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The Study of Microsilica and Nanosilica with Special Reference to Recycled Aggregate Concrete

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Abstract— **In the present study recycled aggregates are used in the concrete and the effect of nanosilica and microsilica on recycled aggregate concrete has been investigated. In the first series of tests natural aggregates are replaced by recycled aggregates in varying percentages i.e. 20%, 30%, 40% and 50%. In the second series of tests, cement was partially replaced by microsilica and nanosilica by 5%, 8% and 10% and 1%, 2% and 3% respectively both in natural aggregate concrete and recycled aggregate concrete. Further, cement was replaced by both nanosilica and microsilica i.e. (1%, 2%) and (5%, 8%) respectively in concrete containing fresh aggregates as well as partial recycled aggregates. The results obtained from the study showed that a maximum decrease of 18% was observed when 50% recycled aggregates are used. The addition of both nanosilica and microsilica improved the compressive strength at early ages in natural as well as recycled aggregate concrete. The maximum compressive strength was observed in concrete containing 2% nanosilica& 5% microsilica. Maximum compressive strength for nanosilica and microsilica was observed at 2% and 8% respectively. Increase in about 30% of strength was observed when combinations of 1% nanosilica with 8% microsilica& 2% nanosilica with 5% microsilica were used.**

Key Words : 1.Recycled aggregates 2.Microsilica, 3. Nanosilica 4.RAC
Sub Area : Construction Technology & Management
Broad Area :Civil Engineering

I. INTRODUCTION

Concrete, being most extensively used construction material is primarily responsible for depletion of natural resources since its main constituent materials such as aggregates are drawn from nature, therefore, several countries are facing acute shortage of natural aggregates. Construction activities demand a significant amount of natural materials, such as sand and gravel, and extraction of these natural materials modifies the course of rivers and its beds, creating environmental problems. The enormous use of concrete causes rapid depletion of natural resources. Simultaneously, significant quantities of construction and demolition waste are generated from activities such as construction, renovation, and demolition of building and civil engineering structures. Several countries around the globe have been facing problems related to disposal of these waste materials owing to lack of sufficient space for dumping of these materials. Therefore, recycling of these construction and demolition waste for the production of aggregates is a solution to a number of problems faced by human civilization.

Construction waste is occupying significant space at landfills sites and the source of such a huge amount of demolished concrete may be the following

1. Many old buildings and other structures have overcome their limit of use and need to be demolished;
2. Structures even adequate to use are under demolition because there are new requirements and necessities;
3. Creation of building wastes which result from natural destructive phenomena (earthquakes, storms etc.)

Recycled aggregate concrete

The aggregates retrieved by crushing and screening of waste concrete is generally termed as Recycled Aggregates (RA).The concrete manufactured with these aggregates as partial of full replacement of Natural Coarse Aggregate (NCA) is generally known as Recycled Aggregate Concrete. Therefore, utilization of recycled aggregates (RAs) as a replacement of natural aggregate (NA) in concrete is increasing now a days to overcome the shortage of natural aggregate.

Recycled aggregates in India

Indian construction industry today is amongst the five largest in the world and at the current rate of growth, it is slated to be amongst the top two in the next century. Aggregates supply has also emerged as a problem in some of the metropolis in India. With the shortage as likely seen today the future seems to be in dark for the construction sector. The requirements of natural aggregates are notonly required to fulfill the demand for the upcoming projects, but also are the needs of the extensive repairs or replacements required for the existing infrastructure and dilapidated buildings built few decades back. Construction and demolition disposal has also emerged as a problem in India. India is presently generating construction and demolition waste to the tune of 10-12 million tons, which is comparable to some of the developed nations and these figures are likely to double fold in the next 7 years. The management of construction and demolition waste is a major concern due to increased quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all the concern about environment degradation. Although a substantial portion of construction materials could be substituted by re-processed construction waste material, these options are not

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exercised in developing countries due to lack of knowledge and insufficient regulatory frameworks resulting in waste getting piled up causing disposal problems. The increasing problems associated with construction and demolition waste have led to a rethinking in developed countries and many of these countries have started viewing this waste as resource and presently have fulfilled a part of their demand for raw material. Since concrete composes 35% of the waste as per the survey conducted by Municipal Corporation of Delhi, India may also have to seriously think of reusing demolished rubble and concrete for production of recycled construction material. Work on recycled concrete has been carried out at few places in India but waste and quality of raw material produced being site specific, tremendous inputs are necessary if recycled material has to be used in construction for producing high-grade concrete.

Microsilica

Silica fume, also known as microsilica, is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Silica fume is an ultrafine airborne material with spherical particles less than 1 µm in diameter, the average being about 0.1 µm. This makes it approximately 100 times smaller than the average cement particle. The unit weight, or bulk density, of silica fume depends on the metal from which it is produced. Its unit weight usually varies from 130 to 430 kg/m^3. The specific gravity of silica fume is generally in the range of 2.20 to 2.5. In order to measure the specific surface area of silica fume a specialized test called the "BET method" or nitrogen adsorption method must be used. Based on this test the specific surface of silica fume typically ranges from 15,000 to 30,000 m^3/kg.

Microsilica is also known by other names such as

1. Condensed silica fume
2. Micropoz
3. Silica dust
4. Volatilized silica

Microsilica is not

1. Precipitated silica
2. Fumed silica
3. Gel silica
4. Colloidal silica
5. Silica flour

Metals That Produce Silica Fume

- Silicon metal - typically greater than 97% silicon
- Ferrosilicon alloys -ranging from 40 to 90% silicon alloyed with iron.

Effect of microsilica on concrete

Mechanism: Silica fume improves concrete through two mechanisms:

Pozzolonic effect: When water is added to cement, hydration occurs forming two products, as shown below:

$OPC + H_2O \rightarrow CSH$ (Calcium silicate hydrate) $+ Ca(OH)_2$.

In the presence of SF, the silicon dioxide from the ORISIL SF will react with the calcium hydroxide to produce more aggregate binding CSH as follows:

$Ca(OH)_2 + SiO_2 \rightarrow H_2O + CSH$.

The reaction reduces the amount of calcium hydroxide in the concrete. The weaker calcium hydroxide does not contribute to strength. When combined with carbon dioxide, it forms a soluble salt, which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide is present in concrete2.

Micro filler effect: Silica Fume is an extremely fine material, with an average diameter100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro filler effect greatly reduces permeability and improves paste-to aggregate bond in SF concrete compared to conventional concrete. The silica fume reacts rapidly providing high early strength and durability. The efficiency of silica fume is 3-5 times that of OPC and consequently concrete performance can be improved drastically.

Advantages of microsilica

High performance concrete

For high performance concrete, silica fume is a tool that can be applied for:

1. Shotcrete
2. Chloride resistance
3. Sulfate resistance
4. High strength
5. Abrasion resistance
6. ASR
7. Heat of hydration
8. Underwater concrete
9. SCC Pumping aid
10. Corrosion resistance

Advantages of nanosilica

1. Pozzolanic activity is even higher than microsilica.
2. Increases compressive strength especially at early ages.
3. Higher corrosion resistance property than ordinary fly ash concrete.
4. Increases density and performance of concrete
5. Increases splitting tensile strength.
6. Increases flexural strength of concrete at early age.
7. Had to be add in small percentage generally ranging from 1% to 4%.
8. Improves permeability of concrete.
9. Reduces capillary absorption.

Objective of the study

This study aims to explore the possibility and effect of replacement of natural aggregate with recycled aggregate using cement replacement techniques at micro & nano level.

1. To explore the possibility of partial replacement of natural aggregates by recycled aggregates at varying percentages in concrete.
2. To study the effect of partial replacement of cement with nanosilica on compressive strength of concrete containing natural aggregates and recycled aggregates in different percentages i.e. (30% & 40%).
3. To study the effect of partial replacement of cement with microsilica on compressive strength of concrete containing natural aggregates and recycled

aggregates in different percentages i.e. (30% & 40%).

4. To compare the effects of partial replacement of cement with both nanosilica and microsilica in varying percentages respectively on compressive strength of concrete containing natural aggregates and recycled aggregates in different percentages i.e. (30% & 40%).

Scope of the Study

The experimental work carried out in this investigation consisted of testing 240 number of cubical specimen×150mm×mofforsizethe150compressive strength of NAC,

RAC and RAC containing nanosilica and microsilica. The detailed scope of work has been given below:

- Testing of constituent material of concrete i.e. cement, sand, coarse aggregates, fine aggregates and recycled aggregates for their physical properties as per relevant code.
- Designing of concrete mix for characteristic strength of 50N/mm^2.
- Casting of cubical specimens of normal concrete, recycled aggregate concrete and recycled aggregate concrete blended with microsilica and nanosilica.
- Curing of test specimens for different curing periods i.e. 7days and 28 days.

24 number of specimens were cast with normal grade concrete, 36 number of specimens were cast with recycled aggregate concrete, 60 number of specimens of natural aggregate concrete containing microsilica&nanosilica and 120 number of specimens of recycled aggregate concrete were cast containing microsilica and nanosilica.

The **hardness** value depends on RAC's compressive strength. If the compressive strength decreases, the hardness value also decreases. Very little information is available in the literature regarding the hardness of RAC. Topcu (1997) found the hardness value for natural concrete as 21.3 MPa, while it declines and becomes 11.6 MPa for 100% RAC.

Variation in flexural strength of RCA concrete

Replacement Level	Variation in Flexural Strength as compared to natural concrete	Reference
25%	2.2% Increase	Poon 2002
25%	16% Decrease	Alam et al. 2013
50%	6.25% Increase	Poon 2002
50%	32% Decrease	Alam et al. 2013
75%	10.8% Increase	Poon 2002
100%	13% Increase	Poon 2002
100%	31% Decrease	Katz 2003

Effect of microsilica and nanosilica

The fundamental processes that govern the most pertinent issues to the study of concrete technology (strength, ductility, early age rheology, creep, shrinkage, durability, fracture behavior, etc.) are affected (dominatingly or not), by the performance of the material at the nanoscale. The use of supplementary cementing materials have become an essential part of the Portland cement concrete production, and the research on new materials with supplementary cementing potential is receiving considerable attention from the scientific point of view.

Influence on Fresh and mechanical properties

Experiments using nanosilica and silica fume were conducted and the results showed that with 5% replacement of cement by nS (mean size 15±5 nm), 7 & 28-days compressive strength of mortars were increased by 20% and 17%, respectively, whereas 15% silica fume replacement increased mortar strengths by 7% and 10% compared with those of control Portland cement mortar. With the experimental analysis, it was proved that the compressive and flexural strengths of the cement mortars with nanosilica and with nano-Fe_2O_3 were both higher than that of the plain cement mortar with the same water to binder ratio (Li et al., 2004).

In a study to evaluate the effect of silica fume on the compressive strength, split tensile strength and modulus of elasticity of low quality coarse aggregate concrete was conducted whose results indicated that the type of coarse aggregate influenced the compressive strength, split tensile strength and modulus of elasticity of both plain and silica fume cement concretes. Incorporation of silica fume enhanced the compressive strength and split tensile strength of all concretes especially that of the low quality limestone aggregates (Abdullah et al., 2004).

In an experiment it was showed that the compressive and tensile strengths increased with silica fume incorporation, and the results indicated that the optimum replacement percentage is not constant but depends on the water- cementitious material ratio of the mix. They also found that compared with split tensile strengths, flexural strengths have exhibited greater improvements (Bhanja and Sengupta, 2005) while in another, it was showed experimentally that the compressive strengths of mortars with nano-SiO_2 particles were all higher than those of mortars containing silica fume at 7 and 28 days (Jo et al.,

2007). It was demonstrated that the nano particles are more valuable in enhancing strength than silica fume. The addition of nanosilica and silica fume enhances mechanical properties of cement-based materials. Various conclusions were made regarding the effect of nanosilica that made cement paste thicker and accelerated the cement hydration process.

TABLE: Compressive strength (MPa) after 7 and 28 days comparing the mortars containing nanosilica and silica fume (Jo et al., 2007).

MIX	Compressive strength at 7 days	Compressive strength at 28 days
OPC	18.3	25.6
SF5	22.5	35.1
SF10	24.7	37.4

SF15	26.1	38.0
NS3	39.5	54.3
NS6	46.1	61.9
NS10	49.3	68.2
NS12	50.7	68.8

Compressive strengths of hardened cement paste increased with increasing the nano-SiO_2 content, especially at early ages. The pozzolanic activity of nano-SiO_2 is much greater than that of silica fume (Qing et al., 2007). The effect of silica fume on compressive and split tensile strength of lightweight concrete after high temperature was studied in which the level of importance of percentage of silica fume and heating degree on compressive and splitting tensile strength was determined by using analysis of variance (ANOVA) method (Tanyildizi and Coskun, 2008).

Researchers carried out an experimental investigation to study the effect of nanosilica on rheology and fresh properties of cement pastes and mortars. It was seen that nano-SiO_2 modified the characteristics of fresh mortars. The mortar with nanosilica showed the higher torque along all the testing period due to the plastic viscosity and yield stress increase (Senff et al., 2009). The addition of nanosilica reduced the spread diameter on the flow table of mortars, due to the gain in cohesiveness of the paste. By adding nS, the beginning of setting was anticipated and the dormant period was reduced. Samples with nS (0–7 wt. %), SF (0–20 wt. %) and water/binder ratio (0.35–0.59), were investigated through factorial design experiments. Nanosilica with 7 wt. % showed a faster formation of structures during the rheological measurements.

It was investigated that there are effects of size of nS on compressive, flexural and tensile strength of binary blended concrete. It was found that the cement could be advantageously replaced by nS up to maximum limit of 2.0% with average particle sizes of 15 and 80 nm. Although the optimal replacement level of nanosilica particles for 15 and 80 nm size were gained at 1.0% and 1.5%, respectively (Givi et al., 2010).

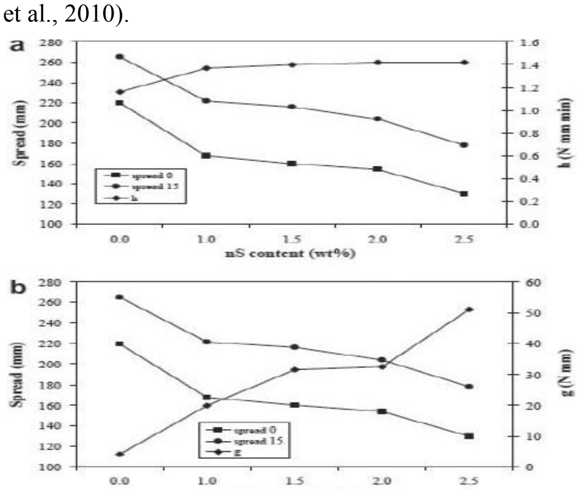

Figure: Influence of nS content on spread (after 0 and 15 strokes) and rheological parameters estimated after mixing (Senff et al., 2009)

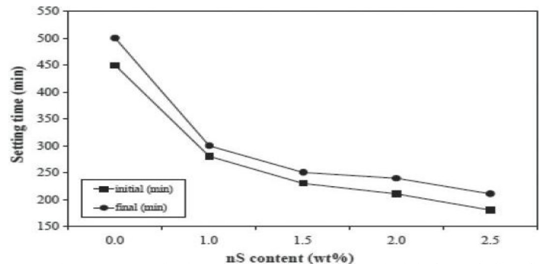

Figure: Variation of setting time (initial and final) on the mortar with the nS content (Senff et al., 2009).

The effect of micro and nanosilica under various dosages of carboxylated- polyether-copolymer-type superplasticizer on the rheological properties of grouts in the fresh state was determined. Data mentioned that the maximum strength in nS-system was reached at 1.0 wt%, whereas in SF-systems, it was at a level of replacement in the order of 15 wt%. In addition, the highest compressive strength was obtained in SF-systems (Zapata et al., 2013). In another experiment, the addition of nanosilica (NS), nano-Al_2O_3 (NA) and nano-Fe_2O_3 (NF) powders and their binary and ternary combinations on the compressive strength of cement mortars containing flyash (FA) was determined and the results showed that addition of any single type of oxide powders at 1.25% increased compressive strength of the mortars much further than the other proportions (Oltulu and Sahin, 2013).

Thus, it was found that in most of the cases, addition of nanosilica and silica fume enhanced the compressive strength and flexural strength with optimized percentages.

Influence on durability properties

The water absorption, capillary absorption and distribution of chloride ion tests indicated that the nanosilica concrete has better permeability resistance than the normal concretes. This was evident from the studies carried out that the water permeability resistant behaviour whose results showed that nS concrete is stickier than normal concrete due to the larger specific surface area (Ji, 2005). Through various experiments carried out, it was evident that for mixtures with 0.35W/B, the water absorption and apparent porosity reached the maximum values for mortars with 7% nS (Senff et al., 2010). The factorial design showed that the unrestrained shrinkage and weight loss of mortar did not follow a linear regression model and the mortars with nS showed higher values than SF. With 7 days the shrinkage increased 80%, while at 28 days it increased 54%. The chloride permeability of concrete containing nano-particles (TiO_2 and SiO_2) for pavement and compared with that of plain concrete, concrete containing polypropylene (PP) fibers and concrete containing both nano-TiO_2 and PP fibers (Zhang and Li, 2011). The test results indicated that the addition of nano-particles refines the pore structure of concrete and enhances the resistance to chloride penetration of concrete. The nS addition decreased the apparent density and increased the air content in the mortars. It was investigated that the addition of superplasticizers in 1% w/w of cement reduced the water demand and the strength increase varied from 30% to 35% (StefanidounadPapayianni 2012); Quercia et al., 2012) addressed the characterization of six different amorphous silica samples with respect to their application in cement paste. It was determined that the addition of 0.5 to 4.0% nanosilica to the cement paste reduced the water demand without the use of superplasticizers. A linear relationship between the deformation coefficient and the specific surface area of nS/mS particles was confirmed. Higher deformation coefficients (Ep) for amorphous silica with high content of nanoparticles were found which were bigger than that of cement. Guidelines in compressive strength assessment of concrete modified with silica fume due to magnesium sulfate attack were suggested. These guidelines could be used to check the safety of any structural element subjected to any concentration of magnesium sulfate attack after any service time knowing the mix proportions of the used concrete mix. Application of these guidelines shows the hazards of using Portland cement and silica fume in concrete subjected to magnesium sulfate attack.

Influence on microstructural properties

The Scanning Electron Microscope (SEM) observations revealed that the nano-particles were not only acting as filler, but also as an activator to promote hydration and to improve the microstructure of the cement paste if the nano-particles were uniformly dispersed (Li et al., 2004). The results of the experimental analysis indicated that nano-scale SiO_2 behaves not only as a filler to improve microstructure, but also as an activator to promote pozzolanic reaction (Qing et al., 2007); Jo et al., 2007).

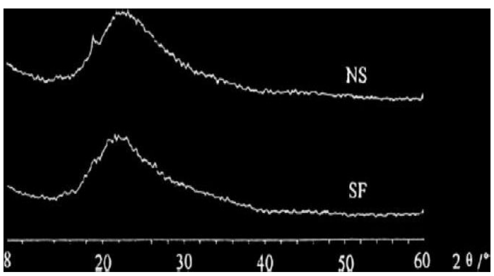

Figure 2.4 XRD powder pattern of nanosilica and microsilica (Qing et al., 2007).

The X-Ray Diffraction (XRD) showed the presence of CH, already after 9 hours, in samples with nanosilica addition. The nS addition contributed to an increased production of CH at early age compared with samples without nanosilica (Senff et al., 2010). Impressive changes were recorded in the structure of nanomodified samples as the calciumsilicate crystal size was larger in samples with high nano-SiO_2 content (Stefanidou and Papayianni (2012). This was obvious in pastes with 5% nanoparticles where crystals were formed at 14 days, while at the same age, in pastes with 1% nano-SiO_2 the average crystal size was 600 nm. Microstructure observation also recorded a denser structure in nano-modified samples. The results showed that nS can reduce the size of CH crystals at the interface more effectively than SF (Qing et al., 2007).

It was showed that C–S–H gels from pozzolanic reaction of the agglomerates cannot function as binder. The nano-indentation test results revealed that the pozzolanic C–S–H gels from reacted agglomerates showed nearly the same properties as the C–S–H gels from cement hydration (Kong et al., 2012).

The effect of colloidal nanosilica on concrete and significant improvement was observed pertaining to refinement of pore structure and densification of interfacial transition zone. Micro-structural and thermal analyses indicated that the contribution of pozzolanic and filler effects to the pore structure refinement depended on the dosage of nanosilica (Said et al., 2012).

Effect of nanosilica and microsilica combined on the compressive strength of NAC.

In this section, the main concern is to study the compressive strength of concrete containing two percentages microsilica and two percentages of nanosilica in combination and compare it with the mix containing 0% microsilica and 0% nanosilica

Table 4.3: Compressive strength of concrete containing nanosilica, microsilica and fresh aggregates silica:

s.no.	Mix designation	%age replacement by recycled aggregates	% replacement by nanosilica	%age replacement by microsilica	Compressive strength in Mpa	
					7 day	28 day
1	F0	0	0	0	48.73	58.92
2	F1+5	0	1	5	56.15	70.05
3	F1+8	0	1	8	58.30	74.70
4	F2+5	0	2	5	60.73	73.24
5	F 2+8	0	2	8	55.97	69.97

CONCLUSIONS

In the present study, it was observed that decrease in compressive strength of concrete due to addition of recycled aggregates can be compensated by addition of nanosilica and microsilica. The strength can only be compensated when nanosilica&microsilica are added in limited quantity. Nanosilica and microsilica were used in the mix to improve the early strength of concrete. On the basis of the results obtained in this study, the following conclusions can be drawn:

The percentage increase in replacement of natural aggregates by recycled aggregates decreased the compressive strength of concrete. The 6.2% decrease in strength was found to be up to 40% replacement of aggregates. However, 50% replacement of natural aggregates by recycled aggregates resulted in 17.97% decrease in strength compared to natural aggregates concrete. The decrease in compressive strength due to addition of recycled aggregates may be due to the increased porosity and decreased crushing strength and impact value of recycled aggregate.

Maximum strength was achieved with nanosilica in both natural and recycled aggregate concrete when its percentage value is 2%.

Maximum strength was achieved with microsilica in both natural and recycled aggregate concrete when its percentage value is 8%.

Maximum strength was achieved with combined microsilica and nanosilica when its percentage is (1%NS + 8%MS) & (2%NS+8%MS) was used in both natural and recycled aggregate concrete.

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REFERENCES

1. Alam M.S., Slater E., &Billah A., 2013, Green Concrete Made with RCA and FRP Scrap Aggregate: Fresh and Hardened Properties, *Journal of Materials in Civil Engineering, Vol.25,* pp 1783-1794.
2. Berra M., Carassiti F., Mangialardi T., Paolini A.E. &Sebastiani M., 2012, Effects of nanosilica addition on workability and compressive strength of Portland cement pastes,*Construction and Building Materials, Vol. 35,* pp 666–675.
3. Heidari A. &Tavakoli D., 2013, A study of the mechanical properties of ground ceramic powder concrete incorporating nanosilica particles, *Construction and Building Materials,Vol. 38,* pp 255–264.
4. Kawashima S., Hou P., Corr D.J. & Shah S.P., 2013, Modification of cement-based materials with nanoparticles, *Cement & Concrete Composites, Vol. 35,*pp 8-15.
5. Kong D., Du X., Wei S., Zhang H., Yang Y. & Shah S.P., 2012, Influence of nanosilica agglomeration on microstructure and properties of the hardened cement-based materials.*Construction and Building Materials, Vol. 37,* pp 707–715.
6. Kwan W.H., Ramli M., Kam K.J. &Sulieman M.Z., 2012, Influence of the amount of recycled coarse aggregate in concrete design and durability properties, *Construction andBuilding Materials, Vol. 26,* pp 565–573.
7. Oltulu M. &Sahin R., 2013, Effect of nanosilica, nano-Al_2O_3 and nano-Fe_2O_3 powders on compressive strengths and capillary water absorption of cement mortar containing fly ash: A comparative study, *Energy and Buildings, Vol. 58,*pp 292–301.
8. Said A.M., Zeidan M.S., Bassuoni M.T. &Tian Y., 2012, Properties of concrete incorporating nanosilica, *Construction and Building Materials, Vol. 36,*pp 838–844.
9. Senff L., Hotza D., Lucas S., Ferreira V.M. &Labrincha J.A., 2012, Effect of nanosilica and nano-TiO_2 addition on the rheological behavior and the hardened properties of cement mortars*, Materials Science and Engineering, Vol. 532,*pp 354– 361.
10. Stefanidou M. &Papayianni I., 2012, Influence of nanosilica on the Portland cement pastes, *Composites, Vol. 43,*pp 2706–2710.
11. Waste management world, 2011, Rebuilding C&D Waste Recycling Efforts in India, Available online:
12. http://www.waste-management-world.com/articles/print/vol.12/issue-5/features/rebuilding-c-d-waste-recycling-efforts-in-india.html