Study on the in situ-expanded geosynthetic bags for emergency restoration of ground subsidence: (I) the conceptual approach

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ABSTRACT: In the current restoration system, it takes a lot of time to repair due to traffic control, transporting fill materials to be restored and the complicated procedure of constructing. These require that the fast emergency restoration technology. However, it happened frequently that re-subsidence (secondary deformation) of ground restored by poor compacting in sink hole zone. For this reason, the in situ-expanded geosynthetic bags for standard restoration system of ground subsidence was suggested to rapid restoration. Basic studies of the conceptual approach on the application mechanism of in-situ expanded geosynthetic bags and the its key feature of compressive strength (expanding ratio & compressive strength), expansion pressure (act as a compacting pressure), etc. were carried out and discussed to identify the feasibility.

Keywords: Sink hole, in situ expanded, geosynthetic bags, compressive strength, expansion pressure

1 INTRODUCTION

Various technical solutions are proposed for restoration of ground subsidence in urban areas. The restoration of ground subsidence in urban areas is mainly based on the technique of a liquid inflating mixture injection as a trenchless method to fill the inner cavity to be restored. In the case of an open cut method, the problematic parts such as leakage and erosion in sink hole are cut, repaired, and then filled (Figure. 1). The full compaction is hard to achieve faithfully during backfilling, thus the secondary depression phenomenon occurs frequently due to poor compaction. This poor compaction is mainly result from underground obstacles such as pipelines and leads another ground subsidence.

In the case of the trenchless method, a large amount of liquid inflating agent is required, which requires a much larger amount than the target filling liquid, and the leaking of inflating agent cause some misinstallation that they are positioned a wrong spot rather than the target position, thereby disturbing the ground. In the case of cut and cover method, there is a disadvantage that the indirect cost of controlling traffic system is excessively generated until the completion of all the processes.

However, EPS is well known as the light weight backfill material for backfilling an embankment, which is applied to road ground, alternate filling material, etc., and it is advantageous that the quality control is easy with the lightweight filler material manufactured in the factory and the same quality control can get by the standardized construction technique (Figure. 2).

The notion of an expandable filler such as EPS applied to the ground subsidence in urban areas is a in situ expanded geosynthetic bag for open cut method. The purpose of this study is to investigate the applicability and requirements of in situ expanded geosynthetic bags for the development of emergency rescue technology considering the urban conditions.

Figure 1. The ground subsidence in urban area (S. Korea)

Figure 2. EPS block for embankment

2 BASIC CONCEPT ON USING THE EXPANDED GEOSYNTHETICS BAGS FOR GROUND SUBSIDENCE

Currently, it is time-consuming to transport, supply of good quality soil and mortar for restoring the ground subsidence in urban area. And the social non-operational cost due to the control of the vehicle is additionally generated to control the traffics.

In technically, it is necessary to faithfully carry out the compaction work during the filling process in order to secure the sufficient capacity of the recovery sink-hole area. However, in many cases, the compaction work cannot be performed sufficiently due to the underground obstacles (concrete structure, water supply and drainage pipes, gas pipes, etc.). To improve these present technical limitations, it is necessary

to minimize the backfilling process and compaction work carried, the restoration working time, to easy build up the restoration section.

From the viewpoint of emergent recovery, the development of new materials and new construction methods is required to enable recognition of the ground subsidence as well as to be able to respond quickly. Also, it is better if non-experts can easily perform the restoration work. It is more effective that the materials used for restoration are supplied in a form that can be provided at all times. The requirements of the material for back-filling a sink-hole are summarized as follows.

- Good compaction strength same as a well-grounded ground
- Minimization the use of heavy equipment to ensure compaction
- Applicable to underground conditions where compaction is difficult
- Produce active compaction without additional compaction.
- Minimize work time
- Non-professional
- Easy to management

To achieve these requirements, an in situ expanded geosynthetics bag infused with an inflating agent is proposed. As a sandbag-like structure, a lightweight inflating agent filled bag for sink-hole restoration can quickly secure a filler material such as an EPS block which is controlled expansion behavior at the site. The expansion behavior after injection of the inflating agent into the geosynthetic bag can induce the compaction effect by the expansion pressure which is controlled the directionality, and it is possible to install the filler having sufficient compaction strength even in the space where compaction is impossible. A conceptual diagram is shown in Figure 3, where the infill is injected into the geosynthetics bag in a basic ground subsidence. When backfilling with an expandable geosynthetics bag, additional reinforcement layers can be placed on top and bottom to improve ground strength.

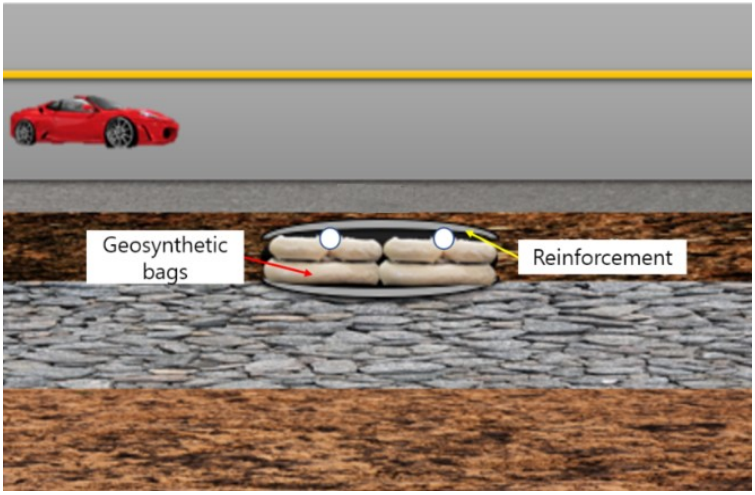

Figure 3. conceptual drawing of expandable geosynthetic bags for ground subsidence

The size of the geosynthetic bag to be used should be determined according to the size of sink-hole, and the inflation rate, expansion pressure, and compressive strength after swelling of the agent should be controlled to fulfill the required level considering the ground condition.

3 REQUIREMENT OF THE EXPANDED GEOSYNTHETICS BAGS AND ITS PREDOMINATLY PROPERTIES FOR RESTORATION OF GROUND SUBSIDENCE

The expansion strength of geosynthetic bag filled with inflating agents, which functions as backfill soils, affects directly the stiffness of ground restored, so that the required compressive strength should be meet the specific value which is not defined yet. An objective procedure for establishing appropriate criteria for this value is also needed. The proposed value of compressive strength was about 0.4 MPa for the conventional liquid inflating agent. It is necessary to evaluate the applicability of the proposed geosynthetic bag through lab tests on the expandability, expansion direction, expansion pressure, post - hardening compressive strength, applicability of the in - situ expanded geosynthetic bag which is conceptually proposed.

A set of preliminary tests was conducted to confirm the feasibility of the performance of the in situ expanded geosynthetic bag. Using a commercial inflating agent, basic tests were conducted to defined the proper expansion pressure, the compressive strength after expansion, the direction of expansion, and the applicability of the product.

By using 3 kinds of bi-liquid type inflating agents with maximum expansion rates of 10, 15, and 20 times at 5~10 min. of curing time, the compressive strengths after 1 hour and 72 hours were evaluated. The specimens were prepared in cylindrical form with a diameter of 50 mm and a length of 100 mm, and the uniaxial compression behavior was evaluated. The results are shown in Table 1. The suggested values are enough to secure sufficient bearing capacity after curing as a backfill soil.

The inflating pressure during the inflating process in geosynthetic bag was measured and the results are shown in Table 2. The inflating agent was injected into a plastic bag of about 100 ml volumes and the inflating pressure in the inflation process was measured. The pressure value obtained on the load cell was measured by inducing free expansion between two load plates without controlling the direction of expansion. We can confirm the feasibility of applying the inflation bag as a backfill material to the area where compaction is difficult, and confirm that further study is needed on the in situ expanded geosynthetic bag to secure the direction of inflation pressure.

Table 1. expansion behavior and compressive strength of bi-liquid inflating agents.

Terms	Inflating agent		
	Type A – 10x	Type B – 15x	Type C – 20x
Initial volume (cm^3)	109.0	109.0	109.9
Final volume (cm^3)	643.7	1248.2	1687.8
Expansion rate (%)	586	1136	1536
Compressive strength at 1hr (MPa)	1.80	1.73	1.66
Final compressive strength at 72hrs (MPa)	3.33	2.50	1.67

Table 2. expansion pressure of bi-liquid inflating agents.

Terms	Inflating agent								
	Type A – 10x			Type B – 15x			Type C – 20x		
ton/㎡	55.20	57.77	55.61	83.16	81.53	86.02	112.96	114.08	127.14

4 FUTURE WORKS

It has been confirmed that the application of the proposed in-situ expandable geosynthetics expansion bag for emergency restoration of ground subsidence can be applied as a material capable of exhibiting sufficient compressive strength and expansion pressure through a preliminary test. Additional studies should be carried out on the relationship between the content of the expanding agent and the expansion bag size,

the quantification of the expanding pressure, the determination of factors for controlling the expansion behavior of the agent, and the securing of structural control technology of the geosynthetic bag for controlling the expansion directionality.

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