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New Evaluation Methodology for Solidification Product Durability Assessment

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***Abstract*—**This paper deals with a proposal of a new methodology for durability assessment of solidification product for its safe further use. The new methodology is based on a review of the current state of assessment of treated waste in Czech Republic and abroad. The aim of the paper is to propose an optimal evaluation methodology for verifying properties of solidification product to ensure its safe further use in building industry.

***Keywords*—**Solidification/stabilization, durability, waste.

I. Introduction

PROBLEMS of waste production and subsequent disposal of waste are frequently discussed, as well as searching for new possibilities leading to minimization of waste production. The important group of waste, that has significant impact on the environment, is a group of hazardous wastes. The question of its safe deposition or successful disposal is worldwide very actual and new proper ways of its disposal in light of both economic and ecological point of view has been developed. One of the effective possibilities of its safe disposal is their solidification/stabilization (S/S) and results of different technologies are widely published in recent years [1]-[15].

The need to solve the issue of hazardous waste management in the Czech Republic results from the outputs of current statistics on the production of hazardous waste in the Czech Republic, when form the environment protection point of view there is very negative trend in the category of hazardous waste production. The waste production in the category of hazardous waste between years 2003 and 2009 had increasing tendency, in 2010 the production of hazardous waste decreased again, however, in 2011 there was again an increase in the production of hazardous waste about 3.2% comparing the year 2010 [16].

Another factor having a negative impact on the environment is the fact that the most common method of waste disposal in the Czech Republic - including hazardous waste - is currently being landfilling although there is general effort to reduce the total amount of waste sent to landfills strongly supported by waste legislation. In 2011 the landfilling of the wastes occupied 97% of different types of waste disposal.

But nowadays the waste disposal technologies are among the fastest growing branches of the Czech Republic national economy and the development of this area is mainly stimulated by the permanent increasing of environmental protection requirements.

The cement based S/S process is also one of the most progressive methods of physic-chemical treatment of waste that currently cannot otherwise be effectively used and that can significantly contribute to the effectiveness of the waste disposal. It is also the one of the most often used technologies for waste disposal around the world if we do not count landfilling. S/S processes are characterized by the decrease of the waste surface, but the content of hazardous substances remains. A barrier is being formed between the hazardous substances and surrounding environment and the contaminants are chemically bounded to the matrix consisting of organic or inorganic inert substances.

Since the cement based S/S process does not reduce the amount of pollutants contained in waste, but it rather creates the physical and chemical barriers that prevent these pollutants to from getting into the environment, it is necessary to examine the stability of the cement matrix with inbuilt waste.

II. Current Situation in the Czech Republic

A fundamental document in the field of waste management in Czech Republic is Government Regulation No. 197/2003 Coll., The Waste Management Plan which establishes basic principles and measures for all relevant aspects of this branch. In connection with the current trend, when efforts to prevent waste generation or its minimization are dominating, there are also set out some precautions to encourage changes in production processes and in this context it is also recommended to work out life cycle analysis of products, etc. Significant space in the Plan is also devoted to hazardous wastes - to the possibility of preventing their production as well as to the treatment with them.

Another important document overarching the field of waste management is the State Environmental Policy of the Czech Republic (SEP CR), which is based on fundamental precautions of The Waste Management Plan. The area of wastes falls under the Chapter "Sustainable Use of Natural Resources, Material Flows and Waste Management". The need to prevent the use of primary source material and vice

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versa to deal more effectively with secondary via their reuse is emphasized. In terms of European legislation a key document is the European Parliament and the Council Directive No. 2008/98/EC on waste, which specifies the requirements for waste management rather on a general level, a specific solution is always determined by national legislation. The implementation of these requirements of the European Directive was implemented through an amendment to Act No. 185/2001 Coll., on waste from year 2010; however, other amendments occurred in following years.

The trend of waste recovery is encouraged by the legislation as well. International law of EU and OECD countries respects the requirements of a large international market with secondary raw materials and it adapts gradually the mode of regulation, control and monitoring. Established modes are introduced for the Czech Republic as a member country of the OECD and EU and are regulated by the Act on Waste No. 185/2001 Coll.

Insufficient use of secondary raw materials and wastes in the Czech Republic in recent years primarily stems from the low price for waste disposal to landfill as compared with the costs of their recycling. However this price is now increasing every year and currently it moves around thousands of CZK for landfilling of one ton of hazardous waste and around hundreds of CZK for landfilling of one ton of other waste. The fee also needs to be paid by the waste producer even when he is a landfill operator and the landfill is placed at own land. The fee for hazardous waste landfilling consists of two constituent parts. The basic part is transferred to the account of the municipality in whose territory the landfill is placed on, then there is a „risk part“ of the fee which is the income of The State Environmental Fund of the Czech Republic (SEF). The rate of the risk part of the fee has increased in 2009 from 3300 CZK to 4500 CZK per ton. The Supreme Audit Office (SAO) the Czech Republic audited that the amount of deposited hazardous waste is increasing. The statutory rate of this fee is therefore now 6200 CZK per ton of deposited waste (including the basic parts and the risk part of the fee), with the fact that the landfill operator adds and charges his own part of the fee. Comparing the fee for hazardous waste landfilling in the Czech Republic with this fee in all other EU countries we find out that the fee is highest in the Czech Republic. In other countries the most expensive fees move up to around 1 600 CZK per ton (two other states of the EU), in other states are around 700 CZK.

Legislative requirements for treated waste including S/S products in the Czech Republic and abroad are mainly focused on the environmental protection. For this reason the leachability tests and ekotoxicity tests are considered to be the most important and from the results of these tests can be assessed if potentially hazardous substances were successfully fixed in a matrix of S/S product. In Czech legislation only conditions under which it is possible to use the waste on the surface are anchored. These requirements do not include the requirements for mechanical properties of S/S product. Unlike the Czech Republic, solidified waste is being further used in a much greater extent abroad (USA, UK) and therefore it is also needed to determine more in detail the possible side effects to the environment.

Valid Waste Act (185/2001 Coll.) in the Czech Republic prefers the material use of waste before the other methods of its disposal, but the society is not yet ready to accept this trend of further use of waste and therefore the legislation does not address enough this issue of screening properties of the treated wastes. Another reason why it is not considered as important to use treated wastes is sufficient primary raw material resources of Central Europe. The legislation of the Czech Republic does not include any mechanical and technological requirements for use of treated wastes on the surface, but it includes only the basic requirements regarding the impact on the environment. Therefore it is necessary to establish mandatory requirements for the entire European Union, which would have to drive all the Member States concerning the efficient use of wastes and the definition of funding for science and research necessary for improving technology for treating wastes.

The current Czech legislation is very weak from the perspective of further use of treated waste as well because the evaluation of the durability, which is not verified, but is very important for the further use of S/S product. Mainly for this reason – the lack of mechanical and technological requirements and durability verification - optimal methodology for evaluating the S/S product was designed on the basis of various tests those will ensure the attainment of quality S/S product that can be further used in building industry.

Fig. 1 summarizes the current insufficient legislative requirements on the environment, since it deal with wastes – only – but it is not specified what kind of waste is involved. With the tests laid down by Czech legislation long-term stability and durability of S/S product cannot be guaranteed, in fact it is not assured that S/S product will not have a negative impact on the environment during its further use.

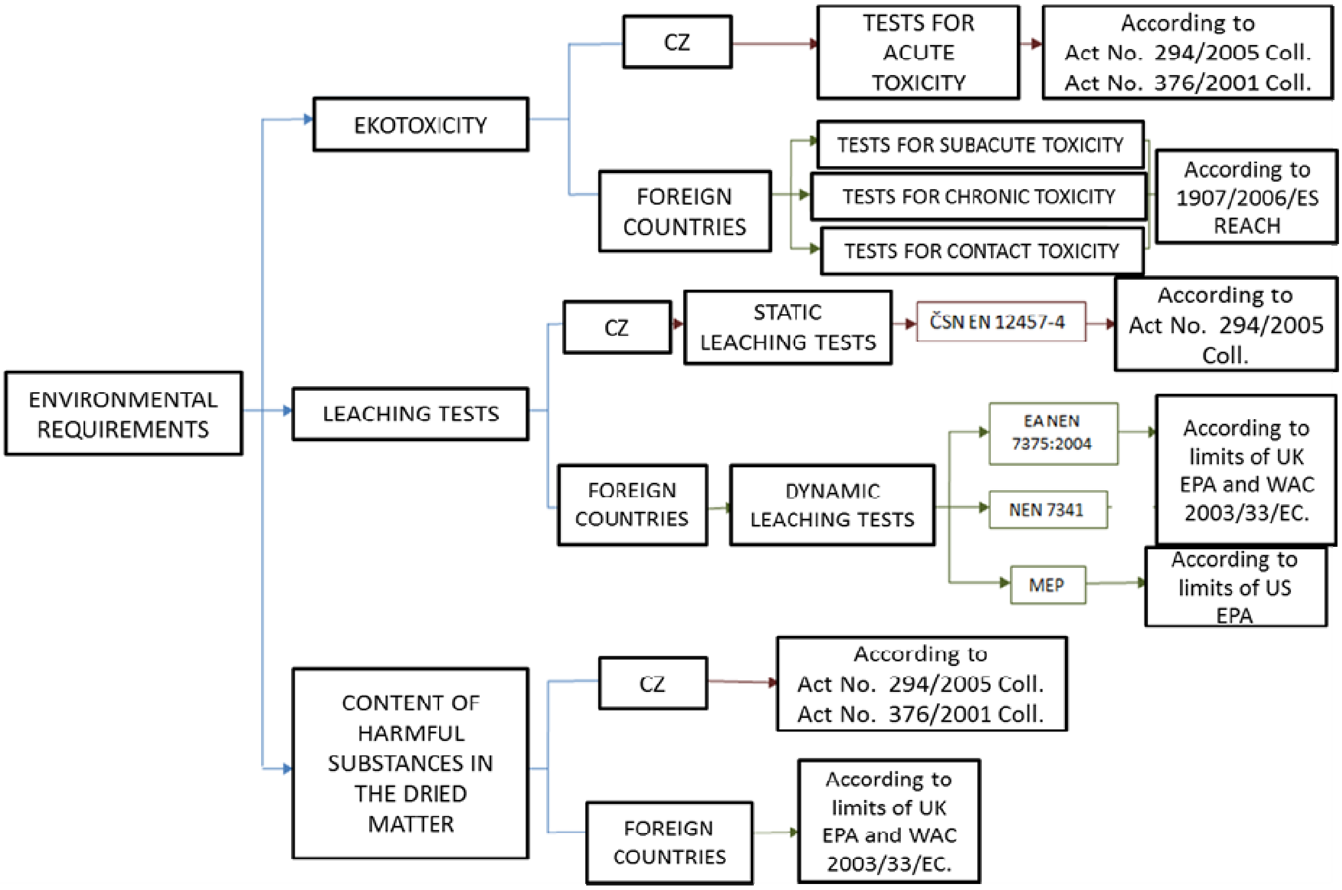

Fig. 1 Diagram of the current state of S/S product testing in terms of legislative requirements on the environment in the Czech Republic and abroad

III. Proposal of a New Evaluation Methodology

A very important characteristic of S/S product in terms of time is its durability. Determination of durability allows verifying the ability S/S product to resist changing of external influences such as wetting, drying and exposure to freezing temperatures.

If the waste treated by S/S technology meets the legislative requirements for the environment, it is necessary to find further possible use of this material, for example in the building industry. But it is necessary to set requirements that must the S/S product meet in terms of durability for its further safe and effective use. Testing the long-term durability of S/S products differs depending primarily on their final place of use and way of further use. However, it is necessary to take into account also these circumstances:

- The type of S/S technology that was used for treating the waste,
- The ratio of hazardous waste and used binder,
- The type of binder used,
- Amount and type of contaminants in HW (mineralogical and chemical composition of HW)
- The form of the final product.

While assessing the long-term durability it is also necessary to take into account whether the S/S product will be a part of some composite material where the synergistic effect can be applied, or its properties will be sufficient without further processing into another material. On Fig. 2 you can be seen the distribution of individual tests depending on the place of S/S processing.

In situ S/S is used primarily for the purpose of remediation of old contaminated sites. Among the most important tests that can be used to determine success of S/S and to estimate the long-term durability of solidificated product mainly include the determination of permeability, leachability, unconfined compressive strength (UCS) and the Acid-neutralizing capacity (ANC). Permeability tests, leachability tests and ANC determine the ability of solidified waste (contaminated soil) to prevent the release of hazardous substances into the environment, particularly into the groundwater. UCS is performed on drill cores, which should be performed at various time intervals from the beginning of in-situ S/S. S/S product should have adequate strength due to the transfer of load induced on the surface layer, the ability to withstand various shocks and above all to withstand pressures of surrounding soil or water. The most effective is to perform leaching tests and UCS tests on drill cores after 28 days, 90 days, 1 year , 2 years, 5 years, 10 years and 20 years to evaluate the long-term durability. The drill cores must be assessed also visually in terms of porosity, the number and size of cracks and overall assessment of degradation in certain time after remediation. In the case that HW (the contaminated soil) is mined and in the same place at the landfill treated by S/S technology and then S/S product is further used at the previous landfill site, then ex - situ testing according to Fig. 2 must be undertaken.

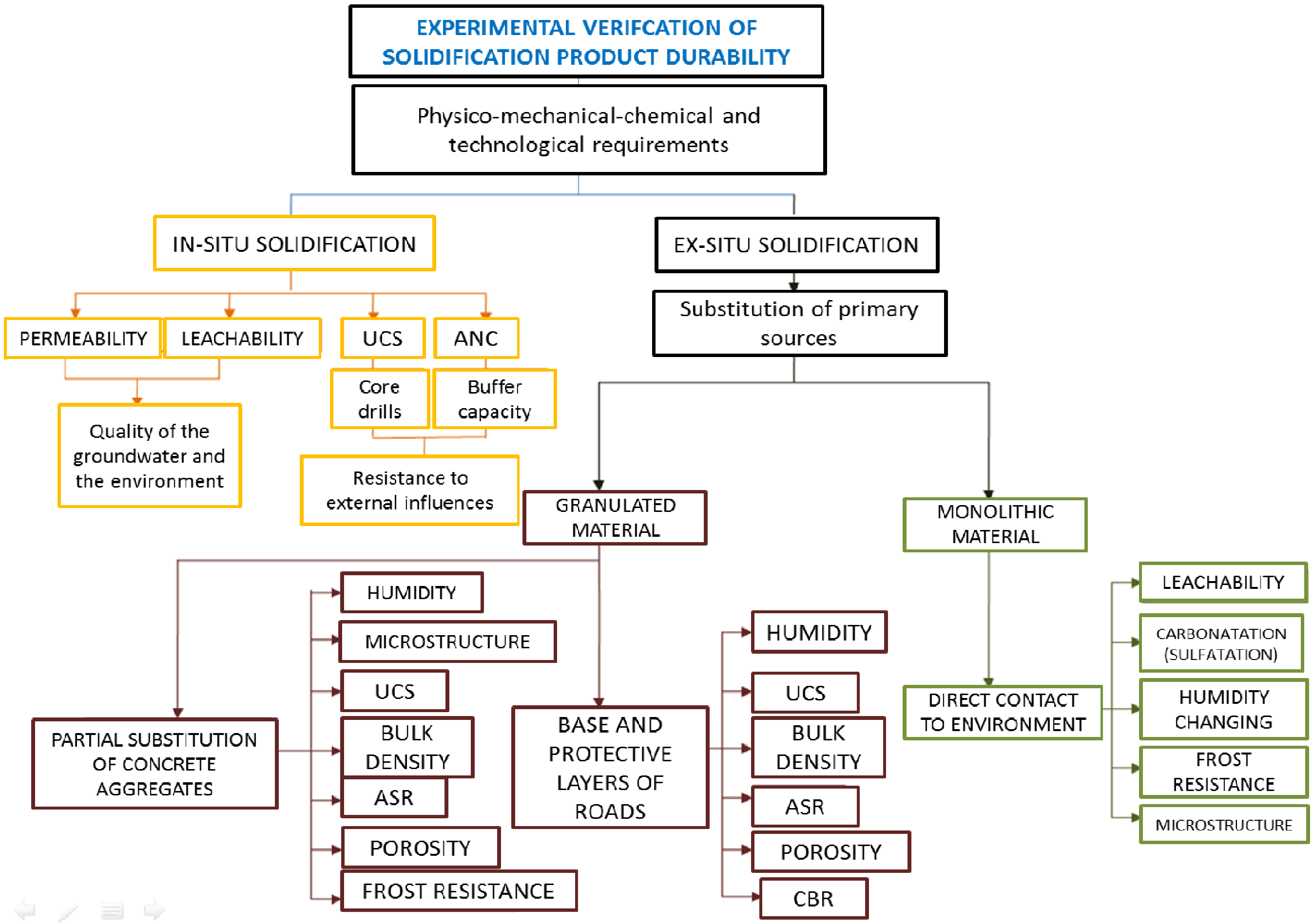

Fig. 2 New evaluation methodology for solidification product durability assessment

Ex situ S/S is being processed off the site of final placement of treated waste and it is usually done on S/S line. The most effective use of S/S product in granular form is either as a partial replacement of aggregates of lower strength classes of concrete or as a substitute material of currently used materials for the base and protective layers of roads. S/S products in form of granule are being used abroad as well as a substitute aggregate in the production of concrete paving. In this type of use must be the S/S product tested for long-term durability at least according to the tests referred to Fig. 2. As already has been stated, in the largest extent the solidified waste is used in construction engineering for road base layers. The granulated material is loosely deposited on the base layer (usually compacted soil), then it is evenly spreaded and compacted with the help of rollers. In this case, the S/S product must have some strength, which is a function of porosity and bulk density, then also it must have constant properties while changing the humidity and constant degree of compaction (CBR). If S/S product is used as a substitute for natural aggregates in aggregates bonded with cement, there cannot occur any alkali-silica reaction between the individual components.

Another possible solution is the use of S/S product in monolithic form. This kind of S/S product used in building industry is in the in a direct contact with the external environment, because it is not incorporated into any other material, as for example in their use as a substitute aggregates for concrete. Due to the direct contact of S/S product with the environment, more stringent requirements must be laid down on both the environment (higher risk of leaching pollutants) and the physico-mechanical properties (greater stress). In terms of long-term durability the most important properties for monolithic S/S product are frost resistance, resistance to humidity changing. The microstructure study using scanning electron microscopy and X-ray Diffraction can help to find out if the carbonatation or sulfatation occurs during time. The carbonatation has a positive effect on the fixation of some contaminants and it also increases the strength of S/S product, but with this process associated volume changes cannot be forgotten - they can become significant during carbonatation/sulfatation and they may result into unexpected cracking, which can cause intensive leaching of contaminants into the environment [17].

IV. Conclusion

On the basis of tests those can verify the impact of the S/S product use on the environment and they also enable the assessment of S/S product durability, the optimal testing methodology was proposed from the point of view of its further use in building industry. These physic-mechanical-chemical and technological requirements for solidified wastes are described on Fig. 2. It would be appropriate to include these requirements into Czech legislation in the near future to have an optimal way for assessing the S/S product suitability for its further effective use.

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