Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 241-250, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.22

IMPROVEMENT THE COMPRESSIBILITY IN RESIDUAL SOILS BY USING STYRENE BUTADIENE RUBBER

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ABSTRACT

A new stabilizing agent was sophisticated to improve the geotechnical performance and applicability of residual soils. The laboratory test includes specific gravity, sieve analysis and hydrometer test with consistency limits test to classify the used soils and standard compaction test with compressibility tests to evaluate the stabilizer effect on engineering soil properties. Two types of soils MH and SM were mixed with various amount of polymer SBR (Styrene Butadiene Rubber) 2.5, 5, 7.5, 10, and 12.5 % by weight and compacted at the optimum moisture content (OMC) and maximum dry density (MDD). The virgin soil and the stabilized samples were subjected to consolidation test to determine their compressibility at different curing times 1,3,7,14,28 days. The results of the test show that the SBR significantly improved the compressibility of residual soil. Where the plasticity index decreasing in both soils used by 81% and 77% in MH and SM soil respectively. While Increase in the pre-consolidation pressure ($P_{c)}$ about 62.5% and 300% at MH and SM respectively. The compression index (C_c) decreases 256% and 200% at MH and SM soils respectively. Curing time had an effect on all geotechnical soil properties were tested after 14 days curing

KEYWORD: Chemical stabilization, Polymer additives, Consolidation, SBR, Curing time.

1. INTRODUCTION

Residual soils are wide range separated in tropical and subtropical region in the word and the well-known type of it's the lateritic residual soil at reddish color (Eberemu A.O, 2011). Therefore, it was commonly used in different engineering practices such as the construction of earth dams, embankments, highways, airfield, water canal, foundation materials to support structures,…. etc.(Badmus B.S., 2010). This type of soil is unsuitable to be used in different construction practices as a local soil, either because of inadequate strength or excessive volume change with varying moisture content, or because of loss of strength on wetting. These also tend to have high plasticity and low strength (Huat Bujang B.K. et al., 2004). In recent years, the types of desert soil start to reduce, therefore; the construction companies turn to use the un-desert soil with need to be stabilized.

Application stabilizing refers to any physical, chemical or biological method, or any combination of such methods, which employed to improve the geotechnical soil properties of a locally available soil to make it adequately serve an intended engineering purpose over the service life of an engineering facility (Sayed Abolhassan Naeini et al., 2012, Naderi Nia and Naeini S. A., 2009). Chemical stabilization can be divided into two categories: traditional stabilizers and nontraditional soil stabilization additives. Traditional stabilizers, as cement, lime, fly ash, bituminous product, have been intensely researched and their fundamental stabilization mechanisms have been identified. Nontraditional soil stabilization additives consist of a variety of chemical agents that are diverse in their composition and in the way they interact with the soil. Most nontraditional stabilizers can be classified into seven items: ionic, enzymes, lingo sulfates, salts, petroleum resins, tree resins, and polymers (Jeb S. Tingle et al., 2007). The use of polymeric materials as a stabilizer in soil improvement is growing daily. Unfortunately, there is no clear procedure to follow for selecting this type of stabilizers and no study has completely tackled on these materials (Sayed Abolhassan Naeini et al., 2012, Naderi Nia and Naeini S. A., 2009).

Styrene Butadiene Rubber (SBR) is an example of the liquid additives, which is a random copolymer, derived from styrene and butadiene monomers. There are two classes of SBR, emulsion SBR (E-SBR) and solution SBR (S-SBR) (Matzen D. and Straube E., 1992). Solution (SBR) is one of the polymer groups that have colossal potential applications in different industries (ADOMAST, 2011). SBR can be considered as one of the inexpensive chemicals, widely available, non-toxic, and readily soluble in water. Furthermore, it can be applied as local soil stabilizer in construction site work with no specific required instrumentations (Ahmed F. et.al, 2013).

This experiment was studied the compressibility of the residual soil by using one dimensional

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consolidation (oedometer) test to evaluate the polymer effect on remolded samples for two residual soils used .

2. MATERIALS

2.1. Soils

The soils used in this study were brought from two sites in Malaysia as shown in Fig.1. all samples of soil carried from one meter or less from ground surface and then air dried in lab. The soil properties were classified into high plasisity silt MH and silty sand SM soil respectively, according to the Unified Soil Classification System (USCS), as illustrated inTable1 and Fig.2.

2.2. Polymer

Next Base Technology (NBT II) is the commercial name for the chemical additives that were used in this experiment, which has a scientific name as SBR "Styrene Butadiene Rubber". SBR was provided by Next Base Technology Company in Malaysia. Table 2 refers to the chemical composition of the polymer.

Fig. (1): Part of Malaysian Map, Location of the soils used: (1) MH and (2) SM

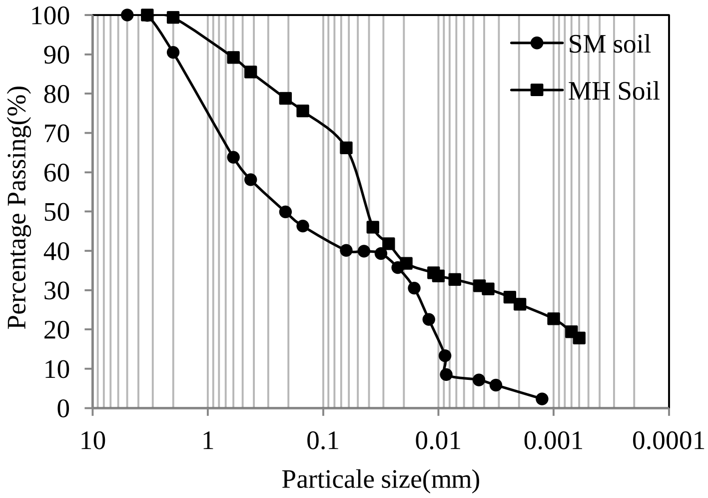

Fig. (2): Distribution curve for two soil used SM and MH

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Table (1): Soils properties.

Properties	MH soil	SM soil
Gs %	2.46	2.67
Color	Black to gray	Reddish yellow
L.L%	54	42
P.L%	34.5	30.5
P.I%	19.5	11.5
Cu	-	55.6 >3
Cz	-	0.072<1
pH	3.8	4.6
Organic content (OC)%	12.5	7
MMD g/cm^3	1.51	1.89
OMC %	24	13.7
USCS	MH	SM
e%	90.3	66
Sand %	35.5	60
Silt %	39.3	34.4
Clay %	25.2	5.6

Table (2): Chemical composition of the SBR

Test	Property	specification
PH	5.72	BS.1377: Part3:1990
Diffractive Index	1.402	ASTM D1747-09
Density	1.050	
Shear Strength	increase with time*	ASTM D196-99
Viscosity	increase with time*	ASTM D196-99
Conductivity	130.3 µs/cm	
Carbonate (total hardness)	8 mg/L	

***at room temperature and without cover**

3. SPECIMENS PREPARATION

The quantities of polymer and curing time are used in this experiment as listed in Table 3. All samples were oven dried (105 -110^{o}C) over 24hours after passing from ASTM. Sieve No.4 (opening size 4.75 mm).The polymer was diluted as a percentage by weight with distilled water at optimum moisture content (OMC) which obtained from compaction test then added to the soil by hand mixing until reaching to the uniform color then the sample was stored in a plastic bag and plastic container to maintain on its moisture. Basic soil properties conducted on virgin soils and the mixture as consistency limits, specific gravity and classification test (wet sieve analysis with a hydrometer) also pH test for soils and chemical composition of the polymer were done. Furthermore, the engineering properties tests such as consolidation and compaction tests are conducted for all soil mixture percentages.

Table (3): Mix design program

Soil ratio	Liquid stabilizer % by weight	Curing time (Days)
1	0.0	---------
1	2.5	1,3,7,14,28
1	5	1,3,7,14,28
1	7.5	1,3,7,14,28
1	10	1,3,7,14,28
1	12.5	1,3,7,14,28

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4. RESULTS AND DISCUSSION

4.1. Index properties

After mixing the soil with SBR, it shows reduction in plasticity index at small percentage and then increases with SBR% increases. These results can be attributed to the three reasons , first one the liquid stabilizer effect on soil by aggregation and flocculation to the soil particles by means less specific surface and hence less liquid limit (Lambe and Whitman, 1969)(Omotosho P.O. and J.O., 1992) (Suksun Horpibulsuk et al., 2011). The second, the polymer is work as a waterproof effect to prevent the water molecules from attack the soil particles. The third reason, the polymer is work as a cementation bond to join the particles togather and fill the spaces between it.

When the liquid chemical percentage was overfilled voids the soil becoming more friable and more plasticity. The Atterberge limits results for soil MH show improved index properties at small percentage of SBR with a decrease in liquid limit (L.L) and then increase L.L value more than the untreated soil value. It is also found an increase in plastic limit (P.L) at same SBR percentages and hence decrease in plasticity index (P.I) at low SBR percentage by weight. The liquid limit decreases from 54% to 46% and P.I decreases from 16.5% to 9.1% at untreated soil and 2.5% SBR respectively, while beginning to increase with SBR% increases.

The plasticity index results were presented in Fig. 3. The results for SM soil show reduction in plasticity index for all SBR percentages lesser than the untreated soil and the maximum reduction in 5%SBR was from 11.5 to 6.5 and the L.L decrease was from 42.2% to 38.8% at untreated soil and 5%SBR respectively . These results may be attributed to the texture of the soil used where more than 90% from particles size were sand and silt fraction while less than 10% clay fraction. The liquidity of this soil at untreated phase was attributed to the mineralogical composition that respect to residual soils. Fig. 4 refers to the plasticity index results for the SM soil.

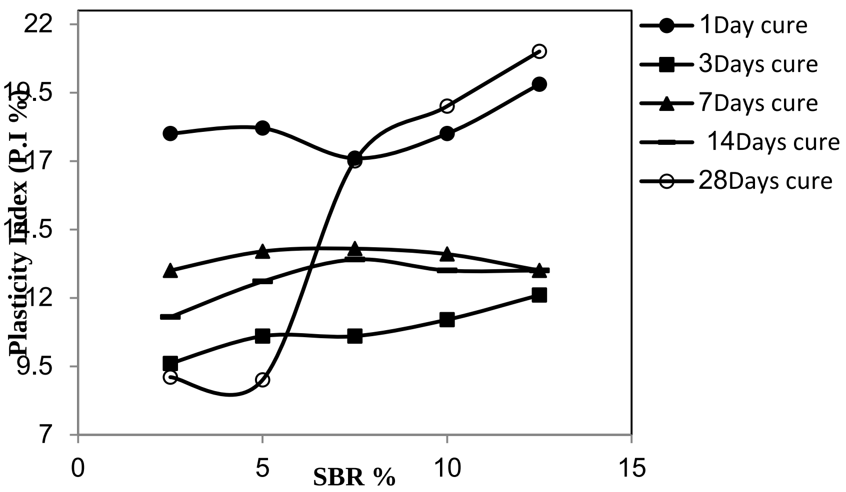

Fig. (3): Effect of SBR on plasticity index of MH soil at different curing time

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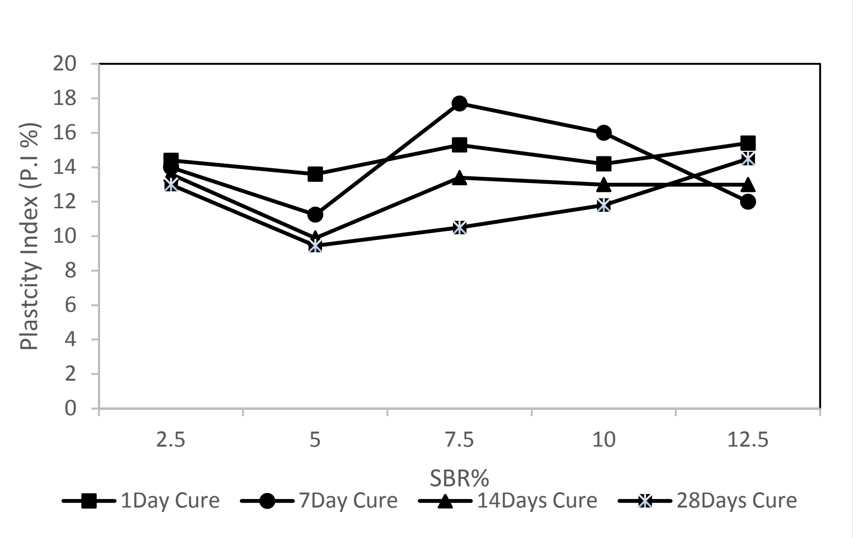

Fig. (4): Effect of SBR on plasticity index of SM soil at different curing time

4.2. Compaction

The maximum dry density (MDD) and optimum moisture content (OMC) effected by stabilizer amount. Table4 summarized the compaction test result for soils used. It can be concluded from the results that the MDD decreases for all stabilizer percentage used in both soils while the OMC slight increases in small percentages and then decreases. The decrease in MDD and increase in OMC were attributed to the density of stabilizer less than the density of the soil and the stabilizer used by weight when mixed with the soil. On the other hand, the stabilizer was affected by the increase of the lubricant of the soil particles and the high viscosity of liquid stabilizer. Similar behavior was also observed by (Ammar Abbas Mohammed et al., 2008) when they studied the effect of the bituminous on sandy soil.

Table (4): Effect of SBR on MDD and OMC for soils used

Stabilizer %	MH soil		SM soil	
	MDD g/cm^3	OMC %	MDD g/cm^3	OMC %
0	1.52	24	1.89	13.7
2.5	1.48	24	1.79	16
5	1.47	23.5	1.775	15.8
7.5	1.43	22.3	1.772	15
10	1.42	23.5	1.75	14.5
12.5	1.42	25.5	1.73	14.2

4.3. Consolidation

This test was carried out to establish the settlement coefficients such as pre-consolidation pressure, compression index, void ratio - SBR percentage and coefficient of volume compressibility. These coefficients can be discussed under the effect of different SBR percentage with curing times.

4.3.1. Pre-Consolidation pressure

The variation of pre-consolidation pressure with SBR percentage for both types of soils were used in this study as shown in Figs.(5–6). The trend shows increase in pre-consolidation pressure 62.5% from 400kPa to 650kPa after 28 days curing at 2.5% SBR percentage in silty soil, while at lateritic soil the increase in pre-consolidation pressure was 300% from 165kPa to 660kPa. at 28 days curing in 5% SBR percentage. It can also be observed that the pre-consolidation pressure increases more than the untreated soil in lateritic soil while in silty soil the increase at small SBR percentage and then start to decrease lesser than the untreated soil. These results refer to increase the ability of the resistance of compressibility in soil at small SBR percentage. These results attributed to the increase of the agglomeration

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and flocculation with decrease amount of the fine particles due to the cementation effect increase between the soil particle in soil Skelton.

The increase of SBR percentage in fine soil (silty) may cause the lubricant effect between soil particles that lead to decrease in pre-consolidation pressure as it is concluded by (Ammar Abbas Mohammed et al., 2008). The results obtained from this study when compared with typical failure pressure for soils type as in Table 5 can give a concluding remarks that the soil after being treated becomes more than weather rock pressure.

Table (5): Max. pressure carrying for typical materials after,(Abeele W.V., 1985)

Materials	Pressure kPa
Soft clay	45
Submerged loose sand	60
Dry loose sand	100
Stiff clay	175
Submerged dense sand	240
Hard clay	400
Dry dense sand	500
Weathered rock	500
Hard rock	10000

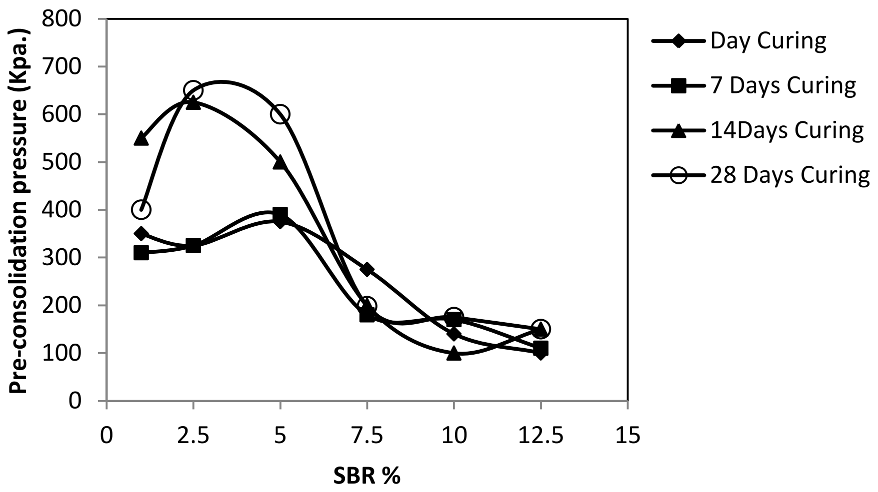

Fig. (5): Pre-consolidation pressure affected by SBR% with curing time MH soil

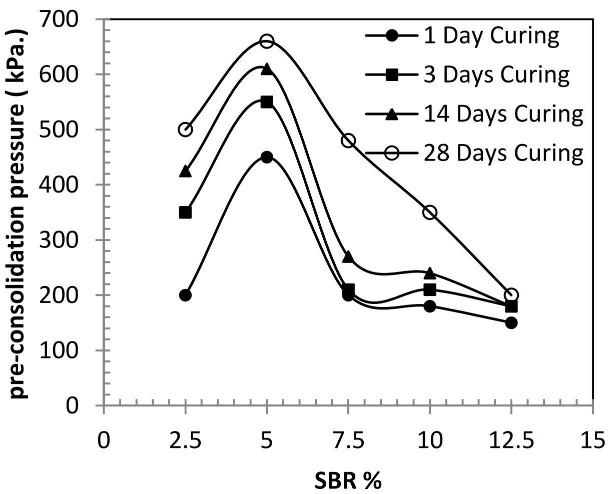

Fig. (6): Pre-consolidation pressure affected by SBR% with curing time SM soil

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4.3.2. Compression index

The compression index is used as an indicator to improve soil under different applied load. In this study, the compression index (C_c) decreases with SBR percentage and increases also with curing time increase. Figs. (7 -8) had Cc results for both types of soil and it is found that the optimum results in silty soil was the decrease of 256% from 0.21 to 0.059 after 28 day curing from untreated soil (0% SBR) to 2.5% SBR. It is also found Cc reduction in lateritic soil about 200% from 0.0325 to 0.011 after 28 days curing from untreated soil (0% SBR) to 5% SBR. The results obtained from this study when compared with typical value for soils type as in Table 6. The soil after being treated became very slightly compressible at lateritic soil and slightly compressible at silty soil.

Table (6): Degree of compressibility of soil after, (Sureban V., 2011)

Cc	Degree of compressibility
0 - 0.05	Very slightly compressible
0.05 - 0.1	Slightly compressible
0.1- 0.2	Moderately compressible
0.2 - 0.35	Highly compressible
>0.35	Very highly compressible

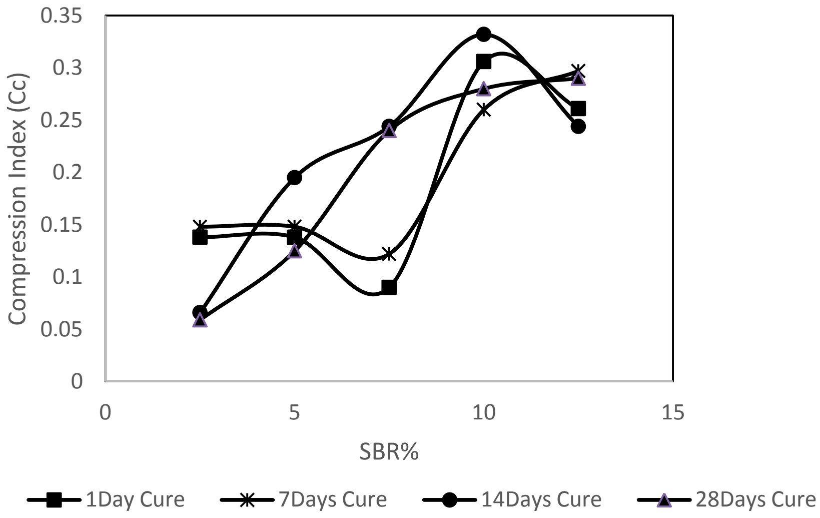

Fig. (7): Effect curing time on compression index at different SBR percentage, MH soil

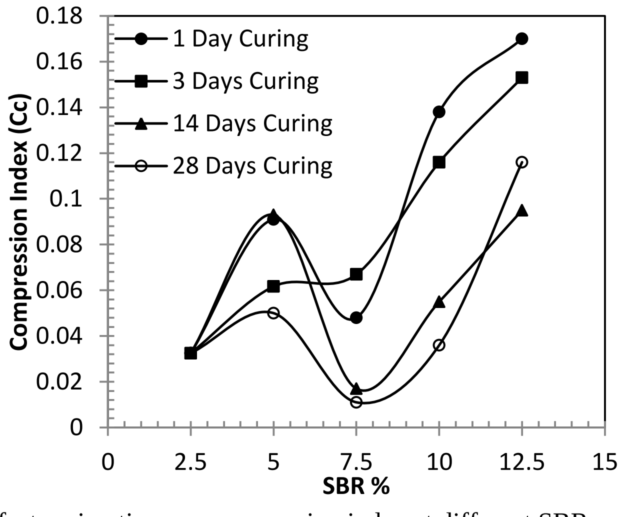

Fig. (8): Effect curing time on compression index at different SBR percentage, SM soil

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4.3.3. Void ratio –SBR

Chemical stabilizer was effected on initial void ratio directly after mixing with the original soil by increasing the initial void ratio compared with untreated soil due to flocculated and agglomerated effect and decreasing the clay particles percentage in soil skeleton, similar result concluded by (Khairul Anuar Kassim and Chow Shiao Huey, 2000). It is also found that there is an increase of the initial void ratio with increase of water content for all curing time; this conclusion is a similar results were obtained by (Mohammad S. Pakbaz and Alipour, 2012, Shubber et al., 2008). Figs. (9-10) show that the void ratio was affected with SBR% in both soils used by increasing the initial void ratio to increase of the SBR percentage and curing time.

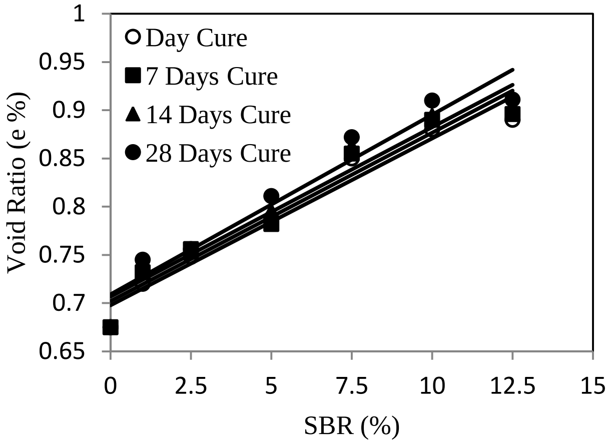

Fig. (9): Effect SBR percentage and curing time on initial void ratio of MH soil

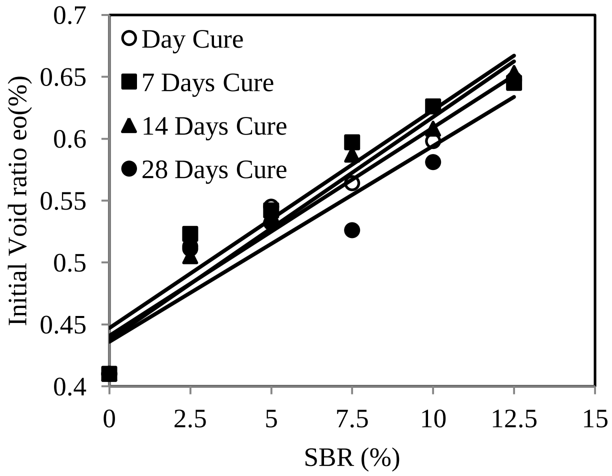

Fig. (10): Effect SBR percentage and curing time on initial void ratio of SM soil

4.3.4. Coefficient of volume compressibility

Coefficient of volume compressibility was a function of the difference between the change in thickness and the change in pressure on the average thickness sample. This parameter refers to the volume change effect in the compressible layer in soil body and the increase in this parameter refers to improve the resistance of compressibility (Badmus B.S., 2010). In this study, the results show an increase of Mv with an increase of SBR percentage. These results also show a decrease in Mv with curing time increase for both types of soil used. The Coefficient of volume compressibility increase about 960% from 0.099 to 0.194 m^2/MN and 193% from 0.093 m^2/MN to 0.111 m^2 /MN 2.5%SBR- MH and 5%SBR-SM respectively as shown in Figs. (11-12)

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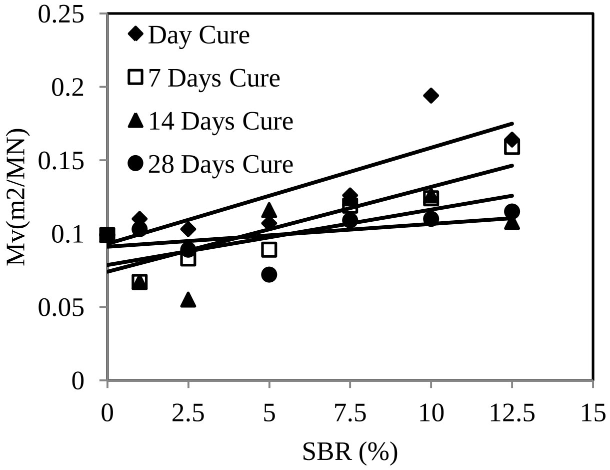

Fig. (11): Effect SBR percentage and curing time on coefficient of volume compressibility of MH soil

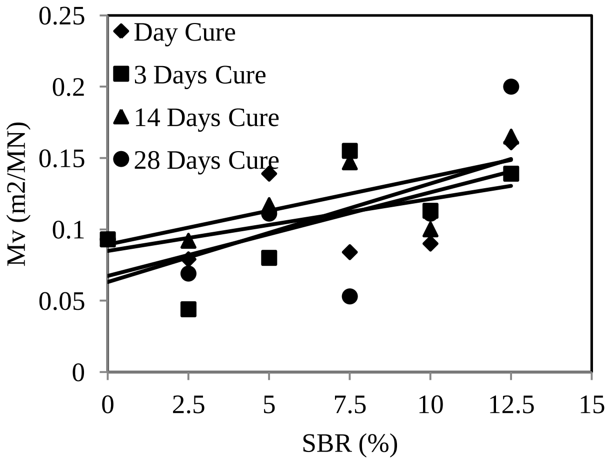

Fig. (12): Effect SBR percentage and curing time on coefficient of volume compressibility of SM soil

5. CONCLUSIONS

Based on the results obtained from this study, the following conclusions were made:

1. The plasticity index was affected by chemical stabilizer by decreasing in both soils used by 81% and 77% in MH and SM soil respectively.

2. The compressibility characteristics improved by:

i. Increase in the pre-consolidation pressure ($P_{c)}$ about 62.5% and 300% at MH and SM respectively.

ii. Decrease in the compression index (C_c) about 256% and 200% at MH and SM soils respectively

iii. Initial void ratio (e_o) in stabilized soils increases with SBR percentage increase and with curing time at small ages and then decreases with curing time increase.

iv. Coefficient of volume compressibility (M_v) has not clear effect but generally increase with SBR% increase.

3. Curing time had an effect on all geotechnical soil properties after 14 days curing.

4. The soil texture directly effects on the polymer percentage, the optimum SBR percentages increase with the percent of the coarse soil increase.

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