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Fully Replacement of Natural Sand With hydro Sluiced Bottom Ash in High Performance Concrete with Nanosilica

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Abstract: Generally the river sand is used as a fine aggregate in concrete and is obtained by mining the sand from river bed. Increased sand mining not only affects the aquifer of the river bed but also causes environmental problems. In recent days the demand for river sand is increasing due to its lesser availability. Hence the practice of replacing river sand with hydro sluiced bottom ash is taking a tremendous growth. It is also inferred from the literature that replacement of normal sand with hydro sluiced bottom ash produces no appreciable increase in compressive strength due to the variation in the pore size of concrete at micro level. This paper presents the optimization of fully replacement of hydro sluiced bottom ash by natural sand with nano silica in high performance concrete. The ordinary Portland cement is partially replaced with nano-silica by 0.25%, 0.5 % , 0.75% and natural sand is fully replaced with hydro sluiced bottom ash. The studies reveal that the increase in percentage of partial replacement of nano silica increased the compressive, tensile and flexural strength of concrete. It was found that 0.55 water/cement ratio produced higher compressive strengths, tensile strength and better workability for partially replaced with nano-silica by 0.75 % mix, proportion. Specifically compressive and tensile strength ranged from 21.06 -35.2 N/mm^2 and 10.06 -15.5 N/mm^2 for the mixes considered. These results compare favourably with those of conventional concrete.
Keywords: compressive strength, flexural strength, bottom ash, nano silica, tensile strength.

I INTRODUCTION

Concrete is the second most consumed substance on Earth after water. Sand only production is growing by 8.2 % annually, and is expected to rise from 8.44 billion usages to 12.4 – 13.56 tonnes by 2050. The demand of natural sand is quite high in the developing countries due to the rapid infrastructural growth. Normally particles are not present in river sand up to required quantity. Digging sand, from river bed in excess quantity is hazardous to environment. The deep pits dug in the river bed, affects the ground water level. In order to fulfill the requirement of fine aggregate, some alternative material must be found. The cheapest and the easiest way of getting substitute for natural sand is obtained from bottom ass , limestone quarries, lateritic sand and crushing natural stone quarries is known as manufactured sand. The bottom ash is a waste material that is generated from power plants (NLC). Concrete made using partial replacement of bottom ash 20% and manufacturing sand of 25%, 50%, 75%, 100% for cement and fine aggregate respectively. The compressive strength of concrete increases when percentage of manufacturing sand increases up to 75% and decreases when 100% replacement. The split tensile strength varies marginally.[1] The various strength properties studied consist of compressive strength, flexural strength and splitting tensile strength. The strength development for various percentages (0-50%) replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages.[2] The mechanical properties of special concrete with 30% WBA replacement by weight of natural sand is found to be an optimum usage in concrete in order to get a favourable strength and good strength development pattern over the increment ages.[3] In NLC, About 1.3 million tons of fly ash is being generated every year as a waste product in all three power plants. The disposal of fly ash is posing a problem to the thermal power station. Normally fly ash is disposed as slurry in ash ponds. This kind of disposal makes the land as a waste land and cannot be used any purposes. However utilizing the fly ash potential as a pozzolanic material, fly ash is being extensively used by the NLC in construction activities apart from being supplied to cement industries, brick manufactures at free of cost. Coal bottom ash (CBA) and fly ash were utilized in partial replacement for fine aggregates and cement respectively in the range of 0, 5, 10, 15 & 20% (equal percentages). The results of compressive strength at 7, 28, 56 & 90 days curing are presented because of the pozzolanic reaction; other properties investigated include physical properties, fresh concrete properties and density. The results showed that for a grade 35 concrete with a combination of CBA and fly ash can produce 28 day strength above 30 MPa.[4]**.** The impacts of other nano materials such as CNTs, nano TiO_2, nano Al_2O_3 and nano TiO on concrete are also promising. While nano materials acts as fillers and provide nucleation sites for cement hydration, nano SiO_2 also acts as a pozzolanic material, increasing the amount of stiff CSH within the hydrated cement paste, resulting an improved microstructure .The concrete produced with 10% micro- SiO_2 and 2% nano- SiO_2 show higher degree of quality in their compressive strength, less water absorption and more electrical resistance in comparison with the others.[5] The ordinary Portland cement is partially replaced with silica fume and natural sand is replaced with manufactured sand by four proportions. The results indicated that there is an increase in the compressive and flexural strength.[6] Limestones are generally obtained from the calcareous remains of marine or fresh water organisms embedded in calcareous mud. They change from the soft chalks to hard crystalline rocks. The use of limestone as a concrete aggregate has sometimes been suspect on account of the unsuitability of the poorer grade rocks, and also because of a widespread fallacy that limestone concrete is less resistant to the action of fire than concrete made from other aggregates. Laterite stone is commonly used for the construction purpose. There are several laterite stone quarries in Konkan region. During excavation of laterite stone, around 25–30 per cent laterite stone scrap is generated. It is estimated that about 2.83 cum of the laterite stone scrap is generated during excavation of about 11.33 cum of the laterite stone. This laterite stone scrap creates problem in quarries and needs removal for further excavation. In order to add value to this waste material, it is felt necessary to manufacture the blocks using different constituents that are suitable for the construction. In this In this overview determine the Compressive strength, toughness index and water absorption capacity of the laterite stone scrap blocks.[7] The natural sand was replaced with coal bottom ash by 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% by weight, as water absorption of bottom ash was more so that quantity of water was increased to achieve 100 mm slump. The results shows that the compressive strength, split tensile strength and flexural strength decreased as the percentage of replacement coal bottom ash increased as compared to controlled concrete.[8] By practice it shows that conventional mix has more strength than bottom ash sand mix so we will be adding various % of nanosilica to the bottom ash mix and compare the values of compressive strength, corrosion resistance, tensile strength and economy in practice between the conventional and the M sand with 0.75% nano silica mix. Since we are replacing nanosilica with cement the strength increases and the porosity decreases as the nano materials fill the fine pores between the aggregates and the cement. The practicality for its usage in the marine environment, Nuclear power plants, Chemical Industry, etc are studied.

II EXPERIMENTAL INVESTIGATION

2. Materials Used

2.1. Cement: Ordinary Portland cement (OPC) 43 grade conforming to IS 8112 – 1989, and specific gravity of cement is found to be 3.15. The properties of cement given in Table 1.

2.2. Fine aggregates: Local clean river sand fineness modulus of medium sand equal to 2.36 conforming to grading zone of III of IS: 383-1970. The specific gravity of fine aggregate is 2.54. The sieve analysis of fine aggregate given in Table 2.

2.3. Hydro Sluiced Bottom Ash: Hydro Sluiced Bottom ash is replaced is fully replacement of river sand .It is collected from NLC India. The bulk density of bottom ash 1360 kg/m^2 and the specific gravity 2.47 and fineness modulus of bottom ash is 2.36.the maximum size of the aggregate is 4.75 mm. The testing of bottom ash is done as per Indian standard specifications IS: 383 – 1970. The properties of Bottom Ash given in Table 3.

2.4. Course aggregates: Locally available well graded aggregates of normal size greater than 4.75 mm and less than 16 mm having a fineness modulus of 2.72 was used as coarse aggregates. The aggregates are tested as per the procedure given in BIS: 2386

2.5. Nano-silica: The nano silica is partially replaced for cement. Steel Authority of India has provided necessary facilities to produce annually about 3000 tons of nano silica at their Bhadravathi Complex. In India, However, the nano silica of International quality is marketed by Elkem Metallury (P) Ltd. The properties of nano silica given in Table 4.

Table 1: Properties of OPC Cement

Physical properties of cement	
Initial setting time(minutes)	55 mins
Final setting time(minutes)	275 mins
Standard consistency	31.0%
Specific gravity	3.14
Fineness of cement	10%
Chemical properties of cement	
SiO_2	20 - 21
Al_2O_3	5.2 - 5.6
Fe_2O_3	4.4 - 4.8
CaO	62 - 63
MgO	0.5 - 0.7
SO_3	2.4 - 2.8
Loss on ignition (LOI)	1.5 - 2.5

Table - 2: Sieve analysis of fine aggregate

IS sieve designation	Weight of retained on sieve (gm)	River sand % Passing	Requirement IS:383 - 1970
10mm	0	100	100
4.75 mm	16	98.4	90 - 100
2.36mm	82	90.2	85 - 100
1.18mm	150	75.2	75- 100
600nm	133	61.9	60- 100
300um	298	32.1	13 - 40
150um	257	6.2	0 - 10

Table – 3: Chemical properties of Bottom Ash

Chemical ingredient	% by mass
SiO_2	79.65
Al_2O_3	14.71
Fe_2O_3	3.20
CaO	0.39
MgO	0.55
SO_3	0.70
Loss on ignition (LOI)	0.67

Table 4: Properties of Nano - Silica

Physical properties of Nano - Silica	
Specific Surface Area	200 m^2 / g to 300 m^2 / g
Particle Size	≤ 1
Specific gravity	0.13 to 0.14
Chemical Composition of Nano – Silica	
$Si\ O_2$	94.3
$Al_2\ O_3$	0.58
$Fe_2\ O_3$	0.30
$Ca\ O$	0.24
$Mg\ O$	0.44
$K_2\ O$	0.67
$Na_2\ O$	0.36

III EXPERIMENTAL PROCEDURE

The mix ratio is prepared for M30 grade concrete for both conventional sand and also Bottom ash Sand. The Cube size of (150 x 150 x 150) mm Specimen is prepared for compressive strength. The cylinder of height 30 cm and 15 cm diameter is prepared for tensile strength.The specimens are tested for 7 days, 14 days and 28 days with each proportion of nano silica and bottom ash Sand mix. Totally there are 45 cubes and 45 cylinders are casted. The specimen size of (70x10x10) cm is used for flexural strength test. For durability test mortar specimen is prepared in a mix ratio of 1:3, the cube size of (50 x50 x 50) mm is prepared for water absorption test, acid penetration test and for RCPT a concrete disc of size 85 mm diameters and 50 mm thickness. The specimen is tested 28 days totally for 30 cubs and 15 cylinders. All the specimens are demoulded after 24 hours, and curing is done in water for 7 days, 14 days and 28 days. The Scanning Electron Microscope (SEM) is used to determine the particle size of Nano –silica. Figure1.A Shows the SEM picture of NC Concrete, Figure1.B SEM picture of Bottom ash Sand Concrete and Figure1.C SEM picture of Bottom ash Sand with 0.75% of Nano-silica.

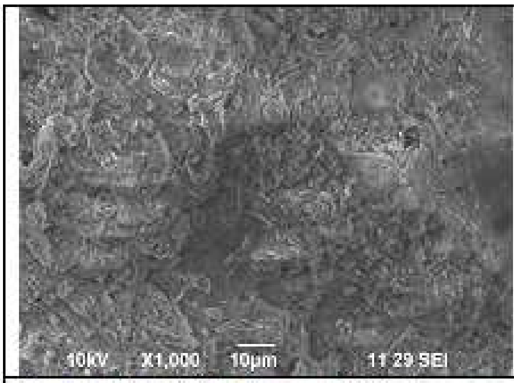

Figure 1.(a) SEM Picture of NC Concrete

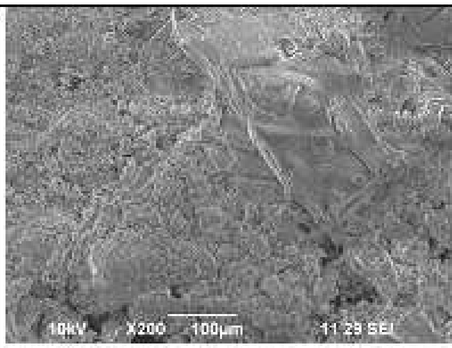

Figure 1.(b) SEM picture of bottom Ash Sand

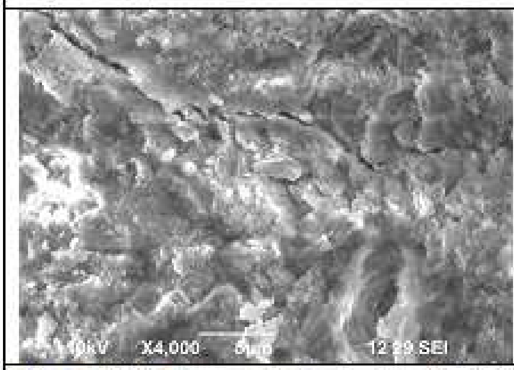

Figure1.(c) Bottom Ash Sand with 0.75% Nano Silica concrete

IV RESULT AND DISCUSSION

4.1. Compressive strength of concrete

The test is carried out conforming to IS 516 -1959 to obtain compressive strength of concrete at the 7days, 14 days and 28 days. The cubes are tested using 400 tonne capacity HELICO compressive testing machine (CTM) .The results are presented in Fig.2.

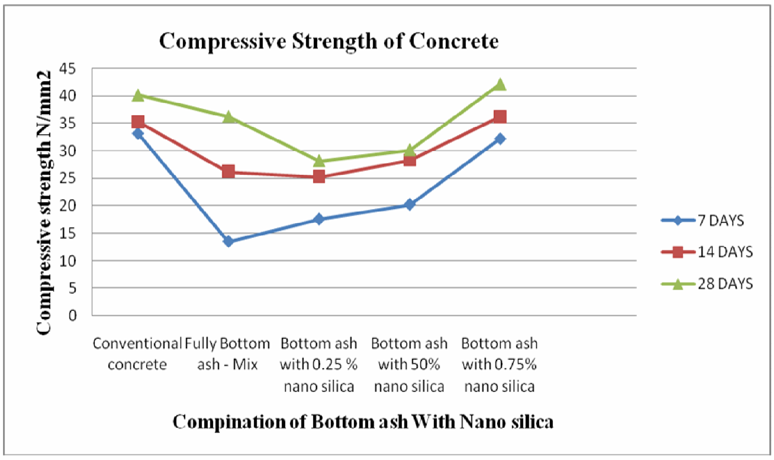

Fig.2. Compressive strength of concrete

The 7days compressive strength of bottom ash concrete 59 .2 % of compressive strength is reduced when compared to the normal river sand and of bottom ash with 0.75% nano silica concrete. The compressive strength of normal river sand and bottom ash with 0.75% nano silica concrete is more or less same and bottom ash with 0.5% nano silica concrete found to be 38.9 % and bottom ash with 0.25% nano silica concrete found to be 46.9% of compressive strength is reduced when compared to the normal river sand and of bottom ash with 0.75% nano silica concrete.

The 14 days compressive strength bottom ash concrete found to be 27% , bottom ash with 0.25% nano silica concrete found to be 30 % found and bottom ash with 0.5% nano silica concrete to be 21.91 % of compressive strength is reduced when compared to the bottom ash with 0.75% nano silica concrete and normal river sand concrete. The compressive strength normal river sand and bottom ash with 0.75% nano silica concrete is more or less same.

The 28 days compressive strength of bottom ash with 0.75% nano silica concrete are found to be 4.71% more than the normal river sand concrete and fully replacement of bottom ash concrete, bottom ash with 0.25% nano silica concrete and bottom ash with 0.5% nano silica concrete found to be 37.76%, 33.31% and 38.48% of compressive strength is reduced when compared to the bottom ash with 0.75% nano silica concrete.

Results of this test are show in table .5.

Table 5: Compressive strength of concrete

S. No	Type of mix	7Days Strength N /mm^2	14 Days Strength N /mm^2	28 Days Strength N/mm^2
1	Conventional mix	33.13	35.25	40.12
2	Fully Bottom ash Sand Mix	13.51	26.16	26.22
3	Fully Bottom ash +0.25% Nano-silica	17.56	25.15	28.15
4	Fully Bottom ash +0.5% Nano silica	20.23	28.25	30.13
5	Fully Bottom ash +0.75% Nano silica	32.16	36.18	42.13

4.2. Tensile strength of concrete

The test is carried out conforming to IS 516 -1959 to obtain tensile strength of concrete at the 7 days, 14 days and 28 days. The cylinders are tested using 400 tonne capacity HELICO compressive testing machine (CTM) .The results are presented in Fig.3.

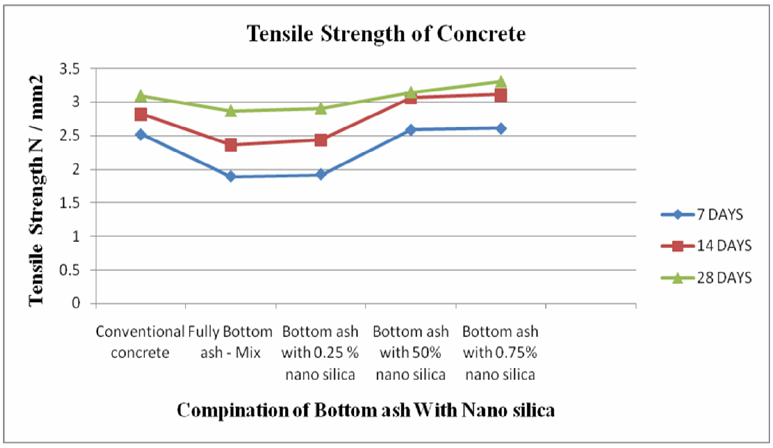

Fig.3.Tensile strength of concrete

The 7days tensile strength of bottom ash concrete found to be 27 .5 % and bottom ash with 0.25% nano silica concrete found to be 26.64 % of tensile strength is reduced when compared to the bottom ash with 0.75% nano silica concrete and tensile strength of normal river sand and bottom ash with 0.75% nano silica concrete and bottom ash with 0.5% nano silica concrete is more or less same.

The 14 days tensile strength of bottom ash concrete found to be 24 .11 % and bottom ash with 0.25% nano silica concrete found to be 21.86 % of tensile strength is reduced when compared to the bottom ash with 0.75% nano silica concrete and tensile strength of normal river sand and bottom ash with 0.75% nano silica concrete and bottom ash with 0.5% nano silica concrete is more or less same.

The 28 days tensile strength of bottom ash with 0.75% nano silica concrete are found to be 6.31% more than the normal river sand concrete and fully replacement of bottom ash concrete, bottom ash with 0.25% nano silica concrete and bottom ash with 0.5% nano silica concrete found to be 13.26%, 12.08 % and 4.8% of tensile strength is reduced when compared to the bottom ash with 0.75% nano silica concrete. Results of this test are show in table .6.

Table 6: Tensile strength of concrete

S. No	**Type of mix**	**7Days Strength N /mm^2**	**14 Days Strength N /mm^2**	**28 Days Strength N/mm^2**
1	Conventional mix	2.52	2.82	3.1
2	Fully Bottom ash Sand Mix	1.89	2.36	2.87
3	Fully Bottom ash +0.25% Nano-silica	1.92	2.43	2.91
4	Fully Bottom ash +0.5% Nano silica	2.59	3.06	3.15
5	Fully Bottom ash +0.75% Nano silica	2.61	3.11	3.31

4.3. Flexural strength of concrete

The test is carried out conforming to IS 516 -1959 to obtain flexural strength of concrete at the 7days, 14 days and 28 days are tested using loading frame 750 kN. The results are presented in Fig.4.

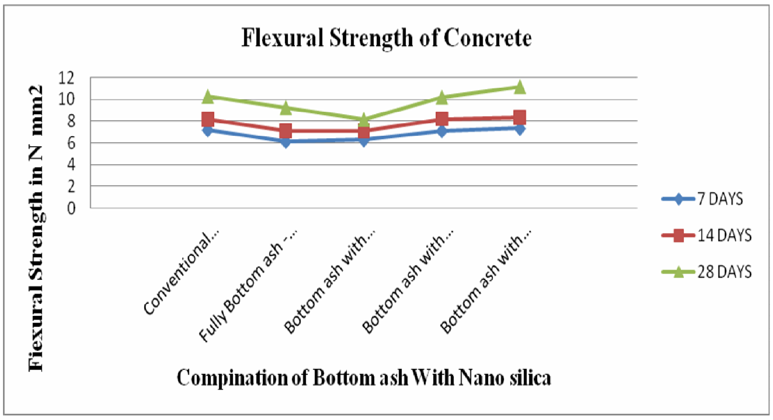

Fig.4.Flexural strength of concrete

The 7days flexural strength of bottom ash concrete found to be 16.48 % and bottom ash with 0.25% nano silica concrete found to be 14.40 % of flexural strength is reduced when compared to the bottom ash with 0.75% nano silica concrete and flexural strength of normal river sand and bottom ash with 0.75% nano silica concrete and bottom ash with 0.5% nano silica concrete is more or less same.

The 14 days flexural strength of bottom ash concrete found to be 14 .85 % and bottom ash with 0.25% nano silica concrete found to be 14.97 % of flexural strength is reduced when compared to the bottom ash with 0.75% nano silica concrete and flexural strength of normal river sand and bottom ash with 0.75% nano silica concrete and bottom ash with 0.5% nano silica concrete is more or less same.

The 28 days flexural strength of bottom ash with 0.75% nano silica concrete are found to be 7.9 % more than the normal river sand concrete and fully replacement of bottom ash concrete, bottom ash with 0.25% nano silica concrete and bottom ash with 0.5% nano silica concrete found to be 17.29%, 26.98 % and 8.69 % of flexural strength is reduced when compared to the bottom ash with 0.75% nano silica concrete. Results of this test are show in table .7.

Table 7: Flexural strength of concrete

S. No	**Type of mix**	**7Days Strength N /mm^2**	**14 Days Strength N /mm^2**	**28 Days Strength N/mm^2**
1	Conventional mix	7.21	8.19	10.27
2	Fully Bottom ash Sand Mix	6.13	7.11	9.23
3	Fully Bottom ash +0.25% Nano-silica	6.28	7.10	8.15
4	Fully Bottom ash +0.5% Nano silica	7.12	8.21	10.19
5	Fully Bottom ash +0.75% Nano silica	7.34	8.35	11.16

4.4. Water absorption test

This test is done as per procedure given in ASTM C 642-97 by oven-drying method. The results are presented in Fig.5. For this test 50mm x 50mm x 50mm cubes are cast. After 24 hours of remolding, the specimens are kept immersed in water. At the end of 28 days, the specimens are taken from the curing tank and air-dried to remove the surface moisture then taken the initial weight (W1) is taken. The final weight (W2) is taken to the specimens are dried in an oven at a temperature of 100+10^o C for 48 hrs, and allowed to cool at room temperature.

The 28 days water absorption of bottom ash with 0.75% nano silica concrete are found to be 38 % , 41% , 34.08% ,and 13.80% of water absorption is reduced when compared to the normal river sand ,fully replacement of bottom ash , bottom ash with 0.25% nano silica concrete and bottom ash with 0.5% nano silica concrete. Bottom ash with 0.75% nano silica concrete is best impermeability of concrete compare to other mix ratio. Nano silica is the good durability of concrete. Results of this test are show in table .8.

% of Water absorption

% of water absorption = [(W2 – W1)/W1] x 100
Where,
W1 = weight of oven dried sample in air.
W2 = weight of surface dry sample in air after immersion in water.

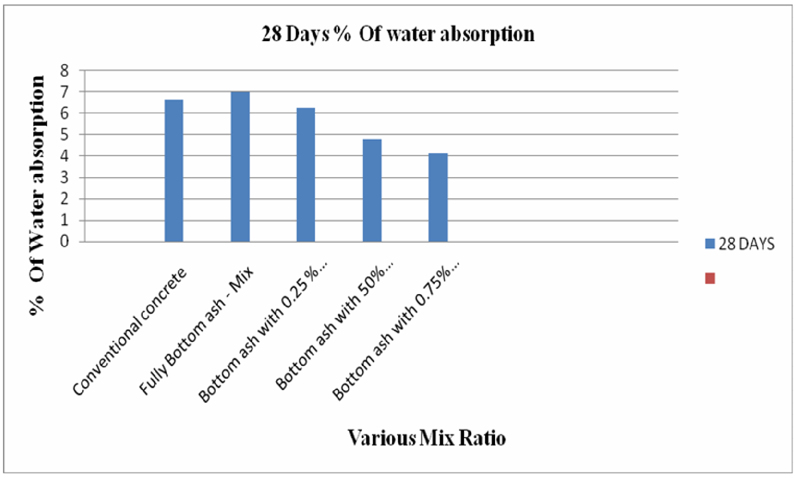

Fig.5. % of water absorption test

Table 8: % Water absorption test

S.No	**Type of mix**	**% Water absorption test**
1	Conventional mix	6.65
2	Fully Bottom ash Sand Mix	6.99
3	Fully Bottom ash +0.25% Nano-silica	6.25
4	Fully Bottom ash +0.5% Nano silica	4.78
5	Fully Bottom ash +0.75% Nano silica	4.12

4.5. Acid penetration test

This test is done as per procedure given in ASTM C 642-97 by oven-drying method. The results are presented in Fig.6. For this test 50mm x 50mm x 50mm cubes are cast. After 24 hours of remolding, the specimens are taken the initial weight (W1) after kept immersed in HCL (pickling solution). At the end of 28 days, the specimens are taken the finial weight (W2) is taken. The 28 days acid penetration of bottom ash with 0.75% nano silica concrete is high resistance in permeability and high durability of concrete compare to the other mix ratio. Results of this test are show in table .9.

4.6. Rapid chloride penetration test

This test is conducted as per ASTM C1202-09. The results are presented in Fig.7. Concrete disc of size 85 mm diameters and 50 mm thickness average value of three samples. The specimens are carried at different stages, allowed to cure for 28 days and then they are subjected to RCPT test by impressing a voltage of 60v. The permeability of fully replacement of bottom ash mix is very high when compared to the bottom ash with 0.75% nano silica concrete and conventional mix. Bottom ash with 0.75% nano silica concrete is to found 35.34% ,49.29% ,36.32% and 46.95 % found to be to less than normal river sand, fully replacement of bottom ash, bottom ash with 0.25% nano silica concrete and bottom ash with 0.5% nano silica concrete.There is a significant improvement in the durability of concrete because of high pozzolanic nature of the nano-silica and its void filling ability. The RCPT values show in table 10.

The columbs value ≥ 4000 the Chloride Ion high. In between 2000 – 4000 the Chloride Ion moderate,1000 – 2000 the Chloride Ion low **,** In between 100 – 1000 the Chloride Ion very low and ≤ 100 negligible.

The constituents are weighted and the material is mixed by hand mixing. The mixes are compacted using table vibration. The water binder ratio (W/B) adopted is 0.375 concrete and mortar. The specimens are demoulded after 24h, cured in water for 7, 14 and 28 days and then tested for its compressive, tensile and durability test as per indian standards. There is a significant improvement in the strength of concrete because of high pozzolanic nature of the nano silica and its void filling ability.

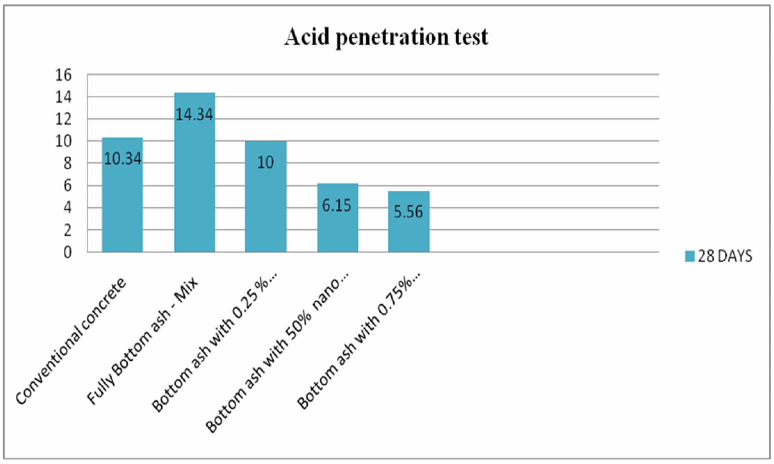

Fig.6. Acid penetration test

Table 9: Acid penetration test

S.No	Type of mix	% Acid penetration test
1	Conventional mix	10.34
2	Fully Bottom ash Sand Mix	14.34
3	Fully Bottom ash +0.25% Nano-silica	10
4	Fully Bottom ash +0.5% Nano silica	4.78
5	Fully Bottom ash +0.75% Nano silica	4.12

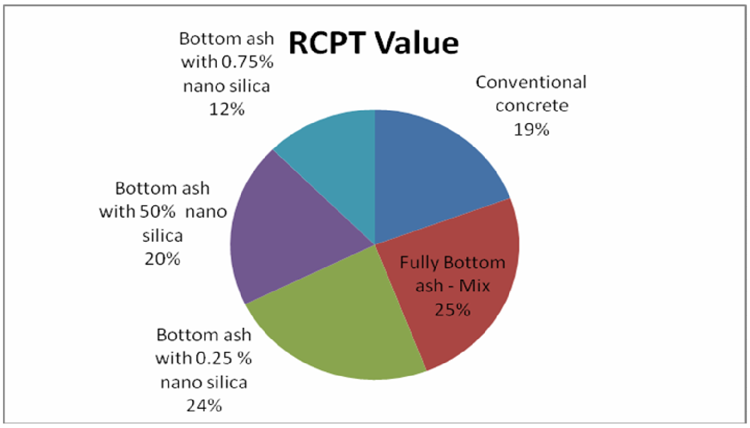

Fig.7.Rapid chloride penetration test

Table 10: Rapid chloride penetration test

S.No	Type of mix	% Chloride Ion passing
1	Conventional mix	652.5
2	Fully Bottom ash Sand Mix	831.86
3	Fully Bottom ash +0.25% Nano-silica	795.28
4	Fully Bottom ash +0.5% Nano silica	662.5
5	Fully Bottom ash +0.75% Nano silica	421.86

V. CONCLUSION

Addition of nano-Silica leads to a significance increase in the characteristic strength and durability of concrete.

Replacement of cement with 0.75% of nanosilica gives more strength than the bottom ash mix and also the durability has been increased compared to the bottom ash sand Mix. The self weight of the Nano mix is lighter than the bottom ash sand and the conventional mix. The workability decreases with the addition of Nano-Silica compared to the conventional mix and the bottom ash sand mix.The penetration level of chlorides and acids are less in Nano concrete compared to that of conventional and fully replacement of bottom ash sand.

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