Reuse of sedimentary lime and incinerator ash for the production of Structural concretes

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Abstract: This paper presents the results of an experimental investigation on the effect of different amounts of incinerator ash as fine aggregates replacement and sedimentary lime substitution of cement for the production of Structural concretes. Lime was used to replace 25%, 50%, 75%, and 100% of the total cement volume and ash particles were used as a partial replacement for sand by 50 % of concrete mixtures. The fresh concrete mixtures exhibited lower unit weight and acceptable workability compared to plain concrete. It was found that at the age of 28 days, the compressive strengths of concrete mixtures to decrease below the plain mixtures. In samples F50L25 a good compressive strength was achieved after 28 days of curing. Given the experimental data show new possibilities for this waste materials reuse as structural concrete and give great advantages in waste minimization as well as resources conservation and reduce the cost of materials.[Maleki Ravasan R. Azardoust A, dalili osgouei A. **Reuse of sedimentary lime and incinerator ash for the production of Structural concretes** . *Life Sci J* 2013;10(5s):248-252] (ISSN:1097-8135). http://www.lifesciencesite.com. 44

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1. Introduction

Large quantities of waste materials and by-products are generated from manufacturing processes, service industries and municipal solid wastes. As a result, solid waste management has become one of the major environmental concerns in the world (Ferreira et al, 2003). With the increasing awareness about the environment, scarcity of land-fill space and due to its ever increasing cost, waste materials and by-products utilization has become an attractive alternative to disposal. High consumption of natural sources, high amount production of industrial wastes and environmental pollution require obtaining new solutions for a sustainable development (Rafat, 2010).

Cement is among the most energy-intensive materials used in the construction industry and a major contributor to CO2 in the atmosphere (Altwair & Kabir, 2010). However, the production of Portland cement, an essential constituent of concrete leads to the release of a significant amount of CO2 and other greenhouse gases. One of the biggest threats to the sustainability of the cement industry is the dwindling amount of limestone in some geographical regions (Malhotra, Worrell & Galtisky, 2004).

Cement conservation is the first step in reducing the energy consumption and greenhouse-gas emissions. Resource productivity consideration will require us to minimize Portland cement use while meeting the future demands for more concrete (Malhotra, 1999). This must be the top priority for a viable concrete industry. there is steady growth in the use of Portland cement blends containing cementitious or pozzolanic by-products, such as ground granulated blast-furnace slag and fly ash, vast quantities of these by-products still end up either in low-value applications such as landfills and road subbases, or are simply disposed by ponding and stockpiling (Chimenos et al,2005).It’s necessary to reduce the quantity of concrete used in buildings, to replace as much Portland cement as possible by supplementary cementitious materials, especially those that are by-products of industrial processes, such as fly ash, rice husk ash, palm oil fuel ash, slag, metakaolin and silica fume, and use that concrete wisely (Chimenos et al, 1999; Malhotra, 1999).

Mehta said that numerous case histories have shown successful substitution of natural aggregate with crushed concrete from demolition. Also, recycled water from ready-mixed concrete plants has been used as a substitute for fresh mixing water for concrete (Mehta, 1952).

This paper is a review of the research work done in order to promote industrial waste into concrete for common use in building construction, with the aim of emphasizing the feasibility of use incinerator ash as fine aggregate replacement and sedimentary lime as normal cement substantial have been investigated and compared with control samples.

2. Materials and Methods

In order to investigate the mechanical properties of concrete that containing lime as binder and Incinerator Ash, specimens of a cube shape of 150×150×150 mm were fabricated. These specimens were different in the content of Ash particles as fine aggregates and lime as a portion replacement of cement in concrete.

2.1. Materials

2.1.1. Aggregates

Coarse aggregate: The course aggregate was a 25 mm and Unit weight of 1684.7 kg/m^3 supplied from Charm Shahr in Tabriz, which was used together with coarse and fine sand of the same source.

Fine aggregate: The fine aggregate was natural sand of 4.75 mm maximum size obtained from Charm Shahr in the area of Tabriz in Iran. The properties of the fine aggregate was determined and fulfilled according to I.Q.S. No. 45/1984, I.Q.S. No. 30/1984 and I.Q.S. No. 31/1981.

2.1.2. Incinerator Ash

These particles were industrial aggregate of 4.75 mm maximum size and Unit weight of 1684.7 kg/m^3.

2.1.3. Cement

Type I Portland cement (Soufian cement factory) was used in all types of aggregate content mixtures.

2.1.4. Lime

This type of lime obtains from the water refining of Zarineh Roud River that passing from Tabriz Petrochemical region and created in two roles:
a) Precipitate calcium bicarbonates in the form of calcium carbonate according to the following chemical reactions:

$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$

Magnesium bicarbonates are changed into soluble magnesium carbonates up to 50 ppm of $CaCO_3$ according to the following chemical reaction:

$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow MgCO_3 + CaCO_3 + 2H_2O$

b) By injection of an excess dose of lime, magnesium is precipitated in the form of magnesium hydroxide according to the following chemical reactions:

$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3 + 2H_2O$

$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2 + Ca^{2+} + 2H_2O$

As magnesium hydroxide precipitates, the silica and practically all the colloids are also precipitated by adsorbtion. Thus ensuring a fouling index within the permissible limits for a good working of the reverse osmosis plant. A Sample of the Incinerator Ash and sedimentary lime is shown in Fig1.

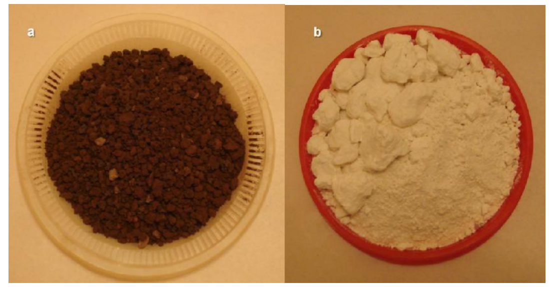

Fig.1. (a, b) Samples of waste materials: (a) Incinerator Ash, (b) sedimentary lime.

2.2. Mixture proportioning

A concrete mix, commonly used in the locality as structural concrete of 40 MPa strength, was chosen for the field trial concrete. This was used as the reference mix and other mix proportions were formulated based on this mix to include the lime as substantial of cement and incineration ash as fine aggregate replacement mentioned above. The purpose of the trial was to determine the following effects on field concrete. The experimental setup and specimen fabrication are summarized in Tables 1 and 2, respectively. To unify the Ash and lime content, a designated percentage for each mix types were converted to a total fine aggregate and cement volume percentage. The equivalent values of Ash and lime contents are given in Table 2. Specimens were remolded 24 hour after casting, and were kept in a curing room at a temperature of 25 ºC, with a relative humidity of 60%, until the time of testing. A normal, non-air-entrained, Portland cement concrete, was designed as the control mix according to B.S.1881, part 7. The mix required a 0.48 water–cement ratio. Other constituents are given in Table 3 for P, F, FL and LC specimens. P control mix was used as the basis for preparing of concrete mixes specified by F, FL, and LC mixes. In the F mixes, the fine aggregates of the control mix were replaced by incineration ash, and in the FL mixes, the sand in the control mix was replaced by incineration ash and lime were replaced by normal cement. In the LC mixes, sedimentary lime was used as replacements for cement, respectively. For a F50L25 mix, incineration ash replaced 50% of the sand volume and sedimentary lime replaced 25% of the cement volume in concrete mixtures.

Table 1 Experimental program

Specimen designation	Fine mineral Aggregate (%)	Coarse mineral Aggregate (%)	Cement (%)	Lime (%)	Incinerator Ash aggregate (%)	Replication test	compressive
p	100	100	100	0	0	3	
F50	50	100	100	0	50	3	
F50L25	50	100	75	25	50	3	
L25C75	100	100	75	25	0	3	
L50C50	100	100	50	50	0	3	
L75C25	100	100	25	75	0	3	
L100C0	100	100	0	100	0	3	

Table 2: Concrete mixture proportions

Specimen	Cement (kg)	Lime (kg)	Gravel (kg)	Sand (kg)	Ash Aggregate (kg)	W/C
p	406	0	1027	747	0	0.48
F50	406	0	1027	373.5	373.5	0.48
F50L25	304.5	101.5	1027	373.5	373.5	0.48
L25C75	304.5	101.5	1027	747	0	0.48
L50C50	203	203	1027	747	0	0.48
L75C25	101.5	304.5	1027	747	0	0.48
L100C0	0	406	1027	747	0	0.48

2.3. Specimen and tests of specimens

Cubes of concrete of 150×150×150 mm were molded for compressive strength, and fresh and dry density tests.

2.4. Test of specimens

1. Casting, compaction and curing: Accomplished according to B.S.1881, part 7 and B.S.1881, part 6 (British Standard Institution, 1952).
2. Slump test: Fulfilled according to B.S.1881, part 2.
3. Fresh densities: Measured for all cubes after molding and compacting immediately according To B.S.1881, part 5. The fresh density represents the mean of fresh densities for 3 cubes.
4. Compression strength test: Concrete cubes were prepared according to B.S.1881, part 7. The Forney machine was used for the compression test. The cubes were tested immediately after taken out of water while they were still wet. The average of compression strength of 3 cubes was recorded for each testing age.

3. Results and Discussion

3.1. Properties of fresh concrete

The properties of the fresh concrete including the slump, Water absorption and unit weight are as follows.

3.1.1. Slump test

The results of the slump tests indicate that the slump is decreasing with increasing the lime and ash particles ratio. The reductions of slump are 30.17%, 42.57%, 46.66%, 57.29%, 71.23% and 85.31% for L25C75, L50C50, L75C25, L100C0, F50 and F50L25, respectively. This reduction may be attributed to the fact that the water absorption of lime and ash particles is more than the normal cement and natural fine aggregate. So that the replacement of lime and incinerator ash in concrete mixtures reduced workability and in order to have normal concrete workability, the mixture needs extra water. The replacement of lime and incinerator ash in the same time in concrete mix decreasing the workability more than other components. In LC mixtures the slump reduction is lower than F mixtures.

3.1.2. Unit weight

The unit weight of the concrete ranged from 2386 to 2227 kg/m3, depending on ash and lime contents. The results indicate that the Unit weight tends to decrease by different percentage of lime and ash particles replacement in normal concrete. The unit weights of the L25C75, L50C50, L75C25, F50 and F50L25mixes were reduced 4.78%, 5.07%, 5.51%, 6.43% and 6.64% respectively, compared to plain concrete. This trend may be attributed to the density of the lime and ash particles being lower than the normal cement and sand by 22.9% and 34.1%, which leads to a reduction in the density. Thus, concrete containing incinerator ash and lime could be used wherever lightweight concrete is required. The F50L25 mix that incineration ash replaced 50% of the sand volume and sedimentary lime replaced 25% of the cement volume has lowest unite weight. There for with increasing amount of lime and ash particles volume in concrete the unit weight will decrease.

3.1.3. Water absorption

Due to increasing the replacement of lime with cement in concrete the water absorption increased. The water absorption of the F50L25, L25C75, L50C50 and L75C25 mixes were increased 4.22%, 26.09%, 37.33% and 40.61% respectively, compared to plain concrete. But in the F50 % mixes the water absorption decreased 5.7% respectively.

3.2. Compressive strength

The compressive strength test results for the concrete mixtures are given in Table 3 and loading states of cubic specimens containing lime are shown in Fig. 2. The results show a tendency for compressive strength values of concrete mixtures to decrease below the plain mixtures. The compressive strength of the L25C75, F50L25, F50% and L50C50 mixes were decreased 27.92%, 47.64%, 55.31% and 61.87% respectively.

Table 3: Compressive strength of concrete containing waste industrial material (Mpa).

Specimen	Compressive strength (28 days)
p	40.68
F50	23.1
F50L25	21.3
L25C75	29.32
L50C50	15.51
L75C25	4.75
L100C0	Not enough bonding

Fig. 2. (a, b, c) Testing compressive strength of concrete specimens: (a) specimens before testing, (b) Loading of specimens, (c) after testing.

Pezzi reports that once the sand volume substituted with aggregates increased, the compressive strength of composites decreased slightly in comparison with the reference mortar (Pezzi et al, 2006).

The L75C255 L100C0 mixes weren't suitable among the other samples. The mix that lime completely replaced by cement, the cubic specimen was decayed after bring up from water. Decayed states of cubic specimen containing lime as cement replacement is shown in Fig 3.

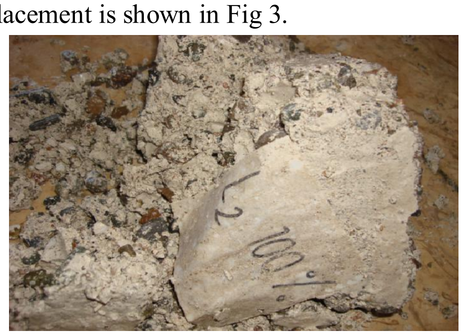

Fig. 3. Decayed states of L100C0 mix.

The research shows that the best volume of replacing lime with normal cement in order to production of structural concretes is less than 25 percent of cement volume in concrete mixtures. In case that we want to use lime and incineration ash in same mixture the suggested mixture is F50L25 respectively.

The reduction of compressive strength in mixtures containing ash particles can be attributed to the decrease in adhesive strength between the ash particles and the cement paste. The higher water absorption of ash particles may restrict the water necessary for cement hydration from entering through the structure of the concrete specimens during the curing period. The Hardness of Ash particles is lower than the natural sand particles so it may be attributed to the compressive strength of the concrete containing ash particles being lower than the concrete containing sand as fine aggregate. Adhesive strength in the mixtures that lime replaced with cement is lower than cement and it may cause to decrease the compressive strength.

Except the L50C50, L75C255 and L100C0 mixes, all of the compressive strength values are higher than the minimum compressive strength required for structural concrete which is 17.24 MPa.

4. Conclusions

The key findings of the use of sedimentary lime and industrial incinerator ash for the concretes production are as follows.

1. Workability of new concrete mixtures was reduced with increasing lime and ash concentration. According the workability of those mixtures, those mixtures are pretty good to work based on the consideration that has a low workability for different applications.

2. Using presented concrete mixtures were reduced the total weight of concrete structures.

3. The results show a tendency for compressive strength values of concrete mixtures with increasing the ash particles and lime ratio. Lower Adhesive strength of lime with aggregates may cause to decrease the compressive strength.

4. Use of incinerator ash as aggregates and sedimentary lime as cement replacement has two main advantages: (a) it creates opportunities to decrease carbon emissions and reduces the use of new virgin aggregate and the associated environmental costs of exploitation and transportation and (b) it reduces unnecessary landfill of valuable materials that can be recovered.
5. These results demonstrated the potential of reusing an abundant industrial by-product, at present Land filled, for the production of Structural concretes.

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