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Structural behavior and *m*–*k* value of composite slab utilizing concrete containing crumb rubber

Bashar S. Mohammed *

Universiti Tenaga Nasional, Civil Engineering Department, kM7, Jalan Kajang-Puchong, 43009 Kajang, Selangore, Malaysia

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ABSTRACT

Many research works have been conducted to study the fresh and hardened properties of concrete containing crumb rubber as replacement to fine aggregate. The outcome of these researches indicated that though the compressive and flexural strength of crumb rubber concrete (CRC) decreased as percentage of fine aggregate replacement increased; the CRC has lower unit weight, better slump values, better toughness and absorb more energy before failure. In view of the fact that the main strength of composite floor slab lies within the bond between the concrete and the profiled steel sheeting, therefore the using of more ductile concrete such as CRC to toping the profiled steel sheeting could produce a new composite slab system. Two sets of slabs; each set comprising three CRC composite slabs and one conventional concrete slab has been tested with two shear span (450 and 900 mm). The results showed that the CRC slabs behavior could be characterized as ductile, while the *m*–*k* value has been found to be 80.7 and 0.037, respectively.

1. Introduction

Waste tires caused a serious disposal problem and continue to accumulate at increasing rates. If not managed properly, the waste tires will present increasing environmental problems. Therefore, exploitation of the crumb rubber from this scrap tires as sustainable building materials in the construction industry helps preserve the natural resources and also helps maintain the ecological balance. Many researches has been conducted to determine the properties of fresh and hardened concrete containing crumb rubber (rubbercrete), where the main properties of the rubbercrete which have been reported are as following:

1. Due to the low specific gravity of crumb rubber particles; the unit weight of the rubbercrete decreases as the percentage of crumb rubber replacement increases [1–5].
2. The non polarity of crumb rubber causes water to be repelled and the air to consequently be trapped on the surface; the air content in the rubbercrete increases as the rubber content increases [1,6,7].
3. The slump value of conventional concrete can be improved by replacing part of the fine aggregate with crumb rubber [1,2,8–11].
4. The compressive and flexural strength decrease as crumb rubber content increases [1,8,12–18].
5. Since the modulus elasticity (ME) of concrete depends on the modulus elasticity of the aggregates and their volumetric proportion in the matrix; the ME of rubbercrete decreases as the crumb rubber content increases [11,19,20].
6. Rubbercrete does not exhibit brittle failure under compression or splitting tensiles. Where the rubbercrete exhibits high capacity for absorbing plastic energy under both compression and tension loading. Also the rubbercrete posses' higher toughness, where most of the total energy generated is plastic [11,13,16,21–25].
7. The rubbercrete still can be used in the mild environment, whereas the additional of rubber to concrete will not dramatically affect the durability of concrete [26,27].

Composite slabs consist of profiled steel sheeting and in situ reinforced concrete topping. Advantages and disadvantages of using composite concrete slabs have been reported by other researchers [28–32]. The shear bond between the profiled steel sheeting and concrete is difficult to predict theoretically since it is dependent upon several inter-related parameters including the geometry and flexibility of the profiled steel sheet itself. Given that the profiled steel sheeting is a ductile material and the conventional concrete is a brittle material. Therefore, the using of lighter in weight and more ductile material such as rubbercrete could yield better composite action between the profiled steel sheeting and the rubbercrete.

* Tel.: +60 125756460; fax: +60 389212116.
E-mail address: bashar@uniten.edu.my

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2. Experimental program

2.1. Concrete materials and mix proportions

For the purpose of the current investigation, crumb rubber particles of mesh 30 were used as partial replacement by volume (10%) for the fine aggregate in the manufacturing of rubbercrete mixes. The materials used in the mixes were Ordinary Portland Cement, river sand, mineral rock as coarse aggregate with maximum size of 10 mm, crumb rubber and potable water. The properties of the sand and crumb rubber are presented in Table 1 and the ingredients of the conventional concrete and crumb rubber concrete mixes are shown in Table 2. The sieve analysis of the crumb rubber was carried out according to Florida Method of test for testing of ground tire rubber, FM 5-559 [33], whereas for fine a and coarse aggregate, the sieve analysis was carried out in accordance with the requirement of ASTM C136 [34]. The sieve analysis is shown in Fig. 1. The selection of mix proportions in this study was designed according to ACI 211.1-91 [35]. The maximum coarse aggregate size of 10 mm has been chosen to ease the flow of the concrete into the profiled sheet and provide better composite action.

Table 1
Properties of the sand and crumb rubber.

Property	Fine aggregate	Crumb rubber
Specific gravity	2.66	0.54
Fineness modulus	2.45	2.36
Water absorption (%)	3.5	–

Table 2
Ingredients of conventional and rubbercrete mixes.

Ingredient	Conventional concrete	Rubbercrete
Cement (kg/m^3)	592.68	592.68
Coarse aggregate (kg/m^3)	673.35	673.35
Sand (kg/m^3)	775.96	698.37
Crumb rubber (kg/m^3)	0	16.41
Water cement ratio (%)	0.41	0.41

2.2. Profiled steel sheeting

The profiled steel sheeting used in this investigation is LYSAGHT BONDEK® II (Fig. 2). The thickness of these profiled steel sheets is 1 mm. The cross sectional area of the profiled steel sheeting (A_p) and the tensile yield strength (p_{yp}) were 980 mm^2 and 550 MPa, respectively.

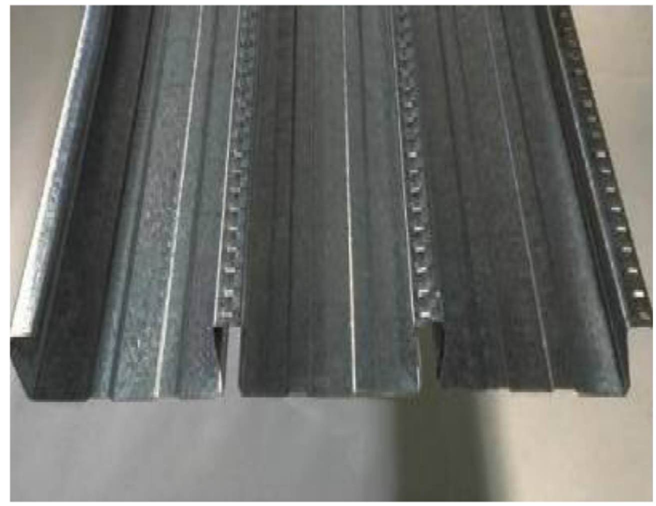

Fig. 2. Profiled steel sheeting used in the study.

Table 3
Properties of rubbercrete.

Compressive strength (MPa)	28.9
Modulus elasticity (GPa)	14.5
Tensile strength (Mpa)	3.7
Splitting strength (MPa)	4.4

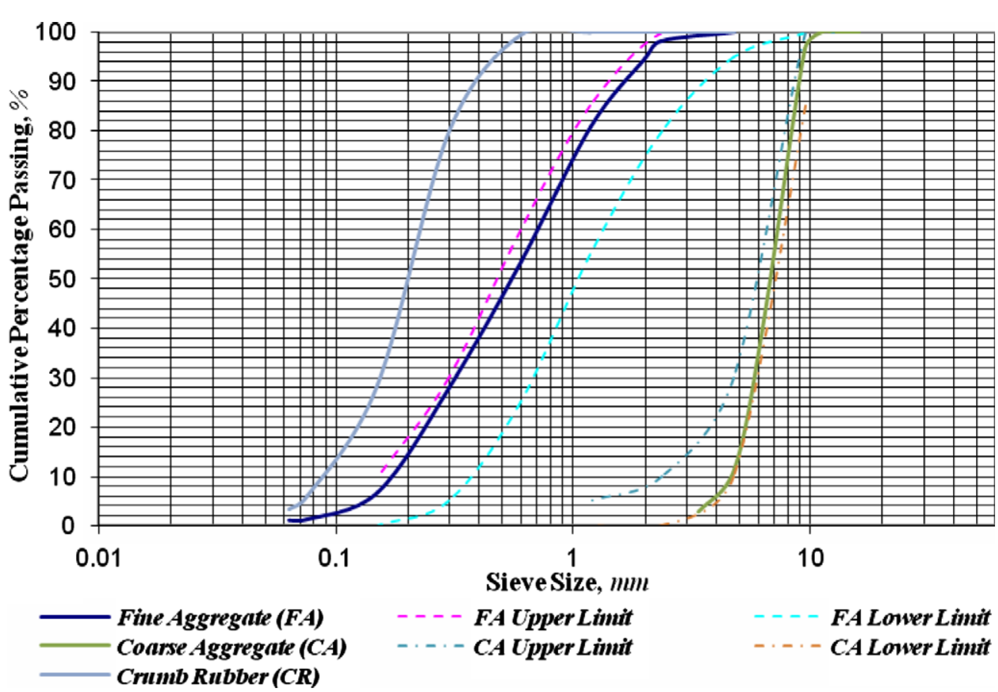

Fig. 1. Fine aggregate, coarse aggregate and crumb rubber particles size distribution.