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Research Article

Effect of Internal Curing with Super-absorbent Polymer on the Surface Hardness of Normal Strength Concrete

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Abstract

The traditional curing methods for concrete might be difficult for reinforced concrete tall building and some dangerous parts, such as in a tall building. Thus, using internal curing methods with different agents which exposed to be a perfect method to reduce risk for labors and reduce the difficulty of curing. Even though, the internal curing has a positive impact on the mechanical properties, such as compressive and tensile strengths, the hardness of the concrete cured with internal curing agents encounter an issue due to leaving voids in concrete. This investigation highlights the influence of super absorbent polymer on the surface hardness and void content in the normal strength concrete. As a result, it was found that the surface hardness of the concrete improves up to 19% due to inclusion of 0.08% of super absorbent polymer to cement ratio. However, the velocity of passing wave through concrete via ultra-pulse velocity device was reduced due to increasing the length of path of the wave from separating voids in the concrete.

Keywords: Moisture Content, Self-concrete Curing, Super-absorbent Polymer, Surface Hardness, Ultra Pulse Velocity.

Introduction

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing [1]. Basing on this definition, the criteria must be considered for curing of concrete are moisture content in concrete, temperature inside concrete, the time provided to mature the strength of concrete starting from placing concrete and finishing around 15 years [2]. In addition, the temperature and relative humidity of the surrounding atmosphere [3].

Proper curing has a strong effect on the mechanical properties of hardened concrete, such as strength and non-mechanical properties for instance durability, abrasion resistance, resistance to freezing and thawing [1].

Moisture Content in Concrete

Curing is designed primarily to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength [3]. Thus, properly cured concrete has an adequate amount of moisture for continued hydration and development of strength [4]. However, the curing of concrete is either external or internal, the curing water penetrate at the depth near the surface of concrete due to present voids on the surface of concrete from the mold surface and lubricant oils [5].

Concrete Curing Temperature

The hydration of cement influenced by the ambient temperature of concrete especially at the early age of the concrete, which improved the compressive strength up to 18% [6-8]. However, the compressive strength was negatively influenced with high curing temperature after 28 days [7,9]. The best way for controlling the effect of curing temperature on the compressive strength of concrete was gradualling increase in temperature with the age of concrete [6].

Curing Period

The period of time that concrete should be protected from freezing, abnormally high temperatures, and against loss of moisture depends upon a number of factors, for instance; the type of cementing materials used; mixture proportions; required strength; size and shape of the concrete member; ambient weather, and future exposure conditions [1-3, 5].

The often specified seven-days curing commonly corresponds to approximately 70 percent of the specified compressive strengths. Longer time may be needed for different material combinations and lower curing temperature. ACI committee 308 recommended the minimum curing period based on the type of portland cement, as shown in Table 1.To control moisture loses could require that several different procedure be initiated in sequence (Initial, Intermediate, and Final) curing.

Table 1. Minimum curing periods based on the type of Portland cement [4]

Type of Portland cement	Minimum curing periods, days
Type I	7
Type II	10
Type III	3
Type IV	14
Type V	14

Initial Curing

Initial cure concrete immediately after placement and it can be via two processes (fogging and evaporation retardant) [10]. However, initial curing measuresmay need to be continued or repeated until finishing is complete [4].

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Initial curing measures should be applied immediately after the bleed water sheen has disappeared, because the concrete surface is protected against drying as long as it is covered with bleed water [4]. If the finishing begins immediately after the disapperance of the bleed water, it is unnecessary to apply initial curing measures. Excess water from a fog spray or an evaporation reducer should be removed or allowed to evaporate before finishing the surface [8].

Intermediate Curing

Intermediate curing measures are required whenever the concrete surface has been finished before the concrete has reached final set [4]. The methods could be used for intermediate curing are evaporation reducers, foging, and curing compounds. In addition, the curing compounds can be an effective intermediate curing method or precursor to other final curing methods, such as water curing or protective coverings, minimizing water loss during the last stages of the setting process [4].

Final Curing

The concrete surface should be protected against moisture loss immediately following the finisher or finishing machine. Significant surface-drying can occure measures are delayed until the entire slab is finished because the peak rate of evaporation from a concrete surface often occurs immediately after the last pass of finishing tools.

When the conclusion of finishing operations coincides with the time of finish set, as indicated in Figure 1. The final curing is applied at exactly the right time to reduce the peak rate of moisture loss [4].

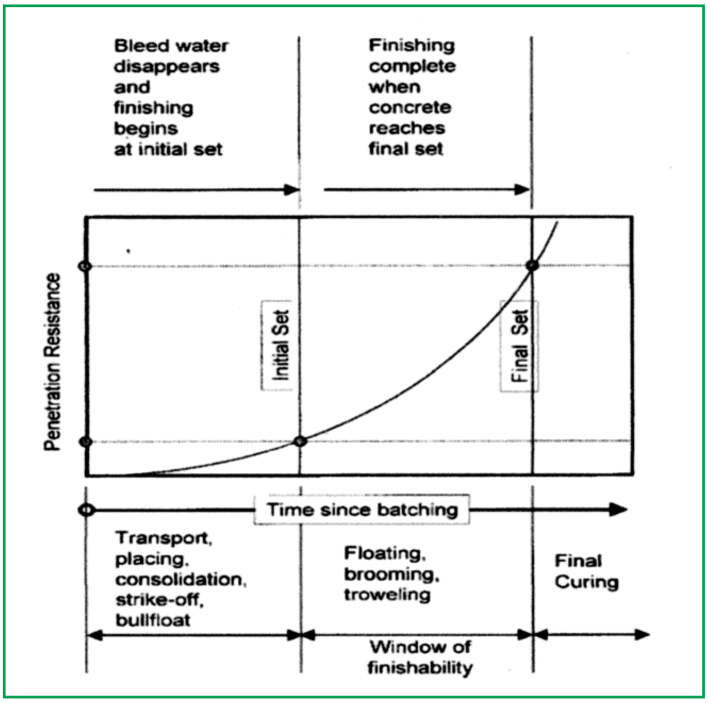

Figure 1. Curing stages in concrete [4]

Literature Review

Self-curing Concrete

Various autonomic and autonomous healing methods can terminate concrete crevices. Various crux self-healing mechanisms restore the content of concrete inside the cracing area, including further hydration of internal tricalcium silicates, polyurea formation from isocyanate reaction with entrapped ambient humidity and clay swelling which permits the nanoscale calcium carboante blokages of slits. Cyclization through cyanoacrylate and mercaptoethanol accelerates the process of crack repair. Accessory materials such as indroduced crystalline admixtures, powders, polymers, fibers, resins or capsules were used to maintain a self-healing agent in the crevice zone until it was cracked. With the aid of an organic concrete matrix, healants are embedded in tandem. For sundry uses, equipment such as glass, micro-bacteria, carbohydrates, swollen micro-gels or enzymes are introduced into concrete which effect collaborative, environmental or living repair systems. The self-healing system, though high-eficiency and durabale, must battle with more realistic constraints while the material is practiced commercially.

Concrete is an ideal construction material that has low cost, formidable compressive strength, prevents rusting when reinforced, and can be crafted into a variety of shapes and sizes [11]. Nevertheless, cracks are an inherent feature of concrete products that enable it to resist the movement imposed by the atmosphere, foundation variations, or natural disasters. These crevices gain access to a hostile atmosphere that may cause reinforcement rust, decay the concrete matrix and mar the stiffness and the durability of concrete details [12]. Inelligently conceived self-healing materials can challenge detriorative mechanisms and extend the wear-interval of congrete over a standard serviceable lifetime of eighty to one hundred years [13].

Mechanisms and Benefits of Self-Curing in Concrete

The addition of lightweight aggregates (LWAs) or superabsorbent hydrogel particles has been tested most frequently to increase the amount of retained internal water in cementitious composites [14]. For the most commonly-performed carbonate reactions between Ca^{2+} and (bi)carbonate anions, the dissolution of the latter is the rate-determining step in the interfacial charge transfer, and its equilibrium concentration in the paste pore solution determines if full consumption of the initially added free Ca^{2+} was possible.

Increasing the quantity of internal water in the concrete network permits both the internal re-wetting of hardening concrete and enhanced resistivity against permeation of aggressive ions and gases for improved carbonation, carbonation strengthening, and/or enhanced crack shutting. The enthalpy of water replacing in the porotic capillary network then fuels autogenous healing the width of micro- and fine-cracks by filling up to 50% of the crack cracks. Adsorbed internal water equaling 165 parts per 1000 inactive elements for capillary condensation corresponds to a distance of 1 mm, enough to bridge capillary length microcracks.

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Reduce the water evaporation rate, enhance the carbonation, and/or hydrocarbonate the binder completely by increasing the dissolved Ca/CO_3 ions to reform hydration products. Engage autogenic healing of internal cracks and separate aggregates from the mortar matrix during sustained loading by internal water storage/releasing capabilities.

Concrete is the most widely-produced and utilized construction material in the world due to its low-cost, versatility and compressive strength [15]. Its key hydration product, calcium silicate hydrate (C-S-H) gel, gradually fills the microscale voids between cement particles, hardening into a solid matrix over time. But permeable materials like concrete inherently lack the capability to fully self-cure, so their long-term durability and sustainability are gradually compromised. Most common maintenance activities aim to maintain or restore the target properties of materials by removing the degraded or damaged portions and filling the voids with new materials. In contrast to typical materials which explicitly aim to heal by creating new bondlines, the multi-scale composites are designed to indirectly cancel the negative impacts of developing heterogeneous trial microstructures by blending in active self-healing phases. Two main mechanisms have been explored to enhance the self-curing capabilities of concrete materials [13]. Both principles have been translated to practice inside cementitious composites to resistor to early-age cracking and engage autogenic.

Internal Curing Agents

Another study with the same internal curing agents had high strength and low carbonation ratio. Thus, it was understood that small crystallite size of internal curing agent has an effect on decreasing the carbonation of concrete and increasing physical and mechanical properties. The internal curing agents that have performed in relevant studies are relatively costly but have self-crystallification properties such as high temperature stabilizer, aerogel, metal organic gels. Most of these internal curing agents vary on a broad line and they contain a certain amount of macro pores, connected pores in the structure of mesopores and micropores. Therefore, the internal curing agents commonly reduce the effective strength and promote the restriction of daily volume stability at the same rate and they need longer process of maintenance.

Regarding the internal curing agents entirely crystallized after the procedure and their volume stabilized, they are less susceptible to the temperature variance and have fewer porosities and pore radius compared to inner walls and they show more inner curing capacity and therefore they enhance the durability and mechanical performance of the high performance concretes.

In recent years, a large number of experiments and studies have been made to make the concrete more durable and sustainable [16]. Researchers also use internal curing agents to the mixture to optimize the required mechanical and durability properties of the concrete. Depending on the material used to exhibit internal curing properties, these agents are classified as super absorptive polymers, super elastic rubber particles, crystalline compounds or

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prewetted light weight aggregates with lower surface moisture content than normal aggregates [17]. A study that conducted with a photo scanning electron microscope and micro analysis to determine the capability of the mixtures with crystalline internal curing agents in order to decrease carbonation of the recycled aggregate concretes was detected by Nair et al. The mixtures where the desorption temperature of the curing agents as an indicator of self-crystallification properties were low and with smaller crystallite size were found to exhibit low carbonation depth, high compressive strength and E-modulus [18].

Super-absorbent Polymers

The use of Super-absorbent Polymers (SAPs) in concrete production goes against the common logic of avoiding water excess during its mixing, which is particularly important in mass concrete works under severe environment; however, within the so-called self-curing approach, SAPs rise an opposite philosophy believing that a continuous moisture guarantee realized through SAPs balance the damaging conditions and cracks [11]. Even though it exists some scepticism about this type of curing in some extremes cases, it has to be underlined that attention in the production and application of SAPs increases more and more, and they become also responsive to the production of water soluble salts improving drastically the concrete repellant capacity. A safe and guaranteed concrete life is paramount, especially in the production of massive building construction or infrastructures, since achieving a satisfactory serviceability of the concrete through its durability under severe environment means the deferral or at least the drastic reduction of maintenance.

SAPs have been employed in concrete technology since the mid-1990s, as internal curing agents specifically used to reduce the amount of the internal water sitting in the most internal region of the matrix too distant from the contact with the further recharging, and thus unable to be involved in the progresses of the hydration stepping. SAPs have also the unique skill to absorb large amount of water, limiting the free one to be evaporated on the matrix, determining shrinkages and cracks. Other mentioned positive effects regard the possibility to reach and maintain a soften and plastic matrix with a better performance, rapid hardening and volumetrically stable. Furthermore, for the concrete, possessing a stiffness and load-bearing actions once the set is reached, means achieving a reduced permeability due to the microporosity reduction [19].

Sustainable construction involves the development of materials that are able to promote durability and service life. Among these materials, self-curing concrete using superabsorbent polymers (SAPs) has been identified as an innovative solution. These polymers have a unique character: when in contact with water they absorb many times their weight and turn it into a solid or semi-solid state, thus increasing their volume, known as swelling. This results in a decrease in their porosity and an improvement in their surface energy and mechanical properties [20].

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Research Significant

It was found a good impact of using internal curing on the mechanical properties of normal strength concrete, but these agents left the voids in the concrete which may reduce the hardness roughly and increase voids in the concrete. However, the using internal curing could make production of concrete in an easy way especially in the construction of tall and high-rise building.

Experimental Program

Materials

The crushed stone pebble with maximum size 9.52 mm to be greater than the size of polymer after water absorption before using in the concrete mix and pulverized stone fine aggregate were used with the properties as illustrated in Table 2. Besides, the properties of the macro size Super-Absorbent Polymer were tabulated in Table 3.The ordinary Portland cement Type I was used in this investigation and their physical properties was tabulated in Table 4 [21].

Table 2. Properties of aggregates

Screen Analysis		
Sieve size, mm	**Pebbles, pass%**	**Sand, pass%**
12.5	100	-
9.5	100	100
4.75	27.59	100
2.36	2.65	100
1.18	0.92	100
0.6	-	90.88
0.3	-	45.39
0.15	-	10.53
0.075	-	3.1
Compacted bulk density, kg/m^3	1660	1500

Table 3. Properties of super-absorbent polymer

Properties	Value
Size before saturation with water, mm	2.0
Size after saturation with water, mm	7.0
Water absorption, g per one gram of SAP	37.5

Table 4. Physical properties of the ordinary Portland cement

Properties	Value
Compressive strength, at 7 days, MPa	24
Normal Consistency, %	33
Setting time, minutes	
Initial	130
Final	250

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Preparation of the Specimens

To find the influence of Super-Absorbent Polymer on the properties of normal strength concrete, such as surface hardness, compressive strength, density, velocity of passing wave from UPV via concrete.

Three control samples were prepared for obtaining different grades of concrete including 20, 30, and 40 MPa and denoted as A0, B0, and C0. Moreover, the amount of super-absorbent polymer varied from 0.08%, 0.16%, and 0.24%, as shown in Figure 2.The program for this investigation is explained in Table 5.

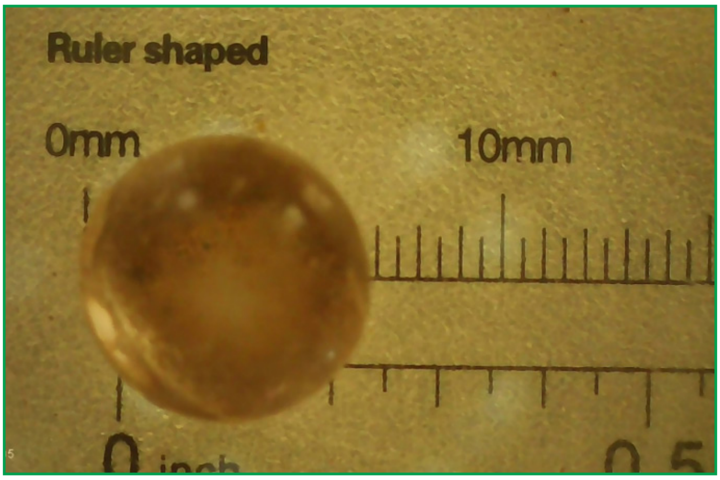

Figure 2. Super-absorbent polymer after absorpting water

Table 5. Mix proportions of different grades of concrete with varying amount of super-absorbent polymer

Code	Mix proportions W:C:S:G	SAP/C , %
A0, A1, A2, A3	0.66:1:2.106:2.32	0.08, 0.16, 0.24
B0, B1, B2, B3	0.56:1:1.6:1.93	
C0, C1, C2, C3	0.49:1:1.23:1.61	

To investigate the effect of Super-absorbent polymer on the surface hardness of different grades of normal strength concrete, the number of concrete cubes with side length 100 mm, which considered for testing compression test, was 72 cubes for 7 and 28 days of the ages of concrete. In addition, the side length of concrete cubes for testing ultra-pulse velocity and Schmidt rebound hammer test was 200 mm basing on the limitation for the concrete samples from British standard, and the number of samples was 36 which used for both 7, and 28 days age of concrete.

Process of Mixing

The process of mixing was started with adding pebbles and crushed fine aggregate to the pan mixer for 1 minute. Then, half of the required amount of water and mixing was continued for 30 seconds. Next, the total amont of cement was added during 30 seconds and the remain part of water was added to the

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pan mixer and mixing was continued for 30 seconds. At this time, the Super-Absorbent Polymer was added to the uniform concrete mix and the process was continued for 30 seconds extra. Finally, the concrete was cast and left in the laboratory temperature and humidity until the time of test for cube compressive strength with the side length of 100 mm, surface hardness [22], and UPV test conducted on the concrete sample size based on British Standard [23,24] at 7 and 28 days age of concrete.

Tests of the Mechanical and Some of Non-Mechanical Properties of Cement Concrete Incorporating SAP

Compressive strength

The main mechanical property of concrete incorporating super-absorbent polymers is the compressive strength which influences directly by curing conditions and the presence of the acid materials. As per British Standard, a total of 6 concrete cubes were tested to enhance reliability of adding SAP in the normal strength concrete. Three of them were tested at 7 days and remain concrete cubes were tested at 28 days [25].

Density of hardened cement concrete

The density of concrete incorporating SAP was indicated and influenced due to left the sphere shape of voids in the concrete and it was determined before the compression test of the same cube sample [26].

Schmidt rebound hammer test

The surface hardness of concrete directly influenced with incorporating super-absorbent polymers in concrete, thus the percentage of voids in the hardened concrete as a result. Therefore, the surface hardness of the concrete was examined with manual rebound Schmidt hammer test, as shown Figure 3. In addition, the size of the sample of concrete cubes with side length 200 mm was selected with British Standards [23,24].

(a) (b)

Figure 3. (a) Rebound Schmidt hammer and (b) Ultra-Pulse Velocity tests on concrete contain Super-Absorbent Polymer

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Ultra-pulse velocity test

The void in concrete includes super-absorbent polymers were tested via Ultra-Pulse Velocity test. In addition, the minimum lateral dimension was determined for 54 kHz transducer frequency as 83 mm and it was adopted 200 mm, as shown in Figure 3 [24].

Moisture content test

The value of Schmidt rebound hammer and the velocity of ultra-pulse velocity test were influenced with the moisture content in the tested concrete [22-24]. Therefore, the moisture content was recorded in the concrete cubes before ultra-pulse velocity and Schmidt rebound hammer tests at the different ages 7 and 28 days, as shown in Figure 4 [27-29].

Results and Discussion

To demonstrate the effect of internal curing on the surface hardness and the void content in the normal strength concrete, Schmidt rebound hammer test and ultra-pulse velocity test were conducted with the consideration of moisture content in the concrete before testing. In addition, the density of hardened concrete was measured in each stage of this investigation [26].

Effect of super-absorbent polymer on the surface hardness of normal strength concrete

The mix proportions designed to the three different concrete grades including 21, 31 , and 41 MPa to find the effect of internal curing on the different grades of concrete to demonstrate the correct percentage and how can make the researchers sure about these results.

The surface hardness of concrete is influenced by the percentage of voids in the matrix of concrete. However, the super absorbent polymer has a positive impact on the mechanical properties of concrete, it leaves the sphere hole in the concrete. Therefore, the surface hardness is influenced with adding SAP to the concrete, especially the cover of the concrete due to moving the particles of SAP to the upper portions of concrete, as shown in Figures 4 and 5.

Figure 4. Moisture content measure in concrete

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It can be seen in Figures 5 and 6, the surface hardness of the concrete enhances around 19.3% with adding SAP of 0.036% from the total mass of water at 7 and 28 days in the age of the concrete. In addition, there is no negative impact of adding macro SAP to the hardness of normal strength concrete.

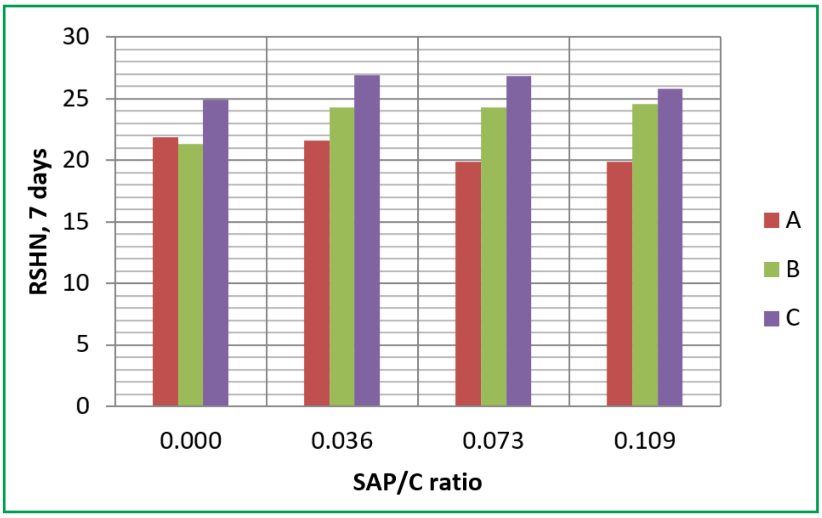

Figure 5. Rebound hammer test number versus super-absorbent polymer content for concrete at 7 days

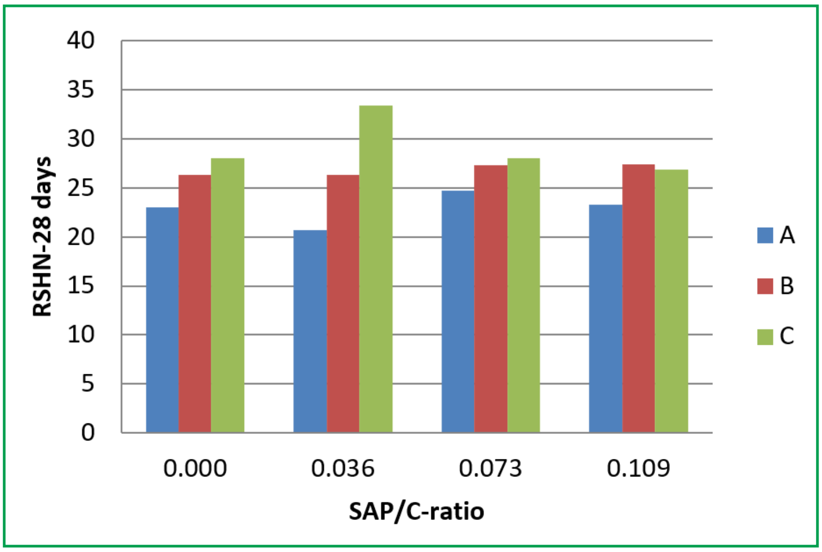

Figure 6. Rebound hammer test number versus super-absorbent polymer content for concrete at 28 days

Effect of super-absorbent polymer on the compressive strength of normal strength concrete

Including macro size of SAP into normal strength concrete improves the compressive strength and there is no negative effect of SAP on it, as shown in Figures 7 and 8. The compressive strength improves up to 13.4% due to internal curing of concrete with macro size of SAP, even though it left voids as indicated in the results of ultra-pulse velocity test, as shown in Table 6 and Figure 9.

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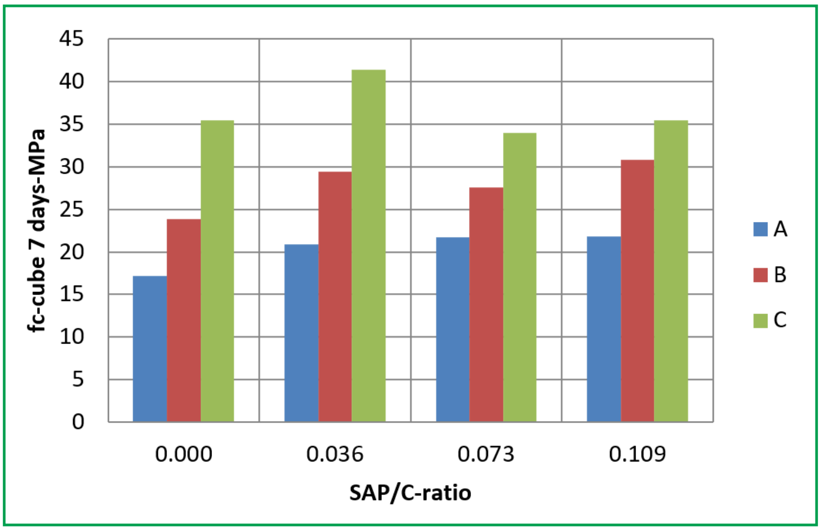

Figure 7. Cube concrete compressive strength at 7 days versus super-absorbent polymer content

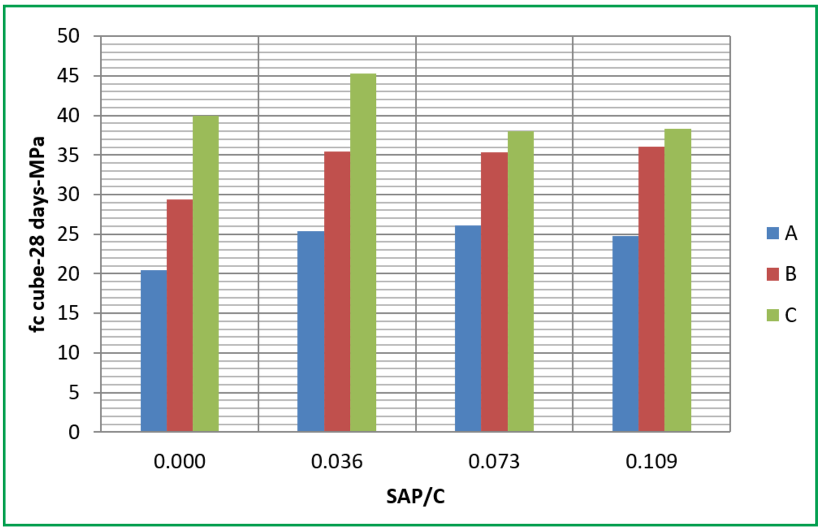

Figure 8. Cube concrete compressive strength at 28 days versus super-absorbent polymer content

Table 6. Results of UPV test for each mix

Mix Code	Velocity, m/s
A0	3147
A1	2787
A2	4867
A3	2888
B0	3843
B1	5425
B2	5659
B3	3787
C0	5518
C1	3121
C2	5385
C3	3959

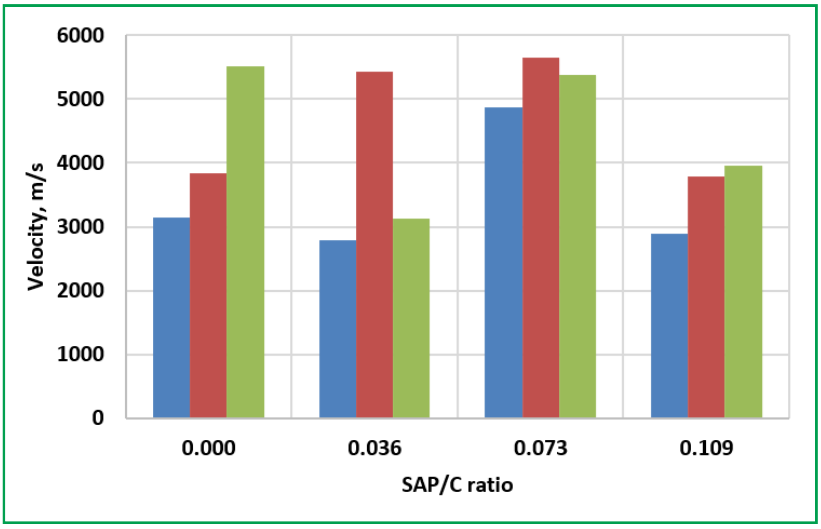

Figure 9. Velocity of wave versus super-absorbent polymer content

Effect of super-absorbent polymer on the density and void ratio of normal strength concrete

The density of concrete influences with the percentage of voids which entrapped into the concrete matrix with adding SAP, as shown in Figures 10 and 11. It can be seen from Figures, the values of concrete densities are decreased with adding more amount of internal curing water.

However, the density of concrete included internal curing water from macro SAP decreases as a result of increasing the void content, the amount of moisture in concrete still inside to improve the compressive strength, as shown in Figures 12 and 13.

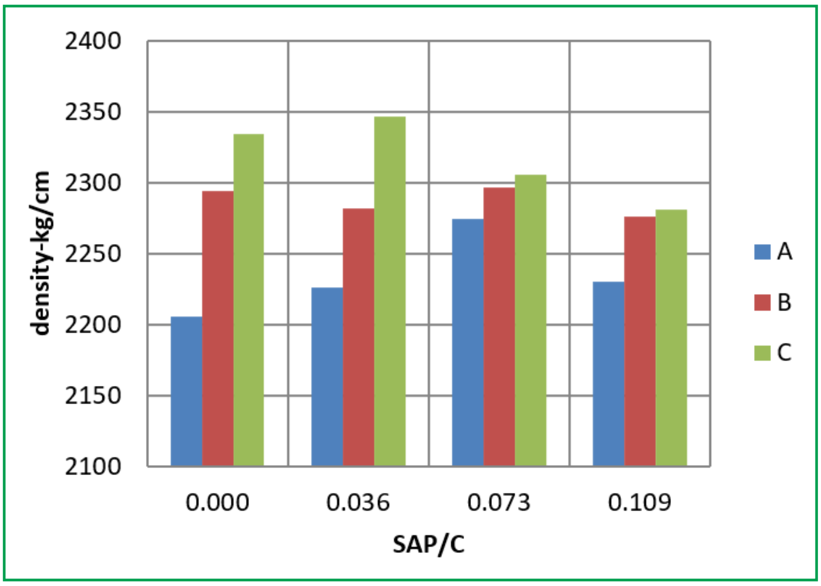

Figure 10. Concrete density at 7 days versus super-absorbent polymer content

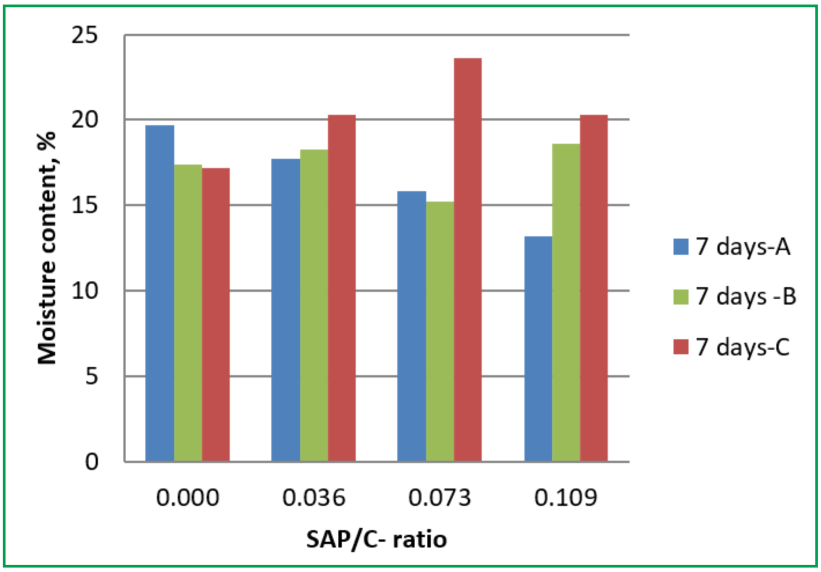

Figure 11. Moisture content in concrete at 7 days versus super-absorbent polymer content

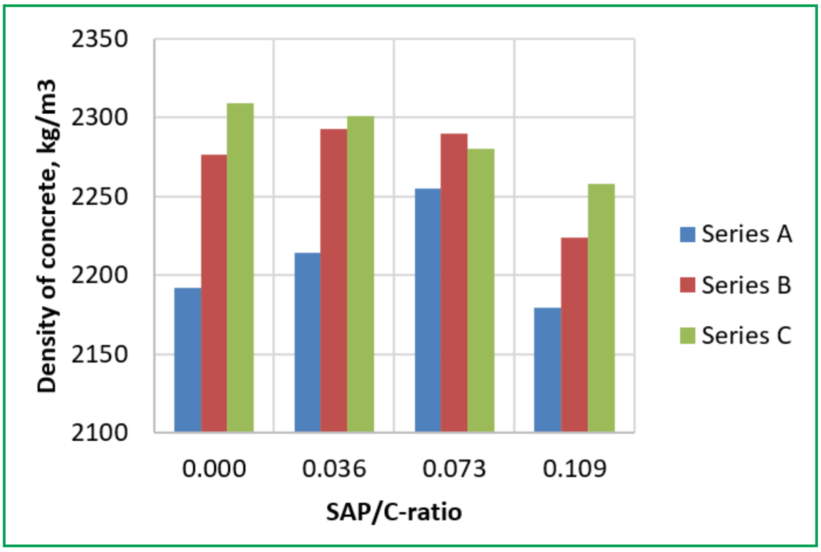

Figure 12. Concrete density at 28 days versus super-absorbent polymer content

Prediction of concrete compressive strength including the effect of surface hardness, ultra-pulse velocity, and super-absorbent polymer content using dimensional analysis [30]

The concrete compressive strength of normal strength concrete containing super-absorbent polymer effecting by variables which are tabulated in Table 7. The total number of parameters in the set V is 4.

$$\therefore \{V\} = \left\{C_s, \frac{R_n S_w}{T_w}, V_{up}, \gamma\right\} \quad (1)$$

where,

- Cs: Concrete compressive strength of normal strength concrete containing super-absorbent polymer, N/mm^2
- Rn: rebound number in the Schmidt hammer test
- Sw: mass of super-absorbent polymer saturated with water, g
- Tw: mass of mixing water, g
- Vup: velocity of wave from ultra-pulse velocity test, mm/s
- γ: Unit weight of concrete, N/mm^3

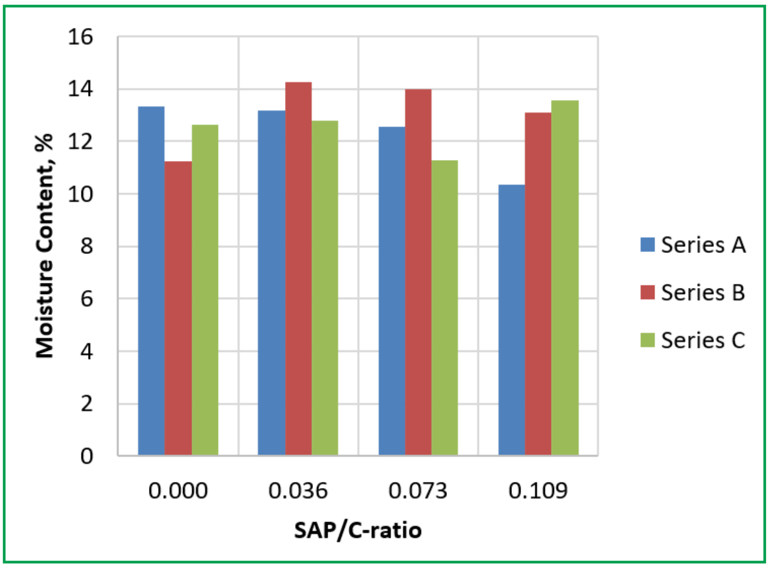

Figure 13. Concrete moisture content at 28 days versus super-absorbent polymer content

Table 7. Primary dimensions in MLT and FLT systems for variables in {V} which influence on concrete compressive strength of normal strength concrete including the effect super-absorbent polymer

Variable No.	Parameters	Primary dimensions in MLT system	Primary dimensions in FLT system
1	Cs	[M1L-1T-2]	[F1 L1 T0]
2	$(R_n S_w)/T_w$	[1]	[1]
3	Vup	[M0L1T-1]	[F0 L1 T-1]
4	γ	[M1L-2T-1]	[F1 L-3 T0]
	n=4	m=3	m=2

The number of Π-dimensionless groups and repeating variable is two. The γ and Vup are selected as a repeating variables. Consequently, the Π-dimensionless groups are as Equations (2) and (3).

$$\Pi_1 = (C_s)(\gamma)^a\left(V_{up}\right)^b \quad (2)$$

$$\Pi_2 = \left(\frac{S_w R_n}{T_w}\right)(\gamma)^a\left(V_{up}\right)^b \quad (3)$$

The dimensional form for Equation 2 can be stated as follows

$$[M^0L^0T^0] = [M^1L^{-1}T^{-2}][M^1L^{-2}T^{-1}]^a[M^0L^1T^{-1}]^b$$

Then, equating the powers for primary dimensions are carried out as follows:

- Equating exponents of mass M: 0=(1).1+(1).a+(0).b⟹a=-1
- Equating exponents of length L: 0=(-1).1+(-2).a+(1).b⟹b=-1
- Equating exponents of time T: 0=(-2).1+(-1).-1+(-1).-1=0 satisfy

Thus, the first Π-dimensionless group as Equation 4.

$$\Pi_1 = \frac{C_s}{\gamma.V_{up}} \tag{4}$$

The dimensional form for Equation 3 can be stated as follows

$$[M^0L^0T^0] = [M^0L^0T^0][M^1L^{-2}T^{-1}]^a[M^0L^1T^{-1}]^b$$

Then, equating the powers for primary dimensions are carried out as follows:

- Equating exponents of mass M: 0=(0).1+(1).a+(0).b⟹a=0
- Equating exponents of length L: 0=(0).1+(-2).a+(1).b⟹b=0
- Equating exponents of time T: 0=(0).1+(-1).0+(-1).0=0 satisfy

Thus, the second Π-dimensionless group as Equation 5

$$\Pi_2 = \frac{S_wR_n}{T_w} \tag{5}$$

The final form of dimensionless groups are

$$\Pi_1 = \beta_1.\Pi_2^{\beta_2}$$

Nonlinear multiple regression was used to estimate the value of constants β1, and β2 based on the 9 data from this study. Their values are 0.328, and 0.023, respectively. The final form of the equation becomes Equation (6).

$$C_s = 0.328 \times \left(\frac{S_wR_n}{T_w}\right)^{0.023} \times \gamma \times V_{up} \tag{6}$$

The proposed Equation 6 has coefficient of determination 0.91 for predicting compressive strength including the effect of super-absorbent polymer via surface hardness and velocity of ultra-pulse velocity test.

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Evaluation the proposed equation for predicting compressive strength including super-absorbent polymer

The proposed equation which was predicted by dimensional analysis in this study. The evaluation was conducted by calculating the compressive strength (Cs test/Cs predicted) for 9 mix proportions in this study. In addition, the coefficient of determination R^2 was 0.910, and mean value was 1.128 which means the proposed equation was underestimate the values of the compressive strength for concrete containing voids from including super-absorbent polymers, as shown in Figure 14.

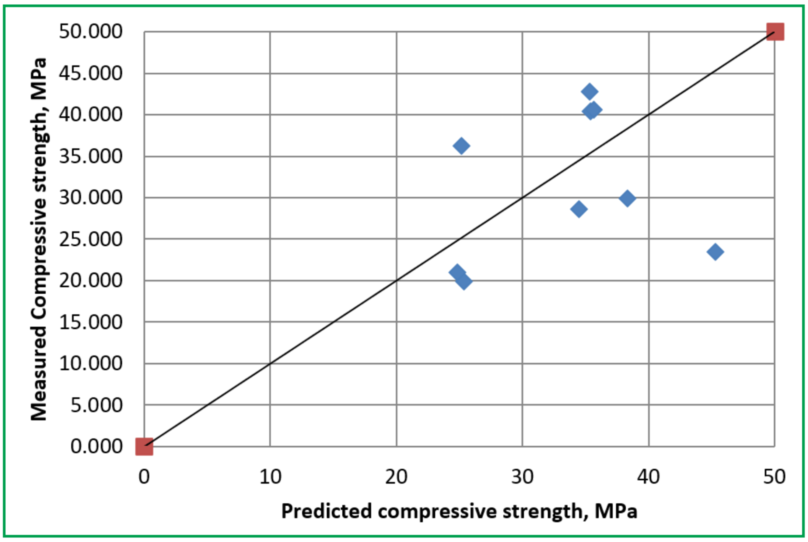

Figure 14. Comparison between measured experimental results of compressive strength and predicted values in the proposed Equation 6

Conclusions

The following concluded points could be drawn while adding macro size of SAP in the normal strength concrete and explain their effect on the properties of concrete.

1. The surface hardness of concrete includes SAP in macro size improves up to 19.3%. However, the density of concrete reduces from leaving voids in concrete.
2. The surface hardness of concrete included internal curing water with SAP has not effected with moisture content in concrete even after 28 days.
3. The compressive strength of concrete includes SAP enhances up to 13.4% due to continuing the hydration of cement from remaining moisture in concrete up to 10% till 28 days from the concrete age.
4. Effect of macro SAP on the readings of Ultra-Pulse Velocity were negative due to increasing the length of path of wave in this device.
5. It is found that the proposed equation for predicting the concrete compressive strength for normal strength concrete containing SAP has shown a good agreement with the test results.

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List of Abbreviations

Symbol	Description
C	Portland cement
Cs	Concrete compressive strength of normal strength concrete containing super-absorbent polymer, N/mm^2
G	Natural gravel
RSHN	Rebound Schmidt hammer test
Rn	rebound number in the Schmidt hammer test
S	Natural sand
SAP	Super-absorbent polymer
Sw	mass of super-absorbent polymer saturated with water, g
Tw	mass of mixing water, g
Vup	velocity of wave from ultra-pulse velocity test, mm/s
W	Tap water
γ	Unit weight of concrete, N/mm^3
Π	dimensionless group

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Conflicts of Interest

The authors declare that they have no competing interests.

Author Contributions

Ferhad Rahim Karim: conceptualization, methodology, software, data curation, writing-original draft preparation, visualization, investigation, writing-reviewing and editing.

Data Availability Statement

The data used to support the findings of this study are included within the article.

References

[1] S. H. Kosmatka, B. Kerkhoff, and W. C. Panarese, Design and Control of Concrete Mixtures, EB001, 14th ed. Shokie, Illinois, USA: Portland Cement Association, 2002.

[2] ACI Committee 308, "Guide to Curing Concrete," U.S.A2008.

[3] ACI Committee 308, "Specification for Curing Concrete," U.S.A2011.

[4] J. A. Zemajtis, "Role of Concrete Curing," America's Cement Manufacturers2022.

[5] Cement Concrete and Aggregates Australia, "Curing of Concrete," 2006.

[6] D. O. Olanrewau, A. Y. Akinsaya, and Q. A. Olowu, "Effect of high curing temperature on mechanical propertties of concrete," presented at the 2nd World Conference on Technology, Innovation and Entrepreneurship, Istanbul, Turkey, 2017.

[7] J. Fladr and I. Broukalova, “Influence of curing temperature on the mechanical properties of high-performance concrete,” presented at the International Conference Building Materials, Products and Technologies, 2019.

[8] A. Kaleta-Jurowska and K. Jurowski, “The influence of Ambient Temperature on High Performance Concrete Properties,” MDPI-Materials, vol. 13, 2020.

[9] I. B. Topcu and M. U. Toprak, “Fine aggregate and curing temperature effect on concrete maturity,” Cement and Concrete Research, vol. 35, pp. 758-762, 2004.

[10] ACI 308R, “Guide to External Curing of Concrete,” Farmington Hills, MI 483312016.

[11] W. Z. Taffese, “Data-driven method for enhanced corrosion assessment of reinforced concrete structures,” Ph.D, University of Turku, Turku, Finland, 2020.

[12] M. Amran, A. M. Onaizi, R. Fediuk, N. I. Vatin, R. S. M. Rashid, H. Abdelgader, et al., “Self-Healing Concrete as a Prospective Construction Material: A Review,” materials: MDPI, vol. 15, 2022.

[13] D. A. Triana-Camacho, J. H. Quintero-Orozco, E. Mejia-Ospino, G. Castillo-Lopez, and E. Garacia-Macias, “Piezoelectic composite cements: Towards the development of self-powered and self-diagnostic materials,” Cement and Concrete Composites, vol. 1, 2023.

[14] K. W. Shah and G. F. Huseien, “Biomimetic Self-Healing Cementitious Construction Materials for Smart Buildings,” biomimetics, MDPI, vol. 5, 2020.

[15] C. Chen, S. Chen, Y. Zhenyao, X. Shi, and T. Ma, “The effect of Alchohol consumption on Brain Ageing: A new causal inference framework for incomplete and massive phenomic data,” 2024.

[16] N. Tran, N. Tuan, J. R. Black, and N. Tuan, “High-temperature Stability of Ambient-cured One-part Alkali-activated Materials Incorporating Graphene for Thermal Energy Storage,” 2024.

[17] M. Raghav, T. Park, H. Yang, S. Lee, S. Karthick, and H. Lee, “Review of the Effects of Supplementary Cementitious Materials and Chemical Additives on the Physical, Mechanical and Durability Properties of Hydraulic Concrete,” materials: MDPI, vol. 14, 2021.

[18] F. J. Vazquez-Rodriguez, N. Elizondo-Villareal, L. H. Verastegui, A. M. A. Tovar, J. F. Lopez-Perales, J. E. C. de Leon, et al., “Effect of Mineral Aggregates and Chemical Admixtures as Internal Curing Agents on the Mechanical Properties and Durability of High-Performance Concrete,” materials: MDPI, vol. 13, 2020.

[19] M. H. B. Souza, B. A. Teixeira, P. C. Goncalves, L. R. R. Silva, M. L. N. M. Melo, V. A. S. Ribeiro, et al., “Effects on the propeties of Self-Compacting Cement Paste (PAA) with the Addition of Superabsorbent Polymer,” materials: MDPI, vol. 15, 2022.

[20] S. Gupta, K. Harn-wei, and P. Sze-dai, “Autonomous Repair in Cementitious Material by Combination of Superabsorbent Polymers and Polypropylene Fibres: A Step Towards Sustainable Infrastructure,” presented at the World Sustainable Built Environment Conference - Track 12:Emerging Green Construction Technology and Materials Hong Kong, 2017.

[21] ASTM C150-22, “Standard specification for portland cement,” vol. C01.10, ed, 2022.

[22] ASTM C805-13a, “Standard test method for rebound number of hardened concrete,” ed, 2013.

https://doi.org/10.70028/sgm.v2i2.46

[23] BS EN 12504-4, “Testing Concrete-Part 4: Determination of ultrasonic pulse velocity,” vol. BS EN 12504-4, ed, 2004.

[24] BS 1881-203, “Testing Concrete Part 203: Recommendations for measurement of velocity of ultrasonic pulses in concrete,” ed, 1986.

[25] BS EN 12390-3, “Testing hardened concrete,” in Part3: Compressive strength of test specimens, ed. London, 2009, p. 16.

[26] BS EN 12390-7, “Testing hardened concrete: part 7: density of hardened concrete,” ed. Brussels, 2019.

[27] A. S. Ali and F. R. Karim, “Influence of internal curing on the properties of non-fibrous high strength concrete-A critical review,” Journal of Cement Based Composites, vol. 3, pp. 1-6, 2020.

[28] F. R. Karim, “Influence of Internal Curing with Lightweight Pumice Fine Aggregate on the Mechanical Properties of Cement Mortars,” Construction, vol. 2, pp. 104-113, 2022.

[29] F. R. Karim, A detailed study of Building Material Tests vol. 1. Sulaimani, Iraq, 2022.

[30] F. R. Karim, “Behaviour of Under-reinforced Shallow Fibrous Concrete Beams Subjected to Pure Torsion,” Ph.D., Civil Engineering Department, University Sains Malaysia, Penang, Malaysia, 2016.