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Strength Characteristics of Superplasticizer-retempered Concrete using Chryso Quad 622 under Tropical Construction Site Conditions in Nigeria.

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Abstract
Scholarly evidence suggests that the southwest region of Nigeria has more manufacturing, construction, and engineering sectors, which increase population, social crises, seasonal flooding, and environmental pollution. These have significantly affected the ease of transporting construction materials in the metropolis. Additionally, some studies note that the average tropical-hot ambient temperatures of 32°C often impact the early setting of ready-mix concrete due to excessive evaporation and insufficient moisture for hydration, resulting in lower concrete strength and durability. Many construction industries rely on ready-mix concrete for their operations. Over the years, challenges faced by ready-mix concrete in Lagos include, but are not limited to, untimely delivery, which results in premature stiffening. These problems directly and indirectly affect project costs, quality, and functionality of the structure. Studies show that stakeholders suffer losses from wasted concrete while relying on the common practice of restoring (retempering) stiff concrete with water, re-mixing, heating, or retardants, which often falls short of the international standards. Experts have long emphasized the importance of maintaining the integrity, performance, durability, and ecological sustainability of such concrete in engineering projects. This study aims to address these concerns by using natural aggregates at a 0.4 w/c ratio with an adopted admixture (Chryso Quad 622 TDS) superplasticizer for retempering stiff concrete. Observations indicate that retempered concrete at 30, 60, 90, and 120 minutes showsa significant increase in compressive and flexural strengths compared to the control specimen. Correlation and regression analyses reveal a strong relationship between the control and superplasticized-retempered concrete. This research provides scientific evidence and valuable information for practitioners and academia on the use of superplasticizer retempering, forming a basis for decision-making among stakeholders.

Keywords: Southwest, Concrete, Chryso-quad-622, Ready-mixed, Retempering, Superplasticizer, Workability, Re-mix.

Introduction
Industrial and construction activities in the Southwestern Part of Nigeria contribute significantly to the country's economy(Oyeleye, 2022), with Lagos State being a key focus. A notable feature of Lagos metropolis is the severe traffic congestion and persistent flooding during the rainy season, leading to traffic gridlock and making it difficult to deliver ready-mix concrete for civil and building projects. This results in delays of construction timelines and economic losses throughout the construction industry value chain. As a result, most time-sensitive construction materials are

wasted, causing cost overruns, losses for stakeholders, and extended project durations that increase overall construction costs.

Ready-mix concrete is one of the subcontractor's deliverables produced in the best international standard method within a controlled, conducive off-site environment and transported to the job site in fresh slurry or unhardened. Ready-mix concrete is better in quality control, transportation, and placement. Conventionally, concrete with a late arrival at the site has to be subjected to retempering to restore its slump(Mane and Kulkarni, 2011), which involves adjusting the plastic state using water, admixture, or retardant to regain workability before placement. The associated characteristics challenges around Lagos, such as but not limited to traffic jams, flooding of highways, inadequate accessibility to delivery trucks, community disorder, youth rampage or riot, machine breakdown, and adverse weather – high temperatures (Yazan, 2005),etc, predominant on the job site in the study area, compelling various construction industries to the practice of reversing concrete in its plastic state by the retempering method (Mahzuz *et al*., 2025).

Retempering, therefore, is the process of adding water, admixture, or both to concrete in the stiff state to restore or adjust the lost workability due to time lag or delay(Bayer, 2023; El-ashkar *et al*., 2015; Sobhani *et al*., 2012; Yaligar *et al*., 2013). The American Concrete Institute (ACI 16) (2000) describes retempering of concrete as the act of adding water and remixing of concrete or mortar on account of significant loss of workability to be placed. Although the practice has become the norm among contractors in the built environment, without adjusting the other concrete materials and mix proportions, which will be detrimental to the strength and durability of the hardened concrete(Adebayo, 2023; Sobhani *et al*., 2012).

Debate among expert centers on whether retempered concrete or mortar is adequate (Sobhani*et al*., 2012), particularly regarding its properties as the fundamental component of structures in terms of strength, stability, durability, and cost-efficiency. Experimentally, the compressive strength of concrete depends on factors such as the choice, proportions, and shape of aggregates, as well as the water content. Therefore, the integrity of water-retempered construction materials, which comprise approximately 60% of the total materials used, warrants questioning (Yaligar *et al*., 2013). Recent developments in retempering have increased the need for admixtures, such as retarders or superplasticizers, to enhance the strength of retempered concrete; however, standardized materials and procedures for this process are still in a developmental stage (Mahzuz *et al*., 2025). To date, little scholarly attention has been given to establishing a standardized material and procedure for retempering.

In the current economy, wasting materials is unacceptable, and maintaining the integrity of concrete is crucial for the safety of life and property. The dilemma surrounding this issue is overwhelming. Over the decades, researchers and stakeholders have focused mainly on the cost-effectiveness of construction projects through reducing materials and waste, especially concrete, which is the core of this study. Efforts have been geared to the conservation of resources over the year in attaining sustainable goals, which some experts, like Mane *et al*. (2022), opined

Previous studies have shown that retempering with water alone increases the water-to-cement ratio of the mixture, resulting in substantially low compressive strength(Adebayo, 2023; Sobhani *et al*., 2012). Scholars observed that this may be due to deficient water at the initial batching or high rate of hydration and evaporation during the hot-dry season (Erdogdu, 2005; Zeyad and Almalki, 2020). Also, the practice of mechanical re-mixing of concrete in the drum to restore concrete that has suffered delays in application, which has reached the plastic state or initial setting, is commonly adopted on the job site and is detrimental to the concrete's optimum performance. Experts postulated that concrete must be applied/cast within 1.5 hours after the addition of water (ASTM C94/C94M-24, 2024); hence, retempering by re-mixing overstay concrete beyond the initial setting time is inappropriate.

Further research conducted on admixture chemical retardants, such as lignosulfonate, dextrin, gluconate-based, and melamine-based polymer dispersion conforming to ASTM C494 Type F,on retempered concrete properties (workability and compressive strength): observed a reduction in strength in comparison to the control specimen *(*Mahzuz *et al*., 2025; Mane *et al*., 2022). Although retardants allow rework without water addition, and concrete maintains its workability without affecting the water-to-cement ratio(BS EN 206, 2013+A2:2021),experts postulated the possibility of chemical attack (Pethkar et al., 2020), which is detrimental to concrete performance. Study of Erdogdu (2005) examined withholding water or the controlled water addition method of re-tempering conforming to ASTM C94, 1933, and BS EN 206, 2013. The study observed that water-holding/controlled-water is subject to thorough re-mixing and expert precision to maintain maximum water-to-cement ratio. However, most site conditions may not support the absolute precision required for maximum w/c ratio for water-holding adoption, hence the method is inappropriate for job site environments, which should conform to the expected standard.

Results from an earlier study by Adebayo (2023) show a stronger connection between retempered concrete and superplasticizers such as Rheobuild 858 and Conplast SP430, which produce positive mechanical strength. A deeper analysis reveals that the chemical comes with several negative effects that are not reported, hence its usage damages the campaign for economic and ecological sustainable goals. Economically, research by Pethkar *et al*. (2020)reported that itis the most expensive retempering material, and increasing the dosage often extends mixing times due to the fluidity of the superplasticizer, leading to higher workability but lower consistency because of the wet environment it creates. As a result, such concrete may experience segregation and bleeding (Zeyad and Almalki, 2020). There is a knowledge gap regarding the appropriate superplasticizer, the optimal dosage, and mixing time in relation to consistency.

Besides, despite the importance of concrete retempering, there is relatively little research conducted, and no recommended standardized superplasticizer material, dosage, and procedure that align with international standards. In this study, a specified dosage (1kg per 50kg of cement) of a new superplasticizer, “Chryso Quad 622,” conforming to EN 934-2:2009 and approximately equivalent to ASTM C494 Type F, has been adopted for its compatibility with most cement types and for achieving a lower water-to-cement ratio, which results in an early increase in concrete's compressive strength. Therefore, the study aims to identify the necessary adjustments to the superplasticizer dosage to maintain concrete's workability and strength over 30-minute, 60-minute, 90-minute, and 120-minute periods. From this perspective, the information gained provides a foundation for quality control and serves as a template for stakeholders. Consequently, this will contribute to the body of knowledge in concrete production, research, and development. The study examines the impact of retempering variables on concrete properties and establishes thresholds for acceptable or adequate levels of these variables in concrete retempering. It also seeks to validate appropriate remedial measures by comparing the strength and durability of fresh mixed and retempered concrete. Understanding this characterization is vital for ensuring valuable information is retrieved for stakeholders, quality control, waste minimization, longevity lifecycle, and effective performance of structures (Mahzuz *et al*., 2025).

Materials and Methods of Testing

Materials

The experiment was conducted under controlled environmental conditions in the Department of Civil Engineering Laboratory at the University of Ibadan, and was monitored by the laboratory technologist. Locally sourced binder was grade 42.5N Type I CEM II Ordinary Portland Cement, OPC, conforming to Nigerian cement standards, NIS 444-1: 2003 and EN 197-1:2011 specifications. It is among the most commonly used cements in the construction industry, delivered in 50kg bags. A preliminary test conducted on cement in conformity with ASTM C150 is shown in Table 1. Portable water from the available source in the faculty was used for mixing and curing.

Table 1: Properties of Cement

Oxide composition	Cement (%)
SiO_2	20.68
Al_2O_3	6.12
Fe_2O_3	3.8
CaO	63.68
MgO	1.21
SO_3	2.68
Loss of Ignition	1.55
Specific gravity	3.15

The fine aggregate used was carefully selected sharp sand excavated from a non-salty riverbed, purchased from a sharp sand merchant market, and delivered to the laboratory in bags. Adequate attention was given to draining and drying excess moisture in the open air for 72 hours. The coarse mixed aggregate, with 20mm + 12.5mm diameters, consisted of irregularly shaped crushed rock stones conforming to ASTM C33, as shown in Table 2, to enhance strength and durability. A commonly used superplasticizer (Chryso Quad 622) in Lagos's construction industry, which conforms to EN 934-2 and is equivalent to ASTM C494 Type F, with a specific gravity of 1.11, was used for experimentation. This chemical, well-known among Lagos's construction industries, helps maintain workability and concrete strength while reducing the carbon footprint.

Test 2: Physical properties of Fine aggregate

Properties	Natural River Sand
Fineness modulus	2.81
Specific gravity	2.61
Silt content	1.49%
Water absorption	1.29%

Method

The expected concrete strength is 40 MPa (40 N/mm²), which is the characteristic strength at 28 days. The analyzed and designed target strength was 48.25 MPa. The free water content is 210kg/m³, with cement content at 525kg/m³, and aggregate contents of 636.5kg/m³ for fine aggregates and 1038.5kg/m³ for coarse aggregates, proportioned in a ratio of 1: 1.21: 1.98 (Cement: Fine: Coarse aggregate) at a 0.4 water-to-cement ratio. Fine aggregate was carefully selected to ensure it was free of contaminants such as salts or foreign constituents and was sieved according to parameters that conform to the work of Chokkalingam and Rajakannu (2018), as shown in Table 3a & 3b and Figure 1. The relationship between the mixed coarse aggregates is displayed in Figure 2, which aims to enhance concrete strength. Additionally, the fineness modulus was 3.02, the specific gravity was 2.81, and the coarse aggregates had a fineness modulus of 4.77 and a specific gravity of 2.72 (Kavathe and Kulkarni, 2015).

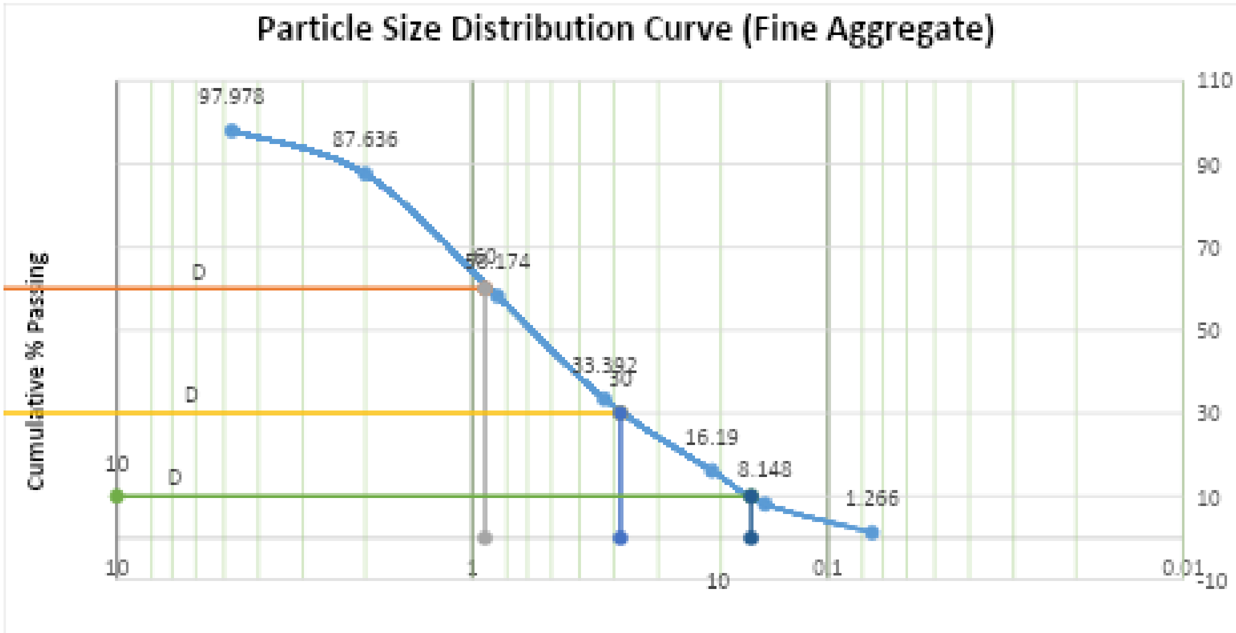
Table 3a: Sieve Analysis Value for Fine aggregate (River Sand), 20mm and 12.5mm Coarse Aggregate

Sieve designation (mm)	Cumulative % passing of River sand	Sieve designation	Cumulative % passing (12.5mm)	Sieve designation	Cumulative % passing (20mm)
4.75	97.978	16.00	0	40	0
2	87.636	12.50	2.83	20	46.17
0.85	58.174	10.00	69.33	10	97.53
0.425	33.392	4.75	97.67	4.75	100
0.212	16.19	0.00	0.00	0.00	0.00
0.15	8.148	0.00	0.00	0.00	0.00
0.075	1.266				
Pan	0				

Table 3b: Sieve Analysis Value for Fine Aggregate

Sieve Size (mm)	Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative % Retained	Cumulative % Passing
4.75	10.11	10.11	2.022	97.978
2	51.71	61.82	12.364	87.636
0.85	147.31	209.13	41.826	58.174
0.425	123.91	333.04	66.608	33.392
0.212	86.01	419.05	83.81	16.19
0.15	40.21	459.26	91.852	8.148
0.075	34.41	493.67	98.734	1.266
Pan	6.33	500.00	100.00	0

Fineness Modulus = Sum %Cumulative Retained/100 = 3.03



Results on Sieve Analysis (Fine Aggregate)

D60(mm)	= 0.9213	Cu=D60/D10=	5.6080
D30(mm)	= 0.3830	Cc =D30 =	0.9692
D10(mm)	= 0.1643		

Cc=Coefficient of Curvature = D30 = 0.9692

Cu=Coefficient of Uniformity = D60/D10
Cu = 5.6080

Mixing

This proportioning of natural aggregate concrete materials for the mixture was based on weight in kilograms, carried out in a controlled environment of the campus laboratory. Some trial mixing was done to ascertain the quantity of superplasticizer to be used for the mixing to achieve maximum strength. For all experiments, a fixed parameter – water-to-cement ratio, cement, fine and coarse aggregates, and1kg superplasticizer of the weight of cement mixed with a 0.4 water-to-cement ratio was used for the concrete production. Retempered concrete with superplasticizer, Ms, as tagged. The control concrete specimen, Mc, represents the concrete without retemperingand admixture of superplasticizer. The other specimens, and others, are retempered concrete with water, Mw; concrete retempered with water and cement, Mwc, shown in Table4.

Mixing of concrete materials in accordance with the proportioning was thoroughly done in a metal 0.045m³ concrete mixer for 3 minutes each for the samples and discharged into a nonabsorbent container for both control and retempered mixes following the retempering time.

Table4: Designation of experimental

	Name	Designation	Retempered Time			
1	Control Mix	Mc	Mc30mins	Mc60mins	Mc90mins	Mc120mins
2	Retempered concrete with water	Mw	Mw30	Mw60	Mw90	Mw120
3	Retempered concrete with water + cement	Mwc	Mwc30	Mwc60	Mwc90	Mwc120
4	Retempered concrete with superplasticizer	Ms	Ms30	Ms60	Ms90	Ms120

Test conducted on Fresh and Hardened Concrete

Fresh concrete workability tests were conducted using the slump cone apparatus for the test following the procedure outlined in ASTM C143-05a. while the compaction factor was carried out in accordance with BS EN 12350-4:2000 specification, and Vee-Bee consistency test in accordance with BS EN 12350-4:2000. Retempered of concrete after 30 minutes, 60 minutes, 90 minutes, and 120 minutes which indicate the minimum initial, and final setting time at a maintained ambient Temperature of 32 °C, which is the peak tropical-hot weather of the region in September, was observed.

An experimental test for hardened concrete portrayed the procedure methodically specified by the British Standard, BS EN 12390-3:2019, for destructive tests using the compressive cube test (BS EN 12390-1:2000), was followed. This was preceded by the preparation of specimens cast into (150 x 150 x 150)mm metal molds, which were cured for a few days before being subjected to a compressive load. The slit tensile test (BS EN 12390-6:2000 & ASTM C496-04)was cast in five layers, compacted well into plastic molds of (100 x 200) mm cylinders, and a flexural test in accordance with BS EN 12390-5:2009, cast in layers into 100 x 100 x 500 mm metal molds and compacted.

Water Curing was applied for 7, 14, and 28 days before crushing. In each sample case, the specimen was allowed a 1-day moisture-drain period, cubes were weighed, and finally subjected to crushing using a universal crushing machine, where it was subjected to a compression load.

Figure 1: Slump Test

Figure 2: Compaction Factor Test

Figure 3: Compressive Test of Cube

Figure 4: Flexural Test of Concrete

Result and Discussion

Results

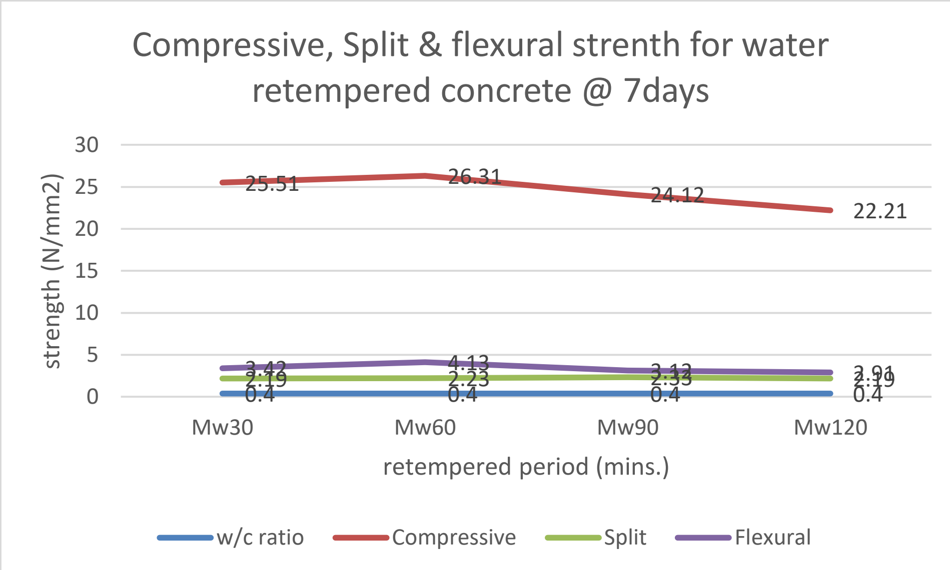


Fig 3: Variation Strength vs Retemper period for Retempered Concrete with Water (Mw) at 7days

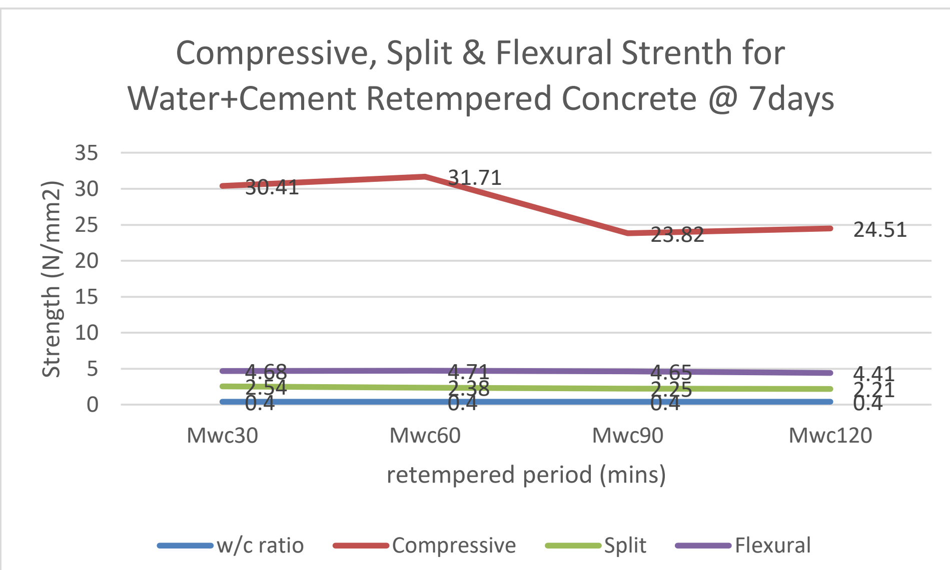


Fig 4: Variation Strength vs Retemper period for retempered concrete with water+cement (Mwc) at 7days

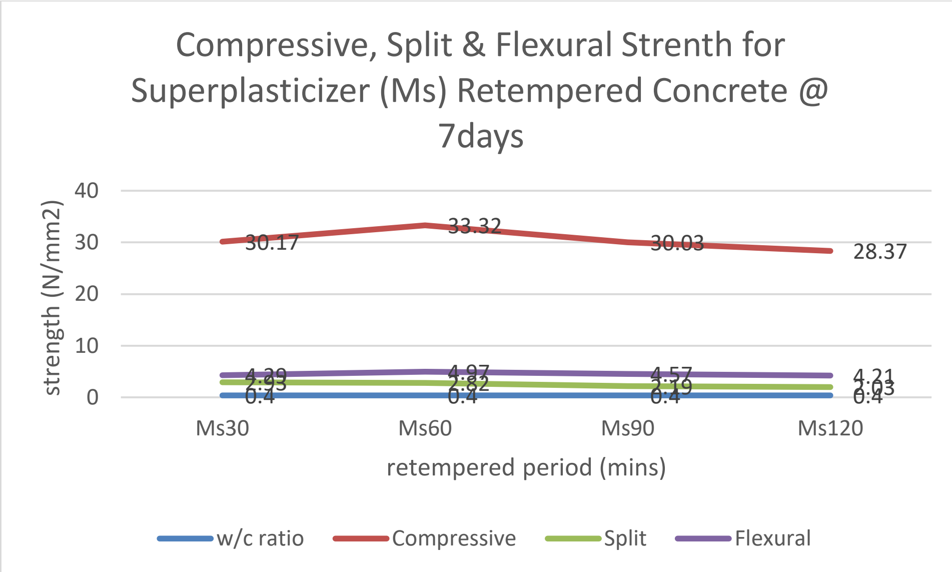


Fig 5: Variation Strength vs Retemper period for retempered concrete with superplasticizer (Ms) at 7days

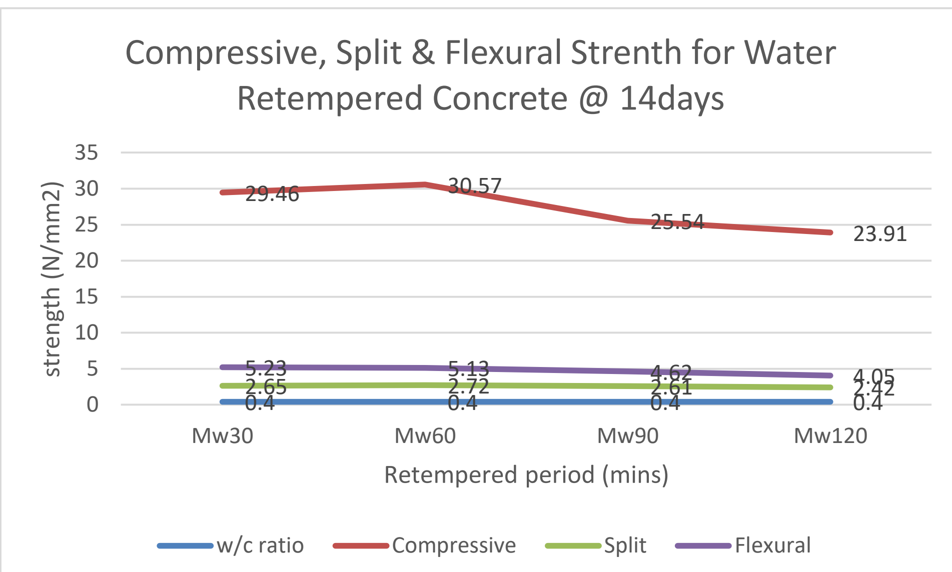


Fig 6: Variation Strength vs Retemper period for Retempered Concrete with Water (Mw) at 14days

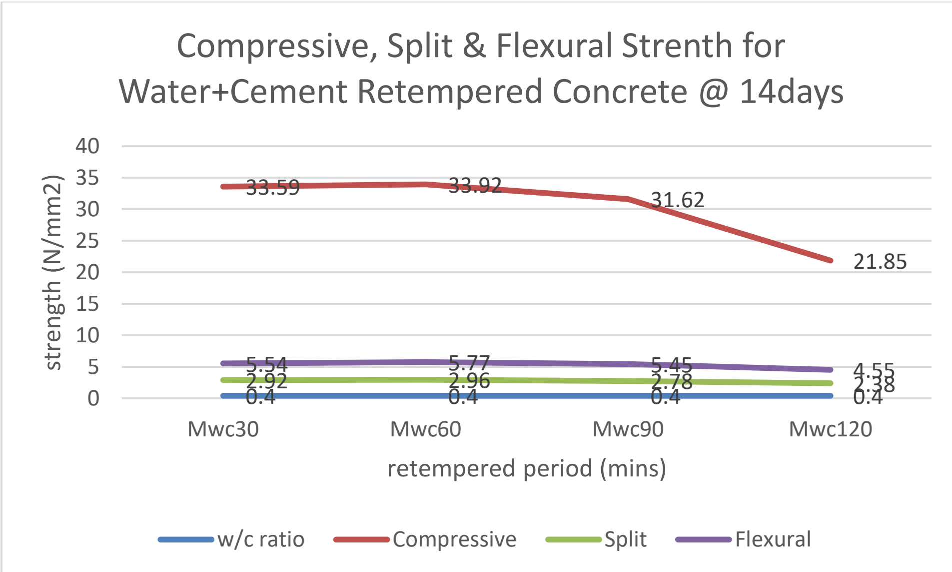


Fig 7: Variation Strength vs Retemper period for retempered concrete with water+cement (Mwc) at 14days

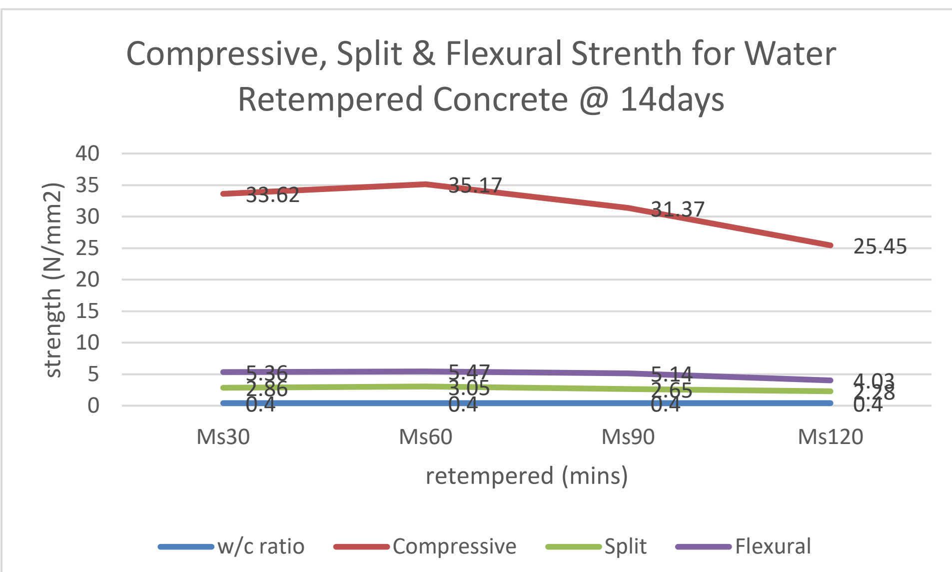


Fig 8: Variation Strength vs Retemper period for retempered concrete with superplasticizer (Ms) at 14days

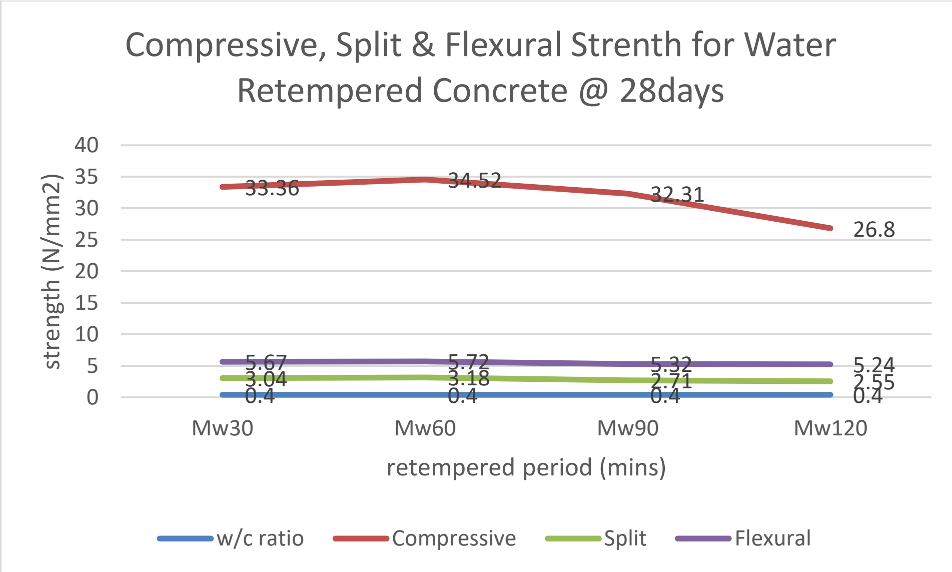


Fig 9: Variation Strength vs Retemper period for retempered concrete with water (Mw) at 28days

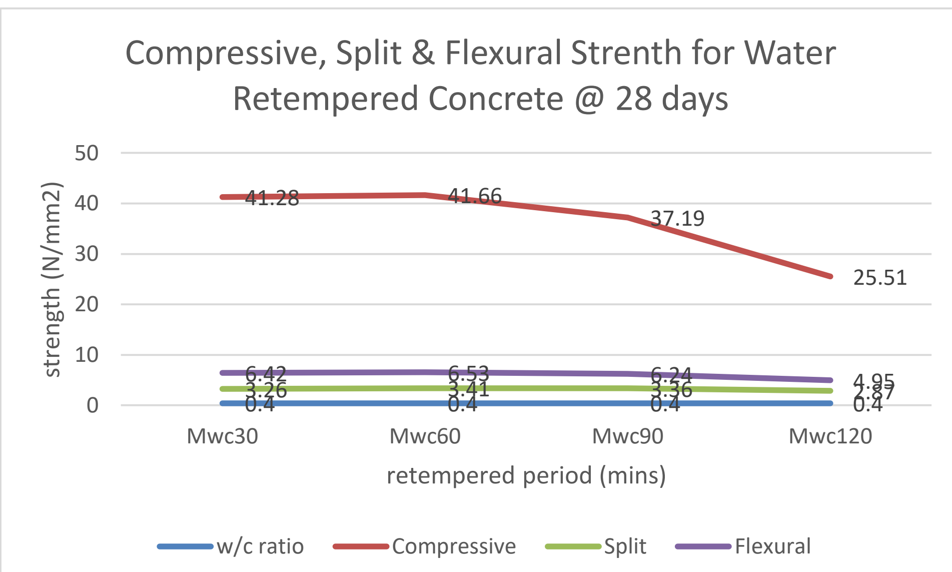


Fig 10: Variation Strength vs Retemper period for retempered concrete with water+cement(Mwc) at 28days

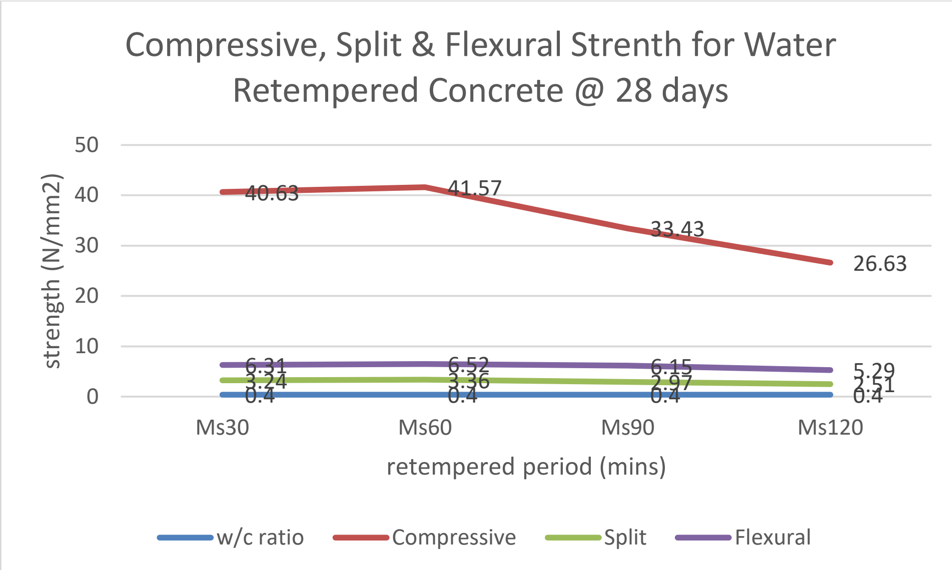


Fig 11: Variation Strength vs Retemper period for retempered concrete with superplasticizer (Ms) at 28days

The sample results of the control (Mc), retempered with water (Mw), water plus cement (Mwc), and superplasticizer (Ms), are displayed in Table 5. The compressive, split, and flexural strengths were examined at ages 7 days, 14 days, and 28 days using water curing alongside corresponding retempering periods at 30 minutes, 60 minutes, 90 minutes, and 120 minutes. The sequential representation of the collated data follows the trend of academic ethics and the submission patterns of some prolific authors.

As the experiment analysis depicts, the specimen of retempered concrete with superplasticizer increases consistently compared to the control concrete, followed by the retempered specimen with water plus cement, albeit those retempered with water or re-mixed decrease both in compressive and flexural strength. Across all specimens, it has been observed that the compressive and flexural strength of the retempered concrete dwindled from 90 minutes above in all the retempered materials used.

Besides, from the observation, retempering stiff concrete for maximum strength is advantageous up to the limit of 60 minutes, which is in compliance with Mane et *al*. (2022).The experiment reveals that raising re-mixing temperatures negatively affect the strength performance of concrete, which conform to the report of Zeyad & Almalki, (2020). Hence, heating, remixing, and water addition methods do not support the effective performance of stiff concrete. Also, it was observed that the workability test for 40 MPa concrete and the retempered concrete was lower to concrete retempered with water and re-mixed.

Correlation between the control specimen and the superplasticizer retempered

A statistical approach for across-examination of the control concrete samples and the superplasticized retempered concrete indicates that there is an association of Ms with the control, Mc. The experiment reveals that there is relatively significant performance of Ms with the conventional concrete. This is shown in the correlation in Table 6, reflects the correlation of Ms dosage with the slump increase but reduction in strength, further corroborate the study of Mahzuz *et al.*(2025).

Table 6: Correlation analysis between untampered, Control concrete (Mc), and the tempered with superplasticizer (Ms)

	Mc	*Ms*
Mc	1	0.999718085
Ms	0.999718085	1

Conclusions

The study assesses the characterization of the mechanical properties of a nascent superplasticizer-retempered concrete in comparison with the unretempered concrete with the intent of postulating a standard chemical admixture dosage for restoring delayed concrete, while maintaining the concrete performance and structural durability. The experiment was conducted, and the following conclusions were drawn:

i. From the point of view of the mechanical strength, retempering methods are optimum with Ms or Mwc; hence, both are adequate for retempering. Mwc is not economically and environmentally sustainable in terms of global carbon footprint.

ii. The conventional methods adopted on the job site with re-mix, waterhold, water addition, steam, etc, do not support the best practice, and should be discouraged. The fact remains that some of the reasons are the effect of these methods on strength, permeability properties of concrete, and the close monitoring demanded for their usage.

iii. From the standpoint of the superplasticizer's effectiveness to maintain the slump status of concrete, it is highly recommended to use Ms while discouraging the use of Mwc, Mw, etc on job-site.

iv. Also, the results of the study are testing methods and equipment specific, and different procedures may give varying outcomes. The research scope is delimited to concrete production, but aspects of concrete production, such as mortar, concrete masonry unit, etc, were not explored. Hence, the scalability of these findings to real-world applications should be considered for future studies.

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