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Effect of heating on the behaviour of bentonite in the presence of salt solution

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Due to its high swelling tendency, layers of compacted bentonite is provided as a buffer materials at the nuclear waste repository site around the world. The development of the diffuse double layer (DDL) by the mineral montmorillonite, which is present in bentonite, provides the bentonite its swelling characteristics when permeated with water. The basic engineering properties, hydraulic conductivity and swelling behaviour of different bentonitehave been investigated by many of the researchers. However, when the bentonite is exposed to a higher temperature, it may undergo a transformation in its mineralogical composition and severely loses its tendency to develop the DDL. This in turn will impact the bentonite's swelling and hydraulic characteristics. Therefore, it is essential to investigate the influence of temperature on the swelling and hydraulic characteristics of bentonite.

Most of the earlier studies were mainly conducted on oven dried soil at room temperature in the presence of deionized (DI) water as the pore fluid. Considering that the an extremely large storage period and generation of high temperature caused by the decay of radionuclide's, the bentonite's functionality under complex thermal and chemical conditions must be ensured.

Previous studies [1, 2, 3] have shown a reduction in the swelling and liquid limit with an increase in the temperature. Similarly, previous studies [4] have indicated a substantial impact of salt solution on swelling, hydraulic and consolidation tendency of bentonite.

From the previous sinvestigatios it can be concluded that the temperature and salt have a definite impact on the behaviour of bentonite. However, no studies have been performed to investigate the collective influence of salt solution and temperature on the bentonite. Hence, the primary objective of this present study to investigate the combined impact of temperature on swelling and hydraulic behaviour of the bentonite.

Materials and Methods

Bentonite investigated in this research is in powdered form obtained from local source. Since an initial temperature of 250^0C was observed in the Yuca mountain repository site [5], a temperature of 300^0C was selected for study. Furthermore at higher temperature such as 500^0C the montmorillonite undergoes a significant change in its swelling behaviour [6], the study was also performed at 500^0C. Since most of the waste contains ions like Na^+ and Ca^{2+}, solutions of NaCl and $CaCl_2$ were selected for this study. After pre-heating the bentonite at 300 and 500^0C for 24 hours in a muffle furnace, various experiments were performed as per relevant ASTM standards.

Results and Discussions

The data in Table 1 compares the liquid limit, plastic limit and free swelling of pre-heated bentonites in the presence of 0 N, 0.1 N NaCl and 0.1 N $CaCl_2$ solution. The data shows that the liquid limit, plastic limit and free swelling of bentonite decreases due to increase in the temperature. The data also shows that the heating has less effect on liquid limit, plastic limit and free swelling for the bentonite in the presence of NaCl and $CaCl_2$ salt solution. The data also indicates that with the rise in the temperature from 300^0C to 500^0C, the salt has minimal impact on the behaviour of bentonite. By pre-heating the bentonite, the plasticity behaviour alters due to reduction of interlamellar water and the influence of the DDL becomes negligible. Therefore, the variation in the liquid

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limit with the salt was minimal for the bentonite pre-heated at 500^{0}C. However, as the DDL is dominant for the bentonite at 25^{0}C, the variation in the liquid limit was higher due to a change in the salt.

Table 1. Properties of pre-heated bentonite in presence of salt solution

Salt concentration (N)	Liquid limit (%)			Plastic limit (%)			Free swelling (mL/2g)		
	25^{0}C	300^{0}C	500^{0}C	25^{0}C	300^{0}C	500^{0}C	25^{0}C	300^{0}C	500^{0}C
0 N	259.2	169.2	85.3	44.5	35.1	23.6	18	12	7
0.1 N NaCl	142.7	96.2	78.3	31.5	22.1	22.5	14	8	5
0.1 N $CaCl_2$	123.8	87.1	74.5	30.1	23.8	21.7	11	7	4

The plot in Fig. 1 indicates the influence of heating on the swelling potential and swelling pressure of bentonite in the presence 0.1 N of NaCl and $CaCl_2$ solution. The plot also shows that the swelling potential and swelling pressure decreases with increase in the temperature and salt. However when permeated with the salt, the bentonite pre-heated at a higher temperature shows a neglible impact due to presence of salt on its swelling behaviour.

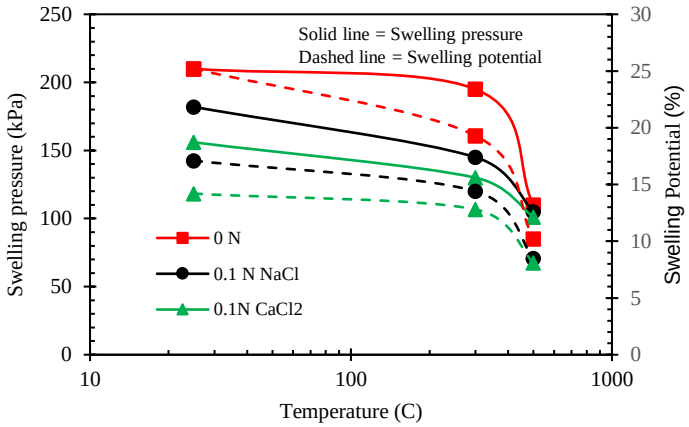

Figure 1: Effect of pre-heating on swelling behaviour of bentonite.

Conclusions

The study was perfomed to investigate the impact of pre-heating on the behaviour of bentonite in the presence of salt solution. The study concluded that the swelling and plasticity behaviour of bentonite decreases due to pre-heating at a higher temperature. The result also concluded that the bentonite pre-heated at a higher temperature undergoes a marginal change in its behaviour due to the exposure of salt solution.

Data Availability Statement

The data of the research work can be found on request.

Contributor statement

Anil Kumar Mishra: Conceptualization, Formal analysis, Review and Editing; Prashant Kumar: Origional draft, Investigation

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