Using recycled concrete aggregates in precast concrete hollow blocks

Über die Vewendung von wiederaufbereiteten Beton-Zuschlagstoffen in vorgeformten Beton-Hohlblöcken

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Among the construction waste that could be recycled, we can mention the aggregates resulting from crushed concrete. While the acquired knowledge about the use of recycled aggregates in new concrete mixes is fairly large, the use of such aggregates in the production of concrete blocks is very limited. This research aims to study the influence of the use of recycled aggregates in precast concrete hollow blocks on their compressive strength. Tests were carried out to determine the rate of recycled aggregates content to be used in the manufacture of concrete blocks in order to obtain blocks having suitable compressive strength. Tests were executed on several series of blocks whose composition includes recycled aggregates and on one series of reference blocks whose composition consisted exclusively of natural aggregates. Tests results have provided the maximum percentage of recycled aggregates that can be included in new concrete block mixes without affecting blocks compressive strength. Tests have shown that the use of recycled aggregates in concrete blocks could give a compressive strength similar to that of blocks manufactured without any recycled aggregates. It has been shown also that using recycled aggregates in the manufacture of concrete blocks without any natural aggregates is not economical at all because of the need to add a relatively high quantity of cement necessary to obtain the required compressive strength.

Keywords: recycled aggregates / precast concrete hollow blocks / compressive strength / workability / superplasticizer

Schlüsselwörter: wiederaufbereitete Zuschlagstoffe / vorgeformte Beton-Hohlblöcke / Druckfestigkeit / Umformbarkeit / Fließmittel

1 Introduction

While the acquired knowledge about the use of recycled aggregates in new concrete mixes is fairly large [1–3], the use of such aggregates in the production of concrete blocks is very limited [4, 5]. This research aims to study the influence of the use of recycled aggregates in precast concrete hollow blocks on their compressive strength.

Concrete blocks containing recycled aggregates have a lower strength than blocks with natural aggregates. This is due to the weaker density of recycled aggregates in comparison to natural aggregates [4]. Our previous researches [5] showed that the use of recycled aggregates with a 10% cement addition compared to normally used cement quantity could allow the production of concrete blocks having compressive strengths similar to those of concrete blocks with natural aggregates. Moreover, to assure the workability of concrete which has been affected due to the addition of cement and the absorption of recycled aggregates, water addition is needed. Since the principal responsible of the concrete deficiency is the addition of water, we aimed to substitute in some mixes the addition of water by adding water-reducer superplasticizer.

This research represents tests carried out on blocks whose composition includes natural and different percentage of recycled aggregates, as well as on blocks whose composition consisted exclusively of natural aggregates. It shows the effect of the percentage of used recycled aggregates on the compressive strength of blocks, as well as the addition of cement and water and the addition of cement and superplasticizer.

The objective of this research is to study the influence of recycled aggregates used in new concrete mixes for producing precast concrete hollow blocks. This study aims to determine the percentage of recycled aggregates to be used in the manufacture of concrete blocks in order to obtain blocks having suitable physical and mechanical properties, i. e. workability and compressive strength.

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Table 1. Concrete mixes of blocks

Tabelle 1. Zusammensetzung der Betonblöcke

Constituents	Unit	1	2	3	4	5	6	7
		RA50	RA50+C+W	RA50+C+SP	RA30	RA30+C+W	RA30+C+SP	NA
Cement Addition	%[1]	–	10%	10%	–	10%	10%	–
NA 0–6 mm	%[2]	100%	100%	100%	100%	100%	100%	100%
NA 6–12 mm	%[3]	50%	50%	50%	70%	70%	70%	100%
RA 6–12 mm	%[3]	50%	50%	50%	30%	30%	30%	–
Water Addition	%[4]	–	10%	–	–	10%	–	–
Superplasticizer	%[5]	–	–	0.25%	–	–	0.25%	–

Table 2. Concrete mixes of blocks (by weight and volume)

Tabelle 2. Zusammensetzung der Betonblöcke (Gewicht und Volumen)

Constituents	Unit	1	2	3	4	5	6	7
		RA50	RA50+C+W	RA50+C+SP	RA30	RA30+C+W	RA30+C+SP	NA
Cement	kg/m³	144	158	158	144	158	158	144
NA 0–6 mm	kg/m³	1435	1435	1435	1435	1435	1435	1435
NA 6–12 mm	kg/m³	359	359	359	503	503	503	718
RA 6–12 mm	kg/m³	359	359	359	215	215	215	–
Water	l/m³	144	158	–	144	158	–	144

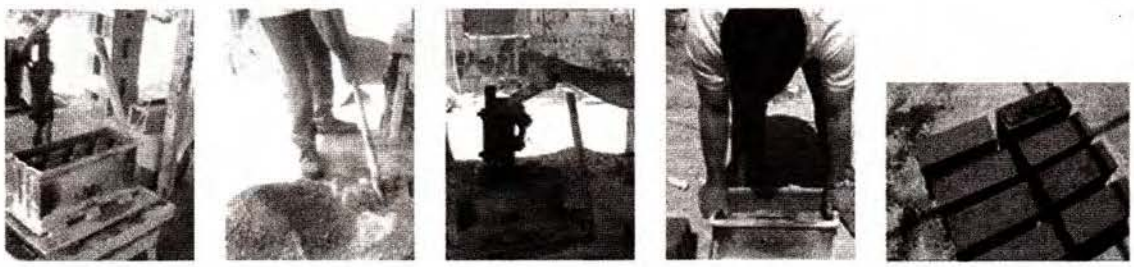

Figure 1. Production of precast concrete hollow blocks, a – mold; b – preparation of mix; c – block molding; d – block demolding; e – manufactured blocks.

Bild 1. Herstellung der vorgeformten Beton-Hohlblöcke, a – Form; b – Herstellung der Mischung; c – Füllung der Form; d – Entformung; e – hergestellte Blöcke.

2 Test description

This research was carried out at the Laboratory of Civil Engineering at the Lebanese University, except the compression tests which were done at the Laboratory of Civil Engineering at Notre Dame University. Six series of three concrete blocks each were prepared using natural and recycled aggregates, and one series of reference blocks without any recycled aggregates, *Tables 1* and *2*. The used recycled aggregates were obtained from crushing demolished structural concrete. The composition of concrete required to produce blocks containing only natural aggregates (mix 7) was established based on the experience and tradition of local industry. The results presented in this paper correspond to the mean value of 3 specimens of hollow blocks of 40 cm length × 20 cm height × 15 cm thickness. The different stages of blocks manufacture and the testing of blocks, *Fig. 1*, *Fig. 2*.

Previous tests have shown that recycled aggregates absorb a higher amount of water than natural aggregates [4, 5]. The water demand is due to the porosity and angularity of recycled aggregates. With the aim to avoid affecting concrete characteristics

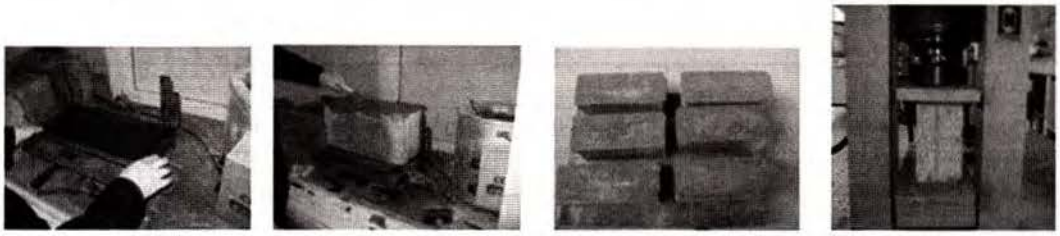

Figure 2. Testing of precast concrete hollow blocks, a, b, c – preparation of blocks for testing; d – block during compression test.

Bild 2. Untersuchung der vorgeformten Beton-Hohlblöcke, a, b, c – Vorbereitung der Blöcke zum Testen; d – Block während Druckversuch.

Table 3. Density and compressive strength of concrete blocks

Tabelle 3. Dichte und Druckfestigkeit der Betonblöcke

Constituents	Unit	1	2	3	4	5	6	7
		RA50	RA50+C+W	RA50+C+SP	RA30	RA30+C+W	RA30+C+SP	NA
Density	kg/m³	2259	2218	2289	2269	2231	2366	2352
Strength at 28 days	MPa	4.47	6.45	6.27	4.58	6.62	6.75	4.15
Standard Deviation	MPa	0.08	0.25	0.45	0.13	0.26	0.17	0.18

due to the increase of water content, the water addition in some mixes was substituted by using water-reducer superplasticizer.

All blocks specimens were immersed in water maintained at a temperature of 20 ± 2 °C for 72 h. The air humidity was between 65% and 75%. The compression tests were carried out after 7 days from the date of manufacturing using a PERRIER compression machine with a loading capacity of 1500 kN and equipped with measurement module 705. The load was applied with a constant speed of 5 kN/s. The test was considered complete when the specimen was broken. The recorded parameter given by the testing machine dial pointer was the concrete blocks compressive strength. The standard deviation values for all tests were ranged between 0.08 and 0.45 MPa.

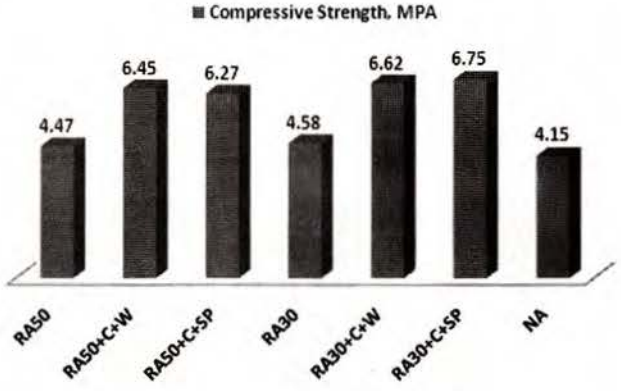

Figure 3. Compressive strength of concrete blocks.

Bild 3. Druckfestigkeit der Beton-Blöcke.

3 Test results

Based on blocks tests, the density and the 28-day compressive strength of each block were determined. The test results are presented in *Table 3* and *Fig. 3* for each concrete mix.

3.1 Effect of recycled aggregates percentage

- Mixes without any addition of cement, water or superplasticizer (mixes 1 and 4):
  Blocks containing 30% recycled aggregates (RA30) show 2.5% increase of strength comparing with blocks containing 50% recycled aggregates (RA50). Comparing the test results for blocks with natural aggregates (NA), the strength is not affected at all by the recycled aggregates; it even increases in comparison with the strength of blocks which does not contain any recycled aggregates. This increase amounts to 8.5% for RA30 and 5.9% for RA50.
- Mixes with addition of cement and water (mixes 2 and 5):
  Blocks containing 30% recycled aggregates (RA30+C+W) show 2.6% increase of strength comparing with blocks containing 50% recycled aggregates (RA50+C+W).
- Mixes with addition of cement and superplasticizer (mixes 3 and 6):
  Blocks containing 30% recycled aggregates (RA30+C+SP) show 7.7% increase of strength comparing with blocks containing 50% recycled aggregates (RA50+C+SP).

3.2 Effect of cement and water addition

When evaluating the effect of 10% water addition in mixes 2 and 5 comparing with mixes 1 and 4, we should take into account the 10% cement addition in mixes 2 and 5. As stated in paragraph 1 above, this 10% cement addition (compared to normally used

cement quantity) is necessary for the production of concrete blocks with suitable compressive strength. Furthermore, the water addition is needed to maintain the workability of concrete which will be affected due to addition of cement and to absorption of recycled aggregates.

- Mixes with 50% RA (mixes 1 and 2):
  An increase of 44% in the strength of blocks containing 50% recycled aggregates (RA50+C+W) is observed when water is added, comparing with blocks without any addition.
- Mixes with 30% RA (mixes 4 and 5):
  The percentage increase of strength of blocks containing 30% recycled aggregates (RA30+C+W) is 45% when water is added, comparing with blocks without any addition.

3.3 Effect of superplasticizer

When evaluating the effect of superplasticizer comparing with water addition, we do not have to take into account the added quantity of cement since such quantity is added with water too.

Test results show that the effect of superplasticizer is more considerable for blocks containing 30% recycled aggregates (RA30+C+SP) than for blocks containing 50% recycled aggregates (RA50+C+SP). The positive effect of superplasticizer is revealed by the 7.7% increase of strength as stated above.

- Mixes with 50% RA (mixes 1, 2 and 3):
  An increase of 44% in the strength of blocks containing 50% recycled aggregates (RA50+C+W) is obtained when water is added, while this increase is of 40% when superplasticizer is added (RA50+C+SP). The use of superplasticizer did not show any effect on the blocks compressive strength.
- Mixes with 30% RA (mixes 4, 5 and 6):
  The percentage increase in the strength of blocks containing 30% recycled aggregates (RA30+C+W) is 45% when water is added, while it is 47% when superplasticizer is added (RA30+C+SP). The superplasticizer addition provoked minor upgrading of blocks compressive strength comparing with water addition.

4 Conclusions and recommendations

The obtained test results show that the compressive strength of the concrete blocks manufactured with recycled aggregates depends on:

- the percentage of recycled aggregates;
- the cement addition;
- the water addition;
- the use of superplasticizer.

For the manufacture of concrete hollow blocks containing recycled aggregates, we can give the following conclusions and recommendations:

- Blocks containing 30% recycled aggregates have compressive strength bigger than blocks containing 50% recycled aggregates. This increase of strength is the same for blocks without any addition of cement, water or superplasticizer comparing to blocks with addition of cement and water (2.5 to 2.6%). This increase is more considerable when comparing to blocks with addition of cement and superplasticizer (7.7%).
- We can use up to 50% recycled aggregates without affecting blocks compressive strength as long as a small cement quantity is added.
- The increase of concrete compressive strength of blocks with addition of cement and water is satisfactory for blocks containing 30% recycled aggregates (increase of 45%) and for blocks containing 50% recycled aggregates (increase of 44%).
- The advantage of the substitution of superplasticizer use for water addition is somewhat remarkable for blocks containing 30% recycled aggregates.

Notes:

NA: natural aggregates
RA: recycled aggregates
C: cement
W: water
SP: superplasticizer
(1): percentage of cement addition comparing to normal quantity (used in mixes 1, 4 and 7)
(2): percentage of 0-6 mm aggregates
(3): percentage of 6-12 mm aggregates
(4): percentage of water addition compared to normal quantity (used in mixes 1, 4 and 7)
(5): percentage of cement weight

5 References

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