Influence of Replacement Level of Recycled Aggregate on the Properties of No Fines Concrete

A Project Report

Submitted by

S. Krishna Priya - 0720101006

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(An Autonomous Institution Affiliated to Anna University, Coimbatore)

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Certified that this project report entitled "**Influence of Replacement Level of Recycled Aggregate on the Properties of No Fines Concrete**" is the bonafide work of **Ms. S.Krishna Priya - Register No. 0720101006** who carried out the project work under my supervision.

Signature of the Head of the Department

Dr.S.L.Narashimhan,

Professor & Head,

Department of Civil Engineering,

Kumaraguru College of Technology

Signature of the Supervisor

Dr.P.Eswaramoorthi

Professor,

Department of Civil Engineering,

Kumaraguru College of Technology

Certified that the candidate with university Register No. 0720101006 was examined in project viva voce Examination held on 04/05/09

Internal Examiner

External Examiner 4/5/09

DEPARTMENT OF CIVIL ENGINEERING

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(An Autonomous Institution Affiliated to Anna University, Coimbatore.)

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Title of the Paper : INFLUENCE OF RECYCLED AGGREGATE ON THE PROPERTIES OF NO FINES CONCRETE

Dr. S. PRABAVATHY
Chairman, AICE'09

Dr. S. BALAKRISHNAN
PRINCIPAL

KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE , TAMILNADU

DEPARTMENT OF CIVIL ENGINEERING

INNOVATIONS IN CIVIL ENGINEERING - ICE'09

CERTIFICATE

This is to certify that Mr/Ms S. Krishna Priya - PG Student

of Kumaraguru College of Technology, Coimbatore.

has participated ~~and presented a paper~~ in the National Conference on "INNOVATIONS IN CIVIL ENGINEERING - ICE'09" during 21st, April 2009.

Title Influence of replacement level of recycled aggregate on the properties of no fines concrete.

Dr.P.ESWARAMOORTHI & Mrs.K.RAMADEVI
CO-ORDINATORS

Dr.S.L.NARASIMHAN
CONVENOR

Prof.R.ANNAMALAI
VICE PRINCIPAL

ABSTRACT

In the present study, Control No-Fines (CNF) concrete mixes of Aggregate/Cement Ratios (ACR) varying from 5:1 to 8:1 with water/cement ratios 0.35, 0.4 and 0.45 were prepared to find an optimum mix yielding the highest strength. Later an investigation was undertaken to examine the suitability of recycled concrete aggregate for use in no-fines concrete to replace the coarse aggregate.

Two optimum water cement ratios were selected based on the higher strength values obtained for each set of ACR. Recycled no-fines (RNF) concrete mixes were cast for these optimized water cement ratios. An analysis comparing the mechanical properties of the CNF concrete mix and RNF concrete mixes with replacement levels 25% and 50% is presented.

Compressive strength was evaluated on concrete cubes at 7^{th} and 28^{th} days of curing. Flexural strength and split tensile test was conducted on beam and cylinder specimens Basic tests were also conducted to determine the fineness modulus, specific gravity &water absorption of natural and recycled coarse aggregate.

From the present study, it can be concluded that, no fines concrete can be used for structural applications. Also, demolished concrete can be effectively used for 25% replacement of coarse aggregate in no- fines concrete.

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SYMBOLS AND ABBREVIATIONS

CA	Coarse Aggregate
ACR	Aggregate Cement Ratio
WCR	Water Cement Ratio
CNF	Control No – Fines
RNF	Recycled No – Fines
RNF - 25	Recycled No – Fines concrete with 25% Replacement of Coarse Aggregate with Recycled/ Demolished Concrete
RNF - 50	Recycled No – Fines concrete with 25% Replacement of Coarse Aggregate with Recycled/ Demolished Concrete
	By-product being used constantly
›	Standardized By-product
	By-product being Studied
I I	By-product required to be Used
●	By-product being Studied Intensively
?	By-product not yet Used or Studied

RECYCLED AGGREGATE

CHAPTER 1
RECYCLED AGGREGATE

1.1 Introduction

Recycling is the act of processing the used material for use in creating new product. It is a relatively simple process. It involves breaking, removing and crushing existing concrete into a material with a specified size and quality. The quality of concrete with recycled concrete aggregates is very much dependent on the quality of the recycled material used. Reinforcing steel and other embedded items, if any, must be removed and care must be taken to prevent contamination by other materials.

Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Figure 1.1 Recycled Aggregate

1.2 Need for Recycling

Sustainable development is an important factor, which is directly connected with harmonious coexistence of human beings and nature. Large quantities of construction and demolition waste are disposed all over the world. Using these construction and demolition waste is effective for reduction of concrete waste. Moreover, extraction of sea sand is being prohibited from the viewpoint of environmental disruption. Production of alternative aggregate is important for reduction of environmental protection which emphasizes the need for use of recycled aggregate.

Reusing materials reduces disposal volumes and costs, conserves natural resources, and may even generate revenue.

1.3 Categories of Recycled Aggregate[5]

The current usage and research and development on the reuse of by-products related to concrete can be classified into the following three categories:

- Category 1: Use of by-products, from non-construction industries to concrete
- Category 2: Use of by-products, from concrete to concrete
- Category 3: Use of by-products, from concrete to other materials

TABLE 1.1 BY-PRODUCT MATERIALS USED IN CONCRETE

Category 1: From concrete to concrete
sludge from concrete plants→ cement, ○sludge water from concrete plants→ concrete
○ reuse of attached mortar in agitator drum using retarder
. reuse of refused concrete (concrete, cement, aggregate), ● recycled aggregate
Stone powder from recycle treatment of aggregate

Category 2: From non-construction industries to concrete	
Usage	By-product materials
Cement	sulfur, fly ash, blast furnace slag, converter slag, copper slag, mold sand for cast iron, ○ burned ash of garbage (for Eco-cement), tires, wooden panels of pinball machines, waste oil as fuel
Mineral admixtures	○ ground granulated blast furnace slag, ○ fly ash, ○ silica fume, □ground granulated glass, burned ash of garbage, □dust from ion casting, ○ lime powder, □stone powder, burned ash of sewage sludge, □ rice husk ash
Chemical admixtures	lignin, etc.
Aggregate	○blast furnace slag, ○copper slag, ○ferro-nickel slag, □ electric furnace oxidized slag, □crushed glass, ○ fly ash aggregate, □bricks, roof tiles, pottery, melted slag from burned ash of garbage, melted slag from burned ash of sewage sludge, □dust from ion casting, □ chopped plastics, □ paper, □mud

Category 3: From concrete to other materials
crushed concrete – sub base material for pavement
crushed concrete - filler for asphalt concrete , ground stabilizer
sludge from concrete plants into cement – alkalizing material for soil or water, ground stabilizer
? demolished concrete members – foot protection of levees, fish reefs

Symbols
: being used constantly, ○: standardized, :being studied, □:required to be used, ● : being studied intensively, ? : not yet used or studied

1.4 Historical Background[12]

The applications of recycled aggregate in the construction areas are wide and they had been used long time ago.

Wilmot and Vorobieff (1997) stated that recycled aggregate have been used in the road industry for the last 100 years in Australia. They also stated that the use of recycled aggregate for the construction and rehabilitation of local government roads has a great improve in the last five years.

C & D Recycling Industry (n.d.), the fact file stated that from the time of the Romans, the stones from the previous roads were reused when rebuilding their vaunted set of roads. It also stated that since the end of world war two, the recycling industry had been well established in Europe.

According to Seecharan (2004), the Detroid News stated that in 1980s, the old concrete crushed into a powder was a popular road builder at Michigan, USA.

1.5 Applications of Recycled Aggregate[12]

Traditionally, the application of recycled aggregate is used as landfill. Nowadays, the applications of recycled aggregate in construction areas are wide.

• Concrete Kerb and Gutter Mix

Recycled aggregate have been used as concrete kerb and gutter mix in Australia. According to Building Innovation & Construction Technology (1999), Stone says that the10mm recycled aggregate and blended recycled sand are used for concrete kerb andgutter mix in the Lenthall Street project in Sydney.

Figure 1.2: Application of Recycled Aggregate as Road Kerb
(Source: Building Innovation & Construction Technology, 1999)

• Granular Base Course Materials

According to Market Development Study for Recycled Aggregate Products (2001), recycled aggregate are used as granular base course in the road construction. It also stated that recycled aggregate had proved that better than natural aggregate when used as granular base course in roads construction. They also found that when the road is built on proved working surface for pavement structure construction.

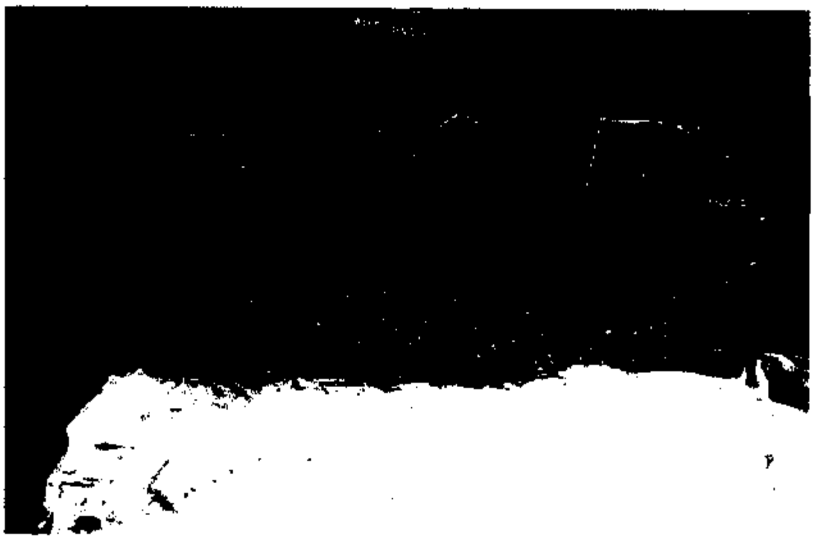

Figure 1.3: Recycled Aggregate used as Granular Base Course
(Source: Mehus and Lillestol (n.d))

• **Embankment Fill Materials**

Market Development Study for Recycled Aggregate Products (2001) stated that recycled aggregate can be used in embankment fill. The reason for being able to use in embankment fill is same as it is used in granular base course construction. The embankment site is on the wet sub grade areas. Recycled aggregate can stabilize the base and provide an improved working surface for the remaining works.

• **Paving Blocks**

Recycled aggregate have been used as paving blocks in Hong Kong. According to Hong Kong Housing Department (n.d.), recycled aggregate are used as typical paving blocks. A trial project had been started to test the long – term performance of paving blocks made with recycled aggregate in 2002.

Figure 1.4: Typical Paving Blocks

(Source: Hong Kong Housing Department, (n.d.)

• **Backfill Materials**

Recycled aggregate can be used as backfill materials. Mehus and Lillestol (n.d) found that Norwegian Building Research Institute (n.d) mentioned that recycled concrete aggregate can be used as backfill materials in the pipe zone along trenches after having testing in laboratory.

Figure 1.5: Recycled Aggregate as Backfill Materials

(Source: Mehus and Lillestol (n.d))

• **Building Blocks**

Recycled aggregate used as building blocks. Mehus and Lillestol (n.d) stated that Optiroc AS had used recycled aggregate to produce the masonry sound insulation blocks. The masonry sound insulation blocks that produced had met all the requirements during the laboratory testing.

Figure 1.6: Recycled Aggregate used as Building Blocks
(Source: Mehus and Lillestol (n.d))

•Aggregate for construction

Recycled aggregate has been used to replace both the fine and coarse aggregate in concrete. It has also been used to replace the cementitious material in concrete. Many researches have been conducted to test the feasibility of using the recycled coarse and fine aggregate.

1.6 Advantages[12]

• Environmental Gain

The major advantage is based on the environmental gain. According to CSIRO (n.d.).construction and demolition waste makes up to around 40% of the total waste each year (estimate around 14 million tones) going to land fill. By recycling this material. it can reduce the amount of natural resources extracted. Therefore. natural aggregate can be used in higher grade applications.

• Saves Energy

The recycling process can be done on site. If everything can be done on the construction site. from the process of recycled aggregate, to manufacture and using them. it can save energy to transport the recycled materials to the recycling plants.

• Cost

The cost of recycled aggregate is cheaper than virgin aggregate. According to PATH Technology Inventory (n.d.). the costs of recycled concrete aggregate are sold around $3.50 to $7.00 per cubic yard. It depends on the aggregate size limitation and local availability. This is just around one and half of the cost for natural aggregate that used in the construction works. The transportation cost for the recycled aggregate is reduced due to the weight of recycled aggregate is lighter than virgin aggregate. Concrete Network (n.d) stated that recycling concrete from the demolition projects can save the costs of transporting the concrete to the land fill (around $0.25 per ton/ mile), and the cost of disposal (around $100 per ton). Beside that. Aggregate Advisory Service (n.d.) also states that the recycling site may accept the segregates materials at lower cost than landfill without tax levy and recycled aggregate can be used at lower prices than primary aggregate in the construction works.

• **Job Opportunities**

There will be many people involved in this new technology, such as specialized and skilled persons, general workers, drivers and etc.

• **Sustainability**

The amount of waste materials used for landfill will be reducing through usage of recycled aggregate. This will reduce the amount of quarrying. Therefore this will extend the lives of natural resources and also extend the lives of sites that are used for landfill.

• **Market is wide**

The markets for recycled concrete aggregate are wide. According to Environmental Council of Concrete Organization (n.d), recycled concrete aggregate can be used for side walk, curbs, bridge substructures and superstructures, concrete shoulders, residential driveways, general and structural fills. It also mentioned that recycled concrete aggregate can be used in sub bases and support layers such as unstabilized base and permeable bases.

1.7 Disadvantages [5],[12]

Although there are many advantages of using recycled aggregate. There are still some disadvantages of using recycled aggregate.

• **Hard to have permit**

Jacobsen (1999) stated that it is hard to get the permit for the machinery that needed air permit or permit to operate during the recycling process. These has to depend on the local or state regulations whether this technology is implemented or not.

• **Lack of Specification and Guidelines**

According to Kawano (n.d), there is no specification or any guideline when using recycled concrete aggregate in the constructions. In many cases, the strength characteristic will not meet the requirement when using recycled concrete aggregate. Therefore, more testing should be considered when using recycled concrete aggregate.

• **Water Pollution**

The recycled process will cause water pollution. Morris of National Ready Mix Concrete Association (n.d) had mentioned that the wash out water with the high pH is a serious environmental issue. According to Building Green (1993), the alkalinity level of wash water from the recycling plants is pH12. This water is toxic to the fish and other aquatic life.

• **Cost**

The cost of transporting and treating demolished concrete is not low, because demolished concrete is typically produced in small quantities at different sites. Also, quality varies considerably; so much energy and significant costs are required to treat the demolished concrete. However, the machines for processing demolished concrete have improved remarkably.

• **Poor Image**

People tend to think that by-products are not of high quality. Of course, if the by-product had higher quality, it would already be in the market, so there must be some disadvantages. However, over-specified materials are often used in applications where by-products might satisfy the requirements, so the right materials must be used in the right places.

• **Lack of experience**

In construction areas, when we introduce new materials or new construction methods, experience is required in order to ensure safety. This may be a contradicting requirement, and may sometimes constitute a barrier to introducing new technology. Therefore demonstration and test projects should be constructed in order to introduce new technologies to construction sites. Recently, the time taken to create standards for new construction materials has become shorter than in the past.

• **Low quality**

Generally, recycled materials are of lower quality than virgin materials. However, for concrete materials, there are many techniques to apply such materials to structures without degrading the quality of structures. Performance-based design methods are favorable for using recycled materials.

We must recognize that trials to raise the quality of recycled materials lead to improvements in technologies. For example, machines for processing recycled aggregate from demolished concrete have been replaced by a crushing machine for new aggregate, but the requirement to obtain more recycled aggregate with low water absorption led to improvements in the machine. Recently, new types of processing machines have been developed which enable even higher quality recycled aggregate to be produced with lower energy consumption.

•**Variations in quality**

The quality of demolished concrete varies from site to site and the amount produced from each site is small. Almost all recycling plants are small and lack large stock yards. This fact cause wide variations in the quality of recycled materials from the plants, and is also the case for other by-products. Wide variations require frequent quality control testing and may trigger concern about the quality of structures made using such concrete.

However, should the same quality control standards be applied for recycled materials? For example, aggregates used in demolished concrete have already passed the standards for concrete aggregate, so we may be able to eliminate some testing. Additionally, easy and frequent quality control test methods could be more effective when using recycled materials.

•Too many kinds and too large amounts of by-products

Today mass-consumption society generates large quantities of many kinds of wastes and by-products. Repeated recycling use for the same purpose is ideal, but economic barriers exist. The easiest approach is disposal, but this leads to environmental problems and exhausts resources.

People like to think that the second easiest solution is to use these materials as construction materials and that almost all kinds of waste can be used for either concrete or asphalt concrete, and if this is not possible, then as a soil substitute.

Are construction sites litter boxes? We should not choose the easy way out. We must consider the feasibility of reusing these materials again as well as the performance of the structures. Crushed glass aggregate will not only create an alkali-aggregate reaction problem but will also create difficulty when reusing glass aggregate concrete. The same applies for plastics aggregate.

•Inefficient supply system

The supply system for concrete materials in Japan is very efficient and stable, making it very difficult for new materials to enter the market. A rise in of supplying cost is vital for low-price concrete materials.

The key to suppressing the cost of recycled materials is information. An information network connecting demolition sites, treatment plants and re-usable sites is essential, which will help minimize the cost of transportation and storage.

• Lack of proper information

There are two aspects of information. One concerns item b) lack of codes, specifications, standards and guidelines. Have we been announcing the correct information on recycled materials, such as what kinds of recycled material are available, and what kind of usage is recommended? The other aspect is information regarding the supply.

NO - FINES CONCRETE

CHAPTER 2

NO – FINES CONRETE

2.1 Introduction

No-fines construction is very simple in basic concept. No - fines concrete is a made up of only coarse aggregate, cement and water. This concrete is obtained by omitting the fine aggregate from the mix so that there is an agglomeration of nominally one - size coarse aggregate particles, each surrounded by a coating of cement paste up to 1.3 mm thick. Very often only single sized coarse aggregate of size passing through 20 mm retained on 10 mm is used.5% oversize and 10% undersize are allowed but no material should be smaller than 5 mm. Sharp edged Coarse aggregate should be avoided as, local crushing can occur under load.

Single sized aggregates make a good no –fines concrete, which in addition to having large voids and hence light in weight, also offers architecturally attractive look.

2.1.1 Historical Background

No-fines concrete lends itself to use in housing systems building; it has in fact been used for this purpose for about 60 years.

The first no-fines concrete houses were built in the Netherlands after World War I with crushed clinker as the aggregate. Later about 50 houses were built in Scotland using the same material.

In 1937 the Scottish Special Housing Association (SSHA) was set up to provide work for unemployed coalminers. Because the labor was inexperienced in construction, traditional methods of building were discarded in favor of the no-fines system, but the construction manager decided to use crushed whinstone plentifully available there—instead of clinker. This gave a stronger, more uniform concrete.

About 900 houses were built by this method in Scotland before World War II and these are still in good condition. Since the end of the war the SSHA has developed the system to build houses with the minimum of labor and yet without sacrificing design standards. Most of the housing has been simple 2-story homes and 3- or 4-storyapartment buildings. Twelve 10-story apartment buildings have also been built using load bearing no -fines walls.

The SSHA builds more than 4000 houses a year, mostly of the no-fines type. The system has therefore become a significant factor in Scottish housing—thanks to a housing association rather than a contractor.

George Wimpey and Company Ltd., one of Britain's largest contractors and homebuilders, developed the no-fines system on a commercial basis and introduced it to world markets. Wimpey adopted the system after World War II, when there was an acute housing problem in Britain. Hundreds of thousands of houses were needed but materials and skilled labor were in short supply. Since then the company has developed the method into what has been described as Britain's most successful housing system.

2.1.2 Mix Proportion[17]

No - fines concrete is generally made with the aggregate / cement ratio ranging from 5:1 to 10:1.Unlike the conventional concrete, in which the strength is primarily controlled by the water/ cement ratio, the strength of no - fines concrete, is dependent on the water/cement ratio, aggregate / cement ratio and unit weight of concrete.

The water/ cement ratio for satisfactory consistency will vary between a narrow range of 0.38 and 0.52.Water/cement ratio must be chosen with care. If too low a water/ cement ratio is adopted, the paste will be so dry that aggregates do not get properly smeared with paste which results in insufficient adhesion between the particles. On the other hand, if the water/cement is too high, the paste flows to the bottom and makes that portion dense. This condition also reduces the adhesion between aggregate and aggregate owing to the paste becoming very thin.

2.1.3 Workability[17]

No standard method is available, like slump test or compacting factor test for measuring the consistency of no – fines concrete. Perhaps a good, experienced visual examination and trial and error method may be the best guide for deciding optimum water/cement ratio.

2.1.4 Compaction[17]

No - fines concrete does not pose a serious problem for compaction. Uses of mechanical compaction or vibratory methods are not required. Simple rodding is sufficient for full compaction.

2.1.5 Formwork and Curing[13],[17]

No - fines concrete does not give much side thrust to the formwork as the particles are having point to point contact and the concrete does not flow. Therefore, the side of the formwork can be removed in a time interval shorter than for conventional concrete. However, formwork may be required to be kept for a longer time, when used as a structural member, as the strength of concrete is comparatively less.

Moist curing is important, especially in a dry climate or under windy conditions, because of the small thickness of cement paste involved.

2.1.6 Density and Compressive strength[13],[17]

For a given type of aggregate, the density of no – fines concrete depends primarily on the grading of the aggregate. With one size aggregate, the density is 10% lower than when a well graded aggregate of the same specific gravity is used. No – fines concrete, when conventional aggregates are used may show a density of about 1600 to 1900 kg/m^3 , but when no- fines concrete is made by using light weight aggregate, the density may come to about 360 kg/m^3.

The compressive strength of no - fines concrete varies between1.4 and 14 MPa.The increase in strength with age is similar to that of ordinary concrete.

2.1.7 Bond strength[13],[17]

The bond strength of no - fines concrete is very low and therefore reinforcement cannot be used in conjunction with no - fines concrete. However, if reinforcement is required to be used in no - fines concrete. it is advisable to smear the reinforcement with cement paste to improve the bond and also to protect it from rusting. The easiest way to coat the reinforcement is shotcreting.

2.1.8 Modulus of Rupture[13]

The Modulus of Rupture is about 30% of the compressive strength, a proportion which is higher than for normal weight concrete.

2.1.9 Drying Shrinkage[17]

The drying shrinkage of no - fines concrete is considerably lower than that of conventional concrete. No - fines concrete made with river gravel, may show a drying shrinkage of the order of 200×10^{-6} which is only about 50% of the conventional concrete .Since there is only a thin layer of paste existing between aggregates and aggregates. and since the aggregates are having point to point contact. the value of drying shrinkage has become low. However the rate of drying shrinkage is generally much higher than conventional concrete. For no - fines concrete 50% to 80% of the total drying shrinkage takes place within about 10 days. The corresponding value for conventional concrete in 10 days is 20 to 30%.Further all the drying shrinkage will get completed in just over a month.

2.1.10 Thermal Conductivity[17]

The value of coefficient of thermal conductivity of no - fines concrete is much less than conventional concrete.

2.2 Applications [13],[17]

- It can be used for load bearing cast-in situ external walls for single storey and multistory buildings.
- It can be used for temporary structures because of low initial cost and also for the ease with which it can be broken and reused as aggregate.
- The best application of no – fines concrete is that it can be used as a drainage medium in parking lots. tennis courts. trails, play areas as it allows rainwater to seep directly into the ground. groundwater is

recharged, water resources are preserved, storm water runoff is reduced or eliminated, and water quality is improved

- It can be used for the construction of pavements, low speed roadways etc.

2.3 Advantages[13],[17]

- Owing to slightly higher thermal insulating property, it can be used for external walls for heat insulation.
- Because of rough texture, it gives a good base for plastering.
- Even if the outside surface of the no – fines concrete wall is subjected to rain beating, the inside of the wall will be free from dampness because of low capillary action on account of large voids as rate of water penetration is low.
- Where sand is not available or there is scarcity of sand, no – fines concrete should become a popular construction material.
- Architects consider this as an attractive construction material.
- Since no – fines concrete does not segregate, it can be dropped from a considerable height and placed in high lifts.
- Since sand is absent and the cement content of no- fines concrete is low, its cost is comparatively low.(In lean mixes, the cement content is estimated as 70- 130 kg of cement per cubic metre of concrete)
- Because of absence of capillaries, it is highly resistant to frost, provided that the pores are not saturated, in which case, freezing would cause a rapid disintegration.
- It has lower drying shrinkage and lower density. The lower density of no-fines concrete helps in reduction of dead load increases the progress of the construction and lowers haulage and handling costs.
- Although the strength of no – fines concrete is considerably lower than that of normal weight concrete, coupled with lower self weight, is

sufficient for use in buildings, even of many storeys and in many other applications.

2.4 Disadvantages[13],[17]

- High absorption of water (up to 12% by mass) makes no- fines concrete unsuitable for use in foundation. Although under less severe conditions, the absorption is less, it is still necessary to render external walls on both sides, a practice which reduces the permeability to air as well as the sound absorbing properties of no - fines concrete. Where the acoustic properties are considered to be of paramount importance, one side of the wall should not be rendered.
- No-fines concrete has lower strength compared with normal concrete because of the presence of large voids.

OBJECTIVE AND SCOPE OF THE PROJECT

CHAPTER 3

OBJECTIVE AND SCOPE OF THE PROJECT

3.1 Project Objective

- To investigate the performance characteristics of no fines concrete
- To examine the suitability of recycled aggregate for use in no-fines concrete to replace the coarse aggregate with two replacement levels.

3.2 Project Scope

- Review of recycled aggregate and no - fines concrete
- Cast control no- fines concrete and recycled coarse aggregate no – fines concrete specimens with two replacement levels.
- Test the cast specimens
- Analyze the results and propose recommendations for future work

LITERATURE REVIEW

CHAPTER 4

LITERATURE REVIEW

4.1 Review of Recycled Aggregate

Keun-Hyeok Yang et al. (2008)

Test results of nine recycled aggregate concretes and a control concrete using only natural aggregates are reported .The recycled aggregates used were classified into three different types according to their measured specific gravity and water absorption, namely , RGI for recycled coarse aggregate having a specific gravity of 2.53 and water absorption of 1.9%; RGIII for recycled coarse aggregate having a specific gravity of 2.4 and water absorption of 6.2%; and RS II for recycled fine aggregate having a specific gravity of 2.36 and water absorption of 5.4%.The replacement levels of both coarse and fine aggregates were 30.50 and 100% in separate mixtures. Slump loss and the amount of bleeding with time were recorded for fresh concrete. Compressive and tensile strengths, moduli of rupture and elasticity, and unrestrained shrinkage strain were also measured for hardened concrete. The properties of fresh and hardened concreter tested, together with a compressive database reported in the literature, were evaluated with respect to the relative water absorption of aggregates combining the quality and volume of recycled aggregates used. In addition, the properties of hardened concrete with different replacement levels and quality of recycled were compared with the design equations of ACI 318-05 and empirical equations proposed by OLuokun for natural aggregate concrete, whenever possible. Test results clearly showed that the properties of fresh and hardened concrete containing recycled aggregates were dependent on the relative water absorption of aggregates .In addition, the moduli of rupture and elasticity of recycled aggregate concrete were lower than the design equations of ACI 318-05. when the relative water absorption of aggregates is above 2.5% and 3.0% respectively.

Dae-Jung Moon.et al(2008)

Recycled concrete powder, which was generated by crushing waste concrete, was reutilized as concrete material. The experiment intends to perform several tests for the exploitation of recycled concrete powder as cementitious material. The recycled concrete powder significantly influences the properties of mortar according to the type of recycled concrete powder, replacement ratio, and mix design. The flexural strength and compressive strength after 28 days of the mortar mixed with matrix recycled concrete powder was slightly larger than that of mortar using demolished recycled concrete powder. Thus, the use of recycled concrete powder will be promoted and realized through the utilization of self-consolidating concrete, pavement concrete, and roller compacting concrete.

Justin Benge.et al (2008)

The use of reclaimed concrete as aggregate for new concrete and its influence on the mechanical properties has been investigated. The replacement of both fine and coarse aggregate was tested. Three different mixes were prepared, the first mix, or control mix, was prepared with natural aggregate, two additional mixes were prepared with different percentage of substitution of coarse aggregates. Weight evolution of the concrete as a function of age was measured on 2"x2"x2"concrete cubes subjected to different relative humidity conditions. Compressive strength was evaluated on concrete cylinders (4" x 8") at different ages: 3, 7, 14, 21 and 28 days. Porosity of different mixes with the same water to cement ratio is compared. The same procedure of testing was used with reclaimed concrete from existing structures (demolition products) and with concrete from laboratory testing. An analysis comparing physical and mechanical properties of the three mixes is presented.

Yasutaka Sagawa.et al.(2007)

In this study, the strength and the carbonation speed of the mortar incorporating recycled fine aggregate were examined. Strength and carbonation speed could be evaluated by total water-cement ratio, which was obtained by summation of water content and total water absorbed in aggregate. Pore volume between 50nm and 2μm in new cement matrix phase was porous and loose when recycled fine aggregate with high water absorption was used in mortar. Performance of mortar incorporating
recycled fine aggregate correlated closely with pore volume between 50nm and 2μm in new cement matrix phase. It was suggested that water included in recycled aggregate moved to new cement matrix phase during cement hydration.

Zeinab Salah Ell Din Houssieen (2006)

It is an economic concept to get red of any demolished type by using in constructions, so, in Egypt; there are many activities in the field of recycled aggregate for using in different ways. This study aims to identify the properties for concrete of demolished aggregates as coarse and fine aggregates. Local aggregates such as siliceous, limestone, basalt as coarse aggregates and siliceous sand as fine aggregate and air cooled slag (course and fine) were used to study their physical and mechanical properties. In addition, concrete mixes of the used aggregates were prepared to investigate the effect of using demolished aggregates with every type of the local aggregates separately at the percentages (25, 50, and 75) %.Concrete mixes properties were investigated for fresh and hardened states. Those properties were slump, and density in fresh state, compressive, flexural, tensile strengths, and drying shrinkage in hardened state

M.Kalaiarasu.et al.(2006)

This study describes about the investigation undertaken to examine the suitability of recycled concrete as a substitute for fine aggregate. Recycled concrete (artificial sand) is used for 40% of fine aggregate and natural sand is retained for the remaining part.HPC of M 60 grade is attempted, with different replacement levels of cement with silica fume. Maximum 28 day compressive strength of 71.70 MPa with 15% replacement of cement with silica fume was observed for water -binder ratio of 0.32 acid resistance and chloride impermeability increases with increase of silica fume content.

Nelson, Shing Chai NGO (2004)

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The aim for this on – going project is to determine the strength characteristic of recycled aggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete. The scope of this project is to determine and compare the high strength concrete by using different percentage of recycled aggregates.

The investigation was carried out using workability test, compressive test, indirect tensile test and modulus of elasticity test. There were total of eight batches of concrete mixes, consists of every 20% increment of recycled aggregate replacement from 0% to 100%.

Moreover, 100% of recycled aggregate mix batches included fly ash, water/cement ratio of 0.36 and 0.43. The workability of concrete considerably reduced as the amount of recycled aggregate increased. This was evaluated through standard slump test and compacting factor test. For strength characteristics, the results showed that a gradually decreasing in compressive strength, tensile strength and modulus of elasticity as the percentage of recycled aggregate used in the specimens.

4.2 Review of No- fines concrete

Vernon R. Schaefer et al. (2006)

Portland cement pervious concrete (PCPC) is being used more frequently due to its benefits in reducing the quantity of runoff water, improving water quality, enhancing pavement skid resistance during storm events by rapid drainage of water, and reducing pavement noise. In the United States, PCPC typically has high porosity and low strength, which has resulted in the limited use of pervious concrete, especially in hard wet freeze environments (e.g., the Midwestern and Northeastern United States and other parts of the world). Improving the strength and freeze-thaw durability of pervious concrete will allow an increase in its use in these regions. The objective of this research is to develop a PCPC mix that not only has sufficient porosity for storm water infiltration, but also desirable strength and freeze-thaw durability. In this research, concrete mixes were designed with various sizes and types of aggregates, binder contents, and admixture amounts. The engineering properties of the aggregates were evaluated. Additionally, the porosity, permeability, strength, and freeze-thaw durability of each of these mixes was measured. Results indicate that PCPC made with single-sized aggregate has high permeability but not adequate strength. Adding a small percent of sand to the mix improves its strength and freeze-thaw resistance, but lowers its permeability. Although adding sand and latex improved the strength of the mix when compared with single-sized mixes, the strength of mixes where only sand was added were higher. The freeze-thaw resistance of PCPC mixes with a small percentage of sand also showed 2% mass loss after 300 cycles of freeze-thaw. The preliminary results of the effects of compaction energy on PCPC properties show that compaction energy significantly affects the freeze-thaw durability of

PCPC and, to a lesser extent, reduces compressive strength and split strength and increases permeability.

L. K. Crouch et al. (2006)

This Tennessee Concrete Association sponsored study used a two-fold approach to obtain information on pervious PCC static modulus of elasticity (ASTM C 469), split tensile strength (ASTM C 496), and flexural strength (ASTM C 78). In the first approach existing correlations for normal PCC were applied to pervious PCC field and laboratory data. Secondly, the impact of effective void content on the previously mentioned properties was determined.

Thirty-three pairs of field cores and cylinders from various locations in Tennessee were used to evaluate the Ahmad and Shah correlation between compressive and split tensile strength. Predicted and measured values differed by twenty percent or less in 91.9 percent of the cases.

The average compressive strength and unit weight of twenty-three sets of laboratory cast cylinders were used to predict static modulus of elasticity using the ACI 318 equation.

Predicted and measured values differed by twenty percent or less in 87 percent of the cases. Further, the relationship was found to be conservative (measured greater than predicted) in 82.6 percent of the cases.

Twelve pairs of field sawed beams and cores as well as six sets of laboratory cast cylinders and beams were used to evaluate the Ahmad and Shah and ACI 318 correlations between flexural and compressive strength. For the Ahmad and Shah relationship, predicted and measured values differed by twenty percent or less in 88.8 percent of the cases. For the ACI 318 relationship, predicted and measured values differed by twenty percent or less in 61.2 percent of the cases. The relationship was conservative in 66.7 percent of the cases.

All parameters declined with increasing effective void content; correlation coefficients ranged from 0.3827 to 0.7805.

Paul James Harber (2005)

Considerable research has been conducted on environmentally sustainable development. This has lead to the use of no-fines concrete in place of conventional concrete and asphalt surfaces. This material dramatically reduces environmental degradation and the negative effects associated with urban sprawl. No-fines concrete has been used as an effective method for treating and reducing negative environmental impacts.

Problems plagued the initial development, with the pores becoming clogged and stopping the water from passing through, causing ponding and reducing the skid resistance of the road surface. The second problem was concerned with the unsightly ravelling that occurs on the surface shortly after construction and the unsafe perception that this creates.

This thesis analyses the effectiveness of no-fines concrete in pavement applications. This was achieved by analyzing the properties and characteristics of no-fines concrete. The performance of no-fines concrete was compared with concrete sample that is comparable to the material used for the construction of conventional concrete road pavements.

The analysis was undertaken by conducting a number of standard concrete tests and comparing the characteristics of the no-fines and conventional concrete samples. The tests included both fresh and hardened concrete tests to obtain a complete picture of its properties during the construction and working phase. The tests conducted to determine the fresh concrete properties were the slump, VEBE and compacting factor tests. These were complimented by hardened concrete tests including the following: compressive strength, indirect tensile strength, modulus of rupture and elasticity and skid resistance.

It was found that no-fines concrete pavements possess some positive features like increased skid resistance and high permeability but lacks the high strength required for highly trafficked areas. No-fines concrete has proven to have properties suitable for use in low volume traffic areas. The properties found may change depending on the aggregate particle chosen, however this aspect requires further investigation. Nonetheless, if no-fines concrete pavements can be implemented, it will have numerous positive affects on the environment.

Nader Ghafoori et al. (2004)

No-fines concrete is made from a uniformly graded coarse aggregate and a cement-water paste. Because of its excellent drainage properties. no-fines concrete is found to be beneficial in areas that receive frequent and sometimes excessive rainfall. This paper discusses thickness design of no-fines concrete parking lot pavements. Based on the engineering properties of the no-fines concrete mixtures developed in the laboratory, and various traffic conditions and sub grade characteristics, the thickness requirement of no-fines concrete pavements was determined. Two design procedures, American Association of State Highway and Transportation Officials (AASHTOJ and Portland Cement Association (PCA). were used for the thickness evaluation of no-fines concrete parking lots. Test results obtained in the laboratory indicate that, with proper proportioning and densification, no-fines concrete can be successfully utilized as a surface paving material for the construction of parking-lot pavements. The thickness design tables indicate that PCA design procedure is more reasonable for thinner pavements, whereas AASHTO yields a more conservative outcome for thicker pavements. For intermediate traffic categories, both design methods provided similar thickness results.

Paul D. Tennis. et al. (2004)

Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater and minimize storm water runoff. This introduction to pervious concrete pavements reviews its applications and engineering properties, including environmental benefits, structural properties, and durability. Both hydraulic and structural designs of pervious concrete pavements are discussed, as well as construction techniques.

T Abadjieva et al. (1994)

No-fines concrete is a form of lightweight porous concrete, obtained by eliminating the sand from the normal concrete mix. The advantages of this type of concrete are lower density, lower cost due to lower cement content, lower thermal conductivity, relatively low drying shrinkage, no segregation and capillary movement of water. better insulating characteristics than conventional concrete because of the presence of large voids.

This paper presents the results of an investigation to determine the performance characteristics of concrete mixes made without fine aggregates. Single sized course aggregates fraction 13.5-19 mm from Kgale Hill quarry and Ordinary Portland cement were used in the experiments. Concrete mixes with different aggregate/cement and water/cement ratios were prepared to find an optimum mix yielding the highest strength. The influences of the above factors on the density, dynamic modulus of elasticity, compressive, tensile and flexural strength were studied experimentally. It was found that the strength of no-fines concrete is lower that that of normal weight concrete, but sufficient enough for structural use. Due to its high ratio of continuous voids. this concrete has high water permeability. The suggested mixtures can be used for cast in-situ walls in low-rise. low cost housing (later plastered externally to reduce air and water permeability).

John Kyrle Moss (1961)

Like many other successful ideas, no-fines construction is very simple in basic concept. No- fines concrete is a mix containing only carefully graded clean aggregate—approximately 3.4 to 3.8 inch(1)* in size—and Portland cement. These are combined at rates of one part of cement with 8 to 10 parts of aggregate. No fine material—either sand or gravel—is included.

Such mixtures produce an open textured cellular concrete with a high volume of voids and good insulating properties. The U-value for an external 10-inch(2) wall with an internal dry lining is 0.20 Btu per hour square foot degree F. (3) The mix is lighter than normal weight concrete and it is very strong; walls made with it are load bearing.

Fresh no-fines concrete compacts well inside formwork under its own weight and needs no mechanical compaction. It lends itself to use in housing systems building; it has in fact been used for this purpose for about 60 years.

No-fines concrete has considerable drainage property and a relatively low strength. A wide aggregate grading range, with higher percentage of aggregate in lower bound, improves strength properties; however such grading results in lower drainage capability. The objective of this paper is to make high- performance single-sized No-fines Concrete mixes using polymer modification. An experimental program was carried out to study the parameters of water- cement ratio, aggregate-cement ratio, type of polymer, polymer content, setting time and curing period. The test specimens were 6x12 in. cylinders and were cast using hand rodding compaction in accordance with ASTM C 31-69. Initially a proper capping method was established to minimize its influence on the concrete strength. Then water-cement ratio of the concrete was optimized based on elimination of aggregate segregation in the fresh concrete and reaching the highest possible strength. Later, two mixes with different ratios for aggregate- cement were selected, one with low cement content, and another with high cement content. These mixes were polymer modified by Styrene-butadiene and Acrylic latex. Test results indicate that Styrene-butadiene polymer improves the strength performance of low-cement No-fines concrete, however Acrylic latex is beneficial in both mixes. The Acrylic modified mixes were more time sensitive than the Styrene-butadiene mixes. As a result, the Styrene-butadiene mixes are more applicable in practice.

EXPERIMENTAL PROGRAMME

CHAPTER 5

EXPERIMENTAL PROGRAMME

5.1 Materials and Methods of Testing

No fine concrete mixes of aggregate/cement ratios 5:1 to 7:1 with water/cement ratios 0.35, 0.4 and 0.45 using Portland Pozzolona cement and one sized ordinary dense course aggregates fraction 20-10 mm were prepared to find an optimum mix yielding the highest strength. Later an investigation was undertaken to examine the suitability of recycled concrete aggregate for use in no-fines concrete to replace the coarse aggregate with two replacement levels.

Recycled coarse aggregate no fines concrete mixes were prepared for two optimum water /cement ratios for each set of aggregate/cement ratio and compared with control no fines concrete made with natural aggregate. The replacement levels were 25% and 50%.

Cubes with a side of 150 mm, beams 500 x 100 x 100 mm and cylinders with diameter 150 mm and height 300 mm were prepared using gentle rodding only. Vibration and workability tests cannot be done due to very little cohesion between particles. Only a visual check to ensure even coating of all particles was used. The samples were cured in water, which is very important because of the small thickness of the cement paste involved.

5.2 Quantities of Materials

The quantities of materials for different ACR ranging from 5:1 to 7:1 are given in tables 5.1 to 5.6.

TABLE 5.1 QUANTITIES OF CEMENT AND CA FOR ACR 5:1

Quantities in kg	For 1 cube	For 3 cubes	For 6 cubes	For 1 beam and 1 cylinder
Cement	1.13	3.40	6.80	3.40
CA	5.67	17.01	34.02	18.00

TABLE 5.2 QUANTITY OF WATER FOR ACR 5:1

Water Cement Ratio		0.35	0.4	0.45
Quantity of water in kg	3 cubes	1.19	1.36	1.53
	6 cubes	2.38	2.72	3.06
	1beam and 1 cylinder	1.19	1.36	1.53

TABLE 5.3 QUANTITIES OF CEMENT AND CA FOR ACR 6:1

Quantities in kg	For 1 cube	For 3 cubes	For 6 cubes	For 1 beam and 1 cylinder
Cement	0.95	2.83	5.67	3.00
CA	5.67	17.01	34.02	18.00

TABLE 5.4 QUANTITY OF WATER FOR ACR 6:1

Water Cement Ratio		0.35	0.4	0.45
Quantity of water in kg	3 cubes	0.99	1.14	1.28
	6 cubes	1.98	2.27	2.55
	1beam and 1 cylinder	1.05	1.20	1.35

TABLE 5.5 QUANTITIES OF CEMENT AND CA FOR ACR 7:1

Quantities in kg	For 1 cube	For 3 cubes	For 6 cubes	For 1 beam and 1 cylinder
Cement	0.81	2.43	4.86	2.57
CA	5.67	17.01	34.02	18.00

TABLE 5.6 QUANTITY OF WATER FOR ACR 7:1

Water Cement Ratio		0.35	0.4	0.45
Quantity of water in kg	3 cubes	0.85	0.97	1.10
	6 cubes	1.70	1.94	2.19
	1beam and 1 cylinder	0.90	1.03	1.16

TEST RESULTS ND DISCUSSIONS

CHAPTER 6
TEST RESULTS AND DISCUSSIONS

6.1 Test Results

6.1.1 Basic Tests

Table 6.1 shows the test results for the basic tests conducted on the Coarse Aggregate samples

TABLE 6.1 BASIC TEST RESULTS OF CA

Properties of CA	Normal CA	Recycled CA
Fineness Modulus	6.0	6.07
Specific Gravity	2.58	2.60
Water Absorption	0.4%	3.0%

6.1.2 Compressive Strength

Compressive strength was evaluated on concrete cubes after 7 and 28 days of water curing. The compressive strength of CNF concrete was found out and two optimum water cement ratios were selected based on the higher strength values obtained for each set of ACR. RCF concretes were cast for these optimized water cement ratios. The comparison between the compressive strengths of CNF concrete and RNF concrete is given in the form of a bar chart for each set of ACR.

The colored values denote the optimum water cement ratios for which RNF concrete specimens were cast for each set of ACR.

The compressive strength test results for ACR 5:1 are given in tables 6.2 to 6.4. Figure 6.1 shows the compressive strength testing apparatus.

TABLE 6.2 COMPRESSIVE STRENGTH TEST RESULTS FOR CNF CONCRETE WITH ACR 5:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	5:1	0.35	5.08	2030	12.44	1946
2	5:1	0.40	5.77	2073	11.11	2044
3	5:1	0.45	5.67	2124	10.81	2086

TABLE 6.3 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 25 CONCRETE WITH ACR 5:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	5:1	0.35	4.88	2173	12.03	2048
2	5:1	0.40	5.56	2095	10.97	2074

TABLE 6.4 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 50 CONCRETE WITH ACR 5:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	5:1	0.35	4.53	2103	11.3	2000
2	5:1	0.40	4.96	2100	9.9	2089

The compressive strength test results for ACR 6:1 are given in tables 6.5 to 6.7.

TABLE 6.5 COMPRESSIVE STRENGTH TEST RESULTS FOR CNF CONCRETE WITH ACR 6:1

S.No	ACR	WCR	7 days		28 days	
			Comp. strength N/mm^2	Density Kg/m^3	Comp. strength N/mm^2	Density Kg/m^3
1	6:1	0.35	3.05	2025	9.18	1916
2	6:1	0.40	1.24	1799	4.66	1886
3	6:1	0.45	3.61	1973	5.48	1965

TABLE 6.6 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 25 CONCRETE WITH ACR 6:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	6:1	0.35	3.00	2133	9.11	2286
2	6:1	0.45	3.60	2090	5.37	2074

TABLE 6.7 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 50 CONCRETE WITH ACR 6:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	6:1	0.35	2.87	2186	8.26	2290
2	6:1	0.45	3.05	2100	4.93	2180

The compressive strength test results for ACR 6:1 are given in tables 6.8 to 6.10.

TABLE 6.8 COMPRESSIVE STRENGTH TEST RESULTS FOR CNF CONCRETE WITH ACR 7:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	7:1	0.35	1.37	1827	3.40	1906
2	7:1	0.40	2.45	1889	4.29	1886
3	7:1	0.45	4.72	1960	6.29	1911

TABLE 6.9 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 25 CONCRETE WITH ACR 7:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	7:1	0.40	2.00	1890	4.20	1996
2	7:1	0.45	2.67	2000	6.09	2100

TABLE 6.10 COMPRESSIVE STRENGTH TEST RESULTS FOR RNF – 50 CONCRETE WITH ACR 7:1

S.No	ACR	WCR	7 days		28 days	
			Comp strength N/mm^2	Density Kg/m^3	Comp strength N/mm^2	Density Kg/m^3
1	7:1	0.40	1.76	1967	3.86	2000
2	7:1	0.45	2.34	2100	5.55	2145

Figure 6.1 Compressive Strength Testing Apparatus

6.1.3 Split Tensile strength and Flexural strength

The split tensile strength and flexural strength test results for CNF concrete are given in table 6.11 and that for RNF concrete are given in table 6.12. Figures 6.2 and 6.3 show the split tensile strength and flexural strength testing apparatus respectively.

TABLE 6.11.SPLIT TENSILE AND FLEXURAL STRENGTH TEST RESULTS FOR CNF CONCRETE

Sl. No	ACR	WCR	Split tensile strength N/mm^2	Flexural strength N/mm^2
1	5:1	0.35	0.93	0.8
		0.40	1.34	1.00
		0.45	1.03	2.06
2	6:1	0.35	0.83	1.65
		0.40	0.65	1.96
		0.45	0.65	0.47
3	7:1	0.35	0.49	0.67
		0.40	0.42	0.78
		0.45	0.58	0.90

TABLE 6.12.SPLIT TENSILE AND FLEXURAL STRENGTH TEST RESULTS FOR RNF – 25 AND RNF - 50 CONCRETE

Sl. No	ACR	WCR	Split tensile strength N/mm²		Flexural strength N/mm²	
			For 25% replacement	For 50% replacement	For 25% replacement	For 50% replacement
1	5:1	0.35	0.89	0.84	0.75	0.72
		0.40	1.08	1.20	2.00	0.89
2	6:1	0.35	0.78	0.75	1.63	1.50
		0.45	0.64	0.59	0.45	0.42
3	7:1	0.40	0.39	0.38	0.74	0.70
		0.45	0.56	0.52	0.89	0.81

Figure 6.2 Split Tensile Strength Testing Apparatus

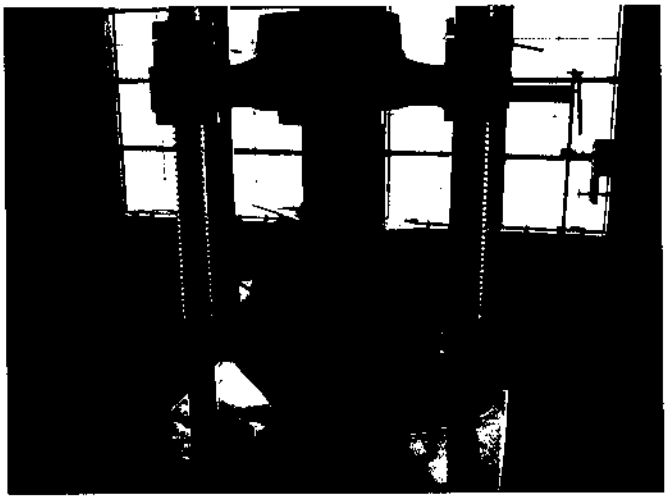

Figure 6.3 Flexural Strength Testing Apparatus

6.2 Discussion of Test Results

6.2.1 Density

The lower density of no-fines concrete helps in reduction of dead load increases the progress of the construction and lowers haulage and handling costs. The density values of CNF concrete and RNF concrete are nearly the same.

6.2.2 Compressive strength

No- fines concrete has lower compressive strength values than normal concrete but sufficient enough for structural use. It varies between 1.4 to 14 N/mm^2

For 25% replacement level, the compressive strength of RNF concrete is slightly lesser than CNF concrete. The decrease is between 0.8 to 3%.For 50% replacement level. the decrease is between 10 to 11%.

Figures 6.4 to 6.6 show the comparison of compressive strength test results for various ACR for the two replacement levels graphically..

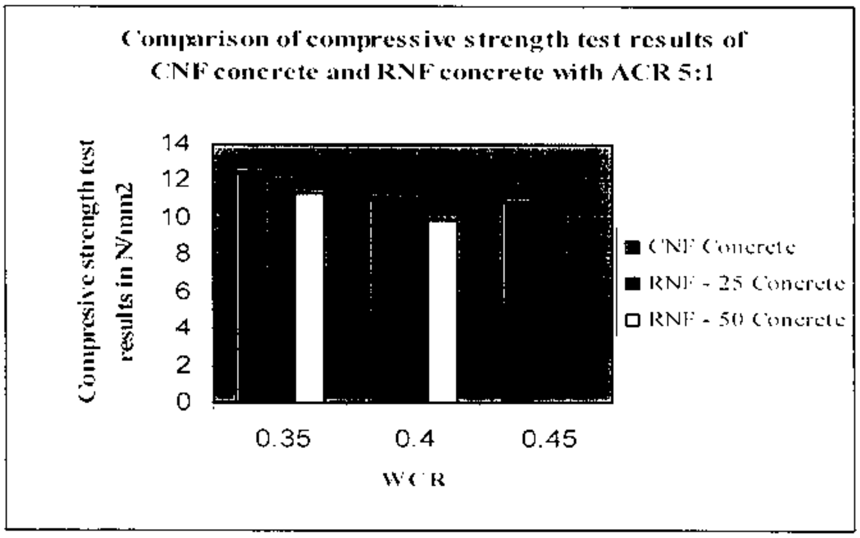

Fig.6.4 Comparison of compressive strength test results of CNF concrete and RNF concrete with ACR 5:1

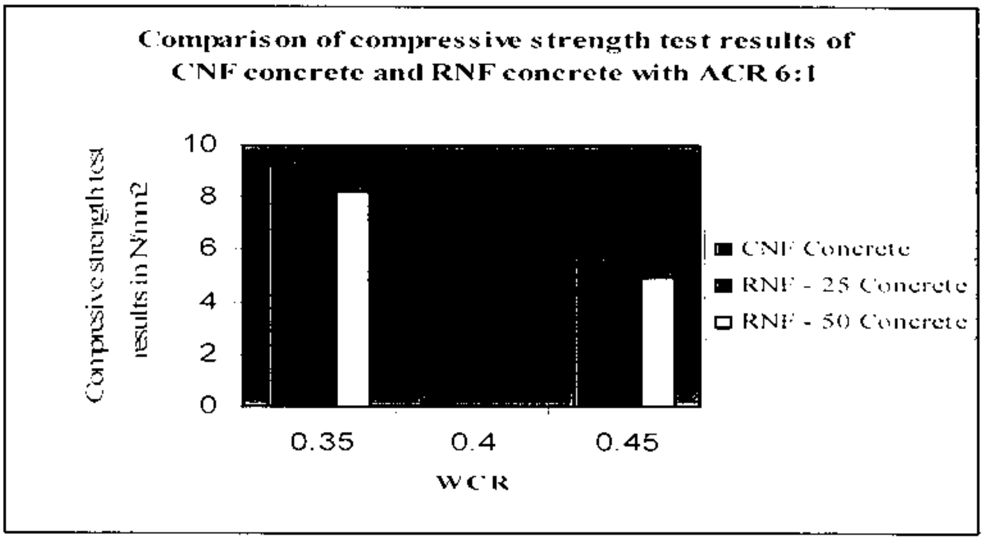

Fig.6.5 Comparison of compressive strength test results of CNF concrete and RNF concrete with ACR 6:1

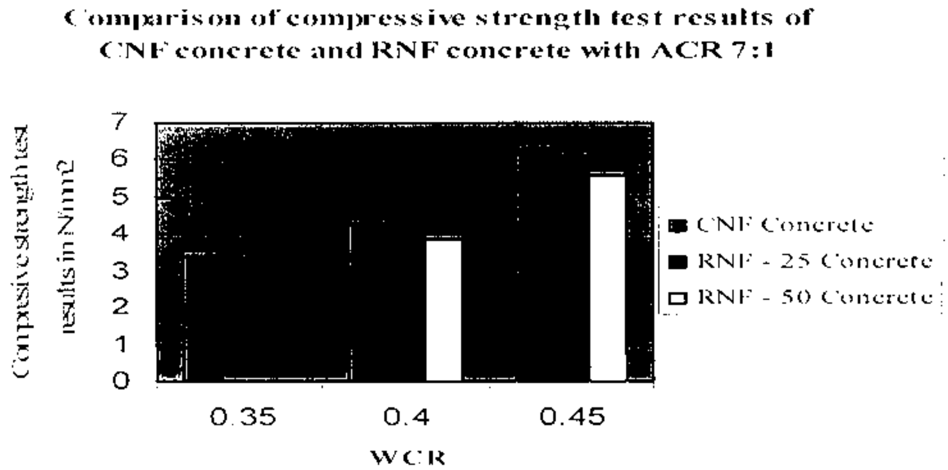

Fig.6.6 Comparison of compressive strength test results of CNF concrete and RNF concrete with ACR 7:1

6.2.3 Split tensile test and Flexural test

For 25% replacement level, the splitting tensile strength decreases by about 2 to 4 %. The flexural strength decreases by about 2 to 4 %. For 50% replacement level, the split tensile strength decreases by about 9 to11 %. The flexural strength decreases by about 10 to 12%.

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions from the Study

- ✓ From this study, it was observed that, though no fines concrete has lower strength values, but it has desirable strength values to be used for both structural and non-structural purposes.

- ✓ Abolishment of fine aggregate from normal concrete mixes lead to higher porosity and lower cement requirement. It also saves the energy required in extraction, transportation of sand.

- ✓ No fines concrete has a lower density and lower normal weight than the traditional concrete mixes. Since it compacts well due to its self weight, it needs no mechanical compaction. As it is a light weight concrete, the necessity for stronger shuttering requirement is not needed.

- ✓ No-fines concrete can be used effectively for load bearing walls, as drainage medium in play areas & tennis courts and for pavements, temporary structures.

- ✓ Also, demolished concrete can be effectively used for 25% replacement of coarse aggregate in no- fines concrete owing to only a marginal decrease in compressive strength values. But for 50% replacement level, the decrease in strength values is 10% and more which is not desirable.

7.2 Recommendations for Future Work

- Use of No-fines concrete with reinforcement

- Production of high strength No- fines concrete by impregnating fibres and polymers

- Production of Less- fines concrete to improve the lower strength property of No-fines concrete

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