RESEARCHERID
THOMSON REUTERS

[Amani* *et al.*, 7(6): June, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXPERIMENTAL STUDY ON "M25 GRADE RECYCLED AGGREGATE CONCRETE WITH ADDITION OF NANO-SILICA"

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DOI: 10.5281/zenodo.1299022

ABSTRACT

Due to growing environmental awareness, as well as stricter regulations on managing construction waste, the world is increasingly turning to researching properties of construction waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other constructional branches. Although demolished material is still today considered waste and is categorized in construction waste catalogues, in most countries in the world, it is most definitely not waste, neither by its physical and chemical properties nor according to data on its use as valuable material for different purposes. Considering the specificity of physical and chemical properties of construction materials and a series of possibilities for their use in the field of civil constructions, this report demonstrates the possibilities of using recycled or reclaimed aggregate as partial replacement of natural coarse aggregate in concrete, where recycled aggregate is obtained from demolition of RCC building. To date, these types of wastes have been widely used as aggregate for civil works worldwide.

The application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nano materials, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. This study concerns with the use of Nano silica to improve the compressive strength of concrete. An experimental investigation has been carried out by replacing the cement with Nano silica of 2%.

The report presents an investigation of mechanical and durability properties of concrete by adding recycled aggregate and Nano-silica as replacement of coarse aggregate in various percentages. The coarse aggregate has been replaced by recycled aggregate accordingly with 30% is by weight of coarse aggregate for M25 mix and the same adding 2% Nano-silica by weight of water and coarse aggregate. The tests have been made to study the strength properties for 7, 28 and 56 days.

KEYWORDS: Recycled Aggregate, Nano-Silica, Strength Properties, Demolition.

1. INTRODUCTION

1.1 General

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated material of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Of the various technologies in use, Nano-technology looks to be a promising approach in improving the properties of concrete.

Environmental control is an increasingly pressing concern in the construction industry. Natural resources are consumed in its day-to-day operations and waste is generated. Construction activities thereby impose significant environmental impacts over the entire construction life cycle. Waste management in the construction industry has not been successfully controlled, and it is challenging to initiate improvement. It has been thought that the reuse and recycling of materials will provide effective means to reduce the impact on limited landfill spaces and also improve waste management.

However, much effort has been made to recycle and conserve precious natural resources, and repeated recycling can be suitable for concrete. An effective method would be the use of recycled aggregate (RA) in the production of concrete. RAC is created by mixing RA along with other natural ingredients, including cement, water, fine aggregate and other materials. As concrete is composed only of cementations materials, and the powders generated during the production of RA can be reprocessed as cement resources, repeated recycling is possible.

1.2 Concept of Recycled Aggregate in Concrete

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions.

Concrete has been proved to be a leading construction material for more than a century. It is estimated that the global production of concrete is at an annual rate of 1 m^3 per capita. The global consumption of natural aggregate will be in the range of 48.3 billion metric tons after 2015. Over 1 billion tons of construction and demolition waste (C&DW) is generated every year worldwide. At the same time, large quantities of natural aggregates are extracted for construction every year leading to the large scale depletion of natural aggregate and the increased amount of C&DW. In view of the increased volumes of construction and demolition waste and the advantages offered by the use of admixtures in modern concrete it is considered very beneficial from different prospects with similar performance characteristics of natural aggregate concrete. The behavior of the recycled aggregate concrete strength characteristics with full replacement of recycled coarse aggregate are the significant findings of the earlier researchers. The partial replacement of the recycled coarse aggregate to the natural coarse aggregate is also essential to understand the mechanical behavior of the concrete in general.

The present thesis gives a brief status of recycled aggregate concrete made out of recycled aggregate, summarizes and critically analyses the strength characteristics of RAC. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

1.3 Historical Development of RAC

The use of old construction materials in new constructions is not a new technique. Many civilizations have used and reused the construction materials of earlier civilizations or their own destroyed architectures either due to war or due to natural disaster to construct new structures. The best example is that the construction of Vatican Basilica with the stones of ruined Romanesque. Though the '3R' formula i.e. Reduce, Reuse, Recycle is one of the best policies to achieve the sustainable construction, due to partial implementation of this technique in most of the countries still lots of quantities of construction and demolition waste is lying in the site and deposited on landfills to overcome these difficulties.

1.4 Indian Scenario

Protection of environment, conservation of natural resources, and sustainable Constructions are the three important essences of any modern development. Today, sustainable development has been advocated throughout the world. Construction industry is a massive consumer of natural resources and a huge construction and demolition (C&D) waste producer as well. Generally, C&D waste coming from construction industry consists mostly of inert and non-biodegradable material. Furthermore, concrete rubble has been found to be a major portion consisting around 40% present in C&D waste. The C&D waste normally dumped on the roadside, causes problems to traffic and environment. Moreover, it is an additional workload to the local administration. On the other hand, the resources of natural coarse aggregates are scarce and depleting very fast as the construction activities are increasing day by day. Now-a-days, sustainable constructions, environmental problems and protection of natural aggregate resources are the crucial issues in the construction industry. The use of recycled aggregate in concrete will be an important step towards sustainable construction and the conservation of natural resources as well. Construction by nature is not an environmental-friendly activity, demolition, renovation activities and natural disasters like Tsunami, earthquake, war, and cyclones takes place. A part of this C&D waste comes from the municipal stream also. In India, the total quantum of waste from the construction industry has been estimated to be between 12 million to 14.7 million ton per annum out of which seven to eight million ton are concrete and brick waste.

(*Source: Technology information, forecasting and assessment council (TIFAC), Department of science and technology, Government of India)

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The huge quantities of C&D waste, coming from different sources creating many impacts on the environment. However, some waste management options namely:

i) Reduce, ii) Reuse, iii) Recycle, iv) Compost, v) Incinerate vi) Landfill

Table 1.4 Quantity and make up of C& D waste per annum in India

CONSTITUENT	QUANTITY GENERATED IN MILLION TON PER ANNUM
Soil, sand and gravel	4.20 to 5.14
Bricks and masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.30
Wood	0.25 to 0.30
Others	0.10 to 0.15

Hence, the RA obtained from C&D wastes have been limited to lower grade Concrete applications only. The quality and performance of recycled aggregate obtained from C&D waste generally depends on their separation process and condition of the separated material. The final quality and performance of RA are mainly dependent on many factors like

- The properties of parental rock,
- Source of c & d collected,
- The age of demolished structure,
- Water cement (w/c) ratio and grade of old concrete used,
- Type of cement and Admixtures used,
- The quality and quantity of adhered cement mortar present on the Surface of recycled aggregate

In India, nearly 50% of Construction & Demolition (C&D) waste is being re-used and recycled while the remainder is mostly land filled because the construction industry is not aware of the effective recycling techniques and recycling possibilities [Waste Management World (2012)]. Furthermore, the Bureau of Indian Standards (BIS) does not provide any specifications or standards for practicing the recycled aggregate in construction activities.

1.5 World Scenario

The construction industry contributes substantially to the generation of solid waste in almost all the countries. The Construction Materials Recycling Association (CMRA) has conducted a study on construction and demolition waste, related to the buildings and it was estimated to be around 136 million tons of waste material. Also, it was reported that apart from the building waste, a millions of tons of waste is coming from road, bridge, and airport construction and renovation. In developed countries the annual per capita building and construction waste generation were 500 – 1000 kg and in the European countries the building and construction waste was estimated to be around 175 million tons per year (Nitivattananon and Borongan 2007). The construction and demolition waste generation scenario in Asian countries is also in the same trend. It was reported that Asia alone generates about 760 million tons of construction and demolition waste every year (World Bank 1999). According to the annual report of Dubai municipality’s Waste Management Department, there was about 27.7 million tons of construction waste, generated from various construction sites in the city in 2007 (Shrivastava and Chini 2009). This was recording growth in construction waste generation of 163% in comparison to the waste generated in 2006.

Out of the total construction demolition waste, 40% is of Concrete , 30% ceramics, 5% plastics, 10% wood, 5%metal, & 10% other mixtures. As reported by global insight, growth in global construction sector predicts an increase in construction spending of 4800 billion US dollars in 2013. These figures indicate a tremendous growth in the construction sector, almost 1.5 times in 5 Years. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of coarse aggregate & 33-40% is of fine aggregate. . The use of recycled aggregate generally increases the drying shrinkage creep & porosity to water & decreases the compression strength of concrete compared to that of natural aggregate concrete. It is nearly 10-30% as per replacement of aggregate. Recycling reduces the cost (LCC) by about 34-41% & CO2 emission (LCCO2) by about 23-28% for dumping at public / private disposal facilities.

1.6 Introduction to Nano Silica

Nano-science plays an important role in producing innovative concretes in the 21st century. Nano-science enables scientists to work at atomic and molecular levels in order to produce new materials with new physical and chemical properties.

Nano materials are gaining widespread attention to be used in construction sector so as to exhibit enhanced performance of materials in terms of smart functions and sustainable features. During the last one decade a number of nano materials such as nano silica, nano titania, carbon nano tubes and nano alumina have been explored and among them nano silica has been used most extensively. A number of publications appeared towards the use of Nano silica in cementations system is mainly due to the fact that concrete remains the most complex material and its hydration mechanism is still not completely understood. Consequently, researchers are focusing on the basic science of this material at nano or atomic level.

Further, researchers are continuing to improve the durability and sustainability of concrete, and they have realized significant increment in mechanical properties of cementations materials by incorporating nano silica. With regard to issues such as strength, resistance, durability, and high performance, the construction industry is one of the important users of nano materials

1.7 Necessity of The Project

Urbanization growth rate in India is very high due to industrialization. Growth rate of India is reaching 9% of GDP. Rapid infrastructure development requires a large quantity of construction materials, land requirements & the site. For large construction, concrete is preferred as it has longer life, low maintenance cost & better performance. For achieving GDP rate, smaller structures are demolished & new towers are constructed. Protection of environment is a basic factor which is directly connected with the survival of the human race. Parameters like environmental consciousness, protection of natural resources, sustainable development, play an important role in modern requirements of construction works. Due to modernization, demolished materials are dumped on land & not used for any purpose. Such situations affect the fertility of land.

It is now widely accepted that there is a significant potential for reclaiming and recycling demolished debris for use in value added applications to maximize economic and environmental benefits due to issues relating to sustainability and limited natural resources it is clear that usage of recycled aggregate is essential. To use recycled aggregate in structural applications , mineral admixture like Nano-silica should be added to improve the strength properties efficiently.

1.8 Objectives of The Project

The objective of this work is to explore the feasibility and effect of recycled aggregate on strength properties of RAC with addition of NS. This will help in conserving the natural resources and keeping ecological balance to fulfill present demand of construction material in infrastructure development sector which is increasing at alarming rate. Following are the objectives of the present study:

→ To carryout tests on recycled aggregates and determine the feasibility to use in concrete.
→ To evaluate strength properties of RAC with addition of NS at ages of 7,28 and 56.
→ To determine the effect of recycled aggregates on the strength properties of RAC.
→ To compare the results of strength characteristics of RAC with addition of NS with NAC at all the ages.

2. REVIEW OF LITERATURE

2.1 General

In this chapter the works of various authors on the use of RA as alternative material to natural aggregate and strength properties of RAC are presented. A few relevant works Out of the numerous works done in this field have been highlighted in the next section.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Wan jo et.al (2007) studied the characteristics of cement mortar with Nano SiO2 particles experimentally and observed higher strength of these blended mortars for 7 and 28 days. The microstructure analysis showed that SiO2 not only behaves as a filler to improve microstructure, but also as an activator to the pozzolanic reaction.

Parekh and Modhera (2009) determined the use of recycled aggregate in concrete and supposed that can be useful for environmental protection and economical terms. Reasons, of use of recycled aggregate concrete in pavement construction, with technical proofs are explained here in detail. Individual performance of recycled fine aggregate in concrete, use of silica fumes in recycled aggregate concrete, use of fly ash in recycled aggregate concrete etc are shown with experimental reasons.

Nilli et.al(2009) discussed the combined effect of micro silica and colloidal nano silica on properties of concrete and found that concrete will attain maximum compressive strength when it contains 6% micro silica and 1.5% nano silica. The highest electrical resistivity of concrete was observed at 7.5% micro and nano silica. The capillary absorption rate is lowest for the combination of 3% micro silica and 1.5% nano silica.

Alirza Naji Givi (2010) studied the size effect of nanosilica particles. They replaced cement with nanosilica of size 15nm and 80nm with 0-5, 1, 1.5 & 2% b.w.c. An increase in the compressive strength was observed with 1.5% b.w.c showing maximum compressive strength. A comparison between particle size showed that for 80nm particles the maximum strength was more than for 15nm particles, also a considerable improvement in flexural and split tensile strength of Nano SiO2 blended concrete was observed.

Sadrmotazi (2010) has studied the effect of PP fiber along with nano SiO2 particles. The nanosilica was replaced up to 7% which improved the compressive strength of cement mortar by 6.49%. PP fiber amounts beyond 0.3% reduces the compressive strength but beyond 0.3% dose of PP fiber increases the flexural strength, showing the effectiveness of nano SiO2 particles. Also up to 0.5% PP fibers in mortar water absorption decreases which indicates pore refinement.

Vivekvardhan et al (2010) worked on Strength properties of the treated and untreated coarse aggregate were compared. The results indicated that the compressive, flexure and split tensile strength of recycle aggregate is found to be less than the natural aggregate.

Surya Abdul Rashid (2011) worked on the effect of Nano SiO2 particle on both mechanical properties (compressive, split tensile and flexural strength) and physical properties (water permeability, workability and setting time) of concrete which shows that binary blended concrete with Nano SiO2 particles up to 2% has significantly higher compressive, split tensile and flexural strength compared to normal concrete. Another inference drawn was that partial replacement of Nano SiO2 particles decreases the workability and setting time of fresh concrete for samples cured in lime solution.

Alireza Naji Givi et.al (2012) studied the effect of Nano SiO2 particles on water absorption of RHA blended concrete. It is concluded that cement could be replaced up to 20% by RHA in presence of Nano SiO2 particle up to 2% which improves physical and mechanical properties of concrete.

Said e.alt (2012) examined the effect of colloidal Nano silica on concrete by blending it with class F fly ash and observed that performance of concrete with or without fly ash was significantly improved with addition of variable amounts of Nano silica. The mixture containing 30% FA and 6% CNS provides considerable increase in strength. Porosity and threshold pore diameter was significantly lower for mixture containing Nano silica. The RCPT test shows that passing charges and physical penetration depth significantly improved.

Mukharjee and Barai et al (2014) analyzed the compressive strength characteristics of Interfacial Transition Zone (ITZ) of concrete containing recycled aggregates and nanosilica. An improvement in the compressive strength and microstructure of concrete was observed with the incorporation of nano-silica.

MechaGajhi et al (2014) worked on the behavior and strength characteristics of concrete containing recycled Concrete aggregate and found that selected types of RCA show a real possibility for use as aggregate in concrete. When concrete with a RCA replacement of 100% was compared with NAC 100% there was a small

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

decline in strength, but when concrete with a RCA replacement of 30% was compared with NAC 100% the results showed almost equal strength. A slight reduction in durability performance was found for RAC30% compared with NAC100%, but similar dimensional stability performance in terms of specific creep and drying shrinkage was measured for RAC30% and NAC 100%.

2.2 Summary

The review of a number of literature shows the importance of this field of research. The findings show that a number of non material's like SiO2, TiO2, Al2O3, colloidal Nano silica, metakaolin and others can be incorporated to improve the properties of concrete and also effect of recycled aggregate on strength characteristics of Concrete. The results show the improved characteristics of the concrete in terms of compressive, tensile and flexural strength. The current study is concerned with the incorporation of Nano SiO2 with the use of RA as alternative to regular aggregate in concrete.

3. RECYLED AGGREGATE AND NANO SILICA

3.1 General

The concrete industry consumes a large amount of natural resources that cause substantial environmental, energy and economic losses as it exploits 50% raw material, 40% of total energy, as well as generates 50% of total waste. Large amounts of solid waste are produced in the process of constructing new buildings and demolishing old ones all around the world. In last 20 to 30 years certain countries have started the reutilization of construction and demolition waste as new construction material. This is being one of the main objectives with respect to sustainable construction activities. Concrete waste, which falls into the Construction and Demolition (C & D) waste category, is generated when creation of new, or modifications to existing urban infrastructure such as transport systems, communication networks and buildings are made. With the increased urbanization of the worlds growing population there is also an increase in C & D waste generation. This prompts a realization that built-in urban infrastructure along with C & D waste contains a large stock of materials, and that efficient management of concrete, steel, bricks, their waste, is necessary to sustain the future growth and increased demand for construction materials. It seems that there is a common understanding and consensus that depletion of natural resources is a real threat, landfill space is becoming scarce, and the waste disposal causes significant environmental and social impact. There is also a general consensus that recycled C & D waste including RC aggregates can be used for construction purposes. The main source of raw material for recycling of concrete waste comes from demolition of concrete structures. The quality and purity of the raw material affect the quality of recycling products and ultimately commercial acceptance of concrete recycling products.

Concrete has been proved to be a leading construction material for more than a century. It is estimated that the global production of concrete is at an annual rate of 1 m3 per capita. The global consumption of natural aggregate will be in the range of 48.3 billion metric tons after 2015. Over 1 billion tons of construction and demolition waste (C&DW) is generated every year worldwide. At the same time, large quantities of natural aggregates are extracted for construction every year leading to the large scale depletion of natural aggregate and the increased amounts of C&DW. The construction and demolition waste are primarily used for landfill sites which are causing significant damage to the environment and developing serious problems. The use of the recycled aggregates created from processing of construction and demolition waste in new construction has become more important over the last two decades as it conserve the non-renewable natural resource of virgin aggregates .for economical and environmental reasons and because of the increased amount of recycled aggregates production, there has been a growing global interest in maximizing the use of recycled aggregates in construction.

3.2 Classification of Aggregates

Aggregates are generally classified as below:

Natural Aggregate: Construction aggregates produced from natural sources such as gravel and sand, and extractive products such as. Crushed rocks, Sand and gravel, Crushed river gravel

Manufactured Aggregate: Aggregates manufactured from selected naturally occurring materials, by-products of industrial processes or a combination of these, some of the examples are Foamed Blast Furnace Slag (FBS), Fly Ash Aggregate, Manufactured Sand, Polystyrene Aggregate (PSA),Expanded Clays, Shale's and Slates
Recycled Aggregate: Aggregates derived from the processing of materials previously used in a product and/or in construction, some of the examples are Recycled Concrete Aggregate (RCA), Recycled Concrete and

Masonry (RCM), Reclaimed Aggregate (RA)3 Reclaimed Asphalt Pavement (RAP), Reclaimed Asphalt Aggregate(RAA),Glass Cullet, Scrap tiers ,Used Foundry Sand etc

3.3 Recycled Aggregates

Construction materials are increasingly judged by their ecological characteristics. Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other applications. Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality.

Use of recycled aggregate (RA) in concrete can be described in environmental protection and economical terms. The application of recycled aggregate to use in construction activities have been in practice by developed European countries and also of some Asian countries. This paper reports the results of an experimental study on the mechanical properties of recycled aggregate concrete (RAC) as compared to natural aggregate concrete (NAC).

3.4 Sources of Recycled Aggregates

Traditionally, Portland concrete aggregate from the demolition construction are used for landfill. But now days, Portland concrete aggregate can be used as a new material for construction use. According to recycling of Portland Cement Concrete, recycled aggregates are mainly produced from the crushing of Portland concrete structure and buildings. The main, reason for choosing the structural building as the source for recycled aggregate is because a huge amount of crushed demolition Portland cement concrete can be produced.

3.5 Importance of Recycled Aggregates in Concrete

The benefits to the environment of using RAC include economic aspects, reduction of environmental impacts and saving on resources. Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other applications. The quality of concrete with RCA is very dependent on the quality of the recycled material used. There is a range of environmental and economic benefits in recycling concrete rather than dumping it or burying it in a landfill. These advantages include.

- → Cheaper source of aggregate than newly mined.
- → Reduction of landfill space required for concrete debris.
- → Using recycled material as gravel reduces the need for gravel mining.
- → Increasingly, high-grade aggregate for road construction is available only at greater distances, increasing the associated economic and environmental cost impacts associated with the longer haulage distances versus using recycled aggregate.

Hence, the use of RA in construction work as structural grade concrete may consider for economic viability and environmental concern as well reduction of waste materials.

3.6 Applications of Recycled Aggregates

Presently, usage of recycled aggregate made out from demolished waste is not preferably used for structural purposes. Most of the unprocessed crushed concrete aggregate is sold as 37.5 mm or 50 mm fraction for pavement sub-bases. After removal of contaminants through selective demolition, screening, and or air separation and size reduction in a crusher to aggregate sizes, crushed concrete can be used as

1.New concrete for pavements, 2.Shoulders, 3. Median barriers, 4. Sidewalks, 5.Curbs, 6.Gutters,7. Soil-cement pavement bases, 8. Lean-concrete bases, 9. Bituminous concrete,10. Road construction,11. Noise barriers and embankments,

Structural Applications

1. Commercial/Municipal Base, 2. Residential Base, 3.Many types of general bulk fills Bank protection, 4. Base or fill for drainage structures, 5. Bridge foundations, 6.Structural grade concrete

3.7 Limitations of Recycled Aggregates

Limitations or disadvantages of recycling of construction material are :-

- ➢ Less quality (e.g. compressive strength reduces by 10-30%).
- ➢ Duration of procurement of materials may affect life cycle of project.
- ➢ Land, special equipments machineries are required (more cost).

- Very high water absorption (up to 6%).
- It has higher drying shrinkage & creep.

3.8 Nano Silica

Nano silica is a new Pozzolonic material which is available in water in both solid and liquid form. In the concrete industry, Nano silica is one of the most famous materials that determine viscosity and filling state of the concrete. Nano-silica in particular has found wide usage in construction field because of its high reactivity and very large specific surface area, which results in a high degree of pozzolonic activity. Nano-silica, further accelerates the dissolution of C3S and formation of C–S–H with its activity being inversely proportional to the size, and also provides nucleation sites for C–S–H .Even small additions (0.6 wt. % binder) of NS is very efficient for the improvement in mechanical properties of cement-based materials. This is especially pronounced at early ages and for concretes with regular strength grade.

Adding Nano particles in concrete could maintain its strength during physical and chemical reactions and also compress the particles. From the Nano-indentation studies, it was observed that the Nano-silica addition significantly alters the proportions of low stiffness and high stiffness (C–S–H) modification effects of colloidal Nano Silica on cement hydration and its gel property.

3.9 Importance of Nano Silica (NS)

Nano Silica (NS) can contribute to efficient 'Particle Packing' in concretes by densifying the micro and nanostructure leading to improved mechanical and durability properties. NS can control degradation (through blocking of water entry on account of pore refinement) of the fundamental binder system of hydrated cement i.e., C-S-H gel caused usually due to calcium leaching out when immersed in water. NS improves behavior of freshly mixed cement concretes by imparting segregation resistance and by enhancing both workability and cohesion of the matrix. Nanotechnology increases the durability of concrete. In other words, it decrease carbonation risk, penetration of chlorine and so forth.

3.10 Benefits of Nano Silica

- Low maintenance.
- Reduces the thermal transfer rate.
- Increases the sound absorption of acoustic absorber.
- Increases the reflectivity of glass.
- Improves segregation resistance.
- Fix micro-cracking.
- Corrosion-resistance.
- Low life-cycle cost

3.11 Applications of Nano Silica

Application of concrete can be anywhere, both in infrastructure and in buildings. Following are major applications of NS.

- It is added to increase the cohesiveness of concrete.
- It is also used to reduce the segregation tendency.
- It can be used to produce HPC concrete with high compressive strength , anti-bleeding properties and high workability.
- Nano-silica is used as additive in eco-concrete mixtures.
- Nano-silica is applied in HPC and SCC concrete mainly as an anti-bleeding agent.

some explorative applications of NS in high performance well cementing slurries , specialized mortars for rock-matching grouting and gypsum particleboard can be found, but NS is not used in practice yet.

4. MATERIALS AND METHODS

Materials used in the mix design are investigated in the following sections:

4.1 Cement

The cement used was ordinary Portland cement of 43 grade (ultra-tech cement) in accordance with IS: 12269 – 1987. The cement should be fresh and of uniform consistency where there is evidence of lumps or any foreign matters in the material, it should not be used. The cement should be stored under dry conditions and for a short duration as possible. The properties of cement are presented in the table 4.1 below

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4.1: Properties of Cement

S.No	Property	Value
1	Specific gravity	3.15
2	Normal consistency	32%
3	Initial setting time	165 min
4	Final setting time	355 min
5	Fineness	2.21%

4.2 Fine Aggregate

River Sand conforming to grading zone-2 was used as fine aggregate in concrete. table 4.2 presents the properties of Fine aggregate

Table 4.2: Properties of Fine Aggregate

S.No	Property	Value
1	Specific gravity	2.64
2	Bulk density Loose state Compacted state	1630kg/m3 1700 kg/m3
3	Fineness modulus	2.32

4.3 Coarse Aggregate

Crushed metal with 60% passing 20mm and retained on 10mm sieve and 40% passing 10mm and retained on 4.75mm sieve was used in the investigation. Properties of coarse aggregate are presented in the table 4.3 below

Table 4.3: Properties of Coarse Aggregate

S.No	Property	Value
1	Specific gravity	2.82
2	Bulk density Loose state Compacted state	1440kg/m3 1682 kg/m3
3	Fineness modulus	6.62

4.4 Recycled Aggregate

Recycled aggregate used in the investigation was collected from a dismantled 15-20 years old 3 stair building near M.V.P Colony, Visakhapatnam. The properties of RA are presented in the Table 4.4.

Table 4.4 Physical Properties Of Recycled Aggregate

S.No	Property	Value
1	Specific gravity	2.91
2	Bulk density Loose state Compacted state	1240 kg/m3 1520 kg/m3
3	Fineness modulus	8.16

ISSN: 2277-9655
Impact Factor: 5.164
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4.5 Water

Potable fresh water from University lab tap which is screened or free from any organic or acid concentration was used for mixing the concrete. Table 4.5 presents the properties of water

Table 4.5: Properties of Water

S.No	Property	Value
1	Density	1000kg/m3
2	PH	7

4.6 Mineral Admixtures

Nano-silica bought from Bee-chems Pvt.Ltd., Punjab, was used as mineral admixture to improve strength characteristics of Recycled aggregate concrete. table 4.6 presents the properties of Nano Silica used in the investigation

Table 4.6: Physical Properties of NS

S.No	Property	Value
1	Grade	CemSynXTX
2	Active nano content (%wt/wt)	40-41.50
3	pH (20 degree c)	9.0-10.0
4	Specific gravity	1.20-1.22

4.7 Mix Design

To investigate the different effects of recycled coarse aggregate on the properties of cement concrete, Design mix M25 with 3 groups of different mix in each design mix were prepared. The design proportion of cement, sand, coarse aggregate, recycled coarse aggregate and water were as per IS 10262:2009. The mix design procedure and calculation are shown in below.

Target strength:

In order that not more than the specified portions of test results are likely to fall below the characteristic strength (F_{act}), the concrete mix has to be designed for somewhat higher target average compressive strength (F_{act}).

F_{ck}=f_{ck}+ts (s) ,F_{ck} = target average compressive strength at 28 days, F_{ck} = characteristic compressive strength at 28 days =25 Map,S=Standard deviation= 4 (from TableNo.- 1 of IS: 10262:2009), t=1.65 (from TableNo.- 2 of IS: 10262:2009)**,** Therefore,, **F_{ck} = 25+1.65(4) =31.60 N/mm2. Cement content (c) = 360 kg/m3.Fine aggregate (fa) = 740 kg/m3, Coarse aggregate (Ca) = 1185 kg/m3, Water= 180.00 liters. Therefore mix design is 1:2.05:3.30.**

QUANTITIES OF INGREDIENTS

Mix	Cement(Kg)	Fine aggregate(kg)	Coarse aggregate(kg)	Water (kg)	W/C
M25	360	740	1185	180	0.50

MIX PROPORTION

	Mix	Cement	FA	CA	W/C
Ratio	M25	1	2.05	3.30	0.50

4.8 Mixing Procedure

The mixing procedures were divided into three stages. In the first stage, all the binders were weighted accordingly and mixed by hand until all the constituents mixed uniformly. This was to make sure that all the binders were mixed thoroughly to produce a homogenous mix. The second stage involves mixing the binders with the aggregates for about 5 minutes. At the final stage, measured water was added into the concrete mix. This step was crucially important to make sure that the water was distributed evenly so that the concrete will have similar water-binder ratios for every specimen. After that, the concrete was then poured into the mould.

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4.1.6 Preparing test specimens

Moulds of distinct sizes and shapes (cubes, cylinders and beams) are used to produce the specimens. The concrete was poured into the mould in three layers where each layer was compacted using a tamping rod. The specimens were removed from the moulds after 24 hours and are cured by dipping in moist environment.

4.9 Preparing Test Specimen

Moulds of distinct sizes and shapes (cubes, cylinders and beams) are used to produce the specimens. The concrete was poured into the mould in three layers where each layer was compacted using a tamping rod. The specimens were removed from the moulds after 24 hours and are cured by dipping in moist environment.

4.10 Curing of Test Specimen

The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours + ½ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 220to 320C. After the period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24hours, stored in clean water at a temperature of 240to 300C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 27 0+ 20C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

4.11 Experimental Study

Tests on Hardened Concrete, The following strength tests are carried out after the making of concrete.

4.11.1 Destructive Tests

4.11.1.1 Compressive Strength Of Concrete Specimen

Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition.. Specimens when received dry shall be kept in water for 24 hours before they are taken for testing.

In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Fig 4.11.1.1 Compression Testing Machine

The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area.

$$\text{Compressive strength, } \mathbf{f_{ck}} = \frac{P}{A}$$

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Where,

P is maximum load applied on the specimen &

A is area of cross section

The compressive strength test was conducted on cube test specimens for concrete mixes made with conventional aggregate and recycled coarse aggregate. The test was conducted on test specimens at the ages of 7, 28 and 56 days after proper curing till the day of test. Similarly compressive strength test was carried out on concrete mixes with Nano silica along with conventional aggregates and recycled coarse aggregates.

Table 4.11.1.1 Values of Compressive Strength for different mixes

MIX	Compressive Strength, N/mm^2					
	7DAYS		28 DAYS		56 DAYS	
	LOAD	STRENGTH	LOAD	STRENGTH	LOAD	STRENGTH
NAC	537	23.86	710	31.55	713	31.70
RAC30	580	25.77	676	30.04	683	30.37
R30+2NS	566	25.15	696	30.96	740	32.88

I.11.1.2 Split Tensile Strength Test

The split tensile test were conducted as per IS 5816:1999. The size of cylinder is 300mm length with 150mm diameter. The specimen were kept in water for curing for 7 days,14 days and 28 days and on removal were tested in wet condition by wiping water and grit present on the surface. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

The Split Tensile strength test was conducted on cylinder test specimens for concrete mixes made with conventional aggregates and recycled coarse aggregates (for every percentage of replacement). The test was conducted on test specimens at the ages of 7, 28 and 56 days after proper curing till the day of test. Similarly, Split Tensile strength test was carried out on concrete mixes with Nanosilica along with conventional aggregates and recycled coarse aggregates.

Fig 4.11.1.2 failure of cylindrical specimen in Split tensile test

The maximum load applied to the specimen was then recorded and the appearance of the concrete for any unusual features in the type of failure was noted. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area. Average of three values was taken as the representative of batch.

$$f_t = \frac{2P}{\pi D L}$$

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Where,

f_t is value of split tensile strength,
P is the maximum load applied on the cylindrical specimen,
D is the diameter of the specimen &
L is the length of the cylindrical specimen

Table 4.11.1.2 Average Values of Split Tensile Strength at all ages

MIX	Split Tensile Strength, N/mm^2					
	7DAYS		28 DAYS		56 DAYS	
	Load	Strength	Load	Strength	Load	Strength
NAC	173	2.4	178	2.50	210	2.96
RAC30%	156	2.26	161.66	2.32	176	2.49
R30+2%NS	170	2.33	193	2.73	216	3.06

I.11.1.3

The specimen shall be placed in the machine in such a manner that the load shall be applied to the uppermost surface of the mould, along two lines spaced 20.0 or 13.3 cm apart. The axis of the specimens shall be carefully aligned with the axis of the loading device. The load shall be applied without shock and increasing continuously at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for 10.0 cm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

The Flexural strength test was conducted on prism test specimens for concrete mixes made with conventional aggregates and recycled coarse aggregates The test was conducted on test specimens at the ages of 7, 28 and 56 days after proper curing till the day of test. Similarly, flexural strength test was carried out on concrete mixes with Nano silica along with conventional aggregates and recycled coarse aggregates.

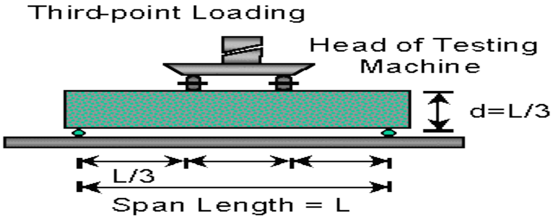

Fig 4.11.1.3 three pointed loading

The flexural strength of the specimen is expressed as modulus of rupture f_b which is given by

$$f_b = \frac{pl}{bd^2} \ (a>13.33)$$

Where,

P is maximum load applied on the specimen,
a is crack width,
l is the length of the specimen (prism)
b is the breadth of specimen
d is depth of specimen

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Table 4.11.1.3 Average Values of Flexural Strength for all mixes

MIX	Flexural Strength, N/mm^2					
	7DAYS		28 DAYS		56 DAYS	
	LOAD	STRENGTH	LOAD	STRENGTH	LOAD	STRENGTH
NAC	1293	6.26	1520	7.54	1593	7.80
RAC30%	1193	5.84	1433	7.00	1453	7.10
R30%+2%NS	1280	6.22	1513	7.41	1520	7.42

4.11.2 Non Destructive Tests

4.11.2.1 Rebound Hammer Test

Rebound hammer test is used to find out the in-situ compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992.

The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the Spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer

Fig 4.11.2.1 Digital Rebound Hammer

The rebound hammer test and UPV test were conducted on cube test specimens for concrete mixes made with conventional aggregate and recycled coarse aggregate (for every percentage of replacement) to study the integrity in terms of homogeneity and also to assess the quality of the concrete at the age of 28 days after proper curing. Similarly, rebound hammer test and UPV test were carried out on concrete mixes with Nanosilica along with conventional aggregate and recycled coarse aggregate.

Table 4.11.2.1 Values of Rebound Hammer For All Mixes at 28 Days

Mix	Sample no	Rebound hammer values			Average values
NCA	1	33.5	29.5	32	31.67
	2	31.5	32	32.5	32
	3	29.5	30	34.5	31.34
RCA 30%	4	29.5	30.2	30.2	30
	5	30.3	31.2	30.6	30.7
	6	29.8	30.4	30.4	30.2
RCA 30% + 2% NS	7	33	30	31.7	31.56
	8	31.3	32.4	31	31.5
	9	30.5	32.5	31.8	31.6

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4.11.2.2 Ultra Pulse Velocity Test

The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc.
This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part 1) – 1992. The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc.
Ultrasonic testing equipment includes a pulse generation circuit, consisting of electronic circuit for generating pulses and a transducer for transforming electronic pulse into mechanical pulse having an oscillation frequency in range of 40kHz to 50kHz, and a pulse reception circuit that receives the signal. The transducer, clock, oscillation circuit, and power source are assembled for use. After calibration to a standard sample of material with known properties, the transducers are placed on opposite sides of the material. Pulse velocity is measured by a simple formula

Fig 4.11.2.2 UPV Test Equipment

Table 4.11.2.2 Values of Ultra Pulse Velocity Test For All Mixes At 28days

MIX	S.NO	VALUE 1		VALUE 2	
		Time µ-sec	Velocity	Time µ-sec	Velocity
NAC	1	31.8	4717	31.9	4702
	2	31.9	4702	31.4	4777
	3	31.8	4717	31.6	4746
RAC30%	1	31.3	4792	31.9	4702
	2	31.9	4702	31.8	4717
	3	30.9	4854	31.9	4702
RAC30+2NS	1	30.8	4870	31.8	4717
	2	32.4	4629	32.1	4672
	3	30.9	4854	30.9	4854

5. RESULTS ANALYSIS AND DISCUSSION

5.1 Compressive Strength

The values of compressive strength obtained from the test for Natural Aggregate Concrete (NAC), Concrete with 30% of Recycled Aggregate with Nano silica along with conventional aggregate and recycled aggregate were results were represented in the form of curves in Fig 5.1 & 5.2

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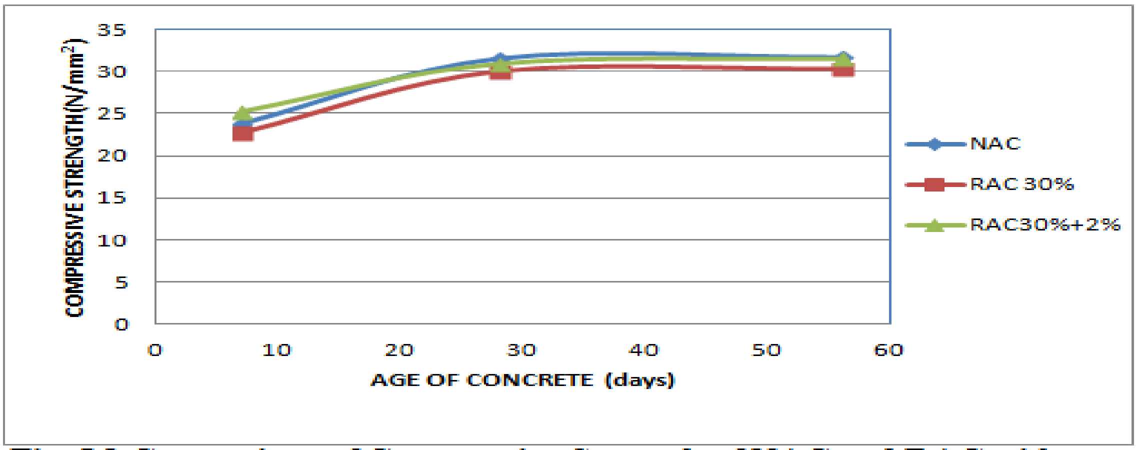

Fig. 5.1 Comparison of Compressive Strength of NAC and RAC with age

The 7days Compressive Strength of NAC is 32.28% more when compared to 28 days strength. While 56 days compressive strength of NAC is just 0.47% more than 28 days compressive strength of NAC. The 7days Compressive Strength of RAC 30 is 32% more when compared to 28 days strength of RAC 30 while 56 days compressive strength of RAC 30 is more than 28 days compressive strength of RAC 30 by 1.06%. The 7days Compressive Strength of RAC 30 + 2 NS is 32.28% more when compared to 28 days strength of RAC 30 + 2 NS while 56 days compressive strength of RAC 30 + 2 NS is just 0.47% more than 28 days compressive strength of RAC 30 + 2 NS by 8.69%.

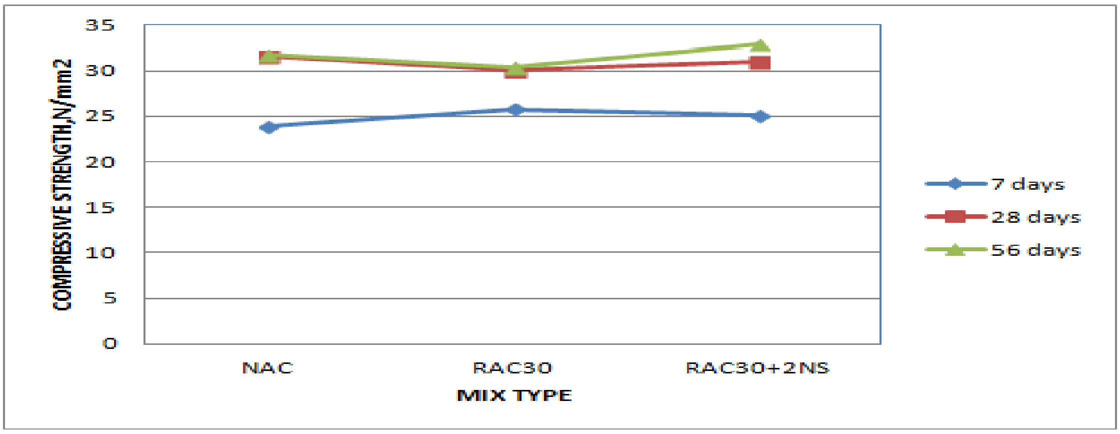

Fig.5.2 Variation of Compressive Strength with various type of mixes at 7, 28 and 56 days

At 28 days compressive strength of RAC with 30% of recycled aggregate is less by 4.78% and RAC with 30% of recycled aggregate and 2% of NS is less by 1.87% when compared to NAC whereas RAC30 + 2NS is 3.06% more when compared to RAC30. From the Table 5.1 it is observed that when compared to NAC compressive strength of RAC is more in the initial stages than lateral stage i.e at 56 days.

5.2 Split Tensile Strength Test

The Split Tensile strength test was conducted on cylinder test specimens for concrete mixes made with conventional aggregates and recycled coarse aggregates (for every percentage of replacement). The test was conducted on test specimens at the ages of 7, 28 and 56 days after proper curing till the day of test. Similarly, Split Tensile strength test was carried out on concrete mixes with Nanosilica along with conventional aggregates and recycled coarse aggregates.

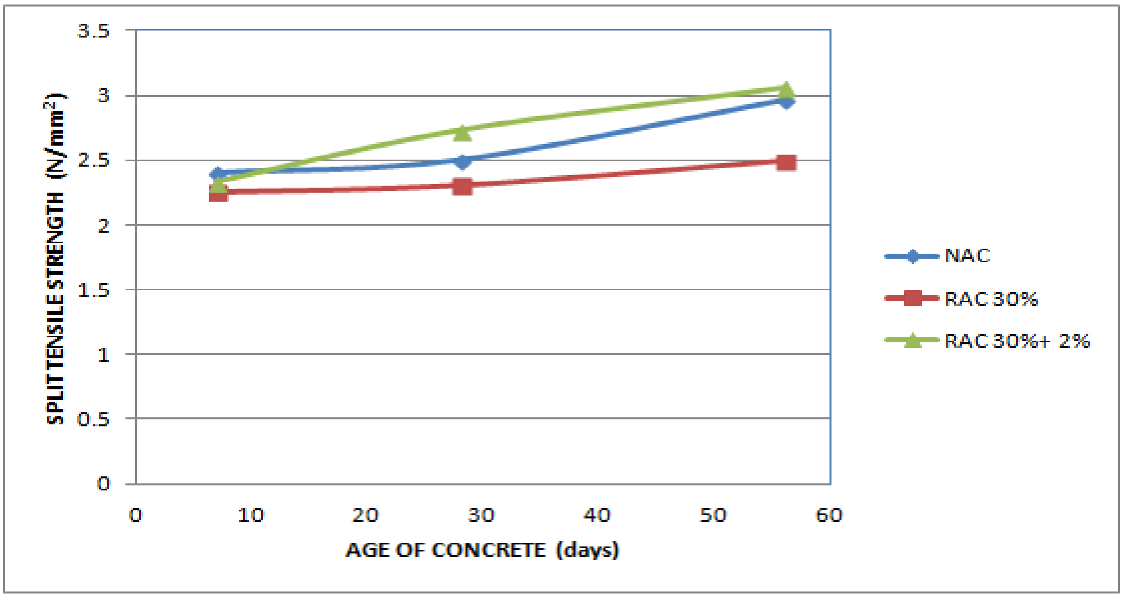

Fig.5.2 Comparison of Split Tensile Strength of NAC and RAC with Age

The 7days Split tensile Strength of NAC is 4.16% more when compared to 28 days Split tensile strength of NAC while 56 days Split tensile strength of NAC is more than 28 days Split tensile strength of NAC by 18.4%.The 7days Split tensile Strength of RAC 30 is 6.19% more when compared to 28 days Split tensile strength of RAC 30 while 56 days Split tensile strength of RAC 30 is more than 28 days Split tensile strength of RAC 30 by 7.79%.The 7days Split tensile Strength of RAC 30 + 2 NS is 9.2% more when compared to 28 days Split tensile strength of RAC 30 + 2 NS while 56 days Split tensile strength of RAC 30 + 2 NS is more than 28 days Split tensile strength of RAC30 + 2 NS by 12.08%.

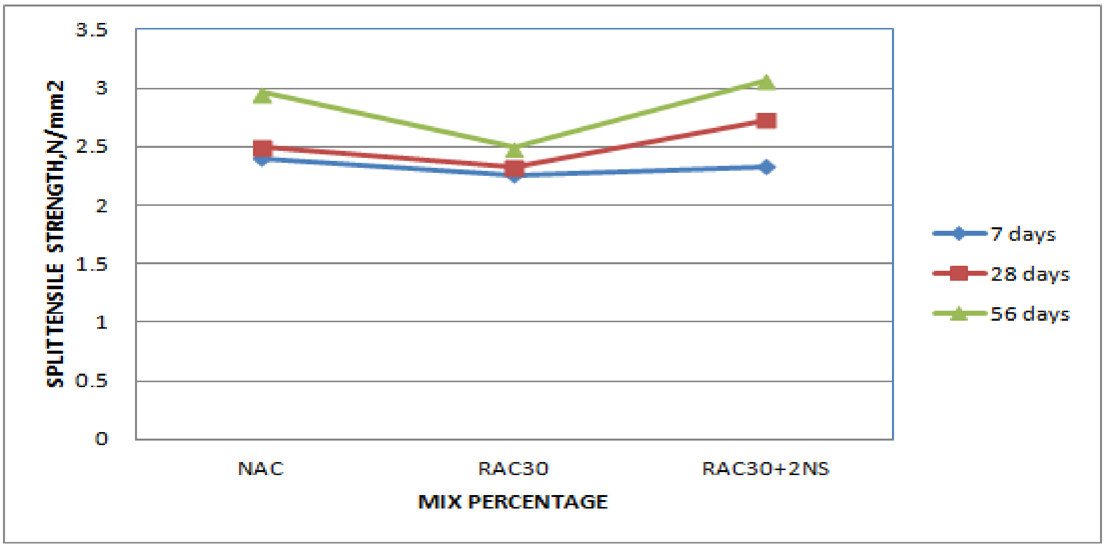

Fig.5.2 Variation of Split Tensile Strength with various mix types at 7, 28 and 56 days

The 28 days split tensile strength of RAC is observed to be more with the addition of NS. 28 days split tensile strength of RAC with 30% of recycled aggregate is more by 7.2% and RAC with 30% of recycled aggregate and 2% of NS is more by 9.20% when compared to NAC whereas RAC30 + 2NS is 17.67% more when compared to RAC30.From the table 5.2, it is observed that when compared to NAC split tensile strength of RAC is less in the initial stages than lateral stages i.e at 56 days.

5.3 Flexural strength test

The Flexural strength values obtained from the test for Natural Aggregate Concrete (NAC), Concrete with optimum percentage of Recycled Aggregate (30%) and concrete with Nanosilica (2%) along with conventional aggregates and recycled aggregates were presented in table 5.3 . Also the results were represented in the form of curves in Fig 5.3A & 5.3B.

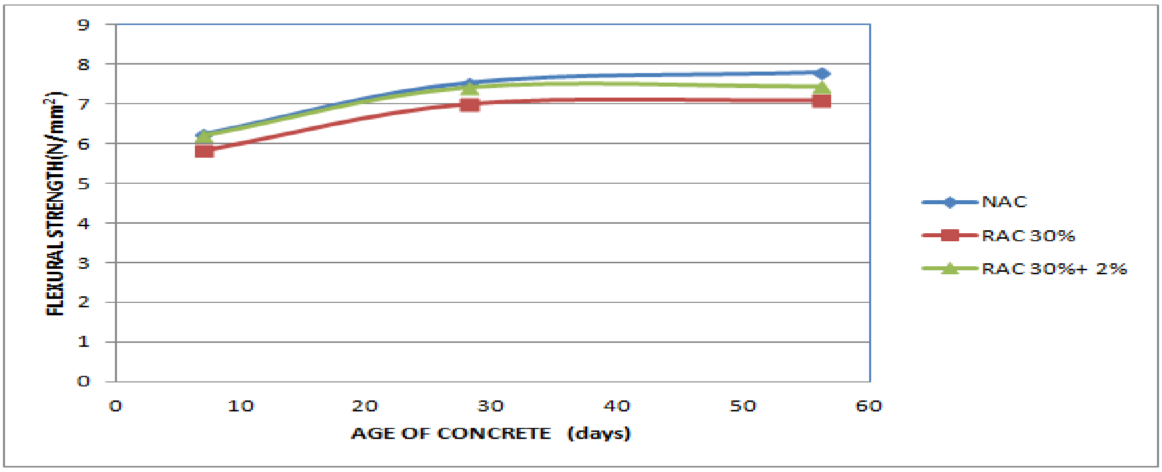

Fig.5.3 A) Comparison of Flexural Strength with age of concrete for various mixes

The 7days Flexural Strength of NAC is 20.44% more when compared to 28 days Flexural strength of NAC while 56 days Flexural strength of NAC is just 3.44% more than 28 days Flexural strength of NAC. The 7days Flexural Strength of RAC 30 is 7.19% more when compared to 28 days Flexural strength of RAC30 while 56 days Flexural strength of RAC 30 is just 1.42% more than 28 days Flexural strength of RAC30.The 7days Flexural Strength of RAC 30 + 2 NS is 19.13% more when compared to 28 days Flexural strength of RAC 30 + 2 NS while 56 days Flexural strength of RAC 30 + 2 NS is just 0.26% more than 28 days Flexural strength of RAC 30 + 2 NS.

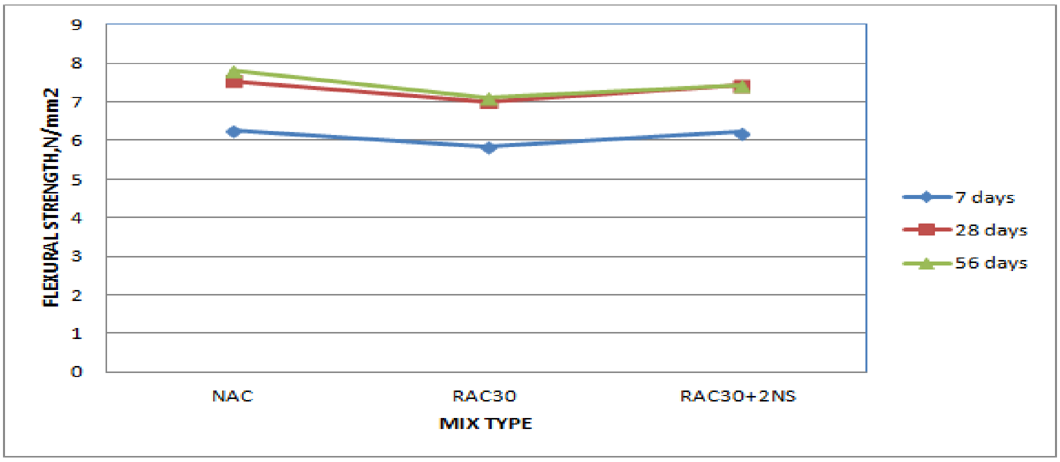

Fig. 5.3 B) Variation of Flexural Strength of NAC & RAC with mix type at 7, 28 and 56 days

The 28 days flexural strength of RAC is observed to be less with the addition of NS. 28 days flexural strength of RAC with 30% of recycled aggregate is decreased by 7.16% and RAC with 30% of recycled aggregate and 2% of NS is decreased by 1.72% when compared to NAC whereas RAC30 + 2NS is 5.85% more when compared to RAC30. From the table 5.1 it is observed that when compared to NAC flexural strength of RAC is less in the initial stages than lateral stages i.e at 56 days.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

NON DESTRUCTIVE TESTS

Rebound Hammer Test

The values of rebound strength obtained from the test for Natural Aggregate Concrete (NAC), Concrete with optimum percentage replacement of Recycled Aggregate (30%) and concrete with Nanosilica (2%) along with conventional aggregates and recycled aggregates.

Ultra Pulse Velocity Test

The ultra-pulse velocity values obtained from the test for Natural Aggregate Concrete (NAC), Concrete with optimum percentage replacement of Recycled Aggregate (30%) and concrete with Nanosilica (2%) along with conventional aggregates and recycled aggregates

6. CONCLUSION

The following conclusions are drawn from the experimental study.

1. From the results, it is observed that the values of slump of RAC with and with out addition of nanosilica are less than NAC.
2. Density and specific gravity property are less for recycled aggregate than norma. aggregate.
3. From the results it is observed that compressive strength of RAC30 with and without nanosilica are observed to be more in the initial stages than lateral stages when compared to NAC. Whereas split tensile strength and flexural strength are found to be less.
4. The 28 days Compressive Strength of RAC30 is less by 4.78 % when compared to NAC. Whereas RAC 30+2 NS is 1.87 % less when compared to NAC.
5. The 28 days Split Tensile Strength of RAC 30 is less by 7.20 % when compared to NAC while RAC 30+2 NS is 9.20 % more when compared to NAC.
6. The 28 days Flexural Strength of RAC 30 is less by 7.16 % when compared to NAC while RAC 30+2 NS is 1.72% less when compared to NAC.
7. All the strength characteristics of RAC30 increases with addition of 2% of Nano-sillica but workability characters such as slump may decrease when compared to Normal concrete design mix.
8. To make use of recycled aggregate and to obtain strengths almost equal to normal aggregate concrete (NAC), it is recommended to use Nano-sillica(NS) along with replacement of normal aggregate with recycled aggregate.
9. Usage of Recycled aggregate concrete (RAC) helps in decrease of solid waste such as demolished construction material, roads, water tanks, old RCC structures.

7. ACKNOWLEDGEMENTS

The Author would like to thank all the persons who helped in the completion of his experiment ta l work. Also thanks are extended to ASR College of Engineering, Tanuku, INDIA for support throughout the execution of the experimental work

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CITE AN ARTICLE

Amani, K., Rao, P. N., & Kumar, V. R. (2018). Recycled Aggregate, Nano-Silica, Strength Properties, Demolition. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 7*(6), 487-506.