

# Hydrothermal synthesis of zeolitized aggregates from construction and demolition waste

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## INTRODUCTION

This work focuses on the fabrication of aggregates using construction and demolition waste (CDW), a priority waste type within current European circular economy policies. The European Union (EU) generates approximately 800–900 million tonnes of CDW per year, accounting for more than 35% of the total waste generated at EU level, with a comparable share reported for Spain (Cristóbal García et al., 2024). Given the huge volumes involved, there is an urgent need to develop valorisation routes that enable the incorporation of CDW into high-value applications beyond conventional low-grade uses such as backfilling. In this context, the present study evaluates the feasibility of producing zeolitized aggregates from mixtures of kaolin and CDW via the hydrothermal treatment.

## MATERIALS AND METHODS

Five CDWs supplied by two different treatment plants located in the Community of Madrid (El Molar and Navalcarnero, Spain) were evaluated as precursors for developing high performance aggregates. The CDWs consisted of rest of concrete, aggregates, ceramics and asphalt. Spherical granules ( $\varnothing \sim 10$  mm) were manually shaped from mixtures of kaolin and CDW at proportions of 0, 25, 50, 75 and 100 wt.%. The granules were fired at 600 and 800 °C for 2 h and subsequently subjected to alkaline hydrothermal treatment (HT) at 120 °C for 24 h using a 4 M NaOH solution at a liquid-to-solid ratio of 6 ml/g, following the protocol described by Moreno-Maroto and Alonso-Azcárate (2024). The resulting materials were finally characterized, with special attention to their mineralogical composition through quantitative X-ray diffraction with Rietveld refinement and compressive strength as the average value resulting from testing 10 specimens using a Nannetti® CC96/2006 press (Table 1).

## RESULTS AND DISCUSSION

Results show that firing at 600 °C did not lead to successful integrity of the aggregates after hydrothermal treatment for several formulations, particularly for those formulations containing the highest contents of mixed aggregates (i.e., samples Z20, Z32 and Z40, whose compositions can be seen in Table 1), which disintegrated under alkaline conditions. However, increasing the firing temperature to 800 °C enabled the formation of mechanically stable aggregates for all CDW formulations. All successful hydrothermal treatments promoted zeolite formation, with values reaching up to 30% for mixtures containing intermediate quantities of CDW. In parallel, compressive strengths values comparable to or exceeding those of kaolin aggregates were achieved, demonstrating that high CDW contents can be incorporated without compromising mechanical performance.

## CONCLUSIONS

The results demonstrate that several CDW types can be successfully valorised into zeolitized aggregates through alkaline hydrothermal treatment. Firing at 800 °C proved essential to ensure aggregate integrity and effective zeolite formation, particularly for mixed CDWs. Zeolite contents up to ~33% were achieved at intermediate CDW proportions (25–50%), while compressive strengths comparable to or higher than those of kaolin-based aggregates

were obtained, in some cases using 100% CDW, with values reaching up to 9 MPa. These results highlight the feasibility of incorporating high CDW contents while maintaining both functional and mechanical performance.

**Table 1.** Zeolite content and compressive strength (*S*) for the material fired at 600 °C and 800 °C. In bold, the highest values for each CDW.

Sample	CDW %	Firing at 600 °C		Firing at 800 °C	
		Total zeolites (%)	S (MPa)	Total zeolites (%)	S (MPa)
A6 recycled sand / pre-screened aggregate / mixed recycled concrete	100	5.3	<b>5.85</b>	0.7	5.14
	75	8.5	4.08	13.1	2.51
	50	17.9	2.39	<b>25.7</b>	3.87
	25	<b>23.2</b>	3.44	21.6	<b>6.48</b>
P40 mixed ceramic pre-screened aggregate / dirty line (not aggregate) / suitable for general fill (low-grade soil use)	100	3.7	2.10	2.5	<b>8.58</b>
	75	<b>25.0</b>	3.29	11.6	3.03
	50	14.7	1.78	<b>25.1</b>	4.07
	25	9.2	<b>5.09</b>	24.6	4.39
Z20 mixed aggregate / concrete	100	-	-	3.0	<b>6.17</b>
	75	-	-	9.1	2.26
	50	<b>20.0</b>	1.84	28.1	1.42
	25	19.8	<b>2.55</b>	<b>32.7</b>	4.35
Z32 mixed aggregate / concrete, asphalt	100	-	-	3.4	<b>7.01</b>
	75	-	-	10.5	1.71
	50	-	-	<b>28.4</b>	1.33
	25	<b>28.3</b>	<b>2.76</b>	26.8	5.18
Z40 mixed aggregate / ceramics	100	-	-	5.6	<b>5.31</b>
	75	-	-	10.6	1.7
	50	-	-	29.6	1.34
	25	<b>33.2</b>	<b>2.47</b>	<b>28.0</b>	3.79
Kaolin	0	25.3	4.70	22.6	4.91

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