Chapter 17
Behavioural Study on Concrete with Organic Materials for CO_2 Absorption

K. Srinivasan and M. C. Sashikkumar

Abstract From the past two decades, the emission of carbon dioxide has been increased dramatically across the globe. Concrete is the widely used versatile construction material. Hence, this research work was conducted in order to control the emission of carbon dioxide with the help of this widely used material for a sustainable environment. An attempt has been made in the admixing of processed organic materials such as potato peel and seaweed in different proportions to the concrete mixture. Different proportion of mix were the addition of seaweed at 5% by weight of the cement, potato peel at 5% by weight of the cement, both potato peel and seaweed at 5% each by weight of the cement. Test methods such as carbonation and titration method were conducted to find the carbon dioxide absorption percentage; along with the conventional pressure sensitive test at 28 and 56 days. Combined addition of potato peels and seaweeds have improved the compressive strength, carbonation depth and amount of carbonation absorbed. When comparing the specimens with both potato peel and seaweed cured at 28 days and 56 days have showed in the ranges between 42.6 and 45.5 MPa; between 1.9 and 2.4 g; and between 1.9 and 2.6 mm, respectively.

Keywords Carbonation depth · Absorption of CO_2 · Potato peel · Seaweed · Amount of CO_2 absorbed

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V. S. Kanwar et al. (eds.), *Proceedings of International Conference on Innovative Technologies for Clean and Sustainable Development (ICITCSD – 2021)*,
https://doi.org/10.1007/978-3-030-93936-6_17

17.1 Introduction

Across the globe, it is evident that the amount of CO_2 concentration in the atmosphere has increased to multi fold, including the contribution by the cement manufacturing industry (Carstensen and Rapf 2008). Though globalisation and industrialization were the primary reasons, significant contributions were through the adoption of various methods, processes, technologies, deforestation and societal ignorance by human kind. Ecological balance and environmental stability are the two essential aspects that the human kind to be taken cared. Global warming has occurred more than two decades due to the emission of greenhouse gases that has accounted for nearly 72% of the total emissions of both CO_2 and greenhouse gases. The major CO_2 gas is released from vehicles. Particularly, the emissions due to CO_2 have changed dramatically and have increased in the last five decades with the present increment of almost around 3% every year. The influence of the wants and needs of infrastructure development has made the human kind to utilize various natural resources that had depleted the sources. Among the widely used materials, concrete is the most used versatile material across the globe and presently, it is the need for a greener concrete (Tanaka and Stigson 2009). Due to its flexibility and simplicity in its manufacturing, the material was extensively used for infrastructure development both in the urban and rural areas.

However, concrete do have certain deficiencies over a period of its use. Most important deficiency is its durability aspects. Because concrete has two stages for its use viz. fresh and set concrete; and concrete (Neville 1995) is a heterogeneous material where it is susceptible to natural formation of porosity due to the addition of varied sizes of ingredients. The porosity, over the ages of concrete has a tendency to absorb/allow materials from environment due to its capillary action. It is drastically getting increased leading to serious effects like global warming. To control this, CO_2 absorbing concrete cubes was made by using the organic materials such as potato peels and seaweeds.

17.1.1 Potato Peels in Concrete

Though potatoes are rich in potassium, phosphorus, magnesium and nitrogen. Raw or cooked sources of potato peel, regardless of cooking methods, contains good sources of protein, fibre and ash content. However, after effectively utilized in the food industry, there were increased concern over the disposal of potato peels that it might contain potato blight, a type of fungus that causes problems in decomposition or environmental concern because of possible microbial spoilage. Valorisation of potato peels are in the construction industry, environmentally friendly light weight bricks, generation of biomass/biogas; other potential uses of potato peels are in abundant nutritive materials, apoptotic, antibacterial, low value animal feed, agricultural fertilizer, antioxidant, anti-inflammatory and chemo-preventive (Nandita and Rajini 2004). Presence of significant sources of Chlorpropham, used during the storage process of potatoes are also a great concern to be considered. It is to mention here that, there were no studies conducted on the significant utilization and/or inclusion of potato peels in the manufacturing of concrete. Hence, in the present study, to assess the potentials, an alternate way to utilize the waste sources were carried out.

17.1.2 Seaweeds in Concrete

Though the characteristics of seaweeds were that as a bio-degradability material but it provides heat insulation and heat capacity. Seaweeds (Brown 1998) are available as an abundant material across regions with higher humidity, where these could be obtained as a natural waste material. Seaweeds (Majid et al. 2019) have good sources as gel and thickening agent or resin characteristics that it could be used as binder material in the concrete composite. Seaweeds are used in the construction industry in order that it has improved the bond strength, improved strength and durability, and has potential to be utilised as an additive in the manufacturing of concrete. Hence, the CO_2 absorbing capacity was assessed in the present study, seaweeds were added both as individually and combined with potato peels.

17.2 Experimental Methods

17.2.1 Materials Used

In the present study, PPC 53 grade was used as binder material. Clean river sand was used as fine aggregate in accordance with IS: 383 and conforming to Zone – II with a specific gravity of 2.67. Broken granites was used as coarse aggregate with sizes range between 10 and 12 mm with the specific gravity of 2.88. Potable quality tap water was taken during the preparation of the mix. A water binder ratio of 0.39 was adopted with regard to the consistency of the binder material. Curing periods of 28 days and 56 days were adopted.

Potato peels were obtained as a waste material from food manufacturing industries. The sources of the skins of potatoes were potassium, further, it offers good adhesive and can be used as a binding material. Figure 17.1 shows the potato peels used in the present study. The peels were dried in a compact fluidized bed heater at 80 °C for a period of 3 h or until the peels were completely dried. Then the dried peels were ground finely into powdered and were used in the manufacturing process of concrete.

Seaweeds were obtained from commercial source and were used in the present investigation in order to fix the CO_2. Figure 17.2 shows seaweeds of the type Eucheuma Cottonii, that were used in the present study. The seaweed gels were

Fig. 17.1 Potato peels as obtained from the food manufacturing industries

Fig. 17.2 Seaweed as obtained from commercial source

dried in a compact fluidized bed heater at 80 °C for a period of 3 h or until the peels were completely dried. Then the dried peels were ground finely into powdered and were used in the manufacturing process of concrete.

17.2.2 Preparation of Specimens

Concrete mix grade of M_{40} in accordance with standard guidelines (IS 456 2007) and (IS 10262 2009) were adopted. Initially, binder materials and powdered peels and weeds were mixed thoroughly, and fine and coarse aggregates were added. The dry ingredients were mixed well. Then water was added as per the water cement ratio. Addition of peel powder, weed powder and combined peel and weeds powder in the mix were at 5% each by the weight of cement. Water reducing admixture of 0.3% by weight of cement was taken and added during the preparation of mix. Table 17.1 shows the details of specimens prepared for 28 days curing period and Table 17.2 shows the details of specimens prepared for 56 days curing period. Required number of cube specimens of size 150 × 150 × 150 mm were prepared as per the standard procedure. The specimens were then cured for the periods of 28 days and 56 days. After curing, the specimens were allowed to sun dried and kept ready for various tests. Figure 17.3 shows portion of specimens kept ready for tests.

Table 17.1 Details of preparation of specimens for 28 days

S. no.	% of addition	Specimens		
		Compressive strength test	Carbonation test	Titration method
1	Control	CS1 – CS3	CT1 – CT3	TM1 – TM3
2	5% of potato peels	CS4 – CS6	CT4 – CT6	TM4 – TM6
3	5% of seaweeds	CS7 – CS9	CT7 – CT9	TM7 – TM9
4	Combined 5% of potato peels & 5% of seaweeds	CS10 – CS12	CT10 – CT12	TM10 – TM12

Table 17.2 Details of preparation of specimens for 56 days

S. no.	% of addition	Specimens		
		Compressive strength test	Carbonation test	Titration method
1	Control	CS13 – CS15	CT13 – CT15	TM13 – TM15
2	5% of potato peels	CS16 – CS18	CT16 – CT18	TM16 – TM18
3	5% of seaweeds	CS19 – CS21	CT19 – CT21	TM19 – TM21
4	Combined 5% of potato peels & 5% of seaweeds	CS22 – CS24	CT22 – CT24	TM22 – TM24

Fig. 17.3 Portion of specimens kept ready for tests

17.2.3 *Testing of Specimens*

17.2.3.1 Compressive Strength

Compressive strengths of the specimens were obtained using a standard compressive testing machine. Uniform loading was applied at a constant load rate until the failure of specimen and loading was stopped. Measurements were taken at the maximum failure load and tabulated. Compressive strength was calculated using the standard formula. Figure 17.4a, b shows the testing arrangements.

17.2.3.2 Titration Method (Deziel 2018)

Cured and dried concrete specimens were wiped off and placed in the laboratory CO_2 atmosphere. Laboratory CO_2 gas was produced using Sodium Carbonate and Sodium Chloride. A mix of 106 g of Sodium Carbonate and Sodium Chloride produces 44 g of CO_2. Hence, inside the chamber, a known quantity of the mix was placed. The initial amount of CO_2 gas was as 44 g and the final reading after passing it through the concrete cubes was noted. The difference in the g was noted as the amount of CO_2 absorbed by the specimen. The amount of CO_2 was calculated using the Titration method.

For this test, the concrete cubes were kept in air tight chamber in which CO_2 gas was produced by the mixture of sodium carbonate and hydrochloric acid. The mixture produces CO_2 gas, water and sodium chloride salt. The produced CO_2 gas was allowed to pass into the air tight chamber where the concrete cubes was placed for a period of 24 h. After 24 h, the remaining unabsorbed gas was collected into a balloon containing excess of Sodium Hydroxide solution through absorption and was converted into Sodium Carbonate for an equivalent amount. Presence of CO_2 in such a closed environment provides the necessary contact period with NaOH for complete absorption. The mixture containing excess of Sodium Carbonate and Sodium Hydroxide was treated with standard Hydrochloric Acid. The Titration 1 was carried out with the first colourless phenolphthalein indicator endpoint that the neutralization have caused the excess Sodium Hydroxide and was converted to Sodium Bicarbonate from Sodium Carbonate. Continuation to this, Titration 2 was carried out with the Methyl Orange indicator end point that has converted all the Sodium Bicarbonates in to water and CO_2. The difference in the millilitres between the first and second endpoints were used to calculate the CO_2 unabsorbed by the specimen. Figure 17.5a, b, c, d, e, f shows the testing arrangement. Amount of CO_2 was calculated using the formula.

$$\text{Amount of unabsorbed}\, CO_2 = \left(\text{Volume of titrant in litre} \times \text{Molarity of standard acid} \times \text{Molecular weight of}\, CO_2\right)$$

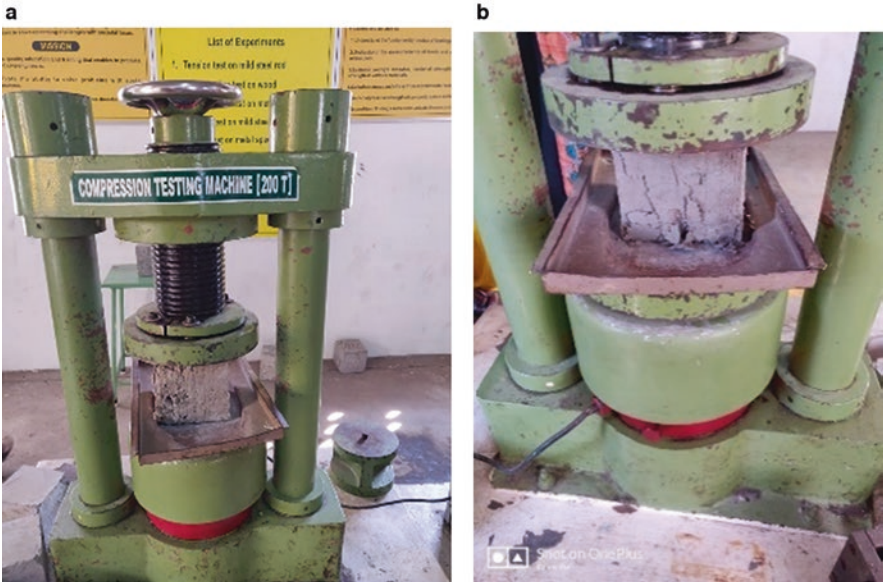

Fig. 17.4 (**a**) Compressive strength testing with specimens loading. (**b**) Compressive strength testing with failure of specimen

Form the initial and final absorption values, the CO_2 absorption capacity of the specimens were calculated.

17.2.3.3 Carbonation Depth

The carbonation depth (BS EN 14630 2006) test was conducted. Specimens were exposed in the CO_2 open environment for the periods of 28 days and 56 days. After the period of exposure, the specimens were split into two parts and observed. The phenolphthalein indicator was applied on the broken surfaces of the specimen and observed for change in the appearance of colour. Carbonation depth was measured and it is proportional to the square root of time. Figure 17.6a, b, c, d, shows the arrangement of testing for carbonation depth.

Fig. 17.5 (**a**) CO_2 gas produced. (**b**) CO_2 gas in airtight chamber. (**c**) Experimental setup. (**d**) HCl reacting with Na_2CO_3. (**e**) Titration Process. (**f**) Balloon containing excess NaOH

Fig. 17.6 (**a**) Specimens for CO_2 open atmosphere. (**b**) Specimens for CO_2 atmosphere. (**c**) Splitting of specimen. (**d**) Splitting of specimen

17.3 Results and Discussion

17.3.1 Compressive Strength

Figure 17.7 shows the compressive strength values at 28 days curing period. Specimens CS4 – CS6 with potato peel only showed lower compressive strength among other mixes. Similarly, specimens CS7 – CS9 with seaweed only showed lower compressive strength than control specimen but higher than specimens with potato peels only. While specimens CS10 – CS12 with both potato peel and seaweed showed higher compressive strength among other mixes. A percentage increase of 5.5% was observed. The increase in compressive strength in the combined addition might be due to the chemical reaction occurred between both the added potato peel and seaweed that would have provided the necessary pore filling characteristics.

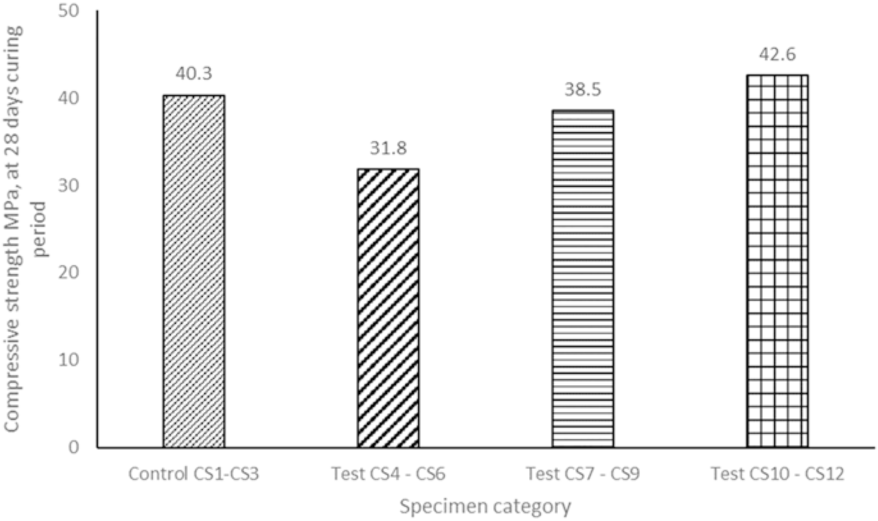

Fig. 17.7 Compressive strength at 28 days

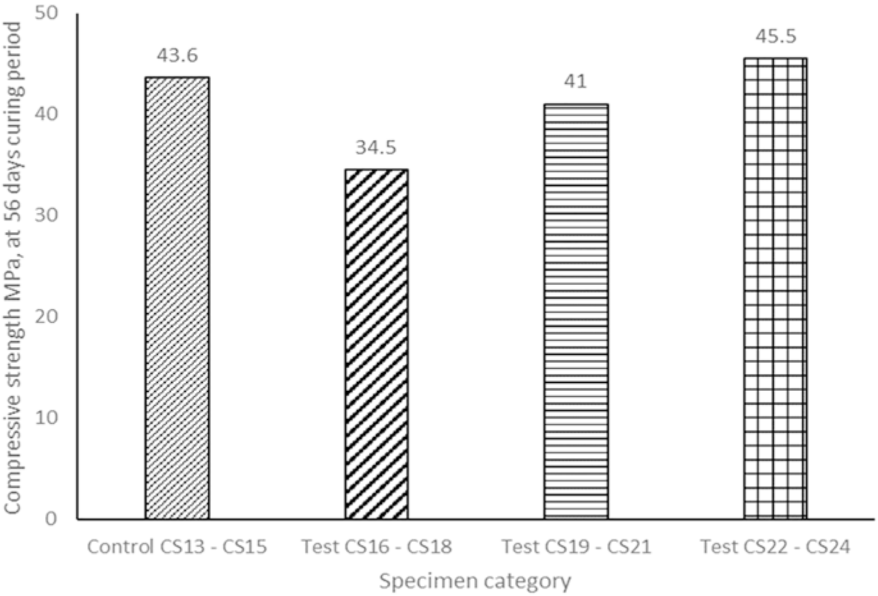

Fig. 17.8 Compressive strength at 56 days

Figure 17.8 shows the compressive strength values at 56 days curing period. Specimens CS16 – CS18 with potato peel only showed lower compressive strength among other mixes. Similarly, specimens CS19 – CS21 with seaweed only showed lower compressive strength than control specimen but higher than specimens with potato peels only. While specimens CS22 – CS24 with both potato peel and seaweed showed higher compressive strength among other mixes. A percentage increase of 4.0% was observed. The increase in compressive strength in the combined addition might be due to the chemical reaction occurred between both the added potato peel and seaweed that would have provided the necessary pore filling characteristics.

On the other hand, when comparing the specimens with both potato peel and seaweed cured at 28 days and 56 days have showed 42.6 MPa and 45.5 MPa, respectively, which was an increase of 6% that was effected due to the increased period of curing.

17.3.2 Titration Method

The amount of unabsorbed CO_2 was calculated using titration method for each type of concrete cubes casted and it was founded that CO_2 absorption capacity was varied for various cubes. From the initial and final absorption values, the absorption capacity of the specimens was calculated. Figures 17.9 and 17.10 shows the absorption capacity of the specimens at 28 days and 56 days, respectively.

From Fig. 17.9, it can be understood that the specimens added with potato peels and seaweeds have showed good absorption characteristics for CO_2. Further, the combined use of potato peels and seaweeds have showed better absorption characteristics than these were used individually. Control concrete also have showed little absorption of CO_2 that might be due to the inherent characteristics of concrete and

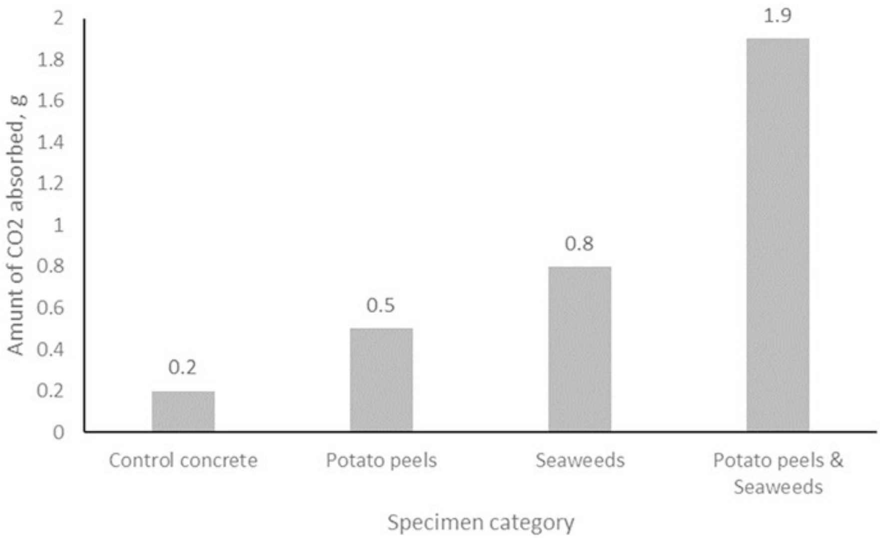

Fig. 17.9 Specimens at 28 days

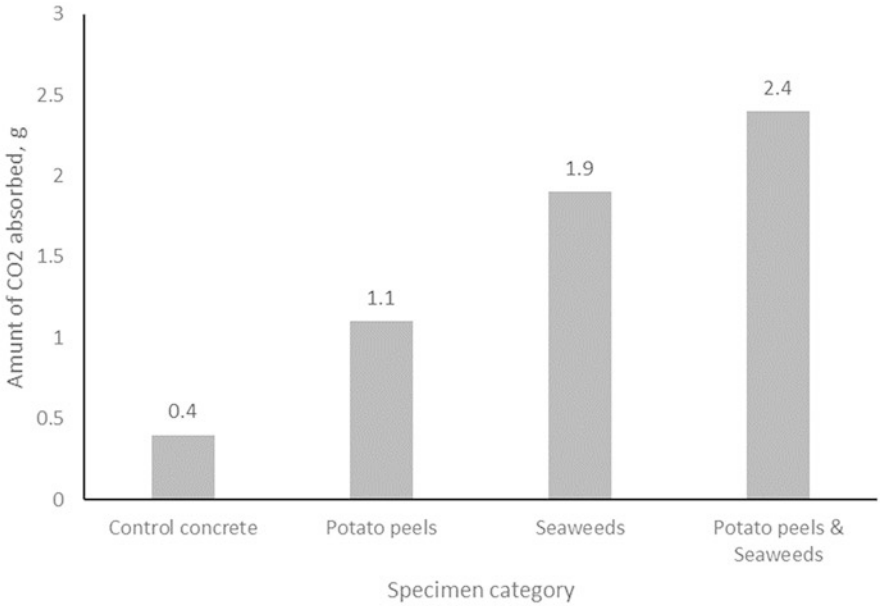

Fig. 17.10 Specimens at 56 days

its porosity. Specimens added with potato peels, seaweeds and combined with both have showed a percentage increase in the absorption were 60%, 75% and 100%, respectively, when compared with control specimens at 28 days. From Fig. 17.10, similarly, specimens added with potato peels, seaweeds and combined with both have showed a percentage increase in the absorption were 63%, 78% and 83%, respectively, when compared with control specimens at 56 days. Specimens with increased curing periods have proportionally increased the absorption characteristics of the specimens. Specimens with combined addition of potato peels and seaweeds have showed significant improvement. Hence it can be inferred that when the ages of concrete increases, then the absorption characteristics capacity can also be increased.

On the other hand, when comparing the specimens with both potato peel and seaweed cured at 28 days and 56 days have showed 1.9 g and 2.4 g, respectively, which was an increase of 20% that was effected due to the increased period of curing.

17.3.3 Carbonation Test Using Phenolphthalein Indicator

Figure 17.11a, b, c, d shows the representation of carbonation on the concrete cubes that were exposed to CO_2 open environment for period of 28 days and 56 days. It was evident that the control specimen did not showed any colour change and hence

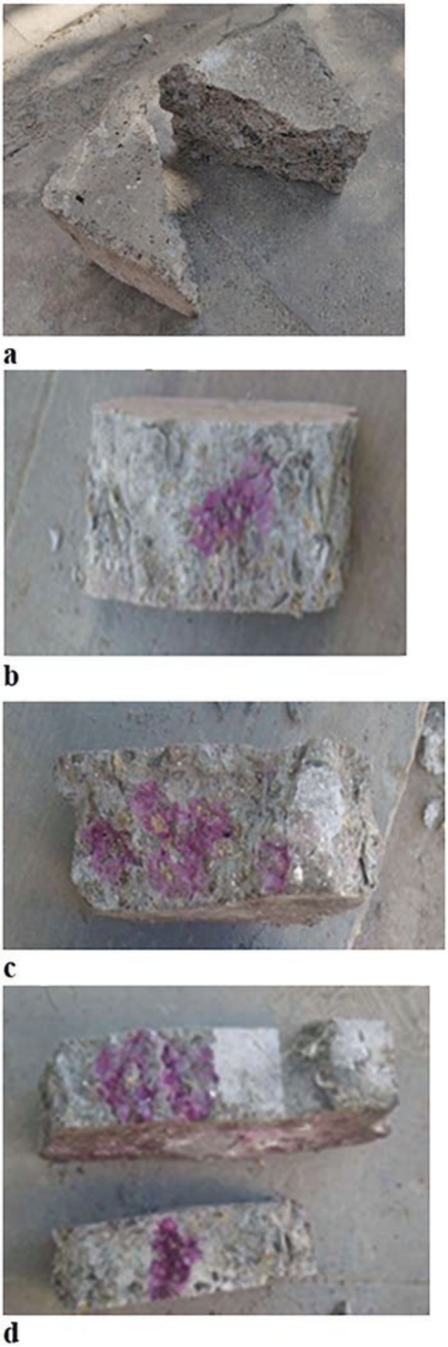

Fig. 17.11 (**a**) Control specimen at 56 days. (**b**) Specimen with potato peel at 56 days. (**c**) Specimen with seaweed at 56 days. (**d**) Specimen with Potato peels and Seaweeds at 56 days

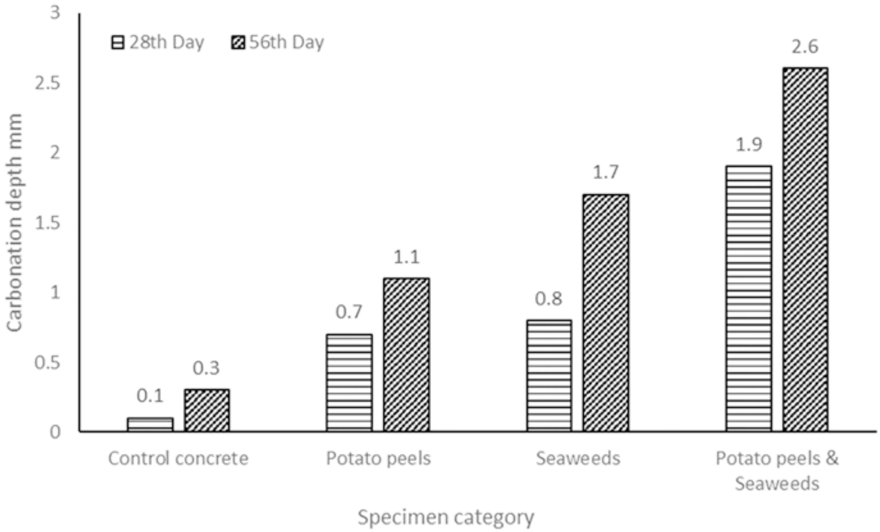

Fig. 17.12 Carbonation depth measurements of concrete cubes

no carbonation was occurred. However, the test specimens have showed the occurrence of carbonation on the top and bottom surface of the concrete cubes.

From Fig. 17.12, it can be understood that the specimens added with potato peels and seaweeds have showed good depth characteristics for CO_2. Further, the combined use of potato peels and seaweeds have showed better depth characteristics than these were used individually. Control concrete also have showed little depth of CO_2 that might be due to the inherent characteristics of concrete and its porosity. Specimens added with potato peels, seaweeds and combined with both have showed a percentage increase in the depth were 85%, 87% and 95%, respectively, when compared with control specimens at 28 days. Similarly, specimens added with potato peels, seaweeds and combined with both have showed a percentage increase in the depth were 73%, 82% and 88%, respectively, when compared with control specimens at 56 days.

On the other hand, when comparing the specimens with both potato peel and seaweed cured at 28 days and 56 days have showed 1.9 mm and 2.6 mm, respectively, which was an increase of 27% that was effected due to the increased period of curing.

Specimens with increased curing periods have proportionally increased the carbonation depth of the specimens. Specimens with combined addition of potato peels and seaweeds have showed significant improvement. Hence it can be inferred that when the ages of concrete increases, then the depth of carbonation capacity can also be increased.

17.4 Conclusion

From the above findings, the following conclusions were made (i) Combined addition of both potato peels and seaweeds have showed better performance than individual. It was inferred from this, there might be suitable chemical reaction occurred in the combined addition. (ii) It can be inferred that when the ages of concrete increases, then the depth of carbonation capacity can also be increased. When comparing the specimens with both potato peel and seaweed cured at 28 days and 56 days have showed in the ranges between 42.6 and 45.5 MPa; between 1.9 and 2.4 g; and between 1.9 and 2.6 mm, respectively, which was an increase of 6%, 20% and 27%, respectively that was effected due to the increased period of curing. However, this required a thorough microscopic study and examinations about the compounds formed. (iii) It was further concluded that combined addition of potato peels and seaweeds have improved the compressive strength, carbonation depth and amount of carbonation absorbed. (iv) Hence, the proposed findings can be utilised in the construction industry as pavement blocks, concrete blocks and kerb stones where most of CO_2 emissions occurred on the roads can be absorbed by the combined addition.

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