CHARACTERIZATION AND MECHANICAL PROPERTIES OF CONCRETE MIXTURES MADE WITH SEDIMENTARY LIME AND INDUSTRIAL INCINERATOR ASH

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Abstract: 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 (IA) as fine aggregate replacement and sedimentary lime (SL) as normal cement substantial have been investigated and compared with control samples. IA were used to replace 5%, 10%,15% up to 80% of the total mineral fine aggregate's volume and SL was used to replace 10%, 15% up to 50% of the total normal cement volume in concrete. The mixtures tests included compressive strength, tensile strength, modulus of elasticity, chloride penetration and drying shrinkage. 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 F50L25 mixtures a good mechanical properties were 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.

Keywords: *Sedimentary lime, Incinerator ash, Structural concrete, cement, fine aggregate, green concrete*

1.0 Introduction

Regulations on waste elimination make waste management significant problem for the public authorities today (Aubert *et al.*, 2004). So that during recent years there has been a growing emphasis on the utilization of waste Materials and by-products in construction materials (Rafat, 2010). Cement is among the most energy-intensive materials used in the construction industry and a major contributor to CO^2 in the atmosphere (Altwair and Kabir, 2010). 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; Mehta, 1999). Mehta (2009) said that using less cement in concrete productions can save 50% of clinker production.

Municipal solid waste ash (MSWA) is the by-product produced during the combustion of municipal solid waste. Two types of the ashes are produced as a result of the incineration process; bottom ash and fly ash. Municipal solid waste combustor ash is a relatively lightweight material compared with natural sands and aggregate (Malhotra, 2000; Chimenos *et al.*, 1999). Ferreira *et al*. (2003) published various uses of MSW fly ash, which included: (i) construction materials; (ii) geotechnical applications; (iii) agriculture; and (iv) miscellaneous applications.

Hamernik and Frantz (1991) shows that MSW fly ash could be used as partial replacement for cement in concrete mixes as a supplementary cementitious material as it contains some quantities of typical cement minerals, although in lesser quantity than cement clinker. In other research, Bertolini *et al*. (2004) showed that bottom ashes from MSW incineration are potentially attractive as mineral additions for the production of concrete. When MSWI bottom ashes were added to the concrete mix after being dry ground, strength and durability of concrete were negatively affected by entrapment of gas bubbles.

Mangialardi (2001) studied the sintering process of MSW fly ash in order to manufacture sintered products for reuse as concrete aggregates. Four types of fly ash resulting from different Italian MSW incineration plants were studied. He concluded that: sintering process of untreated MSW fly ashes proved to be ineffective for manufacturing sintered products for reuse as a construction material.

MSW fly ash can also be used in concrete as aggregate. MSW fly ash could be processed into pellets and used as lightweight aggregates Rebeiz and Mielich (1995) have advocated the possible use of MSW ash in construction applications including the innovative use in the production of polymer concrete. Pera *et al*. (1996) examined the use of MSWI bottom ash as alternative aggregate for concrete having a characteristic 28-day compressive strength of 25 MPa. They concluded that concrete with 50% bottom ash satisfy the requirements to be used as a building concrete presenting characteristic 28-day strength of 25 MPa. When the gravel is entirely replaced by bottom ash the strength decreases due to the softness of aggregates. Collivignarelli and Sorlini (2002) assessed the feasibility of concrete production using stabilized MSW incineration fly ashes in addition to natural aggregates. They concluded that MSWI fly ashes showed good chemical and physical quality for the production of concrete mixtures.

This paper summarizes the results of a research aimed at studying the use of sedimentary lime as cement substantial and industrial incinerator ash as replacement of fine aggregates for the production of structural concrete.

2.0 Materials and Methods

The study was designed in three steps. First, the binding abilities of sedimentary lime (SL) were investigated and an acceptable level of SL in total binder was determined. In the second step, incinerator ashes (IA) were use as replacement of fine aggregates and acceptable level of IA in total fine aggregates volume was determined. And at last concretes with the formerly determined level of SL and different portions of incinerator ashes were studied for their consistency, fresh and hardened concrete properties. 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.

2.1. Materials

2.1.1 Aggregates

Coarse aggregate: The coarse 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

Ash particles provided by Tabriz Petrochemical Company in Iran. The Chemical composition of Incinerator Ash is presented in table 1.

Table 1: Chemical composition of Incinerator Ash

Compounds	Abbreviation	% Weight
Iron oxide	Fe_2O_3	47.3
Lime	CaO	18.6
Phosphorus pent oxide	P_2O_5	13.5
Alumina	Al_2O_3	2.27
Magnesia	MgO	1.84

Incinerator bottom ash is the coarse residue left on the grate of waste incinerators. Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials (oil and biological sludge). Combustion of these materials creates solid wastes called ash, which can contain any of the elements that were originally present in the waste. Incinerators reduce the solid mass of the original waste by 80–85% and the volume by 95-96 %, depending on composition and degree of recovery of materials such as metals from the ash for recycling. Incineration markedly reduces the amount of waste for disposal and thus decreases the burden on landfill sites (Olie *et al.*, 1977). These particles were industrial aggregate of 4.75 mm maximum size and Unit weight of 1684.7 kg/m3. Data regarding the properties of the aggregates and the ash particles are given in Table 2 and the gradation of sand and Incinerator Ash is presented in Fig. 1.

Table 2: Properties of aggregate

Aggregate type	**Specific gravity**	**Absorption (%)**	**Fineness modulus**	**Unit weight (kg/m3)**
Coarse aggregate	2.46	2.56	NA	1684.7
Fine aggregate	2.54	4.91	3.16	1760.4
Incinerator Ash Particles	1.17	17	3.07	1160.2

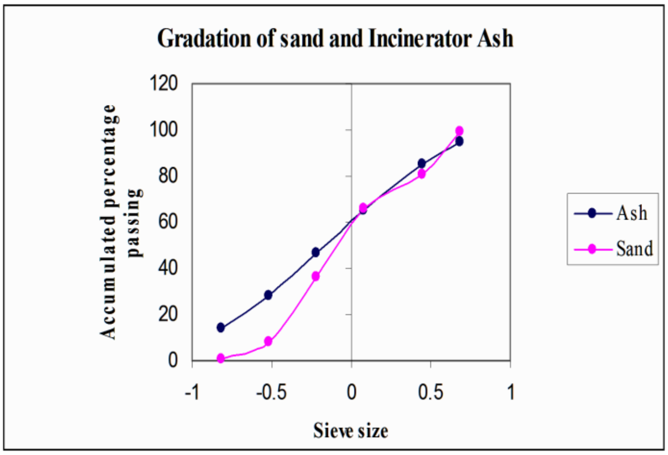

Figure 1: Gradation of sand and Incinerator Ash.

2.1.3 Cement

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

2.1.4 Lime

Sedimentary lime obtained by water refining process of Zarineh Roud river that passes 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:

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O \quad (1)$$

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

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

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

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3 + 2H_2O \quad (3)$$

$$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2 + Ca^{2+} + 2H_2O \quad (4)$$

As magnesium hydroxide precipitates, the silica and practically all the colloids are also precipitated by adsorption. 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 Fig 2.

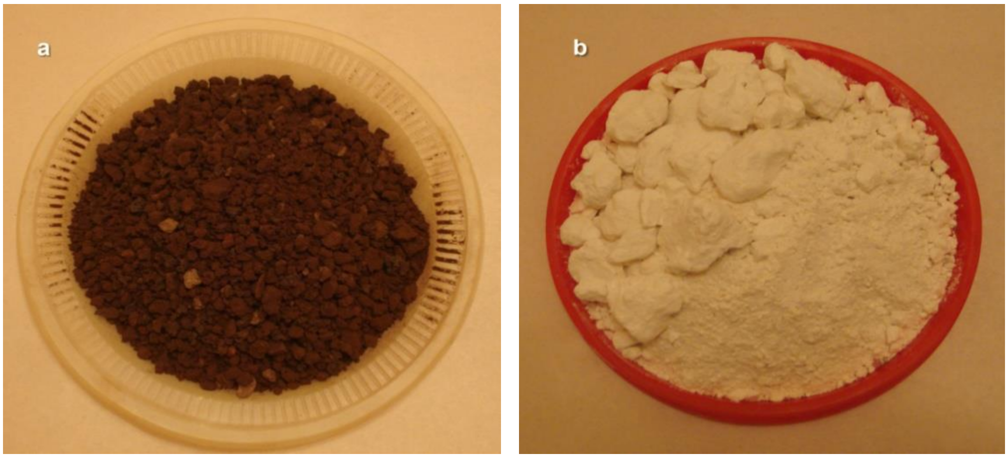

Figure 2: (a, b) Samples of waste materials: (a) Incinerator Ash, (b) sedimentary lime

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 3 and 4, 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(British Standard Institution, 1952). 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 IA, and in the FL mixes, the sand in the control mix was replaced by IA and SL 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 3: Experimental program

Specimen designation	Fine mineral Aggregate (%)	Coarse mineral Aggregate (%)	Cement (%)	Lime (%)	Incinerator Ash aggregate (%)	Replication compressive test
P	100	100	100	0	0	3
F5	95	100	100	0	5	3
F10	90	100	100	0	10	3
F15	85	100	100	0	15	3
F20	80	100	100	0	20	3
F25	75	100	100	0	25	3
F30	70	100	100	0	30	3
F35	65	100	100	0	35	3
F40	60	100	100	0	40	3
F45	55	100	100	0	45	3
F50	50	100	100	0	50	3
F55	45	100	100	0	55	3
F60	40	100	100	0	60	3
F65	35	100	100	0	65	3
F70	30	100	100	0	70	3
F75	25	100	100	0	75	3
F80	20	100	100	0	80	3
L10C90	100	100	90	10	0	3
L15C85	100	100	85	15	0	3
L20C80	100	100	80	20	0	3
L25C75	100	100	75	25	0	3
L30C70	100	100	70	30	0	3
L40C60	100	100	60	40	0	3
L50C50	100	100	50	50	0	3
L75C25	100	100	25	75	0	3
F50L25	50	100	75	25	50	3

Table 4: 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
F5	406	0	1027	709.6	37.4	0.48
F10	406	0	1027	672.3	74.7	0.48
F15	406	0	1027	634.9	112.1	0.48
F20	406	0	1027	597.6	149.4	0.48
F25	406	0	1027	560.2	186.8	0.48
F30	406	0	1027	522.9	224.1	0.48
F35	406	0	1027	485.5	261.5	0.48
F40	406	0	1027	448.2	298.8	0.48
F45	406	0	1027	410.8	336.2	0.48
F50	406	0	1027	373.5	373.5	0.48
F55	406	0	1027	336.1	410.9	0.48
F60	406	0	1027	298.8	448.2	0.48
F65	406	0	1027	261.4	485.6	0.48
F70	406	0	1027	224.1	522.9	0.48
F75	406	0	1027	186.7	560.3	0.48
F80	406	0	1027	149.4	597.6	0.48
L10C90	365.4	40.6	1027	747	0	0.48
L15C85	345.1	60.9	1027	747	0	0.48
L20C80	324.8	81.2	1027	747	0	0.48
L25C75	304.5	101.5	1027	747	0	0.48
L30C70	284.2	121.8	1027	747	0	0.48
L40C60	243.6	162.4	1027	747	0	0.48
L50C50	203	203	1027	747	0	0.48
L75C25	101.5	304.5	1027	747	0	0.48
F50L25	50	100	1027	373.5	373.5	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.

2.3.1 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.

5. Tensile strength and modulus of elasticity: The tensile splitting strength is carried out according to ASTM C 496. The static modulus of elasticity indices were implemented according to ASTM C469.

6. Chloride Penetration and Expansion Characteristics: The drying shrinkage test is carried out according to ASTM C157 and rapid chloride permeability test (RCLP), using the procedure described in ASTM C-1202.

3.0 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 39.29%, 67.72%, 77.54%, 88.42%, 30.17%, 42.57%, 46.66% and 64.31% for F20, F40, F60, F80, L25C75, L50C50, L75C25 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. In precast applications and large sites based on the following consideration: Workability has a broad range from very low (at slump = 0–25 mm) applied for vibrated concrete in roads or other large sections, to high workability (at slump = 100–180 mm) applied for sections with congested reinforcement (Koehler and Fowler, 2003). Concrete products with lime as binder and incinerator ash are able to use in low slump needs in ordinary constructions. 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 Water Absorption

Water absorption tests were carried out on cube specimens. The results indicate that concretes mixtures containing lime and ash particles showed higher water absorption ratios than conventional concretes. But the water absorption of the F10, F20 and F50 is lower than conventional concretes and F60 has similar absorption in caparison with plain concrete. The water absorption of the F30, F40, F70, F80, L25C75, L50C50, L75C25 and F50L25 mixes were increased 9.93%, 12.26%, 7.48%, 11.11%, 26.09%, 37.33% 40.61% and 4.22% compared to plain concrete. But in the F10, F20 and F50 mixes the water absorption were decreased 4.41%, 1.48%, 4.41% respectively. The porosity of the adhered mortar causes the water to penetrate into the accessible pores and leads to an increase in the water absorption capacity in comparison with conventional concrete.

3.1.3 Unit Weight

The unit weight of the concrete ranged from 2386 to 2156 kg/m3, depending on ash and lime contents. The results (Table 5 and Fig. 3) indicate that the Unit weight tends to decrease by different percentage of lime and ash particles replacement in normal 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. For example, this kind of concrete can be used in structures to reduce earthquake damage. The F80 mix that incineration ash replaced 80% of the sand volume has lowest unite weight. Therefore, with increasing amount of lime and ash particles volume in concrete the unit weight will decrease.

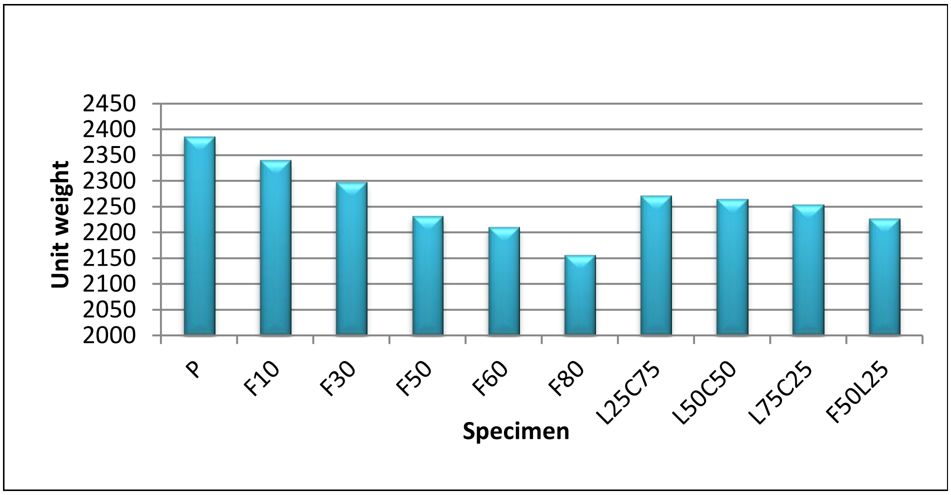

Figure 3: Unit weight of concrete mixtures

Table 5: Unit weight of concrete containing waste industrial material

Specimen	Unit weight (Kg/m^3)	Specimen	Unit weight (Kg/m^3)
P	2386	F70	2175
F5	2352	F75	2164
F10	2340	F80	2156
F15	2337	L10C90	2346
F20	2331	L15C85	2311
F25	2301	L20C80	2293
F30	2297	L25C75	2271
F35	2267	L30C70	2269
F40	2245	L40C60	2267
F45	2240	L50C50	2265
F50	2232	L75C25	2254
F55	2225	F50L25	2227
F60	2210	……….	……

3.2 Hardened Concrete Properties

3.2.1 Compressive Strength

The compressive strength test results for the concrete mixtures are presented in Fig. 4 and loading states of cubic specimens containing lime are shown in Fig. 5. The results show a tendency for compressive strength values of concrete mixtures to decrease below the plain mixtures.

The L75C25 mixes weren’t suitable among the other samples. The samples that lime completely replaced by cement, the cubic specimen was decayed after bring up from water. 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 and L75C255 mixes, all of the compressive strength values are higher than the minimum compressive strength required for structural concrete which is 17.24 MPa. 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.

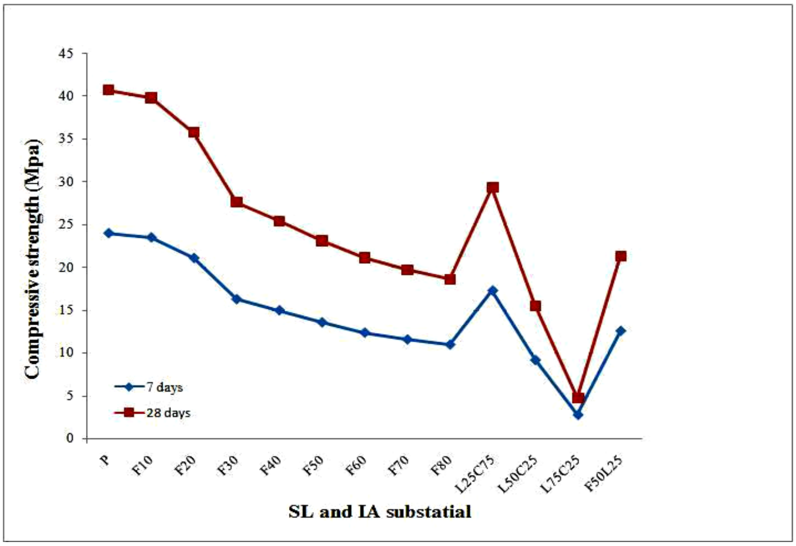

Figure 4: Compressive strength of concrete containing waste industrial material (7 days and 28 days).

Figure 5: (a, b, c) Testing compressive strength of concrete specimens: (a) specimens before testing, (b) Loading of specimens, (c) after testing.

3.2.2 Tensile Strength

A comparative study of the tensile splitting strength provides the results summarized in Table 6 and Fig 6, which shows the average values and variations obtained for each concrete in comparison with P mixes. These results show that the tensile splitting strength of concrete mixtures is prone to decrease with the increase of the ash particles and lime ratio in these mixtures. This trend can be attributed to the decrease in adhesive strength between the surface of ash particles and the cement paste which may limit the hydration of cement. Therefore the hydration developed slightly with time.

Table 6: Average tensile strength for the test age of 28 days

Specimen	$f_{ct,28}$ (MPa)	Specimen	$f_{ct,28}$ (MPa)
P	3.80	F70	2.66
F5	3.80	F75	2.65
F10	3.78	F80	2.59
F15	3.63	L10C90	3.61
F20	3.58	L15C85	3.55
F25	3. 27	L20C80	3.33
F30	3.15	L25C75	3.25
F35	3.08	L30C70	3.17
F40	3.03	L40C60	3.09
F45	3.00	L50C50	2.40
F50	2.90	L75C25	1.31
F55	2.84	F50L25	3.7
F60	2.76	……….	……

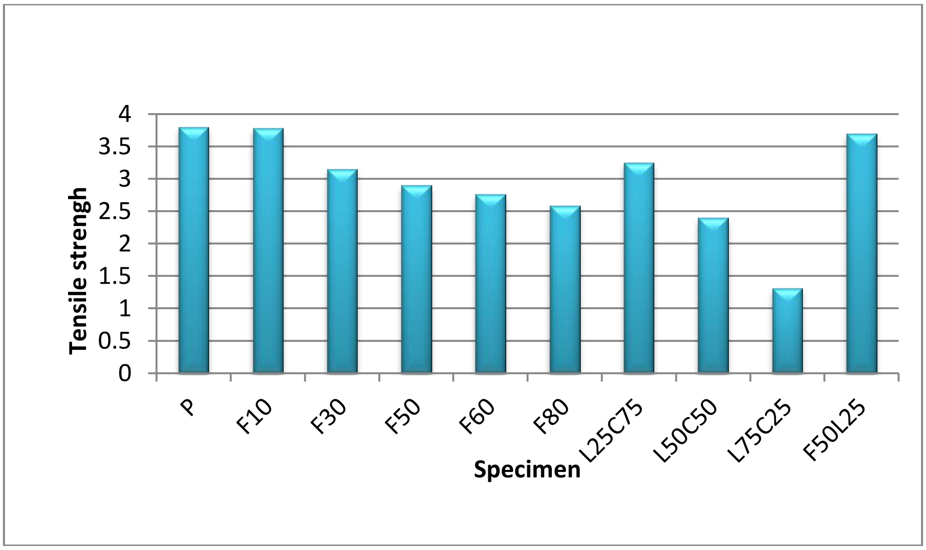

Figure 6: Influence of IA and SL content on the concrete tensile strength.

3.2.3 Modulus of Elasticity

The results of the static modulus of elasticity at different ages are given in Table 7, which includes the average Values and variations obtained for each material in comparison with P mixes. In this way, specimens with the lowest static modulus of elasticity were those corresponding to concrete containing lime as cement substitute. The modulus of elasticity for samples has been reported to be in the range of 30–96% the normal concrete.

Table 7: Average static modulus of elasticity for the test age of 28 days

Specimen	$E_{c,28}$ (MPa)	Specimen	$E_{c,28}$ (MPa)
P	31958.32	F70	19360.96
F5	31722.12	F75	19123.84
F10	30714.38	F80	18571.41
F15	29750.24	L10C90	31142.64
F20	28940.87	L15C85	28588.60
F25	26547.93	L20C80	26728.49
F30	24887.74	L25C75	24901.32
F35	24219.45	L30C70	21640.42
F40	23059.65	L40C60	18772.29
F45	22717.63	L50C50	18253.57
F50	21775.19	L75C25	10041.29
F55	20974.43	F50L25	20863.34
F60	20527.67	……….	……

3.2.4 Shrinkage Characteristics

Volume changes in concrete due to hydration reactions, drying, wetting and drying and thermal variation occur even without application of any loads. Under normal field conditions, drying shrinkage is an important phenomenon which induces time dependent deformations and is sometimes called creep under zero loads. The results of the drying shrinkage at different ages are given in Table 8. Fig 7 presents the test results for the shrinkage of concrete with 10, 20, 30, 40 and 50% IA. The results show that the shrinkage of concrete containing incinerator ash was lower than that of concrete without incinerator ash, but concretes mixtures containing lime showed higher shrinkage than conventional concretes. In F50L25 mixes the shrinkage of concrete is similar to P mixes.

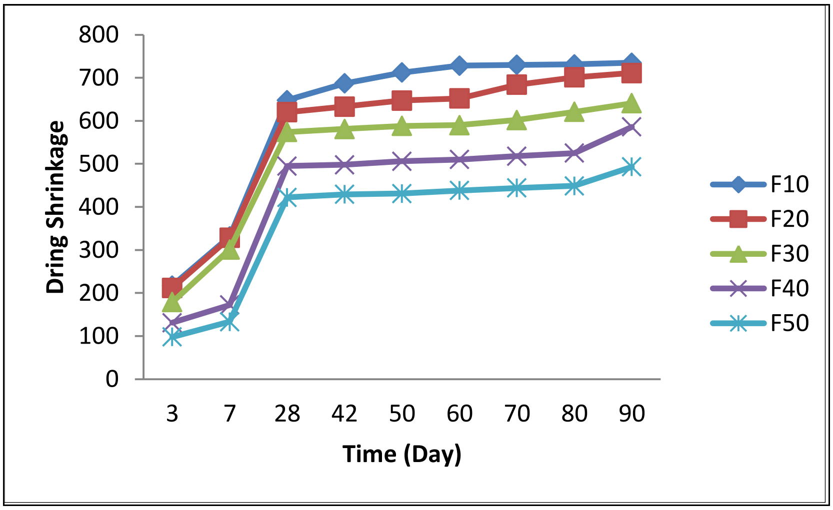

Figure 7: Test results of drying shrinkage of concrete containing IA (F10, F20, F30, F40 and F50).

Table 8: Drying Shrinkage (micro-strain) Data (3, 7, 28, 60, 80, 90 Day)

Specimen	3 Day	7 Day	28 Day	60 Day	80 Day	90 Day
P	220	335	660	732	735	739
F5	218	333	651	730	734	737
F10	217	331	648	728	731	735
F15	215	329	633	720	728	729
F20	212	328	620	652	701	711
F25	191	318	587	612	665	685
F30	179	301	574	590	621	641
F35	154	188	531	562	598	611
F40	131	172	495	510	525	586
F45	111	159	471	461	477	578
F50	98	133	422	438	449	493
F55	87	119	387	411	420	461
F60	72	99	356	309	357	400
F65	60	87	321	288	311	352
F70	56	72	205	255	286	318
F75	48	64	188	241	269	263
F80	32	42	150	222	231	238
L10C90	213	350	659	669	729	738
L15C85	215	349	661	675	732	739
L20C80	221	341	666	687	738	744
L25C75	228	336	669	733	738	749
L30C70	228	338	673	739	741	755
L40C60	229	340	680	744	747	758
L50C50	230	340	687	749	752	760
L75C25	236	342	701	749	767	767
F50L25	219	331	663	732	733	736

3.2.5 Chloride Resistance

This test method consists of monitoring the amount of electrical current passed through 51-mm thick slices of 102-mm nominal diameter cores or cylinders during a 6-h period. A potential difference of 60 V dc is maintained across the ends of the specimen, one of which is immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The chloride ion penetration of concrete mixtures was determined at 28 and 90 days of age. Table 9 and 10 summarizes the rapid chloride penetrability data at 28 day and 90 day, respectively. Based on the results, concrete with IA and SL together showed the lowest penetration of chloride ions. This behavior can be related to pore refinement and decrease in permeability produced by pozzolanic reaction.

Table 9: Rapid Chloride Penetrability Data (28 Day)

Specimen	W / (C+PP)	Charge Passed (coulombs)	Chloride Penetrability
F5	0.4	3172	Moderate
F10	0.4	3018	Moderate
F15	0.4	2911	Moderate
F20	0.4	2838	Moderate
F25	0.4	2745	Moderate
F30	0.4	2665	Moderate
F35	0.4	2574	Moderate
F40	0.4	2466	Moderate
F45	0.4	2315	Moderate
F50	0.4	2271	Moderate
F55	0.4	2241	Moderate
F60	0.4	2199	Moderate
F65	0.4	2175	Moderate
F70	0.4	2151	Moderate
F75	0.4	2133	Moderate
F80	0.4	3120	Moderate
L10C90	0.4	3150	Moderate
L15C85	0.4	3113	Moderate
L20C80	0.4	3076	Moderate
L25C75	0.4	3012	Moderate
L30C70	0.4	2975	Moderate
L40C60	0.4	2942	Moderate
L50C50	0.4	2915	Moderate
L75C25	0.4	2863	Moderate
F50L25	0.4	2013	Moderate

Table 10: Rapid Chloride Penetrability Data (90 Day)

Specimen	W / (C+PP)	Charge Passed (coulombs)	Chloride Penetrability
F5	0.4	918	Very Low
F10	0.4	818	Very Low
F15	0.4	780	Very Low
F20	0.4	756	Very Low
F25	0.4	712	Very Low
F30	0.4	696	Very Low
F35	0.4	657	Very Low
F40	0.4	645	Very Low
F45	0.4	609	Very Low
F50	0.4	587	Very Low
F55	0.4	543	Very Low
F60	0.4	511	Very Low
F65	0.4	501	Very Low
F70	0.4	487	Very Low
F75	0.4	477	Very Low
F80	0.4	465	Very Low
L10C90	0.4	1016	low
L15C85	0.4	1015	low
L20C80	0.4	971	Very Low
L25C75	0.4	944	Very Low
L30C70	0.4	942	Very Low
L40C60	0.4	872	Very Low
L50C50	0.4	804	Very Low
L75C25	0.4	776	Very Low
F50L25	0.4	374	Very Low

4.0 Conclusions

From the results presented in this paper, using concrete Containing Incinerated Industrial Ash and sedimentary lime, the main conclusions are:

1. The slump values of concrete mixtures showed a tendency to decrease below the slump of the reference concrete mixture. 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. The unit weights values of concrete mixtures with increasing lime and ash particles concentrations present lower unit weights compared to plain concrete. Using presented concrete mixtures were reduced the total weight of concrete structures.

3. Satisfactory quality of concrete with low strength requirements (compressive strength up to 40 MPa) may be achieved using two waste materials, namely SL and IA, simultaneously. The compressive strength values of all concrete mixtures tend to

decrease below the values for the reference concrete mixtures with increasing the ash particles and lime ratio. The study indicated the possibility that IA reduces cohesion in concrete.

4. A reduction in the static elastic modulus of elasticity was observed in all the mixtures.

5. According to the results it may be recommended to replace up to 25 % of cement by SL and to use such binder where a low strength of concrete elements is required. And the proper content for IA should not exceed 50% of fine aggregate volume. The proper content of SL and IA in the FL mixes was F50L25 mixtures.

6. For enhancing the chloride penetration resistance, the addition of IA and SL was found to be effective. Addition of IA as fine aggregate replacement is proved to be an efficient way to improve the dry shrinkage of concrete.

7. Use of IA as aggregates and SL 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. 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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