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Experimental Investigation of Bituminous Concrete Mix Using Ceramic Waste and Rice Husk Ash as a Partial Replacement of filler and aggregate

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Abstract: Bitumen is a complex structure which is made up of hydrocarbons. bitumen is used in worldwide in road construction. But bitumen is become costly day by day and lack of traditional resources so opening the another industrial by-products or wastes materials as a replacement of filler material in road construction. Various waste materials available in the different industries, refineries, agricultural products etc. Such like a brick dust, ceramic waste, silica, rice husk ash, plastic powder, glass powder etc materials to be found in worldwide.in this study two major waste materials ceramic waste and rice husk ash used as a filler in bituminous concrete and also partial replacement of aggregate by white marble chips. Ceramic waste (CW) and Rice husk ash (RHA) are by-products which is a excessive Environment hazard causing damage to the land and Surrounding range in which it is discarded. To deal with this problem, here the study emphases on a laboratory evaluation of the mechanical performance of bituminous concrete mixes using ceramic waste and RHA as a different proportion 5%,7%,9% and 2.5%,3.5%,4.5% respectively at a different bitumen content as a partial replacement of filler and aggregate material. In this Experimental Investigation Marshall stability test considered as a design and evaluation of bituminous paving mixes. CW and RHA is a better option in low to medium traffic roads so minimize the hazardous effect around the land.
Keywords: Bituminous concrete, Marshall Parameters, Ceramic waste, Rice husk ash, Environment

I. INTRODUCTION

Bituminous concrete is the most often used pavement material due to its construction techniques. The ever-increasing economic cost and lack of availability of ordinary material have opened the opportunity to explore locally available waste material. If industrial waste materials can be suitably used in road construction, the pollution and disposal problems may be partially reduced.[2]
Ceramic industry of India become enlarge day by day that manufacturing tiles, floor tiles, bricks, sanitary ware, refractory materials and ceramic materials for domestic purposes.in India it has been estimated that 30% of the daily production waste during transportation or manufacturing. The ceramic waste is escalating up day by day, because of its massive usage in up-to-date way of construction movement. So, one solvable solution has to be essential for the ceramic manufacturing for fading the waste dump at ceramic industries is reutilizing, recycling and swap of concrete ingredients.
Rice Husk Ash (RHA) is a by-product material from the combustion of rice husk. While, rice husk is generated from the production of the rice which is extremely prevalent in east and south east of Asia. The husk of the rice is removed in the farming process before it is sold and consumed. It constitutes 20% of the approximately 500 million tons of paddy produced in the world.[1]
Nowadays, there is an increasing importance in the utilization of waste materials which is one of the main target schemes for the environmentally friendly processes. In the case of construction industry, there was an increasing trend towards the development and consumption of waste as supplementary cementitious materials. The common pozzolanic agents from biomass and industry by products such as RHA, Ground Granulated Blast Furnace Slug (GGBFS) and fly ash are becoming active areas of research due to the positive environmental effects in addition to the economic issue.[1]

II. MATERIALS

A. Ceramic waste powder

Ceramic waste powder found in white color.it look like fine white powder that can easily passed in 0.075mm sieve so in this this powder used as a filler. The ceramic waste was accumulated from the locally available manufacturing unit in Morbi, Gujarat, India. Specific gravity of ceramic waste powder is 2.30 and water absorption is 2.40%. this powder used as a filler in this study. ceramic waste powder with the chemical properties presented in Tables has been used in this study.

1) Chemical properties: The table below provides the chemical properties of these ceramic Waste Powder

TABLE 1

CHEMICAL PROPERTIES OF CERAMIC WASTE POWDER

Particular materials	Ceramic Powder (%)
SiO_2	63.29
Al_2O_3	18.29
Fe_2O_3	4.32
CaO	4.46
K_2O	2.18
Na_2 O	0.75
MgO	0.72

B. White marble chips

Marble chips (White limestone) are mostly made up of calcium carbonate, which is an alkaline compound. Being alkaline, it reacts with hydrochloric acid to produce calcium chloride, water and carbon dioxide. Calcium chloride is white, water and carbon dioxide are colourless. Large lumps of marble chips are crushed to smaller and all impurities are removed.in this study marble chips used as a fine aggregate.

1) Physical properties: The table below provides the Physical properties of these white Marble chips.

TABLE 2

Physical Properties Of White Marble Chip

Appearance	White solid
Odour	Odourless

2) Chemical properties: The table below provides the chemical properties of these white Marble chips.

TABLE 3

Chemical Properties Of White Marble Chip

Solubility	Negligible (< 0.1%)
Specific Gravity	2.83
pH	8 – 9
Calcium Carbonate	90- 100%

C. Rice husk ash

Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. This rice husk is mostly used as a fuel in the boilers for processing of paddy. Rice husk is also used as a fuel for power generation. Rice husk ash (RHA) is about 25% by weight of rice husk when burnt in boilers. It is estimated that about 70 million tons of RHA is produced annually worldwide. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped.so it is safe option to use as a filler in bituminous concrete mix for this study.

1) Physical properties: The table below provides the Physical properties of these Rice Husk Ash.

TABLE 4 Physical Properties Of Rha

Particulars	properties
Colour	Grey
Shape texture	Irregular
Mineralogy	Non-crystalline
Particle size	<45 micron
Odour	odourless
specific gravity	2.3
Appearance	Very fine

2) *Chemical properties:* The table below provides the Chemical properties of these Rice Husk Ash.

TABLE 5. CHEMICAL PROPERTIES OF RHA

Particulars	proportion
Silicon dioxide	86.94%
Aluminium oxide	.2%
Iron oxide	.1%
Calcium oxide	03.-2.2.%
Magnesium oxide	0.2 -0.6%
Sodium oxide	0.1%- 0.8%
Potassium oxide	2.15-2.30%

III.OBJECTIVE

A laboratory evaluation of the mechanical performance of bituminous concrete mixes using ceramic waste and rice husk ash as a Partial replacement of filler and aggregate material.

IV.EXPERIMENTAL WORK

A. *Aggregate testing*

The aggregate performance tests were performed on the various specified properties, and the resulting test results were compared with the allowable values in the MORTH specification, as shown in the table.

TABLE 6: Test Results Of The Ingredient Aggregates

Name of test	Test Results	Permissible value	Is standard
Aggregate Impact Value, %	9.93 %	24% maximum	IS : 2386-Part IV:1963
Water Absorption, %	0.50 %	2% maximum	IS : 2386-Part III:1963
Specific Gravity	2.82	2 – 3	IS : 2386-Part III:1963
Los Abrasion value%	19.08 %	Maximum 30%	IS : 2386-Part IV :1963

B. *Bitumen Testing*

Bitumen grade was used in this study is VG-30. Sample of bitumen were tested for penetration test, ductility test, viscosity test and softening point test. The penetration and viscosity test was to obtain consistency of bitumen at some specified temperature and designate grade of asphalt while softening point test is to obtain temperature for bitumen melt. The test results of different bitumen tests results are shown in table:

TABLE 7
Test results of ingredient bitumen sample.

Name of test	Test Results	Permissible Value	IS Standard
Penetration at 25ºC/100 gm /5 sec, mm	57 mm	50-70	IS: 1203:1978
Ductility, cm	80.15 cm	75 cm minimum	IS: 1208:1978
Softening Point	45.5 ºc	40 ºc to 55 ºc	IS: 1205:1978
Viscosity at 60ºC, Poise	1087 poise	1000±200	IS: 1206 (Part I) – 1978

C. Gradation of Bituminous Concrete

Below given table is satisfying the criteria as per the MORTH .in this study bituminous concrete grade 2 design used for whole design.

TABLE 8
Gradation Of Bituminous Concrete

Sieve Size mm	Actual % passing			% Passing proposed mix design			Total Passing %	Limit as per MORTH
	10mm	White marble chip	filler	10mm	White marble chip	filler		Table - 500/18
				35.0%	60.0%	5.0%	100.0%	Grading 2
19	100	100	100	35	60	5	100	100
13.2	94	100	100	32.9	60	5	97.9	90-100
9.5	62	100	100	21.7	60	5	86.7	70-88
4.75	30	89	100	10.5	53.4	5	68.9	53-71
2.36	17.2	72.3	100	6.02	43.38	5	54.4	42-58
1.18	1.02	66.4	100	0.357	39.84	5	45.19	34-48
0.6	0.569	38.2	100	0.19	22.92	5	28.11	26-38
0.3	0.338	24	100	0.11	14.4	5	19.51	18-28
0.15	0.338	17.6	73.6	0.11	10.56	3.7	14.37	12-20
0.075	0.338	5.0	40.1	0.11	3	2	6.085	4-10

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D. Mix Design Proportion for Bituminous Concrete grade 2

TABLE 9
Mix Design Proportion For Bituminous Concrete Grade 2

Bitumen Content	Correlation Ratio	Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5%	1	14.21	4.46	2.6503	2.4536	7.54	9.51	17.05	55.77
5%	0.96	14.43	4.67	2.6132	2.4367	6.89	10.65	17.54	60.71
5.5 %	1	15.74	5.44	2.6058	2.4510	5.76	11.78	17.60	67.16
6%	1	12.26	5.91	2.5886	2.5680	5.19	12.90	18.09	71.31

E. Modified Marshall test(ASTM D6927-15)

The method is to measure the conflict of the compressed cylindrical form of the asphalt mixture with the plastic bending when the sample is loaded in the diametrical direction at the deformation rate50.8 mm/minute. The Marshall stability is defined as the most load carry by the bitumen sample at temperature of 60°C. The flow value is defined as the bend occurred when Load to maximum load. The flow rate is measured in 0.25 mm units. In the Marshall Stability Test, try to achieve the optimum binder content for the type of aggregate mixture used and to estimate the traffic intensity

Fig 1 Marshall test apparatus with mould testing
(Source –MEFGI highway laboratory)

F. Mix Design Results of Bituminous Concrete Grade-2 without any additive

In the Marshall method, in order to find the optimum binder content (OBC), the Marshall sample was prepared by varying the percentage of the vg30 binder without any modifier. Stability and flow analysis were performed on Marshall Core samples with 4.5% to 6% different bitumen content. The obtained test values are graphically drawn. The output of the stability and flow values is shown in Table and below.

TABLE 10
Stability Of Normal Mix Sample Prepared With Different Percentage Of Bitumen

Material	10mm	White marble chips	Filler	Total
proportion	35%	60%	5%	100

1) Optimum Bitumen Content
2) Max stability = 5.5 percent bitumen content.
3) Max G_m = 6 percent bitumen content.
4) Maximum air void = 4.5 percent bitumen content.
5) The optimum bitumen extent is the average of above = 5.33 percent.

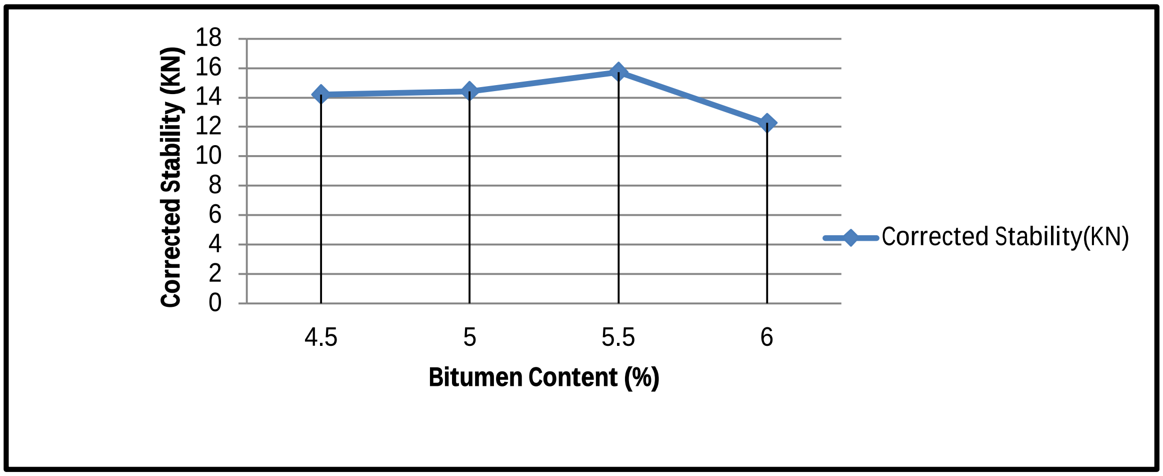

Figure 2 Variation of Stability Value to the Variation in Bitumen Content

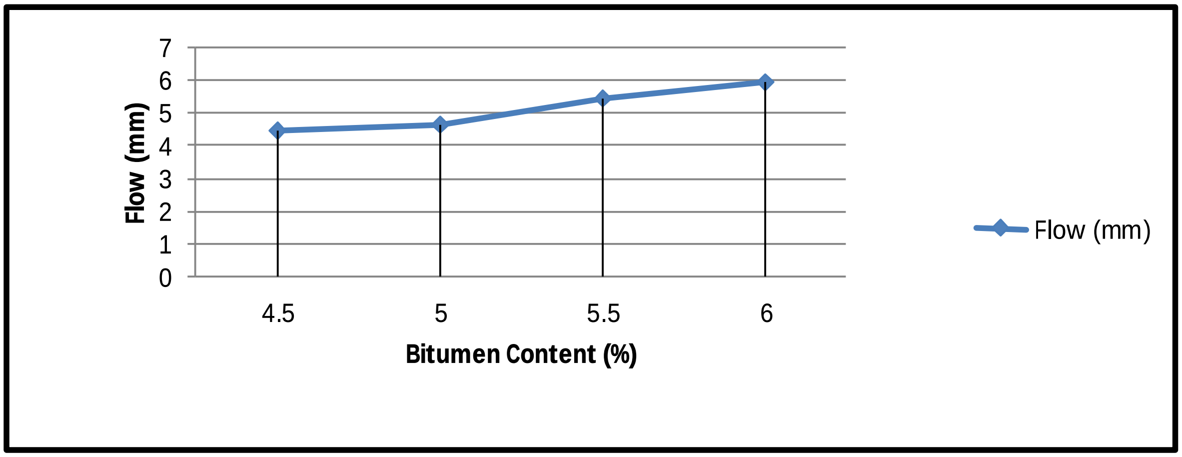

Figure 3 Variation of Flow Value to the Variation in Bitumen Content

G. Mix Design Results of Bituminous Concrete Grade-2 with White Marble Chips

TABLE 11

Stability Of Normal Mix Sample Prepared With White Marble Chips At Different Percentage Of Bitumen

Bitumen Content	Correlation Ratio	Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5%	1.04	14.47	4.43	2.6503	2.4632	7.16	9.55	16.71	57.15
5 %	1	15.32	4.82	2.6292	2.4797	5.72	10.74	16.46	65.24
5.5 %	0.96	14.23	4.87	2.6086	2.4510	5.38	11.78	17.16	68.64
6 %	1	12.45	5.81	2.5886	2.5791	3.87	13.53	17.40	77.75

1) Optimum Bitumen Content
2) Max stability = 5 percent bitumen content.
3) Max Gm = 6 percent bitumen content.
4) Maximum air void = 4.5 percent bitumen content.
5) The optimum bitumen extent is the average of above = 5.16 percent.

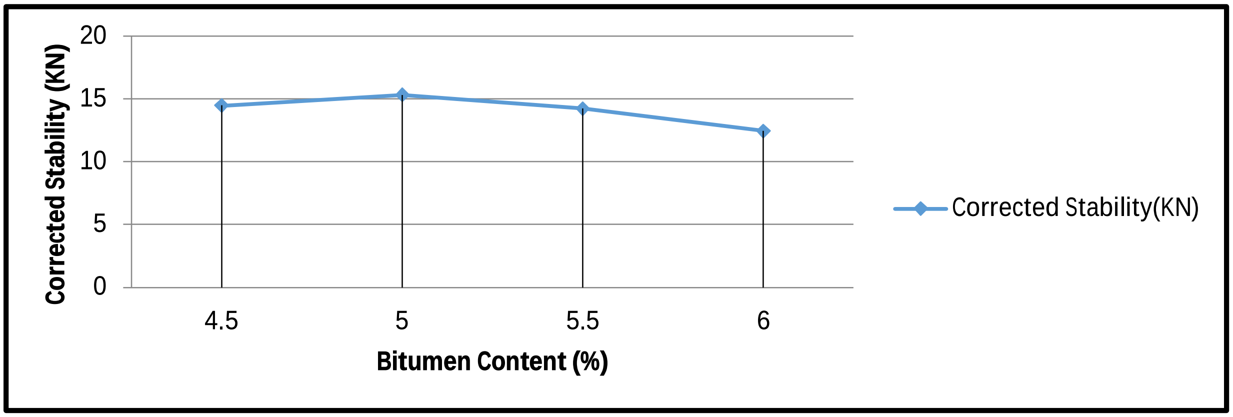

Figure 4 Variation of Stability Value to the Variation in Bitumen Content

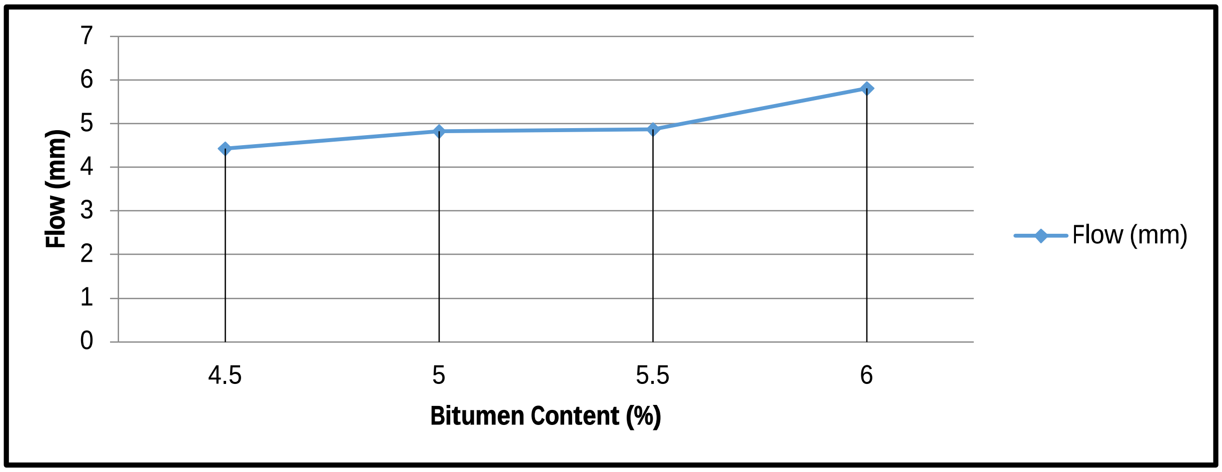

Figure 5 Variation of Flow value to the Variation in Bitumen Content

H. Mix Design Results of Bituminous Concrete Grade-2 with ceramic-waste

1) The ceramic waste powder was used in the bituminous mixes of BC Grade-2 and stability-flow characteristics of the mix was carried out using Marshall Method of bituminous mix design.
2) The optimum binder content (OBC) of 4.5%,5%, 5.5 %, 6%,6.5%,7% and fine aggregates replaced with white marble chips, ceramic waste powder used as a filler 5%, 7% and 9% of ceramic-waste to determine the Stability and Flow characteristics of the modified mix. The output is shown in the following table and figure.

TABLE 12
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 5 % Ceramic-Waste Powder Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5 %	0.96	12.82	5.60	2.35	2.37	5.71	10.13	15.84	63.95
5 %	1.04	14.88	6.80	2.38	2.39	4.20	11.48	15.68	73.21
5.5 %	1.09	15.89	7.17	2.49	2.48	4.00	11.77	15.77	74.63
6%	1.04	15.50	7.54	2.53	2.52	3.95	12.15	16.1	75.46
6.5%	1.09	14.81	5.48	2.52	2.48	1.58	13.97	15.55	89.83
7%	1.09	12.8	4.20	2.52	2.49	1.19	14.38	15.57	92.35

TABLE 13
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 7% Ceramic-Waste Powder Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5 %	0.78	12.97	5.72	2.34	2.32	8.54	8.23	16.77	49.07
5 %	0.96	14.70	6.60	2.38	2.37	4.20	12.30	16.50	74.54
5.5 %	0.78	14.90	7.87	2.41	2.40	4.14	11.79	15.93	74.01
6%	0.78	15.45	6.32	2.44	2.43	4.09	12.31	16.4	75.06
6.5%	1.09	13.17	6.10	2.49	2.45	1.60	15.94	17.54	90.87
7%	0.93	11.77	4.00	2.45	2.41	1.22	16.60	17.82	93.15

TABLE 14
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 9% Ceramic-Waste Powder Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5 %	1.04	12.14	5.62	2.37	2.35	8.43	9.31	17.74	52.48
5 %	0.93	15.53	6.31	2.38	2.37	4.21	11.47	15.68	73.15
5.5 %	0.96	15	7.48	2.40	2.39	4.17	11.98	16.15	74.17
6%	1	13.48	6.50	2.43	2.42	4.11	12.79	16.9	75.68
6.5%	0.96	13.21	5.54	2.47	2.43	1.61	14.69	16.3	90.12
7%	0.96	11.07	4.18	2.44	2.39	2.04	16.95	19.02	89.11

TABLE 15
Optimum Bitumen Content For Replacement Of Cw Filler At Different Percentage

CW replacement	Max stability	Max Gm	Max air voids	Optimum bitumen content
5%	5.5	6	4.5	5.33
7%	6	6.5	4.5	5.66
9%	5	6.5	4.5	5.33

I. Mix Design Results of Bituminous Concrete Grade-2 with Rice husk ash

1) The Rice Husk Ash was used in the bituminous mixes of BC Grade-2 and stability-flow characteristics of the mix was carried out using Marshall Method of bituminous mix design.
2) The optimum binder content (OBC) of 4.5%, 5%, 5.5%,6%,6.5%,7% and fine aggregates replaced with white marble chips, filler replaced by 2.5%, 3.5% and 4.5% Rice Husk Ash to determine the stability and flow ability of the modified mixture. The output is shown in the following table.

TABLE 16
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 2.5% Rice Husk Ash Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5%	0.93	10.12	5.31	2.36	2.35	4.23	8.12	12.35	65.74
5 %	0.96	13.27	5.89	2.38	2.37	4.20	9.34	13.54	68.98
5.5 %	1.04	15.72	6.60	2.39	2.38	4.18	10.30	14.48	71.13
6%	0.93	16.48	6.31	2.38	2.31	2.94	11.66	14.6	79.86
6.5%	0.96	12.90	4.31	2.40	2.47	2.91	12.78	15.69	81.45
7%	0.96	12.31	3.76	2.34	2.29	2.13	13.12	15.25	86.03

TABLE 17
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 3.5% Rice Husk Ash Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5 %	1.04	13.01	5.70	2.37	2.36	4.21	8.76	12.97	67.54
5 %	1	12.53	6.76	2.39	2.38	4.18	8.94	13.12	68.14
5.5 %	0.96	14.64	6.98	2.40	2.32	3.33	10.08	13.41	75.16
6%	1.09	12.40	5.42	2.40	2.34	2.5	12.15	14.65	82.93
6.5%	0.96	15.10	5.00	2.37	2.32	2.10	13.68	15.78	86.69
7%	0.93	11.72	3.96	2.36	2.33	1.27	14.83	16.10	92.11

TABLE 18
Corrected Stability Of Different Sample Prepared With Different Percentage Of Bitumen And 4.5% Rice Husk Ash Replacement As A Filler

Bitumen Content	Correlation Ratio	Corrected Stability (KN)	Flow (mm)	G_t	G_m	V_v %	V_b %	VMA %	VFB %
4.5 %	1.19	12.31	5.32	2.34	2.33	4.27	8.04	12.31	65.31
5 %	1.09	12.04	5.70	2.36	2.35	4.23	9.12	13.35	68.31
5.5 %	0.96	13.21	6.85	2.37	2.32	2.10	11.56	13.66	84.62
6%	0.96	10.61	7.45	2.39	2.35	1.67	12.45	14.12	88.17
6.5%	0.93	10.30	5.10	2.40	2.36	1.66	12.90	14.56	88.59
7%	0.96	9.71	4.28	2.35	2.31	1.70	13.68	15.38	88.94

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TABLE 19
Optimum Bitumen Content For Replacement Of Cw Filler At Different Percentage

RHA replacement	Max stability	Max Gm	Max air voids	Optimum bitumen content
2.5%	6	6.5	4.5	5.67
3.5%	6.5	5	4.5	5.33
4.5%	5.5	6.5	4.5	5.5

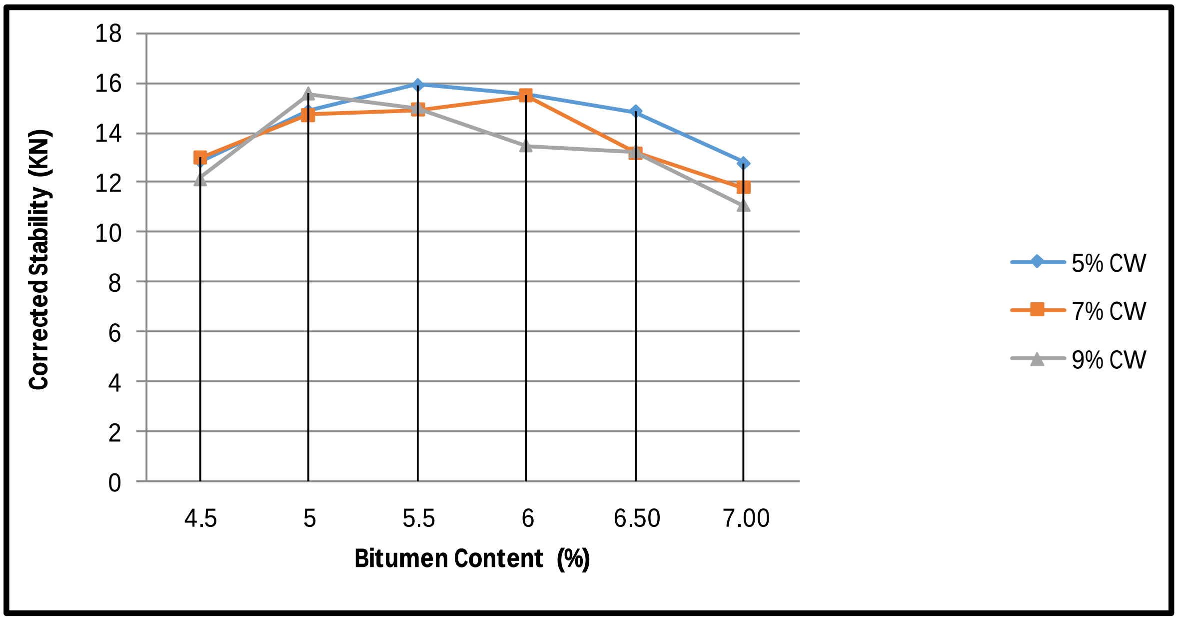

Figure 6 Variations in Stability Value of Ceramic Waste Powder replacement bituminous mix

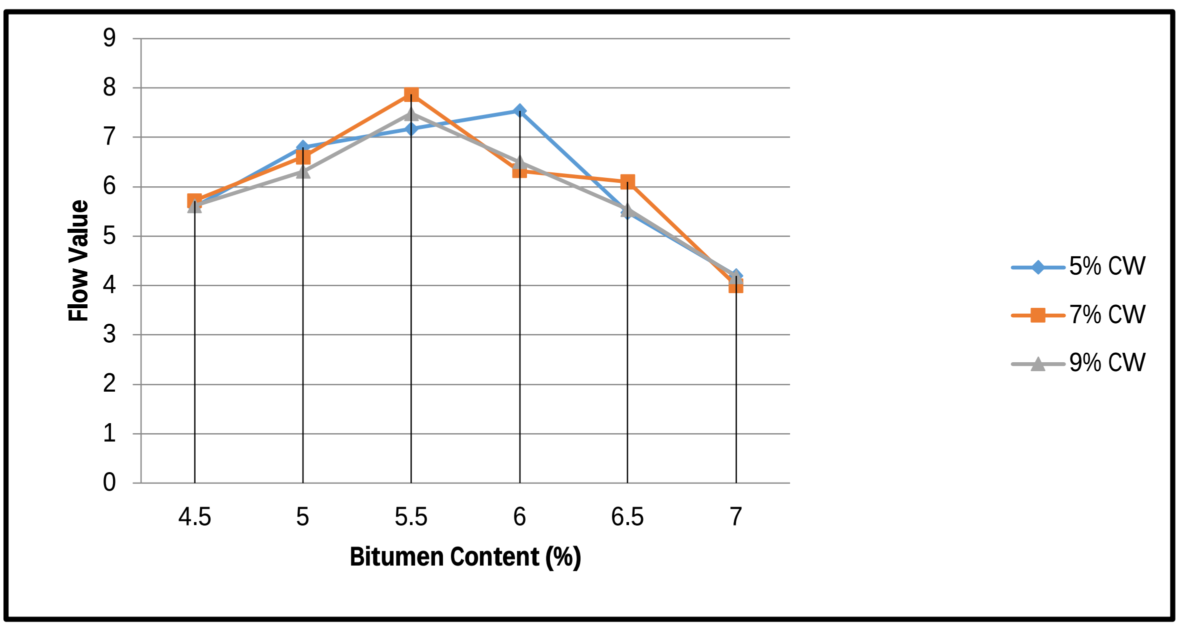

Figure 7 Variations in Flow of Ceramic Waste Powder replacement bituminous mix

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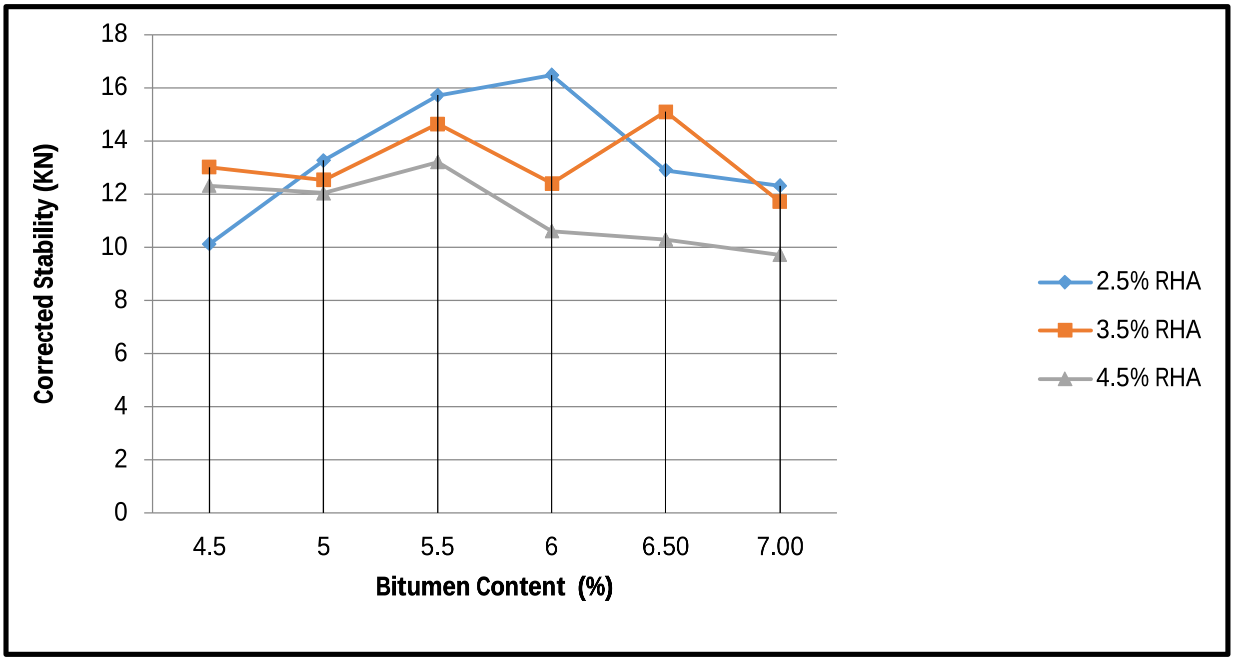

Figure 8 Variations in Stability Value of Rice Husk Ash replacement bituminous mix

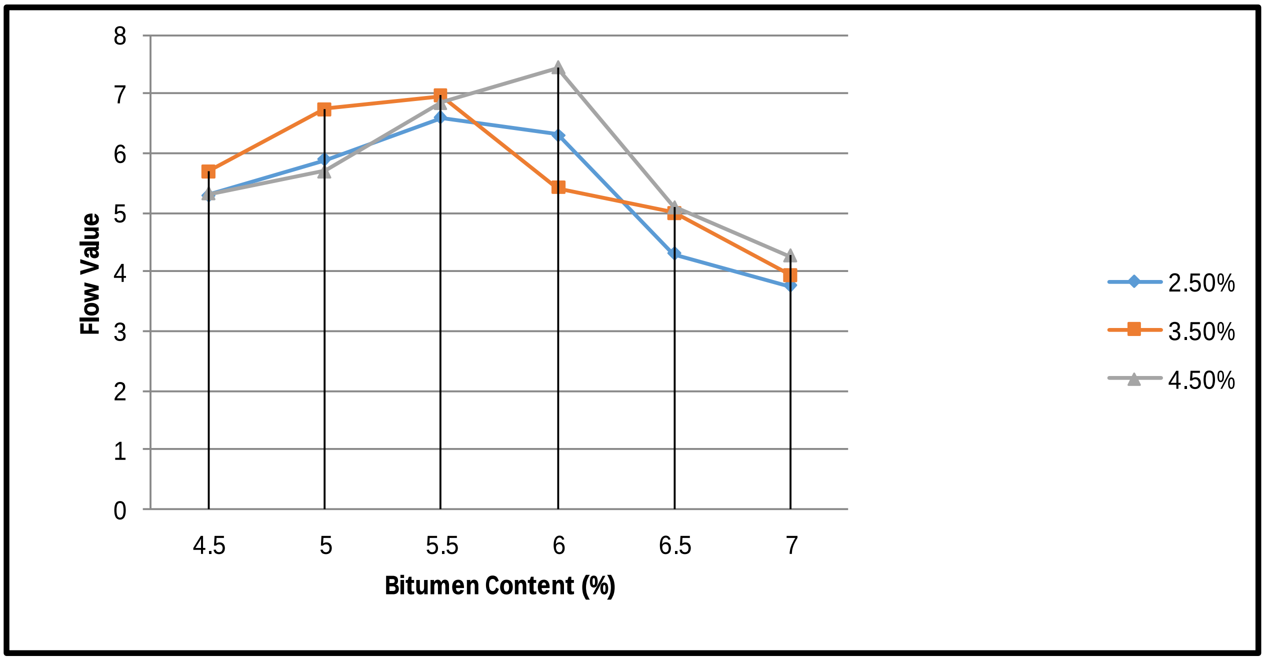

Figure 9 Variations in Flow of Normal and Rice Husk Ash replacement bituminous mix

V. CONCLUSION

Based on the laboratory experiments and analysis, the following conclusions are drawn.

1) It is observed that, for 5% ceramic filler the stability value increases from 12.8KN to 15.89KN, for 7% ceramic filler this value increases from 11.77 KN to 15.45 KN and for 9% ceramic filler the stability value increases from 11.07KN to 15.53KN at OBC.
2) It is observed that, 2.5% RHA filler the stability value increases 10.12KN to 16,48KN, for 3.5% RHA filler this value increase from 11.72KN to 15.10KN and for 4.5% RHA filler the stability value increases from 9.71KN to 13.21KN at OBC.
3) Above result shows that as the amount of CW filler content increases the flow value also which indicates that ceramic waste containing mixes will deform more under traffic load and gives higher flexibility.

4) 2.5% of RHA filler is good replacement option for conventional mineral filler for better roads.

It was concluded that ceramic industrial waste and rice husk ash can be utilized as a replacement for traditional mineral fillers and also partially replacement of white marble chips in bituminous concrete mixes. The utilization of ceramic waste and RHA in the asphalt concrete mixes may solve the significant disposal problem to save the environment.

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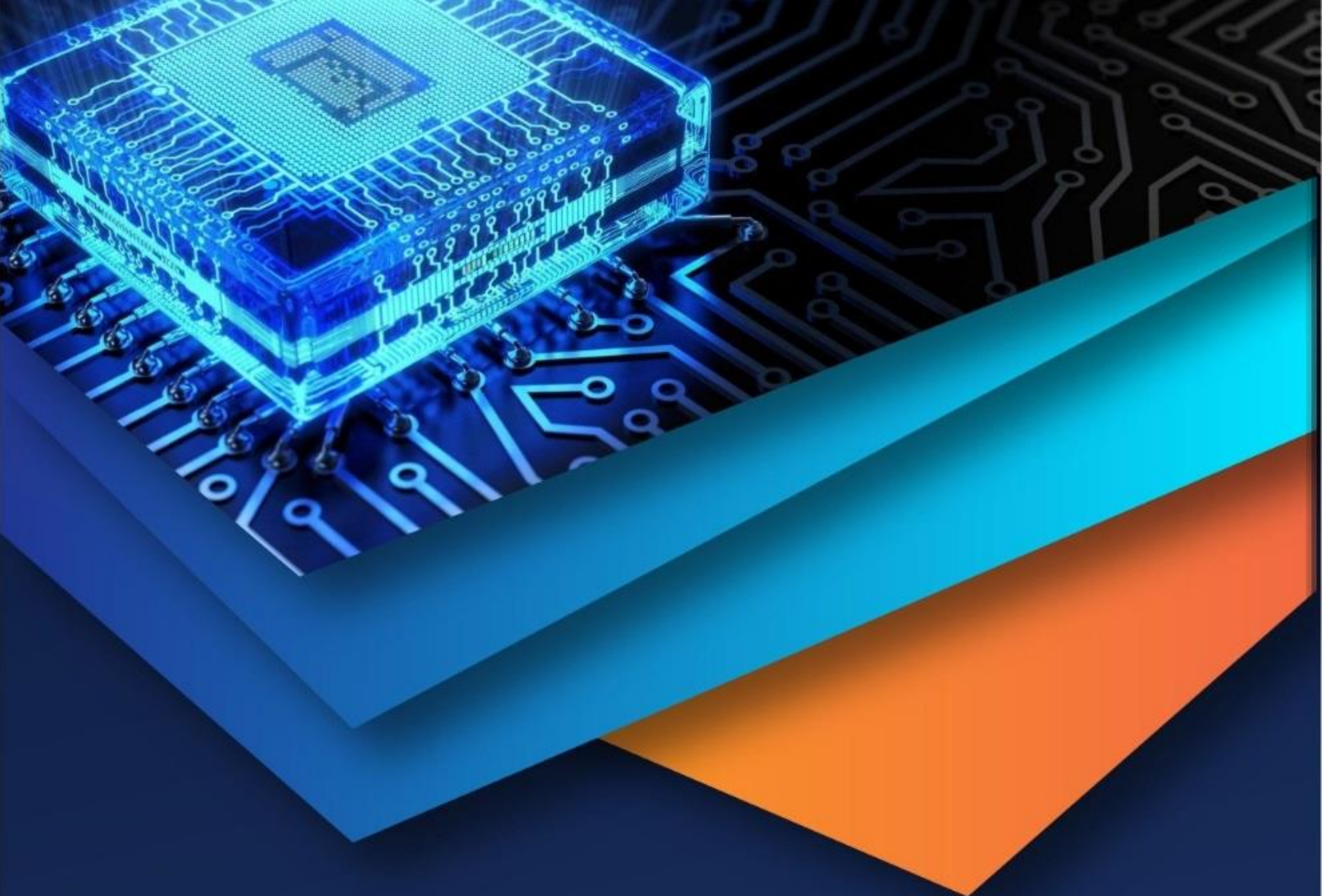

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