Waste Recycling

Wydawnictwo IGSMiE PAN

Kraków 2005

WASTE RECYCLING

EDITED BY

ZBIGNIEW WZOREK, JOANNA KULCZYCKA,

PETER FEČKO, MÁRIA KUŠNIEROVÁ

Kraków 2005

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CORRESPONDENCE ADDRESS
Minerals and Energy Economy Research Institute
Polish Academy of Sciences
Division of Strategic Research
31-261 Kraków, ul. Józefa Wybickiego 7
tel. (0-12) 632-33-00, fax. (0-12) 632-35-24

TECHNICAL EDITOR
Anna K. Nowak
Zbigniew Wzorek

Kraków 2005

Printed in Poland

ISBN 83-89174-83-9

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Introduction

Natural environment protection within the range of waste management has been carried out in systematic and organised way only for several years. Waste storage was recently the most acceptable and most often applied method of waste utilization. Practically from the industrial revolution outbreak to the turn of seventies of XX century every production processes were conducted without taking heed of natural environment, generating enormous quantities of waste. This policy, sacrificing natural environment for economy, leads to its appalling destruction and reduction of natural resources.

Accrescent pressure on removal of negative environmental results brings legislative changes and redesign social mentality. Nowadays the fundamental goal of natural environmental protection is not only the control of pollution level and waste utilization but also prevention of its formation.

Polish and European Union regulations establish an order of waste treatment:

- prevention of waste formation and minimalization of its quantities as well as negative impact on environment
- assurance of recovery (mostly recycling) for that waste, which can not be avoided under specific techno-economic conditions
- waste neutralization (except storage), safe for human health and environment waste storage

Modification of the way of waste processing necessitates developing improved low- and non-waste technologies with lower energy consumption as well as new methods of waste recycling and secondary raw material management.

This book contains discussion on current and important problems of waste management including obligatory regulations and accommodation of Polish low to European Union standards. Moreover raises problems connected with more commonly demanded and used environmental management mechanisms (LCA- Life Cycle Assessment) and its economical evaluation (LCC- Life Cycle Cost). Those techniques are realized by introduction of ideas of sustainable development and required by EU legislation best available techniques (BAT).

Authors represents international group of specialists in the range of waste management. Problems discussed in the following chapters concern methods of waste limitation and prevention of its formation, possibilities of recycling as well as waste utilization and energy production, etc.

This book contains:

- problems with using biotechnology in waste management
- selected solutions in the range of sewage treatment and utilization
- problems connected with waste combustion and toxic gaseous products emission (dioxins)
- exemplary utilization methods of post-flotation tailings, ashes from solid waste combustion
- proposals of rubber waste recycling

Wide range of treated subjects allows for almost profound look at waste management and prevention. Besides measurable economical and ecological benefits connected with mentioned solutions educational values are also particularly valuable.

16. Experimental characterization of granulated cork lightweight concrete*

16.1. Introduction

Cork (bark of the plant *Quercus Suber L*, commonly called cork-oak) is a material whose characteristics are of considerable interest for the construction industry. It is regarded as a strategic material with enormous potential and many uses. Cork is secularly known for its reduced density, elasticity, compressibility, water impermeability, vibration absorption, thermal and acoustic insulation efficiency [1-3]. This material is normally used in construction without structural functions and have similar properties to expanded polystyrene, vermiculite, expanded pearlite, expanded glass and expanded clay of small dimension.

Efforts have been made in recent decades to widen the scope for using cork as a building material by improving the quality and performance of already-existing products, producing new compositions and by incorporating cork into new materials.

The Portuguese cork industry has shown a growing interest in expanding the use of cork in the building sector. This fact is extremely relevant because Portugal is the single largest cork producer and exporter, being responsible for over 51% of world production.

The industrial transformation of cork oak creates diverse by-products such as remaining portions of virgin cork oak and different types of inferior quality cork. Granulated cork and cork dust are obtained by grinding the industrial wastes with distinct dimensions and characteristics [1].

The replacement of conventional aggregates by granulated cork particles in concrete mixes seems to be advantageous because of the inherent properties of cork, like lightweight, thermal and sound insulation and vibration absorption. The granulated cork is classified as an ultra-lightweight aggregate, commonly containing a specific mass lower than 300 kg/m^3 [2].

In this context, an experimental programme was carried out to evaluate the possibility of incorporating this by-product in non-structural lightweight concrete that can be used in floor filling and levelling and insulation due to its reduced density. Different laboratorial mixes were tested, replacing totally or partially the sand or the coarse aggregate of conventional concrete by granulated cork.

In the first stage of the experimental work the physical and chemical properties of granulated cork particles were determined. Properties such as water absorption, specific mass and grading curve were estimated using laboratory testing. Concrete mixes were made using a constant water/cement ratio of 0.9, with different cement contents and different total replacing percentages of conventional aggregates (sand and course aggregate) by granulated cork. Total replacement of sand or course aggregates by granulated cork was tested too. Results obtained are presented and analysed.

16.2. Materials, Mixes and Curing

Granulated cork particles were subjected to the following tests: determination of specific mass; determination of apparent specific mass; determination of water absorption (porosity); grading curves.

The specific mass was determined according to test procedure for lightweight aggregates for concrete. It is known that specific mass is the ratio between the mass and the volume effectively occupied

* Said Jalali, Rute Eires, Aires Camões, Department of Civil Engineering,University of Minho, Campus de Azurém, Guimarães,Portugal

by granulated elements. This volume was measured verifying the volumes occupied by the cork particles. The specific mass obtained by the average of two tests was 384.5 kg/m^3.

The apparent mass was obtained by filling a recipient with granulated cork particles without any compaction. The apparent mass obtained was 160.0 kg/m^3.

The porosity of the granulated cork was determined by water absorption tests. The porosity obtained was 172.6%.

The water absorption of cork is extremely high and is important as it affects the water/cement ratio (W/C) and, hence, the strength and density of the corresponding concrete. A considerable part of the absorbed water occurs in the first hour but continues to increase with time.

The grading curves of the granulated cork and the common aggregates (river sand and granitic course aggregate) used were obtained according to the common rules for mortars and concrete aggregates. The curves are presented in Figure 16.1 and the main results are summarized in Table 16.1.

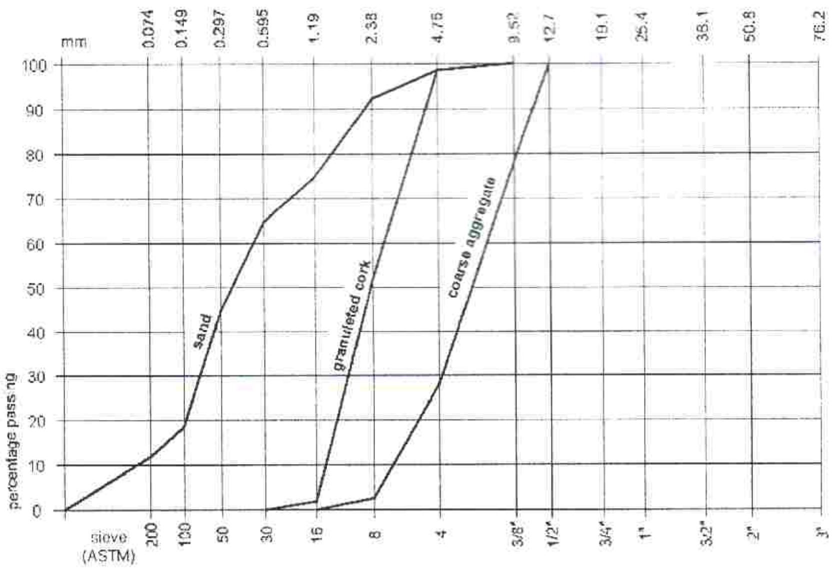

Figure 16.1
Size analysis of cork particles and conventional aggregates

Table 16.1
Main results from grading curves

Material	D_{max} (mm)	fineness modulus
Granulated cork	4.76	4.47
Sand	2.38	2.08
Coarse aggregate	12.70	5.92

The cement used was a Portland cement type CEM I 32.5.

Cubic specimens of 50 mm edge were moulded in order to evaluate the compressive strength. The specimens were removed from the forms 24 hours after casting and were stored in a chamber with constant temperature of 21°C and a constant relative humidity of 80%.

In order to obtain a lightweight non-structural concrete with a compressive strength of about 1.0 MPa several types of compositions were tested.

The first stage of this research work was to evaluate the compressive strength and the weight of the compositions in order to estimate the adequate proportions of cement, granulated cork particles and water. The compositions tested are presented in Table 16.2. Because of the high water absorption of cork the water/cement ratio (W/C) was kept at 0.9. Only in the mixture that contains course aggregate and low cork content (mix C) the W/C was fixed around 0.50.

Figure 16.2 shows the specimens moulded using lightweight cork concrete

Table 16.2
Compositions tested

Mix	Cement [kg/m^3]	Sand [kg/m^3]	Cork [kg/m^3]	Course aggregate [kg/m^3]	Water [l/m^3]	W/C
A1	88	-	123	-	80	0.91
A2	146	-	90	-	131	0.90
A3	140	-	90	-	126	0.90
B	95	112	133	-	86	0.90
C	189	-	76		96	0.51

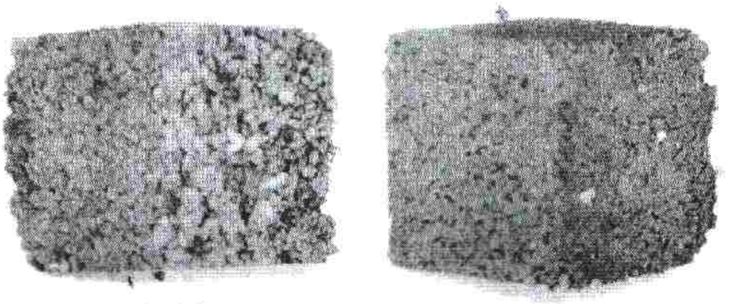

Figure 16.2
Lightweight cork concrete specimens

16.3. EXPERIMENTAL RESULTS

Table 16.3 presents the main results obtained in the experimental program and Figures 16.3 show the variation of the compressive strength test results with time. Each value presented in Table 16.3 is the average obtained from three specimens. In this table f_{cm} is the average compressive strength and γ_m is the average specific mass.

The compressive strength was measured at 1, 7 and 28 days of age. The specific mass was obtained by weighting all the specimens before the compressive strength testing.

Table 16.3
Specific mass and compressive strength of tested mixes

Mix	γ_m (kg/m^3)	f_{cm} (MPa)		
		1 day	7 days	28 days
A1	283	0.250	0.592	0.858
A2	354	0.300	0.900	1.480
A3	343	0.374	0.840	1.110
B	418	0.392	0.770	0.730
C	1040	0.548	1.252	1.300

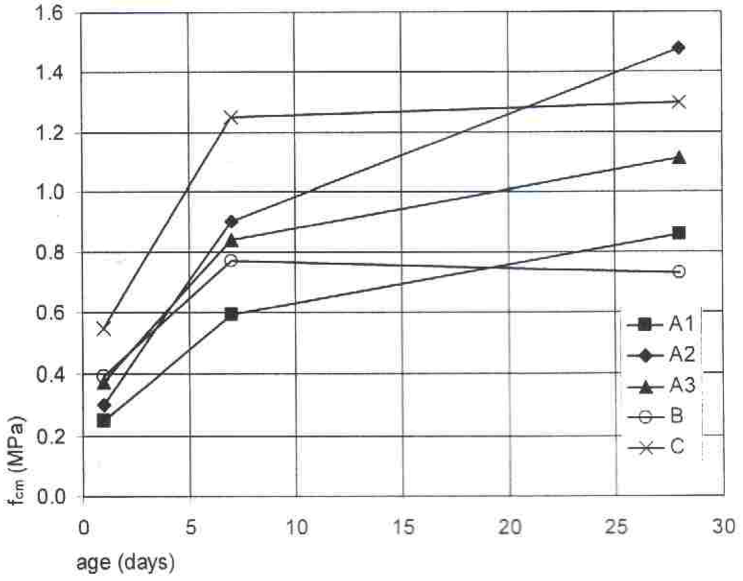

Figure 16.3
Compressive strength

16.4. DISCUSSION

According to the test results it is possible to obtain non-structural lightweight concretes. The results indicate that the specific mass of the specimens varies between 283 kg/m^3 and 1040 kg/m^3. According to the mix design the specific mass decreases as the cork content increased and conventional aggregate dosage was reduced.

The compressive strength test results indicate that the mixes with 100% replacement of stone aggregates by granulated cork the specimens achieved a 28 days compressive strength that varied between 0.858 MPa and 1.480 MPa. The compressive strength of Mix B, made with sand and cork as aggregates, was about 0.7 MPa and in mixture C, incorporating cork and coarse aggregate, was almost twice as much around 1.3 MPa. Taking into account the high value of the W/C ratio, due to high water absorption of the granulated cork, the obtained compressive strengths seem reasonable and satisfactory for the applications as lightweight non-structural concrete.

The mixture A1 made with the highest cork content and low cement dosage seems to be the most advantageous. This composition presents the lower specific mass and the higher by-product content. So, the use of this mixture represents a higher economy of material (namely cement) and of costs and can be considered the most environmental friendly mix of the ones studied. Adding conventional aggregates or higher dosages of cement slightly increases the compressive strengths.

By observing the fracture to the specimens it was possible to verify that the cork particles were pulled out from the cement matrix. This was taken as evidence of weak interfacial bonding between the cork and matrix.

16.5. CONCLUSIONS

Results obtained from this research work indicate that it is possible to produce for practical applications lightweight non-structural concrete mixtures incorporating high volumes of a by-product from cork industry. The corresponding compressive strength values can be considered satisfactory for the given applications.

It is noted that results obtained clear the way for higher sustainability of construction by using an industrial waste, hence, favouring a significant energy saving. The research work also contributes towards the growth and sustainability of the existing cork industry [4].

ACKNOWLEDGEMENTS

The authors would like to express their acknowledgment to Fundação para a Ciência e Tecnologia for financing this research work through project POCTI/ECM/55889/2004

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