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Reuse of thermosetting plastic waste for lightweight concrete

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Abstract

This paper presents the utilization of thermosetting plastic as an admixture in the mix proportion of lightweight concrete. Since this type of plastic cannot be melted in the recycling process, its waste is expected to be more valuable by using as an admixture for the production of non-structural lightweight concrete. Experimental tests for the variation of mix proportion were carried out to determine the suitable proportion to achieve the required properties of lightweight concrete, which are: low dry density and acceptable compressive strength. The mix design in this research is the proportion of plastic, sand, water–cement ratio, aluminum powder, and lignite fly ash. The experimental results show that the plastic not only leads to a low dry density concrete, but also a low strength. It was found that the ratio of cement, sand, fly ash, and plastic equal to 1.0:0.8:0.3:0.9 is an appropriate mix proportion. The results of compressive strength and dry density are 4.14 N/mm^2 and 1395 kg/m^3, respectively. This type of concrete meets most of the requirements for non-load-bearing lightweight concrete according to ASTM C129 Type II standard.

Introduction

In Bangkok, the quantity of solid wastes is expanding rapidly. During the last two decades, the average solid waste generation has increased from 3260 tons/day in 1985 to 6633 tons/day and 13,000 tons/day in 1995 and 2005, respectively (Bangkok Metropolitan Administration, 2005). It is estimated that the rate of expansion is doubled every 10 years. This is due to the rapid growth of the population as well as the industrial sector. Among these solid wastes, plastic and foam wastes comprise up to 20% of the total waste.

Plastics can be separated into two types. The first type is thermoplastic, which can be melted for recycling in the plastic industry. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. The second type is thermosetting plastic. This plastic cannot be melted by heating because the molecular chains are bonded firmly with meshed crosslinks. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane. At present, these plastic wastes are disposed by either burning or burying. However, these processes are costly. If the thermosetting plastic waste can be reused, the pollution that is caused by the burning process as well as the cost of these waste management processes can be reduced.

To achieve this purpose, a study of these thermosetting plastics for application into construction materials has been conducted, particularly for the concrete wall in buildings. In Thailand, lightweight concrete is extensively used for the construction of interior and exterior walls of buildings for the case where the walls are not designed for lateral loads. This is due to the special characteristics of lightweight concrete. At present, non-structural lightweight concrete block can be produced commercially up to a density of 600kg/m^3, which is only 1/4 of normal weight concrete, and only 1/3 the normal weight of ordinary brick. Secondly, its thermal conductivity is about 0.089–0.150W/mK, which is only 1/10 of the brick wall. Its compressive strength is in the range of 2.5–10.0N/mm^2, which is 2–3 times greater than that of the bricks that are generally made in Thailand. Bricks are typically used for non-load-bearing walls, and their compressive strength is not greater than 3.0N/mm^2. Therefore, the utilization of lightweight concrete for wall is superior to bricks.

The manufacturing technology of lightweight concrete may be separated into three main types. The first type is called no-fine aggregate concrete. Here, the fine sand is removed from the concrete mixture, resulting in voids between pieces of coarse aggregate, which leads to a low density concrete. The second type is called aerated concrete. This process produces the voids in the concrete mass by using agents such as aluminum powder or foaming solvent. The third type is made from lightweight aggregate, for example, pumice material. In this research, the technology of aerated concrete to produce lightweight concrete has been employed. Since the specific gravity of thermosetting plastic is about one-half of the typical fine and coarse aggregates, its density is lower than the aggregates that are used in the normal mixed design of concrete. An application of thermosetting plastic waste in the concrete therefore corresponds to the third type of lightweight concrete.

During the past decade, several researchers have studied the utilization of solid wastes in concrete and construction materials. Rebeiz (1996) investigated the strength properties of un-reinforced and reinforced polymer concrete using an unsaturated polyester resin based on recycled polyethyleneterephthalate (PET) plastic waste. The results showed that the resins based on recycled PET can be used to produce a good quality of precast concrete. However, it was reported by Naik et al. (1996) that compressive strength decreased with an increase in the amount of the plastic in concrete, particularly above 0.5% plastic addition to total weight of the mixture. Sikalidis et al. (2002) investigated the utilization of municipal solid wastes (MSW) for the production of mortar. These wastes are composed of two fractions: the heavy component comprising mainly earthen material, such as stone, broken ceramics, and glass; and the light materials being mainly paper, wood, light plastics, leather and cloth pieces, various fibers and other similar combustible materials. It was found that the MSW was economically feasible for the production of mortar. Choi et al. (2005) investigated the effects of waste PET bottles aggregate on the properties of concrete. The waste plastic could reduce the weight by 2–6% of normal weight concrete. However, the compressive strength was reduced up to 33% compared to that of normal concrete. Similarly, the results of Batayneh et al. (2006) showed the deterioration of compressive strength with an increase in the proportion of plastic content. For the plastic proportion of 20% of sand, the compressive strength was reduced up to 70% compared to that of normal concrete. Recently, Marzouk et al. (2007) also studied the effects of PET waste on the density and compressive strength of concrete. It was found that the density and compressive strength decreased when the PET aggregates exceeded 50% by volume of sand. The density and compressive strength of concrete were between 1000–2000kg/m^3 and 5–60MPa, respectively. However, the PET bottles are made of thermoplastic, which is a valuable material because it can be recycled by melting. In Thailand, this plastic material is separately collected for recycling. However, thermosetting plastic cannot be melted and is thus difficult to recycle. Thus, it would be very interesting to investigate the utilization of thermosetting plastic waste as a component in concrete material, particularly for lightweight concrete.

This paper therefore presents an investigation of lightweight concrete using thermosetting plastic waste, especially amino-melamine. The technology of aerated concrete is adopted by applying aluminum powder to produce lightweight concrete. Lignite fly ash is also selected as an admixture to improve the concrete strength. The appropriate mixed proportions for the ratio of cement, sand, fly ash, and plastic have been investigated. The compressive strength and dry density have been tested to determine the suitable proportion that meets the requirements of non-structural lightweight concrete.

Section snippets

Ordinary portland cement

This cement type conforms to cement type I as per ASTM C150-94. …

Sand

Natural river sand was used after separating by sieve in accordance with the grading requirement for fine aggregate (ASTM C33-92). …

Thermosetting plastic

In this study, melamine which is a widely used type of thermosetting plastic has been selected for application in the mixed design of concrete. The melamine industry was first developed in Switzerland in 1938. Since then, it has grown rapidly in various countries in the world. In Asia, melamine was first …

Mix design method

The materials employed for the mix proportion were as follows: (a) portland cement type 1, (b) sand according to grading requirement for fine aggregate (ASTM C33-92), (c) water, (d) thermosetting plastic (melamine) ground and processed under sieve analysis, (e) lignite fly ash from Mae Moh mine, and (f) aluminum powder. An appropriate mix proportion was determined to meet the specification for non-load-bearing lightweight concrete according to ASTM C129-05 Type II standard.

To determine the …

Methods of testing

Mortar was mixed in a standard mixer and placed in the standard mold of 50×50×50 mm according to ASTM C109-02. In the pouring process of mortar, an expansion of volume due to the aluminum powder reaction had to be considered. The expanded portion of mortar was removed until finishing. The fresh mortar was tested for slump according to ASTM C143-03. The specimens were cured by wet curing at normal room temperature. The hardened mortar was tested for dry density and compressive strength for the …

Mix number 1 (determination of melamine content for the first trial mix design)

The first trial mix design was to determine the proportion of melamine plastic. The results of compressive strength and dry density for 7 days age are shown in Fig. 2, Fig. 3, respectively. It was found that the highest compressive strength (3.31 MPa) was obtained from the second group for the ratio of cement: sand: melamine plastic of

1.0:1.0:1.0, as shown in Fig. 3. This is about 5% less than the value of the individual unit (3.5 MPa) as specified for non-load-bearing lightweight concrete …

Conclusions

Based on the above results, the following conclusions can be drawn:

(1) The utilization of melamine plastic as an admixture in the concrete can reduce the density of concrete due to its low specific gravity. However, the compressive strength tends to decrease also because the bonding between plastic particles and cement paste is weak. …

(2) The addition of fly ash increases the compressive strength. However, the dry density tends to also increase due to the relatively high specific gravity. In addition, …

…

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Recommended articles

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