USE OF RUBBER WASTE IN CONCRETE TO REDUCE ENVIRONMENTAL POLLUTION- AN OVERVIEW

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ABSTRACT

With on growing industrial development, tonnes of solid waste are generated every year. Managing, disposing and recycling of these waste has turned out to be a great challenge in recent times. Typically, waste generated from industrial and domestic activities is dumped in open spaces. However dumping of solid waste in open spaces is hazardous to environment; therefore researchers have explored new means to effectively manage such waste. Tyre wastes have no exception; it cannot be readily recycled or reused. They are dumped in open grounds around the world. In Pakistan they pose a bigger threat as they are burnt, which results in emission of harmful gases in the atmosphere. Therefore, it is necessary to reuse these rubber wastes to reduce environmental pollution. Rubber wastes can be used in concrete as a partial replacement of aggregates resulting in lightweight concrete. Using rubber wastes in concrete enhances the impact resistance, thermal insulation and sound insulation at affordable strength. This paper reviews the viable use of rubber wastes in concrete industry to address the problem of disposal of such wastes.

KEYWORDS: *Rubber wastes, lightweight concrete, aggregate, impact resistance.*

INTRODUCTION

Solid waste management has become a major challenge for modern civilization in recent times. Solid waste is defined as "Any unwanted and discarded materials that are in solid, liquid, or gaseous state resulting from commercial, industrial, and agricultural operation or from community activities".[1] Yearly generation of solid waste depends on the living standards, climatic conditions, and cultural practices of the area; therefore its range is different for different countries. Ahmad et al.[2] reported that solid waste generation for developed countries ranges between 1.1 to 5.1 kg per capita per day and for developing countries it ranges between 0.4 to 0.9 kg per capita per day. For Pakistan, it ranges from 0.28 to 0.61 kg per capita per day and its growing rate is 2.4% per year.[3] Most of the solid waste generated every year is stockpiled, which is harmful for atmosphere. Sometimes solid waste is burnt to reduce its volume but this practice is even more harmful to atmosphere as burning of solid waste produces harmful gases in the atmosphere. Therefore, innovative techniques for managing solid waste need to be determined.

Scrap tyres holds a major portion of total solid waste generated every year. Scrap tyre generation rate for industrialized countries is 9 kg per capita per year.[4] In most countries, scrap tyres are dumped in landfills but this practice is discouraged to avoid the rapid filling of these spaces. Also, landfills act as source for contamination of land and water resources. In developing countries scrap tyres are burnt as a fuel or to lengthen the life span of stockpile. But burning of tyres releases toxic gases and tiny particles; which can cause lung diseases. Therefore, new techniques to effectively manage these rubber wastes are explored by researchers; incorporating rubber wastes in concrete is one of such approach. Using rubber wastes in concrete could result in enhanced thermal insulation, at affordable strength.

In Pakistan, no reliable data is available about the waste tyre generation rate. They are often dumped in open spaces. But mostly they are collected in local stockpiles, to be eventually used as a fuel in brick kilns. The high energy content and ability to burn for longer period of time make the tyres a preferable fuel for kiln owners. As already mentioned, burning of tyres results have serious environmental impacts.

Obviously burning of tyres is not an acceptable solution to the growing problem of solid waste management posed by scrap tyres. The alternative is to recycle scrap tyres in producing other by-products. Currently, very little recycling of scrap tyres is carried out; rubber mats, pedal rubber, and inner tubes of rubber tyres are common by-products of recycling. Fortunately, another recycling

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option exists in the concrete industry where scrap tyres can be used as partial replacement of aggregates. This is an attractive option because it has the potential of generating environmental benefits in two ways. First, the scrap tyres can be diverted away from solid waste landfills without hazardous emissions associated with the burning of tyres option. Secondly, the production of aggregate for concrete by mining virgin natural resources has its own adverse environmental impacts.[5] Hence, if the natural aggregates are replaced with rubber tyre aggregates then additional environmental benefits can be realized as well.

This paper investigates the viability of using scrap tyres as partial replacement for natural aggregates in concrete. The effects of such a replacement on fresh and hardened properties of concrete are analysed. In order to achieve this objective, extensive survey of published literature in this area was carried out. The relevant findings from this survey are summarized in this paper.

CLASSIFICATION OF SCRAP TYRES

Various researchers have used scrap rubber in different sizes for civil engineering applications. Rubber are made free from threads in cutting machines and then shredded/ ground to specified size for intended use. Classification of rubber used in various studies on the basis of particle size is as follows:

CHIPPED RUBBER

Chip rubber is obtained by mechanical shredding of scrap tyres and is used as replacement for coarse aggregate in concrete. Shredding of tyres is done in two steps; primary shredding followed by secondary shredding. Size of scrap tyres is reduced to about 100 mm in length after primary shredding and to about 13 mm after secondary shredding.[6]

GROUND RUBBER

Grinding of chip rubber is done to obtain ground rubber which is used as replacement of fine aggregate in concrete. Grinding of chip rubber is done in two steps; magnetic separation followed by screening. Size of rubber chips is reduced to about 0.15 mm after grinding.[7] Ground rubber is generally used for rubber chips passing through sieve no. 100.

CRUMB RUBBER

Crumb rubber is used as filler in concrete in addition/replacement of cement. Crumb rubber is obtained from three processes; Micro-mill, granular-mill and cracker-mill process. Crumb rubber is generally used for rubber particles passing through sieve no. 200 and their size varies from 4.75 mm to 0.075 mm.[7] Size of particles ranges from 5mm to 0.5 mm after grinding by cracker-mill process, and 9.5 mm to 0.5 mm after grinding by granular-mill process.

MANAGEMENT OPTIONS

Most commonly used management options for scrap tyres are listed below:

STOCKPILING

The most convenient method of disposing a waste is dumping it in landfill/ stockpile. Therefore, majority of scrap tyres are dumped in landfills around the world. But due to their larger volume they quickly consume valuable space. Also, tyres have the tendency to entrap methane gas, causing them to become buoyant. As tyres rise up, they damage landfill liners and pollute ground water and local surface. To overcome the drawback of void space, shredded tyres are now preferred in landfills. Also, due to their cost effectiveness they are preferred as cover material and backfill for leachate collection systems, gas venting systems and operational liners. But landfilling of scrap tyres is hazardous to environment and therefore is discouraged.

RECYCLING

Only 2–5% recycled rubber is used by rubber and tyre manufacturing industry worldwide. Lack of demand for recycled tyre is the major reason why rubber recycling industry is not flourishing rapidly. However, this trend is changing due to innovative applications of scrap tyre-derived rubber.

CIVIL ENGINEERING APPLICATIONS

During recent years civil engineering applications for scrap tyre rubber are becoming more and more popular because they are economically advantageous and technically feasible. Rubber chips can be used as replacement of conventional materials, such as gravel, road fill and crushed stone or sand. Using rubber as construction material could yield benefits of good thermal insulation, improved drainage properties and reduced unit weight.

RESEARCH FINDINGS

Use of scrap tyre rubber as a partial replacement of aggregates in concrete has been investigated by many researchers. The findings suggest beneficial impacts on certain properties of concrete. In light of such results, many have called for promoting the use of scrap tyre in concrete because it can reduce the solid waste problem as well as achieve desirable properties.

AIR CONTENT

It is reported that air entrainment in concrete mixes increases with addition/ replacement of scrap rubber.[8] Similar findings have also been reported by other researchers.[9,10, 11] Rubber particles have the tendency to entrap air due to its non-polar nature. Also, rubber particles repel water; and therefore air may adhere to it resulting in concrete having higher air content.[10]

WORKABILITY

Khatib and Bayomy[9] reported that concrete containing rubber aggregate have comparable or higher workability than concrete containing natural aggregates. Aiello and Leuzzi,[12] investigated slump for concrete containing crumb rubber and rubber chip aggregate as partial replacement of natural aggregate. Results obtained suggested that concrete containing crumb rubber showed better workability than control concrete, and concrete containing chip rubber. Other researchers have reported similar findings as well.[13,14]

UNIT WEIGHT

Shah,[11] investigated unit weight of concrete containing rubber aggregate as partial replacement of coarse aggregate. Results obtained from unit weight test are provided in Table 1.

Table 1: Unit Weight and Water Absorption for Rubberized Concrete (Shah, 2012)

	Days	Control Concrete	5% Re-placement	10% Re-placement	15% Re-placement
Unit Weight (kg/m3)	7	2200	2160	2140	2100
	14	2390	2330	2310	2260
	28	2411	2357	2330	2260
Water Absorption (%)	7	14.31	19.82	25.49	28.69
	14	14.25	15.11	19.54	20.41
	28	14.23	15.15	15.34	15.46

It shows that unit weight of rubberized concrete progressively decrease with increase in rubber content. It was observed that reduction in unit weight occurred due to lower unit weight of rubber aggregate in comparison to natural aggregate. Siddiqui[10] also observed that unit weight of rubberized concrete decrease because of low specific gravity of rubber aggregate in comparison with natural aggregate and higher air content of rubberized concrete.

WATER ABSORPTION

Water absorption of concrete containing rubber aggregates increases with increase in rubber content as depicted in Table 1. Shah[11] reported that scrap rubber is porous in nature; therefore rubberized concrete mix has a tendency to absorb more water than ordinary concrete mix. It is further reported that more water can entrap in rubberized concrete mix due to weak bond of rubber particles with cement paste.

THERMAL AND SOUND INSULATION

Increase in thermal resistance and sound insulation of rubberized concrete is reported with increase in rubber content.[15] Lower thermal conductivity of rubber aggregate in comparison to natural aggregate is the main reason for increased thermal resistance of rubberized concrete. Moreover, poor bonding between cement paste and rubber particles aids to the increased thermal resistance of concrete containing rubber aggregate.[16] Corinaldesi et al.[17] determined thermal insulation of rubberized mortar and found it to be greater than that of cement mortar. Pitisukontasukkul[18] investigated thermal and sound insulation of pre-cast concrete panels and concluded that both the sound and thermal resistance of pre-cast concrete panels increased by using rubber aggregate as volume replacement of fine aggregate.

COMPRESSIVE STRENGTH

Several authors[19,20,21] have reported the effect of scrap rubber on compressive strength of concrete. Results reported by other researchers indicate that compressive strength of rubberized concrete mix is dependent on the size, proportion and surface texture of rubber particles in the mix. Eldin and Senouci[19] investigated compressive strength of concrete mixes containing coarse rubber chips and fine ground rubber aggregate as partial replacement of natural aggregate. Reduction in compressive strength of approximately 85% and 65% was reported when natural aggregates were fully replaced with coarse rubber chips and fine ground rubber respectively. It was further reported that concrete specimens resulting from both type of mixes exhibited ductile failure and higher ability to absorb plastic energy under compressive load. Topcu et al.[21] and Khatib and Bayomy[9] also reported that compressive strength loss in concrete containing coarse rubber chips is more than concrete containing fine ground rubber. However, Fatuhi and Clark[22] and Ali et al,[23] reported that higher compressive strength can be achieved by pre-treatment of rubber aggregate. Pre-treatment of rubber aggregates make the surface of rubber rough, which result in better bounding with cement paste, and, therefore, higher compressive strength may be achieved. Pre-treatment may vary from plasma pre-treatment and acid pre-treatment. Commonly, alkaline solution sodium hydroxide (NaOH) is used for acid pre-treatment of rubber particles. Treatment of rubber particles improves the strength of concrete by imparting roughness to the surface of rubber particles. Arin et al.[24] used fly ash as filler in rubberized concrete mixes containing different sizes of rubber aggregates and compared the compressive strength of such mixes. His results showed that by increasing fly ash content, the compressive strength of rubberized concrete increases to an acceptable value. Results of his study (Figure 1) suggested that compressive strength of rubberized concrete not only depends on rubber content but is also dependant on the size of rubber particles. Larger size particles at higher replacement ratios show lower decrease in compressive strength than that of smaller size particles.

Turatsinze et al.[25] used rubber aggregate in self-compacted concrete and found that compressive strength was reducing with increase in rubber content. He commented that the reason for lower compressive strength is due to the addition of rubber aggregates to concrete which makes the concrete non-homogenous as rubber aggregates are lighter in nature. He further commented that rubber does not affect the rate of gaining strength.

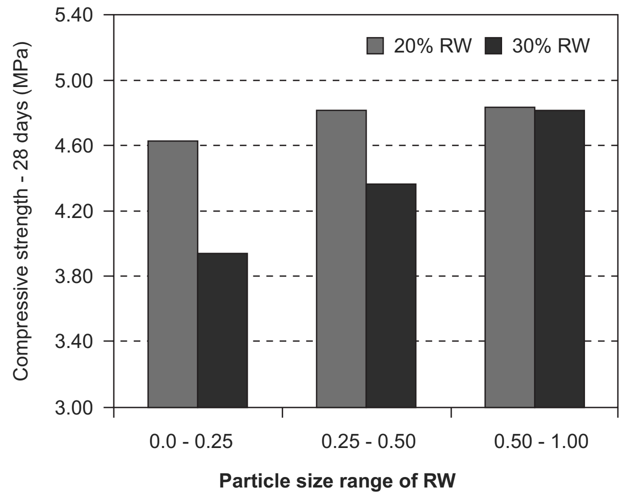

Figure 1:Compressive Strength versus Particle Size of Rubber Waste[24]

FLEXURAL STRENGTH

It is evident from the graph shown in Figure 2 that flexure strength of concrete mix decreases with increase in content of rubber chip and ground rubber.

Azmi et al.[13] also reported progressive loss in flexure strength on addition of rubber aggregate. It was further reported that at same level of replacement the decrease in flexure strength of concrete was not as substantial as the loss in compressive strength. Aiello et al.[12] determined flexure strength of concrete having rubber aggregate replaced for both fine and coarse aggregate in volume ratios. His results depicted that more reduction in flexure strength was observed for coarse aggregate replacement in comparison with fine aggregate replacement.

IMPACT RESISTANCE

Topcu and Avcular[26] reported that concrete containing rubber aggregate showed higher impact resistance than concrete containing natural aggregate. This increase

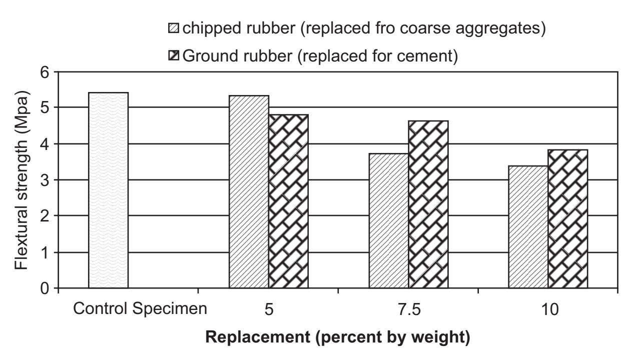

Figure 2: Flexure Strength of Rubberized Concrete

in impact resistance can be credited to enhanced ability of rubber aggregate to absorb plastic energy. Sallam et al.[27] determined impact resistance of concrete containing rubber aggregate as volume replacement of fine aggregate. Results showed that concrete containing rubber aggregate showed more resistance to crack initiation under impact loading. It is reported that rubber particles in concrete absorbs more plastic energy compared to natural aggregate. Moreover, the ability of rubberized concrete to allow large deformation helps in energy dissipation thereby increasing impact resistance.[26]

DURABILITY

Ganesan et al.[28] investigated the durability for self-compacting rubberized concrete with and without steel fibers. Water permeability, chloride ion permeability, abrasion resistance, and resistance to seawater attack and acid attack were investigated. Water permeability for self-compacting rubberized concrete was found to be lower, as rubber particles act as barrier for the passage of water. Chloride ion penetration was also decreased due to higher insulating nature of rubber aggregate. Decrease in abrasion resistance of self-compacting rubberized concrete with increase in rubber content is reported, because of decrease in compressive strength with addition of rubber aggregate. Resistance to seawater attack was found to be better for self-compacting rubberized concrete than ordinary self-compacting concrete due to less reactive nature of rubber particles. Resistance to acid attack was also increased with addition of rubber in concrete. Several other authors also reported that rubber concrete show better resistance to freeze and thaw than ordinary concrete.[10,16,29]

POTENTIAL APPLICATIONS OF RUBBERIZED CONCRETE

Fatuhi and Clark[22] have suggested that rubberized concrete could be useful as vibration damper in foundation pads for heavy machinery and in railway stations. Furthermore, it was suggested that it can be used in railway buffers, barriers and bunkers to provide better resistance to impact loading. It was also suggested that due to its lower density rubberized concrete can be good building material for architecture applications, such as false facades, nailing concrete and stone backing. Topcu and Avcular[21] suggested that rubberized concrete may be used in buildings as shock-wave absorber during earthquake, in sound barriers and in highway construction as a shock absorber.

CONCLUSIONS

The viability of rubber aggregates in concrete and effect of rubber on various properties of concrete was addressed in this review paper. The following observations were made on the basis of literature surveyed about rubberized concrete properties:

Modification in physical properties of concrete incorporating rubber aggregate was noticed. Workability, water absorption and air content progressively increased with increase in rubber content. The unit weight of rubberized concrete was reduced with increase in rubber content, due to the low specific gravity of rubber particles.

Incorporating rubber aggregate is highly detrimental to the compressive strength of rubberized concrete. Decrease in flexure strength was also noticed with increase in rubber content but this reduction was not as detrimental as of compressive strength. Impact resistance on the other hand increases with increase in rubber content. It is due to the elastic nature of rubber particles which enables rubberized concrete to allow large deformations.

Based on the properties studied for concrete containing rubber aggregate it could be concluded that rubber can be incorporated in concrete to improve certain properties and reduce the problem of disposal of scrap tyres rubber. Using scrap tyres rubber in concrete will address many environmental problems related to improper disposal of scrap tyres.

REFERENCES

1. *Huebsch, R., 2011. "About Solid Waste, eHow contributor 2011, Retrieved July 2011, from http://www.ehow.com/about6173230solid-waste.html*

2. *Ahmed, S. P., Kazmi, S., Danyal., "Solid and Hazardous Waste: A Great Threat". 4th International Environmentally Sustainable Development Conference (ESDev-2011)*

3. *EAR 1993: Draft environmental assessment report, Stockholm, November 1993.*

4. *Reschner, K., 2008. "A Summary of Prevalent Disposal and Recycling Methods, Scrap Tire Recycling". http://www.entire-engineering.de/Scrap_Tire_Recycling. pdf.*

5. *Rehan, R. and Nehdi, M. 2005 "Carbon dioxide*

Emmissions and climate chanrge: policy implication for the cement industry", Evirnment Science and Policy, Vol. 8, No. 2, 105 – 114.

6. *Read, J., Dodson, T., Thomas, J., 1991. "Experimental project – use of shredded tyres for lightweight fill". Oregon Department of Transportation, Post Construction Report for Project No. DTFH -71-90-501-OR-11, Salem, OR.*

7. *Heitzman, M., 1992. "Design and construction of asphalt paving materials with crumb rubber". Transportation Research Record No. 1339, Transportation Research Board, Washington, DC.*

8. *Fedroff, D., Ahmad, S., and Savas, B. Z., 1996. "Mechanical properties of concrete with ground waste tyre rubber". Transportation Research Board, Report No. 1532, Transportation Research Board, Washington, DC, pp. 66–72.*

9. *Khatib, Z. K., Bayomy, F.M., 1999. "Rubberized portland cement concrete". ASCE Journal of Materials in Civil Engineering 11 (3), 206–213.*

10. *Siddique, R., and Tarun, R. Naik, 2004. "Properties of concrete containing scrap-tyre rubber – an overview". Waste Management 24, 563–569.*

11. *Shah, 2012. "Evaluation of thermal and mechanical properties of concrete containing rubber aggregate". M.Sc thesis, University of Engineering and Technology, Peshawar.*

12. *Aiello, M. A., Leuzzi, F., 2010. "Waste tyre rubberized concrete: Properties at fresh and hardened state". Waste Management 30, 1696–1704.*

13. *Azmi, N. J., Mohammed, B. S., Al-Mattarneh, H. M. A., 2008. "Engineering Properties of Concrete Containing Recycled Tire Rubber". International Conference of Construction and Building Technology.*

14. *Raghvan, D., Huynh, H., and Ferraris, C.F., 1998. "Workability, mechanical properties and chemical stability of a recycled tire rubber-filled cementitious composite". Journal of Materials Science 33 (7), 1745–1752.*

15. *Etebar, K ., Kew, H. Y., Limbachiya, M. C., and Kenny, M. J., 2008. "Investigation into the potential of rubberized concrete products". Excellence in Concrete Construction through Innovation, Proceedings of the conference held at the Kingston University, United Kingdom, 9 - 10 September 2008.*

16. *Nehdi, M., and Khan, A., 2001. "Cementitious Composites Containing Recycled Tire Rubber: An Overview of Engineering Properties and Potential Applications". Cement, Concrete, and Aggregates, CCAGDP, Vol. 23, No. 1, June 2001, pp. 3–10.*

17. *Corinaldesi V., Mazzoli, Alida., Moriconi, G., 2011. "Mechanical behaviour and thermal conductivity of mortars with waste plastic particles". Key Engineering Materials (Volume 466), Pages 115-120, January, 2011*

18. *Sukontasukkul, P., 2009. "Use of crumb rubber to improve thermal and sound properties of precast concrete panel". Construction and Building Materials 23, 1084–1092.*

19. *Eldin, N. N., Senouci, A. B., 1993. "Rubber tyres particles as concrete aggregate". Journal of Materials in Civil Engineering, 5 (4), 478–496.*

20. *Rostami, H., Lepore, J., Silverstraim, T., and Zundi, I., 1993. "Use of recycled rubber tyres in concrete". In: Dhir, R.K. (Ed.), Proceedings of the International Conference on Concrete 2000, University of Dundee, Scotland, UK, pp. 391–399.*

21. *Topcu, I.B., Avcular, N., 1997a. "Analysis of rubberized concrete as a composite material". Cement and Concrete Research 27 (8), 1135–1139.*

22. *Fatuhi, N. I., and Clark, N. A., 1996. "Cement-based materials containing tire rubber". Construction Building Materials, Vol. 10, No. 4, pp. 229-236.*

23. *Ali, N. A., Amos, A. D., and Roberts, M., 1993. "Use of ground rubber tires in portland cement concrete". In: Dhir, R.K. (Ed.), Proceedings of the International Conference on Concrete 2000, University of Dundee, Scotland, UK, pp. 379–390.*

24. *Arin Yilmaz and Nurhayat Degirmenci., 2009. "Possibility of using waste tire rubber and fly ash with Portland cement as construction materials". Waste Management 29, 1541–1546.*

25. *Turatsinzea A., Garros., 2008. On the modulus of*

elasticity and strain capacity of Self-Compacting Concrete incorporating rubber aggregates, Resources, Conservation and Recycling 52 (2008) 1209–1215

26. *Topcu, I.B., Avcular, N., 1997b. "Collision behaviors of rubberized concrete". Cement and Concrete Research 27 (12), 1893–1898.*

27. *Sallam, H. E. M., Sherbini, A. S., Seleem M. H., and Balaha, M. M., 2008. "Impact resistance of rubberized concrete". Engineering Research Journal, Minoufiya University, Vol. 31, No. 3.*

28. *Ganesan, N. Bharati, R, and Shashi Kala, A.P, 2012. "Strenght and durability rubberised concrete" The Indian Concrete Journal.*

29. *Benazzouk, A., Queneudec, M., 2002. "Durability of cement–rubber composites under freeze thaw cycles". In: Dhir, R.K. et al. (Ed.), Proceedings of the International Conference on Sustainable Concrete Construction, University of Dundee, Scotland, UK, pp. 356–362.*