GRINDING OF CALCINED CLAY IN VERTICAL ROLLER MILLS – IMPACT ON REACTIVITY

Caroline Woywadt[1], Nancy Beuntner[2], Paul Waibl[2], Karl-Christian Thienel[2], Joachim Gilles[3]
[1]Gebr. Pfeiffer SE, Kaiserslautern, Germany; caroline.woywadt@gebr-pfeiffer.com
[2]Institute for Construction Materials, University of the Bundeswehr München, Germany;
nancy.beuntner@unibw.de, paul.waibl@unibw.de, christian.thienel@unibw.de
[3]TBS Transportbeton Rhein-Neckar GmbH & Co. KG, Germany; joachim.gilles@tbs-transportbeton.de

Extended Abstract

Despite the future importance of calcined clay as supplementary cementitious material there is still limited information available on the impact of grinding on its properties. This is not at last due to the lack of industrial production sites and thus far hardly enough material for full scale grinding tests. The process of grinding has significant effect on the reactivity and performance of SCMs [1, 2], but specific procedures for grinding of calcined clays have not yet been established [3]. Several influences originating from grinding of calcined clays are known based on laboratory tests. Insufficiently calcined clays caused some problems [4]. The particle size distribution is influenced by the type of equipment [3]. Mineralogical composition especially of common clays (e.g. content of clays and quartz) will impact the particle size distribution and may lead to an enrichment of calcined clay particles in the finer fraction [5] but the quartz will also promote a deagglomeration effect [4]. The fineness of calcined clays can significantly affect compressive strength of concretes made with blended cements [6, 7].

The performance of a grinding system is defined by a required throughput at a required fineness paired with a low specific thermal and electric energy consumption. Vertical roller mills systems are much more energy-efficient than ball mill systems. The difference in specific power consumption is even higher when grinding to high fineness.

The design of an industrial grinding plant is based on tests with a pilot plant on a laboratory scale. The design of the test mill is similar to the later industrial mill and ensures the transferability of the parameters relevant for the rating of the industrial mill.

The pilot plant at Gebr. Pfeiffer with several vertical roller mills (VRM) is in use since many decades for testing different materials with a wide variation in characteristics such as feed moisture, feed granulometry, grindability, abrasivity, etc. The required product fineness is varying from very coarse products (top size 500 µm) to products with very high Blaine figures (10000 cm²/g and more) or d_{50} values of less than 10 µm.

Ideally, a representative sample of the feed material used later on for the industrial application is ground in the test mills available in the test station (). Especially the throughput rate and the specific energy consumption when obtaining the project-relevant product fineness are decisive for the rating of design and process. However, the wear behaviour of the grinding elements, the mill housing and the classifier are also determined during the tests on the basis of characteristic values for the wear rate and jet wear. With the help of these values, it is possible to select the optimum wear materials for the subsequent large-scale plant in order to guarantee the longest possible service life.

The test procedure for grinding cementitious materials in a pilot plant with a vertical roller mill (VRM) will be described with a special focus on calcined clay. The subsequent scale-up and rating of an industrial vertical roller mill based on those results will be explained.

The specific test results of the pilot plant VRM, for e.g. specific power consumption at a required fineness and wear rate of the grinding parts will be compared for different calcined clays, Portland cements and granulated blast furnace slags. Table 1 shows a comparison of specific energy consumption and wear characteristics for CEM I, ground granulated blast furnace slag (GGBFS) and different calcined clays.

Table 1: Comparison of specific energy consumption for grinding of CEM I, GGBFS and calcined clays

Material	*Spec. power consumption in VRM in kWh/t*	*Fineness Blaine in cm²/g*	*Fineness d50 in µm*	*Abrasive Wear (grinding parts in VRM) – normalized*	*Erosive Wear (VRM internals)*
CEM I	33 – 38	5500	~9 - 10	1	high – very high
GGBFS	35 – 40	6500	~7 - 13	2 – 4	high – very high
Calcined Clay A	40	11000	10.3	9	high
Calcined Clay B	35	10000	12.5	9	high
Calcined Clay C	31	12500	7.4	1 – 3	low

The performance of calcined clays can be influenced by the grinding process. Impacts of process parameters on the product properties will be detailed. The reactivity (determined by R^3-Test and solubility of Si and Al ions) depends on product fineness and grinding parameters. Increasing the fineness of the material from 7600 to 12500 cm^2/g results in 15 % better reactivity. The activity index, determined as compressive strength according to DIN EN 196, reaches up to 80% for mixtures with a replacement level of 40 wt.-% calcined clay after 28 days.

Conclusion

Grinding of calcined clays in VRM is an energy-efficient process. The performance of calcined clays is impacted by the grinding process parameters. Reactivity and activity index show very promising results for calcined clays ground in a pilot VRM.

Keyword: vertical roller mill, energy efficiency, pilot plant, reactivity, activity index

References

[1] Ramanathan, S., et al., Mechanically activated mine tailings for use as supplementary cementitious materials. RILEM Technical Letters, 2021. 6: p. 61-69.
[2] Gmür, R., K.-C. Thienel, and N. Beuntner, Influence of aging conditions upon the properties of calcined clay and its performance as supplementary cementitious material. Cement and Concrete Composites, 2016. 72: p. 114-124.
[3] Hanein, T., et al., Clay calcination technology: state-of-the-art review by the RILEM TC 282-CCL. Materials and Structures, 2022. 55(3): p. 29.
[4] Irassar, E.F., et al., Calcined illite-chlorite shale as supplementary cementing material: Thermal treatment, grinding, color and pozzolanic activity. Applied Clay Science, 2019. 179: p. 105143.
[5] Sposito, R., et al., Physical and mineralogical properties of calcined common clays as SCM and their impact on flow resistance and demand for superplasticizer. Cement and Concrete Research, 2022. 154(106743).
[6] Ferreiro, S., D. Herfort, and J.S. Damtoft, Effect of raw clay type, fineness, water-to-cement ratio and fly ash addition on workability and strength performance of calcined clay – Limestone Portland cements. Cement and Concrete Research, 2017. 101: p. 1-12.
[7] Vizcaíno Andrés, L.M., et al., Effect of fineness in clinker-calcined clays-limestone cements. Advances in Cement Research, 2015. 27(9): p. 546-556.