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Investigating pushing resistance of RCC of roads pavement with natural pozzolans

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ABSTRACT

In addition to the easy implementation, asphalts pavement has weaknesses such as changing its properties with temperature and perdurable deformations on pavement surface. On the other hand, concrete pavements has less maintenance costs and more useful life than asphalt pavements. As RCC pavements has faster implementation and less costs than usual concrete pavements and needs the least repairmen and maintenance, so it can be a suitable alternative for asphalt pavements and decrease government costs in this regard. There are many studies being done in this context as using these materials, in addition to decreasing cement consumption and costs, improves concrete properties. In this study, RCC pavement and effect of pozzolans on RCC properties of road pavement will be investigated. RCC pavement and different effects of pozzolans (silica fume, fly ash, zeolite and slag of melt iron) on RCC properties which constitutes 0, 5,10 and 15 weight percent of pozzolans in RCC and effect of pushing resistance in laboratory conditions will be investigated.

KEYWORDS
pushing resistance, silica fume, fly ash, zeolite,slag of melt iron

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1. Introduction

RCC is a new method for implementing massive concrete that its idea dated to 1960s and its usage development traced to 1980s. concrete pavements are used for highways, streets, local roads, parcking and other infrastructures. When concrete pavements are designed appropriately by durable materials, can pass many exploitations and service periods successfully without needing maintenance or little maintenance. The first usage of RCC for making pavement was in 1930 by engineers group of America army for building industrial floors. After that, group used RCC for building runway in Washington airport in 1942. Other usage of RCC in large scale was in industrial area in Vancouver in 1976. RCC components are cement, water and sand. Today, using pozzolan materials as the materials with cement properties and another alternative in part of Concrete mix are considered highly that while reducing cement consumption, improving concrete properties. This study will investigate different types of pozzolans and their effects on RCC properties for paving road. Cement materials using in RCC are including Pozzolan Portland (P-P) or overhead added separately. Choosing cement is done based on plan resistance and the age considered for plan resistance. Similar to other methods of concrete pavement, cement materials are one of the main materials in making RCC pavements. Considering pollution caused by cement production and high emissions of carbon dioxide, using natural and artificial pozzolans of cement materials as a complementary alternative for cement got special importance and researches done in this context are increasing.

2. Pozzolans

Pozzolans including silica or silica-Aluminum material which do not have adhesive value alone or have little adhesive value, but in the vicinity of humidity, during chemical reaction with calcium hydroxide at room temperature, it creates compositions with cement property. Existence of pozzolans in cement can mix with lime in cement paste and causes C3S and C2S reactions, combine in moist environment and produce appropriate silicate hydrates as adhesive gel. Production of this adhesive material fill empty spaces during the time as its volume is more than primary material. Filling empty spaces increase resistancy, modulus of elasticity, decrease coefficient or ratio of Poisson and improve other mechanical feature of cement paste. Portland cements shows good resistancy against sulfates attack and some other destructive factors. This is due to the pozzolanic reaction to leave less lime so can go out and decrease concrete permeability. But resistancy against freezing and melting till next periods in which, the most reaction of pozzolans decrease porosity of cement paste can not be created.

3. Types of pozzolans

Based on general categorization of pozzolan materials, they are divided into the two categories of natural and artificial pozzolans.

Natural pozzolans: they are used for producing one pozzalan from existing materials in the earth. Usually production procedure including crushing, grinding, separating sizes and in some cases, applying activation heat. Artificial pozzolans (By-product) are cases which are not mentioned in production processes as the main objective. By-products of industries can cause the production of pozzolan with special processes and also without them. Among these two groups, today more attention given to the naturalized pozzolans, maybe one of its reasons is relating to the environment protection. Different types of artificial pozzalons are: furnace slag, fly ash of melt iron, rice husk ash and silica fume.

4. Pozzolanic reaction

In fact, it is a mineral chemical reaction which happens in portland cements containing pozzolan. This reaction is an acid- base reaction during which, calcium hydroxide ($Ca(OH)_2$) reacts with silicic acid (H_4SiO_4) or $Si(OH)_4$) and produce calcium silicate hydrate ($CaH_2SiO_4 \cdot 2\ H_2O$) that is known as C-S-H in cement industry. During hidration, two main combination of cement including tricalcium silicate (C3S) and di-calcium silicate (C2S) are representing silicon oxide and calcium oxide respectively, calcium silicate hydrates (C-S-H) and hydroxide are released. General procedure of this reaction is as follow:

2(3CaO-SiO2) + 6H2O→ 3CaO.2SiO2 .3H2O + 3Ca (OH) 2

2(2CaO.SiO2) + 4H2O→ 3CaO.2SiO2 .3H2O + Ca (OH) 2

3CaO.Al2O3 + 31H2O + 3CASO4→ 3CaO. Al2O3 .3CaSO4 .31 H2O

4CaO.Al2O3.Fe2O3 + 10H2O + 2Ca (OH) 2 → 6CaO. Al2**O**3. Fe2O3. 12 H2O

$Ca(OH)_2 + H_4SiO_4 \rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \rightarrow CaH_2SiO_4 \cdot 2\ H_2O$

Also, this reaction is shown in short form as below:

CH + SH → C-S-H

In figure(1), pozzolanic reaction is shown. In fact, pozzolanic reaction change CH with lower density and larger pores into the denser C-S-H and smaller pores.

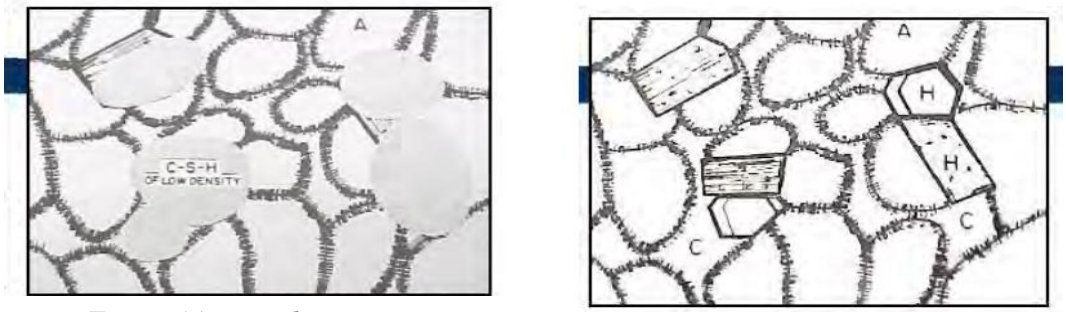

Figure (1): pozzolanic reaction

5. Silica fume

Silica fume is a kind of industrial pozzolan with high purity of SiO2 which is used for increasing and improving different concretes properties and producing formidable concretes. It is about one decade that this material is available for engineers in Iran. It is can be used for improving strength and resistance against freezing in RCC. Quality of RCC is relating to the obtained degree of compaction directly and dry unit weight can be considered as density measurement.

6. Fly ash

Fly ashes including very fine ashes produced from collecting dust particles emitted from burning coal of thermal power plants. Because of sudden change of coal temperature, most of minerals existing in molten coal forming small molten drops that most of them during a sudden cold converted to the glass particles. Fly ash as a filling mineral material in mix with less cement paste can be used for increasing efficiency and RCC density. For increasing amount of fine particles, fly ash can be used as an alternative for some part of sand. Using fly ash in RCC is an effective solution for supplying needed fine particles for complete density.

7. Zeolite

Before 1950, researchers were seeking to form natural and geochemical known minerals for producing zeolites and they thought that forming zeolites needs temperature between 200-400 centigrade and tens of atmospheric pressure. But in 1957, chemists could produced zeolites in low temperature (100 centigrade) and in industrial scale.

8. slag of molten iron

Iron slag is a By-product of steelmaking process. In iron and steelmaking industries, there are different types of iron slag resulted from different methods from steelmaking processes including: pig iron slag which is a product of high blast furnaces, steelmaking slag, slag of electric arc furnace, slag of open steelmaking furnace, converter slag furnace which is known as LD_2. Steelmaking slag is a non-metallic combination which contains calcium silicate, iron oxide, aluminum, manganese, calcium and magnesium which are produced with steel at the same time. Iron slag of high furnace is a non-metallic combination which contains silica and silicates of calcium aluminosilicates and the other base elements and they are produced in high furnace with melton iron.

9. Specifications of consumed materials and mix plan

9.1. The mixing ratio of materials and samples making method

For making samples of RCC, in this research ratios which are common in Spain are used which are shown in table 1.

Sand size with 10 to 20 mm	209	Kg/M^3
Sand size with 0 to 10	1472	Kg/M^3

mm		
Sand size with 0 to 5 mm	214	Kg/M^3
Pozzolan	80	Kg/M^3
cement	155	Kg/M^3
water	99	Kg/M^3

9.2. Rock materials

Rock materials used in this research are natural kind of broken grain that in table 2, used sand grains are proposed in detail.

Number of Breathalyzer	Percent of total balances	Percent of the remaining	Weight in $1m^3$
3/4 inch	100	0	0
1/2 inch	80	20	379
3/8 inch	66	14	265/3
Score 4	50	16	303/2
Score 8	40	10	189/5
Score 16	32	8	151/6
Score 30	25	7	132/65
Score 50	20	5	948/75
Score 100	16	4	75/8
Score 200	8	8	151/6
Sub breathalyzer	0	8	151/6

9.3. Cement

In this research, for making RCC samples, Portland cement of type 1 are used.

9.4. Water

Water used for making RCC mix in this project was drinking water.

9.5. Consumption pozzolans

9.5.1. Slag of molten iron was provided as By-product of Isfahan iron foundry.

9.5.2. Zeolite

Used zeolite in this research was Clinoptilolite type which was extracted from mine located 30 kilometers north of Semnan. According to the ASTM C618 standard, total of three oxide (SiO_2+Al_2O_3 +Fe_2O_3) should be more than 70%.

9.5.3. Silica fume

Physical and chemical properties of silica fume used in making samples was industrial type and product of Ferrosilicon Company.

9.5.4. Fly ash

Fly ash produced from emission gasses of coal-fired furnace which is a different composition based on natural coal and considered as a waste material of thermal power plants.

10. Devices and making method

For providing mixes, electrical mixer was used and samples were molded in metal cube castings with 15*15*15 dimensions. For creating concrete density, standard hammer used in modified proctor experiment with 45cm and 45.7 kg fall height was used. Molds were concreting in 3 layers that in each layer, 150 impacts were hit on concrete surface and its thickness before condensation was 7cm.

Samples of each mix group were made with keeping amount of rock materials and all cement materials content (including cement and silica fume, zeolite, fly ash and slag of molten iron) and just with changing percentage of replacement of silica fume, zeolite, fly ash and slag of molten iron with cement. For mixture, firstly all rock and cement materials were mix without water for 3 minutes. Then water was added gradually and mixer worked for 7 minutes. After preparing concrete and molding, samples surface covered with wet canvas for 24 hour and after opening molds, concrete samples were transferred to the reservoir and after 27 days, they were removed from water reservoir for doing experiments.

Naming mix plan is as table 3:

(Portland cement) P: concrete including cement of type 2 Portland

(Zeolite)Z: it states natural pozzolan of zeolite and the number after that shows pozzolan percentage which substitutes cement.

(Silica fume): it shows pozzolan of silica fume and the number after that shows pozzolan percentage which substitutes cement.

(Fly Ash) FA: it shows pozzolan of fly ash and the number after that shows pozzolan percentage which which substitutes cement.

(Iron slag) IS: it shows pozzolan of Iron slag and the number after that shows pozzolan percentage which substitutes cement.

Example 1: plan PZ0.5 is a plan in which, 5% of zeolite was used as cement substitute.

Weight percent to the cement	**Pozzolan name**	**Plan name**
---	Cement type2	P(Portland Cement)
5%	Zeolite	PZ0.5(Zeolite)
10%	Zeolite	PZ0.1(Zeolite)
15%	Zeolite	PZ0.15(Zeolite)

5%	Silica fume	SF 0.5(Silica fume)
10%	Silica fume	SF 0.10(Silica fume)
15%	Silica fume	SF 0.15(Silica fume)
5%	Fly Ash	FA 0.05 (Fly Ash)
10%	Fly Ash	FA0.1 (Fly Ash)
15%	Fly Ash	FA0.15 (Fly Ash)
5%	[Iron slag	Iron slag)(IS0.05
10%	Iron slag	Iron slag)(IS0.10
15%	Iron slag	Iron slag)(IS0.15

11. Results analysis

In figure 1 shows pushing resistance of pure sample without pozzolanic material during 28 days. 28 days resistance of sample shows average including 3-test of 24.1 MPa.

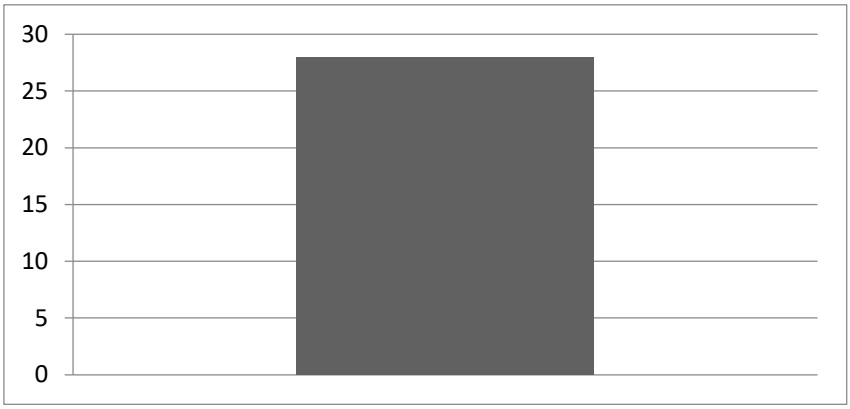

Figure 1: 28 days resistance of concrete without pozzolan

Figure 2 shows ratios of 10%, 5% and 15% of pozzolans of zeolite, fly ash, silica fume and Iron slag to the 28 days concrete sample.

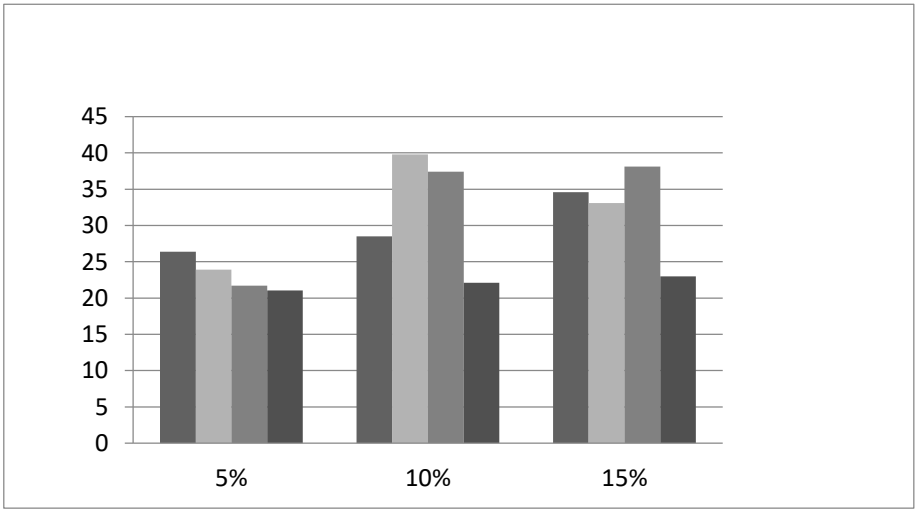

Figure 2: pushing resistance with ratio of pozzolans to

the 28 day sample.

In results of 28 day, it is shown that silica fume in 15% ratio has better resistance than 10% and 5% and also zeolite in 15% ratio has better resistance than 10% and 5% but ash fly in 10% has better resistance than 15% and 5%. Iron slag shows less resistance than the other pozzolans and slag resistance is the same resistance of sample without pozzolan.

Figure 3 shows pushing resistance of pure sample without pozzolanic material during 42 days. 42 days resistance of sample shows average including 3-test of 28.3 MPa.

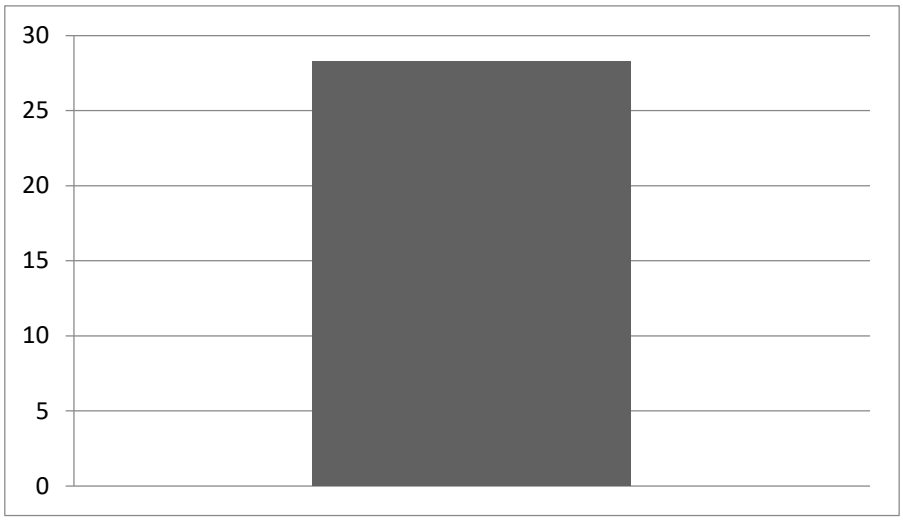

Figure 4: pushing resistance with ratio of pozzolan to the 42-day sample

In results of 42-day sample it is shown that silica fume, unlike the 28-day sample, has better resistance in 10% ratio than 15% and 5% ratios and also zeolite has better resistance in 15% ratio than 10% and 5%ratios but its resistance has considerable increasing and there's not much difference. Fly ash, unlike the 28-day sample, has better resistance in 15% ratio than 10% and 5%ratios that these amounts of 15% and 10% are so little which is show the consistancy of this pozzolan effect during longtime. Iron slag just the same as 28-day sample shows less resistance than the other pozzolans and ratios has a little difference in samples resistance and slag resistance is the same as resistance without pozzolan.

Considering investigation of 28-day and 42-day samples and effect of pozzolans on increasing resistance of concrete sample, this issue could be explained in this way that existence of pozzolans causes filling holes and empty spaced among small rocks and 5% of pozzolans in comparison between 28-day sample and 42-day sample show that resistance of 42-day sample with 5% slag fume than 28-day sample, has increased 10 MPa and also 42-day sample of fly ash than 28-day

sample show 17.3 MPa resistance increase and also in zeolite, 42-day sample shows 34MPa resistance increase than 28-day sample and also in iron slag ,42-day sample shows 3MPa resistance increase than 28-day sample. But 10% of pozzolans in comparison between 2-day sample and 42day sample shows that resistance of 42-day sample with slag fume has 16MPa increase than 28-day sample and also fly ash of 42-day sample has has 16MPa increase than 28-day sample and in zeolite, 42-day sample shows 19MPa resistance increase than 28-day sample but molten iron slag of 42-day sample shows 2MPa increase than 28-day sample. Considering comparison between 28-day sample with 42-day sample , it is shown that with increasing concrete life, resistance of samples with added pozzolan had appropriate resistance that results differences is shown in figure 5.

As in Azadi and Abedi research shows that amount of fly ash usually mentioned as 21%-31% of cement materials, added percentage of this pozzolan in this research has good impact and causes fast increase of resistance.

In mentioned research which studied impact of molten iron slag on RCC dams, substitution of slag in concrete causes resistance reduction and penetration and efficiency of concrete increase that indicates combination of lime cement with molten iron slag as a reason of this issue. Considering added results of zeolite from Valipour et al research, it can be concluded that zeolite exists because it is formed by hydro Aluminum silicate base with some cations and alkali and alkaline earth metal oxides. This combination of crystalline silicate Creates extensive and continuous chain Which decreases heat of cement and increases concrete resistance in combination with cement hydration. In Hasani and Abedin research by using silica fume, rollability of RCC has improved and better density and consequently, special weight and more pushing resistance could be achieved that can be say that silica fume in addition to filling empty spaces among concrete small rocks with free lime, reinforce silica gel and increase pushing resistance considerably.

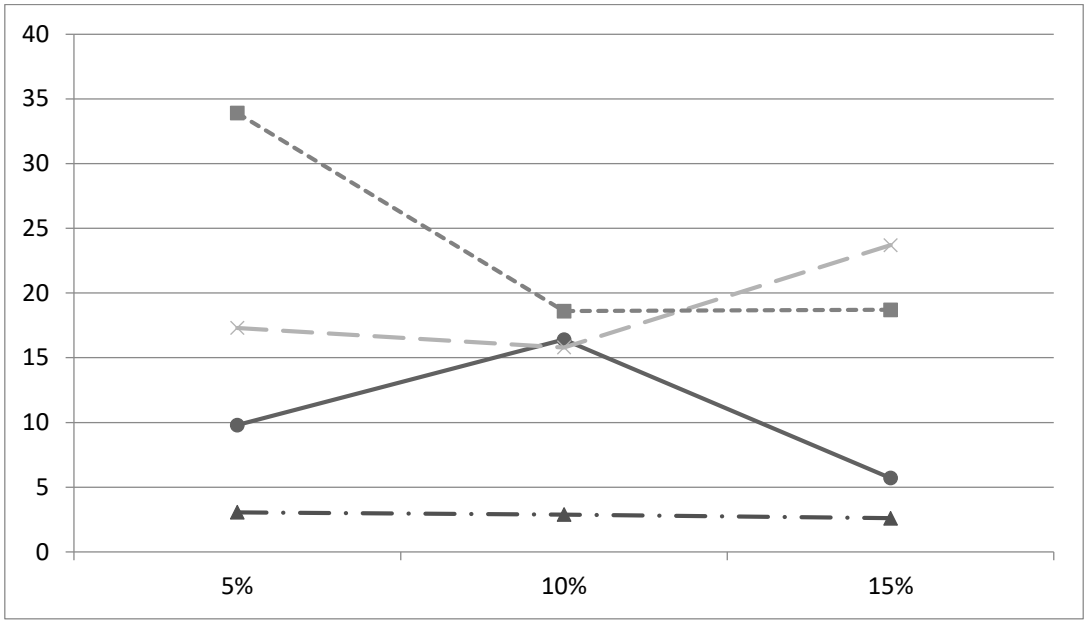

Figure 5: pushing resistance difference among 42-day and 28-day samples

12. investigating costs

RCC is usable for any main activity in which, concrete with low slump could be loaded to that location, embeded and make it densier. RCC is appropriate for cases in which it is needed that activity being done with the least cost. In fact this method is a competitive method with another applicable structural elements in roads pavement. The main benefits of this method are:

Costs: history of RCC against usual concrete show that cost of implementing each square meter with RCC is less than usual concrete. Costs decrease is about 25%-50%. This reduction in costs is because of consumption materials, easiness and simplicity of implementation. Other reason of cost reduction is reducing time of pavement implementation of RCC.

Fast implementation: as mentioned, this fast method reduces costs in comparison with implementation method of usual concrete. Reducing implementation time from few years to the few months not only eliminates operational costs but also costs such as monitoring, likely costs of related equipment stop and costs relating to the seasonal stop of work. Basically, operation by by RCC in addition to the technical issues, causes a main advantage called economizing plan in dealing with time. Possibility of RCC compaction by vibratory mesh rollers provides enginners with great advantage as it is so fast while has lower cost. On the other hand, amount of consumed cement in RCC helps project economy greatly. Portland cement usually is used as adhesive material in RCC RCC but different types of natural and artificial pozzolans are good alternatives for part of cement. Pozzlans causes increasing

RCC efficiency, decreasing cement consumption highly and also using machines optimally.

Conclusion

Portland cement is one of the main materials for making concrete. As there's a need for construction all around the world, as a result, there's an increasing need for building materials and consequently, Portland cement in industrial and developing countries. Also production of Portland cement releases high amount of carbon dioxide which has a important role in global warming.

1. Results of 28-day sample indicates that silica fume shows better resistance by 15%.
2. Ash fly in 10% ratio, shows better resistance in 15% and 5% ratio which is because of existing pozzolan in cement.
3. In 28-day sample, iron slag shows less resistance than other pozzolans that this volcanic pozzolan and combination with lime causes decreasing resistance.
4. In 28-day sample of zeolite also 15% ratio has better resistance than 10% and 5% ration in which, akali metal oxides in the pozzolan in combination with hydration of cement causes reducing heat inactivation and increasing cement resistance.
5. Also 42-day sample of pozzolan zeolite shows 34MPa significance increasing in resistance than its 28-day .
6. 42-day sample of iron slag shows 2MPa increasing in resistance than its 28-day sample which has tangible performance than the other pozzolans in resistance issue.
7. Portland cement usually is used as adhesive material in RCC but different types of natural and artificial pozzolans are good alternatives for part of cement.
8. Ash fly improves mix resistance regarding pozzolanic features and when it is used instead of part of cement, it reduces need of concrete mixes for water.
9. Pozzolans can be used as a filling mineral material in mixes with low cement paste for increasing efficiency and density of RCC.
10. Due to the pozzolans role in filling empty spaces among seeds causes increasing resistance and better efficiency at the time of compaction.

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