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TERMIT's Circular Economy

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Abstract TERMIT d.d. is a mining company for the production and processing of silica sands and the production of auxiliary casting materials. In 2004 Termit decided to rehabilitate open pits with non-dangerous and inert waste, and started with processing this waste into artificial soil Tersan. At the moment 10 different construction composites are produced from 24 different wastes of various suppliers. Majority of the waste used for rehabilitation presents used Termit's silica sand sold to foundries. Returning used sand to Termit lowers foundries' expenses for their waste disposal, lowers burden on municipal waste dumps, and stores silica sand on known place that might be useful for future generations. In 2017 Termit started project with ZAG where various waste materials containing enough SiO_2 and Al_2O_3 will be up-cycled into porous lightweight insulating alkali activated materials/foams. Therefore several waste materials from Termit, which are in abundance, were tested. Results of chemical analysis are presented in this article.

Keywords: • circular economy • rehabilitation materials • construction composites • alkali activated materials • lightweight porous insulating material •

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1 Introduction

TERMIT d.d. is a mining company established in 1960 for the production and processing of silica sands and the production of auxiliary casting materials. Termit's silica sands are used in civil engineering and for sports facilities. At the moment Termit is the largest European manufacturer of coated silica sands, producing cores and forms for casting using Croning, cold box, and inorganic methods from its own sands. Termit covers the majority of the casting market in Central and South-East European countries.

Termit produces sands in opencast mines located in the Moravče tertiary basin. Approximately 200,000 tons of silica sands are produced per year. According to the Slovene law all pits have to be rehabilitated after excavation ends[1] which can be done using natural material obtained on the market, or by alternative solution using waste material. To rehabilitate opencast mines, enormous amount of materials to replace the excavated sands are required.

Termit decided to try the alternative in 2004, i.e. by contacting industries generating large quantities of non-dangerous and inert waste, Termit started to process this waste and use it to produce appropriate rehabilitation materials. Majority of the waste used for rehabilitation presents used Termit's silica sand sold to foundries. Returning used sand to Termit lowers foundries' expenses for their waste disposal, lowers burden on municipal waste dumps, and stores silica sand on known place that might be useful for future generations. Since 2004 Termit was granted the permit for processing waste into artificial soil, which got name Tersan. At the moment 10 different construction composites are produced from 24 different wastes of various suppliers.

In 2017 Termit started another circular economy project, where various waste materials were tested for the suitability for up-cycling into porous lightweight insulating alkali activated materials/foams that could be used in the building industry. Aim is not just to lower the amount of different wastes, but to produce useful functional product with added value.

[1] Zakon o rudarstvu (ZRud-1), Uradni list RS, št. 14/14.

2 Rehabilitation of open pits

2.1 Problem of rehabilitation

At the beginning of 2004, Termit was faced with a great challenge how to rehabilitate a 2 million-m^3 mine that increased due to Termit's operations by 150,000 m^3 every year. There were two options: purchase natural materials on the market, transport them across the whole country and open a new wound in the nature elsewhere, or alternatively, contact industries generating large quantities of non-dangerous and inert waste, process this waste and use it to produce appropriate rehabilitation materials. According to expenses and effect on nature, second option was chosen and casting industry, where Termit's sands are used to make moulds and cores for casting metals, was contacted.

Sands that are used in casting can not be re-used in the process because along the casting procedure they lose needed properties. Therefore used sands present waste, financial burden for foundries and ecological burden for nature due to dispose of the used sands at waste dumps, while Termit could primarily use these sands for rehabilitation as the most appropriate material.

Due to win-win situation on both ends, i.e. Termit and casting industry, Termit implemented a closed loop for castings sands already in 2005 and won an environment-friendly award for the process of rehabilitation using the artificial material the same year.

2.2 Industrial symbiosis

In 2004 Termit was the second in Slovenia to have been granted a permit for processing waste into the artificial soil for rehabilitation of opencast mines with silica sands. The rehabilitation materials production was certified and production of construction composites started with all Slovenian technical approvals. In the beginning 742 tonnes of waste material was recovered, but now already over 70000 tonnes, which for some years represents over 1 % of all recovered waste in Slovenia.

Termit currently produces 10 different construction composites made from 24 different wastes of various suppliers. The Slovenian National Building and Civil Engineering Institute, who issued the Slovenian technical approval for Termit's manufactured construction composites, oversees production of construction materials.

Termit established an efficient and effective example of industrial symbiosis, successfully attracting large industries – casting, civil engineering, paper, glass, municipal waste, etc. From industrial waste, Termit manufactures custom-made geotechnical composites that match the natural geological soil structure.

Recovery of waste and manufacture of construction composites is done in several steps:

- all waste and accompanying documentation is checked and waste weighted;
- structure and composition of waste is examined;
- waste is sieved, larger pieces grinded, and impurities removed to special containers;
- moisture of waste is measured and dry weight calculated;
- in accordance with the formula specific wastes are mixed with autochthonous materials and other components in order to obtain a homogenous material;
- moisture content is measured once again and if the moisture level is appropriate, such construction composite can be used on the site.

When using the material, geotechnical rules are considered:

- materials are used in layers;
- each layer is compacted to at least 96% using heavy construction machinery.

With the right ratio of materials, moisture, and compaction, all potentially hazardous substances in waste become permanently immobilised to not to present problem for environment.

By manufacturing construction composites from waste generated in various industries, Termit contributes to the sustainable development in the field of environment at least in 3 ways:

- use of construction composites enables a quick and quality rehabilitation under controlled conditions, thus nearing the original state or mostly exceeding it;
- manufacture of construction composites from waste helps industries that are generating large quantities of waste, e.g. casting, paper, timber, and stone industry, to lower large financial burden with returning the used material to Termit instead of disposing it on dumping sites;
- by recovering construction composites from large quantities of waste, Termit extends the lifespan of municipal waste dumps, thus reducing the costs of waste collection for everyone and following the development strategy of the Republic of Slovenia and the requirements of the European Union, which state that as much waste as possible should be recovered.

At the same time, Termit helps the environment and restores nature to its original state for everyone (**Figure 1**).

Figure 1: Opencast mines before (left) and after (right) rehabilitation, foto: Termit.

3 Up-cycling with alkali activation technology (AAT)

3.1 Waste material as a burden or as a material of the future

Consumption of raw materials for modern style of life is an unavoidable fact leaving behind large quantities of waste. Due to limited quantities of existing raw materials there is serious concern about nowadays technologies and products used. At the same time quantities of wastes are getting bigger and bigger. Therefore it is necessary to start using waste material as the source material for alternative products with similar properties to the current products available on the market.

With this bearing in mind Termit started in 2017 project with ZAG, where the focus is to use Termit's abundant waste material as the main source material that would be used as precursor for synthesis of alkali activated materials (hereinafter: AAM), often also called geopolymers.

3.2 Introduction into AAM

AAM are produced from precursors that contain sufficient amount of amorphous SiO_2 and Al_2O_3, that are activated with alkalis and alkali glasses or even with their waste material alternatives. After dissolution of ingredients in the waste material precursor, potential additional secondary reactions along with mechanics of continuum hindered by viscosity take place. In few hours of process the alumina-silicate 3-dimensional O-Si-O-Al-O network forms. This process is followed by curing at different temperatures which can affect the final mechanical properties of synthesized AAM.

AAM have potential to replace several construction products used nowadays (Provis, 2010, Zhang, 2014). So far there are several products already available on the market and few structures that are made completely from geopolymers:

- geopolymer concrete, sprayed geopolymer fire-resistant foam, low temperature geopolymer bricks, (www.renca.org)
- geopolymer concrete, (http://www.geocement.in/geo_home.php)
- fire resistant in- and out-door paint, (https://www.inomat.de/)

- geopolymer fiber-reinforced mortar for structural rehabilitation, for corrosion prevention, water-activated geopolymer mortar for surface reinforcement, (http://infrastructure.milliken.com/geopolymer/)
- in 2013 1st building with geopolymer concrete used for structural purposes was built in Australia, i.e. University of Queensland's Global Change Institute, (www.geopolymer.org, 2013)
- in 2014 geopolymer concrete aircraft pavements were built in Australia, i.e. Brisbane West Wellcamp Airport, (Glasby, 2015)

With using AAM instead of traditional products, CO_2 footprint is significantly reduced, which makes AAM nature-friendlier product.

3.3 Experimental

In Termit d.o.o. up to 2 kg of different waste materials were taken in their open waste dumps for preliminary research of materials' potential for alkali activation. Materials are presented in **Table 1** (with laboratory sample name, description of the sample and waste label from the Classification list of waste from Official Gazette of the Republic of Slovenia, no. 20/01 Annex 1).

Table 1: Analysed Termit's samples collected from waste dump piles and from production plant.

Laboratory sample label	Sample	Waste label
Wastes from MFSU of adhesives and sealants (including waterproofing products)		08 01
V-160/17	Wastes from MFSU and removal of paint and varnish	08 01 99
Wastes from power stations and other combustion plants (except 19)		10 01
V-161/17	Bottom ash, slag and boiler dust	10 01 01
Wastes from casting of ferrous pieces		10 09
V-175/17	Furnace slag	10 09 03
V-162/17	Casting cores and moulds which have not undergone pouring other than those mentioned in 10 09 05	10 09 06
V-174/17	Casting cores and moulds which have undergone pouring other than those mentioned in 10 09 07	10 09 08
V-165/17	Flue-gas dust other than those mentioned in 10 09 09	10 09 10
Wastes from manufacture of glass and glass products		10 11
V-166/17	Solid wastes from on-site effluent treatment other than those mentioned in 10 11 19 (gypsum)	10 11 20
Wastes from manufacture of ceramic goods, bricks, tiles and construction products		10 12
V-167/17	Waste preparation mixture before thermal processing	10 12 01
V-168/17	Waste ceramics, bricks, tiles and construction products (after thermal processing)	10 12 08
Wastes from shaping and physical and mechanical surface treatment of metals and plastics		12 01
V-169/17	Wastes not otherwise specified	12 01 99
Waste linings and refractories		16 11
V-170/17	Refractory materials	16 11 06
Construction and demolition wastes		17 09
V-171/17	Glass wool	17 09 04
V-222/17	Rock wool	17 09 04
V-264/17	Rock wool	17 09 04
Not waste		
V-162/17 Q	Quartz sand MAP-1	Not waste
V-163/17	EKOSANDS aggregates made from used casting cores	Not waste
V-164/17	AGREGAT S aggregates made from used casting cores	Not waste
V-173/17	Green clay	Not waste
V-172/17	Phenol sludge - hydrophobic	Not waste
V-172/17 SI	Phenol sludge - sandy (inside)	Not waste
V-172/17 SO	Phenol sludge - sandy (outside)	Not waste
V-295/17	Red clay	Not waste
V-296/17	Sludge after separation in silica quarry	Not waste
V-161/17 C	Coal	Not waste

Source of labels: Official Gazette of the Republic of Slovenia, no. 20/01 Annex 1

On collected samples first dried on 70 °C for 24 h in WTB Binder dryer and then with IR dryer at 105 °C to constant mass, grinded in vibrating disk mill (Siebtechnik) and sieved below 90 μm, X-ray fluorescence (XRF, Thermo Scientific ARL Perform'X Sequential XRF) was performed to classify waste materials' potential for alkali activation.

3.4 Results and discussion

Waste V-169/17 was the only material that was excluded from all further investigations because sample included plastic which is not the material used in our project. Results of chemical analysis performed on the remaining samples with XRF where mass percent of oxides is close or above 0,1 % are presented in **Table 2**.

Table 2: Mass percentage of oxides measured with XRF. Oxides presenting majority in each individual sample are in grey boxes.

Laboratory sample label	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3	ZnO	ZrO_2	BaO	PbO
V-160/17	0,5	1,9	0,9	4,7	0,3	0,09	0,08	88,3	0,8			0,2				
V-161/17	0,3	9,4	10,5	26,9	1,0	2,7	4,1	25,3	0,6		0,4	16,8				
V-161/17 C		2,0		8,9		2,0	0,3	13,9	0,4		0,3	21,7		0,2	0,3	
V-162/17			2,5	95,6			0,1	0,1	0,08			0,5				
V-162/17 Q			0,2	98,2			0,05	0,2	0,1			0,4				
V-163/17	0,6	0,6	3,9	90,7			0,3	0,9	0,2			1,2				
V-164/17	1,5		0,6	94,0			0,1	0,2	0,08			0,8				
V-165/17	0,9	0,8	8,2	83,1			0,3	1,3	0,8			2,3				
V-166/17	0,6	1,6	0,4	6,2		31,9	0,4	46,9				0,2				3,4
V-167/17	0,3	1,4	23,1	61,6			4,4	3,4	0,2	0,8	1,5	1,5			0,4	
V-168/17	0,6	0,3	49,3	42,9			3,2	0,6	0,2	0,2	0,3	1,2			0,1	
V-170/17	0,3	0,7	44,1	43,1	0,3		0,3	4,3	0,8	0,5		3,5		0,5	0,2	
V-171/17	16,5	3,7	2,5	65,9			0,3	7,1	0,1			0,6				
V-172/17		0,1	3,8	87,6		0,1	0,4	4,9	0,2			0,6				
V-172/17 SI		0,1	0,1	98,0			0,09	0,2	0,2			0,5				
V-172/17 SO		0,1	1,3	92,7			0,2	0,3	0,5	0,08		1,1				
V-173/17	0,5	3,6	17,6	62,8	0,2		2,7	5,1	0,7			5,8			0,08	
V-174/17	0,2	0,3	3,6	87,7			0,2	0,5	1,0		0,3	5,0	0,09			
V-175/17	0,3	3,4	6,2	56,1		0,4	0,3	24,1	0,4	0,1		2,7	4,6		0,09	
V-222/17	2,1	9,8	17,3	43,5	0,3		0,8	16,8	1,3		0,3	6,7			0,07	
V-264/17	2,1	10,1	16,3	40,6	0,1		0,3	16,2	1,5		0,2	10,9				
V-295/17		0,5	8,9	83,8			0,8	0,3	0,3			3,6				
V-296/17		0,2	8,7	87,3			0,8	0,2	0,3			1,5				

All analysed samples contained SiO2, just 3 of them, i.e. wall paint (V-160/17), coal (not waste, V-161/17 C), gypsum (V-166/17) below 10 %. Due to the lack of most important ingredient in alkali activation, all 3 samples (V-160/17, V-161/17 C, V-166/17) were excluded from further analysis. The rest of the samples contain sufficient amount of Si and Al to be further processed, only X-Ray Diffraction (XRD) analysis will have to be performed to determine the amount of amorphous and crystalline phase to estimate the amount of amorphous SiO2 and Al2O3 whose content play crucial role in alkali activation technology.

4 Conclusion

Beside its core business (manufacturer of coated silica sands, and of casting cores), company Termit is an important manufacturer and seller of construction composites that are technically, ecologically, and economically suitable for rehabilitating degraded surfaces.
Recovery of waste materials into rehabilitation materials and their use is a sustainable alternative to rehabilitation using natural materials, without creating new wounds in the nature and with returning material where it was excavated for future generations.

Majority of Termit's wastes shows potential to be used as precursors in alkali activation process with which waste material will become source material and the product will have added value. In this manner the amount of waste will be lowered, raw materials will be saved, contribution of CO_2 will decrease, and economy will become circular.

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