Study of Strength Characteristics of sub-base/ Base Course Using Recycled Aggregate, Cement and Pond Ash

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Abstract— **In recent years, the emphasis was given to increase the sustainability of environment and better ways have been explored to manage wastes materials such as coal ash, plastic, rubber, construction and demolition waste, broken glass, scrap tyres, steel furnace slag etc. which are creating a number of problems in handling and disposing. These waste materials are disposed off either in low lying areas or in land fill sites which result in filling of land fill site at a very fast rate. So, reducing, reusing and recycling are the need of hour to save the natural resources as well as to save the land fill site which are otherwise going to create space problems for disposal of waste material. It is estimated that 10-12 million tons of construction and demolition waste (CDW) is generated in India every year which needs a huge space for disposal. It is also surveyed that there is a huge deficit of about 750 million cubic meter aggregates to achieve the targets of road sector in India (www.urbanindia.nic.in). One way of achieving this is to introduce recycled aggregates from these wastes of construction and demolition works into pavements.**

Index Terms— Recycled, Material, RCA,
Sub area : Construction Technology
Broad Area : Transportation Engineering

I. INTRODUCTION

CDW can prove to be very useful to meet the demand and supply gap of road sector. The bricks, metal and wood items are reused in new construction but the concrete and masonry waste which forms more than 50% of CDW are still not recycled in India. Therefore, there is need to recycle these concrete waste which are creating disposal problem in construction industry. These recycled concrete aggregates (RCA) which are cheaply available from construction and demolition sites can be used in highways construction *i.e.* in base or sub-base layers of pavement. As the finance and funds are major problem in construction of rural roads, RCA can prove to be best alternative for rural roads which is cheap and sustainable option.

There are many advantages that lead to the use of RCA materials as pavement material in bases/sub-bases of roads. The main advantages of using RCA in the construction industry are of sustainable values and environmental issues. The wastes from construction and demolition works are of large volume and increasing over time. To overcome this issue, sustainable construction is one of the strategies to be considered by the construction industry.

II. OBJECTIVES

The precise objectives of the study are as follows:-

- The main objective of this research is to understand better the mechanical behavior of recycled mixtures in order to evaluate whether they are gainfully useful as granular material in the base or sub-base layer of road pavement. Moreover, RCA mixtures treated with admixtures are investigated to evaluate the improving range in mechanical performance.
- To analyze the cost of construction of flexible pavement with RCA mixture sub-base and compare the cost with pavement comprises of moorum sub-base course on a rural road where finance and funds are major problems for their development. Moreover, stage construction is done for the design and development of rural roads where these cheap recycled materials can be gainfully used.

III. SCOPE OF THE WORK

In the present study, an attempt is made to study the gainful use of RCA with admixing agent cement and pond ash. Pond ash which is also a waste material from thermal power plants is used to improve the strength characteristics of RCA mix. The mix of RCA with admixtures cement and pond ash is used in construction of rural road where stage construction is done and is design for presently low traffic volume. The study deals with the strength characteristics of sub-base/base layer of pavement which is improved with addition of cement and pond ash. Analysis of the cost of construction of rural road and comparison of cost of construction of pavement with RCA sub-base course and moorum sub-base course is made. It will increase the environmental sustainability and play an important role in reduction of depletion of natural resources.

IV. METHODOLOGY

- Collection of waste material *i.e.* pond ash and recycled concrete aggregates (RCA).
- Crushing, sieving and Laboratory testing of aggregates i.e. RCA
- Evaluation of compaction characteristics by performing Modified Proctor test
- Evaluation of strength characteristics by performing UCS test
- Optimization of cement content for the mixes.
- Evaluations of CBR for the mix at optimum cement contents.

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- Cost analysis of rural road with different lead of material availability.

V. Unconfined compression test

The samples are prepared and compacted and corresponding water content on dry and wet side of optimum (for modified standard Proctor tests) and tested in an unconfined compression testing machine. A series of unconfined compression test are carried out on RCA with various percentages of cement content and pond ash. Each sample of diameter is 150mm and length is different it varies 260mm to 300mm. The mix with different percent of pond ash (10 and 20%) and cement content (2.0, 4.0, 6.0 and 8.0%) are homogenously mixed in the dry state. Then water is added and thoroughly mixed. Cylindrical samples of dimensions 150mm diameter and 260mm to 300mm height are prepared. The cast specimens are kept at ambient temperature for a period of 24 hours and cured in water for a time period of 7 days. Load deformation behavior of RCA with pond ash and different percentage of cement as specified above are studied. Unconfined compressive strength of stabilized mix is performed by following two steps as specified in the following paragraphs:

1. RCA is added with different percentage of pond ash (10 and 20%). The U.C.S. is significantly increased from 10% of pond ash to 20 % pond ash replacement
2. RCA is added with 10% and 20% of pond ash and different percentage of cement content (2.0, 4.0, 6.0 and 8.0%) and U.C.S. is increased.

Table : Unconfined compression test for different cement content

S.NO.	Soil Mix RCA-I : RCA-II : Pond Ash	Cement content	Unconfined Compressive Strength (kg/cm^2)
1	50:40:10	2 %	9.228
2	50:40:10	4 %	12.11
3	50:40:10	6 %	16.726
4	50:40:10	8 %	19.61
5	50:30:20	2 %	12.112
6	50:30:20	4 %	15.57
7	50:30:20	6 %	19.03
8	50:30:20	8 %	20.763

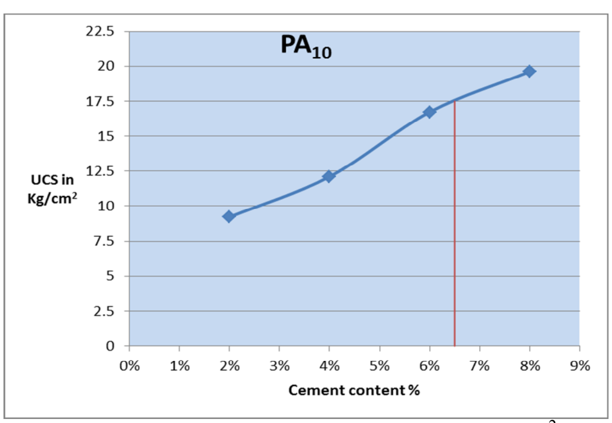


Fig. 4.7: Graph showing cement content for 17.5 kg/cm^2 UCS for PA_{10}

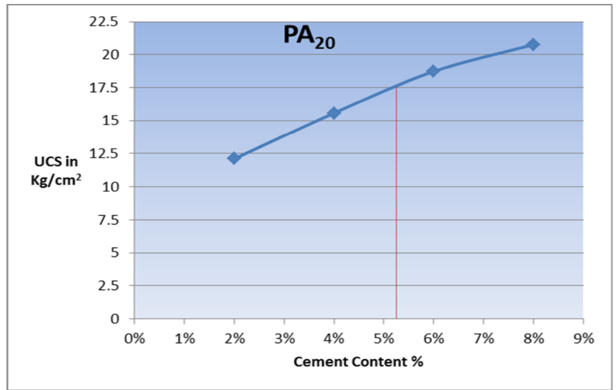


Fig. 4.8: Graph showing cement content for 17.5 kg/cm^2 UCS for PA_{20}

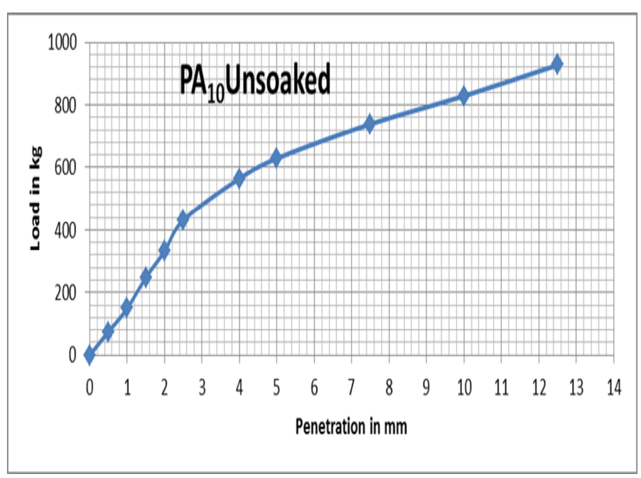
The Graphs 4.7 and 4.8 shows the cement content for average compressive strength of 17.5kg/cm^2. From these graphs it is clear that the mixes PA_{10} with 6.50% of cement content and PA_{20} with 5.25% of cement content give average compressive strength required for sub-base or base course in pavement. So it can be easily concluded from graphs that 6.50% and 5.25% are optimum cement content for PA_{10} and PA_{20} respectively.

CBR method

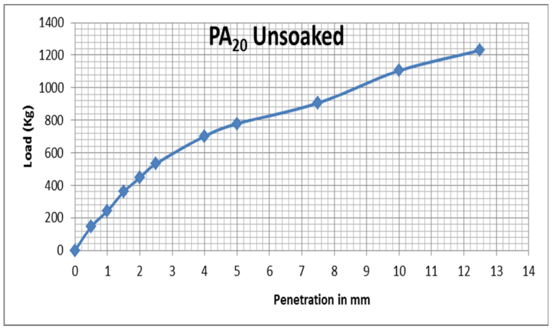
The samples are prepared by mixing 50% RCA-I, RCA-II (40% and 30%) and pond ash (10% and 20%) by weight. California Bearing Ratio tests, both soaked and unsoaked are conducted. The optimum cement content which gives unconfined compressive strength (UCS) of 17.5kg/cm^2 is selected for the CBR test. As per Highway Material and Pavement Testing Manual by Khanna & Justo (2012), 17.5kg/cm^2 is the minimum compressive strength requirements for base/sub-base course of pavement in case of soil-cement mix. So, the CBR test at two levels of pond ash i.e. PA_{10} and PA_{20} are selected from UCS test results.

Table 4.6: CBR test

S.NO.	Soil Mix- RCA-I : RCA-II : Pond Ash	Cement content	Unsoaked CBR Value (%)	Soaked CBR Value (%)
1	50:40:10	6.50 %	31.04	22.11
2	50:30:20	5.25%	38.41	26.16

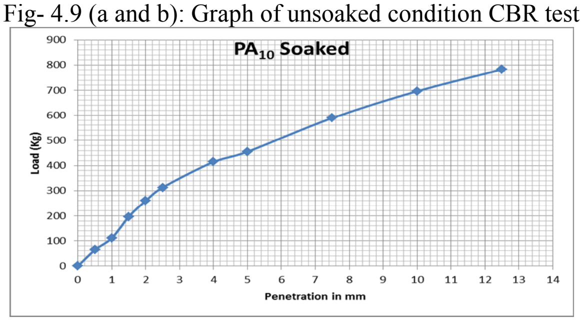


(a)



(b)

Fig- 4.9 (a and b): Graph of unsoaked condition CBR test



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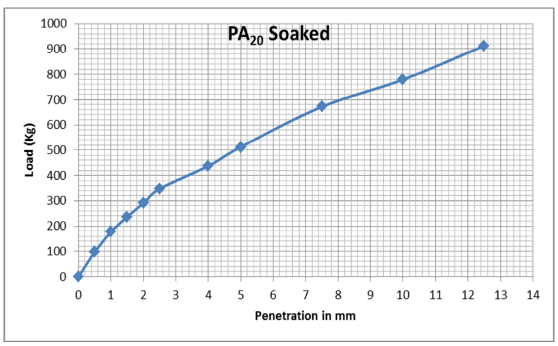

(b)

Fig- 4.10(a and b): Graph of soaked condition CBR test

VI. ANALYSIS OF RESULTS

Optimum moisture content and maximum dry density

The test results in Table 5.1 indicate for the mixes of RCA-I, RCA-II,Pond Ash and cement. The optimum moisture content increases with increase in cement content and pond ash but the MDD increases with increase in cement content and decreases with increase in pond ash content in the mix. For example the MDD decreases (from 1.894 gm/cc to 1.753 gm/cc) with increase in pond ash level from 10% to 20% at same cement content of 2%.

Table 5.1: Compaction test for different mixes

S.NO.	Soil Mix- RCA-I : RCA-II : Pond Ash	Cement content	MDD (gm/cc)	OMC (%)
1	50:40:10	2 %	1.894	7.1
2	50:40:10	4 %	1.895	7.4
3	50:40:10	6 %	1.897	7.9
4	50:40:10	8 %	1.903	8.6
5	50:30:20	2 %	1.753	9.1
6	50:30:20	4 %	1.767	9.6
7	50:30:20	6 %	1.781	10.1
8	50:30:20	8 %	1.790	10.5

The decrease in dry density of soil by addition of Pond ash may be due to low specific gravity (Density low) of Pond ash. The variation of O.M.C. and maximum dry density with varying percentage of coal ash is depicted in Figs. 5.1 and 5.2.

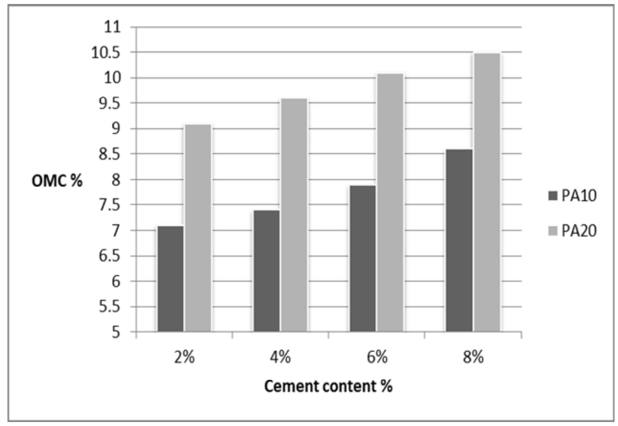

Fig. 5.1 : O.M.C. of PA_{10} and PA_{20} mixes at different cement content

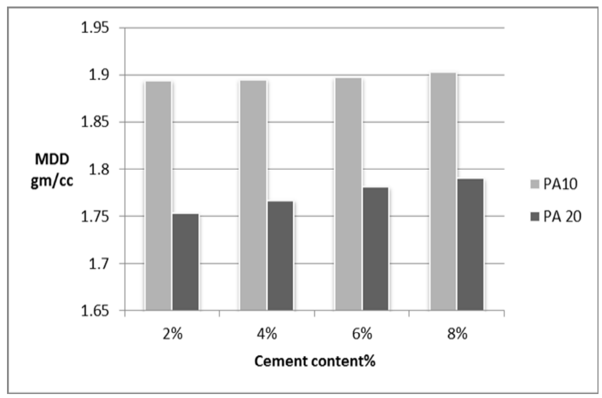

Fig. 5.2 : MDD of PA_{10} and PA_{20} mixes at different cement content

VII. UNCONFINED COMPRESSIVE STRENGTH

Unconfined compressive strength is an important parameter in pavement design. By the British standards which are also used for Indian conditions, a compressive strength of soil cement mixes equal to 17.5 kg/cm^2 at 7 days curing is considered to be satisfactory for use in sub-base or base course of road pavements in light and medium traffic and under normal climatic condition.

Table 5.2: UCS Test for different mixes

S.No.	Soil Mix- RCA-I : RCA-II : Pond Ash	Cement content	Unconfined Compressive Strength (kg/cm^2)
1	50:40:10	2 %	9.228
2	50:40:10	4 %	12.11
3	50:40:10	6 %	16.726
4	50:40:10	8 %	19.61
5	50:30:20	2 %	12.112
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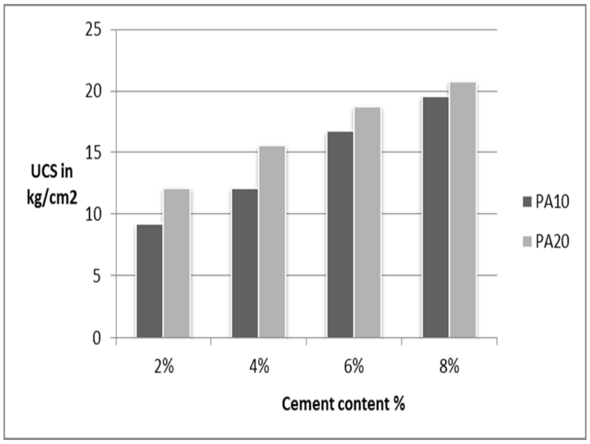

Fig. 5.3: UCS strength of PA_{10} and PA_{20} mixes at different cement content

Fig. 5.3 shows the comparison of UCS strength of PA_{10} and PA_{20} mixes at different cement content. It clearly shows that the UCS strength increases with increase in cement content as well as pond ash content.

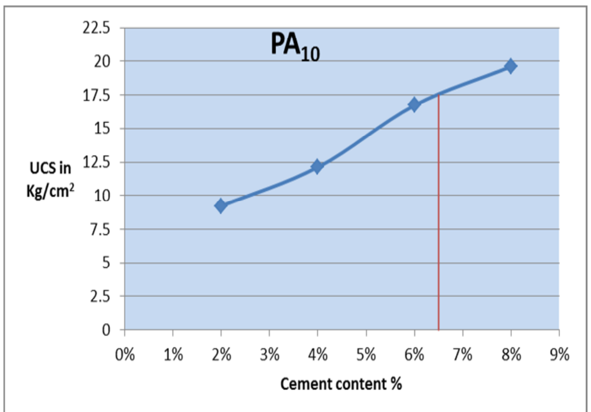

Fig. 5.4: Graph showing cement content for 17.5 Kg/cm^2 UCS for PA_{10}

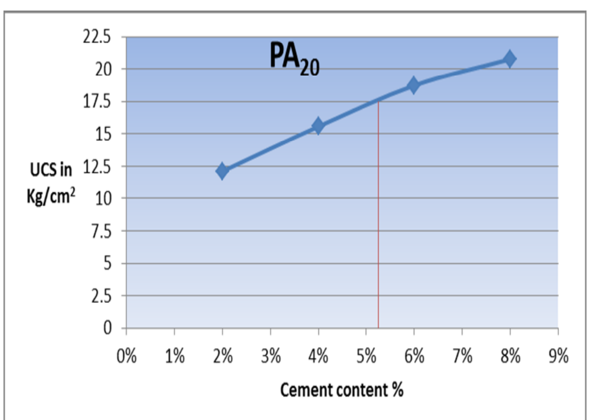

Fig. 5.5: Graph showing cement content for 17.5 kg/cm^2 UCS for PA_{20}

The Figs. 5.4 and 5.5 shows the cement content for average compressive strength of $17.5 kg/cm^2$. From these graphs it is clear that the mixes PA_{20} with 6.50% of cement content and PA_{20} with 5.25% of cement content give average compressive strength required for sub-base or base course in pavement. So it can be concluded from graphs that 6.50 and 5.25% are optimum cement content for PA_{10} and PA_{20} respectively.

C.B.R test

The optimum cement content is determined from UCS test in section 5.2. Table 5.3 shows the proportion of RCA-I, RCA-II andpond Ashin PA_{10} and PA_{20} mixes and their respective unsoaked and soaked CBR value for the mixes. It is clear that PA_{20} mix has higher CBR value of 26.16% as compare to PA_{10} (22.11% CBR value).

Table 5.3: CBR test results

S.NO.	Mix- RCA-I : RCA-II : Pond Ash	Optimum Cement content	Unsoaked CBR Value (%)	Soaked CBR Value (%)
1	PA_{10} (50:40:10)	6.50 %	31.04	22.11
2	PA_{20} (50:30:20)	5.25%	38.41	26.16

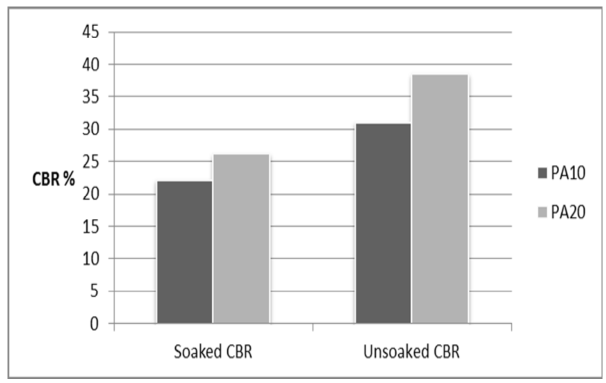

Fig. 5.7: Soaked and unsoaked CBR values of PA_{10} and PA_{20}

Designs for pavement thickness

After doing testing on various samples, with the help of CBR design chart recommended by Indian Road Congress IRC: SP: 20: 2002 the total thickness is found out to cover the sub grade for all samples. Two subgrades of CBR 3% and 5% are selected for design and the pavement is designed for moorum sub-base and RCA sub-base at different leads. The rural road is designed for a traffic of 125 vehicles per day exceeding 3 tons laden weight.

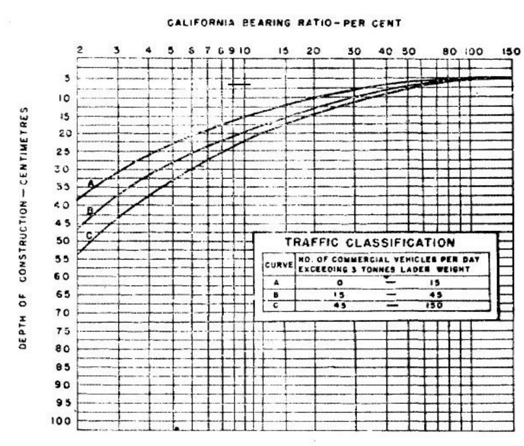

Fig. 5.8: CBR curves for flexible pavement design (IRC-SP:20:2002)

VIII. COST ANALYSIS OF FLEXIBLE PAVEMENT

The cost analysis of flexible pavement on subgrade with CBR of 3% and 5% is done and the cost is calculated for 1 km length and 3.5 m width of rural highway. The cost is calculated with moorum sub-base as per DSR-2013. The design of flexible pavement is done on the basis of ISP 20.

Table 5.9: Cost comparison of pavement with different sub-base material

CBR of Subgrade	Lead in km	Pavement cost in Rs.		Decrease in value in %
		Moorum Sub-base	RCA Sub-base	
3%	50	2818528.62	2769691.00	1.73
	100	2999522.38	3021222.00	-0.72
	150	3130699.88	3267218.00	-4.36
5%	50	2410551.13	2391771.44	0.78
	100	2488119.86	2540596.60	-2.1
	150	2565767.38	2684251.88	-4.6

It is clear from the Table 5.9 that the RCA sub-base is economical than the moorum sub-base up to 50 km lead. After that the cost of construction increases with increase in distance as shown in Table 5.9. But there are some indirect benefits of using RCA sub-base which cannot be covered in direct cost analysis. These indirect benefits cannot be ignored as use of waste material will save raw natural resources, the disposal space requirements and also reduce the quarrying and depletion of virgin aggregates. Therefore this will preserve natural resources and also extend the lives of sites used for landfill. The indirect benefits are:-

- In RCA sub-base, the percentage of RCA and Pond ash is 80% and 20% respectively which forms the mix. As both are waste materials, so the utilization of waste material is done otherwise space for disposal of these waste creates problems.
- Utilization of waste materials increases the life span of landfill site which are getting filled day by day and giving rise to problem of disposal of waste.
- Utilization of waste materials saves the natural resources which are going to extinct one day.

CONCLUSIONS

RCA is a demolition waste which could be utilized with admixtures pond ash and cement in sub-base course of rural road pavements.The present study has shown quite encouraging results and following important conclusions and recommendations can be drawn from the study:

REFERENCES

1. The OMC of mixture PA_{10}(50% RCA-I, 20% RCA-II, 10% Pond ash) and PA_{20}(50% RCA-I, 30% RCA-II, 20% Pond ash) increases with increasing the percentage of pond ash. The maximum dry density (MDD) is observed to decrease with increase in the percentage of pond ash.
2. The optimum moisture content (OMC) of RCA-pond ash-cement mix increases with increase in cement content of the mix and the increase is linear with increase in cement content.
3. The Unconfined Compression Strength increases with increase in Pond ash from 10% to 20% (i.e. from PA_{10} to PA_{20} mix) in mix for same cement content.
4. The mix with 50% RCA-I (retained on 4.75 mm IS sieve), 30% RCA-II (passing through 4.75 mm IS sieve), 20% Pond ash and 5.25% cement content which gives maximum 26.16% soaked CBR strength.
5. It can be concluded from the analysis of cost of Rural Road that there is decrease in cost of pavement upto 50kms lead for 3% CBR sub-grade and upto 50 kms lead for 5% CBR sub-grade by replacing Moorum with a mix of 50% RCA-I, 30% RCA-II, 20% Pond ash and 5.25% cement. Hence, this proportion may be economically used in road.
6. The cost analysis shows that the difference cost of construction on RCA sub-base and moorum sub-base is marginal up to a lead to 100kms and beyond 100 kms the increase is not so significant that the indirect benefits of using RCA sub-base can be ignored. So, having the indirect advantages of using RCA sub-base which can't be measured in terms of cost, the RCA sub-base can be used with marginal increase in direct cost.

7. Agrela F, Barbudo A, Ramirez A, Ayuso J, Carvajal MD, Jime´nez JR, 2012, Construction of road sections using mixed recycled aggregates treated with cement in Malaga, Spain, *Resource, conservation and Recycling,* Vol. 58, pp. 88–106.
8. Ahmed Ebrahim Abu El-Maaty Behiry, 2013, Utilization of cement treated recycled concrete aggregates as base or sub-base layer in Egypt, *Ain Shams Engineering Journal, Elsevier*.
9. Arulrajah A, Piratheepan J, Ali M., 2012, Geotechnical properties of recycled concrete aggregate in pavement sub-base applications, *ASTM Geotechnical Testing Journals,* vol. 35 no. 5, pp. 1–9.
10. Arulrajah A, Piratheepan J, Bo MW, 2012, Sivakugan N.,Geotechnical characteristics of recycled crushed brick blends for pavement sub-base applications, *Canadian Geotechnical journal,* vol. 49, pp. 796–811.
11. Arulrajah A, Piratheepan J, Disfani M, 2013, Geotechnical and geo environmental properties of recycled construction and demolition materials in pavement sub-base applications, *ASCE Journal of Materials in Civil Engineering,* Vol. 25, pp. 1077-1088.
12. Arulrajah A, Piratheepan J, Disfani M., 2012, Resilient moduli response of recycled construction and demolition materials in pavement sub-base applications, *ASCE Journal of Materials in Civil Engineering,* Vol. 21, pp. 576-586.
13. Cerni G, Cardone F, Bocci M, 2012, Permanent deformation behavior of unbound recycled mixtures, *Construction Building Material*, vol. 37, pp. 573–580.

Delhi Schedule of Rates - 2013
14. Fabiana DA, Conceic,o L, Liedi B., 2011, Laboratory evaluation of recycled construction and demolition waste for pavements, *Construction Building Material,* vol. 25, pp. 2972–2679.
15. Gilpin R, Robinson J, David WM, Helen Hyun,2004, Recycling of construction debris as aggregate in the Mid-Atlantic Region USA,*Resource, conservation and Recycling,* Vol. 42, 275–294.
16. Hansen T.C, 1985, Elasticity and Durability shrinkage of Recycled aggregate concrete", *ACI Journal,* pp. 102-109.
17. Hansen T.C, Narud H, 1983, Strength of recycled aggregate concrete made from crushed concrete coarse aggregate, *Concrete International design and construction,* Vol.5, no.1, pp.79-83.
18. Highway Material Testing (Laboratory Manual) by S.K. Khanna and C.E.G Justo, Edition 2012.
19. Hilmi A, Aysen M, Goktepe AB, 2006, Analysis and design of a stabilized fly ash as pavement base material, *Science Direct, Elsevier*, vol. 85, pp. 2359-2370.
20. IS 2720 Part 8: Bureau of Indian Standard Code of Practice, New Delhi, Determination of water content-dry density using modified Proctor test.
21. IS 2720 Part16: Bureau of Indian Standard Code of Practice, New Delhi,Laboratory determination of CBR.
22. IRC SP 20 : Bureau of Indian Standard Code of Practice, Spacial Publication, New DelhiManual On Route Location Design, Construction And Maintenance Of Rural Roads, 2002.
23. Jayasinghe C, Mallawa RS, 2009, Flexural strength of compressed stabilized earth masonry materials, *Materials & Design journal,* vol. 30, pp. 3559-3568.
24. Jimenez JR, Ayuso J, Agrela F, Lopez M, 2012, Utilization of unbound recycled aggregates from selected CDW in unpaved rural roads, *Resource, conservation and Recycling,* Vol. 58, pp. 88–97.
25. Lokeshappa B and Dikshit AK, 2011, Disposal and Management of Flyash, *International Conference on Life Science and Technology,* Vol. 3, pp. 11-15.
26. Ministry of Road Transport & Highways-Specifications for Road and Bridge Works (fourth revision) Published by IRC, 2012.
27. Park T.,2003, Application of construction and building debris as base and sub-base materials in rigid pavement, *Journal of Transportation Engineering,* Vol. 129, No. 5, pp. 558-563.
28. Rafat Siddique, 2003, Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete, *Cement and Concrete Research,* vol. 33, pp. 539–547.
29. Reddy, R.M., Kumar, N.D., Prasad, K.N. and Rao, K.M, 1999, Beneficial use of Fly ash in sub base course, *Proceeding National Seminar on Fly ash Characterization and its Geotechnical applications, Bangalore*, pp. 203-207.
30. Sridharan, A., Pandian, N.S. and Sriniwas Rao P, 1988, Fly ash & construction material in Embankments, *Fourth International Symposium on environment geo-technology and global sustainable development, Massachusetts,* pp. 420-430.
31. Thomas B, Walter J, Ali M, 2000, Utilization of construction and demolition debris under traffic-type loading in base and sub-base applications, *Transportation research board 79th annual meeting, Washington, DC.*
32. Toth, P.S., Chan H.T. and Cragg, CB, 1988, Coal ash as structural fill with special reference to Ontario experience, *Canadian Geotechnical journal,* vol.25, pp. 694-704.
33. Van de Ven MFC, 2005, Material recycling-general report in 2nd International symposium of treatment and recycling of materials for transport infrastructure, Paris, France, October 24–26.
34. Vegas I, Ibaez JA, Lisbona A, Faras M, 2011, Pre-normative research on the use of mixed recycled aggregates in unbound road sections, *Construction Building Material,* vol. 25, pp. 2674–2682.
35. www.urbanindia.nic.in, Chapter 4, Construction and demolition waste cited on (25-07-2014)
36. Xuan DX, Houben LJM, Molenaar AAA, Shui ZH, 2012, Mechanical properties of cement-treated aggregate material – a review, *Materials & Design journal,* vol. 33, pp. 496-502.
37. CBR curves for flexible pavement design (IRC-SP:20:2002)

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