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Investigation of properties of LDPE and HDPE modified Asphalt ConcreteS

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Abstract — *Almost 1300 million tons of solid waste is generated throughout the world per anum and will reach 2.20 billion tons till 2025. Plastic waste constitutes a major portion of generated solid waste, which is not biodegradable and is causing serious threat to human and aquatic life. Plastic waste accumulation on land and water bodies is a major source of concern for many developing countries. Many researchers have utilized such waste in asphalt concrete mix. LDPE and HDPE waste form a sizable portion of accumulated Plastic waste. This paper aims to investigate characteristics of HDPE and LDPE modified asphalt concrete by replacing 5%, 15% and 25% of Natural aggregates with LDPE and HDPE waste aggregates. Methodology process consisted of collection of plastic waste, sorting into LDPE and HDPE, heating, shredding and mechanical pulverization into the required aggregate sizes. FTIR tests were performed to verify the plastic waste as LDPE and HDPE. Specific gravity of HDPE and LDPE were also determined and were found to be 1.19 and 0.91 respectively. Air voids were found to increase with increase in percentage replacement. It was also determined that density of HDPE and LDPE modified mixtures decreased to 2071.32 and 1941.26 kg/m^3 respectively at 25% replacement. Marshal test was also performed to investigate flow and stability of LDPE and HDPE modified samples and were found to increase to 13.8 mm and 15.6mm at 15% replacement respectively and decrease to 14.2mm and 12.6mm at 25% replacement.*

Keywords*-Asphalt concrete, Plastic waste, FTIR of Plastic waste, LDPE, HDPE, Stability and flow*

I. INTRODUCTION

The term solid waste can be understood as any disposed of, discarded and useless materials such as municipal waste, sludge from filtration plant, waste from construction, demolition, industrial and domestic activities etc. [1]. According to the estimation of World Bank SWM, throughout the world 1300 million tons per year waste is generated and this will probably reach to 2200 million tons per year in the next decade. [2] According to World Health Organization more than 1.5 M human deaths are caused due to improper Solid waste management [3]. The rate of generation of solid waste varies from region to region due to various factors contributing to it. Waste produced in ton/annum in different major cities in Pakistan is shown in table 1 [4].

Table 1 Waste Generation in major cities of Pakistan

S. No	City	Annual Generation (Tons/annum)
1	Sibi	9855
2	Karachi	2420680
3	Hyderabad	275940
4	Gujranwala	224475
5	Bannu	8760
6	Peshawar	205860
7	Faisalabad	329230
8	Quetta	90155

Unlike developed countries, no city of Pakistan has proper solid waste management system. Due to lack of sustainable planning and design of landfills, collected wastes results in open land pits, ponds, natural streams, open flat grounds, and cultivable lands. Solid Waste is harmful to the public health in case of blocking of sewerage system, and creating breeding places for germs, mosquitoes and flies. So, causing water borne and water related diseases like malaria and cholera. Improper solid waste management causes more than 40% of the deaths in Pakistan [5]. 45% of the collected waste at dump site is plastic waste. Plastic waste is nonbiodegradable and stays there for decades. Waste like plastic bottles can stay up to 500 years and glass up to million years to degrade. Table 2 describes time taken by various items to degrade [1].

Table 2 Time taken by various items to degrade

S.NO	Item	Time to degrade
1	Wool Gloves	1 year
2	Wooden Sticks	13 years
3	Plastic Bags	10-20 years
4	Plastic Bottle	100 years
5	Glass	1000 years

II. LITERATURE REVIEW

Vijay Rohilla et al (2016) tried to define appropriate fraction of plastic that can be added to bitumen. The scope of the research was to investigate the use of HDPE as Polymer additives. The impact of varying temperature during mixing, mixing time, and HDPE content on the Marshall Stability, Marshall Quotient, and flow was investigated. The binders were prepared at 145-155 and 165°C temperatures. The mixing time was 30mins whereas HDPE content was 4–6% and 8% and 5–15. The results showed a considerable rise in the Marshall Stability (strength) values. Four percent HDPE, 165°C of mixing temperature, and 30 min of mixing time were finest conditions for flow, Marshall Stability, and Marshall Quotient (MQ) [6].

Serken Tapkin (2007) studied the impact of plastic fibers in asphalt concrete by using polypropylene fibers in asphalt concrete. The flow values decreased while Marshal stability values increased for fiber reinforced samples also it was observed that the fatigue life increased, amount of reflection cracking decreased and there was good to prolonged fatigue life, and rutting. Therefore, it was concluded that using polypropylene fibers modifies asphalt mixture in a very advantageous way [7].

Esmaeil Ahmadinia et al. (2011) used plastic bottles in asphalt in the amount of 2%, 4%, 6%, 8% and 10 replacements by weight of bitumen [8]. Suitable amount of PET was established to be 6%. PET has a noteworthy encouraging outcome on the properties of asphalt. M. Shoaib et al (2012) added 3% and 5% shredded plastic aggregates in asphalt mixes and investigated their impact on stability. Afroz Sultana et al. (2012) coated natural aggregates with plastic and determined their crushing, abrasion values [9]. Thorat et al. (2013) added waste plastic replacement with bitumen and investigated penetration and ductility properties [10]. While Nouman Iqbal et al. (2013) investigated flash and fire point of plastic and studied strength of asphalt samples with 25% replacement of natural aggregates with plastic aggregates [11]. The research validated the possibility of advantageous effects that can be attained by using recycled plastic as replacement of coarse aggregates in concrete. 5%, 10%, 15%, 20%, 25% & 30% of plastic waste as pelletized coarse aggregate were examined.

III. METHODOLOGY

In order to collect plastic waste, field visits to phase 7 Hayatabad dumpsite were conducted to collect waste being produced in Peshawar, Pakistan. collected Plastic waste was then sent to Royal PVC Industry and AL hafiz Crystoplast in Hayatabad Industrial state Peshawar. Plastic waste was sorted to HDPE and LDPE according to resin code system. Shredding of waste was done in mechanical shredder as shown in figure 1 plastic was then heated to remove moisture present in plastic waste as shown in figure 2. The obtained plastic was again heated to moldable form and kept for cooling in air before pulverization. Lump of HDPE Plastic waste are shown in figure 3.In the final step of plastic aggregate formation was pulverization by Jaw crusher into desired shape as shown in figure 4.

Figure 1 Shredding of Plastic of Waste

Figure 2 Moisture Removal Process from Plastic Waste

Figure 3 Lump of HDPE plastic waste

Figure 4 (a) HDPE aggregate and (b) LDPE aggregate

The following scheme was adopted for modified sample testing as shown in table 3.

Table 3 Scheme adopted for the study

No.	Name	Mix Description
HDPE modified Mixture		
1	HDPE5	HDPE 5% replacement
2	HDPE15	HDPE 15% replacement
3	HDPE25	HDPE 25% replacement
LDPE modified Mixture		
4	LDPE5	LDPE 5% replacement
5	LDPE15	LDPE 15% replacement
6	LDPE25	LDPE 25% replacement

After the calculation 1200 gm of normal aggregate were taken for preparation of control sample and Optimum binder content was calculated, for this Asphalt mixes of three different Bitumen content with 4%, 4.5% and 5% were prepared and tested. Optimum binder content was found to be 4.5% for control sample.

All the aggregate was made dried at 105 ±5 ^{o}C and selected aggregate with HDPE and LDPE replacement were taken preheated as shown in fig 3.22. Required amount of bitumen according to OBC was taken and pre heated in oven. Aggregate including plastic aggregate were heated to 160 ±10 C. Both Aggregate and binding material were placed in the mixing pan and manually mixed till the aggregate were coated with binding material as seen in fig 3.23. A cleaned mold was taken and pre heated on a hot electric plate. Marshall Mold was 10.16 cm in diameter, 7.62 cm high and provided with extension collar and a base plate. 35 blows of specified hammer were given to the asphalt sample. The weight of compaction hammer was 4.536 kg and falling a height was 45.72 cm. Specimen in the mold was reversed and 35 number of blows were given on the other side. Asphalt sample were then cautiously taken out the mold and placed on a level surface for cooling. During Marshall testing load was applies at standard rate. Maximum load and flow was measured for each mix.

IV. ANALYSIS, RESULTS AND DISCUSSION

For identification of plastic solid waste as LDPE and HDPE plastic waste the specimen were tested using FTIR spectroscopy test in MRL of UoP Pakistan. FTIR spectra of both the specimen as shown in figure 4.3 were examined in range of 1500 cm $^{-1}$ to 1000 cm^{-1} for the peak at 1377 cm^{-}1, which is designated to the Long chain and short chain branching termination. LDPE and HDPE have almost same IR spectra with some minor change in the peak and specified wavenumber range. The specimen of LDPE showed peak at 1376.99 cm^{-1} which revealed that the plastic waste is LDPE waste whereas there was no peak for HDPE waste.

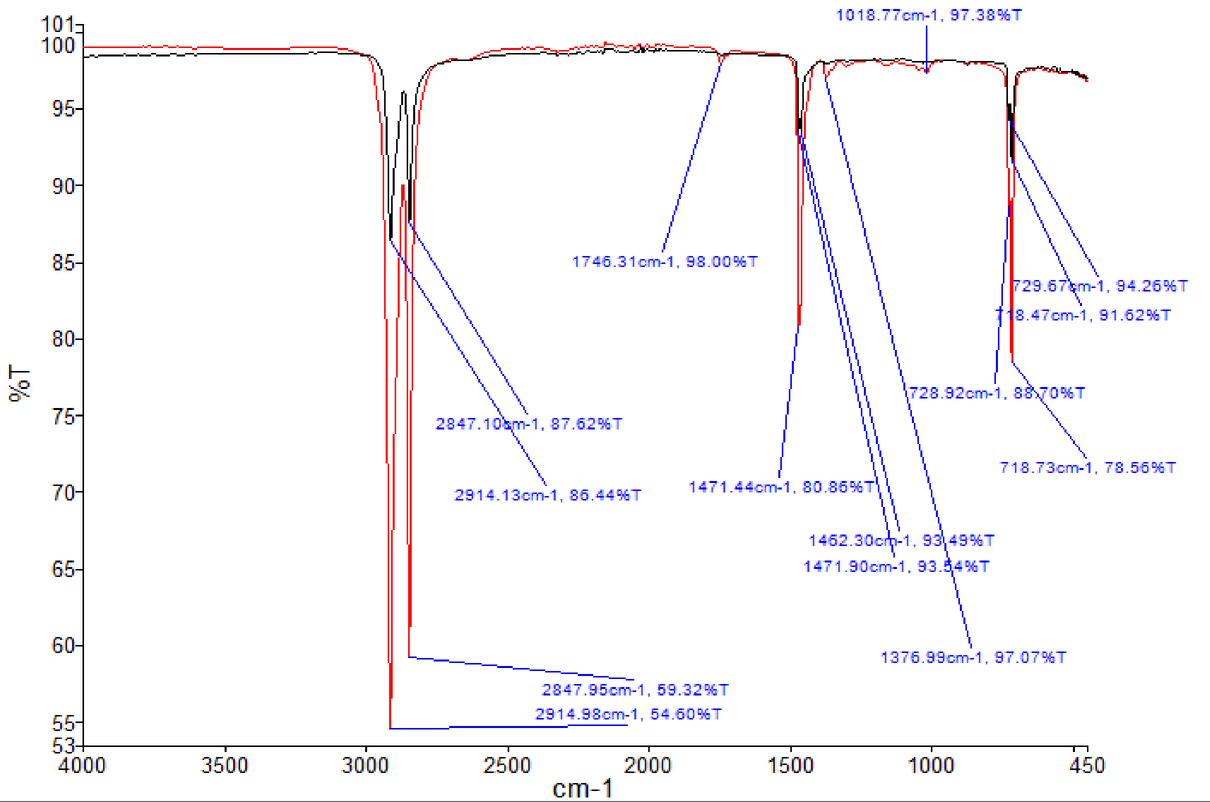

Figure 5 FTIR spectra of LDPE (red) and HDPE (black)

Sample of LDPE and HDPE replacement at different proportions resulted in lesser Bulk and theoretical maximum density compared to control sample. All the values for each Trail Mix were calculated and the average results are presented in Table no 4 and Table no 5

Table 4 Densities of HDPE modified samples

Sample	Average Bulk Density (Kg/m^3)	Average Theoretical Maximum Density (Kg/m^3)
Control	2445.31	2548.71
HDPE 5	2371.50	2499.51
HDPE 15	2231.43	2373.42
HDPE 25	2071.32	2252.96

Table 5 Densities of LDPE modified samples

Sample	Average Bulk Density (Kg/m^3)	Theoretical Maximum Density (Kg/m^3)
Control	2445.31	2548.71
LDPE 5	2351.53	2461.38
LDPE 15	2098.38	2281.32
LDPE 25	1941.26	2162.91

As shown in table 6, the air voids in control and HDPE 5, HDPE 15 AND HDPE 25 are 4.06, 5.12, 5.98 and 8.06 respectively. Similarly, the air voids in LDPE 5, LDPE 15 AND LDPE 25 are, 4.46, 8.02 and 10.25 respectively as shown in table 7. These tables show that with increase in percent replacement of LDPE and HDPE, percent air voids also increases. Similarly, it was also observed that there were more air voids in LDPE replacements compared to HDPE replacements above 5%.

Table 6 Air voids in HDPE modified samples

Sample	Average Bulk Density (Kg/m^3)	Average Theoretical Maximum Density (Kg/m^3)	Air Voids %
Control	2445.31	2548.71	4.06
HDPE 5	2371.50	2499.51	5.12
HDPE 15	2231.43	2373.42	5.98
HDPE 25	2071.32	2252.96	8.06

Table 7 Air voids in LDPE modified samples

Sample	Average Bulk Density (Kg/m^3)	Average Theoretical Maximum Density (Kg/m^3)	Air Voids %
Control	2445.31	2548.71	4.06
LDPE 5	2351.53	2461.38	4.46
LDPE 15	2098.38	2281.32	8.02
LDPE 25	1941.26	2162.91	10.25

Marshall Stability and flow results for control and plastic waste modified mixes is presented in graphs. Flow and stability of the plastic waste modified sample increases with increase in percent replacement compared to zero percent replacement. The available graph shown at figure 6 and figure 7 explains that In between 25% and 15% there is an optimum value because at 15 % the values of flow and stability are maximum. Similarly, as shown in figure 8 and 9, the flow and stability LDPE modified mixes increases till 15% replacement and there is an optimum value of replacement between 15 and 25%.

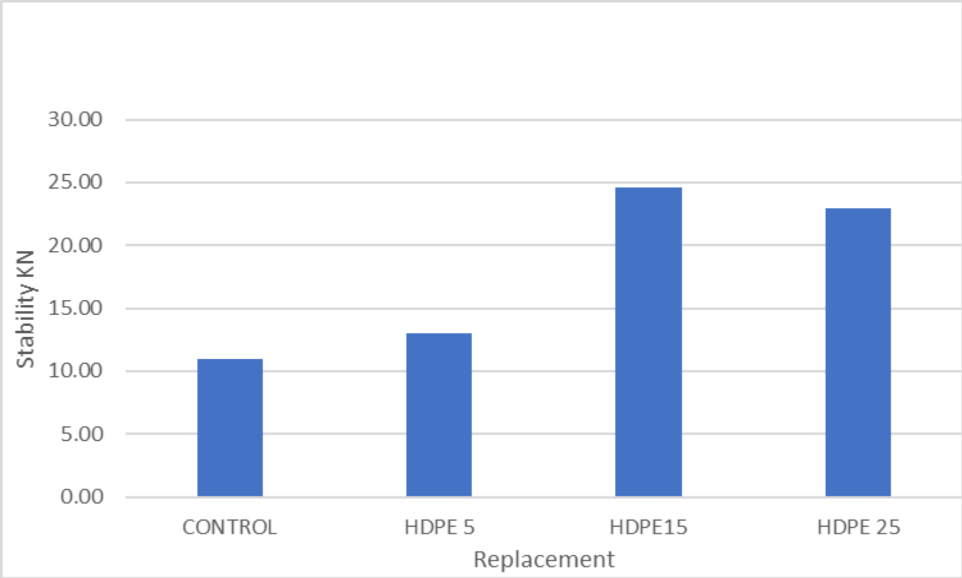

Figure 6 Stability of HDPE modified Mixes

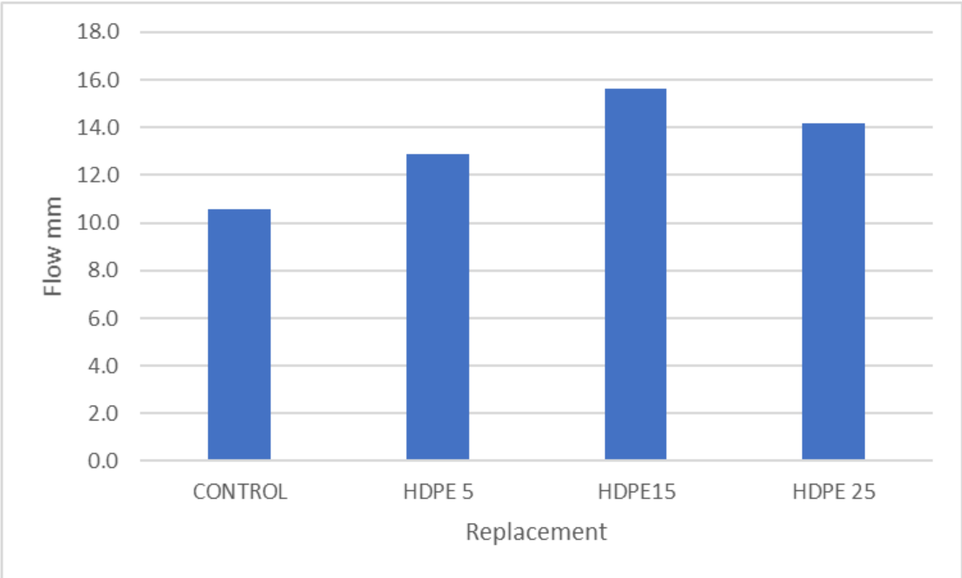

Figure 7 Flow of HDPE modified Mixes

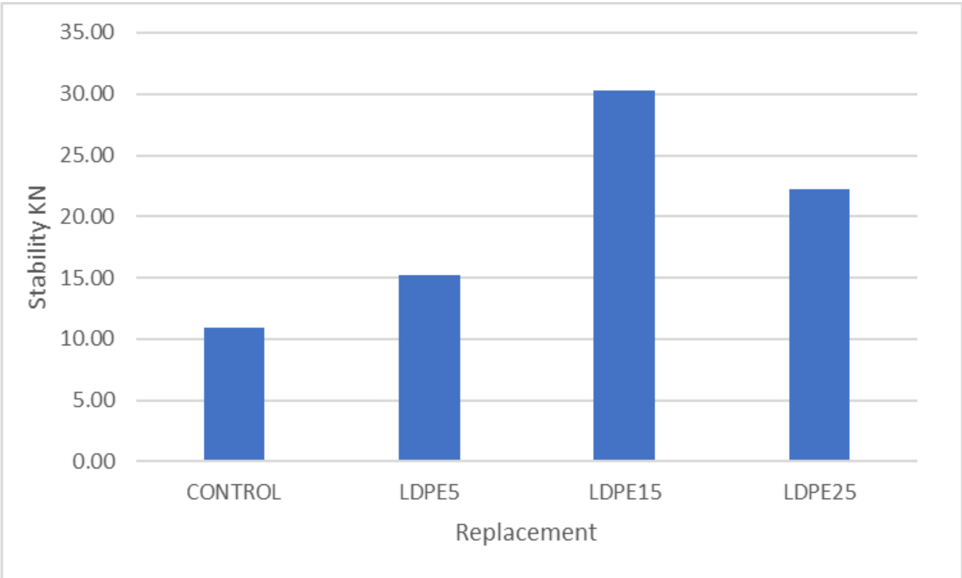

Figure 8 Stability of LDPE modified Mixes

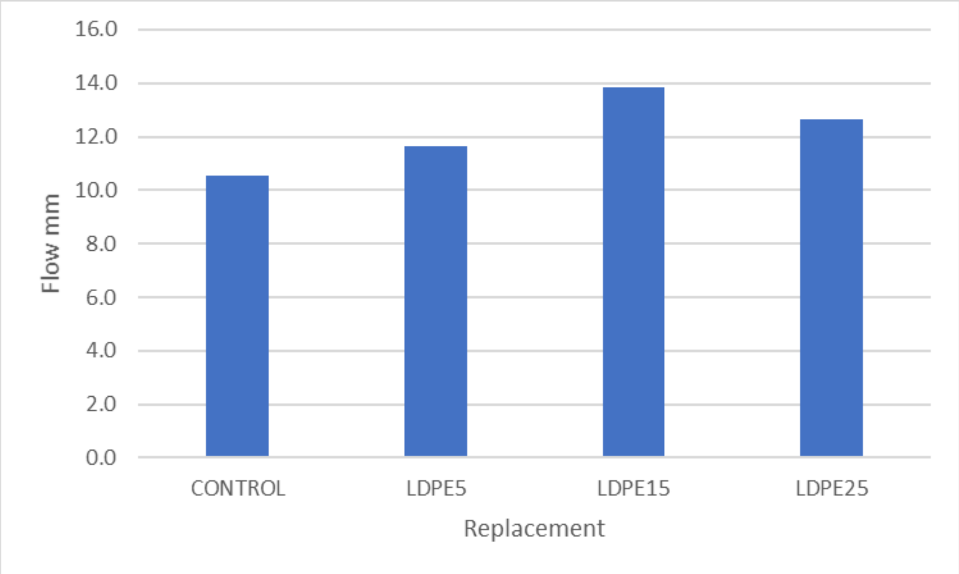

Figure 9 Flow of LDPE modified Mixes

V. CONCLUSIONS

The paper derives the following conclusions

1. FTIR spectra of LDPE plastic waste shows peak of almost 1377 cm^{-1} which characterise LDPE and HDPE.
2. LDPE and HDPE Plastic aggregate replacement have shown different results.
3. Increasing percent replacement of HDPE and LDPE results in decrease in Density of Asphalt mix. LDPE modified asphalt has lesser density
4. Increase in percent replacement plastic aggregate of LDPE and HDPE increases the percent air voids of the modified asphalt Mix. LDPE 25 % replacement has high value of air voids compared to HDPE
5. Stability and flow results were within the range and LDPE showed better result than HDPE, stability increases with increase in plastic waste replacement till 15%. At 25% replacement the stability decreases for both LDPE and HDPE.

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