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Using computer technology for laboratory results (data) evaluation

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Summary

The article is focused on topics dealing with methods of processing a large data volume, applied in civil engineering. Evaluation of a large data volume retrieved during laboratory tests on laboratory samples pieces can be efficiently evaluated only using automated methods and computers. The article describes process of evaluation of output data, resulting from tests of thermo insulation chamotte (fire brick) samples that were prepared using waste raw materials, cenospheres, ash and slag. In particular, it describes using Microsoft Excel environment with a Visual Basic routine application.

KEYWORDS: insulating, fire brick, fly ash, waste raw material, Visual Basic, Microsoft Excel

1. INTRODUCTION

During finding new possibilities how to produce lightweight heat insulating fire brick material on basis of waste products, a large variety of new material compositions is being designed and large amount of testing samples tested in wide range of laboratory tests, is carried out. Large amount of measured values to be further processed and evaluated as the result of experimental works carried out on testing bodies is getting

The paper is divided into two main parts.

The first part of the paper describes the results of research performed to maximize utilization of waste materials in light-weight heat insulating fire brick. Waste from thermal power stations – ash, slag, and cenospheres – has been judged.

The second part of the paper deals with possibilities how to process measured data, how to think of the data, how to define data measured inaccurately, or how to define samples with extremely high (good) properties or data with extremely low (bad) properties. This part of the paper indicates and describes programme algorithm processed in VB software which significantly improves and makes easier evaluation of the measured values.

2. WASTE MATERIALS IN INSULATING FIRE BRICK

Light-weight refractory products may be light-weighted in various ways – using burning out additives, volatile substances, by foaming, using light-weight opening materials, etc. Using of volatile additives, sawdust, provides unpretentious production equipment and simple production process, the disadvantage is low dimension product accuracy of and need of the following calibration.

The aim of experimental works has been reviewing of possibility for using waste products from thermal power stations as a light-weight medium in a fire brick material which was not produced by drawing from a plastic body on a screw press but from a wetted body (crumbs) by pressing on a hydraulic press. The presswork from semi-dry mixture has many advantages. From the ecological point of view, this technology is profitable because a waste material is being processed and also when using non-burning out light-weight medium (ash, slag, cenospheres), harmful emission content produced during burning process of shaped products is significantly lower. From economical point of view, using waste product in a material content significantly reduces material costs in production and heat energy savings during product drying when amount of dried out water is two thirds lower than during production from plastic body which is not negligible as well.

2.1 Used raw materials

Kaolinitic clay has been used for a production of testing samples as a binder. **Ash, slag, and cenospheres,** and referential **keramzit** were used as light-weight medium (opening material).

Ash originates as a waste product from coal burning. From chemical point of view, it is an inert material composing mainly of particles of SiO_2 and Al_2O_3. Its granulometry is 0 – 1000 µm, powder density 750 – 1100 kg·m^{-3} and firing loss content max. 1% of mass. Price 40 CZK (circa 1.4 EUR) per ton.

Slag (from electric power stations) originates as a waste product during coal burning in thermal power stations. From chemical point of view, it composes mainly of particles of SiO_2 and Al_2O_3 and contents 15 – 45 % of water of its mass. Powder density of a dry slag is 600 – 800 kg·m^{-3}, of a wet one 900 – 1000 kg·m^{-3}, price 26 CZK (circa 1 EUR) per ton.

Cenospheres are aluminate-silicates hollow particles of a spherical shape originating during coal burning. They can be obtained either by ash washing or they are industrially produced. The mineralogical content of cenospheres is mostly mullite and β-cristobalite, powder density is about 420 kg·m^{-3}. It is a secondary waste product which corresponds with the price of 12 000 CZK (circa 430 EUR) per ton.

Keramzit (trade name) is a ceramic granulation product originating during clay burning in rotary kilns under 1160 to 1200 °C which forms characteristic spherical shape of porous hollow grains, powder density is 650 (500) kg·m^{-3} and water absorptive capacity max. 5%, price 1295 CZK per m^3.

2.2 Testing samples

The testing samples may be divided according to used light-weight medium to four basic groups. Material compositions 1 to 3 are only with cenospheres, material compositions 4-6 use keramzit as a light-weight medium, 7-9 use slag, and 10 to 12 use ash.

Table 1. Material compositions

Material composition	1	2	3	4	5	6	7	8	9	10	11	12
Chamotte opening material 0.5-1mm		10	20									
Chamotte opening material 1-3mm	30	30	30									
Keramzit 0-1mm					10	20						
Keramzit 0-4mm				45	45	45						
Slag							45	55	65			
Ash										25	35	45
Cenospheres	45	35	25	30	20	10	30	20	10	50	40	30

2.3 Assessment of utility properties and description of microstructure

Three testing samples were pressed for each material composition, each of them was fired in a tunnel kiln under a fire temperature 1050 °C, 1100°C, and 1250 °C.

Figure 1. Images of fired samples

The testing samples were tested in a wide range of laboratory tests. Macroscopic and microscopic descriptions were made (Figure 1). Shrinkage by drying, firing and overall material shrinkage were assessed. Mass density, apparent porosity, absorptive capacity, and apparent density by hydrostatic weighting were measured, further coefficient of heat conductivity λ, strength in pressure in a cold state were assessed, mineralogical composition of material by RTG diffractive analysis was

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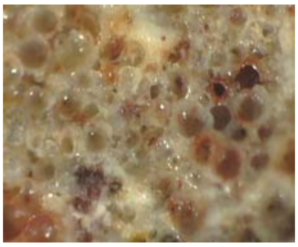
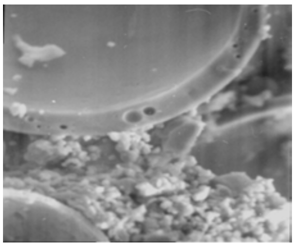
found out, and theoretical chemical composition of the material was calculated from chemical composition of a material. REM (Raster Electron Microscopy) test serving for more detailed description of material microstructure was carried out as a complementary test (Figure 2).



Optical microscope, enlarged 160times



REM, enlarged 1000times

Figure 2. Characteristic microstructure of samples with cenospheres

The output of a whole experiment, observation, and measurement is a large amount of data (over 400 measured values) even the fact that only twelve material compositions were tested. Possibilities, how to process measured data, are listed in the next chapter, see Chapter 3.

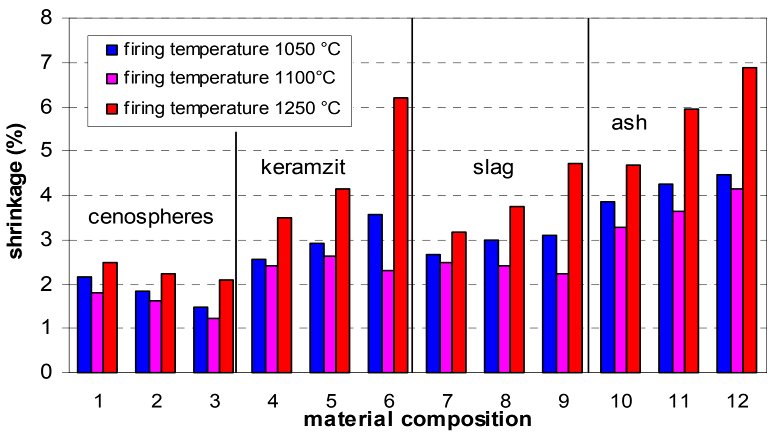


Figure 3. Shrinkage by drying and firing

2.3. Discussion of results

Usage of sawdust as a burning out light-weight substance is recessed due to both ecological and technological reasons. Overall material shrinkage during production of plastic body when using sawdust is up to 15%.

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When using our chosen light-weight substance, the overall material shrinkage is between 2-7%. Very good results were reached when using cenospheres and slag. Material shrinkage increases with firing temperature, Figure 3.

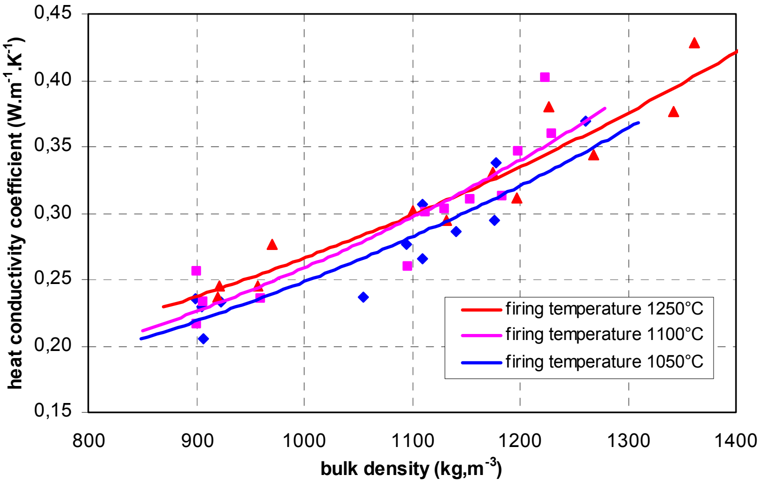

Figure 4. Effect of firing on heat conductivity

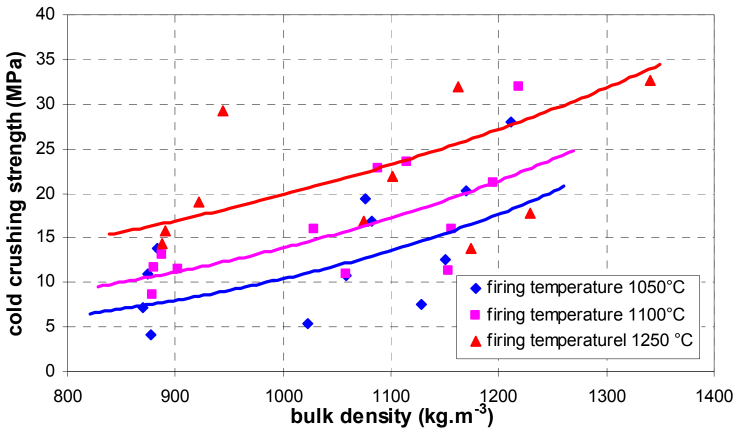

Figure 5. Effect of firing on strength

Coefficient of heat conductivity λ is very important characteristics of heat insulating shaped bricks. As you can see on the following figure (Figure 4), the influence of firing temperature on this characteristic is not significant, only direct dependence between bulk density and heat conductivity which is generally known

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was confirmed. Values of coefficient of heat conductivity were in a range from 0.2 to 0.43 $W.m^{-1}.K^{-1}$.
Strength in pressure is a decisive criterion for light-weight insulating materials only if we want to use them as structural materials. Sufficient handling strength was confirmed for all the testing samples (Figure 5).

Bulk density of the samples prepared according our designed material compositions ranged on the upper limit of bulk densites for heat insulating materials; value 1350 $kg.m^{-3}$ cannot practically be reckoned for heat insulating material but structural insulating material.

With respect to low values of overall linear material shrinkage (3% on the average), it is possible to produce shaped bricks with sufficient accuracy even without consequent calibration which reduces production cost of the material. Material costs are lower as well – use of waste product in a material composition, and negligible is not financial savings during drying of shaped bricks, either.

Study has unambiguously approved that it is possible to produce insulating fire brick on basis of waste products from crumbs and that characteristics of such a material are comparable with the material which is industrially produced and supplied to domestic market.

3. USE OF COMPUTATIONAL ENGINEERING FOR PROCESSING OF LARGE AMOUNT OF MEASURED VALUES

3.1. Microsoft Excel

Big advantage during analysis of measured values is using table editor Excel which is very obviously used at present. This programme enables quick data processing; its output may be various types of graphs. However, if volume of measured values is too large, the work with editor Microsoft Excel does not provide an easy survey that leads to unnecessary mistakes during result processing.

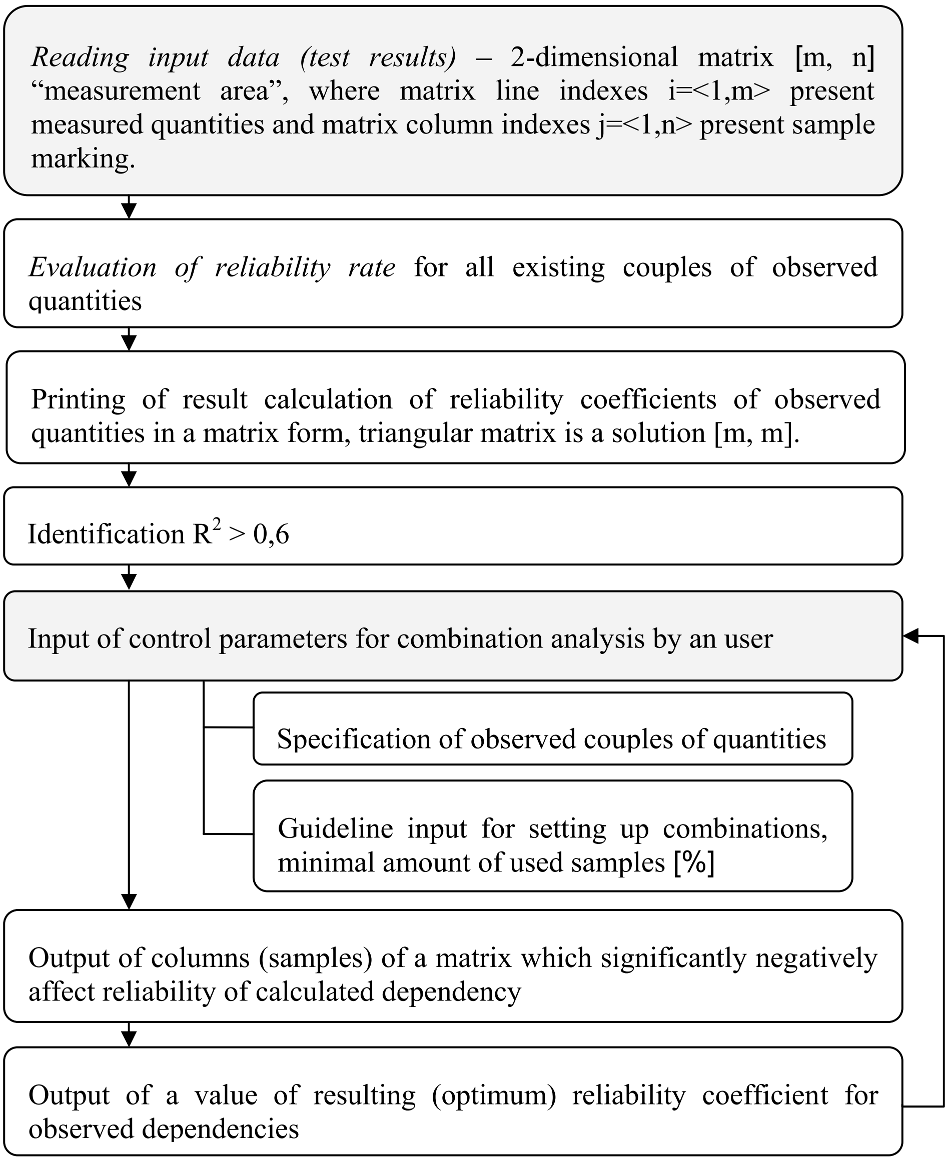
3.2. Reasons and goals of VB software

Very frequent operation carried out during evaluation of measurement results is finding out the dependence rate of observed (measured) quantities. The dependence rate is being expressed by reliability coefficient R^2 ranging within the interval <0,1>.

In case that reliability coefficient has been assessed for all observed samples, this value will be surely much lower than if it was assessed only for selected samples;

minimum amount of chosen samples must be defined by user. For samples excluded from a selection, it is necessary to find the reason of their exclusion from an observed data file. Several basic cases may happen here:

- Bad sample preparation, technology failure, low-class sample
- Exceptionally good, quality sample
- Laboratory test carried out badly.



The outputs of software set up in VB are:

- Uniquely defined samples which significantly deviate from statistic file, a task for a user is to reversely find out why the given deviation happened.
- Graphically processed results for optimum combination of measured samples

3.2. Software algorithm for optimization of values of reliability coefficient

Detailed protocol about measurement history is carried out by a user during preparation of testing samples and during execution of laboratory tests. After result evaluation, a matrix [m,n] of a "measurement area" is set up which is further used by a programme.

The algorithm is shown above.

4. CONCLUSIONS

The results of carried out experimental work showed a possibility of using waste products in a material composition of heat insulating fire brick.

For processing of measured values, programme Microsoft Excel has been used, because it makes work with measured data easier. All existing dependencies of measured values on all the testing bodies were tested; the number of testing samples has not been optimized due to large volume of measured samples. The output of software suggested by us is graphical dependencies with coefficient value higher than 0.6, some of which are mentioned in the article.

Optimization of number of samples included in calculated dependency and mostly determination of samples which does not comply with the given dependency, is important for user from the point of view of feedback on such an abnormality (substandard behaviour) of a defined sample for mistake removal in a technology of sample preparation or, on the contrary, for selection of convenient change (technology, raw material, etc.) leading to improve utilization properties of a material.

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