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Investigation of mechanical properties of castable with respect to their application as ceramic anchor elements

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Summary

Burnt refractory building materials are commonly used as ceramic anchor elements, particularly ordinary and high-aluminous fire clay. One of the most important material properties affecting their reliability are sufficient bending strength and shear strength both in normal and increased temperatures.

The study compares properties of high quality compact fire clay with fire clay castable of ULCC, LCC, MCC, and RCC type. Influence of burning temperature has been watched for high-temperature concrete on resulting physical mechanical properties of the material. The use of computer technology is important particularly for reviewing of measured data and optimization of material mixture.

KEYWORDS: castable, ceramic anchor elements, medium cement castable, low cement castable

1. INTRODUCTION

Putty, mortar, daub, castable and also castable shaped bricks concreted and pre-burnt in production plants belong among non-shaped refractories.

Anchor elements anchoring the walling made of refractory monolith together with curtain wall of a kiln belong among castable elements used during construction of kiln structures, as well. Anchor material is being selected particularly according to its usability temperature. It is possible to use anchors made of high-temperature steel, high-quality fire clay and/or castable anchor elements. Anchoring system and achor material have major influence on service life of kiln walling.

The submitted paper deals with material suitable for production of castable anchor elements being used in practice more and more often. This is why their utility properties are subjected to interest not only of producers and consumers of such materials. The paper deals with material utility properties of castable anchors under both ordinary and increased temperatures and its goal is examination of applicability of various kinds of castables for these special purposes.

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It is necessary to be highlighted that the mentioned work would be very problematic without use of computational technology.

2. CASTABLE ANCHOR ELEMENTS

Castable monolithic walling is anchored to a curtain wall of a kiln by a system of anchors which enables exchanging individual segments without affecting kiln stability. There exist a whole range of anchor elements serving for this reason such as anchor fire clay stones, steel anchors, prefabricated cones and anchor blocks. Anchor system is decisive for service life and efficiency of monolithic walling. Steel anchor could be used up to 1.200 °C, ceramic or castable anchors for temperatures over 1.200 °C. Distances of anchor elements are specified.

Figure 1. Steel anchor elements

3. PREPARATION OF TESTING SAMPLES

The submitted work observes various kinds of castables varying mainly by amount of alumina cement and plasticizer. Alumina cement is being gradually substituted by appropriate finely grounded component in form of micro-filler.

The following four types of castables have been selected for our study as well as high-quality compact fire clay – traditional anchor material – for comparison. The examined castables:

- regular cement castable (RCC), testing bodies marked R
- medium cement castable (MCC), testing bodies marked M
- low cement castable (LCC), testing bodies marked L
- ultra low cement castable (ULCC), testing bodies marked U

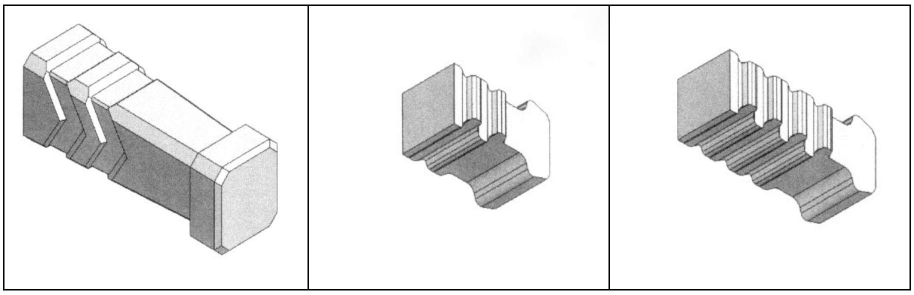

Figure 2. Ceramic anchor elements

The preparation of testing bodies has been carried out in a traditional way. First, individual components of castable mixtures were weighted accurately, each mixture was poured into a mechanical mixer and after partial dry mixing, batch water was added. After mixing, the mixture was poured into forms and vibrated. After 24 hours, the bodies were formed and marked with high temperature colour for further identification.

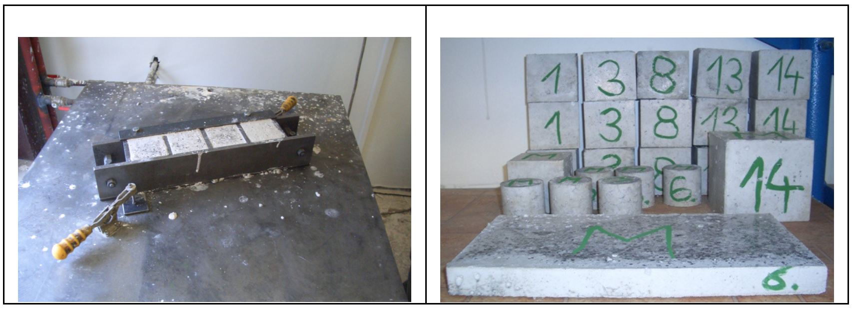

Figure 3. Vibrating into forms and set of testing bodies

Before burning process started, the testing bodies were measured and weighted in a dry state. Further, they were heated in a chamber kiln under temperatures 300, 800, 1.300, and 1.450 °C in form of cubes with 70 mm edges. Always three pieces of each mixture under each temperature.

The cones were burnt under temperature 600 °C as well as the plate for cutting the samples for strength in bending test under increased temperatures and cubes with 100 mm edge for testing of carrying capacity in heat were burnt under temperature 1.450 °C. Temperature raise in a kiln was linear 5.5 °C per minute, holding time under maximum temperature 5 hours.

Cooling was autogenous. After being burnt, the testing bodies were measured again for assessment of permanent length changes in heat.

4. PROCEEDED LABORATORY TESTS

The range of physical-mechanical tests and examinations were carried out in order to enable assessing convenience of various types of castables as materials for ceramic anchor elements. Permanent length change of testing bodies burnt under temperatures 300, 800, 1.300, and 1.450 °C was observed. Volume mass was determined and apparent porosity by means of hydrostatic weighting method on fragments of the testing bodies, too. Compressive strength in cool state was determined on the testing bodies dried under 110 °C and burnt under 300, 800, 1.300, and 1.450 °C. Tensile strength in bending in cool state and under increased temperature was observed for the testing bodies pre-burnt under 600 °C. Temperature of fracture was 20, 300, 800, and 1.300 °C. The testing bodies pre-burnt under 600 °C were determined on bearing capacity in heat and resistance against sudden temperature changes (Fig. 4).

Figure 4. Determination of resistance against sudden temperature changes

Figure 5. ULCC material texture after its drying (enlarged 40x)

Figure 6. ULCC material texture after burning under 1.450°C (enlarged 40x)

Microscopic observation of individual types of castables was also made. Computational technology enabling image transfer from microscope to PC monitor was used for observation of microstructure of the testing bodies in variable enlargements which enabled further image processing. Using the software LUCIA,

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size and occurrence of individual pores were measured, pores with minimum and maximum radius etc. Also influence of burning process on microstructure of the material was observed.

ULCC material microstructure (Fig. 5) is relatively softened after drying, aggregate grains are bound by a hydraulic bond. After castable burning under temperature 1.450 °C (Fig. 6), it is possible to observe significant material sintering and glass phase content. Aggregate grains are bound by a ceramic bond.

5. RESULT DISCUSSION

The testing bodies from four castable mixtures varying in cement amount were examined. Mixture R belongs to a category of common castables contained 20 % of alumina cement. Mixture M belongs to a category of castables with medium amount of cement, it contained 12 % of alumina cement. Mixture L belongs to a category of castables with low cement amount, it contained 5 % of alumina cement. Mixture U belongs to a category castables with ultra-low cement contents; it contained 2 % of alumina cement.

The testing bodies produced from these castables were examined and compared together with burnt refractory material, high-quality, compact fire clay of which most of anchor elements are ordinarily made.

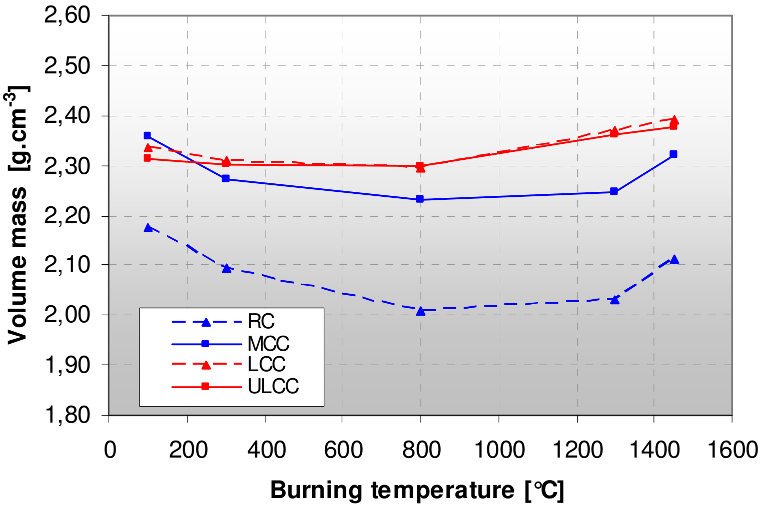

Figure 7. Effect of burning temperature on material compactness

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The Fig.7 shows that raising cement content in the mixure decreases volume mass and compactness of castable. Drop in volume mass was observed particularly for samples pre-burnt under temperature 800 °C which corresponds to temperature of hydraulic bond transformation to a ceramic bond. The result of sintering process over temperature 800 °C is raising volume mass with burning temperature (Fig. 7). Difference between the mixture with cement content 5 % and 2 % (LCC and ULCC) is minimum.

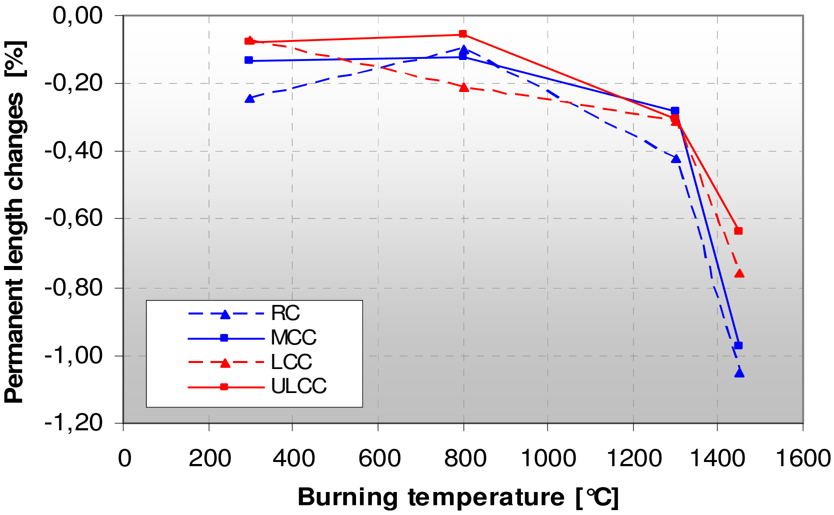

Figure 8. Effect of burning temperature on permanent length changes

Material compactness corresponds with its permanent length changes apparently from the following graph (Fig. 8). Increase of length changes related again with initiation of material sintering is apparent under temperatures higher than 800 °C. Influence of cement content on permanent length change is not significant enough and all values range in tolerance $\pm 0{,}15\%$ up to temperature 1.000 °C, after that, cement content shows more significantly.

Cement content has, however, significant effect on material strength in compression (Fig. 9). Compression strength in cool state rises with burning temperature and under temperatures over 1.000 °C is the strength higher for the mixtures with ultra low and low cement content than for the rest two mixtures. Strength of ULCC mixture burnt under 1.450 °C temperature is more than three times higher than for ordinary castable.

Compression strength in bending under increased temperature could be evaluated similarly as compression strength in cool state; again, the highest strengths were reached for LCC and ULCC mixtures. These mixtures with lowered cement content proved good both for fracture temperatures over 1.000 °C and lower temperatures. Ordinary castable and high-quality fire clay which has also been subjected to this test, reached strengths ten to fifteen MPa lower. Under fracture temperature 1.300 °C, the differences between materials are not so significant and it can be assumed that they will become even less significant with rising temperature.

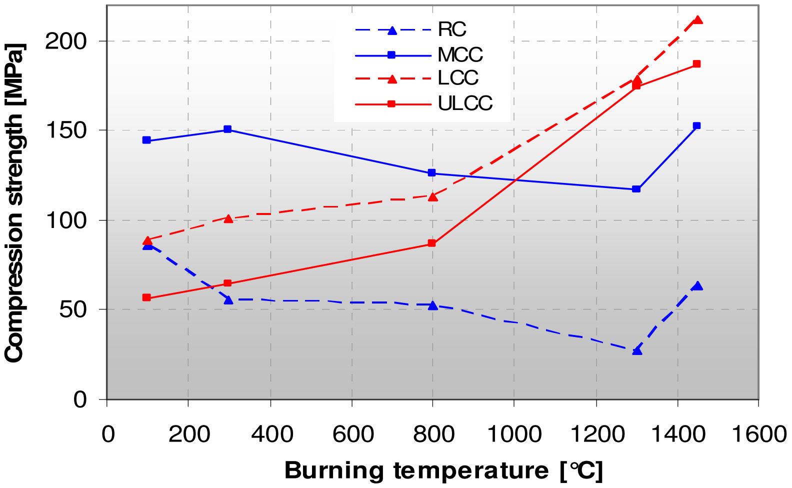

Figure 9. Effect of burning temperature and cement on compression strength

All castable mixtures stand the testing of resistance against sudden changes of temperatures (Fig. 4) and their failure was minimum, nearly insignificant in comparison with fire clay material; it manifested only with tiny cracks after 30th testing cycle. Fire clay material fell into two parts already after 20th testing cycle. The best evaluated with respect to this test was material ULCC.

5. CONCLUSION

After finishing all tests and after comparing all measured data by means of computational technology, material with ultra-low cement content (2 %) ULCC was recommended for production of ceramic anchor elements. This material stand good in all proceeded tests and therefore it is possible to be recommended as very convenient material for production of ceramic anchor elements.

This type of refractory shows low permanent length changes and reaches high volume masses due to its cement amount. Due to excellent sintering of aggregates and micro-filler with matrix during burning process, hard ceramic bond originates which provides high both compression strengths in cool state and tensile strengths in bending also under increased temperatures. Castable of a type ULCC is also possible to be used in applications over 1.500 °C.

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