Use of Recycled Concrete Aggregate in Construction

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Abstract – Recycled aggregates comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. This study aims to develop the best economic solution by use of that demolition debris as recycled aggregate in structural concrete to reduce the environmental impact, the main objective of this paper is to investigate the hardness properties of Recycled Aggregates & Recycled Concrete Aggregate including abrasion test, impact value test & water absorption test on aggregates while slump, compressive strength, tensile strength & modulus of elasticity on fresh & hard concrete, which will give a better understanding on the properties of concrete with recycled aggregates, as an substitute material to virgin coarse aggregate in structural concrete.

To determining the above properties of the recycled aggregate by studying the influence of limited percentage of recycled aggregate in concrete. The Laboratory trials were conducted with the aggregate size of 10-20mm, there were total of six batches of two concrete mixes M30 with 0.42 w/c & M20 with 0.5 w/c, consist of 00%, 40% & 60% of recycled aggregate replacement. The workability of concrete will be decreased as the amount of recycled aggregate increased but in the end, is considerable in the mix as it is still under the limits. This was evaluated through standard slump test. For strength characteristics, the results showed a gradually decreasing in modulus of elasticity, tensile strength, compressive strength as the percentage of recycled aggregate used in the specimens increased but at last most of the results were satisfactory & under the limits.

1. INTRODUCTION

This paper is concerned about the recycled aggregates obtained from the C&D waste of concrete. C&D materials means any material, matter or thing which is generated as a result of construction and demolition work. It is a mixture of materials arising from site clearance, dugout, construction, refurbishment, renovation, demolition and road works. Over 80% of C&D materials are idle and are known as public fill. Public fill includes debris, rubble, and earth and concrete which is convenient for land redemption and site development. Properly sorted concrete can be recycled for use in construction.

Concrete is the premier construction material across the world and the most widely used in all types of construction works along with infrastructure, defense installations, low and high-rise buildings, and environmental protection facilities while aggregate plays one of the most vitally important part in concrete production as it profoundly influences concrete properties and performance. Regarding aggregate usage in concrete, a conservative estimate is that in a general way 4.5 billion tons of concrete aggregates are consumed worldwide per year. This figure is assumed to represent total aggregate making, along with usage in concrete and road base. Aggregate usage in concrete constitutes perhaps between 25 and 35 percent of the total aggregate production.

Construction activity leads to generation of solid wastes, which include gravel, sand, bricks, stone, concrete, bitumen, metal, wood etc. The management of construction and demolition waste is a dominant matter for town architect due to the growing measure of demolition's rubble, continuing shortage of dumping sites, booming in conveying and laying charge and above all growing concern about pollution and environmental deterioration.

2. EXPERIMENTAL WORK

It took some effort to transform the demolished rubbles into the required size of recycled aggregates. Materials other-than recycled aggregates was collected from the local construction site. Materials are natural coarse aggregate, natural fine aggregate, cement and super-plasticizer will be collected from the ITM Global School construction site venue-near Turari village, AH-43 near ITM University Gwalior. These materials will be available and escorted easily at the laboratory in the ITM University though there is a construction under progress in that school which is linked with ITM University. Following are the description of the materials;

- Natural coarse aggregate of 20mm
- Natural coarse aggregate of 10mm
- Natural fine aggregate(sand) of size less than 2.36 mm
- Cement OPC 53 grade
- Super-plasticizer – Aster super-plasticizer ASP200
- Recycled aggregates- Recycled aggregates are collected from Neoteric Garden Palace near sun-valley, nearly 5kms from ITM University, Gwalior. There was a retaining wall which was demolished due to the failure at foundation level. It was 2 years old which is good for the project point of view. Recycled aggregates which are to be tested must have the age of one year of serving in the concrete structures so it will be considered as well stressed aggregates in terms of different stresses. Wall was demolished and the debris in the form of boulders was packed in the emptied cement bags and then escorted through loading vehicle to the laboratory of ITMU.

Rubbles are hammered to the required size of "recycled aggregate" on which tests were to be performed. Debris sized of 80-150 mm boulders. It was hammered twice to prepare main content. Firstly it was hammered to separate aggregates from mortar and then again hammered to make the aggregate of required size i.e. 20mm and 10mm.

Sieve analysis- sieve analysis was done to separate the hammered aggregates in the necessary sizes 10mm & 20mm.

2.1. Mix design-

The selection of materials to be mix and their required quantity must have done through a process called mix design. There are lots of methods for determining concrete mix design. In this project, mix was prepared according to IS 10262-2009 & MORT&H for two mix designs of compressive strength M20 & M30.

The design of a concrete mix is usually based on compressive strength which is sufficient to achieve the 2 principal requirements of the hardened concrete for obtaining good quality concrete;

- Water / cement ratio should be low enough to give the required strength for structural strength and durability purposes.
- The mix should be workable and cohesive enough to ensure a thoroughly compacted and homogeneous material.
- The mix design of RAC is no different from that of conventional concrete and the same mix design procedures can be used. But in practice, some modifications may take place;
- Trial mixes should be made to obtain the required workability and the most suitable w/c ratio.

When coarse aggregate is used with natural sand, it may be assumed at the design stage that the free water / cement ratio required for a certain compressive strength will be the same for RAC as for conventional concrete. If trial mixes shows that the compressive strength is lower than required, adjustment of water / cement ratio should be made.

2.2. Mix proportion and batches-

M30- The mix design M30 was designed for slump 40-70 mm. Admixture (Aster Super-plasticizer 200) is used. The mix proportion is taken by weight is shown below;

Cement	Sand (fine aggregate	Coarse aggregate (20mm)	Coarse aggregate (10mm)	Water	Admix
1	1.87	2.43	0.94	0.42	5.26 (gm)

Table 2.1 Ratio of mix by weight

Mass of cement (OPC 53grade)	380kg /m3
Water	160
Sand	711
Coarse aggregate 20mm 10mm	1283 924 359
Admixture	1.9
Water/cement	0.42

Table 2.2 Proportion of materials used in 1 cubic meter

M20- The mix M20 was designed for slump 25mm, no admixture was used in it according to IS mix design for M20. The mix proportion is taken by weight is shown below;

Cement	Sand (fine aggregate)	Coarse aggregate (20mm)	Coarse aggregate (10mm)	Water
1	2.4	3.54	1.37	0.5

Table 2.3 Ratio of mix by weight

Mass of cement (OPC 53 grade)	290kg /m3
Water	145
Sand	696

Coarse aggregate 20mm 10mm	1429 1029 400
Admixture	-
Water/cement	0.5

Table 2.4 Proportion of materials used in 1 cubic meter:

2.3 Percentage replacement of RA-

Two mixes M20 & M30 will be designed for same replacement of recycled aggregates with natural aggregates. RA00, RA40, RA60 are the three batches prepared for M20 & M30 consecutively, overall six batches were made. The initial mix batch will be 100% natural aggregate mix batch (RA00 means replacement of recycled aggregate with natural aggregate is 0%), second mix batch was 60% natural aggregate and 40% recycled aggregate (RA40) and third mix was 40% natural aggregate and 60% recycled aggregate (RA60). M20 & M30 mix design has different water cement ratio, cement content, different proportion of coarse and fine aggregates. The only main difference is that admixture is used in M30 and not used in M20 mix design.

2.4 Mixing & casting of concrete specimens-

The objective of mixing is to obtain a uniform and consistent of cement, water, aggregate, sand and any admixtures used in the concrete and also to meet the requirement of the standard. There are 12 cubes and 12 cylinders in 6 batches of 2 mix design, mixed and was molded according to MORT&H & IS 10262-2009.

Specimen casting-

M20:

RA00% 2 cubes and 2 cylinders (full NA)

RA40% 2 cubes and 2 cylinders (NA60%)

RA60% 2 cubes and 2 cylinders (NA40%)

M30:

RA00% 2 cubes and 2 cylinders (full NA)

RA40% 2 cubes and 2 cylinders (NA60%)

RA60% 2 cubes and 2 cylinders (NA40%)

Specimen size:

Cube mould size: - 150×150×150

Cylinder mould size: - 100×200

Cubes will be tested for compression test and elastic modulus test, and cylinder will be for split tensile strength.

3. TEST AND RESULT DISCUSSION

a. Introduction-

Series of test was accomplished on the natural and recycled aggregate, concrete cubes & cylinders to get the strength characteristics of the recycled concrete aggregate for probable application in normal strength concrete. The compressive, tensile and bond strengths of concrete are relatively important mechanical properties of hardened concrete including recycled aggregate concrete. The recycled concrete must embrace the same conventional concreting practices to guarantee the hardened concrete properties. This part will discuss on the results that obtained from the testing and compare them to the standards accordingly. The results are such as abrasion test, impact value test, water absorption & specific gravity of aggregates, slump test, compression test, split tensile test and modulus of elasticity.

b. LA Abrasion test result analysis-

The LA abrasion value of the recycled aggregate is 30% of 12-20mm sized fraction. This value is higher than that of virgin aggregates which has abrasion value 25.5%. Recycled aggregates are well washed and prepared for the testing and it shows good strength but not more than virgin aggregates. Aggregates with lower abrasion value percentage are comparatively stronger. It is possible to allow for the abrasion loss in the mixture proportion because the aggregate itself does not break down. Instead, the maximum LA abrasion value for aggregates is 30% for cement concrete pavement course. Therefore, the result is acceptable in this experiment. Table form comparison will be given below;

Aggregate type	Abrasion value (%)
RA	30%
NA	25.5%

Table 3.1 Abrasion value comparison

c. Impact value test result analysis-

The impact value of the recycled aggregate is 9.1% of 12-20mm sized fraction. Two tests were conducted and the mean value is 9.1% which is good but not better than natural aggregate whose mean value of two tests are 6.15 %. Besides, both the aggregate types are exceptionally strong as their value lies below 10% according to the transportation engineering lab manual 2013. Aggregate strength percentage lower than 10% is exceptionally strong and those vary between 10-20% will be categorized as strong while those of vary between 20-30% will be taken as satisfactory for cement concrete surface course and those which varies from 30-45% will be taken in the category of cement concrete base course while not as surface course.

And here we have the aggregate better than 10% which can be easily used in the structural cement concrete. Therefore, the results are easily acceptable in this experiment. Table form comparison will be given below;

Aggregate type	Impact value
RA	9.1%
NA	6.15%

Table 3.2 Impact value comparison

d. Water absorption and specific gravity test results and analysis-

The results have shown the higher water absorption of 2% of recycled aggregates. Because it has little mortar attached to the surrounding of the recycled aggregate. It indicates that the cleanliness & washing of the recycled aggregate is still need to be done properly to get the results near to as of natural aggregates. The percentage of water absorption for the natural aggregates is 0.99% which is better than that of recycled aggregates. The average permissible water absorption of aggregate should not be greater than 2%. Though, normal weight aggregates of higher absorption values may be acceptable depends on local performance. As far as concern about this experiment, the water absorption of recycled aggregate does not exceed permissible value so it is acceptable.

Now concerning about specific gravity of the recycled aggregates, it shows the result varies between 2.19 – 2.43 which is nearly 2.31 by taking average of two readings, while the specific gravity of natural aggregates varies around 2.58 which is ok. The normal specific gravity varies from 2.5 to 3. Specific gravity helps in identification of stone, to measure the strength and quality of the aggregates, in such case, quality does not matter much where strength of the aggregates have passed their test (as stated in the earlier test analysis) so this can also be accepted.

Aggregate type	Water absorption	Specific gravity
RA	2%	2.31
NA	0.99%	2.58

Table 3.3 Water absorption & specific gravity value comparison

e. Slump test result and analysis-

There are two mixes of M20 & M30 designed for 25±5mm slump with w/c ratio 0.5 & 50-75±10mm slump with w/c ratio .42 respectively. The slump value was used as indication of mix workability. The slump of M20 RA00 is about 21.5mm, M20 RA40 is about 18mm & M20 RA60 is about 19mm with no admixture added. Whereas M30 RA00 is 55mm, M30 RA40 is 41.5mm & M30 RA60 is 42.5mm as shown below in the table. The measured slump for natural aggregate is within the limitations while slump of mix in which recycled aggregate was added is slightly low (2 to 3mm) which can be considered, this difference is not so big and can be covered with little alterations in the testing. So there must be no difficulty in casting, placing & finishing.

Batch	M2O	M3O
RA00	21.5mm	55mm
RA40	18mm	41.5mm
RA60	19mm	42.5mm

Table 3.4 Slump test comparison

f. Compression test result and analysis-

The characteristic strength for this project is 20MPa & 30MPa. From the obtained result, it shows that the batches that have met the target strength with 0% & 60% (RA00 & RA60) replacement of natural aggregate of both the mixes by gaining 30.5MPa & 33.3MPa for M30 and 24.4MPa & 22.75MPa for M20 batch mix. The compressive strength for other batch with 40% (RA40) replacement of natural aggregate is around 25MPa & 18MPa for mixes M30 & M20 respectively, this shows that these batches of different mixes does not achieve the target strength. It means that the RA60 batch can be used in the structural construction where compressibility mainly tends to affect the structure. Strength of the concrete can also be controlled by decreasing water cement ratio. RA40 batch shows 2 to 5MPa lower than the target strength which can be controlled by decreasing water cement ratio, but according to the results of this experiment RA60 can be easily applied at the place of virgin aggregates. Results can be seen in the table below clearly.

Batch	M20	M30
RA00	24.4MPa	30.5MPa
RA40	18.75MPa	25MPa
RA60	22.75MPa	33.3MPa

Table 3.5 Compression strength value comparison

g. Elastic modulus test result and analysis-

The modulus of elasticity test shows a decreasing trend of modulus of elasticity value when the recycled aggregate percentage increased but up to 40% replacement only while 60% replacement of natural aggregate shows appreciable value which can be considered at real time implementation of concrete as seen in the table below. According to Code of practice for structural use of concrete 2004 second edition Table 2.3, minimum elastic modulus value of M20 is 18GPa & of M30 is 22.2GPa. So according to this, the value of elastic modulus of the mixes in this experiment passes the minimum target strength and hence, can be considered without any difficulty.

Batch	M20	M30
RA00	27.2GPa	29.3GPa
RA40	24.75GPa	27.4GPa
RA60	26.55GPa	30.15GPa

Table 3.6 Elastic modulus value comparison

h. Split tensile strength test result and analysis-

The 28-day standard cured cylinder split tensile strength of all mix batches lies between the target strength except of M30 RA60 batch. RA60 batch of M30 mix shows the split tensile 2.22MPa which is slightly lower according to the standard value which is minimum 2.49MPa for M30 mix. Besides this, all batches of both M20 & M30 mixes lies within the limits of standard values of mixes. Well the difference between minimum value of split tensile of M30 and the original value is very less nearly 0.27MPa which can be controlled and consider because concrete cannot be used as the splitting resistance member. Comparison can be seen in the table below;

Batch	M20	M30
RA00	2.46MPa	3.25MPa
RA40	2.38MPa	3.57MPa
RA60	2.38MPa	2.22MPa

Table 3.7 Split tensile value comparison

i. Summary-

The workability of recycled aggregate concrete is slightly less because the mortar adhered from the original concrete makes the recycled aggregates little porous and absorptive than its natural equivalent, the absorption capacity of recycled aggregate is just twice of natural aggregates absorption capacity but under the limits.

The recycled aggregate test results showed that the recycled aggregate concrete can give strength almost similar to an equivalent concrete with natural aggregates. The use of recycled aggregate does not gravely affect the compressive strength of the concrete. Using 60 % of recycled coarse aggregate in concrete mixes shows comparatively better compressive strength than conventional aggregate concrete in M30 mix and also shows appreciable results in M20 mix with same percentage replacement.

The behavior of recycled aggregate concrete is the same as natural aggregate concrete under split tensile loading in both M20 & M30 mix.

The Elastic modulus of the recycled aggregate concrete also matches its counterpart natural aggregate concrete.

j. Advantages

There are many preferences through using the RA. The major preference is based on the environmental profit. According to Commonwealth Scientific and Industrial Research Organization (CSIRO) construction and demolition waste makes up to around 40% of the total waste each year (estimate around 14 million tons) going to landfill worldwide. Through recycled these material, it can keep diminishing there sources of metropolitan aggregated. Therefore, RA can be used in higher grade applications.

- The cost of RA is reasonable than NA.
- The recycling site may accept these aggregates 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.
- Recycled aggregates have great potential in concrete. According to ECCO (Environmental Council of Concrete Organization), RCA can be used for side walk, bridge substructures, curbs, concrete shoulders, residential driveways, and superstructures, general and structural fills.
- It also mentioned that recycled concrete aggregate can be used in support layers, sub-bases and such as permeable base and unsterilized bases.
- The most considerable advantage is the reduced environmental impact by reducing the amount of debris that must be disposed.
- Less demand for natural aggregates which directs to decreasing in crushing of mountains for consumption of natural aggregates.
- Produce job opportunities in the local area & around and also a financial benefit for business like, Local council engineers;

Concrete subcontractors; Specialist of civil works; Demolition contractors; recycled material plants etc.

Thus, the use of recycled aggregates in concrete provides environmental as well as economics benefits.

k. Disadvantages

The major concern is the variation in concrete strength with recycled aggregate. The strength may vary from customer to customer & job to job. In such projects, the bulk mass of the concrete obtained is from demolition work. Although, the laboratory tests of three different batches took more than two months besides, RA40 batch shows less strength instead of RA60 in which recycled aggregate percentage is more than that of RA40 batch so basically if increment of recycled aggregate by 40% in concrete reduces strengths of concrete than it will do so in the increment of RA by 60% too, besides it strength increases. It means it is unpredictable & it is recommended to perform lab testing before applying RAC into the projects.

4. CONCLUSION

According to the test which has been carried out in the laboratory of ITM University Gwalior, results shown by testing the multiple samples that good quality concrete could be produced with recycled aggregates. The use of aggregates produced from recycled construction and demolition waste should be further promoted. Based on the experimental investigation reported in the work, the following conclusions are drawn:

Test results of recycled aggregates has shown the competitive strength in comparison with natural aggregates so according to this work, it is clear that there is no issue of using the recycled aggregates instead of natural aggregates in the implementations where compression is concerned.

Workability of the concrete is considerable and can be achieved by adding super plasticizers in the mix especially when the mix contains RA more than 40% according to the test results of this project. Adding of admixtures in mix can improve the workability and setting time of concrete can be controlled according to the needs of the implementation of concrete with recycled aggregates.

There is also a noteworthy conclusion that the laboratory test results confirms that the compressive strength, split tensile strength & elastic modulus of recycled aggregate concrete can meet the requirements of normal strength concrete standards. So RAC can be used according to the mixes used in this work.

Hence Recycled aggregate concrete has been proved to perform adequately and in a manner as good as to the concrete containing natural aggregates. It is likely that this study may lead to a greater use of Recycled Concrete Aggregate materials and its diversion from landfills.

Recommendation for further studies in this work line-

As studies have cleared that recycled concrete aggregate can be used as aggregate for new concrete, this is must to get hold of long terms in service performance concrete made with recycled aggregate concrete to evaluate its durability and performance. If supplementary research supports the use of recycled concrete in buildings then existing specification might be revised to permit and persuade the use of recycled concrete aggregate. Using recycled aggregate in concrete mixes leads to protect existing supplies of natural aggregates by breaking off the mountains and directly toying with the nature and to reduce the amount of solid waste that be disposed of in landfills. Advanced testing and analysis on the recycled aggregate concrete is extremely recommended to point out the strength characteristics of recycled aggregates for implementation in high strength concrete. Below are some recommendations for further studies:

- A vital step in maintaining and encouraging the recyclability of concrete is the skill to separate other building materials like wood, polyethylene products, bricks, minerals, etc from the concrete construction that might either be mismatched in a normal preparation process, or may at least check the recycling.
- Other investigations and laboratory tests must be done on the strength properties of recycled aggregates. It is advised that testing can be done on concrete slabs, beams and walls.
- More trials with varying particle sizes of recycled aggregates and percentage replacement of recycled aggregate are also advised to get advanced strength characteristics in the recycled aggregate concrete.
- The affect of pollutants in the demolished concrete from buildings must be studied carefully and examine to make longer life of concrete made with recycled aggregate concrete.
- The fire-resistant characteristic of recycled aggregates must be carefully analyzed.
- Vast work is needed to expand specifications and standards so as to create opportunities for the better use of recycled aggregates.

REFERENCES

[1] Cheng-Chih Fan, Ran Huang, Howard Hwang and Sao-Jeng Chao The Effects of Different Fine Recycled Concrete Aggregates on the Properties of Mortar in ISSN 1996-1944 <www.mdpi.com/journal/materials>

[2] D.V. Prasada Rao and P.L. Sindhu Desai Experimental investigations of coarse aggregates in recycled concrete Vol. 7, Issue 5, pp. 1522-1530 International Journal of Advances in Engineering & Technology, Nov., 2014. ©IJAET

[3] Hisham Qasrawi, Iqbal Marie & Hasan Tantawi Use of recycled concrete rubbles as coarse aggregate in concrete <qasrawi2@yahoo.com>

[4] Horia Constantinescua, Oana Ghermanb, Camelia Negrutiua, Sosa Pavel Ioan Mechanical Properties of Hardened High Strength Concrete, 9th

[5] International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania <www.sciencedirect.com>
[6] Praveen Mathew, Jeevan Jacob, Leni Stephen, Thomas Paul Recycled Aggregate Concrete, a Sustainable Option from Demolition Concrete Waste- A Percentage Replacement Method Vol. 3, Issue 2, February 2014
[7] Rajindervir Singh, Jagmeet singh Recycled aggregate concrete (RAC)- A sustainable approach for construction industry IJREAS volume 5, Issue 11 (November, 2015)
[8] Surya Hani Adnani, Lee Yee Loon, Ismail Abdul Rahman, Hamidah Mohd. Saman, Mia Vimala Soejoso Compressive sterength of recycled aggregate to concrete with various percentage of recycled aggregate <suraya@uthm.edu.my>
[9] Banjad Pecur, N. Stirmer and B. Milovanovic Durability properties of recycled aggregate concrete Department of Materials, Faculty of Civil Engineering, University of Zagreb, Croatia, <ninab@grad.hr>
[10] N.Sivakumar1, S.Muthukumar2, V.Sivakumar2 D.Gowtham2, V.Muthuraj2 Experimental Studies on High Strength Concrete by using Recycled Coarse Aggregate *Vol.4, Issue 01 (January 2014)* <*www.researchinventy.com*>
[11] Amnon Katz Properties of concrete made with recycled aggregate from partially hydrated old concrete Cement and Concrete Research 33 (2003) 703– 711
[12] Sudhir P Patil**,** Ganesh single**,** Prashant D.Sathe, Recycled coarse aggregatesEmail:<Sudhir.patil@mitpune.edu.in>,<ganesh.ingle@mitpune.edu.in>, <Prashant.sathe@mitpune.edu.in>
[13] Mirjana Malešev, Vlastimir Radonjanin and Snežana Marinković Recycled Concrete as Aggregate for Structural Concrete Production <www.mdpi.com/journal/sustainability>
[14] Larbi Belagraa, Miloud Beddar, Study of the Mechanical Performance of a Recycled Aggregate Concrete with Admixture Addition <http://www.scirp.org/journal/ojce>
[15] Mr. Tushar R Sonawane, Prof. Dr. Sunil S. Pimplikar, Use of Recycled Aggregate Concrete *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 52-59 Second International Conference on Emerging Trends in engineering (SICETE)* < *www.iosrjournals.org*>
[16] Dr. M Nagesh, Concrete durability, VTU EDUSAT series 16th Program Government engineering college Ramnagara-562159 E-mail ID:-mandyanagesh@gmail.com
[17] Roz-Ud-Din Nassar, Parviz Soroushian, Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement, SciVerse ScienceDirect, <www.elsevier.com/locate/conbuildmat>
[18] Young P C & Teo DCL, Utilization of recycled aggregate as coarse aggregate in concrete UNIMAS E-Journal of Civil Engineering, vol. 1: issue 1/ august 2009
[19] Vivian W. Y. Tam and C. M. Tam, Assessment of Durability of Recycled Aggregate Concrete Produced by Two-Stage Mixing Approach <v.tam@griffith.edu.au.>
[20] Fuminori Tomosawa and Takafumi Noguchi, Relation between compressive strength and modulus of elasticity of high strength concrete, Dept. of Architecture, Fac. of Engineering, Univ. of Tokyo
[21] Ir Paul T C Pang (chairman) Code of Practice for Structural Use of Concrete 2004 (Second Edition) Buildings Department 12/F-18/F Pioneer Centre 750 Nathan Road Mongkok, Kowloon Hong Kong
[22] KOU, Shicong, Reusing recycled aggregate in structural concrete <http://www.lib.polyu.edu.hk>
[23] Nelson, Shing Chai NGO, High-Strength Structural Concrete with Recycled Aggregates Nov, 2004
[24] Ayed Ahmad Zuhud, Performance of Recycled Aggregate Concrete Nov, 2008
[25] Margaret Mary O'mahony, Recycling of material in civil engineering, Trinity term 1990
[26] Boris Haranki, Strength, modulus of elasticity, creep & shrinkage of concrete used in Florida, University of Florida, 2009
[27] Miss Kwong Man Karen CHIU, The use of recycled cocnrete aggregate in structural concrete around south east Queensland, Nov, 2006
[28] Jianzhuang Xiao, Long Li, Review on Recycled Aggregate Concrete in the Past 15 Years in China, <jzx@tongji.edu.cn>,<liong_9.19@163.com,> <http://www.classie.info/proceedings.htm>
[29] S R Yadav, S R Pathak, Use of recycled aggregate concrete in making concrete – An overview 34th Conference on our world in concrete & structures: 16 – 18 August 2009, Singapore
[30] Katrina McNeil, and Thomas H.-K. Kang, Recycled Concrete Aggregates: A Review International Journal of Concrete Structures and Materials Vol.7, No.1, pp.61–69, March 2013 <tkang@snu.ac.kr>
[31] Dr.N.Suresh Professor, NIE, Mysore, Workability of concrete
[32] K.Anbuvelan, Dr.K.Subramanian, Experimental investigations on Elastic Properties of Concrete containing Steel fibre K.Anbuvelan et al. / International Journal of Engineering and Technology (IJET) <ksanbuvelan@yahoo.co.in>
[33] Chetan S. Patil, Lab manual of concrete technology Sanjay ghodawat group of institutions, atigre, Kolhapur
[34] Centre of science and environment department, Construction and demolition waste <http://www.cseindia.org/>, <cse@cseindia.org>

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