International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

BEHAVIOUR OF RECYCLED AGGREGATE CONCRETE TWO WAY SLABS

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ABSTRACT: *Recycling of demolished concrete is beneficial and necessary from the view point of environmental preservation and effective utilization of resources. For the effective utilization of waste concrete, it is necessary to use demolished concrete as recycled aggregates for new concrete. To make this technology feasible, a significant amount of experimental works have been carried out worldwide. Previous investigations were mainly engaged in the processing of demolished concrete, the mix design, the physical and mechanical properties as well as the durability improvements. It is shown that some mechanical properties of recycled aggregate concrete may be generally lower than those of normal concrete. Research has been conducted on structural behavior of beams, columns, beam-column joints and frames made from recycled aggregate concrete. The major research conclusions by most previous investigators are positive. The crack pattern and failure modes of reinforced recycled aggregate concrete elements are similar to those of the reinforced natural aggregate concrete elements, but the load carrying capacity of recycled concrete elements is somewhat reduced. Little research has been conducted on punching shear and flexure behavior of reinforced recycled concrete slab elements. In this present study it is intended to study about the influence of recycled aggregate on the structural behavior of two way slabs under punching shear and flexural loading.*

Keywords: Recycled aggregates, demolished concrete, flexure, punching shear,two way slabs

1. GENERAL

The construction industry and concrete manufacturers have realised that they will need to use available aggregate rather than search for the perfect aggregate to make an ideal concrete suitable for all purposes. Simultaneously, significant increases in concrete recycling result in hundreds of tonnes of Recycled Concrete Aggregate (RCA) that could be used in the production of concrete for specific purposes. Currently, RCA is mainly being used as a substitute material for natural aggregate in unbound sub-base and base pavement layers in road construction. One of the most significant steps in promoting the use of recycled concrete aggregate in new concrete was, the 1994 publication by the RILEM Technical Committee of 121 titled 'Specification for Concrete with Recycled Aggregate' (RI LEM, 1994). The specification supplemented numerous research efforts from researchers around the world, especially from the United States, Europe and Japan. The research efforts have been oriented towards two principal aims, firstly at increasing the understanding of basic engineering properties of locally manufactured recycled concrete aggregate and secondly at the utilisation of the aggregate in concrete.

1.1 NEED OF THE PRESENT STUDY

The recycled coarse aggregate concrete (RCAC) is a new concrete which is similar to natural aggregate concrete, but the only difference is that the aggregate used is arrived from the demolished concrete waste. Till today the research of RCAC are mostly carried out in countries like United States, Europe and Japan etc., in India its research is at very initial stage. Advanced countries are using this RCAC mostly for the non structural elements because the research is also limited to basic physical and mechanical properties.

1.2 OBJECTIVES OF THE PRESENT WORK

The present investigation aims at conducting a feasibility study of producing recycled aggregate concrete slab elements. Accordingly, the specific objectives of the present work are listed below.

- To conduct feasibility study of mechanical properties of recycled aggregate concrete.
- To conduct feasibility study of punching shear properties of recycled aggregate concrete slab elements.
- To conduct feasibility study of flexural behavior of recycled aggregate concrete slab elements.

2. LITERATURE REVIEW

Ravindraraja (2000) demonstrated that the average value of water absorption in recycled aggregate was 6.35%, where as in natural aggregate it was 0.9%. The absorption capacity of recycled aggregates depends on the quality and quantity of adhered mortar. There was dependence between density and water absorption capacity. Recycle aggregates with adhered motor have lower density and higher wat

Gonzalez et al. (2008) concluded that recycled aggregate concrete shows more water absorption than conventional concrete. Furthermore it is concluded that by addition of silica fume to the recycled aggregate concrete and conventional concrete increases the water absorption.

Gao et al. (2008) found that the traditional testing approach for water absorption cannot give accurate results for recycled aggregate, based upon which, errors in concrete mix designs may result. Patches of cement pastes attached to the surface of recycled aggregate may affect water absorption in a manner different to conventional aggregate. Because of this, the standard duration of 24hour of saturation is not suitable for recycled aggregate. In order to affect by the amount of cement paste sticking on the aggregate, it varies from the site to site after crushing from which the recycled aggregate was generated.

In order to obtain the water absorption rates and corresponding soaking time, real-time assessment of water absorption is proposed to provide values of water absorption at different time intervals. Further, the proposed method can avoid the removal of cement paste during the soaking and drying process of recycled aggregate sample. This approach is simple and more accurate in measuring the genuine water absorption rate of recycled aggregate. This method has been tested and proven to be a good alternative for measuring water

Tam et al. (2008) demonstrated that there are correlations among the characteristics of the Recycled Demolished Concrete (DC) samples, and their Recycled Aggregate (RA) and Recycled Aggregate Concrete (RAC). It is shown that the inferior quality of DC can lower the quality of their RA and RAC. It is important to measure the characteristics of DC to provide a pre-requisite consideration for their RA and RAC applications. This can save time and cost for the production of inferior quality RA and ensure that high quality RA is produced for higher grade concrete applications. RAC design requirements can also be developed at the initial concrete demolition stage.

Gonzalez et al. (2008) concluded that it was possible to produce RC (with 50% of RC aggregates and a quantity of cements 6.2% higher than the one in CC) with almost same strength as CC and with the same consistency. The compressive strength of recycled concrete with silica fume was also similar to that of conventional concrete with this admixture. However, in all cases after 28 days (following the pozzolanic reaction) the RCS displayed greater compressive strength than the CC. In other words, the addition of 8% silica fume to mixes containing recycled aggregates was found to be beneficial in terms of compressive strength. Recycled concrete (RC) and control concrete (CC), recycled concrete with silica fume (RCS) and control concrete with silica fume (CCS) showed similar trends in compressive strength development.

Chakhradhara rao et al. (2011) observed that the concrete cured in air after 7 days of wet curing shows better strength than concrete cured completely under water for 28 days for all coarse aggregate replacement ratios.

Fig.1 Sample of RCA with cement paste residue

Table 1 Mix proportions of concrete (kg/m³) with W/C ratio 0.53

Nomenclature	Replacement of NCA with RCA	W/C	Cement (kg)	Fine aggregate (kg)	NCA (kg)	RCA (kg)
NCAC	0%	0.53	379	804	942	-
RCAC-20	20%	0.53	379	820	754	168
RCAC-40	40%	0.53	379	823	566	337
RCAC-60	60%	0.53	379	833	377	506
RCAC-80	80%	0.53	379	846	188	675
RCAC-100	100%	0.53	379	863	-	843

3. CASTING OF SPECIMENS

The following test specimens were prepared from each of the six concrete mix cases and the details are given below

a. 150mm size standard cubes for cube compressive strength.
b. 150mm diameter 300mm height standard cylinders for Cylinder.
c. Square slabs of size 1100 x 1100 x 50mm with tensile steel reinforcement (as per IS 456 minimum spacing criteria) of 6mm diameter bars at 90mm center to center, with a clear cover of 10mm and the bars are equally distributed in both the ways. The dimensions of the slab specimens. The slabs with the reinforcement arrangement were used for four edges simply supported and for four edges fixed, respectively.

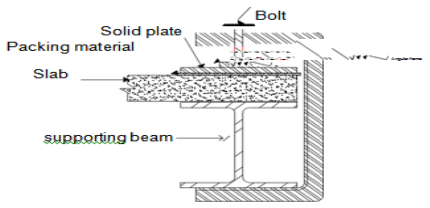

Fig.2 Proposed Edge restraint arrangement of Slab

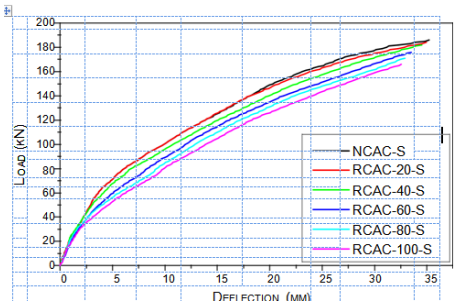

Fig.3 Load Vs deflection curves for simply supported slabs

4. CONCLUSIONS

Based on the results of the experimentation and the analysis of the results, the following conclusions seem to be valid.

1) The literature review carried out led to the identification of the need for conducting the feasibility study of producing recycled coarse aggregate concrete slab elements.
2) The cube and cylinder compressive strength decreases as the recycled coarse aggregate percentage increases. Similarly the split tensile strength also reduces.
3) The cube compressive strength of recycled coarse aggregate concrete (replacing of natural coarse aggregate with recycled coarse aggregate from 20% to 100%) is in the range of 42.52 to 33.48 MPa, where as natural coarse aggregate concrete is having a cube compressive strength of 43.33 MPa.
4) The cylinder compressive strength of recycled coarse aggregate concrete (replacing of natural coarse aggregate with recycled coarse aggregate from 20% to 100%) is in the range of 33.50 to 26.42 MPa, where as natural coarse aggregate concrete is having a cylinder compressive strength of 34.35 MPa.
5) The split tensile strength of recycled coarse aggregate concrete (replacing of natural coarse aggregate with recycled coarse aggregate from 20% to 100%) is in the range of 3.25 to 2.78 MPa, where as natural coarse aggregate concrete is having a tensile strength of 3.35 MPa.
6) The punching shear strength of slab specimen decreases as the percentage replacement of natural coarse aggregate with recycled coarse aggregate increases.
7) The Punching shear first crack load of simply supported natural coarse aggregate concrete slab specimen is 14.60 kN. The first crack load of simply supported recycled coarse aggregate concrete slab

specimens by replacing natural coarse aggregate with recycled coarse aggregate from 20% to 100% is between 14.20kN to 12.20 kN. Therefore, first crack load of recycled coarse aggregate concrete slab specimen decreases by 2.74 to 16.44%, when compared with natural coarse aggregate concrete slab specimens.

8) The Ultimate load in punching of simply supported natural coarse aggregate concrete slab specimen is 48.20 kN. The ultimate load of simply supported recycled coarse aggregate concrete slab specimens by replacing natural coarse aggregate with recycled coarse aggregate from 20% to 100% is in the range of 47.20kN to 41.40kN. Therefore, ultimate load of recycled coarse aggregate concrete slab specimen decreases in the range of 2.07 to 14.11%, when compared with natural coarse aggregate concrete slab specimens.

9) The central deflections corresponding to punching shear first crack load of simply supported recycled coarse aggregate concrete slab specimen is decreases from 3 to 30% when compared with natural coarse aggregate concrete specimens. And the central deflections corresponding to ultimate load decrease from 3 to 15% when compared with natural coarse aggregate concrete specimens. It is clear that similar trend is observed at first crack and ultimate failure stages. But, rate of decrease of deflections at first crack stage is more when compared to that of ultimate stage.

10) The stiffness and stiffness degradation decrease as the percentage of recycled coarse aggregate increases in simply supported slab specimens under punching shear.

11) The energy absorption of simply supported recycled coarse aggregate concrete slab specimens under punching shear decrease from 4.17 to 27.5% when compared with natural coarse aggregate concrete specimens.

12) For the simply supported slab specimens under punching shear, the cracks on the bottom face are radial running predominantly between the loading point and the corners. A circular punching occurred on the top surface (surrounding the patch load), this was reflected on the bottom face with an enlarged area, clearly identifying the truncated cone. It is observed that the bottom perimeter of this truncated cone decreases as the replacement of natural coarse aggregate with recycled coarse aggregate increases, although the overall cracking pattern remains identical for all slab specimens.

13) The average critical section of simply supported recycled aggregate concrete slabs under punching shear is 2.05 times of thickness of the slab.

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