

Investigation on Tensile Strength and Leachate Analysis of Flyash-Lime-Gypsum Composite Mixed with Tire granulates

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ABSTRACT : The objective of present study is to carry out the strength behaviour of reference mix containing fly ash + 8% lime +1.5 % gypsum mixed with 10% ,20% and 40% tire granulates. The curing period was varied from 14 days to 90 days. The specimens were cured by using three different methods of curing. The results of the study had revealed that tensile strength increased with the increase in curing period and with the change in curing method from desiccators to water-filled container. The study had also included leachate analysis conducted on the reference mix mixed with 10% tire granulate, when cured with three different curing methods. The leachate analysis of reference mix with tire granulates have shown a reduction in the leachability of manganese and zinc. Study had revealed that composite made by mixing reference mix with tire granulates has shown a reduction in the leaching of iron in comparison to the reference mix. Beside this, a low level of leaching of manganese, copper, iron and zinc was observed from the reference mix with tire granulates.

KEYWORDS: leachate analysis, tensile strength, tire granulates, fly ash, lime, gypsum.

I. INTRODUCTION

In India the production of waste materials are increasing day by day, which are creating the environmental problems. The best solution to this problem is to utilise the waste materials for the construction purposes. There has been a growing interest in recent years for studying the strength behaviour of waste materials for civil Engineering application. The present work is one such attempt to examine the behaviour of fly ash–lime–gypsum composite mixed with tire granulates. Rao and Dutta (2006) reported 112 million discarded tires in India per year. On the other hand, the production of fly ash in India will be 175 million tons by 2012 (Kaniraj and Gayathri 2003). So far, India has registered only 13% use of fly ash compared with more than 40% use by developed countries, such as Japan, United States, and United Kingdom (Das and Yudhbir 2005). The large quantity of fly ash in India is still dumped in fly-ash ponds. The pollution effect caused by the occasional failure of these ash ponds in rivers has been found even up to 100 km (Das and Yudhbir 2005). A series of laboratory Split tensile tests and leachate analysis were carried out by varying tire granulates content, curing method and curing period. This paper examines the effect of curing period, curing method and variation of tire granulates on the tensile strength of a reference mix containing fly ash, lime, and gypsum mixed with 10%, 20% and 40% tire granulates. Leachate analysis was also carried out to ascertain that new composite material should not have adverse impact on the environment. The results obtained from these tests are presented and discussed in this paper.

II. BACKGROUND

Christ et al. (2010) investigated the potential use of granulated rubber as backfill material for buried pipelines in cold regions. Many researchers have undertaken various studies for tire rubber such as used for sub grade and embankment

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fills (Whetten et al. 1997; Humphrey et al. 1998; Humphrey 2008; Nelson 2009); backfill for retaining walls and bridge abutments (Reid and Soupir 1998; Tatlisoz et al. 1997); sub grade insulation for highways (Humphrey and Eaton 1995; Lawrence et al. 1999); lateral edge drains for highways (Lawrence et al. 1999); vibration damping below rail lines (Wolfe et al. 2004); daily cover and drainage for landfills (Jesionek et al. 1998; Park et al. 2003); and drain fields for septic systems (Lassiter 2009; Zicari 2009). Millions of used tires are stockpiled every year (Rubber Manufacturers Association (2006). One popular process is the shredding of tires into compressible tire-derived aggregate (TDA), which finds use in cap closures, leachate drainage layers, landfill liners, low-density backfill for retaining structures, enhanced substrate for sports fields, rubberized concrete and pavements, and filtration systems (Edil and Bosscher 1994; Moo-Young et al. 2003; Huang et al. 2004; Meiarashi 2004; Ramirez et al. 2004; Zornberg et al. 2004; Edil et al. 2004; Aisien et al. 2006; Pamukcuand Akbulut 2006; Rubber Manufacturers Association 2006; Valdesand Liang 2006). Evidence suggests that the use of TDA to remove contaminants from water is promising (e.g., Rangarajan et al. 1999; Carvalho et al 2010). However, the material swells during sorption due to the physical changes imposed by time-dependent diffusive transport mechanisms and partitioning specific to the wetting fluid (Aminabhavi and Phayde 1995; Kim et al. 1995; Kershaw et al. 1997; Edil et al. 2004; Ahmad et al. 2005; Graham et al. 2006; Lovely et al. 2006). Many researchers have undertaken various studies for the strength of tire rubber alone or mixed with sand/clayey soil (Humphrey and Sandford 1993, Edil and Bosscher 1994, Foose et al. 1996, Wu et al. 1997, Lee et al. 1999, Ghazavi and Sakhi 2005, Rao and Dutta 2006, Cetin et al. 2006, Dutta and Rao 2009). There are numerous case histories on the use of fly ash either alone or mixed with soil, lime, gypsum, or in combination. Fly ash has been typically used for soil stabilization (Chu et al. 1955), as embankment material (Raymon 1961, Jha et al. 2009), structural fill (DiGioia and Nuzzo 1972), replacement for cement (Xu and Sarkar 1994), coastal land reclamation (Kim and Chun 1994), roads and embankments (Kumar 2003), stabilization of coal pillars (Fawconnier and Korsten 1982), and subsidence control (Petulanas 1988).

III. MATERIALS USED AND EXPERIMENTAL PROCEDURE

1. Materials Used

Fly ash is a mineral by-product of coal combustion in thermal power projects. It is a waste material and is dumped on the land adjoining thermal plants and townships. The fly ash used in the study was procured from Ropar Thermal Power Plant, Punjab, India. The fly ash used in the study was of class F type. The fly ash was selected due to its availability in abundance quantity as compared to the class C type. The fly ash is classified as Class F, i.e., low-lime fly ash according to ASTM C 618-89 (ASTM 1992) classification. The locally commercially available lime and gypsum were used in the study. Details on the chemical analysis of fly ash, lime and gypsum are available from Guleria and Dutta (2011).

2. Tire granulates

Tire granulates were derived from waste tires by shredding waste tires. The shredding of tire was done with the help of tire remoulding machine shown in the Fig.1. The tire granulates having particle sizes ranging from 0.425-300mm was used in the study. Fig.2 shows the tire granulates used for the current study. Guleria and Dutta(2013) and Taha *et al.* (2008) reported that the size of tire chip significantly effect the compressive strength of rubber concrete. The authors further reported that large sized rubber particles in rubber concrete reduce the compressive strength. Thus, keeping the above in view, the size of tire granulates was restricted to 0.425-300mm approximately.

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Fig.1 Tire remoulding machine



Fig.2 Photograph of tire granulates.

3. Sample preparation and experimental procedure

a) Tensile strength: The Split tensile strength tests of the study were in accordance with IS: 10082-1981. The strain rate was kept at 0.048mm/min in all experiments. The specimens were prepared as described below. The proving rings of 2KN and 5kN, capacity were used for testing the specimens.

The fly ash was ground lightly by hand with a pestle to separate the individual particles. The metallic mould having size 19 mm inner diameter and 38 mm long were used to prepare cylindrical specimens. Reference mix containing fly ash: lime: gypsum in the proportion of 1:8%:1.5% was taken as per the [Guleria and Dutta \(2011\)](#). In the reference mix, tire granulates in the proportion of 10%, 20% and 40% of dry weight of fly ash was added in the mix. Further, in order to keep the total volume of the cylindrical specimen as constant, fly ash equivalent to the weight of tire granulates was removed and replaced with tire granulates corresponding to 10%, 20% and 40% of dry weight of fly ash. The specimens were cured from 14 to 90 days with the use of three curing methods. The detail of the variables and codification used in the study are shown in Table 1. To ensure uniform compaction, the specimens were compressed statically to the same volume from both ends till the specimen just reached the dimensions of the mould by using the hand compaction effort. The specimens were allowed to dry for 1 day at room temperature. The detail of the curing method, curing period and another parameters used for study has been shown in the table 1.

Table 1 Variables and Range Tested

Variables	Range
Granulates content (%)	10, 20, and 40
Curing period (days)	14,28 and 90
Curing method	M1: The specimen was placed open in the laboratory at room temperature for self curing. M2: The specimen was put in burlap for curing. The burlap was kept wet by sprinkling water regularly. M3: The specimen was placed in a container filled with water with an inflow and outflow.
Codification	For easy reference and identification of specimen, specific

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codification was used. For specimen of the reference mix with tire granulates, a six-letter codification scheme was used. The first two digits of the codification indicate tire granulates content, the next two digit numbers indicate the curing period, and next two digit numbers indicate curing method. For example, 1090M2 indicates the addition of 10% tire granulates, 90 days of curing period and curing by burlap method.

b) Determination of leaching of metals: The leachate sample was prepared by mixing 20ml Diethylene Triamine Penta-acetic acid (DTPA) in the 10gm of sample (reference mix with 10% tire granulates). The sample was shaken to prevent deposition of matter by electric shaker for exactly two hours at 25°C and allow sufficient time for DTPA to dissolve. DTPA acts as a mild chelating agent, which extracts the easily soluble zinc, iron, copper and manganese. And the solution was filtered by using Whatman No. 42 filter paper. The leachate solutions as prepared were analysed with the help of atomic absorption spectrophotometer (AAS) as shown in Fig. 3.



Fig.3 Atomic absorption spectrophotometer (AAS)

IV. SPLIT TENSILE STRENGTH TEST RESULTS

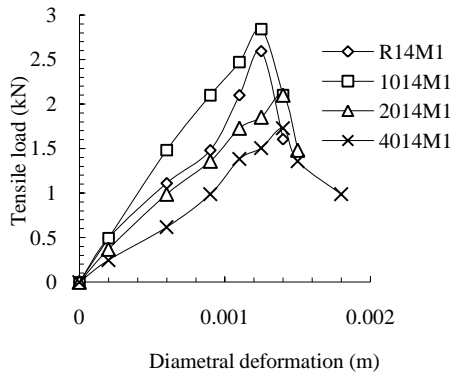
1. Load – Diametral Deformation Behaviour

The tensile load – deformation behaviour of the reference mix and mixed with 10-40 % tire granulates, cured for 14, 28 and 90 days with curing methods M1, M2 and M3 are shown in Figs. 4. A close examination of Figs. 4(a), (b) and (c) reveals that tensile load increases with the change in the curing method from M1 to M3. For example, a peak tensile load of 2.839 KN for specimen 1014M1 increased to 3.95 KN, when the curing method was changed from M1 to M2. The value of peak tensile load of the same specimen further increased to 4.22 KN, when the curing method was changed from M1 to M3. A similar trend of increase in peak tensile load with the change in curing method was observed in the reference mix mixed with 10%, 20 % and 40 % tire granulates as evident from the Fig. 4. A further examination of Figs. 4(a), (b) and (c), reveal an increase in the diametral deformation with the change in the curing method. For example, for specimen 1014M1, the diametral deformation was 1.8×10^{-3} m which increased to 2.2×10^{-3} m with the change in curing method from M1 to M2. The diametral deformation of same specimen further increased to 3.5×10^{-3} m with the change in curing method from M1 to M3. A similar increase in diametral deformation was evident from Fig.4 was also observed for other curing methods and with the inclusion of 10 %, 20 % and 40% tire granulates in reference mix.

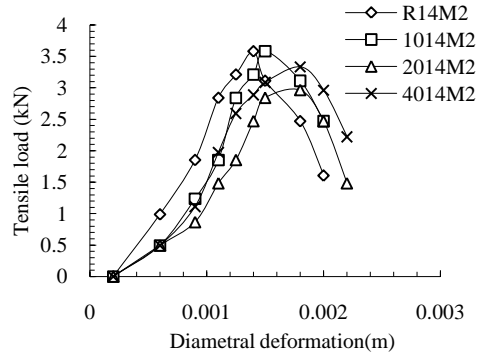
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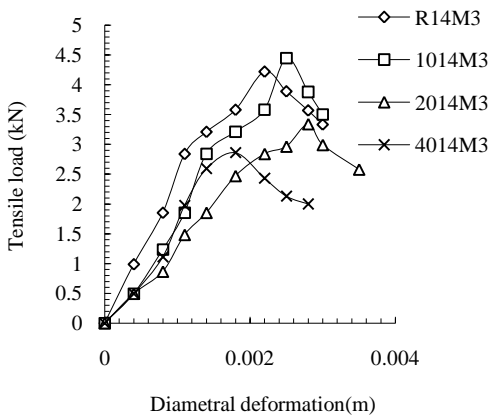
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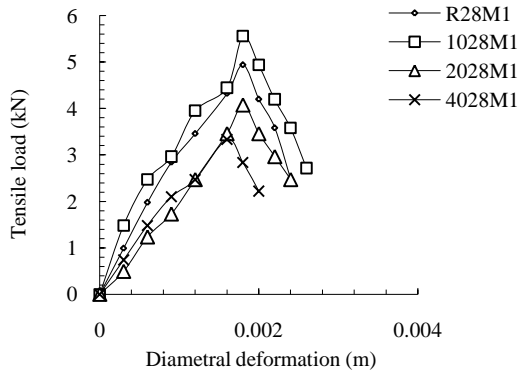
(a)



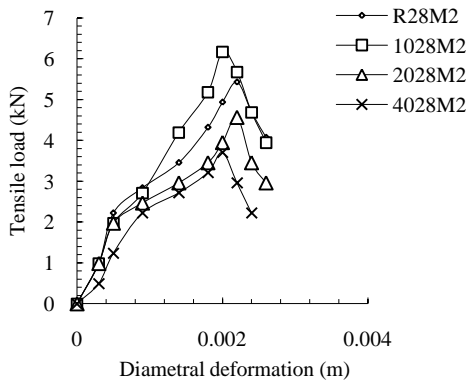
(b)



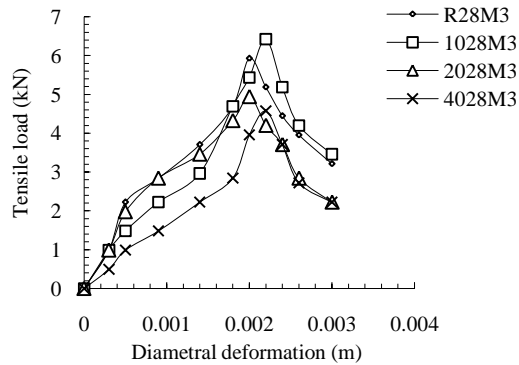
(c)



(d)



(e)



(f)

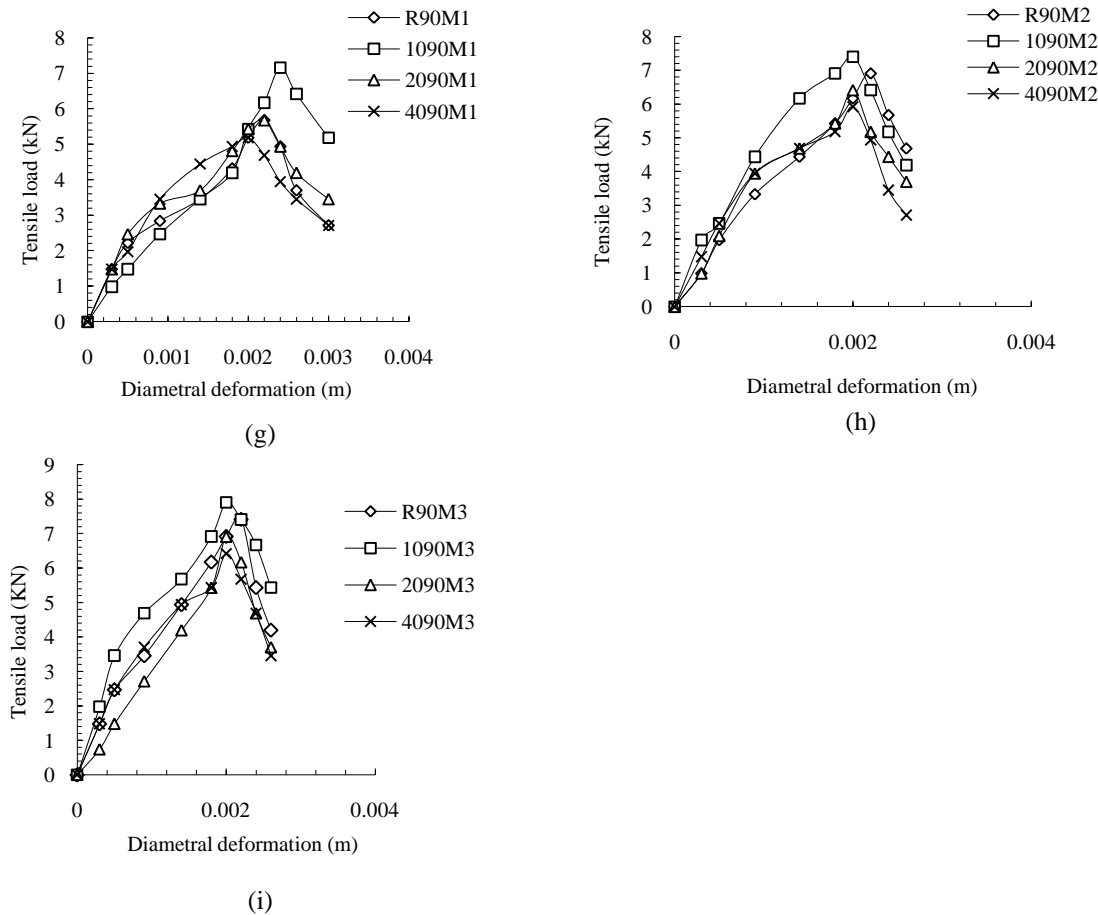


Fig.4 Variation of Tensile load – diametral deformation of reference mix and mixed with 10%, 20%, 40% tire granulates cured with 14 days (a) M1 curing method (b) M2 curing method (c) M3 curing method. Specimens cured at 28 days with use of (d) M1 curing method (e) M2 curing method (f) M3 curing method. Specimens cured at 90 days with (g) M1 curing method (h) M2 curing method (i) M3 curing method.

A further examination of Figs. 4(a), (b), (c) reveals that tensile load increases with the change in the curing period from 14 to 90 days. For example, a peak tensile load of 2.839 kN for specimen 1014M1 increased to 5.56 kN, when the curing period was changed from 14 to 28 days. The value of peak tensile load of the same specimen further increased to 7.16 kN, when the curing period was changed from 14 to 90 days. A similar trend of increase in peak tensile load with the change in curing periods was also observed with the inclusion 10%, 20 % and 40 % tire granulates, as evident from the Fig. 4. A close examination of Fig4 reveals that diametral deformation increases with the increase in curing methods. For example, a diametral deformation of specimen 1014M1 is 1.8×10^{-3} m which get increased to 2.6×10^{-3} m and 3×10^{-3} m with the increase in the curing period to 14, 28 and 90 days. Similar increase in diametral deformation was observed in Fig.4 for other curing periods and with the inclusion of 10 %, 20 % and 40% tire granulates.

2. Split Tensile Strength

The results of the tensile strength of reference mix mixed with 10 % tire granulates and cured at 14, 28 and 90 days with M1, M2 and M3 curing methods are shown in Figs. 5(a), (b), (c) and Table 2 respectively. The Figs. 5(a),(b),(c) and Table 2, reveals that tensile strength of the reference mix mixed with 10% tire granulates increases with the increase in curing period from 14 to 90 days. For example, from Fig. 5(a) the tensile strength of the specimen 1014M1 at 14 days of curing was 245.7 kPa, which increased to a value of 480.72 kPa and 619.5 kPa after 28 and 90 days of

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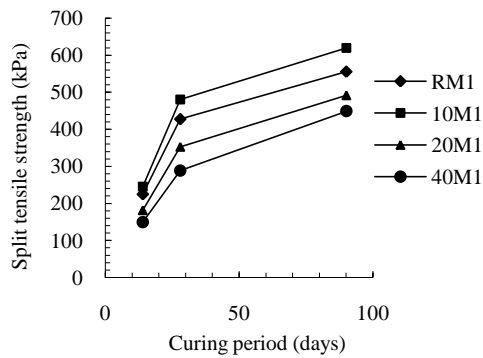
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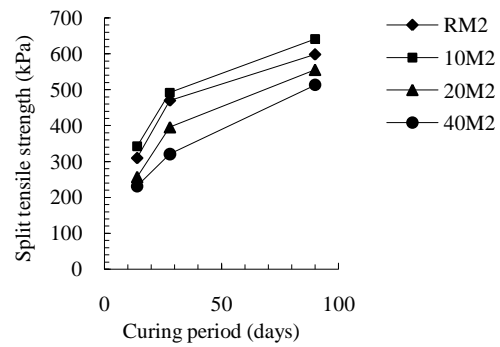
curing period, respectively. A similar trend of increase in tensile strength with the increase in curing periods for variation of tire granulates content (10%-40%) was also observed as evident from Figs. 5(a) to 5(c) and Table 2, respectively. The study was in agreement with [Guleria and Dutta \(2013\)](#), where similar increase in tensile strength has been reported with the increase in the curing period.

Table 2 Split tensile strength of reference mix mixed with 10, 20 and 40 % tire granulates at 14 ,28 and 90 days of curing with curing methods M1, M2, M3.

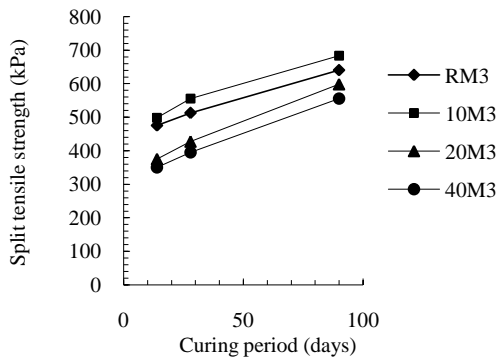
Tire granulates (%)	Curing Period (days)	M1		M2		M3	
		Diametral tensile strain (%)	Tensile strength (KPa)	Diametral Tensile strain (%)	Tensile strength (KPa)	Diametral tensile strain (%)	Tensile strength (KPa)
0	14	2.839	224.335	3.35	309.7	3.55	475.12
	28	4.001	427.3	4.388	470.03	4.646	512.76
	90	5.16	555.49	5.67	598.227	6.195	640.95
10	14	3.097	245.7	3.355	341.84	3.998	498.52
	28	4.388	480.718	4.646	491.40	5.16	555.49
	90	5.937	619.59	6.45	640.957	6.711	683.68
20	14	3.61	181.6	3.87	256.38	4.23	375.24
	28	4.775	352.52	5.16	395.257	5.42	427.30
	90	6.453	491.40	6.969	555.49	7.23	598.22
40	14	3.46	149.56	4.39	288.431	4.668	350.23
	28	4.646	288.43	5.42	320.47	5.937	395.25
	90	6.71	448.67	7.485	512.766	7.743	555.49



(a)



(b)



(c)

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Fig5 Variation of tensile strength with different curing period for the reference mix and with 10, 20% and 40% tire granulates cured with (a) M1 curing method (b) M2 curing method (c) M3 curing method.

Figs.5 (a), (b), (c) and Table 2 reveals that tensile strength of the reference mix, reference mix mixed with tire granulates, increases with the change in curing methods from M1 to M3 respectively. For example, from Table 2, tensile strength of specimen 1014M1 was 245.7 kPa, which increased to 341.84 kPa, when curing methods was changed to M2. Tensile strength of same specimen further increased to 498.52 kPa, when curing methods was changed to M3 method. A similar increase in tensile strength as evident from Fig.5 (a), (b), (c) and Table 2 was also observed in the reference mix mixed with 20% and 40% tire granulates. Figs.5(a) (b) (c) and Table 2 shows the variation of tensile strength of reference mix mixed with 10% to 40% tire granulates at 14 days of curing with M1, M2 and M3 curing methods, respectively. A study of Table 2 reveals a decrease in the tensile strength with the increase in the tire granulates content. For example, a value of tensile strength of 498.52 kPa of specimen 1090M3 with 10% tire granulates at 90 days of curing decreased to 375.24 kPa with the increase in tire granulates content to 20%. The tensile strength of same specimen further decreased to 350.23 kPa with increase in the tire granulates content to 40%. A similar trend as evident from Figs. 5(a), (b), (c) was also observed for different curing methods and curing periods, respectively.

V. LEACHATE ANALYSIS

The maximum increase in tensile strength was observed at 90 days of curing and inclusion of 10% tire granulates in reference mix, hence failed specimen of reference mix with 10% tire granulates were tested for leachability of metals. The results of leachate analysis are shown in Table 3.

Table 3 Leachate analyses of the reference mix, reference mix mixed with 10% tire granulates, cured for 90 days of duration by M1, M2 and M3 curing methods.

Parameter	Reference mix	090M1	1090M2	1090M3	Standards*(Land disposal)(as per mode of disposal)	
					Surface water	Public Sewer
Iron	13.09	10.34	7.650	7.9	NR	NR
Zinc	0.692	1.416	1.534	2.619	5	15
Manganese	0.00	0	0	0.00	-	-
Copper	0.090	0.033	0.136	0.160	3	3

* Standards as given in (Land disposal) as per Govt. of India MoEF, Notification, 25th September 2000, NR-Not reported.

Table 3 reveals that leaching of zinc of reference mix was on lower side in comparison to reference mix mixed with 10% tire granulates and cured with M1, M2 and M3 curing methods. For example, the leachability of zinc of reference mix was 0.692 ppm which increased to 2.619 ppm for the reference mix with tire granulates for M3 curing method. Table 3, further reveals that curing method M1 attributes lesser leaching of zinc in comparison to M2 and M3 curing methods.

Table 3 reveals no evidence of leaching of manganese in reference mix or with inclusion of tire granulates has been observed specimens were cured with different curing methods.

Table 3 further reveals that the leaching of iron from the reference mix was higher in comparison to reference mix mixed with 10% tire granulates with M1, M2 and M3 curing methods respectively. For example, the value of leaching of iron for reference mix was 13.09 ppm which decreased to a value of 10.34 ppm for reference mix mixed with 10% tire granulates cured with M1 curing method. The value of the same specimen further decreased to a value of 7.65 ppm when specimens were cured with M2 curing method. This leaching of iron is attributed to the presence of Fe₂O₃ (4.94%) in fly ash (Chemical analysis reported elsewhere). The study was in agreement with Guleria and Dutta, (2013), where similar decrease in leachability of iron was observed in the specimens of reference mix mixed with tire chips.

A close examination of Table 3, further reveals that the leaching of copper from the reference mix mixed with 10% tire granulates was on higher side in comparison to the reference, when cured with the use of M2 and M3 curing methods.

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For example, the value of leaching of copper for reference mix was 0.090 ppm, which increased to value of 0.136 ppm and 0.160 ppm, with the use of M2 and M3 curing methods, respectively.

Hence from the above, it can be concluded that the composite made from reference mix mixed with 10% tire granulates has shown a reduction in the leaching of copper and zinc in comparison to the reference mix. The potential use of the composite can be used as low cost construction materials.

V. CONCLUSION

In the present paper, reference mix containing fly ash + 8% lime + 1.5% gypsum was mixed with 10%-40% tire granulates cured for 14 to 90 days by three different methods of curing. On the basis of the results of the experimental investigation in the earlier sections, the following conclusions can be drawn.

- (1) The tensile load of the reference mix and with 10% inclusion of tire granulates increased with the increase in curing period, and with the change in curing method.
- (2) The increase in the tensile load was highest with the use of M3 curing method and at 90 days of curing.
- (3) The diametral strain of reference mix and with inclusion of 10% tire granulates in reference mix increases with the change in curing method and increase in curing period.
- (4) The increase in the diametral strain was highest with the use of M3 curing method and at 90 days of curing.
- (5) The tensile strength of reference mix and with inclusion of 10%, 20%, 40% tire granulates increases with the increases in curing periods and with change in curing method. The increase in tensile strength was highest with the use of M3 curing method and with 90 days curing period.
- (6) The tensile strength of reference mix decreases with the increase in tire granulates in reference. The maximum decrease was observed with the inclusion of 40% tire granulates in reference mix.
- (7) The leaching of zinc in the reference mix was observed to be lower side in comparison to reference mix mixed with 10% tire granulates. Study further revealed that M1 curing method attributes lesser leaching of zinc in comparison to M2 and M3 curing methods.
- (8) Leachate analysis of reference mix has shown a reduction in the leaching of copper in comparison to the reference mix with 10% inclusion of tire granulates with M3 curing method.
- (9) No evidence of leaching of manganese in reference mix or with inclusion of tire granulates has been observed with the use of different curing methods.
- (10) Leaching of iron from the reference mix was on higher side in comparison to reference mix mixed with 10% tire granulates when cured with M1, M2 and M3 curing methods.

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