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Investigating the Sway of Marine Brown Seaweed Gel as Natural Polymer in Properties of Concrete

V. Murugappan*and A. Muthadhi

Departmentof Civil Engineering, Puducherry Technological University, Puducherry - 605104, India; murugappan1996@gmail.com

Abstract

In the present study, the effects of the fresh properties as slump, consistency and setting time and hardened concrete's characteristics such as compressive, split tensile and flexural strength for various ages, the brown seaweed (Sargassum wightii) gel was added to cement throughout differing proportions (1, 2, 3, 4 and 5%) by the mass of concrete. Durability and thermal tests such as water absorption, sorptivity, RCPT, acid attack and thermal conductivity also determined at various ages. Micro structural properties of seaweed gel were found out by SEM, FTIR and XRD analysis. Test results show that seaweed gel act as retarding admixture in cement up to 5% of addition. For instance, 5% alginate collections as a percentage of concrete mass showed a comparable compressive strength of about 42MPa. The use of seaweed gel improved the thermal characteristics of concrete by reducing its thermal conductivity roughly 50% for a 5% addition. The seaweed gels up to 5% addition in concrete will significantly improve the fresh-state properties of concrete without affecting its hardened properties. The future is completely dependent on eco-friendly materials; hence the use of natural organic additives to improve the strength and durability of cement concrete would be the better option for sustainability.

Keywords: *Chlorophyll, Green Concrete, Sustainability, Seaweed Gel, Sargassum wightii*

1.0 Introduction

One of the most important artificial materials employed in the structure is cement. About 15% of the total amount of cement is made up of additives. It is essential to employ organic ingredients when making concrete. As ecological awareness for material construction aspects increases, it is projected that the transition between artificial and natural additives will continue[1]. For example, polymeric compounds are now used to change the mechanical and durability qualities of concrete. However, synthetic polymers, i.e., monomer polymerization, may modify the concrete characteristics such as air entrainment, adhesiveness and hydrophobicity. Moreover, these materials are costly and toxic to the environment[2]. Therefore, to overcome those impacts natural, sustainable alternative materials for construction with a lower cost have been adopted and are the light of this research. Even though it has many benefits like being robust, resilient to fire, energy-efficient and having a low carbon footprint the fact that it releases carbon dioxide into the atmosphere has a significant negative impact on the environment. Therefore, to overcome those impacts natural, sustainable alternative materials for construction with a lower cost have been adopted and are the light of this research. Communities must employ sustainable green building and construction resources due to climate change and rising greenhouse gas emissions. For the past 50 years polymeric materials have been crucial to the building industry and several experiments have been conducted in

*Author for correspondence

numerous nations to find new ways to employ polymers in construction. One type of environmentally friendly concrete was polymer concrete, which uses polymer resin instead of regular cement as the binding agent. Concrete has a high quenching ability and yet is relatively in terms of tension and adhesion, and its porosity can result in biochemical and physiological degeneration. In contrast, polymers are less intense when compression but still has greater tensile capacities[3-5].

Considering natural organic materials like oil-soaked fruit and flower pulp, molasses, and lime-based stucco were used in the past to paint the Ajanta and Sirgiriacaves' walls. According to Chandra *et al*., black gramme is a binder used in mortar *and* plaster that renders concrete hydrophobic and sticky. According to Dwivedi*et al.* (2008), black gramme powder also functions as just a natural polymer as well as an inexpensive superplasticizer. Hazarika *et al.*, (2018) investigated the use of aqueous okra extract as a sustainable bio-admixture in cement mortar and concrete manufacture. Due to the increased hydration rate of the cement particles, cement pastes containing bio-admixture form up faster and increase overall compressive strength of the mortar. According to Sathya *et al.* (2015), water hyacinth extract is used as a bio additive in cement and concrete, increasing compressive strength while delaying setting time. The palm liquor made from palm trees was studied by Otoko*et al.* as just a workability enhancer a set retarding additive. Experimental studies conducted by Akindahunsi *et al.* showed that the use of certain natural additives, such as starch admixture, improves the mechanical strength of cement concrete and delays the cement's setting time. The impact of several natural bio-polymeric extract types on the various properties for cement mortar and concrete in their fresh and hardened states was discussed by Karandikar *et al*., in 2014[6-12]. In comparison to contemporary chemical admixtures, they found that natural bio-polymeric materials performed similarly.

Alginate of sea brown algae extract is widely employed as a natural polymer globally and stands out among the list of natural polymers. The compression and tension strength of composites showed a binding mechanism when the addition of 0.5 per cent of seaweed powder to concrete produced the ideal mix composition, according to research by Susilorini *et al.*, on the polypropylene matrix mortar using seaweed as just a natural polymer. To create composite bricks, a sustainable, non-toxic, and locally derived building material, Marin *et al.*, (2010) researched soil stabilization using natural polymers and fibers. According to Heidari *et al.*, the alginate between 0.5 and 1% lowers compressive and split tensile strength. However, the intro of nano, micro, and alginate compensated for this loss in compressive strength. The Cactus extract acts Shanmugavel *et al*., (2020) as a viscous biopolymer using cement pastes to produce sustainable concrete. The findings indicate that as CEX% dosage increased, compression strength, as well as workability, increased as well. The dosage of CEX appears to increase the resilience of concrete against external assaults. According to research done by Engbert *et al*., on the impact of alginate on the hydration of calcium cement, compressive strength rises by around half an hour. While compared to regular concrete, the tensile and compressive strength increases by 110% at 0.1% alginate and 0.02% PCE[13-18]. Alginate boosts the strength characteristics of concrete when its proportion increases up to a particular level. Scarce studies have been conducted using seaweed gel, and along with cactus extract as natural polymer in concrete. In depth investigation is needed to study the effect of brown seaweed gel on the fresh and hardened properties of mortar/concrete.

2.0 Materials and Methods

2.1 Details about materials selected for the study

Ordinary Portland cement 53 grade conforming to IS: 12269-1987 is used as binding material. Locally available M-Sand passing through 4.75 mm sieve is used as fine aggregate. Locally available crushed granite stone of size 20mm, conforming to IS 2386–1963 is used as coarse aggregate[19-20]. The fineness modulus method is used to determine aggregate gradation, which involves passing aggregates through a sieve according to IS standards to define their size. The physical properties of materials used in this study are given in Table 1 and the gradation curve of aggregates is shown in Figure 1.

2.2 Marine Brown Algae Characteristics and Extraction Process

The commercially available marine brown algae *Sargassum*

Table1. Physical properties of the materials used in concrete

Materials	Specific gravity	Fineness modulus (%)	Water absorption (%)	Bulk density (kg/m³)
Cement	3.17	4	-	-
Fine aggregate	2.65	2.57	1.0	1683
Coarse aggregate	2.74	7.8	0.5	1529

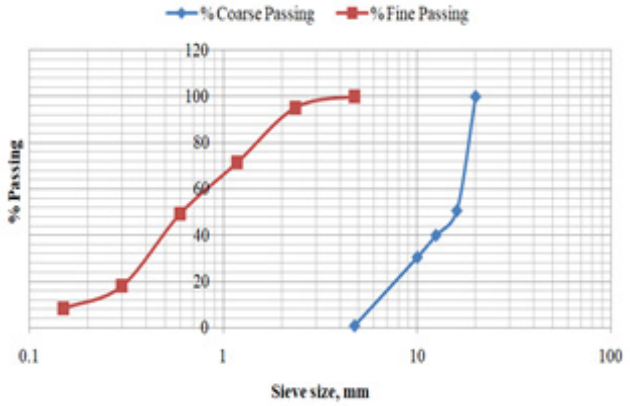


Figure 1. Sieve analysis results of coarse and fine aggregate.

wightii has a moisture content of 40% and pH value of 7.5 with a specific gravity of 1.15 and melting point of 300°C. Materials physical characteristics are visible as shown in Figure 2. The plants are dark brown and 20-30 cm in height with a well-marked holdfast. Leaves 5-8 cm long and 2-9 mm broad are tapering at base and apex. Its habitat was growing throughout the year on the rocks in littoral and sub-littoral regions. This algin-yielding seaweed occurs in harvestable quantities. It was seen widely among Tamil Nadu as Tiruchendur, Tuticorin, Mandapam, Madras and Kovalam regions. The yielding of algin from the species is 31.7%. It was used as raw material in sodium alginate and contains 8-10% of mannitol as a substitute for sugar. The characteristics of alginate depend upon its color, texture and odor[21].

Sargassum family marine brown algae extract acts as a natural component. The seaweed leaves gathered about Ramnathapuram, close to Chennai, just at Kharpick Marine House. The extraction of alginate from marine brown seaweeds by washing and cleaning seaweed leaves in fresh water with 0.2% of formalin (usually 1-12 h) to soften the seaweed tissue, reduce the coloring agents and increase alginate per cent and bleaching of the biomass after that it was sun-dried. Then, seaweed leaves were soaked in freshwater with Enzyme or sodium carbonate for 24 hours. The enzyme will prepare by the percentage addition of sugar, seaweed powder and water for closed and open in position at first 30 days after it was



Figure 2. Sargassum Wightii **(a)** Fresh alginate and dried form**(b)** Liquid Extract **(c)** Gel form.

permanently closed in an air-tight container at 90 days. The seaweed gel was physically or mechanically extracted from the leaves, pressed until all of it was gone, and then filtered to create a natural biopolymer known as seaweed extract. Therefore, different amounts of seaweed extract were added to water, based on the weight of the cement and utilized to mix the concrete[22-24].

2.3 Micro-structural properties of seaweed gel

The X-Ray Diffraction (XRD) pattern of alginate is shown in Figure 3. By examining the nature of the Bragg's peaks that emerge in the XRD pattern, it is possible to determine the composition of the materials. If the peak is quite broad, the substance is amorphous with short range ordering. The material is crystalline if the XRD pattern shows sharp peaks. If you acquire a combination of the two, the substance will display both properties semi-crystalline, but some noisy pattern, then the materials is said to have amorphous nature[25].

FTIR spectrum of *S. wightii* extract was recorded and given in Figure 3. The absorption bands corresponding to the C-H bending or C-O or C-C stretching vibrations of carbohydrates and polysaccharides contained in the *S.wightii* extract are located between 1100 and 1000cm^{-1}. The band seen at 875.1cm^{-1} is caused by an aromatic C-H out-of-plane vibration, indicating the presence of an aromatic ring pigment complex. The C-H bending vibration is responsible for the weak absorption band centered at 637.0cm^{-1} and 690.1cm^{-1}, which also confirms the existence of carbohydrates.

The free O-H and N-H stretching vibrations of the amino acids are responsible for the strong and wide absorption band at 3415.3cm^{-1}. The presence of chlorophyll is verified by the presence of CH stretching vibrations at 2924.1cm^{-1}.The faint absorption bands detected at 2512.6 cm^{-1}correspond to C-O stretching, which is one of the carboxylic group's distinctive peaks. The absorption band centered at 1630 cm^{-1} is caused by the ester group's C-O stretching and N-O asymmetric stretching[26]. The band 1425.9cm^{-1} is caused by the aromatic ring compound's

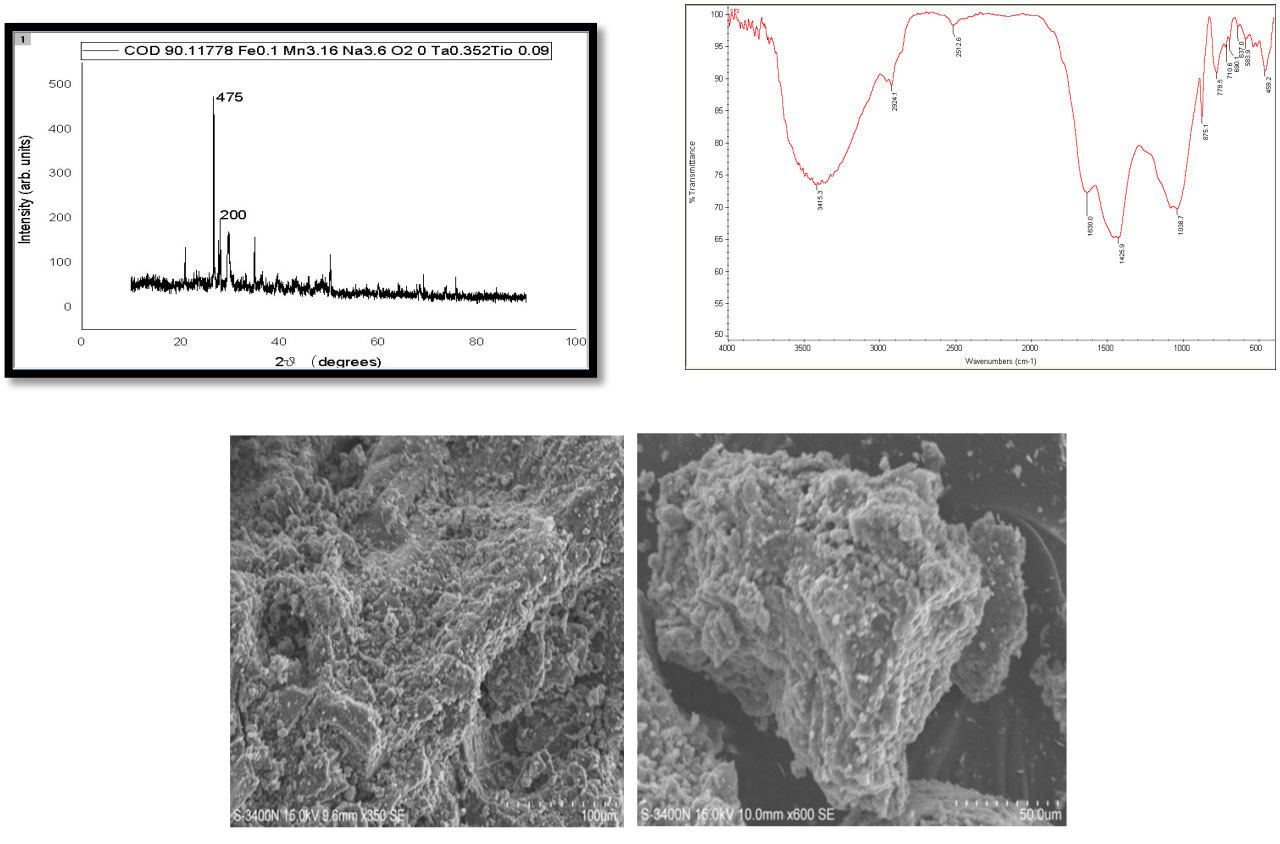


Figure 3. XRD, FTIR spectrum and SEM results collected on the seaweed gel.

C-C stretching vibration. The C-N stretching vibration of chlorophyll is seen by the median absorption band at 1038.7 cm^{-1}. According to the FTIR data, the principal element of the *Sargassum wightii* seaweed extract includes carbohydrate and chlorophyll.

Scanning Electron Microscope (SEM) examines the morphological study of seaweed gel and to identify the texture, pores and size of the material. Figure 3 shows an enlarged view of porous morphology at 100µm and a solid type of material at 50 µm. The texture of the seaweed gel material showed a rubbery kind of material. This analysis also reveals that sodium alginate particles are spherical and semi-crystalline[27]. It might be the development of the network of polymeric chains as polyguluronate forms a bond with cat-ion.

3.0 Experimental Study

3.1 Tests Methods

The Effect of seaweed gel addition on fresh-state properties of concrete was studied by standard consistency, setting time and water retention tests as per IS: 4031(part -5)-1988[28]. The slump cone test was carried out as per IS: 1199-1959[29], to assess the overall workability of the concrete. The cement slump test gauges how fluid new concrete is before it hardens.

The M30 Grade of concrete was proportioned a cement content of 380 kg/m^3, a fine aggregate of 704kg/m^3, a coarse aggregate of 1240 kg/m^3 and water of 160 kg/m^3. In total, six mixes were proportioned by varying seaweed gel from 0 to 5% by weight of cement and with a design mix ratio of 1:1.8:3.2 and water-cement ratio of 0.45. Twenty-four concrete cubes for each mixture series with control concrete were cast (a total of 144 cubes). In these mixture series, seaweed gel was designated from 1 to 5% addition as SWG-1, SWG-2, SWG-3, SWG-4 and SWG-5.

The compressive strength of concrete 100x100x100mm was cast and tested for 3, 7, 28 and 60 days with a w/c ratio of 0.45 according to IS 516-1959[30]. A flexural strength of 100x100x500mm was cast and tested at 28 days as per IS 516-2002. Split tensile tests of 150x300mm size cast and tested according to IS 5816[31]. Thermal conductivity variation in concrete determined 180mm diameter and 10mm thick according to IS 9489 after 28 days of curing.

The durability test i.e., acid and sulphate attack of concrete specimen of size 100mm cube were calculated at 7, 28 and 60 days of curing according to ASTM C1898-20 *and* ASTM C1012(2004) respectively. The water absorption test of 100x100x100 mm cubes cast 28 days ago was measured under specific circumstances according to IS: 1124-1974. The sorptivity test was conducted on a 100mm cube specimen to indicate the impediment to water flow caused by capillary suction on the surface of the concrete sample. The chloride diffusion test predicts the service life of reinforced concrete buildings by indicating the ability of any form of concrete to resist chloride penetration as per ASTMC 1202[32].

4.0 Results and Discussion

4.1 Fresh Properties of Cement with Seaweed Gel

The standard consistency and setting time of cement paste added in various proportions of seaweed gel are in Table 2. The setting time of cement depends upon typical factors such as dosage of alginate gel, type of cement and manual errors. The standard consistency of cement is varied from 28% to 30% in addition to seaweed gel from 1% to 5%. It is clear from the results that the standard consistency of cement paste increased with an increase in the percentage of seaweed gel up to 5%. The result showed that the amount of seaweed gel increased, and the initial and final setting time also increased. It proves that seaweed gel acts as a retarding admixture in cement. The presence of sugar content in the seaweed gel as Guluronic acid (G) 8-12 % retards the setting time of cement. It was also an application while placing concrete in warm conditions, transporting and finishing. The setting time of cement was increased by about 0.5 to 2.33 times from 1 to 5% addition of seaweed gel.

In most cases, standard techniques like ASTM C1506-09 are utilized to assess the cement pastes' ability to retain water. The amount of water filter paper can hold onto for a predetermined period is measured. On the filter paper, the soaking water moves in the direction of the radius of the circle and connected to the quantity of water absorbed. Phenolphthalein, an acid-base indicator, clearly showed the formation of a pink-colored circular ring when the solution of water liberated from the cement paste interacted with filter paper as shown in Figure 4.

Table 2. Fresh properties of cement with seaweed gel

Seaweed Gel (%)	Setting time (min)		Consistency (%)	Water retention test results in radius, (cm)
	Initial	Final		
0	60	185	28	5.5
SWG-1	90	200	28.5	4.5
SWG-2	120	225	29	4.3
SWG-3	150	240	29	4.3
SWG-4	140	220	29.5	4.2
SWG-5	120	185	30	4



Figure 4. Water retention test results of cement mortar with gel.

The radius of this circular ring directly related to the water retention capacity of cement paste. Reference paste produced the color circular ring of radius 5.5 cm and pastes having seaweed gel radius of 4.3, 4.2 and 4 in Table 2. The lower values observed for seaweed-containing pastes indicate that the investigated seaweed gel has water retention capacity. It denotes that the viscosity of the liquid increases with an increase in the capillary movement of water. The smaller radius of the circular ring indicates that seaweed gel concrete also works as a viscosity-enhancing admixture.

Workability of concrete was determined in terms of slump test as per IS 1199, 2018. It was observed that for conventional concrete the slump was 70mm which is treated as medium workability according to IS 456-200 (Figure 5). When alginate gel was added in the concrete from 1% to 5% in the increment of 1% in each proportion gave incremental values in workability from 70mm to 110mm respectively. Addition of alginate gel improves the degree of workability to high, which shows that this material can be used in preparation of self-compacting, pumping concrete and even other types of concrete mixes. Excessive water could be claimed to improve workability because it makes placement and consolidation easier. The negative influence on segregation, finishing processes, and ultimate strength, on the other hand, might be so severe that it should be addressed with extreme caution. Admixture modifications increase concrete lubricity, allowing stiff concrete to extrude more easily, and decrease pump pressures in more fluid concrete applications. A workability-retaining admixture enables variable but predictable slump retention without retardation. The above gel (Seaweedgel) is a promising material, which can be used to improve the workability of concrete.

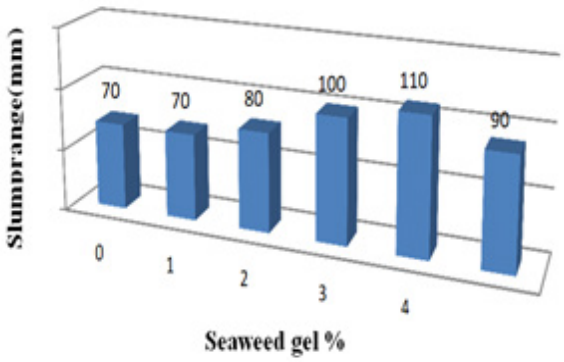


Figure 5. Workability of concrete with seaweed gel.

4.2 Mechanical Properties of Concrete with Seaweed

Effect of seaweed gel addition on compressive strength of concrete was tested at 7 days, 14 days and 28 days and presented in Figure 6. For conventional concrete a compressive strength of 32.43MPa, 40.53MPa and 41.96MPa was observed for 7 days, 28 days, and 60 days respectively. It was observed that the strength development pattern followed was like the compressive strength of cement mortar specimens up to 3% of seaweed gel, irrespective of ages. Rate of increase in compressive strength with 3% addition of seaweed gel at 7 days, 14 days and 28 days was about 12%, 12.2%, 10.6% respectively when compared to conventional concrete. The maximum compressive strength of 28 days attains 43.86 MPa by the addition of 3% marine brown algae in cement. A slight decrease in the rate of increase in compressive strength was observed at 4% addition. In contrary to compressive strength development of cement mortar, similar strength to that of conventional concrete was observed at 5% addition of seaweed gel in concrete at all ages.

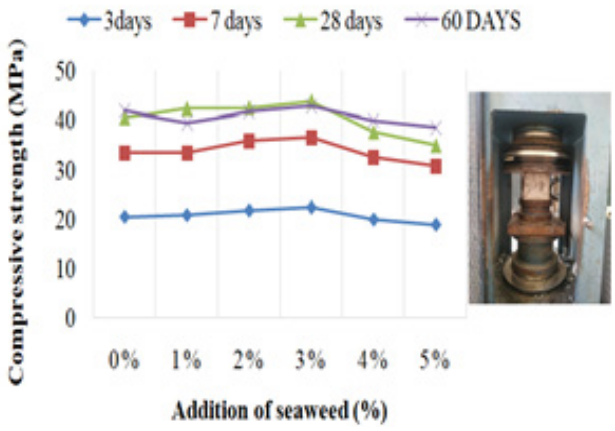


Figure 6. Compressive Strength of concrete with percentage addition of alginate.

Splitting tensile test was conducted according to IS 5816 (1999) at 28 days. The conventional concrete showed as splitting tensile strength of 2.09MPa and the split tensile strength was reduced initially by 12.44% when 1% of seaweed gel was added in concrete when compared with conventional concrete. The remaining mixes i.e., 2% to 5% addition of seaweed gel in concrete showed increase in splitting tensile strength from 2.37MPa to 3.41Mpa respectively. The highest strength was observed in 3% addition of seaweed gel i.e., 38.7% increase when compared with conventional concrete.

Flexural strength of concrete was tested according to IS 516-2002 with four-point loading. The flexural strength of conventional concrete was observed to be 7.31MPa. When seaweed gel was added in concrete from 1% to 5% it was observed that all the percentage addition of seaweed gel gave incremental strength than conventional concrete. When seaweed gel of 3% was added in concrete it showed maximum flexural strength of 10.02MPa of all the mixes. All the mixes showed an increase in flexural strength at a rate of 10.9%, 15%, 36.9%, 8% and 2.7% from 1% to 5% addition of seaweed gel respectively.

4.3 Durability Studies on Concrete with Seaweed Gel

Hydrochloric Acid with 3% as pH was added in water to find the durability of concrete when seaweed gel is added from 1% to 5% in concrete. From Figure 7 it is clearly observed that there is increase in compressive strength from 1% to 4% of seaweed addition. At 28 days the compressive strength for 1%, 2% and 3% addition were increased by 20.8%, 23.1% and 10.39 respectively compared with conventional concrete. For 5% addition of seaweed gel the compressive strength was equal to control concrete. From the results, we conclude that seaweed gel concrete has low water absorption capacity, but it was less exposure to acid attack. This can be explained by high calcium and calcium hydroxide content in the seaweed gel. Hence seaweed gel concrete is more suitable for acidic

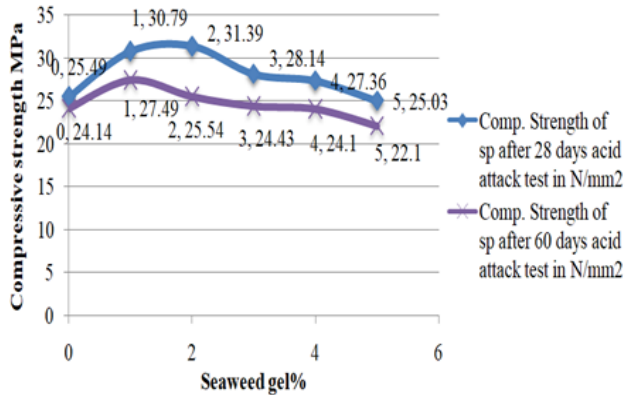


Figure 7. Acid attack strength test results of concrete with seaweed gel at 28 and 60 days.

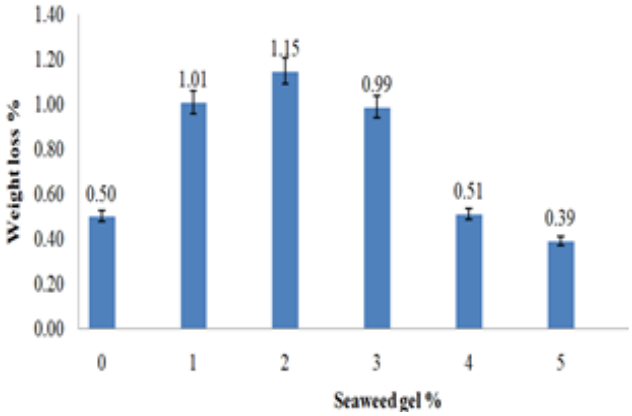


Figure 8. Weight loss results of acid attack test at 28 days.

environment compared to control mix. In comparison to ordinary concrete, overall residual compressive strength for a modified concrete diminishes as the seaweed gel content rises.

The weight loss in acidic environment occurs because of high corrosive nature of sulphuric acid and weakens the binding capacity of strength giving phases (calcium silicate hydrate and calcium aluminum silicate hydrate). The percentage weight loss of concrete cube specimen after 28 days immersion in acidic solution is presented in Figure 8. The control specimen lost 0.5% of its weight while seaweed gel concrete lost 1.15% weight up to 3% and decreases with higher percentage. Figure 8 displays the results of the sulphuric acid attack's residual compressive strength at 28 days.

Rapid Chloride Permeability Test (RCPT) or coulombs test is used to find the chloride ion penetration in concrete. The same pattern of graph to that of thermal conductivity was observed in RCPT test. Table 3 shows the results of chloride ion passes through the concrete at 28 days. When the amount of seaweed gel is increased by 1% to 5% the chloride ions pass through the concrete decreases. This low value of chloride-ion penetrability was expected because of the less porous nature. The chloride resistance of concrete is thus highly dependent on the porosity of cement mortar in terms of pore size, pore distribution and interconnectivity of the pore system. Molecules with high molecular weight may increase the viscosity of pore solution and seaweed gel has high molecular weight compared to the water in control concrete. The chloride permeability rating of various amount of seaweed gel added in the concrete at 0 to 4 % as moderate and 5% as low. Addition of seaweed gel changes range of chloride ion penetrability from moderate to low. Seaweed gel also retards the hydration reaction of cement at 28 days moist curing and makes chloride ion impermeable compared to the control concrete. While compared with moist curing,

Table 3. RCPT Test results and water absorption of concretes with seaweed gel

Sample (%)	Charges passed (Coulombs)	Chloride permeability	Water absorption N/mm²
Reference	3025.46	High	1.55
SWG-1	2884.34	Moderate	1.43
SWG-2	2665.26	Moderate	1.47
SWG-3	2570.13	Moderate	1.45
SWG-4	2260.13	Moderate	1.40
SWG-5	1984.2	Low	1.35

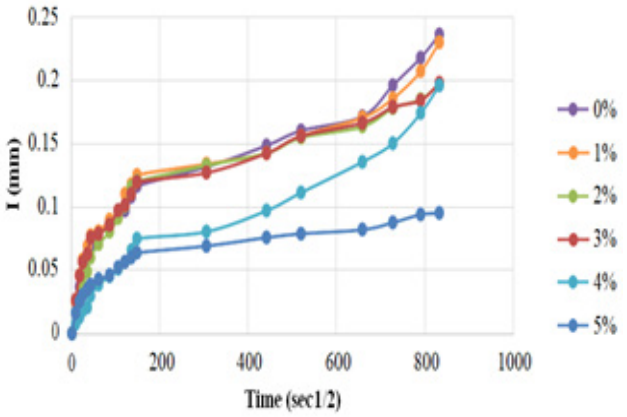


Figure 9. Capillary absorption of concrete with gel at 28days.

the air curing concrete was high permeable, porous capacity to penetrate chloride ions in concrete with seaweed gel.

The rate of water absorption mainly depends on the rate at which water can enter the concrete surface and the amount of voids present. The results show the reduction of water absorption with various percentage additions of seaweed gel admixture may induce the increased rate of the cement hydration process. During the hydration process, the interface of alginate and divalent calcium ions forms a thin film that makes the concrete pores impermeable. As the seaweed gel content increased, pores in the concrete phases decreased due to the formation of calcium complexes. The water absorption decreases with increasing the amount of seaweed gel. Water absorption was reduced by about 9.2%, 12.88%, 20.24%, 21.47% and 27% for the addition of 1, 2, 3, 4 and 5% respectively. Sorptivity test is one of the durability tests to find the capillary suction of water through the pores in cement mortar. The sorptivity is found to depend on the permeability, porosity of concrete and the strength of capillary forces. The results of capillary absorption after 28 days of curing for various amount of seaweed gel are shown in Figure 9. The initial and secondary rate of absorption decreases by increasing the amount of seaweed gel. The initial rate of absorption reduced about 54 % up to 5% addition of gel. The secondary rate of absorption reduced about 77% up to 5% addition of gel.

The thermal conductivity of concrete with the addition of various amount of seaweed gel at different ages were determined at 28 days, to measure one dimensional heat flow using two slab guard thermal conductivity apparatus. The thermal conductivity value decreases by increasing the amount of seaweed gel. Thermal conductivity was reduced by about 6%, 18%, 27%, 36% and 45% by the addition of 1%, 2%, 3%, 4% and 5% gel. This seaweed gel material is acting as a good thermal insulator, which can be used in the hot regions. Conventional concrete showed at thermal conductivity of 0.8w/m^{o} K and when only 1% of seaweed gel was added to concrete the thermal conductivity was reduced by 9.09%. The least thermal conductivity value of 0.45w/m^{o} K was observed for 5% addition of seaweed gel. The percentage reduction in thermal conductivity was 45.45% when 5% seaweed gel was added in concrete when compared with conventional concrete. A steep inclined reduction of 8%-10% for each 1% addition of seaweed gel was observed in each mix when compared with conventional concrete.

5.0 Conclusions

In the present paper, effect of addition of seaweed gel from 1% to 5% on the fresh and hardened properties of concrete was studied. The following salient conclusions are made based on the tests conducted:

- In general, seaweed gel concrete improves the fresh state properties of cement and concrete up to 5 % of addition. The seaweed gel addition of up to 5% increases the initial setting time of cement by about 3.33 times when compared to OPC. Seaweed gel is a promising material to use as a retarder.
- The natural polymer of the bio-additive enhances the workability and decreases the water requirement of the concrete mix. The divalent Ca^{2+} ions link the polymeric chains of pectin present in seaweed gel and thus improve the plasticity of the concrete mix.
- The XRD pattern of seaweed gel (*S. wightii*) shows sharp peaks, conforming to the crystalline nature of the material. According to the FTIR data, the principal elements of the *S. wightii* seaweed extract include carbohydrates and chlorophyll. The texture of the seaweed gel material showed a rubbery type of material.
- Influence of seaweed gel addition on the compressive strength development was marginal by about 12% concrete up to 3%. At 5% addition, comparable compressive strength as that of

conventional concrete was obtained. Flexural strength was increased by about 37% in addition of 3% seaweed gel when compared to conventional concrete.

- At 28 days, durability test results shows that the residual compressive strength for 1%, 2% and 3% addition was increased by 20.8%, 23.1% and 10.39 respectively compared with conventional concrete. Hence seaweed gel concrete is more suitable for acidic environment compared to control mix. The additive modified concretes have demonstrated better durability characteristics in terms of resisting chloride penetration with a drastic reduction in the Coulomb charges. Addition of seaweed gel significantly reduced the thermal conductivity of concrete by about 45% for 5% addition and hence improves the thermal properties of concrete.
- It is recommended to use 5% of seaweed gel as natural polymer in concrete to improve the fresh state and durability properties without affecting the properties of concrete to achieve the sustainability.

6.0 Acknowledgements

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