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The Possible Use of Sewage Sludge Ash (SSA) in Self-Consolidating Concrete (SCC) for Environmental Sustainability

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Abstract

Nowadays, waste production is increased due to the growth of technology and excessive use of natural resources as well as production of new chemicals, among which the hazardous wastes are no exception of that stabilization and solidification method is one of the hazardous waste management methods through which the waste materials are stabilized and confined. High flexibility for various pollutant compounds, ease of use, and being economical for large volumes of waste has led researchers to use this method to treat various wastes. In this research, sludge ash from sewage treatment plants uses as waste in order to perform the stabilization and solidification process. Nine mix designs with a water to cement ratio of 0.46; and 0, 6, and 10 percent dried sludge residue of the Alborz Industrial City in Qazvin as the replacement of fine aggregate; 0, 2, and 4 percent of silica fume; and cement content of 600 kg/m3are produced. The mini slump flow, mini V-funnel, compressive strength, electrical resistance tests were carried out on the solidified samples to investigate the effect of waste on the performance of the mortar. The results show that the use of this waste as a substitute for fine aggregate could be taken into consideration.

***Keywords**: Self-Consolidating Mortar, Stabilization and Solidification, Waste, Durability, Fresh Properties, Silica fume, Compressive Strength.*

1. Introduction

Currently, waste management and handling is one of the important challenges and concerns in environmental management around the world. Waste production resulting from various factors has also increased due to the growth of technology and excessive use of natural resources as well as production of new chemical and physical materials. Industrial and household waste management has significant importance due to the environmental issues and high potential of pollution for the surrounding environment.

Release of organic pollutants in the air, heavy metal leaks in groundwater, unsanitary waste disposal, and lack of available spaces to create a sanitary landfill altogether are among the challenges and concerns of industry managers and environmental experts.

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Basically, a waste that has one of the following characteristics is considered as hazardous waste: Incendiary, Flammable, Reactivity, Explosive, Corrosive, Radioactive, Infectious, Irritating, Sensitivity Creator, and ability to accumulate in biomass [1]. According to United States Environmental Protection Agency (EPA), hazardous waste are defined as waste that has one of the four characteristics of flammability, corrosion capability, reactivity, and toxicity [2].

Different types of chemical treatment methods are used in hazardous waste management among which the most common ones are using solubility, neutralization, coagulation and flocculation, stabilization and solidification, oxidation and chemical regeneration, electrolysis and hydrolysis [3].

The stabilization and solidification technology has been used since 1950 for treating nuclear pollutants contaminated with radioactive substances, and since 1980 for treating hazardous wastes (toxic). EPA as one of the largest research centers uses this method to refine the waste [4].

Different definitions of stabilization and solidification terms are provided in the references; including that stabilization is a process in which the inherent risk of waste is reduced by the addition of some substances and transforms the dangerous elements in it in a way that will have the lowest leakage rate into the environment or reach it to a lower level of toxicity [1]. Solidification refers to a process that the waste pollutant material is encapsulated in a solid body and eventually a solid matter is formed. It is not coercion during this process that a chemical composition takes place between the contaminated material and the added materials. At the end of this process, solidification products can be integrated blocks, granular particles, and other physical forms known as solids [2].

This method has high flexibility for various pollutant compounds and is economic for large volumes of waste [5].According to the definition of waste management law in Iran, specifical or hazardous wastes are referred to as all wastes requiring special care due to the high level of at least one of the hazardous properties such as toxicity, pathogenicity, explosivity of flammability, corrosivity and similar factors; and those medical wastes, as well as a portion of the normal, industrial, and agricultural wastes that require special management, are considered as special or hazardous wastes [6].

The three most useful areas of consolidation and solidification technology are: 1) Waste treatment before safe burial (in terms of leakage problems); 2) Purging the contaminated lands; and 3) Industrial waste treatment (stabilization of non-hazardous and unstable wastes such as sludge) [1].Toxic and hazardous wastes, which are the product of mankind and the result of activities in various sectors of industry, agriculture, services and trade; were buried in land or abandoned in the water during many years, regardless of the engineering and environmental principles, and this lack of attention to the observance of scientific and environmental principles has contaminated water, soil, and air; and puts the human health and other living things in danger [7].

Stabilization and solidification method is one of the ways to treat hazardous waste; the waste material in this process is combined with binders such as cement, pozzolan, lime and geopolymer and are being stabilized and confined in this way. Generally, the physical properties and initial strength of waste, improves during the solidification process, and it becomes less dangerous and its mobility is reduced during the stabilization process. Reduction of the negative effects of pollutants in the hydration process has led to the expansion and development of different methods of stabilization and solidification [5, 8-10].

Cement is one of the binders being used widely in the process of stabilization and solidification. The hardened cement paste generally consists of 50-60 percent H-S-C gel, 20-25 percent Ca (OH)2, and 15-20 percent Ettringite and Monosulfate; the formed H-C-H gel plays an essential role in stabilization and encapsulating of hazardous waste and mechanical resistance of hardened mortar [8].

Formation of Ettringiteas one of the ingredients produced in the process of hydration also could be one of the options for heavy metal absorption in the process of stabilization and solidification by placing heavy metals in their crystalline networks [11, 12]. For instance, making the Chrome motionless is attributed to the replacement of Sulphat with Chrome in Ettringite in some researches [13].

Replacement of pozzolanic materials such as silica fume, fly ash, and slag is known because of consumption of calcium hydroxide and alkalis during the pozzolanic reaction. Using these material results in the production of secondary silica gel and filling of empty space, and also a further reduction in the cavity of capillary [10]. In addition, pozzolanic materials create an alkaline environment suitable for reducing pollutant leaching as a result of chemical reactions in addition to reducing cavities and helping to encapsulate pollutants [14]. However, using silicone additives causes silicates of metals to form in addition to hydroxides of metals (e.g. Zinc). And these compounds, at least, show solubility for themselves relative to hydroxide of metals in a wider range of pH. In other words, metal silicates are in a more insoluble range than hydroxides of metals [15].This method, in addition to treating the waste resulted from the incinerator, provide the possibility of using these materials in construction workssuch as road bed as aggregate or cement replacement in concrete [16-18].

Disposal and treatment of wastes produced by human communities are the essential requirements of urban management and public health. Problems of dry sludge production and disposal occurs with the construction of the treatment plant. Since the amount of dry sludge produced in the treatment plants is generally high and no specific consumption has been defined for them, the amount of sewage solids produced in a treatment plant per person per day is reported to be about 35 to 85 grams [19, 20].

One of the major problems regarded in waste management is the problem of sludge accumulation. Therefore, the disposal of these materials in terms of environment and also the storage space constraints is very important, so the proper management of producing sludge in treatment plants is considered necessary. One of the most common methods of sludge disposal is sanitary landfill and using as a fertilizer in agricultural fields. The industrial city of Alborz is composed of residential and industrial areas and is located 10 km from the city of Qazvin. Currently, the sewage collection network imports the produced waste from about 500 large and small factories (except industries such as leather production, slaughterhouses, etc.). Solid waste from sewage treatment is one of the problems that affects the treatment plants and is added annually, thatthe storage and handling of it is costly, which ultimately has environmental degradation in terms of storageand its displacement imposes high costs of the Alborz industrial city of Qazvin due to the effect on the cost of wastewater treatment process.

Since the objective of this research is the stabilization and solidification of urban waste residue and the Alborz industrial city of Qazvin is chosen as the case study, this waste is used as a substitute for fine grained aggregate. Although, utilizing this residue is not the priority of the stabilization and solidification method for constructional works, but as with the research that has been mentioned in the review section of this study, which has examined this residue in civil works, using this residue has been considered as fine aggregate. In addition, according to the specifications of waste particles, its grading and size is much bigger than cement particles and it is mostly similar to fine grained aggregate. The amount of cement materials is considered constant in this research. Furthermore, the effect of adding silica fume instead of cement is also investigated.

2. Materials and Methods

2.1 Materials

Sewage sludge ash used in this project is prepared from sewage treatment plant in the Alborz industrial city of Qazvin. Input wastewater specifications of this treatment plant are presented in table 1. The chemical composition of the (wet) sludge prepared from the above material is given in table 2. The urban sewage waste has been passed through sieve number 8.

The results of waste analysis in table 3 indicate that the amount of heavy metals in the waste is higher than the allowed limit and considered among the hazardous wastes based on the EPA standard.

Heavy metal is an idiom in chemistry, which refers to metals and pseudo metals having environmental effects. This word has raised from the dangerousness and harmfulness of heavy metals on the environment and it more refers to Lead, Mercury and Cadmium (because of their higher density compared to Iron); nevertheless, it includes all the harmful and toxic metals and pseudo metals (regardless of density) such as Arsenic. As indicated in Table 3, these heavy metals, that large amounts of them is highly toxic is several times higher than the allowable limit based on EPA-1311. [2].

Table1. Specifications of sludge from the wastewater treatment plant of Alborz Industrial City

Description	Unit	Amount
Temperature	mg/L	Variable
Color	mg/L	Dark Green
EC	mg/L	1800
PH	mg/L	6.6
BOD	mg/L	1950
COD	mg/L	4600
TSS	mg/L	1600
Phosphate	mg/L	60
Nitrate	mg/L	10
Sulfate	mg/L	183
Nitrogen	mg/L	44
NH4	mg/L	28
SS	mg/L	40
Detergent	mg/L	14.2
NO2+NO3	mg/L	10
Total solids	mg/L	980

Table 2. Chemical composition of the (wet) sludge

Characteristic	Unit	Amount
PH	-	7.8
COD	mg/L	2000
BOD	mg/L	1200
TSS	mg/L	75000

Table 3. Measurement of waste elements by ICP-OES

Element	mg/l	Element	mg/l	Element	mg/l	Element	mg/l
Ag	8.5	Cr	216	Mo	<2	Sc	<10
Al	51000	Cu	153	Na	5200	Sr	327
As	125	Fe	11000	Nd	14	Ti	<0.01%
Be	<1	K	17700	Ni	89	V	29
Ca	56100	La	23	P	2200	Y	12
Cd	<1	Li	19	Pb	295	Yb	<10
Ce	89	Mg	8000	S	4800	Zn	1883
Co	12	Mn	262	Sb	96	Zr	<10

Commercial ASTM C 150 [21] type II Portland Cement is used in all the mortar mixtures. The C3S, C2S, C3A and C4AF contents of the cement by Bogue calculations were 52.72%, 21.52%, 6.61% and 10.68%, respectively. The Physical properties and chemical composition of the cement are given in table 4.

Silica fume is a fine- grain silica with a very high surface area. Accordingly, the used silica fume has 95% SiO2, a particle size of 0.1 lm, and 20 m2/g surface area. The physical properties and typical chemical analysis of silica fume are shown in table 4.

Well-graded silica sand was used as fine aggregate. The specific gravity, absorption and maximum size of the fine aggregates are typically 2.6, 0.6%, and 5 mm, respectively. The grading of the fine aggregate is presented in Fig. 1.

Potable water was used for casting and curing of all mortar specimens. A high range water reducing admixture (HRWRA) based on chains of modified polycarboxylic ether was used to achieve the desired workability. Its specific gravity was 1.1.

Table 4. Chemical and physical properties of cement and silica fume.

Items	Chemical composition (%)	
	Cement	Silica fume
SiO2	21.38	93.6
Al2O3	4.65	1.3
Fe2O3	3.51	0.9
CaO	63.06	0.5
MgO	3.2	1
SO3	1.8	0.1
	Physical properties	
Avg. particle size	10 µm	0.1 µm
SSA (m2 /g)	0.33	20

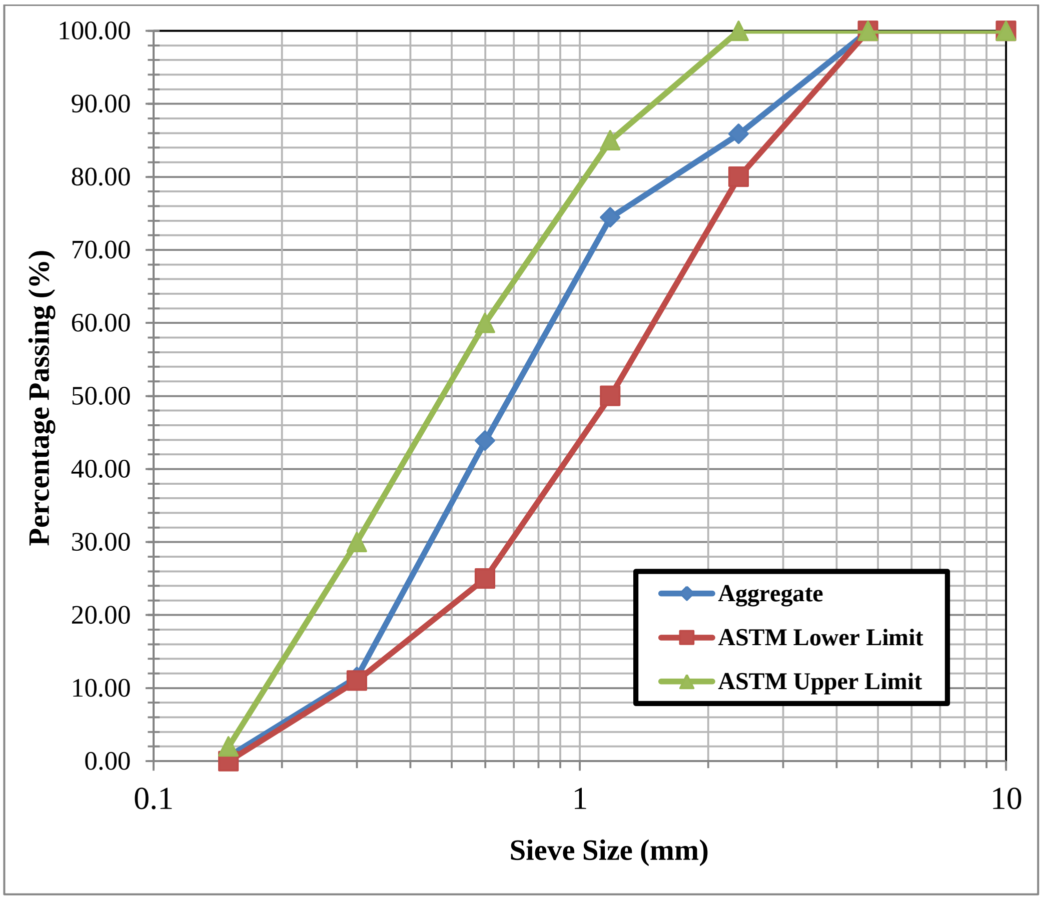


Figure 1. Sand size distribution

2.2 Mix Design and sample preparation

In this research, the waste is used as the replacement of fine graded sand and the amount of cement materials and w/c ratio are considered constant. The reason for keeping the ratio of water to cement constant is to maintain the flowability of specimens and reducing the flowability effects on results. Adding silica fume as the replacement of cement is also examined in this research. The mix designs for the examining waste is defined using the conducted researches and repeated trial and errors. In this regard, observance of the flowability factors, lack of bleeding and segregation are visually performed and also achieving the proper viscosity is done using fresh mortar tests, and then the mix designs are written by chosen codes and surface levels and provided in table 5.

In preparation of specimens, the aggregates, silica fume, stone powder (SP), waste, and cement are being weighted. Then the aggregates, stone powder (SP) were mixed in a rotating planetary type cylindrical mixer with two blades for one minutes. Although the aggregates were saturated surface dry (SSD), a few portions of the water were added in lieu of wetting aggregate surface to prevent suspending of cement particles. Afterward, silica fumesludge and waste dissolved in water, cement and water are added for each plan, respectively. During the mixing materials, the superplasticizeris gradually added to mixer. The dosage of superplasticizer was varied based on slump flow diameter. In this study, slump of all specimens were keep constant. The total mixing time was 5 min and was kept the same for all the mixes. According to the requirements specified by the European Guidelines for SCC [22, 23], all molds were cast with no mechanical vibration. The specimens were kept at a temperature of 24 °C for 48 hours until de-molding. After that, specimens were placed in the curing moist container at a temperature of 22 C.

The results obtained from this test is considered as a criterion for determining filling ability and plastic viscosityof the used mortar. As a result, this test could be used in measurement and verification of mix design.

Table 5. Mix design of specimens

code	Cement (Kg/m3)	SF (Kg/m3)	Natural sand (Kg/m3)	Stone powder (Kg/m3)	SSA (Kg/m3)	SSA(%)	Sp (Kg/m3)	Water (Kg/m3)	w/c
S0SSA0	600	0	1377	153	0	0	4.82	276	0.46
S2SSA0	588	12	1377	153	0	0	5.25	276	0.46
S4SSA0	576	24	1377	153	0	0	5.46	276	0.46
S0SSA6	600	0	1285.2	153	8.91	6	14	276	0.46
S2SSA6	588	12	1285.2	153	8.91	6	14.2	276	0.46
S4SSA6	576	24	1285.2	153	8.91	6	14.42	276	0.46
S0SSA10	600	0	1224	153	153	10	35.04	276	0.46
S2SSA10	588	12	1224	153	153	10	36.96	276	0.46
S4SSA10	576	24	1224	153	153	10	37.12	276	0.46

2.3 Test Procedures

2.3.1. Mini Slump Flow (Spread Measurement)

The mini- conical slump flow test on the fresh mortar is conducted in this research due to the required capabilities. [24]. According to EFNARC code [22] the mini slump flowapparatus test consists of a frustum of cone, a diameter of 70 mm at the top and 100 mm at the base with 60 mm height. After placing the cone at the center of a steel base plate, it was filled with self consolidatingmortar. Then the cone was lifted and theself- consolidatingmortar spreads over. The average of two perpendicular diameters is measured as the mini slump flow of mortar as shown in Fig. 2.

2.3.2. Mini V Funnel

Based on EFNARC [22], the mini V-funnel with perfectly clean interior surfaces is installed and filled with one liter of self-consolidating mortar without any vibration or compaction. Then the upper surface is smoothed with a trowel and then the gate was opened in 10 sec. Simultaneously with the opening of the gate, the time is recorded by a stopwatch and the first light observable from the top view during the discharge of mortar is the time should be recorded. The range of test results for self- consolidating mortar in the mentioned test is suggested 7 to 11 seconds based on the mentioned standard. If the results of mentioned experiments are especially in the lower range of suggested amounts, it indicates that the mix design is good and the flowability and viscosity of the paste are appropriate [22]. The figure of V-funnel is shown in Fig. 3.

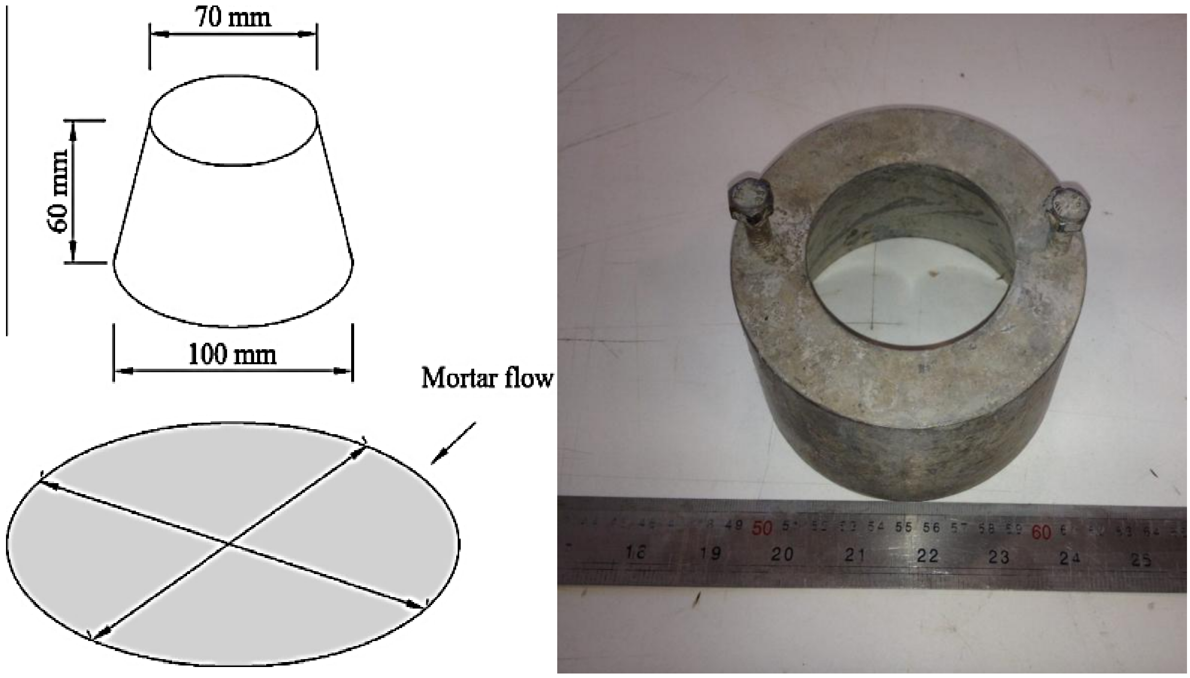


Figure 2.Configuration of mini-slump cone.

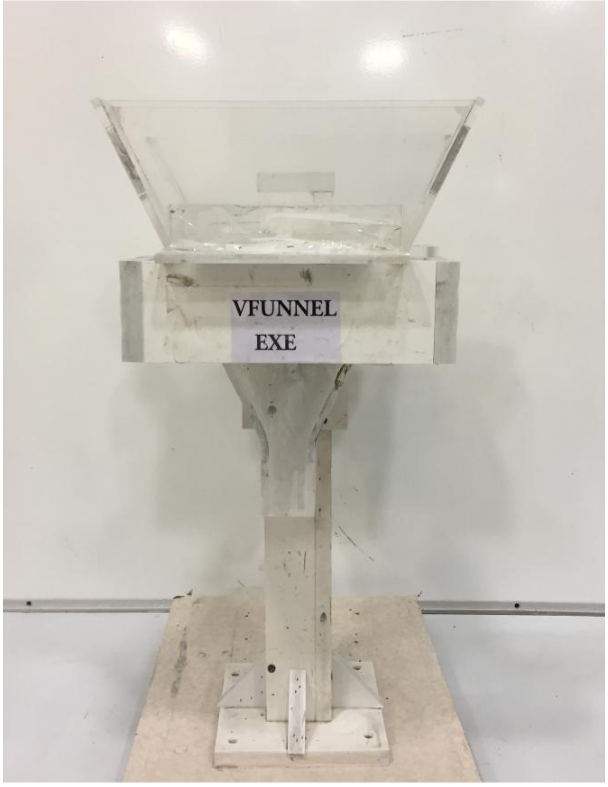


Figure 3.Configuration of mini V-funnel apparatus test.

2.3.3. Compressive Strength

The compressive strength of solidified products is one of the primary properties being measured in solidification. In addition, if the mechanical properties of solidified products are low, they will convert into smaller parts over time and speeds up the pollutant emissions. However, this factor depends on the considered plan for solidification products. [10]. Therefore, in this research, 5×5×5 cm cubic specimens are tested at the ages of 7, 14, and 28 days.

2.3.4. Electrical Resistance Test

Specific electrical resistance of concrete is one of the main parameters in the durability of concrete and corrosion of reinforcements. As the electrical resistance increases, the corrosion passing through the anode and cathode areas on the rebar decreases. Thus, the specific electrical resistance could be considered as an indirect measuring device to express the ability of concrete against corrosion [25].

In this test, an electrical resistance measuring device producing direct current at a frequency of 1.0 KHz, is used. two sheets of copper with a thin layer of low-slump cement paste is used on both sides of saturated cubic specimens of 10×10×10 cm with wet surface (Fig. 4).

The specific electrical resistance is calculated using the following equation.

$$\rho = \frac{ZA}{L}$$

In which; ρ is the specific electrical resistance of concrete (kΩ-cm), Z is the apparent resistance of concrete (kΩ), A is the cross section of concrete (cm^2), and L is the length of test specimens (cm^2).

Figure 4.Electrical resistance device

3. Results and Discussion

3.1. Mini Slump Flow Test

The test results of mini-slump flow and amount of consumed super- plasticizer for different mortars are shown in Fig. 5. As can be seen, the slump number is fixed in the range of 23 to 26, and it is in the standard range of EFNARC, which indicates the increase of super- plasticizer in each step; for example, the average of super-plasticizer reaches to 51, 142, 367 gr in the case of SSA=0%, SSA=6%, SSA=10% respectively, which has an increase of 3 and 6 times relative to the case of SSA=0.Therefore, it shows that SSA greatly reduced the flow ability of mortar and the use of

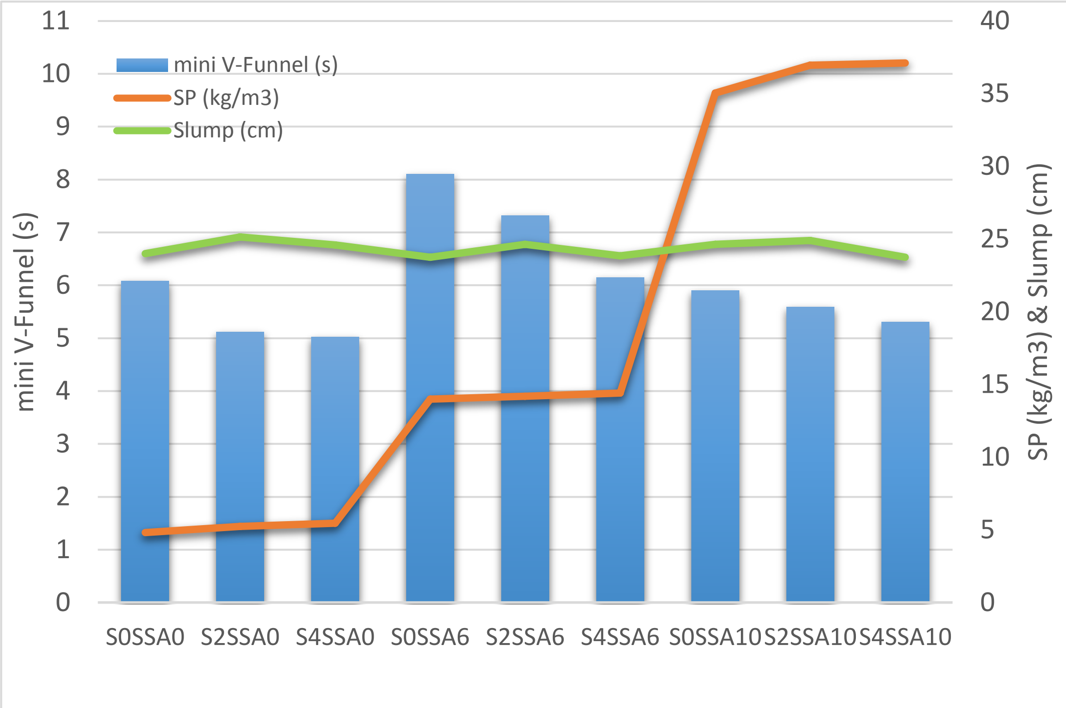


Figure 5.Comparison of the super-plasticizer amount with mini slump flow and mini V-funnel

Super-plasticizer is inevitable, and SCM could not be produced without using super-plasticizer. No signs of segregation and bleeding in the concrete mortar as a fault or disadvantage are observed in the produced specimens. The results indicate that urban waste residue, in the presence of pozzolans and super-plasticizers, could be considered as a replacement for a small portion of fine aggregate in order to achieve the self-consolidating mortar.

3.2. Mini V-Funnel

Figure 6 shows the result of discharge flow times. The time obtained from this test is near the low range of standard and indicates that the mixture has a good filling capability, as it can be seen from the figure. As it can be seen from the test results, the sample S4SSA0 with the discharge time of 5 sec has the least time and the sample S0SSA6 with the discharge time of 8.1 sec has the maximum time for mortar discharge in the mini V-funnel test. The results show that the time of discharge is increased with the increase of silica fume and it's also repeated with the increase of super-plasticizer. The same increase in the discharge time is happeningin the control sample which creates the best finished surface in the laboratory observations. On the other hand, the addition of waste should also be investigated along with the super-plasticizer, however, it is expected that the discharge time of SCM will significantly increase due to the addition of waste, but using super-plasticizer has increased this time to less than 8 seconds. Based on EFNARC standard, the discharge time must be limited to 11 seconds, which is happening in all the specimens. Therefore, the suitable viscosity of mixtures and the accuracy of the proposed mix designs for the self-consolidating mortar is approved.

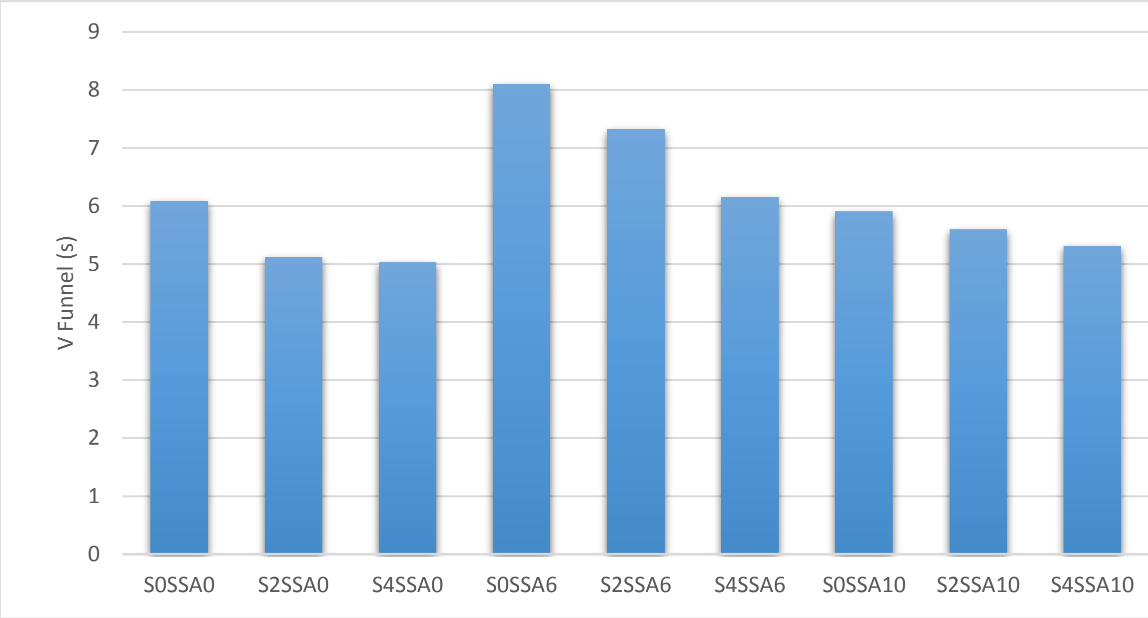
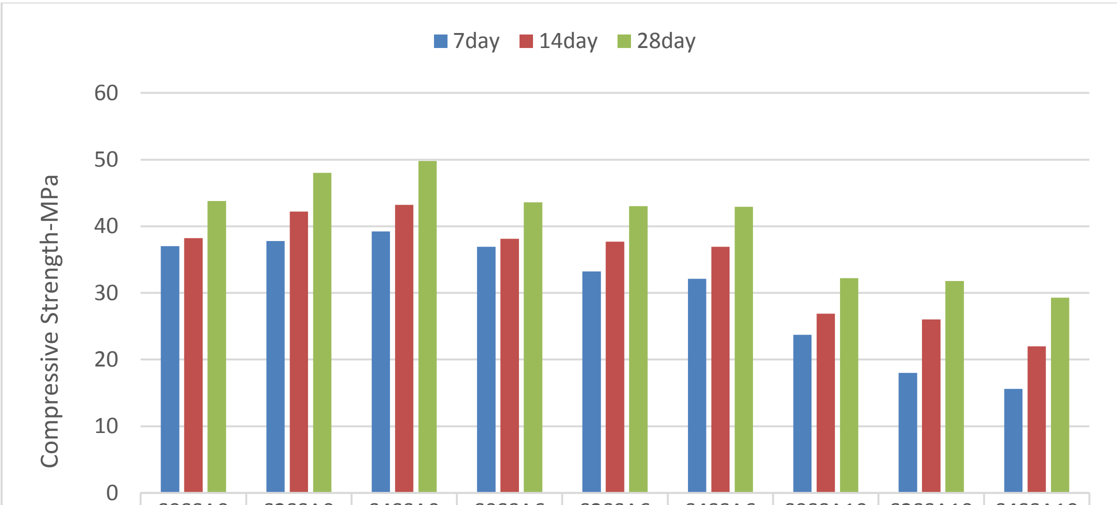


Figure 6. Discharge time of mortars from V-funnel



	S0SSA0	S2SSA0	S4SSA0	S0SSA6	S2SSA6	S4SSA6	S0SSA10	S2SSA10	S4SSA10
7day	37	37.8	39.2	36.9	33.2	32.1	23.7	18	15.6
14day	38.2	42.2	43.2	38.1	37.7	36.9	26.9	26	22
28day	43.8	48	49.8	43.6	43	42.9	32.2	31.8	29.3

Figure 7.Compressive strength of specimens with different ratios of waste to sand

3.3 Compressive Strength Test

Figure 7 shows the compressive strengths of specimens containing waste residue and silica fume with different portions.

The results show that the compressive strength is generally decreased with the increase of waste replacement, which could be described in this way that the waste particles have weaker characteristics compared to sand particles and have less resistance so they break and crush with less force, which leads to the reduction of total matrix resistance. The other reason is the existence of heavy metals and organic materials in the waste residue, which decreases the strength by making disruption in the hydration reaction and preventing the formation of an effective silica gel. Same results have been reported by other researchers [26, 27].

The diagram also shows that a strength decrease in specimens containing waste residue at the older ages is more than the control specimen at early ages which could be due to lack of hydration of cement particles even at older ages. Adding pozzolanic material has increased the compressive strength of specimens, which is the main cause of the formation of secondary silicate gel reducing the cement matrix porosity that reduces the effect of waste residual disorder .

Among the specimens containing waste residue, the maximum compressive strength at the age of 28 days is related to concrete containing 6% waste residue and the least compressive strength is related to concrete containing 10% waste residue and 4% silica fume.

As it is specific from (Fig. 8), the amount of decrease is in comparison to the control specimens. For example, the mortar containing 4% silica fume and 10% waste residue in comparison with the control sample at the age of 28 days has resulted in a decrease in compressive strength of about 41 percent, in the event that this strength in the specimen at the age of 7 days has reached to 60 percent decrease. It could be concluded that the existence of silica fume has resulted in more decrease of compressive strength at early ages and as the specimen age increases, this reduction is lowered and these results indicate the inappropriate performance of silica fume at early ages and appropriate performance of silica fume at higher ages.

The decrease amount of strength in specimens in Fig. 9 is relative to specimens without silica fume. For example, the mortar containing 4% silica fumein comparison to the mortar without silica fume at the age of 28 days has caused the increase of compressive strength for about 14 percents, as well as in the mortar containing 10% waste residue and 4% silica fume, the amount of compressive strength in comparison with the specimen without silica fume has caused for 9% decrease. By comparing the specimens at the ages of 7 and 14 days in different percentages of waste residue it can be concluded that the existence of silica fume at early ages causes more decrease in compressive strength and this decrease will decline as the age of specimen increases which indicates the inappropriate performance of silica fume at early ages and good performance of silica fume at higher ages.

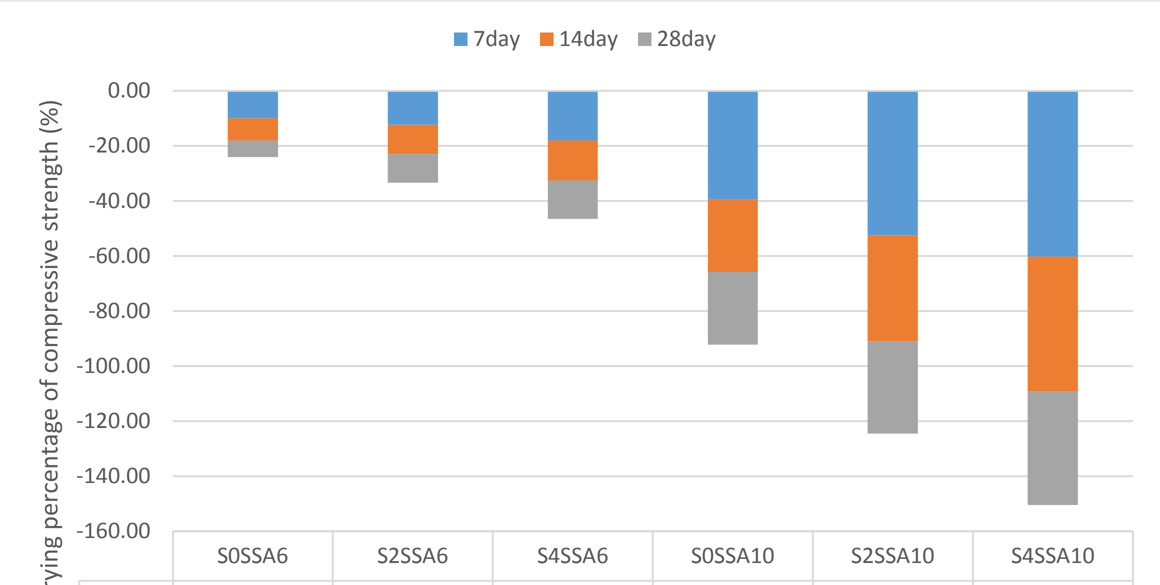
Reduction of compressive strength in the specimens containing waste residue was due to lack of effective encapsulation of the waste containing heavy metals and due to a lot of interference in cement hydration and high porosity of specimens and also the addition of silica fume couldn’t prevent this interference.

US Environmental Protection Agency has suggested a compressive strength of 0.35 MPa (3.5 kg/cm2) for the age of 28 days for the stabilized and solidified materials that have been designed with the purpose of burial at the sanitary landfills [9]. According to the standard value of US Environmental Protection Agency, all the 14 and 28 day specimens containing 6 and 10 percent waste residue have the required strength to be buried in the sanitary landfills.

3.4. Electrical Resistance Test

Figure 10 shows the results of electrical resistance for the mortar specimens. As it is evident from the figure, the electrical resistance has a direct relation to the age of specimens, and the higher the age of specimens and harder the cement paste is, due to the completion of hydration and porosity reduction of specimens, the higher the electrical resistance goes; on the other hand, it can be concluded that the existence of silica fume in concrete is highly related to the compaction of concrete or mortar microstructure and caused the electrical resistance to increase (Fig.10).

On the other hand, it can be claimed that adding waste residue has caused the reduction of electrical resistance. The reason for this could be related to the volume decrease of dense aggregate and porosity increase of self-consolidating mortar as well as adding metal anions with a negative charge in the pore water of mortar specimens. Because the porosity of specimens increases when the waste residue, which are mainly with high porosity, replaces with dense aggregates and this leads to the reduction of electrical resistance of specimens. On the other hand, adding waste residue helps anions to dissolve in the pore water and these anions as an electric current conductor, decreases the electrical resistance too.is shown in Fig. 11, 12.



	S0SSA6	S2SSA6	S4SSA6	S0SSA10	S2SSA10	S4SSA10
28day	-6.00	-10.28	-13.90	-26.44	-33.61	-41.18
14day	-8.00	-10.73	-14.51	-26.28	-38.49	-49.07
7day	-10.00	-12.32	-18.03	-39.46	-52.46	-60.20

Figure 8.Varying percentage of compressive strength of specimens relative to the control sample

	S2SSA0	S4SSA0	S2SSA6	S4SSA6	S2SSA10	S4SSA10
28day	9.42	13.68	-4.44	-4.73	-1.24	-9.09
14day	15.70	18.26	-3.08	-5.14	-3.45	-18.31
7day	4.60	8.29	-10.11	-13.00	-24.16	-34.27

Figure 9.Varying percentage of compressive strength of specimens relative to specimen without silica fume

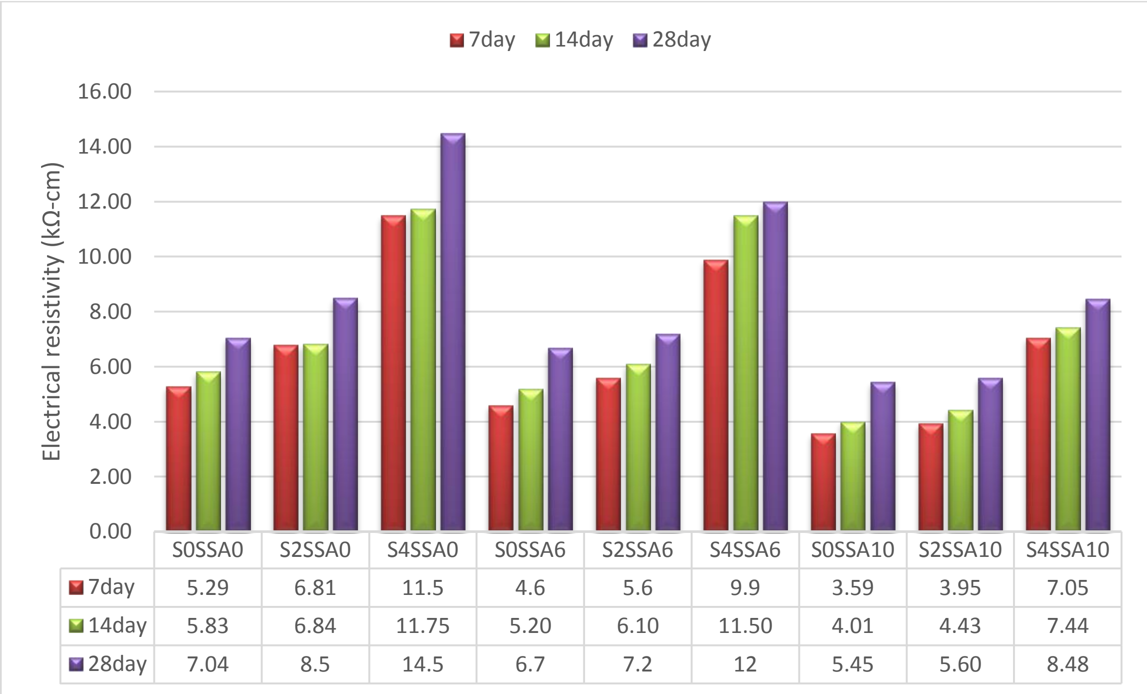


Figure 10.Electrical resistance of specimens with different ratios of waste to sand

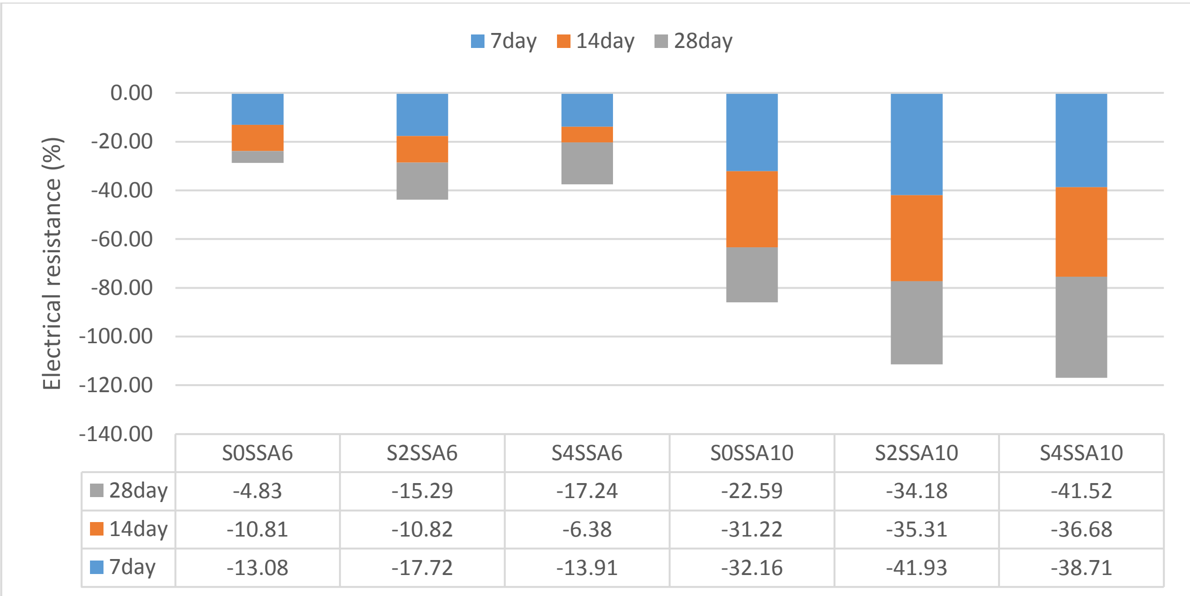
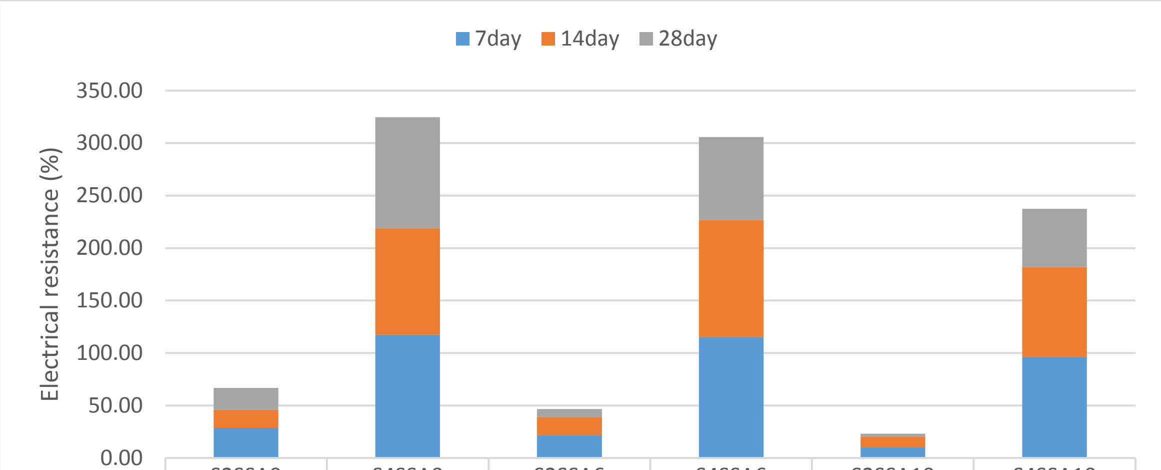


Figure 11. Percent of electrical resistance change in specimens relative to the control specimen



	S2SSA0	S4SSA0	S2SSA6	S4SSA6	S2SSA10	S4SSA10
28day	20.74	105.97	7.46	79.10	2.66	55.60
14day	17.32	101.54	17.31	111.54	10.35	85.54
7day	28.61	117.31	21.74	115.22	10.10	96.32

Figure 12.Percent of electrical resistance change in specimens relative to specimens without silica fume

4. Conclusions

In this research, the possibility of using waste containing heavy metals in self-consolidating concrete was investigated. In this regard, nine different mix designs were implemented in tests such as mini slump and mini V-funnel tests, electrical resistance, compressive strength. The results obtained from this experiment are as follows:

1. The urban waste residue is extremely decreasing the flowability of mortar. Using super-plasticizer to compensate the decease of flowability in mixtures containing waste residue is very essential. The amount of super-plasticizer used in mortars containing 6 and 10 percent waste residue is 3 and 7 times more than the control sample of self-consolidating mortar, respectively, which indicates the extreme decrease of mortar flowability.
2. The values of compressive strength in specimens containing waste residue decrease by the increase of silica fume content, especially in specimens with the age of 7 days, and it should be noted that this decrease gets lesser by the age of specimens increase as the specimens with 28 days of age have a decrease much lesser than early aged specimens. It can be concluded from the results that the existence of waste in designs up to 10% as the replacement of aggregates is acceptable.
3. According to the results of compressive strength tests of mortar specimens in different ages, it is observed that compressive strength of samples decrease generally with the increase of replacement rate, which is due to the decrease of strength in the waste particles in comparison with sand particles and also disruption of heavy metals in the hydration process of cement, but according to the regulations of US Environmental Protection Agency, they have the required compressive strength in order to be buried in the sanitary landfills.
4. As shown by the electrical resistance test results, existence of silica fume and waste residue lead to the decrease of electrical resistance due to the increase of porosity in the self-consolidating mortar and also the increase of metal anions the pore water.

5. References

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