Chemical Separation Techniques for Quantification of Residual Mortar Attached with Recycled Brick Aggregate

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Abstract

Recycling concrete to extract its usable part to use as raw material for further concreting is a trendy subject matter in the field of concrete technology. Coarse aggregate extracted from demolished concrete is proved to be effective for partial replacement of natural aggregates in concrete but they are usually of inferior quality as compared to natural aggregates. Studies reveal that the old mortar, called residual mortar, attached to the surfaces of the aggregates is responsible for this inferior quality. Quantification and removal of this residual mortar is, therefore, of utmost importance for assessing and improving the quality of recycled aggregate. The present study is aimed to investigate the potentials of chemical separation techniques for the removal of residual mortar attached with recycled brick aggregate. Salt-induced chemical separation techniques as specified by the American Society for Testing and Materials (ASTM C88) are applied. The specified standards are modified to some extent according to the recommendations made in works of literature. Four different salts as Magnesium Sulfate, Sodium Sulfate, Sodium Chloride, and Magnesium Chloride are used in different concentrations. A comparison of performance of all the chemicals mentioned above is presented and the best chemical and its optimum concentration is identified. None of the chemicals are found to remove all the residual mortar but treatment with 26% sodium sulfate solution was found to be most effective with a maximum weight loss of 49.02% in 9 cycles.

Keywords: *Recycled Aggregate; Recycled Brick Aggregate (RBA); Residual Mortar (RM); Concrete Recycling; Green Concrete*

1. Introduction

In present days, infrastructural development often involves the demolition of older low-rise buildings which results in tons of demolition waste. These wastes require a large landfill area for proper disposal. Soil and water pollutions are also reported as an environmental impact of demolition waste (Hou et at., 2018; Staunton et at., 2014). Recycling demolished concrete to separate the reusable part is an economic and environment-friendly option to deal with such problems. Aggregates may be separated from demolished concrete and reused. Several studies are available on the usability of recycled aggregate and most of them present promising results. A study was carried to observe the effect of different recycled coarse aggregate (RCA) replacement percentages of 0-100% on recycled concrete under uniaxial compression loading and about 3 MPa reduction of compressive strength were observed for 100% RCA (Xiao et al., 2005). Another study on 96 cube specimens and 8 concrete slabs cast to perform Schmidt rebound hammer, core, and cube testing using 70% replacement of RCA reported that strength of concrete remarkably increased at early ages, while a moderate increase occurred in most cases at older ages (Kazemi et al., 2019). A 16% density loss for 100% use of recycled brick aggregate (RBA) was reported in the literature (Gayarre et al., 2020). The same study also reported a 2% strength loss in every 10% addition of RBA. However, some studies also reported remarkable property degradation for using recycled aggregate. More than 30% reduction in 28-days compressive strength was reported for a 100% replacement of recycled aggregate (Yang et al., 2008). As degradation of concrete properties for using recycled aggregate is reported in most of the studies, it is evident that recycled aggregates are inferior to natural aggregates. Recycled aggregates have limitations such as weaker interfacial behavior between aggregate and cement paste, higher portions of old cement mortar attached, and lower quality (Tam et al., 2007). These limitations restrict the use of recycled aggregate. A gradual reduction of concrete strength after 30% replacement of recycled aggregate was reported (Limbachiya et al., 2000). To improve the quality of recycled aggregates, some techniques need to be developed, such as minimizing the cement mortar portions adhering to recycled aggregate or separate aggregate from cement paste as much as possible to attain the quality comparable to the original aggregate (Tomosawa and Noguchi, 2000). Several attempts are made to remove the residual mortar from recycled aggregate in past years. Several methods for quantification and removal of residual mortar are presented in pieces of literature (Braymand et al., 2017; Abbas et al., 2007). Most of the present studies available in this subject matter are based on recycled stone aggregates but in Bangladesh, most of the older buildings being demolished are made of local brick aggregates which have properties different than stone aggregates. Methods for quantification and removal of residual mortar (RM) proposed by researchers in the case of stone aggregates need to be evaluated for recycled brick aggregate (RBA). The present study is taken into account for the evaluation of chemical separation methods to remove and quantify RM attached to RBA.

2. Materials and Methods

2.1 Materials

2.1.1 Recycled Brick Aggregate (RBA)

Recycled brick aggregate (RBA) for this study was collected from a demolished 2-storied commercial building located at Dinajpur City. Demolished concrete blocks from beams and slabs were collected and crushed to standard aggregate size. Figure 1 shows the collection and processing of RBA.

Figure 1. Collection and processing of RBA

2.1.2 Chemicals

Based on the previous works, four different salts were selected for this study namely, Sodium Sulfate, Magnesium Sulfate, Sodium Chloride and Magnesium Chloride The salts were stored in air-tight condition to prevent crystal formation.

2.2 Methods

Several methods are presented in studies and works of literature for the removal of residual mortar from the recycled aggregate. Among them, mechanical, chemical, and thermal treatments are found to be effective in the case of recycled stone aggregates with sufficient removal of attached mortar (Braymand et al., 2017; Abbas et al., 2007; Tam et al., 2007). Among the proposed methods, the chemical separation technique by salt treatment is adopted for this work.
The method is based on the standard test method for soundness of aggregates by use of sodium sulfate or magnesium sulfate specified by the American Society for Testing and Materials (ASTM C88) and Ministry of Transportation, Ontario (MTO LS-606). However, the original soundness test procedure is modified by researchers to make it applicable for removing and quantifying residual mortar by researchers. The procedure adopted by Abbas et. al., (2007) was applied which may be discussed in two steps:

a. Identification of best performing salt
b. Determination of best concentration and removal efficiency

2.2.1 Identification of Best Performing Salt

To identify the best performing salt among the four salts under consideration, solutions of salts were prepared. As per ASTM C-88 instructions, saturated solutions were prepared (at a temperature of 250C – 300C) so that some extra salt crystal is available in the solution. About 250 gm of recycled brick aggregate was immersed in 1 liter of each solution. The solutions along with aggregates immersed in it were kept undisturbed for a period of 15 days at a controlled temperature of 28±10C. After 15 days, the solutions were drained and the aggregates were examined for possible degradation of the attached mortar. Figure 2 shows the process.

Figure 2. Identification of best performing salt (degradation after 15 days)

After 15 days of immersion, the solutions were drained, the aggregates were oven-dried and sieved with a 4.75 mm standard sieve to observe the mass loss due to degradation of attached mortar. Table 1 shows the mass loss for each solution after the immersion period.

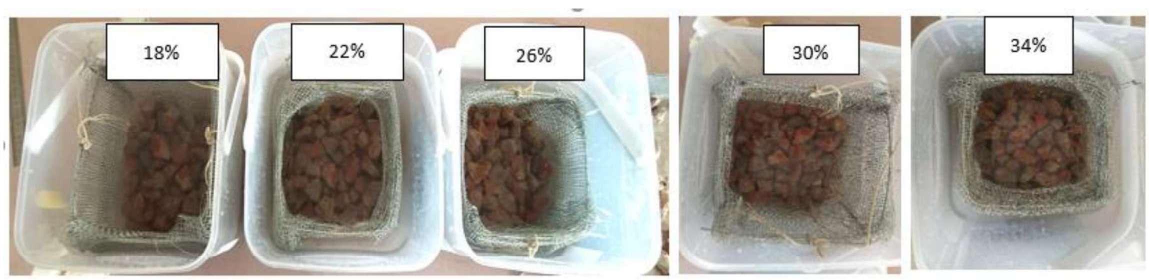
Table 1. Mass loss after 15 days of immersion in different salt solutions

Solution	Initial Mass (gm)	Mass after immersion and sieving (gm)	Mass Loss (%)
Sodium Sulfate	258	164	36.43
Magnesium Sulfate	260	218	16.15
Magnesium Chloride	252	242	3.97
Sodium Chloride	255	250	1.96

Maximum degradation of RM was observed in the case of sodium sulfate solution. Magnesium sulfate also showed some degradation but the chloride solutions were found to be ineffective in removing RM. Therefore, sodium sulfate was identified as the best performing salt.

2.2.2 Determination of Best Concentration and Removal Efficiency

Once the suitable salt is identified as sodium sulfate, its optimum concentration was to be worked out. To do so, solutions of sodium sulfate were prepared with different dosages of salt. Five different solutions with salt concentration as 18%, 22%, 26%, 30% and 34% were tested. About 1.5 kg of oven-dried RBA sample was taken into a wire box and immersed fully in each of the solutions. After every 24 hours cycle, the aggregate specimen was taken out and dried in an oven at a temperature of 110±50C. After drying, the aggregates are sieved through a 4.75 mm standard test sieve, and the materials retained on the sieve are weighted. The process is shown in Figure 3.



RBA immersed in salt solutions of different concentration

Condition after 8th cycle (26% solution)

Figure 3. Determination of best concentration of Na_2SO_4 solution

Efficiency of a particular solution was judged based on the mass loss after a certain cycle. Mass loss after each cycle was calculated as,

$$Mass\ Loss\ in\ Cycle\ (\%) = \frac{M_I - M_F}{M_I} \times 100$$

Here, $M_I = Initial\ mass\ of\ RBA\ and\ M_F = Mass\ of\ RBA\ retained\ on\ 4.75\ mm\ sieve$

The experiments were continued for several cycles with degradation of residual mortar. It was observed that after 9th cycle of the experiment, no further degradation was encountered and therefore, the process was discontinued after 9th cycle.

3. Experimental Results and Discussions

Removal of RM from RBA was measured in terms of mass loss when sieved through a 4.75 mm sieve that separated the removed RM. Table 2 summarizes the computation of RM removal for each of the 5 solutions.

Table 2. RM removal efficiency of Na_2SO_4 solution with different concentration

Concentration	18%		22%		26%		30%		34%	
Cycle	Mass (gm)	Mass Loss (%)	Mass (gm)	Mass Loss (%)	Mass (gm)	Mass Loss (%)	Mass (gm)	Mass Loss (%)	Mass (gm)	Mass Loss (%)
0	1588	0	1579	0	1534	0	1621	0	1595	0
1	1577	0.69	1568	0.7	1511	1.5	1597	1.48	1566	1.82
2	1563	1.57	1545	2.15	1448	5.61	1513	6.66	1454	8.84
3	1512	4.79	1470	6.9	1261	17.8	1280	21.04	1238	22.38
4	1437	9.51	1273	19.38	1021	33.44	971	40.1	921	42.26
5	1347	15.18	1099	30.4	902	41.2	866	46.58	829	48.03
6	1236	22.17	984	37.68	852	44.46	811	49.97	802	49.72
7	1124	29.22	944	40.22	802	47.72	800	50.65	781	51.03
8	1091	31.3	929	41.17	793	48.31	792	51.14	773	51.54
9	1064	33	922	41.61	782	49.02	790	51.26	769	51.79

Total removal of RM from RBA was not attained by chemical separation practiced in this study. More than 50% mass loss was observed in 9 cycles. All the RM from RBA surfaces were cleaned but still, there was some RM attached in between joints to aggregates. The comparative performances of the solutions with different concentrations are presented in Figure 4.

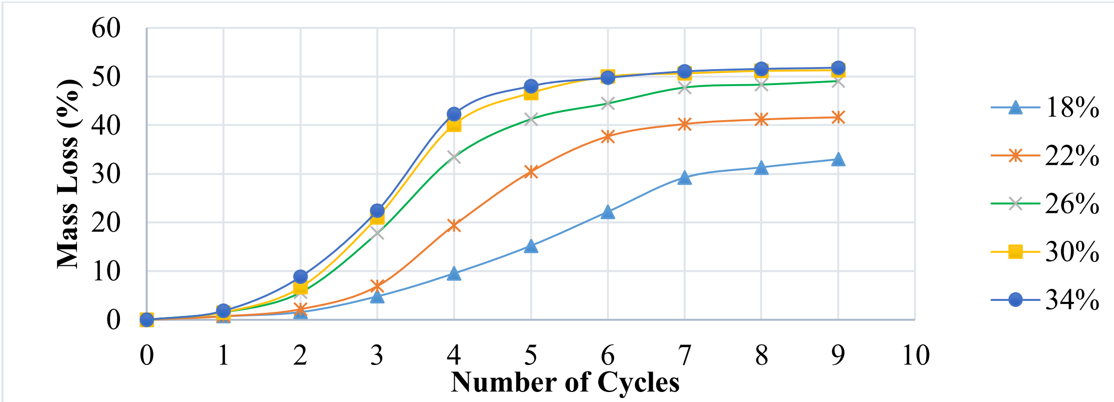


Figure 4. RM removal performance of salt solutions with difference concentration

It was observed that 26%, 30%, and 34% solutions have nearly the same performance with a maximum removal capacity of 49.02 % to 51.79%. However, in the case of the concentrations of 30% and 34%, salt crystals are found to be formed and attached firmly on the surfaces of RBA. For this reason, it is not recommended to use a solution of a concentration of more than 30%. To avoid the salt crystal problem, the solution with 26% concentration is proved to be most suitable for the removal of RM from the surfaces of RBA. The outcome is concurrent to the ASTM recommendation and previous study on recycled stone aggregates (Abbas et al., 2007). Another noticeable matter is that, after the 7th cycle, additional mass loss is very low and hence it may be stated that 26% sodium sulfate solution gives the best performance for removing RM from RBA and it would require 7 cycles to attain its maximum efficiency.

4. Conclusions

Total removal of RM from the RBA sample is not possible by chemical techniques applied in this study but nearly 50% RM can be removed with 26% sodium sulfate solution. So, the technique cannot be used for the quantification of RM but it can be readily used for the treatment of RBA with significant RM removal. For quantification of RM, it is recommended to combine the chemical technique with thermal approaches.

LIST OF ABBREVIATIONS

RBA : Recycled Brick Aggregate
RCA : Recycled Coarse Aggregate
RM : Residual Mortar

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