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Durability assessment of Cow dung ash modified concrete exposed in fresh water

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Abstract
The developing phases of the society in terms of constructions require cement as a key material for development. The raised demand of the cement provoked the higher production of it, and this leads to more greenhouse gases secretion along with the high rate of energy consumption. This issue attracts the attention of researchers to find out alternative material that can partially or fully replace the cement in preparation of the concrete. This will also lead to the overall economy as well as the environment friendly options. This study focuses on the utilization of the waste material as the replacement of cement for eco-friendly construction. Cow dung ash (CDA) was taken in accounts for this study mainly due to this, the material depicts the pozzolanic performance. Previous studies revealed that performance of concrete properties is also enhanced at by incorporation of CDA waste. In this work, CDA modified concrete samples were investigated for the mixes of grade M20 and M25. Ordinary Portland cement was incorporated in the preparation of the sample mixes and the level of substitution with CDA were taken as in the range of 0-10%. To ensure the performance of CDA, modified concrete mechanical properties (compression, tensile, flexural and abrasion) and durability properties (pH value, porosity, water absorption and permeability) were inspected. To investigate the pH of the samples prepared with the utilization of the CDA, the samples were kept in the fresh water for a time period of 56 and 90 days. Then the comparison of the sample was made with the standard sample. Results of compressive, split tensile, flexural and abrasion are depicted for both grades of concrete shows improvement in mechanical strength. Porosity, water absorption and permeability inspected at different replacement level show better performance compared to conventional concrete. The enhancement of concrete properties was observed at 6% substitution levels of CDA and the same has been depicted for both grades. Hence, the CDA can be utilized in preparing the concrete with a certain substitution level to enhance the properties of concrete by making sustainable and eco-friendly construction.

Keywords
CDA, Durability, Waste material, Compressive strength, pH value.

1.Introduction
The utilization of natural resources is comparatively higher in the industry of construction, since it requires a lot of natural aggregates and sand as well as the water [1, 2]. One of the major issues in the construction sector is to develop sustainable concrete to reduce the emission carbon dioxide (CO_2) and other pollutants during the manufacturing process. The cement manufacturing process is complex as well as it emits a lot of pollutants in the environment along with the utilization of large amounts of energy leaving back more and more carbon footprints [3, 4].

Partial replacement of cement with non-polluting materials is to be done to balance the performance and cost. Dumping the waste materials will affect the environment directly [5, 6]. Some of the researchers have tried to modify concrete by utilizing the cow dung ash (CDA) in the past few years, the approach is considered to enhance the concrete durability as well as considering the environmental issues [7, 8]. Aliabado et al. 2014 studied on reusing or recycling waste material in concrete [9]. It has been suggested that cow dung may also improve workability, act as additional binder, has more hardening enzymes and adhesive qualities [9, 10]. The durability of the mixes was found to be enhanced as well as the binding capacity is found to be improved due to the enhancement in the lateritic soil plasticity. The application of cow dung with respect to concrete

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tanks was studied [11]. Rural housing project materials were tried to modify and it has been depicted that the compressive strength of the mixes was found to be enhanced whereas the cost factor was not much affected and on the other hand the properties of the mixes with cattle waste ash were evaluated [12, 13]. It could also reduce the emission of carbon-dioxide and global warming due to cement production. CDA contains approximately 60% of silica and other elements [14, 15]. The silicon dioxide (SiO_2) is tended to be the key component of the ashes of bio waste, these bio wastes include sugar cane leaf as well as their bags also the corn and rice waste is considered in this class [16, 17]. The sustainability of concrete manufacturing can be achieved by utilization of CDA in the concrete preparation and this will reduce the negative impacts on the environment [18]. This has been depicted in the many of the research projects that CDA depicts pozzolanic behaviours, hence it can be utilized in the manufacturing of the concrete [19, 20]. In a country like India, where agriculture and cattle herding are the main source of living in rural areas, a lot of production of cow dung is noticed, it amounts 30 kgs for a single cow in a single day whereas this amount reaches to approximately 12 tonnes in a year for a single cow [21, 22]. Hence, there is an easy and lot of availability of raw material to prepare the required ash for a very large scale of production [23]. This can be achieved with an industry operating on a medium scale, for the production of 1 ton of the ash the approximate cow dung amount required is about 3.5 tons [24, 25]. Microbes are used to form their colonies on concrete when it is in contact with the fresh water, this phenomenon damages the concrete since microbes tend to affect the concrete within pores and capillaries [26]. Structures like bridges, cooling towers etc. are not yet considered or given attention with respect to bacterial growth on it. The aim of this study is to investigate various properties of the concrete, prepared by utilizing CDA with the incorporation of freshwater. Mechanical and durability aspects were examined in this study to conclude that utilization of waste CDA enhances performance of concrete.

The present study is organized into following six sections. Problem statement, research significance and objective were discussed in section 1. Section 2 covered the previous researcher's outcomes and observations. Material characteristics used for the study and testing procedure to fulfil the objective were discussed in section 3. Section 4 examined and explored the outcomes of experiments that were performed to attain the objectives. Section 5 investigated the outcomes with phenomena and compared them with previous researcher outcomes. Finally, it is concluded in section 6.

2.Literature review

The construction industry is evolving with a high intensity and cement proves to be very important in fulfilling the needs of this industry. The rapid urbanization has raised the concern to reduce the demand of cement by utilizing different waste material in the development of concrete. Many researchers used different type of waste materials in production concrete to make environment friendly and green concrete. Indhiradevi et al. (2021) [27], have utilised alternate material in place of conventional material as the ash of woods as well as the CDA and by this effort they have tried to reduce pollution. Their level of substitution varied by 5%, ranging from 5 to 20 percent, they have achieved optimum results of the strength at 5% and 15% substitution value of CDA and ash of woods respectively. Similarly, Yeole et al. (2021) [28] have found that quality as well as the durability of the concrete is improved due to the presence of plant mineral in the CDA that remains in the undigested state. It is also a cheaper material their level of replacement varies with a 5% margin and ranges from 5 to 20%. The optimum result has been found with 10% additives of the CDA. Suresh et al. (2021) [29] have investigated the strength properties as well as the other parameters of mortar and concrete by utilising the waste material in it. Optimum results have been found for the 10% value of the CDA beyond this range the strength reduces. Kamat et al. (2021) [30] have investigated the effect of the CDA substituted with cement, the CDA was acquired after the twelve days of the process of the drying that has been cured at a temperature of 420-550C and the sieving is done with 400-micron sieve after cooling it. This investigation has denoted improvement in strength as well as the best results were obtained for workability and durability compared with conventional mortar. Baldaoo and Ujjwal (2022) [31] investigates the effect of the CDA in mortar and concrete in additive form. Replacement level of CDA waste was taken from 5% to 30% at an interval of 5% for cement concrete development. They observed that 10% of CDA replaced concrete performance are better than conventional mixes. Mishra and Kumar (2022) [32] depicted the properties, concrete modified by rice husk ash (RHA) and CDA. RHA and CDA were replaced by cement in substitution percent from 5%. 10% and 15% combinedly. They estimated the combine effect RHA and CDA over concrete properties in decrement order. But the results show that 10% replacement can be utilized as have less variations in results. Kebede (2022) [33] optimized the outcomes of concrete modified with iron, CDA and fly ash (ICF). Compression strength was taken as a depended parameter for varying quantity of cement (450-500kg/m^3), fine aggregate (600-750 kg/m^3) and waste materials (5-15%). Taguchi and Analysis of variance technique were used to optimize the mixing. From this study, it was observed that incorporation of ICF materials influences the compressive strength most.

3.Material and methodology

The binding material used in this experimental work is ordinary Portland cement (OPC), as per Indian standard (IS) 383, the coarse aggregate was selected for sample preparation and the natural sand confirming to zone-II were incorporated. Crushed quartz stone was used as a coarse aggregate for this study as per the Indian standards specified. Raw material was purchased by local vendors near Jaipur. The CDA is utilized for the various levels of substitution to cement. The physical and chemical composition of the various ingredients of samples is depicted below in the *Table 1* and *Table 2* respectively. The methodology used for this study is depicted in *Figure 1*. Pictorial representation of CDA is shown in *Figure 2* with microscopic image for better understanding particle shape and size of the CDA. *Figure 3* represents the particle size distribution of cement and CDA.

Table 1 Physical properties of raw material

Property	**Cement**	**Fine aggregate**	**Coarse aggregate (10 mm)**	**Coarse aggregate (20 mm)**
Consistency (%)	27	-	-	-
Initial Setting Time (minute)	120	-	-	-
Final Setting Time (minute)	241	-	-	-
Specific Gravity	3.15	2.62	2.70	2.70
Water Absorption (%)	-	1	0.4	0.41
Fineness Modulus	-	2.67	5.79	7.02
Compressive Strength (MPa)	-	-	-	-
7 days	34.6	-	-	-
28 days	44.8	-	-	-

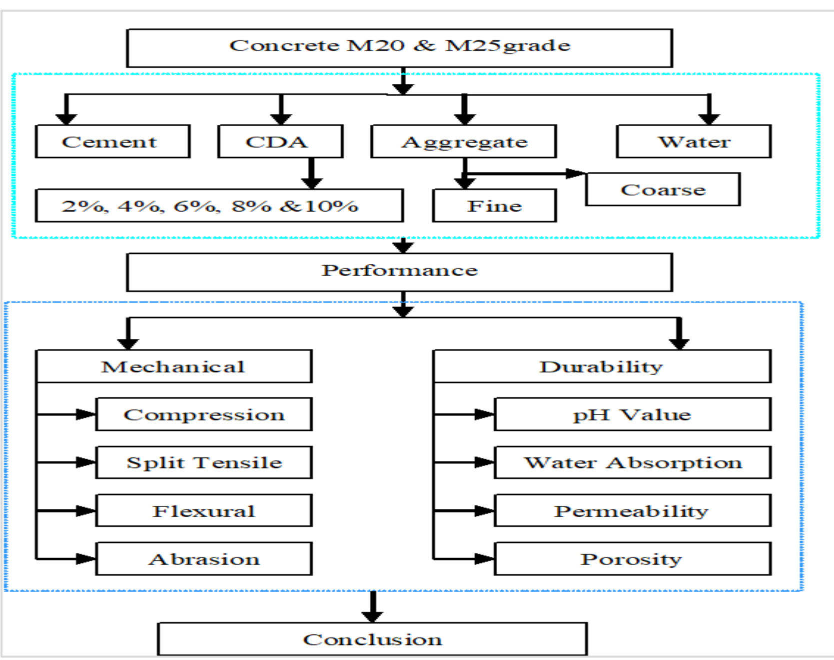


Figure 1 Block diagram of methodology

Table 2 Chemical composition of cement and CDA

Ingredients	OPC	CDA
C	6.56	6.47
O	43.01	49.81
Na	-	1.7
Mg	0.27	3.05
Al	1.02	1.45
Si	6.21	25.85
P	-	1.49
S	1.08	-
K	0.63	1.62
Cl	-	0.63
Ca	39.28	7.3
Ti	0.26	-
Fe	1.69	0.63

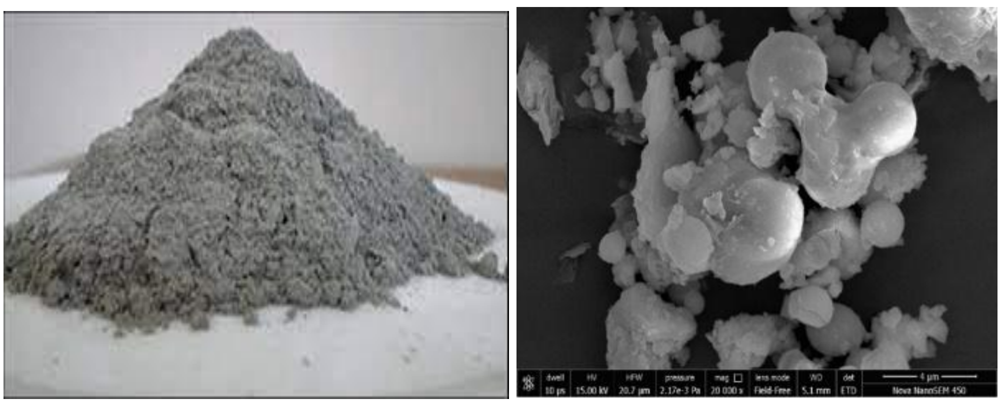


Figure 2 Cow dung ash

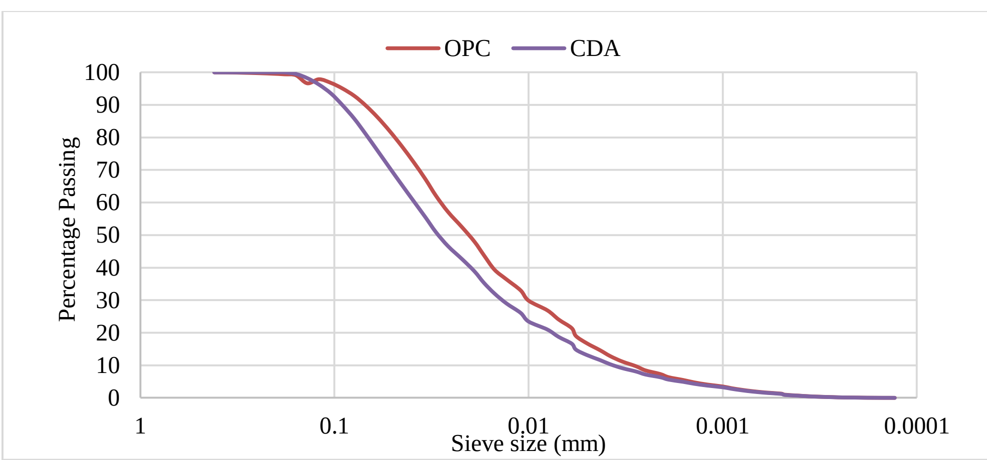


Figure 3 Gradation curve of OPC and CDA

3.1Mix proportioning

For this study M20 and M25 grade was finalized to inspect the behaviour of CDA in concrete. Individual six mixes were prepared for each grade. CDA was replaced with cement at 2% interval till 10%. The mix proportion for all mixes is depicted in the following *Table 3.*

Table 3 Mixing Details for M20 and M25grade concrete with CDA replacement in kg/mm^3

Grade	Cement	CDA	Fine aggregate	Coarse aggregate		Water
				10 mm	20 mm	
M20	340.0	0.0	510	672	448	153
	333.2	6.8	510	672	448	153
	326.4	13.6	510	672	448	153
	319.6	20.4	510	672	448	153
	312.8	27.2	510	672	448	153
	306.0	34.0	510	672	448	153
M25	390.0	0.0	390	468	312	164
	382.2	7.8	390	468	312	164
	374.4	15.6	390	468	312	164
	366.6	23.4	390	468	312	164
	358.8	31.2	390	468	312	164
	351.0	39.0	390	468	312	164

3.2Testing program

As per the specifications of IS 516:1959 [34] and IS 5816: 1999 [35], the samples were investigated for the mechanical properties. Three specimens were prepared for each mix, there were total six mixes that have been tested for the compressive, tensile and flexural strength. The sample size for flexural strength test was kept as per the standard as (500 × 100 × 100) mm, the size of the sample for compressive strength test were kept as (100 × 100 × 100) mm, and the sample size for tensile strength test were kept as 150 mm diameter of the sample and 300 mm height. Mechanical strength was investigated by testing the sample on compression testing machine. For the investigation of void percentage were carried out in accordance with the standards of ASTM C 642-13 [36], the sample size was kept as 100 mm^3. As per the Deutsches Institut Normung (DIN) 1048 [37], the samples were tested for the permeability and the size of samples was kept as 150 mm^3. Standards of IS 1237 were followed to analyse the abrasion resistance for samples prepared with various mixes [38]. The samples prepared with the CDA and exposed to the fresh water were assessed for the surface and internal potential of hydrogen (pH) for an interval of 56 and 90 days.

4.Results

4.1Compressive strength

It is the preliminary concerning factor while checking the feasibility of utilization of any material for replacement in preparation of concrete. The CDA substituted samples were prepared for mix M20 and M25, the samples were tested for the time interval of 56, 90 and 180 days, the compressive strength of these are depicted below in the *Figure 4*. It was discovered that increasing the percentage of CDA in concrete by 6% led to an increase in the material's strength. It's probable that the well-graded particles and interconnected nature of CDA's particles are what contribute to the material's superior performance as a filler in concrete.

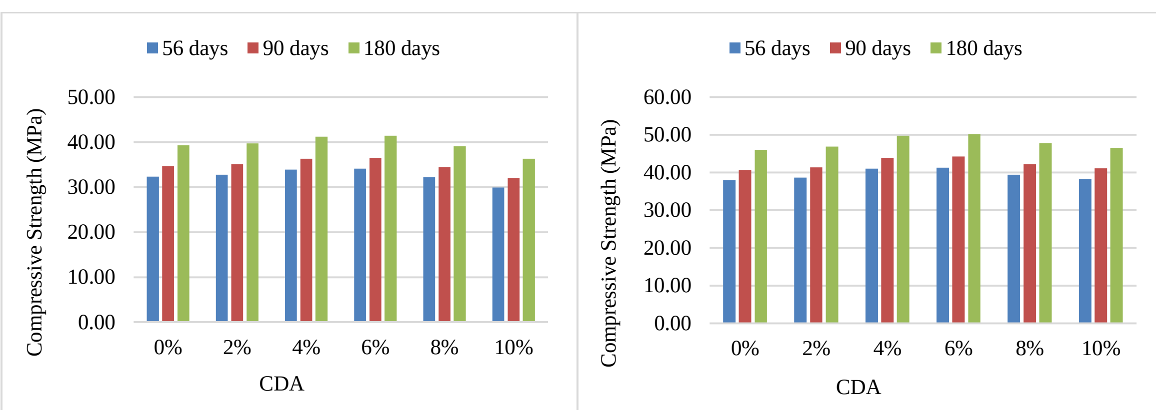


Figure 4 Compressive strength outcomes of CDA modified concrete for (a) M20 (b) M25

4.2Split tensile strength

An increment in the split tensile strength in CDA modified concrete for both mixes were noticed for a substitution level up to 6%, when the substitution level raised above this limit the strength tend to decrease, similar fashion was also noticed in the compressive strength. The results of strength are depicted below in the *Figure 5*. The CDA particle's rough surface and angular form may have allowed for denser packing between the cement in the concrete mixture, which in turn increased the split tensile strength. Since cement replacement of CDA (more than 8% in our study) reduces the free quantity of portlandite, the major element for triggering the pozzolanic process, this has implications for the performance of the concrete.

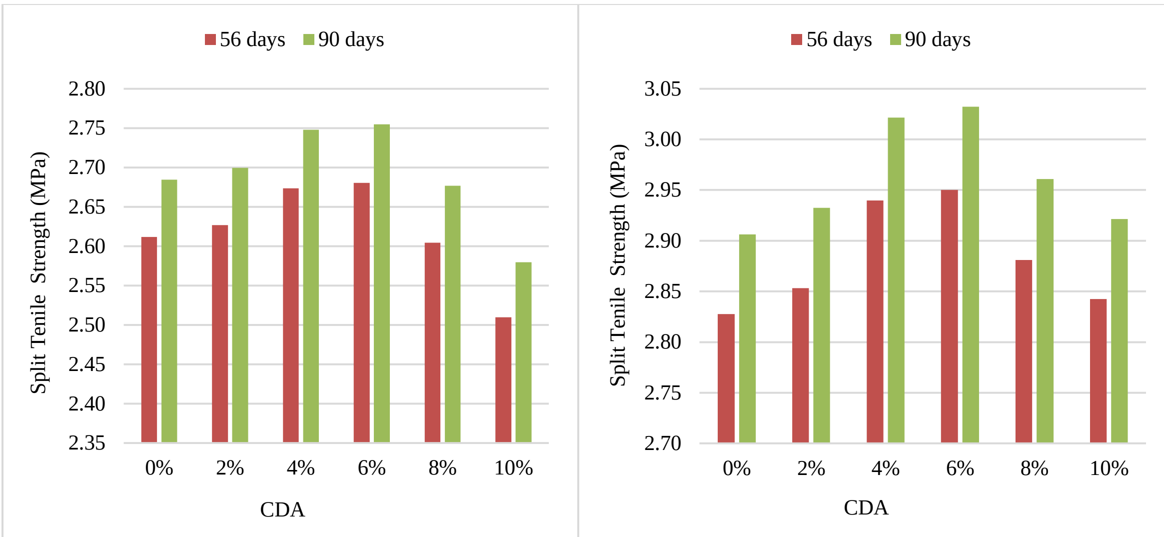


Figure 5 Split tensile strength outcomes of CDA modified concrete for (a) M20 (b) M25

4.3Flexural strength

When compared to the control mix the mix prepared with the incorporation of CDA has depicted increased gain of flexural strength for M20 and M25 as 2.64% and 4.34% respectively. The trend of strength increment is very much similar as observed in the case of compressive strength. The results of flexural strength are depicted in the *Figure 6*. The rough surface and angular shape of CDA particles may have enabled dense packing of cement in concrete, increasing flexural strength. Portlandite, the main element for starting the pozzolanic process, is lowered with the greater cement substitution of CDA more than 8%.

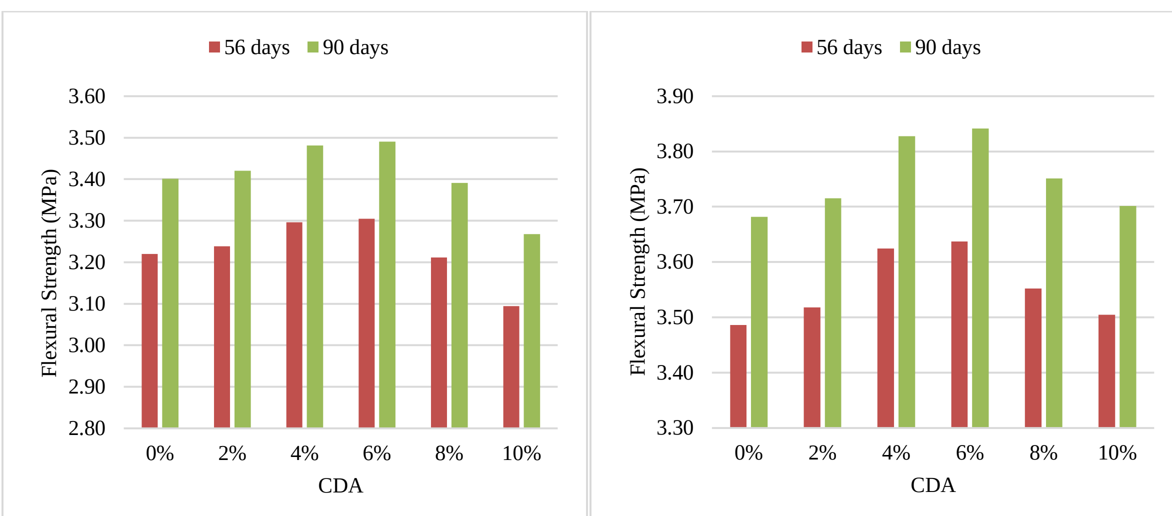


Figure 6 Flexural strength outcomes of CDA modified concrete for (a) M20 (b) M25

4.4Abrasion resistance

The control mix is compared to the depth of wear with the various mixes of the CDA. The result of the same is depicted in the *Figure 7*. The compressive strength of the concrete mix has a direct correlation with the depth of the wear. Substituting CDA for some of the cement enhanced the density of the packing and the thickness of the cement matrix, which likely explains why there was a considerable improvement in abrasion resistance.

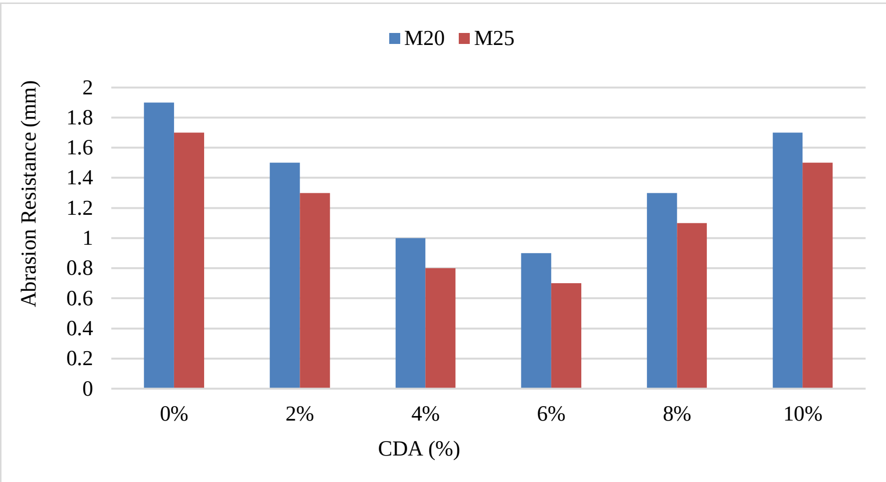
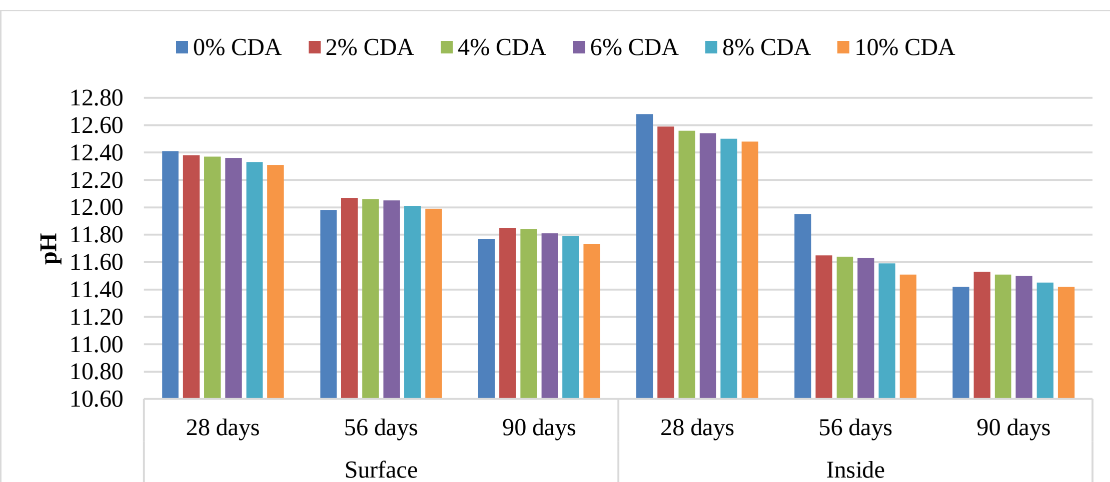


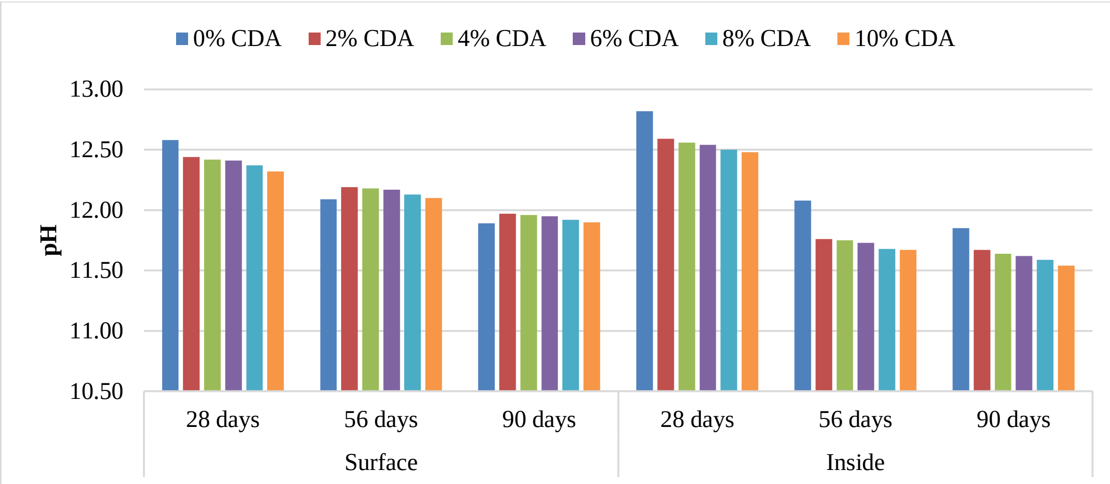
Figure 7 Abrasion Resistance outcomes of CDA modified concrete

4.5pH value

The samples were exposed to the presence of the fresh water for a time period of 28 days and 90 days, later surface and internal pH of the prepared sample of the CDA were observed for the pH. *Figure 8* displays the pH values of concrete. The reduction the pH was observed for the specimens at the level of surface as well as internally [39]. The ordinary sample and sample prepared with the CDA was tested by internal as well as the surface pH reduction on samples cured with fresh water for a time period of 28 and 90 days. Both samples were found with the reduction in pH for internal as well as surface level. *Figure 8* depicts for both concrete grades that CDA sample compared to the control sample shows lower pH reduction. This phenomenon might take place because of free lime (CaO) leaching, the formation of calcium silicate hydrate (CSH) takes place due to the reactivity of free lime (CaO) with the available CDA in the sample.



(a)



(b)

Figure 8 pH value outcomes of CDA modified concrete for (a) M20 (b) M25

4.6Water absorption

Outcomes of water absorption for CDA modified concrete are displayed in *Figure 9*. The comparison of CDA mixes with the control mix has depicted that the mixes, prepared with the incorporation of the CDA have lower water absorption up to the optimum level of substitutions. The mixes M 20 and M 25 have observed with the 6.55% and 6.23% value of water absorption respectively. At a level of 6% substitution of the CDA the mix M 20 was observed with the minimum water absorption and the value stands as 3.61%, whereas, at a level of 4% substitution the mix M 25 observed with the minimum value of water absorption as 3.21%.

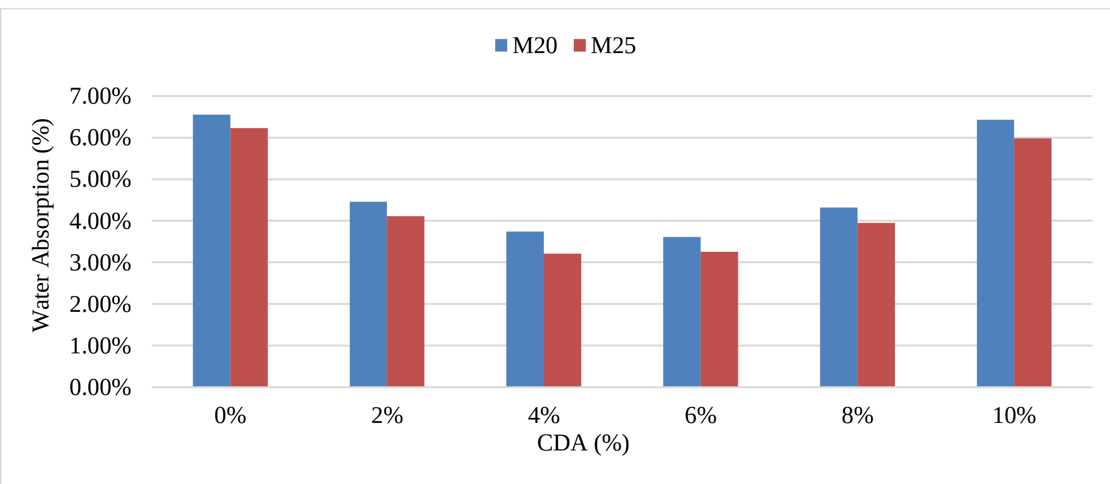


Figure 9 Water absorption outcomes of CDA modified concrete

4.7Porosity

Reduction in volume of voids observed till 6% replacement after that incremental trend was seen. Reduction in voids is mainly due to filler effect generation by incorporation of the CDA. For different mixes the below *Figure 10* depicts voids volume. In order to minimise the occurrence of pore formation in the concrete mixture, it has been determined that a CDA replacement level of 6% is optimal.

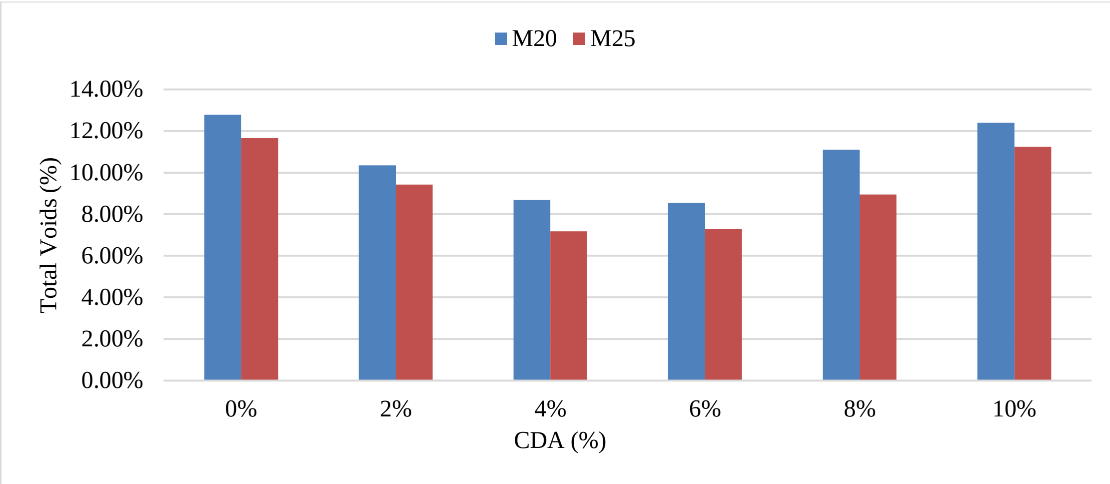


Figure 10 Water absorption outcomes of CDA modified concrete

4.8Permeability

For the different mixes under shown *Figure 11* depicts the results of the permeability. Water penetration was observed to a lesser depth in the sample prepared with the 6% CDA replacement level in the mix. Depth of water penetration is reduced to increase of the CDA content till 6% after that increment is noticed. This reduction in water penetration is mainly due to the reduction voids density of concrete with formation of the high amount of CSH gel of concrete as discussed in the previous section. Depth of penetration is directly proportional to the porosity of samples. As the number of voids in concrete directs the water to penetrate from the specimen.

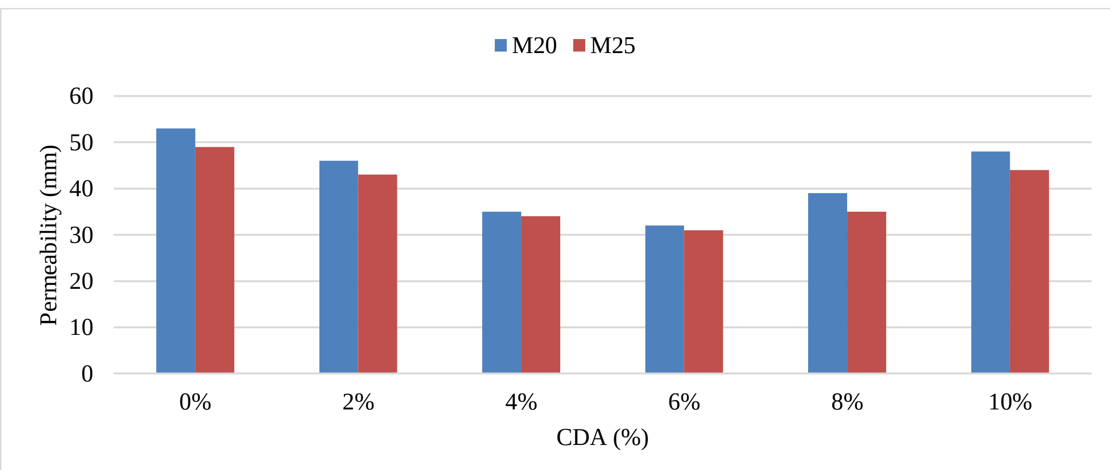


Figure 11 Permeability outcomes of CDA modified concrete

5.Discussion

5.1Compressive strength

Results show that increasing the CDA content initially enhances the compressive strength, but after 6% CDA replacement decrement starts for both grades. Incorporation of CDA at 6% increases compressive strength by 5.3% and 8.87 % respectively for M20 and M25 grade of concrete. Increased pozzolanic reactivity along with the formation of hydration products might be the reason behind the strength enhancement, also the enhanced interaction transition zone improves the strength of CDA modified concrete [29, 40]. It was found that adding 6% CDA to concrete increased the material's strength. It's possible that CDA's greater filler in concrete is the consequence of its well-graded particles and particle interconnecting nature. Other research also reported similar trends with CDA mixed concrete [13, 16, 24].

5.2Split tensile strength

Compared to the control mix, the optimum gain of tensile strength for M20 mix were observed as 2.8%, whereas for mix M25 the gain was 4.2%. CDA particles have a greater filler effect, which decreases linked spaces and increases matrix density, all of which contribute to a higher split tensile strength in concrete [16, 29]. Dense packing between the cement in the concrete mixture may have been made possible by the CDA particle's rough surface and angular form, leading to an increase in split tensile strength [24].

5.3 Flexural strength

The increment in strength is propagated due to the higher angularity and interfacial transition zone (ITZ), this phenomenon leads to the more resistance to the loadings [28]. Similar behaviour was seen with CDA mixed concrete by earlier researchers [20, 24, 28]. Ramachandra et al. [39] also observed enhanced flexural strength for CDA modified concrete. Improved interlocking between the concrete particles and CDA might be the prime reason behind the enhancement of the flexural strength [24]. Since the free quantity of portlandite, the primary ingredient for activating the pozzolanic process, is reduced with increased cement substitution of CDA (more than 8% in our study).

5.4 Abrasion resistance

Within the optimum limit of replacement of the CDA that is 6%, all specimens have depicted raised resistance against the abrasion, whereas above this replacement level, the wear depth has started increasing and resistance goes decreasing. At a replacement level of 6% CDA, the mix has observed with the highest resistance to the abrasion, the dense matrix of the mix provides it with the more resistance to abrasion [15]. Depth wear is directly proportional to the compressive strength of concrete mix [3, 6]. There was a noticeable improvement in abrasion resistance after the CDA was substituted for some of the cement, likely as a result of the increased density of the packing and the increased thickness of the cement matrix [24, 29]. In terms of abrasion resistance, 6% CDA concrete mixes perform the best.

5.5 pH value

Mixes prepared with the CDA have depicted lower reduction in the pH tested at different time periods as compared to the control mix and this has been depicted in the *Figure 12* below. The formation of calcium silicate hydrates due to the reaction of free lime of cement with CDA propagates the leaching of Calcium oxide (CaO), and this is the key reason of the lesser pH reduction phenomenon [7, 25].

5.6 Water Absorption

The filler effect depicted by the CDA is the initial reason of lesser water absorption, although, the influence of cement content reduction might not overcome the influence of the filler effect. Dense microstructure was achieved in the samples of mortar prepared with the incorporation of CDA and this leads to the reduction in the porosity, which indicated that the CDA enhances the packing density in the concrete mix [8, 41]. Increment in water absorption was depicted over 6% CDA replacement is due to increment in the formation of pores concrete mixture. This increment in pores is generated mainly due increase in surface area of particles in cement matrix [30]. Similar trends were observed by many researchers in their previous studies [28, 31].

5.7 Porosity

Incorporation of CDA waste enhances the packing density and this phenomenon is observed for the certain level of replacement. Similar trends were observed by Ramachandran et al. [7] and Yeole et al. [28] research. In addition, some studies have shown that using rough texture CDA (up to a certain limit) creates a more convoluted capillary channel in the concrete matrix, which aids in blocking the admission of undesirable particles [28, 39]. It can be concluded that a 6% replacement of CDA is optimum replacement level to reduce the formation of pores in concrete mix.

5.8 Permeability

The control mix M 20 has been observed with the 53 mm water penetration depth while the control mix M 25 was observed with 49 mm depth. The decrement in the permeability is due to the decreased porosity of the mix along with the enhanced packing density. Water penetration relationship with the void volume depicts their strong co-relation with the permeability. Improved filling ability due to the presence of smaller CDA particles leads to a more compact concrete mixture [28, 32]. Additionally, the CDA particles rough surface roughness provides a greater interlocking with cement paste, leading to increased apparent density and decreased the proportion of permeable gaps. Improved density and a smaller percentage of permeable spaces are the results of using CDA as fine aggregate in concrete. Similar observation was noticed by Fom et al. [20] and Rayaprolu and Raju [15].

Comparative results of mechanical and durability aspects of CDA modified concrete are displayed in *Figure 12*. Incorporation of CDA waste enhances the mechanical and durability behaviour of concrete almost 6% replacement.

The importance of recycling existing resources with low-cost material in achieving the key qualities of concrete, including workability, mechanical, and durability, was investigated in this study. It was common practise to employ CDA as a cementitious material additive for flooring or as a building component, but not for uses subject to significant structural pressures. CDA modified concrete has low thermal conductivity and is lightweight, as described by Ojedokun et al. [22] 15% of the regular Portland cement in the concrete was switched out for the CDA, and the resulting modifications are visible in the buildings [15]. The typical M20 and M25 grade of concrete were used as a comparison. The mechanical, durability activities in the fresh water of control and concrete treated with CDA were investigated by exposing both materials to the water and retrieving them after 28, 56 and 90 days. There was a comparison made between conventional concrete and concrete modified with CDA in terms of pH decrease. Surface pH was raised because it varies with environmental exposure and is therefore affected by carbonation, free chloride ions, microorganisms, and temperature and humidity [25]. In this research, control was found to be more effective at lowering pH than CDA-modified concrete. The strength of CDA modified concrete has improved because CDA reacts with the free lime in the cement, producing more CSH. However, when control sample is exposed to clean water, the unreactive free lime is leached out. After 90 days of exposure in fresh water, concrete amended with CDA exhibited significantly higher compressive strength and split tensile strength than the control sample.

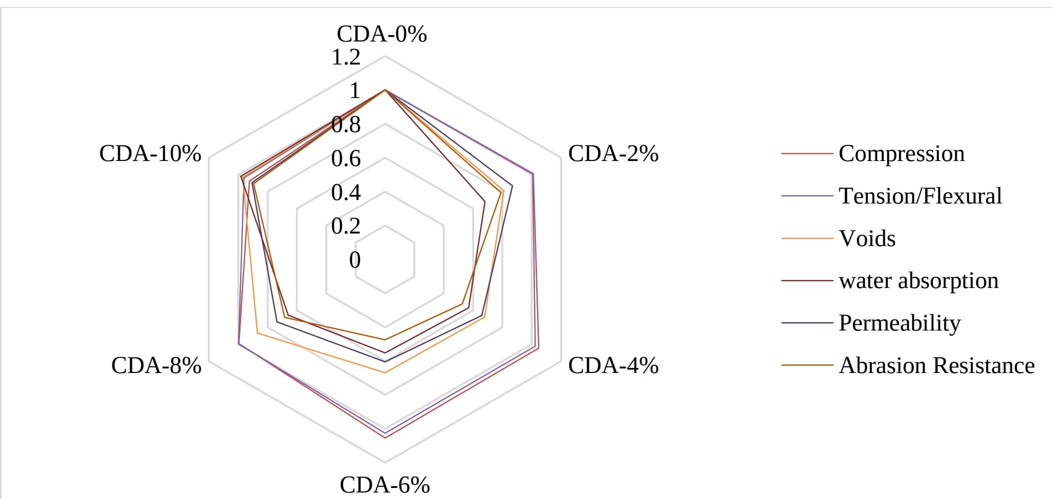


Figure 12 Comparative results CDA modified concrete

5.9Limitation of study

- Increment of CDA waste beyond 6% reduces the overall performances of concrete with respect to conventional concrete.
- The micro structural behaviour of CDA modified concrete is to inspect for further deep analysis.
- X-ray diffraction of CDA modified concrete of is to be analysed to validate the incremental in strength.
- Statistical analysis of data acquired from various results is to be done for further fine analysis of CDA utilization.

A complete list of abbreviations is shown in *Appendix I*.

6.Conclusion and future work

Durability performance of the concrete mixes, prepared with CDA was experimentally studied in this work. The study conclusion is as under:

- The increment in the compressive strength is achieved at the optimum value of CDA replacement that is 6%, further replacement has shown the decrement in results. The results of compressive strength for control mix and mix with 8% CDA replacement are found to be identical.
- Tensile strength results were also observed with the similar trend of compressive strength test results, the optimum value of replacement level for optimum value of tensile strength was 6%, whereas, as observed in the compressive strength

results, control mix and mix prepared with 8% replacement level depicts the identical values of tensile strength.
- Flexural strength test results depicted the increment in value for replacement level till 6%. The replacement above this level observed with the decrement in values. Here, also identical phenomenon was observed as of compressive strength test values.
- The CDA concretes pH value compared to conventional concrete has less pH reduction in all the days of curing.
- Volume of voids, Permeability and water absorption for CDA modified are lower when compared to the control specimen, and this is due to higher packing density. Water absorption and permeability results are in similar trends and strongly correlated with the volume of voids which means reduction in voids are cause of low water penetration and absorption.

Overall conclusion can be made that 6% of replacement CDA is the optimum level of replacement to enhance the durability aspect of concrete. Chemical resistance parameter for CDA modified concrete can be measured in future works. Microstructure analysis can be performed for in depth analysis on CDA modified concrete.

Acknowledgment
None.

Conflicts of interest
The authors have no conflicts of interest to declare.

Author’s contribution statement
Mahim Mathur: Concept and formulation, method of analysis, writing-original draft, analysis and interpretation of results. **R. C. Chhipa:** Supervision, final correction, investigation on challenges and draft manuscript preparation.

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Appendix I

S. No.	Abbreviation	Description
1	CaO	Calcium Oxide
2	CDA	Cow Dung Ash
3	CSH	Calcium Silicate Hydrate
4	DIN	Deutsches Institut Normung
5	ICF	Iron, CDA and Fly Ash
6	IS	Indian Standard
7	ITZ	Interfacial Transition Zone
8	OPC	Ordinary Portland Cement
9	pH	Potential of Hydrogen
10	RHA	Rice Husk Ash
11	SiO_2	Silicon Dioxide