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Polymer Industrial Floors - The Possibility of Using Secondary Raw Materials from Solar Panels

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***Abstract*—**The paper reports on the subject of recycling and further use of secondary raw materials obtained from solar panels, which is becoming a very up to date topic in recent years. Recycling these panels is very difficult and complex, and the use of resulting secondary raw materials is still not fully resolved. Within the research carried out at the Brno University of Technology, new polymer materials used for industrial floors are being developed. Secondary raw materials are incorporated into these polymers as fillers. One of the tested filler materials was glass obtained from solar panels. The following text describes procedures and results of the tests that were performed on these materials, confirming the possibility of the use of solar panel glass in industrial polymer flooring systems.

***Keywords*—**Fillers, industrial floors, recycling, secondary raw material, solar panel.

I. INTRODUCTION

SINCE concrete floors or other mineral-based floors do not create durable, let alone a comfortable environment, such floors without a surface treatment are not suitable to be used in industry. Therefore, these floors are provided with a polymer multilayer final wear layer, which ensures their adequate resistance both to applied loads and external influences. [1]

Floors with a final wear layer have a high mechanical resistance to pressure, abrasion and impact. The wear layers in general increase resistance to mechanical load of the original floors. They have high durability even at elevated temperatures or when exposed to chemical environments such as oil, petroleum products, acids, alkalis, solvents, and various detergents. Multilayer polymer flooring systems have excellent adhesion to a range of materials, such as fresh concrete, tile, metal or wood. Their major advantages include easy applicability and rapid installation and commissioning of these floors as well as a possibility of quick local repairs in case of damage. [5]

Materials used for industrial floorings are most often epoxy and consist of binder components, which themselves include binder and hardener (A and B component) and fillers. Our present research focuses on the replacement of common fillers by secondary raw materials.

II. FILLERS AND THEIR REPLACEMENT

The most commonly used fillers in the industry of polymer flooring materials are both traditional natural fillers such as silica sand, limestone, dolomite, but also manufactured fillers produced directly on the desired properties, such as quartz glass and glass flakes. Due to the shortage of natural resources and to the high cost of industrially produced fillers, we are trying to find suitable materials among secondary raw materials to completely or partially replace natural fillers. [2]

Recently, efforts to enhance the use of secondary raw materials appear in all industry fields and the construction industry is no exception. Whether for environmental, health but mainly for economic reasons: the costs of landfill and mining natural resources continue increasing. Secondary raw materials can be used to partially or fully substitute the primary fillers or may be added to the production with a goal to improve final properties and to reduce the product's price. [3]

III. SOLAR PANELS

One of the options in the use of secondary raw materials can be the use of glass obtained from solar panels.

A solar panel consists of solar (photovoltaic) cells, which may be semiconductor or organic elements changing light energy into electrical energy. Direct conversion of light into electricity is at present addressed by a separate specialization – photovoltaics, which is a method of direct conversion of sunlight into electricity (direct current) using the photoelectric effect on large semiconductor photodiodes. The individual diodes are called photovoltaic cells and are usually linked to larger units - photovoltaic panels. The solar panel is a device that converts solar radiation into heat, which is called sun, solarthermic, but especially solar heat. The operating principle of the collector is simple. Sun rays falling on the collector are converted to heat in an absorber. The produced heat is transmitted from the absorber by an antifreeze medium into a tank, where the heat accumulates or is used for water or swimming poll heating, or for heating in the house.

In the Czech Republic, photovoltaic panels from different manufacturers and in many types are installed; their total number exceeds 10.5 million pieces. Panels are divided by construction and materials into monocrystalline, polycrystalline, amorphous, flat, tubular, etc.

IV. SOLAR PANEL RECYCLING

In the Czech Republic, solar panel recycling is yet a young industry and it can only flourish. In recent years, many

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innovations have been made and industry continues investing heavily in this area. Recycling involves the separation of different materials that were used to manufacture the panels and subsequently the cleanup and reuse of secondary raw materials, and potentially the ecological treatment of the unusable fraction. There are two main technologies for solar panel recycling - thermal and mechano-chemical method; manufacturing companies use one of these technologies, or a combination thereof.

The thermal method involves evaporation of the panel's polymer part at high temperatures. The remaining silicon and metal components are then cleaned and reused in new panels. However, this method is not effective enough, since it requires a high proportion of manual work.

The mechano-chemical method is based on mechanical crushing, subsequent material separation and leaching. This treatment offers a much wider industrial use of obtained secondary raw materials even beyond the photovoltaic industry.

In the Czech Republic there is a non-profitmaking collective system REsolar Ltd. dealing with solar panel recycling. It was founded by two major associations organizing solar panels manufacturers and photovoltaic power station operators (The Czech Photovoltaic Industry Association and The Alliance for Energy Self-Sufficiency),

Expert recycling of solar panel waste is contracted through processors, selected on a competitive basis. In the event that the proceeds from the sale of obtained raw materials exceed the cost for processing (storage, separation, sorting, crushing, chemical processing ...), this is automatically reflected in the processing price in the form of determining a purchase price of the waste.

Solar panel recycling is provided in compliance with Regulation 2012/19/EU. In foreign countries, the amount of recycled solar panels is much larger than in the Czech Republic, where the recycling of solar panels is not yet a completely current topic. In some countries, solar panel recycling moves around 65%, but the waste recovery from the solar panels is still very small. Recycling is considered as only material utilization, while waste recovery is considered as both material and energy recovery.

The Czech Republic has committed itself to compliance with the EU Directive 2012/19/EU, that from 2015, for solar panels at their disposal at least 70% of the panel must be recycled into secondary raw materials, other 10% may be used for example for the production of energy and only the remaining 20% can be disposed of by landfill.

V. PROPOSAL FOR MATERIALS RECIPE TO VERIFY THE USE OF SOLAR PANEL GLASS IN INDUSTRIAL FLOORS

As a part of an ongoing research at the Brno University of Technology, a coating floor material used as a final wear layer was tested to verify the suitability of the solar panel glass used as fillers in industrial floors. This material labeled Lena P 128 is a highly pigmented, low viscosity two-component solvent free epoxy based material prepared according to an original recipe by Lena Chemical Ltd. [6] The product has been designed for creating cast floors, smooth or structured floor coatings and QS systems (floor systems tossed with sand). The resulting floor surface exhibits very good mechanical properties, very good abrasion resistance, very good resistance to chemicals, waterproof, color fastness, quick installation and commissioning and easy maintenance.

The reference material is commonly filled with high-quality quartz sand. For our testing, glass from two types of solar panels was selected. The material was filled with this glass in the percentage of 15, 25, 35, 45, 55% by weight. The chosen solar panels were selected on the basis of their chemical composition - containing a high percentage (more than 60%) of SiO_2; they are QS Solar and LDK Solar panels.

QS Solar is one of the largest module manufacturers based in Shanghai. Panels are manufactured with low cost, high quality and are friendly to the environment. Their most suitable use is for residential houses.

This module is manufactured as a so-called QS Solar thin film module, which means that it is not contaminated by other materials and comprises mainly amorphous silicon.

TABLE I
CHEMICAL COMPOSITION OF QS SOLAR GLASS

Components	Content [%]	Components	Content [%]
Loss by drying (105°C)	0,22	MgO	4,04
Loss by ignition 1100°C	0,5	K_2O	0,171
SiO_2	71,0	Na_2O	12,4
Al_2O_3	0,499	Li_2O	<0,002
Fe_2O_3	0,110	Cr_2O_3	0,005
TiO_2	0,023	BaO	0,009
MnO	0,006	ZrO_2	0,009
CaO	8,45	SrO	0,005

LDK Solar. LDK Solar Company, founded in China, is a leading producer of polycrystalline silicon featuring high purity and is also one of the leading manufacturers of photovoltaic modules (monocrystalline and polycrystalline). Photovoltaic modules are weather-resistant and resistant to ultraviolet radiation and moisture.

TABLE II
CHEMICAL COMPOSITION OF LDK SOLAR GLASS

Components	Content [%]	Components	Content [%]
Loss by drying (105°C)	0,23	MgO	1,44
Loss by ignition 1100°C	1,08	K_2O	0,032
SiO_2	69,5	Na_2O	12,9
Al_2O_3	1,23	Li_2O	<0,002
Fe_2O_3	0,172	Cr_2O_3	0,005
TiO_2	0,023	BaO	0,005
MnO	0,005	ZrO_2	0,008
CaO	10,2	SrO	0,0083

Glass from these solar panels was manually dismantled in the laboratory and subsequently milled and sieved to the desired fraction ≤ 0.63 mm.

VI. BASIC TESTING OF THE PROPOSED MATERIALS

For initial verification of the filler and binder compatibility, basic tests were performed – workability test, applicability of material test and test of the resulting material surface, which was evaluated on material after curing. Results were always compared with the reference material. Workability is compared and assessed according to the comfort of working with the material. To evaluate the applicability and the resulting material surface, evaluation systems were created. [1]

TABLE III
EVALUATION SYSTEM FOR MATERIAL'S APPLICABILITY

Evaluation	Description of evaluation
Convenient	The material showed good rheological properties, was easily applicable with a notched trowel, filled the demarcated area, uniform sintering of the surface was obtained.
Inconvenient	The material showed inconvenient rheological properties, was poorly applicable with a notched trowel, filled poorly the demarcated area, uniform sintering of the surface was not obtained.

TABLE IV
APPLICABILITY TEST RESULTS

Filler content [%]	QS solar	LDK solar
15	Convenient	Convenient
25	Convenient	Convenient
35	Convenient	Convenient
45	Convenient	Convenient
55	**Inconvenient**	**Inconvenient**

TABLE V
EVALUATION SYSTEM FOR MATERIAL'S FINAL SURFACE

Evaluation	Description of evaluation
Convenient	The resulting surface was flat, glossy, with no signs of defects; there was no segregation of individual parts of the binder component.
Inconvenient	The resulting surface was not flat, there was no sintering; present signs of segregation of the binder components; contained holes after dust particles and dark spots-segregated pigments.

TABLE VI
FINAL SURFACE TEST RESULTS

Filler content [%]	QS Solar	LDK Skolar
15	Convenient	Convenient
25	Convenient	Convenient
35	**Inconvenient**	Convenient
45	**Inconvenient**	**Inconvenient**
55	**Inconvenient**	**Inconvenient**

VII. BASIC TESTING OF THE PROPOSED MATERIALS - RESULTS

According to the results of the previous tests, the highest percentage of filling for each glass filler was selected that would suit workability, applicability and the resulting surface. Recipes with 25% QS Solar filling and with 35% LDK Solar filling were thus chosen for further testing. [4]

VIII. FURTHER TESTING OF THE PROPOSED MATERIALS

Materials with the largest filling which met the basic tests demands were further tested for flexural and compressive strengths.

Special silicone molds to produce samples were made for these strength tests. Such molds are more functional because of the ease of sample removal from the mold after curing.

Due to equipment of the testing laboratory, the tests were carried out at the Institute of Technology of Building Materials and Components at the Brno University of Technology and were performed according to the standard CSN EN 196-1. The results were compared with the values reached by the reference sample and declared by the manufacturer of the reference material.

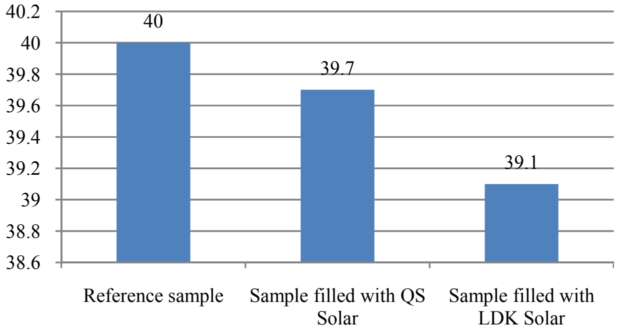

Fig. 1 Flexural strength [N·mm^{-2}]

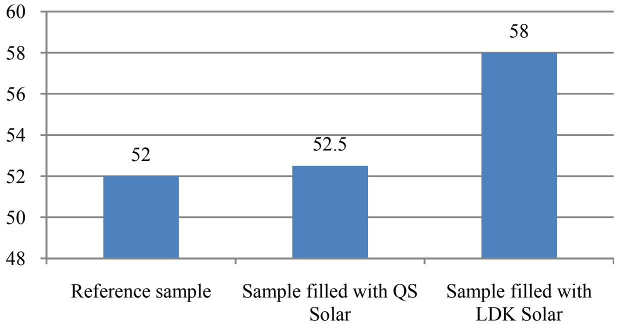

Fig. 2 Compressive strength [N·mm^{-2}]

IX. FURTHER TESTING OF THE PROPOSED MATERIALS - RESULTS

Flexural strength should reach a minimum value 40 N·mm^{-2} as given by the manufacturer of the reference material. Our samples did not reach this value - the strengths of our materials, however, were only slightly lower. Compressive strength of the reference material declared by the manufacturer is 52 N·mm^{-2}. In samples filled both with QS Solar and LDK Solar we have achieved greater strengths and this condition was thus met. For materials used in industrial floorings, compressive strength is more important.

X. CONCLUSION

To determine the suitability of the use of secondary raw materials as fillers in polymer floorings, a commercial binder material Lena P 128 was used. As a substitute for its usual filler, a recycled material - solar panel glass, QS Solar and

LDK Solar types, was selected. These materials were milled and adjusted by the fraction of ≤ 0.63 mm.

Three basic requirements were examined in the first test: workability, applicability, and the resulting surface of the filled material. In the Lena P 128 material, workability of the two tested materials was satisfactory, all percentages fillings. Applicability was convenient for both materials up to 45 % of filling and the resulting surface was convenient up to 25% of filling with QS Solar and to 35 % of filling with LDK Solar.

Flexural and compressive strength tests were subsequently carried out on the two materials. None of the two samples did achieve the required flexural strength of 40 $N \cdot mm^{-2}$, but the results can be considered as very satisfactory. Compressive strength after 28 days must be at least 52 $N \cdot mm^{-2}$ and this condition was fulfilled by the two materials.

Overall, there is a real possibility of the use of the solar panel glass as fillers in industrial floors. At present, it is important to continue the research and modify the materials to meet or exceeded the required flexural strength values. This can be achieved, among other things, by modifying the binder component.

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