LABORATORY PERFORMANCE STUDIES OF BITUMINOUS CONCRETE MIX PREPARED USING COPPER SLAG AS PARTIAL REPLACEMENT OF FINE AGGREGATE

Sudarshan V[1], Dr Suresh G[2]

[1]*M.Tech.(Highway Engineering), UVCE, Karnataka, India. Email- sudarshanv02@gmail.com*

[2]*Professor, Civil Engineering Department, UVCE, Karnataka, India. Email-gsuvce@gmail.com*

……***……..

Abstract: *India is a growing economic country, the growth of this nation depends on growth of all 3 sectors, in that industries comes at secondary sector. Steel industries produces Steel slag as a waste material and likewise other industries also produces their respective kind of slag materials. In the present study copper slag is used as partial replacement of fine aggregate for preparation of Bituminous concrete mix(grade2), The percentage of replacement were 10%, 20%, 30%, 40% by weight of fine aggregates for the bituminous concrete mix. Marshall mix design is carried out for checking its parameters such as stability, flow value, Bulk density, air void etc., through the test it is found that the incorporation of copper slag as partial replacement of fine aggregate increases its stability up to 30% replacement and bulk density increases up to 40% due to higher specific gravity of copper slag. There is a marginal reduction in air void and flow value of Marshall specimen as the percentage of copper slag increases as partial replacement of fine aggregate. Indirect tensile strength of Marshall specimen shows better improvement than Bituminous concrete mix without copper slag as partial replacement of fine aggregate and water sensitivity of the mix decreases as percentage of copper slag increases as partial replacement of fine aggregate.*

Keywords: BC- Bituminous concrete, CS- Copper Slag.

1. INTRODUCTION

In the present world we are encountered with many of the industrial byproducts which are not having any of the usefulness in their respective field, we can use them in different location other than their parent area as one or other form depending upon their availability and economy of the work. The waste material which are available in the locality of any industries, the disposal of material being most unmanageable problem and at the same time it's our responsibility to dispose the waste without disturbing the environment of our mother earth.

The study is conducted to determine the suitability of copper slag to be used in Bituminous mix to replace partially the fine aggregate during mixing and finding the best design mix using method such as the Marshall Mix Design. generally, the fine aggregate for the Bituminous mix consists of natural stones which is hard, durable and strong, like granites. It is hoped that copper slag addition will present greater mechanical and durability performance towards the pavement. Other materials used for mixing are filler, coarse aggregates and binder. In the present study VG-30 bitumen is used as a Binder and stone dust as a filler material for the preparation of Bituminous concrete mix.

2. Objective of the present study

- To study the effect of using copper slag as partial replacement of fine aggregate for the preparation of Bituminous concrete mix by Marshall method of mix design.
- To study effect of Copper slag on Marshall properties, Indirect Tensile Strength (ITS), and Tensile strength ratio (TSR) of Bituminous concrete mix.
- To determine the optimum percentage of copper slag used as partial replacement of the fine aggregate in bituminous concrete mix.

3. LITERATURE REVIEW

Raposeiras A C et al (2016), The study focused on, friction and cohesive qualities of copper slag are broken, in order to incorporate this slag as aggregate in asphalt mixes containing Reclaimed Asphalt Pavement (RAP). The Marshall Quotient is reduced up to 27%, improving the performance of mixes with RAP and obtaining behavior similar to a traditional mixture. This study was conducted by fabricating 140 samples of 101.6 mm diameter and 63 mm nominal height, in seven different types of asphalt mixes with different percentages of copper slag and RAP.

Pundhir N K S et al. (2005), In this study CS was used as fine aggregate (up to 30%) in the design of Bituminous mixes like Bituminous Macadam, Dense Bituminous Macadam, Bituminous Concrete and Semi-Dense Bituminous Concrete. Mechanical properties of mix such as Marshall stability, Indirect Tensile Strength was determined. This investigation aims to use CS as construction material in Bituminous road construction. Delhi quartzite was used as coarse aggregate (20 mm and 10 mm), CS and stone dust as fine aggregate and hydrated lime as filler.

4. METHODOLOGY

In the present study laboratory experimentation was done to use industrial by-products as alternate material for aggregates in bituminous concrete mix. Industrial by-products such as copper slag was used for partial replacement of aggregates in bituminous concrete mix (grade 2). The gradation test was conducted on slag which

showed greater of its percentage suitable as fine aggregates and hence was used to replace fine aggregates in hot bituminous concrete mix. The aggregates passing 2.36mm sieve size were replaced. The percentage of replacement were 10%, 20%, 30%, 40% by weight of fine aggregates for the bituminous concrete mix grade-2. The gradation was considered in accordance with Specifications for roads and bridge works, MORT&H 5th revision. Conventional aggregates were procured from Riteway M Sand Stone Crusher plant near Chandupura circle Ramanagara. The copper slag was procured from Asthra Chemicals situated in Chennai. Viscosity grade-30 bitumen was used as the binder. Laboratory evaluation was done for both control unit as well as the mixes with replacement of industrial by-product (copper slag) in various proportions. Various tests were conducted for aggregates and bitumen, after satisfying the requirements they were used in the mix. Tests on aggregates include aggregate crushing value, aggregate impact value, Los Angeles abrasion value, combined flakiness and elongation index, specific gravity of coarse aggregate and fine aggregate and water absorption test. Tests on bitumen include Penetration test, softening point test, ductility test, specific gravity test and flash and fire point test were conducted. After basic tests, to get a proper mix design Marshall Stability test was adopted, the optimum binder content for bituminous concrete grade II for varying bitumen content of 4.5%, 5%, 5.5%, 6%, was conducted on Bituminous concrete mix and mix containing copper slag as partial replacement of fine aggregate. The Marshall stability test was then conducted for optimum binder content of respective mixes. Indirect tensile strength test, moisture susceptibility test was conducted for to check strength parameters.

5. MATERIALS USED

5.1. Aggregate

Materials retained on 2.36 mm IS sieve is considered as coarser fraction. Stone aggregates were used in the mix. Coarse & fine aggregates were procured from Riteway M Sand Stone Crusher plant near Chandupura circle Ramanagara. Fractions passing 2.36 mm IS sieve size and retained on 0.075mm IS sieve size is considered as fine fractions. The aggregate shall be clean, hard, durable, tough, free from dust or friable matter and organic or other deleterious substances. The test results obtained are presented in Table 1.

Table –1: Properties of Aggregate

Sl No	Property	Test Results	Requirement as per IS: 383-2016
1	Aggregate Impact Value %	23.80	30% max
2	Abrasion Value %	23.60	30% max
3	Combined Flakiness and Elongation Index (%)	22.31	35% max
4	Water absorption %	0.21	2%
5	Aggregate specific Gravity		
a b	Coarse aggregates Fine aggregate	2.69 2.70	

5.2. Bitumen

Bitumen acts as a binding agent to the Mineral fillers, aggregates and stabilizers used in bituminous concrete mix. Bitumen provides durability to the mix. The characteristics of binder which affects the bituminous mix behaviour are visco-elasticity, temperature susceptibility and aging. The behaviour of binder depends on temperature as well as on the frequency and time of loading. It exhibits both viscous as well as elastic properties at the normal pavement temperature. At high temperatures its behaviour is like a viscous fluid and at low level temperature it behaves like an elastic material

Viscosity grade 30 paving bitumen conforming with IS: 73 was used for laboratory work. Different basic tests were done to determine the properties of the bitumen. Properties of the bitumen are indicated in Table 2

Table -2: Test results of Bitumen

Tests	Test Results	Requirements as per IS 73-2013
Penetration at 25^{0}C,	65	Min 45
Softening point (Ring &ball), ^{0}C	58	Min 47
Ductility at 27^{0}C in cm	91	Min 40
Flash Point, ^{0}C	252	Min 220
Specific Gravity, 27^{0}C	1.02	-

5.3. Copper slag

The copper slag was obtained from Asthra Chemicals, in Chennai. Copper slag was used as replacement of fine aggregates passing 2.36mm sieve size. Specific gravity of the Copper slag was found to be **3.12**

6. Gradation of Aggregate

Aggregate size and gradation is one of the important factors in pavements and can influence most properties of bituminous mixes. The coarse and fine aggregate particles were separated into different sieve size and proportioned to obtain the desired gradation. The aggregate gradation (Grading-II) was adopted for Bituminous Concrete mix as per MoRT&H (V Revision) as shown in Table 6

7. Marshall Method of Mix Design

Marshall Stability test is conducted on compacted cylinder-shaped specimens of bituminous concrete mix of 101.6 mm diameter and thickness of 63.5 mm. The loading is applied perpendicular to the axis of the specimen through a testing head consisting of pair of cylindrical segments, and applied at a constant rate of deformation of 51mm per minute at the standard test temperature of 60°C conditioned in water bath before testing.

The 'Marshall Stability' of the bituminous concrete mix specimen is defined as a maximum load carried in kg at the standard test temperature of 60°C when loading is done under specified test circumstances. The Marshall Stability values of a compacted specimen of bituminous mix indicates its resistance to deformation under applied incremental of load.

The 'Flow Value' is the total deformation that the Marshal test specimen under-goes at the maximum breaking load, expresses in mm units. The Flow Value indicates the extent of deformation undergone by Marshall specimen due to loading or its elasticity.

The two major features of Marshall Mix Design method are

- Density-Void Analysis.
- Stability-Flow Tests.

8. Indirect Tensile Strength Test

The resistance of bituminous mixes to fatigue cracking is dependent upon its extensibility and characteristics tensile strength. Tensile stresses are developed at the bottom of Bituminous concrete course due to traffic loading. Indirect tensile strength test is an indicator of strength and adherence against temperature cracking rutting and fatigue. Tensile Strength Ratio value serves as the basis for arriving at stress ratio for carrying out fatigue tests. Fatigue life of the bituminous mix depends on its Indirect Tensile Strength value. In this test, compressive load is applied through a vertical strip on Marshall specimen. Due to the geometry of the specimen, tensile stresses are developed and the specimen fails by splitting into two halves.

9. ANALYSIS OF DATA

Table -3: Marshall Properties of Bituminous Concrete Mix Prepared Using Stone Dust as Filler Material

Bitumen Content, %	Marshall Stability, kN	Flow, mm	Bulk Density, kN/m³	Air voids, %
4.5	8.95	2.16	22.59	6.78
5	10.66	2.63	22.63	5.47
5.5	11.84	3.23	22.77	3.74
6	10.66	4.03	22.56	3.17

Table -4: Marshall Properties of Bituminous Concrete Mix with Copper slag 10 percent as partial replacement of fine aggregate

Bitumen Content, %	Marshall Stability, kN	Flow, mm	Bulk Density, kN/m³	Air voids, %
4.5	9.45	2.1	22.82	6.49
5	12.11	2.6	22.84	5.24
5.5	13.75	3.2	22.98	3.43
6	12.53	3.9	22.81	2.95

Table -5: Marshall Properties of Bituminous Concrete Mix with Copper slag 30 percent as partial replacement of fine aggregate

Bitumen Content, %	Marshall Stability, kN	Flow, mm	Bulk Density, kN/m³	Air voids, %
4.5	14.99	1.90	23.12	6.10
5	15.75	2.43	23.15	4.82
5.5	16.70	3.05	23.24	3.25
6	15.53	3.63	23.06	2.85

Figure -1: Marshall specimen prepared

Figure -2: Temperature of Mixing of constituents

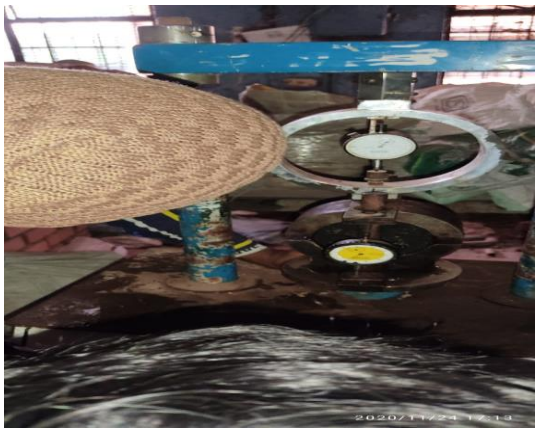

Figure -3: Testing of Marshall specimen

The Optimum bitumen content for the mix design is found by taking the average value of the following three bitumen content found from the graphs of the test results. Bitumen content correspond to maximum stability, 4% air void, and maximum bulk density.

Sieve Size, mm	% Passing (Specified)	% Passing (Mid Limit)	% Retained	Revised %retained	weight of aggregate required	BC without 10% CS as fine aggregate	10% CS	BC without 40% CS as fine aggregate	40% CS
19	100	100							
13.2	90-100	95	5	5	60	-	-	-	-
9.5	70-88	79	16	16	192	-	-	-	-
4.75	53-71	62	17	17	204	-	-	-	-
2.36	42-58	50	12	12	144	-	-	-	-
1.18	34-48	41	9	13	156	140.4	15.6	93.6	62.4
0.6	26-38	32	9	13	156	140.4	15.6	93.6	62.4
0.3	18-28	23	9	12	144	129.6	14.4	86.4	57.6
0.15	12.0-20.0	16	7	4	48	43.2	4.8	28.8	19.2
0.075	4.0-10.0	7	9	6	72	64.8	7.2	43.2	28.8

Table -6: Aggregate Gradation for Bituminous concrete (grade 2) mix and Bituminous concrete mix with different Dosage of copper slag as per MORT&H (V Revision) Specifications

Table -7: Marshall Properties of Bituminous Concrete Mix and Bituminous Concrete Mix Prepared Using Varying dosage of Copper slag as fine aggregate for optimum binder content (OBC)

SL No.	Marshall Properties	Bituminous Concrete with varying dosages of copper slag as a fine aggregate				
		BC	BC+CS10%	BC+CS20%	BC+CS30%	BC+CS40%
1	Optimum Bitumen Content, %	5.42	5.34	5.30	5.26	5.21
2	Marshall Stability, kN	11.64	13.15	15.46	16.61	16.38
3	Flow, mm	3.12	3.02	2.87	2.75	2.62
4	Air voids, %	3.92	4.06	4.17	4.11	3.98
5	Voids in Mineral Aggregate, %	16.29	16.27	16.22	16.17	16.12
6	Voids Filled with Bitumen, %	75.19	75.25	75.31	75.46	75.61

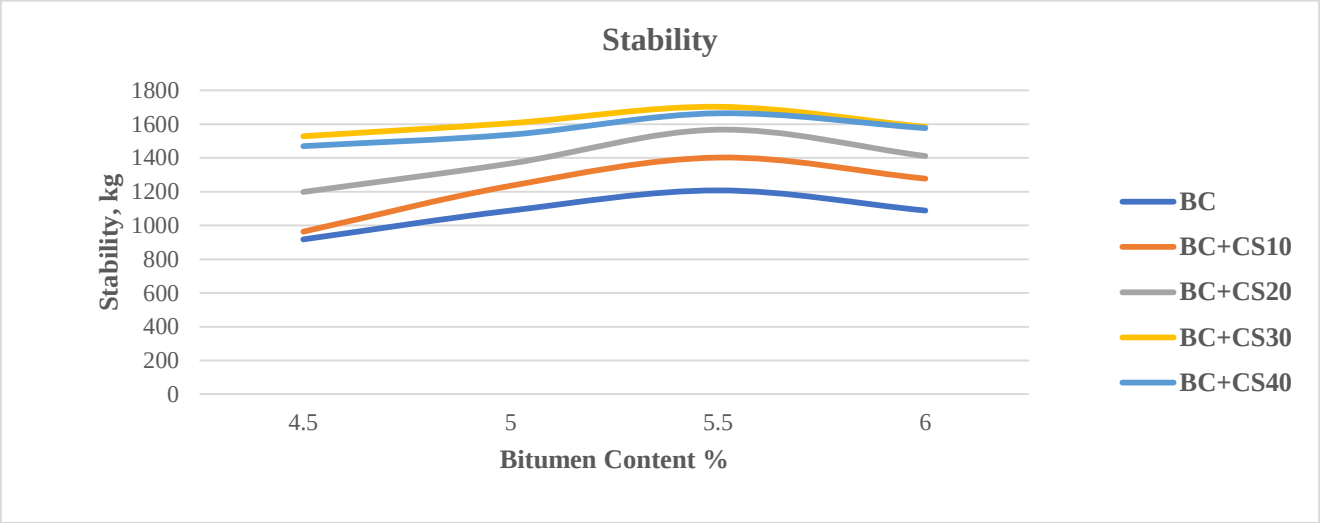

Chart -1: Stability, Comparison between Bituminous Concrete with varying dosages of copper slag as a fine aggregate

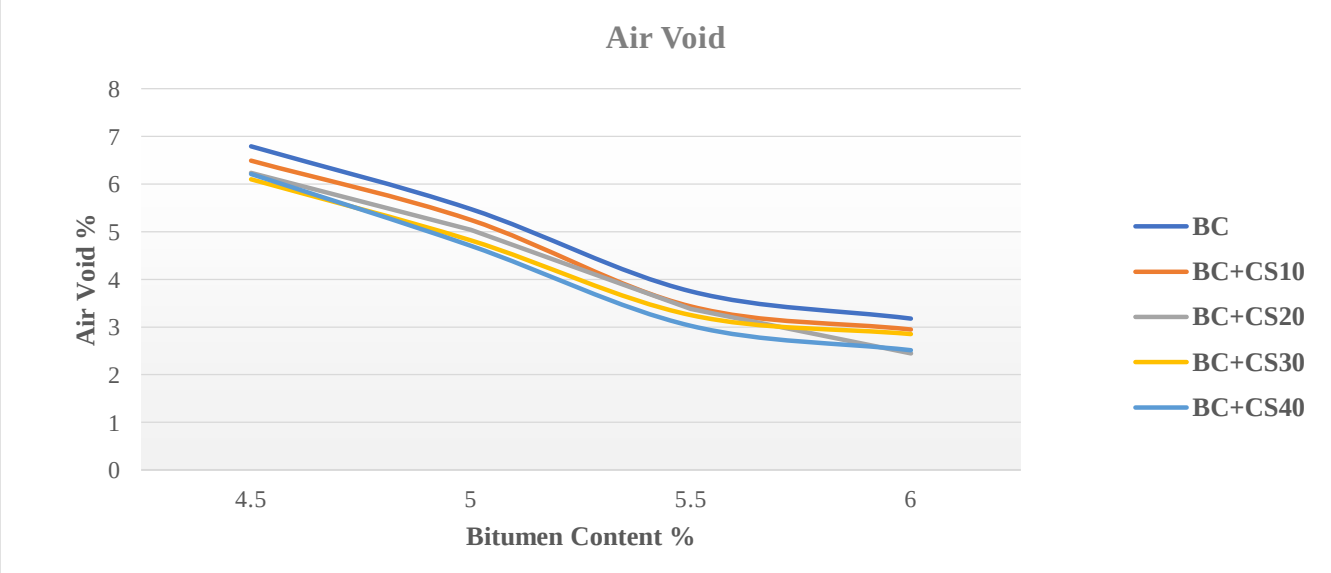

Chart -2: Percentage Air void, Comparison between Bituminous Concrete with varying dosages of copper slag as a fine aggregate

Table -8: Tensile Strength Ratio of Bituminous Concrete mix and mix prepared with partial replacement of fine aggregate using copper slag

Mix Type	Indirect Tensile Strength, N/mm²		Tensile strength ratio, %
	Unconditioned at 25°C	Conditioned at 60°C	
BC	0.83	0.69	84
BC + CS10	0.95	0.81	86
BC + CS20	1.06	0.93	88
BC + CS30	1.18	1.03	88
BC + CS40	1.13	1.01	89

8: DISCUSSION

The Optimum Bitumen Content (OBC) for Bituminous Concrete mix prepared using VG-30 as binder with stone dust as filler is 5.42%.

The Optimum Bitumen Content (OBC) for Bituminous Concrete mix with 10%, 20%, 30%, and 40% copper slag replacement to fine aggregate prepared using VG-30 as binder with stone dust as filler are 5.34%, 5.30%, 5.26% and 5.22% respectively.

The Marshall Stability for Bituminous concrete mix prepared at Optimum Bitumen Content using VG-30 is 1186kg.

The Marshall stability value for Bituminous Concrete mix at 10%, 20%, 30% and 40% partial replacement of fine aggregate with copper slag are 1340 kg, 1575kg, 1693kg and 1669kg respectively.

It is observed that, for the specimen prepared at optimum percentage replacement of fine aggregate with copper slag (30%) has 40.56% higher Marshall stability value when

compared to the specimen prepared without replacement. The Marshall stability value increases up to 30% replacement of fine aggregate with copper slag and decreases for 40% replacement of fine aggregate.

The Voids in Mineral aggregate for Bituminous concrete mix prepared at Optimum Bitumen Content is 16.29.

The Voids in Mineral aggregate for Bituminous Concrete mix at 10%, 20%, 30% and 40% partial replacement of fine aggregate with copper slag are 16.27%, 16.22%, 16.17% and 16.12% respectively.

The Voids in Mineral Aggregate for Bituminous Concrete mix decreases as replacement of fine aggregate with copper slag increases.

The Flow value for Bituminous concrete mix prepared at Optimum Bitumen Content is 3.12.

The Flow value for Bituminous Concrete mix at 10%, 20%, 30% and 40% partial replacement of fine aggregate with copper slag are 3.02mm, 2.87mm, 2.75mm and 2.62mm respectively.

It is observed that, for the specimen prepared at optimum percentage replacement of fine aggregate with copper slag (30%) has 2.75mm Flow value. The Flow value decreases as replacement of fine aggregate with copper slag increases.

The unconditioned Indirect Tensile Strength values of bituminous concrete mix with 0%, 10%, 20%, 30% and 40% partial replacement of fine aggregate with copper slag are 0.83 N/mm^2, 0.95 N/mm^2, 1.06 N/mm^2, 1.18 N/mm^2 and 1.13 N/mm^2 respectively. It is observed that the unconditioned ITS values of bituminous concrete mix with 30% copper slag shows an increase of 42.1% when compared to plain bituminous concrete mix. This variation in strength shows that the bituminous concrete mix with copper slag has better indirect tensile strength than plain bituminous concrete mix.

The Tensile Strength Ratio values of bituminous concrete mix with 0%, 10%, 20%, 30% and 40% partial replacement of fine aggregate with copper slag are 84%, 86%, 88%, 88% and 89% respectively.

9. CONCLUSONS

- There is increase in the value of Marshall stability, Bulk density and VFB in bituminous concrete mixes at optimum percentage of replacement of fine aggregate with copper slag.
- Flow value and air void have decreased with the addition of copper slag as partial replacement for fine aggregate in bituminous concrete mix.
- There is a marginal variation in the Optimum Bitumen Content value with the addition of copper slag as partial replacement of fine aggregate in bituminous concrete mix.
- The indirect tensile strength of bituminous concrete mix with copper slag has increased, indicating improvement in strength characteristics of bituminous concrete mix with copper slag.
- It can be concluded that 30% of copper slag can be replaced as partial replacement of fine aggregate for the preparation of Bituminous concrete mix.
- The TSR values of bituminous concrete mix increases with increase in copper slag content. This is clear indication that Moisture susceptibility decreases with increase in copper slag content.

REFERENCES

1. Mohd Amirul Farez Bin Alunad Azaldin “The Usage of Copper Slag in Bituminous Mix” Universiti Teknologi PETRONAS, 2008.
2. Harpreet Singh, Gurprit Singh Bath, “Use Of Copper Slag As Fine Aggregate” Tangori, Mohali, India, 2015.
3. Raposeirasa A C, Vargas-Ceróna A, Movilla-Quesada D, Castro-Fresno D, “Effect of copper slag addition on mechanical behaviour of asphalt mixes containing reclaimed asphalt pavement” Santander, Spain, 2016.
4. Binod Kumar, “Properties of pavement quality concrete and dry lean concrete with copper slag as fine aggregate” New Delhi, India, 2013.
5. Pundhir N K S, Kamaraj C, Nanda P K. “Use of copper slag as construction material in bituminous pavements” Central Road Research Institute, New Delhi, India, 2005.
6. Asad Iqbal, Moaaz Munir, Nadeem M , Adhban Omar, Masood Ashiq M. “Use Of Copper Slag as Construction Material In Bitumenious Pavements” Wah Cantt, Pakistan, 2018.
7. Chetan M K, Sowmya N, “Utilization of Copper Slag in Bituminous Concrete with a Stone Dust and Flyash as a Filler Material” Sullia, India, 2015.
8. Jayashree B, Santhanu S And Kalaiarasan B “Utilization Of Copper Slag In Bituminous Mix” Chennai, India, 2016.
9. Somnath Singh, Mishra A K,”Utilization Of Copper Slag And Stone Dust In Bituminous Pavement With Hydrated Lime As Filler Material” Gorakhpur, U.P. India, 2016.
10. Sankarlal K R, Ravi E, “An experimental study of alternate materials for dense bituminous macadam surface” Coimbatore, India, 2018.
11. Khanna S K and Justo C E G, Highway Engineering, Ninth edition, Nem Chan Bros, Roorkee, U.K., India, 2011. 12. Ministry of Road Transport and Highways(MORTH) 2013. Specifications for Road and Bridge Works, Fifth Revision, IRC, New Delhi, India.

BIOGRAPHIES

Dr. Suresh G Professor at department of Civil Engineering, UVCE, Bangalore University. He did his M.E. and PhD (Highway Engg.) at department of Civil Engineering, UVCE. He is having 25+ years of experience in teaching profession (Civil/highway/Pavement Engineering).

Sudarshan V
B.E. (Civil), M.Tech. (Highway Engg.), Dept. of Civil Engg., UVCE, Bangalore University, Bengaluru.