Advanced Materials Research Vol. 338 (2011) pp 566-571
Online available since 2011/Sep/02 at www.scientific.net
© (2011) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.338.566

Properties of Coconut Fiber/Rubber Cement Board for Building Partitions

Yu-Wen Liu[1,a], Huang Hsing Pan[2,b], Chao-Shun Chang[3,c] and Kun-Sheng Pann[4,d]

[1]Dept. of Civil and Water Resources Eng., National Chiayi University, Chiayi 60004, Taiwan

[2]Dept. of Civil Engineering, Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan

[3]Dept. of Construction Engineering, Kaohsiung First University of Science and Technology, Taiwan

[4]Dept. of Civil Engineering and Engineering Informatics, Cheng Shiu University, Kaohsiung, Taiwan

[a]yuwen@mail.ncyu.edu.tw, [b]pam@cc.kuas.edu.tw, [c]cschang@nkfust.edu.tw, [d]kspan@csu.edu.tw

Keywords: lightweight coconut fiber/rubber cement board, partition, heatproof, thermal conductivity

Abstract. Due to recycling of scrapped tire rubbers and coconut fibers, a new building material composited of rubber particles, coconut fibers and cement is applied to building partitions. A lightweight coconut fiber/rubber cement board (LCRCB) consists of rubber/cement board as a sandwich layer and coconut fiber/cement as the matrix, where the sandwich layer containing three fractions of the rubber from 30% to 50%, and the matrix with a constant ratio of 15% coconut fibers in volume. Results show that the measured properties of LCRCB are found with water absorption between 13.8% and 15.4%, unit weight of 1400-1480 kgf/m^3, bending strength of 1.97 MPa and coefficients of thermal conductivity in 0.261~0.286 kcal/m·^{o}C·hr,. After the impact test, LCRCBs show no cracks, detachment, pinholes and the split on the impacted surface. Besides, LCRCB satisfies the 2nd degree requirements of incombustibility based on national standards. To be a building partition, LCRCB also shows no smoke toxicity in burning.

Introduction

Many junk tires treated as the waste are always discarded, and this leads to a big trouble to the environment all over the world. Due to the heat value of tires up to 37 MJ/kg [1], the industries, such as cement furnace, power plant and paper plant, considered junk tires as a substitute fuel in early stage. However, the air emitted from burning tires containing cancer-induced ingredients could endanger the human life, and also, the residues after the burning have a large amount of ashes. The air pollutions and the ashes reducing overall benefits of recycling let us re-evaluate the applications of junk tires. Recently, rubber particles departed from junk tires by means of liquid nitrogen can add in asphalts or cementitious concrete that would provide more commercial profits for junk tires recycling. Junk tires used liquid nitrogen techniques can obtain many scrapped rubbers that improves the recycling benefits [2].

Some researches selected recycling rubbers as the inclusion for improving the properties of cement concrete [2-7]. The literatures making use of tire rubber particles in cement-based materials focused on the use of rubbers as the aggregate in concrete, and investigated mechanical properties of rubber/concrete composites only. Results indicated that material properties of rubberized concrete have lower density, more toughness and ductility, higher impact resistance, lower compressive and splitting tensile strength, and more effective sound insulation. For the safety reasons, rubber/concrete composites were difficult to be used as building materials due to its poor fireproof property.

Here, we add scrapped tire rubbers and coconut fibers previously as the wastes into cement paste to produce a coconut fiber/rubber cement board (CRCB) suitable for the building partitions in use. A structure of CRCB is like the sandwich with a rubber/cement board embedded in the central region of the coconut fiber/cement board. As a building partition, the weight of CRCB should be less that of cement partitions in order to lighten total building weight. Therefore, a lightweight CRCB with the unit weight less 1840 kgf/m^3 is designed, and it is so-called LCRCB. In this paper, we propose mixture proportions and manufacture techniques of LCRCB first, and then measure material proportions of LCRCB including bulk specific gravity, water absorption, flexural strength and impact resistance. Finally, the heatproof, thermal conductivity, and smoke toxicity of LCRCB partition are examined.

Material and Experimental Tests

Materials. Material constituents of LCRCB consist of cement-based binder, tire rubber particles and coconut fibers. The constituents of the cement-based binder include: (1) Type I Portland cement (ASTM C150), (2) slag furnace with a specific gravity of 2.89 supplied by China Hi-Ment Corporation (Taiwan), and (3) fresh water.

Rubber particles with the size less than 5 mm and the absolute density 460 kgf/m^3 are chosen. Fig. 1 shows the size and the shape of scrapped tire rubber particles. The coconut fiber shown in Fig. 2 has a specific gravity of 0.62 and 92 % water content after 24 hours' absorption test.

Fig. 1 Scrapped tire rubber particles

Fig. 2 Coconut fibers

Mixture Proportions. To make LCRCB, we first mixed rubbers and the cement together to form a rubber/cement board. Next, a mixture of coconut fibers and the cement poured into the mold of slab as a bottom layer, the rubber/cement board considered as the fillet was embedded in the middle part of the bottom layer, and finally a coconut fiber/cement material as a top layer of the slab covered the rubber/cement board to assemble LCRCB, shown in Fig. 3.

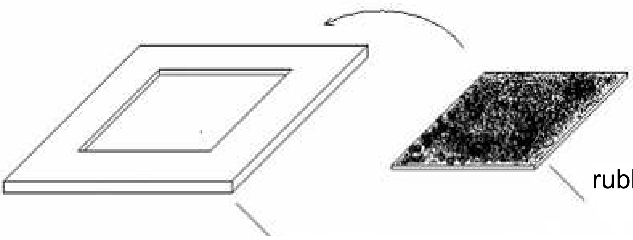


Fig. 3 LCRCB schematic diagram

Mixture proportions of rubber/cement board and coconut fiber/cement board are shown in Table 1. In rubber/cement materials, the binder mixes 70% cement and 30% blast furnace slag by weight with the water-to-binder ratio of 0.5, and rubber/cement materials marked by C5R30, C5R40 and C5R50 represent the board containing rubber particles of 30%, 40% and 50% in volume, respectively. For the coconut fiber/cement material shown in Table1, the water-to-binder ratio is 0.4 and 15% coconut fibers in volume are used.

Table 1 Mixture proportions of rubber/cement and coconut fiber/cement [kg/m^3]

Material	Water	Cement	Slag	Rubber	Coconut fiber	Air content
C5R30	394	591	197	345	---	5
C5R40	334	500	167	460	---	5
C5R50	273	409	136	575	---	5
coconut fiber/cement	446	780	334	---	77	4

Experimental Method. Each batch of materials was prepared for the tests, where three samples with the size of 100×100×10mm for absorption test and bulk specific gravity test, and six samples with 250×350×20mm for flexural strength test.

To examine the impact endurance, three samples with the size of 300×300×10mm were taken in accordance with ASTM C1185. To find heat-resistant capability of LCRCB, the dimension of 200×200×10mm was tested in accordance with ASTM C518. Two specimens with 220×220×10mm were used to measure the fireproof capability which in accordance with ASTM E84-01. Besides, the smoke toxicity test with the size of 20×20×20mm in accordance with NES 713 for LCRCB was also investigated. All samples were removed from the mold after 24 hours' casting, and placed indoor for curing and for testing.

Results and Discussion

Bulk Specific Gravity. Specific gravity for rubber/cement boards, coconut fiber/cement board, and LCRCBs is 1.18~1.36, 1.56, and 1.4~1.48, respectively.

Water Absorption. The moisture content for LCRCB in the air indoor is about 5 % ~ 6 %. The water absorption of LCRCBs immersed in water for 24 hours is within the range of 13.8% ~ 15.4%, shown in Fig. 4. LCRCB with C5R50 sandwich layer has larger water absorption than the others, and with C5R30 is the least one. It seems that the more rubber in LCRCB, the more water absorption. Fig. 4 also shows that LCRCB reaches its 40% ~ 50% water absorption at the first 0.5 hour, and 60% water absorption at the first 3 hours, compared with that at 24 hours, respectively. The experimental results display that the major part of water absorption for LCRCB occurs at the first 3 hours.

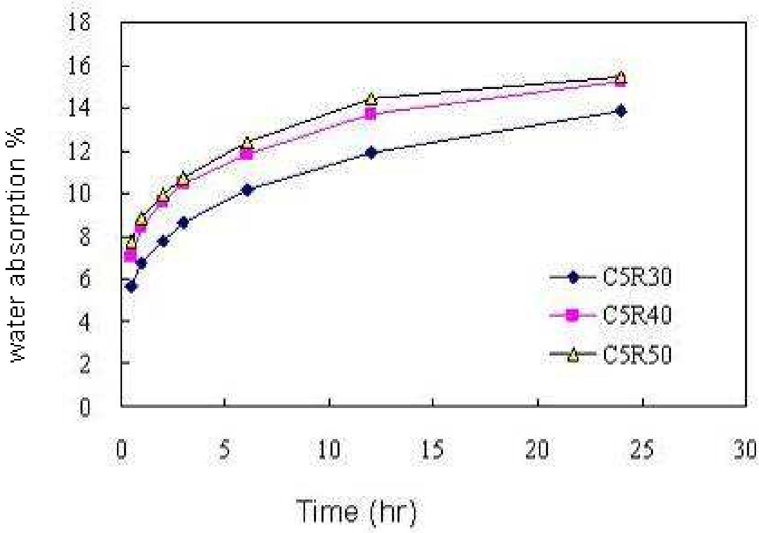


Fig. 4 Water absorptions of LCRCB

Flexural Strength. We applied the bending load to LCRCB in accordance with ASTM C1185, and the section of profile after bending breaking for LCRCB is shown in Fig. 5. LCRCB was failed and divided into two pieces after the bending test, and each part contains rubber/cement in the middle and coconut fiber/cement in both sides. Experimental results indicate that the flexural strength of LCRCB is about 785 N or 1.97 MPa. The flexural strength for rubber/cement board and coconut fiber/cement board is 0.89~1.77 MPa and 3.94 MPa respectively. LCRCB's flexural strength lies in between rubber/cement board and coconut/fiber cement board, and is about 25%~75% greater than rubber/cement board and 50% lower than coconut-fiber cement board. Meanwhile, we compare the flexural strength of LCRCB with three rubber contents in sandwich layer, and find that rubber contents have a less contribution to the flexural strength of LCRCB.

Fig. 5 Profile of bending breaking for LCRCB

Impact Resistance. LCRCB subjected to the impact test shows that the overall indentation diameters for LCRCB with C5R30, C5R40 and C5R50 are all 24mm. The sandwich layer consisting of rubber/cement board does not affect the indentation diameter in LCRCB under impact test.

To look into the surface of LCRCB after the impact test, shown in Fig. 6, the testing surface on the LCRCB has a obvious indentation (Fig.6 (a)), and the reverse side of impacted surface shows a convex surface combining with some obvious cracks nearby (Fig. 6 (b)). Comparisons of three LCRCBs (with C5R30, C5R40 and C5R50) show that, after the impact results, the outer layers of LCRCB made from the coconut fiber/cement matrix provide mostly impact resistance, and the sandwich layer produced by rubber/cement board has a less contributions in impact resistance.

(a) Impacted surface

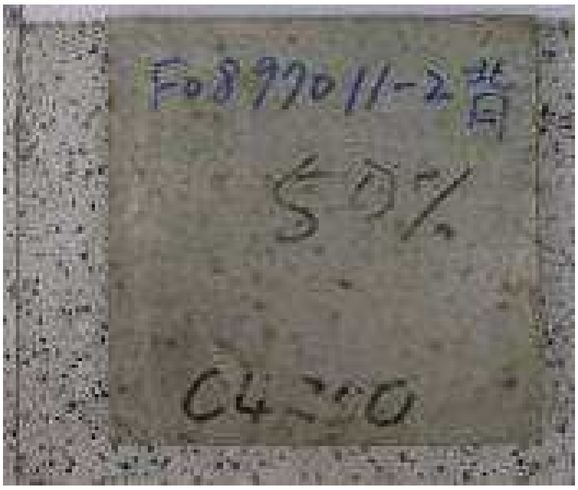
(b) Reverse side of impacted surface

Fig. 6 Surface of LCRCB after the impact test

Fireproof Capability. LCRCBs were tested by incombustibility test following ASTM E84-01 or CNS 6532, where CNS means Chinese National Standards (national standards in Taiwan). Fig. 7 shows the heating surface of LCRCB after 10 min. at 750 ^{o}C heating temperature. All LCRCBs on the heating surface do not have any passed through melting along the thickness direction, and do have the deformation retarding fireproof capability. Also, the reverse side of heating surface does not find any cracks or obvious deformations.

Exhaust gas temperature curves for LCRCB do not go beyond the standard temperature curve (representative time-temperature curve, ASTM E84-01), the area in time-temperature curve (t·dθ) and the time of remaining flame is all equal to zero, and the values of smoke coefficient are 0 and 2 respectively. Meanwhile, the temperature on the reverse side of heating surface is about 33°C, and the weight losses are 20.1g, 20.3g and 53.3g. From this incombustibility test, LCRCBs we made satisfy the 2^{nd} standard of incombustibility claimed by CNS 3802.

(a) Heating surface



(b) Reverse side of heating surface

Fig. 7 Surface of LCRCB after 10 min at 750˚C heating temperature

Thermal Conductivity. To be a substitute material of cement boards using in the building partitions, the heat-resistant capability of LCRCB should be known. We use thermal conductivity coefficient instead of the heat-resistant capability to represent heat conductivity in LCRCB. The measured thermal conductivity of LCRCB for 30%, 40% and 50% rubbers in the filling layer is 0.286, 0.274 and 0.261 kcal/m·^{o}C·hr, respectively. LCRCB with increasing rubbers in the sandwich layer will reduce the coefficient of thermal conductivity.

Smoke Toxicity. LCRCB was also tested by the smoke toxicity test. Results show that the heating temperature to produce toxic smokes is at 1135.4 ^{o}C, and the weight loss after the heating is 21.3%. Smokes emitted from LCRCB during the smoke toxicity test were analyzed and found the constituents with 0.35% CO_2, 2.33 ppm NOx, no SO_2 and $COCL_2$.

Conclusions

The following conclusions are drawn from the test results.

(1) Bulk specific gravity of LCRCBs containing C5R30, C5R40 and C5R50 sandwich layer is 1.48, 1.46 and 1.40, respectively. The unit weight of LCRCBs is less 1840kgf/m^3, and categorized a lightweight material in cementitious materials.

(2) Rubber/cement boards at the first 0.5 hour maintain 44%~61% water absorption compared with that at 24 hours. The absorption speed of rubber/cement board is gradually steady after 6 hours in water absorption test.

(3) The moisture content of LCRCB is about 5~6%, and water absorption reaches 13.8%~15.4%. Half of water absorption occurs at the first 0.5 hour, and most of water absorption is achieved at the first 3 hours in water absorption test.

(4) The fracture bending load and flexural strength of LCRCB is 785 N and 1.97 MPa, respectively. The flexural strength of rubber/cement board and coconut fiber/cement board is 0.89~1.77 MPa and 3.94 MPa in turns. Rubber contents in sandwich layer have less effective to the flexural strength of LCRCB.
(5) From the impact results, LCRCB did not find any cracks, detachment, pinholes and split on the impacted surface. The outer layers of LCRCB provide mostly impact resistance, and the sandwich layer has a less contributions to impact resistance of the partition.
(6) Thermal conductivity of LCRCB for 30%, 40% and 50% rubbers in the sandwich layer is 0.247 ~ 0.286 kcal/m·^{o}C·hr respectively. Increasing rubbers in the sandwich layer will reduce the coefficient of thermal conductivity of LCRCB.
(7) After the incombustibility test, the heating surface of LCRCB did not find any melting evidence, and the reverse surface showed no cracks or obvious deformations. The temperature on the reverse side of heating surface is about 33°C during incombustibility test. LCRCB partitions satisfy the 2nd standard of incombustibility test.
(8) When LCRCB were heated to 1135.4 ^{o}C, the partitions emit some smokes containing 0.35% CO_2, 2.33 ppm NOx, no SO_2 and $COCL_2$. To be a building partition, LCRCB shows no smoke toxicity in burning.

Acknowledgements

This work was financially supported by the National Science Council of Taiwan under Contract NSC 97-2221-E-415-011-MY2 and NSC 100-2625-M-151-001.

References

[1] R.K. Dhir, M.C. Limbachiya and K.A. Paine: Recycling and Reuse of Used Tires, Thomas Telford Publishing Ltd., London E14 4JD, Dundee, Mars (2001).

[2] S. Rafat and R.N. Tarun: Waste Management Vol. 24 (2004), p. 563

[3] N.N. Eldin and A.B. Senouci: J Mater Civil Engineering Vol. 5 (1993), p. 478

[4] I.B. Topçu: Cement Concrete Research Vol. 25 (1995), p. 304

[5] D. Fedroff, S. Ahmed and D.Z. Savas: Transp. Res. Rec Vol. 1532 (1996), p. 66

[6] A.H. Toutanji: Cement Concrete Comp, Vol. 18 (1996), p. 135

[7] C.E. Pierce and M.C. Blackwell: Waste Management Vol. 23 (2003), p.197

Product Design and Manufacturing
10.4028/www.scientific.net/AMR.338

Properties of Coconut Fiber/Rubber Cement Board for Building Partitions

10.4028/www.scientific.net/AMR.338.566

DOI References

[3] N.N. Eldin and A.B. Senouci: J Mater Civil Engineering Vol. 5 (1993), p.478.
doi:10.1061/(ASCE)0899-1561(1993)5:4(478)

[5] D. Fedroff, S. Ahmed and D.Z. Savas: Transp. Res. Rec Vol. 1532 (1996), p.66.
doi:10.3141/1532-10

[6] A.H. Toutanji: Cement Concrete Comp, Vol. 18 (1996), p.135.
doi:10.1016/0958-9465(95)00010-0

[7] C.E. Pierce and M.C. Blackwell: Waste Management Vol. 23 (2003), p.197.
doi:10.1016/S0956-053X(02)00160-5