RESEARCH ARTICLE OPEN ACCESS

Influence of Polyethylene Glycol on Asphaltic Concrete for Cubical and Rod shaped Aggregates

U. Arun Kumar*, P.V.V.Satyanarayana**, T. Srikanth***
*(Associate Professor, Department of Civil Engineering, GMR Institute of Technology, Rajam-532127
Email: uakiitm98@gmail.com)
** (Professor, Department of Civil Engineering, AU College of Engineering, Andhra University-Vizag-530003
Email: pasalapudisat@yahoo.co.in)
*** (M. Tech Student, Department of Civil Engineering, GMR Institute of Technology, Rajam-532127
Email: tangudusrikanth513@gmail.com)

ABSTRACT
Aggregates are the principle material in pavement construction. Conventional road aggregates in India are natural aggregates obtained by crushing rocks. Aggregate characteristics such as particle size, shape, and texture etc.., influence the performance and serviceability of pavement. Pavements laid with polymer modified asphalt exhibits greater resistance to rutting, thermal cracking and fatigue damages and hence these were used at locations of higher stress.

The present work concentrates on aggregate characteristics which include the shape indices. The particle shapes namely Cubical and Rod are being used in the study. The study shows the behavior of the two shapes of aggregate in terms of Penetration, Ductility, Softening Point and Marshall Stability tests with varying percentages of asphalt and also with varying the percentages of PEG. The results of unmodified asphalt mix are compared with the modified asphalt mix against some critical Marshall Mix parameters.
***Keywords* -** Asphalt modified with polymers, Flow of asphalt, PEG, Shape of the aggregates and Stability.

I. INTRODUCTION

1.1 AGGREGATES

Aggregates are crystalline or granular rocks that are extracted from natural rock for use in the construction industry. These can be either primary aggregates (extracted from the ground in quarries) or secondary aggregates (recycled from construction waste). Aggregates are an essential material in constructing and repairing entities such as roads, railways and buildings. The aggregates used in this study were separated firstly based on the size and secondly based on the shape (Cubical and Rod).

1.2 ASPHALT

The term asphaltic materials are generally used to denote substances in which asphalt is present or from which it can be derived. Asphalt is defined as an amorphous, black or dark-colored, (solid, semi-solid, or viscous) cementetious substance, composed principally of high molecular weight hydrocarbons, and soluble in carbon disulfide.

Asphalts may occur in nature (natural asphalts) or may be obtained from petroleum processing (petroleum asphalts). Asphaltic mixtures are generally used to denote the combinations of asphaltic materials (as binders), aggregates and additives.

1.3 POLYETHYLENE GLYCOL (PEG)

Polyethylene glycols, also called macro gels, these are manufactured by polymerization of ethylene oxide (EO) with water, mono ethylene glycol or diethylene glycol as starting material, under alkaline catalysis. After the desired molecular weight is reached (usually checked by viscosity measurements as in-process control) the reaction is terminated by neutralizing the catalyst with acid. Normally lactic acid is used, but also acetic acid or others can be found.

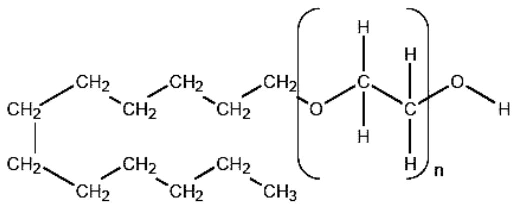


Fig. 1.1: Chemical structure of PEG

The Chemical equation of PEG is:
$HO\text{-}CH_2 – (CH_2\text{-}O\text{-}CH_2)_n\text{-}CH_2\text{-}OH$

II. MATERIALS USED

In this present work, the materials such as Aggregates (Coarse and Fine), Asphalt and PEG were used.

Aggregates of size 20mm, 16mm, 12.5mm, 10mm and 4.75mm were procured from Rapaka a place nearer to Rajam town located in Srikakulam District – Andhra Pradesh. All these aggregates of different sizes were sieved and segregated by taking their shape, length, width and thickness into consideration.

Asphalt of 60/70 grade was procured from HPCL refinery, Vizag – Andhra Pradesh.

PEG was procured from RFCL Industry, New Delhi.

III. TESTS PERFORMED AND THEIR RESULTS

3.1 TESTS ON AGGREGATES

After the sorting of aggregate based on shape, tests such as Los Angeles Abrasion Value, Aggregate Crushing Value, Aggregate Impact Value, Specific Gravity and Water Absorption, Elongation Index and Flakiness Index were conducted to find out the properties of the aggregate. The results of above tests were shown in Table 3.1.Aggregate Shape Analysis was carried out as per one of the standard procedure and the results were shown in Table 3.2. A comparison graph for the above tests with respect to shape of the aggregate is shown in Fig. 3.1.

Table 3.1: Results of tests done on aggregates

Sl. No.	Name of the Experiment	Aggregate Shape	
		Cubical	Rod
1	Los Angeles Abrasion value (%)	18.40	18.76
2	Aggregate Crushing Value (%)	27.66	31.23
3	Aggregate Impact value (%)	25.11	27.48
4	Specific gravity & Water absorption of Agg.	2.67	2.77
5	EI + FI (%)	21.50	21.19

3.2 SHAPE OF AGGREGATES

Aggregate Shape Analysis was performed to know the Elongation Ratio, Flatness Ratio, Shape Factor and Sphericity of the aggregate based on the shape.

Elongation Ratio: It is the ratio of the intermediate diameter to the longest diameter of the aggregate.

Flatness Ratio: It is the ratio of the shortest diameter to the longest diameter of the aggregate.

Shape Factor: It is the ratio of the shortest diameter to the square root of intermediate and longest diameter of the aggregate.

Sphericity: It is a measure of how spherical (round) an object is. As such, it is a specific example of a compactness measure of a shape.

The following formulae's were used to calculate the above said two parameters.

Elongation ratio = $\frac{d_I}{d_L}$ Flatness ratio = $\frac{d_s}{d_L}$

Shape factor = $\frac{d_s}{\sqrt{d_I \text{ X } d_L}}$ Sphericity = $\sqrt[3]{\frac{d_S \text{ X } d_I}{{d_L}^2}}$

3.3 TESTS ON ASPHALT

Tests such as Penetration Test, Softening Point Test and Ductility Test were conducted as per the standard procedure to find out the index properties of the asphalt (Unmodified and Modified). The results of above tests were shown in Table 3.3. A comparison graph for the above tests is shown in Fig. 3.2.

Table 3.3: Results of tests done on asphalt

Sl. No.	% of PEG	Average Penetration value (1/10)mm	Average Softening Point Temp. (^{0}C)	Average Ductility (cm)
1	0.0	69.33	51.5	78.0
2	0.5	67.67	52.5	82.0
3	1.0	66.67	54.0	83.5
4	1.5	66.00	56.0	85.5
5	2.0	65.33	57.5	86.5
6	2.5	64.00	59.5	87.0

3.4 MARSHALL STABILITY TEST

Marshall Stability Test was performed to find out the strength characteristics such as Stability, Flow, Unit Weight, OBC, etc. Marshall Samples were casted as per the standard specification of MORTH using unmodified asphalt for percentages of 3.0%, 3.5%, 4.0% and 4.5% and the same were tested. Samples of asphalt modified with PEG with 0.5%, 1.0%, 1.5%, 2.0% and 2.5% were also casted and tested where PEG content was taken by weight of Asphalt.

Based on the results obtained from the Marshall Tests, comparison graphs were plotted for Stability, Flow, Unit Weight and Optimum Binder Content (OBC). Here *Table 3.4*, *Table 3.5*, *Table 3.6 and Table 3.7* respectively shows the maximum value of Stability, Flow, Unit Weight and OBC obtained from the Marshall Test and the *Fig. 3.3*, *Fig. 3.4*, *Fig. 3.5 and Fig. 3.6* respectively shows the graphical representation of Stability, Flow and OBC. The tables and the figures were shown based on shape of aggregate and % of modifier used against a designated percentage of asphalt.

Table 3.2: Aggregate Shape Analysis test results

Sl. No.	Shape of the aggregate	Sieve size (mm)	d_L (mm)	d_I (mm)	d_S (mm)	Elongation ratio	Flatness ratio	Shape factor	Sphericity
1	Cubical	25 - 20	31.46	25.77	18.37	0.82	0.58	0.65	0.78
		20 -16	26.82	20.32	12.41	0.76	0.46	0.53	0.71
		16 - 12.5	21.4	19.49	12.39	0.91	0.58	0.61	0.81
		12.5 - 10	16.19	12.79	10.08	0.79	0.62	0.70	0.79
		10 - 4.75	11.08	8.44	6.32	0.76	0.57	0.65	0.76
		Average				**0.81**	**0.56**	**0.63**	**0.77**
2	Rod	25 - 20	35.92	29.02	23.46	0.81	0.65	0.73	0.81
		20 -16	30.51	25.61	20.3	0.84	0.67	0.73	0.82
		16 - 12.5	19.93	17.22	13.21	0.86	0.66	0.71	0.83
		12.5 - 10	14.62	12.31	9.36	0.84	0.64	0.70	0.81
		10 - 4.75	10.11	8.99	7.42	0.89	0.73	0.78	0.87
		Average				**0.85**	**0.67**	**0.73**	**0.83**

Fig. 3.1: Graphical representation of the tests done on aggregates

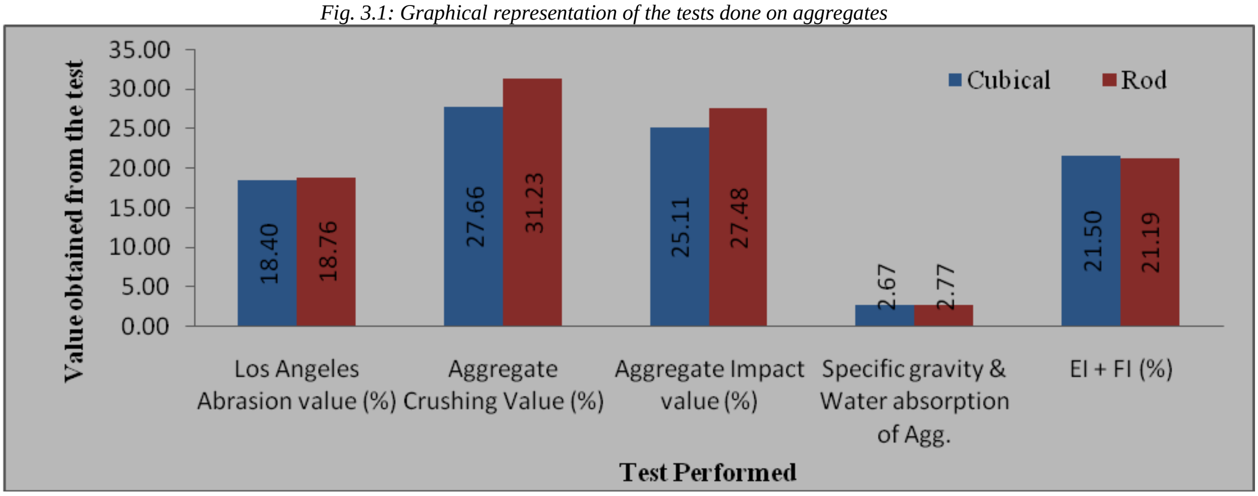


Fig. 3.2: Graphical representation of all the tests on asphalt

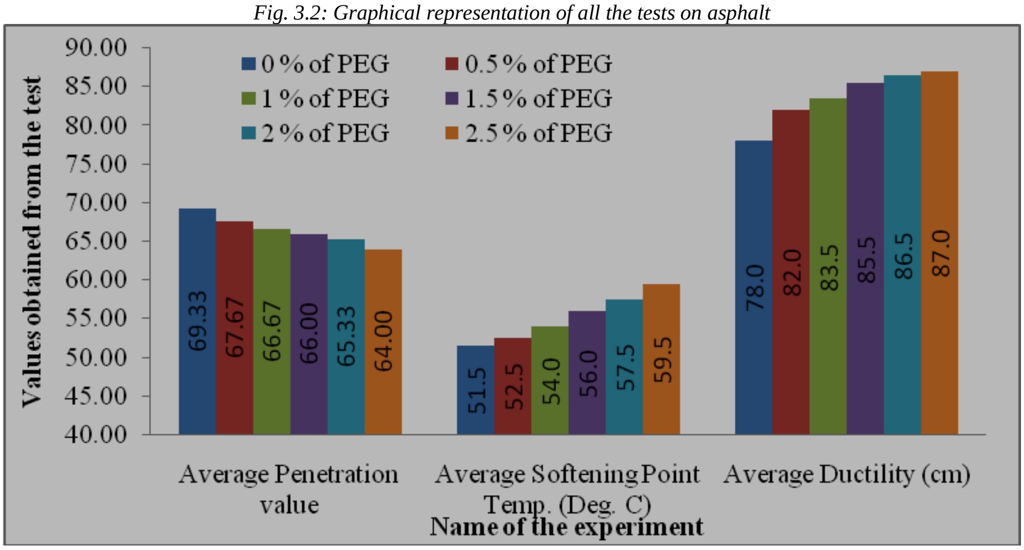


Table 3.4: Maximum Stability (kN) based on Shape and % of modifier

Sl. No.	% Bitumen	% PEG	Stability (kN)	
			Cubical	Rod
1	4.0	0.0	12.017	11.460
2		0.5	12.656	12.088
3		1.0	13.616	13.089
4		1.5	14.848	14.061
5		2.0	14.663	14.054
6		2.5	15.437	15.498

Fig. 3.3: Maximum Stability (kN) based on Shape and % of modifier

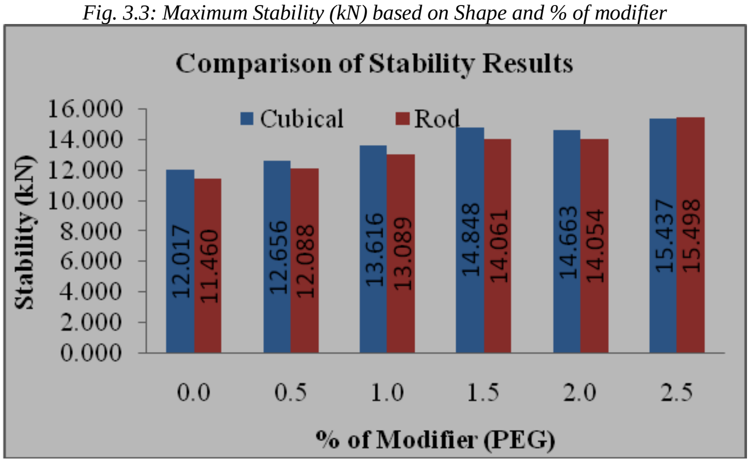


Table 3.5: Maximum Flow (mm) based on Shape and % of modifier

Sl. No.	% Bitumen	% PEG	Flow (mm)	
			Cubical	Rod
1	4.5	0.0	2.867	2.617
2		0.5	3.025	2.775
3		1.0	3.125	2.900
4		1.5	3.500	3.175
5		2.0	3.325	3.075
6		2.5	3.625	3.650

Fig. 3.4: Maximum Flow (mm) based on Shape and % of modifier

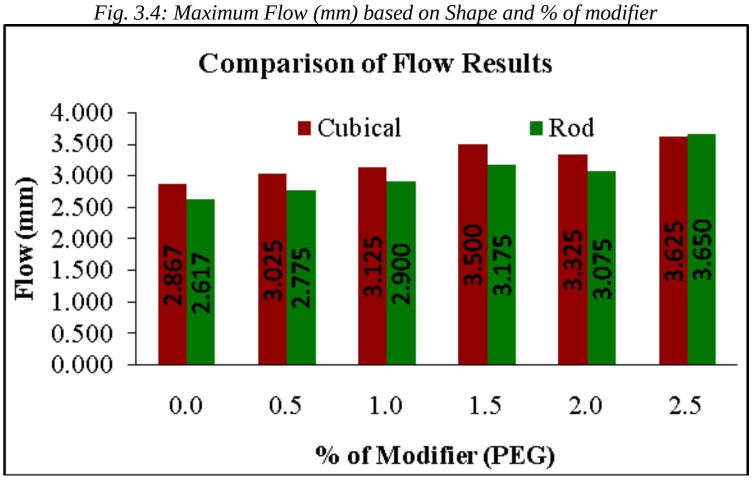


Table 3.6: Maximum Unit Weight (kN/m^3) based on Shape and % of modifier

Sl. No.	% Bitumen	% PEG	Unit Weight (kN/m^3)	
			Cubical	Rod
1	4.0	0.0	23.834	23.723
2		0.5	23.846	23.734
3		1.0	23.859	23.756
4		1.5	23.866	23.775
5		2.0	23.861	23.769
6		2.5	23.879	23.786

Fig. 3.5: Maximum Unit Weight (kN/m^3) based on Shape and % of modifier

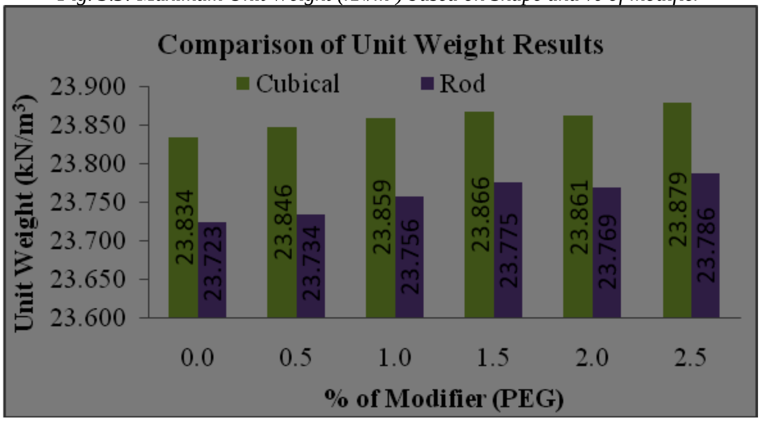
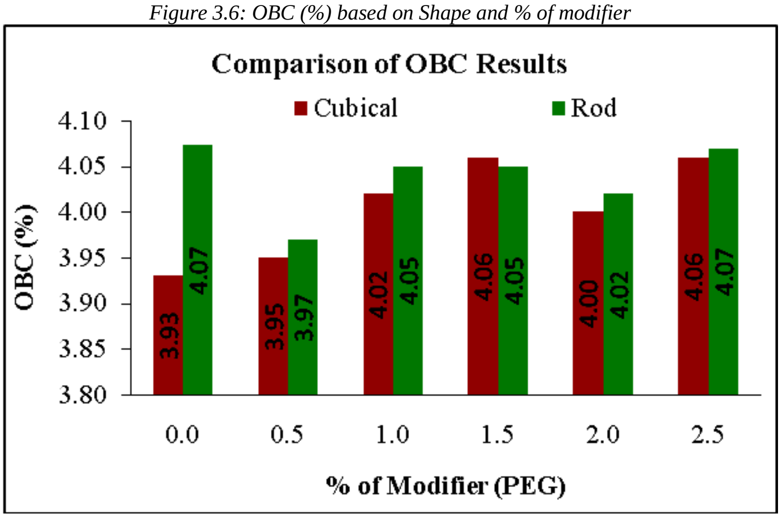


Table 3.7: Maximum OBC (%) based on Shape and % of modifier

Sl. No.	% PEG	OBC (%)	
		Cubical	Rod
1	0.0	3.93	4.07
2	0.5	3.95	3.97
3	1.0	4.02	4.05
4	1.5	4.06	4.05
5	2.0	4.00	4.02
6	2.5	4.06	4.07

Figure 3.6: OBC (%) based on Shape and % of modifier



IV. CONCLUSIONS

1. It was observed that the cubical aggregates produced better results in Los Angeles Abrasion Test **(18.40%),** Aggregate Crushing Value **(27.66%)** and Aggregate Impact Test **(25.11%)** when compared with Rod shape. The combined Elongation and Flakiness Index **(21.19%)** shows better result in Rod shaped aggregates when compared with Cubical shape.
2. It was observed that as the % of PEG is increasing the Ductility and Softening Point test results were also increasing but quite obviously there is a decrease in the Penetration test which in turn matches with the standard trend.
3. The percentile increments of Marshall Properties for Cubical shaped Aggregate:
   Stability was increased as shown below i.e., **5.31%, 13.30%, 23.55%, 22.01%** and **28.45%** when percentile of modifier is of 0.5, 1, 1.5, 2 and 2.5 respectively when compared with unmodified asphalt.
   Flow was increased as shown below i.e., **5.58%, 8.99%, 22.07%, 15.97%** and **26.43%** when percentile of modifier is of 0.5, 1, 1.5, 2 and 2.5 respectively when compared with unmodified asphalt.
4. The percentile increments of Marshall Properties for Rod shaped Aggregate
   Stability was increased as shown below i.e., **5.70%, 15.90%, 26.47%, 25.48%** and **40.87%** when percentile of modifier is of 0.5, 1, 1.5, 2 and 2.5 respectively when compared with unmodified asphalt.
   Flow was increased as shown below i.e., **6.90%, 14.49%, 29.68%, 23.69%** and **52.47%** when percentile of modifier is of 0.5, 1, 1.5, 2 and 2.5 respectively when compared with unmodified asphalt.

REFERENCES

Journal Papers:

[1] Amit gawande, G. S. Zamre, V. C. Renge, G. R. Bharsakalea and Saurabh Tayde (2012) Utilization of Waste Plastic in Asphalting of Roads, *Scientific reviews and Chemical Communications, Volume 2, pp. 147 – 157*.

[2] K. Lee, T. Park, R. Salgado, C. W. Lovell and B. J. Coree (1997) Use of Pyrolyzed Carbon Black as Additive in Hot Mix Asphalt, *Journal of Transportation Engineering, pp. 489 – 494*.

[3] Meor Othman Hamzah, Marliana Azura Ahmad Puzi and Khairun Azizi Mohd Azizli (2010) Properties of Geometrically Cubical Aggregates and its Mixture Design, *International Journal of Research and Reviews in Applied Sciences, Volume 3, pp. 249 – 256*.

[4] Mutiu Akinpelu, Bamidele I. O. Dahunsi, Oladipupo Olafusi, Olufemi Awogboro and Adedeji Quadri (2013) Effect of Polythene Modified Bitumen on Properties of Hot Mix Asphalt, *ARPN Journal of Engineering and Applied Sciences, Volume 8, pp. 290 – 295*.

[5] P.K Jain, Ambika Behl and Girish Sharma (2012) Study on Waste Polyvinyl Chloride Modified Bitumen for Paving Applications, *ARRB Conference, pp. 1 – 15*.

[6] Seracettin Arasan, A.Samet Hasiloglu and Suat Akbulut (2010) Shape Properties of Natural and Crushed Aggregate using Image Analysis, *International Journal of Civil and Structural Engineering, Volume 1, pp. 221 – 233*.

Code Books:

[7] Bureau of Indian Standards (BIS) (1963), Methods of test for Aggregate for concrete, Part I Particle Shape and Size, *IS: 2386 (Part – I), New Delhi, India*.

[8] Bureau of Indian Standards (BIS) (1963), Methods of test for Aggregate for concrete, Part III Specific Gravity, Density, Voids, Absorption and Bulking, *IS: 2386 (Part – III), New Delhi, India*.

[9] Bureau of Indian Standards (BIS) (1963), Methods of test for Aggregate for concrete", Part IV Mechanical Properties, *IS: 2386 (Part – IV), New Delhi, India*.

[10] Bureau of Indian Standards (BIS) (1978), Methods of testing Tar and Bituminous Material: Determination of Index properties of bitumen, *IS: 1201 to 1220 - 1978, New Delhi, India*.