Green Environmental Protection as a Result of Systems Thinking

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***Abstract*—Many scholars interested in environmental management discuss it from different aspects; the overwhelming majority of companies are trying to implement environmental management from theoretical point of view into everyday situations. It is important to underscore the fact that environmental management is a concept used every bit as theory as in practice in different aspects from different point of views. The similar case exists in concepts of management, organization and quality; the content of environmental management is dealt with insufficiently examined theory basis and also the interpretation and use in business practice is not systematical and consistent. In our research we propose a model of recycling isolating materials, made of hard polyurethane and lightweight concrete, with aggregates containing expanded glass as an innovative construction material- green lightweight composite. The scope of the aforementioned model is to plan production processes without waste and to improve energy efficiency in buildings. The model proposed solution enables a process alternative to be enhanced in sustainable development. Composites characteristics of density, compressive strength and thermal conductivity are changing in dependency of the type and part of waste as well as the type and part of fresh binding components. Method shows great possibilities for increasing use of construction waste isolating materials from hard polyurethane and lightweight concrete with aggregates containing expanded glass in order to benefit from better use of available capacity of existing construction waste.**

***Index Terms*—Composite, environmental management, innovation, system thinking.**

I. Introduction

Construction, one of the oldest activities of mankind, has an important effect on the socioeconomic development and at the same time sets an indelible seal on the surroundings and the environment. It influences the economical dynamics of society and also has an important effect on the environment and surroundings. The activities connected with constructions have long-term effects on the change in the appearance of a region, as well as on natural resources and waste management. The current environmental policy is based upon the concept of sustainable development. Innovation is of vital importance not only for those who want to increase or sustain economic growth in a given area (region, state and the like) but also for those who benefit(in)directly [1]. According to this, producing as much as possible is no more a central issue that should affect or change the economic course of development or improve quality of life [2]. Since the majority of natural resources are not unlimited and renewable, we can ensure equal opportunities to future generations only provided that we employ responsibility in the field of resources management. In its sustainable development strategy, the EU has set the severing of links between economic growth, use of natural resources and production of waste as one of its primary goals.0020The model of green lighweight composite as an innovative material for construction is developed to incorporate environmental performance in the design of building operations and minimize construction waste [3].

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II. Modern Trends Requiring Systems Thinking

There are several trends in world-wide life requiring systems thinking, such as:

- United Nations are the widest organisation of humankind and exist to work for holism in detecting and solving of the world-wide problems;
- Many other international organisations exist for the same basic reason;
- Sustainable Development is an important concept, which humankind has launched through United Nations and several other international organisations in order to solve the problem of survival of humankind: we all need interdependence of both our care for economic development and for nature, because both of them together, in synergy rather than in separation, support our survival;
- Since the times of enlightment several centuries ago, humankind has been working for its economic development, including its development od knowledge, including science and its application; this development resulted in enormous amounts of new findings, discoveries, and innovations, as well as in a more and more narrow specialisation;
- The unavoidable specialisation has become exaggerated: along with deep and crucial insights it has caused many oversights, resulting in small and huge problems, all way to world wars, many other wars, profit (as motive) killing profit (as outcome) by causing huge medical, reparation, nature renewal, etc. costs; all these trends required and require increasingly the international bodies and actions mentioned above under the motto: Think globally, act locally;

- Science and its application resulted, among other effects, in humankind's capacity to master more and more complex, not only complicated, issues, all the way to the most modern computer-supported tools (1) able to bring data, messages, even information from other planets that are many million kilometres away from Earth, (2) able to enter human body, (3) cure diseases as never before, etc.
- Etc. Most of the amassing results of modern times result from combinations of
- Deep, and hence one-sided, specialisation, and
- Bridges for co-operation between mutually different and interdependent specialists, based on application of (informal or formal) systems thinking.
- Systems thinking, rather than systems theory, are a millennia old practice of the successful practitioners and scientists and artists, which has made and makes them different from the less successful ones. (All losers are more or less one-sided thinkers and actors.)
- The exaggerated specialisation of the modern times caused the need for systems thinking to receive support from systems theory. It can teach humans to live consciously in the way that has always made a part of humans successful without possessing a theory as their background of their success [4].

(For details see: Dyck et al, 1998; Mulej *et al*., 2000; Mulej, 2004; Rebernik *et al*, 2004; etc) [4].

In the 19th century, there were authors claiming the humankinds' need to consider relations, interdependences, not parts of the world as independent entities only. Their background may have been consciously or subconsciously the ancient Chinese notion of interdependence called yin and yang, and/or the ancient Greek notion of interdependence called dialectics. Both mean interdependence. In the 19th century one has seen Idealistic Dialectics, Materialistic Dialectics, and several more notions and teachings about holistic thinking.

One can reach several centuries back. Many know that there has been, centuries ago, a certain Leonardo da Vinci. He is known as artist of the supreme quality, but he was also a great researcher. One can find in him a pioneer in the fields of creative thinking, accelerated learning, and innovative leadership; [5]:

TABLE I: HOW TO THINK LIKE LEONARDO DA VINCI [5]

7 DA VINCIAN PRINCIPLES	*1) What is it?*	Look at your own mind map from the perspective of the 7 Da Vinci principles
1 Curiosita	An insatiably curious approach to life and an unrelenting quest for continuous learning.	Am I asking right questions?
2 Dimonstrazione	A commitment to test knowledge through experience, persistence, and willingness to learn from mistakes.	How can I improve my ability to learn from my mistakes and experiences? How can I develop my independence of my thought?
3 Sensazione	The continual refinement of the senses, especially sight, as the means to enliven experience.	What is my plan for sharpening my senses as I age?
4 Sfumato (Literaly "Going up in Smoke")	A willingness to embrace ambiguity, paradox, and uncertainty.	How can I strengthen my ability to hold creative tension to embrace the major paradoxes of life?
5 Arte/Scienza	The development of the balance between science and art, logic and imagination. "Whole brain" thinking.	Am I balancing Arte and Scienza at home and at work?
6 Corporalita	The cultivation of grace, ambidexterity, fitness, and poise	How can I nurture the balance of body and mind?
7 Connessione	A recognition of and appreciation for the inter-connectedness of all things and phenomena. Systems thinking.	How do all the above elements fit together? How does everything connect to everything else?

III. EXPERIMENTS

The model of recycling construction waste of concrete from lightweight aggregates containing expanded glass was developed in order to include environmental performance in the design of building operations and minimizing construction waste [6]. We focused on identifying opportunities to improve the environmental aspects of LWC and the next step was to recycle crushed construction waste of concrete from lightweight aggregates and fresh concrete from lightweight aggregates as a binding. Recycling was the next activity at normal room conditions:

1) Rest construction waste was assembled from LWC with aggregates containing expanded glass and hard PU,
2) Then crumbled into small pieces,
3) The crumbled construction waste of concrete from LWC with aggregates containing expanded glass and hard PU(mechanical reprocessing) was taken as a raw input material in the processing line to the standard mould,
4) Volume of standard mould was charged and used for preparation of concrete specimens for compression test with "new" raw material,
5) Binding reaction occurred between new raw materials of fresh LWC with aggregates containing expanded glass and rest (waste) material of LWC with aggregates containing expanded glass and hard PU,
6) Binding process or the binding reaction refers to hydration of cement and
7) Quality control was implemented [7].

Fig. 1. "New" ligweight composite, LWC from aggregates containing expanded glass and hard PU

A control lightweight concrete mixture was prepared with

containing only normal Portland cement (NPC), and with waste LWC with aggregates containing expanded glass and hard PU. A mixture containing different parts of waste LWC and hard PU as a replacement of the aggregate in weight basis was prepared. The concrete samples were cured at 65% relative humidity at 20 ℃ temperature. The density, compressive strength and thermal conductivity of the hardened concrete and the properties of fresh concrete including density, and slump workability were measured. The consistency of the fresh concrete used to fill the mould was 380. Concrete was compacted traditionally by vibration. A test cube of recycled "new" material from LWC with aggregates containing expanded glass was prepared for studying the characteristics. The cubes were stored in a room at a temperature of 20+/- ℃. Tests were conducted after 28 days. We used scanning electron microscope Leitz–AMR 100. The conductive sample was scanned with an electron beam under high vacuum. The emitted electrons were detected and effect the picture contrast. The acceleration current was 20 kV for the secondary electron image. Thermal conductivity instrument was tested using Kemtherm QTM-D3, Kyoto Electronics by stationary hot-wire method i.e. by heating at a defined time, the temperature increase is noted and the thermal conductivity of the sample calculated; the testing range was 0,02 – 10 W/mk, warm up was 30 min and measurement duration was 60 s. Characteristics such as density, compressive strength and thermal conductivity from the new recycled material have been compared with the normal existing concrete from lightweight aggregates [8].

IV. Results

This chapter focuses on a practical example of successfully integrating waste management principles and reusing with the reuse and recycling of construction waste of concrete from lightweight concrete with aggregates containing expanded glass and hard PU. New economic issues dictate the redefining of economic interests in the wake of the recognition, that the natural environment is a limited production factor and not, as had previously been considered, the only supplier of raw materials [9]. The objective of this study was to investigate waste management and recycling of construction waste of concrete from lightweight aggregates (density from about 600 kg/m^3) and hard PU (density from about 40-60 kg/m^3). A commercially-available concrete from lightweight aggregates Poraver® and hard PU were selected for this investigation. The volume of the standard mould used for preparation of concrete specimens for compression test, dimensions 150 x 150 x 150 mm, was charged with rest, construction waste material of concrete from lightweight aggregates Poraver® and hard PU, the rest of the volume with new raw materials of concrete from lightweight aggregates Poraver® or hard PU was used as binding. It was added to the mould separately and not during the mixing of concrete, because we firstly investigated the capability of fresh LCW as a binding and the ratio between waste and fresh LCW with aggregates containing expanded glass [10]. The mould was first charged with waste material and then filled with fresh concrete. Another possibility for this is during the mixing of concrete. In this case waste LCW will assume the role of LWA. A prescription of raw materials of concrete from lightweight aggregates Poraver® was used, as supplied producer. Characteristics such as density, compressive strength and thermal conductivity of produced material samples in the scope of the research are given in Table II [11].

TABLE II: Characteristics of Recycled Material, and Concrete from Lightweight Aggregates Poraver®

Test cube	-	Mass of LWC kg	Density kg/m^3	Compressive strength N/mm^2	Thermal conductivity W/mK
1	-	1.93	571.9	4.44	0.18
2	-	1.95	577.8	4.67	0.18
3	-	1.99	589.6	4.36	0.18
	Mass of waste LWC kg	Mass of recycled LWC kg	Density kg/m^3	Compressive strength N/mm^2	Thermal conductivity W/mK
4	0.2	2.15	637.0	4.31	0.19
5	0.2	2.14	634.1	4.22	0.19
6	0.2	2.18	645.9	4.04	0.19
7	0.4	2.12	628.2	3.33	0.21
8	0.4	2.12	628.2	3.64	0.21
9	0.4	2.13	631.1	3.82	0.21
Test cube	Mass of waste hard PU / kg	Mass of recycled LWC kg	Density kg/m^3	Compressive strength N/mm^2	Thermal conductivity W/mK
10	0.003	1.72	509.6	2.22	0.21
11	0.003	1.69	500.7	2.00	0.21
12	0.003	1.68	497.8	2.31	0.21
Test cube	Mass of waste hard PU and LWC kg	Mass of recycled LWC kg	Density kg/m^3	Compressive strength N/mm^2	Thermal conductivity W/mK
10	0.015	1.90	563.0	2.44	0.2
11	0.015	1.96	580.7	2.67	0.2
12	0.015	1.91	564.9	2.227	0.2

Standard LWC	Recycled LWC((0.2 kg)	Recycled LWC (0.4 kg)

Recycled material has higher density, compressive strength and thermal conductivity similar to the standard one. Characteristics of density, compressive strength and thermal conductivity are changing depending on the types and parts of waste, as well as the types and parts of fresh binding components. Data concerning the 28-days cube compressive strength values of the materials are given in Table II. The 28 days cube compressive strength values of the concrete samples were changed according to the material mixing ratios. Due to low ratio of the LWC waste in the material composition finally caused maximum compressive strength values at the end of 28 days was maximum. The compressive strength values of lightweight concrete samples were under 4.36 N/ mm^2. By reason of the low compressive strength, the lightweight concrete with LWC waste additive can be recommended for use as a coating and dividing material in

constructions, because of its insulating features.

The thermal conductivity of produced material samples was observed. Thermal conductivities of samples no 3, 4 and 5 were 0.19 W m^{-1} K and of samples 7 and 8 and were determined as 0.21 W m^{-1} K. Evaluating the thermal conductivities of produced material samples together with their compressive strengths and density, shows into suitable for use as a recycled LWC produced from waste LWC with aggregates containing expanded glass and hard PU in building as a coating and dividing material for features to be insulated [12]. Thus, a new recycled material LWC material with aggregates containing expanded glass and hard PU was created with new characteristics of density, compressive strength and thermal conductivity, which conforms with the compressive strength class and rules on heat protection and energy efficiency use of energy in buildings (OJ RS No.42/2002). Fig. 1 presents the new recycled product. It can be used for heat protection and efficient use of energy in buildings.

V. Conclusion

Our results show that concrete waste material of concrete from lightweight aggregates and LWC with aggregates containing expanded glass and hard PU can be incorporated in to the recycling process [13]. We showed that specific selection of technological procedure and the quantity of remaining waste concrete from lightweight aggregates and LWC with aggregates containing expanded glass and hard PU, can play a crucial role for the characteristics of the recycled material. Thus, a new recycled material has been created with new characteristics of density, compressive strength and thermal conductivity, which conforms with the Rules on heat protection and efficient use of energy in buildings (SI OJ RS No.42/2002) and can be used for heat protection and efficient use of energy in buildings. Laboratory density, compressive strength and thermal conductivity tests results showed that LWC can be produced by the use of waste LWC with aggregates containing expanded glass and hard PU. However, the use of waste LWC with aggregates containing expanded glass and hard PU seems to be necessary for the production of cheaper and environment-friendly composite with the density, compressive strength and thermal conductivity similar to control LWC containing with only with aggregates containing expanded glass [14].

The method shows great possibilities for increasing the use of construction waste materials from lightweight concrete with aggregates containing expanded glass and hard PU in order to benefit from better use of the available existing construction waste. The suggested recycling and experimental study is a very effective tool for the solution (with aggregates containing expanded glass) recycling problems [15]. The model is confirmed by patent notification Nr. P-200600191, the conclusion for patent publication being dated 15.11.2006, and was tested during construction practice. It was awarded by WIPO (World Intellectual Property Organization) in 2008.

According to other building materials, it could be supplied cheaply. As to the observations, tests, experiments and evaluations on lightweight concrete material samples, it was concluded that the lightweight concrete with waste LWC, and with aggregates containing expanded glass can be used as a coating material in during construction. The challenge of addressing climate change in the context of moving society towards the environmental, economic and social goals of sustainability requires radical innovation of cleaner technologies and processes which meet individual and social needs at acceptable costs with significantly reduced environmental impacts.

References

[1] D. Kralj, "Dialectal System Approach Supporting Environmental Innovation for Sustainable Development," *Kybernetes*, vol. 37, no. 9/10, pp. 1542-1560, 2008.

[2] D. Kralj, "Experimental study of Recycling Lightweight Concrete with Aggregates Containing Expanded Glass," in *Proc. saf. Environ. prot.*, vol. 87, issue 4, pp. 267-273, 2009.

[3] D. Kralj, "Kazalniki in Kazalci Ravnanja z Okoljem v Podjetjih," *Organizacija (Kranj)*, vol. 42, št. 2, pp. A71-A80, 2009.

[4] M. Mulej and Z. Zenko. *Introduction to Systems Thinking with Application to Invention and Innovation Management*, Maribor. Management Forum, 2004

[5] M. Mulej, *System Thinking PF*, Maribor: SI, 1992.

[6] D. Kralj, "Study of recycling lightweight concrete with aggregates containing expanded glass," in *Advances in materials science research*, (Advances in materials science research, vol. 4), New York: Nova Science Publishers, cop. 2011, pp. 145-176.

[7] D. Kralj, "Environmental waste management in construction industry," in *Environmental management*, 1st published. Rijeka: Sciyo, cop. 2010, pp. 35-68,

[8] D. Kralj, "Green management and leadership for Greenovate organizational development," in *Proc. 2012 ICOI the International Conference on Organizational Innovation*, Surabaya: Airlangga University, pp. 1465-1478, 2012.

[9] Z. Song and D. Kralj, "Energy Management and Energy Management Systems Standard EN 16001: 2009," in *Proc. International Conference on Business and Information 2011*, Bangkok: International Business Academics Consortium: Academy of Taiwan Information Systems Research, pp. 10, 2011.

[10] D. Kralj, "Leading "greenovate" change," presented at the 5th WSEAS international conference on climate changes, global warming, biological problems (CGB '12), Sliema, Malta, September 7-9, 2012.

[11] D. Kralj, "Modeling of Recycling Isolating Materials from Hard Polyurethane and Lightweight Concrete with Aggregates with Expanded Glass for Improvement Energy Efficiency of Buildings," Ph.D dissertation, Faculty of Chemistry and Chemical Engineering Maribor, Maribor Univ., Maribor, Slovenia, 2009.

[12] D. Kralj, "Lighweight Concrete Recycling," SI patent SI 22133, April 30, 2007.

[13] *Environmental Management- Integrating Environmental Aspects to Product Design and Development,t* ISO Standard ISO 14062:2002(E)

[14] *Recycling materials*, 1 ed., Maribor: Pivec, pp. 216, 2009.

[15] S. Zhu and D. Kralj. (May 2012). Sustainable Teaching and Innovation for Zero Waste. *Adv. mat. res.* [Online]. *230-232*. pp. 1322-1326. Available: 10.4028/www.scientific.net/AMR.

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