JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# A STUDY ON RECYCLED CONCRETE AGGREGATE ALONG WITH QUARRY FINES IN HIGH STRENGTH CONCRETE

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***Abstract :*** History of cementing material is as old as history of engineering construction such as in monument construction of Egypt, Greek, India and Rome. The usage of concrete dates backto starting of 20th century after discovery of cement. Conventional concrete making constituents are cement, fine aggregates, coarse aggregate, water and mineral or chemical admixtures. On the other hand, usage of natural aggregates from river beds/banks and other sources such as rocks can seriously create environmental threats.
Analysis was made by replacing RCA in following percentage 0%, 25%, 50%, 75%, 100% and all samples have 25% & 50% ( by weight ) quarry dust as fine aggregate replacement.
**Keywords: Recycled Concrete Aggregate & Quarry Fines**

## 1 INTRODUCTION

Twenty first century is known as concrete era. Concrete is most widely used substance in the world, and is second only to water as the most consumed substance on the planet. It is roughly estimated that in 2006 between 21 and 31 billion ton of concrete (containing 2.54 billion tons of cement) was consumed globally. Ingredients of conventional concrete are coarse aggregate, fine aggregate, cement and water. Fly ash, copper slag, washed bottomash (WBA), quarry dust, quarry fines, foundry sand, construction & demolition waste, spentfire bricks and silica fume can be used as alternatives to conventional concrete ingredient. Conventional concrete ingredients can be substituted by recycled concrete aggregate as coarse aggregate and quarry fines as fine aggregate.

### *1.1 Forecast for Construction Material*

New studies from the Fredonia cluster, Inc., a Cleveland-based trade research firm forecastsworld demand for cement to grow at a rate of 5.3 percent per annum 3.6 billion metric tonsin 2012 and for construction aggregates to grow at a rate of 4.7 percent annually through 2011 to twenty 26.8 billion metric tons. By the tip of 2017, worldwide sales of construction aggregates square measure forecast to expand quite five percent per year to 53billion metric tons.

Fredonia cluster report estimates that the Cement production by plants in Asian country isready to extend at a rate of 8.2 percent per year to 237 million metric tons in 2012. The forecast for Construction aggregates demand in Asian country is predicted to rise at a 7.7 percent annual pace to 1.6 billion metric tons in 2011.

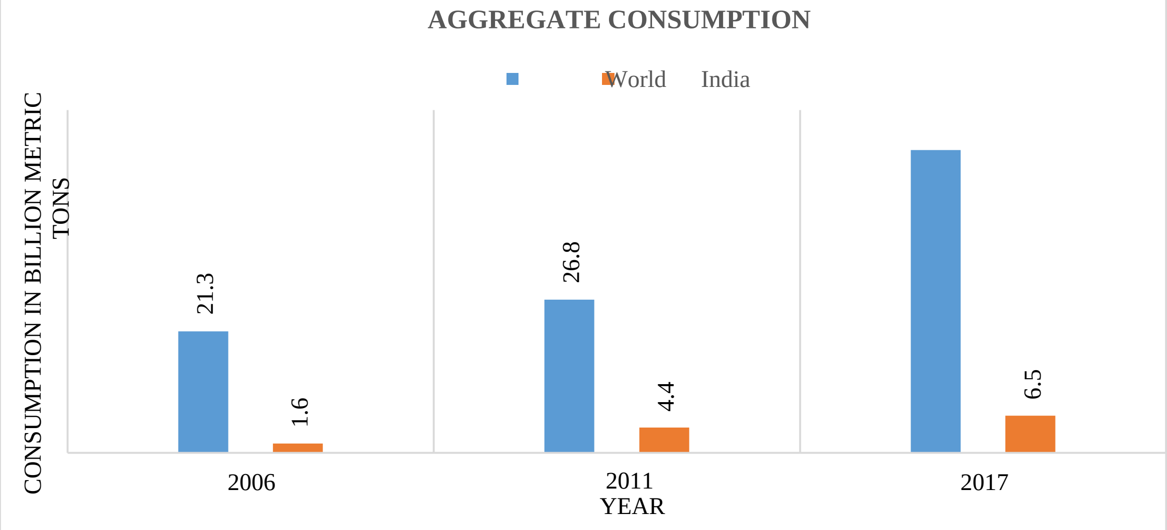



Figure 1.1 Comparison of aggregate consumption in World and India.

*1.2 Aggregate Demand in India*

Demand for construction aggregates in Asian nation amounted to 0.1 billion metric tons in 2006, creating the country the third biggest aggregates market within the Asia/Pacific regionand fourth largest market within the world (after China, the US and Japan). Sales in Asian nation have up a median of 7.7 % annually over the past 10 years, surpassing each regionaland world averages. A chop-chop advancing economy and rising standards of living have helped increase overseas investment in Asian nation, stimulating massive amounts of Industrialization and infrastructure-related construction activity. However, Indian product demand (relative to construction payment and on a per capita basis) is considerably below regional and world averages.

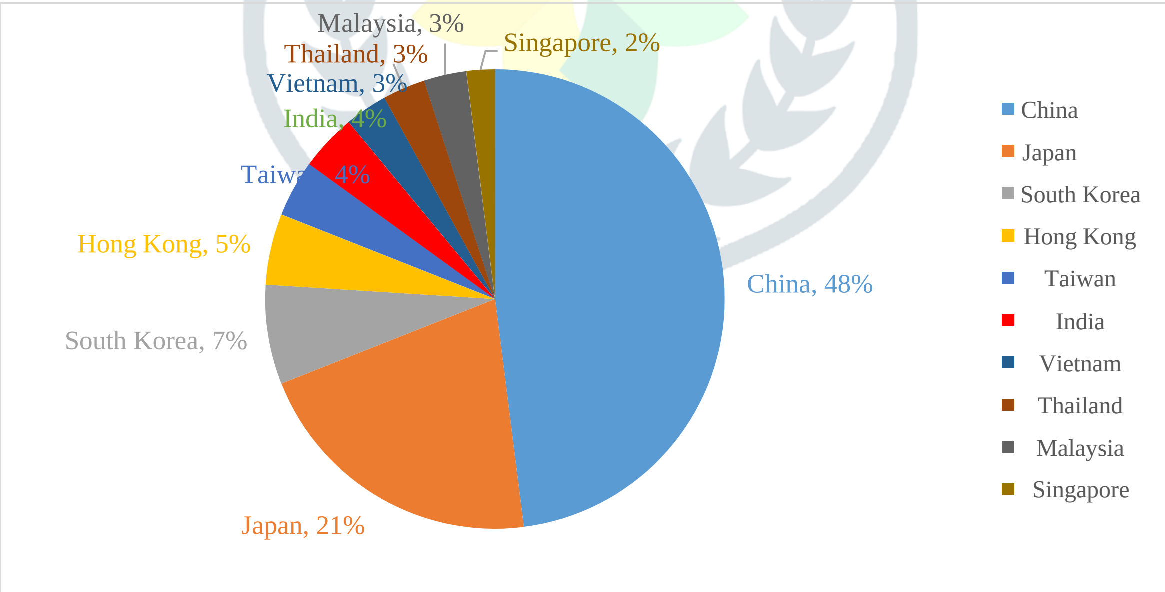
*1.3 Current scarceness of Natural Aggregates*

There is intense decline in sensible quality mixture on the market for housing industry. The assembly of concrete needs the usage of non-renewable natural resources. Aggregates represent giant proportion of concrete and will be as high as 70-85% of total volume of concrete. The aggregates is sometimes acquire through mining a quarry or extraction from domestic riverbeds and banks to attenuate depletion of natural resources, there has been ANaccrued effort to recycle concrete and use alternative alternatives to ingredients of concrete.Out of the varied various recycled concrete mixture from construction and demolition wasteand quarry fine from stone crushers is also the promising one. The environmental impact ofwaste concrete is substantial. Not solely there's the environmental impact of transporting thewaste concrete far from the location however the waste concrete conjointly fills up valuablearea in landfills.

*1.4 Construction and Demolition Waste Generation in DifferentCountries*

In North America the development and demolition waste contributes around 25 – 40% of the whole waste generated relying upon the region (Tabsh and Abdel Fatah 2009). The development Materials utilization Association (CMRA) has conducted a study onconstruction and demolition waste, associated with the buildings and it absolutely was calculable to be around 136 million tons of waste matter. Also, it absolutely was reportedthat with the exception of the building waste, an uncountable tons of waste is coming backfrom road, bridge, and aerodrome construction and renovation. In developed countries the annual per capita building and construction waste generation were 500 – 1000 kg and within the European countries the building and construction waste was calculable to be around 175 million tons per annum (Nitivattananon and Borongan 2007).

**The European Demolition Association estimates that regarding 200 million tons of wastegenerated annually, out of that 30% of this amount being recycled. However, there was giantdistinction within the quantities of utilization within the region wise as an example, The Netherlands and Belgium bring home the bacon**
utilization rates of regarding ninetieth, whereas, alternative European countries like European country and Spain, the utilization ratewas below 100% (Collepardi 2002). The Japan and European country have conjointly reached the utilization rates of around 96% and 86% severally. The number of C& D generated within the North American nation in 2012 was calculable at about 480 million tons.
Figure 1.2 C &D waste in Asia [57]




*1.5 Construction and Demolition Waste Generation in India*

The construction trade contributes well to the generation of solid waste in the majority the countries. The development and demolition waste generation state of affairs in Asiancountries is additionally within the same trend. It absolutely was reported that Asia alone generates regarding 760 million tons of construction and demolition waste once a year (World Bank 1999).

1.6 *Construction and Demolition Waste Management*

Three R's (3Rs) classify waste management ways in step with their desirability in terms of waste reduction. These "3R's" area unit the inspiration of most waste reduction ways. The aim of this is often to extract the most sensible advantages from product and to come up with the minimum quantity of waste.

***(a)*** *Reduce:*

- The reduction of waste will happen only if everyone reduces waste generation.

- Every individual needs to contribute in doing this. There is imperative want of publicawareness regarding waste generation. There ought to be awareness in the least levels of Society, which can encourage them to alter their casual habits, that creates waste.

- Public- non-public Partnership ought to be engaged during this awareness activity.

***(b)*** *Reuse:*

- Utilization price of any item ought to be noted to those who area unit victimization it.

- Organizations operating for underneath privilege society ought to work for establishing centers which offer product for secondary use. Such centers are often discovered at the supply.

Private sector involvement ought to be inspired, repairing facilities ought to be offered thus product are often used as per its utilization price. NGOs, self -help cluster etc. and will organize workshop, seminars that encourage individuals to use waste matter to make some ornamental articles.

***(c)*** *Recycle:*

The process of remodeling materials into secondary resources for producing new product is thought as usage.

- Waste usage results in less utilization of raw materials, saves on lowland area, reduces the quantity of energy needed to manufacture new product. If truth be told usage will forestall the creation of waste at the supply.
- Promoting/motivating voters to start out segregation of waste at supply involving co-operatives, private, and industrial sectors for applicable mass awarenesscampaigns.

- Source separation by keeping recyclables and organics waste separate at supply i.e.,at the purpose of generation facilitate reprocess, recycling.

- There ought to be plant at native level.

### 1.7 *Effects of Sand and Gravel Mining*

- Extraction of bed material in more than refilling by transport from upstream causes the bed to lower (degrade) upstream and downstream of the positioning of removal.

- In-stream environs is compact by increase in stream gradient, suspended load, sediment transport, sediment deposition. Excessive sediment deposition for refilling will increase cloudiness that prevents penetration of sunshine needed for chemical process and reduces food accessibility of aquatic fauna.

- Bed degradation area unit answerable for channel shifting, inflicting loss of properties and degradation of landscape, it can even undermine bridge supports, pipe lines or alternative structures.
- Degradation might amendment the morphology of the stream bed that constitutes one facet of the aquatic environs.
- Degradation will exhaust the whole depth of gravelly bed material, exposing alternative substrates that will underlie the gravel that might successively have an effect onthe standard of aquatic environs.
- Lowering of the geological formation will destroy bank vegetation.
- Excessive pumping of $H_2O$ within the method of mining in abandoned channels depletes $H_2O$ inflicting scarceness of irrigation and beverage. In extreme cases it's going toproduce ground fissures and subsidence in adjacent areas.
- Flooding is reduced as bed elevations and flood heights decrease, reducing hazard for human occupancy of floodplains and also the risk of harm to engineering works.
- The offer of overbank sediments to floodplains is reduced as flood heights decrease.
- Rapid bed degradation might induce bank collapse and erosion by increasing the heights of banks.
- Polluting $H_2O$ by reducing the thickness of the filter material particularly if mining is going down at prime of recharge fissures.
- Choking of filter materials for ingress of $H_2O$ from stream by merchandising of finermaterial, compaction of filter zone due to movement of significant vehicles. It additionally reduces the porosity and porousness of the filter material.
- Removal of gravel from bars might cause downstream bars to erode if they after receive less bed material than is carried downstream from them by watercourse transport.
- Ecological effects on bird nesting, fish migration, angling, etc.
- Direct destruction from significant instrumentality operation; discharges from instrumentality and provision.

- Bio security and tormentor risks.

## 1.8*Alternative Hurtful Impacts of Indivisible Mining*

- Loss of bank environs ensuing from direct removal of vegetation on the stream bankto facilitate the employment of a dragline or through the method of lowering the geologicalformation, bank undercutting, and channel incision.
- The physical composition and stability of substrates area unit altered as a results of in-stream mining and most of those physical effects might exacerbate sediment entrainmentwithin the channel.
- Furthermore, the method of in-stream mining and gravel laundry produces fine sediments underneath all flow conditions, leading to a deposition of fine sediment in rifflesfurthermore as alternative habitats at low discharge.
- Excess sediment is taken into account the best waste material in waters and constitutes one amongst the main environmental factors within the degradation of stream fisheries.

Table 1.1 Estimate of waste produced by Central Government

| **Year** | **Agency** | **Estimate in Million Tons** |
|---|---|---|
| 2000 | Ministry of Urban Development(2000) | 10-12 |
| 2001 | TIFAC (2000) | 12-15 |
| 2010 | Central Pollution Control Board | 12 – 14.7 |
| October 2013 | Ministry of Urban Development (2013) [6] | 10-12 |
| March 2016 | Ministry of Environment and Forests [7] | 530 |

## 1.9 *Objective and Aim of Study*

With passage of time availability of natural resources that used in construction sector goingto deplete and there may be chances that their quality also becomes low. We can say that construction industry has become a victim of its own success and therefore facing tremendous challenges. RCA and QF may be the alternatives to the modern concrete ingredients. In recent times, more concrete recycling has taken place, thus helping in minimizing the use of natural resources.

- ❖ To determine the physical properties of RCA, QF and their influence on concrete.
- ❖ To determine the properties of fresh concrete made from conventional aggregatesand having different percentage of RCA i.e. 0, 25, 50, 75, 100% along with QF i.e., 25% & 50% in fixed proportion in HSC.
- ❖ To determine the properties of fresh concrete made from conventional aggregates and having different percentage of RCA with QF in HSC.
- ❖ To Investigation and laboratory testing on high strength concrete up to 60MPa having different percentage of RCA with QF as aggregates.

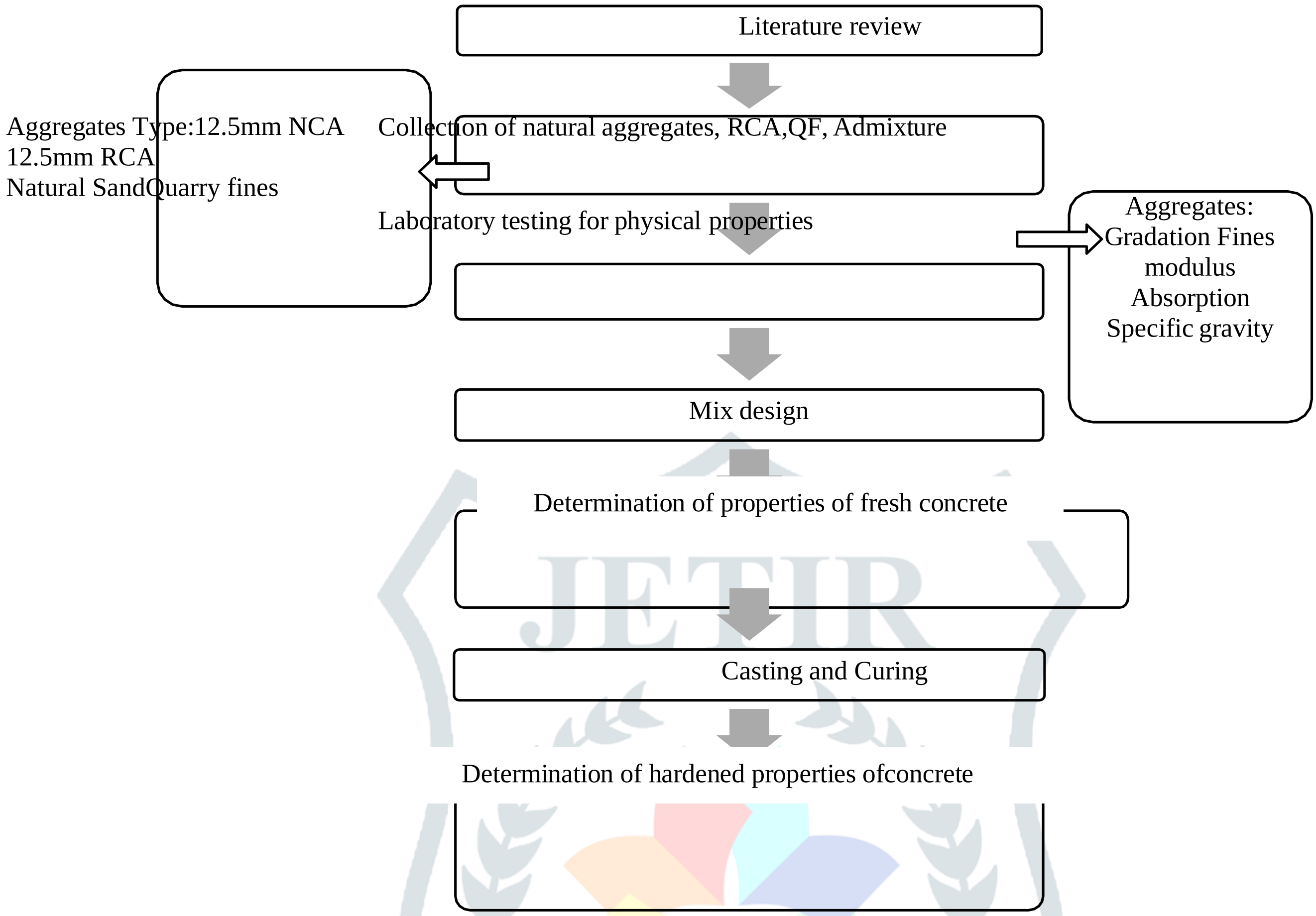
### *1.1 0 Scope*

Sustainable construction rather than impressive idea now is a necessity. Urbanization growthrate in India is very high due to industrialization. Concrete is preferred as it has longer life,low maintenance cost & better performance. With the passage of time design life and serviceable requirement of structure came to a termination. Waste from wrecked building are normally known as C&D waste. Presently C&D waste and QF are used as landfills, sub-base coarse filling material in road construction and refusal in dumping yards. Refusal of C&D waste and QF causes severe environmental impact.

### *1.11 Structure of Project Work*

- **Literature review:** To carry out proper investigation of the strength characteristicsof concrete made up of RCA and quarry fines. For the fulfillment of the objectives given above, various necessary data & literature are collected from different books, journals & Internet.
- **Collection of the recycled concrete aggregate and quarry samples**: Recycled concrete aggregate is produced from demolished slab at college construction site. Hammer is used to demolish slab and sieve to required size. Quarry dust is collected from construction site at college.

*1.12 Study Framework*




## 2 LITERATURE REVIEW

This chapter presents the literature review of recycled concrete aggregate, quarry fines andhigh performance concrete.

### 2.1 *Recycled Concrete Aggregate*

The use of previous construction materials in new construction is not a brand new thought. Employment C& D remains dates back to the time of the Roman civilization, UN agency usually reused materials from previous structures in reconstruction new structures like roads, palaces. In recent years, the employment of construction and demolition waste to supply aggregates appropriate for structural concrete is rising as a commercially viable and technically possible operation. Such employment processes have additional advantage of reducing lowland disposal, whereas protective parent resources and reducing environmentalimpact.

The application of destroyed concrete structure as lowland are in use since last decade of twentieth century. There has been abundant analysis supported the utilization of recycled mixture that has been meted out all round the world. The analysis on recycled mixture that has been meted out indicated that the efficacious application of crushed mixture in concreteare often achieved. This eminent analysis has been achieved in several countries. This chapter presents literature reviews on the consequences of varied factors on the recycled mixture from previous researches.

**Yong-Huang carver et al (2004)** judge the optimum mixture for concrete created with recycled concrete aggregates. Mistreatment analysis of variance and significance take a lookat, associate degree optimum mixture of concrete qualifying the specified engineering properties with the recycled concrete aggregates will simply be designated. They complete that each slump and compressive strength of concrete having water/cement quantitative relation of 0.5, volume quantitative relation of coarse mixture of 42.0%, 100% natural stream sand, 0% crushed brick, and as-is recycled mixture while not water-washed mixture.The ensuing concrete has slump of a hundred and eighty metric linear unit and a compressivestrength of 30.17 MPa at 28 days that is applicable for many concrete structures.

**Yasumichi Koshiro et al (2014)** studied the applying of entire concrete waste utilize modelto supply recycled mixture category H and also the quality of concrete mistreatment these recycled materials was tested and applied to fair-faced concrete structures of a brand new building. Fine powder, a by-product within the employment method, was additionally reusedas a fabric for clay tiles to hide the ground of the new building. Conclusion drawn from studies square measure recycled mixture concrete have comfortable quality to be used for structures and Recycled fine powder was used as a fabric of clay tiles. Once the fine powdercontent is between 10% and 20%, the absorption quantitative relation of the merchandise iscorresponding to that of standard clay tiles and also the weight is a smaller amount.

**According to Lapp W. Tabsh et al (2009)** toughness and soundness take a look at results on the recycled coarse mixture showed higher proportion loss than natural mixture, howeverremained inside the appropriate limits. The compressive and ripping tensile strengths of concrete created with recycled coarse mixture depend upon the combination proportions. They finished that the strength of recycled concrete is 10–25% under that of typical concretecreated with natural coarse mixture.

**Sumaiya Binte Huda and M. Shahria Alam (2009)** studied the mechanical behavior of three generations of 100% continual recycled coarse mixture concrete. They use 3 totally different generations (1st, 2nd and 3rd) of continual recycled concrete were created victimization 100% recycled coarse mixture (RCA) as a replacement of natural coarse mixture wherever RCA was recycled 3 times over its generation. The results show that the continual recycled concrete knowledgeable about slightly lower compressive strength than the management concrete; but, all mixes with success achieved their target strength at 56thday expect the third generation concrete. Another attention-grabbing finding of this study shows that even the third generation concrete might surpass the target strength by a minimum of 25% whereas considering long run strength gain. The majority density and relative density of various generations of continual recycled coarse mixture ablated with theredoubled range of repetitions.
**Vivian W.Y. tammy et al (2007)** instructed two-stage mix approach (TSMA) for recycledmixture in concrete combine. Based mostly upon the experimental works, enhancements onstrength and rigidity of RAC victimization TSMA were compared with those of ancient mix procedure supported totally different percentages of RA replacements. The results were thenoptimized victimization general regression neural networks (GRNN) and RA replacementsof 25–40% and 50–70% were found to be best once TSMA was adopted.

**Ilker Bekir Topcu and Selim Sengel (2004)** studied the properties of concretes created with waste concrete mixture (WCA) and finished that the particular gravity of WCAs was under that of traditional crushed aggregates; Water absorption quantitative relation was found to be a lot of higher compared thereupon of traditional crushed aggregates.

## 2.2 *Quarry Fines*

About 20 to 25 percent of the whole production in every device unit is missed because the waste material: quarry fines. Quarry fines square measure produced of rock. It is conjointlyreferred as gravel sand, stone sand, device sand and crushed fine mixture. Such quarry finessquare measure presently created from exhausting rock quarries. Quarry fines is increasinglyand a lot of turning into more accepted as another to natural sand wherever the standard sources are getting less out there thanks to resources being depleted, mining permissions forbrand new deposits being more durable to get and therefore they ought to build use of ever growing stockpiles of quarry fines.

## 3 MATERIALS AND TESTS ON MATERIALS

This chapter discusses the different material used in concrete matrix and characteristics of the material. Characteristics of material determined with the help of experiments conductedin lab and as mentioned by manufacturer. River sand, crushed natural coarse aggregate (NCA), recycled concrete aggregate (RCA), quarry fines (QF), silica fume, admixture, cement are used in this study.

### 3.1.1 *Natural Coarse Aggregates*

In this study, coarse aggregates from crushed igneous rock having maximum size 16mm areused. Tests such as sieve analysis, specific gravity, aggregate impact value, water absorptionare perform to determine physical properties.

#### 3.1.1.1 *Sieve Analysis of Natural Coarse Aggregate*

Aggregate having size range of 4.75-80mm are considered as coarse aggregate. Hand sievingis done to determine the particle size distribution of coarse aggregate. 300mm diameter sieveis used for sieving and are arranged in decreasing order of aperture size from 16mm to 4.75mm. IS: 2386 (Part I)-1963 guidelines are followed for sieve analysis.

Table 3.1 Sieve analysis of Natural Coarse Aggregate

| Sieve Size(mm) | Weight Retained | Cumulative Retained | % Retained | % Passing |
|---|---|---|---|---|
| 20 | 0 | 0 | 0 | 100 |
| 16 | 370 | 370 | 12.33 | 87.67 |
| 12.5 | 330 | 700 | 23.33 | 76.67 |

| | | | | |
|---|---|---|---|---|
| 10 | 1290 | 1990 | 66.33 | 33.67 |
| 4.75 | 800 | 2790 | 93.00 | 7.00 |
| Pan | 210 | 3000 | 100.00 | 0.00 |

### 3.1.1.2 *Specific Gravity and Water Absorption of Natural Coarse Aggregate*

Specific gravity (G) is defined as the ratio of weight of given volume of aggregates at a given temperature to the weight of an equal volume of distilled water at that temperature. Guidelines from IS: 2386 (part III) – 1963 are used for determination of specific gravity andwater absorption by Pycnometer.

Table 3.2 Determination of Specific Gravity and Water Absorption of NCA

| | Symbol | Weight (gm) |
|---|---|---|
| Weight of SSD natural coarse aggregate | A | 1265 |
| Weight of Pycnometer , NCA and Water | B | 2330 |
| Weight of Pycnometer and Water | C | 1516 |
| Weight of oven dried NCA | D | 1236 |

$$G = \frac{D}{A-(B-C)} \qquad (1)$$

Water absorption (percentage dry weight) = $100 \frac{A-D}{D}$

**Result**: Specific gravity of NCA, $G_C$ = 2.74 and water absorption is 2.34%.

### 3.1.1.3 *Aggregate Crushing Value of Natural Coarse Aggregate*

Aggregate crushing value gives a relative measure of the resistance of aggregate to crushingunder gradually applied compressive load. Guidelines specified in IS: 2386 (Part IV) 1963 are used for determination of aggregate crushing value.

Table 3.3 Determination of Aggregate Crushing Value of NCA

| | Abbreviation | Weight(gm) |
|---|---|---|
| Weight of Surface dry aggregate | A | 2000 |
| Weight of fraction passing 2.36mm sieve | B | 375 |

**Result:** Aggregate crushing value of natural coarse aggregate is 19.

### 3.1.1.4 *Aggregate Impact Value of Natural Coarse Aggregate*

Aggregate impact value gives the relative measure of resistance of an aggregate to sudden shock or impact. IS: 2386 (Part IV)-1963 guideline is followed for aggregate impact value determination.

Table 3.4 Determination of Impact Value of NCA

| | Symbol | Weight (gm) |
|---|---|---|
| Weight of empty Container | A | 1510 |
| Weight of Container + NCA | B | 2150 |

| | | |
|---|---|---|
| Weight of oven dried NCA | C | 640 |
| Weight of crushed NCA passing from 2.36mm Sieve | D | 41 |

Aggregate impact value = $\frac{D}{C} \times 100$ (4)

**Result:** Aggregate impact value is 6.40%.

*3.1.2 Natural Fine Aggregate*

Aggregates coarser than 75µ and finer than 4.75mm known as fine aggregates. River sand is used as fine aggregate. Tests such as sieve analysis, specific gravity, and material finer than 75µ value, water absorption and bulking are performed to determine physical properties.

### 3.1.2.3 *Aggregate Impact Value of Recycled Concrete Aggregate*

Aggregate impact value gives the relative measure of resistance of an aggregate to sudden shock or impact. IS: 2386 (Part IV)-1963 guidelines are followed for aggregate impact valuedetermination.

Table 3.12 Determination of Impact value for RCA

| | Symbol | Weight (gm) |
|---|---|---|
| Weight of empty Container | A | 1510 |
| Weight of Container + RCA | B | 2070 |
| Weight of oven dried RCA | C | 560 |
| Weight of crushed RCA passing from 2.36mm Sieve | D | 128 |

*Aggregate impact value* = $\frac{D}{C} \times 100$ (12)

**Result**: Aggregate impact value of RCA is 22.86%.

### 3.1.3 *Quarry fines*

Quarry fines are remains of stone crusher industry. It is also referred to as crushed rock sand, 'stone sand', 'crusher sand' and 'crushed fine aggregate'. Such quarry fines are currently produced from hard rock quarries. Quarry fines is increasingly becoming more accepted as an alternative to natural sand where the traditional sources are becoming less available due to resources being depleted, mining permissions for new deposits being harderto obtain and the need to make use of ever growing stockpiles of quarry fines Aggregates coarser than 75µ and finer than 4.75mm known as fine aggregates. Quarry finesalong with sand is used as fine aggregate. Tests such as sieve analysis, specific gravity, material finer than 75µ value, water absorption are performed to determine physicalproperties.

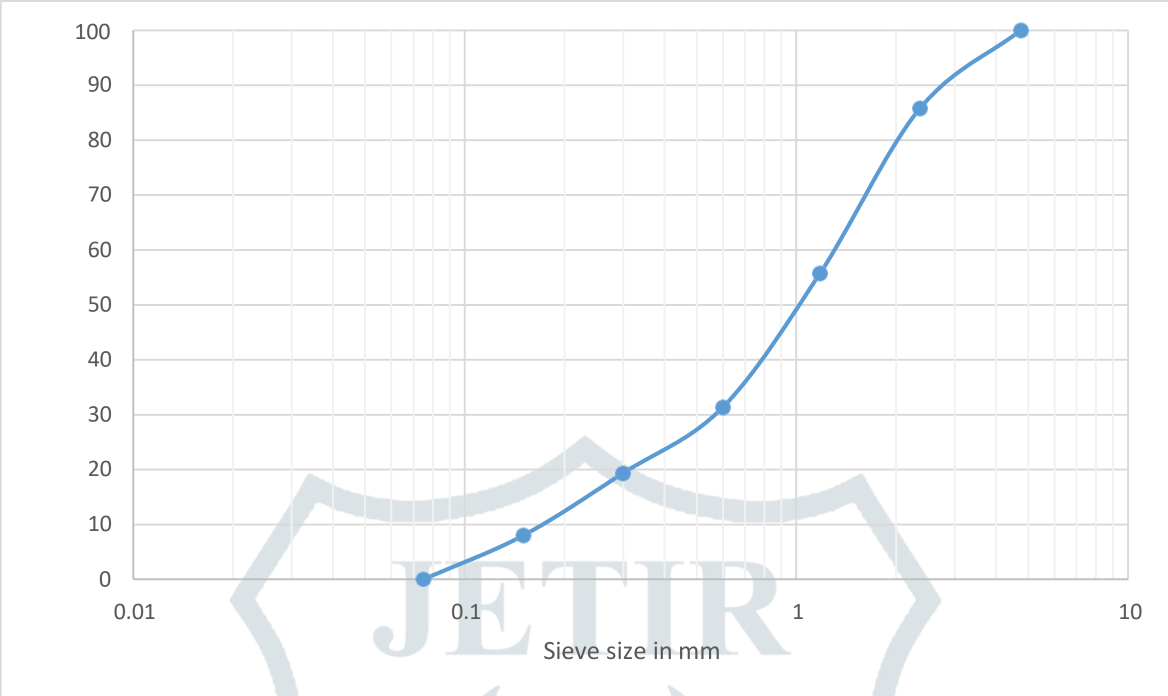
### 3.1.4.1 *Sieve analysis of Quarry fines*

Sieve shaker operating manually is use for sieve analysis. 200mm diameter sieve is use forsieving and are arrange in decreasing order of aperture size from 4.75mm to 75µ. IS: 2386 (Part I)-1963 guidelines are followed for sieve analysis.

Table 3.13 Sieve analysis of Quarry Fines

| Sieve Size(mm) | Weight Retained(gm) | Cumulative Retained(gm) | % Retained | % Passing |
|---|---|---|---|---|
| 4.75 | 0 | 0 | 0 | 100 |
| 2.36 | 215 | 215 | 14.33 | 85.77 |
| 1.18 | 450 | 665 | 44.33 | 55.77 |
| 0.60 | 365 | 1030 | 68.67 | 31.33 |
| 0.30 | 180 | 1210 | 80.67 | 19.33 |
| 0.15 | 170 | 1380 | 92.00 | 8.00 |

| | | | | |
|---|---|---|---|---|
| 0.075 | 45 | 1425 | 95 | 5.00 |
| Pan | 75 | 1500 | 100 | 00 |



*Determination of Specific Gravity of Quarry Fines*

Specific gravity is determined by procedure defined in IS: 2386 (Part III) – 1963.Pycnometer is used for determination of specific gravity, GQ

## 3.1.4 *Water*

Municipal tap water within the laboratory used for casting all samples.

## 3.1.5 *Silica fume*

Silica fume is a by-product of silicon metal and ferrosilicon industries. Due to very reactivepozzolanic it is very useful in concrete industry. It is used in making high strength concreteand can be very durable. Silica fumes mainly consist of non-crystalline silicon di-oxide. Thesingle particles of silicon are extremely small, approximately 1/100 the size of average cement particles. Because of its very fine particles, large surface area and high silica oxidecontent gives silica fumes to a very reactive pozzolana when used in concrete. Its specific gravity is 2.2.

## 3.1.4 *Admixture*

Super plasticizer BASF Master Polyheed 997 is mid-range water reducing admixture it givehigh strength, increases concrete durability, enhanced service life of concrete structure. Byapplying it produces, high grade concrete with minimum micro-silica. It is generally used inthe production of high quality ready mix concrete.

Using Rheodynamic concrete technology, it provides a concrete mix with exceptional placingcharacteristics and accelerated cement hydration for early strength development and high quality concrete. Specific gravity of BASF Master Polyheed 997 is 1.145.

### 3.1.4.1 *Features*

- True mid-range water reduction (5-15%) and excellent performance across a wideslump range.
- Reduced water content for a given level of workability.
- Provides better slump retention.
- Provides excellent workability.
- Enhanced later-age strength.
- Excellent finish ability, even with manufactured sands and in lean mixtures.

### 3.1.4.2 *Benefits*

- Can be used in a wide variety of concrete mixtures as a multi-purpose admixture meeting performance requirements.
- Faster setting at higher dosages compared to other mid-range water-reducingadmixtures.
- Enhanced flow ability, strength and durability.
- Reduces effort required to finish.
- Increases service life of structures.

## 3.1.5 *Cement*

Ordinary Portland cement of grade 43 was used for making both normal concretes and recycled aggregate concretes with quarry fines. The cement was fresh and without any lumps. The various tests performed to determine the physical properties of cement as per Indian standard IS: 8112:1989 and are listed in table 3.16. The cement was stored carefullyto prevent deterioration in its properties due to moisture. Standard consistency, Initial and final setting time, compressive strength are various test which are performed.

Table 3.16 Properties of Cement

| Property | Result |
|---|---|
| Standard consistency | 31% |
| Initial Setting Time | 40 min |
| Final Setting time | 375min |
| Strength test | 44.30 MPa (28 Days) |

*2 Mix Design*

This study compared conventional concrete with concrete made up of RCA (in variable proportion) and QF (50% used with natural fine aggregate) in two grades that are M40 and M60. Concrete design mixM40 was designed with regard to IS: 456-2000 for moderate exposure condition. Concrete mix design M60 is designed with regard to ACI: Manual of Concrete Practice along with silica fumes. Weight batching is used for mix design.

*3.2.1 Mix Designation*

**3.2.1.1 Mix Designation for M40 cubes**

Table 3.17 Mix designation for M40 Cubes

| Concrete specimen | 7 days specimen | 28 days specimen |
|---|---|---|
| Dimension(cm) | 15X15X15 | 15X15X15 |
| Control concrete | NC4A | NC4B |
| Natural fine aggregate replaced by 25% of Quarry fines | $NQ_1 4A$ | $NQ_1 4B$ |
| Natural fine aggregate replaced by 50% of Quarry fines | NQ4A | NQ4B |
| 25% RCA CONCRETE | NDQ4A | NDQ4B |
| 50% RCA CONCRETE | NEQ4A | NEQ4B |
| 75% RCA CONCRETE | NFQ4A | NFQ4B |
| 100% RCA CONCRETE | NGQ4A | NGQ4B |

Table 3.18 Abbreviations for Mix design

| Abbreviation | Used for |
|---|---|
| N | Person (Name) |
| C | Control cube |
| 4 | Mix40 |
| 6 | Mix60 |
| M | Beam |
| D | 25% RCA concrete |
| E | 50% RCA concrete |
| F | 75% RCA concrete |
| G | 100% RCA concrete |
| A | cube for 7 days strength test |
| B | cube for 28 days strength test |
| $Q_1$ | Natural fine aggregate replaced by 25% of Quarry fines |
| Q | Natural fine aggregate replaced by 50% of Quarry fines |

*3.2.1.1 Mix designation for M40 Mix*

Table 3.19 Mix designation of M40 for Beam

| Concrete Specimen | Designation |
|---|---|
| Dimension (cm) | 15X15X70 |
| Control concrete | NC4M |
| Natural fine aggregate replaced by 25% of Quarry fines | $NQ_1 4M$ |
| Natural fine aggregate replaced by 50% of Quarry fines | NQ4M |
| 25% RCA CONCRETE | NDQ4M |

| | |
|---|---|
| 50% RCA CONCRETE | NEQ4M |
| 75% RCA CONCRETE | NFQ4M |
| 100% RCA CONCRETE | NGQ4M |

*3.2.1.2 Mix designation for M60 cubes*

Table 3.20 Mix designation for M60 Cubes

| **Concrete specimen** | **7 days specimen** | **28 days specimen** |
|---|---|---|
| Dimension(cm) | 15X15X15 | 15X15X15 |
| Control concrete | NC6A | NC6B |
| Natural fine aggregate replaced by 25% of Quarry fines | $NQ_1$6A | $NQ_1$6B |
| Natural fine aggregate replaced by 50% of Quarry fines | NQ6A | NQ6B |
| 25% RCA CONCRETE | NDQ6A | NDQ6B |
| 50% RCA CONCRETE | NEQ6A | NEQ6B |
| 75% RCA CONCRETE | NFQ6A | NFQ6B |
| 100% RCA CONCRETE | NGQ6A | NGQ6B |

*3.2.1.3 Mix designation for M60 Beams*

Table 3.21 Mix designation of M60 for Beams

| **Concrete Specimen** | **Designation** |
|---|---|
| Control concrete | NC6M |
| Dimension (cm) | 15X15X70 |
| Natural fine aggregate replaced by 25% of Quarry fines | $NQ_1$6M |
| Natural fine aggregate replaced by 50% of Quarry fines | NQ6M |
| 25% RCA CONCRETE | NDQ6M |
| 50% RCA CONCRETE | NEQ6M |
| 75% RCA CONCRETE | NFQ6M |
| 100% RCA CONCRETE | NGQ6M |

*3.2.2 Mixing Method: Two stage mixing method*

Two-stage mixing method is used for mixing. The two-stage mixing method divides the water into two equal proportions that is added at different stages of the mixing. This createsareas of high and low w/c ratio paste thereby improving the characteristics of the concrete. The Two-stage mixing method increases compressive strength, tensile strength, depth of chloride penetration and depth of carbonation.

RCA used in saturated surface dry condition after washing from flowing water. So that all the lose mortar and fines adhere to it, washed away. For M60 grade of concrete cementiciousmaterial, silica fume is added. Subsequently, based on the method of weight batching, test mixes is designed, casted cured.

*3.2.2.1 Concrete mix design of Grade M60 by ACI: 211.4R-08*

Table 3.28 Mix proportions of M60 control cube

| **Materials** | **Quantity (Kg/m3)** |
|---|---|
| Water-cement ratio | 0.28 |
| Water content | 126 |
| Cement | 432 |
| Silica fumes | 21 |
| Natural fine aggregate (Sand) | 664 |
| Natural coarse aggregate | 885 |
| Admixture (@2%)(SP) | 8.6 |

Table 3.29 Mix proportion NQ$_1$6 concrete

| | | **Quantity (Kg/m$^3$)** |
|---|---|---|
| Water-cement ratio | | 0.28 |
| Water content | | 126 |
| Cement | | 432 |
| Silica fumes | | 21 |
| Aggregates | Natural river sand | 498 |
| | Quarry fines | 166 |
| | Natural coarse aggregate | 885 |
| | Recycled concrete aggregate | -- |
| Admixture(SP) | | 8.6 |

Table 3.29.1 Mix proportion NQ6 concrete

| | | **Quantity (Kg/m$^3$)** |
|---|---|---|
| Water-cement ratio | | 0.28 |
| Water content | | 126 |
| Cement | | 432 |
| Silica fumes | | 21 |
| Aggregates | Natural river sand | 332 |
| | Quarry fines | 332 |
| | Natural coarse aggregate | 885 |
| | Recycled concrete aggregate | -- |
| Admixture(SP) | | 8.6 |

Table 3.30 Mix proportion NDQ6 concrete

| | | Quantity (Kg/m$^3$) |
|---|---|---|
| Water-cement ratio | | 0.28 |
| Water content | | 126 |
| Cement | | 432 |
| Silica fumes | | 21 |
| Aggregates | Natural river sand | 332 |
| | Quarry fines | 332 |
| | Natural coarse aggregate | 663.75 |
| | Recycled concrete aggregate | 221.25 |
| Admixture(SP) | | 8.6 |

Table 3.31 Mix proportion NEQ6 concrete

| | | Quantity (Kg/m$^3$) |
|---|---|---|
| Water-cement ratio | | 0.28 |
| Water content | | 126 |
| Cement | | 432 |
| Silica fumes | | 21 |
| Aggregates | Natural river sand | 332 |
| | Quarry fines | 332 |
| | Natural coarse aggregate | 442.5 |
| | Recycled concrete aggregate | 442.5 |
| | Admixture(SP) | 8.6 |

## 4 EXPERIMENTS, RESULTS & DISCUSSIONS

### 4.1 Test on Fresh Concrete

*4.1.1 Workability Test*

The word workability or workable concrete signifies much wider and deeper meaning than the other terminology consistency often used loosely for workability. Consistency is a general term to indicate the degree of fluidity or the degree of mobility. The factors helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are : (a) Water Content (b) Mix Proportions (c) Size of Aggregates (d) Shape of Aggregates (e) Surface Texture of Aggregate (f) Grading of Aggregate (g) Use of Admixtures.

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It indicates the characteristic of concrete in addition to the slump value. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence.

**Figure 4.1:** Slump cone test

Table 4.1 Slump Test Result of M40 Grade concrete

| **Mix Proportion** | **Slump Results(mm)** |
|---|---|
| NC4 | 105 |
| $NQ_14$ | 110 |
| NQ4 | 100 |
| NDQ4 | 100 |
| NEQ4 | 83 |
| NFQ4 | 80 |
| NGQ4 | 55 |

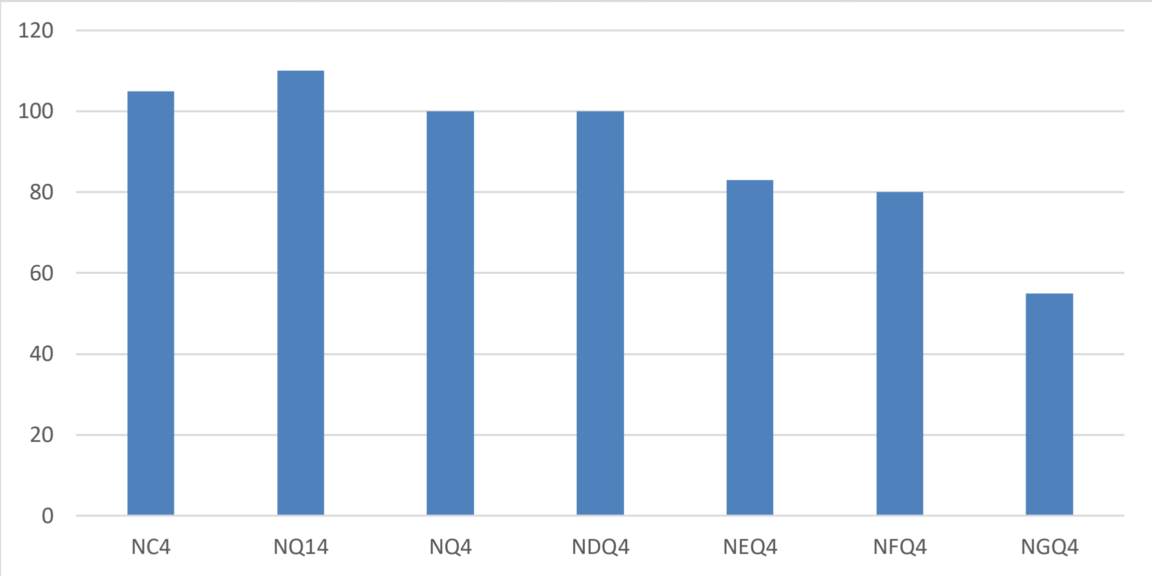



Figure 4.2 Slump Test Result of M40 Grade concrete

**Discussion:**

1. The slump value of $NQ_14$ Mix is more than of all other Mix i.e., 110mm where we used 25 % of Quarry fines.

2. The slump value of NQ4 & NDQ4 are similar i.e., 100mm.

3. The slump value of NGQ4 is less than of all other mix i.e., 55mm

Table 4.2 Slump Test Result of Grade M60 concrete

| **Mix Proportion** | **Slump Results (mm)** |
|---|---|
| NC6 | 85 |
| $NQ_16$ | 78 |
| NQ6 | 75 |
| NDQ6 | 70 |
| NEQ6 | 60 |
| NFQ6 | 45 |
| NGQ6 | 35 |

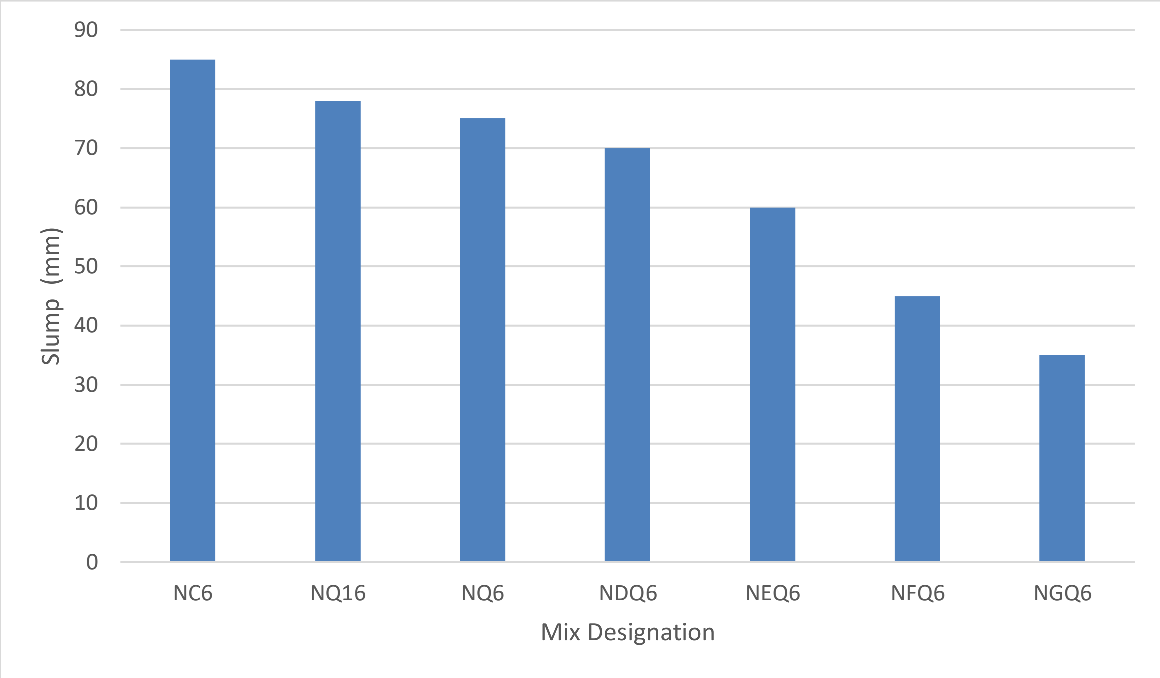



Figure 4.3 Slump Test Result of Grade M60 concrete

**Discussion:**

1. The slump value of NC6 is more than of all other mix i.e., 85mm.
2. The slump value of NGQ6 is less than of all other mix i.e., 35mm.

*4.2 Test on hardened concrete*


*4.2.1 Compression Test*

Test specimens of size 150×150×150 mm were used for determination of compressive strength of concrete. The concrete mixes having varying percentage of RCA (0%, 50% of Quarry fines as fine aggregate, 25%, 50%, 75% and 100%) as replacement of coarse aggregate were casted, cured and tested.
Figure 4.4: Compression test at lab

*4.2.3 Split Tension Test:*

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. Moreover, the concrete is very weak in tension due to its brittle nature. Hence. It is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

***Concrete pouring and compaction***

- After the mixture is prepared, it is poured into the oiled mould in layers approximately 5 cm deep.

- Then, each layer is compacted either by hand or by vibration.
- For manual compaction, use tamping bar.
- Distributed bar stroke uniformly in order to compact it properly.
- Minimum tamping bar stroke for each layer is 30.
- Penetrate strikes in to the underlying layer.
- Apply the rode for the entire depth of bottom layer.
- Complete top layer compaction.
- Lastly, the surface of the concrete should be finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation.

**Figure 4.9: Split Tension test**

Table 4.7 Split Tension Test of M40

| **Mix designation** | **Split Tension Strength at 28 days(N/mm$^2$)** |
|---|---|
| NC4 | 2.4 |
| NQ$_1$4 | 2.52 |
| NQ4 | 2.67 |
| NDQ4 | 2.0 |
| NEQ4 | 1.7 |
| NFQ4 | 1.4 |
| NGQ4 | 1.22 |

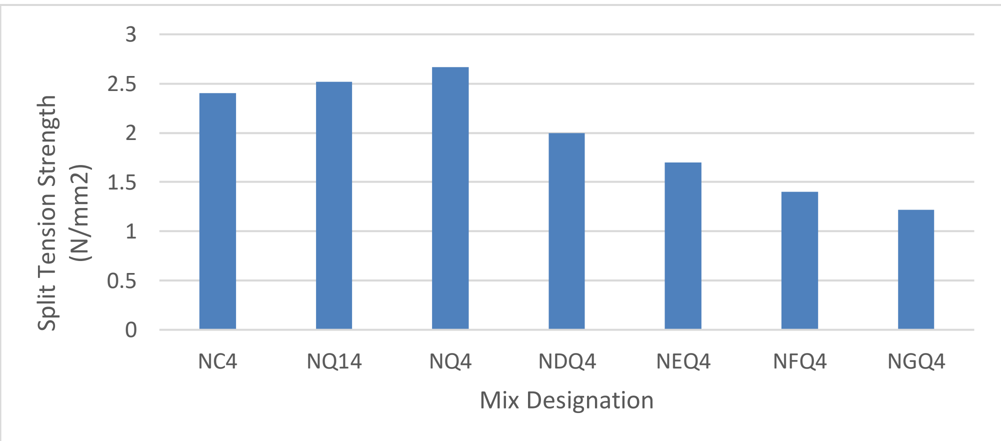


Figure 4.10: 28 Days Split Tension Test of M40

**Discussion:**

1. The Split Tension strength (28 days) of NQ4 Mix Sample strength is more than of all other Mix samples.
2. The Split Tension strength (28 days) of NGQ4 Mix Sample strength is less than of all other Mix samples.

Table 4.8 Split Tension Test of M60

| **Mix designation** | **Split Tension Strength at 28 days(N/mm$^2$)** |
|---|---|
| NC6 | 2.3 |
| NQ$_1$6 | 2.5 |
| NQ6 | 2.7 |
| NDQ6 | 2.1 |
| NEQ6 | 2.0 |
| NFQ6 | 2.0 |
| NGQ6 | 1.83 |

Figure 4.11: 28 Days Split Tension Test of M60

**Discussion:**

1. The Split Tension strength (28 days) of NQ6 Mix Sample strength is more than of all other Mix samples.
2. The Split Tension strength (28 days) of NEQ6 & NFQ6 Mix Sample are similar in strength.
3. The Split Tension strength (28 days) of NGQ4 Mix Sample strength is less than of all other Mix samples.

## 5 CONCLUSIONS

Based on the obtained results the influence of normal and recycled aggregates along with quarry fines on strength, the following conclusions and suggestions were mentioned.

- Value of RCA concrete slump is less than conventional concrete slump due to high water absorption.
- Compressive strength of M40 mix RCA concrete upto 50% replacement is more than conventional concrete mix and with further increase of RCA there is considerable decrease in compressive strength.
- Flexural strength of M40 RCA concrete upto 25% replacement is little more than conventional concrete.

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