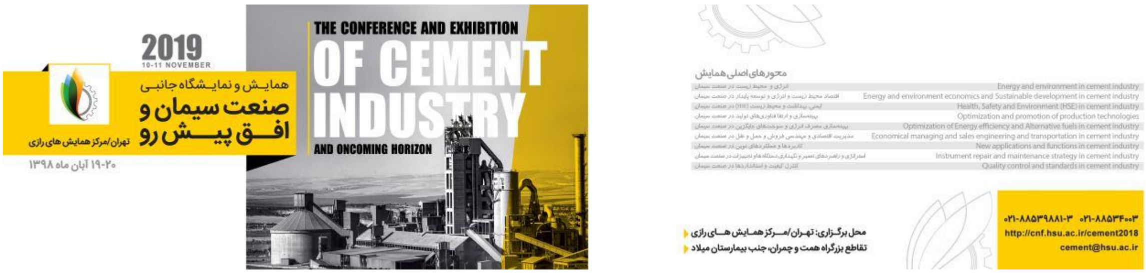

Investigation of compressive strength of ordinary concrete produced by industrial waste ash as a partial replacement of cement

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ABSTRACT

Due to the expansion of urbanization and the increase in the amount of waste, one of waste disposal ways is to burn it in incinerator plants. On the other hand, the disposal of ash resulting from these wastes is one of the concerns of these plants. In this study, laboratory experiments were carried out to produce concrete incorporating ashes from industrial waste incinerated in the SAVEH waste technology complex as a partial replacement of the cement. In this research, the effects of adding these industrial waste ashes on the compressive strength of ordinary concrete were investigated. Concrete mixing design was performed according to national concrete mixing plan of Iran. Also, the ash contents incorporated into concrete are 0%, 10%, 20% and 30% of cement. The results show that as the ash content increases, the compressive strength of the concrete decreases, but the compressive strength obtained is still acceptable for the construction of concretes requiring less compressive strength, such as filler concrete or lightweight concrete in the building flooring. On the other hand, the use of this industrial waste ash incorporated into the concrete as a partial replacement of cement not only eliminates the concern of the incinerator plants to dispose this pollution, but also reduces the cement consumption and consequently reduces the greenhouse gases comes from the cement production.

Keywords: Industrial waste ash, cement, compressive strength, ordinary concrete

1. INTRODUCTION

Due to the development of urbanization and industrialization of cities, the amount of municipal waste has increased rapidly and the disposal of waste has resulted in high costs due to the increased volume of waste production. On the other hand, the scarcity of landfills and the high costs are raising the concern of many municipalities. Different kinds of wastes such as municipal, hospital and industrial wastes are hazardous wastes that can contaminate air, soil, surface water and groundwater if they are disposed unprincipled. One of the different ways for preventing such contaminants is to burn them using waste incinerators.

PASMAND ZIST technology company has started its activities as the first company in the field of solid waste management concentrated with the supervision of the waste management team of SAVEH and MARKAZI province with a land area of 23 hectares. Recently this company with a license from the Ministry of Industry, Mine & Trade, the license of Department of Environment, and the Ministry of Health and Medical Education is operating as a leading waste management company in Iran.

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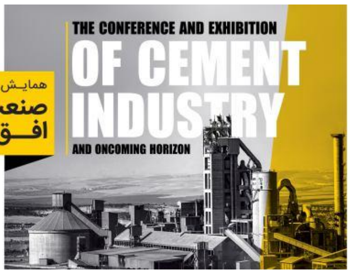


In order to provide a safe and secure environment, PASMAND ZIST technology company has employed up-to-date technology and facilities and appropriate operating practices as well as relevant principles and standards.

In addition, nowadays, as the industries expand and the waste generation increases in communities, the compliance of national and international standards and the use of new technologies in waste management assures the complex to deliver the right services to customers.

The incinerator furnaces of the PASMAND ZIST technology company shown in Fig. 1 include a solid incinerator rotary furnace and a 25 ton / day fluid bed liquid incinerator with European technology designed to eliminate solid, liquid, and sludge industrial and special wastes. The operating temperature in this furnace is between 1150 °C to 1250 °C which has the capability of eliminating all types of industrial and special wastes including types of waste from the oil, gas, and petrochemical industries, types of pesticides other than organochlorine, types of sludge, types of medical and hospital wastes and other hazardous burnable industrial wastes. The components of this fluid bed incinerator furnace include key components such as maintenance silo of solid, liquid, and feeder wastes, incineration furnace, heat recovery system, air pollution treatment and control system.

One of the characteristics of this incinerator is that the amount of exhaust gas emitted from the furnace is lower than national and international standards. The incinerator is also equipped with a system for measuring exhaust gas emissions and minimal adverse environmental effects.

Fig. 1 – Incinerator furnace

Today, concrete is one of the most widely used building materials in the world. The most polluting part of the concrete industry is the cement manufacturing process. On the other hand, the annual consumption of natural raw resources, such as clay, limestone and other natural raw materials, is also significant for the production of cement. In addition to consuming enormous resources, significant volumes of air, water and soil pollutants are also generated by cement production.

This massive cement production in addition to consuming large amounts of energy, releases large amounts of carbon dioxide. Therefore, it is necessary to reduce the cement consumption in concrete as much as possible. One of these solutions is to replace waste ash instead of a portion of cement used in concrete. The main problem we face is that the concrete produced using the industrial waste ash instead of a portion of cement shall have the required strength, reliability and durability and shall also be economically justifiable. The effect of ash addition on compressive strength of concrete has been already investigated by various researchers [1-7]. In this study, the effect of incorporating 0%, 10%, 20% and 30% ash from industrial waste incinerated in SAVEH waste technology company as a partial replacement of cement on the compressive strength of concrete was investigated.

2. MATERIALS

The characteristics of used materials including cement, industrial waste ash, water and aggregates to produce concrete are as below:

2.1. Cement

The cement used in the construction of concrete samples is the Type II cement (with the cement strength class of 315) manufactured in the cement plant of JOUVEYN, Iran.

2.2. Industrial waste ash

The ash needed to be replaced as a part of the cement was obtained from SAVEH waste technology company. Due to some impurities in the ash, that was passed a sieve number 18 (1 mm) prior to use in the concrete.

2.3. Water

Consuming water is drinking water of SABZEVAR with good PH.

2.4. Aggregates

The aggregates used in the concrete consist of two samples of coarse and fine gravels along with a sample of sand obtained from the aggregates of RIVAND, a village close to SABZEVAR, Iran. The grading diagrams of aggregates are shown in Fig. 2.

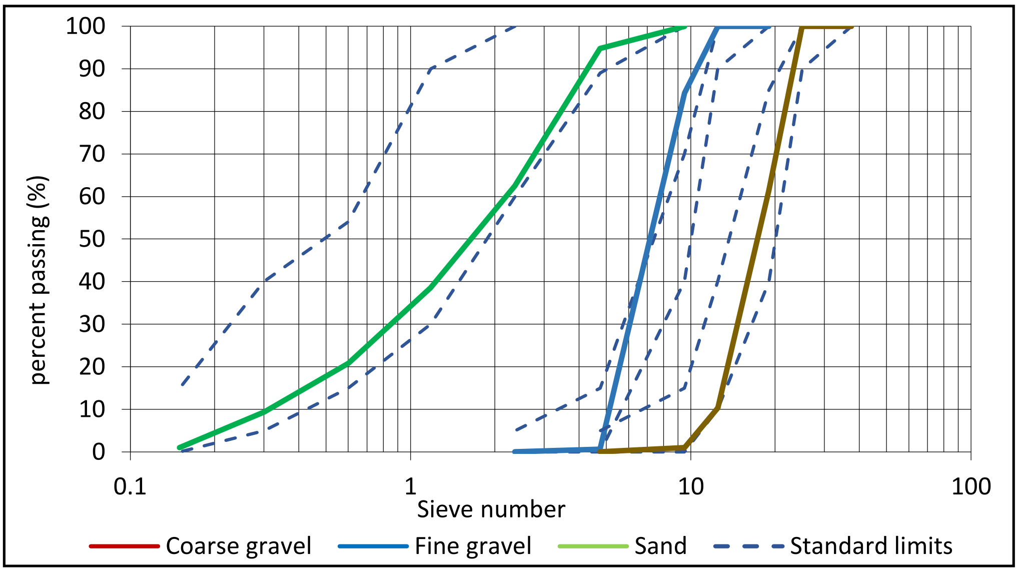
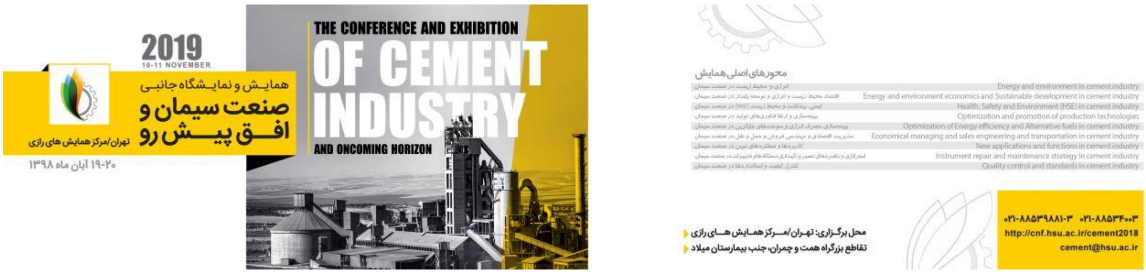


Fig. 2 – Grading diagrams of sand, fine and coarse gravels

3. CONCRETE MIXING DESIGN

Concrete samples were manufactured according to the national Iranian concrete mixing design published in journal no. 479. After preparing the materials and mixing them for 5 minutes, standard cubic molds of 150 × 150 × 150 mm were used to make the samples.



Also, the fresh concrete compaction was carried out using standard bars in three layers and each layer was compacted with 25 beats. Grading correction is based on the Iranian mixing design bylaw and the modified grading chart is shown in Fig. 3.

All samples were removed from the molds after 24 hours and placed in a limestone pond at 25 °C. The specifications of the samples under the test are presented in Table 1. In all designs, cement grade, water to cement ratio and type of grading are considered constant and all designs try to keep all conditions constant and only change the ash content.

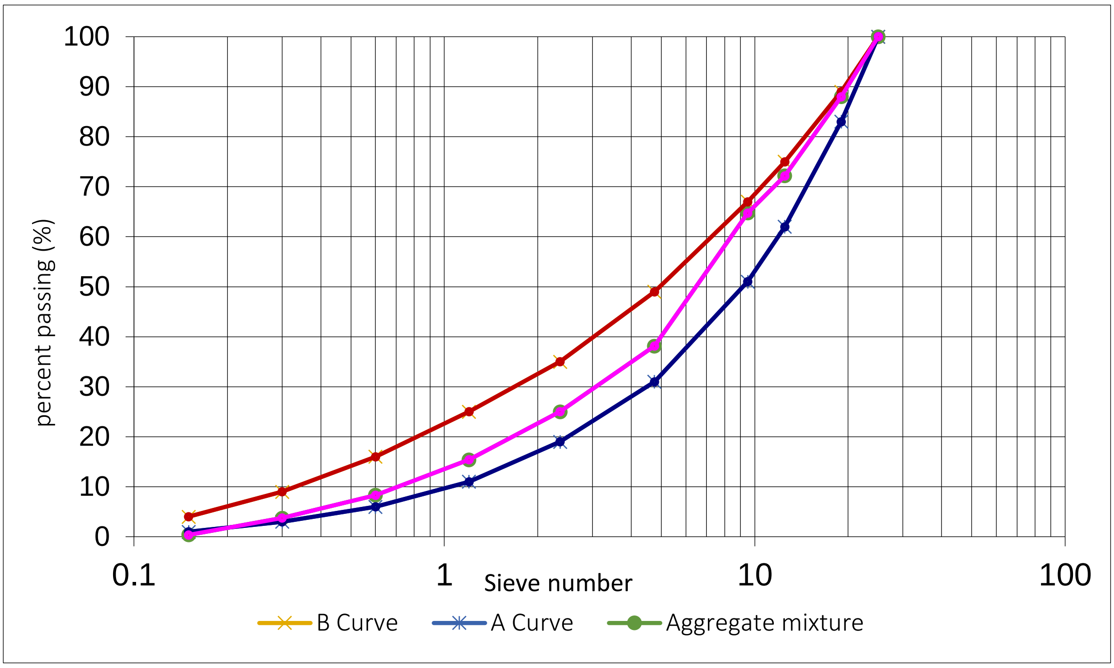


Fig. 3 – Modified grading diagram (Note: B curve and A curve are based on Iranian mixing design bylaw)

Table 1 – Concrete mixing design (kg/m^3)

Plan	Ash (٪)	Ash (kg)	Water (kg)	Cement (kg)	Coarse gravel (kg)	Fine gravel (kg)	Sand (kg)	Slump (cm)
A28	0	0	173	402	563	526	726	7.5
B28	10	40.2	173	361.8	563	526	726	7.5
C28	20	80.4	173	321.6	563	526	726	7.5
D28	30	120.6	173	281.4	563	526	726	7.5

Water to cement (W/C) ratio

Using the diagram on Fig. 4-1,page 13,the Iranian mixing design bylaw and considering the assumed compressive strength of the ordinary concrete with no industrial waste ash in this study (equals to 30 MPa) and the standard deviation obtained in Section 3.2.2, Table 3.3 of the mentioned bylaw (equals to 10.5 MPa) as well as the consumed cement with the strength class of 325 (the strength class of consumed Portland cement type II was 315, which can be considered as 325 when using the mentioned diagram according the Iranian mixing design bylaw) and finally, considering the sharpness percentage of the aggregates, the W/C ratio was defined as 0.43.

4. TEST METHOD

The experiments for measuring the compressive strength of concrete were carried out based on Iranian concrete standard. The concrete samples reach the ultimate strength by applying compressive axial force at a specified speed. Compressive strength is obtained by dividing the maximum force tolerated by the sample into the cross-sectional area of the sample. Finally, the compressive strength of the cubic samples was converted to the compressive strength of standard cylindrical samples of 150 × 300 mm by applying the coefficient according to the Iranian concrete regulations.

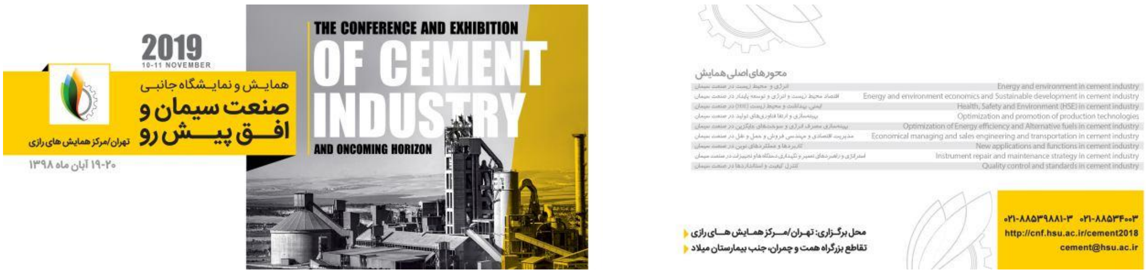
To investigate the effect of industrial waste ash on compressive strength of ordinary concrete, the samples were produced with 0%, 10%, 20%, and 30% industrial waste ash as a partial replacement of cement. The number of samples per each ash percentage was three and so the mean compressive strength of these three samples was reported as corresponding concrete compressive strength.

The compressive strength of the samples was measured after 28 days using a compression test jack (Fig. 4).

Fig. 4 - Compressive strength measuring device

5. RESULS AND DISCUSSION

Fig. 5 shows the compressive strength results of 28-day concrete samples with 0%, 10%, 20%, and 30% industrial waste ash. It can be seen that as the content of industrial waste ash increases, the compressive strength of concrete decreases and this decrease for the concrete samples including 10%, 20% and 30% ash (compared to the control concrete sample without ash) was 21%, 42% and 49%, respectively.



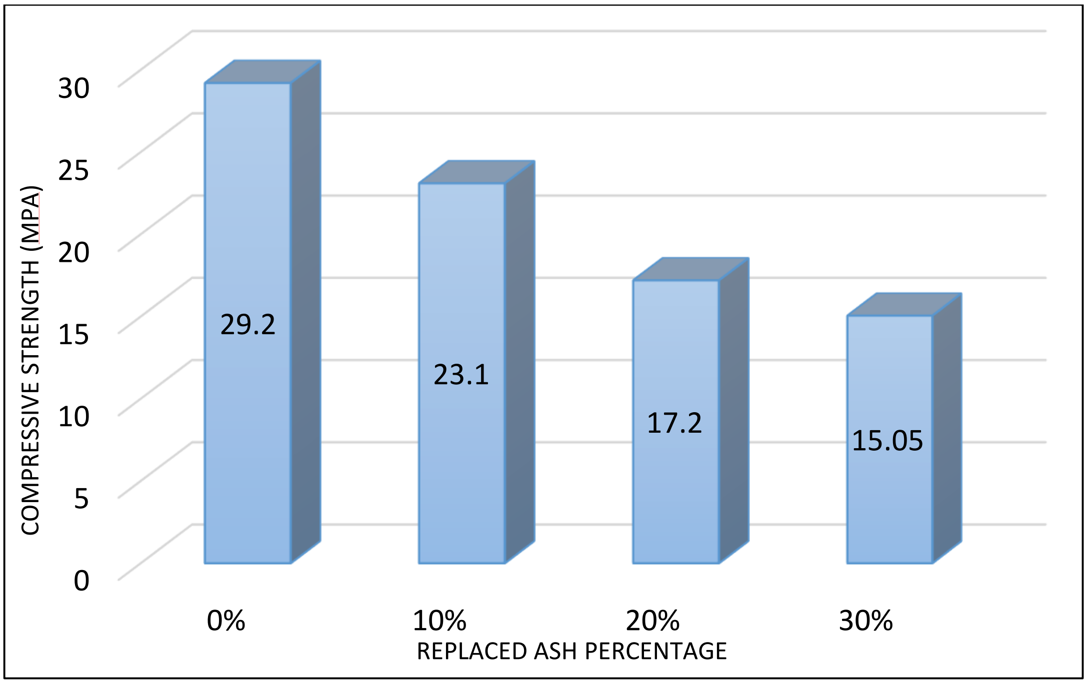


Fig. 5 – Compressive strength of concrete samples

According to the results obtained in this study, the following observations during the experiments may be the possible reasons for the reduction of compressive strength of concrete with industrial waste ash:

- During the construction of concrete samples with industrial waste ash (compared to the control concrete samples with no ash), some lipids have been observed. This lipid might be a reason for a part of reduction in the compressive strength of concrete samples with ash.

- As can be seen in Fig. 6, when the concrete samples were removed from the molds after 24 hours, there was a swelling at the upper surface of the concrete samples with ash indicating an increase in the volume of concrete after initial hardening. The higher ash percentages, the higher amount of swelling. No swelling was observed in the ash-free sample as seen in the left sample of Fig. 6.

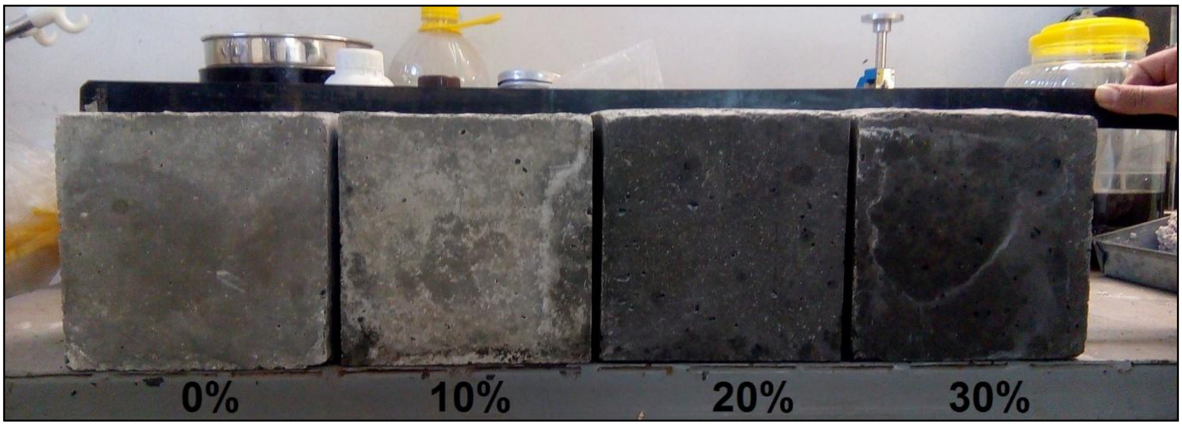


Fig. 6 – Swelling in concrete surface

It is worth mentioning that incorporating ash into concrete also affects on the color of the fresh concrete. On the other hand, as the amount of ash increases, the color of the concrete becomes darker. After drying, however, the intensity of the color difference diminishes and almost all samples come close to the color of the control concrete sample.

6. SUMMARY AND CONCLUSION

Based on the experimental results obtained from the present study, the following can be deduced:

- The results show that despite the decrease in compressive strength with the increase of industrial waste ash, the produced concrete can still be used for the construction of concrete that requires less compressive strength, such as filler concrete or lightweight concrete in building flooring.

- Due to the volume increase observed in the concrete samples with the content increase of ash, this ash may be used in the manufacture of concrete filling cracks and the repair of concrete surfaces that do not require high compressive strength. Expansion cement is the hydraulic cement consist of calcium silicates, calcium aluminates and calcium sulfates which exhibit significant volumetric expansion after capture and in the initial stage of hardening. The presence of these substances in the ash may have caused the expansion which shall be confirmed by tests such as XRD.

- It is also useful to note that since the results are exclusively related to the ash present and the methods used in this experimental study, and the waste might have different combinations each time it is burned, and could have different effects on the results, it would require a broader laboratory program to be more definitive and accurate.

7. ACKNOWLEDGEMENT

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8. REFRENCES

1. ASTM. (2004). Standard specification for expansive hydraulic cement. *ASTM Standards*.
2. Tay, J. H. (1990). Ash from oil-palm waste as a concrete material. *Journal of Materials in Civil Engineering*, *2*(2), 94-105.
3. Siddique, R. (2010). Use of municipal solid waste ash in concrete. *Resources, Conservation and Recycling*, *55*(2), 83-91.
4. Pavlík, Z., Keppert, M., Pavlíková, M., & Volfová, P. (2011). Environmental friendly concrete production using municipal solid waste incineration materials. *WIT Transactions on Ecology and the Environment*, *148*, 325-334.
5. Keppert, M., Pavlík, Z., Cerny, R., & Reiterman, P. (2012). Properties of concrete with municipal solid waste incinerator bottom ash. *Int Proc Comput Sci Inf Technol*, *28*, 127-131.
6. MANGA, V. A. (2016). Effect on compressive strength of concrete with partial replacement of cement by municipal solid waste incineration ash.
7. Lynn, C. J., OBE, R. K. D., & Ghataora, G. S. (2016). Municipal incinerated bottom ash characteristics and potential for use as aggregate in concrete. *Construction and Building Materials*, *127*, 504-517.
8. Department of Housing and Urban Development, Building and Housing Research Center, "National Concrete Mix Design Method", Journal No Z-479, (2007)