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## Impact of recycled aggregates on selected physical and mechanical characteristics of cement concrete

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### Abstract

The issue of using construction rubble was recognized in Europe not earlier than in the nineties of the twentieth century. This was due to economic and ecological considerations. However, recycled aggregate is characterized by high volatility of physical and mechanical properties. The quantity and type of various kinds of impurities harmful to the durability of concrete is virtually unpredictable. For over twenty years various organizations in different countries have tried to sort out this problem and possibly unequivocally define the criteria for the suitability of different types of recycled aggregates to the production of concrete. The article presents and compares the most important guidelines, currently in force, regulating the scope of use of recycled aggregates (RILEM as well as Japanese, German and European standards). The article also contains the results and the analysis of comparative studies of selected physical and mechanical characteristics of concrete produced with the use of natural aggregate and concrete produced with the use of recycled aggregate obtained from milling of masonry.

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### 1. Introduction

Recycling refers to reusing waste or worn parts to manufacture new products. Depending on base material, various types of recycling can be distinguished, including for instance chemical, energy, organic or raw material

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recycling. According to the definition in standard [1], the aggregate obtained from processing inorganic material previously used in construction is called recycled aggregate.

Construction rubble was used for construction purposes as early as in ancient times. A number of Roman aqueducts were made of recycled aggregate. Brick rubble was reused on a mass scale in more recent time, i.e. in 1940s and 50s, for instance for rebuilding ruined cities after World War II. The beginning of the “new era” in recycling of construction rubble in the mid-seventies coincided with the emergence of numerous environmental movement. At this time the first standard regulating the rules on the use of secondary aggregate to produce concrete was developed in Japan. Within a short time economic factors also started to play a role. The aggregate obtained from recycling became a commercial product [2]. The first international symposium devoted to the issue of producing concrete with the use of recycled aggregate was held in Rotterdam in 1985.

## 2. Regulations and recommendations on the scope of application of recycled aggregates

The issue of reusing construction rubble on a larger scale was recognized in Europe not earlier than in the 1990s. This was due to both economic and ecological considerations [3]:

- The cost of mining and transporting natural aggregates are high and have a continuously upward trend,
- Large areas in Europe have no easily accessible postglacial deposits of construction aggregate and it needs to be obtained from quarries,
- Large quantities of rubble resulting from the demolition of various types of building structures fill landfills, destroying the landscape and causing irreparable ecological damage,
- Disposing of rubble to landfills becomes more and more expensive.

We can distinguish the following groups of construction waste, suitable for recycling:

- construction rubble (brick, concrete),
- waste generated during construction (rubble, mortar, packaging material, plastics),
- soil and rocks,
- rubble from the demolition of roads and streets.

Recycled aggregates are characterized by highly volatile physical and mechanical properties. The quantity and type of various kinds of contaminations contained in the aggregate and harmful to concrete durability is virtually unpredictable. For over twenty years various organizations in different countries have tried to sort out this problem and clearly define the criteria of usefulness of different types of recycled aggregates to produce concrete.

According to RILEM (*Reunion Internationale des Laboratoires et Experts des Materiaux, Systemes de Construction et Ouvrages*) recommendations on coarse aggregate (> 4 mm), the recycled aggregate can be divided into the following three categories (Table 1.)

- RCAC Type I – rubbles originally coming from masonry,
- RCAC Type II – rubbles originally coming from concrete,
- RCAC Type III - a mixture of natural and recycled aggregates.

According to a Japanese standard coarse recycled aggregate should not contain more than 10 kg/m<sup>3</sup> plaster, clay lumps and other contaminants with density of less than 1950 kg/m<sup>3</sup>. However, the content of other contaminations with density lower than 1200 kg/m<sup>3</sup> and diameter of more than 1.2 mm (including bitumen, paints, textiles, paper, wood) should not exceed 2 kg/m<sup>3</sup>.

A German standard [4] divides recycled aggregate into four types: concrete aggregate (type I), the aggregate from construction elements (type II), the aggregate from masonry (type III) and mixed aggregate (type IV). Selected parameters and acceptable qualitative composition of aggregate is presented in Table 2.

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