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Influence Of Clay and Rubber On The Performance Of Egyptian Asphalt

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Abstract

The study was carried out to explore the addition effect of clay, modified clay, rubber, and mixture of both rubber and activated clay on the physical properties of asphalt (60/70). All materials were characterized by SEM. All additives were blended with asphalt in various percentages (starting from 2% to 8%). The blended asphalt were characterized using softening point (°C), and penetration test, and compared with that without additives. There is an increase in the number of pores for both activated clay and rubber compared to that of the non-activated clay. The results of the study indicated an increase in softening point and decrease in penetration. The best improvements in the modified binders were obtained using the mixture of rubber and activated clay. An increase of 28.8% in softening point was obtained by rubber-activated clay mixture. A decrease of24 % in penetration was obtained by rubber-activated clay mixture. The best improvements in the modified binders were obtained at the higher weight percentage of additive.

Keywords: Asphalt, clay, activated clay,rubber, softening point, penetration

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1. Introduction

Bitumen, which remains after vacuum distillation of crude oil, is a complex mixture of organic and inorganic compounds. Such compounds maybe separated into asphaltenes and maltenes. Asphaltenes are defined as the black-colored fraction of bitumen that is insoluble in n-heptane. Maltenes, composed of saturated compounds, aromatic compounds and resins, are soluble in n-heptane [1]. Bitumen binder is readily adhesive, highly waterproof, and durable making it a valuable engineering material. Bitumen has uses that range from the construction of the pavements of roads with an aggregate to waterproofing membrane in roofing and structural applications. It has been widely used as a binder in the construction of highways and runways for a long time due to its good viscoelastic properties [1]. Bitumen binder is a thermoplastic liquid which behaves as an elastic solid at low service temperatures or during rapid loading. At high temperatures or during slow loading, it behaves as a viscous liquid. The physical properties and chemical structures of asphalts will be changed when exposed to heat, oxygen, and ultraviolet (UV) light, which is called aging [2–4]. So the ideal asphalt [5] should possess both high relative stiffness at high service temperatures (summer) to reduce rutting and shoving, and increased adhesion between the asphalt and aggregate in the presence of moisture to reduce stripping.

Several additives are being used to increase the performance of asphalt binders. It has been found that physical properties, rheological behaviors of bitumen could be obviously improved due to the introduction of clay, since, the gallery spacing is increased and the resulting morphology is an intercalated structure[6-8].

Clay is used as a secondary modifier to further enhance the performance properties of asphalt. Both types of sodium montmorillonite (Na-MMT), and organophilicmontmorillonite (OMMT) nano-clays, were found to increase the viscosity of asphalt; and the stiffness (complex modulus), while the phase angle decreased. Also, Na-MMT and OMMT nano-clays have promising potential to reduce the permanent deformation rutting of asphalt pavements [9].

Elastomers and reclaimed rubbers are used. Elastomers such as styrene butadiene-styrene copolymer (SBS), styrene-butadiene rubber (SBR) and natural rubber can be used with bitumen. The application of mixing rubber with asphalt materials in roadwork could improve the quality of road pavement, extend service life of the road, and reduce expenditures in maintaining road pavement. Elastomer modification of bituminous materials is manifest in the following ways;softening temperature is increased, cold flow is reduced, change in penetration with temperature is reduced, brittleness temperature is lowered, elastic recovery is impartedresistance to deformation under stress is increased markedly, ductility is increased, particularly at low temperatures [10].

Plastics such as polyethylene (PE), polypropylene (PP), polystyrene and ethylene vinyl acetate(EVA) are used with bitumen. EVA and low density polyethylene (LDPE) are used as thermoplastics[11]. Mixing polymers into bitumen has important consequences on the engineering properties of bituminous materials. The extent of modification and the improvements in the performance characteristics depend on bitumen nature, polymer chemical nature, its dosage and chemical compatibility, molecular weight, particle size, as well as blending process conditions such as type of mixing/dispersing device, time and temperature playimportant role in determining the modified asphalt properties [12].Bitumen modification by polymers improves its mechanical properties, increases the viscosity, allows an expansion of temperature range of service and improves the deformational stability and durability of bitumen [13].High molecular weight polymers have profound effects on the properties of bitumen. As the molecular weight of polymers increases, their compatibility with bitumen sharply decreases [14-15].

The aim of the present work is to add different additives such as clay, activated clay, rubber, and a mixture of rubber-clay to bitumen 60/70 with different percentages. Physical properties of bitumen such as penetration test, and softening point were examined for each added material, and the results were compared to determine which material is the most effective in improving physical properties of bitumen 60/70.

2. Materials and methods

2.1 Materials

Local asphalt of penetration grade 60/70, produced by Amriya Petroleum Companyin Egypt was used. Its physical properties, and chemical constituents are shown in Table 1. Local organo clay taken from El Amriyacompany was added to the asphalt with different amounts. The physical, and chemical constituents of clay are shown in both tables 2, and 3.Activated clay was also added to asphalt with different amounts. Rubber tires of power wheels were also used to investigate their effects on the physical properties of asphalt.

Table 1 : physical and mechanical properties of asphalt 60/70

Properties	Values
Penetration at 25 °C 25 g, 5 s, 0.1 mm	65
Kinematics viscosity at 135 °C, C.st	45.8
Ductility at 25°C, 5 cm/min, cm	Less than 100
Flash point,°C	330
Softening point °C (Ring and Ball)	45.8

Table 2: clay physical constants

Molecular weight (g/mol)	540.46
Average density (g/cm^3	2.35
Crystal system	Monoclinic
Member of	Smectite group
fracture	Uneven to lamellar
luster	Earthy (dull)
Mohs scale Hardness	1.5-2.0
Average specific gravity (g/cc)	2.3-3.0
Color	White,yellow
cleavage	Perfect in one direction (basal)
characteristic	Crystal expand to many times their volume when added to water
Field indicators	Softness, and soapy feel

2.2.1. Preparation of asphalt with clay:
About 230 grams of the base asphalt (60/70) were heated to 140 °C and stirred for about5mins, the temperature was raisedto160°C, then four different percentages of clay (2%, 4%, 6%, and8% by weight) were added slowly to the base asphalt with continuous stirring at 160 °C for about two hours until it achieves a completely homogenous asphalt blends.All the prepared binders were left to cool at room temperature [16].

2.2. Methods:

2.2.2. Activation of clay:
Clay was activated by air-drying and grinding. The clay sample was weighed into flask and sulphuric acid solution was added. The resulting suspension was stirred at room temperature for 24 h [17]. At the end of the experimental duration, the resulting slurry was poured into a Buchner funnel to separate the acid and clay. The residual clay was washed several times with

distilled water and dried. After drying at 105˚C for 4 h, the activated samples were stored in tightly closed plastic bottles [17].

Table 3: chemical analysis of clay

constituents	Raw clay (wt.%)	Room temperature (wt.%)	Water free (calculated) (wt.%)
SiO_2	48.11	49.94	54.32
TiO_2	4.16	5.65	6.68
Al_2O_3	14.56	14.42	17.05
Fe_2O_3	7.48	8.48	10.03
FeO	0.19	0.03	0.03
MnO	0.05	0.02	0.02
MgO	2.73	2.44	2.88
CaO	1.93	1.69	2.00
Na_2O	0.12	0.06	0.07
K_2O	0.92	0.42	0.50
Li_2O	-	0.002	0.00
P_2O_5	0.07	0.05	0.06
H_2O+ (loss on ignition at 1000°C)	4.59	5.38	6.36
H_2O- (moisture content determined byheating to 105 °C and measuring weight difference)	14.75	15.12	-

2.2.3. Preparation of asphalt with activated clay:
About 230 grams of the base asphalt (60/70) were heated to 140 °C and stirred for about 5mins, the temperature was raisedto160°C, then four percentages of activated clay (2%, 4%, 6%, and 8% by weight) were added slowly to the base asphalt with continuous stirring at 160 °C for two hours until it achieves a completely homogenous asphalt blends. All the prepared binders were left to cool at room temperature [16].

2.2.4. Preparation of rubber tires:
Rubber wastes were sorted, impurities, and foreign materials were removed. Rubber tires were cut into small pieces by saw, grinded into different sizes. Rubber of particle size 1 mm was separated by mechanical sieve for usage.

2.2.5. Preparation of asphalt with rubber tires:

About 230 gramsof the base asphalt (60/70) were heated to 140 °C and stirred for About 5mins, the temperature was raisedto160°C then four percentages of rubber tires (2%,4%, 6%, and 8% by weight) were added slowly to the base asphalt with continuous stirring at 160 °C for two hours until it achieves a Completely homogenous asphalt blends. All the prepared binders from were left to cool at room temperature [16].

2.2.6. Preparation of asphalt binder with a mixture of rubber tires and clay:

About 230 gramsof the base asphalt (60/70) were heated to 140 °C and stirred for About 5mins, the temperature was raisedto160°C then four percentages of a mixture of rubber tires and activated clay (2%, 4%, 6%and 8% by weight) were added slowly to the base asphalt with continuous stirring at 160 °C for two hours until It achieves a Completely homogenous asphalt blends. All the prepared binders were left to cool at room temperature [16].

2.3. Testing procedures:

The principal test methods on the modified blends of the asphalt binder and unmodified asphalt are:

2.3.1. Physical properties:

Penetration test at 25 °C according to ASTM D5-97, Softening point (Ring and Ball) according to ASTM D36-95 were carried out. Figures 1, and 2 show the apparatus used for measuring both penetration, and softening point.

3. Results and Discussions:

3.1. Scanning electron microscope (SEM):

Figure 3 presents SEM image of the pores of clay. A particle size of 10 µm can be seen in the figure. On the other hand, Figure 4 presents SEM micrographs of thepores of activated clay. Figure 5 shows the internal pores of rubber. As shown in the figure, there is an increase in the number of pores for both activated clay and rubber compared to that of the non-activated clay. Consequently, a well-developed porous network for both activated clay and rubber resulted in improving the physical properties of asphalt.

3.2 Penetration test:

3.2.1. Effect of adding clay on the penetration of asphalt:

Fig.6 shows that the penetration value decreased with increasing weight of clay at 25°C. The decrease in the penetration value for asphalt with macro clay ranged from 3.1 % to 18%.

3.2.2. Effect of adding activated clay on the penetration of asphalt:

Fig.7 shows that the penetration value was decreased with increasing weight of activated clay at 25°C. The decrease in the penetration value for asphalt with macro activated clay ranged from 4.6 % to 21.5 %.

3.2.3 Effect of adding rubber on penetration of asphalt:

Fig.8 shows that the penetration value was decreased with increasing weight of rubber at 25°C. The decrease in the penetration value for asphalt withrubber was from 6.2 % to 23%.

3.2.4 Effect of adding a mixture of activated clayand rubber on penetration of asphalt:

Table 4 shows that the penetration value was decreased when adding a weight 2% of a mixture of activated clay and rubber with varying percentages for both substances at 25°C. The decrease in the penetration value for asphalt with a mixture of activated clay, and rubber ranged from 10.3% to 20%.

Table 4: Effect of adding a mixture of 2%, and 4% (activated clay and rubber) on penetration

2% of a mixture of activated clay and rubber	Penetration 0.1 mm	4% of a mixture of activated clay and rubber	Penetration 0.1 mm
50 % rubber and 50 % activated clay	59	50 % rubber and 50 % activated clay	57.5
33 % rubber and 67 % activated clay	53	33 % rubber and 67 % activated clay	52.5
33 % activated clay and 67 % rubber	52	33 % activated clay and 67 % rubber	49.5

On the other hand, the penetration value was decreased when adding a weight 4% of a mixture of activated clayand rubber at 25°C. The decrease in the penetration value for asphalt with a mixture of activated clay, andrubber ranged from 11.5% to 24%.

3.3. Softening point temperature:

3.3.1. Effect of adding clay on softening point of asphalt:

Fig. 9 shows that the softening point temperature was increased with increasing weight of clay. The increase in softening point temperature of asphalt by adding macro clay ranged from 0.5 % to 9.1%.

3.3.2. Effect of adding activated clayon softening point of asphalt:

Fig. 10 showsthat the softening point temperature was increased with increasing weight of activated clay. The increase in softening point temperature of asphalt by adding macro activated clay ranged from 1.5 % to 15.7%.

3.3.3. Effect of adding rubber on softening point of asphalt:

Fig. 11 shows that the softening point temperature was increased with increasing weight of rubber. The increase in softening point temperature of asphalt by adding rubber ranged from 2.6 % to 22.3%.

3.3.4 Effect of adding a mixture of activated clay and rubber on softening point of asphalt:

Table 6 showed that softening point temperature increased when adding 2% weight of a mixture of activated clay and rubberwith varying percentages for both substances. The increasein the softening point temperature of asphalt with the addition of the previous mixture activated was from 6.7% to 24.5%.On the other hand, softening point temperature increased when adding a 4% weight of a mixture of activated clay and rubberwith varying percentages for both substances. The increase in the softening point temperature of asphalt with the addition of the Previous mixture was from 9.1% to 28.8%.

Table 6: Effect of a mixture of 2%, and 4% (activated clay and rubber) on softening point

2 % of a mixture of activated clay and rubber	Softening point °C	4 % of a mixture of activated clay and rubber	Softening point °C
50 % rubber and 50 % activated clay	49	50 % rubber and 50 % activated clay	50
33 % rubber and 67 % activated clay	54	33 % rubber and 67 % activated clay	55
33 % activated clay and 67 % rubber	57	33 % activated clay and 67 % rubber	59

4. Conclusions:

- In this study, four different materials including clay, activated clay, rubber, and a mixture of rubber-activated clay were used for improving asphalt physical properties. All materials were characterized by SEM. Based on the results of this study, the conclusions can be drawn in the following:
- There is an increase in the number of pores for both activated clay and rubber compared to that of the non-activated clay.
- Consequently, a well-developed porous network for both activated clay and rubber resulted in improved physical properties of asphalt.
- The addition of 4% weight percent of activated clay and rubber mixture increases the softening temperature by a factor of 28.8 compared to the base asphalt.
- The addition of 4% weight percent of activated clay and rubber mixture decreases the penetration by a factor of 24 % compared to the base asphalt.

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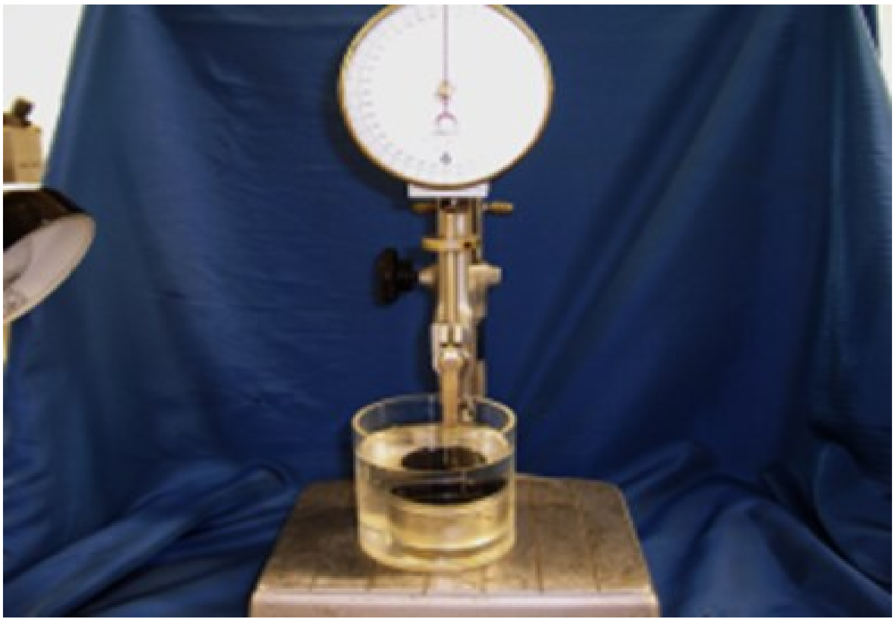

Figure 1: Penetration test apparatus

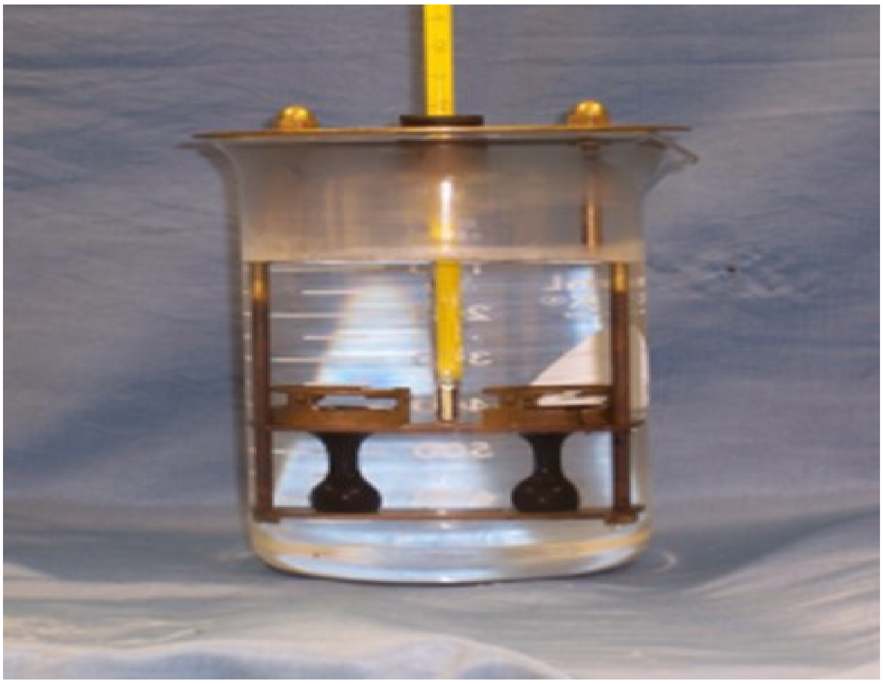

Figure 2: Softening Point test apparatus

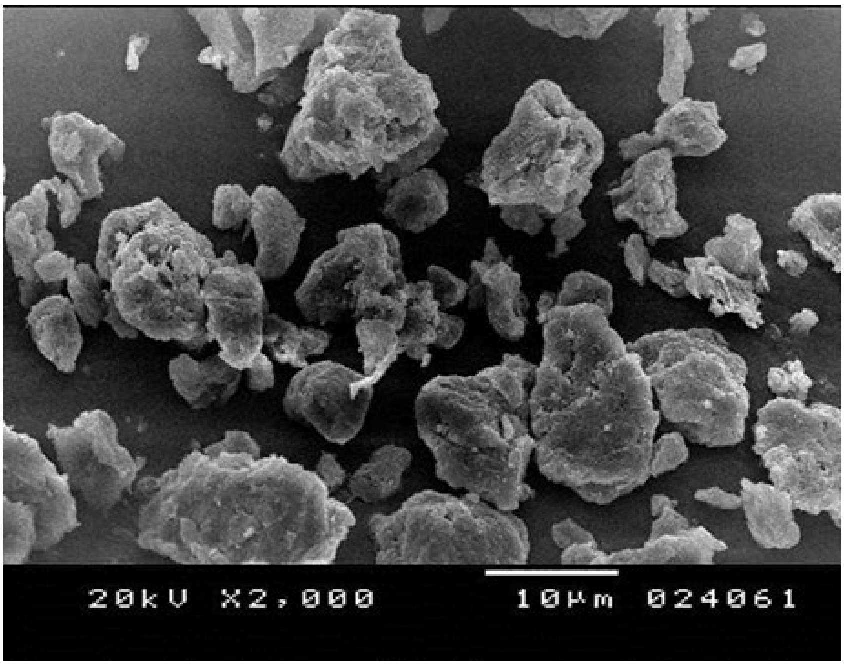

Figure 3: SEM of clay

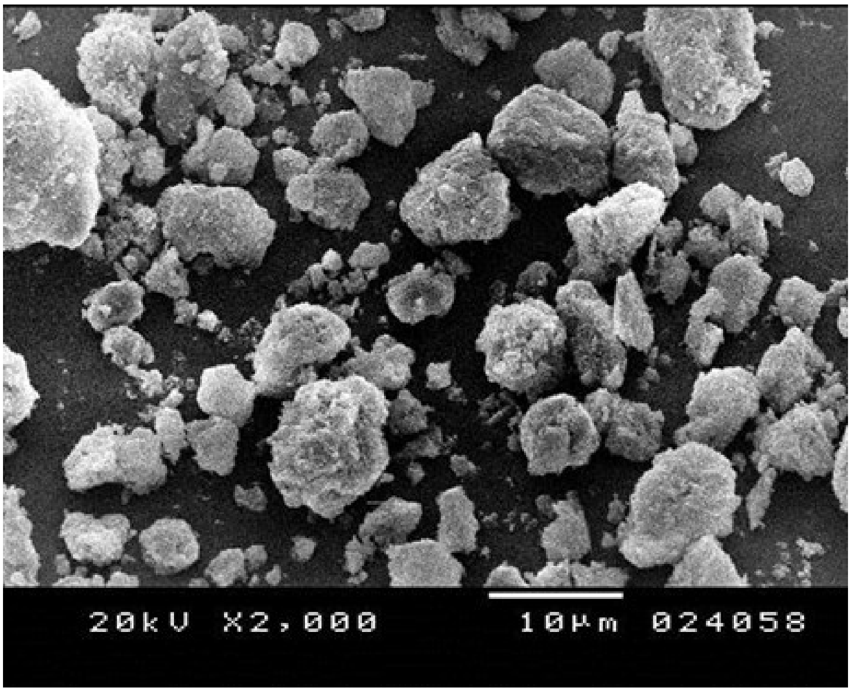

Figure 4: SEM of activated clay

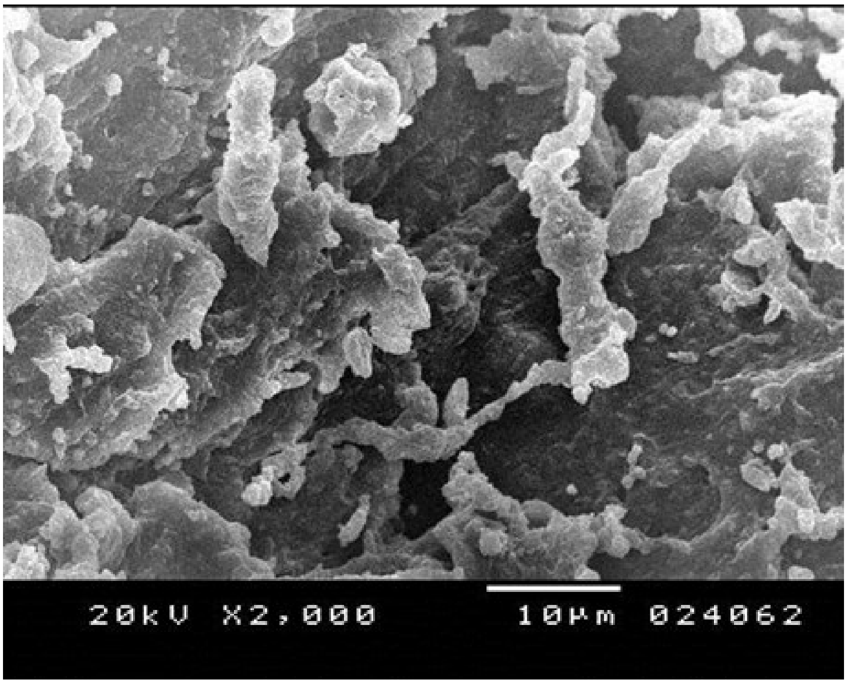

Figure 5: SEM of rubber

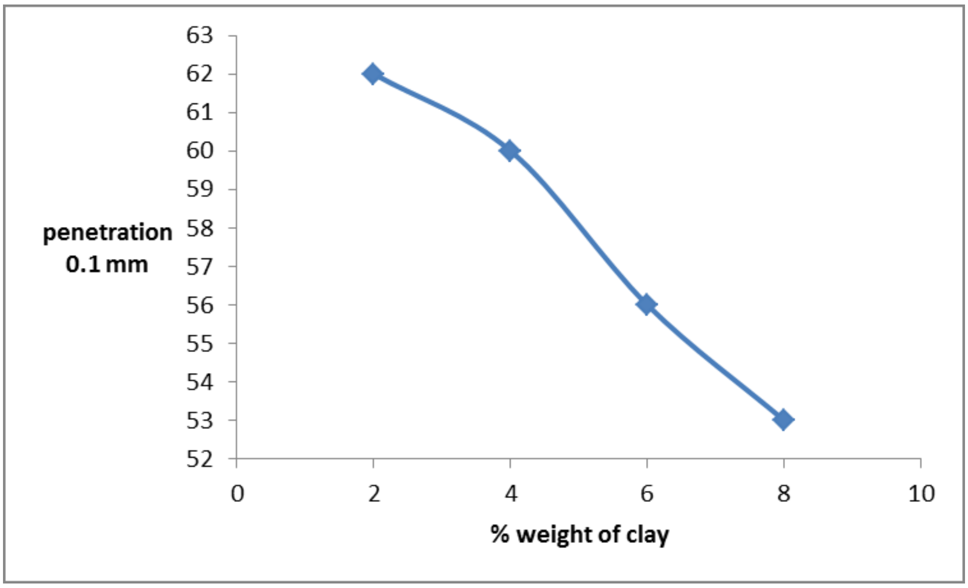

Figure 6: effect of % weight of clay at 25°C on penetration.

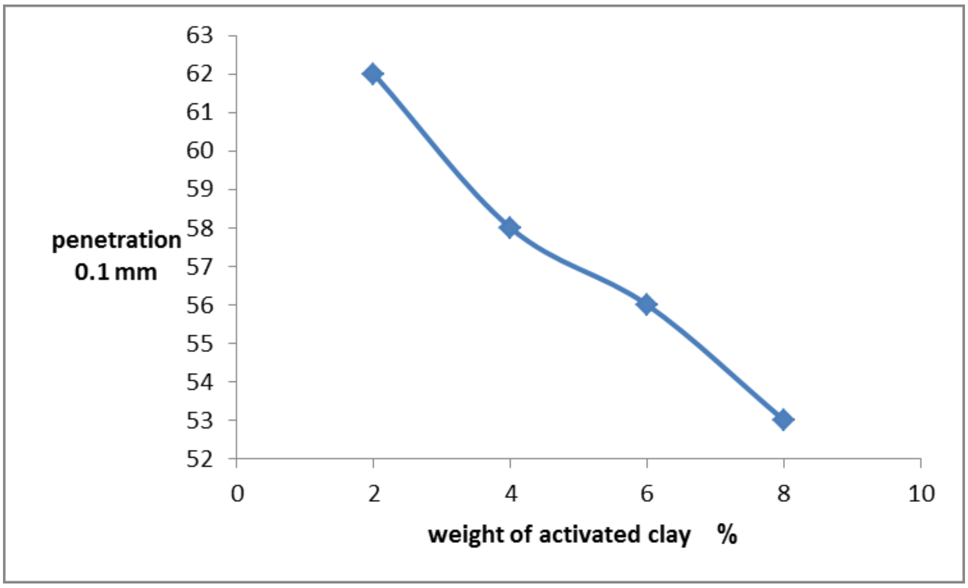

Figure 7: Effect of % weight of activated clay at 25°C on penetration.

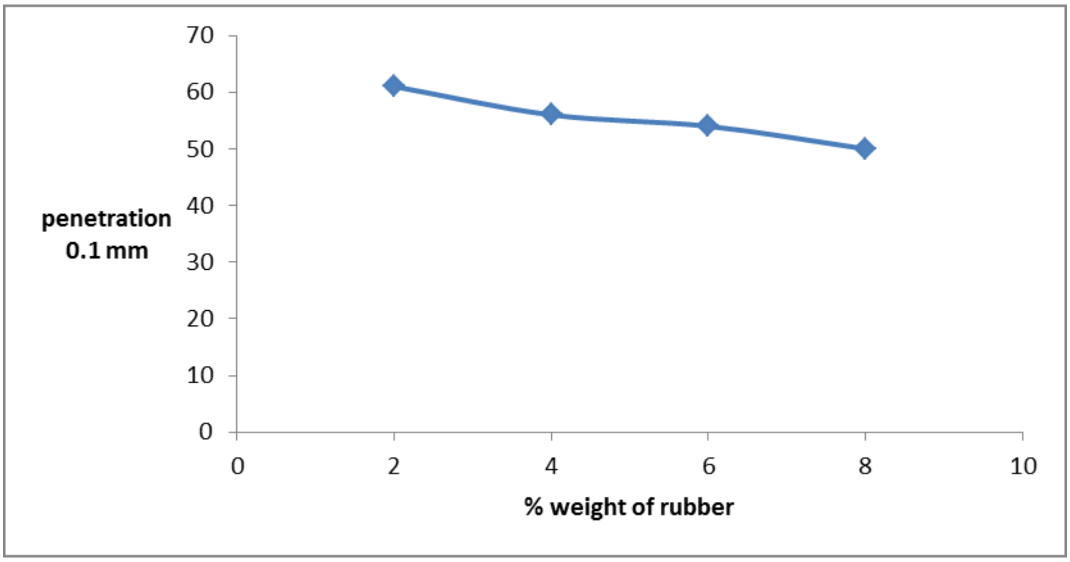

Figure 8: Effect of % weight of rubber at 25°C on penetration.

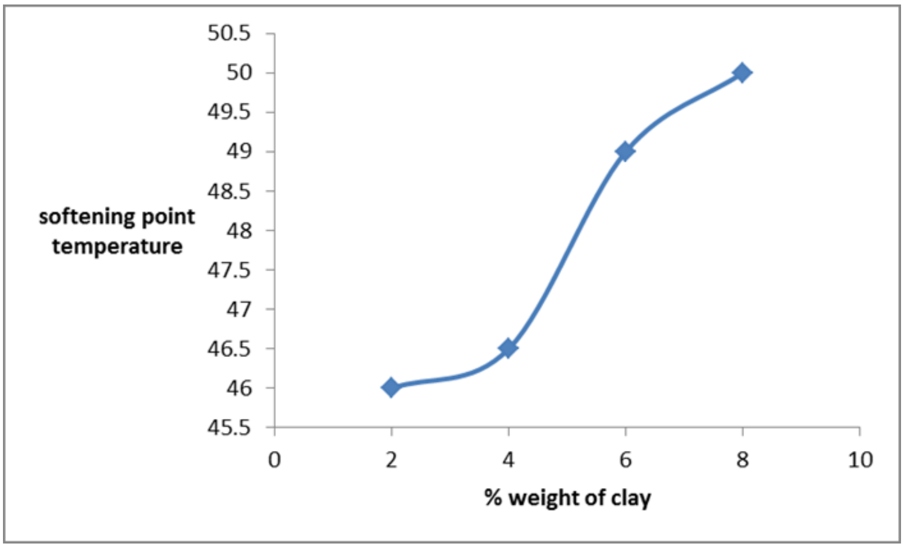

Figure 9: Effect of % weight of clay on softening point temperature

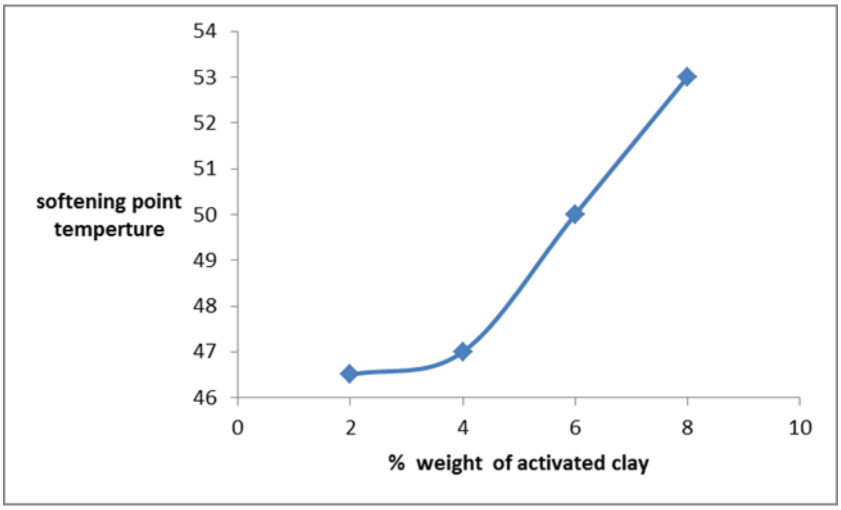

Figure 10: Effect of % weight of activated clay on softening point temperature.

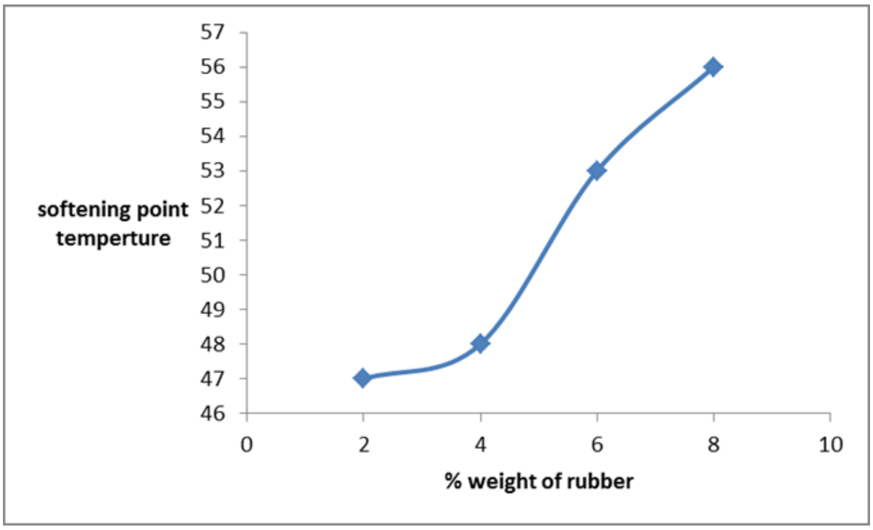

Figure 11: Effect of % weight of rubber on softening point temperature.