steel fibre-reinforced mortar's strength analysis were probably not taken into account in the research project.

The study paper may have implications for how to use rice husk ash and nano-silica fume in mortar mixtures to increase the strength and longevity of concrete constructions. The building sector may be significantly impacted concerning cost- and sustainability-effectiveness by this. Nevertheless, more investigation and evaluation will be required to validate the efficacy of this methodology in real-world scenarios.

References

[1] S. Kumar and B. Rai, ``A review on wider application of supplementary cementitious materials on the development of high-performance concrete,'' *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 9, no. 8, pp. 187-204, 2018.

[2] X. Lu, W. Zhou, C. Qi, and M. Yang, ``Enhanced plant restoration in open-pit mines using maize straw and ultrasonically pre-treated coal fly ash,'' *Sustainability*, vol. 12, no. 22, p. 9307, 2020.

[3] S. Mehdipour, I. M. Nikbin, S. Dezhampanah, R. Mohebbi, H. Moghadam, S. Charkhtab, and A. Moradi, ``Mechanical properties, durability and environmental evaluation of rubberized concrete incorporating steel fiber and metakaolin at elevated temperatures,'' *Journal of Cleaner Production*, vol. 254, p. 120126, 2020.

[4] S. H. Lee, S. Kim, and D. Yoo, ``Hybrid effects of steel fiber and carbon nanotube on self-sensing capability of ultra-high-performance concrete,'' *Construction and Building Materials*, vol. 185, pp. 530-544, 2018.

[5] W. Khan, K. Shehzada, T. Bibi, S. U. Islam, and S. W. Khan, ``Performance evaluation of Khyber Pakhtunkhwa Rice Husk Ash (RHA) in improving mechanical behavior of cement,'' *Construction and Building Materials*, vol. 176, pp. 89-102, 2018.

[6] M. Khan, Y. Abbas, and G. Fares, ``Review of high and ultrahigh performance cementitious composites incorporating various combinations of fibers and ultrafines,'' *Journal of King Saud University-Engineering Sciences*, vol. 29, no. 4, pp. 339-347, 2017.

[7] P. Li, Q. Yu, and H. Brouwers, ``Effect of PCE-type superplasticizer on early-age behaviour of Ultra-High Performance Concrete (UHPC),'' *Construction and Building Materials*, vol. 153, pp. 740-750, 2017.

[8] L. Nilsson. (2018) Development of uhpc concrete using mostly locally available raw materials. [Online]. Available: https://shorturl.at/tvxZ8

[9] M. Zhou, W. Lu, J. Song, and G. C. Lee, ``Application of ultra-high performance concrete in bridge engineering,'' *Construction and Building Materials*, vol. 186, pp. 1256-1267, 2018.

[10] M. Alkaysi, ``Strength and durability of ultra-high performance concrete materials and structures,'' Madison, Wisconsin: American Society of Agronomy, Tech. Rep., 2016.

[11] H. Huang, X. Gao, L. Li, and H. Wang, ``Improvement effect of steel fiber orientation control on mechanical performance of UHPC,'' *Construction and Building Materials*, vol. 188, pp. 709-721, 2018.

[12] M. A. Ibrahim, M. Farhat, M. A. Issa, and J. A. Hasse, ``Effect of material constituents on mechanical and fracture mechanics properties of ultra-high-performance concrete,'' *ACI Materials Journal*, vol. 114, no. 3, 2017.

[13] J. Du, W. Meng, K. H. Khayat, Y. Bao, P. Guo, Z. Lyu, A. Abu-Obeidah, H. Nassif, and H. Wang, ``New development of Ultra-High-Performance Concrete (UHPC),'' *Composites Part B: Engineering*, vol. 224, p. 109220, 2021.

[14] H. Bahmani and D. Mostofinejad, ``Microstructure of ultra-high-performance concrete (uhpc)- a review study,'' *Journal of Building Engineering*, vol. 50, p. 104118, 2022.

[15] Y. Zhu, Y. Zhang, H. H. Hussein, and G. Chen, ``Flexural strengthening of reinforced concrete beams or slabs using Ultra-High Performance Concrete (UHPC): A state of the art review,'' *Engineering Structures*, vol. 205, p. 110035, 2020.

[16] J. Li, Z. Wu, C. Shi, Q. Yuan, and Z. Zhang, ``Durability of Ultra-High performance concrete - A review,'' *Construction and Building Materials*, vol. 255, p. 119296, 2020.

[17] M. Alkaysi, S. El-Tawil, Z. Liu, and W. Hansen, ``Effects of silica powder and cement type on durability of ultra high performance concrete (uhpc),'' *Cement and Concrete Composites*, vol. 66, pp. 47-56, 2016.

[18] M. Amran, S.-S. Huang, A. M. Onaizi, N. Makul, H. S. Abdelgader, and T. Ozbakkaloglu, ``Recent trends in Ultra-High Performance Concrete (UHPC): Current status, challenges, and future prospects,'' *Construction and Building Materials*, vol. 352, p. 129029, 2022.

[19] F. U. Shaikh and S. W. Supit, ``Compressive strength and durability properties of High Volume Fly Ash (HVFA) concretes containing Ultrafine Fly Ash (UFFA),'' *Construction and building materials*, vol. 82, pp. 192-205, 2015.

[20] K. Rassiah, M. H. M. Ahmad, and A. Ali, ``Effect on mechanical properties of rice husk/e-glass polypropylene hybrid composites using Sodium Hydroxide (NaOH,'' *Journal of Advances in Technology and Engineering Research*, vol. 2, no. 4, pp. 105-112, 2016.

[21] P. Chindaprasirt, C. Jaturapitakkul, and T. Sinsiri, ``Effect of fly ash fineness on compressive strength and pore size of blended cement paste,'' *Cement and Concrete Composites*, vol. 27, no. 4, pp. 425-428, 2005.

[22] S. J. Choi, S. S. Lee, and P. J. Monteiro, ``Effect of fly ash fineness on temperature rise, setting, and strength development of mortar,'' *Journal of Materials in Civil Engineering*, vol. 24, no. 5, pp. 499-505, 2012.

[23] J. Prasara-A and S. H. Gheewala, ``Sustainable utilization of rice husk ash from power plants: A review,'' *Journal of cleaner production*, vol. 167, pp. 1020-1028, 2017.

[24] E. Menya, P. W. Olupot, H. Storz, M. Lubwama, and Y. Kiros, ``Production and performance of activated carbon from rice husks for removal of natural organic matter from water: A review,'' *Chemical Engineering Research and Design*, vol. 129, pp. 271-296, 2018.

[25] M. Yaqoob, S. Salim, M. Ali, M. M. Wasim, Z. Ullah, and S. Khalil, ``Usage of green material in building construction evaluating its outcome on varied properties of concrete,'' *Journal of ICT, Design, Engineering and Technological Science*, vol. 5, no. 2, pp. 24-30, 2021.