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A Study on the Optimum Mix Proportion of the Stabilizing Liquid Used for Excavation of the Deep and Massive Slurry Wall

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Abstract

This study investigates experimentally the optimum mix proportion and design factors of the stabilizing liquid used for excavation of the massive and deep slurry wall in LNG in-ground tank before pouring concrete. Considering those site conditions, the stabilizing liquid used for excavation of slurry wall has to be satisfied with some requirements including specific gravity, fluid loss, cake thickness, funnel viscosity and sand content in order to construct the safe and qualified slurry wall.

For this purpose, we select materials including bentonite, polymer and dispersion agent. After performing many tests for materials and mix design process, we propose the optimum mix proportion that the upper limit ratio of bentonite is 2.0%, polymer is 0.1% considering the funnel viscosity and dispersion agent is 0.05% considering the fluid loss of the stabilizing liquid. Also, we select all materials which are consisted of GTC4 as bentonite, KSTP as polymer and Bentocryl 86 as dispersion agent.

Based on the results of this study, the optimum mix proportion of the stabilizing liquid is applicable to excavate the deep and massive slurry wall in LNG in-ground tank successfully.

Keywords: fluid loss, cake thickness, funnel viscosity, sand content, deep and massive slurry wall

1. Introduction

Recently, Korea government has a plan to construct LNG (Liquefied natural gas) in-ground tank to supply stably in near Seoul and another large city. Inchon is proved to have the best situation for storage and supply of LNG. Now, 6tanks of in-ground type having the largest storage capacity about 200,000*kl* in the world have been constructing in regular sequence.

Especially, slurry wall of LNG in-ground type having the deep and massive section is planed in pouring by the combined high flowing concrete after excavation of soil.

Namely, slurry wall must maintain the stability during excavating soil and pouring concrete without collapse. Also, during cutting over primary element in the excavation of secondary element or soil mixing wall (S.M.W) and guide wall in the excavation of primary element, the stabilizing liquid can be polluted by cement or seawater.

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Therefore, the selection for the optimum mix proportion of the stabilizing liquid satisfied with the required properties including specific gravity, fluid loss, cake thickness, pH, funnel viscosity and sand content is very important process in a view point of safe and qualified slurry wall. Basically requirements of the stabilizing liquid to apply in LNG in-ground tank are as followings

(1) Stabilization of the trench (prevention of collapse)

The stabilizing liquid should be made the mud cake on the face of excavating trench to transfer the inner pressure on the face of excavating trench and to stabilize the trench. The trench should be stabilized until the installation of the re-bar cage and pouring the concrete after excavation. So the value of fluid loss should be low as possible and the mud cake should have a thin and strong film.

(2) Pouring of the good quality concrete

It needs to keep the low value of specific gravity and viscosity for filling of the concrete, to decrease the quantity of slime in the stabilizing liquid and to prevent from mixing slime with concrete.

During excavation, the stabilizing liquid is required the function for stability of the trench wall and excavated muck transportation and separation. And when installation of the re-bar cage and pouring of the concrete, also the stabilizing slurry is required the function for stability of the trench wall and placement with the qualified concrete.

Also, two kinds of the stabilizing liquid will be used. One is used for excavating soil, another is used for pouring of the qualified concrete after slime replacement.

The purpose of this study is to design the requirements for materials of the stabilizing liquid and to select the optimum mix proportion of the stabilizing liquid used for excavation of the deep and massive slurry wall in Inchon LNG in-ground tank.

After investigating materials used in the stabilizing liquid and testing various factors for the mix design proportions, the optimum mix proportion used in the stabilizing liquid will be proposed in this study. All works and mix design procedure for the stabilizing liquid shall be performed in accordance with standards, codes as referenced.[1-2)]

2. Flow chart of mix design and procedure

2.1 Flow chart of mix design

The flow chart to determine the optimum mix proportion of the stabilizing liquid is shown as following Fig. 1.

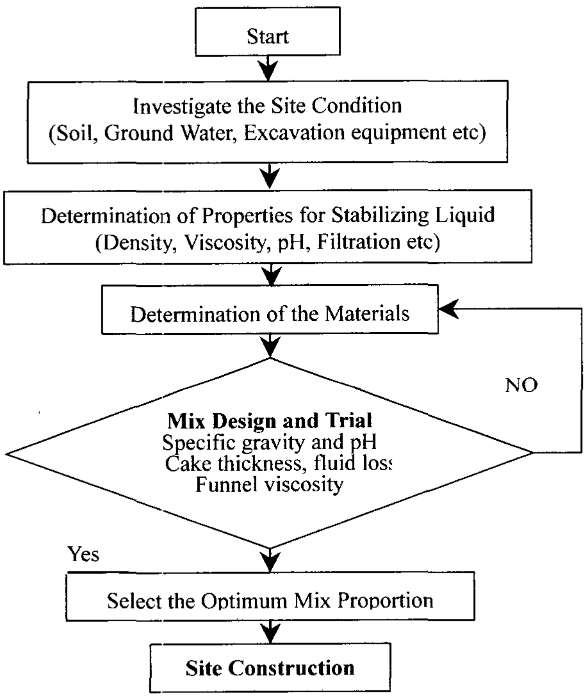

Fig. 1 Flow chart for the mix design process

2.2 Soil and construction conditions

2.2.1 Soil investigation

Need protection (SMW) being employed for protecting the collapse of trench walls.

2.2.2 Ground water investigation

In-ground water level is GL -1.5~-2.5m.

2.2.3 Excavating equipment

Rotary excavator & bauer trench cutter BC-30, BC-40.

2.2.4 Excavated depth, width, element length

Depth is max 78.4m, width is 1.7m and element length is max 7.25m.

2.3 Codes and standards

2.3.1 API

This code means American Petroleum Institute–RP 13B-1-1990 and recommended Practice Standard procedure for Field Testing Water-Based Drilling Fluids

2.3.2 JBAS

This code means Japan Bentonite Manufacturers Asso-cia-tion Standard and standard testing method follows Japanese association of bentonite industry

2.4 Measuring methods and instruments

2.4.1 Specific gravity

1) Measuring method : A unit weight of stabilizing liquid
2) Measuring instrument : Mud balance

2.4.2 Funnel viscosity

1) Measuring method :
The time for 946cc to flow through a standard funnel of 1500cc volume (In case of JBAS, 500cc/500cc)
2) Measuring instrument : Marsh funnel visco-meter

2.4.3 Fluid loss and cake thickness

1) Measuring method : As a pressure of 7 kg/cm^2 (in case of JBAS, 3 kg/cm^2) is applied through the Pressure inlet, and the volume of filtrate collected in 7.5min (in case of JBAS 30min) is recorded. And after test, measure the thickness of mud cake adhered to filter paper.
2) Measuring instrument : Filer press, Vernier caliper

2.4.4 pH-value

1) Measuring method : Concentration index of Hydrogen
2) Measuring instrument : pH Electro-meter

Table 1 Required performances and control criteria

Items \ Spec.	Control criteria		Test method
	Excavation slurry	Qualified slurry	
Specific gravity	Below 1.1	Below 1.08	Mud balance electric scale
Fluid loss (cc)	Below 15.0	Below 15.0	Filter pressure (7 kg/㎠, 7.5min)
Cake thickness (㎜)	Below 5.0	Below 1.5	Vernier calipers after filtering
pH	7.5~12.5	7.5~12.5	pH meter
Funnel viscosity (sec)	30~45	30~45	Funnel visco-meter (946cc/1500cc)
Sand content (%)	Below 5.0	Below 1.0	Sand content meter

Table 2 Properties of all materials for stabilizing liquid

Bentonite (GTC4)		Polymer (KSTP)	Dispersion agent (Bentocryl 86)
Physical	Rheological		
Water content (10.8%)	Water transmission (17.9 mℓ)	Type (White powder)	Specific gravity (1.3)
Specific gravity (0.8)	Gel strength (5.7 lbs/100ft^3)	Viscosity (870cp) (1% solution)	pH (8.0)
pH (10.2)	Marsh viscosity (42.8s)	pH (7.9) (1% solution)	Boiling point (65℃)

2.5 Required performances and control criteria

Considered site conditions, required performances and the control criteria of the stabilizing liquid can be classified and specified into specific gravity, viscosity, pH and sand content as following Table 1.

Qualified slurry means that it has low specific and little slime distinguished from circulating slurry to substitute the stabilizing liquid with the good concrete. It will be installed the re-bar cage after substitution of circulating slurry with qualified slurry when the excavation is ended.

3. Experimental investigation

3.1 Materials

Generally, the stabilizing liquid is consisted of three or four constituent parts including bentonite, polymer, dispersion agent and water dis-leakage agent. Properties of materials used for the stabilizing liquid give as following Table 2. All materials should be selected considering actual applications in site, high quality, market share and enough capacity of supply in Korea.

3.1.1 Bentonite

Bentonite means stabilizing liquid used only bentonite without another materials (polymer, dispersion agent and so on). Generally speaking, when bentonite are used in site condition having shallow depth about 15~30m, It is become very effective.

Site conditions of Inchon LNG in-ground tank having deep and massive slurry wall about 72~78m excavation depth and 1.7m thickness are contained with an elementary particle like clay and is located in the sea-girt, it is no effective using only bentonite considering viscosity, fluid and so on. Considered actual test results, the upper limit ratio of bentonite only shows 3.0% because the value of funnel viscosity in the case of bentonite 4.0% mixture is too high. Therefore, bentonite must use the mixture of below 3.0% to stabilize the trench and not only bentonite but also polymer and dispersion agent.

3.1.2 Polymer

Since trench protection (SMW) being employed for protecting the collapse of trench walls, polymer which is low-viscosity / low-density and is able to be well replaced with concrete shall be selected as a material of the stabilizing liquid. KSTP as a polymer improved in reducing viscosity compared to old type having a high viscosity is selected and used in trial mixing of the stabilizing liquid.

By checking of the actual test results, the value of funnel viscosity is too high in the case of polymer 0.2%, so the upper limit of polymer is best range about 0.15%.

3.1.3 Dispersion agent

During cutting over primary element in the excavation of secondary element or soil mixing wall in the excavation of primary element, the stabilizing slurry can be polluted by cement or seawater.

Therefore, dispersion agent must use in the stabilizing liquid in order to protect cohesion by cement. Bentocryl 86 as a dispersion agent is selected and used. Also, Tests for the anti-cement nature of stabilizing liquid by addition of cement in the mixture after 24hours will be performed.

Considered actual test results, care has been not to increase the addition of dispersion agent. It will be effective to add 0.2%. But after deterioration by solid or cement, dispersion agent of 0.05% to reduce the specific gravity can be added.

3.1.4 Water dis-leakage agent

Considered the actual data measured of soil conditions in Inchon LNG site, any dis-leakage was not need to use because there was small leaking of liquid even in the gravel layer existing in the depth of 50m. These data were measured during off hour after excavation. Now, sand content of slurry is high after excavation, because it is now the qualified slurry. So the measured trench depth was decreased because slime accumulated on the bottom of trench. Trench depth and slurry level were measured from top of guide wall. Accumulated leakage depth means the length between the initial slurry level and the measured slurry level. The gravel layer exists about GL-50m~55m. So all measured data include the gravel layer.

Bite is as same as gut. Bite 1 and 3 are same element. So slurry level is same. Trench situation is shown as follows Fig. 2. The leakage velocity calculated from the actual data is shown as Table 3.

This table shows that the maximum leakage velocity is under 0.05 m/hr. According to the Japanese standard, it shows that leakage velocity under 0.2m/hr means small leakage, and then it deals with small leakage to use high viscosity of the stabilizing slurry or dis-leakage agent.

Now, the maximum leakage velocity (under 0.05 m/hr) is very small. Considered that leakage velocity of site conditions is very small even in the gravel layer, dis-leakage agent is not to be used.

3.1.5 Materials selected and used in the stabilizing liquid

All materials are shown as Table 4. After carrying out various tests for the design factors to determine the optimum mix proportion of the stabili-zing liquid used in slurry wall excavation of LNG in-ground tank. We will select the optimum mix proportion of the stabilizing liquid and use those materials in actual site.

3.2 Details of the trial mix condition

Mixing conditions and test process are divided into 5steps from series A to E as followings. Tests for the stabilizing liquid will be checked two times (Immediately after mixing and after 24hours) considering excavation term of slurry wall construction. All test results will be evaluated by viscosity, gravity, pH and fluid loss.

3.2.1 Slurry test for bentonite only (Series A)

Mixing conditions of slurry test to compare with the relationship between dosage ratio of GTC4 as a bentonite only are shown as Table 5.

3.2.2 Slurry mud test (Series B)

Mixing conditions of slurry mud test to compare with the relationship between dosage ratio of GTC4 as a bentonite and KSTP as a polymer are shown as Table 6.

Dosage ratio of KSTP to evaluate the fluid influence by polymer is divided into 3 ranges (0.09~0.12%). Dosage ratio of GTC4 is also selected with a test range of 1.0~3.0%.

3.2.3 Cement test by adding Bentocryl 86 (Series C)

During cutting over primary element or soil mixing wall in the excavation of the primary or secondary element, the stabilizing liquid can be polluted by cement.

Therefore, to compare test results with cement tolerance by adding dispersion agent (Bentocryl 86) or not, C series test performs as Table 7.

Dosage ratio of Bentocryl 86 is divided into 3 ranges (0~0.10%) to evaluate the dispersed influence.

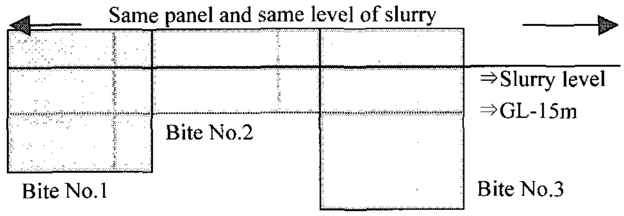

Fig. 2 Trench situation and bite number

Table 3 The leakage velocity of the actual data

Test date (days)	Checking time (hr)	Accumulated leakage depth (cm)	Leakage velocity (cm/hr)
1	13.5	38.0	2.81
	6.5	18.5	2.85
	8.0	22.7	2.84
2	3.0	8.5	2.83
3	10.5	30.0	2.86
4	8.0	20.0	2.50
5	9.0	26.0	2.89
6	10.0	19.0	1.90
7	6.25	19.5	3.12
8	4.0	15.5	3.88
9	4.16	19.0	4.52
Maximum			4.52

Table 4 Materials used in slurry mixing

Polymer	KSTP
Bentonite	GTC4
Dispersion agent	Bentocryl 86
pH adjust	Na_2CO_3 and $NaHCO_3$
Cement	Ordinary Portland Cement (Type 1)

Table 5 Mixing conditions of series A (GTC4 only)

No.	GTC4 (%)	KSTP (%)	Bentocryl 86 (%)	Cement (%)
A-1	1.0	-	-	-
A-2	2.0	-	-	-
A-3	3.0	-	-	-
A-4	4.0	-	-	-

Table 6 Mixing conditions of series B (GTC4+KSTP)

No.	GTC4 (%)	KSTP (%)	Bentocryl 86 (%)	Cement (%)
B-1	1.0	0.09	-	-
B-2	1.0	0.10	-	-
B-3	1.0	0.12	-	-
B-4	1.5	0.09	-	-
B-5	1.5	0.10	-	-
B-6	2.0	0.09	-	-
B-7	2.0	0.10	-	-
B-8	2.0	0.12	-	-
B-9	3.0	0.10	-	-

Table 7 Mixing conditions of series C (Bentocryl 86)

No.	GTC4(%)	KSTP(%)	Bentocryl 86(%)	Cement(%)
C-1	1.5	0.10	-	1.5
C-2	1.5	0.10	0.05	1.5
C-3	1.5	0.10	0.10	1.5
C-4	1.8	0.09	-	1.5
C-5	1.8	0.09	0.05	1.5
C-6	1.8	0.09	0.10	1.5
C-7	2.0	0.10	0.05	1.5
C-8	2.0	0.10	0.10	1.5

3.2.4 Cement test by adding $NaHCO_3$ (Series D)

If the stabilizing liquid was polluted by cement which was produced during cutting over primary element or soil mixing wall, the quality of stabilizing liquid can be changed by intrusion of Ca^{++}. Therefore, when Na_2CO_3 or $NaHCO_3$ was added in the stabilizing liquid polluted by cement(Ca^{++}), the quality of stabilizing liquid will be improved because the polluted Ca^{++} will be removed by forming solid $CaCO_3$ with adding Na_2CO_3 or $NaHCO_3$. To compare with test results with cement tolerance of the stabilizing liquid by adding Na_2CO_3 and $NaHCO_3$, Series D test performs as Table 8. Dosage of $NaHCO_3$ is divided into 3 ranges (0~0.15%) to evaluate the sedimentation influence by $NaHCO_3$.

3.2.5 Seawater influence test (Series E)

To compare test results by adding seawater, series E performs as Table 9. Dosage content of seawater is divided into 4 ranges (500 ~2,000ppm) to evaluate the infringement influence by seawater.

4. Test results and discussion

4.1 Preparatory test results for trial mix series

Table 8 Mixing conditions of series D ($NaHCO_3$)

No.	GTC4 (%)	KSTP (%)	$NaHCO_3$ (%)	Bentocryl 86 (%)	Cement (%)
D-1	2.0	0.10	0	0.05	1.5
D-2	2.0	0.10	0.10	0.05	1.5
D-3	2.0	0.10	0.15	0.05	1.5

Table 9 Mixing conditions of series E (Seawater)

No.	GTC4 (%)	KSTP (%)	Seawater (ppm)	Bentocryl 86 (%)	Cement (%)
E-1	1.8	0.1	500	0.05	1.5
E-2	1.8	0.1	1,000	0.05	1.5
E-3	1.8	0.1	1,500	0.05	1.5
E-4	2.0	0.1	0	0.05	1.5
E-5	2.0	0.1	500	0.05	1.5
E-6	2.0	0.1	1,000	0.05	1.5
E-7	2.0	0.1	1,500	0.05	1.5
E-8	2.0	0.1	2,000	0.05	1.5

Table 10 Test results for mixing bentonite only (GTC4)

No.	GTC4 (%)	PH	Funnel viscosity (sec)	Specific gravity	Fluid loss (cc)
A-1	1.0	9.9	29.2 (21.1)	1.002	7.3 (14.5)
A-2	2.0	9.9	30.5 (22.2)	1.006	9.8 (19.5)
A-3	3.0	9.9	37.2 (27.8)	1.020	11.7 (22.1)
A-4	4.0	9.9	62.1 (48.6)	1.025	15.2 (29.3)

*All items tested by API, ( ) means the converted value by JBASA

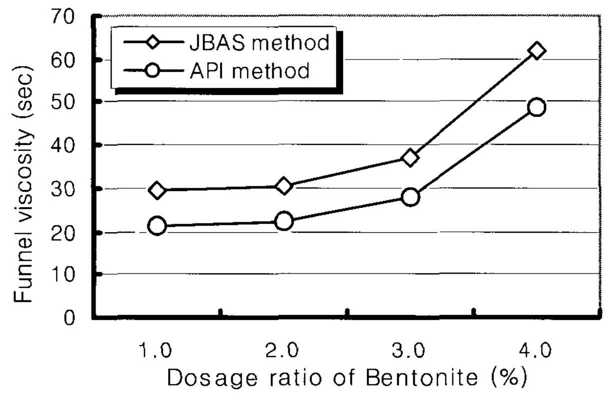

Fig. 3 Funnel viscosity for dosage ratio of Bentonite

Based on the preparatory test results for the trial mix series, properties of the stabilizing liquid for various materials adding proportion according to the proposed mix series from series A to E are tested and analyzed.

It is careful items according to decision of the initial optimum mix proportion at every using time. As the progress of excavation, characteristics of the stabilizing liquid are changed, it is very important to select the initial optimum mix proportion satisfied with site specifications. In the primary element, the stabilizing liquid should be controlled in a low fluid loss. Dosage ratio of bentonite (GTC4) is 2.0% in starting time. But if specific gravity of the circulated stabilizing liquid were over 1.04, the adding ratio of bentonite should be controlled again in order to decrease specific gravity of the stabilizing liquid. Considered the mixed cement from the primary element in the secondary element, better mix proportion should be chosen. Test results according to the trial mixing series are shown as followings.

Table 11 Test results for slurry mud test (bentonite+polymer)

No.	Funnel viscosity (sec)	pH	Fluid loss (cc)	Specific gravity	Cake thickness (㎜)	Remark
B-1	31.66 32.63*	10.3 10.3	15.2 15.5*	1.005 1.005*	0.20 0.32*	-
B-2	31.81 33.08*	10.3 10.5	14.7 15.0*	1.005 1.005*	0.25 0.35*	-
B-3	32.56 33.69*	10.2 10.3	11.0 14.1*	1.007 1.007*	0.35 0.40*	-
B-4	32.81 33.88*	10.4 10.5	9.5 11.2*	1.006 1.006*	0.35 0.40*	-
B-5	33.14 34.48*	10.4 10.5	9.9 11.4*	1.008 1.009*	0.30 0.40*	-
B-6	34.01 35.53*	10.5 10.7	9.6 10.2*	1.009 1.010*	0.30 0.30*	Good
B-7	34.55 36.27*	10.5 0.7	9.5 10.0*	1.016 1.008*	0.30 0.40*	Good
B-8	36.13 38.42*	10.5 10.8	8.9 9.0*	1.008 1.009*	0.50 0.35*	-
B-9	38.16 41.19*	10.6 0.8	8.8 9.1*	1.013 1.013*	0.40 0.35*	-

* mark means test results after 24hours by the elapsed time

Table 12 Test results for adding Bentocryl 86

No.	Funnel viscosity (sec)	pH	Fluid loss (cc)	Specific gravity	Cake thickness (㎜)	Remark
C-1	30.34 31.05*	11.8 12.5	12.1 12.9*	1.001 1.001*	0.40 0.35*	-
C-2	30.40 30.86*	11.9 12.5	10.5 12.5*	1.002 1.002*	0.35 0.40*	-
C-3	30.58 30.70*	11.8 12.5	10.0 11.9*	1.002 1.002*	0.40 0.45*	-
C-4	39.84 30.96*	11.9 12.5	12.0 14.8*	1.002 1.002*	0.45 0.70*	-
C-5	30.67 31.25*	11.8 12.4	10.9 11.7*	1.002 1.003*	0.40 0.40*	-
C-6	30.64 31.53*	12.0 12.6	9.7 11.1*	1.001 1.002*	0.40 0.40*	Good
C-7	31.53 32.31*	11.8 12.6	9.0 11.4*	1.001 1.002*	0.35 0.30*	Good
C-8	31.31 32.65*	11.8 12.5	9.1 9.5*	1.001 1.001*	0.45 0.30*	Good

* mark means test results after 24hours by the elapsed time

Table 13 Test results for cement tolerance test by NaHCO3

No.	Funnel viscosity (sec)	pH	Fluid ,oss (cc	Specific gravity	Cake thickness (㎜)	Remark
D-1	33.06 34.08*	11.8 2.2*	8.6 9.8*	1.010 1.010*	0.30 0.30	-
D-2	32.62 32.71*	10.8 2.0*	8.5 9.6*	1.010 1.010*	0.35 0.40*	Good
D-3	32.74 32.98*	10.6 2.0*	8.0 9.2*	1.012 1.013*	0.35 0.40*	Good
D-4	33.82 34.56*	10.7 2.2*	7.7 8.5*	1.016 1.015*	0.35 0.50*	-

* mark means test results after 24hours by the elapsed time

4.2 Test results for mixing bentonite only (Series A)

Test results of bentonite mixture (GTC4) only are shown in the following Table 10 and Fig. 3.
Considered test results, the upper limit ratio of bentonite only shows 3.0% because the value of funnel viscosity in the case of bentonite 4.0% mixture is too high. Therefore, bentonite must be used in the mixture of below 3.0% to stabilize the trench and we determine to use not only bentonite but also polymer and dispersion agent.

4.3 Test results for slurry mud test (Series B)

Table 11 and Fig. 4 show test results for series B. Compared test results for series B using bentonite and polymer, dosage ratio of bentonite and polymer have an effect on the funnel viscosity and fluid loss of the stabilizing liquid. That is to say, the more dosage of bentonite and polymer increase, the higher funnel viscosity and gel strength of the stabilizing liquid become. Therefore, considering the site conditions, we determine dosage ratio of bentonite by 1.8 ~ 2.0% and dosage ratio of polymer by 0.09 ~ 0.1% range.

4.4 Test results for adding Bentocryl 86 (Series C)

Test results for cement tolerance by adding Bentocryl 86 are shown in Table 12 and Fig. 5.

Compared test results for series C based on adding ratio of the dispersion agent (Bentocryl 86) in the stabilizing liquid polluted by cement, dosage ratio of dispersion agent has an effect on the funnel viscosity and fluid loss of the stabilizing liquid. Namely, in cases of the optimum condition as bentonite 1.8 ~ 2.0% and polymer 0.09 ~ 0.1%, the more dosage of dispersion agent (Bentocryl 86) increases, the lower funnel viscosity and fluid loss become. After 24hr this trend is increased. It means that dispersion influence is increased by adding of Bentocryl 86.

Therefore, considering the site conditions, we determine dosage range of dispersion agent by 0.05 ~ 0.1%.

4.5 Test results for adding $NaHCO_3$ (Series D)

Test results for cement tolerance by adding $NaHCO_3$ are shown in Table 13 and Fig. 6.

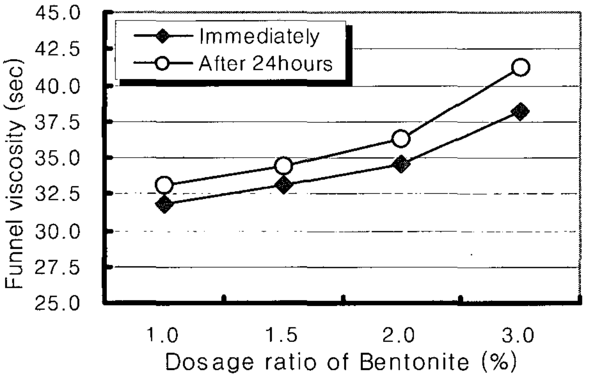

Fig. 4 (a) Funnel viscosity for dosage ratio of Bentonite(+KSTP)

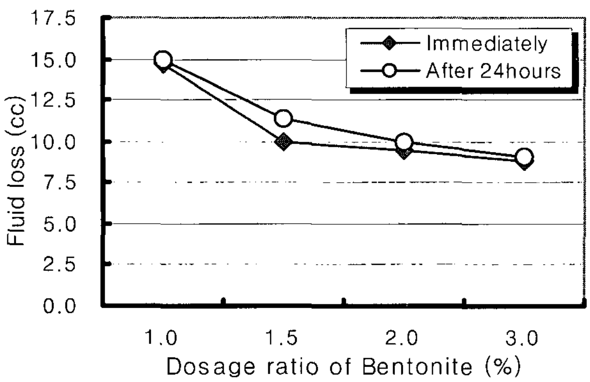

Fig. 4 (b) Fluid loss for dosage ratio of Bentonite(+KSTP)

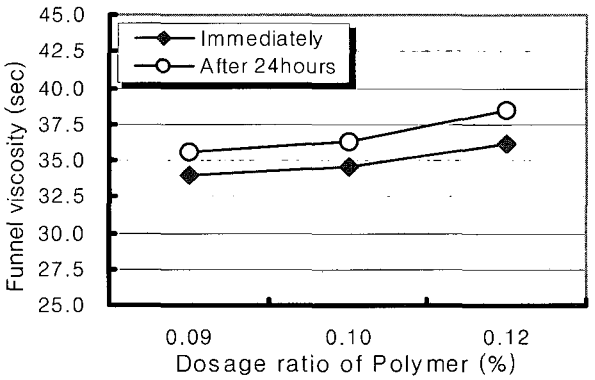

Fig. 4 (c) Funnel viscosity for dosage ratio of Polymer(+KSTP)

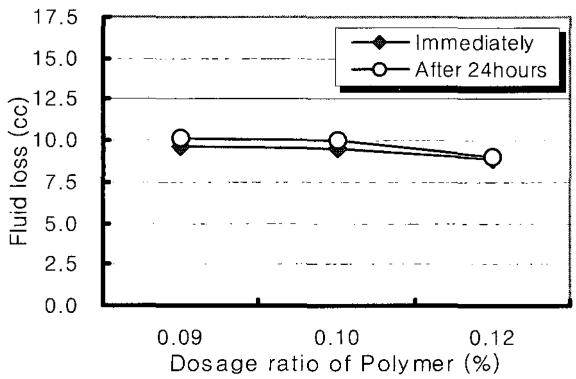

Fig. 4 (d) Fluid loss for dosage ratio of Polymer(+KSTP)

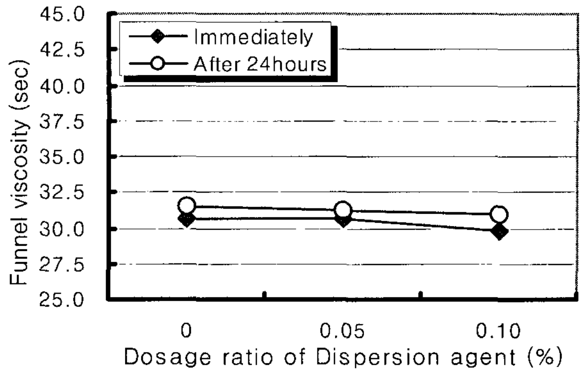

Fig. 5 (a) Funnel viscosity for dosage ratio of Bentonite (+KSTP)

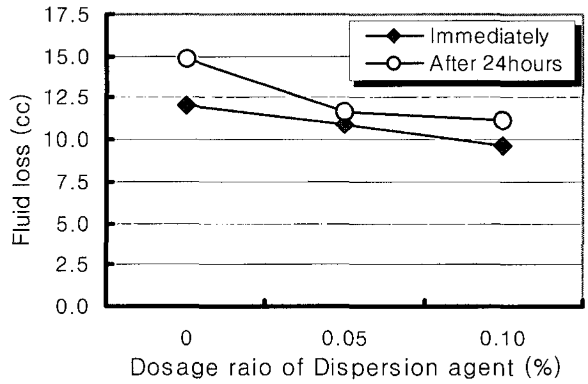

Fig. 5 (b) Fluid loss for dosage ratio of Bentonite (+KSTP)

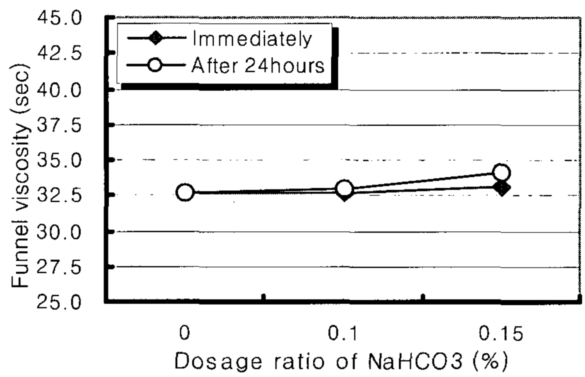

Fig. 6 (a) Funnel viscosity for dosage ratio of NaHCO3

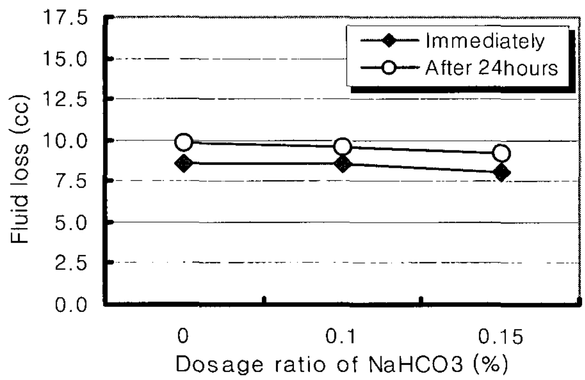

Fig. 6 (b) Funnel viscosity for dosage ratio of NaHCO3

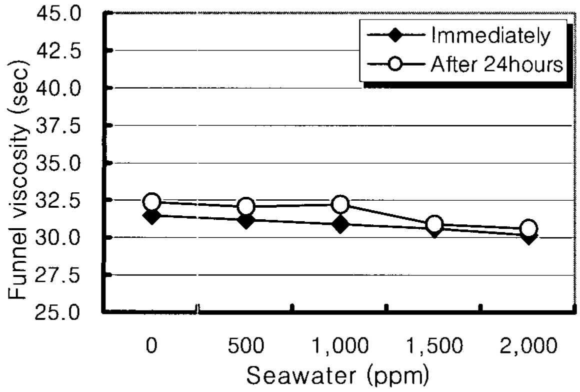

Fig. 7 (a) Funnel viscosity for dosage content of seawater

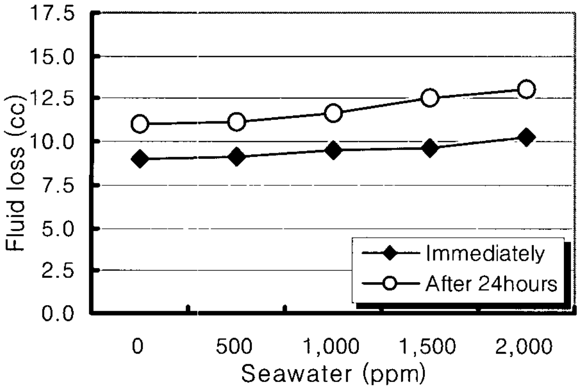

Fig. 7 (b) Fluid loss for dosage content of seawater

Table 14 Test results for adding seawater

No.	Funnel viscosity (sec)	pH	Fluid loss (cc)	Specific gravity	Cake thickness (㎜)	Remark
E-1	31.1 32.73*	10.3 .0.5	9.4 9.9*	1.000 1.001*	0.25 0.30*	-
E-2	30.09 31.13*	10.3 .0.4	10.5 11.4*	1.001 1.001*	0.30 0.30*	-
E-3	30.86 30.4*	11.7 .2.4	11.2 11.7*	1.002 1.002*	0.40 0.40*	Good
E-4	31.53 32.31*	10.1 .0.3	9.1 11.0*	1.001 1.002*	0.30 0.30*	-
E-5	31.21 32.05*	11.9 .2.5	9.13 11.1*	1.002 1.001*	0.35 0.45*	Good
E-6	30.95 32.18*	10.1 .0.3	9.5 11.7*	1.001 1.002*	0.40 0.45*	-
E-7	30.55 30.95*	10.1 0.3	9.7 12.6*	1.001 1.002*	0.40 0.55*	-
E-8	30.22 30.56*	12.C .2.5	10.3 13.0*	1.002 1.002*	0.45 0.65*	-

* mark means test results after 24hours by the elapsed time

Compared test results for series D by adding of $NaHCO_3$ in the stabilizing liquid polluted by cement, It is very important that addition of $NaHCO_3$ has an effect on the pH, funnel viscosity and fluid loss. Namely, because Ca^{++} of cement is reacted with $NaHCO_3$ and formed $CaCO_3$, the performance of stabilizing liquid polluted by cement can be improved. Therefore, when stabilizing liquid is polluted by cement in the excavation process of slurry wall, the performance of the stabilizing liquid by adding NaHCO3 as the range of 0.1~0.15% should be improved.

4.6 Test results for adding seawater (Series E)

Test results for adding seawater are shown in Table 14 and Fig. 7. Compared test results for series E by addition of seawater in the stabilizing liquid, it is clear that seawater has an effect on the funnel viscosity and fluid loss. Namely, the more ppm of seawater increases, the higher fluid loss become and the lower funnel viscosity becomes.

But most of performance of the stabilizing liquid are satisfied with its specification. Also, because ppm of seawater in Inchon site soil is tested below 400ppm, the infringement by seawater is proved to be no problem.

5. Conclusions

After checking and analyzing test results through various trial mix in order to select the optimum mix proportion of the stabilizing liquid used for excavation of the deep and massive slurry wall, we achieved the following conclusions.

1) The upper limit ratio of GTC4 using bentonite is selected by 2.0% considering trial test results for the funnel viscosity and fluid loss.

2) The upper limit ratio of KSTP using polymer is selected by 0.1% considering trial test results for the funnel viscosity and fluid loss.

3) The upper limit ratio of Bentocryl 86 using dispersion agent is selected by 0.05% considering trial test results for the fluid loss and economy.

4) Based on the above test results according to the materials ratio separately, the optimum mix proportion is proposed as follows(Table 15)

Table 15 The optimum mix proportion of the stabilizing liquid

GTC4 (%)	KSTP (%)	BC86 (%)	Cement (%)	pH	Funnel viscosity (sec)	Fluid loss (cc)	Cake thickness (㎜)
2.0	0.1	0.05	-	10.7	32.2	7.2	0.30
				11.2	33.0*	8.9*	0.33*
			1.50	11.6	32.6	8.7	0.30
				12.3	33.1*	11.6*	0.35*

* Those test results are checked after 24hours

5) All test items is checked and tested by API testing method. Namely, Funnel viscosity was tested using test equipment having 946cc/1500cc volume and Fluid loss was tested using test equipment having 7kg/㎠-7.5min.

References

1. American Petroleum Institute (API) RP 13B-1, "*Recommended practice standard procedure for field testing water-based drilling fluids*," 1990.
2. Japan Bentonite Manufacturers Association standard (JBAS) 101-77, "*Standard testing method*," Japaness association of bentonite industry. 1977.
3. Kwon, Y.H. and Ariyama, M., "A study on the mix design for stabilizing liquid of slurry wall," *proceeding of the Korea Concrete Institute*, Vol.11 No.1, 1999.5, pp.457~462.