Significance of Demolished Concrete in Pavement Construction

Ravinder

Abstract— **The purpose of this research was to study the behavior of recycled coarse aggregates when it was included in Plain Cement Concrete. Slump test was performed on freshly mixed concrete, and compression test was performed on hardened concrete. 150 samples of concrete were prepared with RCA and natural aggregate, changing their mixture design parameters, including coarse aggregate proportion**

Index Terms— **Plain Cement Concrete, Compressive strength, compression testing machine (CTM)**
Sub Area : Transportation/Highway Engineering
Broad Area :**Civil Engineering**

I. INTRODUCTION

Use of RCA conserves virgin aggregate, decreases the impact on landfills and energy consumption, increases cost savings in the transportation of aggregate and waste products. Indian economy is of developing nature. So the problem of demolished waste is not huge as in developed countries. But it is not far off when India may have to face this problem. In the down town areas of the metropolitan cities concrete towers are replacing the old buildings causing generation of demolished waste which needs to be transported and dumped. It is estimated that the construction industry in India generates about 10-12 million tons of waste annually. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000million m^3 [chapter 4, *urbanindia.nic.in*]. An additional 750 million m^3 aggregates would be required for achieving the targets of the road sector. Recycling of aggregate material from construction and demolition waste may reduce the demand-supply gap in both these sectors. Thus in a developing country like India, effective use of demolished concrete could be of great help in reduction of concrete waste and maintaining a pollution free environment . There are several barriers in use of RCA in concrete. Cost of concrete crushers is very high which increases the initial cost for plant. In addition, maintenance cost of concrete crushers is also significant.

II. OBJECTIVES OF THE STUDY

The study on use of demolished concrete in pavement construction consists of conducting laboratory investigations on cement concrete prepared by using demolished concrete to estimate its suitability for pavement construction. The main objectives of study are:

1. To prepare mix design for M40 concrete with varying proportions of recycled aggregates.
2. To determine the compressive strength of the samples at the end of 7, 28, 56 and 90 days.
3. To determine the flexural strength of the samples at the end of 7,28, and 90 days

III. LITERATURE REVIEW

In Lowa [Kumar,Satish,2002] recycled concrete was first used in 1976 for the production of new concrete where a 41 years old pavement was crushed and demolished concrete was used for the construction of 1 mile long and 22.5 cm thick highway pavement. In other construction of 17 mile long and 20 cm thick highway pavement, crushed concrete was used in Lowa in 1978. The Minnesota department of transportation recycled 16 mile long plain concrete pavement into a new concrete pavement on trunk highway in 1980. In Netherland, recycled aggregates are used for partition walls in apartments. After the damage caused in Second World War, countries like Germany, England, Netherland and other European countries have tried to use recycled concrete in new construction and made a lot of investigations over it. Some countries have developed code of practice for the use of recycled aggregates. In India recycled aggregates are not much used, but its future seems bright and one can predict remarkable contribution of recycled aggregates.

The ability to resist compression loads is called Compressive strength. It is found that the use of RCA in the concrete mix decreases compressive strength compared to natural aggregate. But it is also found that, at 28 days, all mix designs usually exceed 50MPa compressive strength [Shayan 2003]. In one study it is found that the compressive strength of natural concrete was 58.6 MPa, and the RCA concrete ranged from 50.9 to 62.1 MPa. The compressive strength for 50% RCA concrete was higher than 100% RCA concrete [Poon 2002]. In other study it is found that the loss of compressive strength is in the range of 30-40% for the concrete made with RCA at 28-days [Katz 2003]. There was very less reduction in 28- and 56-day compressive strength when natural aggregate was partially replaced with RCA and a much greater reduction when RCA was used in full [Abou-Zeid 2005].

The compressive strength is most affected by the w/c ratio [Lin 2004]. Other influential parameters include fine recycled aggregate content, cleanness of aggregate, interaction between fine recycled aggregate content and crushed brick content, and interaction between w/c ratio and coarse RCA content [Lin 2004]. At a constant w/c ratio, air-dried RCA containing concrete had the highest compressive strength compared to oven-dried and saturated surface dry RCA [Poon 2003]. Particularly at lower w/c ratios, unwashed RCA reduces compressive strength. Compressive strength is 60% of virgin concrete at 0.38 w/c and 75% at 0.6 w/c [Chen 2003].

Manuscript received Dec, 2020
Ravinder , Assistant Professor- Civil Engineering Department, HCTM Technical Campus Kaithal , (Haryana), India

In a study it is found that there is a strong interaction between maximum aggregate size and water-cement ratio when compared with compressive strength development [Tavakoli 1996a]. Due to a lower w/c ratio Compressive strength may increase for RCA, 14% and 34% respectively in comparison of natural aggregates. However, compressive strength may decrease for RCA since it has a higher air entrainment, 25%, compared to virgin aggregate 23% [Salem 2003]. The most of strength loss for RCA concrete can be caused by the presence of material smaller than 2 mm because natural sand has greater strength than RCA fines. It is recommended that RCA fines should not be more than 50% of the sand content [Shayan 2003]. Bonding between the RCA and the cement can be affected by loose particles created during the crushing process. Treating the RCA by impregnation of silica fume resulted in an increase in compressive strength of approximately at 30% at 7-days and 15% at 28-days. If RCA is exposed to ultrasound then it results in a uniform increase of 7% compressive strength over time [Katz 2004]. Compressive strength of the final concrete is affected by the age at which RCA has been crushed. For example, crushing concrete into RCA after three days compared to one day resulted in a seven percent increase in compressive strength of the new RCA concrete at 7 days. The difference in compressive strength of the new RCA concrete increased to 13% at the age of 90 days [Katz 2003]. The compressive strength of the original crushed concrete affects the compressive strength of the RCA concrete [Tavakoli 1996a]. However, it is also found that RCA concrete can produce higher compressive strengths than the original concrete [Ajdukiewicz 2002]. For example, an 80 MPa concrete was produced from an original 60MPa concrete [Ajdukiewicz 2002]. There was the same basic trend in all strength development when laboratory made RCA and field demolished RCA were compared [Tavakoli 1996a]. Presence of admixtures in the original concrete had not much impact on the compressive strength of the new RCA concrete [Hansen 1984].Slag added RCA concrete develops strength over a longer period of time compared to normal concrete. [Sagoe-Crentsil 2001]. Some research showed that compressive strength is dependent on the amount of time the RCA spent in the stockpile after crushing [Rashwan 1997]. For example, concrete made with RCA that was in the stockpile one day had a 25% higher compressive strength than concrete made with RCA that was in the stockpile 28 days. Concrete made with RCA that was in the stockpile seven days had 7% lower compressive strength than concrete that was in the stockpile 28 days [Rashwan 1997]. If RCA concrete is exposed to 600 ^{0}C temperature then it showed good performance with a loss in compressive strength of 20-25% [Abou-Zeid 2005]. In s study it is also found that RCA concrete fails due to passage of cracks through the RCA, however when virgin concrete fails it is usually due to bond failure at the aggregate-paste interface [Salem 2003]

In 2002,Buyle-bodin, F.et. al. showed a comparison between the behavior of RAC and natural aggregates. The affect of both the composition and the curing conditions was discussed. It was observed that durability of RAC is controlled by flow properties of high total W/C ratio and air permeability. The diffusion of CO_2 is faster, that leads to a weaker resistance of RAC to environmental attacks.

In 2003, Hendricks, F. et.al developed the approach called design for recycling can be used to optimize design of constructions for later use and the design for disassembly can be used for demolition. For the technical aspects two models were developed concerning degradation processes and the high graded applications. These models were based on life cycle assessment method.

In 2006, Poon C.S.et.al studied the environmental effects of using recycled aggregates. Concrete mixes were prepared with varying proportions of recycled aggregates. The proportion of recycled aggregates was kept varying from 0% to 100%. Target strength was kept 35 MPa. The investigations were made on affect of recycled aggregates on slump value and bleeding. The effects of delaying the bleeding tests and using fly ash on the bleeding of concrete have been examined. From this study it was found that the use of recycled aggregates caused higher rate of bleeding. The slump of concrete mixes or without recycled aggregates was increased due to replacement of cement by 25% fly ash. It reduced bleeding rate and bleeding capacity with only minor negative effects on concrete strength at or before 28 days, but it gave positive effects on strength at age of 90 days.

In 2006 , Rao, Aakash,et.al. investigated the effect of recycled aggregates concrete that can be used in lower end application of concrete. It was found that RCA can be used for making normal structural concrete with the addition of fly ash, condensed silica fume etc.

In 2007, Zhang, Xue-bing et.al. generated a formula for additional water requirement in recycled aggregate concrete. They found that the specific absorption of coarse aggregates increases as the time of water absorbing goes on. The speed of water absorption was greatest in first 10 minutes. Then it decreased and changed very little. The specific absorption and water absorption speed of RCA are greater than those of crushed stones and pebble, within the same time.

Márcio Muniz de Farias,et al(2013), Aggregates were recycled from the demolition of the National Stadium in Brasilia, Brazil, and subjected to a series of laboratory test. The results were compared with the requirements necessary for use in granular sub-bases and bases, and also for dense asphalt concrete surface courses.The loose aggregates met all the requirements set by Brazilian standards to be used in sub-base and base layers, even for the case of pavements of highways with heavy traffic. When used in dense hot mix asphalts, with conventional and modified asphalt-rubber binders, the recycled mixtures also met all requirements set by Brazilian standards. In some case, such as rutting in traffic simulator, the recycled mixtures performed even better than traditional mixtures using naturalcalcareous aggregates.

Lester B. Pearson International Airport (LBPIA)

Seow(**2016**)LBPIA has its own mini-ecosystem having forests, grasslands, creeks, and streams, as well as runways, terminal buildings, and roadways. The GTAA found that it was necessary to preserve and protect these natural resources while meeting the demands of a growing air travel industry [GTAA 2007]. LBPIA was the first North American airport to achieve ISO 14001 certification in 1999. To obtain this certificate an Environmental Management System was established for all aspects of airport operations to monitor and improve environmental performance. To make such environment the GTAA set goals to make continual improvement, prevent pollution, and comply with legislation. [Seow 2005]. During demolition of Terminal 1 and more recently Terminal 2, targets called for a minimum of 80% and 85% respectively of concrete, rubble, metals, wood, and other material waste to be reused and recycled. 253,000 tonnes of concrete waste was produced during the demolition of terminal 1 that was 100% recycled. [GTAA 2007, Seow 2005] Recycling was achieved by establishing an on-site mobile crushing plant.

Vishal V Panchal et al. (2017) The results of normal aggregate and construction demolition aggregate compared to study the effect on theproperties of road pavement.Thus the Marshall Stability of construction demolition wastes was found10.15 KN which satisfies the requirementcriteria for DBM course as per given in MORTH specification.The above result shows that CDW aggregate can be used in pavement design as a DBM course which minimise therequirement of conventional aggregate and can be helpful in controlling the environmental pollution.To use the CDW aggregate in pavement design, we need to segregate it from its various constituents that causesrampant growth of construction sector as to establish a new crusher and segregation plant.With rapid increase in industrialization and infrastructure development which leads to the generation of CDW wasteand by disposing it, in a river or use it as a land fill it causes environmental pollution. So, to minimise it we can recycleand reuse the CDW waste as aggregate in road pavement design which will control the land pollution.To use conventional aggregate, we need crushing and segregation plant so in the same manner, to use CDW aggregatewe also required recycling plant. The cost difference in both the process seems to be same and other process of road construction is same for both the aggregate.

Youyun Li (2017) The effect of compaction was best when the moisture content of C&D waste was controlled at 15%-16% and the quality ratio of fine materials and coarse materials of C&D waste was 0.328 and 1.1-1.2 before and after rolling, respectively. It indicates that the content of fine material is greatly increased after simple treatment, and the road performance is improved. With the increase in the number of rolling times, the compaction degree of the embankment filler increased gradually, and the compaction rate increased in the initial stages, while decreasing gradually in the later stages. Under the condition that the thickness of the loose layer is 20 cm, the compaction times are suggested to be controlled 15–20 times, which can meet the requirement of compaction. The field deflection test showed that the average deflection of the embankment was 0.66 mm, and the resilient modulus was 162.7 MPa, which meets the requirements of relevant specifications. It demonstrates that the construction of subgrade filled with C&D waste is feasible.

IV. METHODOLOGY

Preparation of Samples for Flexural Strength

Preparation of material, proportioning, weighing, mixing of material and workability for the flexural strength should be same as in section 3.2.

Size of Specimen

Cast iron mould of beams used to cast sample for flexural strength were of dimensions 100mm×100mm×500mm.

Casting of Beams

Moulds were cleaned and oiled same as the cubic mould. Fresh concrete was poured into beam moulds. Compacting, curing and opening of moulds should be done in same manner as done in case of cubic moulds.

Testing of Samples for Flexural Strength

Flexural testing machine was used to determine the flexural strength. The bed of the testing machine should be provided with two steel rollers, on which the specimens were to be placed or supported The load should be applied through two similar roller, mounted at the third points of the supporting span, the rollers were at the distance of $1/3^{rd}$ of the length of beam from either side. The load should be divided equally between the two loading roller, and all rollers should be mounted in such a manner that the load applied axially and without subjecting the specimen to any torsional stresses or restraints.

Procedure

Test specimens submerged in water should be taken out and wiped off to remove the water and any impurities on surface.

Placing the Beams in the Machine

The bearing surfaces of the supporting and loading rollers should be wiped, and any loose sand or other material removed from the surfaces of the specimen where they were to make contact with the rollers. The specimen should then be placed in the machine in such a manner that the load should be applied to the uppermost surface. The axis of the specimen should be carefully aligned with the axis of the loading device. Nothing should be used between the bearing surfaces of the specimen and the rollers, the load should be applied without shock and increasing continuously. The load should be increased until the specimen fails, and the maximum load applied to the specimen during the test should be recorded.

Calculation

The flexural strength of the specimen should be expressed as the modulus of rupture σ Calculated as below

$$\sigma = \frac{FL}{bd^2}$$

Where

- *F* is the load (force) at the fracture point in MPa
- *L* is the length of the support (outer) span in mm
- b is width in mm
- d is thickness in mm

Sulphate Resistance of Concrete

Procedure of test should be same as of compressive strength except curing of samples. Curing of samples should be done in $MgSO_4$ solution for desired time period after keeping the cubes in water for 28 days.

Methodology of the present study includes the procedure of study. As discussed in chapter 1 , the main objectives of the study were to find out the compressive strength, flexural strength and sulfate resistance of the concrete made with demolished concrete. It was estimated that whether RCA concrete was usable in pavement construction. Methodology of this study has following parts:

1. Literature review of the available studies in various journals, conferences etc.
2. Collection of RCA and natural aggregate.
3. Investigation of physical and mechanical properties of concrete with of RCA and natural aggregate which includes sieve analysis, bulk density of aggregates (coarse+fine), water absorption of aggregates(coarse+fine) and specific gravity of aggregates(coarse+fine).
4. Mix design of concrete (M40).
5. Casting of test samples. (Cube for compressive strength and sulfate resistance, beams for flexural strength).
6. Curing of samples in water tank for specified time period. (curing in $MgSO_4$ solution for sulfate resistance).
7. Samples testing for compressive strength, flexural strength and sulfate resistance at specified time periods.
8. Analysis and discussions of test results.
9. Conclusions and recommendations.

Mix design is done to select the mix material and their required proportions. There are a lot of methods to determine the mix design. The methods used in India are in compliance with Bureau of Indian Standards (BIS). The motive of mix design is to determine the proportion in which concrete ingredients like cement, water, fine aggregates and coarse aggregates should be mixed to provide specified strength, workability, durability and other specified requirements as listed in standards such as IS: 456-2000. The designed concrete mix must define the material and strength, workability and durability to be attained. Concrete mix design guidelines are given in IS: 10262-1982. In the study, 5 batches of mixes were prepared. These batches were designated as m0, m1, m2, m3 and m4. Batch m0 was taken as control mix. The natural coarse aggregate was replaced by recycled aggregate in proportion of 0%, 10%, 20 %, 30% and 40% in m0, m1, m2, m3, and m4 respectively as given in table 4.1. Content of sand, cement and water were kept constant in every batch. In the study properties of concrete such as compressive strength, flexural strength and sulphate resistance of concrete were determined.

Table 4.1 Proportions of Natural and Recycled Aggregates in Batches

Type of Mix Used	Recycled Aggregate (%)	Natural Aggregate (%)
m0	0	100
m1	10	90
m2	20	80
m3	30	70
m4	40	60

Material Properties

The physical and mechanical properties of all ingredients like sand, natural coarse aggregates, cement and demolished coarse aggregates are per IS: 2386-1963 were determined.

Cement

OPC (Ordinary Portland Cement) of grade 43 was used which conformed to IS: 8112-1989. Testing of cement was done as per IS: 4031-1968. The physical properties of cement are given below in Table 4.2

Table 4.2 Physical Properties of Cement of Grade 43

S.No.	Properties	Apparatus used	Observed Values	Values Specified by IS:8112-1989
1.	Fineness Percentage	90μm I.S Sieve	4	Not more than 10
2.	Soundness(mm)	Le Chatelier Method	1.0	Not more than 10
3.	Normal consistency	Vicat apparatus	30	…………..
4.	Specific gravity	Le Chaterlier"s flask	3.76	……….…...

Natural Fine Aggregates

Natural coarse sand was used as fine aggregate. The sand conformed to zone II as per IS: 383-1970. The grading of fine aggregates and other properties are given in table 4.3

Table 4.3 Sieve Analysis of Fine Aggregates
Weight of sample =1000gm

IS Sieve Size(mm)	Weight Retained(gm)	Cumulative Weight Retained(gm)	Cumulative %Age of Weight Retained(gm)	Percentage Passing
4.75	156	156	15.6	84.4
2.36	57	213	21.3	78.7
1.18	113	326	32.6	67.4
0.6	111	437	43.7	56.3
0.3	376	813	81.3	18.7
0.15	145	958	95.8	4.2
0.075	30	988	98.8	1.2

∑F=389.3
Fineness Modulus(F.M)=3.89
Sand conforming grading zone II of I.S 383-1970.

Casting of Specimens

As discussed in section 4.1, five batches of mixes were prepared as per the mix design of M40. First mix named m0 was taken as control mix. The ratio is 1:1.23:2.52 for cement, fine aggregates and coarse aggregates respectively. Water cement ratio was taken as 0.38 with the super plasticizer (0.6%of cement). Five batches of concrete mix were prepared with varying proportion of recycled coarse aggregates as discussed earlier in section 4.1. After preparing the batches, workability of concrete was measured by slump test and compaction factor test. The test samples were 150mm×150mm× 150mm cube for compressive strength, 100mm×100mm×500mm beam for flexural strength and 150mm×150mm×150mm cube for sulfate resistance. The samples were cast according to IS: 516-1959. The samples were tested at the age of 7, 28, 56 and 90 days for compressive strength.

Properties of Fresh concrete (Workability)

There are a lot of methods of for measuring workability of concrete. Each method measures only a specified aspect of it and there is really no method which measures the workability of concrete in its totality. So, it is assumed that none of the methods are wholly satisfactory. But by checking the uniformity of the workability it was easier to ensure a uniform quality of concrete and hence uniform strength for a particular job. In the present study, two tests were performed to find workability.

1. Slump Test
2. Compaction Factor Test

After casting samples were kept in water for curing for specified period. In case of sulphate resistance testing, cubes were kept in sulphate solution after keeping them in water for 28 days. Sulphate solution curing was done for specified time period.

Compressive Strength

The dried cubes were tested at the age of 7, 28, 56 and 90 days. The cubes were tested on compression testing machine (CTM) after drying at room temperature as per IS: 516-1959 as shown in Figure 4.3. The load was applied at rate of 350MPa/minute in a uniform and continuous manner. Impacts were prevented during the application of load. Application of load was kept continued until the sample failed and maximum load carried by the sample was recorded. Three samples for each test reading were tested. Final value of test is taken as an average of three samples.

Figure 4.3 Test for Compression Strength In CTM.

V. RESULTS AND DISCUSSION

Workability

As discussed in chapter 4, workability varied with change in proportion of demolished aggregates. The slump values and compaction factor values did not show a uniform pattern as the percentage of demolished aggregates was uniformly varied. Super plasticizer was used to maintain the workability as water absorption increased due to presence of demolished concrete aggregates water cement ration (W/C) water kept constant (0.38). Figure 5.1 gives the variation of slump values versus type of mixes. Figure 5.2 gives the variation of compaction factor versus type of mixes.

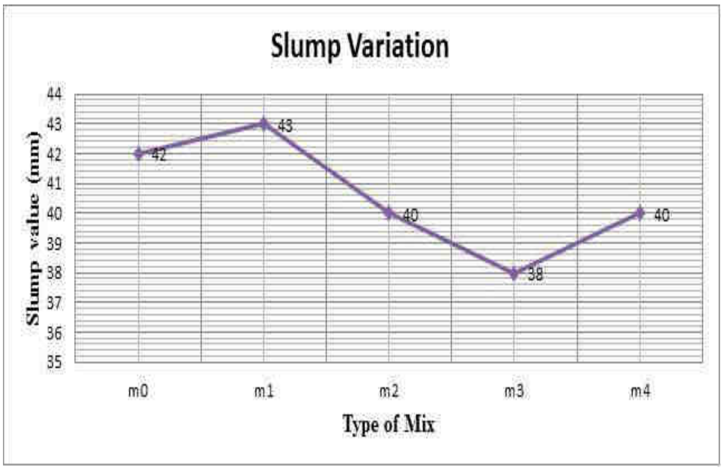

Figure 5.1 Variations of Slump Values with Type of Mix Used

Variation of Compressive Strength with Age

Table 5.1 gives the test results of compressive strength at 7, 28, 56 and 90 days. Water cement ratio was kept as 0.38 for all mixes. Super plasticizer used was 0.6% of cement. Table 5.2 gives the percentage reduction in compressive strength for all mixes at different number of days.

Table 5.1 Test Results for Compressive Strength

S.No.	Mix	W/C	Compressive strength (MPa)			
			7 Days	28Days	56 Days	90 Days
1.	m0	0.38	42.43	50.06	51.20	51.8
2.	m1	0.38	42.47	50.36	50.89	51.23
3.	m2	0.38	41.84	50.20	50.68	50.80
4.	m3	0.38	42.60	49.11	50.68	51.4
5.	m4	0.38	40.27	52.36	53.24	53.26

CONCLUSIONS

The research on usage of RCA in construction of pavement is very important because material waste is gradually increasing with the increase in urban development and increase in population. Recycled aggregates are easily available while natural aggregates need mining and their cost is much higher than the cost of natural aggregates. Recycled aggregates are cheaper than the virgin aggregates, so builders can easily afford these for construction purpose if their strength is equal or comparable to natural aggregates.

The study examines the properties of RCA when used with natural coarse aggregates. A lot of studies have been carried out on use of RCA concrete in construction. But in case of highway construction some more investigation is required. The main objective of the study was to investigate whether RCA can be used as material aggregates for concrete pavement construction. Compressive strength, flexural strength and sulfate resistance of RCA concrete is examined, where it was observed that mixing of RCA cause increased water absorption. To avoid this, super plasticizer is used to reduce the cement consumption. Concrete mix of M40 was designed as per properties of aggregates. The results of this study showed that RCA concrete gave comparable strength to conventional concrete. This indicated that RCA concrete can be viable source for construction of pavements. From the results, it is also found that workability of concrete is decreased due to higher water absorption. Whenever recycled aggregate is applied, water content is monitored carefully in concrete mix as water absorption is increased due to presence of porous mortar. In this study, super plasticizer (0.6% of cement) is used to overcome this problem.

Following conclusions can be drawn from results and discussion of results from the study:

1. The compressive strength of all mixes exceeded at the age of 28 days. Compressive strength of control mix i.e. of m0 is 50.05 MPa which is greater than the target strength of 48.25 for M40 concrete. Compressive strength of m1 is slightly increased to 50.36. So the compressive strength increases by 0.5%.
2. For m2, compressive strength is increased to 50.20 MPa, it also showed an increase in compressive strength by 0.3%. Compressive strength of m3 is decreased to 49.11 MPa that showed a decrease in compressive strength by 1.9%. Flexural strength also followed the same pattern as of compressive strength.
3. Flexural strength of control mix is 5.32MPa at age of 28 days. Flexural strength of mix m1 increased to 5.60 MPa. It shows that the increase in flexural strength is 5% for m1. For m2 flexural strength at age of 28 days is 5.40MPa, which shows an increase in flexural strength by 1.5%.
4. Flexural strength of mix m3 is 5.38 and the flexural strength increased by 1 %. For the mix m4, flexural strength is 5.40 MPa. It shows that the flexural strength increased by 1.5 % at the age of 28 days.
5. In this study, trial castings were done to arrive at water content and desired workability. So it was advisable to carry out trial castings with demolished concrete aggregate proposed to be used in order to arrive at the water content and its proportion to match the workability levels and strengths requirements respectively.

REFERNENCES

1. Abou-Zeid, M.N., Shenouda, M.N., McCabe, S.L., and El-Tawil, F.A. (2005). “Reincarnation of Concrete,” Concrete International, V. 27, No.2, February 2005, pp. 53-59.
2. Ajdukiewicz, A., and Kliszczewica, A. (2002). “Influence of Recycled Aggregates on Mechanical Properties of HS/HPS,” Cement and Concrete Composites, V. 24, No. 2, 2002, pp. 269-279.
3. Bairagi, N. K., Vidyadhara, H. S., and Ravande, K. (1990). “Mix Design Procedure for Recycled Aggregate Concrete,” Construction and Building Materials, V. 4, No. 4, December 1990, pp. 188-193.
4. Buyle-Bodin, F., “Influence of industrially produced recycled aggregates on flow of properties of concrete.” Materials and structures/ Mate’riaux et. Construction, Vol. no. 35, September-October 2002,pp 504-509.
5. Chen, H.J., Yen, T., and Chen, K.H. (2003). “Use of Building Rubbles as Recycled Aggregate,”Cement and Concrete Research, V.33, No.1, pp. 125-132.
6. FHWA. (2004). “Transportation Applications Of Recycled Concrete Aggregate: FHWA State of the Practice National Review September 2004,” U.S. Department of Transportation, Federal Highways Administration, Washington, DC.
7. GTAA. (2007). “Reducing, Reusing and Recycling Terminal 2,” Toronto Pearson Today: Terminal 2, Terminal 2 Commemorative Issue, Greater Toronto Airports Authority, Toronto, ON.
8. Hansen, T.C., and Hedegard, S.E. (1984). “Properties of Recycled Aggregate Concretes as Affected by Admixtures in Original Concretes,” ACI Journal, January-February 1984, pp. 21-26.
9. Harrington, J. (2004). “States Achieve Recycling Success,” Roads and Bridges, V.42, No.7.
10. Hendricks, Ch. F., “Use of Recycled materials in constructions”, Materials and structures/ Mate’riaux et. Construction, Vol. no. 36, November 2003,pp 604-608.
11. IS: 456-2000, “Indian Standard Code of practice for plain and reinforced concrete”, (second revision), Bureau of Indian Standard, New Delhi.
12. IS: 383-1963, “Indian Standard Specifications for Coarse and Fine Aggregate from Natural Sources for Concrete”, Bureau of Indian Standard, New Delhi.
13. IS: 516-1959, “Methods of Tests for Strength of Concrete”, Bureau of Indian Standard, New Delhi.
14. IS: 10262-1982, “Recommended Guidelines for Concrete Mix design”, Bureau of Indian Standard, New Delhi.
15. IS: 2386(Part-1)-1963, “Methods of Test for Aggregate for Concrete (Part-1 Particle Size and Shape)”, Bureau of Indian Standard, New Delhi.
16. IS: 8112-1989, “Specification for 43 Grade Ordinary Portland Cement”, Bureau of Indian Standard, New Delhi.
17. IS: 4031-1968, “Indian Standard Definitions And Terminology Relating To Hydraulic Cement”, Bureau of Indian Standard, New Delhi.
18. Katz, A. (2003). “Properties of Concrete Made with Recycled Aggregate from Partially Hydrated Old Concrete,” Cement and Concrete Research, V. 343 No. 5, pp. 703-711.
19. Katz A. (2004). “Treatments for the Improvement of Recycled Aggregate,” Journal of Materials in Civil Engineering, V. 16 No. 6, November/December 2004 pp. 597-603.
20. Kumar, Satish(2002), “ Design of concrete mix using aggregate from Demolished Concrete”, M.Tech Thesis.
21. Lin, Y.H., Tyan, Y.Y., Chang, T.P., and Chang, C.Y. (2004). “An Assessment of Optimal Mixture for Concrete Made With Recycled Concrete Aggregates,” Cement and Concrete Research, V. 34, No. 8, pp. 1373-1380.

22. Mehta, P.K. (2001). "Reducing the Environmental Impact of Concrete," Concrete International, V. 23, No.10, October 2001, pp. 61-66.
23. Meyer, C. (2008). "The Greening of the Concrete Industry," 2nd Canadian Conference on Effective Design of Structures, paper #97, McMaster University, Hamilton, ON, 2008.
24. Naik, T.R., and Moriconi, G. (2005). "Environmental-Friendly Durable Concrete Made with Recycled Materials for Sustainable Concrete Construction," International Symposium on Sustainable Development of Cement, Concrete and Concrete Structures, Toronto, Ontario, October 5-7, pp. 277-298.
25. Oikonomou, N.D. (2005). "Recycled Concrete Aggregates," Cement and Concrete Composites, V. 25, No. 2, pp. 315-318
26. Olorunsogo, F.T., and Padayachee, N. (2002). "Performance of Recycled Aggregate Concrete Monitored by Durability Indexes," Cement and Concrete Research, V. 32, No. 2, 2002, pp. 179-185.
27. Poon, C.S.(2007), "Influence of recycled aggregate on slump and bleeding of fresh concrete," Material and Structure, v.40, pp. 981-988.
28. Poon, C.S., Shui, Z.H., Lam, L., Fok, H., and Kou, S.C. (2003). "Influence of Moisture States of Natural and Recycled Aggregates on the Slump and Compressive Strength of Concrete," Cement and Concrete Research, V.34, No.1, 2004, pp. 31-36.
29. Poon, C.S., Kou, S.C., and Lam, L. (2002). "Use of Recycled Aggregates in Molded Concrete Bricks and Blocks," Construction and Building Materials, V. 16, No. 5, pp. 281-289.
30. Rao, Aakash(2007)," Use of aggregates from recycled construction and demolition waste in concrete", Resources, Conservation and Recycling, V. 50, Issue 1, pp. 71-81.
31. Rashwan, M.S., and AbouRizk, S. (1997). "The Properties of Recycled Concrete," Concrete International, V. 18, No.7, July 1997, pp. 56-60.
32. Sagoe-Crentsil, K.K., Brown, T., and Taylor, A.H. (2001). "Performance of Concrete Made with Commercially Produced Coarse Recycle Concrete Aggregate," Cement and Concrete Research, V. 31, No. 5, pp. 707-712.
33. Salem, R.M., Burdette, E.G., and Jackson, N.M. (2003). "Resistance to Freezing and Thawing of Recycled Aggregate Concrete," ACI Materials Journal, V. 100, No. 3, May-June 2003, pp. 216-221.
34. Seow, K. (2005). "Old Terminal 1 Decommissioning and Demolition," Annual Conference of the Transportation Association of Canada, Calgary, AB, 2005.
35. Shayan A., and Xu, A. (2008). "Performance and Properties of Structural Concrete Made with Recycled Concrete Aggregate," ACI Materials Journal, V. 100, No. 5, September-October 2003, pp. 371-380.
36. Shing Chai NGO, Nelson(2009), " High-Strength Structural Concrete with Recycled Aggregate," Research Projects.
37. Tabsh, Sami W.(2009), " Influence of recycled concrete aggregates on strength properties of concrete", Construction and Building Material, v.23, Issue 2, pp. 1163-1167.
38. Tavakoli, M. and Soroushian, P. (1996a). "Strengths of Recycled Concrete Made Using Field-Demolished Concrete as Aggregate," ACI Materials Journal, V. 93, No. 2, March-April 1996, pp.182-190.
39. Turley, W. (2013). "On the road: acceptance of recycled aggregates by state DOTs is slow but making progress – Road building Trends," C&D Recycler, September-October, 2003.
40. Xue –bing Zhang (2016), "Additional absorbed water in recycled concrete", J.cent. South Univ. Techno.(2007).

BIOGRAPHY

Corresponding Author, Ravinder , Assistant Professor- Civil Engineering Department, HCTM Technical Campus Kaithal , (Haryana), India. He has published one Research paper in International Journal