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IMPROVEMENT OF EXPANSIVE SOIL BY USING SILICA FUME

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ABSTRACT

Expansive soils are characterized by their considerable volumetric deformations representing a serious challenge for the stability of the engineering structures such as foundations. Consequently, the measurements of swelling properties, involving swelling and swell pressure, become extremely important in spite of their determination needs a lot of time with costly particular equipment. Thus, serious researches attempts have been tried to remedy such soils by means of additives such as cement, lime, steel fibers, stone dust, fly ash and silica fume. In this research the study of silica fume has studied to treatment expansion soil, the clay soil was brought from Al-Nahrawan in Baghdad. The soil selected for the present investigation prepared in laboratory by mixing natural soil with different percentages of bentonite (30, 50 and 70% by soil dry weight). The test program included the effect of bentonite on natural soil then study the effect of silica fume (SF) on prepared soil by adding different percentage of silica fume (3, 5, and 7 by weight) to the prepared soils and the influence of these admixtures was observed by comparing their results with those of untreated soils (prepared soils). The results show that both liquid limit and plasticity index decreased with the addition of silica fume, while the plastic limit is increase with its addition. As well as, a decrease in the maximum dry unit weight with an increase in the optimum water contents have been obtained with increasing the percentage of addition of the silica fume. It is also observed an improvement in the free swell, swelling pressure by using silica fume. It can be concluded that the silica fume stabilization may be used as a successful way for the treatment of expansive clay.

KEYWORDS: Improvement; Expansive Soil; Silica Fume; Swell Pressure; Free Swelling

تحسين الترب الانتفاخية بغبار السيلكا

م. كوثر يلي حسين السوداني

الجامعة التكنولوجية / قسم هندسة البناء والانشاءات

الخلاصة

ان الترب الانتفاخية تكون معرضة الى تشوهات حجمية كبيرة لذلك تشكل تهديدا على استقرارية المنشآت و الاسس. لذلك فان معرفة خصائص الانتفاخ مثل الانتفاخ و ضغط الانتفاخ اصبح ضروريا جدا. على الرغم من ان قياس خصائص الانتفاخ يستهلك وقتا ويتطلب معدات خاصة و باهضة. لذلك تم دراسة معالجة الترب الانتفاخية باستعمال مختلف الاضافات مثل الاسمنت, و الالياف الحديدية, غبار الحجر, الرماد المتطاير, وغبار السيلكا.

في هذا البحث تم دراسة اضافة غبار السيلكا الى التربة الانتفاخية لمعالجة نسبة الانتفاخ/ الانكماش حيث تم استعمال تربة طينية من منطقة النهروان في بغداد وتم مزجها مع نسب مختلفة من مادة البنتونايت (30, 50, 70 %) من وزن التربة.ان برنامج الفحوصات المختبرية التي اجريت في هذا البحث تضمن ايضا تأثير البنتونايت على التربة الاصلية ومن ثم غبار السيلكا على التربة حيث تم اضافتها بنسب مختلفة (3, 5, 7 %) من وزن التربة المحضرة. وقد تم مراقبة تأثير اضافة هذه المادة على التربة بدون وجود اضافة و مع وجود الاضاف ومقارنة النتائج. وبينت النتائج ان اضافة غبار السيلكا الى الترب الانتفاخية تؤثر على حدود القوام حيث يقل حد السيولة ومؤشر اللدونة و يزداد حد اللدونة للترب وبينت النتائج ايضا ان بزيادة نسبة غبار السيلكا في الترب الانتفاخية تقل الكثافة الجافة العظمى و يزداد محتوى الماء المثالي. اضافة الى ذلك بينت النتائج الى ان الانتفاخ وضغط الانتفاخ للترب تتحسن بوجود غبار السيلكا في التربة الانتفاخية.

1. INTRODUCTION

The swelling behavior of expansive soils frequently leads to undesirable effects and problems, such as differential settlement and ground heaving. Recently, a greater attention and concern have been considered concerning expansive soils. Several methods have been investigated to observe and regulate the volumetric change of expansive soils. One of these method is using admixtures to control such change leading to soil stabilization. Several additives have been effectively used to remedy such soils and reaching soil stabilization by means of cement, lime and fly ash (Chen, 1975); (Liao, 1984); (Locat et al., 1990); (Ali et al., 1992); (Bell, 1996); (Sivapullaiah et al., 1996); (Du et al., 1999); (Kaniraj and Havanagi, 2001); (Cokca, 2001); (Consoli et al., 2001); (Nalbantoglu and Gucbilmez, 2001); (Nalbantoglu, 2004); (Kumar and Sharma, 2004); (Kate, 2005). As stabilization of expansive soils using admixtures improves soil strength through controlling their volumetric change potential, thus additional new methods still needed for reduction in soil swelling and increasing its strength properties ((Puppala and Musenda, 2002) and (Mo and Yasrobi, 2008). Many investigations have studied natural fabricated and by product materials and their use as stabilizers for the modification of clayey soils. (Prabakar et al., 2003), (kalkan and Akbulut, 2004), (Cetien et al., 2006), (kalkan, 2006), (Akbulut et al., 2007).

2. MATERIALS USED

2.1. The Soil

In the present study, the soil samples used were prepared in the laboratory by mixing natural soil with different percentages of bentonite. The natural soil was brought from Al-Nahrawan area (23 km east Baghdad). The bentonite used in this study was obtained commercially. Different physical and chemical properties of the natural soil were determined using the standard tests. Details of such properties are presented in Table 1. Fig. 1 shows the grain size distribution of the soil.

The natural soil was dried in the laboratory at 60˚C for 48 hours then grinded and sieved (passing No. 40 (0.425mm) U.S). Four type of soil samples were prepared and as follows:-

Soil type A: The natural soil was brought from Al-Nahrawan region.

Soil type B: Represents as laboratory prepared soil made by mixing natural soil with bentonite at a ratio of (30%) by weight.

Soil type C: Represents as laboratory prepared soil made by mixing natural soil with bentonite at a ratio of (50%) by weight.

Soil type D: Represents as laboratory prepared soil made by mixing natural soil with bentonite at a ratio of (70%) by weight.

Table 2 shows the physical and chemical properties and classification indices of the four soils.

Table 1. Physical and Chemical Properties of Soil Used.

No	Index property	Natural soil	Bentonite
1	Natural water content (w.c, %)	2.0	-
2	Liquid limit (LL, %)	44	512
3	Plastic limit (PL, %)	19	38
4	Plasticity index (PI, %)	25	474
5	Specific gravity (Gs)	2.69	2.26
6	Gravel (>2mm) %	0	-
7	Sand (0.06 to 2mm) %	16	-
8	silt (0.005 to 0.06mm) %	34	-
9	Clay (less than 0.005mm) %	50	-
10	Gypsum content %	6.71	-
11	SO_3 content %	3.12	-
12	Soil symbols (USCS)	CL	-

Table 2. Shows the Physical Properties and Classification Indices of The Four Soils.

Soil type	Liquid Limit	Plastic limit	Plasticity Index	Specific gravity	Max.dry density	%Optimum moisture
A	44	19	25	2.69	17.13	17.5
B	89	22	67	2.55	15.11	22.7
C	120	26	94	2.47	14.73	24.2
D	150	30	120	2.38	14.08	26

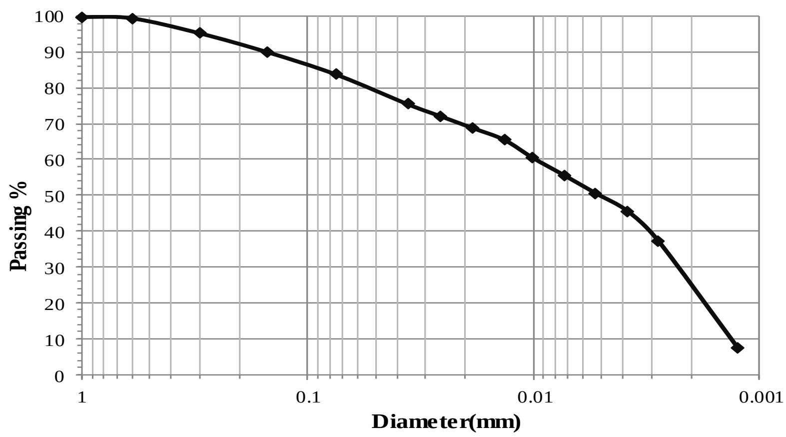

Fig. 1. Grain Size Distribution of Soil Type A (Natural Soil).

2.2. The Silica fume material (SF)

Silica fume (SF), which is also known as micro-silica, is a secondary product resulting from the reduction of high-purity quartz with coal in electric furnaces during the manufacture of silicon and ferrosilicon alloys. It can be also gathered from other silicon alloys such as ferromagnesium, ferromanganese, ferrochromium and calcium silicon (ACI Committee 226. 1987). Silica fume is composed of very fine vitreous particles of around 100 times smaller than the average of cement particles and a surface area of approximately 20,000 m2/kg (215,280 ft2/lb) when measured by nitrogen absorption techniques. Silica fume is considered as a very effective pozzolanic material due to its high silica content and its extreme fineness (ACI Committee 226, 1987), (Luther, 1990) one of its main uses is to improve concrete properties, by increasing its compressive strength, bond strength, and abrasion resistance, and reducing its permeability. Therefore, it helps in protection of the reinforcing steel from corrosion. The chemical composition of the silica used in the present study given by the manufacturer is applicable according to the ACI Committee 226 requirements is presented in Table 3.

3. SAMPLE PREPARATION

To study the effect of silica fume on swelling soil, three percentages of silica fumes were used (3, 5 and 7%). Two types of compaction were used Procter compaction and static compaction. For the first type the specimens were prepared at the maximum dry density and optimum moisture content for four soil types, while the second type, the specimens were prepared at a dry of density of (17.13 kN/m3) and moisture content of (17.5%). To prepare samples for swelling, air dry soil was mixed with the necessary amount of distilled water to give its initial moisture content. The soil was mixed thoroughly by hand and stored in a desiccators for18 hours at 20°C to obtain the uniform moisture distribution.

The static compaction method was followed the preparation of soil samples using a special mold and a compression testing machine. Load was applied statically to the soil sample at a compression rate of 0.04mm/sec. until the depth of penetration approach the required height (1.5cm). The load was maintained on the specimen for about five minutes after reaching the required height to prevent the occurrence of rebound after static load removal.

Table 3. Chemical Composition of Silica Fume Used in the Tests.

Composition	Silica fume
SiO_2	98.87 %
Al_2O_3	0.01%
Fe_2O_3	0.01 %
CaO	0.23 %
MgO	0.01 %
K2O	0.08 %
Na2O	0.00 %

4. RESULTS AND DISCUSSIONS

4.1. Effect of Bentonite on the Properties of Natural Soil

The results of liquid limit test are displayed in Fig. 2. This Figure is clearly shown the effect of bentonite addition on the liquid limit. The addition of the percentages 30, 50 and 70% of bentonite to the original soil results in an increase in the L.L of around 89, 120 and 150 % respectively. The reason is the high activity of bentonite and its tendency to absorb water. The variation of specific gravity for the soil- bentonite mixture with different proportions is illustrated in Fig. 2. It is obviously shown the decrease in soil specific gravity with increasing bentonite addition, which is attributed to the lower specific gravity of bentonite (around 2.26) compared to that of the natural soil (2.69). In Fig. 2, the effect of bentonite content on the compaction characteristics of mixtures are illustrated. It could be clearly observed that by increasing the bentonite content in the mixtures, the optimum water content increases while the maximum dry unit weight decreases. Due to high activity of bentonite, the absorbed water surrounding the clay particles which has considerable volume, leads to an increase in the water content and a decrease in the dry unit weight (Kaya et al., 2006).

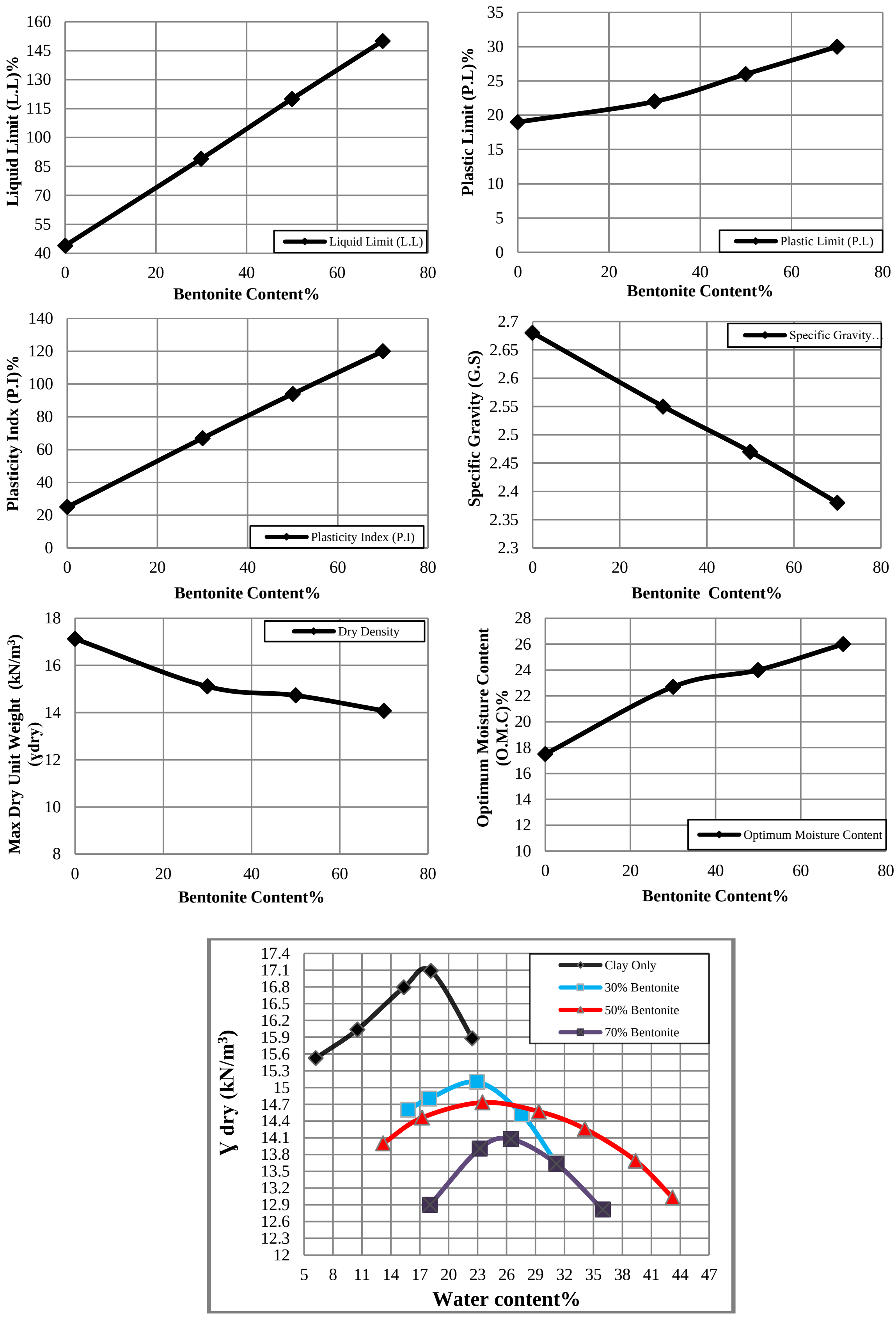

Fig. 2. The Effect of Bentonite on the Atterberg's Limit, Specific Gravity and Compaction Characteristics.

4.2. Effect of silica fume on the properties of prepared soils:

The effect of adding silica fume to the soil on its Atterberg limits are shown in Figs. 3, 4 and 5. It can be noticed that there is a decrease in liquid limit and plasticity index with the addition of silica fume due to that SF coats and binds all clay particles which possesses little cementitious value and large particles which called the pozzolanic reaction between SF and aluminous material as stated by (Abd El-Aziz et al., 2004). Figs. 3, 4 and 5 show the specific gravity values of the soil mixed with different proportions of silica fume. The figure shows a decrease in specific gravity of soil with increasing SF content due to the lower specific gravity value of silica fume (2.2). The relation of the dry unit weight with water content for different SF contents are illustrated in Figs. 3, 4 and 5. Decreases in compaction effect is clearly seen which are due to the reduction in the parallel orientation to the clay particles. Likewise, the optimum moisture content also generally increases with increasing SF percent's. The increase may be attributed to the SF addition, which leads to decrease the quantity of free silt clay fraction and forming coarser material with large surface areas. Thus, much water will be needed for these processes to occur. Moreover, this will also involve more water needed for soil-SF mixtures compaction as stated by Harichane et al., (2011b). In the same way, the reduction in the maximum dry unit may be due to the replacement of soil by the silica fume in the mix which has relatively lower specific gravity compared to that of the natural soil.

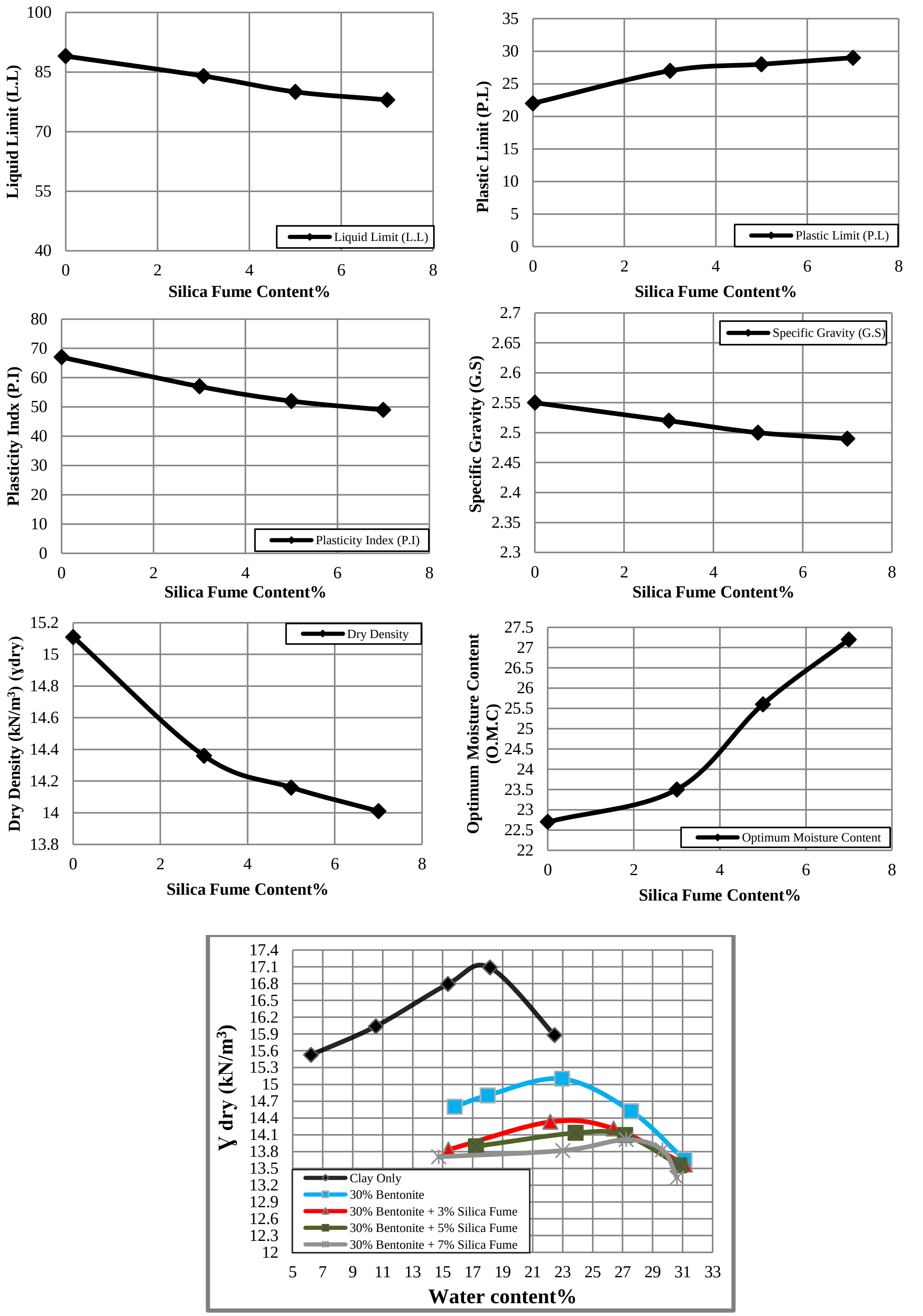

Fig. 3. The Effect of Silica Fume on the Atterberg's Limit, Specific Gravity and Compaction Characteristics for Soil Type B.

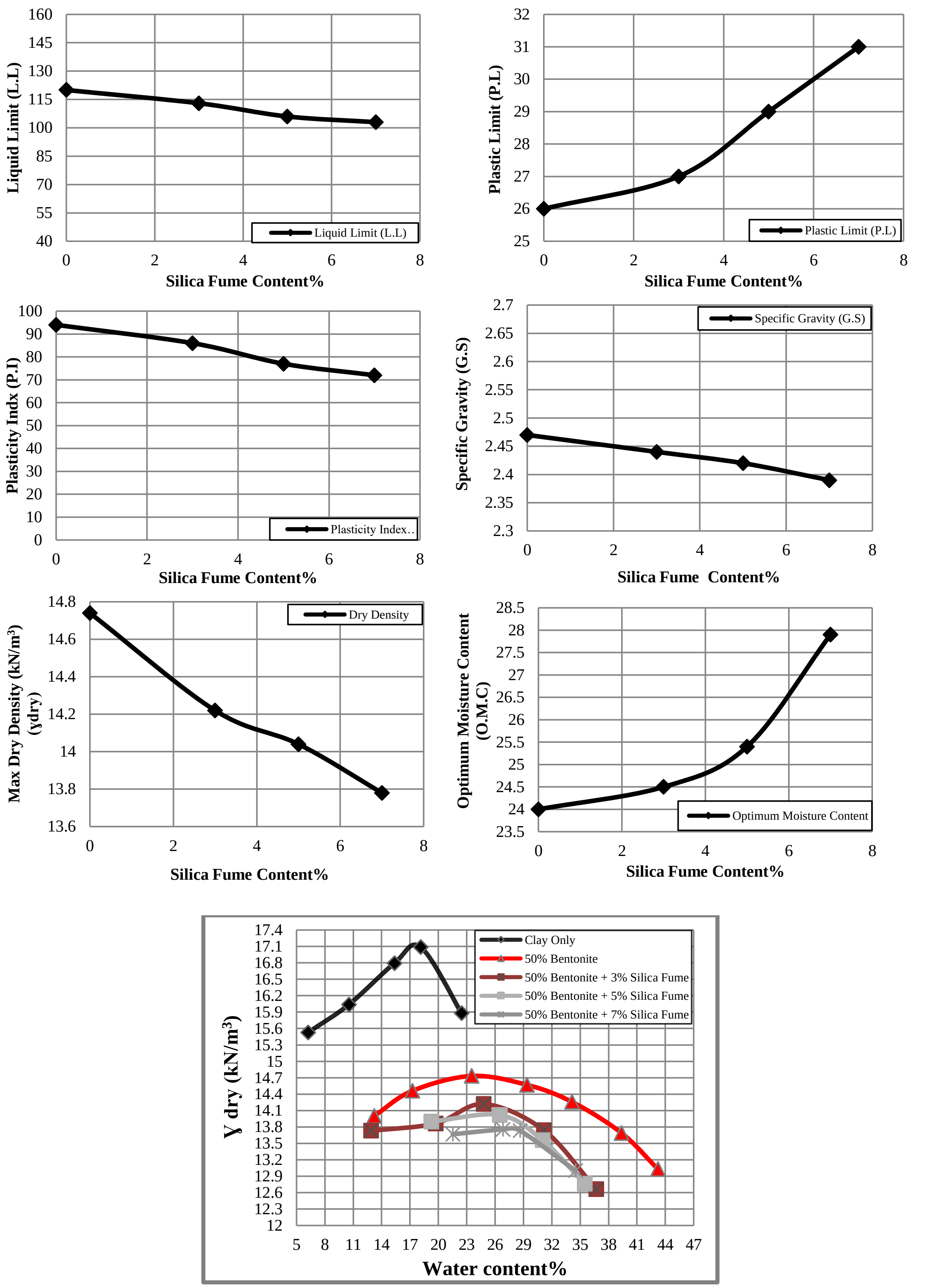

Fig. 4. The Effect of Silica Fume on the Atterberg's Limit, Specific Gravity and Compaction Characteristics for Soil Type C.

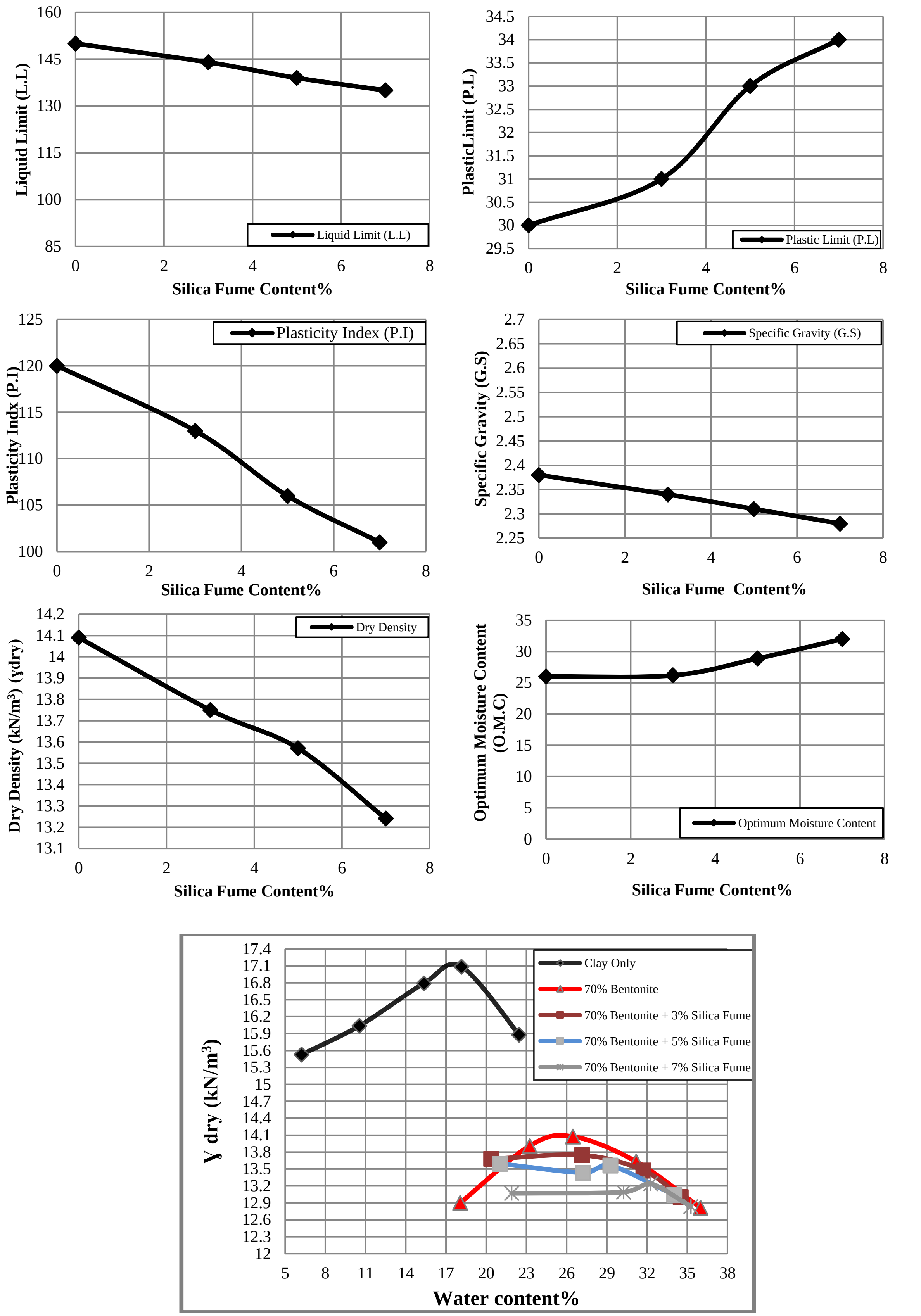

Fig. 5. The Effect of Silica Fume on the Atterberg's Limit, Specific Gravity and Compaction Characteristics for Soil Type D.

4.3. Effect of Bentonite on Swell and Swell Pressure:

Fig. 6 show the effect of bentonite in different percent on the free swell and swell pressure of the natural soil. From these figure it can be observed that the free swell and swell pressure highly increase with increasing percentage of bentonite due to the natural sodium bentonite is high swelling clay composed mainly of sodium montmorillonite.

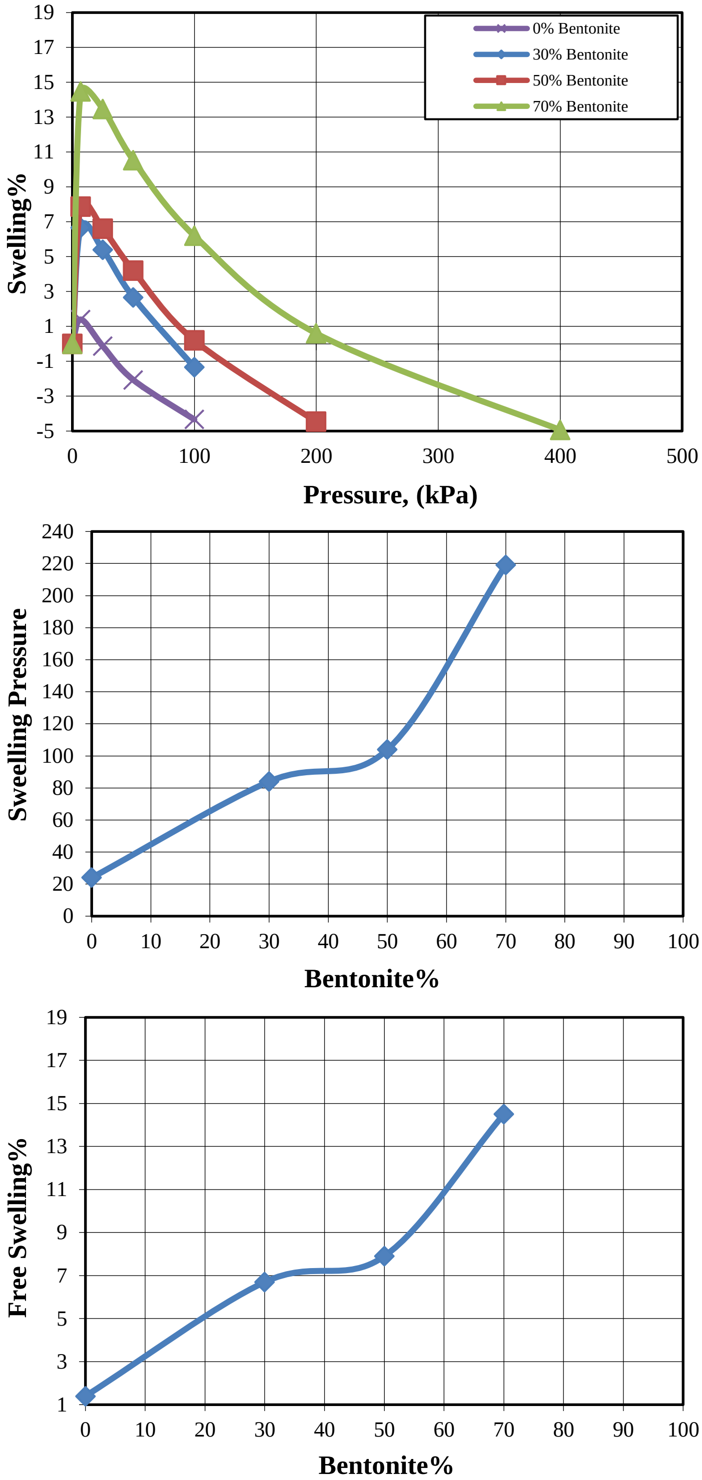

Fig. 6. Effect of Bentonite on Swell and Swell Pressure.

4.4. Effect of Silica Fume on Swell and Swell Pressure for Prepared Soil

The results of free swell, swelling pressure tests before and after the treatment are shown in Fig. 7. A significant decrease of free swell, swelling pressure values is clearly shown with increase silica fume addition. The reduction in the swelling and swelling pressure values of the improved soils may be due to the addition of non-expansive silt-size particles to the expansive soil and the interaction between the soil and silica fume particles. The silica fume used in this experimental study is mainly consisted of spherical non-crystal silicate, aluminum, and iron oxides compounded with some microcrystal material and unburned carbon (Table 3). Consequently, the specific surface area and water affinity of the inspected soil samples decrease, which refers to the reduction in the swell-shrinkage values such as free swell and swelling pressure.

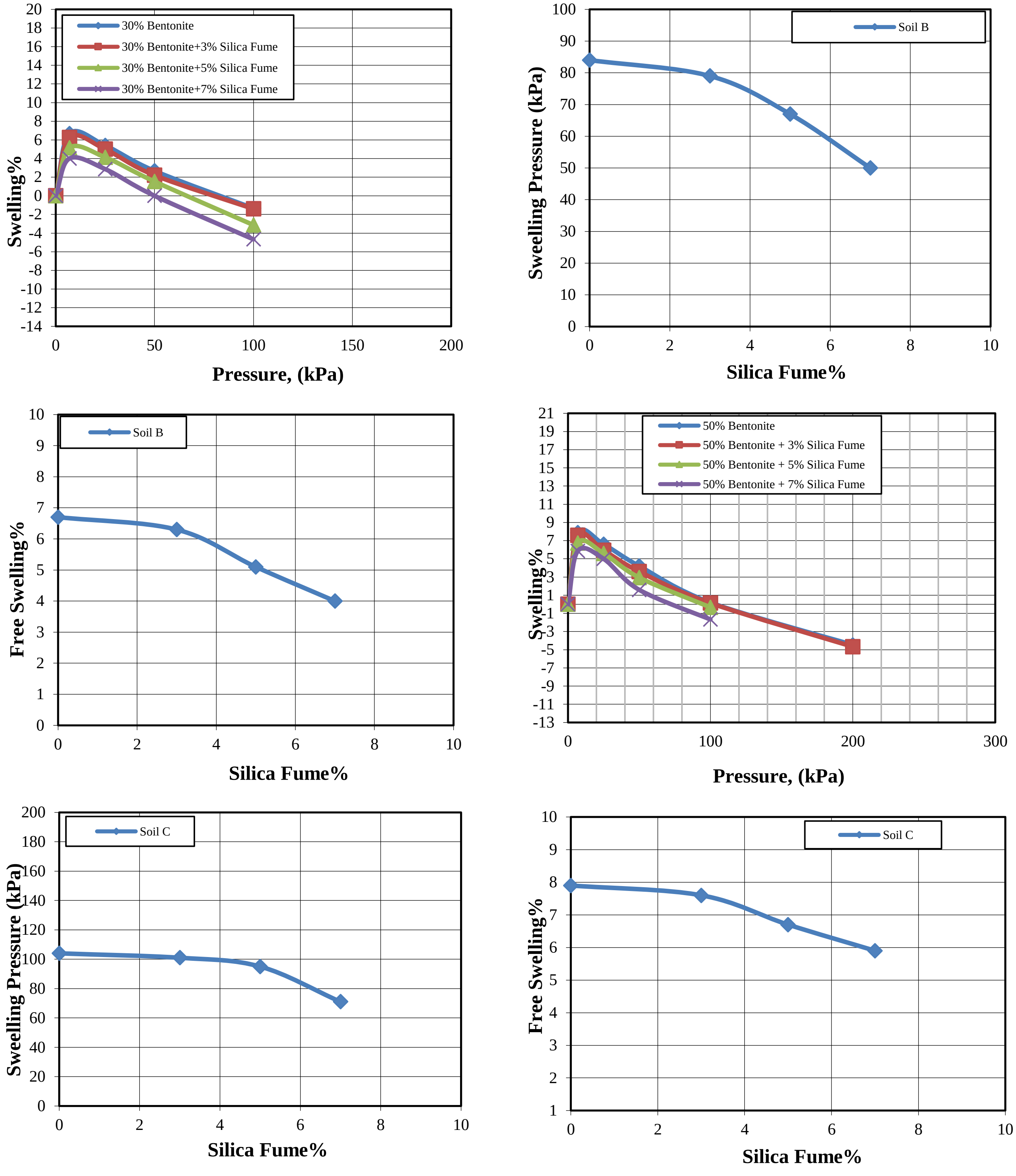

Fig. 7. Effect of Silica Fume on Swell and Swell Pressure for Prepared Soil.

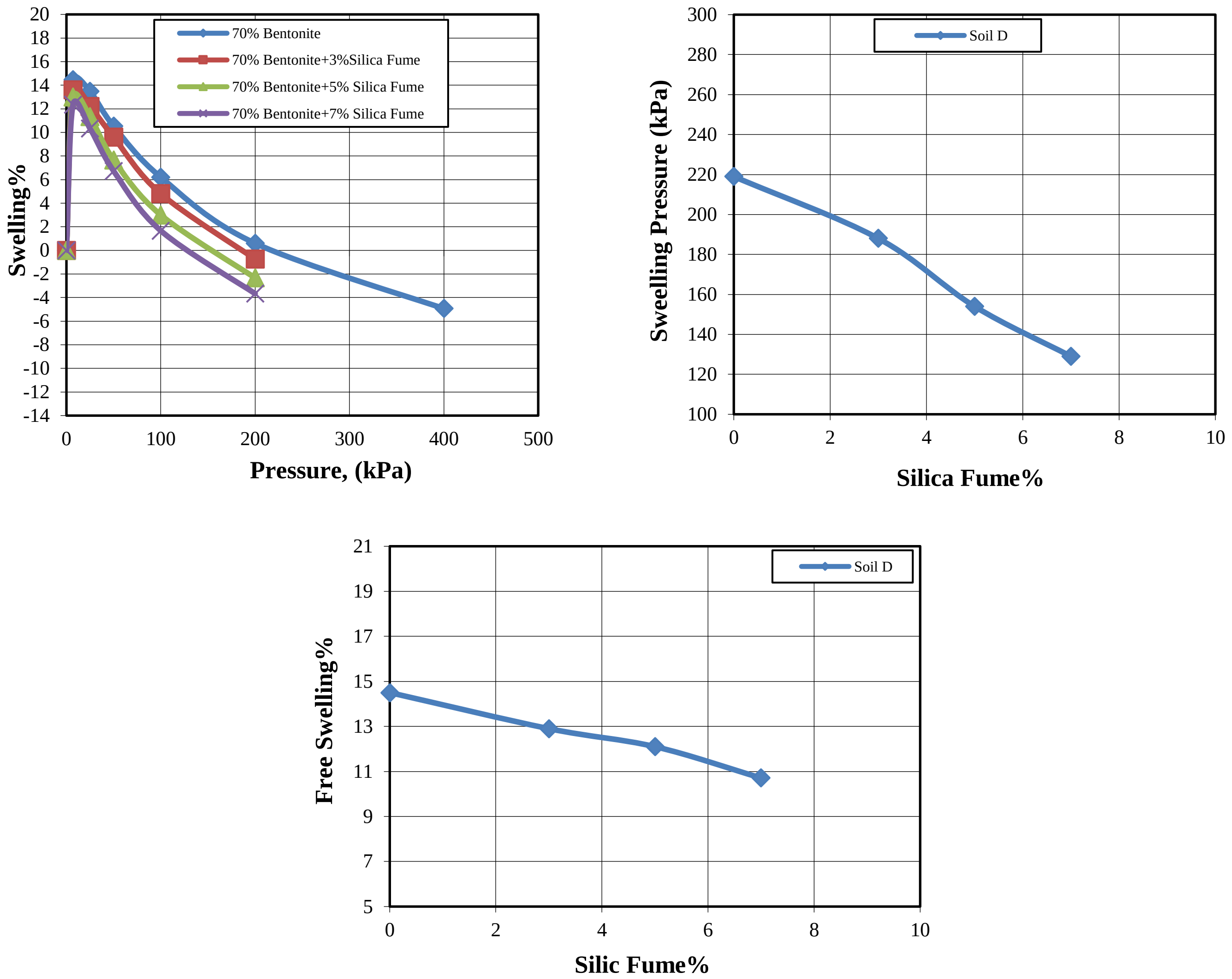

Fig. 7. Continued …

5. CONCLUSIONS

The present research investigated the effect of silica fume on the engineering characteristics of expansive clay. The following conclusions may be drawn:

1. The liquid limit highly increases with increasing of bentonite percentage. While the liquid limit slightly decrease with increasing of silica fume percentage.
2. The plastic limit increase with increasing of bentonite percentage. While the plastic limit slightly increase with increasing of silica fume percentage.
3. The plasticity index highly increase with increasing of bentonite percentage. While the plasticity index decrease with increasing of silica fume percentage.

4. The specific gravity decrease with increasing of bentonite percentage. While the specific gravity decrease with increasing of silica fume percentage.
5. The max. dry density decreases with increasing of bentonite percentage.
6. The optimum moisture content increase with increasing of bentonite percentage.
7. Free swell and swell pressure highly increases with increasing of bentonite percentage. While free swell and swell pressure decrease with increasing of silica fume percentage.

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