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Thermal Effect on Lateral Earth Pressure of Cement Treated Clay Layer

Anuchit Uchaipichat

Department of Civil Engineering, Vongchavalitkul University, Nakhon Ratchasima, 30000, Thailand

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ABSTRACT

This paper presents the simulation results of lateral earth pressure of cement treated clay affecting by temperature changes. The examples of facilities generating heat are underground nuclear waste repositories, buried high-voltage cables and buried hot pipes. The simulation results show that the active and passive earth pressures increase linearly with increasing depth. The negative values of lateral pressure occur in the most of the active pressure cases while the positive values of lateral pressure occur in all cases of passive pressure. Moreover the active pressure decreases with increasing temperature while the passive pressure increases with increasing temperature. For the temperatures of 20, 40, 60 and 80oC, the active pressure decreases with increasing cement content while the passive pressure increases with cement content. For temperature of 100 , with increasing cement content, the active earth pressure decreases for cement content less than 10 percent and increases for cement content greater than 10 percent while the passive earth pressure increases for cement content less than 10 percent and decreases for cement content greater than 10 percent.

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INTRODUCTION

The thermal effect on soil behaviors is an interested topic in several geotechnical engineering problems. In several circumstances, soils may experience temperature changes, such as underground nuclear waste repositories, buried high-voltage cables and buried hot pipes. Several researchers have developed predictive capabilities associated with topics such as the storage of nuclear wastes, remediation of contaminated sites, and movement of pollutants.

For these facilities generating heat, retaining structures are often used as both temporary and permanent structures. The calculation of lateral earth pressure distribution on the structures is very important for analysis and design of these types of structure. Several investigators have reported that temperature changes can affect the shear strength, which is the important parameter in design of retaining structures (e.g. Sherif and Burrous 1969; Maruyama 1969; Lagurous 1969; Hueckel and Baldi 1990; Kuntiwattanakul *et al*. 1995; Tanaka *et al*. 1997; Cui *et al*. 2000; Graham *et al*. 2001). Thus, the soils under temperature changes need to be treated. The typical method of soil treatment is soil stabilization by adding agents, such as lime, cement and lime-fly ash. However, investigations on thermal effect on stabilized soil are limited.

Recently, Uchaipichat (2010) investigated the thermal effect on unconfined compressive strength of cement treated clay and reported a decrease in unconfined compressive strength with increasing temperature for all values of cement content. The experimental results also show an optimum cement content at which a reduction in strength with increasing temperature is minimized.

The main objective of this paper is to simulate the thermal effect on lateral earth pressure of cement treated clay. Both active and passive earth pressure conditions are simulated and presented.

Lateral Earth Pressure on Retaining Structures:

Rankine (1857) proposed the theory of lateral earth pressure, in which a frictionless between the wall of retaining structure and the soil is assumed. In case of active pressure, the retaining structure moves away from the earth while the structures moves into the soil in case of passive earth pressure. The active and passive earth pressures can be expressed as,

Corresponding Author: Anuchit Uchaipichat, Department of Civil Engineering, Vongchavalitkul University, Nakhon Ratchasima, 30000, Thailand
E-mail: anuchitu@yahoo.com

$$\sigma'_a = K_a \sigma'_v - 2c\sqrt{K_a} \quad (1a)$$

$$\sigma'_p = K_p \sigma'_v + 2c\sqrt{K_p} \quad (1b)$$

in which, σ'_a and σ'_p are the active and passive earth pressures, σ'_v is the effective vertical stress, c is cohesion, K_a and K_p are the active and passive coefficients of lateral pressure, which can be expressed as,

$$K_a = \tan^2(45 - \phi/2) \quad (2a)$$

$$K_p = \tan^2(45 + \phi/2) \quad (2b)$$

in which, ϕ is the internal angle of friction.

In case of undrained analysis for clayey soils, the internal angle of friction is equal to zero $(\phi = 0)$ and the cohesion (c) is replaced by the undrained shear strength (S_u). Thus, K_a and K_p become unity and Equations (1a) and (1b) become,

$$\sigma_a = \sigma_v - 2S_u \quad (3a)$$

$$\sigma_p = \sigma_v + 2S_u \quad (3b)$$

Simulation of Variation of Lateral Earth Pressure with Temperature:

The simulation of variation of lateral earth pressure with temperature is performed using the experimental results on thermal effect of unconfined compressive strength of cement treated clay reported by Uchaipichat (2010). Both active and passive earth pressures for temperature ranging from 20 to 100^{o}C are simulated using lateral earth pressure theory proposed by Rankine (1857)

Material Properties:

Thermal effect on unconfined compressive strength of cement treated clay was investigated by Uchaipichat (2010). The clay samples were collected at a depth of 1.5 m below the ground surface from the area within the main campus of Vongchavalitkul University, Nakhon Ratchasima, Thailand. The average unit weight of cemented sample is 14 kN/m^3. The results show a decrease in unconfined compressive strength with increasing temperature for all values of cement content. The undrained shear strength, which is a half of unconfined compressive strength, can be plotted against temperature as shown in Figure 1. The relations between undrained shear strength and temperature can be expressed as,

$$S_u = -80.4 \ln T + 446.4 \quad \text{for cement content = 2\%} \quad (4a)$$

$$S_u = -115.1 \ln T + 740.6 \quad \text{for cement content = 5\%} \quad (4b)$$

$$S_u = -246.7 \ln T + 1478.0 \quad \text{for cement content = 10\%} \quad (4c)$$

$$S_u = -859.9 \ln T + 4280.2 \quad \text{for cement content = 20\%} \quad (4d)$$

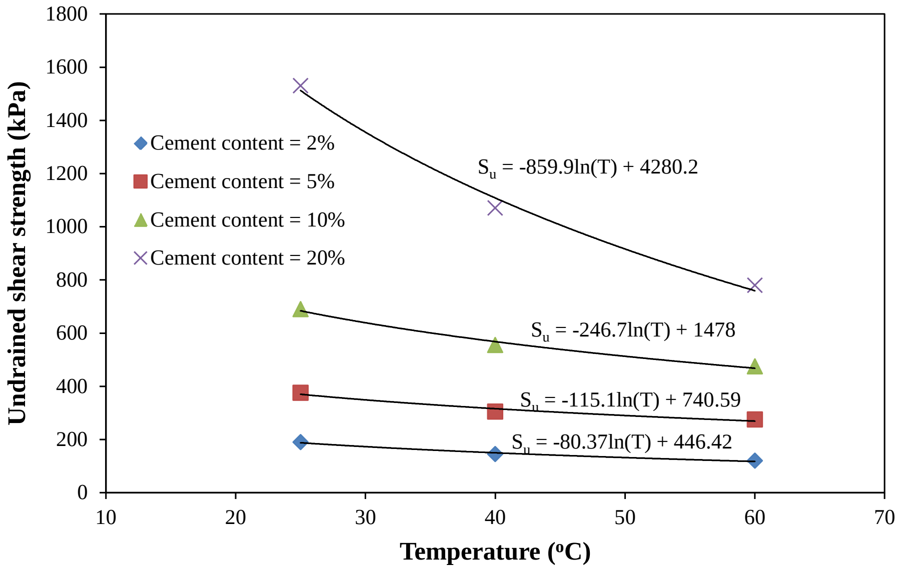

Fig. 1: Variation of undrained shear strength with temperature.

Active and Passive Earth Pressures at Various Temperatures:

The simulation of active and passive earth pressures for cement treated clay at temperature ranging from 20 to 100°C is performed using Equation (3a). The undrained shear strength at various values of cement content and temperature can be obtained from Equations (4a) to (4c).

Figures 2 and 3 show the variation of active and passive pressures with depth at various temperatures for values of cement content of 2, 5, 10 and 20 percent. It can be noticed that the active and passive earth pressures increase linearly with increasing depth. It is obvious that negative values of lateral pressure occur in the most of the active pressure cases while the positive values of lateral pressure occur in all cases of passive pressure. It can also be seen that the active pressure decreases with increasing temperature while the passive pressure increases with increasing temperature. This behavior can be clearly noticed in Figures 4 and 5, which present the variation of active and passive pressures with temperature at various depths for values of cement content of 2, 5, 10 and 20 percent.

Figure 6 shows the variation of active earth pressure with cement content at various temperatures. It can be noticed that the active pressure decreases with increasing cement content for the temperatures of 20, 40, 60 and 80°C. For temperature of 100°C, the decrease in active earth pressure with increasing cement content occurs for the cement content ranging from 2 to 10 percent and the increase in active earth pressure with increasing cement can be found for the cement content greater than 10 percent.

The passive earth pressure, however, increases with cement content for the temperature of 20, 40, 60 and 80°C as shown in Figure 7. For temperature of 100°C, the results show the increases in passive earth pressure with cement content for cement content ranging from 2 to 10 percent and the decrease in passive earth pressure with increasing cement for cement content greater than 10 percent.

Conclusions:

Simulation of thermal effect on lateral earth pressure of cement treated clay is performed using the theory proposed by Rankine (1857) and material properties reported by Uchaipichat (2010). The simulation results show that the active and passive earth pressures increase linearly with increasing depth. The negative values of lateral pressure occur in the most of the active pressure cases while the positive values of lateral pressure occur in all cases of passive pressure. Moreover the active pressure decreases with increasing temperature while the passive pressure increases with increasing temperature. For the temperatures of 20, 40, 60 and 80°C, the active pressure decreases with increasing cement content while the passive pressure increases with cement content. For temperature of 100°C, with increasing cement content, the active earth pressure decreases for cement content less than 10 percent and increases for cement content greater than 10 percent while the passive earth pressure increases for cement content less than 10 percent and decreases for cement content greater than 10 percent.

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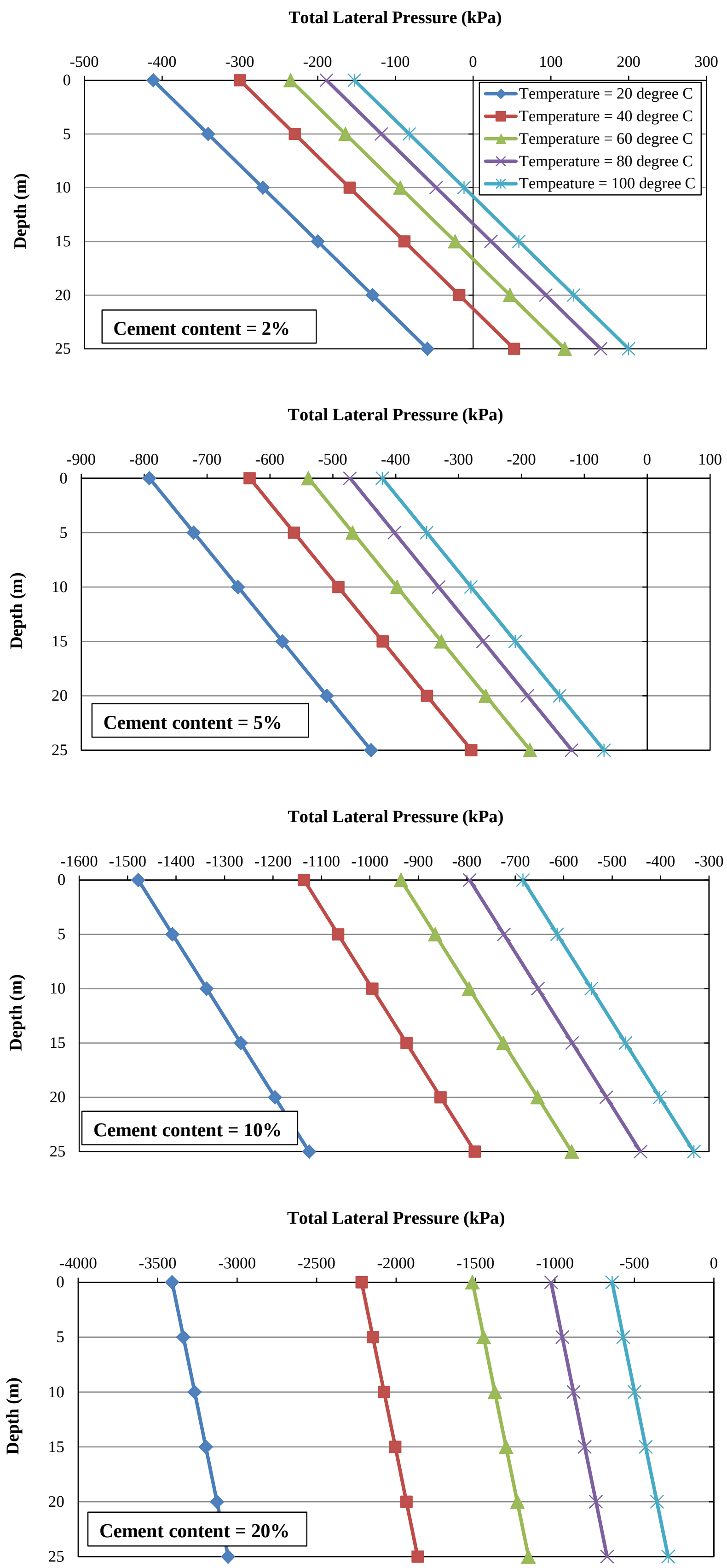

Fig. 2: Variation of total lateral active earth pressure with depth at various temperatures.

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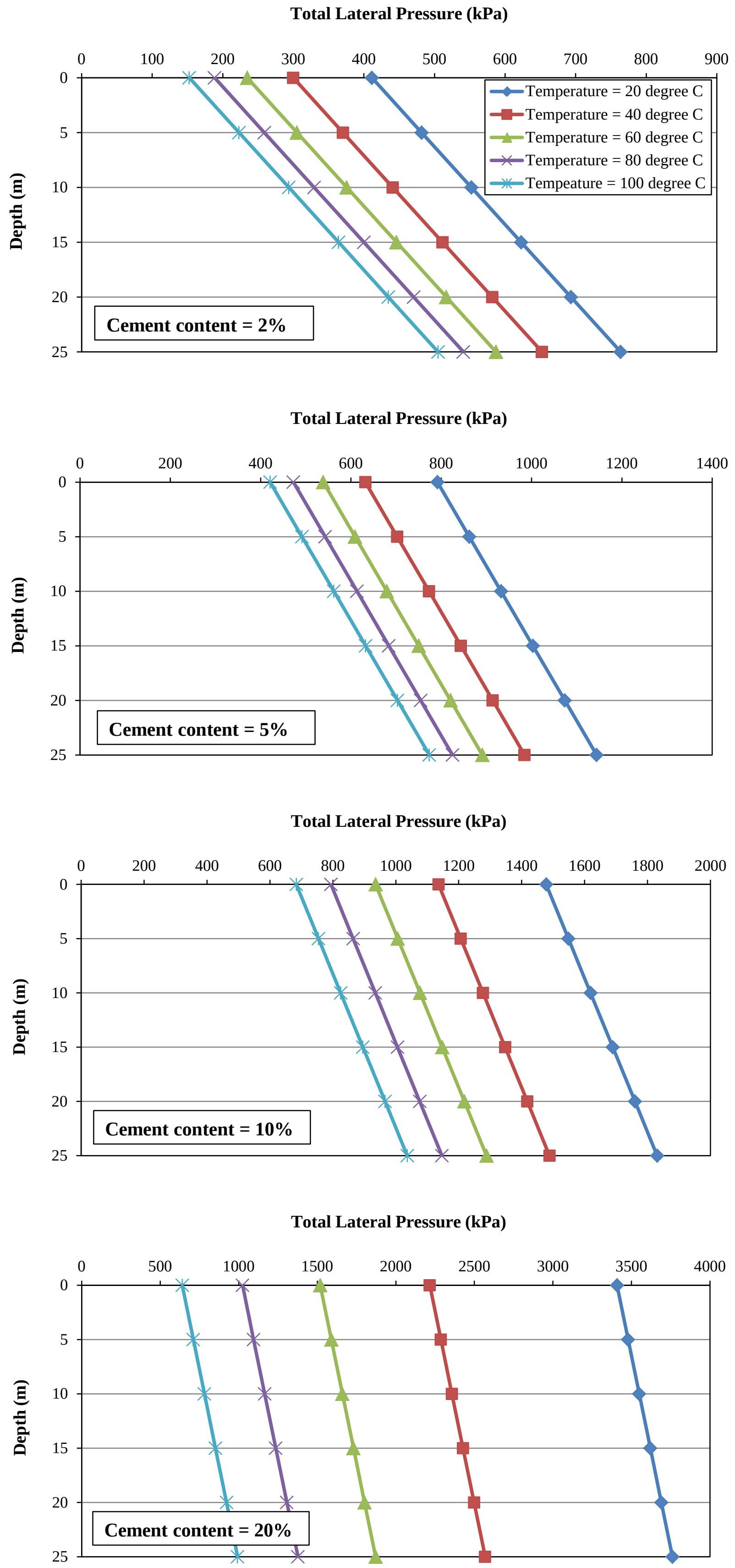

Fig. 3: Variation of total lateral passive earth pressure with depth at various temperatures.

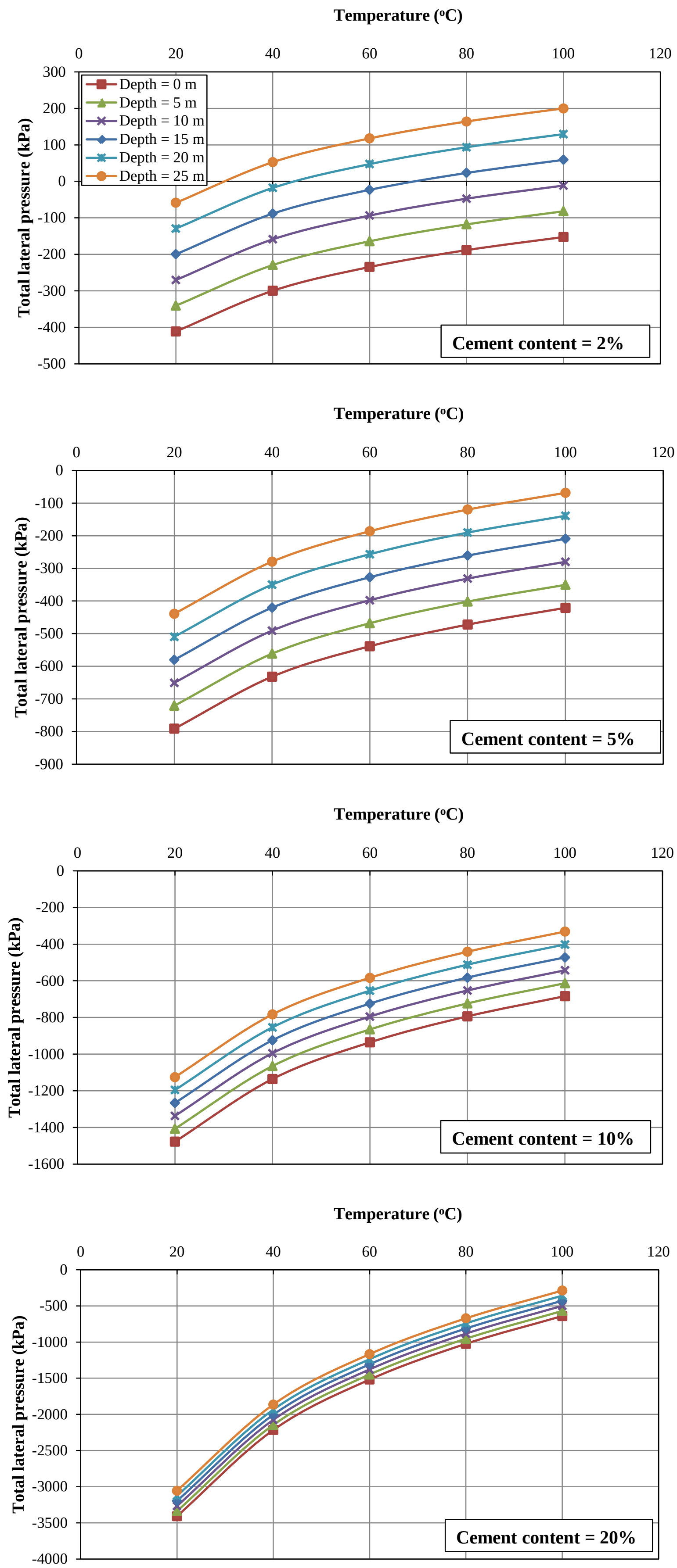

Fig. 4: Variation of total lateral active earth pressure with temperature at various depths.

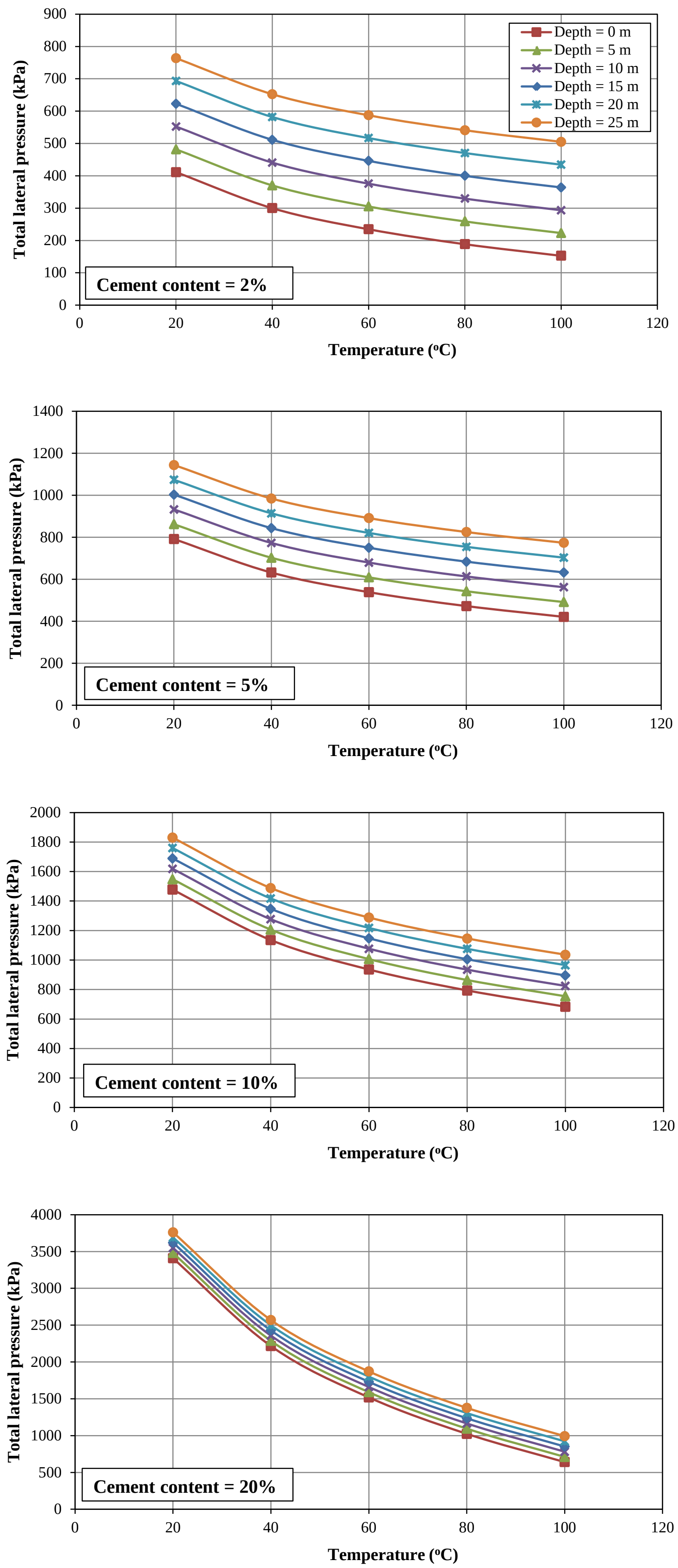

Fig. 5: Variation of total lateral passive earth pressure with temperature at various depths.

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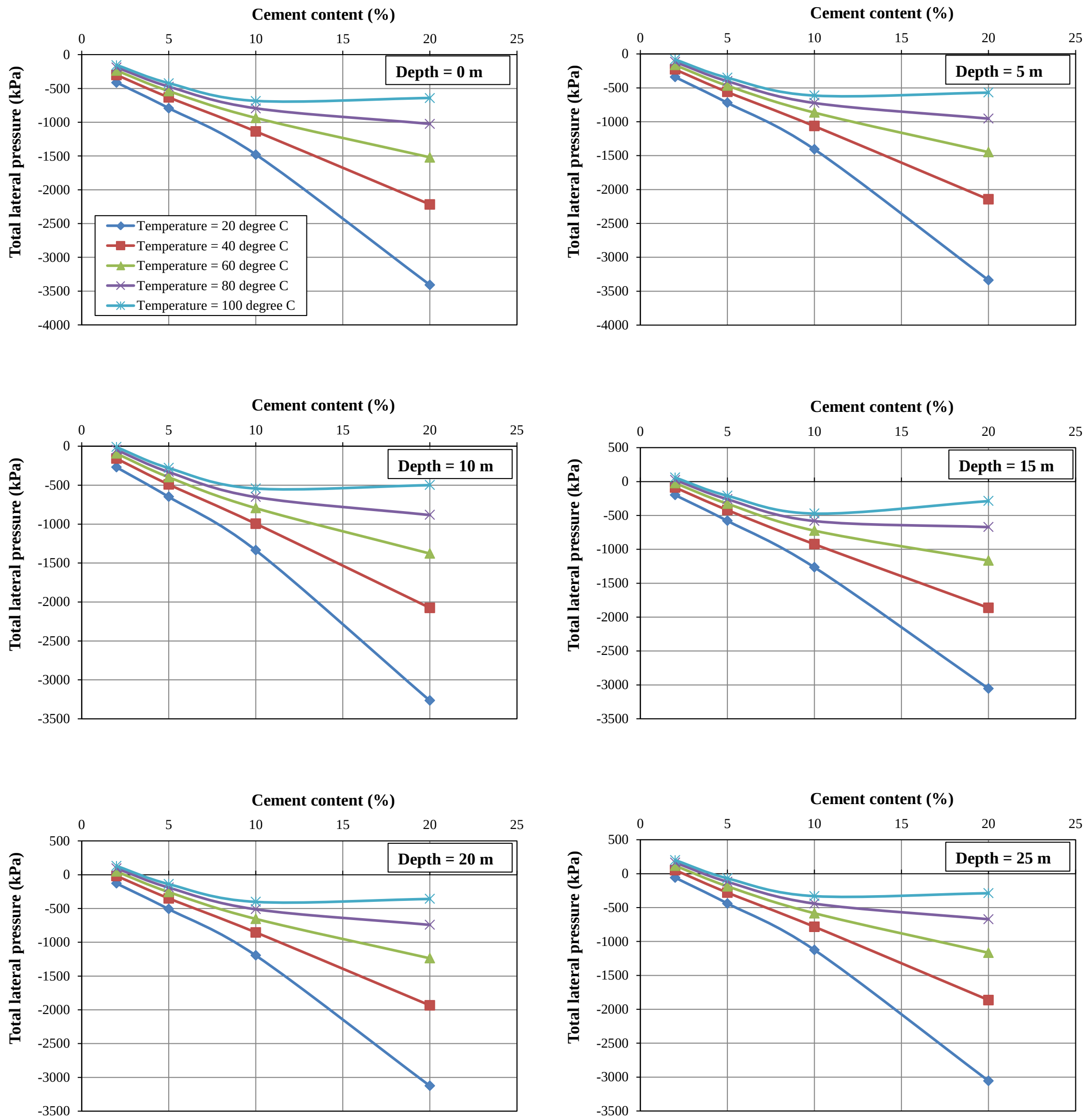

Fig. 6: Variation of total lateral active earth pressure with cement content at various temperatures.

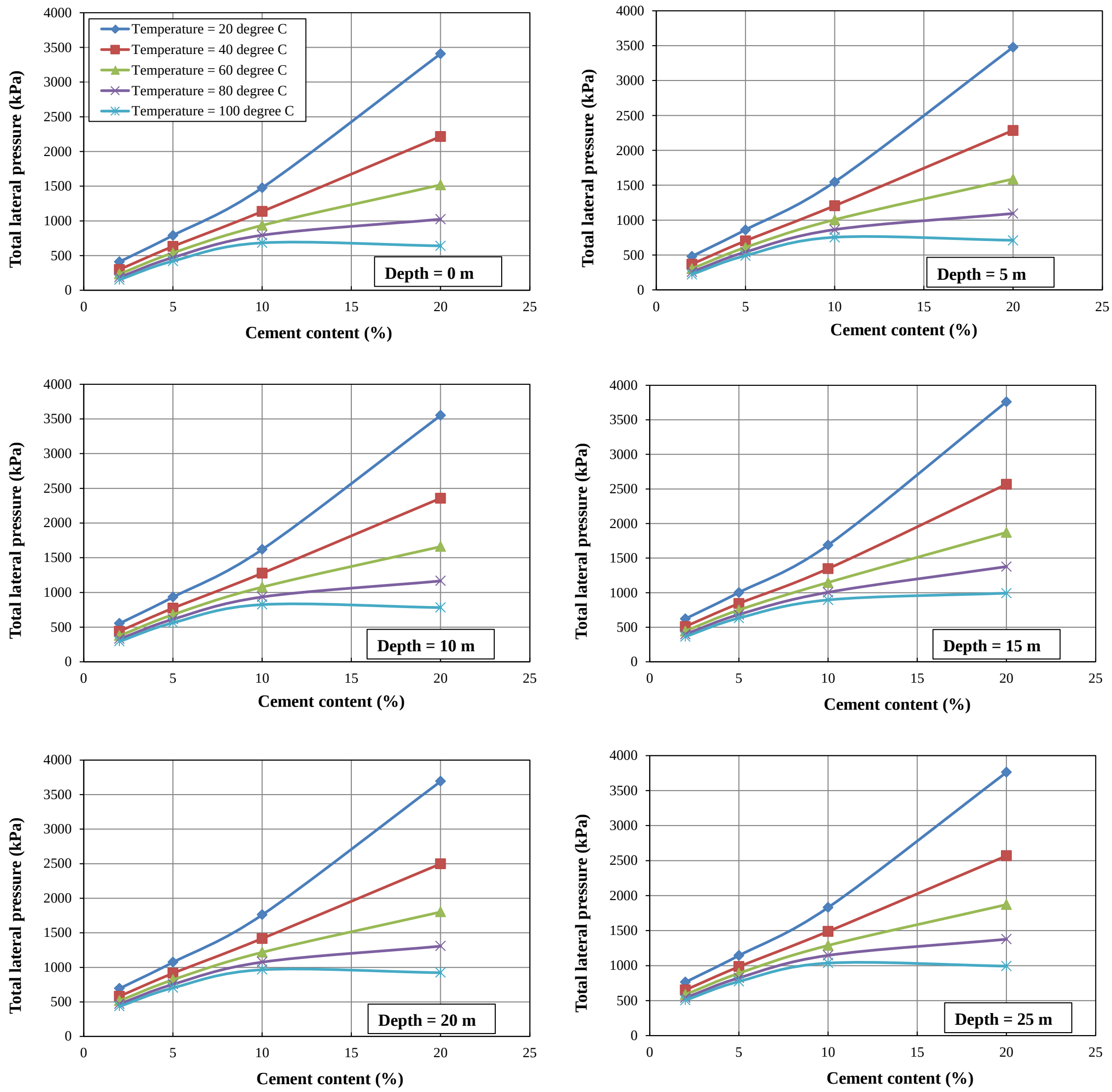

Fig. 7: Variation of total lateral passive earth pressure with cement content at various temperatures.

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