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Cement content for underwater concreting

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The paper discusses the quantity of cement required for underwater concreting or for concreting by displacing bentonite slurry using a tremie. It gives the opposing viewpoints and neatly summarises the differing arguments in an easy-to-read table.

The question is often asked whether a richer mix, *i.e.*, more cement per unit volume of concrete, is required while concreting underwater. Opinions on this differ. Those who believe that the concrete mix becomes less durable and weak due to high slump and high water-cement ratio, generally recommend a minimum of 400kg of cement per m³ of concrete. In certain specific instances such as small diameter short piles or thin cut-off walls of 10 to 15m depth the use of 10 per cent extra cement over and above that required for normal mixes is often recommended. According to another viewpoint regardless of high slump and high water-cement ratio, underwater concreting is as efficient as concreting, above water there being no reduction in strength in the former. There is, therefore, no need for a richer concrete mix for underwater concreting. Yet another point of view is that if concreting underwater is done by tremie process, a richer concrete mix is not necessary. If other methods such as bucket pouring is used, about ten per cent extra cement is necessary. The use of extra cement or a certain minimum quantity of cement is very often reasoned from durability considerations. However, there are no durability test results reported in literature on this type of concrete.

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Various recommendations for underwater concreting or concreting by bentonite displacement using a tremie are presented in *Tables* 1 and 2.

TABLE 1 Concreting by displacing bentonite slurry

Requirement for	*Sliwinski and Fleming (1975)*	*Hodgson (1976)*	*FPS† (1973)*	*Fintel (1974)*	*Gerwick (1973)*	*IS:2911(part III)-1973*
Slump	150-200mm	150-200mm	175mm desired	150-200mm	150-200mm	150-200mm
Flow-table	—	470-540mm	—	—	—	—
Water-cement ratio	0.6	0.6	0.6	0.45	0.45	—
Coarse aggregate	Natural rounded stone, of 20-mm maximum size if possible	20-mm maximum size	20-mm to 40-mm	40-mm rounded aggregate for large pours, 20-mm rounded aggregate for normal pours, 10-mm rounded aggregate for restricted pours	20mm	—
Sand	Natural sand in grading zone 2 or 3	zone 3	—	—	—	—
Sand content	34-45 per cent of total aggregate weight	35 per cent by weight with 15 per cent passing sieve 300 μ	—	45 per cent	45 per cent	—
Cement	Not less than 400kg/m³ of ordinary Portland cement or sulphate-resisting cement	400kg/m³	400kg/m³ cement conforming to BS 12 or sulphate-resistant cement conforming to BS 4027	350-400kg/m³ ASTM type II cement	400kg/m³	10 per cent more than required in normal case
Additives	Use of plasticisers in the form of air entraining agents, retarders, etc recommended	Plasticising agents recommended but not super-plasticisers	—	Use of plasticisers and water reducing agents recommended; 4 per cent air entrainment desirable	Water reducers and retarders such as Sika Plastiment, 60 g/per bag of cement recommended	—

†Federation of Piling Specialists, London

Discussion

A study of *Table* 1 reveals that for good quality of concrete by the bentonite slurry displacement method using a tremie, apart from specifications of gradation, size and quantity of sand and coarse aggregate, the cement content should be 400kg per m³. But for mixes of lower water-cement ratio of less than 0.45, and of 150 to 200mm slump (which is achieved by the use of plasticisers and water reducing agents), a cement content of 350 to 400kg per m³ may be sufficient. It is important to note that the above recommendations are made for use on large works such as thick diaphragm walls, large diameter piles and other marine structures of larger depths. On the other hand, in the case of small diameter short piles and thin cut-off walls, a cement content of 350kg per m³ (equal to the cement used in nominal mix of 1:2:4 with 10 per cent more cement) provides concrete of adequate strength and quality.

A study of *Table* 2 indicates that for concreting done under 10-m deep seawater with special KDT pipes, the strength of concrete cores was as high as 197kg/cm² even for a low cement content of 270kg per m³ and a water-cement ratio of 0.64. When the cement content was increased to 370kg per m³ and the water-cement ratio reduced to 0.48, the strength observed was 363kg/cm², which was indeed high.

A comparison of *Tables* 1 and 2 show that it is reasonable to infer that from strength considerations the cement content used for concreting underwater or under bentonite suspension, is more than that required. However, from other considerations such as lack of quality control, importance of the substructure, difficulty in rectifying bad concrete, and durability, it is desirable to use more cement until additional test data is available. More cement is also required for large diameter deep piles and thick diaphragm walls at deeper depths where the concreting by tremie under bentonite suspension cannot be compared with concreting underwater for several reasons.

Conclusions

(*i*) The quality of tremie concreting done underwater by special KDT pipes is good in spite of using a low quantity of cement, 270 to 320kg per m³. The compressive strengths of cores taken from underwater structures were comparable with laboratory values of strength.

(*ii*) For structures where thin, easily displaceable bentonite slurry is used, the quality of tremie concreting under bentonite slurry is comparable to that of underwater concreting.

(*iii*) For small-diameter bored piles and thin cut-off walls constructed to relatively small depths of 10 to 15m a cement content of about 350kg per m³ of concrete is sufficient for tremie concreting. But for large-diameter deep-bored piles or thick diaphragm walls and other substructures at deeper depths the present minimum cement content of 400kg per m³ of concrete is justified till more data become available.

(*iv*) Where a higher strength of concrete is desired, a richer concrete mix with greater cement content may be designed.

(*v*) It is hoped that work will be done to obtain a greater number of cores from underwater and from bentonite displaced concretes and their strengths compared with laboratory samples. Such an exercise will give the necessary confidence which cannot be obtained by any other means. Until such time, there would appear to be no alternative but to err on the safe side.

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TABLE 2 Concreting underwater using KDT tremie pipes

Requirement for	A	B	C	D
Slump, mm	180 to 200	180 to 200	180 to 200	180 to 200
Flow table	—	—	—	—
Water-cement ratio	0.48	0.46	0.54	0.64
Aggregate size, mm	25	40	25	25
Cement, kg/m³	370	370	320	270
Compressive strength, kg/cm²	363	302	234	197

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