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Analysis of Concrete Strength Using Date Seed and Date Seed Ash in Partial Replacement of Fine and Coarse Aggregate

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Abstract

The aim of the study was to determine the influence of Date Seeds (DS) and Date Seed Ash (DSA) in partial replacement with Fine Aggregate (FA) and Coarse Aggregate (CA) in concrete. Various concrete mix proportions were prepared by replacing a portion of FA and CA with DS and DSA in varying proportions. The study provides the insights into the slump test, temperature and compressive strength of concrete using DS and DSA. The value of slump test with 2% and 3% DSA replacement with Fine Aggregate (FA) gets 3 cm and zero value respectively. Compared to 11 cm for standard plain concrete. The value of slump test with 1% and 2% DS replacement with Coarse Aggregate (CA) found 9 cm and 8 cm respectively. The temperature for plain concrete, with DS and DSA was in the range of 27.5 ℃ to 29.6 ℃. The compressive strength of the standard cube was tested 14.56 N/mm^2 after 7 days. However, with 2% and 3% DSA replacement, the strength observed 18.44 N/mm^2 and 17 N/mm^2 respectively. After the 28 days of curing, the compressive strength of standard cube reached 27.11 N/mm^2 while with 2% and 3% DSA replacement, it measured 19.40 N/mm^2 and 18.33 N/mm^2 respectively. The outcome of this research has significant implications for sustainable construction practice, more efficient and optimize mixing designs in the middle east.

Keywords
Date Seed (DS), Date Seed Ash (DSA), Sand replacement, Coarse Aggregate (CA). Fine Aggregate (FA).

1. Introduction
Concrete is the second-most-used building material. One of its main components is cement; its production, which dissipates large amounts of fossil fuels, generates approximately 7% of global CO_2 emissions, contributing negatively

to the increase in environmental pollution (B. Thomas et al., 2020). Therefore, the growing demand and surging prices of raw materials challenges the constructional field. It's adaptability, durability, and cost-effectiveness make it a preferred choice for numerous applications, including buildings, bridges, roads, and other infrastructure projects. With the increasing demand for sustainable and resilient structures, understanding concrete performance is crucial to optimize its use in construction and minimize environmental impact (Kim. Y.R, 2009). The Date Seeds (DS) is the huge waste of agriculture in all over Oman. Furthermore, when waste DS are incinerated Date Seed Ash (DSA) is produced. Considering the reasons, the DS and DSA can be used as one of the optional materials in concrete This study's problem statement centers on to analyze how DS and DSA can be used to enhance the compressive strength of concrete. Hence, to understand the behavior of the material and form issues, as well as how they affect the mechanical characteristics of concrete, are important and need more investigation.

1.1 Research Objectives

The main objectives of this study are as follows:

1. To examine the impact on concrete's compressive strength of using Date Seed (DS) as a partial replacement for Coarse Aggregate (CA).
2. To assess the effect of Date Seed Ash (DSA) in partial replacement of coarse particles in concrete.
4. To evaluate the impact of DS and DSA on the development of concrete's workability, slump test and temperature.

2. Literature Review

The cost and environmental impact is associated with this traditional material. Due to this reason fly ash, stone dust, waste construction materials are used for research purpose by various researchers to reduce the concrete cost without compromising the strength of the concrete (Wang, G et al. 2020; Golewski and Szostak, 2021; N. F. A. Jamaludin et al.2022; S. Zhang et al. 2022; M. Czop et al.2022; Silva, L.S. et al. 2023). The few studies show fly ash may be used to replace a portion of the cement, which decreases the need for cement manufacturing and the accompanying environmental impact (P. Nath and P. Sarker, 2011). Concrete's workability, toughness, and long-term strength development are all improved by fly ash's pozzolanic characteristics. By reacting with calcium hydroxide during hydration, fly ash creates a denser microstructure, which increases the concrete's compressive strength and durability (Elazizi et al., 2017). In recent years, the construction sector has given a lot of attention to the use of sustainable materials. The combination of environmentally friendly additives demonstrates the possibility of optimizing concrete mixes, considering material behavior, form concerns, and the overall objective of obtaining greater compressive strength with a decreased environmental effect (Prusty and Patro, 2015; Chithra, S et al. 2016; Zou, F et al. 2020). According to Thomas B.S. et al., (2021) the seeds, which are normally regarded as agricultural waste, provide an opportunity for sustainable concrete manufacturing by substituting some of the conventional CA. The DS are also one of the good alternatives hence, to solve this problem an inventive strategy to improve concrete's compressive strength while minimizing its environmental effect and cost is to use DS and DSA as sustainable additions. The behavior of concrete with DS and DSA is still not fully understood, despite the increased interest in environmentally friendly construction methods. To close this knowledge gap and open the door for more study, a specific issue description is required. This study's problem statement centers on to analyze how DS and DSA can be used to enhance the compressive strength of concrete (Al-Kutti, W. et al. 2018). Hence, to understand the behavior of the material and form issues, as well as how they affect the mechanical characteristics of concrete, are important and need more investigation. Considering the reasons, the DS and DSA was used as one of the materials in concrete as a partial replacement of sand and aggregates. The aim of the project was to examine the influence of incorporating DS and DSA on compressive strength of concrete. How does the strength influences with different proportions of these materials in concrete. It examines the compressive strength and other parameters of concrete by replacing the DS with CA and DSA with FA replacement. Initially, the study started on DS as a replacement for CA but was not successful. Hence, DSA is used as part of a strategy to replace the sand to increase concrete's compressive strength and to reduce the environmental effect of the concrete.

3. Adopted Methodology and Experimental Procedure

The experimental procedure involves a series of sequential steps to systematically investigate the behavior of the concrete properties such as slump, temperature and compressive strength in concrete incorporating DS and DSA. The adopted methodology is given in Figure 1.

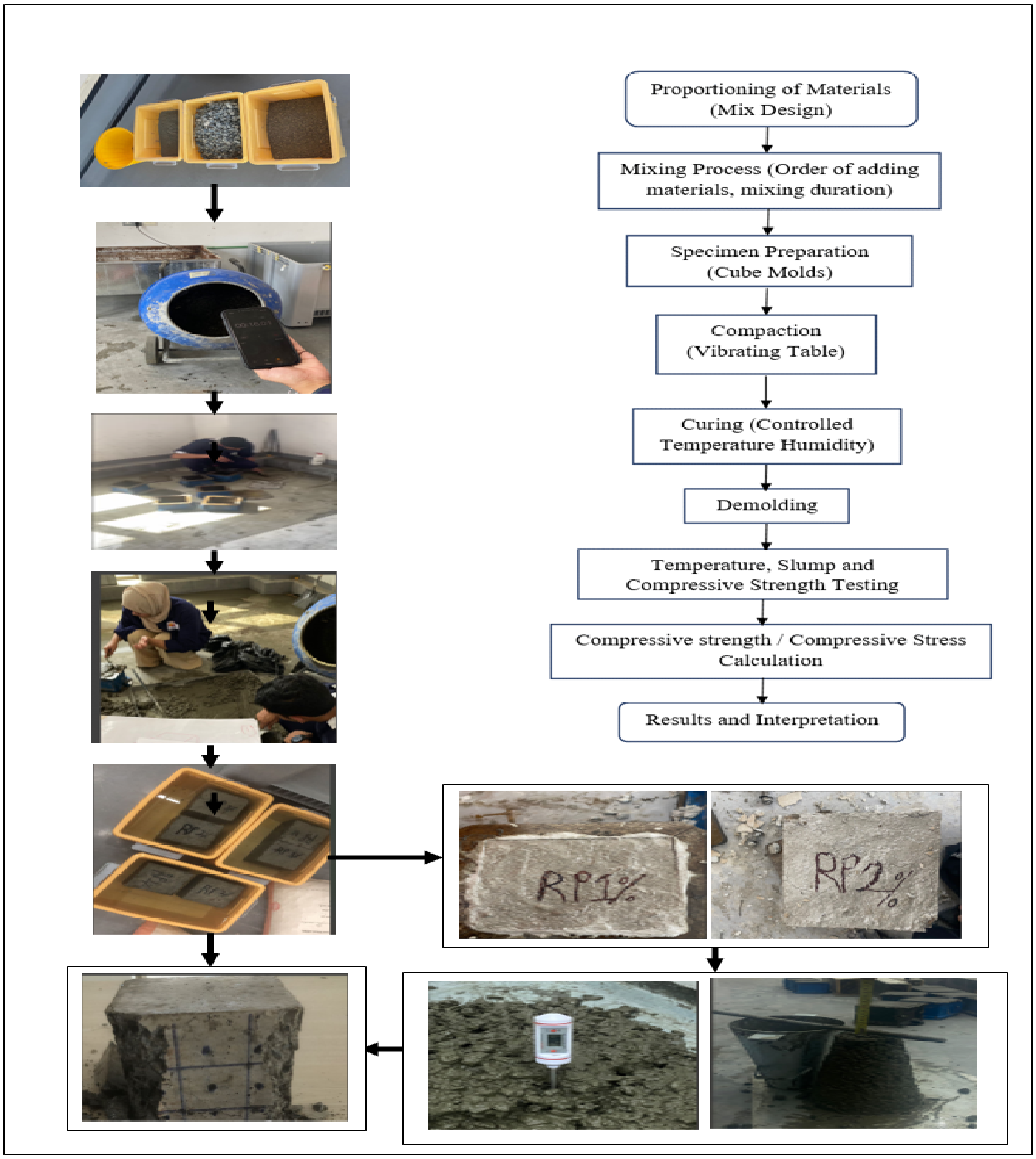

Figure 1. The methodology adopted to evaluate the concrete strength via DS and DSA.

3.1 Mix Design

The first step involves the proportioning of materials, known as mix design. In this step the bestcombination of concrete constituents, including DSA was used. The amounts of cement, FA, CA and DSA, were chosen depending on the requirements of the mix design. The mix proportion for C30 grade concrete is given in Table 1.

Table 1. Mix proportion of C30 grade concrete as per the British Standard (BS) code method.

Materials /m³ of concrete	Water	Cement	Fine Aggregate (FA)	Coarse Aggregate (CA)	Date Seed Ash (DSA) with 1% replacement	Date Seed Ash (DSA) with 2% replacement	Density
Kg/m³	225	432.7	498.69	1163.61	4.97	9.958	2320
Quantities in (Kg)	5.46	10.5	12.1	28.27	0.121	0.242	-

The concrete was mixed up to 5 minutes in a high-speed mixer to obtain a consistent and homogeneous concrete mixture. A standard plain concrete of C30 grade was prepared with four different mix proportion of concrete to compare results. In first two samples, The CA were replaced with DS by 1% and 2% by its weight. The cube failed during curing due to more water absorption (Figure 2). Thereafter, DS burned to form DSA and replaced with FA by 2% and 3%.

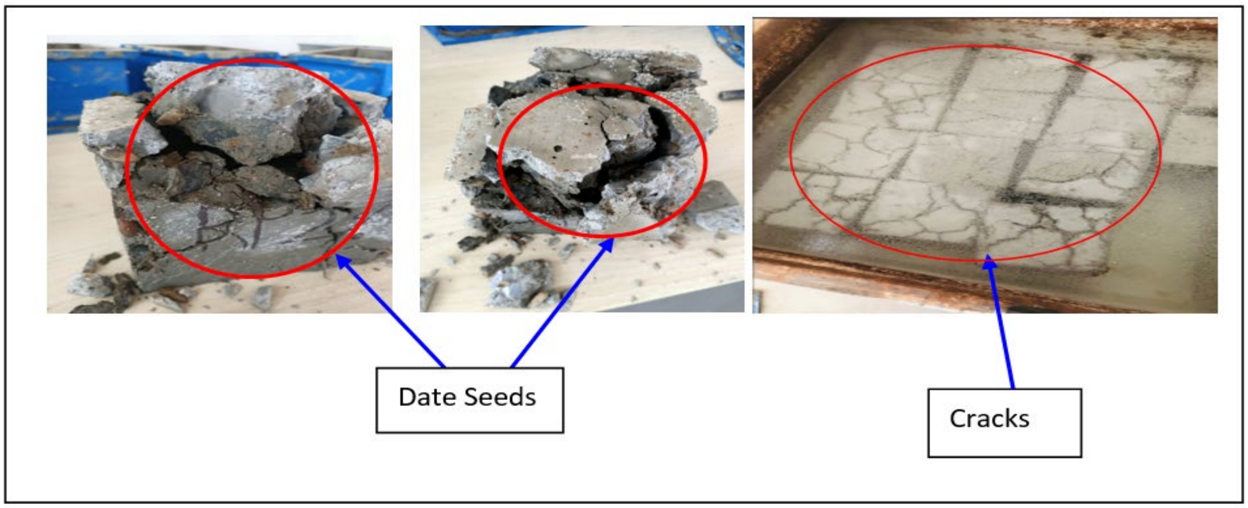

Figure 2. Failed concrete cube during and after curing when CA replaced with DS.

3.2 Specimen preparation: To ensure the consistency and comparability with established practices, concrete cube of standard size of 150 mm x 150 mm x150 mm were prepared for testing. A total nine cubes were prepared to perform the experiments.

3.3 Filling and compaction of concrete: The concrete was filled in the specimen in 3 layers with 56 strokes in specimens to prevent concrete from segregation. The vibration was applied to ensures the removal of air voids and enhances the density and cohesion of the mix, influencing the compressive strength of the cured specimens.

3.4 Curing: The cube was removed from mould after a day and kept in curing for 7 and 28 days. It can gradually acquire the necessary qualities over this curing period and grow stronger (Golewski, 2020).

3.5 Demolding: After curing of 7- and 28-days period, the concrete specimens demolded to prevent damaging of the specimens. This technique must be done carefully. The specimens were labeled for identification during testing after being de-molded.

3.6 Compressive Strength Test: The Compression Testing Machine (CTM) applies a controlled force of 3 kN/sec over the cube until a failure happens. Based on the cross-sectional area of the cubes and the highest load at failure, the compressive strength of the concrete was determined.

4. Data Collection

4.1 Coarse and Fine Aggregate: The CA of varying size with angular shape used was in the range of 4.75 mm to 20 mm. The specific gravity of the CA was 2.6. The size of the FA was smaller than 4 mm.

4.2 Cement: The Ordinary Portland Cement (OPC) of 43 Grade was used as per the Omanian Standard Specification (OS 7:2001 OPC). The chemical composition is given in Table 2.

Table 2. Chemical composition of ordinary Portland cement used in the study. (Source: S.K. Al-Oraimi et al. 2007)

Component	**Ordinary Portland Cement (%)**	**Component**	**Ordinary Portland Cement (%)**
SiO_2	21.94	Mn_2O_3	0.05
Al_2O_3	4.95	Cl	0.01
Fe_2O_3	3.74	LOI	1.78
CaO	62.33	IR	0.24
MgO	2.08	C	NA
SO_3	2.22	C (Isolated)	NA
K_2O	0.56	pH	NA
Na_2O	0.32	SI (isolated)	NA
TiO_2	0.17	SIC	NA

NA: Not applicable

4.3 Date Seed and Date Seed Ash:

The Dates seed were air dried for approximately two weeks and subsequently burned in open air until they had their internal content (Figure 3). Thereafter, this burnt seeds were grinded by conventional methods and then manually sieved to achieve a particle size of less than 200 microns, approximating that of sand.

Figure 3. Date Seeds used in the experiment in the first stage after washing kept for drying.

The DS has various chemical contents as shown in Table 3 (G.I. Gunarani and S P Chakkravarthy, 2017; OS7 (MOCI), 2001).

Table 3. Chemical composition of the Date Seed (DS) in normal and calcinated condition.

Sr. No.	Element Name	Symbol used to denote	Normal DSA In (%)	Calcinated DSA In (%)
1	Potassium	K	43.02	37.06
2	Oxygen	O	28.85	31.21
3	Phosphorous	P	7.40	8.55
4	Chlorine	Cl	5.54	4.74
5	Calcium	Ca	5.52	3.82
6	Magnesium	Mg	3.50	3.67
7	Sulphur	S	2.77	2.61
8	Silicon	Si	0.89	1.90
9	Iron (Ferrous)	Fe	0.70	3.61

5. Results and Discussion

The results of the experiment determine the behavior of concrete during the replacement of CA and FA encompassing slump, temperature and workability.

5.1 Numerical Results

The summary of the overall results is given in Table 4 to compare the results.

Table 4. The comparison of results and outcome of the whole study.

Sr. No	**Type of Concrete**	**Value of Slump Test of Concrete (cm)**	**Value of Temperature of Concrete (°C)**	**Compressive strength after 7 days (N/mm^2)**		**Compressive strength after 28 days (N/mm^2)**	
				DT	**NDT**	**DT**	**NDT**
1	Standard (Plain Concrete)	11	27.5	14.56	19.21	27.11	-
2	1 % DS replacement with CA	9	28.6		-		-
3	2 % DS Replacement with CA	8	28.4		-		-
4	2 % DSA replacement with FA	3	29.5	18.44	14.65	19.40	24.95
5	3 % DSA replacement with FA	0	29.6	17.00	12.95	18.33	22.0

5.2 Graphical Result

The compressive test was performed on the hardened concrete sample to investigate the compression strength. Figure 4 depicts the results of slump and temperature tests post concrete mixing after the mixing of concrete to measure the workability of concrete. The temperature for 3% DSA replacement was observed 29.6 °C whereas for 2% DSA replacement it stood at 29.5 °C. The temperature with 1% and 2% DS replacement was observed 28.6 °C and 24.4 °C respectively, compared to standard concrete at 27.5 °C. Slump values with 3% and 2% DSA replacement were observed zero and 3 cm respectively. The slump values with 2% and 1% DS replacement were observed 8 cm and 9 cm. compared to 11cm for standard concrete. Additionally, it was observed that increase content of DSA replacement led absorption but lower slump values.

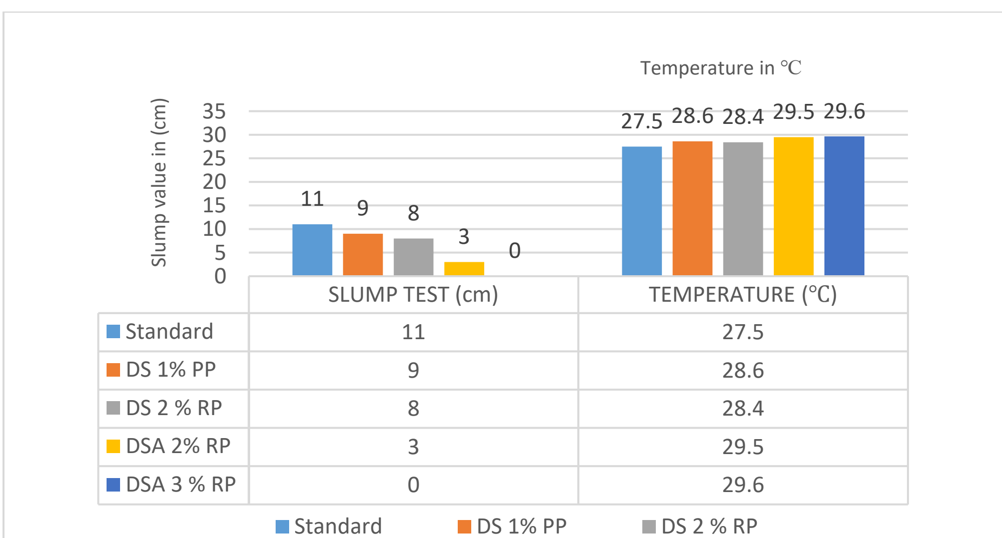

Figure 4. Slump and temperature tests before curing of concrete.

5.1 Compressive strength of concrete using Destructive Test (DT) and Non-Destructive Test (NDT) after 7 days of curing with 2% and 3% DSA replacement

Figure 5 illustrates the outcomes of Destructive and a Non-Distractive Test (NDT) conducted at 7 days of curing for both standard concrete and concrete with DSA replacement over all cubes. These results exhibit variation due to the presence of sugar in DSA, which absorbs water from the mixture, thereby reducing the concrete's hardness. A recent study by K.W. Tahnoon et al. (2023) studied the impact of sugar on concrete in Oman's climate and found that sugar acts as a strong retarder, effectively controlling the setting time when combined with increased gypsum levels and a fixed sugar content. Another study from Saudi Arabia indicated that adding up to 0.1% sugar by weight of cement had minimal effect on the 28-day compressive strength. However, compressive strength notably decreased when sugar content exceeded 0.1%. Thus, the recommended range for sugar addition is between 0.05% and 0.1%. Interestingly, a slight strength increase was observed with 0.25% sugar, though more visible cracking occurred, sparking ongoing discussions about the effects of higher sugar dosages on strength. The compressive strength of standard concrete assessed using DT was observed 14.56 N/mm^2. In contrast, the compressive strength for 2% and 3% DSA replacement with FA was observed 18.44 N/mm^2 and 17 N/mm^2 respectively. Using NDT, the compressive strength of standard concrete was determined 19.21 N/mm^2.while for 2% and 3% DSA replacement, it was observed 14.65 N/mm^2 and 12.95 N/mm^2 respectively. The DT result observed higher strength compared to plain concrete whereas NDT reflects lower strength of concrete.

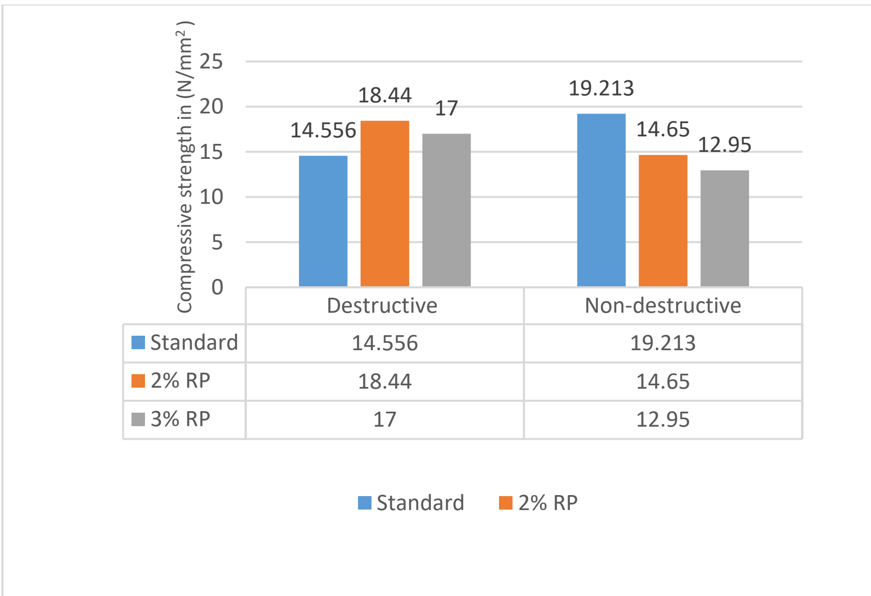

Figure 5. Compressive strength of concrete at 7 days: Destructive v/s Non-Destructive testing.

5.2 Compressive strength of concrete using Destructive Test (DT) and Non-Destructive Test (NDT) at 28 days of curing with 2% and 3% DSA replacement:

The compressive strength of concrete containing 2% DSA replacement with FA was measured 19.4 N/mm^2 using DT and increased to 24.95 N/mm^2 with NDT. Similarly, for concrete with 3% DSA replacement with FA, the compressive strength was observed at 18.33 N/mm^2 with DT and 22 N/mm^2 with NDT. The finding demonstrates a notable decrease in compressive strength measured by DT as the percentage of DSA changes from 2% to 3%. Furthermore, it was observed that these strengths are lower than plain concrete.

6. Conclusions

In the conclusion, the uses of Date seeds (DS), Date Seed Ash (DSA) showed the promising results in terms of the workability of concrete. Slump tests results reveal a direct correlation between DS and DSA content and increased slump value. The minor variations observed in temperature characteristics suggest that the incorporation of DS and

DSA did not significantly affect the temperature of concrete. However, it was observed that concrete containing DS failed during curing tests due to water absorption by seeds. Additionally, the research results indicate mixing of the DSA in partial replacement of FA increase concrete strength after 7 days with 2% DSA. But after 28 days it was observed that the compressive strength decreased when mixed with 3% DSA. These findings underscore the need for further research into optimized concrete mixing designs incorporating Date Seed Ash (DSA) to improve construction practices and structural design.

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Biographies

Dr. Tauseef Ahmad Ansari is an Assistant Professor in the Civil Engineering Department at the University of Buraimi, Sultanate of Oman. He earned his bachelor's degree in civil engineering from R.T.M. Nagpur University, India, in 2007. He subsequently completed a Master of Technology and a Ph.D. in Water Resources Engineering at the Visvesvaraya National Institute of Technology (VNIT), Nagpur, India, from 2008 to 2017. Dr. Ansari's research interests focus on the application of geo-informatics in groundwater management, the impacts of urbanization on water resources, flood analysis, land use and land cover changes, and rainfall-runoff relationships, utilizing remote sensing and GIS technologies. He is currently preparing a research project proposal centered on urban flooding. He has authored more than 20 research publications in peer-reviewed journals and presented at numerous professional conferences. Recently, Dr. Ansari assumed the role of Head of the Civil Engineering Department at the University of Buraimi. His teaching portfolio includes courses in Surveying, Fluid Mechanics, Strength of Materials, Engineering Hydrology, Environmental Engineering, and Remote Sensing and GIS. In addition to his teaching and research responsibilities, he is involved in program review and course specification updates for accreditation applications to the Ministry of Higher Education, Research, and Innovation (MOHERI). Dr. Ansari also serves as a reviewer for esteemed peer-reviewed journals, including the Arabian Journal of Geosciences and the Journal of Earth Science Informatics.

Yahya Al-Kaabi is a Teaching Assistant at the University of Buraimi. With a strong background in Civil Engineering, Yahya combines his engineering expertise with data science to develop predictive models for applications such as optimizing concrete compressive strength. He is deeply involved in academic research and teaching, mentoring students while contributing to projects that integrate machine learning with engineering solutions.

Bashar Mohammed Alhumaidi is a student at the University of Buraimi who completed his graduation in the year 2023 and working in one of reputed construction company in Oman. He is the student who completed this in his Graduation Project.