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RECOMMENDATIONS FOR RECYCLING, PROCESSING AND REUSE OF CONCRETE

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ABSTRACT

Some countries started to recycle concrete material in order to reuse it in structural or other issues. Some of them, like Germany, Australia and Canada have established their own recommendation guide for recycling concrete [1,2,]. This recycling consists of crushing old concrete into aggregates, and then processing it into new mixture using the recycled aggregates with specified sizes [3,4]. The aim of this recycling is to save nature from deforestation and dryness, by reducing the need to gravel and so the quarries work, and also to economize the waste management [5,6].

The present research work consists of an experimental study treating the impact of using recycled aggregates on the concrete behavior and on the country's economy. We are especially interested in determining the best composition for the new mixture of concrete resulting from reusing different types of recycled aggregates. Different types of tests have been done depending on the aggregates sizes, their origin and their state (burned or safe). The analysis is based on the comparison between compressive strength, water-cement ratio, slump, porosity and durability. Otherwise, the impact on economy is analyzed, a priori, by studying the effect of reducing the price of the resulting concrete on construction spending. The resulted recommendations indicate the sizes of aggregates which may constitute the best composition for recycling and processing concrete, and the best use for each type of concrete depending on behavior and economy effect.

Key words: Recycling, reuse, aggregates, concrete, tests.

INTRODUCTION

The problem of concrete waste management was urgently imposed in Lebanon after the war of July 2006. In fact, the government should get rid quickly of the huge amount of demolished concrete in order to provide new houses and infrastructure. This necessity has shown the importance of having some recommendations for concrete recycling, processing and reusing. Meanwhile, these recommendations are also necessary for countries threatened to catastrophic effects like seism and hurricane which may cause destruction of buildings or other concrete constructions.

This study treats the impact of using recycled aggregates on the concrete behavior and thus on the country's economy. Many types of recycled aggregates are considered. They are based on the choice of the original concrete and the aggregates sizes. All strength values obtained from tests correspond to 15 cm diameter cylinders.

NOMENCLATURE

C: Concrete
R: Recycled
W: Washed aggregates
F: old concrete set to Fire
N: Newly manufactured (less than 3 months)
O: Old concrete (obtained from the demolition of old buildings
Type A: aggregates ranged between 8 and 16 mm
Type B: aggregates ranged between 4 and 16 mm

VISUAL ASSESSMENT

The examination of burned constructions has shown that concrete with calcareous aggregates resists to fire less than concrete with silica aggregates. In fact, after three hours of fire, concrete with original silica aggregates was still resisting which was not the case for concrete with calcareous aggregates. However, only calcareous aggregates have been used herein because the majority of the actual Lebanese sources of aggregates for construction result from calcareous mountains.

EXPERIMENTAL TESTS

New concrete mixture has been made according to the following composition for 1 m^3 of concrete:

- Aggregates 5/16 : 1240 Kg
- Sand : 580 Kg
- Cement: 350 Kg
- Water: 200 Kg

New recycled aggregates used in this research work correspond to this crushed recent concrete.
Old and burned recycled aggregates are obtained from the demolished constructions after the war in Lebanon of July 2006.

Recycled aggregates have been separated into four ranges: between 4 and 8 mm; between 8 and 16 mm; between 4 and 16 mm; and between 0 and 4 mm.
The test results have shown that up to 40 % of recycled aggregates (obtained form old concrete and hollow blocks) can be used in the new mixture for the production of new tiling and hollow blocks (see also [7]). This percentage limit is due to respect a compromise between the compressive strength decreasing and the porosity increasing. This confirms the practice in the field, see [8,9,10].

The aggregates sizes have been divided into two categories: A (between 8 and 16 mm), and B (between 4 and 16 mm). A30 means that 30% of the A category aggregates are used in the correspondent composition. For each test, six cylindrical specimens have been crushed. The presented results for strength correspond to the mean values.

A new mesh concept has been proposed to separate the aggregates. It consists of round openings instead of traditional square. This concept has permitted to preserve the initial sharp form of aggregates and thus has improved the bond with mortar.

At first, the recycled aggregates have been used in the new mixture without washing. This choice was considered in order to determine the impact of the washing procedure on economy. Also, as a hypothesis for all types of concrete mixture related to this research work, the water-cement ratio (W/C) and the compressive strength retained correspond to the same type of firm concrete.

Some other results have shown that porosity for recycled aggregates is bigger than for ordinary concrete. This remark has been noted by many other researchers [10]. Durability tests have also been undertaken. The corresponding results are given in table 3. The durability indices are obtained using the slake durability apparatus which consists on assessing the resistance offered by aggregates to weakening and disintegration when subject to changes in water content.

OBSERVATIONS

The shape of failure for all recycled concrete cylinders is diabolical (two cones, see fig. 1).

All results are compared between each other and with ordinary concrete. Table 1 presents the comparison between new recycled concrete from washed or unwashed recycled aggregates and its reference concrete. Table 2 shows the difference between the old concrete obtained from the demolished buildings whether it was burned or not.

TABLE 1: COMPARISON BETWEEN NEW RECYCLED CONCRETES

	mean aggregate size	Recycled aggregate percentage	W/C	Slump (cm)	Strength (MPa)
NC			0.55	2.5	24
RCN-A30	12	30	0.77	3	20.33
RCN-B30	10	30	0.77	4	18.4
RCNW-A20	12	20	0.66	2.3	16.75
RCNW-B20	10	20	0.66	2.3	16.83
RCNW-A30	12	30	0.73	4	13.9
correlation					
strength	-0.14	0.17	0.44	-0.19	1.00
slump	-0.03	0.88	0.77	1.00	

TABLE 2: COMPARISON BETWEEN OLD RECYCLED CONCRETES

	mean aggregate size	Recycled aggregate percentage	W/C	Slump (cm)	Strength (MPa)
OC					30
RCOW-A30	12	30	0.92	1.5	15.25
RCOW-A10	12	10	0.72	4	16
RCOW-B10	10	10	0.72	3	20
RCFW-A10	12	10	0.72	3	16.25
RCFW-B10	10	10	0.75	5	15.66
correlation					
strength	-0.57	-0.40	-0.46	-0.05	1.00
slump	-0.49	-0.77	-0.68	1.00	

TABLE 3: Durability Indices for different types of aggregates

Type	RCN-A30	RCN-B30	OC	FC
I_d (%)	96.32	96.6	98.4	91.6

If a satisfactory behavior under compression for the unwashed recycled aggregates was obtained, the results have shown a quick decrease of the strength after crushing. This fragile behavior has been smoothed by washing, at preliminary, the recycled aggregates.
The comparison between the ordinary concrete and the recycled concrete, washed or unwashed, has shown that water-cement ratio has increased in order to insure a good work for concrete mixture (slump) and a good mix (cf for example [11,12]) .

Table 1 and table 2 show a different behavior: in the case of recent concrete, the mean aggregate size and the percentage of recycled aggregate do not influence the strength result (correlation of -0.14 and 0.17). Only W/C is important (correlation of 0.44). In the case of old recycled concrete, correlation shows that the aggregate mean size (A or B) is more explicative for the strength than W/C and the percentage of recycled aggregates, even if these parameters are more influent than for recent aggregates.

The slump results show the same tendency: The mean aggregate size has influence only in the old aggregates case (correlation of -0.49). The two other parameters (percentage and W/C) are more explicative than the mean size in both cases. On the other hand, W/C does not show the same trend in table 1. In fact, for unwashed aggregates corresponding to the same W/C and percentage, the strength increases when using coarse recycled aggregates (type A). For all washed recycled aggregates (New or Old Concrete) the strength decreases as W/C increases (see also [13]).

A first conclusion which has to be confirmed by other tests is that recent concrete is not the right material to study recycled aggregate concrete. Therefore, we will focus on table 2 results. This table shows a decreasing relationship between the strength and respectively the mean aggregate size, the percentage of recycled aggregates and W/C. The burned aggregates give results in terms of strength which are too near to judge between A or B composition.

Otherwise, table 3 shows that durability of recycled aggregates is less than old concrete, and there is no significant influence for recycled aggregates sizes on durability. The worst in durability is the burned concrete.

RECOMMENDATIONS

Selling practice of demolished concrete after the war of July 2006 in Lebanon has shown that using 20% of recycled aggregates reduces the price of 1 m3 of concrete of 16%. It is important to note that the closer the construction to recycled aggregates sources, the better saving is obtained. In Lebanon and other countries like U.S.A recycled aggregates are half the price of natural aggregates.

Then:

1- The best composition, in terms of quality-price for new mixtures of structural recycled concrete, corresponds to up 20% of recycled aggregates for both types A and B. When using up to 10% of old recycled aggregates, it is better to use type B, and when using up to 10% of burned recycled aggregates, both types A and B can be used.

2- The analysis of the test results have shown that satisfactory concrete for structural issues can be made with aggregates prepared from recycled concrete. For the same water cement-ratio, comparable results are obtained for ordinary and recycled concrete. Otherwise, we recommend using plasticizers in new recycled concrete mixtures.

3- For constructions threatened to fire, it is advised to use silica aggregates for recycled concrete. More studies must be done for this type of aggregates.

Fig. 1: Failure shape of cylindrical recycled concrete

CONCLUSIONS

Satisfactory behavior for structural and non structural concrete is obtained when using recycled aggregates.
When crushing demolished buildings, it is advised to distinguish between structural concrete and hollow blocks, and between safe and burned concrete. In fact, the resulting behavior of the new mixture depends on the original composition.

The best composition for recycled structural concrete is in general 20%. However, plasticizers should be used in order to obtain a better behavior. More studies must be done depending on the type of aggregates, impact of plasticizers, degree and duration of fire for burned concrete …

Finally, most of actual results in recycled concrete are based on recently manufactured concrete. The present research work has shown a difference in the behavior between recent and old recycled concrete. As it is uneconomic to use recent concrete in recycling, this paper advises to recycle old concrete.

PERSPECTIVES

More tests must be done to assess the impact of all influencing parameters on the recycled concrete behavior. Additional experiences must also be undertaken to determine the best issues for recycled aggregates. Some of them can be used for structural elements, and others for the production of hollow blocks, tiling and even for the use like landfill.

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