Use of anti-washout underwater concrete in marine structures

- 1. Introduction
- Underwater concrete has been in use for a long time.
- Technological progress has mainly proceeded through the development of improved methods of concrete placement and better equipment.
- Anti-washout underwater concrete offers superior performance when the concrete is in fresh state. By adding an anti-washout admixture to concrete, its viscosity is increased and its resistance to segregation under the washing action of concrete can be enhanced.

- The technology was initially introduced from Germany to Japan. Improvements has been made as regards the design of the mix proportions, the implementation methods, and the quality of the admixtures itself.
- Superior features: underwater anti-washout property, self-compacting property, and self-leveling property

Applications:

- Gap filling ability, taking advantages of its flow ability
- High-quality underwater concrete, particularly where segregation is a concern.
- The prevention of water pollution
- Underwater reinforced concrete structures
- Consolidation of stones
- Disaster recovery works, repairs and reinforcement works

- The reliability of anti-washout concrete has been greatly improved compared with conventional underwater concrete. 15-30Mpa are adapted as the design strength.
- Pier footings for the connecting bridge at Kansai International Airport
- Pier work for Akashi Kaikyo bridge
- The admixture is the heart of this concrete.

2. Anti-washout admixtures for underwater concrete

- 2.1 Quality standards for anti-washout admixtures
- Table 1 gives the quality specifications for anti-washout concrete.
- 2.2 Composition
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- The admixtures can be classified into two types;
- -Cellulose-based (Fig.1)
- -Acrylamide-based (Fig.2)

2.3 Effect of anti-washout admixtures on underwater concrete

- 2.3.1 Viscosity effect (anti-washout properties and resistance to segregation)
- Water-soluble polymers dissolve quickly in water and increase the viscosity.
- Through this action, they reduce the segregation.
- The more admixture added and the higher its molecular weight, the greater the viscosity of the concrete, and thus the better the anti-washout properties and the greater the resistance to segregation.

- The viscous behavior of water solution of anti-washout admixtures and those of cement paste incorporating with the admixture are shown in Fig.3.
- The results of underwater dropping tests carried out using mortar to demonstrate the anti-washout properties are shown in Photo.1.
- Generally, the amount of admixtures added is about 2-4kg/m3 (1-1.5%/cement).

2.3.2 Flow property and self-leveling property

- By using a combination of an anti-washout admixture and a high-range water-reducing admixture, the plastic viscosity increases while the yield value is reduced. It gives a self-leveling property, namely, the concrete spreads gradually under its own weight.
- An example of the flow curve is shown in Fig.4.

- 2.3.3 Filling property
- This improves the flow ability of concrete into small gaps and between dense arrangements of reinforcing bars.
- 2.3.4 Retarding setting
- Cellulose-based anti-washout admixtures cause adsorption onto the cement, resulting in retarded setting.
- This is useful in the case of large volume construction, and has an advantages leading to better flatness also improving workability.

3. Qualities of anti-washout underwater concrete

- **3.1 Fresh concrete**
- The fresh concrete has the following properties.
- -Resistance to segregation under washing action of water is greater
- -Better flowability, filling and self-leveling properties
- -Setting time tend to be retarded
- -No bleeding occurs practically
- The factors: anti-washout admixtures, chemical admixtures, other concrete materials, the mix proportions, the mixing methods, temperature, etc.

3.1.1 Resistance to segregation

- **(1)Verification of segregation resistance using the underwater free-dropping test**
- This test can visually demonstrates resistance to segregation in comparison with ordinary concrete.
- Anti-washout concrete and ordinary concrete are dropped freely from a height of 60cm.
- Lower half of the settled concrete are tested.
- The results of such tests are shown in Fig.5.
- The mix proportion of anti-washout concrete is almost unchanged.

- **(2) Effect of anti-washout admixture on the pH value and turbidity of water after concrete dropping**
- The pH values and turbidity（濁度）are reduced due to increasing amount of anti-washout admixtures.
- (3) Others
- When high-range water-reducing admixture is added to the anti-washout concrete, there is a tendency for turbidity to increase as slump flow increases.

- **3.1.2 Flow property**
- The degree of deformation is large even though it appears to be stiff compared with ordinary concrete.
- For this reason, the consistency should be evaluated by means of slump flow.
- **3.1.3 Filling property**
- No testing method suitable for evaluation of filling property has been established.
- When this type of concrete is used in a critical structure, it is customary to use a mock-up (proto type) model.

3.2 Hardened concrete

- **3.2.1 Strength characteristics**
- With the anti-washout underwater concrete, strength is also affected by:
- The anti-washout admixture used.
- Concrete placement method underwater.

- **(1) *Compressive strength***
- Fig.6 shows an example where the underwater dropping height is 20cm.
- The underwater/in-air strength ratio increases in proportion to the amount of admixture.
- **(2) *Young's modulus***
- This modulus is somewhat lower than that of the ordinary concrete.
- **(3) *Flexural, tensile and shear strength***
- The relationships are approximately same as those of ordinary concrete.

- **3.2.2 Bonding strength**
- The lowest strength ratio of all is in horizontal bars in ordinary concrete.
- **3.2.3 Strength of construction joint**
- It is recommended to clean the surface (clean up laitance).
- **3.2.4 Drying shrinkage**
- It is slightly larger.

- **3.2.5 Creep**
- As the unit content of the water is larger, the creep is larger.
- **3.2.6 Durability**
- As long as this concrete is under water, it will not be worse.

3.3 Long distance flow experiment

- Table2 Mix proportion
- Fig.7 The form for the long distance flow experiment
- Photo 2 Measurement of flow gradient for a placement speed of 0.4m/h
- Fig.8 The relationship between flow distance and compressive strength
- Fig.9 The relationship between flow distance and density

3.3.4 Conclusions

- These experiments verify that anti-washout concrete with a slump flow of 50-60cm has a self-leveling and self-compacting properties and that no detrimental segregation was seen as long as the underwater flow distance remained within 10m.　プレパックドでは2m（面積では25倍）
- 4. Examples of construction
- Please check them.