Suitability of Waste Poly-Vinyl-Chloride (PVC) Pipes as a Modifier in the Construction of Pavements in Hot Climates

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(Received September 14, 2020; Revised January 15, 2021; Accepted February 02, 2021)
Online First Publication
DOI: 10.33317/ssurj.226

***Abstract*— Waste Polyvinyl Chloride (PVC) pipes from sewerage system, bottles, credit cards etc. is a non-biodegradable material and adds to the quantity of solid wastes on annual basis. This study aims at its useful deployment as an additive to the bitumen which is used to construct pavements. Waste PVC pipes when used as a modifier in bituminous mixtures, satisfied the requirements as per the standards as indicated by the results. The properties of bitumen mixed with PVC were studied and compared with those of the ordinary bitumen. The performance characteristics of the conventional and modified bituminous mixes were investigated and comparative study was carried out. It was shown by the results that waste PVC has got no issue when utilized in road construction. Flow and Stability of the mix was found to be within the acceptable limits after the PVC waste pipes have been incorporated. On the basis of experimental work it is concluded that the asphalt mixtures with waste PVC modifier can be used up conveniently in the construction of flexible pavement in hotter regions regarding their stability and flow characteristics.**

***Index Terms*— Pavements, Polyvinyl Chloride (PVC), Bitumen, Waste, Modifier.**

I. INTRODUCTION

The world is facing a serious problem of PVC disposal today. Short life PVC products have caused huge amount of problems during the last few decades, when incinerated. The long life PVC materials presently existing on the surface of earth is about 150 million tons. If the current rate of production persists, the world will have to manage a mountain of PVC wastes in 2005, which may be as large as 300 million tons [1]. Plastic can stay on the surface of earth for a period of 4500 years [2]. It appeared a challenging task for the environmental protection agencies to device an effective technique for managing the disposal of this much wastes. In order to do so either they are mixed with the municipal solid wastes or allowed to join the class of thrown away. It is one of the major goals of the researchers to purposefully utilize this waste PVC in a most beneficial manner. This study is also an attempt towards this goal as the only possible way to get rid of this problem seems to be its utilization for beneficial products. In the current era the temperature variation is a hot burning issue due to global warming and there is a significant increase in the traffic intensity in the urban areas. These two issues when coupled together present an alarming scenario for road construction practices and this is the main reason which is demanding for finding ways for improving the road characteristics especially in developing countries where the proper system for pavement rehabilitation and maintenance is almost negligible. Therefore better infrastructure of roads must be eyed upon where the maintenance is economized and systemized.

The variety of literature is available regarding the use of certain substances like rubber and polymers as modifiers in the bituminous mixes in order to improve the strength of asphaltic pavements. By using these modifiers the temperature susceptibility and viscosity were improved and also helped in overcoming problems like bleeding of binder during the climax of summer season and stripping of aggregates in areas vulnerable to moisture damages. But due to the higher costs and limited availability of these polymers numerous studies have been carried out to qualitatively enhance bitumen by using waste polymers [3].

The aggregates having size of about 5mm when replaced by Low Density Polyethylene (LDPE) by 30%, results in an increase of Marshall Stability by 230% [4]. By mixing polythene of low density causes an increase in the resistance against deformation in asphaltic concrete mixes [5]. Recycled polyethylene bag used in bituminous mixes, has got the capability of reducing the permanent deformation in various types of distresses such as rutting and temperature cracking in the surface of pavements [6]. When, 15% Aggregates in asphalt mix were replaced with LDPE having a size of 0.30 to 0.92mm which imparted better resistance against rutting and moisture. The marshal stability was found to be enhanced by 15% in this case [7]. The PVC pipe waste was utilized as a modifier for pavements by an amount of 3% to 5%. By studying the viscoelastic properties of the mix it was found that the strength and stability was improved with the increase in resistance against permanent deformation [8].

The design criteria was worked out for bituminous mix using PVC bitumen binder with an increment of 2.5% starting from 2.5% up to 20%[9]. PVC when melted gains the adhesive properties [10]. This quality enables it to be used in Hot Mixed Asphalt (HMA) in combination with the bitumen which is also a binder itself. The aim of this study was to investigate the strength properties of coarse aggregates and Marshall Design properties of bituminous mixes as specified by the standard, American Association of State Highway and

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Transportation Officials (AASHTO) procedure. It was concluded that the properties lie within the acceptable limits. The PVC added by 10% was found the most suitable to be used in bituminous mixes for the construction of flexible pavement in hotter regions regarding its stiffness, stability and void characteristics.

II. MATERIALS AND METHODS

In the first step the procurement of materials was achieved by fetching waste PVC pipes, available with local recyclers. The bitumen used was also brought from the local market. Several tests were performed to judge the quality of these materials. Table I provides a summarized overview of the results obtained from testing bitumen and aggregates. The coarse aggregate and filler material in the form of stone dust were obtained from the River Kurram, Khyber Pakhtunkhwa, Pakistan.

Table I: Quality of Bitumen and Aggregates

Bitumen		Aggregates	
Penetration Value	70	Los Angeles Abrasion Value	15.8%
Softening Point	40°	Aggregate Impact Value	8.5%
Stripping Value	<2%	Specific Gravity	2.7
Flash Point	243°		
Fire Point	251°		

A. Preparation of Blends

Mixing of waste PVC with bitumen was accomplished in the lab. The waste PVC was thoroughly washed and dried at 60°C. After washing the waste PVC was treated with fire for homogeneous dispersion into bitumen. The bitumen was modified with waste PVC by adding it in two percentage amounts which were 4% and 6% by weight of bitumen respectively. The blends were stored at room temperature for further usage. The physical properties of bitumen with different percentages of PVC were then investigated, as shown in Table II.

Table II: Properties of Modified Bitumen

Description of Properties	Modified Bitumen	
	4% PVC	6% PVC
Penetration value	62	56
Softening point	43°	48°
Stripping value	<2%	<2%
Flash point	253°	259°
Fire point	261°	265°

B. Gradation of Aggregate

The aggregate used to make the bituminous concrete sample were selected in accordance with the specified gradation criteria mentioned in Table III.

Table III: Gradation Criteria for Bituminous Surface Course

Sieve Size, mm	Specified % Passing by Wt.	Adopted % Passing by Wt.
20	100	100
12.5	80 – 100	90
10.00	70 – 90	80
4.750	50 – 70	60
2.360	35 – 50	42.5
0.600	18 – 29	23.5
0.300	13 – 23	18
0.150	8 – 16	12
0.075	4 – 10	7

Marshall Mix design is used for the preparation of different specimens. This method is one of the conventional techniques applied for the selection of asphalt mixes and adopted worldwide. The proportion of mineral aggregate and asphalt should be in accordance with the standards mentioned in American Society for Testing and Materials (ASTM) manuals, i.e., ASTM D 2172 or ASTM PS 90-97.

Marshall Samples were prepared for different binder content at a certain temperature of 139° - 163° to determine the optimum binder content of the mix.

Marshall Stability Parameters at various percentages of binder content are given in Table IV below.

Table IV: Marshal Stability Parameters for Various Mixes

% by Wt. of mix	Bulk Density G_{mb}	Max. Specific Gravity G_{mm}	Stability (Kg)	Flow (mm)	% Air Voids
4.1	2.37	2.503	1230	2.54	5.43
4.56	2.38	2.5	1271	2.85	4.76
5.12	2.41	2.498	1347	3.39	3.78
5.6	2.43	2.495	1168.5	4.20	2.61

The graphic representation in Fig. 1, Fig. 2, and Fig. 3, helps us to decide the optimum binder contents, as shown in figures below:

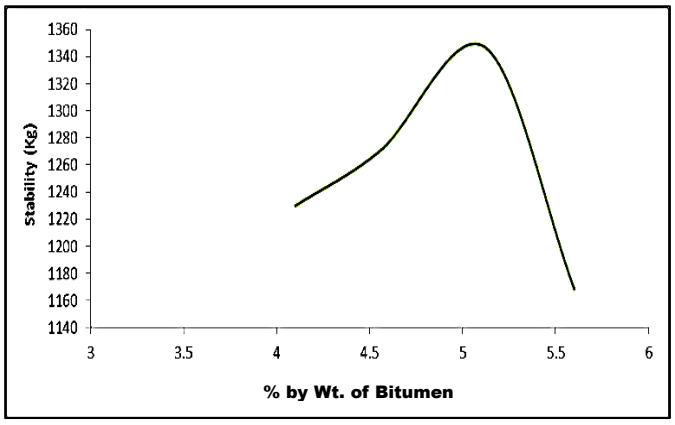

Fig. 1: Effect of Binder Weight on Stability

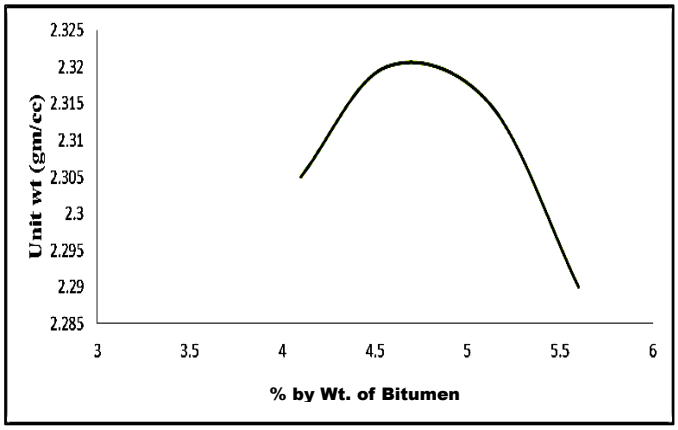

Fig. 2: Effect of Binder Weight on Unit Weight

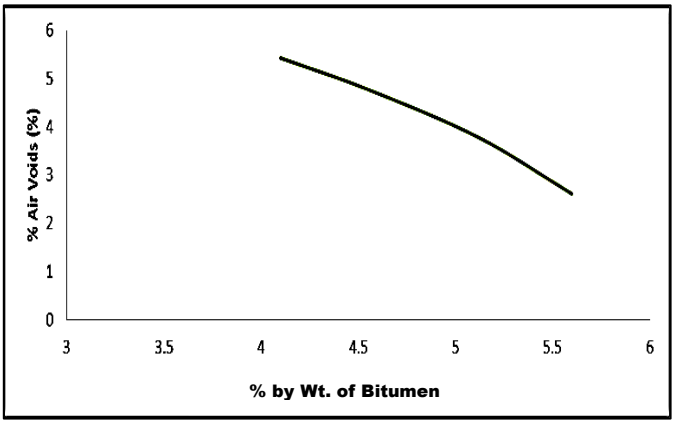

Fig. 3: Effect of Binder Weight on Air Voids

III. RESULTS AND DISCUSSION

The graphic plots given in above mentioned figures i.e., Fig. 1, Fig. 2, and Fig. 3, helps us to decide the optimum binder content. The optimum binder content was selected to be 5%. The Marshall Stability parameters for samples prepared by mixing waste PVC modified bitumen were measured and compiled in the above mentioned table i.e., in Table IV.

It is quite obvious from the results obtained from several tests that the properties of bitumen were modified with the mixing of PVC. The properties of simple bitumen were improved up to certain amount.

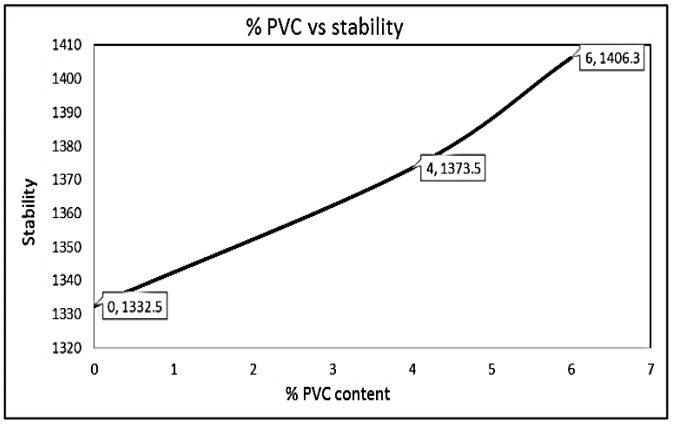

Fig. 4: Trend of Stability by Adding PVC

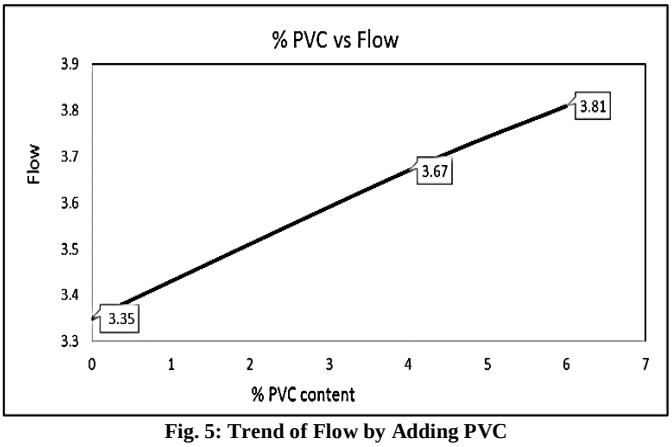

Fig. 5: Trend of Flow by Adding PVC

By examining Fig. 4 and Fig. 5, above, it can be observed clearly that the trend is upwards, which is a manifestation of the fact that the flow and stability is elevated by using waste PVC as a modifier.

The table below i.e., Table V shows the comparison of the results for the current study with the previous study conducted by remarkable researchers. The results shows the same trend and it is evident that the results of the study are correct but the previous study was conducted for different grades of bitumen therefore the values of penetration are totally different from each other.

Table V: Comparison of Results with Previous Studies

Description of Property	Results from this Study	Results from Previous Studies [10], [11]
Penetration 9mm)	62 and 56	42 and 40
Softening point (C°)	43 and 48	52.7 and 53
Flash and fire point (C°)	253, 261 and 255, 265	342, 345 and 337, 340
Optimum binder content (%)	5.1	7.5
Maximum unit weight (kg/m³)	2498	2442
Marshal stability (KN)	11.46	13.6
Flow (mm)	3.39	0.25

IV. CONCLUSION

Waste PVC pipe can be successfully used as modifier with bitumen. The addition of waste PVC increase the softening point and decrease the penetration value which will prove beneficial in hot climate areas and also helpful to overcome the bleeding problems of binders. By using the waste PVC the stability and % air voids, of the bituminous mixes were improved which enables them to withstand larger stresses, imposed upon them by moving vehicular loads without sustaining substantial permanent deformation. It is recommended to test the PVC modified bitumen, with HMA for its performance against rutting with advanced testing equipment like Simple Performance Tester (SPT), Hamburg Wheel Tracking Device (HWTD) and Asphalt Pavement Analyzer (APA), so that the assessment may further be rectified and a clear picture regarding its suitability and consistency for utilization in pavements may be obtained.

ACKNOWLEDGMENT

Profound gratitude and indebtedness is hereby presented to the head of the department of civil engineering, UET Bannu Campus and all the officials for their remarkable support and guidance throughout this piece of study. It is indeed their intellectual guidance, constructive criticism and precious suggestions, which led towards this humble contribution. The efforts and cooperation of the lab supervisor must also be appreciated and acknowledged in this regard. It was the cooperation and full-fledged support on his part which kept the succession of this study in right direction.

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