



ハノイ市における繊維質材料混合流動化処理土の埋戻し地盤への適用に関する研究

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Overview of Liquefied Stabilized Soil (LSS) in Japan and Its Feasibility in Vietnam

2.1 LIQUEFIED STABILIZED SOIL (LSS) – an effective method for utilization of excavated soil in Japan

Mixing lime/cement with in-situ soils to form soil-cement columns start in the late 1970's in Japan (Okumura and Terashi, 1975; Terashi et al., 1979 and 1983; Kawasaki et al., 1981; and Suzuki, 1982). The fundamental mechanical properties and engineering behavior of the cement stabilized soils were investigated by several researchers (Terashi et al., 1979; Kawasaki et al., 1981; Bergado 1996; Tatsuoka et al., 1996; Uddin and Balasubramniam, 1997; Horpibulsuk et al., 2004; Chai, J.C. and Miura, N. 2005), and the method became one of the most widely used soft ground improvement technique. In recent years, how to treat the surplus clayey soils generated from construction sites and dredged mud from harbors is one of the geoenvironmental problems. On the other hand, there is a shortage of sandy soils, such as decomposed granite from mountains and development of sand from rivers, to be used as construction fill material. Therefore, if an effective technique can be developed to use the waste clayey soils as construction fill material these two problems can be solved together. A report by Kuno et al. (1998) pointed out that, excavated soils resulted in 44 million m³ in Japan in 1997. This amount is 18 % increase from 1992. Then, a result of survey for the fiscal year of 2000 (Miki et al., 2005): approximately 208 million m³ of waste soil from construction site in Japan. Yet, only 30 % of them are re-used for construction work while the remainder is simply dumped at inland and/or offshore reclamation sites. So, the question is how to treat the waste clayey soils from construction sites and dredged mud from harbors. And second reason is due to shortage of natural sandy soils for construction fill material. According to the report by Kuno et al. (1998), in 1997, sands used at construction sites are 20.6

millions m³. Among them, new sand is 68 %, recycled sand 29 %, stabilized soil 3 %; there values were 64 %, 34 % and 2 % in 1992 respectively. Another report released by Ministry of Environment of Japan in 2012 highlighted that the residual life of the landfill sites is estimated to be 13.6 years in Japan on average, particularly 4.3 years in Tokyo metropolitan area and 14.0 years in Kinki region. Therefore, it would be concluded from these data that recycling is slowly progressing but a large amount of reusable excavated soil is still dumped at reclamation sites while a large amount of new sand is developed from natural resource. Thus, the effective use of soil generated from construction is an urgent issue. Moreover, since the construction recycling law was established in May 2000 in Japan, the recycling rate for three target items such as concrete mass, asphalt concrete mass and construction wood waste has being increased. On the other hand, the recycling rate of three items such as mixture construction waste, construction sludge and excavated soil with construction works remained at a low level in 10 years ago. Therefore, the increase of recycling rate for these three items was expected.

From this background, "Liquefied Stabilized Soil" (LSS) (Kuno et al., 1997) which is one of the effective methods of using the excavated soil with construction works has become widely. In terms of creating an improved ground by adding and mixing cement stabilizer to the soil material, LSS is classified as slurry based premixed stabilized soil which is one of cement-treated soils. However, the LSS is different from the slurry based premixed stabilized soil (JGS, 2005; Kohata, 2006). Whereas the slurry based premixed stabilized soil is made by homogeneous soil material, the LSS is made by excavated soil from construction site, which is inhomogeneous soil material. And the LSS is considered to be carried to long distance by pump and to be filled to empty space. Then, the LSS have the appropriate flow by adjusting the density of soft muddy soil with high moisture content. The filling characteristics are expressed in parameters such as strength, flow value, density, bleeding ratio. They are decided according to the purpose of the site and produced through a proper mixing proportion after a certain combination of soil tests (Kuno et al., 1995). The strength of LSS is set at the level fitted for the purpose ranging from the strength of such degree so as to permit hand excavation to strength equal to the lean mixture concrete. Regarding the specifications for backfilling, the unconfined compressive strength must be from 0.15 to 0.3 N/mm² (Miki et al., 2005). The fluidity is evaluated by flow value; the spread diameter of LSS originally set in and released vertically for a cylinder measuring 8 cm high and 8 cm in diameter. By changing mix proportion, it is possible to yield the required flow value. The flow value changes along with density and time passage. It is known that a low value of 11 cm is the limit to pump LSS out and 14 to 25 cm is a good range (Kuno et al., 1996). The density is related to all parameters and usually set at 1.4 or higher. The bleeding ratio is restricted to within 1 % in most case or 0.5 % in the case of strictly limited volumetric change like when filling a cavity (Kuno et al., 1997). Past series of experiments show that hardened LSS in ground revealed following characters (Kuno et al., 1998).

1. Easy to re-excavate
2. Little shrinkage in the ground
3. Little corrosion by running water in the ground

4. Almost in-permeable
5. Liquefaction free in earthquake
6. No pH rise around the ground
7. Slurry waste also useful

Figure 2.1 shows a system flow of LSS method (Tomoharu et al., 2005). Excavated soil selected is trucked to LSS plant. After ground and screened it is moved to the mixing process. Water is added and density of slurry is monitored every minute so that it meets the mix design. Sequentially, cementing agents are uniformly mixed among slurry and then LSS has been made and pumped to agitator truck. Finally, LSS is trucked to where backfilling is necessary.

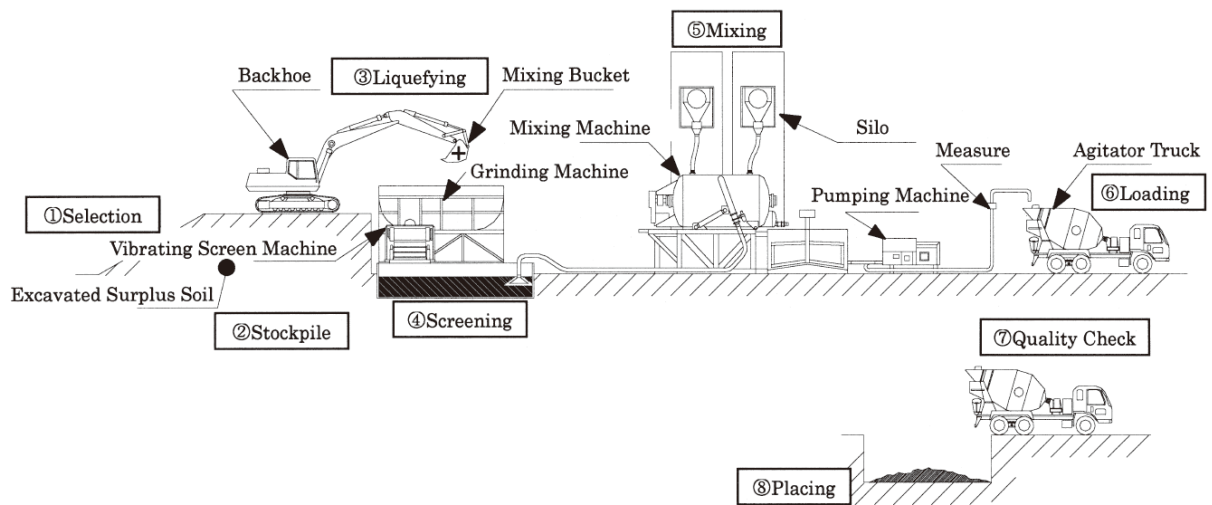


Figure 2.1 Flow of Liquefied soil stabilized method (Tomoharu et al., 2005)

A liquefied soil stabilizing method (LSS method) was proposed by Miki et al. (2005). Mixing soil can be facilitated by turning cohesive soil into slurry by increasing its water content. The mixture cannot be compacted but can be used to fill spaces closely due to its liquidity; strength can be developed after hardening, like placing concrete into a form (Figure 2.2).



a. Sludge stirring



b. Placement of LSS

Figure 2.2 Liquefied soil stabilizing method (LSS method, Miki et al., 2005)

Another method is pipe-line soil treatment system (Figure 2.3). For the purpose of stabilization of dredged mud, pipe-line soil mixing methods are getting popularized in Japan. The pipe-line treatment system has developed as a kind of the pipe-line soil mixing methods. The system is called “Kanro Mixer” installed on the way of dredging pipe-line and feeder devices for mixing materials. The system can be utilized for not only the consolidation of mud but also making the foam mixed soil, producing grainy soil and so on (Miki et al., 2005).

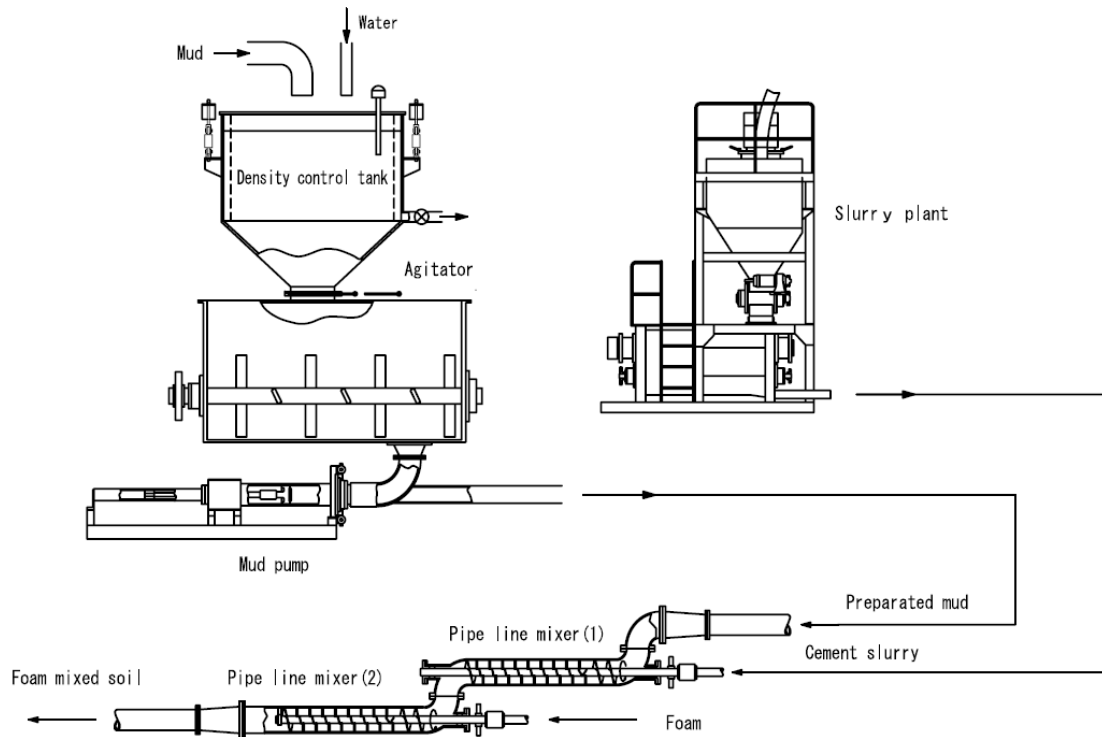


Figure 2.3 Production system for foam mixed lightweight soil

Foam mixed soil has been used extensively in Japan for road widening and back-filling projects, but never throughout the entire road cross-section (Figure 2.4). Cohesive soil taken in situ from the surface of the ground was used to make a high lightweight soil embankment. Geogrid layers were laid at uniform intervals to add reinforcement to the embankment. The slope faces are sprayed with a seed-mud-chemical mixture to create vegetation cover (Miki et al., 2005).



a. Embankment construction in progress b. Completed embankment

Figure 2.4 Light-weight banking method using in-situ surface soils (Miki et al., 2005)

Backfill as seep-proof structure: To protect the dredgings or waste soils from leaking through the rubble mound, it is necessary to place protection inside wharf. It was found that dredged soft soil after being treated with cement was a rational alternative for this protection at a depth of 20 to 40 m. As shown in Figure 2.5 and 2.6, it was decided to place the cement treated soil inside the wharf, with a layer thickness greater than 1.0 m and a slope about 1:3.

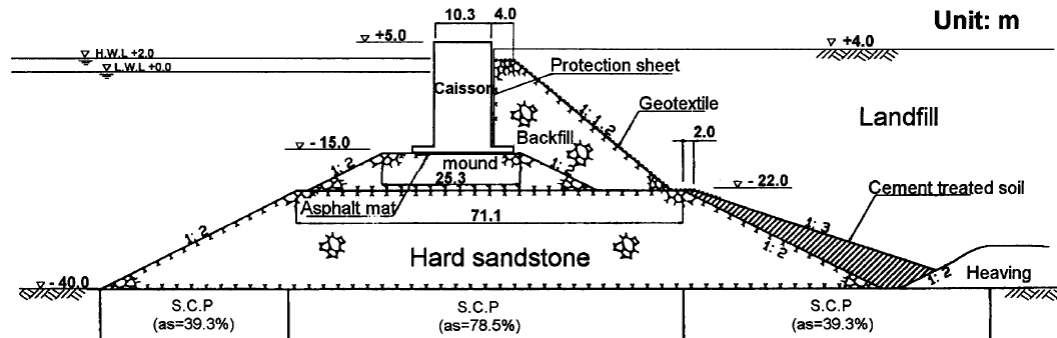


Figure 2.5 Cement treated soil using as slope protection (Tang et al., 2001)

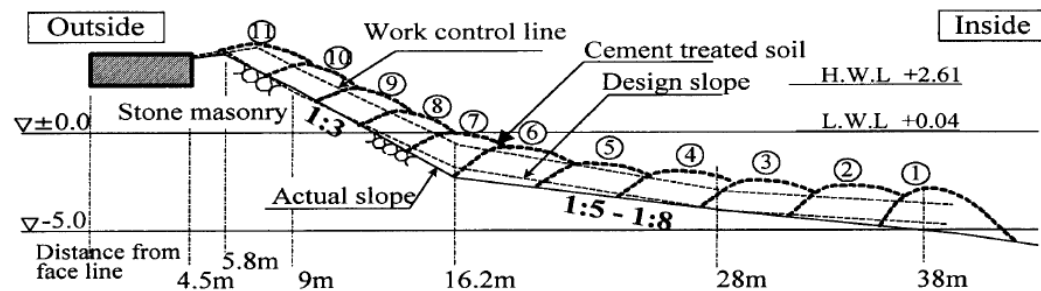


Figure 2.6 Placement of cement treated soil along slope (Tang et al., 2001)

Recently, two stage methods for treatment the dredged mud or surplus clayey soils generated from construction sites was proposed. First stage is that clayey soils were mixed with a small amount of lime/cement to make them stronger enough for transportation. Then improve the mechanical properties of treated clayey soils by adding more lime/cement (Hino et al., 2008) (Figure 2.7). Second stage is combination of lightly cement treatment with dual functions (reinforcement and drainage) horizontal geocomposite (Chai et al., 2011). The drainage effect can accelerate the self-weight consolidation of the clayey soils and the reinforcement effect can improve the stability of the embankment.



Figure 2.7 Two stages construction method using lightly lime/cement treated clayey soils (Hino et al., 2008)

In 1997, Kuno et al. presented one of several applications of LSS method; filling a cavity under pavement of urban road (Figure 2.8). The cavity is inferred mainly in the way that the submerged backfilled sand in the ground is washed out little by little to a nearby open space, for example sewage pipes, and thus, a cavity is created and grown. This application is thought to be possible of decreasing time and cost comparing to a conventional method. Thus two kinds of filed performance tests were conducted in order to verify capability and applicability of the method and acquire necessary field data for future maintenance works. The first field performance test used an on-site plant and a stabilized soil of low strength and relatively high flow condition while the second test use remote plant and stabilized soils of high strength and low flow condition. The tests were evaluated in term of adequate mix proportion, working system, working time, filling outcome, occupation of road, result of quality control test, and so on. Through two sequential field performance tests, it is confirmed that the method possesses good capability of filling cavities under the pavement and make it possible to decrease time and cost.

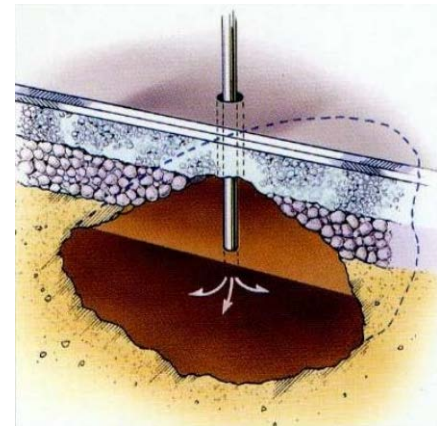


Figure 2.8 Use of LSS for filling cavity under road surface

Murata (2011) reported that LSS consists of slurry made of on-site soil, water, cement and sand of clay as appropriate LSS is used for backfill at upper part of a cut and cover tunnel and as an invert material of a shield tunnel (Figure 2.9). Pit sand is usually used for backfill, but LSS is much better than the sand, because it is easy to use with on-site soil and LSS can be buried without compaction into a narrow space. The lower part of shield tunnel is usually buried by low-strength concrete (unconfined compressive strength: about 10 MN/m^2). From the environmental point of view, however, LSS, which can reuse on-site soil, is now often use. Mixture of LSS was designed from the results of unconfined compressive tests and repeated loading tests. Then, it was designed the unconfined compressive strength of liquefied soil should be 6 MN/m^2 for safety purpose. To hold this strength level for some on-site soil, a very large amount of cement is needed ($300 \sim 400 \text{ kg/m}^3$ of LSS). So, a method to mix wasted fiber materials into LSS has been studied in order to increase the strength and ductility and decrease the total material cost. Studied have been promoted on what types of wasted fiber material are available and what rigidity level of wasted fiber material is needed.

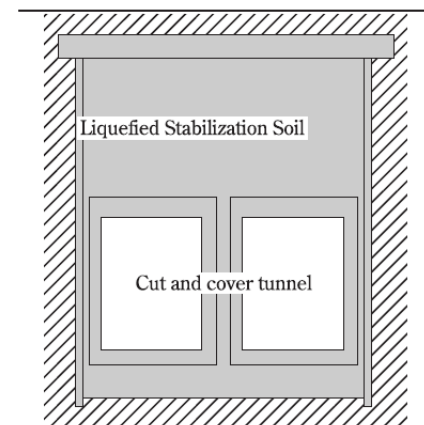


Figure 2.9a LSS used for backfill at upper part of cut and cover tunnel

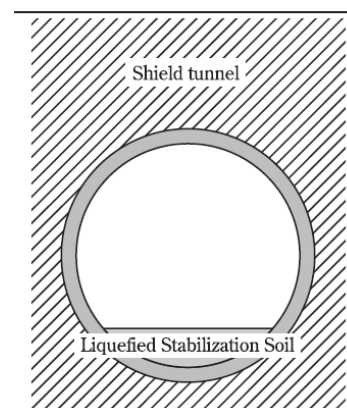


Figure 2.9b LSS used for invert material of shield tunnel

The design of strength and quality control method of LSS used as building foundation is proposed by Tomoharu et al. (2005). The results of the research pointed out that it is feasible for LSS to apply for the building foundation in future perspective. Another application of LSS is for constructing fences or retaining walls. Yoshihiro et al. (2006) reported that concrete block construction, which is common for these structures, tends to collapse under strong earthquakes, thus causing a threat to traffic, whereas liquefied stabilized soil block construction is capable of avoiding such damage due to the greater toughness of the material. Also, soil blocks are advantageous over concrete blocks in term of appearance. In their research, they have examined the effects of adding PVA fiber to LSS blocks under atmospheric condition. Tests were carried out on the drying shrinkage properties, resistance to atmospheric exposure, and uniaxial compressive strength. It found that PVA fiber reduces the drying shrinkage, crack propagation, and compressive strength of LSS block. The following Figure 2.10 is more examples of using LSS for various backfilling works in Japan.

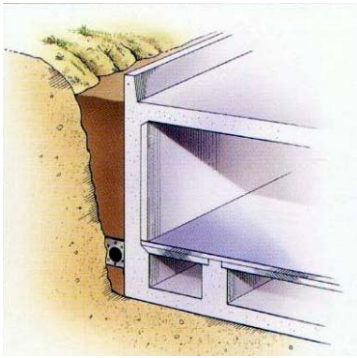


Figure 2.10a Backfilling of building foundation

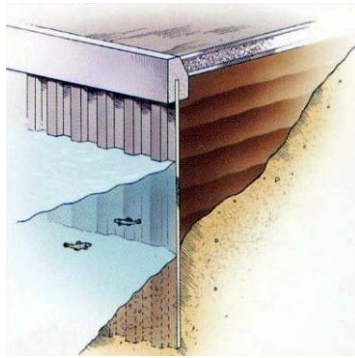


Figure 2.10b Backfilling of underwater seawall

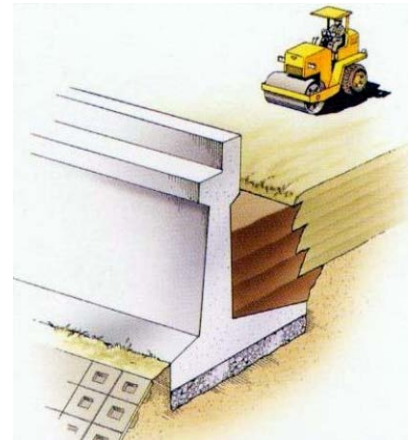


Figure 2.10c Backfilling of abutment

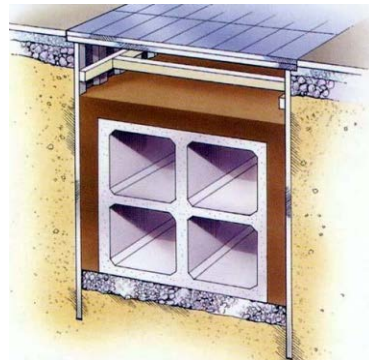


Figure 2.10d Backfilling of box culvert

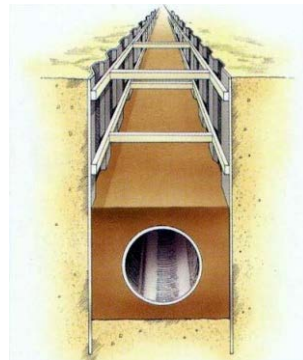


Figure 2.10e Backfilling of underground pipe

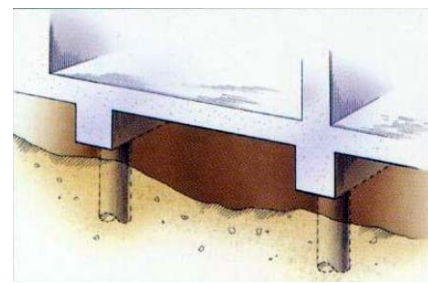


Figure 2.10f Filling of void under floor due to subsidence

Recently, most underground pipelines have been backfilled by LSS (Figure 2.10e). Figure 2.11 shows a construction site of the pipelines using LSS. Kawabata et al. (2008) conducted full scale field test for buried pipe using steel pipe of 3500 mm-diameter and 26 mm-thickness. Five cases of backfilling methods were applied. From the test results, it was found that the behavior of buried pipe was strongly influenced by the stiffness of backfilling method. In particular, the pipe which is backfilled with LSS showed stable behavior. Moreover, Kashiwaghi et al. (2009) and Kawabata et al. (2010) have proposed a method for thrust restraint using LSS. Mode I pit experiments using a model

pipe having a diameter of 260 mm were carried out in order to examine the effectiveness of the LSS for the thrust restraint of buried bend. LSS was applied to the passive area of the model pipe and dry silica sand was used as backfill material. The model pipe was laterally loaded at a speed of 1 mm/min after backfilling to simulate the thrust force. The lateral resistance and horizontal displacement of the model pipe were both measured. The earth



Figure 2.11 Backfilling of LSS

pressure distributions of the passive ground were observed. The results showed that the lateral resistance of the bend in using LSS was increased. It is verified that LSS is an effective backfill material for thrust restraint. Also, other experimental research results showed that the bending stiffness in case using LSS with geosynthetics was increased (Kawabata et al., 2009). In addition, the passive resistance was considerably increased in case using LSS with geogrid (Kawabata et al., 2008).

In 2006, Kohata has proposed a reinforcement method for LSS by mixing crushed newspaper as a fibered material into LSS, and carried out a series of unconfined compression tests and triaxial tests. The results indicated that by reinforcement effect, brittle property of LSS mixed with fibered material after the peak was improved.

2.2 CURRENT SITUATION OF EXCAVATING WORK IN VIETNAM

2.2.1 Road cave-ins

Recent years, more and more cave-ins appear at urban roads of Vietnam, especially in Hanoi and Ho Chi Minh cities (Figure 2.12 and 2.13).



Figure 2.12 Cave-ins and road collapses in Hanoi city



Figure 2.13 Cave-ins and road collapses in Ho Chi Minh city

A report released by Ministry of Construction of Vietnam pointed out that the road cave-ins suggest structural damage to underground soil. Although road cave-in may happen because of excessive extraction of groundwater, a serious problem in big cities of Vietnam, nonetheless, poorly planned underground infrastructure projects is blamed for causing the damage. Hanoi and Ho Chi Minh's roads caved in mainly because soil loosened during underground infrastructure construction and water leaked from ruptured underground pipelines. The earth under cities' roads is crisscrossed with public utility networks supplying electricity, telecommunications services, heating and for drainage. Large underground projects such as subways, shops and tunnels are also intensifying. The roads are often dug open to install or repair various utility networks, which are managed by different utility providers. Sometimes, the same section of a road is repeatedly dug up and repaved by different departments. If backfilled soil has not been sufficiently compacted, loosened soil under the road will be easily washed away by heavy rain, which is resulting in cavities and road collapses, according to the report. Road cave-ins used to occur only on automotive lanes, whereas in the last two years they also affected bicycle lanes and pedestrian walks. Sewage pipes and rainwater drainage pipes usually run underneath bicycle lanes and pedestrian walks, which are more likely to cave in after heavy rainfall. The report suggested that if there is no other underground construction project, usually, the road depression will not be very deep.

Thus, the cavity under the pavement is inferred mainly in the way that the submerged poor backfilled material in the ground is washed out little by little to a nearby open space, for example sewage pipe or base-floor of high-rise building under construction, and then, cavity is creative and grown. On the other hand, the poor backfilled material which is insufficiently compacted causes the instability of water supply pipe. Moreover an over compaction in the construction stage can bad impact on the pipe structure. These are two of reasons make the main water supply pipe line of Hanoi city easier to break (Ministry of Construction, 2014). The line was broken ten times since operated in 2012 until 2014 (see Picture 2.14 and 2.15).



Figure 2.14 Broken water supply pipe line in Hanoi



Figure 2.15 Repairing and backfilling work of the broken water supply pipe line

2.2.2 Inappropriate disposal of excavated soils

Nowadays, excavated soils from construction sites are becoming a serious problem in Vietnam. It becomes more and more difficult to find reclamation sites for excavated

soil to dump around big city. Because of shortage of reclamation sites and part of soil is disposed inappropriate, it causes the environmental pollution (see Figure 2.16).



Figure 2.16 Inappropriate disposal of excavated soils from construction sites in Hanoi

According to a new study released today by Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam, about 1,000,000 m³ of excavated soil will have to be trucked from construction projects to disposal sites in Hanoi city over the next decade or two. The construction of the first phase of the metro line project alone, for example, will generate some 1,500,000 m³ of excavated soil. The study estimates that it could cost 100 million dollars or more to transport and dispose of these soils depending on the future availability of sites. Another project, the City of Hanoi's own water and sewer capital program, will produce more than 800,000 m³ between now and the end of the decade. The question of where to put this extracted soil, according to the Ministry, some area surrounding Hanoi city are now restricting or banning the importation of soils.

2.2.3 Mining of new material from natural resources

In Vietnam, most backfilling material for construction is being extracted from natural sources. Mining of the materials such as sand from river and gravel from mountain has a significant impact on the natural environment. The demand for sand and gravel continues to increase day by day. Excessive instream sand-and-gravel mining causes the degradation of rivers. Instream mining lowers the stream bottom, which lead to bank erosion (see Figure 2.17). Depletion of sand in the streambed and along coastal



Figure 2.17 Bank erosion due to depletion of sand in streambed

areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive instream sand mining is a threat to bridges, river banks and nearby structures (Figure 2.18). Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Instream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire streambed to degrade to the depth of excavation. Sand mining generates extra vehicle traffic, which negatively impairs the environment. Where access roads cross riparian areas, the local environment is being impacted.



Figure 2.18a Sand mining near Thang Long Bridge



Figure 2.18b Sand mining near Can Tho Bridge

2.3 FEASIBILITY FOR UTILIZATION OF LSS IN VIETNAM

From the above discussion about many advantages as using of LSS for construction works in Japan and current situation of excavating works in Vietnam, it can be said that if LSS will be applied in Vietnam, the aforementioned serious problems can be solved. Thus, a feasible research whether LSS can be applied in Vietnam has been carried out by Nguyen et al., 2010. In the research, a series of physical tests for Hanoi clay (Vinh Phuc-Clay) which was obtained from areas around the planned sites of subway at Hanoi and consolidated-undrained triaxial compression tests (CUB tests) were performed to investigate strength and deformation properties of LSS using Vinh Phuc-clay as a base material (Vinh Phuc-clay LSS). The test results were compared with that of LSS using base material of NSF-clay which is common clay for LSS in Japan. The effects of crushed waste newspaper as a fiber material into these LSS were also investigated. In addition, the vibration characteristic of ground in the case using Vinh Phuc-clay LSS for

backfilling of cut and cover tunnel was examined by two-dimensional FEM in his research. The results of the study indicated that Vinh Phuc-clay could provide conditions satisfying LSS' terms determined in Japanese clay, and confirmed that the LSS method is applicable in Vietnam. Moreover, the strength and deformation properties of Vinh Phuc-clay LSS mixed with fibered material has been improved. Also, the LSS shows excess consolidation behavior caused by cementation effect, and remarkable reinforcement effect by adding fibered material in comparison with Japanese NSF-clay LSS. In addition, the result confirmed that the LSS has effect on reduction of ground vibration caused by traffic load.

2.4 SUMMARY

An overview of Liquefied Stabilizes Soil (LSS) has been presented in this chapter. In Japan, the utilization of LSS in construction fields brings double advantages from the environment point of view. Thus, two big problems which are shortage of backfilling material usually extracted from natural sources and excavated soil generated from construction sites have been effectively solved together. On the other hand, at present, Vietnam is facing serious problems concerning the excavating works which excavated soil is inappropriately disposed to surrounding environment due to the shortage of reclamation sites and the negative impacts on living environment and society as mining sand and gravel from river and mountain to be backfilling material for construction works and so on. In 2010, A feasible research on applicability of LSS in Vietnam has pointed out that LSS using Vinh Phuc-clay that spread in Hanoi city of Vietnam can be manufactured conforming to standards designated for Japanese LSS. From these, it should be expected that LSS can be applied in Vietnam as soon as possible.

Based on the above, the aim of this dissertation is to investigate the deformation and strength characteristics of LSS and LSS mixed with crushed waste newspaper as a fiber material which was proposed by Kohata, 2006 and then to promote the use of LSS in Vietnam in near future.

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