

# Use of Industrial Waste Slag Waste Material In Concrete Mixes

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**Abstract-** A modern lifestyle, alongside the advancement of technology has led to an increase in the amount and type of waste being generated, leading to a waste disposal crisis. This study tackles the problem of the waste that is generated from construction fields, such as demolished concrete, glass, and plastic. In order to dispose of or at least reduce the accumulation of certain kinds of waste, it has been suggested to reuse some of these waste materials to substitute a percentage of the primary materials used in the ordinary portland cement concrete (OPC).

The waste materials considered to be recycled in this study consist of glass, plastics, and demolished concrete. Such recycling not only helps conserve natural resources, but also helps solve a growing waste disposal crisis. Ground plastics and glass were used to replace up to 20% of fine aggregates in concrete mixes, while crushed concrete was used to replace up to 20% of coarse aggregates. To evaluate these replacements on the properties of the OPC mixes, a number of laboratory tests were carried out. These tests included workability, unit weight, compressive strength, flexural strength, and indirect tensile strength (splitting). The main findings of this investigation revealed that the three types of waste materials could be reused successfully as partial substitutes for sand or coarse aggregates in concrete mixtures.

## I. INTRODUCTION

Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas. For the purpose of this paper, data was obtained from Jordan to study official figures regarding the quantity of some waste materials and their disposal. Table 1 shows the quantity of solid waste produced by the construction sector, and its distribution by method of disposal, and type of activity. The table indicates that 85% of the total solid waste of 1721.8

tons/ye include materials identified as solid waste, infectious waste or hazardous waste.

Some construction waste materials may have particular health, safety and environmental concerns, such as, asbestos containing materials, materials with lead-based paint coating, and lighting waste. None of these materials are included in this study.

Research into new and innovative uses of waste materials are continuously advancing. These research efforts try to match society's need for safe and economic disposal of waste materials. The use of recycled aggregates saves natural resources and dumping spaces, and helps to maintain a clean environment. This current study concentrates on those waste materials, specifically glass waste, plastics and building construction waste to be used as substitutes for conventional materials, mainly aggregates, in ordinary portland cement concrete (OPC) mixes.

Table 1 Quantity of solid wastes resulted from the construction activity distributed by method of disposing and economic activity, 2004 (ton)

Activity	No. of enterprises	Solid wastes		Method of disposing of solid wastes				
		Enterprises that produce wastes	Quantity of solid wastes	Collection	Storing	Burial	Burning	Selling
Site preparation	21	18	8.1	8.1	0.0	0.0	0.0	0.0
Buildings construction & civil eng. projects	1049	414	1477.5	1333.0	0.0	97.3	40.4	6.8
Buildings installations	42	172	220.0	220.0	0.0	0.0	0.0	1.0
Building completion	66	59	9.6	8.5	0.0	0.0	0.0	1.1
Total	1559	663	1721.8	1574.9	0.0	97.3	40.4	9.2

Department of statistics/environmental statistics 2004.

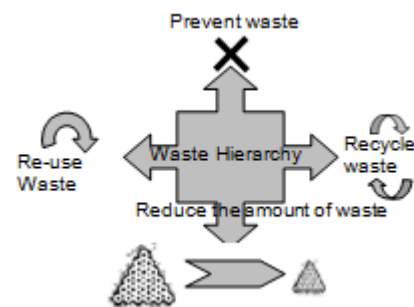


Fig. 1. The waste hierarchy.

Recycling concrete as aggregate offers a solution to the problems encountered with the quarrying of natural aggregate.

gates and the disposal of old concrete. As these substitutes require extensive studies about their effect on the properties of concrete, a number of research studies were performed. Wilson (1993) studied the effect of the irregular surface of the crushed concrete on the properties of the concrete mixes. The use of plastic materials and glass in a number of civil engineering applications has been investigated through a large number of research studies. These have been conducted to examine the possibility of using plastics and glass powder in various civil engineering projects in the construction field (Chanbane et al., 1999; Rindl, 1998; Shayan et al., 1999). Rindl (1998) reported many uses of waste glass, which included road construction aggregate, asphalt paving, concrete aggregate, and many other applications. Shayan (1999, 2002) studied the use of the waste glass aggregates in concrete.

The chemical reaction that takes place between the silica-rich glass particles and the alkali in the pore solution of concrete, alkali-silica reaction is the major concern regarding the use of glass in concrete. Zdenek et al. (2000) reported that the particle size of ground glass used in concrete is proportional to the concrete strength. They also reported that the effect of alkali-silica reaction (ASR) will be eventually eliminated if the particles sizes are small enough. However, it was concluded by Blumenstyk (2003) that using glass from green bottles tends to mitigate ASR due to the existence of chromium oxide which gives glass its green color. Appropriate precautions must be taken to minimize the detrimental ASR effect on the stability of concrete by incorporating a suitable pozzolonic material such as fly ash, silica, or ground blast furnace slag in the concrete mix at appropriate proportions, as specified by Shayan (2002).

Yang et al. (2001) concluded in their research that the use of rubberized concrete should be limited to secondary structural components such as culverts, crash barriers, side walks, running tracks, sound absorbers, etc. Huang et al. (2004) treated the rubberized concrete as a multiphase particulate-filled composite material, and built a model to predict the factors affecting the strength of the rubberized concrete. A parametric analysis was conducted using finite element analysis. Based on their analysis, they concluded that the strength of rubberized concrete can be increased by reducing the maximum rubber chip size; using stiffer coarse aggregate; employing uniform coarse aggregate size distribution; and using harder cement mortar if it has a high strength or using softer cement mortar if it has high ductility. In addition, they concluded that rubber chip content should be limited to a certain range in order for it to be used in practice. Sukontasukkul and Chaikaew (2006) used crumb rubber to replace coarse and fine aggregates in concrete pedestrian blocks. This has produced softer blocks that

provided softness to the surface. In addition, crumb rubber blocks performed quit well in both skid and abrasion resistance tests. Krammart and Tangtermsirikul (2004) investigated the use of municipal solid waste incinerator bottom ash and calcium carbide waste as part of the cement raw materials. They found that the chemical composition of the cement produced from raw materials containing the used wastes was similar to the control cement. They also noted the superiority of the newly produced cement over the control cements in the sodium sulfate solutions.

Although many researchers studied the reuse of some waste materials in concrete, a limited number of reports, data collection, and research on these issues have been reported or performed in developing countries such as Jordan.

The main objective of this study is to investigate the performance of the OPC mix under the effect of using recycled waste materials, namely glass, plastics, and crushed concrete as a fraction of the aggregates used in the mix. This will be demonstrated through experimental laboratory tests, using fine glass and plastic aggregates to substitute a certain percentage of the fine aggregates (sand), whilst using crushed concrete to substitute a certain percentage of coarse aggregates in OPC concrete.

## II. BUILDING CONSTRUCTION WASTE MANAGEMENT

In general, for any construction project, plans for recycling of waste materials should be developed prior to the commencement of work. These plans should identify the types of waste to be generated and the method of handling, and the recycling and disposal procedures. In addition, areas for the temporary accumulation or storage of the construction waste materials should be clearly designated. Collection of data by visiting a number of local construction sites in Jordan provided an important indication of the percentage of particular construction waste materials accumulated at the sites. These can be seen in the diagram shown in Fig. 2, indicating the percentage of each type of waste materials generated on site. The combined information of Table 1 and Fig. 2 shows that 20% of the total quantity of waste of 1721.8 tons consists of glass, plastic, and concrete. The weights of these materials are estimated to be: 35 tons of glass, 52 tons of plastic, and 240 tons of concrete. Hence, this waste should be incorporated in a waste management plan.

The development of an action plan for waste management in every construction case is the responsibility of the owner or his agent. This is to ensure that all waste products generated by a construction project on a property are

surveyed, handled and disposed of in a legal manner for the protection of the environment.

A waste management plan directs the construction activities towards an environmentally friendly process by reducing the amount of waste materials and their discard in landfills. The environmental and economic advantages that occur when waste materials are diverted from landfills include:

- a. conservation of raw materials;
- b. reduction in the cost of waste disposal; and
- c. efficient use of the materials.

Waste materials must be kept clean and in separate batches in order to be used or recycled in an efficient manner. Although separation can take place after the mixed waste is removed from the construction site, separation at the site increases the efficiency of recycling or reuse of that waste. The flow chart in Fig. 3 includes suggestions for a construction waste management plan. The reduction of waste construction materials can be achieved by starting with studying the design details of the building to ensure efficient use of materials, in addition, careful cutting and measuring should be applied accurately. The use of materials that are made from recycled materials and are recyclable should be included in the initial design of the structure. Storage methods should be investigated to prevent damage from mishandling and weather conditions. In addition, the ordering of materials should be made just before the work commences. To complete the waste management plan, there should be an estimation of the amount and type of recyclable and non-recyclable waste materials that are expected to be generated on site. Listing of all the expected quantities of each type of waste gives an indication of what type of management activities are appropriate for the specified waste. At each stage of construction, there should be specific ways to reduce, reuse or recycle the wastes which may be produced.

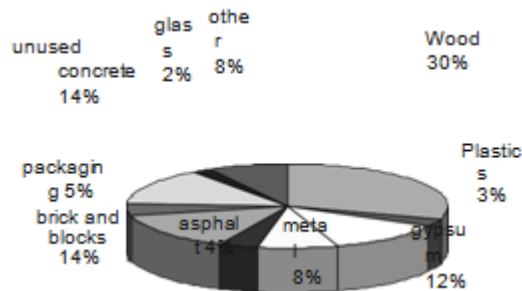


Fig. 2. Percentage, in volume, of construction wastes on site.

This investigation focuses on studying the use of certain construction field wastes, such as crushed glass, plastic particles, and recycled concrete.

### III. EXPERIMENTAL WORK AND TEST RESULTS

#### 3.1. Plastics as a substitute for sand

Waste plastics are reused in this study by grinding them into small sized particles. Fig. 4 shows the grain size distribution of the used plastic particles. It also shows the recommended gradation of the fine aggregates (sand) for concrete mixes according to BS882:1992 (Neville, 1995). The gradation of the used particles falls within the fine aggregates specified gradation limits.

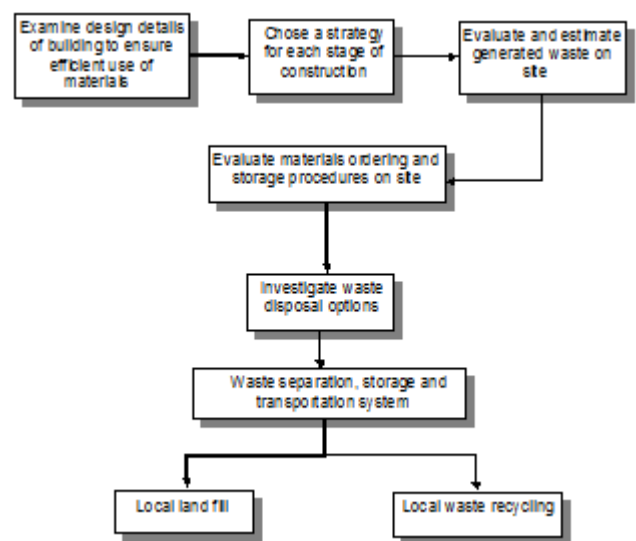


Fig. 3. Flow chart for construction waste management.

The used aggregates in the prepared concrete mixes are local natural materials. Coarse aggregate is taken from crushed limestone, and fine aggregate from natural sand. Tap water at room temperature was used in all of the mixes.

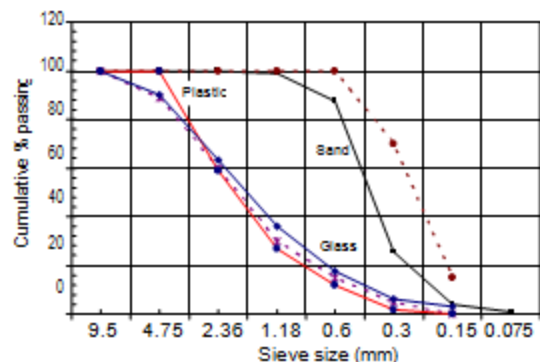


Fig. 4. Gradation curves for the used plastic particles, crushed glass and local sand.

Different percentages of cement, water, fine aggregates, and coarse aggregates were combined in order to produce concrete of the required workability and strength suitable for typical cast-in-place constructions. The used mix proportions are shown in Table 2.

Mixes of up to 20% of plastic particles are proportioned to partially replace the fine aggregates. Fresh mix property tests, such as slump and unit weight tests, were performed immediately after mixing. Cubes of 10 • 10 • 10 cm, cylinders of 15 cm diameters by 30 cm height, and beams of 10 • 10 • 40 cm were prepared from each mix for hardened-state property testing. Tests were performed after 28 days of continuous water curing in accordance with ASTM C192 (Neville, 1995). Effects of the different percentages of plastic particles on slump results and on strength of concrete are shown in Figs. 5 and 6 respectively.

Table 2 Mix proportions and fresh plastic–concrete properties

Plastic (%)	Mix proportions (kg/m <sup>3</sup> of finished concrete)					Nominal w/c ratio	Slump (mm)	Unit weight (kg/m <sup>3</sup> )
	Water	Cement	C.A. <sup>a</sup>	F.A. <sup>b</sup>	Plastic			
0	252	446	961	585	0.0	0.56	73	2320.0
5	252	446	961	555.7	17.8	0.56	73	2307.0
10	252	446	961	526.5	35.5	0.56	69	2856
15	252	446	961	497.2	53.2	0.56	63	2693
20	252	446	961	468.0	71.0	0.56	57	2495

<sup>a</sup> C.A. =Coarse aggregate.

<sup>b</sup> F.A. = Fine aggregate

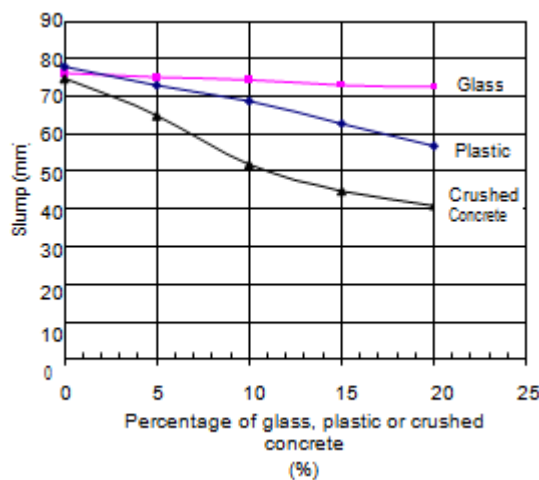


Fig. 5. Workability verses percentage of different wastes in the concrete mixes.

Fig. 5 shows that there is a decrease in the slump with the increase in the plastic particle content. For a 20% replacement, the slump has decreased to 25% of the original slump value with 0% plastic particle content. This decrease in the slump value is due to the shape of plastic particles, i.e., the plastic particles have sharper edges than the fine aggregate. Since the slump value at 20% plastic particle content is 58 mm, this value can be considered acceptable and the mix can be considered workable. Fig. 6 shows that the addition of the plastic particles led to a reduction in the strength properties.

For a 20% replacement, the compressive strength shows a sharp reduction up to 72% of the original strength. With 5% replacement the compressive strength shows a 23% reduction. Similar behavior, but in a lower effect, was observed in both the splitting and flexural strengths of the tested samples. This reduction in strength is due to the fact that the strength of the plastic particles is lower than that of the aggregate. Therefore, both the use of concrete with plastic particles and the percentage of replacement should be controlled, according to the allowable strength of the structural element to be constructed.

### 3.2. Crushed glass as a substitute for sand

The waste glass used in this study was manually crushed in the laboratory and then sieved. The gradation curve of the used crushed glass is shown in Fig. 4. The gradation curve is close to the lower limit of the specified fine aggregate limits according to BS882:1992 Standard (Neville, 1995).

Table 3 Mix proportions and fresh glass–concrete properties

Glass (%)	Mix proportions (kg/m <sup>3</sup> of finished concrete)					Nominal w/c ratio	Slump (mm)	Unit weight (kg/m <sup>3</sup> )
	Water	Cement	C.A	F.A	Glass			
0	252	446	961	585	0.0	0.56	76.3	2305.6
5	252	446	961	555.7	27.44	0.56	75.3	2301.0
10	252	446	961	526.5	54.9	0.56	74.6	2302.2
15	252	446	961	497.2	82.3	0.56	73	2289.3
20	252	446	961	468.0	109.8	0.56	72.7	2.2863

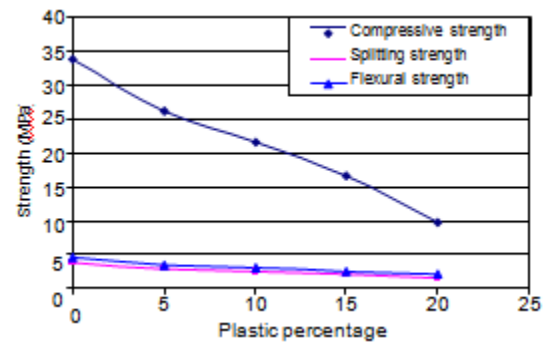


Fig. 6. Relationship between the compressive strength and percentage of plastic content.

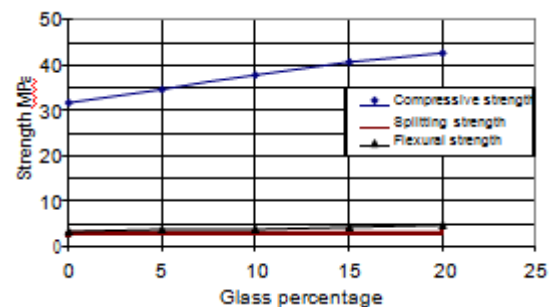


Fig. 7. Relationship between the compressive strength and percentage of crushed glass content.

Table 4 Mix proportions and fresh crushed concrete–concrete properties

Crushed concrete (%) (kg/m <sup>3</sup> )	Mix proportions (kg/m <sup>3</sup> of finished concrete)					Nominal w/c ratio	Slump (mm)	Unit weight (kg/m <sup>3</sup> )
	Water	Cement	C.A.	F.A.	Crushed concrete			
0	252	446	961	585	0.0	0.56	75	2273
5	252	446	961	585	48.05	0.56	65	2311
10	252	446	961	585	96.1	0.56	52	2296
15	252	446	961	585	144.15	0.56	45	2311
20	252	446	961	585	192.2	0.56	41	2315

The percentage of replacing fine aggregates with glass varied from 0% to 20%, each applied in an individual concrete mix. The mix proportions and the fresh concrete properties, slump and unit weight test results, are shown in Table 3.

The effects of different percentages of crushed glass on slump and on the strength of concrete are shown in Figs. 5 and 7 respectively. Fig. 5 indicates that the presence of crushed glass in concrete mixes does not affect the workability of concrete. Fig. 7 reveals that all of the values of the strength (compressive, splitting, and flexural) for up to a 20% glass aggregate substitution are higher than that of normal concrete mixture. This increase of the strength is due to the surface texture and strength of the glass particles compared to that of sand.

**3.3. Crushed concrete as a substitute for coarse aggregates**

The modernization of buildings and/or partial demolition for their maintenance generate a large amount of waste and rubble. This could also occur on site when new structures and buildings are being constructed. Crushed concrete was used to substitute up to 20% (mass ratio) of the conventional natural coarse aggregates used in the mix. The recycled aggregates (crushed concrete) were produced by crushing the old concrete cubes and cylinder tested specimens that were used in previous laboratory tests. The crushed concrete was then screened using the sieve analysis method. This showed that the used recycled aggregates have a similar particle size distribution as that specified for natural aggregates. The mix proportions and the fresh concrete properties, slump and unit weight results are shown in Table 4.

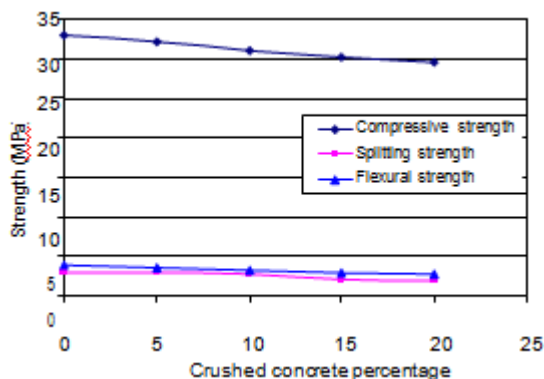


Fig. 8. Relationship between the compressive strength and percentage of crushed concrete aggregates content.

The effect of different percentages of recycled concrete on slump results and strength of concrete are shown in Figs. 5 and 8 respectively. Fig. 5 shows a reduction in the slump value with the increase of the replacement percent- age of the coarse aggregates with recycled crushed con- crete. The reduction of slump for recycled concrete aggregates replacement is due to the fact that absorption of crushed concrete is higher than that of coarse aggregate. Therefore, higher the percentage of recycled concrete aggregate, higher the absorption percentage, the lower is the slump. Moreover, the irregularity of the surface of the recycled concrete aggregates affects the workability of concrete. Due to the reduced workability of the recycled concrete aggregate mixes, either a type of superplasticizers should be used, or the percentage of the recycled concrete aggregate should be controlled. The concrete mixes with recycled concrete aggregates exhibited reduction in com- pressive, flexural and splitting-tensile strengths compared to normal concrete, which can be clearly seen in Fig. 8. The reduction in compressive strength with a 20% substi- tute of recycled crushed concrete is about 13%, which might be considered acceptable as long as it is taken into consideration in the design stage.

**IV. CONCLUSION**

The tests carried out in this study were primarily designed to provide an indication of relative advantages and disadvantages of the use of a number of construc- tion wastes, such as crushed concrete waste, plastics, and glass. This would provide an overview of the reuse of construction waste materials in the construction industry.

Based on the test results and on the physical observa- tions, the following conclusions can be drawn:

1. Waste and recycling management plans should be devel- oped for any construction project prior to the start of work in order to sustain environmental, economic, and social development principles.
2. The increase of the surface area of the recycled crushed concrete, due to its irregular shape, necessitates an increase of cement and water; hence the irregular shape negatively effects the workability of the said mix.
3. A comparison between the cost of crushing glass, plastic, and concrete with that of supplying prime aggregates (gravel) should be considered in the project management plans, taking into consideration the availability of prime materials, and location.
4. The strength of concrete mixes was improved by the par- tial replacement of fine aggregates with crushed glass aggregates, but the high alkali content of such

aggregates would affect the long-term durability and strength, both of which need long-term investigation.

5. Using glass of different percentages showed no significant effect on the slump, unlike the use of plastic and crushed aggregates, which showed that higher the percentage used, the lesser was the slump.
  6. In addition to recycling glass by its use in concrete mixes, glass aggregates can be used aesthetically in masonry, which can give a shiny clean finishing effect on the surface of the concrete product.
  7. When up to 20% of plastic and crushed concrete was used in concrete, the strength of the concrete exhibited lower compressive and splitting-tensile strength than that of normal concrete using natural aggregates. Therefore, it is recommended that concrete with recycled materials of lower strength be used in certain civil engineering applications, especially in non-structural applications, where lower strength up to 25 MPa is required. This will contribute to cutting down the cost of using non-structural concrete.
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