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Effect of Tin Mining Waste as Sand Replacement on Flowability and Compressive Strength of Mortar

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Abstract. Environmental degradation due to excessive sand mining activity and tin tailing waste disposal from mining need to be resolved. Utilization of tin tailing as sand replacement in mortar production would cut amount of waste thrown and decrease river sand consumption. The current study examines the effect of tin tailing content sand replacement on flowability and strength of mortar. Five forms of mixes were produced using different percentage of tin tailing as fine aggregate replacement. Two types of tests were conducted namely flowability test and compressive strength test. The investigation discovers that blending tin tailing affects the flowability of mortar. Utilization of up to 30% tin tailing able to produce mortar with the targeted strength. Usage of high amount of tin tailing causes declination of mortar strength. Recycling tin tailing for use in mortar production saves the use of natural sand and reduce waste disposal.

Introduction

Both sand and aggregate which is the materials that is most mined and used globally are predicted to expand at the highest rate throughout the next twenty-first [1]. Sand extraction is increasing at a rate of 6% annually, which is considered unsustainable because of poor governance and the need to reconsider sand mining and usage [2]. It is widely used in diverse industries for many purposes. Sand typically mined from the river, lake, mining area and sea. However, river sand is the most preferred amongst all owing to its quality. The flourishing concrete trade which produced using sand as one of the mixing ingredients to cater the rising construction industry, has led to a surge in river sand mining trade. Rising consumption of natural aggregates catering the demand of trades would cause ecological imbalance [3]. Uncontrolled sand harvesting can lead to environmental issues, including habitat destruction, erosion, and disruption of ecosystems. The mining activities at the rives causes erosion, collapse of river bank and sedimentation problem [4] , which lead to deprivation of river environment and habitat destruction, primarily for endangered species. In addition, this natural material is also scarce in certain parts of the world [5]. Thus, depletion of natural sand resources due to constant mining can have significant environmental and economic implications. In view of sustainability, recycling local waste material to be used as river sand replacement is one of the options to reduce dependency on natural resource.

In relation to that, the use of generated waste from tin mining activity as sand replacement for construction material production would preserve river sand for future use. The rapid increase in refined tin consumption is exerting pressure on global tin supplies and the nature. In Southeast Asia, Indonesia, Malaysia, and Thailand are recognized as the primary producers or suppliers of tin concentrates and ore. [6]. Tin mining contributes towards the nation's income generation and economic prosperity. At the same time, this industry also generates tailing which considered as waste. The processes of extracting the ore results in massive quantity of tailings disposed thus creating a large idle bare land [7]. According to Agboola et al., [8] it is typically disposed of in secluded areas, often near river banks, farmlands, or mined-out holes. Tin tailing consists of inorganic materials, mainly mixtures of oxides[9]. The tin tailing which is disposed within the processing plant pose soil contamination and may cause the soil to be barren [10]. Continuous practice of tin tailing dumping would cause larger land area become infertile and unsuitable for agricultural activities. Thus, the approach of recycling tin tailing for suitable material production would reduce waste disposal and contribute towards cleaner environment. The approach of substituting tailings as mixing ingredient for material development, contributes to environmental sustainability and efficient waste management [11]. Realization on the importance of preserving environmental cleanliness, Aigbodian et al., [9] discovered that refractory bricks of superior quality can be made from tin tailings and these bricks are essential for lining furnaces because they can endure high temperatures. Another researcher elsewhere Pusporini et al., [12] reported that tin tailing refinement is possible to be conducted. Very limited study reports the utilization of tin tailing as fine aggregate replacement in mortar. Thus, the present research is carried out to explore the influence of tin tailing on flowability and compressive strength of mortar.

Method

Materials Used

Cement, sand, water and tin tailing were used to produce mortar specimens. Ordinary Portland ement (OPC) used is in accordance to to BS EN 197-1 [13]. Water for mixing and curing purpose was obtained from the concrete laboratory, supplied by Jabatan Bekalan Air Pahang. Tin tailing waste were obtained from a mining area in West Malaysia. Tin tailing which were obtained from the disposal area and packed in big jumbo bag is illustrated in Figure 1. Figure 2 illustrate the difference in the appearance of the greyish colored tin tailing and light brownish colour river sand. The details of sand and tin tailing are given in Table 1.

Figure 1. Tin tailing collected from tin disposal area and packed in a jumbo bag.

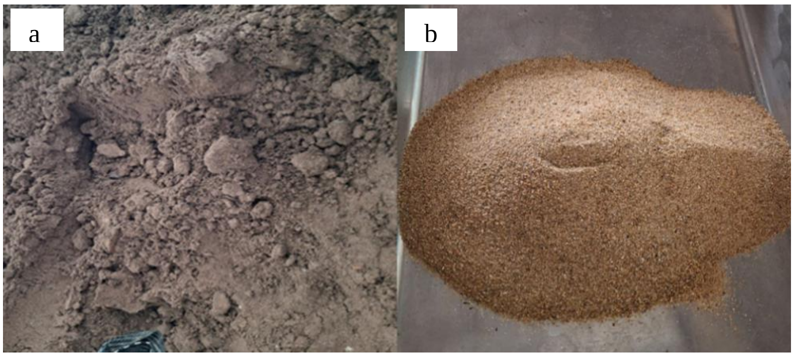

Figure 2. a) Tin tailing and b) natural sand.

Table 1. Details of fine aggregates used

Characteristic	River sand	Tin tailing
Fineness modulus	4.15	2.64
Moisture content (%)	1.52	20.37
Specific gravity	2.66	2.79
Bulk density (kg/m^3)	1624	1427

Mix Proportion and Specimen Preparation

Table 1 tabulates five types of mortar mixes containing diverse content of Tin Tailing (TT) as partial sand replacement that have been utilized in this research work. Mortar identified as TT-0 formed of natural sand as sole fine aggregate and without any TT content, is used as reference specimen. The mortar cube making phase is illustrated in Figure 2. The specimens were created by weighing all the materials and mixing them manually. The mixture was then filled into a cube mold measuring 50 x 50 x 50 (mm^3) in three layers whereby each layer being compacted using a vibrator table. The specimens were left overnight and then removed from the mould the next day. Continuous water curing was applied for all cubes until the testing date. Figure 3 illustrate cube preparation processes.

Table 2. Mix proportion.

Mixes	Cement (kg)	Water (kg)	Sand (kg)	Tin Tailing (kg)
TT-0	240	150	550	0
TT-10	240	150	495	55
TT-20	240	150	440	110
TT-30	240	150	385	165
TT-40	240	150	330	220

Figure 3. 1) raw material was weighed 2) dry ingredients are mixed 3) mortar mixed manually 4) each layer being compacted 5) mortar molded and labeled 6) mortar cured in water

Mortar Testing Method

Testing to determine properties of the mortars were conducted at Concrete laboratory. Flow table test that was done adhering to the procedures stated in ASTM C1437-07 [14]. Compressive strength test was conducted on cubes adhering to ASTM C109 [15]. Figure 4 and 5 illustrate the flowability and compressive strength testing in progress respectively.

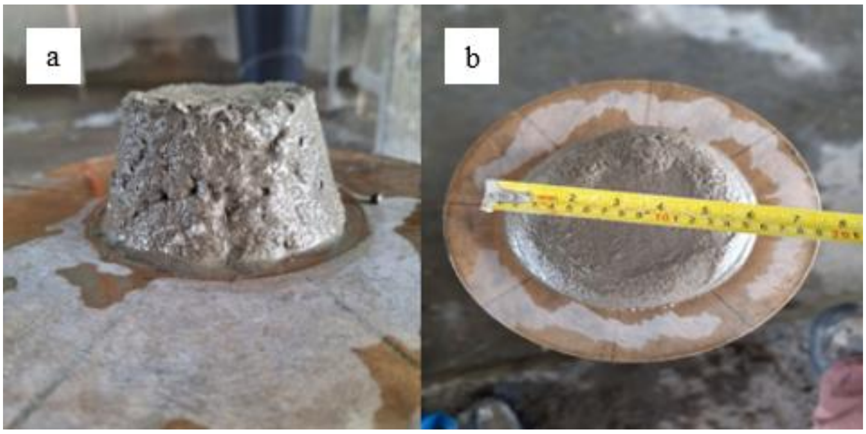

Figure 4. Flowability testing in progress.

Figure 5. Compressive strength testing in progress.

Results and discussion

Flowability

Figure 6 demonstrates that tin tailing inclusion affects the flow properties of the mortar. Utilization of tin tailing up to 20% results in increment in flowability value. However, upon inclusion of 30% tin tailing and more, the flowability value begins to drop. Mix produced using 40% tin tailing exhibit the lowest flowability value. The variation in the physical properties of tin tailing in comparison to sand causes the difference in the flowability result obtained. Water content, concrete packing density, particle shape and related surface area are among the main parameter influencing flow of mortar [16]. However, too many fine particles can cause problems like increased water demand and difficulties in handling and uniformity. Previous researchers [17], [18], [19] have reported that the use of waste materials which has different characteristic as compared to sand affect the flowability of mortar.

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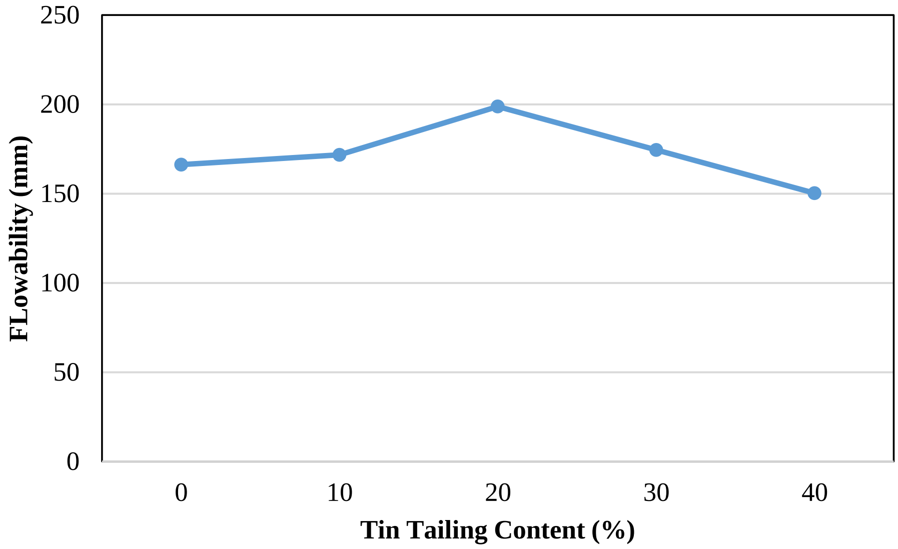

Figure 6. Effect of tin tailing content on mortar flowability.

Compressive Strength

Figure 7 shows that all specimens investigated in this experimental work undergoes strength increase with the prolonged water curing duration. Continual availability of moisture enables uninterrupted hydration process of cement. This enables generation of CSH gel in larger quantity creating a compact internal structure in mortar mix which results in strength enhancement. CSH gel plays the utmost imperative part in contributing to the engineering properties of concrete [20]. Looking at the effect of tin tailing as fine aggregate replacement, integration of tin tailing content up to 30% result in mortar with the targeted strength of 30 MPa. Addition of appropriate quantity of tin tailing fills in the voids within the mortar mix which contributes towards formation of denser internal structure resulting in strength improvement of the composite. Hardened mortar produced using tin tailing at 0%, 10%, 20% 30% and 40% exhibit compressive strength of 33 MPa, 32 MPa, 33 MPa, 34 MPa and 29 MPa. Nevertheless, use of this mining waste at 40% results in strength declination of mortar. Blending high amount of tin tailing with larger surface area than natural aggregate, surges the water requirement. This makes the mixture tough to be mixed homogenously and hard to be compacted finally resulting in mortar with lower strength. Similarly, hardened cement-based composite undergoes strength reduction when natural sand is replaced by waste in excessive quantity that is palm oil fuel ash [21], fly ash [22], beverage glass [23] and copper slag [24].

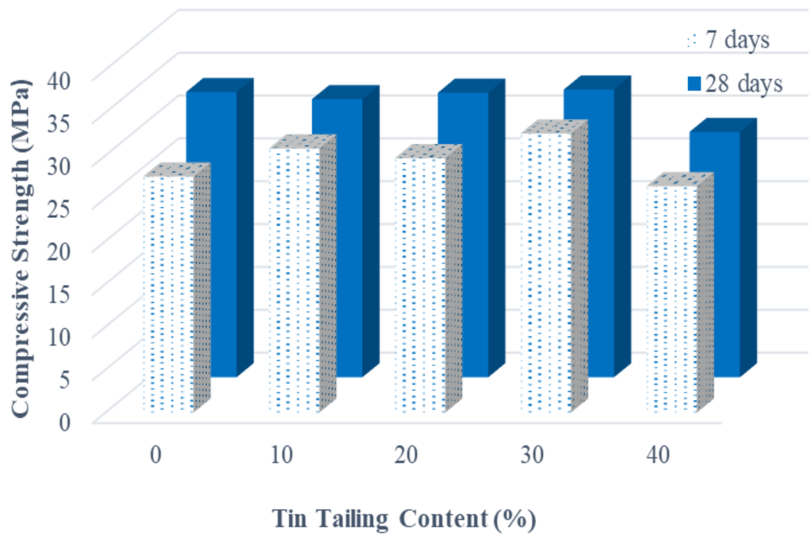

Figure 7. Compressive strength result

Conclusion

Blending tin tailing as natural sand replacement in up to 30% has no adverse effect on strength of mortar. Utilization of tin tailing at 40% is not recommended as it weakens the mortar. The generated tin mining waste should be utilized for development of building material to reduce waste disposal that pollutes the environment. This approach also would be able to ensure river sand is not excessively consumed for construction material production and preserve it for the use of future generation.

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