

AN OVERVIEW OF PRESENT RECYCLING TECHNIQUES FOR CONCRETE AND MASONRY WASTE IN THE CZECH REPUBLIC

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ABSTRACT

Application of recycled materials in the building industry is essential for permanently sustainable development of a country. In the Czech Republic, the use of primary sources and materials is becoming unbearable from both the economical and ecological perspective and so there is an effort to seek the possibility in re-use of those building materials whose live-span has been exceeded. At present, the mostly recycled materials in the Czech Republic come from the recycled waste of bricks, concrete, asphalt, mixed construction waste, various types of aggregates and soil. This contribution brings the recent numbers on construction and demolition waste which has been processed by recycling plants and legislation aspects in the Czech Republic, the experience gained with those companies which cooperate with the Czech Technical University in the recycle improvement program, the experience from experiments with recycled building materials which are tested for future use as ordinary building materials and an overview of prospects and willingness of construction companies in the Czech Republic to use recycled building materials. A part of the contribution is devoted to strengthening of concrete made of recycled masonry aggregate with dispersed synthetic polypropylene fibres, which is now being developed in our department.

KEYWORDS:

Recycled concrete; Czech Republic; state-of-art report; recycled masonry aggregate.

INTRODUCTION

Recycling of construction waste as a self-standing business in the building industry started in the Czech Republic in 1995 by introduction of first crushing and screening machines developed for that purpose. During the first year, the construction companies did not show any interest in the seemingly unreliable second-class aggregate and so the recycled materials were distributed for free. Even then most of the recycled aggregated was headed to dumping grounds. In 1996, the Association for development in recycling of building materials (www.arms.cz) organized the first conference about recycling of construction waste. Only after foreign investors from the old EU countries, who were used to using recycled building materials, came to the Czech Republic, the recycling centres became of an interest. Soon the Czech construction companies followed, which was by the end of 1996. Since then recycling of building materials is viewed as an important means of sustainable development and has become one of the key research issues.

This contribution shows the recent numbers of natural building stone mined in the Czech Republic, the amount of recycled material and some typical prices in CZK and EURO for comparison. The present recycling techniques are introduced along with the machinery of the recycling centres. The legislation in effect is summarized and possible desirable changes are discussed. Then, opinions from within Czech construction companies and recycling centres are presented in the form of a questionnaire. And, results of research on fibre concrete with recycled masonry aggregate are shown along with its intended application, which is conducted in our department.

In order to provide a basis for the numbers shown in this contribution for international comparison, the following information about the Czech Republic is useful. The area of the Czech Republic is 78,866

km² and the population is 10,3 million as of 2006. The GDP per capita as of 2006 is 21,900 USD with the real growth rate of about 6 %, (MF, 2007).

PRIMARY SOURCES AVAILABLE

Building stone mines are not uniformly distributed within the Czech Republic, which is given by the geological conditions. There are about 320 exclusive deposits of building stone and about 200 non-exclusive deposits in the Czech Republic. For example in the year 2005, there were 169 exclusive deposit and about 50 non-exclusive deposit mines in operation, (MIaT, 2007).

The building stone mining shows the following trends over the past years:

The volume of building stone mined was cut by half between the years 1990 and 1992, which may be attributed to the aftermath of the collapse of communist planned economy and gradual transition to free market rules.

A stable volume of building stone mined was at the level of 9 to 10 million m³ per year during 1995 through 2002.

Increased production of building stone after devastating floods in Moravia in 1997 and most significant in Bohemia in 2002, when the output increased by 16 % in exclusive deposits and by 8% in non-exclusive deposits over 2003.

Continuous increase of the volume of building stone mined, which was caused by increased demand due to enhancement in infrastructure, roads and railways. The steady increase was started by rehabilitation of buildings damaged in floods.

Table 1 shows volumes of building stoned mined in the Czech Republic in the period from 1998 to 2006, (MIaT, 2007). Typical prices of building stone in CZK (1 EURO = 28 CZK) sold in the Czech Republic are shown in Table 2.

Table 1: Building stone mined in the Czech Republic from 1995 to 2006 (in thousand m³)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Exclusive deposits	9021	9887	10845	9528	9432	9451	9695	9674	11210	11966	12822	13500
Non-exclusive deposits	NA	NA	NA	NA	850	660	750	900	1000	960	1270	1100
Total	9021	9887	10845	9528	10282	10111	10445	10574	12210	12926	14092	14600

Table 2: Typical prices of building stone in CZK (1 EURO = 28 CZK) sold in the Czech Republic

	Price in CZK per ton	Price in EURO per ton
Sand (0-4 mm)	310 ~ 370	11 ~ 13
Gravel (4-32 mm)	360 ~ 585	13 ~ 21

AMOUNTS OF RECYCLED MATERIALS

Construction and demolition waste, which represents a considerable portion of total waste (22 %), produced by a country, is mostly recyclable. The old EU countries produce yearly about 700 to 800 kg of building waste per capita, while the Czech Republic produces about 400 kg per capita.

After the significant development in recycling of construction waste, which started in the early 1990's and continued until 2003, stagnation was observed in 2004 and 2005, moreover the volume of recycled concrete showed considerable decrease in 2004. The analysis of the recycling of concrete in 2005 confirmed increase and similar trend was detected in recycling of masonry waste and asphalt

waste. The Association for development in recycling of building materials (www.arms.cz) summarizes the yearly output since 1999, (ARMS, 2007). The volumes are shown in Table 3.

Table 3: Volume of building materials processed in recycling centres in the Czech Republic from 2000 to 2005 (in thousand tons)

Year	2000	2001	2002	2003	2004	2005
Masonry	589.4	990	1408.9	1391.6	1664.3	1711.3
Concrete	384.6	614.8	1013.9	1254.6	994	1233.4
Asphalt	317.9	323.9	475.2	516.4	514.2	597.6
Mixed	79	3.9	0.6	59	130.6	122.1
Aggregate	704	513.3	464.2	913.4	718.5	596.2
Soil	261	275.7	339.4	452.1	432.3	298.2
Other	249.6	417.5	300.7	261.4	309.1	134.2
Total	2585.4	3139	4002.6	4848.5	4770.5	4865.4

Typical prices of recycled building materials in CZK (1 EURO = 28 CZK) sold in the Czech Republic are shown in Table 4.

Table 4: Typical prices of recycled building materials in CZK (1 EURO = 28 CZK) sold in the Czech Republic

	Price in CZK per ton	Price in EURO per ton
Recycled concrete aggregate (0-8 mm)	55 ~ 195	2 ~ 7
Recycled concrete aggregate (8-32 mm)	80 ~ 195	3 ~ 7
Recycled masonry aggregate (0-8 mm)	30 ~ 85	1 ~ 3
Recycled masonry aggregate (8-32 mm)	50 ~ 80	2 ~ 3
Recycled asphalt aggregate (0-8 mm)	55 ~ 120	2 ~ 4
Recycled asphalt aggregate (8-32 mm)	85 ~ 120	3 ~ 4

RELATED LEGISLATION

Material use of waste is an appropriate indicator to measure the reuse of waste constituting materials such as construction and demolition waste. It is defined in the Waste Act no. 185/2001 Coll., as amended, as “replacement of primary raw materials by substances obtained from waste that can be considered as secondary raw materials or the use of the properties of waste for the original purpose or for other purposes, except for immediate generation of energy”. This indicator forms a part of the Waste Management Indicators System of the Czech Republic, intended to evaluate the achievement of the objectives of the Waste Management Plan of the Czech Republic (Indicator I.6v – share of all recoverable waste). The Waste Act rules the obligation to develop Waste Management Plans. Material use operations include, above all, such methods of waste use as defined in Annex 3 to the Waste Act and marked with the letter R: retrieval/regeneration of solvents and organic substances not used as solvents (including composting and other organic processes), recycling/retrieval of metals, metal compounds and other inorganic materials, or any application to soil that is beneficial to agriculture and improves ecology. The indicator encompasses all types of waste included in the Waste Catalogue, regardless of their category. The indicator has to be assessed in a comprehensive manner. Generally, it is a complement to indicators of energy use of waste and waste disposal methods. Law gives priority to material use of waste to its energy use. Waste disposal is considered the least desirable and environmentally inappropriate as long as it can be reused. The amount of waste used as materials helps reduce the amount of raw materials extracted from primary sources. This indicator is therefore bound to the material and energy intensity of an economy. It is desirable to increase the share of raw and derived materials that can be retrieved for production from waste. The amount of material reuse, in addition, indicates the overall forwardness of a society, as it knows the price of raw material sources

and prefers increasing the value of waste to exploiting primary sources. In terms of sustainable development, as high shares of material use of waste as is technically feasible and economically acceptable should be striven for. That is why this indicator is an important marker of the sustainability of the current 93 development. It is important that it has a growing tendency, that is, the share of waste used as materials is continually increasing. The importance of material use of waste is highlighted in Section 11 of the Waste Act, which states the priority of such use over any other method of waste treatment. One of the important aspects of advancing material use of waste is the generation of jobs for staff with the least chances on the labour market, including physically and socially handicapped persons. Furthermore, material use of waste reduces the requirements on the size and security of landfills, as some of the reused substances would be labelled and would have to be deposited as hazardous waste.

Existence of a system for quality control of recycled materials which is based on obligatory standards and provisions has an essential influence on application of recycled material in construction. Eventually, such a system would allow consideration of recycled materials already at the design stage as the prices of recycled material would become similar to those of natural building stones.

The experience in the Czech Republic has it that increase in price of recycled material allows reduction of purchase prices of construction waste, which in turn reduces the need of some individuals to dispose of the construction waste in a semi-legal or even illegal way.

As of now, there are no effective standards for quality control and assessment of recycled material, unlike in the Germany, Austria, Switzerland, Belgium, Luxemburg or the Netherlands. A kind of exception is represented by several standards related to road and railway construction, such as:

- ČSN 73 6121 – Compaction of asphalt layers
- ČSN 73 6122 – Poured asphalts
- ČSN 73 6123 – Concrete road surfaces
- ČSN 73 6124 – Aggregate bound with hydraulic binder.
- ČSN 73 6125 – Stabilized sub-course
- ČSN 73 6126 – Uncemented layers

All mentioned standard allow application of recycled materials at a specific construction stage, but the recycled material must satisfy the conditions given for natural building materials.(ME)

The following general conditions for successful recycling should be fulfilled: increasing amount of construction waste, decreasing space in dumping grounds in urban areas, depleted natural resources, increasing costs on transportation and government support. In the Czech Republic, none of those conditions is threatening. Therefore, the government's attempts in promoting the use of recycled building materials are rather flabby. However, one can expect the following measures once needed, increase in tax on construction waste and strict monitoring of dumping grounds. Most probably, any subsidy will be avoided by this kind of tuning of business regulations.

RECYCLING TECHNIQUES

As of December 2005, there were 36 major companies, which at least marginally specialize in recycling of construction waste, operating 75 crushers with the capacity of 25 to 160 tons per hour, which represents an increase of 14 units compared with the number in 2004, and 76 screens (11 units more than in 2004). The total yearly capacity of all the recycling centres in the Czech Republic is about 7.5 million tons, which is 50 % more than the actual production of recycled materials. In order to use the machinery effectively, the companies offer their mobile units to stone mines and sand pit operators, where they are used for grading, or the machinery is lent abroad, (ARMS, 2007).

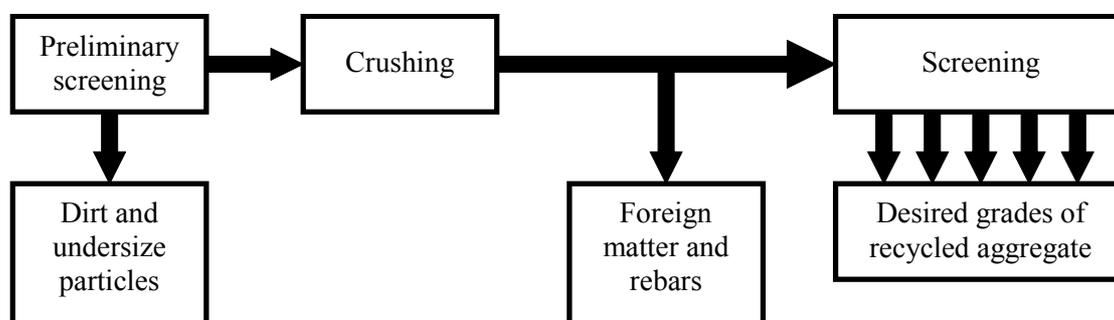


Figure 1: Flow of commonly used construction waste processing

Regarding recycling of masonry waste, most of the recycling centres provide three ranges of grading, which are 0-16 mm, 16-32 mm and 32-80 mm. This material is mostly used in insulation concrete and precast secondary horizontal and vertical structural members, which are during production subjected to vibrating compaction, which reduced the expected excessive creep deformations. Regarding recycling of concrete waste, the recycling centres provide any grading upon demand. Tables 2 and 4 show that the recycled aggregate is considerably cheaper, which however also reflects its properties and subsequently properties of concrete. Generally it is known about concrete made of recycled aggregate that the same amount of recycled aggregate requires higher water-cement ratio for ensuring the same workability, the density of concrete is lower, the compressive strength is 10~15 % lower, the modulus of elasticity is 15~20 % lower, the creep coefficient is up to 50 % higher and the shrinkage is 20~40 % higher.

The crushers and screens used in the Czech Republic are, e.g., Hartl Powerskid PS303PCV with the capacity of about 100 tons per hour and Intermat 2006 produced by Hartl in Austria. The Czech Company PSP Engineering supplies a variety of jaw, impact, hammer, roller and cone crushers, vertical shaft impactors, impact hammer crushers, hammer crushers with rollers and a variety of screens. Recycling in situ with mobile machines is preferred.

OPINIONS FROM WITHIN CONSTRUCTION COMPANIES

An opinion of a designer in Metroprojekt, a.s. (consultant company specialising in design of subway systems and other large-scale projects ordered by the Czech government): “As of now, it is not necessary to use the recycled aggregate since the volume of construction waste is not significant at all. Actually, we use construction waste as filler, but without any conscious planning for saving the environment. It is simply cheaper to bury the waste at the site than to transport it to dumping grounds. Regarding structural design, I would never use concrete with recycled aggregate as I don’t trust it. If I were forced to use it by my bosses, I would require stringent testing of the recycled aggregate with significantly larger statistical sets and much stricter conditions than those for natural stone aggregate. Anyway, there are standards for testing of aggregate, so, if a testing centre guarantees properties of recycled aggregate, I would use, probably. And, if government offers some subsidy for using recycled aggregate, we will use it, of course. But, this is a question for our company’s economists.”

Summary of general opinions:

- Construction companies use recycled construction waste for its low price and mostly for fillers and secondary structures. Companies are forced by investors to do so.
- Price is more important than ecological aspects.
- Construction companies require guaranteed quality of recycled building materials.

OPINIONS FROM WITHIN RECYCLING CENTRES

An opinion of the owner of WECO, s r.o. (the first recycling centre established in Prague): “In 1994, I saw a business opportunity in recycling construction waste which, at that time I felt it, would help to

save the environment. I counted on similar feelings of other people then. The important fact was, though, that originally I worked in a construction company, which provided me the very necessary contacts on potential customers. The major difficulty in my business is its dependence on customers and construction waste suppliers. Another difficulty comes with the heavy bureaucracy related to handling dangerous waste and various certifications required for running the centre, such as amount of noise and dust monitoring, which is a matter of course for us, but the certificates are somehow too expensive. Moreover, government-run construction companies do not understand that saving the primary resources reduced construction costs. In fact, those companies ignore recycled building materials. Since 1994, the conditions for my business deteriorated due to incomprehensive legislation rules and little interest of construction companies. Sometimes, we distribute the recycled aggregate for free in order to empty our stocks. If I ask a construction company, whether they accept such material at such price, mostly they answer “no” without any clear explanation. Somehow, the construction companies regard the recycled materials as dangerous and unreliable. They even refuse them for equipping the construction site, such as temporary roads. Anyway, recycled concrete aggregate is most preferred and constitutes about 1/3 of all orders. Regarding the evolution of business conditions over time, the fuel price doubled, price of construction waste tumbled from 150 CZK to 100 CZK, price of recycled aggregate increased from 100 CZK to 110 CZK on average, wages are increasing, and yet there is no support from the government. I would not have started such business again. Regarding competition among the recycling centres, well, there is a competition, however, the winner is the one who bypasses legislative regulations. Not good. And, regarding keeping up with new development in research on recycled aggregate, we are very eager and very much up-to-date. This may save us.”

Summary of general opinions:

- Very little support from the government. In stead of various kinds of easement and support, the government collects fees on “fresh air”, which required expensive certificated studies. However, some companies do not submit such studies because the fine is much cheaper than the preparation of study itself.
- Construction companies appreciate that recycled building material is less expensive than the natural materials. This advantage is pronounced by setting up mobile machines at demolition sites where new structures are builded immediately.
- Recycled concrete aggregate is preferred by construction companies.
- An increase in price of recycled aggregate is expected due to increasing prices of electric power and fuel. The increase should not be significant, though.

RESEARCH – FIBRE REINFORCED CONCRETE WITH RECYCLED AGGREGATE

Recycling masonry aggregate, according to the amount of construction waste processed in recycling plants during the last six years, see Table 3, is the most used material. The results of experiments with concrete made of masonry waste (made of fired clay bricks) conducted in our department, including fibre-reinforced concrete, proved that production of the so-called brick concrete is possible even without the use of superplasticizers, and so concrete with recycled masonry aggregate can be used in practice more often. The results of the experiments proved an unambiguously positive influence of the synthetic fibres (Forta Ferro) on tensile strength in bending, with an increase of at least 15 % to a nominal value of 4 MPa in dependence on the amount of cement used. The compressive strength of brick concrete is lower than that of the reference concrete made of natural aggregate, which is due to the characteristics of crushed masonry. Nevertheless, the compressive strength is sufficient for its anticipated application in most structures. But there are some structures for application in geotechnical engineering, where not compressive strength, but toughness is decisive. The increased ductility caused by the fibres added is of a major importance regarding the application, where opened cracks are not a limiting factor for reliability of the structure. The new findings from the experiments with recycled aggregated will be used for definition of the not yet existing standards and provisions related to recycling of structures in the Czech Republic.



Figure 2: Specimens with recycled masonry aggregate

The next task of the research and development in application of recycled concrete is determination of characteristics and production procedures of concrete using recycled concrete aggregate. The team will investigate not only the mechanical, physical and rheological properties of recycled concrete, but also ecological deficiency or, on the contrary, the benefits and attainable economical effect.

The anticipated application is strengthening of gravity dams in flood-prone locations, where the post-peak tensile behaviour of the fibre-reinforced brick concrete will be utilized. It is expected that the slabs produced will break to pieces in the dams, however the pieces will stay together. Also the slabs, as they are placed in the dam in horizontal layers, will develop a cascade which will help break the flow of flooding water and thus prevent erosion of the dam.

CONCLUSION

This paper summarized the current situation of recycling of building materials in the Czech Republic. From the presented numbers it is obvious that recycling of building material has an upward tendency. The recycling techniques used are comparable with the techniques used in the old EU countries and as of now there is about 50 % excess in capacity of all machinery, such as crushers and screens. The hindering effect of the outdated legislation is also apparent and some suggestions were discussed. Current opinions of both parties, the recycling centres and construction companies are revealed in order to conceive the background of the issue. The presented example of combination of recycled masonry aggregate with synthetic fibres in concrete mixture, which are a currently investigated research topic in our department, promise broadening of the applicability range of recycled materials.

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