

Present Status of MSW Disposal in Jalandhar and Suitability of Tire Derived Aggregates as a Drainage Material in Cover System of Landfill

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ABSTRACT: The paper discusses the present status of MSW disposal in Jalandhar region of Punjab (India) and the necessity of properly constructed engineered landfill in the studied region for the proper disposal of municipal solid waste. The study aimed at use of different sizes tire chips/shreds of varying aspect ratio used as drainage layer material in landfill cover system with the replacement of natural aggregates completely/partially as a resource conservation measure. In India nearly 200 million tons of scrap tires are discarded every year. The uncontrolled tire dumps stockpiled throughout the countries is now becoming a threat to environment and public health. Large scale reuse and recycling of waste scrap tires is essential to avoid growing stockpiles and associated environmental problems. Prime requirement for the use of waste scrap tires recognized as the reuses must be cost effective on large scale and capable of consuming large quantities of whole tires/tire-shred/chips. The most effective use of shredded tyres is in landfill cover as drainage material. The study includes the determination of permeability of tire chips/shred using different aspect ratios of 1 and 2 of same and varying sizes under the different conditions. Tire derived aggregates are capable of providing free draining. The cover system in the landfill is designed to prevent the infiltration of precipitation into the waste. For the new site, waste scrap tires are proposed as alternative MSW landfill drainage layer material in cover system based upon initial characterization and adequate drainage capability for relatively longer duration (thus to reutilize the waste scrap tire chips in a better manner as combinations of soil - tire chips).

KEYWORDS: MSW, landfill, cover system, tire derived aggregates, permeability.

I. INTRODUCTION

With the rapid growth in urbanization and industrialization, environment pollution of the cities increasing day by day (Puri et al., 2006). This increased pollution of environment (soil & water) causes hazardous problem to the health of public and aesthetic appearance of environment. To establish the safe and secure living environment, Govt. of India had started projects for the development of cities. These projects are Jawaharlal Nehru National Urban Renewable Mission and Smart City Project. Jalandhar city was chosen as a model region of Punjab state, India. Punjab generates nearly 3034.56 tonnes MSW every day (Punjab State Council of Science and Technology (PSCST) 2007). Approximately 1,830 tonnes of waste is generated by the major cities of Punjab (Sethi et al., 2013). Jalandhar is located between the Beas and Sutlej rivers at a distance of 350 km from Delhi. The population of this region is 19,62,700 (Punjab Census report 2011). The projected population of Jalandhar region will be 22,57,105 till the year 2025 and it will increase up to 25,95,670 till the year 2035. Municipal solid waste generation rate in this region varies from 0.2 to 0.6 kg per capita per day (Sethi et al., 2013). A total of 300 - 400 tonnes of solid waste is collected and disposed off in different disposal sites daily in the city (Sethi et al., 2013). Solid waste dumped at different disposal sites causes harmful effects on environment as well as on human health (Puri et al., 2006). Due to this open dumping (irregular dumping of municipal solid waste) on different sites caused many vector borne diseases identified as malaria, dengue and fever (Puri et al., 2006). Additionally, due to inadequacy of engineering techniques in the disposal of municipal solid waste on site, ground water and environment affect at a larger extent. In order to minimize these harmful effects, properly designed engineered sanitary landfill for proper disposal of municipal solid waste landfill is required so that land area may be ultimately preparing for many

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recreational activities. A landfill is the well developed strategy which is designed for the safe disposal of municipal solid waste generated from any urban, suburban area. Landfill system consist different components included liner system, leachate collection system, gas collection system, cover system etc. Landfill cover design generally consists of three layers: the barrier layer, the drainage layer and the cover soil layer. When precipitation occurs, the water infiltrates into the solid waste, mixed with the waste inside, and hence produces the dark brownish colour liquid called leachate. This leachate has harmful effects as it contain organic, inorganic matters and toxic substances which when infiltrates into the ground cause ground water contamination reduce the bearing capacity of the soil and affect the water table. The cover system in the landfill is designed to prevent the infiltration of precipitation into the waste. The drainage layer of cover system made up of granular materials (sand and gravel) but there is scarcity of these materials in the Jalandhar region Punjab. So, alternative materials such as waste tires may be used as a drainage material in the drainage layer of cover system. According to ICRA, in 1990-91 estimated discarded tyre were 22,846 thousand annually in India. From 1994- 95, discarded tire rate was 31,213 thousand annually. Discarded volumes of scrap tires were greater than 75 million cubic meter in 1993. ICRA expect the tire industry to grow by 5% in 2011 to 2012, -2% in 2012-2013 and again increased to 2-4% in 2013-2014, 6-7% in 2014 -2015. These scrap/ discarded tires are piled up in numerous locations, if these scrap tires are piled up in numerous locations illegally it can cause various health hazard, breeding of mosquito's, and nuisance to society etc (Reddy et al., 2010). The reuse of waste tires in the civil engineering applications may be as a whole tire or in the form of shredded tires/chips. The state is seeking for large scale and cost effective use of shredded tires, larger the tyre shreds lower the processing cost large scale uses for civil engineering applications such as retaining wall, embankment, pavement, light weight fill material. But the most effective use of shredded tyres is in land fill cover as drainage material.

II. RELATED WORK

Solid waste management has become a global problem particularly in the developing countries of the world (Ramachandra et al., 2003). Solid waste proved dangerous in nature since they accumulated and contaminated the surface water & ground water. The generation of waste in India cities ranged from 200 to 870 gm/d depending upon the population and the lifestyle of people (Sharholly et al., 2008). Existing research showed that about 90% of the solid waste produced in India was dumped off directly in the landfills in an unsatisfactory manner particularly in bigger cities and towns (Hazara et al., 2009). Developed countries face serious environmental challenges concerning solid waste management due to rapid urban development. Some studied had been carried out by utilizing few samples of waste from the metropolitan cities like Delhi, Ahmadabad & Bangalore (Saha et al., 2010). According to municipal solid waste management rule 2000, the urban development of the respective state governments was responsible for enforcing the provisions of the rule in metropolitan cities (Pomnani and Srinivasarao., 2014).

Tire shreds were proposed and approved as an alternative to drainage stone in the construction of new landfill cell at the Reley Regional Landfill site. Tire shreds could not provide sufficient lateral support to the pipe due to the excessive compressibility. But despite of this disadvantage, tire shreds had been reported for "free draining capacity and high hydraulic conductivity (Warith et al., 2004). Beaven et al. (2006) conducted study that the use of coarser shreds or even whole tires for landfill drainage systems might be advantageous as tire shreds were more economical to produce and may be less prone to clogging than smaller shreds. Reddy et al. (2010) estimated that over 280 million tires were discarded each year in United States and approximately 4 billion tire shreds were discarded each year in worldwide. Naval et al. (2014) conducted studies on the "Characterization and hydraulic performance assessment of different size tire chips and geotextile" used as drainage layer in MSW landfill system and concluded that the geotextile and tire chips may be used as a combination of drainage layer material for all new MSW landfills." Kaushik et al. (2015) observed comparative hydraulic performance of gravel and tire chips used in their different combinations and percentage change in COD, TSS, Ca-hardness and TDS concentration for the real active high strength MSW landfill leachate with time.

III. MATERIAL AND METHOD

The studied area Jalandhar is situated in Doaba region. Jalandhar is located between Beas and Sutlej rivers at a distance of 350 km from Delhi. The state of Punjab is situated northwest in India with a subtropical climate. The state is spread around 29'30" N to 32'32" N latitude and 73'55 E to 76'50 E longitude.

Present MSW status in Jalandhar: The whole state is divided into 7 clusters. Jalandhar cluster contains 26 municipal committees including Municipal Corporation Jalandhar. Solid waste management in Jalandhar municipality is under the

Sanitation Department and the health section department of MCJ, which is entrusted with responsibility for MSW management and sanitation of the city. The municipal area caters to a population of 10,000,00 and is spread over a 120 Km² area. The MCJ is responsible for the management of all kinds of solid waste (household, commercial, market, and institutional). Construction and demolition (C & D) waste is managed by the private contractors. The hazardous waste generated by the industries is taken to a common site developed at Mohali city (Sethi et al., 2013). Most of the final disposal of waste is done in an unscientific manner. Public participation and contribution in maintaining sanitation is almost absent in the city. The average MSW generation rate is 350 TPD in Jalandhar region (Sethi et al., 2013). The waste is 85% residential, 10% industrial and 5% mixed zone (Puri et al., 2006). The MSW integrated management plan includes collection, handling, segregation, transportation and final disposal of waste. Solid waste is collected from bins, collection from residential areas and carried out daily as the organic matter decomposes rapidly due to hot weather. Waste collection is made by cart-pullers from door to door and then segregates the plastic bags, polythene and metal. Non-biodegradable is separated from organic substances. Finally, municipal solid waste is transported from storage places to the dumping grounds.

Materials used in the study are as follows:

- A. Soil characteristics:** As per Jalandhar district board information, the soil of this zone has developed under semi arid conditions. The soil of this zone is alluvial soil of sandy loam to clayey. As Jalandhar lies in sub-tropical region, the average rainfall of this region is 789 mm/year. Average winter and summer temperature varied from 9°C and 46°C respectively. Relative humidity is in the range of 12 to 30% in summer and in the range of 50 to 85% in winter season.
- B. Suitability of tire derived aggregates in the cover system of landfill**
The drainage layer of cover system made up of gravel and sand but there is scarcity of granular materials. In order to minimize this problem, alternative materials may be used (tire chips/shreds) of required grade and quality. Tire chips of aspect ratio 1 and 2 (size 2.5×2.5 cm, 5×5 cm, 10×10 cm and size 2.5×5 cm, 3.5×7 cm and 5×10 cm respectively) and tire shreds of size 17×9 cm were used to perform the experimental study and to check the suitability of tire derived aggregates (tire chips/shreds) as an alternative drainage material.



Figure 2(a) Tire shred sample



Figure 2(b) Normal garden soil



Figure 2(c) 2.5x2.5 cm tire chips



Figure 2(d) 5x5 cm tire chips



Figure 2(e) 10x10 cm tire chips



Figure 2(f) 2.5x5 cm tire chips



Figure 2(g) 3.5x7 cm tire chips



Figure 2(h) 5x10 cm tire chips

C. Experimental setup and test procedure of permeability testing

Permeability test apparatus were used for the experimental study. Fig. 3 showed the schematic representation of the test setup used for the permeability determination. The permeameter was filled with tire chips/shreds of different sizes and aspect ratio in the study. The internal diameter of permeameter was 30 cm and the effective height of permeameter was 60 cm. The valve of permeameter was connected with the upper reservoir containing water and water was allowed to flow out of upper reservoir into the permeameter so that all air bubbles in the permeameter were removed. The stop cock was closed after removing all air and filling permeameter entirely (up to top level with leachate). The tire chip/shred samples of particular size and aspect ratio were placed in the permeameter. Upper drainage plate was placed over the tire chips. Then water was allowed to flow through the tires and established a steady flow. The head of water was kept 5 cm above the upper drainage plate. Steady state flow conditions were established and then water was collected in the lower chamber and hence permeability of tire chips/shreds was determined.

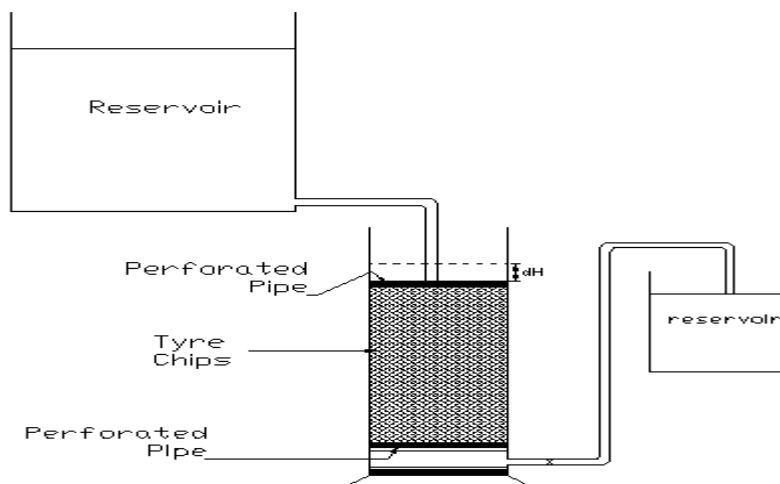


Figure 3: Schematic of Constant head permeameter

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IV. RESULTS AND DISCUSSIONS

The permeability was measured on the different size tire shreds/chips under different test conditions. On tire chips/shreds with aspect ratio 1 (sizes 2.5x2.5, 5x5, 10x10 cm) and aspect ratio 2 (sizes 2.5x5, 3.5x7, 5x10 cm) and tire shreds with average size 17x9 cm, permeability tests was performed to check the suitability of tire derived aggregates in the cover system drainage layer of landfill and following results were obtained.

Table 1: Comparison of permeability of tire chips/shreds (aspect ratio- 1&2, thickness of layer of tire chips/shreds = 30 cm) without soil layer.

Sr. No.	Size		Aspect Ratio	Hydraulic gradient (i)	Time (in sec)	Permeability (k) cm/sec
	Tire Chips (cm)	Tire Shreds (cm)				
1	2.5x2.5	-	1	0.16	10	0.135
2	5x5	-				0.09
3	10x10	-				0.174
4	2.5x2.5	-	1	0.33	10	0.08
5	5x5	-				0.08
6	10x10	-				0.101
7	2.5x2.5	-	1	0.5	10	0.067
8	5x5	-				0.07
9	10x10	-				0.076
10	5x2.5	-	2	0.16	10	0.18
11	3.5x7	-				0.16
12	10x5	-				0.16
13	5x2.5	-	2	0.33	10	0.10
14	3.5x7	-				0.09
15	10x5	-				0.09
16	5x2.5	-	2	0.5	10	0.07
17	3.5x7	-				0.08
18	10x5	-				0.07
19	-	17x9	≈ 2	0.16	10	0.21
				0.33		0.114
				0.5		0.086

Table 1 showed the comparison of permeability values (k) with respect to hydraulic gradient (i) and with constant time (t) of various tire chips sizes with aspect ratio 1 & 2 and tire shred of size (17x9 cm). Firstly, permeability of tire chips/shred was determined without placing any soil layer over it. The thickness of tire samples (tire chips/shreds) was taken 30 cm.

COMPARISON OF PERMEABILITY (k) OF DIFFERENT SIZES TIRE CHIPS (A.R. – 1 & 2) AND TIRE SHREDS WITH HYDRAULIC GRADIENT (i) (without soil layer)

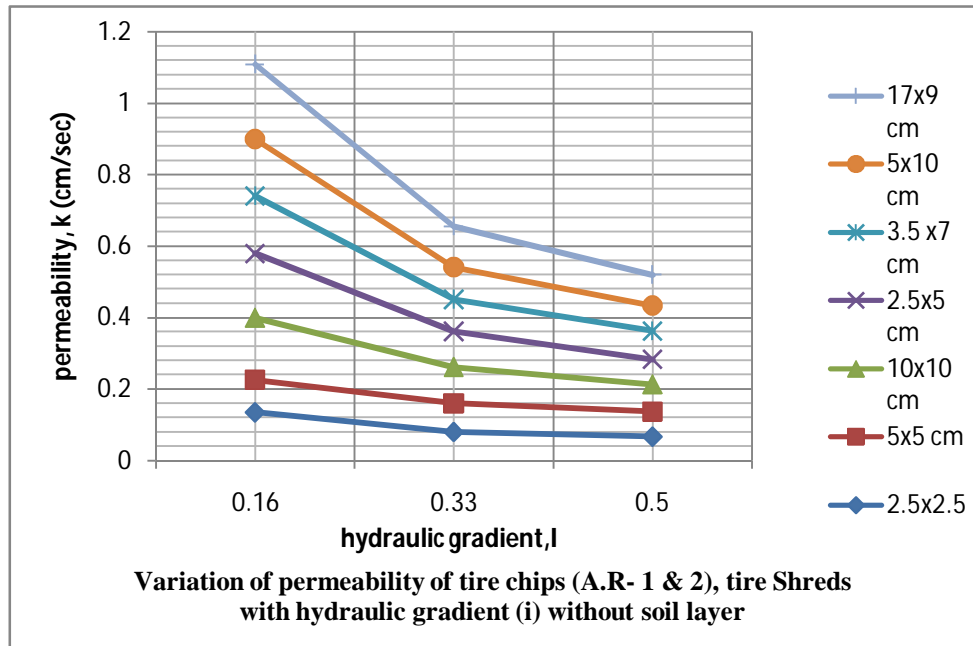


Figure 4: Variation of permeability of tire chips (A.R. - 1&2) and tire shreds with hydraulic gradient without soil layer

Figure 4 showed the variation of permeability of tire chips and tire shreds with hydraulic gradient without any combination with the soil layer. The graph clearly showed that with the increase in hydraulic gradient, permeability of the samples (tire chips/tire shreds) gradually decreased. The tire chips of size 2.5x2.5 cm and 5x5 cm showed sharp decrease in permeability as compared to the other tire chip/shred samples.

Table 2: Comparison of permeability of tire chips/shreds (aspect ratio- 1 & 2 thickness of layer of tire chips/shreds = 30 cm) with soil layer thickness 20 cm.

Sr. No.	Size		Aspect Ratio	Hydraulic gradient (i)	Time (in sec)	Permeability (k) cm/sec
	Tire Chips (cm)	Tire Shreds (cm)				
1	2.5x2.5	-	1	0.1	10	0.155
2	5x5	-				0.127
3	10x10	-				0.145
4	2.5x2.5	-	1	0.2	10	0.09
5	5x5	-				0.11
6	10x10	-				0.099
7	2.5x2.5	-	1	0.3	10	0.066
8	5x5	-				0.089
9	10x10	-				0.083
10	5x2.5	-	2	0.1	10	0.144
11	3.5x7	-				0.150
12	10x5	-				0.156
13	5x2.5	-	2	0.2	10	0.084

14	3.5x7	-	2	0.3	10	0.089
15	10x5	-				0.089
16	5x2.5	-				0.062
17	3.5x7	-				0.066
18	10x5	-				0.066
19	-	17x9	≈ 2	0.1	10	0.21
				0.2		0.141
				0.3		0.104

Table 2 showed the comparison of permeability values (k) with respect to hydraulic gradient (i) and with constant time (t) of various tire chips sizes with aspect ratio 1 & 2 and tire shred of size (17x9 cm). In this case, permeability of tire chips/shred is determined with the soil layer placed over it. The thickness of soil layer was 20 cm with 30 cm tire sample thickness. The result showed that with the increase in hydraulic gradient, permeability of tire chips/shreds gradually decreased.

COMPARISON OF PERMEABILITY (k) OF DIFFERENT SIZES TIRE CHIPS (A.R. – 1 & 2) AND TIRE SHREDS WITH HYDRAULIC GRADIENT (i) (with soil layer of 20 cm thickness)

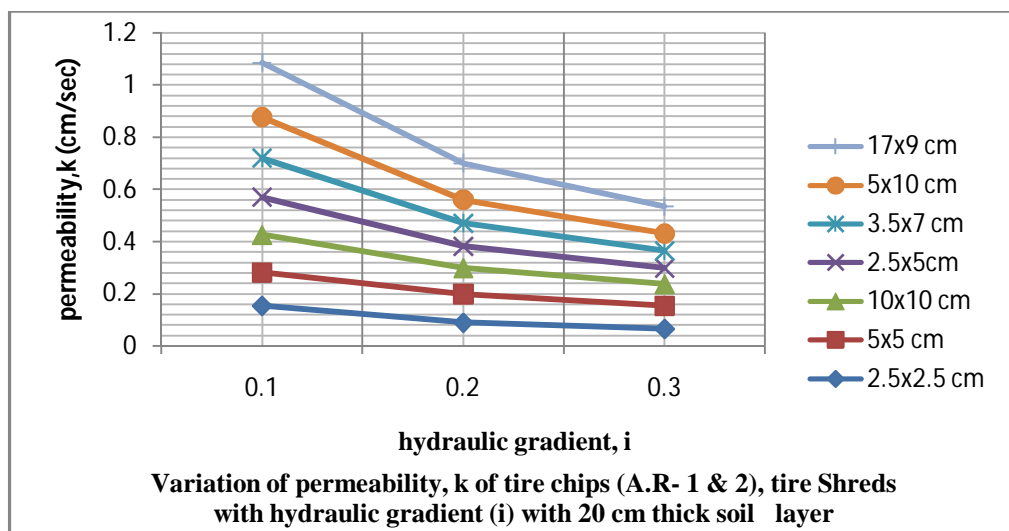


Figure 5: Variation of permeability of tire chips (A.R. - 1&2) and tire shreds with hydraulic gradient with 20 cm thick soil layer

Figure 5 showed the variation of permeability (k) of tire chips and tire shreds with hydraulic gradient. The permeability of tire samples was determined in combination with 20 cm thick soil layer. The graph clearly showed that with the increase in hydraulic gradient, permeability of the samples (tire chips/tire shreds) decreased. The tire chips and tire shreds in combination with the soil layer also gave sharp decrease in permeability and showed free draining characteristics.

V. CONCLUSION

The use of tire derived aggregates proved beneficial when used as an alternative drainage material in the cover system of landfill. The experimental results showed that as the water head increased, hydraulic gradient also increased and hence the permeability decreased. It was clear that the tire chips of 5x5 cm and 2.5x2.5 cm (aspect ratio 1) showed sharp decrease in permeability values. This clearly showed that the same tire chips of aspect ratio 1 were capable of providing relatively faster release of water through them even on relatively high hydraulic gradient value. Experimental investigations were also performed for tire chips and soil (garden soil) mix combination layer that also

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showed gradual decrease in permeability and hence relatively free draining. Due to the better drainage, these sizes of the tire chips/shreds are more effective to use as drainage material in cover system of MSW landfills. These experimental investigations may prove to be very useful for landfill designers in achieving the optimum conditions of free drainage, natural resources conservation and maximum waste reutilization on large scale in geotechnical engineering applications.

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