Recycled sands and aggregates in cement and precast concrete

– a step towards a circular economy in the construction sector

__Christian Glock, Wolfgang Breit, Anja Tusch, Dagmar Däuwel, Molham Kassoum, Kasem Maryamh__ and __Robert Adams__ of the __University of Kaiserslautern__ in Germany look at the SeRaMCo project and research on methods to reuse construction and demolition waste (CDW) in cement and precast concrete productions.

Across the world, raw materials are becoming a scarcer resource. In north-western Europe, the construction sector uses 50% of all raw materials and produces one-third of all waste in the region. Although 70% of waste is recovered, only a low percentage undergoes a high-quality recycling that allows the reuse of these materials in construction (see Deloitte/EU[1,2]).

The researchers and industrial partners of the publicly funded SeRaMCo project – Secondary Raw Materials for Concrete Precast Products* – are researching methods to reuse construction and demolition waste (CDW) in cement and precast concrete products. So far, new processes for effective treatment of materials have been investigated and different methods to reuse the materials tested. As a result, two new cements containing recycled sands have been developed. Moreover, Portland clinker containing 14.2% of recycled aggregates was successfully produced both in laboratory and industrial environments. High substitution rates are not realistic, due to the high silica amount in CDW[3]. Furthermore, new concretes containing coarse recycled aggregates have been developed and a dozen innovative precast products designed.

The SeRaMCo project's aim is to enable the annual use of 13 million tonnes of recycled aggregates and sands in precast concrete and cement in north-western Europe by 2030.

Developing concretes

A central part of the project is the development of concretes for use in structural applications such as walls, paving and pressed concrete blocks, which contain different kinds of recycled aggregates both from known and

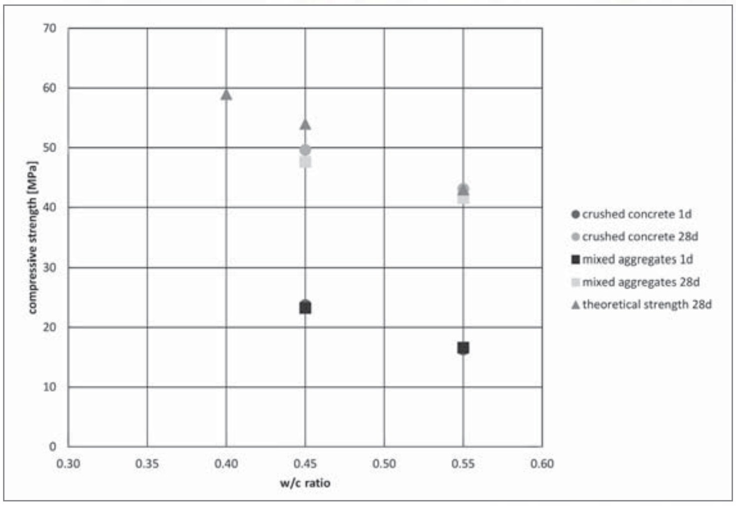

Figure 1: Compressive strength in relation to the w/c ratio and aggregates used.

unknown origins. Recycled aggregates from unknown origin are challenging in that they can consist of variable fractions of crushed concrete, crushed bricks, asphalt, ceramics and lightweight components. Hence, this can result in a higher variability of their properties such as density, strength and durability compared with conventional aggregates.

With respect to the European Standard EN 206[4], recycled aggregates can be divided into two classes: Type A, which consists mainly of crushed concrete; and Type B, which could contain up to 30% of ceramics and bricks. Aggregates of Type A and B were tested in order to examine the influence of recycled aggregates on compressive and splitting tensile strengths. The tested mixtures contained 100% coarse recycled aggregates and natural fine aggregates. Two different water:cement ratios (0.45 and 0.55) were tested to see the impact of the materials on the compressive and tensile splitting strengths. As a reference, a concrete containing 100% natural aggregates was tested. The first results look promising, with the tests showing only insignificant lower values in compressive strength than the reference concrete (Figure 1). This applies for the one-day as well as for the 28-day compressive strengths (see Tusch *et al*[5]).

Compliant

How can you produce concrete paving and pressed concrete from 100% recycled coarse CDW and be compliant with the existing European regulations? In most cases, earth-moist concretes are used, which must be compacted by vibration and imposed load. With regard to the paving blocks, EN 1338[6] has to be respected.

Concrete composition and production processes must ensure sufficient early-age strength as well as achieving the required properties, as a function of the production process. For early-age strength, soil mechanics principles are of importance, while for the later period performance, concrete technology aspects are of greater significance. Table 1 shows these values.

Using the Proctor compaction test procedure, it is possible to find optimal moisture content with suitable selected cement content and a well-graded grain composition. Later on, the developed mixture can be further optimised by varying the cement and/or by adding admixtures and additives to create a mixture suitable for the respective application.

Laboratory testing to develop a suitable mix design for pressed concrete has commenced. The test programme aims

Table 1 – Requirements, objectives and parameters for concretes for concrete paving blocks

	Early-age concrete	Hardened concrete
Required property of concrete	Green strength	Performance characteristics (compressive strength, tensile splitting strength, freeze–thaw resistance, resistance against alkali–silica reaction, resistance against abrasion…)
Target values	Optimal moisture content Mortar content Content of voids According to manufacturing process	Strength, durability
Parameter	Aggregates • grading • content of fines • grain shape Cement • amount • water demand Additives • admixtures • additives Compaction	Aggregates • grading • content of fines • grain shape Cement • amount • water demand Additives • admixtures • additives Compaction
Context	Soil mechanics	Concrete technology

Figure 2: Sample 150 × 150 × 80mm.

Figure 3: Determination of early-age strength.

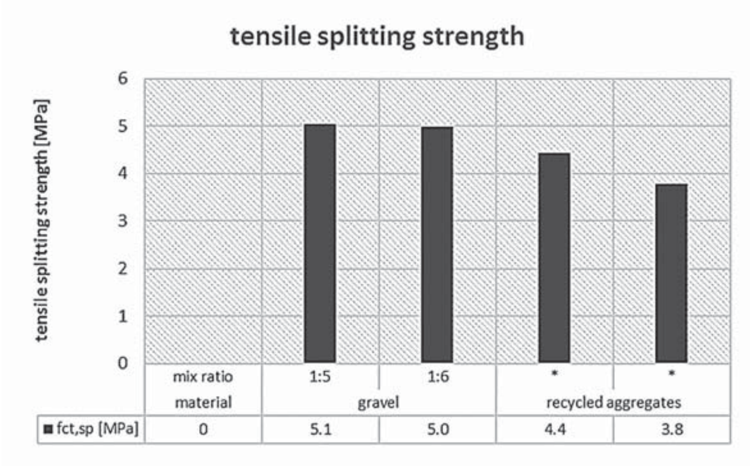

Figure 4: Tensile splitting strength of concrete paving blocks 150 × 150 × 80mm made from gravel concrete and concrete containing recycled aggregates depending on the ratio MV (proportion of cement:aggregates) of 1:5 or 1:6.

** Due to the lower grain densities, the mixtures containing recycled aggregates have different mixing ratios in mass proportions.*

to formulate concretes using recycled aggregates of different maximum grain size, which are suitable for external applications (exposure classes XC4, XF1). Starting from a minimum cement content of 300kg/m^3, these compositions are adjusted to an initial compaction factor C1 consistence (according to EN 206) within the framework of a suitability test. Figure 5 shows the test set-up.

Although the test series have not yet been completed, it is foreseeable that even if the coarse grain fractions are completely replaced by recycled aggregates, it is possible to fulfil the requirements of EN 1338 with regard to tensile splitting strength (mean value ≥3.6MPa, lowest value ≥2.9MPa) (Figure 4) and wear resistance as a function of the mixing ratio.

Outlook

Although the first results look promising, they have to be verified by further tests. The test series for concrete for structural purposes will be redeployed, using the cements developed within the project. The design and production of the newly developed products will be finalised in the coming months, to be showcased in public pilot sites in mid-2020. ■

Note:

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References:

1. DELOITTE. *Study on Resource Efficient Use of Mixed Wastes, Improving management of construction and demolition waste – Final Report*. Prepared for the European Commission, DG ENV, 2017, available at: *http://ec.europa.eu/environment/waste/studies/mixed_waste.htm*.
2. EUROPEAN UNION. Communication from the Commission. *Resource Efficiency Opportunities in the Building Sector*. COM/2014/0445 final, Brussels, July 2014, available at: *https://bit.ly/2JCPRJ0*.
3. TRAUCHESSEC, R., BARNES-DAVIN, L., KROUR, H., DILIBERTO, C., LECOMTE, A., BOLZE, B. and DELHAY, A. Use of recycled aggregates for cement production. *Proceedings of SeRaMCo Conference Circular Concrete*, S.11–12, November 2018, Luxembourg, available at: *https://bit.ly/2VOIK1E*.
4. BRITISH STANDARDS INSTITUTION, BS EN 206. *Concrete. Specification, performance, production and conformity*. BSI, London, 2013+A1:2016.
5. TUSCH, A., BREIT, W. and ADAMS, R. Special challenges for concrete containing recycled aggregates from unknown origin, *Proceedings of SeRaMCo Conference Circular Concrete*, S.7–8, November 2018, Luxembourg, available at: *https://bit.ly/2VNSsBc*.
6. BRITISH STANDARDS INSTITUTION, BS EN 1338. *Concrete paving blocks. Requirements and test methods*. BSI, London, 2003.

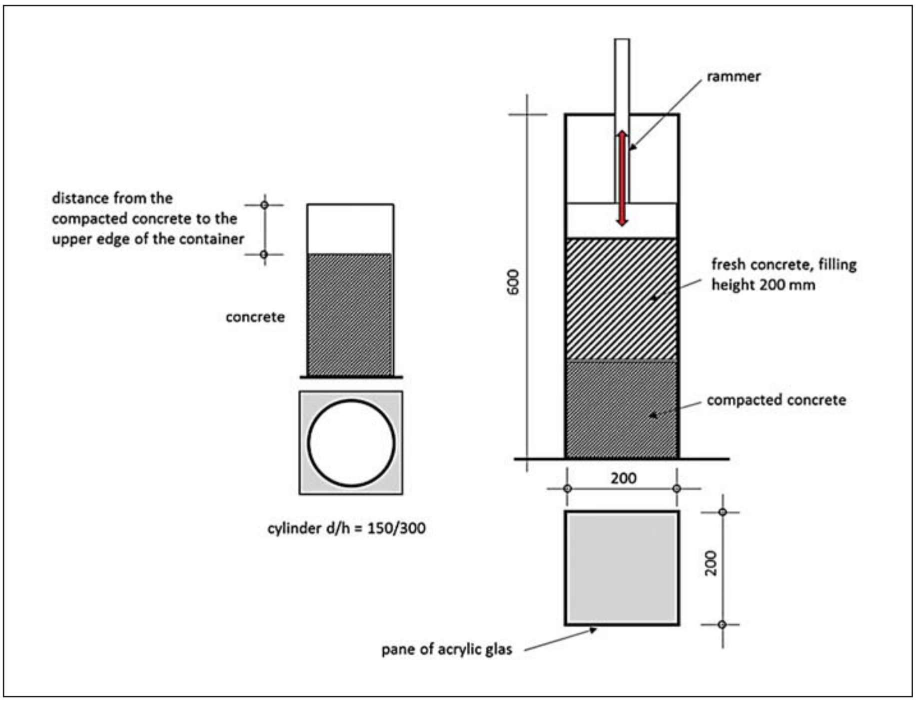

Figure 5: Test set-up for the production of rammed concrete (dimensions in mm). The fresh concrete will be filled into the form in three layers and will then be compacted by a hand rammer. Later, drill cores will be taken from the hardened material to test the compressive strength.