ASSESSMENT OF THE SELF CURING CONCRETE WITH A DIFFERENT ADMIXTURE

VARAMULA SARITHA[1], Dr. S. KAMAL [2], Prof. K. RAJASHEKAR [3]

[1]Research Scholar, Annamalai University, Annamalai Nagar-608002, India

[2] Associate Professor, Annamalai University, Annamalai Nagar-608002, India.

[3] Professor of Civil Engineering & Principal, Siddhartha Educational Academy Group of Institutions-

C. Gollapalli-517505.

Abstract

The usefulness of self-curing concrete that contains internal curing agents like silica fume (SF) and super absorbent polymer (SAP), both separately and in combination, is investigated in this study. Without using conventional water curing, the goal is to evaluate the mechanical and durability-related qualities of concrete, especially in situations where external curing is impractical, like in hot, dry, or water-scarce environments. Compressive strength, split tensile strength, flexural strength, water absorption, volume of permeable voids, and chloride ion permeability were all evaluated for six distinct mix designs based on M30 grade concrete. In the experimental program, silica fume was added to cement in different amounts and SAP was used to replace fine aggregates. To replicate self-curing conditions, the performance of each mix was assessed after 28 days of ambient curing. In order to support the development of long-lasting and environmentally friendly construction methods utilizing self-curing concrete, the study offers insights into how internal curing admixtures affect strength development, pore structure, and resistance to moisture and chemical ingress.

Keywords: Self-curing concrete, Silica Fume (SF), Super Absorbent Polymer (SAP), Compressive strength, Split tensile strength, Flexural strength, Chloride ion permeability, Water absorption

Introduction

Curing is an important step in concrete technology that helps internal chemical reactions happen in hydrated cement paste. This is important for getting the right qualities in hardened concrete by making sure there is enough water and heat over time (ACi, 2001),(Bentz & Weiss, 2011). Good curing maintains the material hydrated, stops it from losing water too soon, and keeps it saturated or almost saturated for as long as it takes to make it strong and long-lasting (Mehta & Monteiro, 2006),(Holt, 2001). Reactive powder concrete, high-performance concrete (HPC), and ultra-high-performance concrete (UHPC) are all forms of concrete that are noted for being very workable, dense, strong, and not letting water through easily (Tayeh et al., 2012),(Tayeh et al., 2013),(Askar et al., 2017). However, using ultra-fine cementitious materials like met kaolin (MK) and silica fume (SF), along with low water–cement ratios, makes it harder to provide internal water for curing. This leads to problems like chemical and drying shrinkage and micro cracking at an early age. As HPC becomes increasingly common, with a water to cementitious material ratio (w/cm) of less than 0.25 and the use of supplemental cementing materials (SCMs), the effect of curing on hydration has become even more clear (Lopez et al., 2008). In this situation, internal curing (IC) has become a useful way to reduce autogenous shrinkage and improve the quality of concrete, particularly in mixes with low w/cm ratios (Bentz, 2007). In many places, the weather is hot and dry, therefore internal curing is a good way to stop concrete buildings from drying out and shrinking too much too soon (Mehta & Monteiro, 2006). In spite of these difficulties, self-curing methods that can efficiently sustain internal moisture and promote hydration without depending on outside water sources are becoming more and more necessary. Several real-world infrastructure projects have effectively used the self-curing technique to solve problems like shrinkage and early-age cracking. To decrease early-age cracking in concrete pavements, for example, the Ohio transportation department used self-curing concrete (Cleary & Delatte, 2008), (Lopez et al., 2010). It was also used along Texas State Highway 121 (Friggle & Reeves, 2008) and in a railroad transit yard in Texas (Villarreal & Crocker, 2007). Over 420,000 m^3 of self-cured concrete were used in the Dallas–Fort Worth area alone (Villarreal & Crocker, 2007), demonstrating the method's scalability. Additionally, normal density self-cured concrete was used in numerous bridge constructions throughout New York and Indiana (Di Bella et al., 2012) and large-scale paving projects like Hutchins, Texas (Cusson et al., 2010). These real-world uses highlight how self-curing concrete can effectively ensure quality and durability in situations where traditional curing is challenging or impractical.

This emphasizes the necessity of investigating and evaluating different admixtures that promote internal curing mechanisms.When cement hydrates, it shrinks and leaves empty pores, which lowers the humidity inside the concrete and causes it to dry out and crack (Yadav et al., 2017), (Liu et al., 2017). Self-curing keeps moisture inside the concrete, which helps to avoid this problem. Self-curing uses materials like polymers or lightweight aggregates to soak up water while mixing and slowly release it while hydrating (Justs et al., 2015). This is different from traditional curing, which uses water from outside sources (ACi, 2001). This is helpful in places where there isn't enough water or where it is hard to cure properly (Mohamad et al., 2017). If the humidity drops below 80%, cement hydration slows down. To keep strength and durability, it's important to keep moisture inside (Selvamony et al., 2010). Self-curing concrete is made by mixing regular concrete with a self-curing agent (Sato et al., 2011). It keeps concrete moist throughout its section and slows down evaporation, unlike methods that only work on the surface (Barrett et al., 2012).

In light of the aforementioned, the current study contributes to the understanding of self-curing concrete by evaluating its durability and mechanical performance using various internal curing agents, particularly silica fume (SF) and super absorbent polymer (SAP), both separately and in combination. Important concrete characteristics like compressive strength, split tensile strength, flexural strength, rapid chloride permeability, water absorption, and volume of permeable voids are all methodically examined in this study. The findings demonstrate that silica fume has the capacity to greatly increase strength and durability, whereas SAP offers only modest gains when applied at the right dosages. This study promotes the practical use of self-curing concrete by identifying efficient admixture combinations that enhance performance without external curing, as traditional curing is frequently difficult in hot, dry, or water-scarce environments. The study offers helpful information for creating internally cured concrete construction methods that are long-lasting, effective, and environmentally friendly.

Literature review

Self-curing concrete has gotten a lot of attention in the last few years as a good way to get rid of the need for outside curing methods. (El-Dieb, 2007) found that self-curing concrete holds water better than regular concrete. This is because it doesn't dry out as quickly and it stays hydrated better when it's sealed or dry. As the material got older, it became less permeable to water and less sorptive, which showed that it was still hydrating and refining its pores.(Prasad et al., 2019) found that adding PEG-400 at doses of 0.5%, 1%, and 1.5% made the material stronger and more durable. The best results came from using 1.5%. The modulus of elasticity of self-curing concrete was similar to that of regular concrete, which shows that it is strong.(Iffat et al., 2017) showed that burnt clay aggregates (brick chips) can be used as internal curing agents. They showed that they are just as durable as externally cured concrete, especially when there isn't much water available.(Lopez et al., 2010) talked about how lightweight aggregates can help self-curing concrete become more durable, resistant to freezing and thawing, and stronger in terms of bond strength.

Several scientists have looked into how well Polyethylene Glycol (PEG) and Super Absorbent Polymers (SAP) work to speed up internal curing. (Manjusha et al., 2022) looked into PEG-600 and PEG-1500 in M30 grade self-compacting concrete. They found that PEG-600 got about 95% of the compressive strength that immersion curing got after 28 days, while PEG-1500 got about 89%. But the strength at a young age was lower than with regular curing.(Mousa et al., 2015) examined both SAP and PEG in concrete mixes. They discovered that SAP levels of up to 15% (by sand volume) and PEG levels of up to 2% (by cement weight) made the material more durable, less porous, and better at holding water. But too much SAP (20%) made it harder for water to be absorbed and caused mass loss.(Chand et al., 2016) found that the best amount of PEG-400 for M20 concrete was 1% and for M40 concrete it was 0.5%.

When PEG was added to M20 concrete, the split tensile strength went up by as much as 11.60% and the flexural strength went up by 8.5%.(Muthukumar & Suganya Devi, 2015) found that adding 1.5% PEG to self-compacting self-curing concrete beams increased the ultimate load by 23.53% and the deflection by 35.48%, which shows that the structure performed much better.(Rozario et al., 2013) looked into how well PEG and fly ash self-curing concrete can resist sulphate. The results showed that chemical penetration and weight loss were lower, which means that the material is more durable in harsh environments.

Because of its pozzolanic properties and small particle size, silica fume (SF) is often used to make things stronger and last longer. When used with internal curing agents, it has been shown to have synergistic effects in self-curing concrete. Magda Mousa and others (Mousa et al., 2015) looked into concrete mixes that had 15% silica fume, 2% PEG, and 15% SAP. Under air curing, these mixes had the best mechanical and durability performance.

They held water well and were resistant to attacks from CO_2 and NaCl for six months.(Subramanian et al., 2015) looked at how well PEG-400 and silica fume worked together in high-strength concrete (M60–M80). The study found that replacing 10% of the cement with silica fume made the material much stronger under compression, and 15% made it much more resistant to chloride. The best strength was found with PEG at 0.4%.(SU, 2011) looked into using silica fume in self-compacting, self-curing concrete along with limestone powder and quarry dust. Silica fume made the early strength development better and the porosity lower, which made the material stronger and better at absorbing water.

METHODOLOGY

The aim of this research is to test the mechanical and long-lasting properties of self-curing concrete by adding different self-curing agents, such as Super Absorbent Polymer (SAP) and Silica Fume (SF). Below is a description of the research methods used in this study:

1.1 Materials Used

1. **Cement**: Ordinary Portland Cement (OPC) of 53 grade was used for all mixes.
2. **Fine Aggregate**: Locally available river sand conforming to IS standards was used.
3. **Coarse Aggregate**: Crushed angular aggregates of maximum size 20 mm were used.
4. **Water**: Potable water was used for both mixing and curing.
5. **Self-Curing Admixtures**:
    a. **Super Absorbent Polymer (SAP)**: Used at 10%, 15%, and 20% replacement of fine aggregate by volume.
    b. **Silica Fume (SF)**: Used as a partial replacement of cement at 15% by weight.

1.2 Mix Proportions

1. The mix design was based on M30 grade concrete following IS:10262 guidelines.
2. A total of six concrete mixes were prepared:
    a. **M1**: Control mix without any self-curing agent.
    b. **M2 to M4**: Mixes with SAP at 10%, 15%, and 20%.
    c. **M5**: Mix with 15% Silica Fume.
    d. **M6**: Mix with 15% Silica Fume + 15% SAP.
3. The water-cement ratio and dosage of superplasticizer were kept constant across all mixes.

1.3 Casting and Curing of Specimens

1. Standard concrete specimens were cast for each mix:
    a. Cubes (150 mm × 150 mm × 150 mm) for compressive strength.
    b. Cylinders (150 mm diameter × 300 mm height) for split tensile strength.
    c. Prisms (100 mm × 100 mm × 500 mm) for flexural strength.
2. All specimens were cured under ambient conditions to simulate self-curing behaviour, with no external water curing applied.

1.4 Tests Conducted

A number of common laboratory tests were used to assess each concrete mix's performance after 28 days. Concrete's load-bearing capacity was ascertained by measuring its compressive strength in accordance with IS 516. The concrete's ability to withstand cracking under tensile stress was evaluated using split tensile strength tests, and its ability to withstand bending was evaluated using flexural strength tests. The Rapid Chloride Permeability Test (RCPT), which quantifies the amount of chloride ion penetration and aids in determining the risk of corrosion in reinforced structures, was conducted in compliance with ASTM C1202 to investigate durability. Furthermore, the water absorption test was performed to determine the concrete's pore structure and the amount of moisture it can absorb. In order to assess the percentage of connected pores and gain insight into the durability and resistance of the concrete to the ingress of harmful substances, the volume of permeable voids test was conducted. When combined, these tests provided a thorough understanding of the self-curing concrete mixes' mechanical and durability properties.

RESULTS

This section presents the results of several tests that were done to see how well self-curing concrete mixes with different additives, like Super Absorbent Polymer (SAP) and Silica Fume, work. The tests look at things like compressive strength, split tensile strength, flexural strength, rapid chloride permeability, and how much water the material can absorb with voids. We tested concrete samples that had been cured for 28 days and compared the results to a control mix to see how well self-curing agents worked. The goal is to learn how these additives affect the strength and durability of concrete, especially when traditional curing methods are limited or not possible.

1.5 Compressive strength of concrete

Table 1 Compressive strengths of different concrete mixes at 28 days

Mix No	Percentage of Self curing agents		Compressive Strength (N/mm²)	Percentage increased or decreased (With respect to Reference Mix)
	SAP	Silica Fume		
M1	0	0	40.22	-
M2	10	0	38.89	-3.31
M3	15	0	40.89	1.67
M4	20	0	39.56	-1.64
M5	0	15	44	9.40
M6	0	15	46.67	16.04

As shown in Table 1, the results show that using self-curing agents, especially Silica Fume, makes concrete stronger at 28 days. The reference mix (M1) without any additives was 40.22 N/mm² strong. When SAP was used by itself at 10% and 20% (M2 and M4), the strength went down a little. But when it was used at 15% (M3), the strength went up by 1.67%, which shows that the right amount of SAP can help build strength. The mixes with 15% Silica Fume (M5 and M6) had the best results, with strength going up by 9.40% and 16.04%, respectively. M6 had the highest strength, which was 46.67 N/mm². This shows that Silica Fume is better than SAP at making concrete stronger and works well in concrete that cures itself. These results show that using self-curing admixtures, especially Silica Fume, can make concrete stronger and last longer.

1.6 Split tensile strength of concrete

Table 2 Split Tensile strengths of different concrete mixes at 28 days

Mix No	Percentage of Self curing agents		Split Tensile Strength (N/mm²)	Percentage increased or decreased (With respect to Reference Mix)
	SAP	Silica Fume		
M1	0	0	3.11	-
M2	10	0	2.83	-9.0
M3	15	0	3.15	1.29
M4	20	0	3.04	-2.25
M5	0	15	3.3	6.11
M6	15	15	3.32	6.75

Table 2 shows that the split tensile strength results at 28 days are much better when Silica Fume is used as a self-curing agent. The control mix (M1) without any additives had a strength of 3.11 N/mm². When SAP was used alone at 10% (M2) and 20% (M4), the strengths were lower by 9.0% and 2.25%, respectively, compared to the control. However, at 15% SAP (M3), the strength went up by 1.29%, which shows that a moderate amount of SAP can help performance. The mixes with 15% Silica Fume, either by themselves (M5) or with SAP (M6), had the best results, with strengths of 3.30 N/mm² and 3.32 N/mm², which were 6.11% and 6.75% higher than the previous best. This proves that Silica Fume works better than SAP to increase tensile strength. Using it in self-curing concrete makes it less likely to crack and improves the overall performance of the structure.

1.7 Flexural strength of concrete

Table 3 Flexural strengths of different concrete mixes at 28 days

Mix No	Percentage of Self curing agents		Flexural Strength (N/mm^2)	Percentage increased or decreased (With respect to Reference Mix)
	SAP	Silica Fume		
M1	0	0	3.24	-
M2	10	0	3.06	-5.56
M3	15	0	3.32	2.47
M4	20	0	3.14	-3.09
M5	0	15	3.39	4.63
M6	15	15	3.42	5.56

1.8 Rapid chloride permeability test

Table 4 Chloride ion permeability based on total charge passed as per ASTM C 1202

Charge passed (in coulombs)	Chloride ion permeability range
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Table 4 shows that chloride ion permeability decreases as the total charge passed reduces, with values above 4000 indicating high permeability and those below 100 considered negligible, based on ASTM C 1202 standards.

Table 5 Rapid chloride permeability test results at 6 hrs for specimens at 28 days

Mix designation	Charge passed, coulombs	Chloride ion penetrability
M1	2656	Moderate
M2	2414	Moderate
M3	2099	Moderate
M4	1982	low
M5	2101	Moderate
M6	1768	low

Table 5 shows that the rapid chloride permeability test results after 28 days show that adding self-curing agents makes the concrete less likely to let chloride ions in. The control mix (M1) had a charge passed of 2656 coulombs, which put it in the middle of the permeability range. Mixes M2, M3, and M5, which had either SAP or Silica Fume on their own, also fell in the moderate range but with lower values. This meant that they worked better than the control. It's worth noting that Mix M4 (1982 C) and Mix M6 (1768 C) had low permeability, which shows that they are much more durable. Mix M6, which combined Silica Fume and SAP, had the lowest charge passed. This proves that it is the most resistant to chloride ion penetration and the most durable mix for protecting against corrosion.

1.9 Water absorption test

Table 6 Water absorption % and voids % in all specimens

Mix designation	Absorption After Immersion (%)	Absorption Percentage Increased or Decreased (With respect to Reference Mix)	Volume of Permeable Pore Space (Voids) (%)	Voids Percentage Increased or Decreased (With respect to Reference Mix)
M1	3.56	-	8.46	-
M2	3.89	9.27	8.87	4.85
M3	4.34	21.91	9.23	9.10
M4	4.89	37.36	10.31	21.87
M5	3.39	-4.78	8.12	-4.02
M6	3.78	6.18	8.73	3.19

The results of the voids and water absorption tests, which are shown in Table 6, show how much water the concrete can absorb as well as the number of permeable pores, two factors that impact durability. The control mix (M1) had 8.46% voids and 3.56% absorption. Concrete with SAP was more porous and less durable, as evidenced by the higher absorption and void content of mixes M2, M3, and M4, with M4 achieving the highest values (4.89% absorption and 10.31% voids). The lowest absorption (3.39%) and voids (8.12%) were found in Mix M5, which contained only Silica Fume, indicating superior pore refinement. Mix M6, which combined SAP and silica fume, demonstrated modest gains over the control, with voids (8.73%) and absorption (3.78%) being marginally higher. The test shows that a denser, less permeable concrete has lower water absorption and void percentages. M5 outperformed the other mixes, confirming that silica fume is an effective way to increase the density and durability of concrete.

DISCUSSION

The findings show that self-curing admixtures, especially Silica Fume, increase concrete strength and durability. The Silica Fume mixtures (M5 and M6) outperformed the control and SAP-only mixes in all tests. Silica Fume's pozzolanic action and pore-refining improved compressive, split tensile, and flexural strengths. SAP combined with Silica Fume (M6) enhanced strength and lowered chloride ion permeability the greatest, but SAP alone exhibited minor gains and even increased porosity at higher doses. The Rapid Chloride Permeability Test showed that Silica Fume mixtures, particularly those containing SAP, had reduced permeability, making them more resistant to chemical assaults and corrosion. Silica Fume decreased porosity and provided a denser matrix, whereas SAP, which was excellent for internal curing, increased water absorption and voids when applied alone. The research found that Silica Fume improves mechanical strength and durability, and its synergy with SAP offers a potential alternative for self-curing concrete in difficult curing settings

CONCLUSION

The current study demonstrated that, in situations where traditional water curing was impractical, the use of self-curing admixtures—specifically, silica fume (SF) and super absorbent polymer (SAP)—significantly enhanced the mechanical and durability performance of concrete. The compressive, tensile, and flexural strengths of the different mixes that were tested significantly improved when silica fume was added, either by itself or in conjunction with SAP. Additionally, the addition of silica fume decreased chloride ion permeability, permeable voids, and water absorption, suggesting a denser and more resilient concrete structure. SAP was most successful when used in conjunction with silica fume, although it provided only modest advantages when used alone. Overall, the study found that self-curing concrete with the right admixture combinations offered a dependable and useful substitute when water resources were scarce or external curing was challenging. These results aided in the creation of long-lasting and sustainable concrete for use in contemporary construction.

REFERENCES

[1] ACi, H. (2001). 308R-Guide to Curing Concrete. *American Concrete Institute International*.

[2] Askar, L. K., Tayeh, B. A., Bakar, B. H. A., & Zeyad, A. M. (2017). Properties of ultra-high performance fiber concrete (UHPFC) under different curing regimes. *Int. J. Civ. Eng. Technol.(IJCIET)*, *8*(4), 965–974.

[3] Barrett, T. J., De la Varga, I., & Weiss, W. J. (2012). Reducing cracking in concrete structures by using internal curing with high volumes of fly ash. *Structures Congress 2012*, 699–707.

[4] Bentz, D. P. (2007). Internal curing of high-performance blended cement mortars. *Materials Journal*, *104*(4), 408–414.

[5] Bentz, D. P., & Weiss, W. J. (2011). *Internal curing: a 2010 state-of-the-art review*. US Department of Commerce, National Institute of Standards and Technology ….

[6] Chand, M. S. R., Giri, P. S. N. R., Kumar, P. R., Kumar, G. R., & Raveena, C. (2016). Effect of self curing chemicals in self compacting mortars. *Construction and Building Materials*, *107*, 356–364.

[7] Cleary, J., & Delatte, N. (2008). Implementation of internal curing in transportation concrete. *Transportation Research Record*, *2070*(1), 1–7.

[8] Cusson, D., Lounis, Z., & Daigle, L. (2010). Benefits of internal curing on service life and life-cycle cost of high-performance concrete bridge decks–A case study. *Cement and Concrete Composites*, *32*(5), 339–350.

[9] Di Bella, C., Villani, C., Phares, N., Hausheer, E., & Weiss, J. (2012). Chloride transport and service life in internally cured concrete. *Structures Congress 2012*, 686–698.

[10] El-Dieb, A. S. (2007). Self-curing concrete: Water retention, hydration and moisture transport. *Construction and Building Materials*, *21*(6), 1282–1287.

[11] Friggle, T., & Reeves, D. (2008). Internal curing of concrete paving: Laboratory and field experience. *Special Publication*, *256*, 71–80.

[12] Holt, E. E. (2001). *Early age autogenous shrinkage of concrete*. University of Washington.

[13] Iffat, S., Manzur, T., & Noor, M. A. (2017). Durability performance of internally cured concrete using locally available low cost LWA. *KSCE Journal of Civil Engineering*, *21*(4), 1256–1263.

[14] Justs, J., Wyrzykowski, M., Bajare, D., & Lura, P. (2015). Internal curing by superabsorbent polymers in ultra-high performance concrete. *Cement and Concrete Research*, *76*, 82–90.

[15] Liu, J., Shi, C., Ma, X., Khayat, K. H., Zhang, J., & Wang, D. (2017). An overview on the effect of internal curing on shrinkage of high performance cement-based materials. *Construction and Building Materials*, *146*, 702–712.

[16] Lopez, M., Kahn, L. F., & Kurtis, K. E. (2008). Effect of internally stored water on creep of high-performance concrete. *ACI Materials Journal*, *105*(3), 265.

[17] Lopez, M., Kahn, L. F., & Kurtis, K. E. (2010). High-strength self-curing low-shrinkage concrete for pavement applications. *International Journal of Pavement Engineering*, *11*(5), 333–342.

[18] Manjusha, P., Ramireddy, Y. V., Basha, K. S., & Mallikarjuna, M. (2022). Effect of leca on corrosion resistance of self-curing concrete. *Neuro Quantol.*, *20*(7), 2649–2655.

[19] Mehta, P. K., & Monteiro, P. (2006). Concrete: microstructure, properties, and materials. *(No Title)*.

[20] Mohamad, D., Beddu, S., Sadon, S. N., Kamal, N. L. M., Itam, Z., Mohamad, K., & Sapua, W. M. (2017). Self-curing concrete using baby diapers polymer. *Indian J. Sci. Technol*, *10*(4), 1–7.

[21] Mousa, M. I., Mahdy, M. G., Abdel-Reheem, A. H., & Yehia, A. Z. (2015). Mechanical properties of self-curing concrete (SCUC). *HBRC Journal*, *11*(3), 311–320.

[22] Muthukumar, P., & Suganya Devi, K. (2015). Flexural Behaviour of Self Compacting Self Curing Concrete Beam. *International Journal on Engineering Technology and Sciences*, *2*(4), 37–40.

[23] Prasad, P., Neeraja, D., & Ravitheja, A. (2019). Effect of LECA on mechanical properties of self-curing concrete. *Materials Today: Proceedings*, *19*, 484–488.

[24] Rozario, A. A., Christy, D. C. F., & Angelin, M. H. (2013). Experimental studies on effects of sulphate resistance on self-curing concrete. *Int. J. Eng. Res. Technol.(IJERT)*, *2*, 1–8.

[25] Sato, R., Shigematsu, A., Nukushina, T., & Kimura, M. (2011). Improvement of properties of portland blast furnace cement type B concrete by internal curing using ceramic roof material waste. *Journal of Materials in Civil Engineering*, *23*(6), 777–782.

[26] Selvamony, C., Ravikumar, M. S., Kannan, S. U., & Gnanappa, S. B. (2010). Investigations on self-compacted self-curing concrete using limestone powder and clinkers. *ARPN J. Eng. Appl. Sci*, *5*(3), 1–6.

[27] SU, K. (2011). SELF COMPACTED/SELF CURING/KILN ASH CONCRETE. *International Journal on Design and Manufacturing Technologies*, *5*(1).

[28] Subramanian, K. B., Siva, A., Swaminathan, S., & Ajin, A. M. G. (2015). Development of high strength self curing concrete using super absorbing polymer. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, *9*(12), 1536–1541.

[29] Tayeh, B. A., Abu Bakar, B. H., & Megat Johari, M. A. (2013). Characterization of the interfacial bond between old concrete substrate and ultra high performance fiber concrete repair composite. *Materials and Structures*, *46*, 743–753.

[30] Tayeh, B. A., Bakar, B. H. A., Johari, M. A. M., & Voo, Y. L. (2012). Mechanical and permeability properties of the interface between normal concrete substrate and ultra high performance fiber concrete overlay. *Construction and Building Materials*, *36*, 538–548.

[31] Villarreal, V. H., & Crocker, D. A. (2007). Better pavements through internal hydration. *Concrete International*, *29*(2), 32–36.

[32] Yadav, N., Deo, S. V, & Ramtekkar, G. D. (2017). Mechanism and benefits of internal curing of concrete using light weight aggregates and its future prospects in Indian construction industry. *International Journal of Civil* Engineering *and Technology*, *8*(5), 323–334.