Use of concrete recycled aggregates as a raw material in lightweight mortar fabrication

González Cortina, Mariano.[1], Saiz Martínez, P[1] Fdez. Martínez, F [2] Viñas Arrebola, C[1]

[1] Architectural Construction and Control Department, Higher Technical School of Building Construction, Universidad Politécnica de Madrid, Avenida Juan de Herrera 6, 28040 Madrid, E-mail: mariano.gonzalezc@upm.es, pablo.saiz@upm.es, carmen.vinas@upm.es
[2] Chemistry and Polymers Department, University school of Technical Industrial Engineering, Technical University of Madrid, Ronda de Valencia 3, 28012 Madrid, E-mail: francisco.fernandezm@upm.es.
Presenting author E-mail: mariano.gonzalezc@upm.es, (+34)913367596

Abstract

Construction and Demolition Waste (CDW) raises an environmental problem due both to the lack of prevention in their production process and little use of recycled material. In order to improve this situation, over the last years the new legislation on the CDW has entered into force, fostering the recovery of waste at its end-of-life and incorporating a study on CDW management during the planning process and a plan on CDW management during the construction phase.
In the development of this research basic materials were used for the cement mortars elaboration in proportion 1:3 and 1:4: cement (CEM II/B-L 32.5 N and CEM IV/B (V) 32.5 N, aggregates (natural aggregates and concrete recycled aggregates) and water. In case of recycled mortars some additive was used.
The methodology of the research is divided in two parts: in the first part the most relevant properties of recycled aggregates such as bulk and dry density, absorption, fines content, fineness modulus and friability coefficient were analyzed. In the second part the following tests were carried out: flexural and compressive strength, bond strength, shrinkage, density and water vapour permeability of mortars elaborated with recycled aggregates with the objective to study their feasibility.
Because of lower density and higher absorption of recycled aggregates recycled mortars present generally poorer properties compared to traditional mortars.
On the other hand, lower density of recycled aggregates presents an advantage in the fabrication of lightweight mortars and thus mortars with lower coefficient of thermal conductivity, what means better thermal behaviour compared to mortars elaborated with natural aggregates. Regarding water vapour permeability, recycled mortars have higher permeability compared to traditional mortars, what enables evacuation of water vapour existing in the interior of a construction avoiding in such a way the condensation in the interior layers of the brick wall. According to the obtained results, recycled mortars develop poorer behaviour compared to traditional mortars. However, these mortars comply with the standards taken as a reference, and their density and water vapour permeability make more attractive the use of these materials in the construction sector.

Keywords: waste treatment, masonry mortar, recycled aggregate, Mechanical properties.

Introduction

One of the main objectives in today's society is the conservation of environment and natural recourses. Current regulations foster the use of recycled aggregates reducing the generation of

waste without control and massive use of natural raw materials. In this sense, the incessant increase of Construction and Demolition Waste (CDW) generation creates a serious problem at the European level. CDW constitutes approximately 25%-30% of all the waste generated in the European Union [1], and although it is considered to be an inert waste, it produces a great visual impact in the landscape.

Presently in Spain the CDW is used mainly as packing for highways stretches and, to a lesser extent, in concrete fabrication. In Spain, the use of the coarse fraction of concrete recycled aggregate is regulated by the Structural Concrete Code [2], recommending substitution of up to 20%.

To increase recycling ratios, various scientific researches have studied the feasibility of incorporating fine fraction of recycled aggregates (RA) in masonry mortars production.

Fernández et al. [3] studied the incorporation of recycled aggregates in masonry mortars using CEM II/BL 32.5N. Obtained results show that replacement ratio of 50% can be achieved in mortar for indoor use.

Saiz [4] studied the possibility to fabricate recycled mortars using 100% of concrete, mixed and ceramic recycled aggregates. The results show that recycled mortars present technical, economic and environmental feasibility independently of the type of the used recycled aggregates, being concrete recycled aggregate one that gave better results.

Materials and Methods

The testing programme was developed using two types of binders: CEM II/B-L 32.5 N and CEM IV/B (V) 32.5 N. There were suggested two cement-to-aggregate by dry weight proportions were 1:3 and 1:4.Recycled aggregates coming from treatment plants were sieved in the laboratory, eliminating material retained on the 4 mm sieve and material passed through 0.063 mm sieve.

The following code was employed for the mixes identification:

M-Nº-Z

Where M = RM= Recycled mortar, TM= Traditional mortar.

Nº = Recycled aggregate type (II = CEM II/B-L 32.5 N and IV= CEM IV/B (V) 32.5)

Z= c/a proportion (X= 1:3 and Y= 1:4)

Results and Discussion

Characterization of aggregates samples was based on the technical requirements regulated by the standard UNE-EN-13139: “Aggregates for mortar”. The results of physical characterization of recycled aggregates are shown in Table 1.

Aggregates Characterization						
Type	UNEEN 933-1	UNE-EN13139	UNE-EN 83115	UNE-EN 1097-3	UNE-EN-1097-6	UNE-EN-1097-6
	Fine content (%)	Fin. modulus (%)	Friability (%)	Bulk. Dens. (kg/m3)	Relat. Dens. (kg/m3)	Water absorption (%)
NA	2.55	4.22	22.60	1550	2400	0.98
RAC	3.98	4.12	23.94	1320	2110	6.05

Table 1. Physical Characterization

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As it is observed in Table 1, the characteristics that mainly differentiate recycled aggregates from natural aggregates are their lower density and higher absorption. Higher absorption

provokes higher water demand in mortars fabricated with recycled aggregates and thus these mortars have higher water-to-cement proportion what limits their mechanical properties.
Regarding the results of the X-ray diffraction test, main crystalline phases obtained are quartz and calcite. Observed phases, with the exception of quartz, do not show a high crystalline state presenting low intensities. Other observed phases are sanidine, phlogopite, albite and gypsum.
The results of the characterization of recycled mortars are shown in Table 2.

Recycled mortar characterization				
Test	**RM-II-X** RM-IV-X	**RM-II-Y** RM-IV-Y	**TM-II-X** TM-IV-X	**TM-II-Y** TM-IV-Y
Workability time (min)	89/92	83/90	118/122	121/126
Dry density(kg/m^3)	1830/1810	1780/1780	2060/2030	1980/1970
Real density(kg/m^3)	2390/2150	2280/2130	2320/2300	2270/2270
Shore hardness (ud)	73/73	72/70	80/78	78/77
Flexural strength (Mpa)	4.74/5.02	3.12/3.42	5.12/5.75	3.87/4.36
Compres.strength (Mpa)	17.41/19.21	9.82/11.92	21.94/23.10	14.75/17.02
Bond strength(N/mm^2)	0.41/0.42	0.37/0.39	0.51/0.50	0.49/0.49
Shrinkage(mm/m)	0.082/0.083	0.090/0.089	0.023/0.025	0.031/0.034
Water vapour.permeability (kg/msPa)	-/5.65x10^{-12}	-/6.34x10^{-12}	-/2.40x10^{-12}	-/3.09x10^{-12}
Note: 1% of additive over the weight of cement.				
Note: same water amount for all types of cement.				

Table 2. Recycled mortar characterization

The time in minutes obtained with CEM II is shorter than that obtained in the mortars elaborated with CEM IV. It happens due to the presence of fly ash in high proportion in this type of cement, leading to the improvement in the workability of mortar.
The decrease in the compressive strength is more important in the mixes made with CEM II compared with mixes made with CEM IV. In case of CEM II the decrease of strength was 20.65% for the dosage 1:3 and 33.42% for the dosage 1:4. In either case, all the mixes comply with the limit of 7.5 N/mm^2 established by the reference standard (UNE-EN 998-1).
Surface hardness of recycled mortars are slightly lower than that of mortars made with natural aggregates. In terms of the type of the used cement, there were observed no differences in hardness.
Both bulk density in hardened state and real density of mortar depend on the density of the materials it is fabricated with, on the particle size distribution and on the water-to-cement proportion.
Generally, bulk density and real density in hardened state are lower in recycled mortars compared with mortars elaborated with natural aggregates.
The results of the bond strength test show poorer behaviour of recycled mortars compared with the reference mortars. However obtained results are higher than the limit of 0.30 N/mm2 established by the standard UNE-EN-998-1 for this type of mortars.
Recycled mortars present higher shrinkage than mortars fabricated with natural aggregates. This is produced mainly by the higher absorption of recycled aggregates. Water vapour permeability values for the mixes containing recycled aggregates are higher with respect to the mixes made with natural aggregates. This characteristics enable the evacuation of water

vapour existing in the interior of the construction avoiding in such a way the condensation in the interior layers of the enclosure wall.

Conclusion

The experimental research leads to the following conclusions:
Recycled aggregates have lower density and higher absorption compared with natural aggregates due to the amount of adhered mortar in this type of aggregates.
Real density of recycled mortars is lower than that of mortars elaborated with natural aggregates due to the lower density of recycles aggregates. This causes a slight decrease of the building permanent loads.
Generally, recycled mortars have poorer mechanical behaviour than traditional mortars. Shrinkage is one of the properties that is affected more significantly. However, recycled mortars comply with all the requirements of the standards taken as a reference.
As a final conclusion, it can be stated that masonry mortars elaborated with CEM IV and 1:3 and 1:4 compounds proportions can incorporate 100% of three types of RA complying with the requirements established by the Spanish standards.

References

[1] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.
[2] Spanish Ministry of Public Works. Instrucción de Hormigón Estructural EHE-08 (Spanish Structural Concrete Code). BOE 2008; 203:258-66.
[3] Fernández, E,; Jiménez, J.R.; Ayuso, J.; Fernández, J.M.; de Brito, J. (2015) Maximum feasible use of recycled sand from construction and demolition waste for eco-mortar production- Part-I: ceramic masonry waste. Journal of Cleaner Production 87, 692-706.
[4] Saiz Martínez, P. (2016). The use of aggregates from Construction and Demolition Waste, CDW, in the fabrication of masonry mortars. Doctoral Thesis. ETSEM, Technical University of Madrid.