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Effect of Binary Blended Fillers on the Durability Performance of Recycled Cold-Mix Asphalt

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Abstract: Cold-mix asphalt is a greener alternative to pavement construction, processed at 10–40 °C, which is typically lower than other techniques like warm-mix asphalt and hot-mix asphalt. Huge amounts of construction and demolition waste, such as broken bricks, recycled concrete aggregates, reclaimed asphalt pavement, ceramic waste, etc., are generated every year due to the acceleration in infrastructure development. The production of such massive amounts causes landfilling issues, and their disposal is a serious issue nowadays. This study examines the effect of binary blended fillers on the performance of cold asphalt mixes using emulsified binders and 50% reclaimed asphalt pavement materials. Moreover, three types of binary blended fillers (BBFs), cement, fly ash, and Stabil Road, were used at different dosages. Overall, 500 samples were prepared for the mix design, and the optimum emulsion content was determined as 11% and 9% for the CM and 50R mixes, respectively, based on the Marshall stability peak value and volumetric properties such as voids in the mineral aggregates, total voids, and dry density. The moisture susceptibility of the recycled cold-mix asphalt (RCMA) mixture was evaluated using the tensile strength ratio. Cantabro abrasion loss was used to assess the cohesion resistance of the mixtures. The dynamic response of the mixes to the applied load was evaluated using the resilient modulus. The results of the present study reveal that using BBFs in the RCMA improved the inter-particle bonding and strength. Furthermore, BBF incorporation enhanced the performance of the recycled cold-mix asphalt.

Keywords: cold mix; reclaimed asphalt pavement; binary blended fillers; durability; resilient modulus

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1. Introduction

Asphalt is the most extensively used material in transportation infrastructure. The production of conventional hot-mix asphalt (HMA) for road construction or maintenance requires high temperatures, consumes significant natural resources, and contributes to huge greenhouse gas emissions. Eco-friendly and sustainable alternatives are needed due to the increased demand and limited availability of natural resources. One such alternative is cold-mix asphalt (CMA), which can be produced at a temperature typically between 10 and 40 °C. This results in a reduced production temperature and a lower consumption of natural resources [1–4]. Using reclaimed asphalt pavement could be another way to reduce the consumption of fresh, natural resources, and it has gained popularity among the paving industries in the last few decades.

Choudhary et al. used different industrial wastes (fly ash, stone, and marble dust) as fillers in the open-graded mix and studied the macroscopic and volumetric properties. A reduction in the voids and a thicker asphalt coating were observed with an increased asphalt content; due to the presence of a thicker asphalt film, the adhesion between the coated particles increased, improving the abrasion resistance and preventing aging [5]. The incorporation of fly ash (5% of total wt. of aggregate) as a filler in cold bituminous emulsion mixtures led to superior performance compared to cement filler for cold bituminous emulsion mixtures (CBEMs), and the results were comparable to an equivalent hot-mix asphalt [6–8]. Furthermore, the CMA mixes' curing processes (both curing time and temperature) significantly impact their performance. Research studies have affirmed that long-term curing (accelerated) (60 °C for 72 h) has provided better results (field simulation) as compared to the average temperature curing (20 °C for 90 days) [9–13]. As per the study conducted by Li et al., the mechanical strength increased as the curing time of cold-mix asphalt mixtures increased. This was due to the hydrophilic nature of the cement, and the prolonged moisture exposure accelerated the bonding and improved the mechanical performance and moisture susceptibility of the cold mix [14,15]. Liu et al. used lime, fly ash, and Portland cement as fillers in sub-base layers with reclaimed asphalt pavement (RAP) materials. It was reported that the overall strength and bearing capacity of the sub-base layers was enhanced [16]. Chegenizadeh et al. recommended a long curing period, which is required in cold-mix asphalt pavement design with RAP incorporation due to the mechanical characteristics of RAP materials with a bitumen emulsion [17]. Some researchers have classified the RAP materials as weak RAP and strong RAP. The RAP materials with a higher degree of agglomeration are termed weak RAP, and the materials having a very low degree of agglomeration are termed strong RAP [18–21].

This study aims to develop special cold asphalt mixture (CAM) types with 50% RAP aggregates by incorporating binary blended fillers (BBFs) such as cement, fly ash, and Stabil Road. The current research is a broader utilization of CAMs with RAP in constructing highway and pavement materials, which provides a sustainable and economical solution. Apart from this, the work is expected to contribute to a thorough understanding of the internal composition of the mixes.

2. Materials and Methodology

2.1. Materials

2.1.1. Aggregates and RAP

The virgin aggregates (VAs) for the present study were collected from a local quarry in Roorkee, India. The physical properties of the VA and RAP materials were determined per the requirement specified in the Indian Scenario [22–24]. The RAP material was collected from the National Highway (NH-344) in the Uttar Pradesh state of India, with a service life of 12 years. The chunks of RAP materials were separated by heating the material in a pre-heated thermostatically controlled oven at 100 °C for 48 h. The binder content of the separated RAP material was determined using ASTM D2172 [25] and was around 5.0% of the total dry aggregate weight.

Aggregate gradation was determined for Mix I (100% VA) and Mix II (50% VA + 50% RAP) as per the Ministry of Roads Transport and Highways (MORTH) [26], as shown in Figure 1.

2.1.2. Filler Additives

There are three different filler additives, ordinary Portland cement, fly ash, and a chemical additive, Stabil-road, which were used to enhance the durability of the considered cold mixes. The specific gravity and water absorption of the Portland cement were 3.15 gm/cc and 1.42%, respectively, determined according to IS:2386 Part-3 [27]. The second filler was fly ash collected from Kota Super Thermal Power Station, Rajasthan, India, an industrial waste with a specific gravity of 2.608 gm/cc and a water absorption of 1.42%. The third filler used in the research was Stabil-road, collected from M/S Viswa Samudra Pvt. Ltd., Hyderabad, India, a chemical stabilizer with a specific gravity of 2.570 gm/cc. The average diameter of Stabil Road was 2559 mm, measured using a zeta sizer ver. 7.11 [28]. The FE-SEM images of the filler additives are presented in Figure 2a–c. Additives were added with the bitumen before the emulsification to improve the uniform particle size, storage stability, curing, and adhesion to the aggregates. Additives were added to the considered and recycled cold mixes to achieve a higher strength and resistance to water damage.

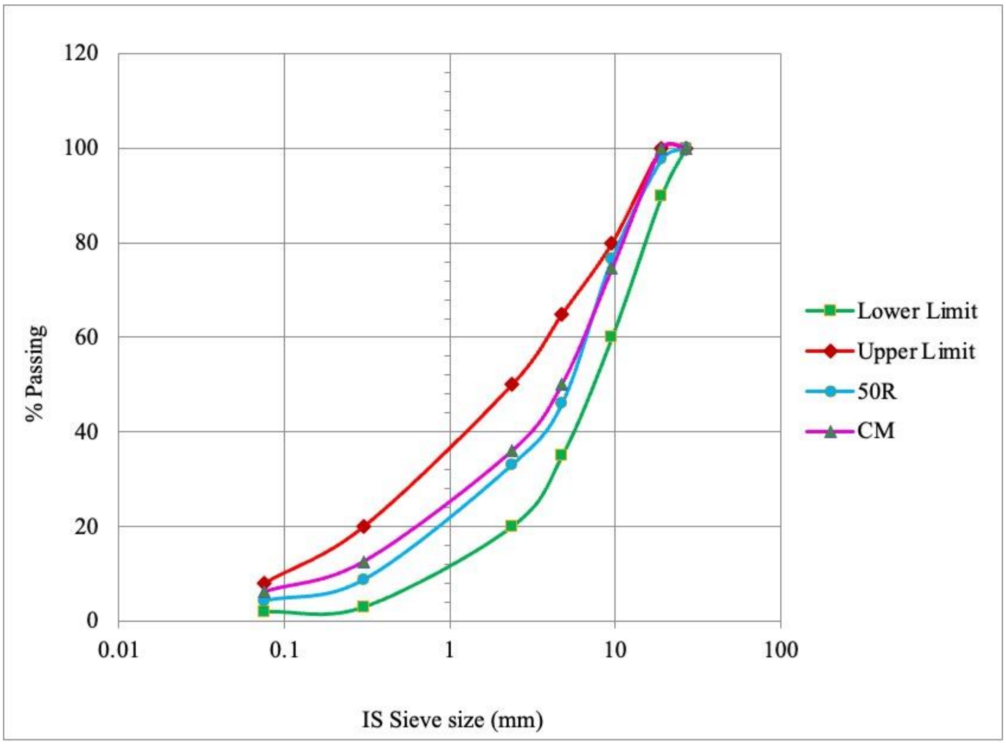
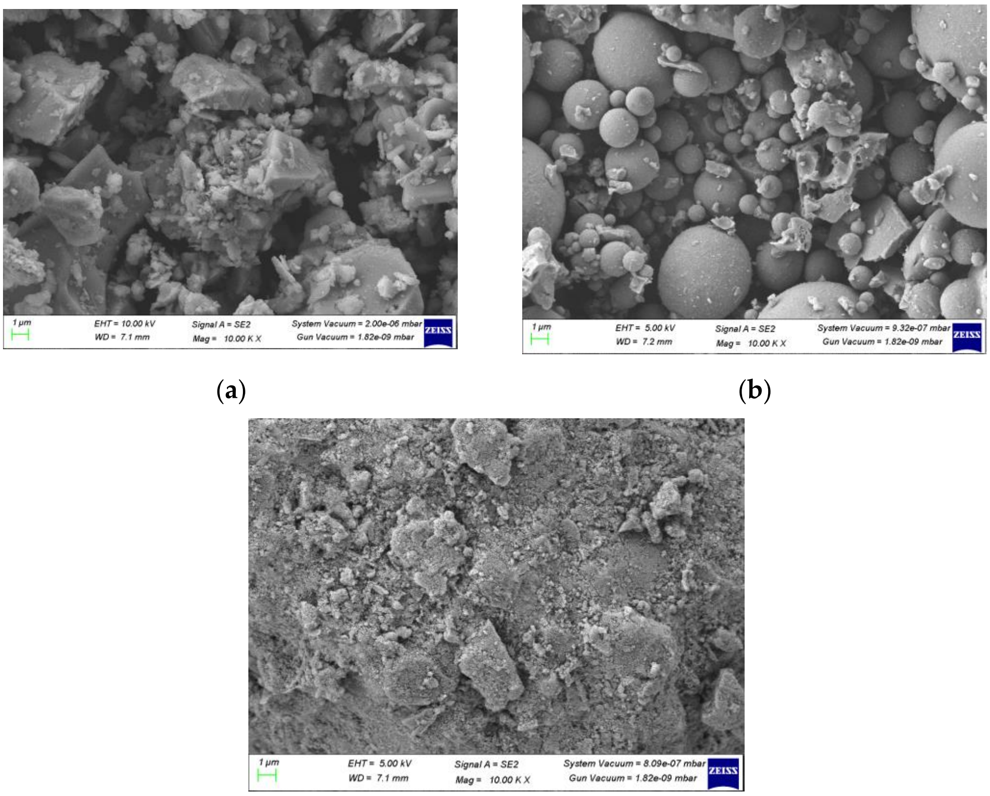


Figure 1. Aggregate gradation per MORTH specification for the control mix (CM) and 50R.



(**a**) (**b**)

(**c**)

Figure 2. FE-SEM images of filler additives: (**a**) cement, (**b**) fly ash, and (**c**) Stabil-road.

2.1.3. Binder (Emulsion)

In this study, the binder was a bitumen emulsion for the mixes. The emulsion is a two-phase system in which water, bitumen, and one more additive are added to enhance its formation and stabilization. Bitumen emulsion (E) is classified according to IRC SP100-2014 [29] as a cationic and anionic bitumen emulsion, depending upon the sand equivalent value. In this research, the sand equivalent was measured with a 67% value, corresponding to a cationic slow-setting Grade-2 (CSS2) bitumen emulsion utilized for designing the cold-mix asphalt.

2.2. Methodology

The cold-mix asphalt was designed per Asphalt Institute MS 14 [30]. All the considered mixes were prepared at room temperature. Figure 3 shows a pictorial representation of the CMA mix design process using the additives, RAP, and emulsion.

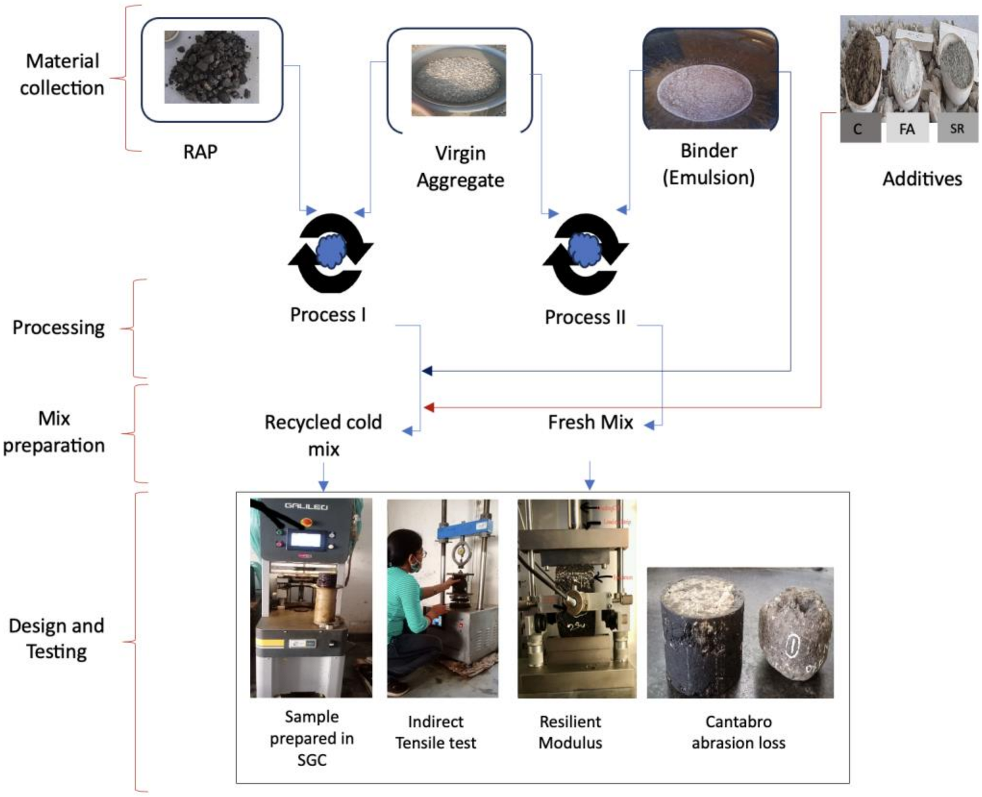


Figure 3. Pictorial representation of the CMA mix design process using RAP, emulsion, and additives.

ASTM D2216 was adopted to determine the moisture content of the cold-mix asphalt [31]. The emulsion used for the present study was CSS2, composed of 40% water and 60% bitumen. The percentage by weight of the emulsion content (P) and initial emulsion content (IEC) of the CMA mix was determined using Equations (1) and (2), respectively, as follows:

$$\mathrm{P} = (0.05\ \mathrm{a} + 0.10\ \mathrm{b} + 0.50\ \mathrm{c}) * 0.70 \tag{1}$$

where:

P = % by weight of the emulsion content based on the dry aggregate weight;
a = % of the retained aggregate weight on the 2.36 mm sieve;
b = % of the aggregate passing 2.36 mm and retained on 0.075 mm;
c = % of the aggregate passing 0.075 mm.

$$\mathrm{IEC} = \mathrm{P}/(\mathrm{X\ in\ \%}) \tag{2}$$

where:

X = the bitumen present in the emulsion (60%).

The quantity of the new bituminous binder was calculated using Equation (3) as per the Asphalt Institute (2007) manual series (MS-20), as follows:

$$\text{Pnb} = \text{P} - \frac{(100 - \text{r}) * \text{Psb}}{100} \tag{3}$$

where:

Pnb = the new bituminous binder to be added as per Asphalt Institute (2007) MS-20.
r = % of virgin aggregate to be added to the recycled mix.
Psb = the average bitumen content in the RAP.

After calculating the initial emulsion content, the optimum asphalt content (OAC) was obtained by varying the IEC by 0.6% and based on the maximum dry density, volumetric analysis, and Marshall stability values. The emulsion demand, initial emulsion content, the quantity of new bituminous binder, the optimum asphalt content, asphalt residue for control, and 50% RAP cold mix are depicted in Table 1.

Table 1. Optimum emulsion content (asphalt residue) for the control mix and 50R.

Mix	Emulsion Content (%), P	New Binder (%), P_{nb}	Initial Emulsion Content (%), IEC *	Optimum Emulsion Content (%)	Asphalt Residue (%)
Control Mix	6.5	-	10.833	11	6.6
50R	5.9	3.4	9.833	9	5.4

* IEC (Initial emulsion content) = P/(X in %), where X = 60%.

As per Asphalt Institute MS14 [30], the minimum coating requirements for the surface and base course are 75% and 50%, respectively. A 95% coating was achieved without BBFs for the control mix, and the emulsion content was around 5.90%. For the present study, 20 cold mixes were designed (Figure 4): 1 control mix with virgin aggregates without binary blended fillers and 1 50% RAP (50R)-incorporated mix without BBFs. The remaining 18 combinations of mixes were as follows: 9 mixes of CM with cement, fly ash, and Stabil Road at 1%, 2%, and 3% as binary blended fillers and 9 mixes of 50% RAP with cement, fly ash, and Stabil Road at 1%, 2%, and 3% as BBFs, and which were named accordingly. For instance, CM mixes with 1%, 2%, and 3% cement as BBFs were termed CM1C, CM2C, and CM3C, respectively. CM mixes with 1%, 2%, and 3% fly ash as BBFs were termed CM1FA, CM2FA, and CM3FA, respectively. CM mixes with 1%, 2%, and 3% Stabil Road as BBFs were termed CM1SR, CM2SR, and CM3SR, respectively. Likewise, the 50R mixes with 1%, 2%, and 3% cement were termed as 50R1C, 50R2C, and 50R3C, respectively. The 50R mixes with 1%, 2%, and 3% fly ash as BBFs were termed 50R1FA, 50R2FA, and 50R3FA, respectively. The 50R mixes with 1%, 2%, and 3% Stabil Road as BBFs were termed 50R1SR, 50R2SR, and 50R3SR, respectively. All the considered mixes were prepared in a Superpave gyratory compactor IIT Roorkee, Uttarakhand, India, with 90–110 gyrations at room temperature, per ASTM D6925-24 [32].

The Marshall stability and flow values for all the considered mixes were carried out on 100 mm diameter and 63 mm height samples following the procedure of ASTM D6925. It should be noted that the data shown here are the mean of five measurements. The samples were conditioned for 24 h at 25 °C. The force was applied at the rate of 55 mm/min, the peak load was noted and is termed the Marshall stability, and the flow corresponding to the peak load was termed the flow value. For evaluating the moisture resistance of the cold mixes, the indirect tensile strength test was carried out on the Marshall samples following the ASTM D6927 procedure [33]. Initially, samples were produced per ASTM D6931 [34] and divided into two subsets. The first subset was water-conditioned at 25 °C for 2 h and was designated as unconditioned. The second subset was conditioned at 40 °C for 23 h and at 25 °C for 1 h and was designated as conditioned. The ratio of a conditioned subset to an unconditioned subset was termed the tensile strength ratio. The resilient modulus of the mixes was carried out at 0.1 Hz, 0.33 Hz, and 10 Hz frequency rates at 25 °C on 100 mm diameter and 63 mm height samples following the procedure of ASTM D7369 [35]. The samples were conditioned initially at 25 °C for 24 h in an environmental chamber. A Cantabro abrasion test was carried out to evaluate the bonding and cohesion in the aggregates and binders, and ASTM D7064 [36] was followed for the Cantabro abrasion. Marshall samples were initially conditioned at 25 °C for 30 min. Postconditioning, the samples were placed in the Los Angeles Abrasion machine without any abrasive charge. Afterward, the machine rotated for 300 revolutions at 33 revolutions/minute.

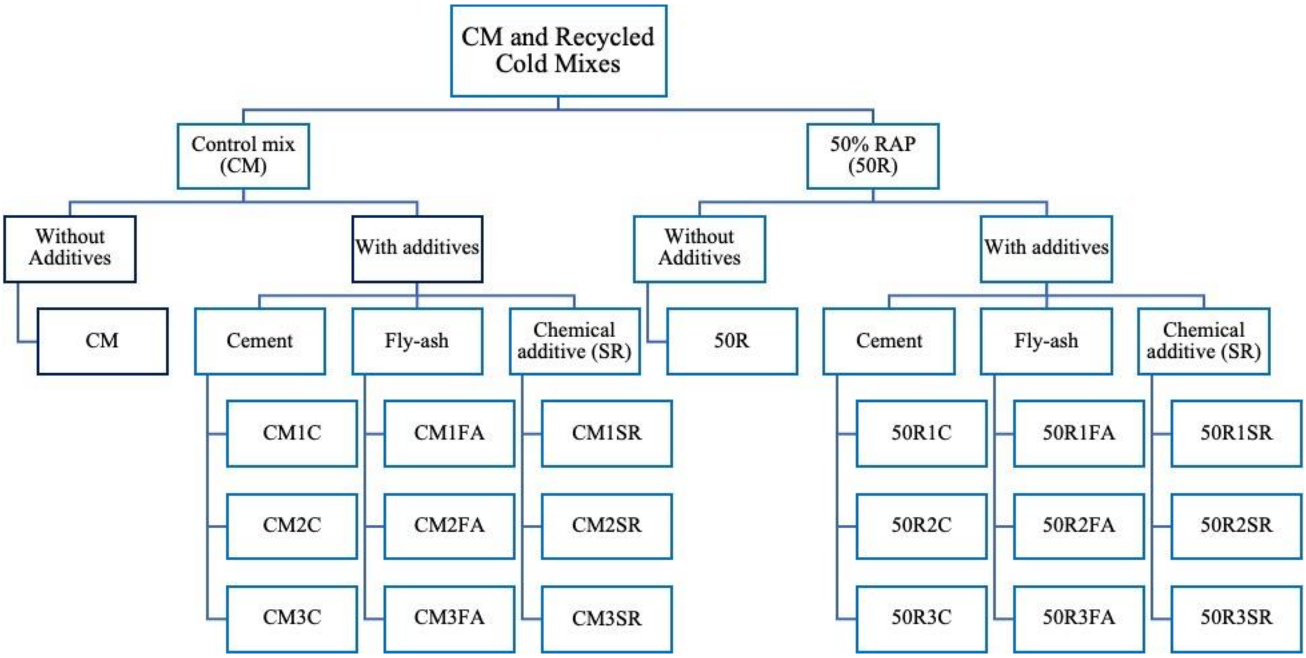


Figure 4. Distribution of mixes.

Asphalt Institute MS-14 was used to determine the volumetric and other conventional properties, such as the voids in mineral aggregates (VMAs), total voids, dry density, and Marshall stability. The optimum asphalt content for the control mix was 6.6%, and the OAC for the 50% RAP was obtained as 5.4% based on the volumetric parameters and Marshall stability values.

3. Result and Discussion

3.1. Marshall Stability

Figure 5 depicts the impact of incorporating the RAP and filler (cement, FA, and SR) on the Marshall stability of the cold mix. All the considered mixes qualified for the minimum recommended Marshall stability of 3.5 kN [29]. RAP incorporation significantly improved the Marshall stability of the cold mix. This can be attributed to the presence of the RAP binder, which enhances the residual binder properties, thereby improving the Marshall stability of the cold mixture. The MS of the CM mix was around 13.6 kN, and, as expected, the RAP incorporation was found to enhance the MS to 21.13 kN. The results show that the incorporation of cement, fly ash, and Stabil road as binary blended fillers improves the Marshall stability of all the considered cold mixes. For instance, cement incorporation significantly improved the Marshall stability of the control mix irrespective of the dosage. However, there was less improvement in the fly ash and Stabil road incorporation than in the cement filler. This might be due to the high pozzolanic reactivity of the cement in the presence of moisture, which improves the Marshall stability. For instance, for the CM mix, 3% cement filler, 2% FA, and 2% SR were the best-performing mixes, with 16.61 kN, 16.14 kN, and 15.75 kN MS, which is around 22%, 19%, and 16% higher as compared to the control mix. Cement was better than the FA and SR fillers for the control mix. Incorporating 1% cement filler and 2% FA with 50% RAP mixtures have a higher performance than other mixtures with 24.3 kN and 21.3 kN, respectively, which is around 79% and 57% higher than the control mix without any additives. Interestingly, the best performance for the 50% RAP cold mixtures was 1% cement; this indicates that RAP incorporation could reduce the cement content and provide better Marshall stability. However, the optimum dosage of FA was the same for the 50% RAP as that of the control mixture.

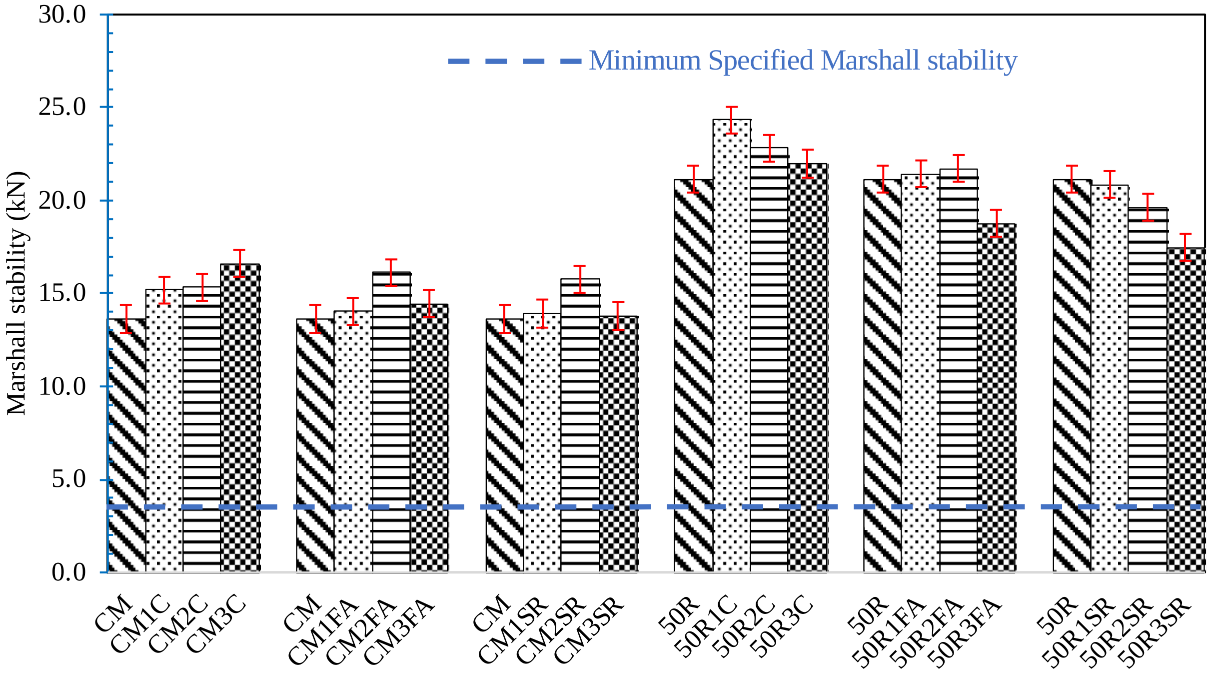


Figure 5. Marshall stability of the CMA mixes with and without RAP.

3.2. Marshall Quotient

The Marshall stability and flow value ratio is termed the Marshall Quotient (MQ); it measures the material resistance against service rutting. As expected, RAP incorporation significantly increases the MQ of the cold mixes, as presented in Figure 6. Interestingly, it was observed that the incorporation of binary blended fillers also improves the MQ of the cold mixes. For instance, the MQ of the control cold mix improved to 5 kN/mm with 50% RAP incorporation, which was 2.3 kN/mm initially without the RAP. The improvement in the MQ might be attributed to the aged binder engulfing the RAP aggregates, increasing the MQ of the mixes. It was observed that BBF incorporation increases the MQ of the cold mixes; however, the improvement in MQ was different for all the three considered binary blended fillers. The maximum MQ was observed for cement-incorporated cold mixtures, followed by fly ash and Stabil Road; this could be due to the highest reactivity of the cement in the presence of moisture.

Furthermore, the increase in the MQ with the BBF incorporation was higher for RAP-incorporated cold mixes than the conventional cold mix. The maximum MQ for the filler was found at 3% cement, 2% fly ash, and 2% SR. Conclusively, a BBF-incorporated cold mix would undoubtedly have higher shear stress and deformation resistance than those without RAP.

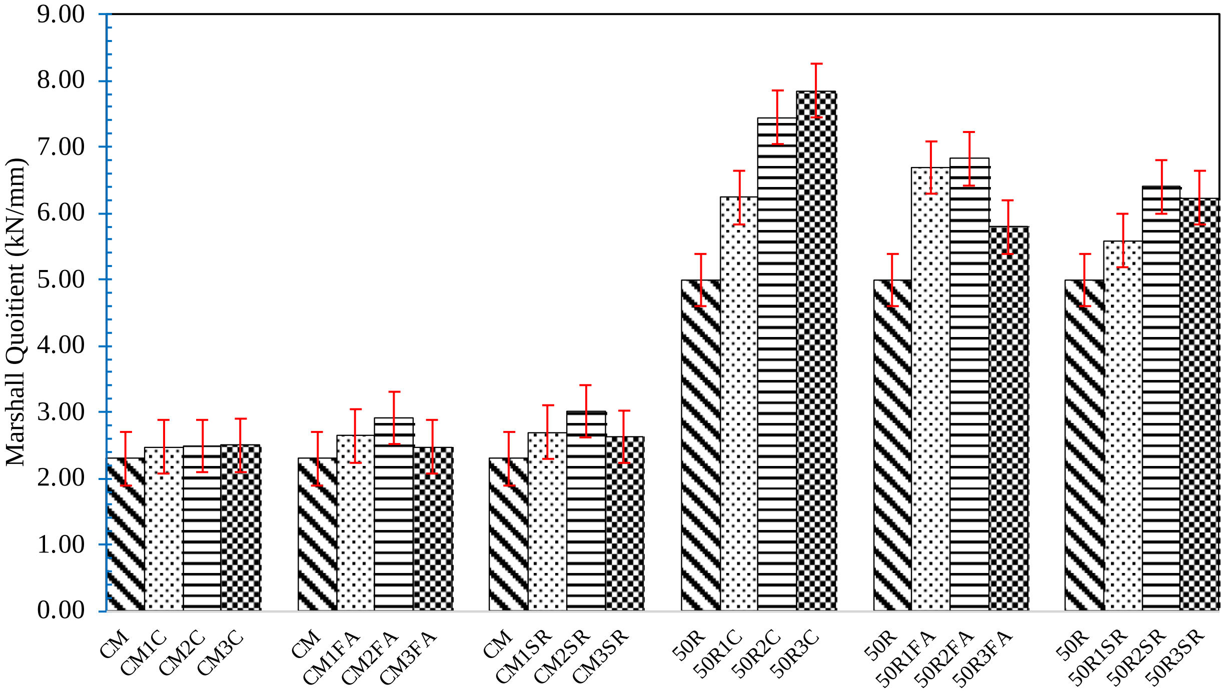
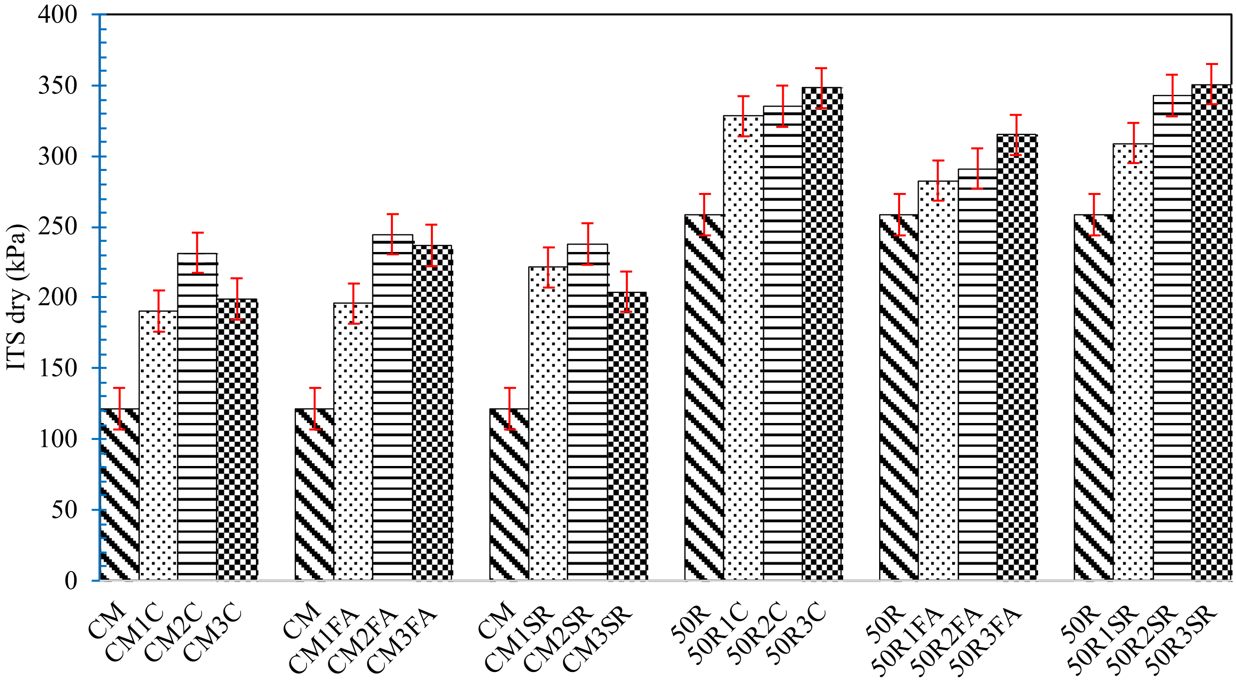


Figure 6. Marshall Quotient of the CMA mixes with and without RAP.

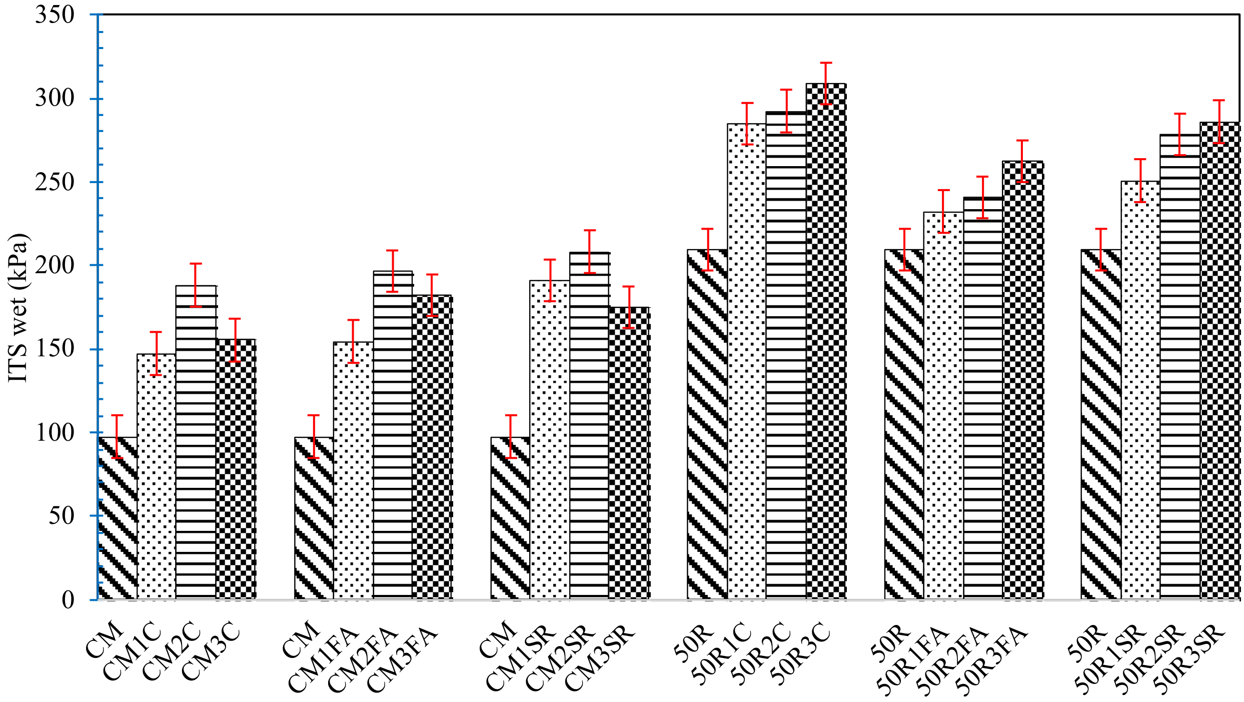
3.3. Indirect Tensile Strength

The indirect tensile strength (ITS) is an important parameter depicting mixtures' tensile strength and moisture resistance. It was found that RAP incorporation improves the ITS_{dry} of the cold mixes. This could be attributed to the fact that the emulsion interacts with the RAP binder and enhances the bonding of the matrix, thereby improving the ITS of the cold mixes. Furthermore, incorporating BBF in the CMA mix increases the ITS_{dry} values significantly, irrespective of the aggregates, i.e., natural and RAP aggregates (Figure 7a). This might be due to the hygroscopic structure and reactive nature of the BBF, which absorbs the excess water to form the secondary binder. The secondary binder forms a firm cement–bitumen paste, which binds the cold mix's internal structure. For example, the ITS_{dry} value of the 50 RAP mix without the BBF was around 258.72 kPa, and after the incorporation of 3% cement, the ITS_{dry} increased to 348.34 kPa. Similarly, with 3% FA, the ITS_{dry} value was around 315.184 kPa, and with the 3% SR, the ITS_{dry} value was around 354.03 kPa, which is about 35, 22, and 37% higher, respectively. The ITS_{dry} value of the control mix was 121.51 kPa, which rose to 231.487 kPa, 244.80 kPa, and 237.89 kPa with the incorporation of 2% C, 2% FA, and 2% SR, which is 91%, 101%, and 96% higher than that of CM, respectively.

For the present study, RAP incorporation does not significantly impact the ITS_{wet} of the cold mixtures. Furthermore, significant improvement in the ITS_{wet} was observed with BBF incorporation (cement, FA, and SR) for natural mixes (shown in Figure 7b). However, a better value of the ITS_{wet} was obtained with cement incorporation when compared to FA and SR incorporation. This phenomenon could be attributed to the highest reactivity of the cement in the presence of moisture. The indirect tensile ratio (ITR) is the indicator of moisture resistance of asphalt mixes. The tensile strength ratio is the ratio of the ITS_{wet} to ITS_{dry}. As per the MORTH specification, the minimum specified value of a moisture-resistant asphalt mixes for paving applications is 80%. For the present study, approximately all of the considered mixes achieved the minimum specified value of 80% ITR (Figure 7c). No significant changes in the moisture resistance were observed for natural mixtures incorporating cement and fly ash; however, SR incorporation significantly improved the ITR for the cold mixes. On the other hand, the opposite trend was observed for RAP-incorporated mixes. For instance, SR incorporation in RAP mixes does not significantly alter the ITR; however, cement and FA incorporation significantly improved the ITR of the RAP cold mix.

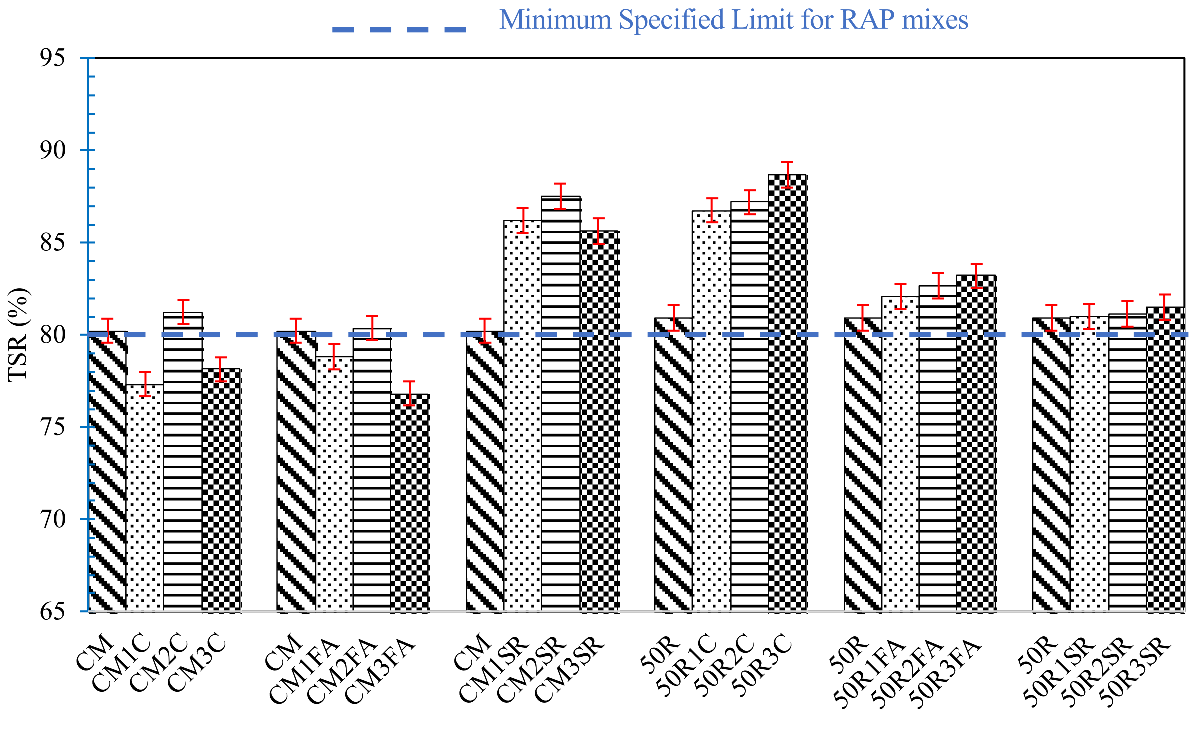


(**a**)



(**b**)

Figure 7. *Cont.*



(**c**)

Figure 7. Tensile strength results for CMA mixes with and without RAP aggregates: (**a**) dry ITS; (**b**) wet ITS; (**c**) TSR.

3.4. Resilient Modulus

The resilient modulus (M_r) is the elastic response of the material to the applied dynamic loading. The M_r values are shown in Figure 8 for all the cold mixes considered for the current study. Like hot-mix asphalt mixes, RAP incorporation increases the resilient modulus of the cold mixtures [37]. This could be due to the diffusion of aged asphalt and soft emulsion, increasing the stiffness of the resulting binder matrix. This diffusion could lead to a higher resilient modulus of RAP cold mixtures. It was also observed that BBF incorporation increases the resilient modulus of the considered cold mixes. With the incorporation of BBF, the micro-sized BBF particles became intermixed with the binder, forming a strong binder filler paste, which in turn enhanced the strength of the binder.

Furthermore, it was noted that cement incorporation significantly increased the resilient modulus value of the considered cold mixes as compared to FA and SR, irrespective of the mix type. This could be attributed to the formation of a strong cement–bitumen paste, which binds the internal structure of cold mixes, resulting in a higher M_r for cold mixes. The binary blended filler incorporation significantly improved the resilient modulus of the control mix irrespective of the dosage. However, there was less improvement in the fly ash and Stabil road incorporation than in the cement filler mixtures. This is due to the presence of highly active material in the cement filler, which improves the resilient modulus in the CM mixtures and 50R mixtures. For instance, for the CM mix, 3% cement filler, 3% FA, and 3% SR were the best-performing mixes, with 5885 MPa, 4125 MPa, and 3297 MPa for the resilient modulus, which is around 123%, 56%, and 25% higher as compared to the control mix. Cement was a better filler than the FA and SR fillers for the control mix. The optimum dose for BBF incorporation to the CM and 50R mixtures was 3% per resilient modulus, implying that the 3% filler incorporative mixes are stiffer than the others.

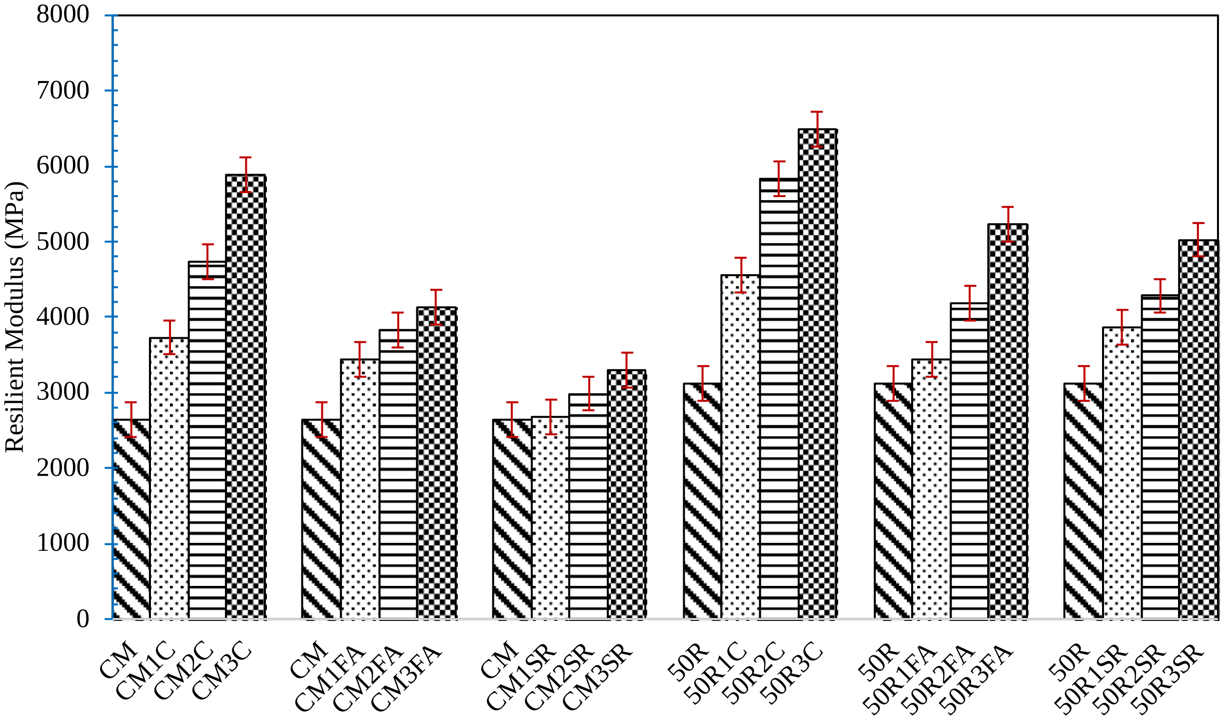


Figure 8. Resilient modulus of the CM and 50R mixes at a 0.5 Hz frequency.

3.5. Cantabro Abrasion Loss

Bonding and cohesion in the aggregates and binders are evaluated using the Cantabro abrasion test. A lower value of Cantabro abrasion was always desired for a raveling-resistant pavement. As expected, the RAP incorporation increased the Cantabro abrasion loss, which is also supported by the other authors [5,38]. RAP incorporation increases the stiffness of the bonding matrix, which results in low resistance toward the abrasion and impact induced by the abrasion test. Furthermore, it is interesting to note that the higher proportions of BBFs were better at resisting the abrasion. This could lead to a conclusion that BBF inclusions could be a good alternative to improve the reveling resistance of the cold mixes (present in Figure 9). The optimum dosage as per the minimum Cantabro abrasion loss for cement, FA, and SR is 3%, as this dosage was able to reduce the Cantabro abrasion loss significantly. The higher dosage of BBFs strengthened the interconnect matrix and improved the bonding of aggregates, thereby improving the impact and raveling resistance in the mix. It was observed that fly ash improved the cohesion and bonding significantly, followed by cement and fly ash.

3.6. Statistical Analysis

The ANOVA (analysis of variance) analysis was performed to determine the statistical significance of the properties of the asphalt mixtures based on laboratory performance and to analyze the data for the different doses of filler additives of the CM and 50R mixes, as presented in Table 2. The statistical confidence was 95%, and the null hypothesis was rejected if the p-value was less than zero. Also, the results were significant when the F critical was less than the F statistical. In this research, the dependent variable is the Marshall stability, and the independent variables were the doses of the filler content. The results shown in Table 2 could significantly influence the mixture's properties.

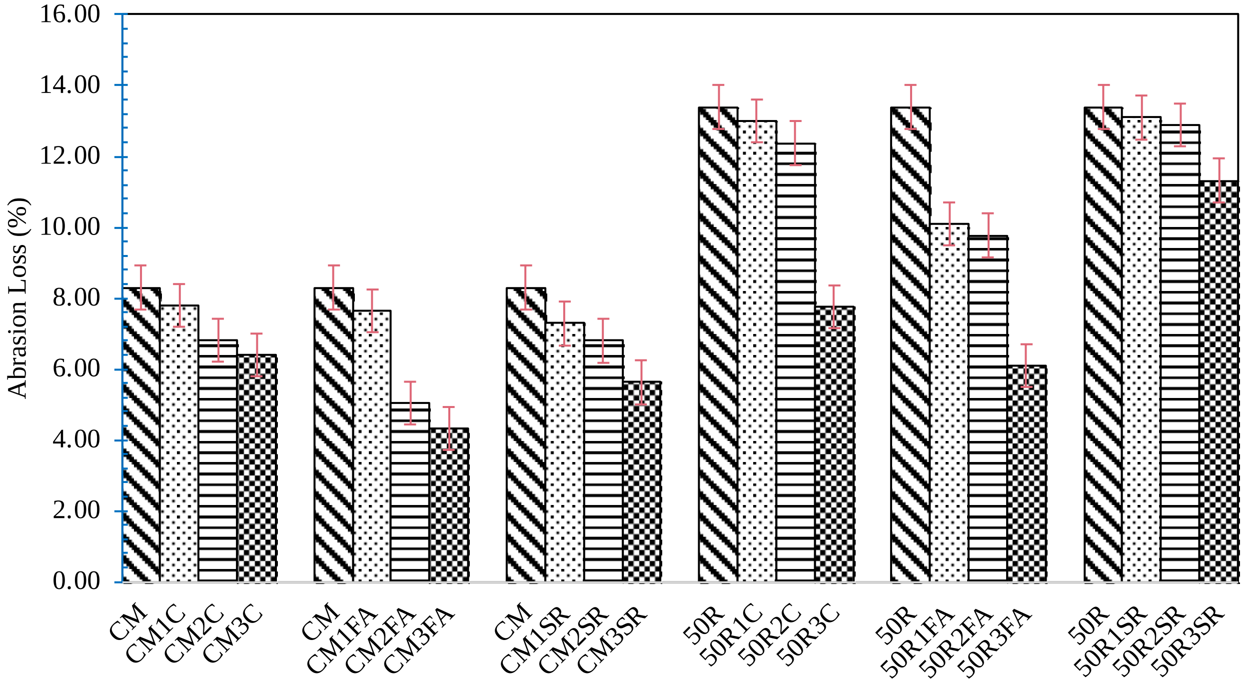


Figure 9. Abrasion loss of the CM and 50R mixes.

Table 2. ANOVA analysis for the CM and 50R mixtures.

Mix	Sum of Squares (SSs)	Mean Square (MS)	F	p-Value	F Critical
CM	30.55503	3.305	3.0066	0.01932	2.3928
50R	25,655.85	2850.64986	29.67199	1.17×10^{-9}	2.392814

4. Conclusions

The present study evaluated the effect of three binary blended fillers (cement, fly ash, and Stabil Road) on the properties of cold asphalt mixes with 50% RAP. The following conclusions can be drawn from the study based on results obtained:

- RAP incorporation in cold-mix asphalt will reduce the initial binder content and provide better a Marshall strength, indirect tensile strength, and resilient modulus. However, the abrasion and raveling resistance deteriorated.
- Incorporating different binary blended fillers increases Marshall's stability; however, the optimum dosage of BBFs is based on the type of material/aggregate used. The binary blended fillers have some active reactions in the presence of moisture, eventually improving the binder matrix and Marshall's stability. The findings confirm that the BBF incorporation imparts higher shear stress and deformation resistance.
- Improvement in indirect tensile strength was observed with the BBF incorporation, and this might be due to the hygroscopic nature of the BBFs, which absorb moisture and initiate the hydration process, which, in turn, forms a secondary binder. This secondary binder forms a firm cement–bitumen paste, which binds the cold mix's internal structure.
- RAP incorporation does not significantly alter the moisture resistance of the cold mixes. However, significant improvement in the ITR was observed post-BBF incorporation. SR was the best-performing BBF for the natural mixes in terms of the ITR. However, cement was the best-performing BBF for the RAP mixes compared to FA and SR.
- RAP incorporation does increase the M_r value of the cold mix; however, this improvement was not more significant. Furthermore, due to the formation of a strong binder–filler matrix, the M_r was higher than in the control mix.

Author Contributions: P.M.: Conceptualization, Methodology, Experimental Work, Data Analysis, and Original Draft Manuscript. G.R.R.N.: Conceptualization, Methodology, and Supervision. P.K.: Conceptualization, Methodology, and Supervision. K.M.: Analysis and Draft Manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

Nomenclature

CMA	Cold-Mix Asphalt	CM3C	CM with 3% C
50R	50% RAP	CM3FA	CM with 3% FA
50R1C	50% RAP with 1% C	CM3SR	CM with 3% SR
50R1FA	50% RAP with 1% FA	FA	Fly Ash
50R1SR	50% RAP with 1% SR	HMA	Hot-Mix Asphalt
50R2C	50% RAP with 2% C	IEC	Initial Emulsion Content
50R2FA	50% RAP with 2% FA	IRC	Indian Roads Congress
	50% RAP with 2% SR	ITR	Indirect Tensile Ratio
50R3C	50% RAP with 3% C	ITS	Indirect Tensile Strength
50R3FA	50% RAP with 3% FA	MORTH	Ministry of Road Transport and Highways
50R3SR	50% RAP with 3% SR	MQ	Marshall Quotient
ANOVA	Analysis of Variance	Mr	Resilient Modulus
BBFs	Binary Blended Fillers	NH	National Highway
C	Cement	OAC	Optimum Asphalt Content
		P	Emulsion Content
CBEM	Cold Bituminous Emulsion Mixtures	RAP	Reclaimed Asphalt Pavement
CM	Control Mix	RCA	Recycled Concrete Aggregates
CM1C	CM with 1% C	RCMA	Recycled Cold-Mix Asphalt
CM1FA	CM with 1% FA	SR	Stabil-road
CM1SR	CM with 1% SR	VA	Virgin Aggregate
CM2C	CM with 2% C	VMA	Voids in Mineral Aggregate
CM2FA	CM with 2%FA		
CM2SR	CM with 2% SR		

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