Partial replacement of natural aggregates and natural bitumen by construction demolition waste and recycled bitumen

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Abstract - *Construction industry generates large amount of waste during the construction of new structure and demolition or reformation of old structures. In the present era even the healthy structures are many times reconstructed for creating more space to meet the present requirements. These activities generate a large amount of waste called construction demolition waste (CDW) giving rise to the problem of disposal in sustainable manner. Due to the mere development in construction industry, construction materials mainly aggregates are getting extinct as it is used in most of civil engineering works. In fact this has led to the use of different materials or recycled materials as a replacement to fresh aggregates. This study evaluates the possibility of designing hot mix asphalt road pavements using construction and demolition waste as coarse aggregates. The percentages of recycled aggregates used in mixtures were 0%, 5%, 10%, 15%, 20%, 25%. The mixtures made with coarse recycled aggregates were found to meet the requirement of stability, flow, VMA and VFA. Partial replacement of CDW for 10% found maximum stability, density and all the Marshall properties were found to be within the limit. In addition to this, attempt has been made to check the suitability of recycled bitumen as a replacement to virgin bitumen by keeping optimum percentage of building demolition waste i.e 10% as constant, and percentage of recycled bitumen was varied , from the tests we found that 15% replacement of recycled bitumen was optimum.*

Key Words: **Construction demolition waste, bitumen, recycled aggregates, Marshal stability, recycled bitumen.**

1.INTRODUCTION

The construction industry has developed rapidly in the past few years due to increase in industrialization and urbanization because of which the interest for construction materials is immense for the development exercises which results in the era of tremendous measure of construction waste. Construction material wastage has brought about the enormous money related difficulties to builders, contractors, temporary workers, and regional authorities and then to the nation [1].

The creation of waste because of the destruction or demolition of structures is more than the wastage which occurs in the construction of new structures; the reason is being in-disciplinary and less focused regarding the issue. It has also given rise to Environmental issues like increase in the flood levels due to the illegal dumping of construction and demolition waste in the rivers, resource depletion, shortage of landfill and the illegal dumping on hill slopes. So there is need of management of construction and demolition waste (CDW). CDW can be defined as "waste which arises from construction, renovation and demolition activities which includes excavated materials, concrete, tiles, bricks, ceramics, asphalt, concrete, plaster, glass, metal and steel, plastics, wood, aggregates etc" [1].

Worldwide there is lot of response to reduce the waste with regulation and legislation. Civil construction generates large amounts of waste during the building of innovative structures and destruction or reformation of aged buildings. India is presently generating construction and demolition waste of 23.75 million tons and worldwide 30.15 billion tons per year [2].

Due to on-going trend of reconstruction of even healthy structures, just for creating more space in order to meet the present requirement, such activities are generating large amount of waste called construction demolition waste (CDW), it also includes excavated materials such as rock, soil, waste asphalt, soil, concrete, bricks, timber, plasterboard, asbestos, and contaminated soil [3].

1.1 Bitumen

Bitumen is a one of the most complex material used in the construction. It is relatively low cost material, it is used for laying of roads to bind aggregates, it is also used as water proofing agent in the road construction. The relationship between temperature and viscoelastic behavior of bitumen is sometimes unsatisfactory as it shows lack of stiffness or elastic response at elevated road temperature, it exhibits sufficient stiffness at road temperature but lacks ductility and is therefore susceptible to brittle behavior at low temperature and resistance to permanent deformation [4].

Currently the continuous concern of saving natural resources and reduction of waste generation is promoting an increase in the recycling of used materials. Continuous study are being done for the extraction and recycling of bitumen from the scrapped pavements.

2. OBJECTIVES AND METHODOLOGY

1. To study the effect of varying percentage of demolition waste as a replacement to natural aggregates on the performance of HMA.
2. To study the improvement in the properties of hot mix asphalt by additions of varying percentage of recycled bitumen.
3. To assess the economics of adding recycled aggregates and bitumen to work out the feasibility.

The collected construction and demolition waste were crushed, sieved and according to gradation it was separated with a required quantity for the analysis. Natural aggregates according to gradation with the percentages of 4%, 4.5%, 5%, 5.5%, 6% of 60/70 penetration grade bitumen was used, and casted moulds. The mixture having 100% natural aggregates is labeled as control mix. By the results we found the optimum percentage of bitumen. By keeping that as ideal then the partial replacement of natural aggregates by recycled construction demolition waste according to gradation was done with optimum bitumen content , 5%, 10%, 15%, 20% & 25% of CDW. From the results found the optimum percentage of CDW, keeping that as constant instead of natural bitumen recycled bitumen was incorporated.

In this study aged scrapped pavement is crushed and then by adding benzene with 500gm for each trial, bitumen is extracted by centrifuge the same will be used as a replacement to fresh bitumen in small proportions like 5%, 10%, 15%, 20%, 25%. The specific gravity of mixtures are found. The aggregates more than 4.75 mm size are conducted by wire basket method, and the sizes below 4.75 mm are conducted by pycnometer method.

3. EXPERIMENTAL RESULTS

This study presents a laboratory investigation aimed to view the properties of hot mix asphalt and the effects of recycled bitumen and construction demolition waste on Marshall Parameters [5].

The trials conducted includes,

(1) Recycled aggregate content in the mixtures: tests are made at (5%, 10%, 15%, 20%, 25% and 100%).

(2) Natural bitumen content: the mixtures are designed by adding (4%, 4.5%, 5%, 5.5%, 6%).

(3) Recycled bitumen content in the mixture: tests are made with (5%, 10%, 15%, 20%, 25% and 30%).

3.1 Marshal stability results for natural aggregates

Table-1: Marshal design results conducted for natural aggregates

% Bitumen Mix	Dai of Mould in cm	Height of Mould in cm	Volume of Mould in Cu.cm	Wt of Core in Air in gm	Wt of Core in Water in gm	Denisty of Core in gm/cc	Theoroti cal Density in gm/cc	% Volume of Bitumen	% Air Voids	% Voids in Mineral Aggrgat es	% of Voids filled with Bitumen	Min Stablility in KN@ 60 C	Max.Flo w Value in mm	stability in kg	marshall quotient m3
B	d	H	V	Wa	Wb	Gb	Gt	Vb	Vv	VMA	VFB				
						Wa/(Wa-Wb)		Gb(Binder Wt/Sp.gr of Binder)	((Gt-Gb)./Gt) 100	Vv+Vb	(100xVb)/VMA	(No.of Dvx3.33 kg)			(stability /flow)
4	10.2	8.5	694.649	1320	800	2.538	2.726	10.154	6.880	17.033	59.6112	4.2	4.8	1326.6	276.375
4.5	10.2	8.5	694.649	1312	799	2.558	2.700	11.509	5.278	16.786	68.5602	5.14	3.9	1696.2	434.923
5	10.2	8.5	694.649	1309	798	2.562	2.670	12.808	4.058	16.867	75.9388	6.15	4.5	2029.5	451
5.5	10.2	8.5	694.649	1290	785	2.554	2.650	14.050	3.605	17.655	79.5782	7.05	4.9	2326.5	474.796
6	10.2	8.5	694.649	1315	799	2.548	2.625	15.291	2.916	18.207	83.983	4.09	5.3	1349.7	254.66

Table 1 shows the results of the Marshall Parameters conducted for natural aggregates and percentage bitumen content. Also given are the core density (Gb), theoretical density,% air voids of Aggregates

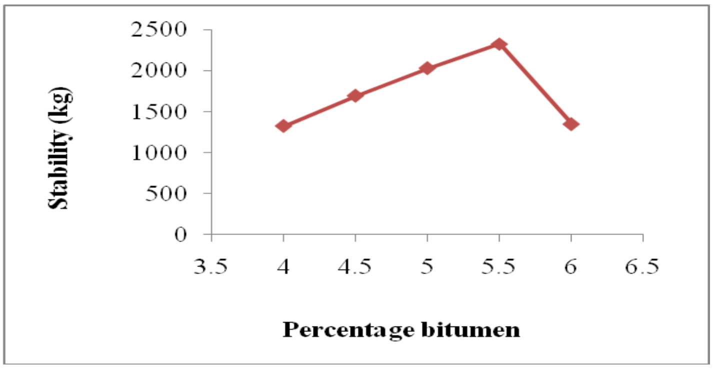

Fig – 1 Graph Showing % bitumen versus stability

The stability has increased from 1326.6 kg at 4% bitumen content to 2326.5 kg at 5.5% bitumen content.

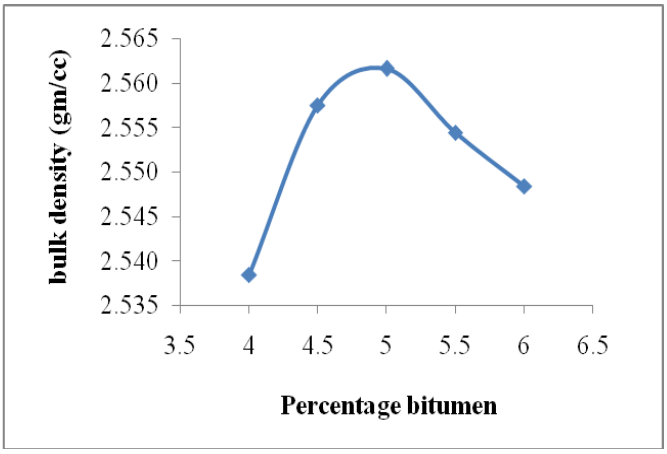

Fig – 2 Graph Showing % bitumen versus bulk density

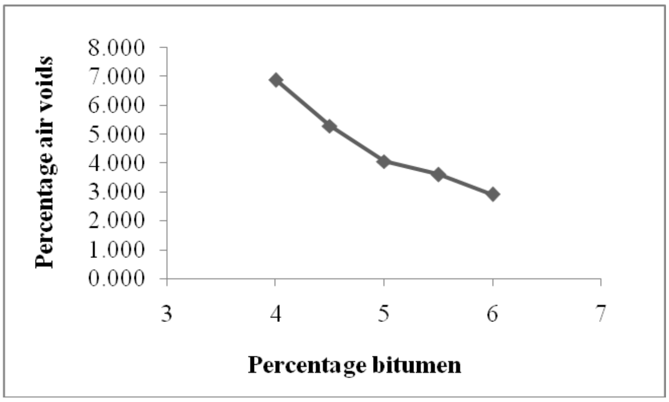

Fig – 3 Graph Showing % bitumen versus percentage air voids

With the increase in the percentage of bitumen the percentage air voids decreased as the air voids were occupied with bitumen after compaction.

From the graphs obtained bitumen content 5.5% as ideal.

3.2 Marshal results for CDW

After obtaining the optimum bitumen content as mentioned above, the natural aggregates were replaced with CDW in varying percentages of 5, 10, 15, 20, 25 and complete replacement was done. The effect of varying percentage of demolition waste on the properties of the mix are shown in table.

Table – 2 Marshall design results for construction demolition waste replacement

% CDW	Dia of Mould in cm	Height of Mould in cm	Volume of Mould in Cm3	Wt of Core in Air in gm	Wt of Core in Water in gm	Density of Core in gm/cc	Theoroti cal Density in gm/cc	% Volume of Bitumen	% Air Voids	% Voids in Mineral Aggrgat es	% of Voids filled with Bitumen	Min Stablility in Kg@ 60 C	Max.Flow Value in mm	marshall quotient in m3
B	d	H	V	Wa	Wb	Gb	Gt	Vb	Vv	VMA	VFB			
						Wa/(Wa-Wb)		Gb(Binder Wt/Sp.gr of Binder)	((Gt-Gb)./Gt) 100	Vv+Vb	(100xVb)/VMA	(No.of Dvx3.33 kg)		(stability/ flow)
5	10.2	8.5	694.649	1085	535	1.97273	2.505	12.05556	3.14621	15.2018	79.3037	1683	6.1	275.9016
10	10.2	8.5	694.649	1300.5	720	2.24031	2.32	13.69078	3.43491	17.1257	79.9429	2002.06	2.35	851.9404
15	10.2	8.5	694.649	1298	700	2.17057	2.165	13.26459	3.56812	16.8327	78.8025	1700	6.05	280.9917
20	10.2	8.5	694.649	1258	664	2.11785	2.19	12.94239	3.7856	16.728	77.3697	1495	6.3	237.3016
25	10.2	8.5	694.649	1249	638	2.04419	2.127	12.49227	3.89328	16.3856	76.2395	1360	5.85	232.4786
100	10.2	8.5	694.649	1079	527	1.95471	2.074	11.94545	5.75168	17.6971	67.4994	1005	6.8	147.7941

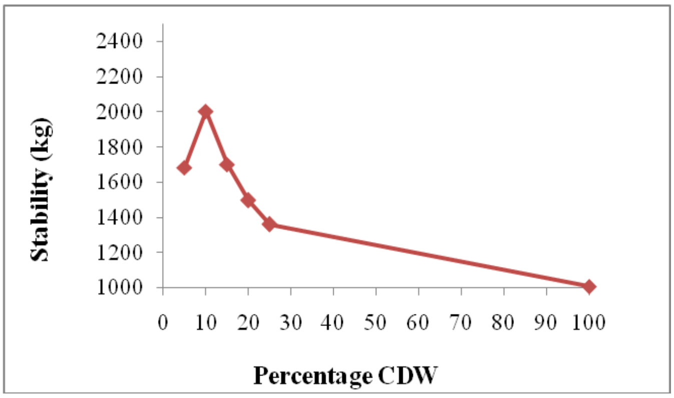

Fig – 4 Graph showing % CDW versus density for optimum bitumen content

Construction demolition waste was replaced with the natural aggregates in varying percentages of 5, 10, 15, 20, 25 and 100% replacement respectively. The addition of demolition waste as replacement to natural aggregates did show an increase in the stability of the mix till 10% replacement after which it started reducing constantly till 100% replacement. The reason for the downward trend after 10% is probably because of the fact that natural aggregates will be much stronger than that of CDW, and the initial increase in stability may be because of the filling up of larger voids by the CDW fines. So from the trials conducted it was found that 10% replacement of fines was found to be ideal.

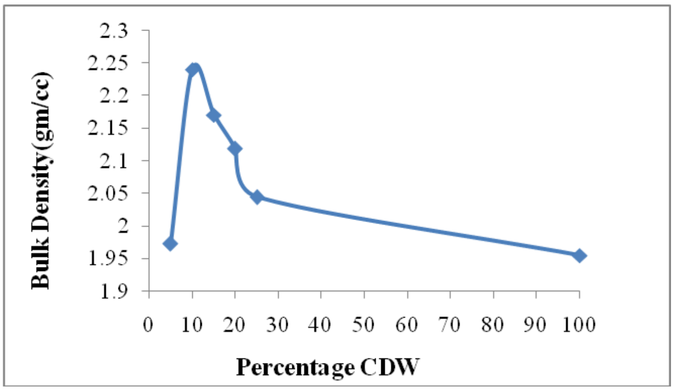

Fig – 5 Graph showing % CDW versus bulk density for optimum bitumen content

Similar to marshall stability, density has also shown an increase till 10% replacement and later is continues to decrease till complete replacement. The density is varying from 1.97 gm/cc to 2.25 gm/cc.

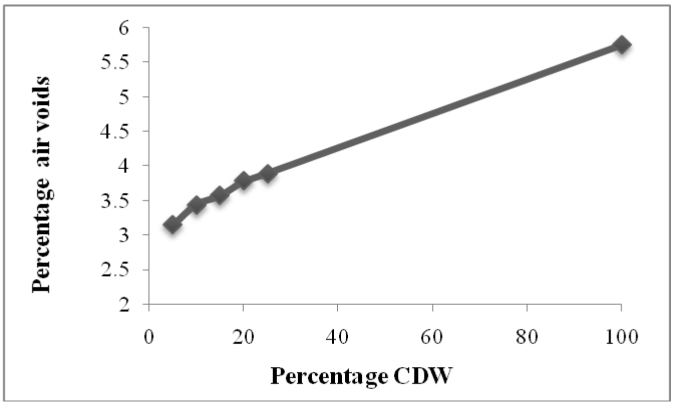

Fig – 6 Graph showing % CDW versus percentage air voids for optimum bitumen content

For the same mixture the air voids have shown constant increase from 3% at 6% for CWD replacement varying from 5% at 100%.

From the discussion made above it is evident that 10% replacement of demolition waste is giving good results for most of the Marshall properties. Hence by keeping 10% CDW as constant further trials were carried out by replacing virgin bitumen with recycled bitumen.

3.2 Marshal results for recycled bitumen

After obtaining the optimum CDW as mentioned above, the natural bitumen were replaced with recycled bitumen in varying percentages of 5, 10, 15, 20, 25 replacement was done. The effect of varying percentage of recycled bitumen on the properties of the mix is shown in table 3.

Table – 3 Marshal design results for recycled bitumen replacement

% of recycled Bitumen	Dai of Mould in cm	Height of Mould in cm	Volume of Mould in Cu.cm	Wt of Core in Air in gm	Wt of Core in Water in gm	Denisty of Core in gm/cc	Theorotical Density in gm/cc	% Volume of Bitumen	% Air Voids	% Voids in Mineral Aggrgates	% of Voids filled with Bitumen	Min Stablility in kg @ 60 C	Max.Flow Value in mm	marshall quotient in m3
B	d	H	V	Wa	Wb	Gb	Gt	Vb	Vv	VMA	VFB			
						Wa/(Wa-Wb)		Gb(Binder Wt/Sp.gr of Binder)	((Gt-Gb)./Gt) 100	Vv+Vb	(100xVb)/VMA	(No.of Dvx3.33 kg)		
5	10.2	8.5	694.649	1310	732	2.266	2.465	11.332	8.066	19.399	58.4174	1347	4.8	280.625
10	10.2	8.5	694.649	1316	742	2.293	2.448	22.927	6.338	29.265	78.3432	1460.94	3.8	384.45789
15	10.2	8.5	694.649	1320	737	2.264	2.431	33.962	6.848	40.810	83.2207	1681.3	5.3	317.22642
20	10.2	8.5	694.649	1323	735	2.250	2.414	45.000	6.778	51.778	86.9092	1548.06	4.5	344.01333
25	10.2	8.5	694.649	1322	733	2.244	2.397	56.112	6.357	62.469	89.8242	1536	6.9	222.6087

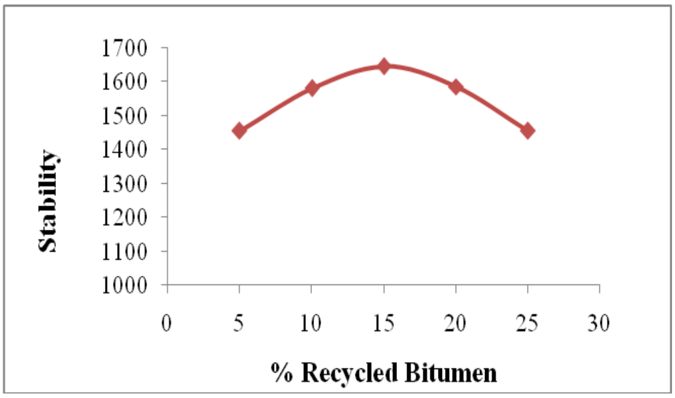

Fig – 7 Graph showing % recycled bitumen versus stability for optimum CDW content

The graph shows an increase in stability varies from 1347 kg at 5% recycled bitumen to 1681.3 kg at 15% recycled bitumen content after which stability decreased to 1320 at 25% replacement. Based on the graph below, 15% replacement if found to be ideal with the stability of 1681 kg..

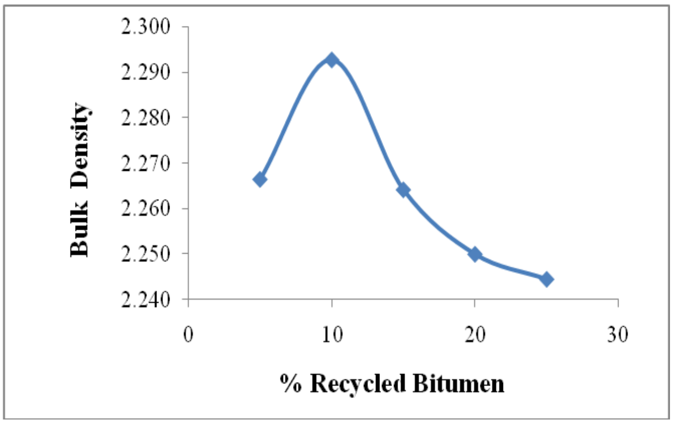

Fig – 8 Graph showing % recycled bitumen versus bulk density for optimum CDW content

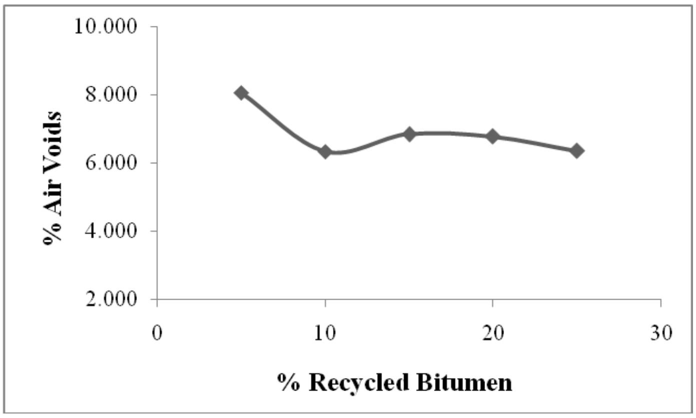

Fig – 9 Graph showing % recycled bitumen versus % air voids for optimum CDW content

Percentage air voids have shown constant decline with the increase in the percentage replacement of recycled bitumen [6].

4. CONCLUSIONS

The objective of the study was to evaluate the effects of recycled aggregates compare to natural aggregates in hot-mix asphalt. Thus, various laboratory tests were conducted to evaluate the characteristics of hot mix asphalt containing recycled aggregates and also this work was conducted for the surface course of the pavement, based on the results of the laboratory tests, the following conclusions were made:

1. Based on the trials conducted on the replacement of natural aggregates with construction demolition waste, a replacement of 10% was found to be ideal, as all the marshall properties such as marshall stability, Density, Air voids, VMA, VFA etc are found to be within the permissible limit as specified by IRC.
2. By keeping 10% construction demolition waste constant, the trails for recycled bitumen demonstrated optimum results at 15% replacement of recycled bitumen with virgin bitumen. And all the marshall properties such as marshall stability, Density, Air voids, VMA, VFA etc are found to be within the permissible limit as specified by IRC. .
3. By using construction demolition waste as recycled aggregates cost can reduce by 10% in natural aggregats for surface course.
4. The marshall quotient value is increased from 474.79 to 851.9 with 10% replacement of Construction demolition waste, which will result in reduced susceptibility to permanent deformation.

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