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APPLICATION OF CONCRETE RECYCLING METHODS AND TECHNOLOGIES GLOBALLY AND IN SERBIA

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Abstract

This paper analyses recycled concrete as an eco-friendly alternative within the circular economy, offering a solution to growing construction waste. It reviews recycled aggregate production technologies and their impact on concrete's key physical and mechanical properties. Relevant standards (SRPS EN 12620 and SRPS EN 206) are examined, demonstrating that up to 30% replacement of natural aggregates guarantees structural stability. Based on global practices and Serbia's current context, it concludes that updated legislative frameworks and processing facilities establish the prerequisites for widespread implementation of recycled materials in domestic construction.

***Keywords**: Recycled concrete, construction waste, recycled aggregate, mechanical properties of concrete*

1. INTRODUCTION AND ECOLOGICAL SIGNIFICANCE

Construction waste (construction and demolition waste) constitutes one of the largest waste streams globally. It is estimated that major construction waste amounts to hundreds of millions of tons annually. The traditional (linear) approach involves the exploitation of natural resources (river gravel, sand and water) and the landfilling of rubble following demolition. [1,3] Concrete recycling offers multiple benefits:

- **Conservation of natural resources** – reduces the need for natural aggregate extraction, the exploitation of which threatens riverbeds.
- **Landfill reduction** – construction rubble occupies vast volumes in municipal and illegal landfills.
- **Energy savings and CO_2 emission reduction** – shorter transport routes (material crushing is often performed directly on-site) directly decrease harmful gas emissions.

2. PRODUCTION TECHNOLOGY AND MATERIAL PROPERTIES

2.1. Recycling Process

The production of recycled aggregate (RA) from waste concrete begins with the selective demolition of structures. The objective is to separate materials (wood, glass,

plastic, metal) to the greatest extent possible to achieve maximum purity of the concrete rubble. Recycling plants can be stationary or mobile. A typical plant consists of: [1]

- **Receiving hopper** (feed hopper).
- **Crushers** (jaw or impact crushers)
- **Magnetic separator** (for extracting scrap reinforcement / rebar).
- **Screens** for separation into different aggregate fractions.



Figure 1. *Typical mobile concrete recycling plant and its key components*

2.2. Properties of recycled aggregate and concrete

Recycled aggregate differs from natural aggregate (river gravel or crushed stone) in that a layer of adhered old cement mortar always remains attached to the aggregate grains. This directly alters its properties: [1]

- **Water absorption** – coarse recycled aggregate absorbs between 3.5% and 10% water, whereas natural aggregate absorbs around 1%. Consequently, the water content must be adjusted during the mixing of new concrete.
- **Physical and mechanical properties** – it exhibits lower bulk density, higher crushability, and greater abrasion loss.

Research indicates that replacing natural coarse aggregate with recycled aggregate up to 30–50% results in a negligible reduction in compressive strength (around 8%). At 100% replacement, the reduction in compressive strength is approximately 13%, while the modulus of elasticity decreases by about 20%. Therefore, in engineering practice, recycled concrete is most used with partial aggregate replacement or for structural elements subject to lower stress levels.

2.2.1. Physical and Mechanical Properties of Recycled Concrete

Compressive Strength

Compressive strength is the fundamental parameter of any concrete. In recycled concrete, it decreases with an increasing replacement percentage of natural aggregate with recycled aggregate. [1,2,3]

- **From 20–30% coarse aggregate replacement** – The reduction in compressive strength is minimal (between 0% and 5%), and in practice, such concrete behaves almost identically to conventional concrete.
- **Over 50% to 100% replacement** – The strength reduction can range from 10% to 25%, depending on the quality of the parent (original) concrete.
- **Cause of the drop in compressive strength** – A weaker "Interfacial Transition Zone" (ITZ). Recycled concrete contains two interfacial transition zones: one between the original aggregate grain and the old mortar, and a new one between the old mortar and the new cement paste. This double transition zone represents the weakest link under compression. [1]

Modulus of Elasticity

This property suffers the most significant negative impact. The modulus of elasticity of recycled concrete is always lower than that of conventional concrete.

- **At 100% replacement of coarse aggregate**, the modulus of elasticity can be 15% to 30% lower.
- **Practical consequence** – due to the lower modulus of elasticity, structural elements made of recycled concrete (e.g., beams and slabs) will undergo greater deflections (deformations) under the same load. This must be considered during structural calculations.

Shrinkage and Creep

Deformations due to shrinkage (moisture loss over time) and creep (deformations under sustained loading) are significantly more pronounced in recycled aggregate concrete (RAC).

- **Shrinkage can be 20% to 50% higher**, while **creep can be up to 30% to 60% higher**.
- **Cause of increased shrinkage and creep** – due to the presence of a higher total volume of cement paste (old paste on the aggregate + new paste in the mix), which is prone to these deformations, as well as the higher water demand during mixing. [2]

Tensile Strength

Interestingly, tensile strength (whether flexural or splitting) does not decrease as drastically as compressive strength, and in some cases, it remains unchanged. The rough surface texture of recycled aggregate enables better mechanical interlocking with the new cement paste, which partially compensates for the inherent weakness of the material. [2,3]

3. GLOBAL APPLICATION OF RECYCLED AGGREGATE

In developed European countries (such as Germany, the Netherlands, and Austria), the use of recycled aggregate is standardized. It is utilized not only for road sub-bases (subbase layers), but also in building construction for structural elements. [1,2,3]

An excellent example of this application is Vienna. In Vienna, recycled concrete was recently implemented for the first time in the construction of a public facility—a new building for municipal waste management staff. The project was executed in accordance with the climate change adaptation strategy. Recycled crushed rock material was used for the concrete, while the building itself features green facades and photovoltaic panels. The objective of the municipal authorities was to demonstrate to investors that recycled concrete is a fully equivalent substitute for conventional concrete, thereby stimulating market demand.

4. CURRENT STATUS AND LEGISLATIVE REGULATION IN SERBIA

The situation in Serbia is changing significantly for the better, thanks to stricter regulations. The key document is the Rulebook on the Regulation, Management, Disposal, and Landfilling of Construction Waste During the Execution of Works ("Official Gazette of RS", No. 81/2024). Key obligations that must be fulfilled by construction waste owners or contractors include:

- **Waste management plan** – The construction waste owner (or contractor) is required to prepare a construction waste management plan prior to obtaining a construction or demolition permit.
- **Source separation** – Hazardous waste (e.g., asbestos sheets or insulation) must first be separated on-site to prevent it from mixing with clean concrete and brick intended for recycling.
- **Prerequisite for an occupancy permit** – Submitting documentation on the movement and storage of construction waste has become a mandatory condition (according to the Law on Planning and Construction) for the investor to obtain an occupancy permit for a new facility.

To ensure structural safety, the European Union (and consequently Serbia, through the standard harmonization process led by the Institute for Standardization of Serbia – ISS) strictly defines the conditions under which recycled aggregate may be used. The two most important standards applied in Serbia are **SRPS EN 12620** and **SRPS EN 206**.

4.1. SRPS EN 12620 – Aggregates for concrete

This standard defines the requirements that the aggregate itself must meet before entering the mixer. It classifies recycled aggregate into different types based on its composition:

- **Type A (high-quality recycled aggregate)** – Contains predominantly crushed concrete and natural stone, with minimal brick impurities (usually below 10%). This is the only type recommended for structural (load-bearing) concreate.

- **Type B** – Contains a higher percentage of bricks, tiles, and other construction site materials. It is used exclusively for non-structural applications (e.g., embankments, masonry blocks, blinding concrete).
- The standard strictly limits the presence of wood, plastic, glass, asphalt, and sulfates in recycled aggregate.

4.2. SRPS EN 206 – Concrete – Specification, performance, production and conformity

This umbrella standard for concrete specifies the rules governing how recycled aggregate may be used in concrete mixes:

- **Coarse aggregate only** – Standards generally permit the replacement of only the coarse fraction (particles larger than 4 mm). The use of fine recycled aggregate (sand) is avoided in structural concrete as it drastically increases water demand and reduces strength.
- **Exposure classes** – The standard restricts the use of recycled concrete depending on the environmental exposure of the structure. For instance, higher replacement rates are permitted for concrete in continuously dry environments (interiors), whereas for concrete exposed to freeze-thaw cycles, de-icing salts, or aggressive chemicals, the use of recycled aggregate is restricted or entirely prohibited.
- **Replacement percentage (20% Rule)** – According to European recommendations and EN 206, if up to 20% Type A coarse recycled aggregate is used, the concrete can be treated (designed and produced) using the exact same rules as concrete made with 100% natural aggregate, without requiring additional complex testing. Higher replacement percentages demand rigorous laboratory testing to verify mix suitability.

5. CONCLUSION

Based on all the relevant data presented, the following conclusions can be drawn:

- **Partial replacement (20–30%)** of coarse aggregate represents an optimal balance between environmental benefits and structural safety, as it does not require altering standard structural calculation methods.
- **For elements where deformations are critical** (such as long-span slabs), designers must pay special attention to the reduced modulus of elasticity and increased creep of recycled concrete, either by adopting larger cross-sectional dimensions or by adding a higher reinforcement ratio.

Technical barriers to the widespread application of recycled concrete in Serbia practically do not exist—the engineering community is well-versed in its properties. The primary challenges are economic and organizational in nature. Increasing the number of stationary plants, enforcing existing legislation in the field, and introducing "green public procurement" (where the state would mandate a specific percentage of recycled materials in public infrastructure projects) represent key steps for the further development of this sector in Serbia.

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