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A Review: Potential of Waste Materials in Tiles Production

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Abstract: The floor is one of the important elements in a building. It should provide a flat surface to the building. Usually, in the construction industry, floor surfaces made of concrete are often used. This is because, concrete floors are stronger, more durable, and economical. Although concrete floors have many advantages, they still have a disadvantage which is a less attractive surface. Besides, the use of existing tiles found on the floor and walls often poses a danger to the user if the tile cracks or breaks. Therefore, floor finishing is essential to overcome this disadvantage. The floor finishes can highlight the beauty and can provide comfort for the users of a building. Among the finishes that are often used in industry is tile. This finish can be used on the floor as well as the walls as an outer layer to produce light tiles, low water absorption percentage, and durable. To overcome this problem, this study was conducted to analyze the use of waste materials as materials replacement in tile making. By finding sources from articles and journals using a four-stage process namely identification, inspection, qualification, and included to identify the physical and mechanical properties of the material based on seven types of testing that have been done namely combustion shrinkage, water absorption, Density, porosity, tensile strength, and compression. The results show that an electric arc furnace (EAF) has a low value for firing shrinkage tests, so this indicates that EAF has a low indicator of flammability compared to other materials. For the water absorption test, the lowest water absorption percentage value for tile manufacturing using substitute material is EAF, with a lower water absorption rate which is from 0.5% to 0.15%. Overall, based on standard testing of EAF, the results show that EAF can meet the standards that have been set to produce tiles. Among the standard features of tiles that can be achieved by EAF are from the firing shrinkage, density, and water absorption.

Keywords: Floor tiles, Waste materials, Electric arc furnace (EAF)

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1. Introduction

The floor is one of the important elements in a building. It should provide a flat surface to the building. Usually, in the construction industry, floor surfaces made of concrete are often used. This is because, concrete floors are stronger, more durable, and economical. Although concrete floors have many advantages, they still have a disadvantage which is less attractive surface. Therefore, floor finishing is essential to overcome this problem. The floor finish can highlight the beauty and can provide comfort for the users of a building.

Among the finishes often used in industry is tile. These finishes can be used on the floor as well as the walls. Many tiles are available in the domestic and foreign markets. In recent years, many innovations have been made in the tile industry such as porcelain tiles and ceramic tiles. Among the main materials used in the manufacture of these two tiles is clay. It is hard, waterproof, and has certain characteristics for special use such as durable and non-slip.

The purpose of this study was to identify the potential of waste materials in tile manufacturing. To compare the results of previous studies in terms of the durability and effectiveness of these wastes in tile making was also the objective of this study. Large-scale dumping of waste will cause problems such as environmental pollution. Besides, the use of existing tiles found on the floor and walls often poses a danger to the user if the tile cracks or breaks. Therefore, by using waste materials, it can produce tiles that are safer and more practical. Among the advantages of tiles made from this waste is that it is cheaper compared to the cost of making porcelain tiles and ceramic tiles. Furthermore, it can also reduce the dumping of waste materials such as EAF, boron waste, borax, red mud, plastic, etc, thus reducing problems on the environment.

2. Methodology

In this chapter, it will discuss in detail the methodology that has been used to identify the methods and materials that can be used in the manufacture of tiles. To achieve the objectives, the methodology must be well known before starting the study. The methodology for this study paper is broken down into four phases. The first phase is the identification. Keywords will be used to search for articles through Google Scholar, Science Direct, and Scopus. The second phase is screening and the third phase is eligibility. The article will be excluded due to overlap, lack of information, duration of the article, and not directly related. The last phase is included in the synthesis process for combining the results of multiple primary research studies. Selected articles will be reviewed and merged. All these criteria will be discussed in detail and the methodological phrases are mentioned in the flow chart in Figure 1. The list of the journal is shown in Table 1.

Table 1: Keywords Results

Database	Keywords
Science Direct	Tiles made from waste, eco friendly tiles, characteristics of floor tiles
Google Scholar	Tiles made from waste, eco friendly tiles, characteristics of floor tiles

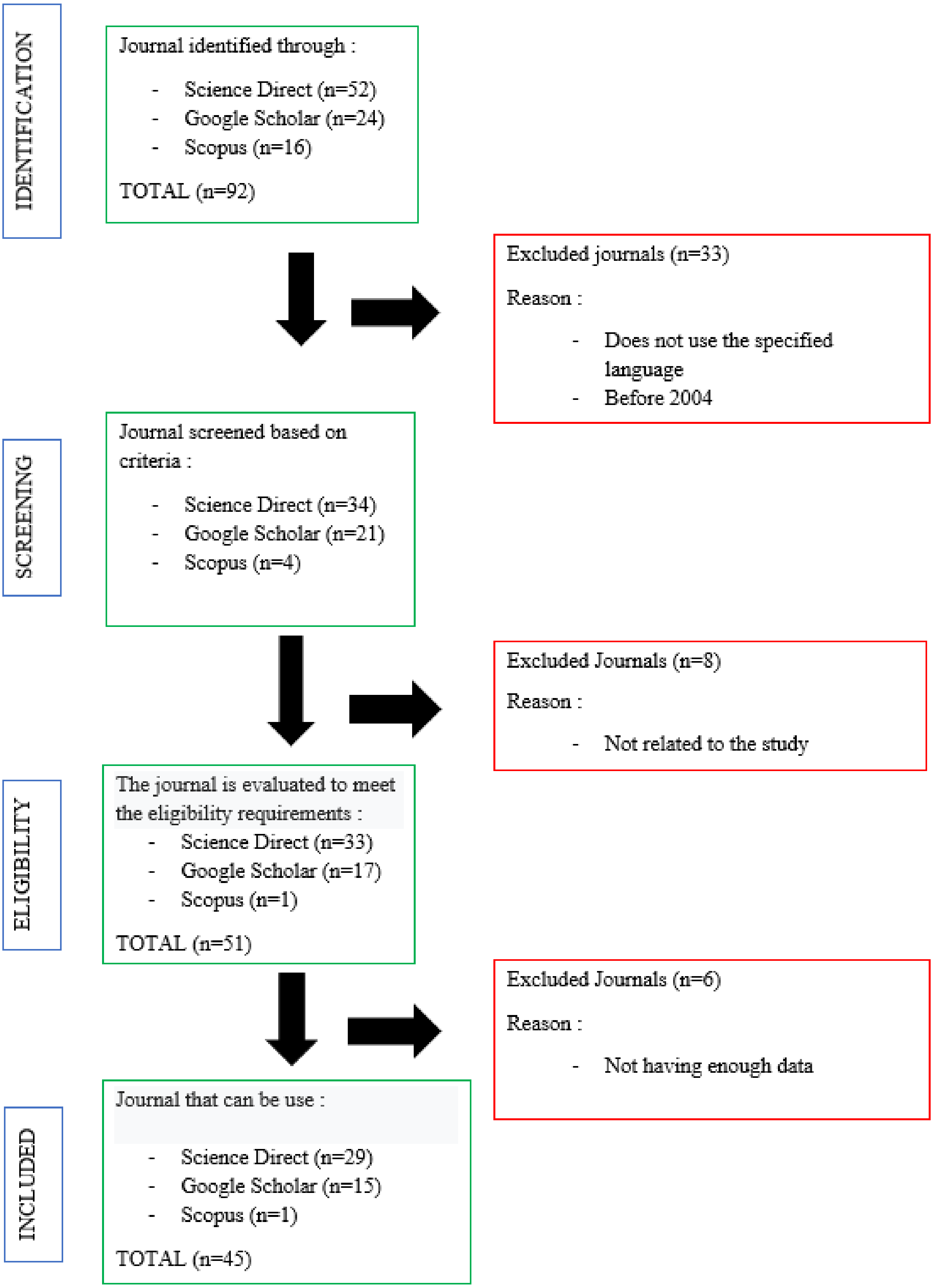

Figure 1: Flowchart of the review process

3. Results and Discussion

Through sources such as journals, there are physical and chemical properties for EAF, plastic waste, boron waste, red mud, and other materials. There are five types of observation which are firing shrinkage, water absorption, density, compression, and tensile strength, the experiments used for this observation which are Water Absorption (WA), Modulus of Rupture (MOR), and Modulus of Elasticity (MOE).

3.1 Firing Shrinkage

Firing shrinkage (shrinkage from dry to flammable) is a comparative indicator of the degree of flammability of a sample. Table 2 shows part of the result for firing shrinkage. After firing, the shrinkage decreases to the maximum shrinkage point (after which expansion occurs as the onset of thawing). As the temperature continues to rise, some of the particles begin to melt and form a glass between the others that pulls them even closer and some of the particles shrink themselves.

Table 2: Firing Shrinkage Result

Author	Type of Waste Material	Waste Material Percentage in Sample (%)	Firing Shrinkage (%)
S. Kurama, A. Kara, H Kurama [1]	Boraks Waste	0	1.25
		5	1.30
		10	1.30
		15	1.40
		20	1.62
A.J. Souza, B.C.A. Pinheiro, J.N.F. [2]	Gneiss Stone Waste	0	5.55
		10	6.50
		20	8.40
		30	8.60
		40	9.40
		50	9.50
Zahide Bayer Ozturk, Elif Eren Gultekin [3]	Blast Furnace Slag	0	0.63
		6	0.72
		11	0.72
		33	0.60
Pao Ter Teo, Abu, Seman Anasyida [4]	Electric Arc Furnace (EAF) Iron Ore	30	2.59
		40	3.92
		50	4.80
		60	2.34

3.2 Density

The density of a material is defined as its mass per unit volume. In other words, density is the ratio between mass and volume or mass per unit volume. This is a measure of how many things or matter an object has in a unit of volume (cubic meters or cubic centimeters). Density is a measure of how tight or close matter is. Table 3 shows part of the result for density. The results show that a higher percentage of waste material will result in high density.

Table 3: Density Result

Author	Type of Waste Material	Waste Material Percentage in Sample (%)	Density (%)
Ridham Dhawana, Brij Mohan Singh Bisht [5]	Fly Ash	0	0.93
		5	0.97
		10	0.99
		15	1.01
		20	1.02
	Plastic Waste	0	0.93
		1	0.99
		2	1.01
		3	1.02

3.3 Compression Strength

Compression testing is used to determine how a product or material reacts when compressed, squeezed, crushed, or flattened by measuring the basic parameters that determine the behavior of specimens under compressive loads. Table 4 shows part of the result for compression strength.

Table 4: Compression Strength Result

Item	Parameter Name	Variable Value	Unit or Dimension
Pao Ter Teo, Abu Seman Anasyida [4]	Electric Arc Furnace (EAF) Iron Ore	0	40
		50	90

3.4 Water Absorption

The water absorption test is a test to determine the moisture content of the sample as a percentage of its dry weight i.e. water content in the specimen [6]. Briefly, the sample is weighed, dried in the oven, and then re-weighed in standard condition. Table 5 shows the information obtained related to the water absorption test. From the table, it shows that different type of wastes gives the different value of water absorption which is the less water absorb is consider as a good result. Electric Arc Furnace (EAF) Iron Ore represents that with a higher percentage of waste material will result in the lowest water absorption percentage value.

Table 5: Water Absorption Result

Author	Type of Waste Material	Waste Material Percentage in Sample (%)	Water Absorption (%)
S. Kurama, A. Kara, H Kurama [1]	Boraks Waste	0	14.0
		5	13.0
		10	13.6
		15	12.3
		20	12.0
A.J. Souza, B.C.A. Pinheiro, J.N.F. [2]	Gneiss Stone Waste	0	5.55
		10	6.50
		20	8.40
		30	8.60
		40	9.40
		50	9.50
Zahide Bayer Ozturk, Elif Eren Gultekin [3]	Blast Furnace Slag	0	0.63
		6	0.72
		11	0.72

		33	0.60
Pao Ter Teo, Abu, Seman Anasyida [4]	Electric Arc Furnace (EAF) Iron Ore	0 50	0.50 0.15
Montero, M. A., Jordán, M. M.S. Hernández-Crespo [7]	Sewage sludge and marble residues	0 22 28 35 40	7 23 27 31 42
A.Arteaga, F [8]	Sludge waste	0 20 30 40 70	13.7 18.4 19.1 20.9 29.0

3.5 Tensile Test

Tensile strength is the maximum pressure that a material can hold while being stretched and pulled before breaking or breaking. In fragile materials, the tensile strength is close to the yield point, whereas, in solid materials, the value of the main tensile strength is higher. The main tensile strength is usually found by performing a tensile test. Table 6 and Table 7 shows part of the result for the tensile test.

Table 6: Tensile Test Result

Author	Type of Waste Material	Waste Material Percentage in Sample (%)	Tensile Test (%)
Ridham Dhawana, Brij Mohan Singh Bisht [5]	Fly Ash	0 5 10 15 20	5.29 10.22 10.75 9.98 9.86
	Plastic Waste	0 1 2 3	5.29 9.72 9.68 9.68
Keshavarz Z Mostofinejad, D.[9]	Porceline Waste	0 20 50 75 100	3.1 2.8 3.0 3.5 4.1

Table 7: Other Tensile Test Result

Author	Type of Waste Material	Results
Chiara Zanelli, Eduardo Domínguez, Claudio Iglesiasc [10]	Boron Waste	Reactivity during combustion increases i.e. the maximum temperature can be reduced from 1200 ◦C to 1140 ◦C. Stoneware tiles have a good technical performance, but sludge tends to lower bulk density and increase closed porosity. Sludge can change the composition of the melt significantly. The actual amount of boron sludge recyclable vitrification tiles is up to 5% by weight.
Siqueira, F. B., & Holanda, J. N. F. [11]	Grit Waste	Formulation of wall tiles containing up to 15% of grit waste heated to temperatures between 1100 ° C to 1180 ° C. It was found that grit waste has a positive influence on the micro-properties and structure of wall tile specimens and shows that grit waste can

		replace traditional calcareous materials in wall tile formulations.
Rao, P. V. C. S., Kumar, V. M., & Arun, A [12]	High Density Polyethylene (HDPE)	This was conducted to study the durability and mechanical properties of composite tiles made and the results obtained from this test can be compared with the properties of ceramic tiles. The compressive strength of the composite tile obtained is as high as 24 MPa and the durability properties of this tile indicate that this material can be used for aggressive heavy environments prone to corrosion.
Haluk Celik [13]	Boron Waste	According to the results obtained, the presence of boron waste compared to the standard wall tile formulation can speed up the vitrification process and improve the physical properties of the body. The overall results show the prospect of using boron waste as a raw material up to 4% for the production of wall tiles, and with specimens containing borax, content shows a lower combustion rate than standard specimens in the factory (1150 ° C).
A. Olgun, Y. Erdogan, Y. Ayhan [14]	Borax	The results show that the strength of wall tiles increases when coal ash and borax are used in the preparation of standard tile compositions. In particular, an increase in strength was observed as the percentage of borax increased to 6% which served as a substitute for potassium feldspar. The results show that borax solid waste can produce useful materials.
Md Nasser bin Samsudin [15]	Palm Ash	This experiment was carried out by making a comparison between palm ash concrete with cement. The Water Diffusion Rate for concrete samples using 0.57 cement water ratio. Samples were preserved for 3, 7, 14, 28 and 90 days in plain water. From the experimental results, palm ash can be used as a substitute for cement. Oil palm ash is also able to provide high compressive strength values such as cement.
Mohd Amirhafizan bin Husin [16]	Board/Wood Dust	In this paper, samples are made in a special design with a length of 50 mm, a width of 10 mm and a thickness of 5 mm. This wood dust is divided into three types of sizes namely small, medium and large size. The sample was made using a compression machine with a pressure of 9.80665 N. The positive results of pressure and hardness tests were achieved after identified the mechanical properties of the sample.
Mohd Syazwan bin Ramli [17]	Batik Water Waste	From the results obtained, the sample that shows the highest compressive strength and bending strength value is concrete that contains 5% batik water residue and is followed by standard tile as well as a sample that contains 10% batik water residue. In conclusion, the use of 5% batik water residue is the optimal value in increasing the compressive strength and bending strength. The remaining use will cause a decrease in the compressive strength and bending of the concrete.
Julius Semanda [18]	Plastic Waste and Eggshell	The study found that the addition of 50% cement to the sample resulted in a 10-fold increase in compression compared to the standard factory sample. The addition of plastic waste reduces the compressive strength. Egg skin has no significant effect on compressive strength. Increased quantities

		of plastic waste and eggshells also result in increased water absorption, while increasing amounts of cement result in reduced water absorption. Increased quantity of eggshells and plastic waste results in reduced density and also reduces the percentage of fragility. From this study, it can be concluded that the eggshell can be used as a filler in the manufacture of floor tiles. Due to the tendency of plastic waste to reduce the compressive strength of the tile, it should be used in the right ratio.
Xiaohong Xu, Jia Song, Yao Li [19]	Red Mud Waste	According to the inspection results, the red mud sample can be used for the interior surface of class II public buildings and the outer surface of buildings (GB6566-2010 China). The main phases of red mud are boehmite, calcite, quartz and gibbsite. The physical properties proposed to achieve good results are 0.12 ~ 9.92% in water absorption and 30.57 ~ 60.96MPa in bending strength.
Kidong Kim, Kicheol Kim, Jonghee Hwang [20]	Liquid Crystal Display (LCD) Waste	This journal examines the use of LCD glass waste as a flux material used to replace traditional feldspar in ceramic tiles. Overall, properties such as water absorption and heat expansion coefficient are positively influenced by LCD waste glass replacement. Furthermore, the Mullite content in the compacted sample is almost unchanged. The results obtained are discussed in terms of the viscosity and composition of glass.
M.A.S. Schettino, F.B. Siqueira, J.N.F. Holanda [21]	Sugarcane Ash Waste	In this journal, the effects of sugar cane ash residue on floor tile compaction response have been studied. The experimental results show that the compaction of the floor tile formulation is influenced by the amount of sugarcane ash waste and the maximum combustion temperature. The optimum amount of sugarcane ash waste is 2.5 wt.% as a quartz replacement that allowed for the production of quality floor tiles.
P. Lertloypanyachai S. Thongsang [22]	Rock Powder	This research examines the influence of stone powder particles used as natural rubber fillers to improve the mechanical properties of rubber floor tiles. It is found that the whole mechanical properties are similar to the standard tiles which do not use stone powder. Therefore, it can be concluded that the rock powder from the asphalt manufacturing process can be used for industrial tile manufacturing of rubber flooring.
Daniela Baruzzo, Dino Minichelli, Sergio Bruckner [23]	Marine Dredging Waste	As a goal of the present research, we have produced and studied samples using not only dredging spoils alone but also mixtures with other waste materials such as bottom ashes from an incinerator of municipal solid waste, incinerated sewage sludge from a municipal sewage treatment plant and steelworks slag. It is observed that, although the shrinkage on firing is too high for the production of tiles, in all the compositions studied the sintering procedure leads to fine microstructures and good mechanical properties.

SK S. Hossain, Vikash Ranjan, Ram Pyare, P.K. Roy [24]	River Silts and Wollastonite Waste	This study investigates the feasibility of using river silt and wastes derived wollastonite as ingredients to produce ceramic tiles. The results obtained show that the use of mud reduces the physical and mechanical properties of tile samples at low temperatures but at high temperatures, the mechanical properties have no changes. In addition, all properties were improved with the addition of wollastonite in place of K-feldspar. This makes it possible that this material can be used in the manufacture of tiles
F.B. Siqueira, J.N.F. Holanda [11]	Grits Waste	This work focuses on the reuse of grits waste, from the cellulose industry, as a raw material to replace traditional carbonate material in ceramic wall tiles. The results showed that the grits waste had a positive influence on the properties and microstructure of the wall tile specimens. The results also revealed that the grits waste from the cellulose industry could be used as a total replacement of traditional calcareous material in wall tile formulations.
Bugra Cicek, Emirhan Karadagli, Fatma Duman [25]	Boron Mining Wastes	The potential of boron waste in the production of ceramic tiles to curb energy consumption in the manufacture of the ceramic has been investigated. The mechanical, chemical and physical properties of the new composition are comparable to those of commercial tiles. The tile sample has water absorption of 19.39% and strength of 20.46 N / mm2 which provides the standard requirements of TS EN ISO 10545, where the floor tile has water absorption of 0.49% and strength of 38.43 N / mm2. This material can be considered to be used for industry.
Fontes, W. C., Franco de Carvalho, J. M., Andrade [26]	Iron Ore Waste	This study aims to examine the use of iron ore waste and help reduce the negative effects of ore waste from mining. The result showed that adequate for plasticity and dryness strength. Expands mullite and glass during combustion, demonstrating relatively suitable processing behavior for full industrial production.
Hojamberdiev, M., Eminov [27]	Muscovite Granite Residue	This study aims to examine the effect of muscovite granite residue on the physio-mechanical properties of ceramic tile to show its suitability for industrial production. The result show with 20% wt of muscovite granite residue showed lower physio-mechanical properties than floor ceramic tile samples containing mullite, calcium aluminosilicate, quartz, and crystalline, with 30% muscovite granite residue. The reason is that lower combustion temperatures cannot accelerate the aggregation of granite waste which behaves like an inert non-plastic material similar to quartz. This result shows that muscovite granite residue can be considered to be used in the production of tiles.

4. Discussion

Overall, according to the result from the four standard tests that have been done which is firing shrinkage, water absorption, compression strength, density, and tensile strength, the Electric Arc Furnace (EAF) is the strongest by physical and chemical properties. The EAF is the best to make the floor tile because it has a low percentage of firing shrinkage with the value of 2.34%, the lowest water absorption which is 0.15%, and the highest compression strength 90 N/mm^2 compared to the other waste materials such as borax waste, gneiss stone waste, blast furnace slag, fly ash and plastic waste. All of this test are compared by using the same percentage per sample. Each material is also compared to standard tile. This project was achieved the expected outcome to identify one of the waste material that can replace the standard material in tiles making. Moreover, The EAF able to bear a huge load in a certain range which is larger than any materials because the high content of EAF makes the porosity percentage decreasing greatly. Lastly, it also has low absorption of water since iron is not permeable to water.

5. Conclusion

The results of this study have shown that the objective has been achieved when used materials such as EAF, plastic waste, boron waste, red mud, and other materials mentioned in subtopic 3.6 serve as side material in tile manufacturing. From the experimental results of the samples obtained, used materials such as EAF can meet the standards that have been set to produce tiles. Among the standard features of tiles that can be achieved by EAF are firing shrinkage, density, and water absorption. Also, tiles containing mud and wollastonite can be suitable tile substitutes as the samples completely replaced by quartz and feldspar at 1100 C meet ISO standards and offer bending strength of 48.82 MPa and water absorption of 0.36% weight. Next, through benchmarks with commercially available ceramic tiles and MS ISO13006: 2014, by standard, steel waste also has great potential for use as floor tiles for heavy-duty. Besides, in terms of the properties and structure of micro, carbonate waste shows a positive influence on the properties and microstructure of wall tile specimens. However, some features still need to be analyzed to be side material in tile making such as chemical reactions on other contents and the right mixing ratio to get the best results, therefore this study still needs more detailed research.

Once the discussion is done, there are some suggestions for improvement that need to be implemented. Among the suggestions for improvement is that tests on physical properties need to be made to ensure that the tile sample is at a suitable level for use in industry or not. However, some journals have not been tested on the physical properties of the sample produced. Among the physical properties tests that can be done are water absorption tests, shrinkage tests, etc. Next, several journals can also add results for color change on samples using different material ratios. For example, to test the sample is light or dark in color. Finally, some journals do not make a thorough comparison. For example, some of these journals do not make comparisons with existing tiles on the market. It is hoped that with the suggestions given, the study of side material in the production of tiles will be more comprehensive and benefit future researchers.

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