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A Review on Application of Seaweed in Construction Industry

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Abstract **-- Now a day's the main focus on sustainable construction are increased, green construction material takes important role in sustainable development. Concrete has become the most popular construction material in the world, sustainable concrete determines the sustainability of a structure. Several efforts have been done to achieve the sustainable concrete. Those efforts make the concrete technology innovation 'green', less energy, and less carbon emission. Seaweed is a pure natural material that offers numerous advantages, such as excellent heat insulation and heat capacity characteristics as well as full biodegradability and strong carbon dioxide fixation. In this paper, utilization of seaweed in construction industry for various applications is critically reviewed.**

Keywords **– Seaweed; construction industries; seaweed resource in India; natural polymer; viscosity modifying admixture; filler material.**

I. INTRODUCTION

Seaweeds are marine resources of non-flowering plants. It grows submerged in intertidal, shallow and subsurface water up to 100 m depth in the sea, brackish water estuaries. Most seaweed belongs to one of three divisions - the Chlorophyta (green algae), the Phaeophyta (brown algae) and the Rhodophyta (red algae). There are about 900 species of green seaweed, 4000 red species and 1500brown species found in nature. Researchers at Fraunhofer Institute for Building Physics (IBP) found a way to utilize species of seaweed by using it as insulation material in construction field. It has been reported that addition of sea weed can hold 20 percent more energy than wood or wood products. Some non-edible seaweed has gelling, thickening properties, binding capacity, and corrosion resistance properties. Many types of seaweeds have many uses, from direct use in dishes or as food supplements, pharmaceutical, fertilizer or biodiesel resource.

In Germany (Tunisia and Albania sea), the seaweed leaves from the Posidonia oceanica plant, more commonly known as Neptune grass seaweed, is virtually non-flammable, resistant to mold, and can be used as insulating material without the need for chemical additives. It can be used as insulation between the rafters of pitched roofs (Fig.1.1), to insulate interior walls, or to reduce the amount of heat lost through building envelopes. Fibers act as a buffer, absorbing water vapor and releasing it again without impairing its own ability to keep the building insulated.

In United Kingdom, seaweed was used as a polymer in natural clay bricks. Bricks are made by the usual method, burning of bricks is not required due to the utilization of seaweeds. The un-burnt bricks made of seaweed resulted in compressive strength two times higher as that of ordinary clay bricks (Fig.1.2). Alginate is a natural hydrophilic polymer extracted from seaweed. Seaweed extract also used as a water repellent layer over the bridges (Fig.1.3).

A. Seaweeds Resource in India

Seaweeds grow abundantly along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman and Nicobar islands. There are also rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu and Chilka in Orissa. Out of approximately 700 species of marine algae found in both inter-tidal and deep water regions of the Indian coast, nearly 60 species are commercially important. Since last decade, Indian seaweeds were more commonly utilized for industrial production of agar/alginate and as fertilizers; their applications in other contemporary area are still unexploited.

A survey of seaweed resources in Tamilnadu coastal was carried in the area between Ramanadapuram district (Valinokkam and Kilakkarai) during January 1989 and March, l990. In the survey from Valinokkam to Kilakkarai, 33 species of marine algae were recorded of which 8 species belong to Chlorophyta, 8 to Phaeophyta and 17 to Rhodophyta. More recently, the Central Marine Fisheries Research Institute and Central Salt & Marine chemicals Research Institute have jointly undertaken the survey of deep water seaweed resources from Rameswaram to Kanyakumari in Tamil Nadu in order to locate and assess the standing crop of seaweeds from the sub tidal region Brown algae such as Sargassum and Turbinaria are collected seasonally from August to January on Southern coast. A standing crop of 16,000 tons of Sargassum and Turbinaria has been reported from Indian waters.

II. APPLICATION OF SEAWEED IN CONSTRUCTION INDUSTRY

The general review of seaweeds in the construction field and the previous work reviews are presented. In construction industries, seaweed has been used as a natural polymer, fibre, viscosity modifying admixtures, filler material, etc.

A. Natural Polymer

Susilorinia et al, (2014) studied the effect of natural polymer modified mortar with seaweed gel (Eucheuma Cottonii) and seaweed powder (Gracilaria Sp.) on compressive and tensile strength of the composite. Figure 2.1 shows the images of seaweed gel and seaweed powder. It was reported that the presence of agarose and agaropectine in seaweed causes very strong gelling and thickening properties, which increase the bonding mechanism. The research has shown that natural polymer modified mortar with seaweed powder (Gracilaria Sp.) resulted in compressive strength of about 30MPa compared to seaweed gel concrete. The optimum mix composition was achieved from 0.5% of seaweed powder addition in concrete.

The compressive strength of seaweed specimen increased as compared to the control specimen. It was found that Polymer modified mortar has good binding properties and adhesion to aggregates and it is very useful for *repairing and retrofitting.* When used together with cement, natural polymer will fill the porous parts and strengthen cement performance. Gracilaria Sp. and Eucheuma Cottonii have similar properties in gelling and thickening and contain agarans and carrageenans that work at cement hydration phase. Natural polymer modified mortar with seaweed powder is very promising to become green construction material for sustainable concrete [1].

Marín et al, (2010) studied the stabilization of soils with natural polymers and fibres to produce a composite bricks, sustainable, non-toxic and locally sourced building material. In this research earth is used as a building material and mixed with natural polymer extracted from seaweed and animal fibre. In this case raw, unprocessed wool, to form a composite stabilized against water erosion, with enhanced binding force, increased compressive strength. Alginate is hydrophilic gelling material and it has a higher water holding capacity. Alginate stabilized soils showed better mechanical characteristics than unstabilized ones and similar to those stabilized with cement and lime. The specimens were tested for their mechanical properties such as density, bending strength and compressive strength. The result showed that the addition of alginate separately increases compressive strength from 2.23 to 3.77 MPa and the addition of wool fibre increases compressive strength of about 37%. Adding alginate and reinforcing with wool fibre doubles the soil compression resistance [2].

Friedmann et al, (2010) conducted research to use alginate as a binding material, and obtained excellent results to improve the cement hydration for internal post-curing with respect to compressive strength and to its frost de-icing salt resistance on high performance concretes [2].

Lee et.al reported that red clay with seaweed glue solution increase the compressive and tensile strength in the ratio of red clay: seaweed- 85:15. The compressive, flexural strength and physical properties of red clay with seaweed gel composites is shown in Table 2.1. The red clay with the seaweed gel composite shows substantially higher compressive and flexural strength when compared to control sample [3].

B. Viscosity Modifying Admixtures

The effects of alginate (seaweed), micro and nano silica as mineral admixtures on the fresh and hardened properties of SCC are investigated by Heidari et.al, (2014). Effect of 0.5% and 1% alginate, along with 10% micro silica, 0.5% nano silica, 0.5% artificial stone resin on SCC was studied. Artificial stone resin is used as the super plasticizer. Properties of hardened SCC such as compressive, split tensile, flexural strength and water absorption was determined**.** Alginate concrete possesses a lower water absorption capacity. In general the use of alginate improved the performance of SCC in fresh state like workability. When compared to the alginate with nano and micro silica together, the use of nano and micro silica in upper percent of alginate increased the strength. Adding 10% micro silica to the cement with 0.5% of alginate and cement with 1% of alginate samples increases compressive strength of about 28% and 66% respectively [4].

Martinez et al, (2014) investigated the use of new viscosity enhancing admixtures on SCC such as nopal mucilage and marine brown algae extract. Brown algae is a semi-pasty dispersion with a high content of polysaccharides, minerals and proteins. This paper presents the rheological properties in rotational and oscillatory shear tests of cement pastes and mortars with w/c ratio of 0.50, containing nopal mucilage and marine brown algae extract.

For comparison purposes, a commercial viscosity enhancing admixtures based on welan gum was used. The results indicate that the new viscosity enhancing admixtures produced a significant increase on the shear viscosity and the yield-stress of pastes, mortars and SCC, which increased with increasing concentration and depending on their molecular nature. It does not affect the compressive and tensile strength of the concrete. SCC mixtures containing nopal mucilage or brown algae extract at concentrations >0.25% were stable and homogeneous with slump flow values higher than 700 mm, indicating that both nopal mucilage and brown algae exhibit adequate characteristics to be used as viscosity enhancing admixtures.

Figure 2.2 shows the visual appearance of SCC mixtures containing nopal mucilage or brown algae and a commercial viscosity enhancing admixtures during the flow spread test at room temperature [5].

C. Filler Material

The non-edible seaweeds are used as bio fillers at different composition in polypropylene to get bio composite. Chitra and Kumari, (2012) investigated the effect on mechanical, thermal and morphological properties of polypropylene bio-composites. The reinforcing filler used was brown sea weed (BS) (Sargassum tenerrium) and red sea weed (RS) (Kappaphy cusalverizzi).

Mechanical, thermal and morphological characteristics of the blend systems were studied to evaluate the effect of filler content on polypropylene. Tensile modulus was found to be increased with the filler content. The thermal stability of the matrix is found to be increased significantly by the presence of filler. SEM observations were made for various blends of polypropylene with brown seaweed and polypropylene with red seaweed are presented for 30% filler content. Table 2.2 shows that addition of 20% filler showing higher thermal stability [6].

Jang et al, (2012) investigated the study on seaweed-reinforced polypropylene bio composites. The seaweeds are pretreated with ethanol, acetone, and sulfuric acid and the thermal and mechanical properties of the bio composites were investigated. The green algae type, with its higher thermal stability, was more suitable as a reinforcement of bio composites than the brown algae type. The impact strength showed a greater increase of 50% for the green-algae-reinforced polypropylene bio composites compared to the increase of 26% for the brown-algae-reinforced polypropylene bio composites. The pretreatment of green algae with sulfuric acid resulted in the highest thermal stability among various pretreatment. Green algae with polypropylene bio composites showed higher thermal stability and greater impact strength than brown algae with polypropylene bio composites. So it can be used as an excellent reinforcement for bio composites [7].

Seaweed (SW) is employed as filler to prepare composites on the basis of a polypropylene (PP) matrix in the ratio of 10 to 50: 10 to 50 (wt % SW: wt % PP) by compounding and injection molding. The tensile, bending and impact properties of the composites were investigated by Hassan et al, (2007). It was reported that, the mechanical properties increase with increasing filler content up to an optimal value, and thereafter with further increase in filler content, the properties either remain constant or show a decreasing trend.

It is observed that with an increase of filler content from 10 to 30% the tensile strength gradually increases (Fig.2.4 (a)), but the tensile strength of the composites are found to decrease with increasing filler loading for weight fractions from 40 to 50%. Figure 2.4 (b) shows that the bending strength increases up to 30% seaweed content, and thereafter remains constant. The 30% SW: 70% PP composite showed the best over-all mechanical performance of the composites prepared [8].

The above literatures give some valuable properties of seaweeds like

- High degree of water retention
- Improved strength and structural compactness
- Improve the fire resistance
- Good alkali resistance
- Non-toxic, odourless, does not harm the skin, harmless to human body.
- High water holding capacity and reduces the heat of hydration.
- Improve the tensile strength of the matrix in fibre form.
- Gives good strength and thermal insulation properties.

III. Summary

Sustainable construction development has become great challenge and mainly concern the green construction materials. In construction industries, seaweed has been used as a natural polymer, VMA, filler material, water repellent etc. Seaweed is expected to perform a excellent green construction material. Addition of seaweed extract into concrete is expected to perform excellent bonding, strength, thermal insulation and durability as the key factor to achieve sustainability.

Figures and Tables

Fig.1.1 Insulation of seaweed fibres between the rafters of pitched roofs

Fig.1.2 Clay Bricks made of sea weed fibres

Fig.1.3 Water sealant layer over the bridge using seaweed extract

Fig.2.1 Image of (a) Raw seaweed (b) Eucheuma Cottonii, gel (c) Gracilaria Sp., powder [Susilorinia et.al – 2014]

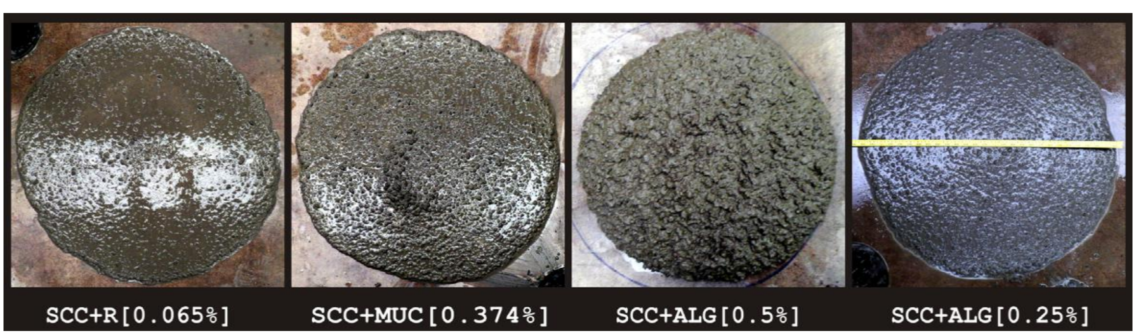
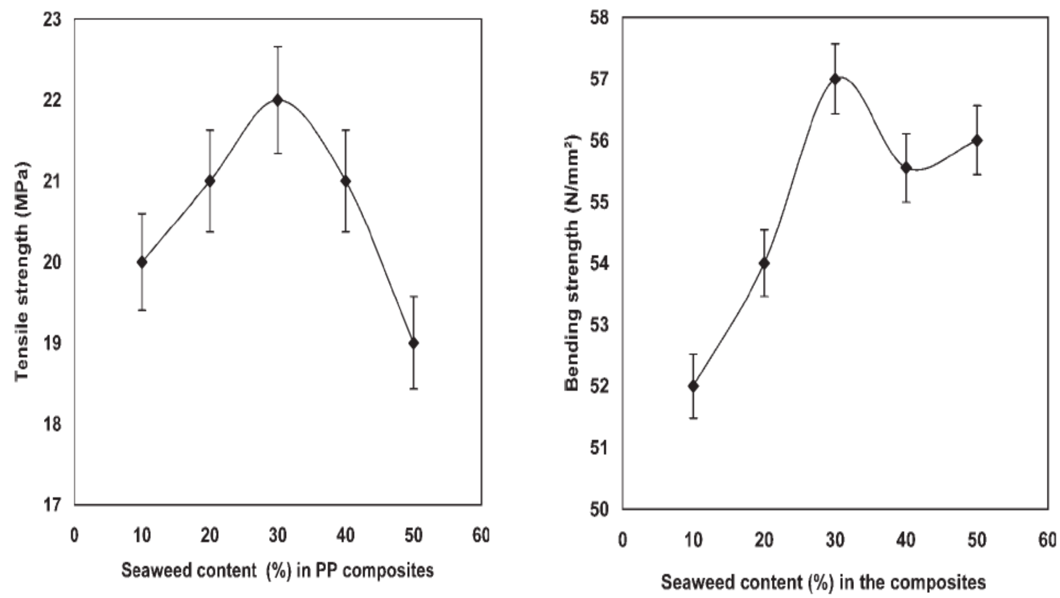


Fig.2.2 Visual appearance of SCC mixtures containing nopal mucilage and marine brown algae extract and a commercial viscosity modifying admixtures during the flow spread test at room temperature [Martinez et.al – 2014].



(a) (b)

Fig.2.4 (a) Tensile strength of seaweed polypropylene bio composites, (b) Bending strength of seaweed polypropylene bio composites, [Hassan et al, 2007].

TABLE.2.1
Physical and Strength Properties of the Red Clay/Seaweed Gel Composites, [Lee et.al – 2007]

Sample ID	Compressive Strength (MPa)	Flexural Strength (MPa)	Water Absorption (%)	Specific Surface Area (m^2/g)	Pore Volume (cm^3/g)
Control	5.01	1.30	31.4	23.77	0.0416
Seaweed	5.77	1.47	31.2	23.22	0.0392

TABLE.2.2
Thermal Stability of PP Seaweeds Composite – [Chitra and Kumari – 2012]

Material	Decomposition temperature(ºC)	
	At 50%	*At 100%*
PP	435	465
PP/RS (20%)	450.4	485
PP/BS (20%)	457.7	520

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