ASPS Conference Proceedings 1: 217-221 (2022)

Proceedings of

12th Structural Engineering Convention - An International Event (SEC 2022)

Available at https://asps-journals.com/index.php/acp

Electrical Resistivity of Crumb Rubber Concrete (CRC) exposed to coastal zone- An Experimental Investigation

Bejay Kumar Yadav[1*], Showmen Saha[2]

[1] Research Scholar,Department of Civil Engineering, National Institute Technology Durgapur,West Bengal 713212, India
[2]Professor, Department of Civil Engineering, National Institute Technology Durgapur, West Bengal 713212, India

Paper ID - 020431

Abstract

Electrical resistivity is a material property that can be used for analysis of concrete durability and also can be used to determine early age characteristic of fresh concrete. Electrical resistivity has developed as a new form of non-destructive testing technique. In this study, an experimental study is carried out to determine the electrical resistivity of crumb rubber concrete exposed to normal and coastal environment. Crumb rubber concrete (CRC) is a concrete in which sand is replaced with fine rubber crumb obtained by shredding of waste vehicle tires. In this study, sand was replaced up-to 15% in multiples of 2.5% and then a set of samples were kept for curing and exposure in normal environment and other set of samples were exposed to coastal environment along the coast of Visakhapatnam, Andhra Pradesh. The result obtained indicated that CRC samples showed lower electrical resistivity in the initial days and then resistivity increased at later stages. Chloride ingression test was also conducted on the samples which indicated that crumb rubber concrete showed better resistance to chloride ion penetration. Overall, the result analysis expressed that samples exposed to coastal zone showed lower resistivity, and CRC samples in case of both curing methods and exposure cases showed better resistivity to electrical conduction and chloride ingression than normal concrete samples. So as CRC shows better durability properties than normal concrete, it can be opted as a choice for concrete structures in coastal areas.

Keywords:Electrical resistivity; durability; crumb rubber concrete (CRC); coastal zone

1. Introduction

Electrical resistivity is the ratio of applied potential difference to the amount of current developed. Electrical conductivity on other hand is the inverse of resistivity. Conductivity of any material is its property to allow the transfer of ions when subjected to any electrical field. In the modern days electrical resistivity has been developing as a non-destructive testing method to determine the characteristics of fresh concrete as well as hardened concrete[1]. The main advantage of these type of testing methods is its ability to provide a quality check in less time using the same specimen every time without disturbing its structure. The electrical resistivity of concrete ranges from 10^5 to 10^{12} ohm-mm.The variation in electrical resistivity can be used to differentiate between the behaviour of concrete and their inter-molecular structure. The most common standard method for determining electrical resistivity is ASTMC 1202[2], often referred to as Rapid chloride permeability test.

The main drawback of ASTMC 1202 is that it uses artificial chloride penetration technique and determines the chloride movement and permeability in concrete. However, the naturalistic condition may defer from this artificial penetration of chloride ion.

The concept of electrical resistivity has also been used for development of novel sensors which can be utilized for Structural health monitoring (SHM). Many cement based and concrete composite based sensors have always been a key-focus in SHM.[3]

Crumb rubber concrete (CRC) is becoming one of the sustainable materials in field of construction industry as it utilizes waste vehicle tires shredded in the size of fine aggregate[4]. The use of waste rubber tire is relatively inexpensive, and also reduces the impact on environment.Every year the Indian tyre production increases by about 10-12% and, an equal amount of tyre are being discarded annually, creating major environmental problems.India's tyre waste account for about 6-7% of the global total tire waste[5]. Globally disposal of tire waste is one of the major issue. The main problem with the recycling of waste tyre is the complexity of materials. Tyres for different vehicle are made with a mixture of natural and synthetic rubbers along with a various combination of

*Corresponding author. Tel: ++91 8145910018; E-mail address: bejay.nitd@gmail.com

Proceedings of the 12th Structural Engineering Convention (SEC 2022), NCDMM, MNIT Jaipur, India | 19-22 December, 2022

Published online: December 19, 2022
doi:10.38208/acp.v1.500

structural reinforcing elements like metals and chemical additives. So separation of different tyres with different properties and their recycling through different process is a tedious and costly job[5]–[7]. Attempts are being made to recycle and use waste scrap tyres in various industries. In the context of civil engineering also, presently, many research is being done to include waste scrap tyres in the form of crumb and chips in place of fine and coarse aggregate. Thus utilization of waste rubber into concrete has opened a new way of sustainably disposing vehicle tires[8]–[11].

In the present study an attempt is made to utilize waste rubber to concrete and also to check its performance in normal and coastal zone using electrical resistivity method.

2. Experimental Program

2.1 Materials

The raw materials used in the study are Ordinary Portland cement 43 grade, conforming to IS: 8112-2013[12]. The specific gravity of cement was 3.15. Normal consistency was 35%, initial and final setting time was 95 min and 170 min respectively. The properties of cement were measured as per IS-4031[13]. The sand used was obtained from the banks of river Damodar, and was confirming to zone II as per IS:383-1970[14]. The specific gravity of sand was 2.62 and fineness modulus 2.81. Coarse aggregate used was a mix of 10 mm and 20 mm in the ratio of 40:60 having an average specific gravity of 2.65. Particle size distribution curve is shown in Figure 1. Scrap vehicle tire were ground into sizes between 0.075 to 2.36 mm. The specific gravity of crumb rubber was found to be 1.12.

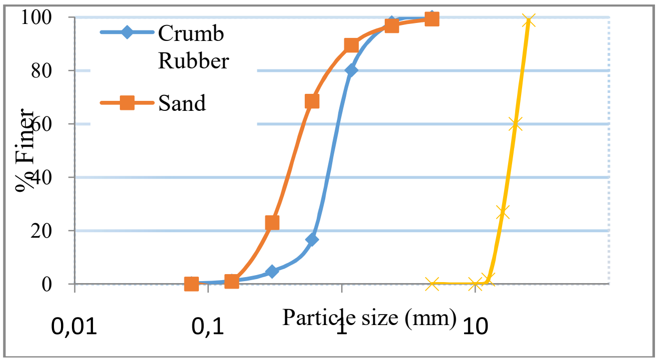

Figure 1: Particle size distribution curve

Metakaolin confirming to IS 456-2016 was used 5% (by weight) to improve strength properties of crumb rubber concrete.

The physical and chemical properties of metakaolin are shown in Table 1 and Table 2

Table 1: Physical properties of Metakaolin

Physical Property	Value
Specific Gravity	2.6
Colour	Off white
Brightness (% ISO)	80-82
Surface Area (m^2/g)	15
Bulk Density (g/cm^3)	0.03 ~0.04

Table 2: Chemical properties of Metakaolin

Ingredient	% by mass
SiO_2	51-53 %
Al_2O_3	42-44 %
TiO_2	<3.00 %
Fe_2O_3	<2.10 %
K_2O	<0.70 %
L.O.I	<0.50 %
CaO	<0.20 %
P_2O_5	<0.20 %
MgO	<0.10 %
SO_4	<0.05 %
Na_2O	<0.05 %

2.2 Specimen preparation and testing

M30 grade concrete was mixed as per IS: 10262-2009[15]andIS 456[16]. Water-cement ratio adopted was 0.42. Crumb rubber was used as a partial replacement for fine aggregate in the proportion varying from 0 to 15% in multiple of 2.5%. The mix proportion of different mix are shown in *CR – crumb rubber; *M – Metakaolin

Table 3.The crumb rubber obtained, was first soaked in 1 N NaOH solution and then washed with clean water for about 30 min and air-dried at room temperature. The main purpose of washing with NaOH was to improve the interfacing bond between crumb rubbers and cement paste by etching the surface of rubber crumb[17]-[18].

For each mix, sample cubes of 150 x 150x 150 mm were prepared. Each sample consists of three specimens. After casting the specimens were demoulded after 15 hr and were taken to their respective place for curing. The compressive strength tests was then performed according to IS: 516 [19] at 7, 28, 56, 90, 120 and 150 days. Cube specimens were also used for determining the electrical resistivity of CRC but only 7.5RM mix cured in normal and sea water were used as only that mix proved to be optimum mix. (Maximum replacement of crumb rubber satisfying minimum strength requirement)

Metal electrodes were fixed on the cube specimens on opposite faces. 30V potential difference was applied on the cube specimens using the electrode attached to concrete cubes. The setup is shown in Figure 2. 30V was applied on the cube specimens for 15 minutes prior to recording the current measurement which was used to calculate the electrical resistivity

$$\rho = [\, V \times A \,] / (\, I \times L \,)$$

ρ – Electrical resistivity

V – Potential difference applied

A – Cross-section area of sample

I – current measured; L- length of sample

For chloride ingression testing, 5mm diameter holes were drilled into the concrete cubes after their designated exposure time (150 days). The holes drilled were up-to depth of cover which is usually used in construction (5mm, 25mm, 40mm, 50mm, 60mm and 75 mm). The pulverized concrete samples obtained after drilling were then subjected to potentiometric titration to determine the percentage of chloride content.

Mix	% by weight CR + M	Gravel (kg/m^3)	Sand (kg/m^3)	Rubber (kg/m^3)	Cement (kg/m^3)	Metakaolin (kg/m^3)	w/c
0R	0 + 0	1283	711	0	380	0	0.42
0RM	0 + 5	1283	711	0	361	19	0.42
2.5R	2.5 + 0	1283	693.23	17.77	380	0	0.42
2.5RM	2.5 + 5	1283	693.23	17.77	361	19	0.42
5R	5 + 0	1283	675.45	35.55	380	0	0.42
5RM	5 + 5	1283	675.45	35.55	361	19	0.42
7.5R	7.5 + 0	1283	657.68	53.32	380	0	0.42
7.5RM	7.5 + 5	1283	657.68	53.32	361	19	0.42
10R	10 + 0	1283	639.9	71.1	380	0	0.42
10RM	10 + 5	1283	639.9	71.1	361	19	0.42
12.5R	12.5 + 0	1283	622.13	88.87	380	0	0.42
12.5RM	12.5 + 5	1283	622.13	88.87	361	19	0.42
15R	15 + 0	1283	604.4	106.6	380	0	0.42
15RM	15 + 5	1283	604.4	106.6	361	19	0.42

*CR – crumb rubber; *M – Metakaolin

Table 3: Mix proportions used in this study

Figure 2: Electrical resistivity setup

3. Results and Discussion

3.1 Evaluation of Compressive strength

The effect of crumb rubber on compressive strength is shown in Fig-3. The compressive strength decreased with increase in rubber percentage.It was observed that crumb rubber content up-to 7.5% can be advantageously utilized in concrete. Above 7.5% replacement the compressive strength obtained

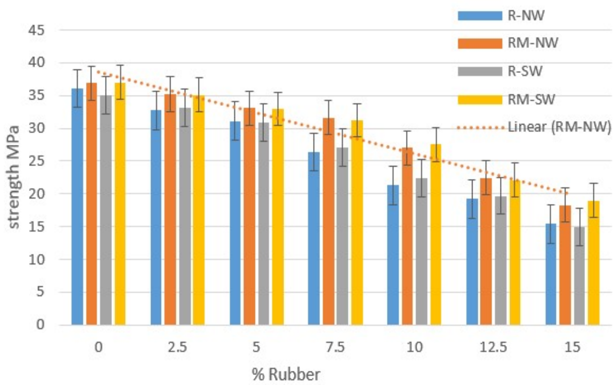

Figure 3: Compressive strength result

was well below the minimum strength value of M30 at 28 days of age. Also the strength of concrete specimens without metakaolin was less than that with metakaolin, hence CRC with metakaolin can be preferred for future studies. The effect of sea water curing on strength of concrete was then analysed, **Erreur ! Source du renvoi introuvable.** and Figure 5. It was observed that the reduction in strength for concrete specimens without crumb rubber content was more. Further the reduction in strength was higher for concrete specimens exposed to coastal zone. Fig-5shows that the percentage reduction in strength for concrete specimens without any rubber content was exponential in nature whereas specimens with rubber content was linear.

The reason for better performance of CRC samples may be due to the reason that fine rubber crumb being hydrophobic and fine in nature blocked the interconnected voids and made concrete impermeable which prevented the entry of sea water moisture to enter the interior of concrete, saving the strength and integrity of concrete. Further, metakaolin being much finer and having cementitious property made concrete more hard and impermeable, which was the reason for CRC samples with metakaolin content to give better results.

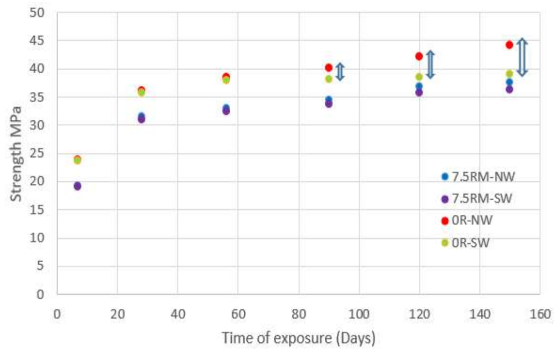

Figure 4: Comparison of compressive strength in different exposures

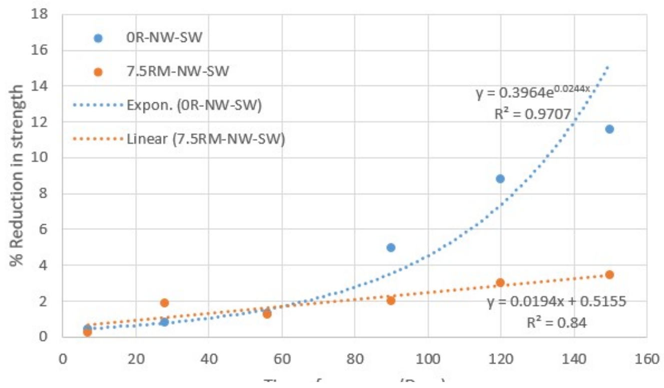

Figure 5: % Reduction in strength with time of exposure.

3.2 Electrical resistivity of Concrete

Electrical resistivity better demonstrates the performance durability aspects and environment friendliness of concrete. It also gives an idea of transport properties of CRC in early as well as hardened stages. Fig-6 and Fig-7 shows the electrical resistivity response of concrete samples. It was observed that when exposure time of more than 28 days was considered the resistivity of CRC samples (7.5% replacement) showed higher resistivity than normal concrete samples. Similar result was posted by Shuaicheng Guo et.al [18].Moreover the samples exposed to sea water curing showed lower resistivity value than the samples cured in normal potable water. The reason may be that due to exposure in sea water salt particles settled on the surface and penetrated into the voids of concrete cubes might have enhanced the conductivity of concrete.

Fig-7 indicated the test result of resistivity up to 28 days, and it showed a controversial result in which CRC sample gave lower resistivity than normal concrete samples. This might be due to the fact that CRC samples take time to dry from inside and the interior structure of CRC samples remains wet up to 14 days, which was observed while performing compressive strength test. This presence of moisture content might have enhanced the conductivity of the concrete and hence gave lower resistivity value.

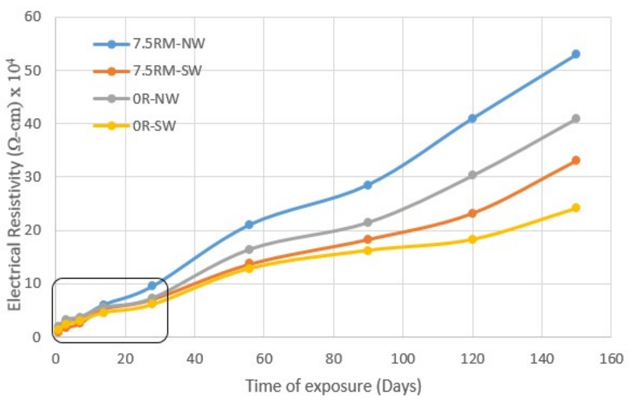

Figure 6: Electrical resistivity (exposure 150 Days).

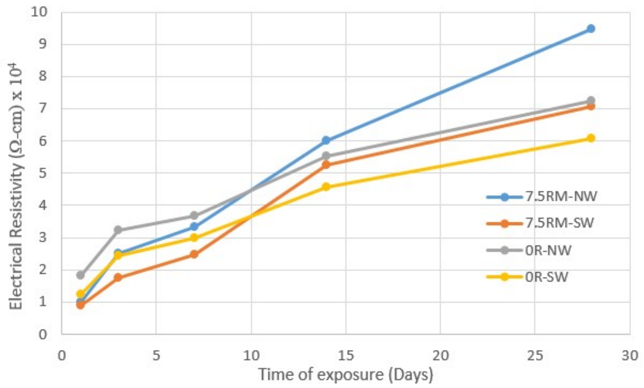

Figure 7: Electrical resistivity (exposure 28 Days)

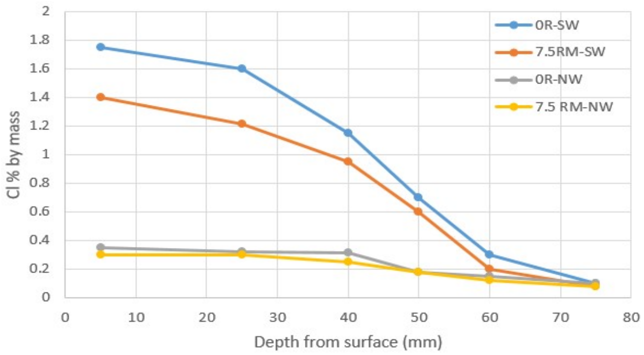

Figure 8: Chloride ingression at 150 Days of exposure

3.3 Chloride ingression test

Chloride ingression test was performed using potentiometric titration technique to find out whether the test result obtained by electrical resistivity which showed that CRC samples had lower permeability was correct or not, so that in future electrical resistivity results could be directly used to decide the transport properties of CRC. The test result of Chloride ingression is shown in Fig-8.

It was observed that chloride ingression in sea water cured samples was more than those cured in normal water. The amount of chloride ingression decreased with increase in depth from the surface of concrete samples. CRC samples (7.5RM-SW and 7.5RM-NW) showed lesser amount of chloride ingression than normal concrete samples. The chloride ingression was tested after an exposure of 150 days, as amount of chloride ingression at early ages is very low to determine and is insignificant. The amount of chloride ingression for CRC reduced by 25% for samples taken from depth of 25 mm (cover adopted for most of the concrete structures), when compared with normal concrete samples. This shows that CRC samples has better resistance to transport properties and hence can have better durability and can be very well utilized for concrete structures exposed to coastal zone.

4. Conclusions

The test results of present study indicates that there is scope for utilization of waste crumb rubber obtained from scrap vehicles tires into concrete as CRC (Crumb Rubber Concrete). Based on the test results obtained from this study the following conclusion can be made:

CRC can be made by replacement of sand with crumb rubber up-to a percentage of 7.5% with use of Metakaolin as supplementary cementitious material. The obtained CRC will have good strength with very less compromise in strength properties. The reduction of strength when exposed to coastal zone or sea water curing in natural environment was found to be less than normal concrete samples, which indicates that CRC can be used advantageously for concrete structures along coastal zone.

Electrical resistivity and Chloride ingression tests done to find the transport properties of moisture into concrete and also to determine the permeability characteristic of concrete also gave positive response to CRC. It showed that both resistivity and chloride ingression was less for CRC samples (7.5 R-SW and 7.5R-NW) as compared to normal concrete samples. Though resistivity below age of 28 days indicated lower resistivity value of CRC, but it was due to the inner moisture content which takes time to dry because of the hydrophobic nature of crumb rubber and not due to ingression of outer moisture content. So, overall from electrical resistivity, chloride ingression test and comparison of reduction in strength due to exposure along coastal zone, it can be concluded that CRC is a better option than normal concrete for use in construction along coastal areas.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

References

[1] T. C. Madhavi and S. Annamalai, "Electrical conductivity of concrete," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 9, pp. 5979–5982, 2016.

[2] ASTM I, "Astm C 1202," *ASTM Int.*, no. 95 mm, pp. 1–6, doi: 10.1520/C1202-10.

[3] W. Dong, W. Li, G. Long, Z. Tao, J. Li, and K. Wang, "Electrical resistivity and mechanical properties of cementitious composite incorporating conductive rubber fibres," *Smart Mater. Struct.*, vol. 28, no. 8, 2019, doi: 10.1088/1361-665X/ab282a.

[4] M. K. Batayneh, I. Marie, and I. Asi, "Promoting the use of crumb rubber concrete in developing countries," *Waste Manag.*, vol. 28, no. 11, pp. 2171–2176, 2008, doi: 10.1016/j.wasman.2007.09.035.

[5] L. Mishra, "Turning waste tyre into 'green steel,'" *The Hindu- Business*, Jul. 2016.

[6] B. S. Thomas, R. C. Gupta, and V. J. Panicker, "Recycling of waste tire rubber as aggregate in concrete: Durability-related performance," *J. Clean. Prod.*, vol. 112, pp. 504–513, 2016, doi: 10.1016/j.jclepro.2015.08.046.

[7] K. B. Najim and M. R. Hall, "A review of the fresh/hardened properties and applications for plain- (PRC) and self-compacting rubberised concrete (SCRC)," *Constr. Build. Mater.*, vol. 24, no. 11, pp. 2043–2051, 2010, doi: 10.1016/j.conbuildmat.2010.04.056.

[8] M. S. Senin, S. Shahidan, S. R. Abdullah, N. A. Guntor, and A. S. Leman, "A review on the suitability of rubberized concrete for concrete bridge decks," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 271, no. 1, 2017, doi: 10.1088/1757-899X/271/1/012074.

[9] B. K. Yadav and S. Saha, "Determination of mechanical properties of rubberized concrete in marine environment," *Int. J. Recent Technol. Eng.*, vol. 8, no. 2, 2019, doi: 10.35940/ijrte.B3527.078219.

[10] G. Xue and M. L. Cao, "Effect of modified rubber particles mixing amount on properties of cement mortar," *Adv. Civ. Eng.*, vol. 2017, 2017, doi: 10.1155/2017/8643839.

[11] A. Yilmaz and N. Degirmenci, "Possibility of using waste tire rubber and fly ash with Portland cement as construction materials," *Waste Manag.*, vol. 29, no. 5, pp. 1541–1546, 2009, doi: 10.1016/j.wasman.2008.11.002.

[12] Bureau of Indian Standard(BIS), "IS: 8112 – 1989, Specification for 43 grade Ordinary Portland Cement." p. 17, 2013.

[13] IS-4031 (Part II), "Methods of Physical Tests for Hydraulic Cement- Determination of Consistency of Fineness By Blaine Air Permeability Method," *Bureau of Indian Standards, New Delhi*. 1999.

[14] I. 383, "Specification for Coarse and Fine Aggregates From Natural Sources for Concrete," *Bureau of Indian Standards,New Delhi*. pp. 1–24, 1970.

[15] Bureau of Indian Standards, "Guidelines for concrete mix design proportioning," *Is 10262 : 2009*. p. New Delhi,India, 2009.

[16] IS 456, "Plain and reinforced concrete- Code of practice," *Bureau of Indian Standards,New Dehli*. pp. 1–114, 2000.

[17] A. Kashani, T. D. Ngo, P. Hemachandra, and A. Hajimohammadi, "Effects of surface treatments of recycled tyre crumb on cement-rubber bonding in concrete composite foam," *Constr. Build. Mater.*, vol. 171, pp. 467–473, 2018, doi: 10.1016/j.conbuildmat.2018.03.163.

[18] S. Guo, Q. Dai, R. Si, X. Sun, and C. Lu, "Evaluation of properties and performance of rubber-modified concrete for recycling of waste scrap tire," *J. Clean. Prod.*, vol. 148, pp. 681–689, 2017, doi: 10.1016/j.jclepro.2017.02.046.

[19] Bureau of Indian Standards, "Method of Tests for Strength of Concrete," *IS : 516 - 1959 (Reaffirmed 2004)*. p. New Delhi,India, 2004, doi: 10.3403/02128947.