

Effect of the addition of fibreglass waste on the properties of dried and fired clay bricks

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Abstract. The main objective of this study was to investigate the effect of the addition of fibreglass waste on the properties of the dried and fired clay bricks. Different amounts of waste glass (0 – 10 wt %) were added to the original brick clay and fired at 1000 °C. The effects on the technological properties of the bricks such as compressive strength, water absorption and density after firing were investigated. Also cracks and fibreglass influence in dried and fired samples were analysed by digital camera and SEM-EDX analysis.

1. Introduction

Fired clay bricks are construction materials which have been used since ancient times and still are used in nowadays. However, demand for higher quality fired bricks are growing in modern construction. Bricks have been designed to become more homogenous and porous, with higher compressive strength due to the ceramic bond from the fusion phase of silica and alumina constituents in clay. The firing process sinters the particles of clay together to form a bond, which gives the bricks its characteristic strength and durability. The sintering process is achieved by heating silicon dioxide or quartz (SiO₂) which occurs naturally in clay and shale to high temperatures, causing it to melt. Sand which consist of quartz function also are to control shrinkage, lamination and to provide gas drainage paths during firing. Upon cooling, the quartz forms a bond between adjacent clay or shale particles at the points of contact [1].

The world production of bricks and ceramic tiles requires massive amount of natural raw materials. These natural raw materials can tolerate further compositional variations and raw material changes, allowing different types of wastes to be incorporated into the internal structure of bricks as part of their own matrix. The amount of inorganic wastes in Europe is estimated to be more than 1,500 million tonnes. Traditionally, non-hazardous inorganic wastes have been disposed in landfills and often dumped directly into ecosystems without adequate treatment [2], [3]. So fibreglass waste can be utilised making clay bricks by substituting natural raw materials and reducing its use rates.

Many studies have shown that the use of waste glass in bricks produces positive effects on the materials properties [1], [2], [4]–[6]. In general glass addition to ceramic matrix accelerates the densification process and mechanical and physical properties are improved already with small amounts of additive, below 10 wt%. Glass rigid nature induces local constrains in the matrix reducing sintering shrinkage and changing the physical properties as compressive strength, water absorption and others [1], [4].



2. Materials and methods

Three basic types of clayey soil from quarry were used – Grey, Red and Composite. Sand used as non-plastic material was obtained from the same quarry. All obtained soils are shown in figure 1. Composite clay is colorful mottled, no carbonate clayey aleirolites and in them occurring like intermediate state - light gray, refractory clays [7]. Analysis and more detail information of clays and sand used in this research can be found in our previous work [8]. All types of clay and sand were homogenized and mixed with water to obtain plastic brick clay mass. Different amounts of waste fibreglass (0 – 10 wt %) were added to this mass. Due to other studies mechanical and physical properties are improved already with small amounts of additive, below 10 wt% [1], [2], [4]–[6]. Samples was extruded and its green size was (L x H x W) 12,0 x 3,4 x 7,0 cm. Samples after forming was dried at 105°C and fired at 1000 °C for 1h. Three mixes were made with 0 wt%, 5 wt% and 10 wt% of fibreglass. Following the particle size distribution and SEM data can conclude that most of fibreglass is dust size - from 20 to 2 µm.

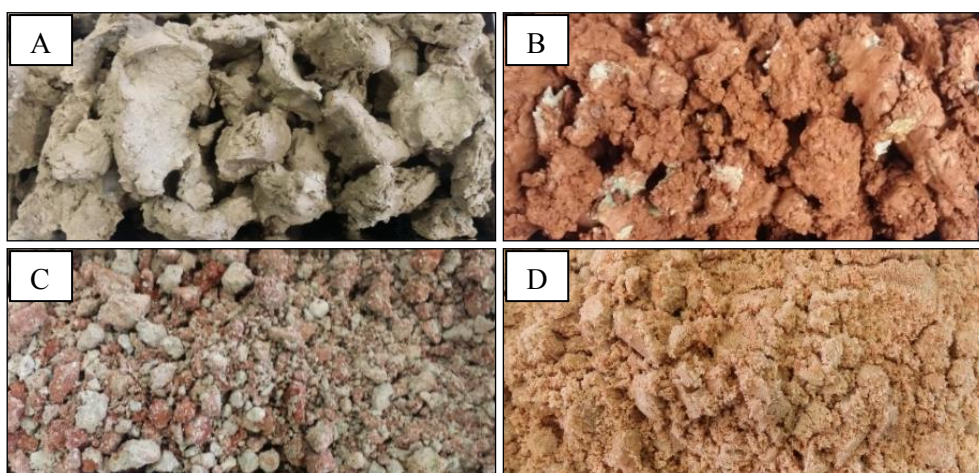


Figure 1. Soil from quarry: A – Grey clay; B – Red clay; C- Composite clay; D – Sand.

Particle size distribution was determined by granulometry analysis done by the pipette method. Raw material was dried at 105°C sieved till <2mm fraction. Oxidation of organic matter was done by hydrogen peroxide (H₂O₂). Samples were dipped in distilled water whit dispersant (Na₂PO₃) +Na₂CO₃ for 24 h. The aim of pretreatment is to promote dispersion of the primary particles, and to get more accurate clay size particle amount in the sample. Suspension was wet sieved on 63 µm sieve. Fraction >63 µm that left on sieve was dried at 105°C and dry sieved. Fraction that passed 63 µm sieve was analyzed by sedimentation method taking samples at appropriate intervals [9].

Crack detection was made of fired and dried samples which were cut in 8-10 pieces. Detection and measurements was made by digital camera (Moticam 2000) and software Motic Images Plus 2.0. The crack amount is expressed as a percentage of the average crack area on the sample area.

For samples morphology and chemical analysis Scanning electron microscope with integrated energy dispersive x-ray spectrometer (SEM-EDX) Hitachi S-900 was used.

3. Results and analysis

3.1. Granulometry

Granulometry was made for all mixes: Mix_7 without fibreglass additive, Mix_7_5% with 5% fibreglass additive and Mix_7_10% with 10% fibreglass additive. Our goal according to Winklers diagram for solid bricks is to make composition with >60% sand size particles, <60% silt size particles and <35% clay size particles (red triangle in figure.2.B)) [10]. As shown in figure.2.B) base

composition Mix_7 is close to this location in diagram. By increasing fiberglass additive proportion, clay size particles increase, but sand size particles decreases (Fig.2.A). So fiberglass additive during mixing crushes due to its fragile nature and mostly are silt size - from 20 to 2 μm .

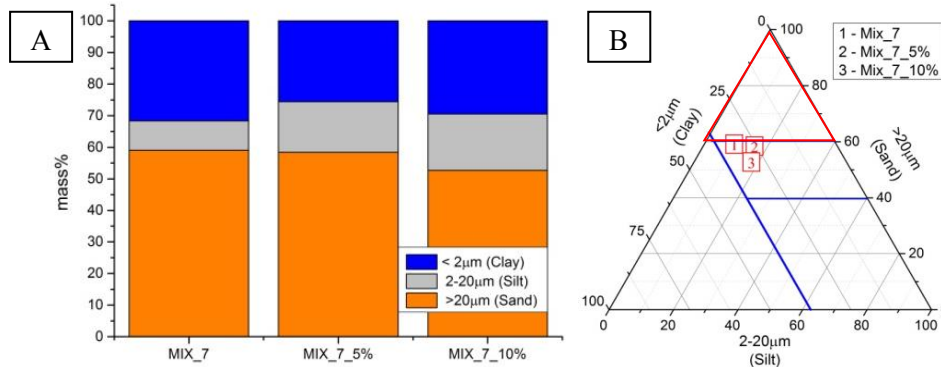


Figure 2. A) Particle size distribution of Mix_7 without fiberglass additive, Mix_7_5% with 5% fiberglass additive and Mix_7_10% with 10% fiberglass additive. B) Mix_7, Mix_7_5% and Mix_7_10% location in Winklers diagram.

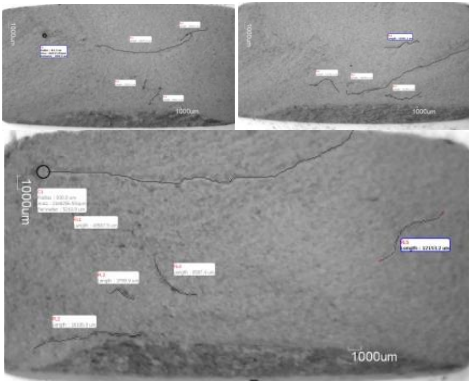
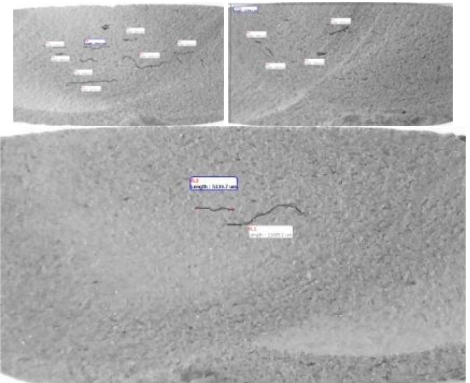
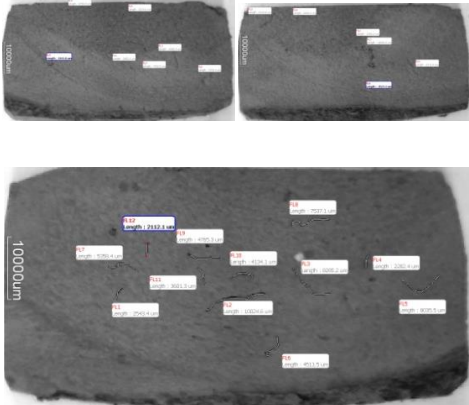
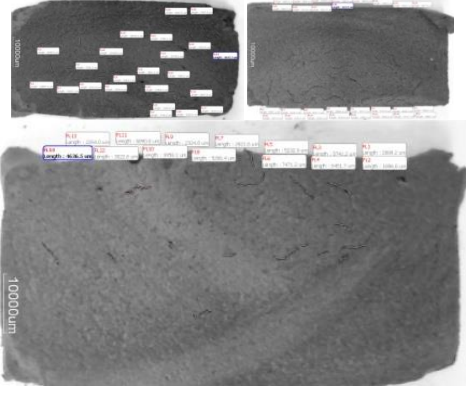
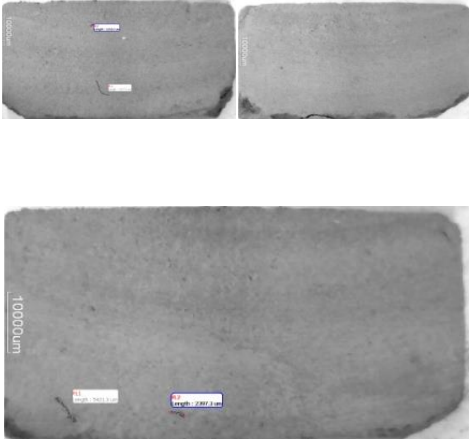
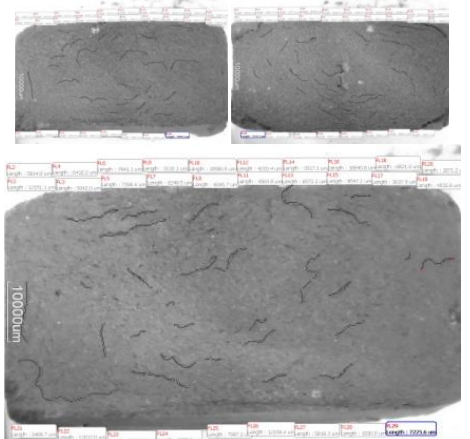
3.2. Cracks

Cracks in solid bricks were measured after drying and firing. The crack amount in table 1 is expressed as a percentage of the average crack area on the sample area. In table 2 are illustrated images of cracks and how they were measured. In both tables are expressed that by increasing fiberglass additive amount, percentage of cracks decreases in dried samples that are also consistent with the drying shrinkage results. Opposite from clays, that have plastic behavior and shrink after water evaporation, the fiberglass in the sample matrix reduces the shrinkage during drying thus avoiding cracking [2]. Opposite results are with fired samples. Firing shrinkage increases and crack amount increases by increasing fiberglass additive. That may be explained by silicon nature to melt around 573°C during heating and shrinking during cooling process [4]. Grate amount of silicon is found in added sand and fiberglass additive. Heating process during firing may be too rapid as well, which can increase absorbed water evaporation rate and cause cracking.

Table 1. Crack amount in dried and fired samples.

Sample	Granulometry (>20 μm / 2-20 μm / <2 μm)	Average drying shrinkage	Crack amount of dried sample	Average firing shrinkage	Crack amount of fired sample
Mix_7	59,09/ 9,3/ 31,61	5,2%	0,26%	-1,14%	0,99%
Mix_7_5%	58,41/ 16,00/ 25,59	3,6%	0,37%	0,15%	1,62%
Mix_7_10%	52,72/ 17,85/ 29,43	2,7%	0,04%	1,27%	2,07%

Table 2. Crack images of dried and fired samples of Mix_7 without fiberglass additive, Mix_7_5% with 5% fiberglass additive and Mix_7_10% with 10% fiberglass additive.

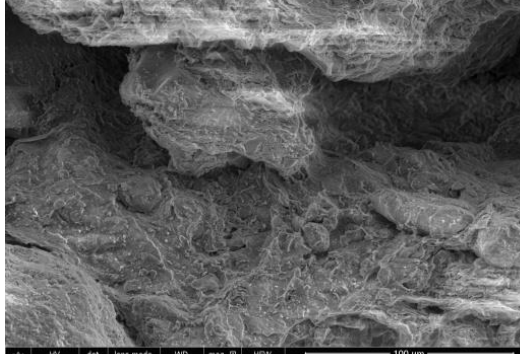
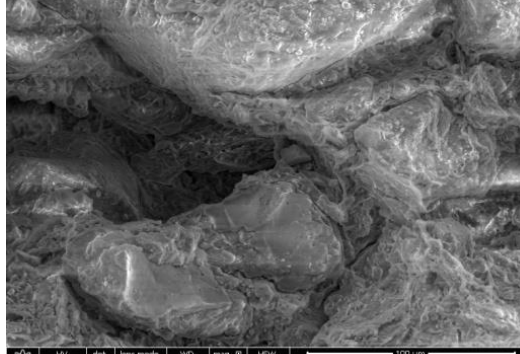
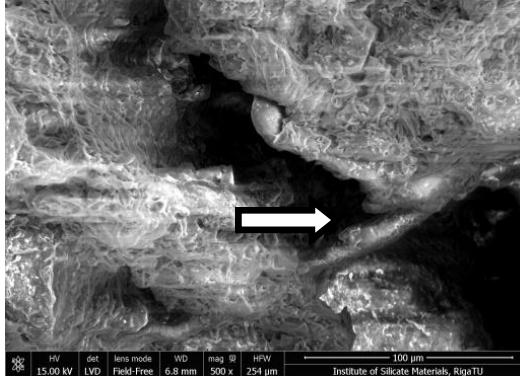
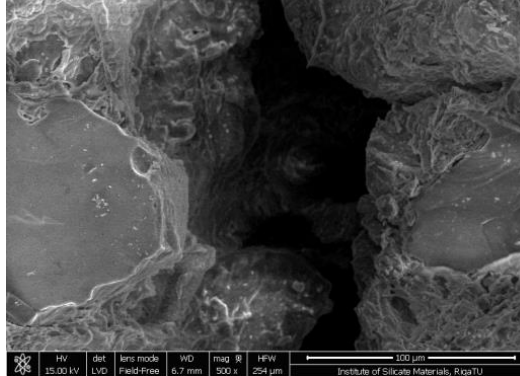
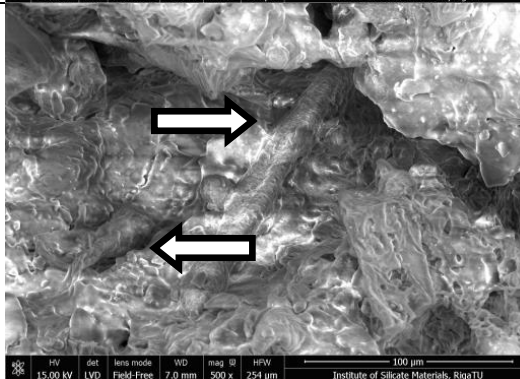
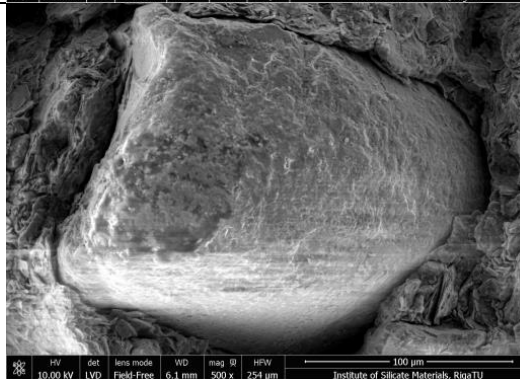
	Dried samples	Fired samples
Mix_7 without fiberglass additive		
Mix_7_5% with 5% fiberglass additive		
Mix_7_10% with 10% fiberglass additive		

3.3. SEM EDX

SEM images were taken of 1000°C fired all three mix samples. As shown in table 3 large quartz grains are embedded within the clay matrix, but the finer fraction of quartz is also distributed around. In samples without fiberglass additive micro-cracks has formed around large quartz particles which also are larger crack formation reason as discussed above due to its nature to dilute during heating and

shrink during cooling process. In samples with fiberglass additive, which is indicated by arrow, clay like structures has grown around them during firing process and additive work like reinforcement.

Table 3. SEM images of Mix_7 without fiberglass additive, Mix_7_5% with 5% fiberglass additive and Mix_7_10% with 10% fiberglass additive.

Mix_7 without fiberglass additive		
Mix_7_5% with 5% fiberglass additive		
Mix_7_10% with 10% fiberglass additive		

Of all three mixes EDX analysis has been made and all typical clay elements have been found like Si, Al, O, K as shown in figure 3. According on our previous research [8] these elements has been found in illite, kaolinite and quartz structures which were detected by XRD analysis. Most common elements found is Si, which is 46% of all scanned area and O (27%). These elements can be found in illite $\text{KAl}_2\text{Si}_3\text{AlO}_{10}(\text{OH})_2$, kaolinite $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ and quartz Si_2O_2 structures [11], [12].

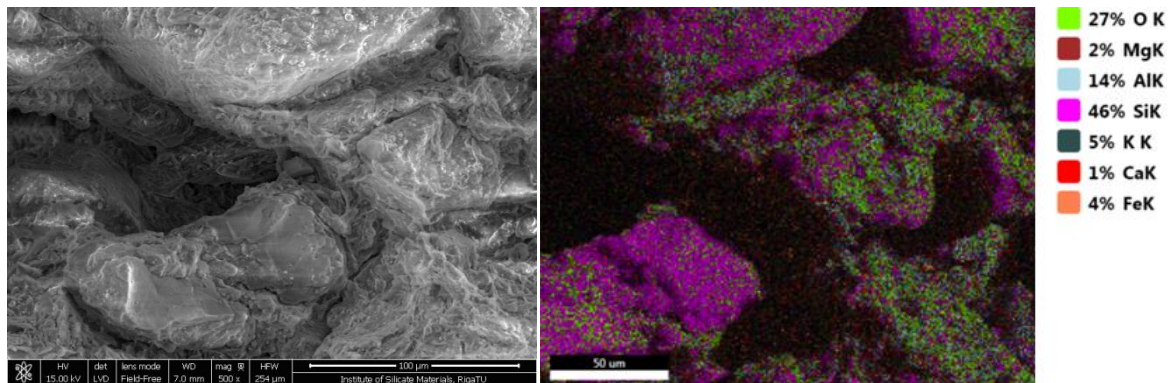


Figure 3. Image of SEM and EDX analysis.

3.4. Technological data

Some technical data are summarized in table 4. Forming moisture for all three mixes is around 18%, which is suitable moisture for clay mixture forming. Increase of fiberglass additive to clay increases the sintering shrinkage, as it was discussed above, leading to a densification of material. Fiberglass additions change the recrystallization processes, leading to the formation of dense clay-glass agglomerates distributed within the three dimensional quartz network [4]. Clay-glass agglomerates affect compressive strength. Sample density, after firing, increases by increasing fiberglass additive amount. As the density of a clay brick increases, its strength also increases.

Water absorption was measured after firing by immersing samples in water for 24 h. As shown in table 4 it is high, but comparable with N. Phonphuak et al. results which were in the range of 14.78 - 18.66%, depending on firing temperature [1]. High water absorption is related with samples open porosity and cracks that accrued after firing process. Thus the pores of fired clay brick are affected of glassy phase formation during firing process.

The compressive strength of clay brick is the most important engineering-quality index for building materials. Compressive strength increases by increasing fiberglass additive amount. As discussed above fiberglass has good adhesion with clay structures and that works like reinforcement, which strengthens the structure. Our sample compressive strength is very similar with C. N. Djangang et al obtained compressive strength with 10% glass powder addition to kaolinite clay which is 10,49 MPa. [4], [13]. With a higher compressive strength, other properties like flexure, resistance to abrasion are also improved. While other properties are relatively difficult to evaluate, the compressive strength is easy to determine [1].

Table 4. Technical data of Mix_7 without fiberglass additive, Mix_7_5% with 5% fiberglass additive and Mix_7_10% with 10% fiberglass additive.

	Forming moisture	Density, g/cm ³	Water absorption	Compressive strength, MPa
Mix_7	18,40%	1,60	13,84%	7,86
Mix_7_5%	18,00%	1,62	16,42%	5,77
Mix_7_10%	17,90%	1,67	14,66%	10,04

4. Conclusion

By addition of fiberglass waste in clay mixtures, we gain several benefits, firstly, the amount of waste is reduced and secondly, properties of clay bricks are improved. Addition of fiberglass waste (size range 20 to 2 µm) show good influence on mechanical characteristics of clay bricks that is compressive strength and density increases by increasing fiberglass amount in mixture. Fiberglass works as reinforcement for clay matrix. However, in future it is planned to use submicron reinforcing materials to gain higher improvement in crack reduction of clay materials.

Acknowledgments

Authors of the article are grateful to Institute of Soil and Plant Sciences of LLU for chance to determine sample granulometry and Institute of Materials and Structures of RTU for chance to make sample compressive strength tests.

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