SIAL® : Geopolymer solidification technology approved by Czech/Slovak Nuclear Authority

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Abstract

Geopolymers are a class of inorganic polymer formed by the reaction between an alkaline solution and an aluminosilicate source. First discovered in Ukraine in the 1950's, today, geopolymers and SIAL® in particular have been noted as an immobilization product which shows potential for the treatment of a number of waste stream scenarios present in the Japanese market today.

The need for geopolymers

The Nuclear Power Plant A-1 located in Jaslovske Bohunice, Slovakia, was completed in 1972 and operated for 5 years until two accidents in 1976 and 1977. After the second accident in February 1977 (INES level 4), the Nuclear Power Plant was permanently shut down for decommissioning. Fuel assemblies and fuel cladding were damaged in the accidents and they led to significant contamination with strontium-90, caesium-137 and transuranic elements. As a consequence of the long-term corrosion of a barrier's material, highly contaminated sludge accumulated and could not be immobilized using conventional methods such as cementation or bitumen treatment due to the presence of radionuclides such as caesium-137. This challenge led to Amec Foster Wheeler developing the licensed geopolymer, SIAL®. Today, it is the most widely proven geopolymer used for on-site solidification of highly active materials such as sludge, resins, sorbents and organic liquids. It is licensed for use by both the Slovakian (ÚJD SR) and Czech Nuclear (SUJB) regulators.

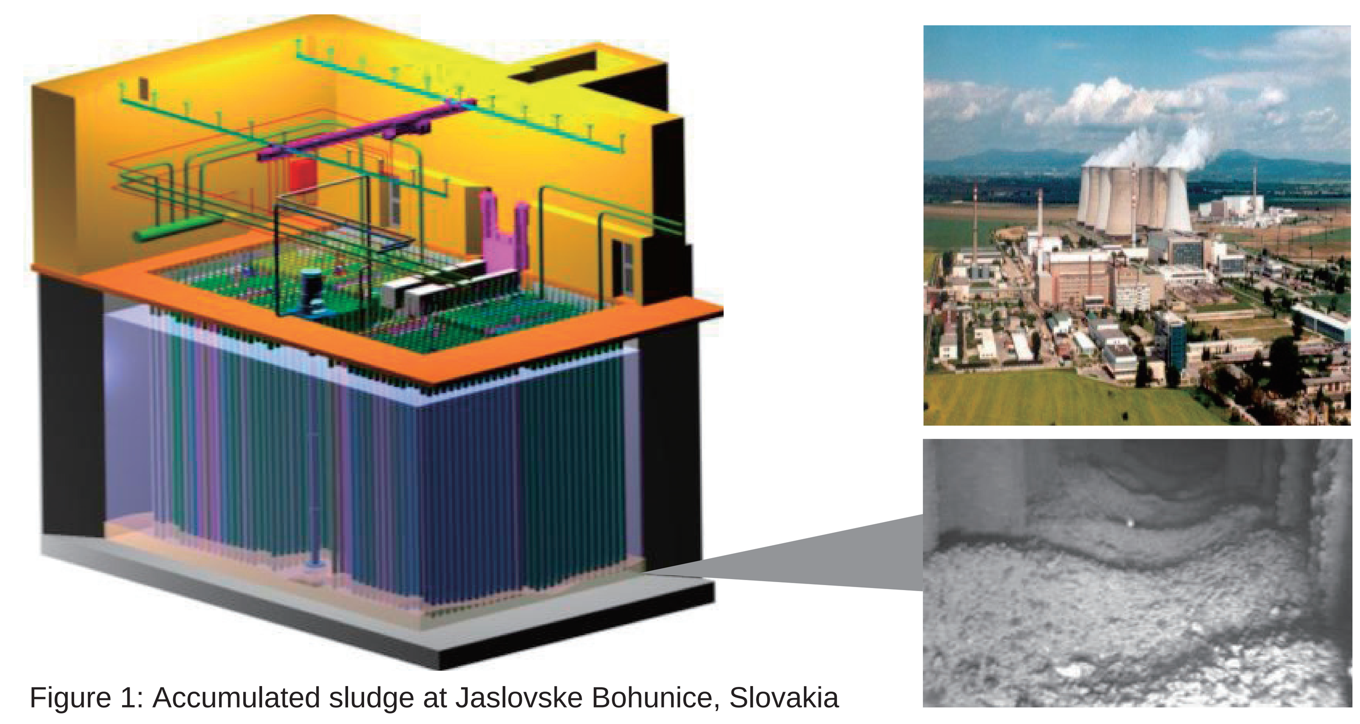

Figure 1: Accumulated sludge at Jaslovske Bohunice, Slovakia

The process

SIAL® can provide efficient and practical on-site treatment of radioactive waste streams at room temperature and can incorporate on average four times as much waste as a cement matrix equivalent. The equipment used to deploy SIAL® is also modular, flexible and versatile.
It can encapsulate waste quicker then cementation and can even set under water. In addition, it is characterized by having excellent mechanical and physical properties, compared with the earlier generation techniques. This includes higher mechanical strength, lower leachability, low volatility, a low fire risk and excellent physical stability in the presence of frost and water (no distortion or cracking).

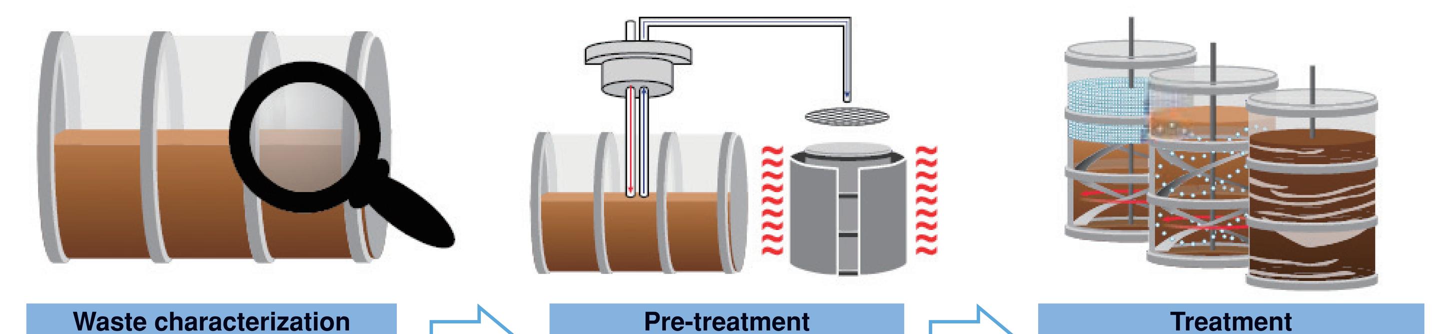

Figure 2: Solidification process

Case study: Jaslovske Bohunice, Slovakia

About 750m³ of radioactive waste (spent resins, sludge and borates) were stored in 14 tanks situated in an auxiliary building of NPP V1. The waste was characterized into two types—resins and crystalline sediment, and sludge. This comprehensive scope of work started with the licensing process and solidification, followed by decontamination and cleaning of the workplace, post-clean up and transportation of all equipment off site. The CEZ Company (waste producer in Czech Republic) also applied this year for extension of the approval for solidification of concentrates and crystalline borates.

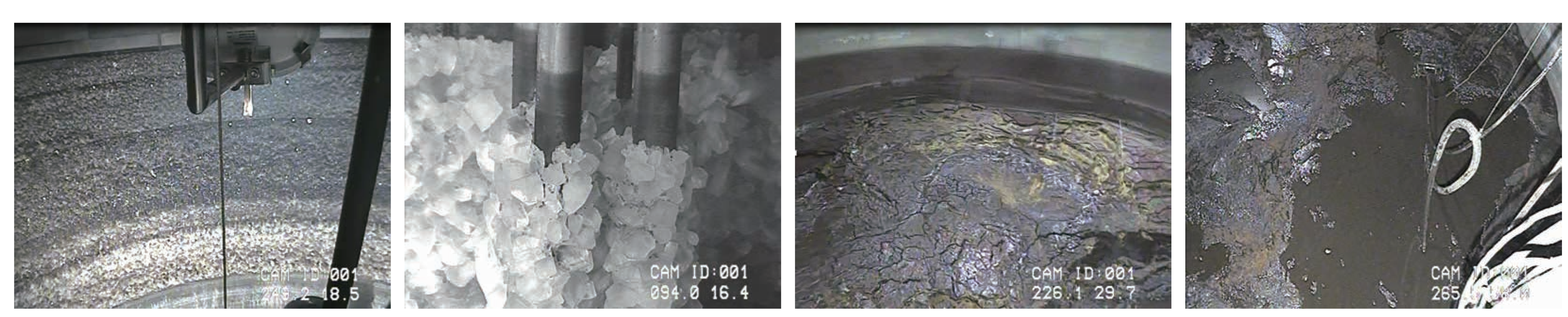

Figure 3: Condition of tank of NPP V1

Application to the Japanese market

Through the lifetime of both Japanese PWR and BWR nuclear reactors, waste with a high sodium sulphate content is produced and it must be solidified before being put in long-term storage. Cementation is the usual solidification approach for this type of waste but it can lead to a large expansion probably caused by the formation of ettringite. Ultimately, the swelling and cracking of the solidified product can lead to a deformation of the waste container itself, influencing its integrity for long-term storage.
In 2015, Amec Foster Wheeler in conjunction with Fuji Electric Co., Ltd. tested a method of sodium sulphate geopolymer encapsulation.
The study, which was reported in the 2015 AESJ fall meeting, concluded that the required performance parameters (e.g., leachability, compressive strength etc.) were comprehensively met.

Figure 4: Samples of sodium sulphate solidification

In 2015–2016, Amec Foster Wheeler in conjunction with Fuji Electric Co., Ltd. assessed ten Fukushima Daiichi waste streams to consider if geopolymer solidification could be applied. These are:

• Sludge (barium sulphate, ferrocyanide nickel, iron hydroxide)	• Ferrocyanide compound
• Slurry 1 (iron hydroxide slurry)	• Titanate
• Slurry 2 (carbonate slurry)	• Titan oxide
• Zeolite	• Chelating resin
• Silicon titanate	• Resin absorbent

Figure 5: Samples solidified with SIAL® geopolymer

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