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Effect of Mixing Time and Two-Stage Mixing Approach on the Fresh and Hardened Properties of Concrete

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Abstract
Concrete mixing is one of the key stages that directly affects the homogeneity of concrete constituents and, consequently, its fresh and hardened properties. The choice of mixing time and mixing method plays an important role in determining workability, compressive strength, and the overall quality of concrete. This study investigates the effect of mixing time and the Two-Stage Mixing Approach (TSMA) on selected fresh and hardened concrete properties. An experimental program was conducted using five concrete mixes made with the same materials and sources. Four mixes were prepared using conventional mixing times of 3, 6, 9, and 12 minutes, while one mix was prepared using TSMA. A total of 30 concrete cubes (150 × 150 × 150 mm) were cast, with six cubes for each mix; three specimens were tested at 7 days and the other three at 28 days. The study included slump, density, and compressive strength tests, in addition to laboratory testing of the constituent materials according to the relevant standards. The results showed a gradual reduction in slump and compressive strength with increasing mixing time in the conventional mixes. The 28-day compressive strength decreased from 41.70 MPa for the reference mix to 37.04 MPa when the mixing time increased to 12 minutes. The TSMA mix exhibited the highest workability, with a slump of 18 cm, but it showed lower compressive strength than the conventional mixes of similar proportions. Overall, the findings indicate that increasing mixing time beyond a certain limit may adversely affect some concrete properties, and improved workability does not necessarily lead to higher compressive strength.

Keywords: Concrete, Mixing time, Two-Stage Mixing Approach, Compressive strength, Workability, Density.

1. Introduction
Concrete is one of the most widely used construction materials worldwide because of the availability of its constituents, the ease of shaping, and the ability to achieve high strength when it is properly designed and executed. The quality of concrete depends strongly on control throughout all production stages, from selecting the materials and their proportions to mixing, transporting, placing, compaction, and curing. Among these stages, mixing is one of the most influential because it ensures uniform distribution of cement paste around the aggregate particles, which directly affects workability, strength, and durability [5,6].

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Mixing time is an important operational variable that affects the quality of both fresh and hardened concrete. Insufficient mixing can lead to poor homogeneity, cement balling, and non-uniform water distribution, which may reduce workability and cause scatter in compressive strength. On the other hand, excessive mixing may not improve the properties any further and can, in some cases, reduce workability because of increased internal friction or moisture loss during mixing, especially in hot and dry climates [3].

Despite the importance of this variable, many construction sites and batching plants still rely on estimated or fixed mixing times without a scientific assessment that matches the type of materials, mixer capacity, or project conditions. This practice may produce concrete with variable properties and non-uniform quality, which ultimately affects the performance of concrete structures.

In recent years, the Two-Stage Mixing Approach (TSMA) has been introduced as a development in mixing techniques. In this method, part of the water and cement is first mixed with the aggregate to form an initial coating layer around the particles, and the remaining materials are then added in a second stage. Several studies reported that this approach can improve the interfacial transition zone (ITZ) between the aggregate and the cement paste, reduce micro-voids, and enhance internal bonding in concrete [11,10].

Other studies also indicated that TSMA may improve compressive strength and durability, particularly in mixes containing recycled aggregates or materials with high absorption, due to better aggregate coating and lower internal porosity [11,9]. However, most previous research focused on recycled aggregate concrete or special applications, while studies addressing the effect of TSMA on conventional concrete and its comparison with different mixing times remain limited, particularly under local conditions.

Accordingly, this study aims to evaluate the effect of varying mixing time and to examine the efficiency of TSMA on selected fresh and hardened properties of concrete through an experimental program based on slump and compressive strength tests at different ages. The results are intended to help identify an appropriate mixing time and assess whether TSMA can improve the quality of concrete and construction efficiency in practical applications.

2. Materials and Methods

This study used common materials employed in conventional concrete production. All materials were carefully selected and laboratory-tested to verify their compliance with the relevant standards and their suitability for the experimental program. The materials included cement, fine aggregate, coarse aggregate, and mixing water. The same sources of materials

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were used in all mixes to keep the properties as constant as possible and reduce the influence of uncontrolled variables.

2.1 Cement

Ordinary Portland Cement (Beni Suef 42.5 N), imported from Egypt and manufactured in Beni Suef Governorate, was used in this study. This cement type is suitable for ordinary concrete works due to its appropriate physical and mechanical properties.

The same cement type was used in all concrete mixes to ensure that one of the most important influencing variables remained constant, so that the differences in the results would be mainly due to the mixing time and mixing method under investigation, rather than a change in binder type.

Laboratory tests were conducted to determine the physical and mechanical properties of the cement used, and the results showed compliance with the relevant standards. The main test results are summarized in Table 1.

Table 1: Physical and mechanical properties of the cement used

Test	Result	Specification
Cement fineness	8.57%	ASTM C204
Initial setting time	120 min	ASTM C191
Final setting time	210 min	ASTM C191
Compressive strength at 3 days	23.03 N/mm²	ASTM C150
Compressive strength at 28 days	44.87 N/mm²	ASTM C150

These results indicate that the cement had suitable fineness, an appropriate setting time for mixing and casting works, and good compressive strength at both early and later ages, making it suitable for the experimental program of this study.

2.2 Fine Aggregate

Clean natural sand supplied from Shat Al-Badin was used as the fine aggregate. The sand was tested to determine its physical properties, particle grading, and cleanliness according to the relevant standards. The tests included specific gravity and absorption according to ASTM C128, the sand equivalent test according to ASTM D2419, and sieve analysis according to ASTM C136. The results showed that the sand had good cleanliness and suitable grading, making it appropriate for concrete production.

Table 2: Physical properties of the fine aggregate

Test	Specification	Result
Specific gravity	ASTM C128	2.711
Absorption	ASTM C128	0.79%
Sand equivalent	ASTM D2419	76.8%
Fineness modulus	ASTM C136	—

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The results indicate that the fine aggregate had suitable cleanliness and grading for use in the concrete mixes.

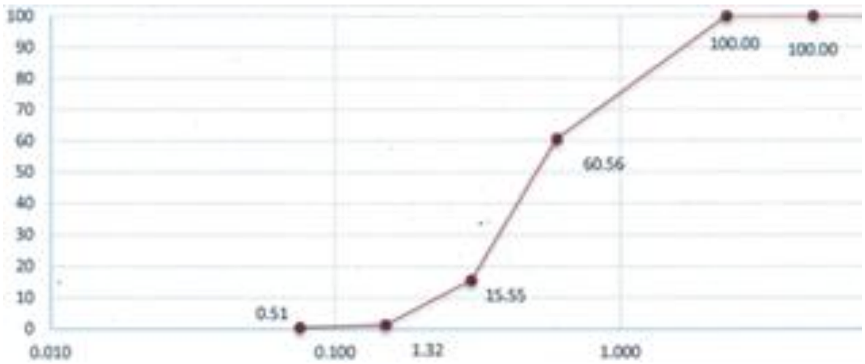

Figure 1: shows the particle size distribution curve of fine aggregates

2.3 Coarse Aggregate

Natural coarse aggregate was supplied from a crusher in the Al-Jahishiyah area near Al-Abyar. Two nominal sizes, 5–10 mm and 10–20 mm, were used to achieve better particle grading, improve packing density, and reduce internal voids. A set of laboratory tests was conducted to evaluate the mechanical and physical properties of each coarse aggregate size, including aggregate crushing value, aggregate impact value, Los Angeles abrasion resistance, magnesium sulfate soundness, specific gravity, absorption, percentage passing the No. 200 sieve, sieve analysis, flakiness index, and chloride and sulfate contents.

Table 3: Mechanical and physical properties of the coarse aggregate

Test	Specification	Result (10–20 mm)	Result(5–10 mm)
Aggregate crushing value (ACV)	BS 812 Part 110	18.48%	-
Aggregate impact value (AIV)	BS 812 Part 112	15.54%	-
Los Angeles abrasion	ASTM C131 / C535	27.41%	29.50%
Magnesium sulfate soundness	ASTM C88	3.87%	5.47%
Specific gravity	ASTM C127	2.535	2.528
Absorption	ASTM C127	1.63%	1.95%
Passing No. 200 sieve	ASTM C117	0.92%	1.01%
Flakiness index	BS 812-105.1	10.24%	16.19%
Chloride content (Cl)	BS 1377: Part 3	0.00221%	0.00287%
Sulfate content (SO4)	BS 1377: Part 3	0.00715%	0.00813%

The results indicate that both aggregate sizes had adequate strength, low impurity levels, and suitable physical characteristics, making them appropriate for the concrete mixes used in this study.

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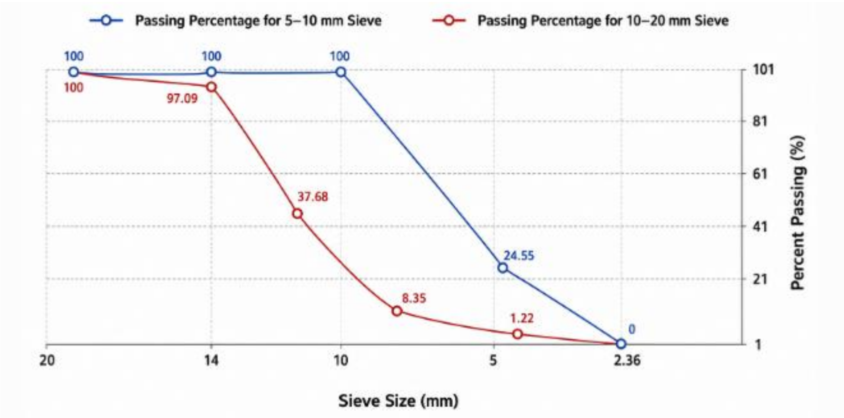

Figure 2: shows the particle size distribution curve of coarse aggregates

2.4 Mixing Water

Potable water was used in all concrete mixes. The water was free from impurities, oils, and harmful salts to avoid any negative effect on setting time, concrete strength, or durability, and to comply with the general requirements for concrete mixing water specified in standard specifications.

3. Mix Design, Batching, and Specimen Preparation

The concrete mixes were designed to evaluate the effect of mixing time and TSMA on selected fresh and hardened properties while keeping most other variables constant so that the observed results would mainly be attributed to the variables under study. Five concrete mixes were prepared. The first mix was considered the reference mix, while the remaining mixes were used to study the effect of changing the mixing time and TSMA. The same type and source of materials were used in all mixes, and the water-cement ratio was kept constant in most of the mixes. The experimental program included four different conventional mixing durations, in addition to one mix prepared using TSMA, for comparison with the conventional mixing method at a similar total mixing time. For each mix, six concrete cubes measuring 150 × 150 × 150 mm were cast, three for compressive strength testing at 7 days and three at 28 days, giving a total of 30 concrete cubes.

3.1 Mix Proportions

Table 4: Details of the concrete mixes used in the study

Mix ID	Mix proportion	w/c ratio	Mixing time	Mixing method
M1	1 : 1.4 : 2.5	0.465	3 min	Conventional
M2	1 : 1.4 : 2.5	0.465	6 min	Conventional
M3	1 : 1.4 : 2.5	0.465	9 min	Conventional
M4	1 : 1.4 : 2.5	0.465	12 min	Conventional
M5	1 : 1.4 : 2.5	0.465	3min	Two-Stage Mixing Approach

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The mixes were produced using a mechanical mixer manufactured by Al-Rawafed (Al-Nahla type). For the conventional mixes, the dry materials were added first, followed by the gradual addition of water during mixing. For the TSMA mix (M5), the mixing process was divided into two stages. In the first stage, part of the cement and water was added to the aggregate and mixed for about 1.5 minutes to form an initial paste coating around the aggregate particles. Then, the remaining cement and water were gradually added, and mixing continued for about 2 additional minutes, giving a total mixing time of approximately 3.5 minutes. The same mixing, casting, and curing conditions were maintained as much as possible for all mixes in order to ensure a reliable comparison between the results.

After mixing, the slump test was performed immediately to assess the workability of the fresh concrete according to the relevant standard. The concrete was then cast into 150 × 150 × 150 mm cube molds in three layers, with each layer properly compacted to reduce air voids and achieve uniform specimens. After 24 hours, the molds were removed and the specimens were transferred to water curing tanks until testing at 7 and 28 days.

4. Results and Discussion

4.1 Slump Test

The slump test was carried out immediately after mixing for all concrete mixes in order to evaluate the workability of the fresh concrete. The results showed a clear influence of both mixing time and mixing method on concrete workability. A gradual decrease in slump value was observed with increasing mixing time in the conventional mixes, where the slump decreased from 13 cm in the reference mix (M1) to 9.5 cm in the longest-mixed sample (M4). This decrease may be attributed to increased internal homogeneity and higher friction between mix constituents during extended mixing, as well as possible moisture loss during the mixing process. In contrast, the TSMA mix (M5) recorded the highest slump value, 18 cm, indicating a noticeable improvement in workability compared with the conventional mixes. This may be due to improved distribution of cement paste around the aggregate particles and better coating of the aggregate, which reduced water absorption by the aggregate.

Table 5: Slump results for the concrete mixes

Mix ID	Slump
M1	13 cm
M2	12 cm
M3	10.7 cm
M4	9.5 cm
M5	18 cm

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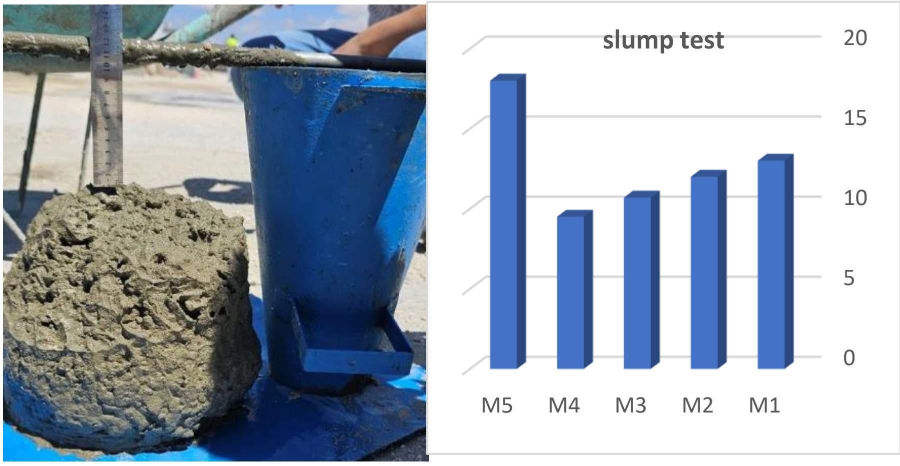

Figure 3: Concrete slump test

4.2 Hardened Concrete Density

The density of hardened concrete was calculated from the weight and dimensions of the cubes after curing in order to evaluate the effect of mixing time and mixing method on the density of the produced concrete. The results showed a noticeable variation in concrete density with changes in mixing time and mixing method. In the conventional mixes, density decreased gradually as mixing time increased, from 2423.703 kg/m³ in the reference mix (M1) to 2352.790 kg/m³ in mix M4. The TSMA mix (M5) recorded a density of 2356.346 kg/m³, which was close to the density of the longest conventional mixing time, indicating that the mixing method had a clear effect on the distribution of constituents and internal voids. The gradual decrease in density with increasing mixing time may be related to moisture loss, improved distribution of the cement paste within the mix, and differences in compaction and workability among the mixes.

Table 6: Hardened concrete density for each mix

Mix ID	**Density (kg/m³)**
M1	2423.703
M2	2410.864
M3	2398.419
M4	2352.790
M5	2356.346

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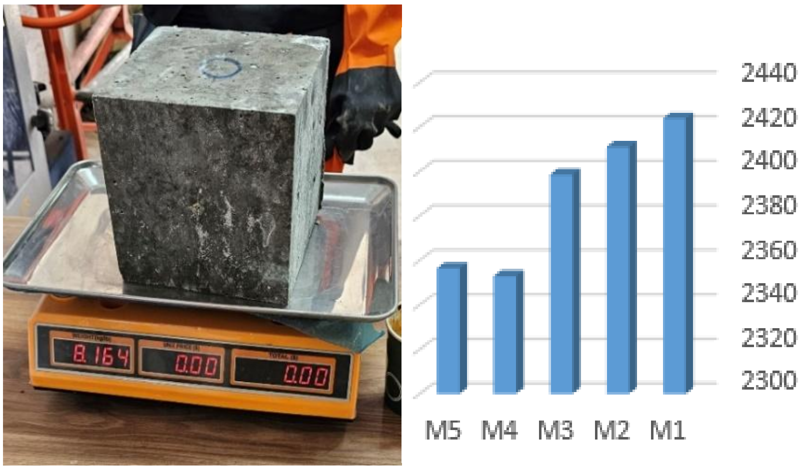

Figure 4: Hardened Concrete Density

4.3 Compressive Strength at 7 and 28 Days

The compressive strength of the concrete specimens was measured using 150 × 150 × 150 mm cubes at both 7 and 28 days in order to evaluate the influence of mixing time and mixing method on the mechanical properties of hardened concrete. The results showed that, in the conventional mixes, compressive strength decreased gradually as mixing time increased. At 7 days, the reference mix (M1) recorded the highest strength among the mixes with similar proportions, reaching 34.14 MPa, while the strength decreased to 32.39 MPa in mix M4 with the longest mixing time. At 28 days, the same trend was observed, where the reference mix (M1) achieved 41.70 MPa, whereas the strength decreased to 37.04 MPa in mix M4. The TSMA mix (M5) recorded 30.50 MPa at 7 days and 33.27 MPa at 28 days, both of which were lower than the conventional mixes with the same proportions. This may be attributed to the influence of the water and cement distribution pattern during the mixing stages on the internal structure of concrete and on the rate of strength development. Overall, the results indicate that increasing mixing time beyond a certain limit may not improve compressive strength, but may instead lead to a gradual reduction in strength due to changes in mix homogeneity and moisture loss during prolonged mixing.

Table 7: compressive strength results

Mix ID	Compressive strength (MPa) 7day	Compressive strength (MPa) 28 days
M1	34.14	41.70
M2	34.01	39.92
M3	33.34	38.98
M4	32.39	37.04
M5	30.50	33.27

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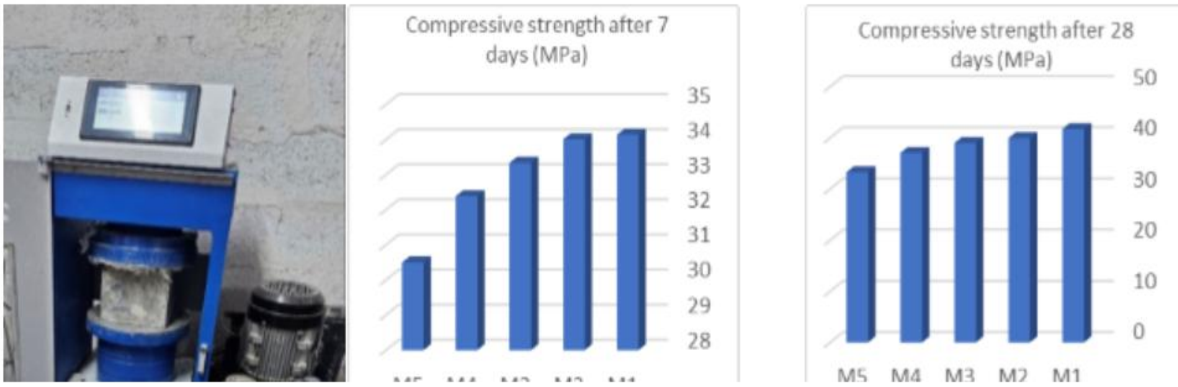

Figure 5: Pressure testing machine and results

5. Conclusions

This study investigated the effect of mixing time and TSMA on selected fresh and hardened properties of concrete through an experimental program that included several concrete mixes with different mixing durations while keeping most mix variables constant.

Based on the experimental results, the following conclusions can be drawn:

1. The slump test showed a gradual decrease in workability with increasing mixing time in the conventional mixes.

2. The TSMA mix achieved the highest slump value, indicating a clear improvement in workability and mix homogeneity.

3. The 7-day and 28-day compressive strength results showed a gradual reduction in strength with longer mixing times, compared with the reference mix.

4. The TSMA mix did not improve compressive strength relative to the conventional mixes with the same proportions, although it improved workability.

5. The results indicate that increasing mixing time beyond a certain limit may negatively affect some concrete properties; therefore, selecting an appropriate mixing time is an important factor in improving the quality of produced concrete.

6. Further research is recommended to investigate TSMA with different mix proportions, other aggregate types, and chemical admixtures, as well as its effect on long-term durability properties.

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