Effect of Firing Temperature on Properties of Clay Tiles

Arya R V[1], Annie Joy[2]
[1, 2] civil department
[1, 2] Toc H institute of science & technology

Abstract- *Modern roof materials such as clay roof tiles are produced from earth, water, air, and fire. The natural components promote a healthy living climate, provide reliable protection for residents and are additionally recyclable. Maintenance & Replacement of clay tiles are simple. Thermal analysis has become a powerful tool to understand the reaction of clay against firing temperatures. The formation of a microstructure with desirable characteristics is considered to influence the frost resistance proprieties of masonry materials. The frost resistance is influenced by the pore-size, pore type, and pore distribution, which depend on firing temperature. This paper presents the review on various research works in the area of effect of firing temperature on properties of clay tiles.*

Keywords- Frost resistance, Pore distribution, Roofing tile

I. INTRODUCTION

Constructing in a cheap manner is a crucial condition for architects and building homeowners, however it's usually neglected that those building materials area unit economical that lasts longer & not invariably those, that price less. Trendy roof materials like clay roof tiles area unit used for single-family homes & flat buildings, work place & industrial complexes likewise as restoration comes. The assembly method is predicated on the four parts of earth, water, air, and fire. The natural parts promote a healthy living climate, give reliable protection for residents and area unit to boot reusable. Once maintenance is critical, it is straight forward and needs solely fast maintenance checks. Replacement of clay tiles is straightforward too.

A. Frost Resistance & Firing Temperature

Frost resistance is outlined because the ability of ceramic tile to face up to freeze/thaw conditions with lowest result. The frost resistance of ceramic tile depends on the tile's consistency and water absorption levels. Frost harm will occur once ceramic tiles absorb wetness through their pores, inflicting the water to freeze internally, once temperatures drop. Since water expands once it freezes, tension is then exerted within the body of the ceramic tile. This internal pressure might become high enough to cause cracks within the ceramic tile.

Frost resistance may be a quality tiles have after they are subjected to water at temperatures less than 0°C while not being broken by stress generated by their wetness content cooling. The tiles are outlined as resistance or not because the water absorption of ceramic tiles is extremely low most ceramic tiles are frost resisitant. Firing temperature is a very important consider clay tile creating business. It influences the minerological, textural & physical formation of clay tiles. The density, water absorption, strength & linear shrinkage properties are directly suffering from firing temperature particularly at vitrification purpose. Vitrification is noticeable at temperatures on top of 900°C. At this time associate amorphous section is made & the pores tend to collapse & become spherical. This development is as a result of melting of the clay & additive particles within the matrix of vaporish. Upon cooling, higher strength & lower water absorption is anticipated. The linear shrinkage & density is dependence on the minerological composition of the samples.

II. CASE STUDIES

Here 5 case studies are considered to study the effect of firing temperature on properties of clay tiles.

A. Case Study 1

Kiyohiko Ikeda et.al [1] in his paper "Influence of firing temperature on frost resistance of roofing tiles" investigated the effect of firing temperature on density, porosity and water absorption of tiles for each freezing temperature. Tiles were fired at different temperatures of 900–1200°C were fractured by four point bending after applying freezing treatment at low temperatures of −10, −30 and −50°C. Fracture stress and fracture toughness increased with the firing temperature, but they dropped above 1100°C & the roofing tile fired at temperatures of up to 1200°C forming mullite with a glass phase from the reaction with quartz and feldspar could minimize the frost damage.

The materials are unfired roofing tiles formed into a roof shape, which consist of kaolin, quartz and feldspar. The test samples cut from the roofing title were fired at 900, 1000, 1100 and 1200 °C. After that, each sample was polished to a size of 3mm × 4mm × 40 mm.

All specimens were immersed in dry ice with ethanol for freezing at low temperatures of −10, −30 and −50 °C after being immersed in a distilled water at room temperature for 24 h. The specimens, frozen by cooling to the respective low temperatures, were returned to room temperature. Each of the 10 specimens was fractured by four point bending with an inner span of 10mm and outer span of 30mm under a 0.05 mm/min cross head speed. Fracture toughness was also measured by the Single Edge V-Notched Beam (SEVNB) method, where V-notches at the center of the specimen's tensile surface were cut before testing. The V-notches could be produced at the bottom of a straight notch cut to a depth of approximately 0.2mm by using a razor blade sprinkled with diamond paste. The bending tests were conducted with a fast cross head speed of 10 mm/min.

B. Case Study 2

Ranogajec. J et.al [3] in his paper "Frost Action Mechanisms of Clay Roofing Tiles: Case Study" investigated the textural characteristics and frost resistance prediction of clay roofing tiles which were fired at five different temperatures (900, 920, 960, 1,000, and 1,020°C). The highest resistance is noticed for the samples fired at 1,020°C where the frost action mechanisms are balanced because the porous structure that compensates the local stresses developed during freezing. The porosity parameters are the most influencing parameters of frost action durability for clay roofing tiles. The clay roofing tiles were shaped and dried in industrial conditions, but fired at five different temperatures (900, 920, 960, 1,000, and 1020°C) in the laboratory.

Frost resistance value was assessed by severe freeze/thaw testing of three specimens for each type of clay roofing tile. Samples were saturated for 24 h by water. The tests were carried out within the temperature interval −15° C to þ15° C performing 35 cycles by removing the samples from the freezing (4 h at −15° C) to the thawing environment (room temperature, 4 h). Frost resistance of the samples was expressed by the number of the passed freeze/thaw cycles.

C. Case Study 3

Rekecki. R et.al [4] in his paper "Effects of Firing Conditions on the Properties of Calcareous Clay Roofing Tiles" studied the effects of firing conditions on the microstructure and physical properties of clay roofing tiles. The effects of oxidizing and reducing atmosphere on Kanjiza clay material with carbonate content up to 22% by weight and the characterization of the final products were studied. The firing was done both in the laboratory and under industrial conditions. The frost resistance capacity values of the fired samples are improved by using a reducing firing atmosphere & the microstructure of the samples fired in reducing atmosphere showed higher glassy phase content and differences in the presence of secondary crystalline phase, plagioclases, and magnetite content.

D. Case Study 4

Leposava Sidjanin et.al [2] in his paper "Influence of firing temperature on mechanical properties on roofing tiles" evaluated the effects of firing temperatures on bending strength and Vickers hardness in fired ceramic roofing tiles from kaolinite and illite-carbonate clay materials. The tiles were fired at 960 and 1050°C following exposures to freezing/thawing cycles. The bending strength and Vickers hardness, before and after cycling were compared & results showed that Vickers hardness HV5 and bending strength increased with increasing firing temperature. Due to the occurrence of micro cracks produced by frost damages the values of bending strength and hardness were lower for after cycling.

E. Case study 5

Chee Lung Chin et.al [5] in his paper "Relationship between the thermal behaviour of the clays and their mineralogical and chemical composition: Example of Ipoh, Kuala Rompin and Mersing (Malaysia)" characterized Thermal behaviour of Malaysia clays using thermogravimetry analysis, differential thermal analysis and dilatometry analysis. Mineralogical analysis (XRD) indicated that Ipoh clay was highly kaolinite reduce fired coefficient of expansion of ceramic tile body, while Kuala Rompin and Mersing clays contained high illite and quartz with the presence of high K2O improve fluxing power and reducing vitrification temperature of ceramic products. The Ipoh clay showed contraction behaviour at 500°C to 650 °C, while both Kuala Rompin and Mersing clays have showed expansion behaviour at 200 °C to 950 °C.

III. FACTORS AFFECTING FROST RESISTANCE

Fracture toughness is the measure of material resistance to brittle fracture when a crack is present. In theory, an infinite stress occurs at crack tip, which means that the smallest external force would make the crack to propagate causing brittle fracture. In reality, crack tip stresses are finite, due to the existence of plastic deformation in materials ceramics have very narrow plastic zone at the tip of the crack due to their ionic and covalent bonds, as well as their porosity. Therefore the determination of fracture toughness for ceramic materials is very important especially in their selection and application.

The porosity is connected to the liquid phase during firing and is affected by the transformations that occur during sintering. For this reason, selection of components and fluxes that affect the microstructure phases and alkaline amounts are important. The microstructure of ceramic materials is composed of crystals, liquid phase and porosity.

A. Fracture Stress and Fracture Toughness

The variation of the fracture stress and the fracture toughness as a function of firing temperature for the roofing tile specimens subjected to freezing treatments. For any freezing temperature, the fracture stress increased monotonically with firing temperature up to 1100°C, but decreased above 1100°C. The tendency was more significant in the case of the specimen frozen at the lowest temperature of −50 °C. The fracture toughness also showed almost the same tendencies as the fracture stress, but there was no significant difference at different freezing temperatures. The variation of the fracture stress and the fracture toughness by firing temperature is related to the firing conditions used to control the microstructure of tiles to produce dense materials by the reaction of feldspar and quartz.

B. Microstructure of Roofing Tile

The effect of firing temperature on density, porosity and water absorption of tiles for each freezing temperature is considered. For all freezing temperatures, the density increased with temperature up to 1100°C, but it dropped above 1100 °C. On the other hand, both porosity and water absorption decreased monotonically up to 1100 °C, but these rose for the freezing temperatures of −10 and −30°C and dropped for room temperature and the freezing temperature of −50 above 1100°C.

C. Total Porosity and Pores Size Distribution

The effects of firing temperatures on bending strength and Vickers hardness in fired ceramic roofing tiles from kaolinite (K) and Illite-carbonate (IC) clay materials is evaluated. Total porosity values of the kaolinite and Illite-carbonate roofing tiles, decreased by increasing the firing temperature. The samples of illite-carbonate system were characterized with a dominant pore interval with a range of 0.5–2.0 µm, while samples of kaolinite system were characterized with the dominant pore interval from 0.064 to 0.5 µm (chart 3). The increase of temperature, from 960 to 1050 °C, influenced the pore enlargement, especially in the case of K system, but diminished the overall porosity. The roofing tiles with pore-size of 0.25–1.4µm suffer more from frost damage. It was expected that the IC roofing tiles would exhibit frost damage.

IV. EFFECT OF FIRING TEMPERATURE ON MECHANICAL PROPERTIES OF CLAY TILES

Bending strength is indicative of the mechanical strength of the tile as whole in relation to aggressions of differing nature, such as dead load & live loads, rolling actions & impacts. Breaking load is an intrinsic tile characteristics i.e., two ceramic tiles made by the same process & differing solely in thickness will have the same bending strength, even though the force required to break them is much larger in the thicker tile.

The Vickers hardness test is used to measure the hardness of material. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness.

The change of bend strength and Vickers hardness HV5, before and after freezing/thawing procedure, with increase the firing temperature from 960 to 1050 °C. The obtained results show that the increase of firing temperatures lead to the increase of mechanical properties where the bending strength and hardness for the K roofing tiles samples were higher. These results correlate well with the samples microstructure. The absence of carbonate and thermal transformations within Al_2O_3–SiO_2 composition, cause a formation of a considerable amount of amorphous/glassy phase and sealed porosity, cause higher values of bending strength and hardness in the samples of K roofing tiles when compared to that of the IC system.For the K system the values of mechanical properties remained greater following freezing and thawing procedures. For each firing temperature, mechanical properties of both K and IC roofing tiles samples were smaller compared to that of non-cycled. The drop of mechanical properties after cycling is likely due to the micro cracks formation, as a consequence of frost damage.

V. CONCLUSION

- For the samples fired below 1100 °C, a slight decrease in fracture stress with lowering in freezing temperature, but for the samples fired at 1200 °C, the obvious decrease in fracture stress was observed.
- The roofing tile fired at temperature up to 1200 °C forming mullite with glass phase from the reaction with quartz and feldspar could minimize the frost damage
- With increasing of the firing temperature, an increase of hardness HV5 and bending strength was observed.
- The peak temperature of the firing regime and the carbonate content of the raw material have positive effects of the reducing atmosphere on the densification properties and the colour of the fired system.
- From the above case studies it was concluded that temperature for firing can be considered between 1100°C to 1200°C.

REFERENCES

[1] Kiyohiko Ikeda, Hyung-Sun Kim, Koichi Kaizu and Atsushi Higashi, "Influence of firing temperature on frost resistance of roofing tiles," Journal of the European Ceramic Society, Vol 24, pp. 3671–3677, April 2004

[2] Leposava Sidjanin, Jonjaua Ranogajec, Dragan Rajnovic, Elvira Molnar, "Influence of firing temperature on mechanical properties on roofing tiles," Materials and Design, Vol 28,pp. 941–947, November 2007

[3] Ranogajec J, P. Kojic, O. Rudic, V. Ducman, and M. Radeka, "Frost Action Mechanisms of Clay Roofing Tiles: Case Study", Journal Of Materials In Civil Engineering, vol. 24, pp. 1254 – 1260, September 2012

[4] Rekecki R, J. Ranogaje, A. Oszko, and Kuzmann E,"Effects of Firing Conditions on the Properties of Calcareous Clay Roofing Tiles," Journal Of Materials In Civil Engineering, vol. 26, pp. 175 – 183, January 2014

[5] Chee Lung Chin, Zainal Arifin Ahmad and Sew Seng Sow, "Relationship between the thermal behaviour of the clays and their mineralogical and chemical composition: Example of Ipoh, Kuala Rompin and Mersing (Malaysia)," Applied Clay Science, vol. 143,pp. 327-335, March 2017

[6] Rajeev P, jay G Sananjayan, and seenuth S.S, "Assessment of Thermal Cracking in Concrete Roof Tiles," Materials design, vol.05, pp.264-285, June 2016

[7] Caesar Abi Shdid, Amir Mirmiran, Ton-Lo Wang, Diego Jimenez and Peng Huang, Uplift Capacity and Impact Resistance of Roof Tiles, Practice Periodical On Structural Design And Construction, vol. 16, pp. 121 – 129, August 2011