# CHARACTERIZATION OF CERAMICS WALL TILES USING LOCAL TALC AS A FLUXING AGENT

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## SUMMARY

*Talc, a magnesium silicate mineral, is abundantly available in Pakistan. Internationally talc is used with other raw materials to produce wall tiles. But due to difference in mineralogical locations of the local talc and other raw materials, a local optimum wall tile composition was needed which can lead to the utilization of abundant talc resources in Pakistan. Considering this fact, here, several different compositions are arranged and analyzed. The variation within these compositions bases on gradual increase in talc percentage which drastically boosted fired strength, stabilized thermal shrinkage, thermal expansion to an optimum level and controlled the excessive water absorption. All these properties variations are in favor of good and free of defects wall tiles. The use of talc indicated that a normal strength (200-220 kg/cm$^2$) can be acquired using 20% talc even at lower temperature of 1030-1050°C compared to 1160-1167°C used in local industry. This substantial decrease of nearly 100°C in production temperature will reduce the energy cost for wall tile production. In addition talc's use is economical because of its cheaper cost than other fluxes like feldspar and lime stone.*

**Keywords:** *Magnesium Silicate, Fluxing Agents, Mineralogical Locations, Fired Strength (FS), Thermal Shrinkage (TS), Thermal Expansion (TE), Water Absorption (WA).*

## INTRODUCTION

At the time of partition of Indian Subcontinent, ceramics tiles and sanitary ware industry was not familiar in Pakistan. One hurdle to ceramics tile production was unavailability of main raw material i.e. china clay. It was only in 1968-69 when china clay was discovered in Swat. So immediately a project based on Swat china clay was started by installing Swat Ceramics Unit at Shaidu near Nowshera in Khyber Pukhtoonkhwa. Gradually several other units were installed later on. But the unavailability of international standard machines in local industries led to poor production quality but also to low production capacity. However in recent years most of the local plants (Table 1) are upgraded with latest equipments and are trying to implement the modern ceramics production techniques.

The thing which varies from one industry to the other is that how do they manage to produce high strength and defect free tiles within minimum possible production cost. This objective needs to consider areas like reduction in energy consumption and selection of those raw materials which have lower cost and good production results.

Our focus is on Talc ($Mg_3Si_3O_{10}(OH)_2$), one of ceramics raw material abundantly available in Pakistan. The huge deposits of soapstone (talc) in Pakistan occur as dolomitic limestone at Sherwan Hazara in Khyber Pukhtoonkhwa, while other small ones are those of Jamrud, Kuram Agency, Landi Kotal, Zhob in Baluchistan, Chalt in Gilgit and Nauseri in Azad Kashmir. This work is an attempt to find a new optimum composition (APPENDIX-I & Table 2) of wall tiles containing maximum possible portion of local talc (Table 3) as a fluxing agent. Talc being cheaper than the other fluxing agents i.e. feldspar and limestone, can decrease fluxes cost by replacing some portion of these costly fluxes in wall tile composition.

### Experimental

Raw material batches were weighed, according to designed composition shown in Appendix I, using digital weighing balance. These batches were ground in a pot mill (grinder) for 40 minutes by adding water. The slurry formed was tested for density and viscosity and was dried at 200°C for 30 minutes. The dried mix was reground in the previously used pot mill for five minutes without the addition of any water in order to get it into powder form. Then 6% moisture

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**Table 1: Production compositions of local tile industries.**

| Industry Name | Clays | | Fluxes | | Fillers |
|---|---|---|---|---|---|
| EMCO Tiles | Kd-7 | Kd-7R | Soda Feldspar | | Quartz |
| Master Tiles | Kd-7 | Kd-7R | Potash Feldspar | | Quartz |
| Shabir Ceramics | Fireclay | N2B | Limestone | | Quartz |
| Karam Tiles | Local clay | Attock Fireclay | Soda Feldspar | | Silica Sand |
| Swat Ceramics | Kd-8 | N2B | Soda Feldspar | Talc | Silica Sand |
| Frontier Ceramics | Kd-8 | N2B | Potash feldspar | Talc | Silica Sand |

**Table 2: Production parameters of local tile industries.**

| Production | Parameters | | | | |
|---|---|---|---|---|---|
| | T ($^oC$) | FS ($Kg/cm^2$) | WA (%) | TS (%) | TE ( $e^{-7}$) |
| Unit A | 1160-1165 | 250-260 | 14-15 | 2-4 | 72-73 |
| Unit B | 1160-1167 | 200-210 | 12-14 | 0.5-3 | 72-73 |
| Unit C | 1150-1160 | 210-220 | 13-15 | 2-4 | 72-73 |
| Unit D | 1155-1160 | 225-235 | 11-12 | 0.2-5 | 72-73 |
| Unit E | 1080-1090 | 220-240 | 15-16 | 1-3 | 72-73 |
| Unit F | 1100-1105 | 230-240 | 13-17 | 1-4 | 72-73 |
| European Std | 1000-1200 | 150+ | <20 | Minimum | 73 |
| Samples | 1160-1165 | 290.45 | 8.5 | 4.42 | 73 |

**Table 3: Mineralogical composition of used talc collected from Sherwan mines.**

| S.No | Compounds | Measure | Characteristics | Measure |
|---|---|---|---|---|
| 1 | $SiO_2$ | 50.05% | Moisture | Max 0.05 % |
| 2 | MgO | 13.71% | Loss on Ignition | 2.86% |
| 3 | $Al_2O_3$ | 26.8 % | CaO | 3.36 % |
| 4 | $Fe_2O_3$ | Less than 5pmm | Heavy Metals | 2.0 ppm |

was given to each batch for making sample tiles in press machine.

After pressing at a pressure of 240 bar green tiles were obtained having 201 mm length and 78 mm width. These green sample tiles were dried at 150°C for 30 minutes so that it was feasible to measure its dimensions and then placing in firing rotary kiln. Repeating the same procedure, several samples tiles bodies (without glaze) of each designed composition were prepared. These green tile bodies were then placed in a rotary kiln at a temperature of 1167°C for 22 minutes firing cycle. After cooling fired biscuits were tested for shrinkage, fracture strength (compression), thermal expansion and water absorption (Appendix II). Similarly a new set of green tile bodies were glazed and placed in glaze firing rotary kiln at a temperature of 1050°C for 17 minutes firing cycle and then the same set of tests were performed for unglazed tile bodies (Appendix III).

## RESULTS AND DISCUSSIONS

*Talc's Effect on Thermal Shrinkage:* It was observed that talc has no drastic effect on the thermal shrinkage of the body rather it controls the moisture expansion by minimizing the porosity, so as a result the shrinkage fluctuated within a certain fixed range of 5.40-5.42% for 10% 15% and 20% talc (Figure 1). It is worth mentioning that the biggest problem most ceramic industries face is to handle the tendency of bodies to shrink as they go through the drying and firing processes. During heating most of the fluxes and clays face drastic variations in shrinkage[1]. This excess or uneven shrinkage causes problems. Bodies distort, cracks form and work even break in half.

But here we got the shrinkage almost constant throughout and this makes talc different from other materials. Basically shrinkage is caused by loss of chemical water, organics, carbonates, sulfates, the coming together of particles by melting of glass from fluxes and especially when air is expelled. The clays in body consist of masses of tightly clustered fine particles with air pores around them if it is not intensely milled [2,3]. Dry clay is about 40% air by volume and 60% actual clay. Now during firing at vitreous state they lose 40% of its volume which translates to shrinkage.

Shrinkage bases on the loss of two types of water in the body, mechanical and chemical [4,5]. Mechanical water is the water added for plasticity and the residual water due to humidity. This water is nearly all driven off by 250 °F (121°C). Chemical water is part of the kaolin crystal and constitutes 5-15% of the weight of the dry body. This water is not driven off until the firing temperature reaches 930-1300°F (500-700C, red heat). When chemical water is driven off the body is quite week and brittle which shrink easily. Talc stabilizes the shrinkage because the chemical water in talc bodies remains inside till quite higher temperature compared to bodies without talc[4].

*Talc's Effect on Thermal Expansion:* Thermal expansion in ceramic bodies is caused by the formation of high expansion materials which is actually the new arrangement of the raw elements added in the body[6,7]. Here thermal expansion increased from $69x10^{-7}/°C$ at 0% talc to $73x10^{-7}/°C$ for 20% talc (Figure 2) due to formation of $MgSiO_2$ and quartz. This expansion is considered quite significant in order to adjust the compression of glaze and to get a permanent glaze body fit. Here the tile is two-part system (body, glaze) and each of them had independent expansion characteristics.

The glaze having fixed thermal expansion ($68x10^{-7}/°C$) was obliged to conform to the body thermally induced size changes. This compromise between two parts makes tiles strong under compression but very week under tension.

The glaze applied was kept under slight compression because a glaze stretched on the body at

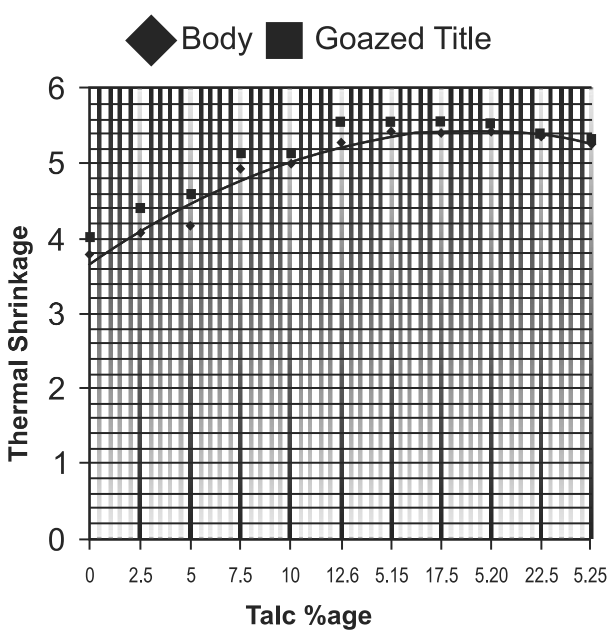


Figure 1: Effect of Talc on Thermal Shrinkage

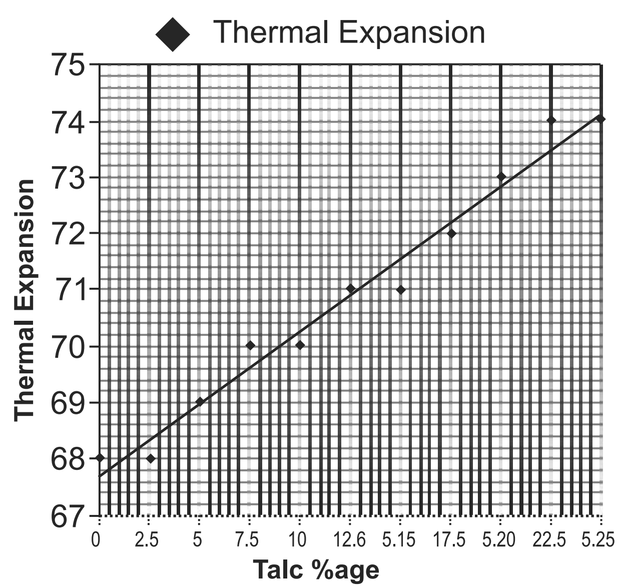


Figure 2: Effect of Talc on Thermal Expansion

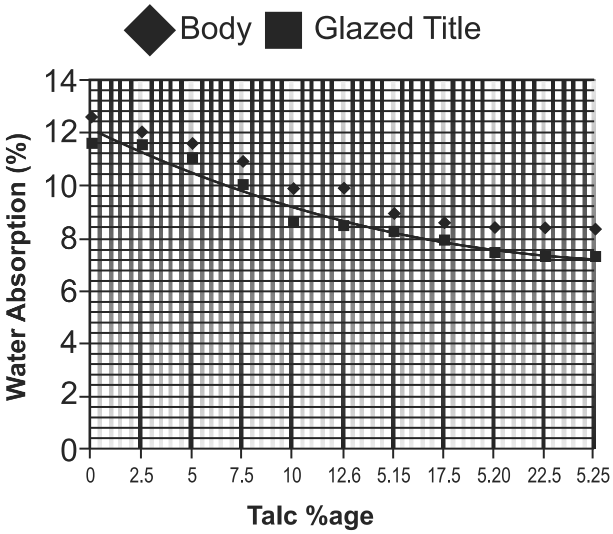


Figure 3: Effect of Talc on Water Absorption (%)

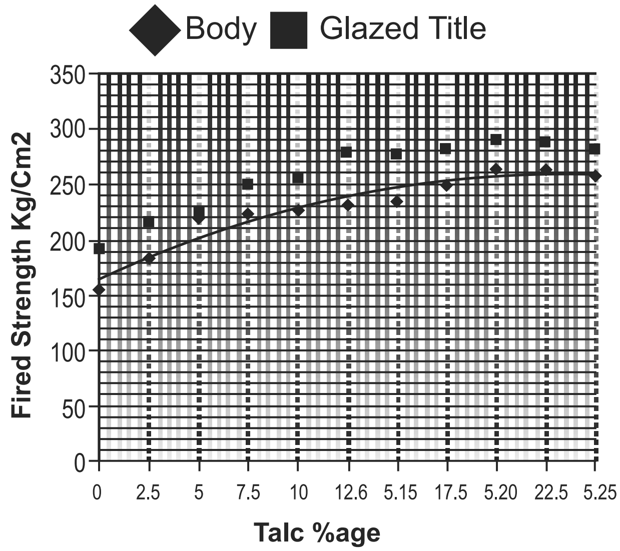


Figure 4: Effect of Talc on Fired Strength

any time (even as a result of contraction due to quick surface cooling) likely to form a network of cracks to relieve the stress. Another factor involved in this body-glaze fit is a reaction layer or interface that bonds them together [8]. This buffer forms as the liquid glaze melt attacks the body, penetrating into it and forming intermediate compositions layered against the body. The temperature, soaking, cooling rate, glaze/ body chemistry and material particle sizes all affect the development of the intermediate zones[8]. The glaze applied was fritted which typically is more reactive and produces a better interface to make a good quality tile.

*Talc's Effect on Water Absorption and Fire Strength:* It was observed that the water absorption decreased from 12.5% at 0% talc to a lower value of 8.29% at 25% talc (Figure 3). This shows that milled talc decreases the porosity and so reduction in water absorption occurs[9]. Usually entry of water causes the decrease of firmness of a body.

Comparison of Figure 3 and Figure 4 makes it clear that increase in talc percentage causes reduction of water absorption which leads to increase in fire strength of tiles. At 20 % talc composition we got a very high fired strength of 290.45 kg/cm$^2$ but fired strength started declining at 22.5% as here the ratio of non plastic material fluxes (soda feldspar and talc) to the plastic materials clays rises up. Another notable aspect is that due to surface coating of glaze each composition has nearly 20% increase in strength compared to the same composition body (unglazed) strength which indicates a best glaze-body fit.

## CONCLUSIONS

Talc can be preferably used as a fluxing agent along with other local raw material for wall tile production. It increases the fired strength, decreases the water absorption and consequently reduces the delayed crazing. It also increases the thermal expansion up to a certain reasonable value. The thermal shrink-

**APPENDIX-I: Samples Percentage Composition**

| Sample No | Clays KD-7 | KD-7R | Talc | Fluxes Na-Feldspar |
|---|---|---|---|---|
| S1 | 42 | 28 | 0 | 20 |
| S2 | 40.5 | 27 | 2.5 | 20 |
| S3 | 39 | 26 | 05 | 20 |
| S4 | 37.5 | 25 | 7.5 | 20 |
| S5 | 36 | 24 | 10 | 20 |
| S6 | 34.5 | 23 | 12.5 | 20 |
| S7 | 33 | 22 | 15 | 20 |
| S8 | 31.5 | 21 | 17.5 | 20 |
| S9 | 30 | 20 | 20 | 20 |
| S10 | 28.5 | 19 | 22.5 | 20 |
| S11 | 27 | 18 | 25 | 20 |

**APPENDIX-II: Fired Tile (Body) Properties**

| Sample No | TS (%) | WA (%) | TE 1/°C | FS (Kg/Cm$^2$) |
|---|---|---|---|---|
| S1 | 3.78 | 12.55 | 68 exp-7 | 153.07 |
| S2 | 4.07 | 11.96 | 68exp-7 | 183.45 |
| S3 | 4.17 | 11.46 | 69exp-7 | 220.76 |
| S4 | 4.93 | 10.86 | 70exp-7 | 222.13 |
| S5 | 5.0 | 9.84 | 70exp-7 | 227.23 |
| S6 | 5.27 | 9.86 | 71exp-7 | 231.01 |
| S7 | 5.42 | 8.89 | 71exp-7 | 235.23 |
| S8 | 5.4 | 8.53 | 72exp-7 | 250.12 |
| S9 | 5.42 | 8.36 | 73exp-7 | 263.26 |
| S10 | 5.37 | 8.35 | 74exp-7 | 261 |
| S11 | 5.27 | 8.29 | 74exp-7 | 258.3 |

**APPENDIX-III: Fired Tiles (Glazed) Properties**

| Sample No | TS (%) | WA (%) | FS (Kg/Cm$^2$) |
|---|---|---|---|
| S1 | 4.02 | 11.55 | 192.7 |
| S2 | 4.42 | 11.49 | 217.13 |
| S3 | 4.6 | 11.04 | 226.31 |
| S4 | 5.15 | 10.02 | 250.01 |
| S5 | 5.13 | 8.57 | 256.03 |
| S6 | 5.56 | 8.42 | 279.57 |
| S7 | 5.57 | 8.22 | 277.15 |
| S8 | 5.57 | 7.92 | 282.16 |
| S9 | 5.53 | 7.42 | 290.45 |
| S10 | 5.4 | 7.29 | 289.4 |
| S11 | 5.33 | 7.26 | 283.08 |

age remains stable within only 1% variation. Talc 20% in listed composition S9 (APPENDIX-I) is recommended for regular production as it has high enough fired strength of 290.45 Kg /cm$^2$, stable shrinkage 5.42%, 73x10$^{-7}$/C° thermal expansion and low water absorption of 8.36%. Also the surface condition has been quite shining and free of all kind of defects.

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