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TITLE OF THE INVENTIONGROUTING LIQUID FOR INJECTION
INTO A GROUND

BACKGROUND OF THE INVENTION

FILED OF THE INVENTION

The present invention relates to a water glass-type grouting liquid for injection into a ground, used for consolidating the ground, and particularly, such a grouting liquid which is easy for controlling a gelation time from short time to long time, and shows high strength after the consolidation in spite that the concentration of the water glass is comparatively low, and moreover, is excellent in penetration, watertight and durability.

DESCRIPTION OF THE PRIOR ART

In the past, a water glass-type grouting liquid for injection into a ground is well known, which comprises water glass and sodium aluminate reactant (see the Japanese Patent Publication No. 26-6630).

In said grouting liquid, the viscosity must be decreased, and moreover, the gelation time must be elongated for improving the penetration thereof. And also, the concentration of water glass must be lowered for decreasing said viscosity, and the amount of sodium aluminate reactant must be lowered for elongating said gelation time.

This causes at the same time that the consolidation strength

of the liquid is extremely lowered, and unreacted water glass is dissolved from the consolidated gel, and thereby the gel is shrunked to give rise to enormous syneresis. As a result, the water-tightness and durability of the gel are weakened.

Moreover, in the past, a grouting liquid containing 50~30 vol.% of water glass (specific gravity : 1.42) and 5~15 vol.% of sodium aluminate (specific gravity : 1.39) is also known (see the Japanese Patent Publication No.44-28535). Also, in the past, a grouting liquid comprising water glass, sodium aluminate and water-soluble aliphatic aldehydes (see the Japanese Patent Publication No.54-22687), a grouting liquid containing phosphates, or alkaline aluminates (see the Japanese Patent Publication No.56-129289) and a grouting liquid containing cement, malic acid, gluconic acid, etc. (see the Japanese Patent Publication No.59-62689) are known.

However, these known grouting liquids are respectively not enough to adjust a gelation time through a broad range from instant to moderate, to obtain high consolidated strength, and to improve water-tightness and durability.

Accordingly, it is an object of the present invention to provide a grouting liquid for injection into a ground, in which it is easy for controlling a gelation time from short or instant time to long or moderate time, it shows high consolidation strength in spite that the concentration of the water glass is comparatively low, and it is excellent in penetration, water-tightness and durability, and in which the disadvantages associated with the

above-described prior art are overcome.

SUMMARY OF THE INVENTION

To achieve the above object, according to the present invention, there is provided a grouting liquid for injection into a ground which comprises ingredients of water glass, alkali metal salt of aluminates and aluminium salt which shows acid by hydrolysis, and especially said ingredients being satisfied with the following conditions of (1) to (5).

- (1) The mol ratio of said water glass is 2.8 or more.
- (2) The SiO_2 concentration of said water glass is 5 to 9 weight/volume % of the whole liquid.
- (3) The total Al_2O_3 amounts in the alkali metal salt of aluminates, and the aluminium salt which shows acid by hydrolysis are 0.5 to 1.6 weight/volume of the whole liquid.
- (4) The value of the Al_2O_3 amounts in the alkali metal salt of aluminates/the Al_2O_3 amounts in the aluminium salt which shows acid by hydrolysis exceeds 3.0.
- (5) The value of the Al_2O_3 amounts in the alkali metal salt of aluminates+the Al_2O_3 amounts in the aluminium salt which shows acid by hydrolysis/ SiO_2 amounts in the water glass $\times 100$ is in the range from 7 to 25%.

BRIEF DESCRIPTION OF THE DRAWING

Fig:1 is a graph illustrating the relationship between sodium aluminate solution(ml) and gelation time(min.) concerning examples Nos.1 to 5 and comparative examples Nos.1 to 5 in Table

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described by way of preferred embodiments in connection with the accompanying drawing.

The water glass used in the present invention has a mol ratio of 2.8 or more, and SiO_2 concentration of 5 to 9 weight/volume %, preferably 6 to 8 weight/volume % of the whole liquid. When the mol ratio is below 2.8, the consolidation strength is not enough. Moreover, when the SiO_2 concentration is below 5 weight/volume %, the gelation time becomes too long, and thus, the adjustment of short gelation time becomes impossible, and also, the consolidation strength becomes lower. When the SiO_2 concentration exceeds 9 weight/volume %, the gelation time becomes too short, and thus, the adjustment of long gelation time becomes impossible, and also, the consolidation strength becomes lower.

The alkali metal salt of aluminates used in the present invention is a reactant or hardener of the water glass, and is exemplarily designated as sodium aluminate, potassium aluminate etc..

Moreover, the aluminium salt which shows acid by hydrolysis acts as an assistant material for said alkali salt of aluminates, and is very characteristic ingredient of the present invention. Hereinafter, the ingredient is shown as "acidic aluminates."

The acidic aluminates shows acid by hydrolysis, and are exemplarily shown as aluminium sulfate ($\text{Al}_2(\text{SO}_4)_3$), aluminium

chloride (AlCl_3), aluminium nitrate ($\text{Al}(\text{NO}_3)_3$), alums such as $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, ammonium alum, sodium alum, etc..

The amounts of said three ingredients of water glass, alkali metal salt of aluminates and acidic aluminates are preferably, the amounts of satisfying the following three conditions of (a) to (c) at the same time.

- (a) The total Al_2O_3 amounts in the alkali metal salt of aluminates and acidic aluminates are in the range of 0.5 to 1.6 weight/volume % of the whole liquid. When the amounts are below 0.5 weight/volume %, the gelation time exceeds 24 hours, and thus, the adjustment of short gelation time becomes difficult, and also, the consolidation strength becomes lower. Moreover, in case of exceeding the amounts of 1.6 weight/volume %, an instant curing occurs, and thus, the adjustment of long gelation time becomes difficult, and also, the consolidation strength becomes lower.
- (b) The value of Al_2O_3 amount (weight) in the alkali metal salt of aluminates/the Al_2O_3 amounts (weight) in the acidic aluminates is over 3.0, preferably in the range of 3 to 10. Even if the value exceeds 10, any special advantages are not expected, or there occurs a tendency of slight decreasing of the consolidation strength.
- (c) The value of deviding the sum of Al_2O_3 amounts in the alkali metal salt of aluminates and Al_2O_3 amounts in the acidic aluminates by SiO_2 amounts of the water glass, and multiplied by 100 is in the range of 7 to 25%. When the value is below

7%, the gelation time becomes too long, and thus, the adjustment of short gelation time becomes difficult, and also, the consolidation strength becomes lower. Moreover, when the value exceeds 25%, the gelation time becomes too short, and thus, the adjustment of long gelation time becomes difficult.

As mentioned above, the present grouting liquid for injection into a ground is composed by containing ingredients of water glass, an alkali metal salt of aluminates, and an acidic aluminates. And thus, it is easy for controlling or adjusting a gelation time from a short or instant time to a long or moderate time, shows high consolidation strength, and moreover is excellent in penetration, watertightness and durability.

These facts are supported by the following functions. In general, the grout composed of water glass and an alkali metal salt of aluminates shows a short gelation time, and is especially difficult of adjusting gelation time in summer season, and moreover shows enormous syneresis and weak consolidation strength.

On the other hand, however, the grout of the present invention composed of water glass, an alkali metal salt of aluminates and an acidic aluminates shows buffering action, and thereby obtains slow and moderate gelation time, and becomes excellent in penetration. Moreover, it is considered that the acidic aluminates show acidity in the liquid, to thereby neutralize the alkali of the water glass, stop the occurrence of syneresis, and improve the consolidation strength.

EXAMPLES

The present invention will now be described in more detail by way of examples, but is not limited by these examples.

1. Material used

(1) Water glass

Three kinds of water glasses shown in Table 1 were used. These water glasses respectively show different mol ratio.

Table 1

Water glass	density(20℃)	SiO ₂ (%)	Na ₂ O (%)	mol ratio
No. 1	1.32	25.5	7.0	3.75
No. 2	1.39	29.0	10.4	2.89
No. 3	1.60	34.7	14.2	2.53

(2) Alkali metal salts of aluminates

Sodium aluminate containing 19.3% of Al₂O₃ and having a density of 1.468 was used.

(3) Acidic aluminates

Aluminium sulfate having a density of 1.273, and containing 8.1% of Al₂O₃ was used.

2. Blending

The water solutions of the water glass shown in Table 1 were prepared as liquid A as shown in Table 2, and water solutions of mixtures of sodium aluminate and aluminium sulfate were prepared as liquid B as shown in Table 2. Concerning mixtures of liquids A and B, gelation times and unconfined compressive strengths of sand gel of Toyoura standard sand were determined. The results of the determination were shown in Table 2. In Table 2, the

gelation times were determined in accordance with "a method of handstanding a cup", and the unconfined compressive strengths were determined in accordance with "A method of testing unconfined compressive strength of soil". Also, in Table 2, W/V% means weight/volume %.

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Table 2

examples		liquid A (500ml)				liquid B (500ml)			composition of A, B mixture						character of A, B mixture		
examples of the present invention	comparative example	water glass (ml)			water (ml)	sodium aluminate liquid (ml)	aluminium sulfate liquid (ml)	water (ml)	SiO ₂ (W/V %)	Amounts in terms of Al ₂ O ₃					gelation time (20°C)	unconfined compressive strength of sand gel (kgf/cm ²)	
		No. 1 in Table 1	No. 2 in Table 1	No. 3 in Table 1						sodium aluminate (g)	aluminium sulfate (g)	total Al ₂ O ₃ (W/V %)	sodium aluminate aluminium sulfate	Al ₂ O ₃ / SiO ₂ x100		impregnation days in water	
																7 days	30 days
1		200	—	—	300	17.5	12.5	470.0	6.73	4.96	1.29	0.63	3.84	9.3	6 0min.	3.8	4.0
2		200	—	—	300	20.0	12.5	467.5	6.73	5.67	1.29	0.70	4.40	10.3	2 8min.	4.0	4.3
3		200	—	—	300	22.5	12.5	465.0	6.73	6.38	1.29	0.77	4.95	11.4	1 4min.	4.2	4.5
4		200	—	—	300	25.0	12.5	462.5	6.73	7.08	1.29	0.84	5.49	12.4	7min.	4.6	4.9
5		200	—	—	300	27.5	12.5	460.0	6.73	7.79	1.29	0.91	6.04	12.5	4min.	5.0	5.1
6		200	—	—	300	42.5	20.0	437.5	6.73	12.04	2.06	1.41	5.84	20.9	4sec.	5.1	5.2
7		—	170	—	330	17.5	12.5	470.0	6.85	4.96	1.29	0.63	3.84	9.1	7 5min.	3.3	3.5
8		—	170	—	330	22.5	12.5	465.0	6.85	6.38	1.29	0.77	4.95	11.2	1 7min.	3.6	3.7
9		—	170	—	330	27.5	12.5	460.0	6.85	7.79	1.29	0.91	6.04	13.3	5min.	3.9	4.1
10		—	170	—	330	42.5	20.0	437.5	6.85	12.04	2.06	1.41	5.84	20.6	5sec.	4.1	4.2
11		—	—	120	380	22.5	12.5	465.0	6.66	6.38	1.29	0.77	4.95	11.6	2 4min.	2.4	2.5
12		130	—	—	370	15.0	10.0	475.0	4.38	4.25	1.03	0.53	4.12	12.1	5 hrs.	2.1	2.2
13		280	—	—	220	30.0	20.0	450.0	9.42	8.50	2.06	1.06	4.13	11.3	5sec.	3.0	3.2
14		200	—	—	300	17.5	20.0	462.5	6.73	4.96	2.06	0.70	2.41	10.4	4 5min.	2.7	2.9
15		200	—	—	300	17.5	30.0	452.5	6.73	4.96	3.09	0.80	1.61	11.9	4sec.	3.2	3.2
16		200	—	—	300	11.0	8.0	481.0	6.73	3.12	0.82	0.39	3.80	6.1	>24 hrs.	1.7	1.8
17		200	—	—	300	50.0	25.0	425.0	6.73	14.16	2.58	1.67	5.49	11.8	instantly cured	2.9	3.0
18		—	130	—	370	42.5	20.0	437.5	5.24	12.04	2.06	1.41	5.84	26.9	8sec.	2.8	3.0
19		200	—	—	300	30.0	10.0	460.0	6.73	8.50	1.03	0.95	8.25	8.9	5min.	4.6	4.8
20		200	—	—	300	32.5	9.0	458.5	6.73	9.20	0.93	1.01	9.89	9.9	8min.	4.3	4.6
21		200	—	—	300	33.0	8.0	457.0	6.73	9.92	0.82	1.07	12.09	10.7	1 3min.	3.9	4.1
22		200	—	—	300	37.0	8.0	455.0	6.73	10.48	0.82	1.13	12.78	16.8	7min.	4.0	4.1
	1	200	—	—	300	20.0	—	480.0	6.73	5.67	—	5.67	—	8.4	1 0 0min.	0.6	0.7
	2	200	—	—	300	22.5	—	477.5	6.73	6.38	—	6.38	—	9.5	4 3min.	0.8	1.0
	3	200	—	—	300	25.0	—	475.0	6.73	7.08	—	7.08	—	10.5	1 9min.	1.1	1.2
	4	200	—	—	300	27.5	—	472.5	6.73	7.79	—	7.79	—	11.5	1 1min.	1.3	1.5
	5	200	—	—	300	30.0	—	470.0	6.73	8.50	—	8.50	—	12.6	3min. 4 0sec.	1.5	1.6
	6	—	200	—	300	20.0	—	480.0	8.06	5.67	—	5.67	—	7.0	7 5min.	0.5	0.7
	7	—	200	—	300	22.5	—	477.5	8.06	6.38	—	6.38	—	7.9	3 8min.	0.8	0.9
	8	—	200	—	300	25.0	—	475.0	8.06	7.08	—	7.08	—	8.8	2 3min.	1.1	1.3
	9	—	200	—	300	27.5	—	472.5	8.06	7.79	—	7.79	—	9.7	1 3min.	1.3	1.4
	10	—	200	—	300	30.0	—	470.0	8.06	8.50	—	8.50	—	10.5	7min.	1.4	1.6
	11	—	200	—	300	—	60.0	440.0	8.06	—	6.18	6.18	—	7.7	4 5min.	0.6	0.6
	12	—	200	—	300	—	75.0	425.0	8.06	—	7.73	7.73	—	9.6	9min.	0.7	0.8

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In Table 2, example Nos.1 to 22 respectively show the examples of the present invention. It is shown from the Table 2 that all examples of the present invention show the gelation time from short or instant time to long or moderate time, and unconfined compressive strengths of 2 to 5 kgf/cm². Moreover, these examples show high consolidation strength in spite that the concentration of water glass is low, compared with the concentration of general water glass.

Example Nos.1 to 10, and 19 to 22 in Table 2 are respectively satisfied with the following conditions of (1) to (5).

- (1) The mol ratio of water glass is 2.8 or more.
- (2) The SiO₂ concentration is in the range of 5 to 9 weight/volume % of the whole liquid.
- (3) The total Al₂O₃ amounts in the alkali metal salt of aluminates and the acidic aluminates are in the range of 0.5 to 1.6 weight/volume % of the whole liquid.
- (4) The value of Al₂O₃ amounts in the alkali metal salt of aluminates/Al₂O₃ amounts in the acidic aluminates is larger than 3.0.
- (5) The value of Al₂O₃ amounts in the alkali metal salt of aluminates plus Al₂O₃ amounts in the acidic aluminates/SiO₂ amounts of the water glass×100 is in the range of 7 to 25%. It is said from these examples that each of these examples is respectively easy for controlling or adjusting the gelation time, and shows the excellent consolidation strength of 3 to 5 kgf/cm².

Examples 19 to 20 respectively show the value of sodium aluminate (Al_2O_3 amount)/aluminium sulfate (Al_2O_3 amount) of more than 3.0. It is said from these examples that they show excellent effects until the value comes to around 10, but when the value exceeds 10, the strength is slightly decreased. (Examples 21, 22).

The comparative examples 1 to 10 show the use of sodium aluminate singly, as a hardener of water glass. Moreover, the comparative examples 11 and 12 show the use of aluminium sulfate singly. It is obvious from the results of these comparative examples that all of them show the low consolidation strengths of 0.5 to 1.6 kgf/cm². Moreover, in comparative examples 11 and 12, some precipitation occurs when liquids A and B are mixed, and thus, they are not homogeneous liquids.

Fig.1 is a graph illustrating the relationship between sodium aluminate solution (mℓ) and gelation time (min.) concerning example Nos.1 to 5 and comparative example Nos.1 to 5 in Table 2. In Fig.1, a solid line shows the data of example Nos.1 to 5, and a dotted line show a data of comparative example Nos.1 to 5.

It is said from Fig.1 that example Nos.1 to 5 forms a moderate inclination curve of gelation time compared with comparative example Nos.1 to 5, and thus, are easy for controlling or adjusting the gelation time from short or instant time to long or moderate time.

In addition, each of example Nos.1 to 5 respectively keeps

comparatively low viscosity until just before the gelation. Accordingly, it is said from the fact that the present grouting liquid can be prepared from an instantly curing liquid to a penetrative liquid having long gelation time.

Moreover, in the present examples, the syneresis of consolidation is very small amounts compared with the comparative examples, and thus, it is said that the present examples are excellent in watertightness and durability.

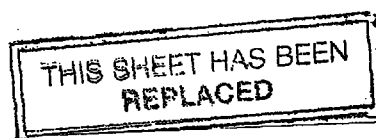
Furthermore, in addition, sodium aluminate was used as the alkali metal salt of aluminates, and aluminium sulfate was used as the acidic aluminates in Table. Of course, same results are expected by using potassium aluminate instead of sodium aluminate, and aluminium chloride, aluminium nitrate, and alums instead of aluminium sulfate.

The effects of the present grouting liquid comprising ingredients of water glass, an alkali metal salt of aluminates and acidic aluminates are as follows.

- (1) It shows high strength after the consolidation in spite that the concentration of the water glass is comparatively low.
- (2) It is easy for controlling or adjusting a gelation time from short time to long time, and keeps low viscosity until just before the gelation, and thus, it obtains water glass grout of from an instant curing liquid to a penetrative liquid having long gelation time.
- (3) It shows high consolidation strength.
- (4) It is excellent in watertightness and durability because of

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small amounts of syneresis.



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What is claimed is:

1. A grouting liquid for injection into a ground which comprises ingredients of water glass, an alkali metal salt of aluminates, and an aluminium salt which shows acid by hydrolysis.
2. A grouting liquid for injection into a ground which comprises ingredients of water glass, an alkali metal salt of aluminates and an aluminium salt which shows acid by hydrolysis, said ingredients being satisfied with the following conditions (1) to (5).
 - (1) The mol ratio of said water glass is 2.8 or more.
 - (2) The SiO_2 concentration of said water glass is 5 to 9 weight /volume % of the whole liquid.
 - (3) The total Al_2O_3 amounts in the alkali metal salt of aluminates and the aluminium salt which shows acid by hydrolysis are 0.5 to 1.6 weight/volume % of the whole liquid.
 - (4) The value of the Al_2O_3 amounts in the alkali metal salt of aluminates/the Al_2O_3 amounts in the aluminium salt which shows acid by hydrolysis is exceeds 3.0.
 - (5) The value of the Al_2O_3 amounts in the alkali metal salt of aluminates+the Al_2O_3 amounts in the aluminium salt which shows acid by hydrolysis/ SiO_2 amounts in the water glass $\times 100$ is 7 to 25%.
3. A grouting liquid for injection into a ground as claimed in claim 1 or 2, wherein said aluminium salt which shows acid by hydrolysis is one or more selected from the group consisting



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of aluminium sulfate, aluminium chloride, aluminium nitrate and alums.

4. A grouting liquid for injection into a ground as claimed in claim 2, wherein the value of Al_2O_3 amounts in the alkali metal salt of aluminates/ Al_2O_3 amount in the aluminium salt which shows acid by hydrolysis is in the range of 3.0 to 10.0.

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