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Sustainable solutions for Workable and Strong concrete: Cordia Gel and Waste Engine Oil Admixtures

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ABSTRACT

To produce high strength or rich cement concrete having low water to cement ratio with adequate workability is the biggest challenge for the construction industry. To achieve the necessary workability, the world is now using costly chemical admixtures. Research should be carried out to explore materials having potential to be utilized as cost-effective chemical admixtures in concrete. The primary goal of this research is to investigate the combined effect of Cordia Gel (CG) and Waste Engine Oil (WEO) as chemical admixtures on fresh and hardened properties of concrete. Fresh properties of concrete were examined in terms of workability and hardened properties were investigated by compressive strength test and Ultrasonic Pulse Velocity (UPV) test on cubical specimen of dimensions 100mm x 100mm x 100mm after 7, 28 and 90 days of curing in water. Four different percentages of WEO (0.5%, 1%, 1.5% and 2%) were used and percentage of CG kept constant as 0.5% with respect to weight of cement and results were compared with the control mix. Results revealed that workability of fresh concrete increased with increasing amount of CG and WEO. However, a decreasing trend was observed for compressive strength and UPV of hardened concrete when higher values of admixtures were added. The usage of CG and WEO as chemical admixtures in concrete can be a sustainable and cost-effective way to achieve the desired results.

Keywords: Cordia gel; waste engine oil; workability; compressive strength; ultrasonic pulse velocity

INTRODUCTION

The need for homes and businesses has expanded in response to the growing global population, which has boosted the construction sector. The building industry is facing several issues as a result of this surge. When trying to make rich cement concrete with a lower w/c ratio and with the appropriate workability and flowability, the construction industry meets its biggest challenge. To retain the necessary workability, the general practice is to use chemical admixtures or water reducers, which are quite costly when employed in large-scale concrete construction projects. Research should be done and usage of different materials, especially recyclable materials in concrete should be encouraged towards contribution to sustainable development, because inappropriate garbage disposal and its recycling is a problem that exists in many parts of the world. One of the hazardous wastes that is harming the environment is WEO. WEO's possible use as a chemical additive has been investigated. The routine upkeep of engines in cars and industrial machinery results in a significant quantity of WEO (Liu et al. 2018; Qurashi and Swamy 2018). Typical pollutants include polychlorinated biphenyl, copper, lead, zinc, magnesium, chlorides, chromium, and arsenic (Falahi-Ardakani 1984; Animashaun et al. 2016). As a result, old engine oil must be disposed of safely, in accordance with any applicable environmental rules, or in accordance with best practices. Each year, over 40 M tonnes of WEO are produced worldwide (Zhang et al. 2017; Spencer Sam et al. 2020). Worldwide, according to an estimation, less than 45% of WEO gets recovered, with the remaining 55% being discarded by the end user Alsadey 2018; Hamad et al. 2003) . Human and aquatic life are equally impacted by waste oil. Oil accumulates at the surface of bodies of water, creating a layer that filters sunlight, halting photosynthesis and depleting the oxygen supply, killing aquatic life. Additionally, waste oil has certain hazardous components that can pass through the food chain and reach people. Health risks might vary from minor symptoms to fatalities. In this situation, it is crucial to manage waste oil properly to avoid or reduce any potential environmental effects (Hamad et al. 2003).

According to reports, blended WEOs can alter the qualities of standard strength concrete both while it's fresh and when it's hardened. Fresh concrete with an admixed WEO has greater workability and air content than plain reference concrete (Hamad et al. 2003), hence, WEO turns out to be a very cost-effective air-entraining admixture, decreasing the admixture cost by roughly 32% (Singh and Kansal 2016). A new material can also be introduced as an admixture along with WEO called Cordia. It is a type of flowering plant, which belongs to the Boraginaceae family of borages, is found growing in tropical and subtropical regions of America, Africa, Asia, and Oceania. Here in Pakistan, the fruit of the Cordia first appears in March or April. It is a kind of fruit that ranges in color from white to brown or even pink. When ripening begins, the look usually becomes darker. The pulp is rather transparent because to the viscid glue-like mucilage that it contains.

For usage in concrete research, it has not been documented or published. The data from this study will serve as a foundation for producing concrete in a more cost-effective and environmentally friendly manner in which the use of CG and WEO as an admixture will prove as a sustainable and affordable solution to accomplish the required goals without negatively affecting the concrete's strength or raising costs.

METHODOLOGY

CEMENT

Ordinary Portland Cement (OPC), confirming to ASTM C150-22, under the brand name *Lucky Cement*, was employed in this study. The chemical composition of the cement as determined by X-ray fluorescence spectroscopy test (XRF), is shown in Table 1.

TABLE 1. Chemical composition of cement

Oxides	Percentage (%)
Lime (CaO)	63.95
Silica (SiO_2)	20.97
Alumina (Al_2O_3)	5.23
Ferric Oxide (Fe_2O_3)	2.92
Magnesium Oxide (MgO)	2.04
Alkalis (K_2Na_2O)	0.80
Sulphur Tri-Oxide (SO_3)	2.58
Loss in Ignition (LOI)	1.44

AGGREGATES

Locally available sand known as *Bholari Sand*, (with maximum size of 4.75 mm, having specific gravity and water absorption as 2.64 and 1.42 % respectively) and coarse aggregates (with a nominal size of 20 mm, specific gravity and water absorption of 2.54 and 1.35 % respectively) were utilized in this research. The particle size distribution of both fine and coarse aggregates is shown in figure 1 and figure 2 respectively.

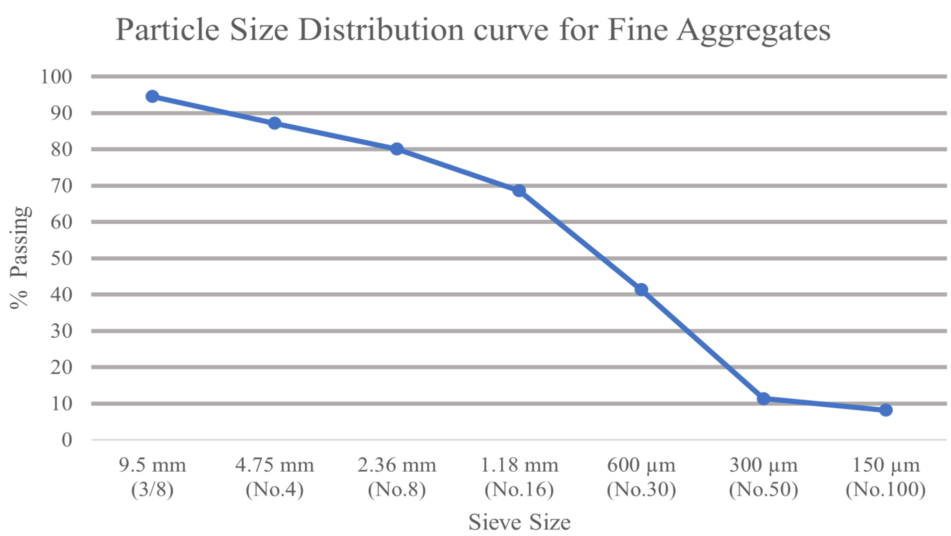

FIGURE 1. Particle size distribution of fine aggregates

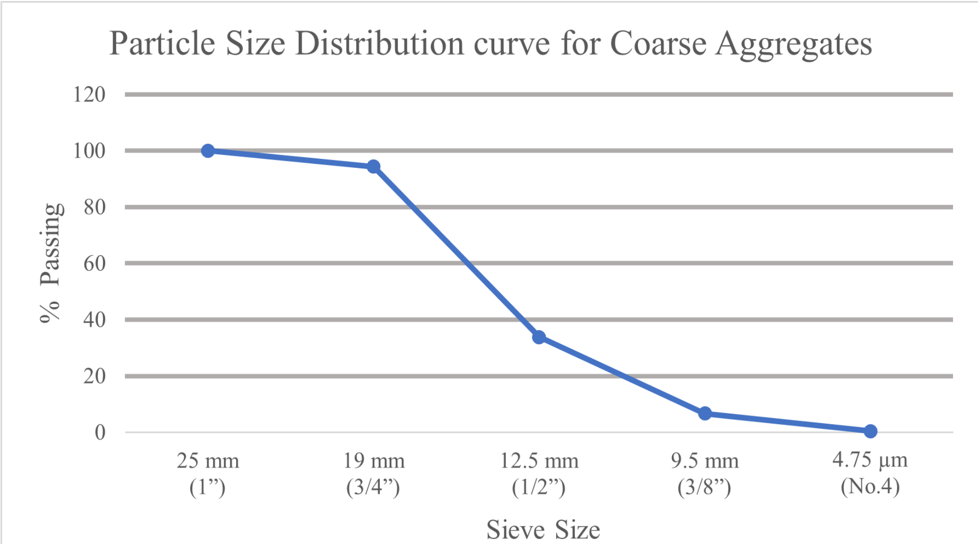

FIGURE 2. Particle size distribution of coarse aggregates

WATER

Tap water available in the concrete laboratory was utilized for the investigation since it was of drinking-quality.

CORDIA GEL

CG which has potential to be used as set retarder because it exhibits all the expected peaks and bands of polysaccharides (sugars) (Dokht et al. 2018) in concrete was obtained from the Cordia fruit which is locally available in the rural areas of Hyderabad region or in the local market at reasonable cost, is shown in figure 3. The chemical composition of CG is shown in table 2.

(a) (b)

FIGURE 3: (a) Cordia fruit (b) Cordia Gel

TABLE 2. Chemical composition of CG (Hashemi Gahruie et al. 2020; Haq & Hasnain 2013)

Chemical compounds	Percentage (%)
Carbohydrate (major sugars-galactose, rhamnose and mannose)	78.00
Uronic acid	10.00
Protein	12.00

WASTE ENGINE OIL

WEO, which has potential to be utilized as air entraining admixture (Hamad et al. 2003) was collected from motor car service shops in Hyderabad city as shown in figure 4, was used in the present study. The chemical composition of WEO is shown in table 3.

FIGURE 4. Waste Engine Oil

TABLE 3. Chemical composition of WEO (Shafiq et al. 2018)

Chemical compounds	Percentage (%)
Lime (CaO)	15.90
Phosphorus Pentoxide (P_2O_5)	8.95
Zinc Oxide (ZnO)	17.70
Ferric Oxide (Fe_2O_3)	0.43
Chlorine (Cl^-)	15.90
Sulphur Tri-Oxide (SO_3)	37.00
Others	4.12

MIX PROPORTIONS

The concrete mix ratio for this study was chosen as 1 : 1.90 : 2.60 @ 0.48 w/c. For determining workability, slump cone method was used and for analyzing the hardened properties, cubical specimen having dimensions of 100mm x 100mm x 100mm were casted. In the first phase, the individual effect of WEO was analyzed on compressive strength and UPV at 28 days with 0%, 0.5%, 1.0%, 1.5% and 2.0% usage with respect to weight of cement and percentage of CG kept constant as 0% as shown in table 4. In the second phase, the individual effect of CG with 0%, 0.5%, 1.0%, 1.5% and 2.0% with respect to weight of cement on compressive strength and UPV at 28 days was determined keeping the percentage of WEO as 0% as shown in table 5. Finally, combined effect of both admixtures was determined using the optimum results. Control mix contained no WEO and CG while other specimen casted for each increment of WEO usage i.e 0.5%, 1.0%, 1.5% and 2.0% and percentage of CG kept constant as 0.5%, which was found to give optimum results in terms to compressive strength and UPV. The percentage usage of admixtures was according to the weight of cement used in the mix. In this way, total 75 number of specimens were casted. 15 specimen from each category were tested for hardened properties at 28 days for first and second phase and 45 specimen were tested for final phase at 7, 28 and 90 days of curing in water. The quantities of constituent materials for combined effect are shown in table 6.

TABLE 4. Concrete mix proportions (first phase)

Mix I.D	Mix proportions (kg/m^3)							
	Cement	Fine aggregates	Coarse aggregates	Water	Admixture w.r.t wt. of cement			
					CG		WEO	
					%	wt.	%	wt.
M-C0-W0	385	725	1005	185	0	0	0	0
M-C0-W0.5	385	725	1005	185	0	0	0.5	1.93
M-C0-W1.0	385	725	1005	185	0	0	1.0	3.85
M-C0-W1.5	385	725	1005	185	0	0	1.5	5.78
M-C0-W2.0	385	725	1005	185	0	0	2.0	7.70

TABLE 5. Concrete mix proportions (second phase)

Mix I.D	Mix proportions (kg/m^3)							
	Cement	Fine aggregates	Coarse aggregates	Water	Admixture w.r.t wt. of cement			
					CG		WEO	
					%	wt.	%	wt.
M-C0-W0	385	725	1005	185	0	0	0	0
M-C0.5-W0	385	725	1005	185	0.5	1.93	0	0
M-C1.0-W0	385	725	1005	185	1.0	3.85	0	0
M-C1.5-W0	385	725	1005	185	1.5	5.78	0	0
M-C2.0-W0	385	725	1005	185	2.0	7.70	0	0

TABLE 6. Concrete mix proportions (combined phase)

Mix I.D	Mix proportions (kg/m^3)							
					Admixture w.r.t wt. of cement			
	Cement	Fine aggregates	Coarse aggregates	Water	CG		WEO	
					%	wt.	%	wt.
M-0	385	725	1005	185	0	0	0	0
M-0.5	385	725	1005	185	0.5	1.93	0.5	1.93
M-1.0	385	725	1005	185	0.5	1.93	1.0	3.85
M-1.5	385	725	1005	185	0.5	1.93	1.5	5.78
M-2.0	385	725	1005	185	0.5	1.93	2.0	7.70

RESULTS AND DISCUSSION

WORKABILITY TEST FOR FRESH CONCRETE (FIRST PHASE)

Workability of concrete was determined with the help of slump cone test having designation BS EN 12350-2 2009. Table 7 and figure 5 displays the results of the slump test at WEO usage rates of 0%, 0.5%, 1%, 1.5% and 2.0% and percentage of CG constant at 0%. Results shows that the addition of admixtures improved the slump value from 5 mm at 0% WEO concentration to 65 mm when then concentration increased to 0.5%. A gradual increase in the slump value was observed when the WEO dosage increased to 1%, 1.5% and 2%, which was achieved as 85 mm, 100mm and 120mm respectively. The increase rate of workability was faster from 0% to 0.5% dosage; however, the rate was slower when dosage increased to 0.5% to 2.0%. The increase in workability is due to the plasticizing and air entraining properties of WEO (Hamad et al. 2003). Air entraining induces tiny air bubbles in concrete which facilitate the easy movement of concrete and increase its fluidity.

TABLE 7. Workability test results (first phase)

S No.	Mix I.D	CG (%)	WEO (%)	Slump value (mm)
1	M-C0-W0	0	0	5
2	M-C0-W0.5	0	0.5	65
3	M-C0-W1.0	0	1.0	85
4	M-C0-W1.5	0	1.5	100
5	M-C0-W2.0	0	2.0	120

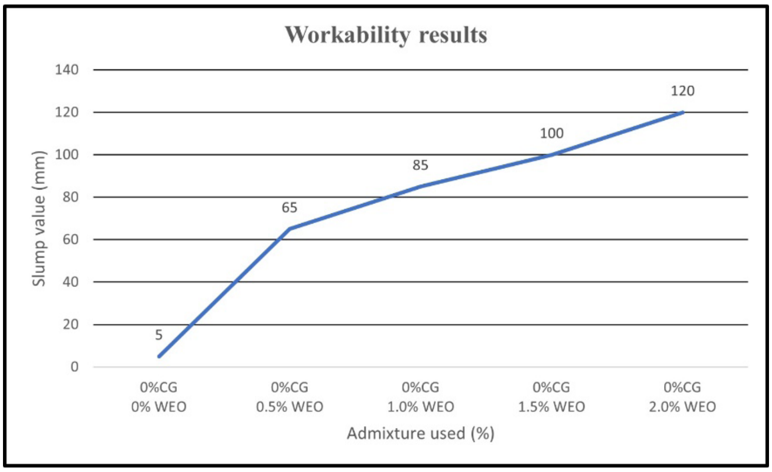

FIGURE 5. Workability test results (first phase)

WORKABILITY TEST FOR FRESH CONCRETE (SECOND PHASE)

Workability of concrete was determined with the help of slump cone test having designation BS EN 12350-2 2009. Table 8 and figure 6 displays the results of the slump test at various CG usage rates of 0%, 0.5%, 1%, 1.5% and 2.0% and percentage of WEO constant at 0%. Results shows that the addition of CG improved the slump value from 5 mm at 0% concentration to 40 mm when then concentration increased to 0.5%. A slow increase in the slump value was observed when the CG dosage increased to 1.0%, 1.5% and 2.0%, which was achieved as 55 mm, 75 mm and 90 mm respectively. The increase rate of workability was faster from 0% to 0.5% dosage; however, the rate was slower when dosage increased to 0.5% to 2.0%. The increase in workability is due to the improved flowing behavior of CG (Hussain et al. 2020). CG has been experimentally found effective to increase the fluidity of the substance when added in the form of gel. However, the slump values obtained from usage of CG are not much higher than those obtained from the use of WEO.

TABLE 8. Workability test results (second phase)

S No.	Mix I.D	CG (%)	WEO (%)	Slump value (mm)
1	M-C0-W0	0	0	5
2	M-C0.5-W0	0.5	0	40
3	M-C1.0-W0	1.0	0	55
4	M-C1.5-W0	1.5	0	75
5	M-C2.0-W0	2.0	0	90

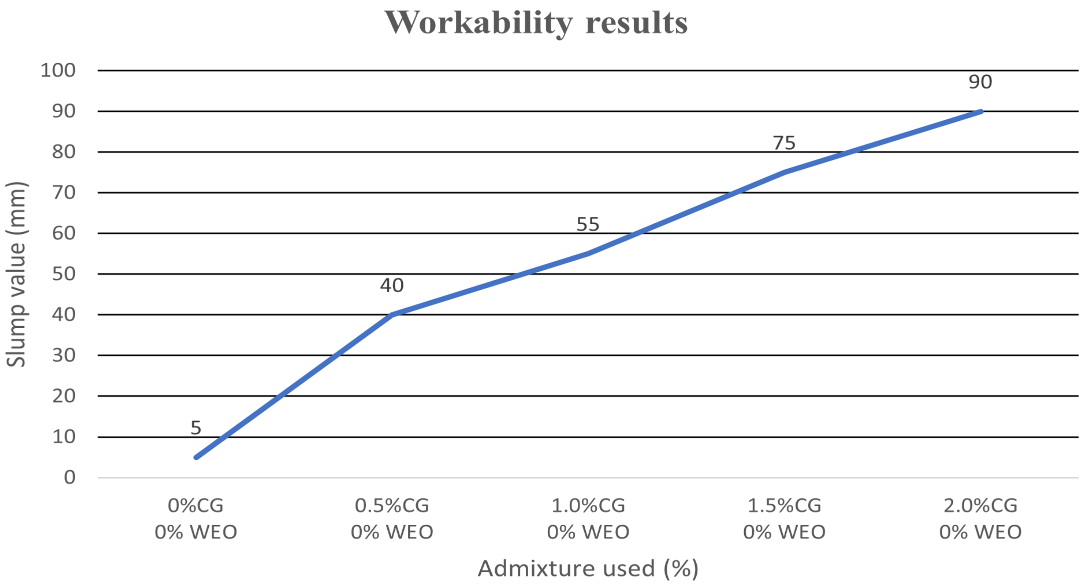

FIGURE 6. Workability test results (second phase)

WORKABILITY TEST FOR FRESH CONCRETE (COMBINED PHASE)

Workability of concrete was determined with the help of slump cone test having designation BS EN 12350-2 2009. Table 9 and figure 7 displays the results of the slump test at various admixture usage rates. Results shows that the addition of admixtures improved the slump value from 5 mm at 0% concentration to 55 mm when then concentration increased to 0.5%. A gradual increase in the slump value was observed when the admixture dosage increased to 1%, 1.5% and 2%, which was achieved as 75 mm, 90 mm and 100 mm respectively. The increase rate of workability was faster from 0% to 0.5% dosage; however, the rate was slower when dosage increased to 0.5% to 2.0%. The increase in workability is due to the improved flowing behavior of CG (Hussain et al. 2020) along with plasticizing and air entraining properties of WEO (Hamad et al. 2003).

TABLE 9. Workability test results (combined phase)

S No.	Mix I.D	CG (%)	WEO (%)	Slump value (mm)
1	M-0	0	0	5
2	M-0.5	0.5	0.5	55
3	M-1.0	0.5	1.0	75
4	M-1.5	0.5	1.5	90
5	M-2.0	0.5	2.0	100

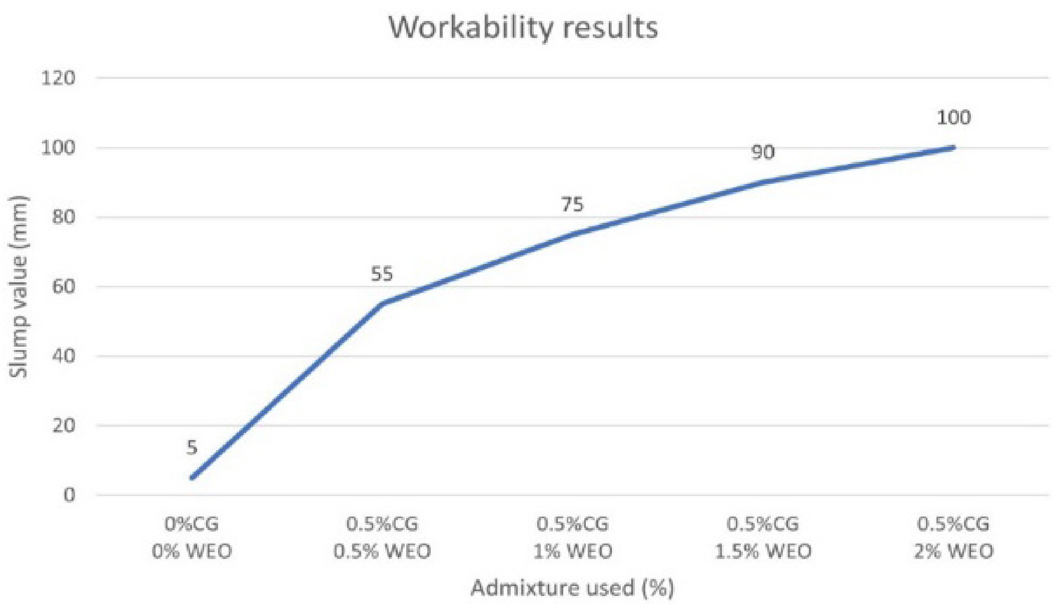

FIGURE 7. Workability test results (combined phase)

COMPRESSIVE STRENGTH TEST FOR HARDENED CONCRETE (FIRST PHASE)

The compressive strength of cubical specimen was determined according to the BS code having designation BS EN 12390 3 2009. Table 10 and figure 8 shows the compressive strength results at 28 days. Results indicate that the strength decreased with addition of WEO to control mix. The initial decrease in compressive strength was rapid from 0% to 1.0% and then the strength gradually decreased from 1.0% to 2.0%. This decrease in compressive strength is due to the increasing percentage of WEO, acting as a dominating admixture, exhibiting properties of an air entrainer, incorporates air voids in the concrete resulting in low strength (Hamad et al. 2003).

TABLE 10. Compressive strength test results at 28 days (first phase)

S No.	Mix I.D	CG (%)	WEO (%)	Compressive strength (MPa)
1	M-C0-W0	0	0	26.61
2	M-C0-W0.5	0	0.5	24.24
3	M-C0-W1.0	0	1.0	21.08
4	M-C0-W1.5	0	1.5	19.24
5	M-C0-W2.0	0	2.0	17.18

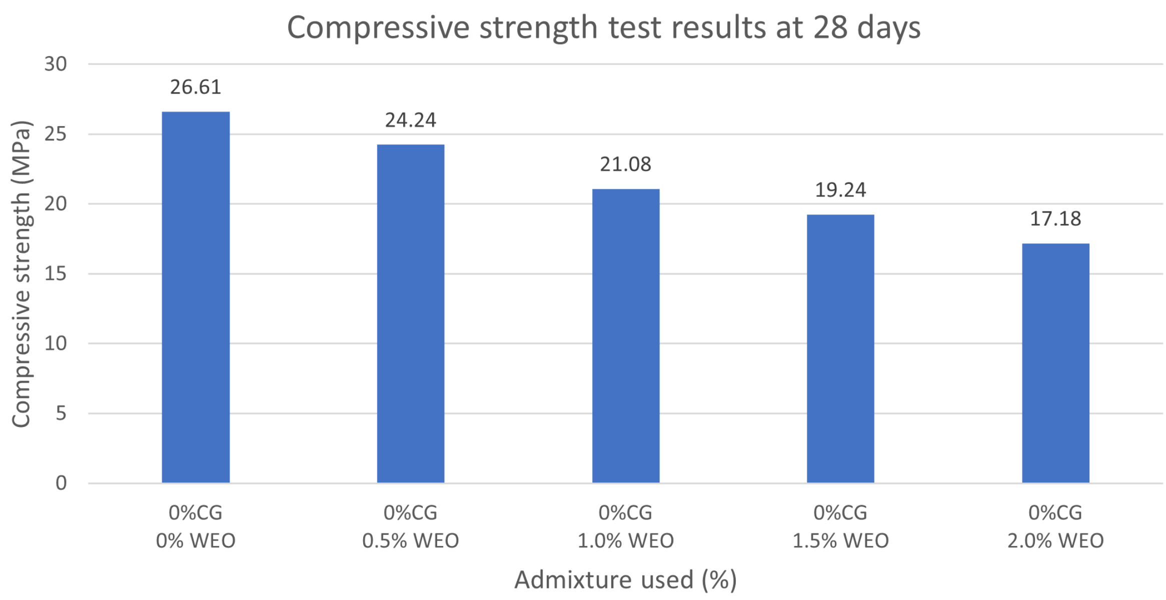

FIGURE 8. Compressive strength test results at 28 days (first phase)

COMPRESSIVE STRENGTH TEST FOR HARDENED CONCRETE (SECOND PHASE)

The compressive strength of cubical specimen was determined according to the BS code having designation BS EN 12390 3 2009. Table 11 and figure 9 shows the compressive strength results at 28 days. Results indicate that initially the strength increased with 0.5% addition of CG to control mix, which is found as higher among the other percentages. However, a decreasing trend in compressive strength was observed when 1.0%, 1.5% and 2.0% dosage was added. The decrease in strength is very gradual and with a small margin. The increase in compressive strength is due to the binding and adhesive nature of CG (Dinda and Mukherjee 2009; Haq 2013), the binding effect which CG exhibit to promote adhesion among the concrete ingredients (Tahir et al. 2019; Ali et al. 2022), Then the decreasing trend in strength is due to the increasing percentage of sugars (galactose, rhamnose and mannose) present in excess quantity in CG (Hashemi Gahruie et al. 2020; Haq and Hasnain, 2013). The optimum value of utilization of CG is 0.5% with respect to weight of cement.

TABLE 11. Compressive strength test results at 28 days (second phase)

S No.	Mix I.D	CG (%)	WEO (%)	Compressive strength (MPa)
1	M-C0-W0	0	0	26.61
2	M-C0.5-W0	0.5	0	27.96
3	M-C1.0-W0	1.0	0	27.85
4	M-C1.5-W0	1.5	0	27.05
5	M-C2.0-W0	2.0	0	26.72

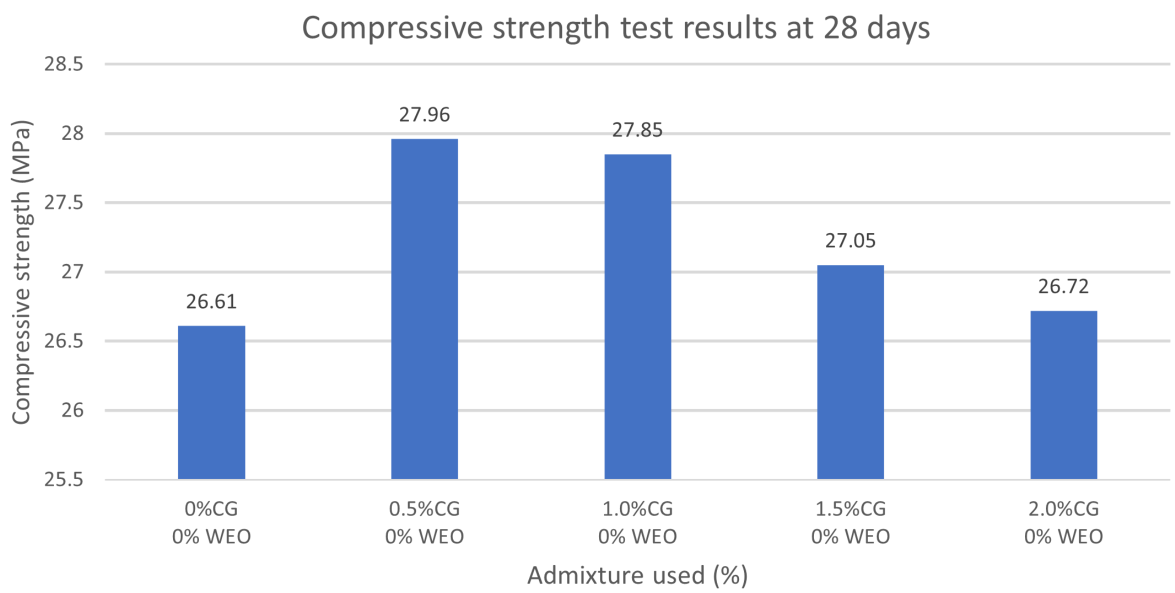

FIGURE 9. Compressive strength test results at 28 days (second phase)

COMPRESSIVE STRENGTH TEST FOR HARDENED CONCRETE (COMBINED PHASE)

The compressive strength of cubical specimen was determined according to the BS code having designation BS EN 12390 3 2009. Table 12 and figure 10 shows the comparison of compressive strength results at 7, 28 and 90 days. Results indicate that initially the strength increased with 0.5% addition of admixtures to control mix. However, a decreasing trend in compressive strength was observed at all the curing ages when 1.0%, 1.5% and 2.0% dosage was added. The initial increase in compressive strength is due to the binding and adhesive nature of CG (Dinda and Mukherjee 2009; Haq 2013), and the binding effect which CG exhibit to promote adhesion among the concrete ingredients (Tahir et al. 2019; Ali et al. 2022), which overall improves the quality of concrete, reducing the voids and cracks and densify the concrete as a whole. Then the decreasing trend in strength is due to the increasing percentage of WEO, acting as a dominating admixture, exhibiting properties of an air entrainer, incorporates air voids in the concrete resulting in low strength (Hamad et al. 2003). The optimum value of utilization of CG and WEO combinedly is 0.5% when the concern is compressive strength.

TABLE 12. Compressive strength test results at various ages (combined phase)

S No.	Mix I.D	CG (%)	WEO (%)	Compressive strength (MPa) at various ages		
				7 days	28 days	90 days
1	M-0	0	0	20.76	26.61	31.19
2	M-0.5	0.5	0.5	24.67	28.06	32.37
3	M-1.0	0.5	1.0	21.24	21.97	28.82
4	M-1.5	0.5	1.5	18.95	21.12	25.26
5	M-2.0	0.5	2.0	17.40	18.23	23.22

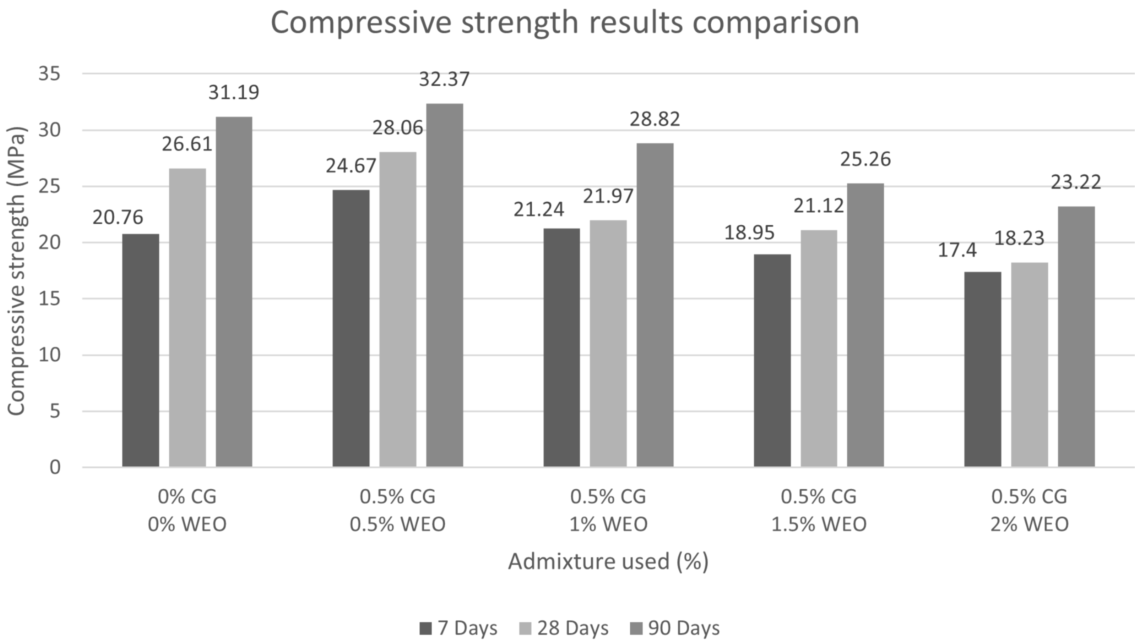

FIGURE 10. Compressive strength test results at various ages (combined phase)

ULTRASONIC PULSE VELOCITY TEST FOR HARDENED CONCRETE (FIRST PHASE)

The Ultrasonic pulse velocity test is a standard test prescribed in British Code having designation BS EN 12504-4 2021. UPV test results were obtained by direct transmission method by using *portable ultrasonic non-destructive digital indicating tester* PUNDIT. Transit time was recorded using the direct transmission technique, minimum 3 readings were taken on each specimen and average value was noted. Total 9 readings were taken on 3 specimens for each mix. Table 13 figure 11 shows the UPV results at 28 days. As per the results, the value of pulse velocity changes as WEO percentage alter. The specimen with control mix were found to have the average transit times and pulse velocity while the specimen with higher WEO dosage were found to have the long transit times and minimum pulse velocity. It is now known that materials with short transit times produce pulse velocities with a higher average than those with long transit times (Ofuyatan et al. 2021). This decrease in pulse velocity value is due to the increasing percentage of WEO which as an air entrainer (Hamad et al. 2003), incorporates air voids in the concrete resulting in flaws that increase the transit time and decrease the pulse velocity. Additionally, it is made quite evident that concrete with higher compressive strength has larger ultrasonic pulse velocities (Kencanawati et al. 2018).

TABLE 13. Ultrasonic pulse velocity test results at 28 days (first phase)

S No.	Mix I.D	CG (%)	WEO (%)	Ultrasonic pulse velocity (km/s)
1	M-C0-W0	0	0	3.191
2	M-C0-W0.5	0	0.5	3.188
3	M-C0-W1.0	0	1.0	3.175
4	M-C0-W1.5	0	1.5	3.133
5	M-C0-W2.0	0	2.0	2.908

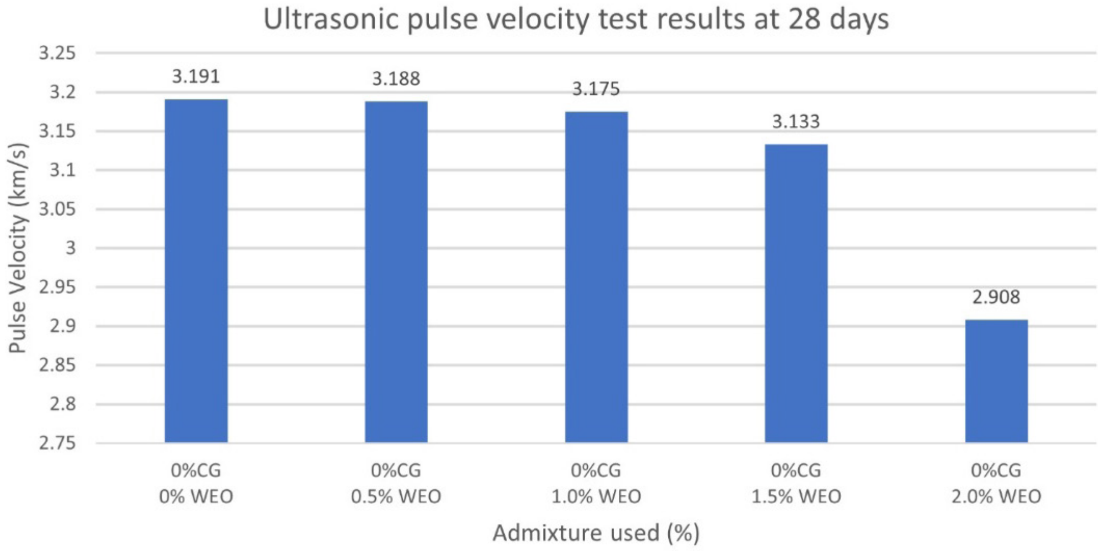

FIGURE 11. Ultrasonic pulse velocity test results at 28 days (first phase)

ULTRASONIC PULSE VELOCITY TEST FOR HARDENED CONCRETE (SECOND PHASE)

The Ultrasonic pulse velocity test is a standard test prescribed in British Code having designation BS EN 12504-4 2021. UPV test results were obtained by direct transmission method by using *portable ultrasonic non-destructive digital indicating tester* PUNDIT. Transit time was recorded using the direct transmission technique, minimum 3 readings were taken on each specimen and average value was noted. Total 9 readings were taken on 3 specimens for each mix. Table 14 figure 12 shows the UPV results at 28 days. As per the results, the value of pulse velocity changes as CG percentages alter. The specimen with control mix were found to have the average transit times and pulse velocity while the specimen with 0.5 % CG dosage were found to have the shortest transit times and maximum pulse velocity. It is now known that materials with short transit times produce pulse velocities with a higher average than those with long transit times (Ofuyatan et al. 2021). This increase in pulse velocity value is due to the binding and adhesive nature of CG (Tahir et al. 2019; Ali et al. 2022), which have reduced the presence of minor cracks in concrete that hinder the wave propagation and increase the transit time. However, a decreasing trend in pulse velocity was observed when 1.0%, 1.5% and 2.0% CG dosage was added. Additionally, it is made quite evident that concrete with higher compressive strength has larger ultrasonic pulse velocities (Kencanawati et al. 2018).

TABLE 14. Ultrasonic pulse velocity test results at 28 days (second phase)

S No.	Mix I.D	CG (%)	WEO (%)	Ultrasonic pulse velocity (km/s)
1	M-C0-W0	0	0	3.191
2	M-C0.5-W0	0.5	0	3.440
3	M-C1.0-W0	1.0	0	3.370
4	M-C1.5-W0	1.5	0	3.220
5	M-C2.0-W0	2.0	0	3.200

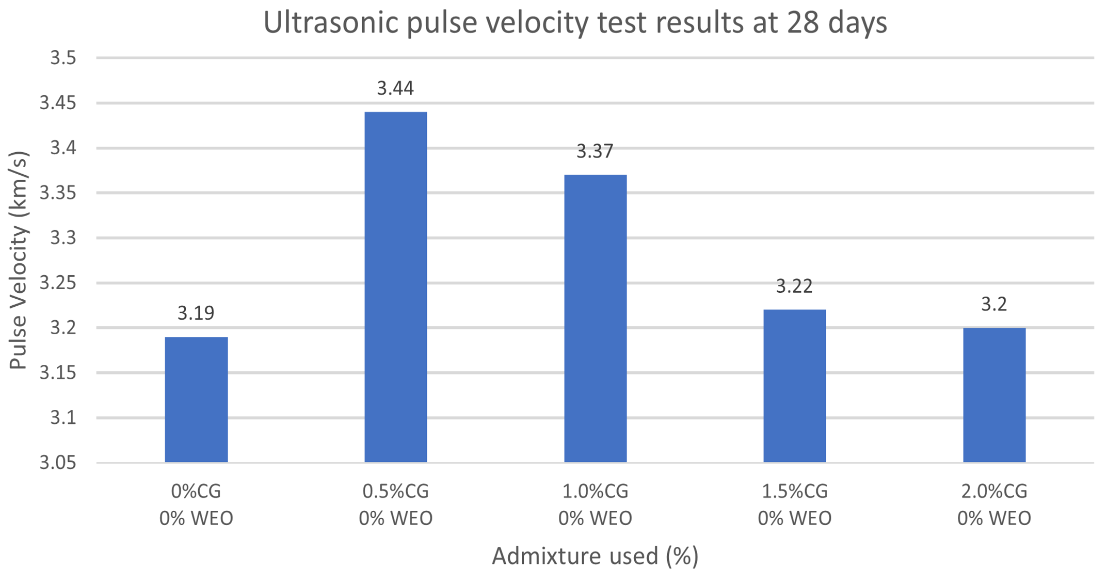

FIGURE 12. Ultrasonic pulse velocity test results at 28 days (second phase)

ULTRASONIC PULSE VELOCITY TEST FOR HARDENED CONCRETE (COMBINED PHASE)

The Ultrasonic pulse velocity test is a standard test prescribed in British Code having designation BS EN 12504-4 2021. UPV test results were obtained by direct transmission method by using *portable ultrasonic non-destructive digital indicating tester* PUNDIT. Transit time was recorded using the direct transmission technique, minimum 3 readings were taken on each specimen and average value was noted. Total 9 readings were taken on 3 specimens for each mix. Table 15 figure 13 shows the comparison of UPV results at 7, 28 and 90 days. As per the results, the value of pulse velocity changes as admixture percentages alter. The specimen with control mix were found to have the average transit times and pulse velocity while the specimen with 0.5 % admixture dosage were found to have the shortest transit times and maximum pulse velocity. It is now known that materials with short transit times produce pulse velocities with a higher average than those with long transit times (Ofuyatan et al. 2021). This increase in pulse velocity value is due to the binding and adhesive nature of CG (Tahir et al. 2019; Ali et al. 2022), which have reduced the presence of minor cracks in concrete that hinder the wave propagation and increase the transit time. However, a decreasing trend in pulse velocity was observed at all curing ages when 1.0%, 1.5% and 2.0% admixture dosage was added. This decrement is due to the increasing percentage of WEO which as an air entrainer (Hamad et al. 2003), incorporates air voids in the concrete resulting in flaws that increase the transit time and decrease the pulse velocity. Additionally, it is made quite evident that concrete with higher compressive strength has larger ultrasonic pulse velocities (Kencanawati et al. 2018).

TABLE 15. Ultrasonic pulse velocity test results at various ages (combined phase)

S No.	Mix I.D	CG (%)	WEO (%)	Ultrasonic pulse velocity (km/s) at various ages		
				7 days	28 days	90 days
1	M-0	0	0	3.061	3.191	3.615
2	M-0.5	0.5	0.5	3.257	3.530	3.798
3	M-1.0	0.5	1.0	3.061	3.369	3.615
4	M-1.5	0.5	1.5	3.002	3.299	3.489
5	M-2.0	0.5	2.0	2.970	3.295	3.490

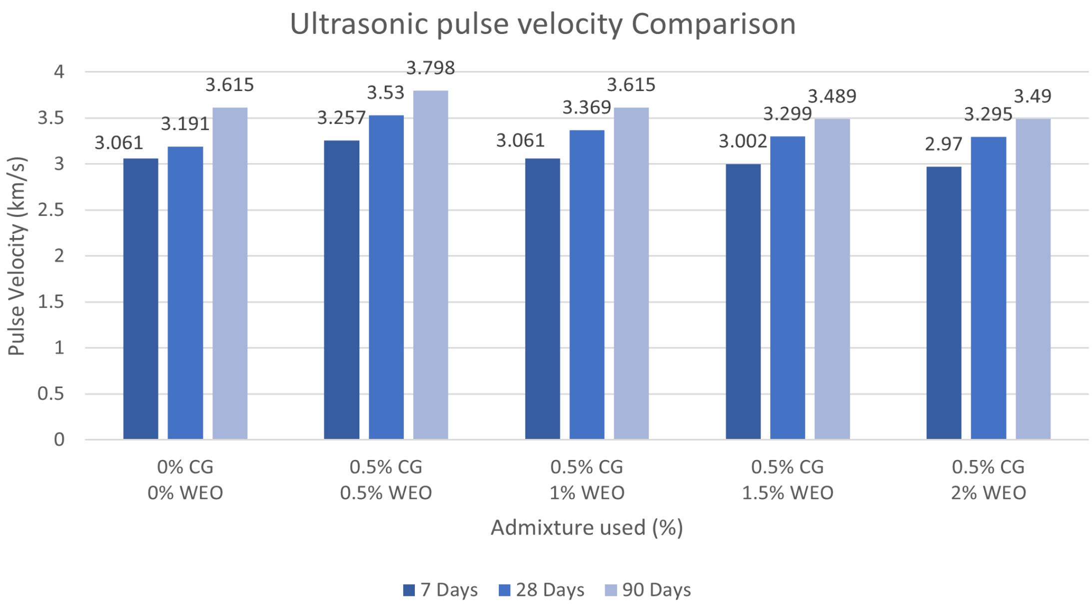

FIGURE 13. Ultrasonic pulse velocity test results at various ages (combined phase)

CONCLUSION

The results of the tests were analyzed, and their conclusions were reached after they were compared to standard concrete.

The combination of CG and WEO as admixtures increased the slump value of fresh concrete from 5 mm at 0% concentration to the maximum value of 100 mm when the concentration increased to 2.0%.

The compressive strength of hardened concrete was observed as maximum at 0.5% addition of CG and WEO, However, a decreasing trend in compressive strength was observed at 1.0%, 1.5% and 2.0% admixture dosage at all 7, 28 and 90 days of curing ages.

The UPV of hardened concrete was measured, and the maximum value was found in the specimen having the percentage of 0.5% of CG and WEO, indicating the good quality of concrete. Further addition of CG and WEO decreased the value of pulse velocity thus making the quality of concrete doubtful.

In summary, it can be concluded that the combination of CG and WEO may effectively be used up to 0.5% by weight of the cement in concrete. However, since compressive strength and UPV may decrease if more than 0.5% is included, higher percentages can be utilized in concrete where strength is not a priority.

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DECLARATION OF COMPETING INTEREST

None

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