# Behaviour of RC Slabs with Recycled Aggregates Subjected to Static and Impact Loading

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**Abstract:** *The waste, generated in the construction, maintenance, repair and disposal phases of a building, is called Construction and Demolition (C&D) Waste. Management of C&D waste is a problem faced not only in India but by the global community and quantum of waste produced occupies a huge fraction of the total solid waste generation by mass. This research work aims at making one such experiment where recycled aggregates are produced from C&D waste thus paves a way, for the effective management of concrete debris. The concrete waste was collected from the waste yard in the college campus, segregated, crushed in jaw crusher, sieved, washed and used for concreting for a mix proportion of M25, as a replacement for natural coarse aggregates in proportions of 0%, 30%, 60% and 100%. On testing, the compressive strength was found to be increasing and split tensile strength and flexural strength were observed to be nearly equal to that of normal concrete mix. Therefore, use of recycled concrete aggregate showed acceptable performance with respect to mechanical properties. The recycled aggregates obtained from waste concrete are more angular and have higher absorption and specific gravity than natural coarse aggregates and it resulted in increased strength and improved load carrying capacity. However, further studies to determine the effect on durability and improvement on workability are necessary.*

**Keywords:** Recycled aggregates, Natural aggregates, Impact test, Static test, First crack and Ultimate failure.

## 1. INTRODUCTION

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works. Among the ingredients for concrete, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. This is mainly because of the running down of quality primary aggregates and greater awareness of environmental protection. Hence the use of recycled aggregate from construction and demolition waste (C&D waste) in concrete is gaining momentum these days. Recycled aggregate concrete may become the need of the day in the years to come. Crushed stone or gravel form the major part. In recent years due to continued large scale extraction, use of aggregates from natural resources has been questioned at international level.

### 1.1 Literature Review

**T. Naresh Kumar[1], N.Venkata Ramana[2], E. Arunakanthi[3]** and **C. Sashidhar[4]** This paper presents the

Behaviour of stone waste aggregate (SWA) concrete slabs under impact loading. The stone waste was obtained during extraction of layered stone (at mines) and at polishing stone industries. This stone waste is converted in useful aggregate and used in the concrete as coarse aggregate in the place of natural aggregate with replacement levels of 0, 25, 50, 75 and 100%. For each replacement level, three slab specimens were cast and tested. 0% replacement level consider as Natural Aggregate Concrete (NAC) slabs. The SWA slabs were compared with natural aggregate concrete (NAC) slabs. The results showed that the SWA slab performance is less than the natural aggregate concrete slabs. From experimental results, regression models were developed to estimate energy absorption at first and ultimate crack stages. In addition to the slab specimens cubes were cast and tested. The cube strength results were used during development of regression models.

**HardikGandhi[1], Dr. DharshanaBhatt[2]** and **Chetnaben Vyas[3]** studied that There is a critical shortage of virgin aggregates and hence the availability of demolished concrete for use as recycled concrete aggregate (RCA) is increasing. Using the waste concrete as RCA conserves virgin aggregates, reduces the impact on landfills, decreases energy consumption and can provide cost savings. Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. Recycled aggregates for application in high strength structural concrete, which will give a better understanding on the properties of concrete with recycled aggregate, as an alternative material to coarse aggregate in structural concrete. In the present study recycled coarse aggregate have been used to replace virgin coarse aggregate. The properties of fresh as well as hardened concrete made of partial/full replacement of recycled coarse aggregate are found out and the results are compared with that of concrete using virgin coarse aggregate.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Cement

Cement paste is the binder in concrete that holds the aggregate (coarse, fine, micro fine) together and reacts to form hardened mass. The property of concrete depends on the quantities and the quality of its constituents.

In this present investigation Ordinary Portland Cement of 53 Grade with a brand name Ultra Tech (Birla Super) used. Tests are conducted in accordance with the Indian standards confirming to IS-12269:1987. The physical characteristic of the tested cement has been shown in table 2.1

**Table 2.1: Physical Characteristics of Cement**

| Physical Properties of Cement | | |
|---|---|---|
| **Test** | **Results** | **Requirements as per IS 12269: 1987** |
| Specific Gravity | 3.20 | 3.15 |
| Fineness of cement | 2.83% | Less than 10% |
| Standard Consistency | 32% | Not Specified |
| Soundness (Le- chatelier's) | 0.5mm | Shall not be more than 10mm |
| Setting time (in minutes) | | |
| Initial Setting time | 105 | Shall not be less than 30 minutes |
| Final Setting Time | 510 | Shall not be more than 600 minutes |
| Compressive Strength (Mpa) (70.5x70.5x70.5mm ) | | |
| 3 Days Strength | 38.7 MPa | Shall not be less than 27.0 MPa |
| 7 Days Strength | 48.2 MPa | Shall not be less than 37.0 MPa |
| 28 Days Strength | 56.8 MPa | Shall not be less than 53.0 MPa |

### 2.2 Fine Aggregate

HPC contains a large quantity of fine cementations materials. Grading of FA should not cause increase in water demand for concrete. It is desirable to use a coarser variety of sand having high fineness modulus. Both natural sand and crushed stone dust can be used as fine aggregate, should consists of rounded particles to reduce water demand. Generally, fractions passing through 4.75 mm sieves and entirely retained on 150μ sieve are used. Locally obtained manufactured sand was used as the fine aggregate in the concrete mix.

The test on fine aggregate was conducted in accordance with IS: 650-1966 & IS: 2386-1968 to determine specific gravity and fineness modulus.

**Table: 2.2 Physical Characteristics of Fine Aggregate**

| Sl. No. | Particular of Test | Results |
|---|---|---|
| 1 | Fineness Modulus | 2.3 |
| 2 | Specific Gravity | 2.608 |
| 3 | Bulk Density (kg/m$^3$)<br>Dense rodded | 1736<br>1560 |
| 4 | Zone | II |

### 2.3 Coarse Aggregate

Coarse aggregates passing 12.5 mm sieve size and retained on 10 mm sieve were used. The sieve analysis of combined aggregates confirms to the specifications of IS 383: 1970 for well graded aggregates. The tests on the coarse aggregate were conducted in accordance with IS 2386-1963 to determine Specific gravity, Bulk density and Fineness modulus. The results were presented in Table 2.3

**Table 2.3: Physical Properties of Coarse Aggregates (12.5mm down size)**

| Sl. No. | Particulars | Results | As Per Is:383-1970 |
|---|---|---|---|
| 1 | Fineness Modulus | 4.2 | --- |
| 2 | Specific Gravity | 2.63 | --- |
| 3 | Bulk Density (Dry-Rodded) | 1673 Kg/m³ | --- |
| 4 | Elongation Index | 11% | 15% |
| 5 | Flakiness | 13.8% | 15% |
|  | Crushing Value | 24.8% | 30% (Max) |
| 7 | Impact | 17.8% | 30% (Max) |
| 8 | Los Angeles Abrasion value | 29.9% | 30% (Max) |

### 2.3 Recycled aggregate concrete (RAC)

There are many reasons why concrete has been the most widely used material in the world for many decades now. The most advantageous characteristics of concrete can be listed as: relatively low cost, grand scale availability of its raw components, durability, workability, how adaptable concrete is to be shaped into any form and its fire resistance. But there is a price to pay for all these benefits, namely, the colossal energy consumption and devastating pollution that results from the manufacturing of cement.

To reduce this impact and achieve a more sustainable product, waste materials can be incorporated into concrete in the form of RA. The most extensively researched material used in the production of RA is waste concrete, that is, fine and coarse debris from demolition sites. Also, less common components such as glass, coal fly ash, plastic, tyres, volcanic ash and foundry sand have been investigated by several researchers. Concrete with RA as a component in the mixing process is referred to as recycled aggregate concrete. Since aggregates are a vital part of concrete, and concrete is widely used in the world today, this thesis presents a brief literature review on the use of RA in the production of concrete, the end product is referred to as recycled aggregate concrete (RAC). The aim of this review is to establish the mechanical properties of RAC and to compare results with the mechanical performance of conventional concrete, that is, concrete made of aggregates that did not incorporate recycled materials as aggregate.

## 3. LABORATORY INVESTIGATIONS

### 3.1 Design of Slabs

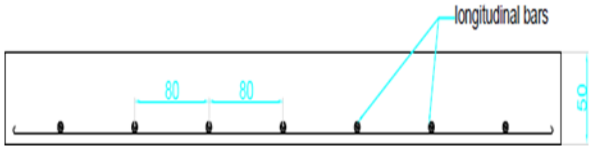
**Table: 3.1The details of the slab design**

| Thickness (mm) | Dimension of slab (mm) | Main | Distribution | Length (mm) | | spacing |
|---|---|---|---|---|---|---|
| | | | | Main | Distribution | |
| 50 | 600X600 | 6 | 6 | 550 | 550 | 80 mm c/c |

### 3.2 Casting of Slab Specimens

This part deals with the casting of reinforced slab specimens. Totally eighteen reinforced concrete slabs were cast and tested, the sizes of the test specimens were selected to suit the capacity of test equipment available in the laboratory. The slabs are designed as two-way slabs by treating as an interior panel (all four sides continuous). The live load considered for this study is 8 kN/m2 and the design is as per IS- 456:2000. The design details of all twelve slabs are as given below in the table. The design of slabs in detail are shown in above table 3.1.

All slabs were (600 X 600) mm with thickness of 50 mm. All the slabs were designed as two-way slabs. The tensile reinforcement ratio varied according to the thickness of slabs. The clear cover to reinforcement was 15 mm on all faces. The typical details of the pattern of the reinforcement and cross section of the slabs are shown in Fig 3.6. Totally twelve (six for static test and six for impact test) test slab specimens are named sequentially as CS, CS + 10%, CS + 20%, CS + 30%, CS+40%, CS+50% were casted. After 24 hours, test specimens were demolded and the test specimens were cured continuously for 28 days. Details of Slabs are given below.

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| Slno | Slabs | No of Specimens |
|---|---|---|
| 1 | M30 | 2 |
| 2 | M30+10%RCA | 2 |
| 3 | M30+20%RCA | 2 |
| 4 | M30+30%RCA | 2 |
| 5 | M30+40%RCA | 2 |
| 6 | M30+50%RCA | 2 |

### 3.3 Casting of Cubes and Prisms

#### 3.3.1 Casting of cubes (150*150*150mm) and prisms (100*100*500mm)

- Initially moulds are cleaned and oiled. The next step involved fixing the mould end plates using nuts and bolts.
- Weigh the amount of cement, silica fume, GGBS, fine aggregates and coarse aggregates for moulds. Materials were first dry mixed, then mixed with 1/3rd amount of total water with super plasticizer and polypropylene and steel fibre are added to M30 concrete. Remaining water was then added and mixed thoroughly to get homogeneous mix.
- Then the mould was fully compacted by using the vibrating machine. Sufficient care was taken to see that concrete was properly filled in corners and the edges of the mould. As soon as the air bubbles stopped to rise, the top surface of the mould was finished with trowel by applying little pressure.

#### 3.3.2 Curing

After 24 hrs concrete specimen are removed from the moulds and kept for curing in water bath for the required days of curing. All Specimens are cured for 3 days, 7 days & 28 days as per standard procedure.

## 4. MECHANICAL PROPERTIES

Testing of hardened concrete place an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control program for concrete which helps to achieve higher efficiency of the material used and greater assurance of the performance of concrete with regard to both strength and durability. One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the require strength. As the hardening of concrete takes time one will not come to know the actual strength of concrete for some time. Tests are made by casting cubes or cylinders from the representative concrete or cores cut from the actual concrete.

### 4.1 Compressive strength

The compressive strength of concrete i.e. ultimate strength of concrete is defined as the load which causes failure of the specimen divided by the area of the cross section in unit- axial compression, under a given rate of loading i.e., 13.73 N/mm2. To avoid large variation in the results of compression test, care should be taken during the casting of the test specimens and loading as well.

The cube mould of 150mm x 150mm x 150mm size is taken as per IS: 516-1959 specification. The cubes were tested in 200T capacity compressive testing machine. Place the specimen in the machine then apply the load continuously, uniformly and without shock. The rate of loading is continuously adjusted in Newton's through rate control valve by hand. The load is increased until the specimen fails and record the maximum load carried by specimen during the test. Fig 1 shows the testing of cube specimen in progress. The compression strength is calculated using the formula,

$$f = P/A$$

Where, **f =** is compressive strength of concrete in N/mm2

**P** = ultimate load resisted by concrete

**Fig.1. Compressive testing of Cubes**

### 4.2 Flexural strength

Flexural strength is expressed in terms of "Modulus rupture" which is the maximum tensile (or compressive) stress at rupture.

**Modulus of rupture**

Modulus of rupture is defined as the normal tensile stress in concrete, when cracking occurs in a flexure test. This tensile stress is the flexural strength of concrete and is calculated by the use of the formula, which assumes that the section is homogeneous.

$$f_b = (p \times l) / (b \times d^2)$$

Where,

$f_b$ = modulus of rupture, N/mm2

b = measured width in mm of the specimen

d = measured depth in mm of the specimen at the point of failure

l = length in mm of the span on which specimen was supported

p = max. Load in N applied to the specimen

- Prisms are tested immediately on removal from the water while they are still in wet condition. The bearing surfaces of the supporting and loading rollers are wiped clean, and loose sand or other material removed from the surfaces of specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3cm apart (If the fracture occurs within the middle third of the span, a>133mm, $f_b = pl/bd^2$.

- If the fracture occurs outside the middle third but deviating by not more than 5 percent of the span length, 110<a<133mm

  Then, $f_b = 3PL/bd^2$

  Where,

  P= Load

  L = span in mm

  a= distance between line of fracture and the nearest support in mm

  b = average breadth of the specimen in mm

  d = average depth of the specimen in mm

If fracture occurs by more than 5 percent outside the middle third, a<110mm, then the results of the test should be rejected.

**Fig. 2. Flexural Test on Beam Prisms**

## 5. STATIC TESTING OF SLABS

### 5.1 General

- A static test setup is fabricated for the test programme, which should have relatively stiff supports and the hydraulic loading assembly is fixed to the supporting frame. Since the study is mainly aimed at evaluation of static response due to load, as also the cumulative effect of such loading on the concrete slab elements, a hydraulic jack type loading has been employed for Static Testing Machine.

- The static testing machine used in the present investigation is of hydraulic loading type instrumented assembly. The detailed view of the above machine is shown in Fig. 3.

**Fig. 3. Static Test Setup**

### 5.2 Instrumentation

The following instrumentation is used in the present experimental investigation to study the behaviour of the slabs under static loading. This consists of two Linear Variable Differential Transducers (LVDT), one at center and another at quarter span and are used to receive displacement variation with time. Load cell attached to the head of the hydraulic jack to record load time history.

From the literature review it has been observed that a single assembly of instrumentation was not possible. The incorporation of electronic devices to record the specimen response to different energy level of impact is proved to be very efficient hence the data acquisition system along with LVDT, accelerometer and load cell is essential. In the present investigation the dynamic response and other parameters are studied with the help of very sensitive electronic devices. The response send by these devices are analyzed through a software programme to get actual experimental values. In addition, the data Acquisition system are used in the present investigation.

### 5.3 LVDT

LVDT (Linear Variable Different Transformer) is a sensitive device, shown in fig 4. used for measuring minute mechanical displacements. It consists of LVDT coil Prising of primary and two secondaries wound on an acrylic bobbin. A ferromagnetic core moves inside the coil. The output is proportional to the displacement. The electric inputs/outputs are termed on to a 6 – pin MS connector.

**Fig. 4. LVDT and its Fixtures**

## 5. IMPACT TESTING OF SLABS

### 5.1 General

Since the study is mainly aimed at evaluation of dynamic response due to load, as also the cumulative effect of such blows on the concrete slab elements, impact test a low velocity drop weight has been employed in the present experimental investigation.

The main objective of this investigation is to study the load-time variation, displacement-time variation and energy absorption capacity of slabs under low velocity repeated impact loading. Such data obtained from tests are to be analyzed to study the behaviour of slab under low velocity repeated impact loading.

### 5.2 Impact Testing Machine

The impact testing machine used in the present investigation is of low velocity drop weight type instrumented impact testing machine: The detailed view above machine is shown in Fig 5. The impact testing machine consists of major three parts are as follows.

In impact test the impact load was applied by means of the free fall of a drop weight from 1m height. For free fall the drop weight was arranged, to fall between the guided cylinder and impact the specimen at midpoint. The drop weight had a steel circular load cell of diameter 5.5cm as shown in the fig below.

**Fig.5. Impact Test Setup**

### 5.3 Instrumentation

The following instrumentation is used in the present experimental investigation to study the impact behaviour of the slabs under low velocity drop weight impact loading. This consists of,

- Two Linear Variable Differential Transducers (LVDT), one at center and another et quarter span and are used to receive displacement variation with time
- An accelerometer are used for recording acceleration time history.
- Load cell attached to the head of striker to record load time history

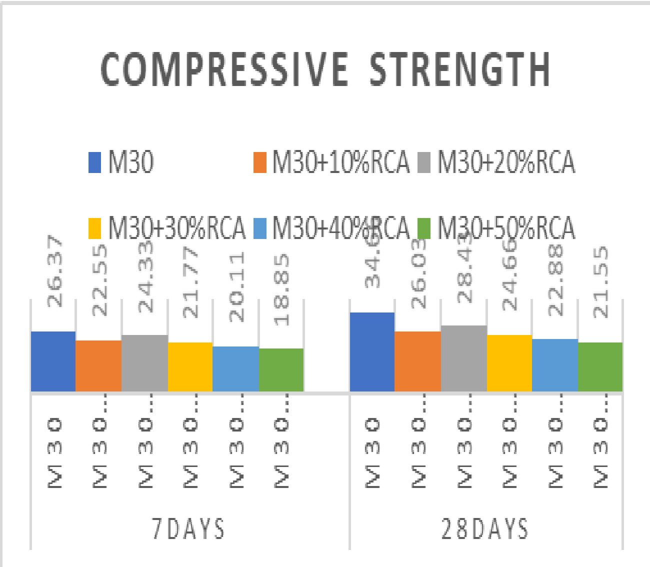
**Fig. 6. Drop Hammer**

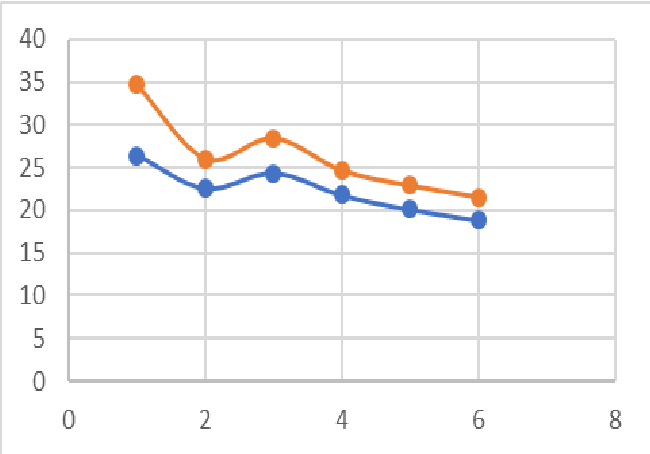
From the literature review it has been observed that a single assembly of instrumentation was not possible. The incorporation of electronic devices to record the specimen response to different energy level of impact is proved to be very efficient hence the data acquisition system along with LVDT, accelerometer and load cell is essential. In the present investigation the dynamic response and other parameters are studied with the help of very sensitive electronic devices. The response sends by these devices are analyzed through a software programmed to get actual experimental values. In addition, the data Acquisition system are used in the present investigation.

## 6. TEST RESULTS AND DISCUSSION OF EXPERIMENTAL PROGRAMME

### 6.1 Compression Test on Standard Cubes

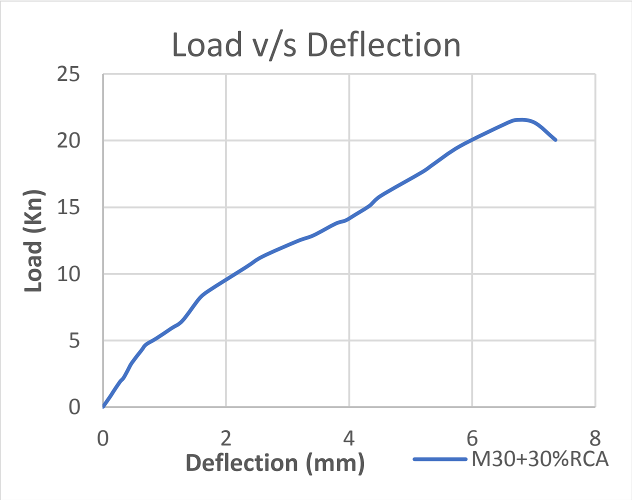
The test is conducted as per IS: 516-1959 (Reaffirmed 2008). The experimental compressive strength values obtained on standard cube specimen of size 150 mm x 150 mm x 150 mm, cured for 7 days and 28 days for all four different concrete matrices are presented in the form of graphs and bar charts shown in figure.

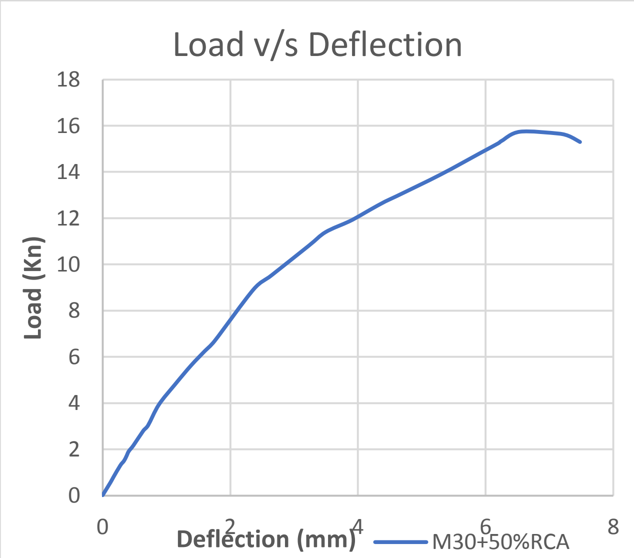


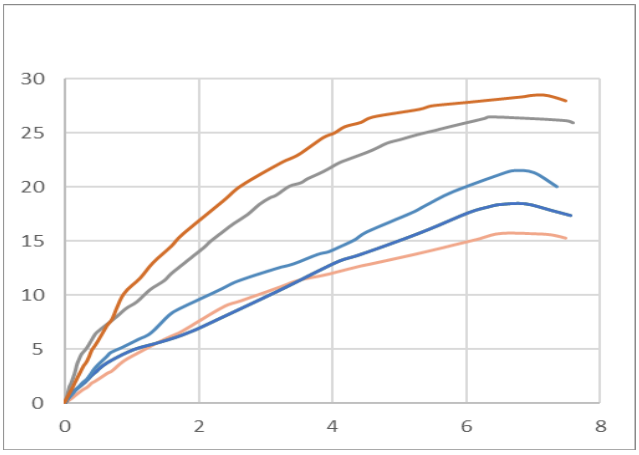




| Compressive Strength | | | | | | |
|---|---|---|---|---|---|---|
| DAYS | M30 | M30+10%RCA | M30+20%RCA | M30+30%RCA | M30+40%RCA | M30+50%RCA |
| 7 | 26.37 | 22.55 | 24.33 | 21.77 | 20.11 | 18.85 |
| 28 | 34.66 | 26.03 | 28.43 | 24.66 | 22.88 | 21.55 |

**6.2 Static Test Results for Slabs**

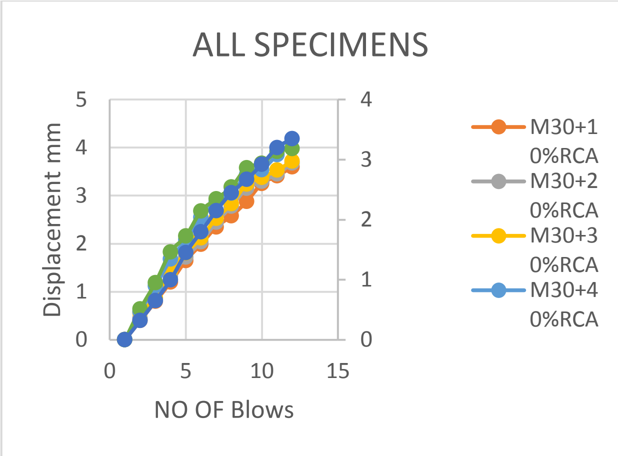



**Combined graph of all Specimens**

### 6.3 Impact Test Results for Slab




## 7. CONCLUSION

In this study it is found that there is not much variation in strength between ordinary concrete and 20% replaced aggregate concrete, which proves the previous works. But when the percentage of aggregate replaced increases there is a constant increase in strengths, which is a controversy to the previous works. Because it has been found that recycled aggregates obtained from recycling concrete are more angular and have higher absorption and specific gravity than natural coarse aggregates it may result on increase of strength and improved load carrying capacity. However, further studies to determine the effect on durability and improvement on workability are necessary.

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