POLYMER MODIFIED BITUMEN IN FLEXIBLE PAVEMENT AND ITS CHARACTERIZATION

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ABSTRACT: *Bitumen is a byproduct obtained in the fractional distillation of crude oil. The use of bitumen as a binder in flexible pavement construction is one of the major applications of the bitumen. Bitumen is also used in designing and pottery applications. As the binder, it is used to bind stone aggregates together to form a mixture which is rolled like a platform and used for traffic movements. The workability of such pavement depends on the qualities of the bitumen, such as strong binding with the aggregate and increased strength under loading. Bitumen is a visco-elastic material which behaves, like a viscous liquid and elastic solid at different temperatures.*

This thesis presents different methods of preparing polymer modified bitumen and it also discusses the characterization. It also concludes the findings and the recommendation of the use of the modified bitumen in flexible pavement applications. Two processes are attempted for the preparation 1. Wet process – mixing polymer in bitumen at hot condition and 2. Dry process – mixing plastics to hot aggregate and then mixing the plastic coated aggregate with bitumen. The first process is a well known process and followed by all the researchers. The second process is new in the area of modified bitumen preparation. In the present research, six different types of polymers such as Polyethylene, Polypropylene, Polyvinyl Alcohol, Polyvinyl Pyrollidone, Acrylonitrile butadiene Styrene and Waste Plastics with different percentages have been used for the modification of bitumen. The modified bitumen is subjected to various characterization studies like basic tests such as Softening point, Ductility, Penetration, Separation and Marshall Stability value (MSV). The results obtained from the basic tests shows that the polymer has changed the basic properties of the bitumen without affecting the basic requirement of the bitumen to perform as a binder in flexible pavement. The softening point of the modified bitumen increases with increase in polymer content, it is observed that as higher the softening point of the bitumen better the resistant to permanent deformation properties like stripping, bleeding and rutting. The decrease in the penetration point of the PMB shows that it can withstand high temperature deformation. The observed ductility values of all PMB except the WP show that the addition of polymer does not impart notable change in the ductile nature of the modified bitumen.

The viscosity study of the PMB on the rotational viscometer has suggested that it, increases or decreases with respect to the polymers used for modification. The change also depends on the percentage of polymer. The viscosity of the unmodified bitumen is modified as a function of mixing 160 °C and laying temperatures 140 °C. It is also observed that the viscosity changes with change in the shear rate and the change in viscosity is also not uniform. The viscosity result provides fruitful data on the performance of the binder at its laying 140oC and mixing temperatures 160 °C. The thermal properties study on the modified bitumen suggests that the use of polymer increases the decomposition temperature of the unmodified bitumen. There is no observation made with a decrease in decomposition temperature, as it is expected that the polymer will decrease the decomposition temperature. Due to the fact that the polymers have low decomposition temperature, the TGA study also reveals that the modified bitumen has a decomposition temperature above 250 °C higher than its working temperature of 180 °C. Different stages of decompositions are also observed. From the study of 3 % and 5 % polymer modified bitumen it is observed that the polymers are uniformly dispersed on the continuous bitumen phase. At 7 % of polymer modification, the dispersion is non uniform and the polymer phase becomes continuous. From this observation it is confirmed that when the percentage of polymer is increased, the polymer will modify the bitumen in a pattern, that the bitumen loses its viscoelastic property and becomes more plastic in nature. The observations also suggest the optimum percentage of polymer to be used for modification.

Keywords: polymers, Flexible pavement

1. INTRODUCTION

Plastics, a versatile material and a friend to common man becomes a problem to the environment after its use. Disposal of a variety of plastic wastes in an eco friendly way is the thrust area of today's research. The authors' innovative techniques to use the waste plastics and the tyre waste for the construction of flexible pavement, for making pathway blocks, and for making laminated roofing sheets form a good solution for the waste disposal problem of both plastic waste and municipal solid waste.

2. CHARACTERIZATION OF WASTE PLASTICS

2.1 Process: I (using Mini Hot Mix Plant)

At first, the aggregate mix was prepared as per IRC specification and then heated in the cylindrical drum to 170 ?C. It was then transferred to the puddling compartment where polymer waste (size between

1.6mm and 4.75mm) was added. As the temperature of the aggregate was around 170 °C and the softening temperature of polymer waste is around 135 °C, the polymer waste got softened and got coated over the aggregate within 30 to 60 seconds. Immediately the hot bitumen 60/70 grade (□ 160°C) was added and mixed in the puddling chamber. The bitumen got coated over the aggregate. As the polymer and the bitumen were in liquid state they got mixed well. The mixture was transferred to the road and it was spread and compacted using 8 Ton rollers.

2.2 Process: II (using Central Mixing Plant)

In this process, the polymer waste was mixed quantitatively with the aggregate using a mechanical device before the addition of bitumen. Central Mixing Plant helps to have better control of temperature and better mixing of material and thereby enabling to have a uniform coating.

The material collected at the tipper was uniform and had a temperature of 140 ºC. This was transported to the spot and road was laid using 'pavers' and 8 Ton roller. The spreading was good and the laying was easy. During the process the materials got mixed

1. at the tipper
2. During the transfer from tipper to pavers and
3. by the pavers during spreading for road laying

Fig. 1: Cleaning Process

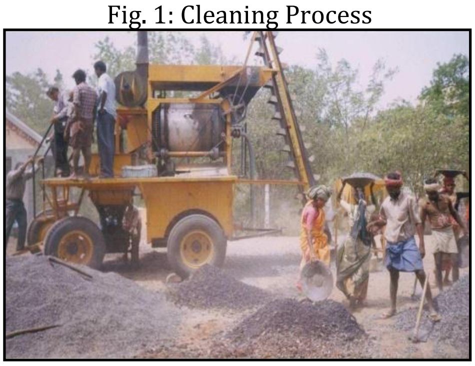

Fig. 2: Heating of Aggregate to 170º C in Mini Hot Mix Plant

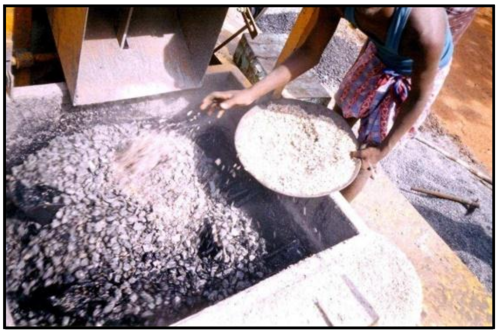

Fig. 3: Adding Waste Polymers to Hot Aggregates

2.3 Binding Property

The molten plastics waste exhibits good binding property. Various raw materials like granite stone, ceramics etc... were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths.

Table 1. Binding Property

Percentage of plastics coating over aggregate	Compression Strength (Tonnes)	Bending Strength (Kg)
10	250	325
20	270	335
25	290	350
30	320	390

The increase in the values of the compression strength and bending strength shows that the plastics can be used as a binder.

2.4 Objectives

The aim of this thesis is to study, the influence and the impact of the polymer over the bitumen properties in Polymer Bitumen composite prepared using wet process and to study the mix properties of the blends prepared using both wet and dry process. The research objectives have been fixed under four major points of discussion

1. to identify the micro (the inner chain alteration and structural changes) and the macro level (Basic and other tests to characterize a bitumen as per standard) impact produced by the polymers over the bitumen
2. to access the viscoelastic properties of the Polymer Bitumen
3. to evaluate the influence of the Polymer Bitumen on the mix properties like Marshall Stability value and voids calculations of the flexible pavements
4. to find out an easy and a suitable method for preparing Polymer Bitumen

Table 2 Composition of bitumen

Component	Percentage
Carbon	80-800
Hydrogen	8-11
Sulphur	0-6
Oxygen	0-1.5
Nitrogen	0-1

2.5 Research Methodology

The research starts with a detailed introduction on the bitumen and Polymer Bitumen; it is followed by a brief literature review on the history of the use of Polymer Bitumen. The next step explains the different methods of preparation of Polymer Bitumen. Two types of methods dry and wet process are followed. In this research six different types of polymers were used and the four series of Polymer Bitumen like 1 %, 3 %, 5 % and 7 % are prepared and the prepared samples are then characterized for its properties like empirical, structural and thermal methods. Finally, the observed data were compared with un polymer bitumen and their natures for the use in flexible pavement application were found out.

3. CHARACTERISTICS OF POLYMER MODIFIED BITUMEN

An alternate use of plastic waste is also under study where plastics is mixed with bitumen and used for preparing the mix. The mix was used to study the basic properties of bitumen like softening point, penetration point and ductility. The penetration value was decreased to a very low value and similarly the ductility. More than 3% addition of waste plastics to the bitumen results in a hard polymer modified bitumen with very poor viscoelastic property (The minimum values for a suitable bitumen
P.V = 80; Ductility ≈ 50).

Table 3. Properties of Polymer Modified Bitumen

% of Plastics	*Ductility (cm)*	*Penetration (mm)*	*Softening Point (ºc)*
1%	64	95	54
2%	55	90	50
3%	20	80	50
5%	11	55	72
10%	7	Nil	75

On comparison it may be inferred that the use of higher percentage of plastics in polymer modified bitumen is not favorable (Table 3).

3.1 Softening Point

The results obtained for the softening point (SP) of all series of Polymer Bitumen with respect to the percentages of polymers incorporated in to the bitumen mixes are tabulated in Table 4.

Table 4 Softening point values of all polymers

Percentage/ Type of Polymers	0	1	3	5	7
PP	45	52	55	58	59
PE	45	47	49	52	55
PVA	45	52	55	58	60
PVP	45	52	55	58	60
ABS	45	55	58	62	68
WP	45	58	62	66	69

3.2 Penetration Point

The results obtained for the penetration point (PP) of all series of Polymer Bitumen with respect to the percentages of polymers incorporated in to the bitumen mixes are tabulated in Table 5

Table 5 Penetration point values of all polymers

Percentage/ Type of Polymers	0	1	3	5	7
PP	90	82.30	78.30	70.60	66.30
PE	90	85.60	80.60	75.30	71.30
PVA	90	82.00	80.00	75.00	72.30
PVP	90	80.60	78.60	73.60	69.60
ABS	90	85.60	82.30	78.60	74.60
WP	90	83.00	82.00	79.60	76.60

3.3 Penetration Index

The results obtained for the penetration index (PI) of all series of Polymer Bitumen with respect to the percentages of polymers incorporated in to the bitumen mixes are tabulated in Table 6

Table 6 Penetration index point values of all polymers

Percentage/ Type of Polymers	0	1	3	5	7
PP	-1.56	0.61	1.16	1.56	1.57
PE	-1.56	-0.6	-0.29	0.36	0.9
PVA	-1.56	0.56	1.23	1.77	2.05
PVP	-1.56	0.56	1.15	1.69	1.91
ABS	-1.56	1.44	2.05	2.66	3.63
WP	-1.56	2.05	2.81	3.67	2.67

3.4 Ductility:-The results obtained for the ductility measurement of all series of Polymer Bitumen with respect to the percentages of polymers incorporated in to the bitumen mixes are tabulated in Table 7

Table 7 ductility point values of all polymers

Percentage/ Type of Polymers	0	1	3	5	7
PP	82.5	87.5	82.5	76.5	75
PE	82.5	85	82.5	81	75.5
PVA	82.5	81.5	82.5	80	81.5
PVP	82.5	82	80.5	81	78

ABS	82.5	80.5	79.5	77.56	75
WP	82.5	80	76.5	61.5	-

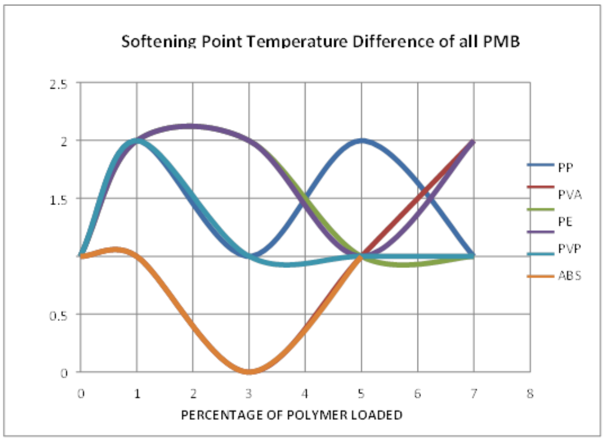

Figure 4 Softening point difference of all Polymer Bitumen

3.5 Marshall Stability Test:-

The results obtained for the Marshal Stability Value (MSV) of all series of Polymer Bitumen with respect to the percentages of polymers incorporated in to the bitumen mixes are tabulated

Table 8 MQ for all Polymers

Percentage/ Type of Polymers	0	1	3	5	7
Values	MQ (MSV (Kg)/F.V (mm))	MQ (MSV (Kg)/ F.V (mm))	MQ (MSV (Kg)/F.V (mm))	MQ (MSV (Kg)/F.V (mm))	MQ (MSV (Kg)/F.V (mm))
PP	82.5	87.5	82.5	76.5	75
PE	82.5	85	82.5	81	75.5
PVA	82.5	81.5	82.5	80	81.5
PVP	82.5	82	80.5	81	78
ABS	82.5	80.5	79.5	77.56	75
WP	82.5	80	76.5	61.5	-

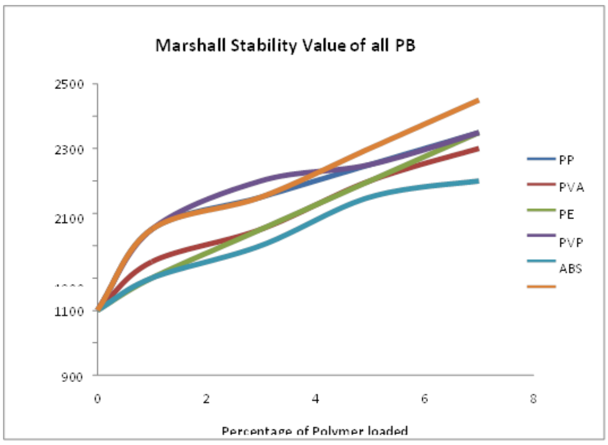

Figure 5 Marshall Stability value of all PB

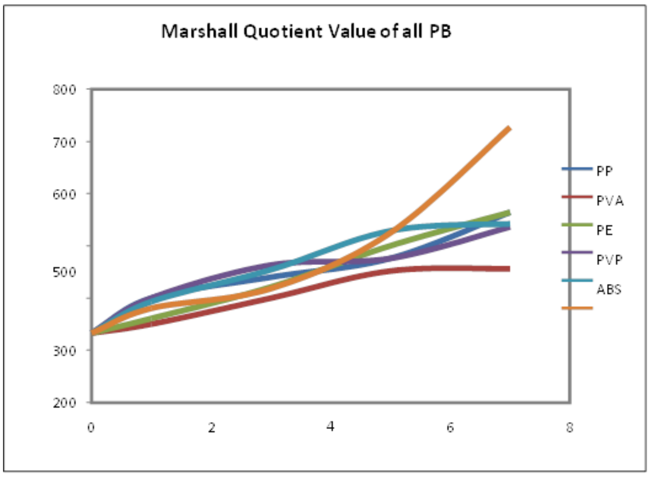

Figure 6 Marshall Quotient Value of all Polymer Bitumen

3.6 Viscosity Study

In the present investigation, viscosity of the Polymer Bitumen and bitumen is measured at two different temperatures 1. At mixing temperature 160 ˚C and 2. At road laying temperature 135 ˚C. At this condition the spreading, mixing and coating of bitumen happens. Viscosity is also studied at shear rates 20 rpm or 6.8 s-1 50 rpm or 10.2 s-1 and 100 rpm or 34 s-1 to analyze the variation of viscosity with respect to the shear rate. This shear rates are chosen as per the recommendations given by Strategic Highway Research Program (SHRP). The kinematic high temperature viscosity is only measured in this study; dynamic viscosity at 60 ˚C is not recorded since the Polymer Bitumen samples like ABS and WP has a SP more than 60 ˚C. Moreover, study at 60 ˚C can be done by Dynamic Shear Rheometer (DSR). Determining the viscosity under these conditions help in, identifying the influence of polymer on bitumen and in finding whether Polymer Bitumen can be used in present methods of road laying.

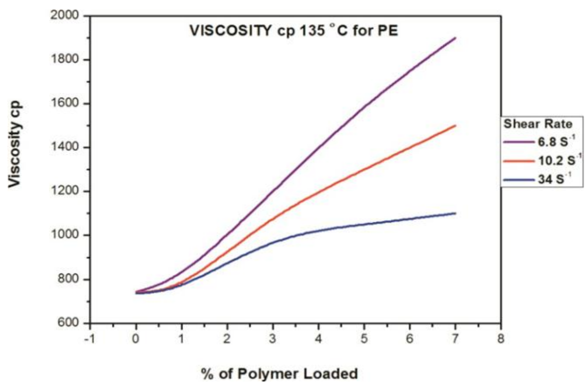

Figure 7 Viscosity of PE PB at 135 °C

The modification of bitumen with PE influences the internal structure of the bitumen, which affects the viscosity. This characteristic is correlated by the FTIR spectroscopic pattern of PE Polymer Bitumen, which shows an increment in the hydro carbon ratio of the bitumen, thus influencing the internal structure. Thus the addition of PE affects the microstructure of the bitumen and hence altering the viscosity at high temperature 135 ˚C results in better resistance against deformations like rutting. At mixing temperature 160 ˚C PE Polymer Bitumen shows low viscosity which makes the bitumen to form uniform coating over the aggregate due to the increase in the flow of the binder. It is concluded from the present study that the PE Polymer Bitumen viscosity values shows modification attributed to its performances in the pavement without failures like rutting and cracking.

Table 9 Physical properties of WP

Commercial Plastic material	Nature of Plastics	Thickness μ	Softening Point Deg C
Cup	PE	150	100-120
Carry bag	PE	10	100-120
Water bottle	PET	210	170-180
Cool drinks bottle	PET	210	170-180
Chocolate covers	Poly ester+PE+metalised	20	155
Parcel cover	polyester	20	155
Supari cover	PE	50	100-120
Milk Pouch	Polyester+PE	60	120-135
Biscuit covers	LDPE	60	100-120
Decoration papers	Polyester+PE	40	170
Film	BOPP	100	110
Foam	PE	50	120-130
Foam	PE	NA	100-110

3.7 Characteristics of plastic coated aggregate

For the asphalt pavement, stone aggregate with specific characteristics is used for road laying. The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity. The aggregate is coated with waste plastic material by the following process. The WP namely film, cups and foams are shredded to the required size of 2.5–4.36 mm. The aggregate is heated to 170 0C. The shredded waste plastic is sprayed over the hot aggregate. Plastics have got softened and coated over the aggregate. The extent of coating is varied by using different percentage of plastics. Higher percentage of plastics up to 25 % is used to evaluate the binding property, whereas lower percentage of plastics like 1–5 % is used to evaluate the properties like moisture absorption and Soundness

Table 9-Type of plastics and variation in binding strength

Type of Plastic	Percentage of Plastics	Binding Strength in Kg
PE	10	325
	20	340
	25	350
Poly propylene	10	350
	20	370
	25	385
PS	10	200
	20	210
	25	215
PE Foam	10	310
	20	325
	25	335
PP Foam	10	340
	20	360
	25	365
Laminated Plastics	10	360
	20	385
	25	400
BOPP	10	380
	20	400
	25	410

3.8 Extraction Characteristics:- The experimental results of extraction of bitumen Table 5.5 from the PCA bitumen mix clearly explain the bonding nature of the bitumen with the PCA. It is observed that the TCE could remove bitumen almost from the plain bitumen coated aggregate, whereas in the PCA bitumen mix, the removal of the bitumen by TCE is a slow process and it is also partial only. The TCE cannot remove completely all the bitumen from PCA bitumen mix. Decaline, an organic solvent could remove both bitumen and plastic on further treatment. Complete removal is possible only by refluxing the PCA bitumen mix with decaline for more than 30 min. Following observations are made from the results of extraction test. In the case of PCA bitumen mix, TCE removes only loosely bonded bitumen. It could not remove the bitumen bonded with the aggregate through the plastics. Decaline being a solvent to plastic could remove the bonded bitumen further. Only after refluxing, complete removal of bitumen and plastic is possible. Moreover, when the percentage of coating of plastics is more, the extent by bitumen removal is correspondingly less. This observation helps to conclude the bonding of bitumen over PCA when it is strong.

Table 11 Results of the bitumen extraction test for the bitumen mix containing the PCA

Plastic content (% by weight	Bitumen extracted after 5 min %	Bitumen extracted after 10 min %	Bitumen extracted after 15 min %
0	96.0	98.0	99.0
0.5	63.5	88.7	92.3
0.75	63.2	86.7	90.7
1.0	61.3	76.7	83.6

4. Field study:

The tests show very good results some of the tests are listed below.

- To measure the roughness of the pavement surface.
- To measure the resistance offered by the pavement surface against skidding of vehicles.
- To measure the pavement macro texture for the geometrical deposition.
- To assess the structural evaluation of flexible pavement for the strength of the pavement
- To Measure the Field Density of the road.
- To study the Gradation of the laid road.
- To carry out different tests on recovered bitumen.
- Examine the condition of the road (cracks, raveling, potholes, rutting, corrugation edge Break)

The Gandhi nagar town is a busy road that is situated in kakainada with heavy traffic over it. All the standard tests have been conducted to study the performance of the road In spite of the heavy traffic, rain, and high temperature this is the only road still remaining in good condition since 2018 whereas other roads were repaired subsequently.

- From the skid resistance studies it has been proved that the entire road was having good skid resistance values.
- From the surface texture studies it has been proved that the roads inside the campus and the other two outside roads have good texture values.
- From the deflection studies it has been proved that all the stretches are reasonably strong.
- From the bump integrator studies it has been proved that the unevenness index value of these three road sections is nearly to 3000 mm/km, which indicates a good surface evenness.

Table 12 Economics of the process

Size of the road	1kmX 3.75 m
Bitumen needed	9 tonnes
Plastics needed	1 tonnes
Bitumen save	1 tonnes
Cost reduced	Rs,18,000

The plastics waste collected is around 650 tonnes/ annum. The roads available are approximately 400km and their annual requirement of plastic waste to lay plastic road is more than 600 tons. So the total waste generated could be used for road laying. The life of the road is increased and hence the maintenance expenditure is reduced.

5. Conclusion:-

The generation of waste plastics is increasing day by day. The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. Stone aggregate is coated with the molten waste plastics. The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many respects.. If they are constructed as plastic tar road, there will be less waste plastic available on the road. The process is ecofriendly. The use of waste plastics in the manufacture of pathway blocks and laminated roofing also help to consume large quantity of waste plastics. These processes are ecofriendly and socially highly relevant, giving better infrastructure. Let us grow with these newer technologies.

The polymer coated aggregate with higher percentage of polymers is compacted into a block. The block shows good compressive strength and bending strength explaining the power of adhesion of the polymers. This property helps to improve the stability of the PCA bituminous mix. Moreover during the mixing of bitumen with PCA the temperature is around 140- 150º C and both polymers and bitumen are in the fluid state. They mix at the surface, and bitumen spreads well resulting in increased bonding between aggregate and bitumen.

The removal of bitumen is very slow and difficult and nearly 85 percentage only is removed. The rest is held at the surface of the aggregate by the coated polymers. The residue, when washed further with a solvent for polymer called decline both bitumen and polymer are removed. The molten polymer acts as a good binder and hence this acts as a good substitute in the preparation of flexible pavement mix. The quantity of bitumen is reduced to the extent of polymer used, in the mix preparation.

PCA helps to

1. Improve the quality of aggregate
2. Improve binding and bonding of bitumen
3. Improve Marshall Stability Value which is the resultant of the above property.

The study clearly shows that the property of bitumen is unaltered in this process and rather the strength of the PCA bituminous mix is increased. The following advantages were observed during the structural and functional evaluation of the polymer modified flexible pavement:

- Better binding property as observed in extraction of binder test.
- Lower penetration value (65mm) and hence higher load carrying capacity
- The Marshall stability value of the Semi Dense Bituminous Concrete (SDBC)has increased by about 30 percentage on using PCA
- Water absorption was found to be less in PCA by 30.80 percentages as compared to plain aggregate which indicates a higher degree of water susceptibility.

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