Effects of high density polyethylene and crumb rubber powder on properties of asphalt mix

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ABSTRACT: In India flexible pavements with bituminous surfaces are widely used. Due to increased traffic intensity of roads, overloading of commercial vehicles and temperature variation of pavements due to climatic changes leads to formation of various distresses like rutting, shoving, bleeding, cracking and patholing of bituminous surfacing. Also in a developing countries like India ,road way construction is taking place at a very high which require large demand of construction material that too ecofriendly and economical. The seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its visco elastic nature .Several types of flexible failure occurs due to this behavior of asphalt binder among which rutting and fatigue cracks are common. Waste plastic materials including high density polyethylene are disposed through landfills and this possesses an environmental pollution due to difficulty in degradation of polymer materials by environmental factors. In India number of vehicles are growing rapidly the waste of tyre rubber becomes a major environmental concern .Crumb rubber is recycled rubber produced from automotive and truck. The use of crumb rubber as an additive in bituminous mixture is considered as a sustainable construction method. Polyethylene is a very popular plastic used widely all over the world. When used for modifying asphalt, polyethylene can improve the rigidity of asphalt pavements, thus their deformation under heavy traffic loads at high temperatures. Rubber has also been used as an asphalt modifier in road pavement. The effects of high density polyethylene and crumb rubber powder on the properties of hot mix asphalt were investigated. In this investigation high density polyethylene and crumb rubber powder are using as additions to bitumen in asphalt mix. The physical properties, penetration, marshal stability test and flow and ductility of un modified and modified asphalt were measured for various high density polyethylene, crumb rubber powder contents. This investigation suggests that lower temperature susceptibility and greater resistance to moisture damage and permanent deformation after addition of HDPE and CRP.

Keywords: Hot mix asphalt, High density polyethylene, Crumb rubber powder

1. INTRODUCTION:

Repeated application of traffic loads causes structural damage to asphalt pavements in the form of fatigue cracking of asphalt bound layer and rutting along wheel tracks. While fatigue failure is the result of flexural cracking of asphalt bound layer, rutting is the manifestation of permanent deformation in different layers of the pavement. The asphalt layer itself may display a significant amount of permanent deformation in hot climatic conditions. Asphalt pavements can also be damaged by climatic factors such as temperature and moisture. Development of modified asphalt materials to improve the overall performance of pavements has been the focus of several research efforts made over the past few decades.

Asphalt modifiers can improve the properties of asphalt and asphalt mixes. Asphalt containing such modifiers is called modified asphalt. Rubber-modified asphalt and polymer-modified asphalt are usually used under conditions involving extreme climatic variations.

In recent years, polymeric materials have usually been used as asphalt modifiers in road construction [1,]; this has been one of the main reasons for decrease in the number of asphalt pavement- related disasters in recent years [2]. The characteristics of blends of asphalt and polymer depend on the type and concentration of the polymer used. Usually, the polymer is used in concentrations of approximately 4–6% of the asphalt weight .Polyethylene is a very popular plastic used widely all over the world. When used for modifying asphalt, polyethylene can improve the rigidity of asphalt pavements, thus decreasing their deformation under heavy traffic loads at high temperatures [3].Rubber has also been used as an asphalt modifier in road pavements since the middle of the last century. McDonald used crumb rubber (CR)-modified asphalt to improve the performance of asphalt mixtures [4-5]. In previous years, CR has been employed widely as an additive for the asphalt mixtures used for road pavements [6]. The moisture damage of hot mix asphalt (HMA) mixtures is one of the commonest forms of damage that occur in asphalt pavements. Moisture damage is defined as the loss of the mechanical properties of materials owing to the presence of water in the HMA mixture.Rutting is one of the major issues related to the HMA mixtures used for road pavements and is usually manifested under heavy traffic loads.

S. K. Palit, K. Sudhakar Reddy and B. B. Pandey reported that Laboratory Evaluation of Crumb Rubber Modified Asphalt Mixes [11]. Al-Hadidy and Tan [12] reported that adding low-density polyethylene to asphalt improves its resistance to deformation at high and moderate temperatures. In addition, its shear resistance is also improved Moatasim et al. [7] found that adding high-density polyethylene (HDPE) to asphalt improves its resistance to deformation under high and moderate temperatures as well as its shear resistance. Further, it also improves the Marshall quotient (MQ) and indirect tensile strength (ITS) of asphalt mixtures. Sinan and Emine [8] investigated the suitability of different types of plastic waste containing HDPE as modifiers for asphalt concrete. Their results indicated that HDPE-modified asphalt concrete exhibits increased Marshall Strength (stability) and a higher MQ value. Al-Hadidy and Tan studied the effects of CR as a modifier on the properties of stone matrix asphalt (SMA) mixtures. They found that the addition of CR to SMA mixtures results in a significant increase in the Marshall stability as well as the MQ and ITS values. Alireza et al. [9] investigated the effects of using reclaimed asphalt pavement (RAP) on the rutting performance of rubberized asphalt mixtures.

The main objective of this study was to investigate the effect of HDPE and CRP as modifiers on the properties of HMA (Marshall Design parameters, moisture sensitivity, and rutting resistance). The physical properties of HDPE and CRP-modified asphalt, such as the softening point, penetration, and ductility, were also evaluated.

2. MATERIALS AND METHODS:

2.1 ASPHALT:

The asphalt used in this study was of 60/70 penetration grade. Several physical tests such as the penetration test, softening point test, ductility test, and specific gravity test were performed to characterize the properties of the asphalt.

Table 1 Properties of asphalt

Property	Test method	Value
Penetration at 25̊C	IS : 1203-1978	66
Ductility 25̊C	IS: 1208-1978	73
Softening point(̊C)	IS: 1205-1978	50
Specific gravity	IS: 1202-1978	1.024

2.2 COARSE AGGREGATES

Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm IS sieve size. Its specific gravity was found as **2.75**. Standard tests were conducted to determine their physical properties as summarized in table t2

Table 2 Properties of aggregates

Property	Test Method	Test Result
Aggregate Impact Value (%)	IS: 2386 (P IV)	14.3
Aggregate Crushing Value (%)	IS: 2386 (P IV)	13.02
Los Angels Abrasion Value (%)	IS: 2386 (P IV)	18
Flakiness Index (%)	IS: 2386 (P I)	18.83

Elongation Index (%)	IS: 2386 (P I)	21.5
Water Absorption (%)	IS: 2386 (P III)	0.1

2.3 FINE AGGREGATES

Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found as **2.6.**

2.4 FILLER

Aggregate passing through 0.075 mm IS sieve is called as filler. The filler shall be cement, fly ash and Stone dust or any other approved non plastic mineral can be used .In this investigation material used is stone dust whose specific gravity is 2.7.

Table 3 Aggregate Gradation for coarse aggregates

Sieve size (mm)	Percentage passing
26.5	100
19	95
9.5	70
4.75	50
2.36	35
0.30	12
0.075	5

2.5 Additives Used:

Polyethylene is the most commonly used plastic in the world .Hence HDPE was used as the asphalt modifier in this investigation. The Physical and Mechanical properties of HDPE are listed in table 4

Table 4 Physical and Mechanical properties of HDPE

Property	Value
Density (g/cm^3)	0.955
Tensile strength (MPa)	27
Flexural modulus(MPa)	1372
Elongation at break (%)	560

A crumb rubber powder that had been passed through an ASTM#10 mesh was also used as an asphalt modifier in investigation.


FIG 1-CRP FIG 2-HDPE

2.6 SAMPLE PREPARATION:

In this investigation, four concentrations (3% ,4%, 5%, and 6%) of HDPE and three concentrations (5%, 10%, and 15%) of CRP based on the asphalt weight were used. The asphalt samples modified with HDPE and CRP in different concentrations were produced using a high-speed stirrer. First, the asphalt was heated, and HDPE was added to it at a shearing rate of 1200 rpm for 15 min at 185˚C. Next, the CRP was added to the asphalt binder and the mixture was stirred at a rate of 4000 rpm for 1.5 h at 185˚C. Finally, in order to remove the air introduced by the high-speed rotation process, the mixture was stirred at a low rate of 200 rpm for 15 min.

2.7 MARSHALL MIX DESIGN:

The Marshall Mix design process is usually performed in accordance with the ASTM D 1559 standard to optimize HMA mixtures. This is done to ensure the formation of voids of the appropriate size in the HMA. It was found that the asphalt concentration corresponding to an air void volume content of 4.0% was 6.3%. Hence, this asphalt concentration was used when preparing all the HDPE and CRP-modified HMA samples, in order to maintain consistency.

The dry process was used to prepare all the test samples. In the dry process, HDPE and CRP were added to the hot aggregates, and the components were mixed thoroughly. This resulted in the HDPE and CRP getting coated on the surfaces of the aggregates uniformly. Next, the asphalt was added to the mixture. The coated aggregates, asphalt, and filler were then mixed at a temperature 185 ± 5˚C for approximately 5 min. This mixture was then placed in Marshall molds and the Marshall mechanical hammer was used for compacting the mixture. A total of 75 blows were made on each face of the specimens at a temperature 10˚C lower than the mixing temperature.

FIG 3-Marshall stability test

3. RESULTS AND DISCUSSION

3.1. PHYSICAL TESTS

The effects of HDPE and CRP on the physical properties (pene-tration, softening point, and ductility) of asphalt were evaluated; the results obtained are shown in Figs. 4, 5, and 6. As can be seen from fig 4, the penetration decreased with increase in the HDPE and CRP contents, with the penetration being lower when 5% HDPE and 10% CRP were used. On the other hand, the softening point increased with increase in the HDPE and CRP contents as shown in fig5. This indicated that the addition of HDPE and CRP results in improvements in the resistance to deformation in moderate and high temperatures. Furthermore, the asphalt samples modified with both modifiers (HDPE and CRP) exhibited lower penetration and higher softening points than those of the samples modified with a single modifier (HDPE), suggesting that the HDPE-and CRP-modified asphalt samples exhibited better properties at high temperatures.

The ductility decreased when HDPE and CRP were added into the asphalt. The ductility decreased with an increase in the HDPE content irrespective of the CRP content. On the other hand, for all HDPE contents, the ductility increased with an increase in the CRP content as shown in fig 6. This may be attributable to the small changes induced in the structure of the asphalt by the modifiers. When HDPE is added to asphalt, a framework is not formed throughout the asphalt; as a result, the asphalt is not very ductile. On the other hand, the added CRP improves the elasticity because the CRP particles can form interconnections. Further, the HDPE may have already formed a partial network across the asphalt, making the asphalt less stiff. Thus, the addition of HDPE and CRP increased the ductility of the asphalt.

Four samples each of the control and modified asphalt mixtures were produced at the optimum asphalt content of 6.3% and used to determine the properties of the modified asphalt mixture samples through the Marshall test. The stability and flow values were calculated after the samples had been placed in a water bath at 60˚C for 30 min and then loaded at a rate of 50.8 mm/min. The test results are shown in fig 7.Fig 7 shows that when 5% HDPE and 10% CRP were used as the modifiers, they increased the Marshall stability of the unmodified asphalt mixture. On the other hand, the flow value decreased with the addition of the modifiers for all HDPE and CRP contents (fig 8).

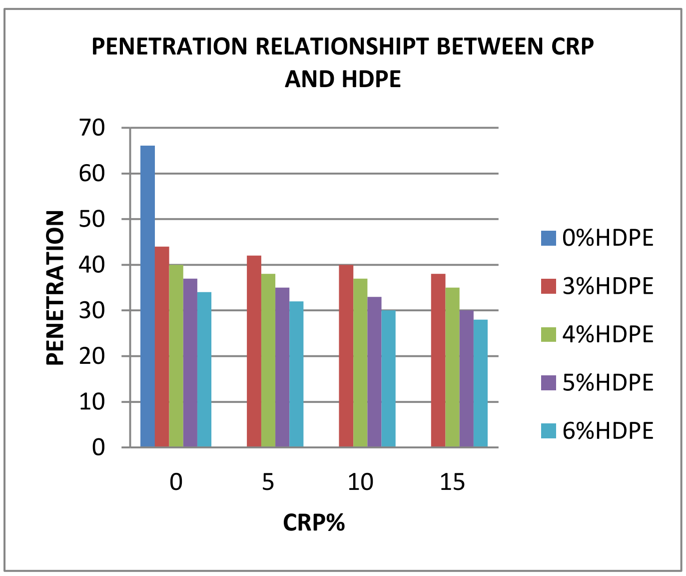

FIG4

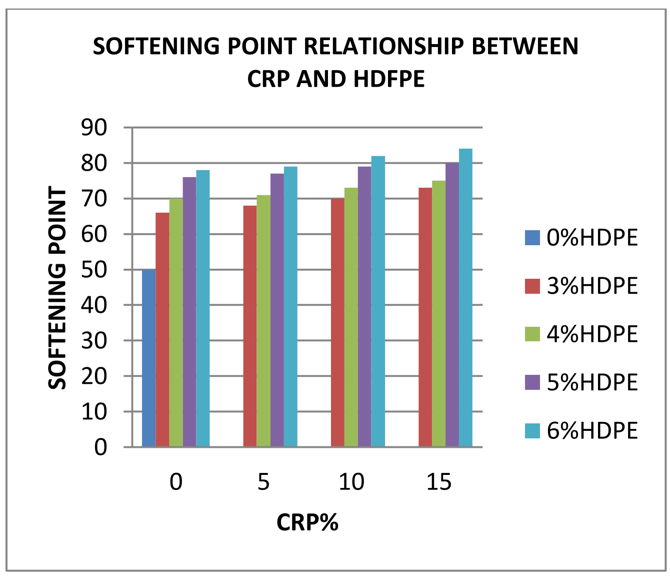

FIG5

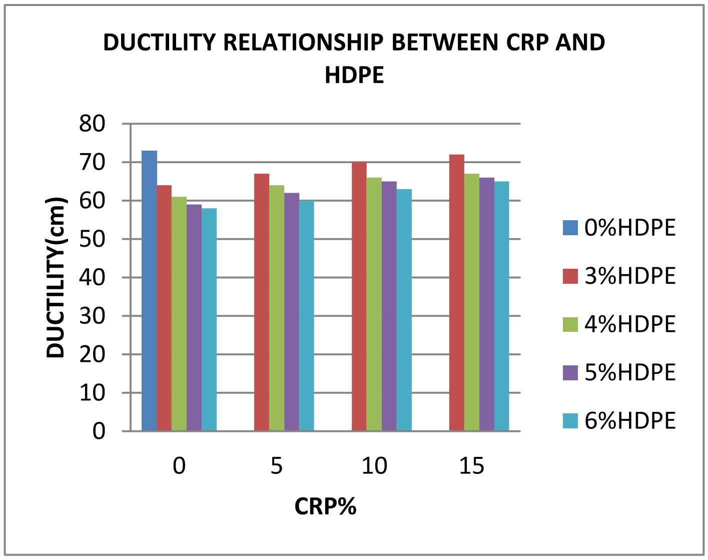

FIG 6

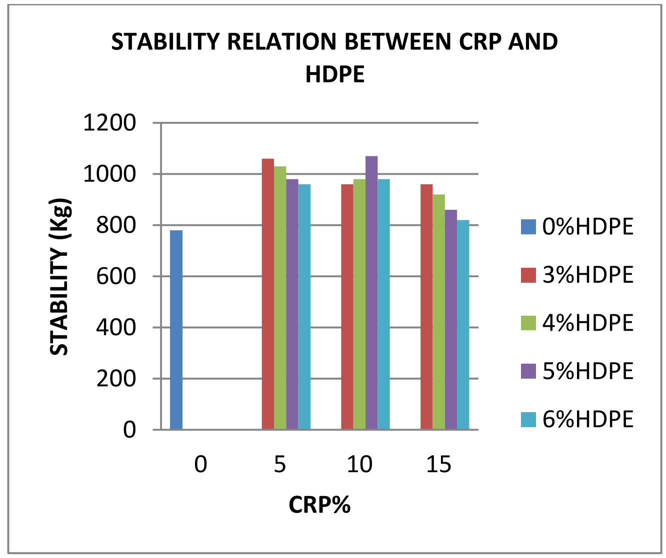

FIG 7

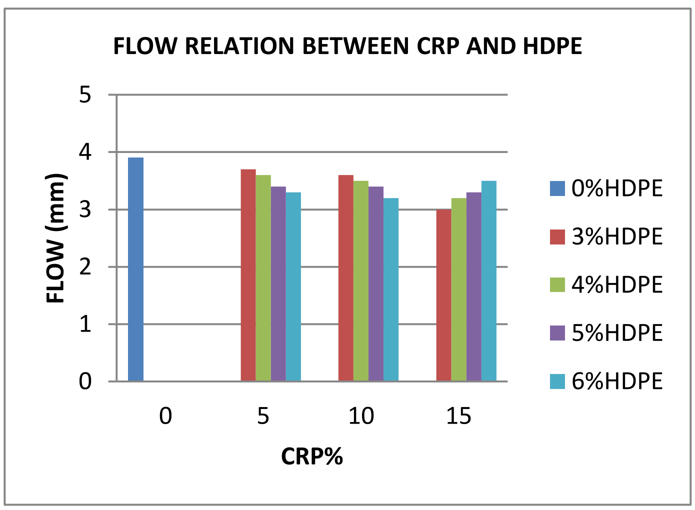

FIG 8

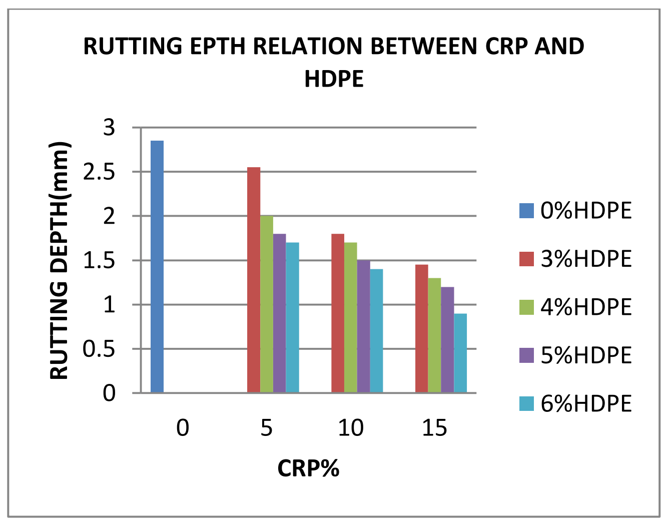

FIG 9

4. CONCLUSION

Based on the results obtained, the following conclusions can be drawn:

1. The penetration decreased with increasing HDPE and CRP con-tents, while the softening point increased, indicating that resistance to deformation in moderate and high temperatures increased with the addition of the modifiers.
2. The ductility decreased when HDPE and CRP were added to asphalt.
3. The Marshall tests showed that addition of 5% HDPE and 10% CRP raised the Marshall stability.
4. The rutting depth decreased with increase in the HDPE and CRP contents. On the other hand, the dynamic stability increased when HDPE and CRP were added to the asphalt mixture. Further, the permanent deformation resistance (rutting resistance) increased with the addition of HDPE and CRP.
5. The optimum contents of the additives were found to be 5% for HDPE and 10% for CRP (by weight of the asphalt binder).

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