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ANCHOR SILICATE EXPANSION MATERIAL WITH INCREASED TEMPERATURE RESISTANCE

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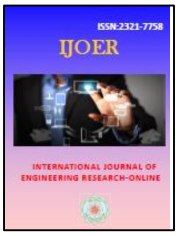

ABSTRACT

The existing research study dealt with the production of expansion anchoring product, which is designed primarily for the construction & energy industry, where the anchoring joint is exposed to operating conditions and higher temperatures. In order to meet the criteria for a strong and secure attachment of the anchored component, it is necessary for the designed material to attain excellent physico-mechanical properties, such as high compressive strength, high flexural tensile strength, tear resistance from the substrate and adequate heat resistance up to 200 ° C (for all of these parameters) associated with moderate expansion and volume stability after maturing. Due to the current trend of new, environmentally friendly fabrics, the use of alternate products as a replacement for the main binder is also part of the development process.

KEYWORDS: Expansion anchoring material, high strength, temperature resistance, volume changes of silicate materials, anchoring

Introduction

The anchoring area is a relatively large area, which deals with joining structures, respectively. Components or individual building elements. Anchoring principles are used in virtually any phase of construction work, from building a roof cladding to structures protruding from the cladding and railings. The function of the anchoring element is to transfer the load, which is either dynamic, static or a combination of the two previous ones, to the anchoring base, which can consist of a wide range of materials (concrete, ceramic masonry elements, etc.). It is also important whether it is a homogeneous material or a diverse composite, and no less important is whether it contains a cavity backing or a compact mass. Requirements for anchoring are derived from the assumed location and method of use. Consequently, according to the specified requirements are chosen anchoring technology, implementation and type of anchoring element.

Due to the extensive scope of the field, it is necessary to distinguish the anchoring elements into pre-built and additionally formed into finished building structures. Pre-built include, for example, concrete bolts and studs, HMS, HTU and ML profiles, anchor plates or HALFEN mounting profiles (for flexible screw connections and frame construction). This type of anchoring creates strong joints that are well resistant to dynamic stress. The main disadvantage is more demanding implementation, worse handling of elements and the necessity to ensure the correct position during the realization of the base in order to connect the anchored parts

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accurately. Only basic information about pre-built anchors will be presented, as this work deals with anchoring to finished building constructions specifically on a silicate basis.

The expansion capacity of anchors and their volume stability are very important especially under non-standard conditions of anchor exposure, when other types of stress, such as cyclic action of elevated temperatures, are also applied to the mechanical stress type. These are relatively specific stress conditions for which there are virtually no adequate products on the market (in the field of silicate materials)[2], as shown in the current work. Consequently, there is a need for extensive research on this topic, which is further addressed in this paper.

Types of Chemical & Flooring Anchors

Chemical and grout anchors are characterized mainly by high load-bearing capacity of the formed joint in comparison with conventional dowels. Their disadvantage is, of course, the cost, more laborious joint formation, the requirements for creating a hole and achieving the required load capacity after a certain time. Therefore, chemical anchoring finds its application especially where high to extreme demands are placed on the strength of the joint and the price of such a joint does not play a decisive role[1].

Silicate Anchoring Materials: Here we distinguish mainly two types of anchors, namely on a pure cement basis, which are widely represented on the market or on a polymer-cement basis, this type is not as common as the previous one, but achieves slightly different properties and is a more expensive variant. Products already available on the polymer-cement base market include Groutex Fill-Inn, Roko Liquid R and Monocrete ARG TH[2].

Polymer cement Anchoring Materials: The use of polymer dispersions as an additive modifying certain properties in polymer cement mortars, concretes and grouts has increased rapidly in recent years. They are most often used in remediation materials, upper bridge layers and floor materials. These materials are prepared by adding the latex or powder polymer to the fresh mass while mixing.

The latex-polymer is in the form of an aqueous dispersion which is added to the mixing water. Polymers supplied in the form of latex are distinguished into[3]:

- Elastomers - Styrene-butadiene, chloroprene, acrylonitrile-butadiene
- Thermoplastics - Acrylic, Styrene-Acrylic, Vinyl Acetate, Ethylene-Vinyl Acetate, etc.

Expansion and expansion reagents of silicate materials

In the course of the development and research of cementitious building materials, relatively considerable efforts have been made to suppress shrinkage, which has caused considerable problems, in particular for massive and transport structures. Most expansion reactions and processes have been relatively well studied and described. All anti-shrinkage additives which are based on self-expansion shrinkage compensation differ only in the amount of active substance from the expansion additives.

Mailvaganam [4] specified the following basic classes of expansion causing impurities:

- Additives that cause expansion during solidification of cementitious materials. These are most often materials that generate gas during solidification. Additives that reduce shrinkage by self-expansion during both solidification and maturing of cementitious materials. These mostly consist of calcium-sulphide-aluminum and limestone materials. These are mainly the same materials used to modify cement.

Kovler and Zhutovsy[5], who also studied the study of expansion additives, recommend mixing admixtures with belitic cements and low reaction heat cements, since generally better expansion results are obtained.

Temperature Resistance of Silicate Materials

The most important factors affecting the strength of joints of chemically bonded anchors have been described in the previous part of the study. However, with regard to the topic of this work, it is necessary to mention the influence of

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elevated temperature on the properties of silicate materials such as concrete, cementitious grouts, pastes, mortars and others.

Silicate materials used in the construction industry are composite materials, where their composition and properties of individual components primarily affect the behavior of the composite during heating. However, it cannot be unequivocally stated how the composite will behave at elevated temperature when the properties of the individual components are known. Other factors, such as the initial moisture content of the system and the ratio of components, also play a major role. Another factor that can cause degradation of these composites is the different thermal expansion between the cement putty and the aggregate used. Aggregates usually occupy 50 - 80% of the volume. In addition to thermal expansion, it is also necessary to mention the porosity of the aggregate, where the porosity of the aggregate, depending on the particle size, permeability and moisture content, may be susceptible to expansion leading to separation of individual grains from cement cement[6]. This is primarily the case with porous aggregates, and there is no risk of this problem with dense aggregates with minimal porosity and low humidity.

Mineralogy of aggregates is also important with regard to the heat resistance of silicate building materials. For example, the most commonly used aggregate in cementitious composites - quartz, which undergoes a crystalline conversion (from cruciform / trigonal α - quartz quartz / hexagonal β - quartz) to 573°C, resulting in an approximately 6% increase in volume. Non-siliceous commonly used aggregates show higher heat resistance, mostly stable up to 600 ° C. This is due to the increased capacity. At temperatures above 600 ° C, calcium, magnesium and dolomitic aggregates decompose into CaO and MgO with simultaneous endothermic CO_2 leakage. Khoury[7] stated that the thermal stability of the aggregate increases according to the following order: siliceous gravel, limestone, basalt and expanded aggregate. He further stated that the expansion of cracking of gravel sands occurs already at 350 ° C, for limestone and basalt up to 600 ° C and the lightweight aggregate is stable even at 600 ° C.

Review of literature

CSA additives and CaO are added in small batches mainly to reduce shrinkage, larger batches are used for expansion masses and especially for chemical prestressing of reinforcement. The most common type of one-component additive is a blend consisting of 30% (C4A3S), 50% CaSO4 and 20% CaO, or may contain a low proportion of the glass phase. The particles tend to be larger than the cement particles.

According to Wakeley[8], the above-mentioned expansion processes practically do not occur in saturated salt concretes. It has also been shown that the use of sodium citrates under specific maturation conditions results in considerable expansion attributable to the delayed formation of ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$).

Nagataki and Gomi[9] report that any use of an expansion additive reduces mechanical strength. Sousa Ribeiro also came to the same conclusion.

In spite of all the constraints and fear of over-expansion, expansive admixtures are not widely used, but are still widely used in grout and repair mortars, or in demolition or chemical pre-stressing of reinforcement.

Objectives of the Present Study

- The aim of the present work is research and development of expansion anchoring material, which is designed mainly for industrial operations (eg engineering and power engineering), where the operating conditions imply unfavourable thermal stress on the anchor joint.
- In order to meet the prerequisites for establishing a strong and safe structural connection of the anchored part, it is necessary that the developed material achieves excellent physico-mechanical properties such as sufficient compressive strength, flexural tensile strength (corresponding to or exceeding the anchoring base) ,
- Tear resistance and showed expansion and volume stability after maturing. The

intention, which will be emphasized greatly, is to ensure the above parameters even during shock temperature stresses with a maximum temperature of 200 ° C.

- It is also intended to use alternative raw materials to modify the matrix composition of the material being developed. This is mainly due to the economic and environmental aspects, which are currently under pressure to use environmentally friendly materials.
- Last but not least, with regard to the partial objectives of the research work, emphasis will be placed on the evaluation of the achieved outputs in terms of practical use of the developed mass and recommendations for possible follow-up research.

Experimental

With regard to the scope of the work, the methodology is divided into following stages

The first stage deals with the selection of suitable raw materials and the design of primary formulas for expansion anchors. Attention is focused on natural materials from both primary sources and alternative components (especially matrix modifications). Among other things, the raw materials were selected on the basis of previous studies focused on a similar issue.

In the second stage, the properties of the initial recipe are verified. Tests were performed to assess the effect of binder amount, expansion additive, filler and CNT reinforcement on mass properties. The development of strength over time and the influence of temperature on the tested parameters were monitored and evaluated. At the end of this stage, a partial evaluation and modification of the formulation of the recipe was carried out in relation to the results of tests performed in this stage with the aim of achieving the required properties of the developed mass.

In stage 3, the properties of modified recipes similar to those in stage 2 were verified and subsequently the technological properties of the material were tested and the material was evaluated from a practical point of view and its use. Among these tests were included especially the test of pulling out of heat-exposed and unexposed anchors and their subsequent analysis by computer (X-ray) tomography.

In the last fourth stage, the final properties of the final recipes are evaluated, both mechanical, utility and technological, incl. recommendations for possible follow-up research.

Step-1 - Selection of Raw Materials and Design of Recipes

The aim of this stage is to use relevant knowledge from previous research and scientific studies to select potentially suitable raw materials, such as suitable binder, filler, additives, admixtures, expansion and diffusion reinforcement. This stage also includes the selection and verification of the amount of the main constituents of the mass, such as the amount of binder, the dose of expansion additives, the amount of admixtures (based on alternative raw materials) and, where appropriate, the use of CNT as Nano finishing. A partial goal of the solution of the last part of this stage was the design of the initial recipe, which is subjected to further testing in subsequent stages and subsequently modified in the following stages so as to achieve controlled and as efficient as possible optimizing its properties with regard to the type of mass being developed. The detailed structure of the contents of the Stage I solution focused on the choice of raw materials and the recipe (Figure -1).

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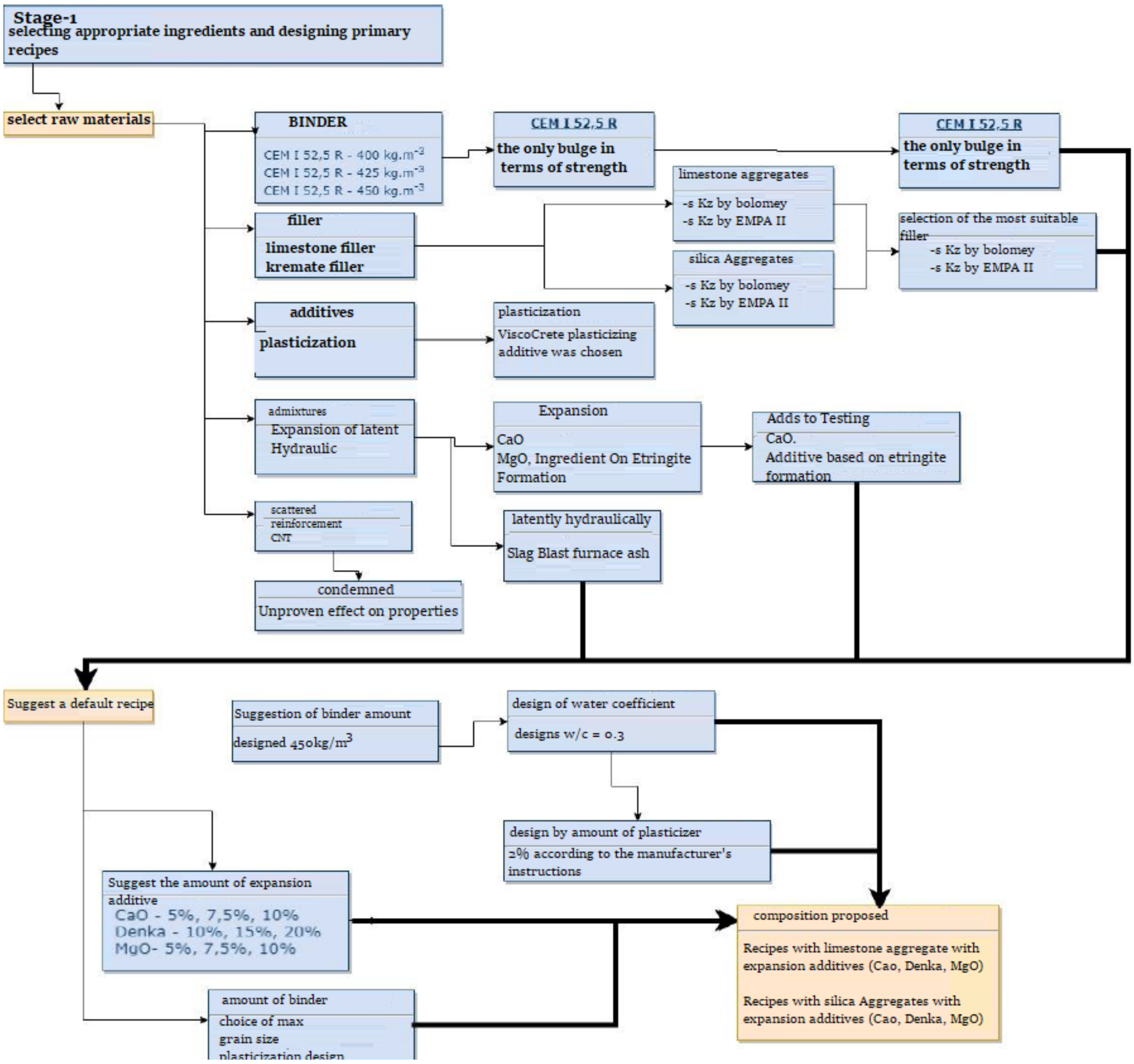

Figure -1: scheme of the first stage

Step-2- ANALYSIS OF PROPERTIES OF DEFAULT RECEPTURES

At this stage, the influence of the individual components of the proposed recipes was thoroughly verified under laboratory conditions. The influence of binder, filler, expansion additives as well as carbon nanotubes (CNT) as a matrix reinforcement element was systematically assessed. The verification was carried out in the form of testing of essential parameters, the implementation of which was chosen on the basis of the required properties of the developed mass and taking into account the previous outputs. Specifically, they are strength characteristics, bulk density, volume changes and temperature resistance. At this stage, the above tests were also evaluated and, in the case of unsatisfactory properties, a modification of the starting formulas was proposed and the above-mentioned essential parameters were re-assessed. A detailed structure of the contents of the Stage II solution focused on the analysis of the properties of the starting formulas is shown in the following diagram (Figure 2).

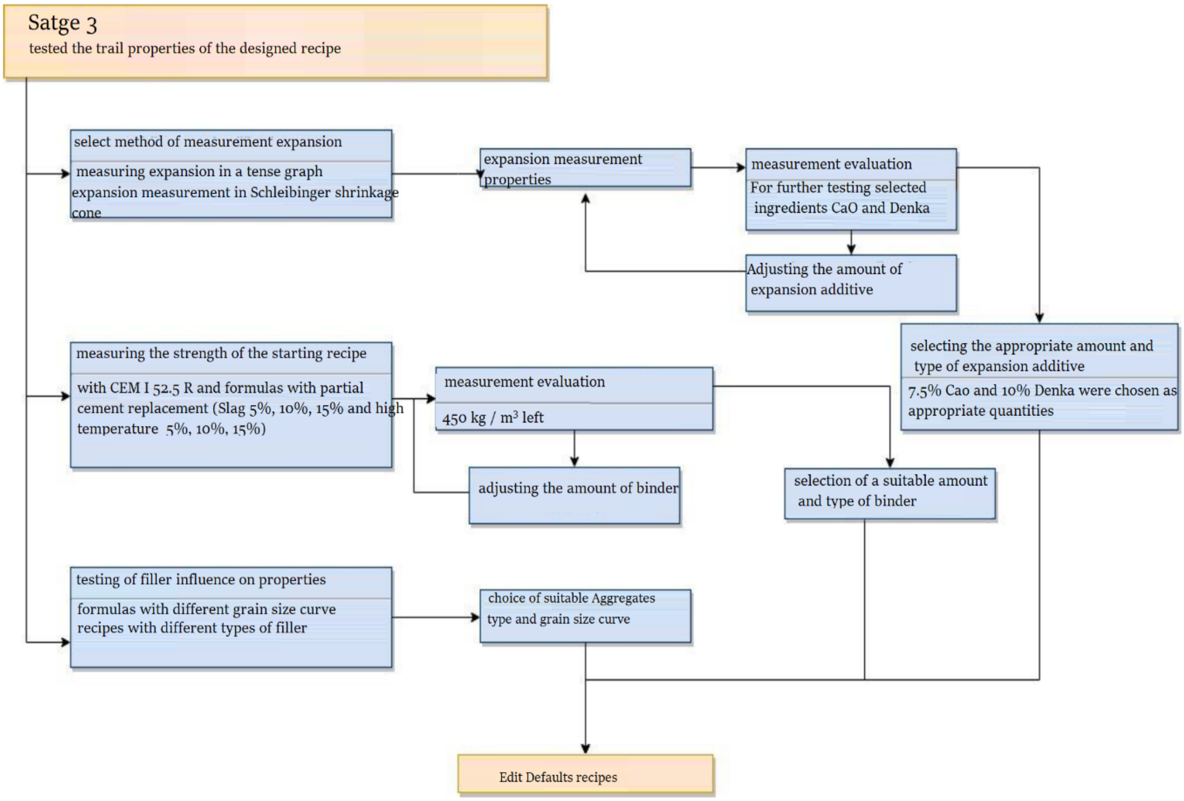

Figure 2: scheme of the second stage

Step-3- Testing Optimal Recipes

This stage emphasizes the assessment of the suitability of the modified formulas with the expected high potential for commercial use. Specifically, these are tests that are particularly important with regard to the practical application of the mass and in order to further adjust the composition of the expansion anchor mass so that it is both optimal and economical in terms of optimal mass. . At the end of this stage, a proposal for final captures or even minor modifications of the composition is made with regard to the evaluation of the tests. Detailed structure of the content of the Stage III solution aimed at testing modified, respectively. Optimal formulas are shown in the following diagram (see Figure 18).

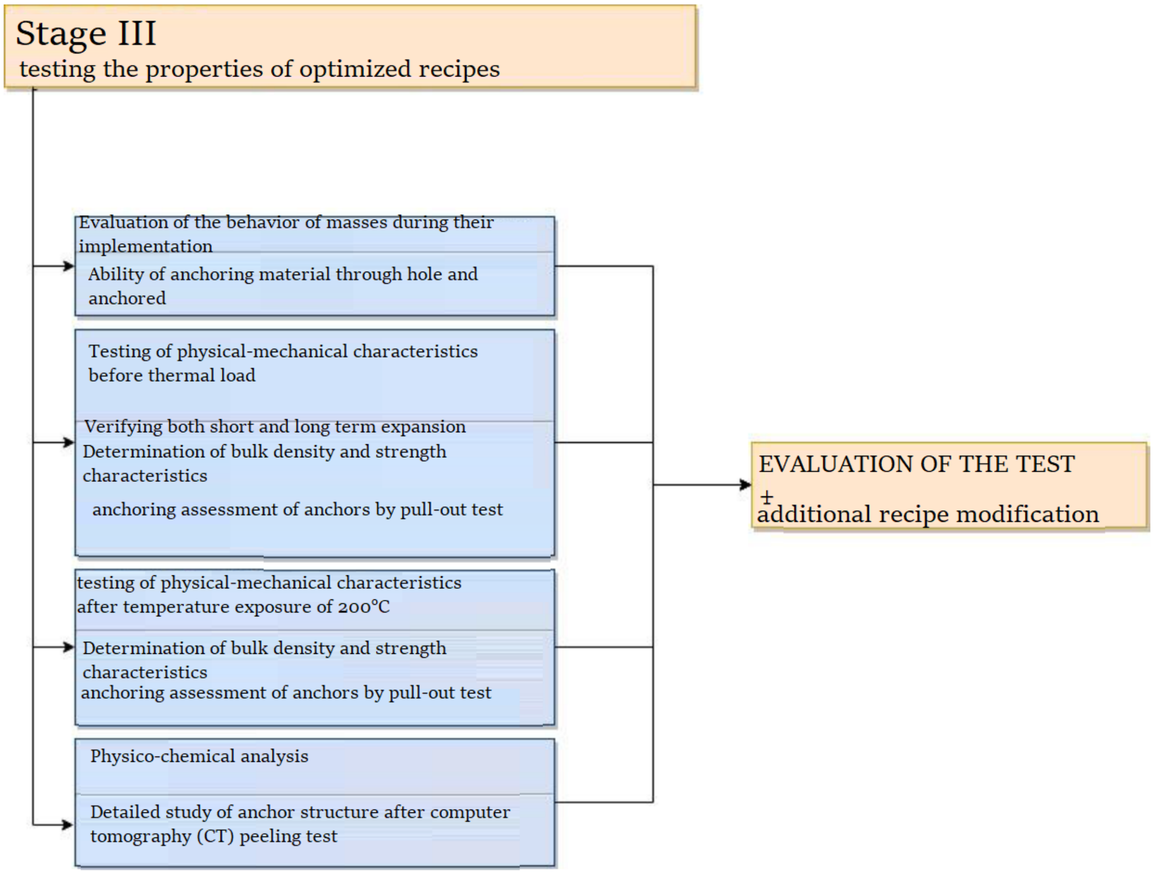

Figure 3: scheme of the third stage

Step -4-Evaluation of Results

The last stage contains a comprehensive evaluation of the results from various points of view, essential with regard to the commercial use of the developed market material as well as any follow-up research. All significant properties (mechanical, technological, utility) were evaluated, including an orientation evaluation of the potential application of the developed material to the building materials for specific applications. The structure of the Stage IV solution focused on the evaluation of results is shown in the following diagram (see Figure 4)

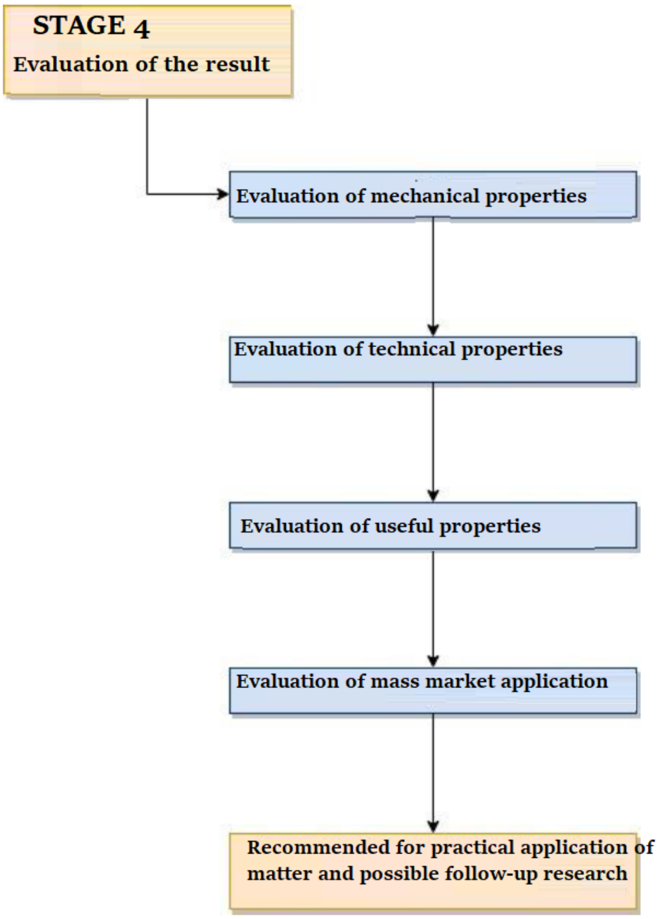

Figure 4: scheme of the fourth stage

Results and Discussion

In terms of partial links to the results and findings of the research work[2], including the findings, both primary and alternative components were selected, from which several initial formulas of anchoring materials were compiled.

- The starting formulas were subsequently tested with a separate focus on the individual components, i.e matrices, fillers, expansion additives and reinforcement. The basic tests were performed by verifying the bulk density and strength characteristics at different ages (2 and 28 days) as well as the temperature load (200 ° C) of the masses being developed. Furthermore, the emphasis was put on the expansion capacity of the developed mass in early age and in longer time intervals.
- In order to verify the ideal amount of binder, 3 formulas were tested with a binder content of 400, 425 and 450 kg/m^3. All test results were in line with expectations. According to the invention, the bulk density, the compressive strength and the flexural strength increase with increasing cement recipe. The highest strength was achieved by the recipe CE-3, which contained 450 kg.m-3 of cement. It reached a compressive strength of 62.0 / 55.1 MPa after 28 days of maturation and a flexural tensile of 6.0 / 5.6 MPa after 28 days. Since the second highest value of compressive strength was just above 50 MPa after the thermal load, the recipe CE - 3 was chosen for further testing.

- When evaluating the effect of substitution of the binder component with secondary raw materials, CEM I was replaced by 52.5 R with cinder and fly ash in the amount of 5, 10 and 15%. The highest density was achieved by the recipe CE-3, the reference. All other formulas with a binder component substitution achieved lower bulk weights, with the binder substitutes showing a lower bulk density than fly ash.
- Compressive strength was reduced by the use of fly ash or cinder, especially after 2 days of maturation, when the difference in strength reached almost 10 - 20 MPa. This is mainly due to the slower hydration and reaction of secondary raw materials in the formation of C-S-H gel. When comparing the two substitutes, the crease-containing formulations showed a lower decrease in compressive strength. As for the amount of substitution, the increasing content of the substitution component resulted in a more marked decrease in strength and a gradual increase in compressive strength.
- The flexural tensile strength copied the results of the compressive strengths, when again the formula reached the highest values without binder replacement. With the difference that smaller decreases in flexural tensile strengths were found in fly ash-containing formulas, which is the opposite of compressive strengths.
- In testing the effect of the expansion additive on the properties of the initial formulation, it was investigated how much this additive would affect the strength of the initial formulation and how it would affect the volume changes. CaO, MgO and Denka were chosen as expansion additives.
- The volumetric weights of the formulas with the expansion additive ranged from 2470 to 2670 kg/m^3, except for the formulas containing Denka, values of approximately 200 kg.m-3 were measured here. The highest values reached the clarecepture containing MgO. The temperature-loaded samples showed a decrease of up to 3.8% compared to the unloaded samples in both cases, after 2 and 28 days maturation.
- Compressive strengths, the best results were achieved with formulas with MgO expansion additive, while the lowest strengths were achieved with formulas containing Denka. As the proportion of expansion additive increased, the strengths decreased. The only two formulas that did not exceed 50 MPa were those with 10% CaO and 15% Denky.
- The highest flexural tensile strengths were obtained with recipe samples with 7.5% CaO, followed by recipe samples with 5% MgO and 5% CaO. The lowest value was achieved by the formula with 15% Denky, which corresponds to the results of compressive strength.
- The highest expansion values were shown by the recipe with 15% Denky, which expanded immediately after mixing and after about 180 minutes reached the peak and then contracted to half the volume change achieved at the peak of expansion. Furthermore, the recipe with 20% Denky, 10 and 7.5% CaO achieved good expansions. Materials with 10% Denky and 5% CaO also showed expansion, but always showed a negative volume change at some stage of maturation compared to the original volume. Other recipes did not expand at all.
- When evaluating the influence of aggregate type and grain size curve on the mass properties, results were obtained which confirmed that the best filler is the Bolomey grain size limestone, as these samples showed the highest bulk density, with the highest compressive and flexural strengths.
- Formulations containing expansion ingredients, however, showed relatively lower the influence of CNT fibers on the properties of the mass had the only result:

an increase in flexural tensile strength, which was not essential. Other strengths or other properties were not particularly affected and therefore its use appears to be uneconomical due to the cost of this component and as a further considerable disadvantage is the significantly more complicated use of nanofibres.

- The evaluation of the results of the starting formulas allowed for suitable modification of the recipes and thus, for example, formulas or components that did not meet strength requirements or did not achieve adequate expansions were eliminated. The properties described below were found in these tests.
- The bulk weights of the tested recipes ranged from 2520 kg.m-3 to 2640 kg.m-3 after 28 days. After thermal exposure, there was a weight loss of 0.4% to 1.2%, probably due to evaporation of free water from the matrix. From the results it is not possible to observe the influence of the expansion additive or the binder substitution with the results of the density.
- The highest compressive strength among the modified formulations reached the CE-3 / S05 / C7.5 recycled rate of 60.2 / 57.6 MPa after 28 days. The second highest compressive strength after 28 days was achieved by the recipe CE- / P05 / C7,5, namely 56.6 / 55.4 MPa.
- The values of flexural tensile strength follow the results of pressure tests. CE-3 / S05 / C7,5 reached the highest values and CE-3 / P05 / C7,5 reached the second highest values. 6%, for other recipes with binder substitutes a decrease of up to 3.5% was achieved.
- Expansion of the masses with partial replacement of the binder component during the first 24 hours measured in the Schleibinger cone, when the expansion additive showed effect immediately after mixing and compared to the original volume, none of the tested masses showed shrinkage. The highest values of the CE-3 / S05 / C7,5 mass, namely 0.138 ‰, the lowest values (0.095 ‰) of the expanded mass reached the CE-3 / P10 / C7.5 mass and showed a partial shrinkage after the initial volume growth. Compared to the formulation without partial replacement of the binder component, there was a slight decrease in the final expansion after 24 hours. This is attributed to the reaction of CaO with amorphous SiO_2 together with water; The origin of amorphous SiO_2 is probably a cement replacement itself.
- The best expansions in the 168-hour horizon were achieved with cinder-containing formulas and, unlike fly ash containing materials, did not exhibit additional shrinkage. The fly ash used to replace the binder component had some influence on the expansion properties of the mass. The volume changes of these formulas did not show a constant expansion. Despite a partial decrease in volume changes compared to the formulas without partial replacement of the binder, the masses showed sufficient expansion. The Oslavan cinder appears to be the better of the two-admixtures, which practically does not show any negative influence on the course of expansions. This value did not exceed 0.5 mm in any case. Compared to fly ash-containing formulas, the difference in values over cinder samples is greater by approximately 0.1 mm when the anchor is loaded with 75kN.
- CT analysis revealed the most common types of failure and the results show that the most frequent failure occurs in formulations containing cinder in the anchor and in the base material, cracks appeared from the base material. In addition, with fly ash containing materials, the formation of cracks through both contact zones was caused by the base material - the anchor mass and the anchor mass - the steel element. From the obtained knowledge it is possible to state

that both materials are able to fill the space and safely anchor the threaded rod, which was used for the test according to EN1881 standard with starting material. It is also important to note that 5% of the binder will save 25 kg of cement per 1 m3, and 10% will replace up to 45 kg of cement per 1 m^3 while maintaining the paint strengths of the required values. , when a positive effect on maturation strength characteristics as well as during volume changes of anchor mass, which showed better compatibility with the expansion component than in the case of high temperature fly ash. And in view of the improved properties of slag-containing materials and the absence of slag utilization in anchorage-expansion materials and in general in building materials (ie the environmental aspect), this component appears to be a raw material with a higher potential for use.

Conclusion

The aim of the current research work was to design and experimentally verify properties anchoring silicate expansion material with increased temperature resistance. The developed material should withstand extreme loads. The requirements for the properties of the developed material were determined by the minimum compressive strength (min. 50 MPa), temperature resistance (up to 200 ° C) and other parameters in accordance with the relevant technical standards. The requirements for the targeted properties of the developed mass corresponded to the real conditions of the industrial operations where the mass is intended. The use of anchoring material should be primarily used for the fixation of large industrial equipment in concrete floors, where at the same time higher temperatures are reached under operating conditions. In optimized recipes, finely ground slag (surface area approx. 390 m^2 / kg) from Oslavany and high-temperature fly ash from the local Power Plant were used as an alternative component for cement substitution.

Despite the achievement of all the goals of the research work and the development of the final formula of anchoring material it is evident that with regard to the complexity of the problem of silicate anchoring materials exhibiting expansion and at the same time temperature resistance there is still room for possible follow-up research. In particular, it would be very interesting and beneficial to verify all the above assessed parameters of optimized anchors in the longer term, ie strength characteristics, volume changes, temperature resistance and resistance of the anchor to pulling off the substrate, eg at the age of 3, 6 and 12 months. Alternatively, it seems interesting to test the resistance of the material to adverse environments including eg aggressive substances, eventually changes in humidity (ambient and the substrate itself), and also to determine the degree of hydration of CaO and its possible binding to hydration products due to the possibility of additional volume changes.

References

1 DEN BRAVEN A.S., Styrene-free Chemical Anchor Vinylester SF. Technical sheet07.51 [online]. Available from: http: //www.denbraven.cz/dokument-produkt/19/en-tl -07-51-rev8-chemicka-kotvavinylester-sf-rl.pdf

2 MÜLLER, J., Development of silicate-based anchor expansion material with heat resistance. Brno, 2016. 85 p., 0 p. Bachelor thesis. Brno University of Technology, Faculty of Civil Engineering, Institute of Technology of Building Materials and Components. Thesis supervisor prof. Ing. Rostislav Drochytka, CSc

3 RAMAKRISHNAN, V. 1992. *Latex-modified concretes and mortars*, Transportation Research

4 MAILVAGANAM, N. P. (1995). Miscellaneous Admixtures. In V. S. Ramachandran (Ed.), Concrete Admixtures Handbook - Properties, Science, and Technology: William Andrew Publishing/Noyes

5 KOVLER, K., ZHUTOVSKY, S. (2006). Overview and future trends of shrinkage research. Materials and Structures/Materiaux et Constructions, 39(293).

6 NAUS, D.J. (2005) The effect of elevated temperature on concrete materials and structures-a literature review, Technical report, Oak Ridge National Laboratory, Oak Ridge, Tennessee

7 KHUORY, G.A., GRANGER, B.N., SULLIVAN, P.J.E., (1985) Transient thermal strain of concrete: literature review, conditions within specimen and behaviour of individual constituents, Magazine of Concrete Research, Vol. 37, No. 132
8 WAKELEY, L. D. (1987). Optimizing workability and expansion of a saltsaturated concrete. Cement and Concrete Research, 17(5)
9 NAGATAKI, S., GOMI, H. (1998). Expansive admixtures (mainly ettringite). Cement and Concrete Composites, 20(2-3).