1.INTRODUCTION

1.1 Aim

In this study, the path was followed is that, have been worked on properties of underwater concrete and is worked to research the most efficient mix for the underwater concrete.

1.2 Scope

In this study orderly include; investigate of literature, find of information about underwater concrete, anti-washout admixtures, and curing of concrete. After the literature research, have done experimental studies. The experiments are; compression test, pulse velocity test. According to the experiments, was decided some properties of performance of the underwater concrete. In addition, different aggregate compositions, fly ash, anti-washout admixture and plasticizer are used in underwater concrete mix.

2.LITERATURE REVIEW

2.1 Specification of Underwater Concrete

2.1.1 Definition

Underwater concrete were used in all over the world in many important projects which is a concrete type that applied at our county rarely. 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. For those used to concreting on dry land,concreting underwater presents various challenges. Transporting, compacting, quality, control, finishing, accuracy must all be carried out successfully in this different enviroment.There are however, many common aspects, chief of which is that air is not required for the setting and hardening of concrete. It sets and hardens just as well, and often even better, underwater but it must be fluid enough to flow into position and be self-compacting as conventional vibration is not practicable underwater. During transporting and placing, conventional concrete and water must be kept apart and, when they inevitably do come into contact, rapid interface flow must be minimized or cement may be washed out to form a weak layer, wash out can be obviated by the use of an admixture to make the concrete non-dispersible but this comes at a cost and contractors unwilling to pay the additional expense involved, often adhere to the more traditional methods of placing underwater.

2.1.2 Methods of Placements of Underwater Concrete

The properties needed for underwater concrete are directly related to the method of placement.

• Tremie (including the 'hydrovalve')
• Pumping with free fall
• Skip (bottom opening)
• Prepacked (preplaced) aggregate concrete
• Prepackaged (above water, under water.)

In addition, the geometry of the finished top surface (horizontal or laid to falls) needs to be taken into account as most concrete placed underwater has a tendency to flow to a level surface. Parameters relevant to each type of placing condition are indicated in Figure 2.1

Relevant parameters

	Placing method					
					Prepackaged	
Parameter	Tremie	Pumping with free fall	Skip	Prepacked (preplaced) aggregate concrete	Above water	Under water
Strength	√	√	√	√	√	√
Durability	√	√	√	√	√	√
Segregation/washout						
Resistance during:						
internal flow	√	√	√			
free fall quiescent		√	√			
free fall turbulent		√				

Figure 2.1: Placing methods of underwater concrete. [3]

The parameters involved in normal concrete mix design and their interaction are given in Figure 2.2 with the additional underwater concrete factor 'washout' and its interactions shown in bold. The placing conditions for a particular application have a significant influence on the degree of washout resistance required. Thus the mix design process needs to take account of this, particularly with regard to aggregate selection, cement content and the use of admixtures.

Unless practical test data relating to the specific combination of aggregates, cements, admixtures and any other constituents are available, the use of trial mix procedures will form an essential part of the mix design process. These are likely to take the form of initial laboratory trials (which may include washout resistance testing) followed by full-scale trial mixes. In the latter case, where new or unusual placing conditions are to be encountered, effective performance in sample pours should also be assessed.

2.2 Strength Properties of Underwater Concrete

2.2.1 Characteristic/Target Strength Relationship of Underwater Concrete

Variation in the compressive strength of concrete specimens are usually assumed to conform to a 'normal' distribution as illustrated in Figure 2.2 For general concreting operations variability of quality control test results is caused by variations in the materials used, production operations and sampling/testing techniques.

The form of a normal distribution curve can be denned entirely by its mean (ra) and its standard deviation *(S),* where

$$S = \sqrt{\frac{\Sigma\,(x-m)^2}{n-1}}$$

and *n* is the number of test results. The area under the normal distribution curve shown in Figure 2.3 represents all the available test results. The characteristic strength (specified strength) is usually identified by the design engineer and is included in the specification (e.g. 30 MPa at age 28 days under standard curing conditions).

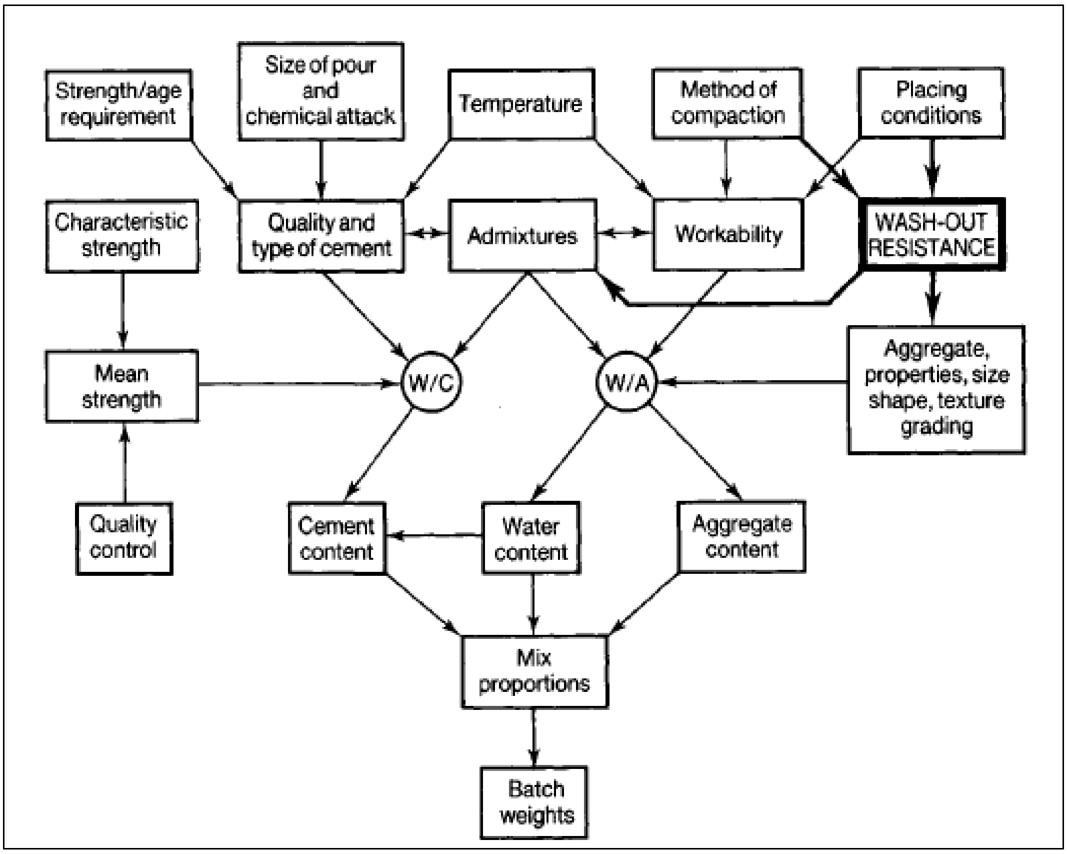

Figure 2.2 : Concrete mix design, parameters and interactions. [4]

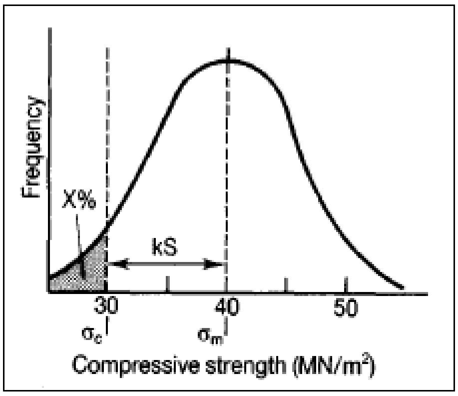

Figure 2.3 : Normal distribution of concrete strengths.[4]

As it is statistically impractical to establish a distribution curve for which zero results are defective, i.e. less than the characteristic/specified strength σ_c) it is common practice to determine the mean/target strength (required average strength) (σ_m) for concrete mix design purposes on the basis of an allowed percentage of defective test results *(X)*, i.e.

$$\sigma_c = \sigma_m + kS$$

where ;

X(%)	*k*
5	*1.64*
2.5	*1.96*
1	2.33

In practice, *S* is based on experience or is assumed to be 4-8 MPa. Typically *X* =5%. Ideally S should be calculated from results taken from the production operation used on the project in question. If these data are not available, values can be assumed such as the 4-8 MPa values recommended by the DOE [1] or by ACI.[2] Thus the mean or target strength for a mix with a characteristic strength of 30 MPa, a standard deviation of 6 MN/m^2 and allowing for 5% defectives is;

$$S_\chi = \sigma_m + kS$$
$$= 30 + 1.64 \text{ x } 6$$
$$= 39.8 \text{ MPa, i.e. } 40 \text{ MPa}$$

Depending on how critical failure of particular components may be,concrete specifications often include safeguards additional to the limitation on the percentage defective test results which fall below the specified characteristic strength. Examples of additional safeguards include:

• The average strength of any three consecutive test specimens must exceed the characteristic strength by a given amount, say 7.5 MPa

• No individual test result may fall below a specified proportion of the characteristic strength, e.g. 85%.

While the above are details associated with specifications, they can have a significant influence on the approach to the selection of the mean/target strength used for concrete mix designs.

The quality of concrete in the finished structure may additionally be affected by variations due to transportation, placing, compaction and curing operations. As these operations can be witnessed in most 'dry' placing condition applications, good supervision can ensure that the quality of concrete in structural components has a known relationship to the characteristic strength based on quality control specimens.

Detailed observation of transportation, placing, compaction and curing is much more difficult to achieve for concrete placed underwater. Thus, while underwater concrete test specimens cast in the dry can be expected to follow a typical normal distribution, much greater variability can be expected in an underwater structure. Allowance can be made for such variations by increasing the standard deviation and thus the margin between characteristic strength and target strength. The extent of the increase is difficult to estimate and needs to take account of detail placing techniques, the resistance of the specific concrete to washout/segregation and flow/self-compaction qualities in relation to placing conditions. It follows that it is better to increase the partial safety factor for materials at the structural design stage. This enables engineering judgment to be exercised in determining the overall safety factor which will also include allowance for the uncertainties in applied loading. These could be considerable in some underwater concrete applications.

2.2.2 Strength/Age Requirement of Underwater Concrete

Specific location conditions dictate the characteristic strength requirements for each application condition. Thus specified grades of concrete vary from 25 MPa for cofferdam plugs to 65 MPa in the splash zone of oil production platforms. In the above examples the rate of gain of strength is relatively unimportant as compressive strength is unlikely to be a critical performance parameter for cofferdam plugs and, in the case of oil rigs, a considerable time will elapse between casting and the concrete being subjected to service conditions.

Thus the characteristic strengths are likely to be defined at an age of 28 days for simplicity and clarity of specification. At one extreme, for concrete placed in situation in the tidal range, perhaps with limited protection, early age strength will be a critical factor. Under such conditions significant strength may need to be developed within a few hours. Such difficulties may dictate the use of precast sections and/or the use of packaging techniques. On the other hand, owing, for example, to tidal conditions, concrete cast underwater has to be placed in lifts. To ensure a good bond/homogeneity between successive placements, slow early age strength development can be particularly advantageous. Such requirements need to be built into the specification and taken into consideration in the mix design.

2.3 Materials of Underwater Concrete

2.3.1 Aggregates

As it is usually impossible to achieve detailed visual inspection during the placing of underwater concrete, and it is usually necessary for the concrete to flow and self-compact, it is important to select aggregates and gradings which are particularly resistant to segregation and bleeding and which have high cohesion.

2.3.2 Coarse Aggregates

It is well known that rounded aggregates achieve more dense packing and have reduced water demand for a given degree of workability than do crushed rock aggregates. Thus the use of rounded aggregates generally tends to increase cohesion for a given sand friction and cement content and to have a reduced tendency to segregation and bleeding. However, strength and abrasion resistance are particularly significant parameters in some underwater applications and it may thus be necessary for these reasons to select crushed rock aggregates. When this is the case particular care must be paid to the overall grading of the aggregate.

2.3.3 Fine Aggregates (Sand) (less than 5 mm)

The only special requirement for the sand fraction over and above those needed for normal concreting mixes is that there should be a significant proportion with a particle size less than 300 μm. At least 15-20% of the sand fraction should pass a 300 (μm sieve as this is necessary to enhance the cohesive properties of concrete to be placed under water. When suitable sands are unavailable it is necessary to increase significantly the cement content of mixes, or add pulverized fuel ash or ground granulated blast furnace slag.

2.3.4 Grading

As underwater concrete needs good flow and self-compacting properties, and sufficient cohesion to resist segregation and bleeding, the aggregate grading requirements are very similar to those needed for concrete pump mixes. [3] Pump mix requirements include the above properties plus the need for the cement paste and/or mortar phase to form a lubricating film on the pipe walls. While this latter requirement is not essential for underwater concrete mixes, it is common practice to have relatively high cement contents to improve cohesion, compensate for segregation effects and allow for the inevitable losses of cement due to 'washout'.

Continuous grading curves have been found to give the best results. Generally 20 mm maximum size aggregate is most satisfactory with a sand content of at least 40% of the total aggregate. The well known Road Note 4 [4] grading curves shown in Figure 2.4 provide a useful guide. Grading curve number 3 is a suitable initial target for trial mixes. However, this needs to be adjusted so that the percentage passing the 300 μm sieve is increased from 5% to about 8%. At no stage should the grading be coarser than grading curve number 2.

To achieve cohesive mixes, the relative proportions of coarse aggregate and sand need to be adjusted to minimize the total voids in the mix. This will depend on the shape of the various particles. If necessary a 'void meter' can be used to optimize the proportions. The Figure 2.4 shows the curve of graded aggregates. This approach is recommended if crushed rock aggregates are used.

2.3.5 Cements

Sulphates in ground water and particularly in sea water present the well known problem of tricalcium aluminate (C_3A) reaction, causing swelling and the related disintegration of concrete. As underwater concretes usually have comparatively large cement contents (over 325 kg/m^3), attack due to sulphates in ground water can be counteracted in the usual way by adjusting the cement content and/or the use of sulphate-resisting portland cement.

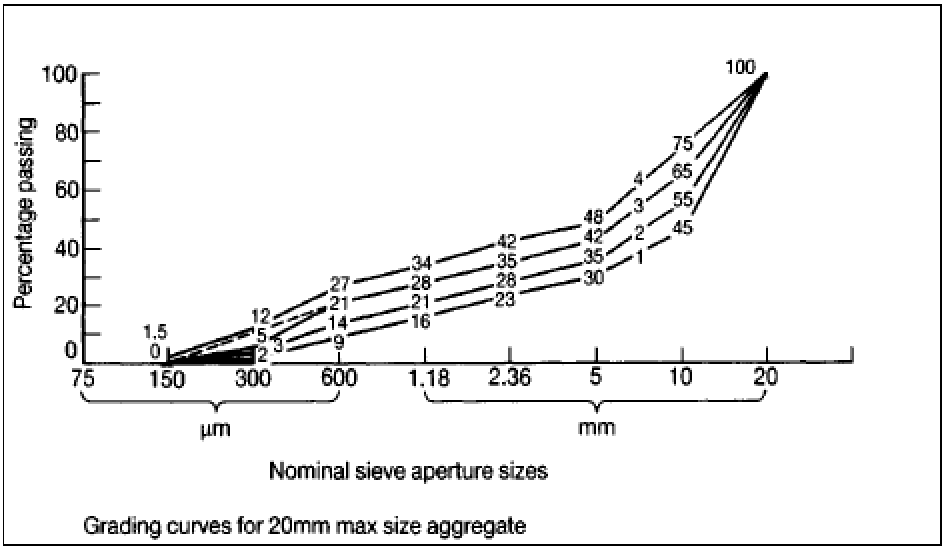

Figure 2.4 : Grading curves for aggregates. [4]

The presence of chlorides in sea water can reduce the above effect of expansion and deterioration of concrete. The gypsum and calcium sulphoaluminate resulting from sulphate attack are more soluble in chloride solutions and are leached out of concrete permanently immersed in sea water. However, concrete in the splash zone and above is particularly vulnerable as not only does sulphate attack occur, but also pressure is exerted by salt crystals formed in the pores of the concrete at locations where evaporation can take place. Chlorides migrate above normally wetted areas owing to capillary action, and the production of concrete with low permeability reduces this effect.

Fundamental to the durability of concrete subjected to attack due to sulphates in ground water and sea water is minimizing the porosity of the concrete at both the engineering level by achieving full compaction, and at the micro level by minimizing the gel pores. The latter can be considerably reduced by using low water/cement ratios. ACI committee 201.2R recommends that water/cement ratios should not exceed 0.45 in conditions of severe and very severe exposure to sulphates i.e. SO_3 content of water exceeding 1250 ppm and 8300 ppm respectively.[5] However, this needs to be accompanied by the use of high cement contents, plasticizers or superplasticizers if a high level of self-compaction is to be achieved. The use of cement replacement materials such as pulverized fuel ash and/or the addition of condensed micro silica (silica fume) can considerably reduce the porosity of concrete and thus its susceptibility to sulphate attack and chloride crystallization.

2.3.5.1 Ordinary Portland Cement (OPC)

OPC or ASTM Type I having not more than 10% C_3A is suitable for underwater concrete construction where the sulphate content (expressed as concentration of SO_3) of ground water does not exceed 1200 parts per million (ppm), and for marine structures which are permanently submerged.

2.3.5.2 Sulphate-Resisting Portland Cement (SRPC)

SRPC (ASTM Type V or Type II with a 5% limit on C_3A) with its reduced tricalcium aluminate content should be used where the SO_3 content of ground water exceeds 1200 ppm. Its use in marine structures in the splash zone and above is less straightforward. While a low C_3A content provides protection against sulphates, it reduces protection to steel reinforcement in chloride rich environments.[6] The C_3A content should not be less than 4% to reduce the risk of reinforcement corrosion due to chlorides.[7]

2.3.5.3 Low-Heat Portland Cement (LHPC)

Large pours of concrete cast underwater are particularly susceptible to thermal cracking as relatively high cement content concretes are used. LHPC (ASTM Type II or Type IV) not only reduces the rate of heat evolution but also provides protection against sulphate attack owing to the low levels of tricalcium aluminate in this cement. The use of cement replacement materials is an alternative method of reducing thermal effects and provides additional benefits.

2.3.6 Admixtures

2.3.6.1 Anti-washout Admixture

Anti-washout admixtures can be used to reduce the risk of segregation and washout with the tremie methods of placement, improve self-compaction/ flow properties and enable methods of placement which are faster and less sensitive to operational difficulties to be used. In particular, combinations of admixtures have been developed to produce a 'non-dispersible concrete' (NDC) which can free fall through a depth of about 1 m of water without significant washout of the cement phase.

2.3.6.2 Cohesion Improvement

Materials that have been tried with varying degrees of success to produce non-dispersible concrete include:[8], [9]

- Natural polymers (gum arabic, methycellulose, hydroxyethylcellulose, carboxymethylcellulose)
- Synthetic polymers (polyacrylonitrile, polyaeryamides, polymethacry-Hc acid, polyacrylates, copolymer of vinyl acetate, maleic acid anhydride)
- Inorganic powders (silica gel, bentonite, micro silica)
- Surface-active agents (air entraining with and without set retarder, plasticizers).

It is essential that the selected materials are compatible with cement hydrates. Several of the above cause severe retardation of the hydration process and limit the use of superplasticizers. The ionic polymers are insoluble in water containing hydration products owing to the presence of calcium ions and thus fail to increase its viscosity. Figure 2.5 gives details of the properties/influences of some of the more commonly used admixtures to improve cohesion in underwater concrete.

2.3.6.3 Flow Improvement

High slump concretes generally flow underwater and the addition of superplasticizers to enhance this property alone is not usually required. However, proprietary underwater concrete admixtures are a blend of several compounds and usually contain a superplasticizer to improve the flowing properties of what would otherwise be a very sticky concrete. The superplasticizers most commonly used in the construction industry are based on melamine formaldehyde and naphthalene formaldehyde. The influence of underwater conctrete is specified on Figure 2.5. While the former are compatible with the soluble polymers used to increase cohesion, naphthalene formaldehyde-based superplasticizers have been found to be ineffective when used with cellulose ether.

Properties and influences of admixtures

Admixture	Property/influence
Micro silica 0.1–0.2 μm microspheres typically over 90% reactive silica	Compatible with cement Increase compressive and tensile strength Increased rate of gain of strength Reduce porosity Increase durability Increases resistance to abrasion–erosion effects Increase cohesion
Non-ionic cellulose ether Derivative, up to 500 cellulose ether units; formula, see Figure 1.4; *n* up to 500; equivalent molecular length 0.5 μm	Compatible with cement Retards hydration reaction Large increase in viscosity Large increase in cohesion Very good segregation resistance Self-levelling/-compacting
Non-ionic polyacrylamide Typical molecular mass 5×10^6, approximately 70000 units; formula, see Figure 1.5; equivalent molecular length 10 μm	Compatible with cement Retards hydration reaction Large increase in viscosity Large increase in cohesion Excellent segregation resistance Flow resistance (20% surface gradient)

Figure 2.5: Influence of admixture for underwater concrete. [8]

2.4 Properties of Underwater Concrete

2.4.1 General

The properties required for concrete are given below as;

- Specified strength and durability
- Self-compaction (i.e. displace accidentally entrained air, and flow to fill formwork)
- Self-levelling or flow resistance (depending on placing conditions)
- Cohesive (i.e. segregation resistance)
- Washout resistance (the degree depending on the method of placement).

The extent of the interelationship between the above properties depends on the mix design approach used to achieve them. Its relationship to the characteristic strength used at the design stage is chosen to take into consideration reductions to be expected for underwater concrete.

2.4.2 Concrete without Admixtures

Well executed tremie/hydrovalve techniques have been found to produce underwater cast concrete with up to 90% of the strength of the same concrete cast in dry conditions. However, if proper control of the base of the tremie pipe is not achieved and/or the concrete is required to flow over significant distances owing to lack of mobility of the placing locations, strengths as low as 20% of the equivalent concrete cast in air can occur. This loss of strength can be attributed to segregation/stratification and/or washout of the cement phase of the concrete.[10] It should be noted that if the whole of a vertically drilled core is analysed for cement content there may be little apparent loss of cement. More careful examination may reveal that a considerable proportion of the cement is in the upper layers of the concrete, possibly appearing as a thick laitance on the top surface. Parts of the concrete are likely to have lost over 25% of their original cement content.

The significance of a full compaction on concrete strength is well known (Figure 2.6). A it is impractical to compact concrete placed underwater by physical means using vibrators or by tamping, it is essential that the concrete should have sufficient workability to displace any accidentially entrained air during the settlement/flow period after the concrete has been placed.

Established practice is to specify slump values of 120-200 mm. These values offer a useful guide for trial mixes but, as concretes with a given slump can have varying flow properties, the ability to self-compact needs to be assessed by practical trials.

In order to reduce porosity and achieve strength requirements at high water content and compensate for segregation/losses, it is necessary to have relatively high cement contents. Traditional mix designs have cement contents of 325-450 kg/m^3. Experience has shown that concrete with relatively low cement content has better abrasion resistance. Where these performance criterion is important and/or where large pours can give rise to thermal cracking problems, it is preferable to use lower end of the above range. However, the cohesion needed to avoid segregation and washout requires a minimum fines content resiulting in the need for cement contents as high as 400 kg/m^3. These conflicting performance requirements have led to the use of admixtures and cement replacement materials.

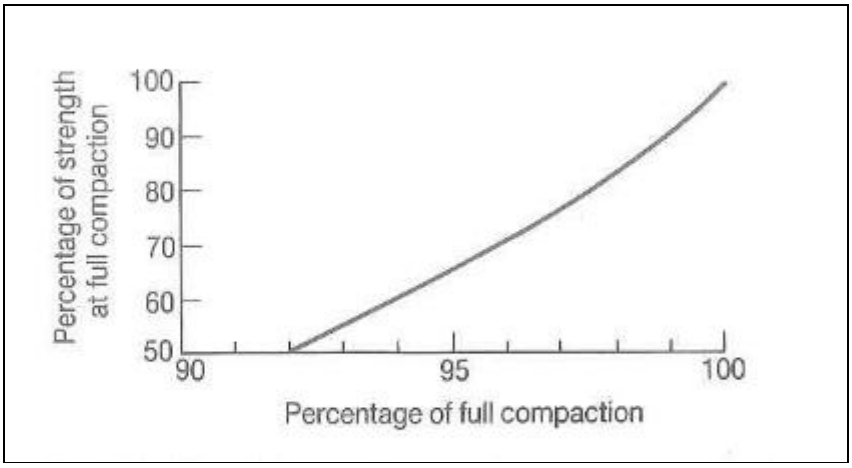

Figure 2.6 : The influence of compaction on the strength of the concrete. [10]

2.4.3 Non-dispersable Concrete

Non-dispersable concretes can be produced with varying degrees of cohesion and wash-out resistance. On the one hand, it is possible to design a mix which reduces the quality uncertainities tremie placed concrete resulting from uncontrolled internal flow velocities and changes in the geometry of the concrete/water interface. The relatively modest increases in cohesive properties required can be achieved by the addition of 10% micro silica(by weight of cement) to a traditional mix containing about 325 kg of cement per cubic metre of concrete.[11] Depeding on strength and flow requirements as a superplasticizer can also be included.

Fully non-dispersible concrete, on the other hand can be discharged from a pump delivery pipe through 1 m or so of water without significant loss of cement. The highly cohesive properties required arre achieved by addition of 2-3% of cellulose either or polycrylamide. They are often blended with a melamine formaldehyde superplasticizer, and in some cases micro silica, to produce the commercially available concrete admixtures. As extensive testing is necessary to ensure the compatibility of the combined ingredients, it is advisable to use to use commercial product rather than combine the basic materials on-site. Nevertheless, it is essential to prepare trial mixes from the combination of aggregates, cement and admixtures used on a specific project to ensure that the required performance is achieved.

2.5 Test Methods of Underwater Concrete

2.5.1 General

It is important to be able evaluate the effects of non-dispersible concrete admixtures not only in terms of obvious short-term parameters but also their influence in the longer term and over the full life of the structure. Tests are required to evaluate segregation resistance, workability/flow, chemical compatibility, influence of admixtures on strength and effectiveness at full-scale.

2.5.2 Washout Tests

Resistance to washout of the cement phase is fundamental to the production of a concrete which can free fall through 1m or so of water without degradation.

2.5.2.1 Transmittance Test

In this case a measured slug of concrete (typically 0.5 kg) is dropped into a vessel containing about 20% of water. The turbidity of the water is measured using standard light transmittance apparatus. By calibration using standard known dispersions of cement in water, the amount of washout occuring as a result of the concrete falling through the water can be determined (Figure 2.7). [12]

A variant of this test is to agitate the water with a laboratory stirrer for a prescribed period. This is a more stringent test but produces similar comparative results.

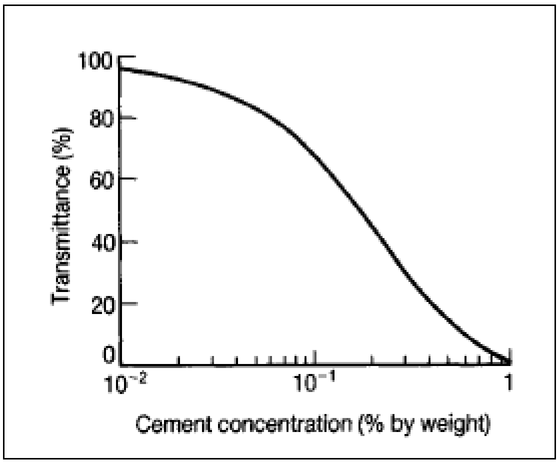

Figure 2.7 : Relationship between cement concentration and transmittance. Ordinary Portland Cement was dispersed in water. [12]

2.5.2.2 Stream Test

This is a straightforward test in which a sample of concrete is placed in a 2 m long channel set at an angle of 20°. A measured volume of water is poured down the channel and depending on the segregation resistance of the concrete, cement is washed out.13 The degree of washout can be judged on a comparative basis by visual observation and on this basis is subjective. However, by standardizing the volume and speed of water flow, and collecting it at the downstream end of the channel, the transmittance of the effluent can be measured as above, thus enabling comparative performance to be judged on a numerical basis.

2.5.2.3 Plunge Test

In this case a sample of concrete is placed in an expanded metal or wire-mesh basket and allowed to fall though 1.5 m of water in a vertically mounted tube. The sample is hauled to the surface slowly (0.5 m/s), weighed and then the process is repeated. A total of five drops has been accepted as standard.[11] While the rate of fall of the basket and concrete is relatively faster than the free-fall speed of concrete alone, the protective effect of the mesh of the basket mitigates against this. The results of the test are repeatable, enabling good comparisons between different concretes to be made. It is generally thought to relate well to practical conditions of free fall from a pump delivery hose through 1-2 m of water. A similar test method (CRD-C61-89A) has been used by the US Army Corps of Engineers.[14] A variation of this test has been used to assess the relative performance of admixtures at a range of velocities of the sample of concrete.

2.5.2.4 Segration Test

A segregation susceptibility test, originally introduced by Hughes,[15] and subsequently revised by Khayat,[16] may be used to evaluate the separation of coarse aggregate from fresh concrete when placed under water. The test describes the scattering of concrete after having been dropped over a cone from two hoppers, once in air and another time through water. The upper hopper is filled loosely with concrete, then a trap door is opened allowing the concrete to drop into the lower hopper. The concrete is then allowed to fall over a smooth steel cone, in air or through water, and scatter on to two concentric wooden discs. The weights of fresh concrete and sieved and oven-dried coarse aggregates which were collected from the two discs are used to determine the separation index *(SI)*.

2.5.3 Workability/Flow

Workability and flow properties are very important for concretes used under water, as tamping and vibration to achieve compaction are impractical, and the full extent of the form work needs to be filled from a relatively few specific pour locations. The standard slump and flow tests (BS 1881: Parts 102 and 105) are appropriate but it is interesting to note that where cellulose ether has been used to produce non-dispersible concrete the slump value gradually increases with time (up to 2 min after removal of the conical mould), and the diameter of the concrete continues to increase following the flow table test. It is common practice to allow sufficient time for the concrete shape to stabilize prior to taking a reading. The US Army Corps of Engineers' standard test method, CRD-C32-84, can also be used for determining the flow of concrete intended to be placed underwater using a tremie.[14]

The value 'slump flow' can also be used [8] where the mean diameter of the concrete in the slump test is measured.

2.5.4 Chemical Compatibility

The chemical compatibility between non-dispersible concrete admixtures and cement needs to be assessed. To determine the influence (usually retarding) of an admixture on early age hydration, the rate of heat evolution using thermocouples in insulated control and live specimens can be used. Of more direct practical value is the speed of setting. The influence of cellulose ether on setting time are given in Figure 2.8. The rate of gain of strength can be determined by casting multiple specimens and testing at intervals over several weeks. Once again comparison with control specimen results enables the influence of the admixture on hydration to be assessed. Alternatively, the modulus of elasticity can be determined electrodynamically. This has the advantage of using the same specimens at each interval of time.

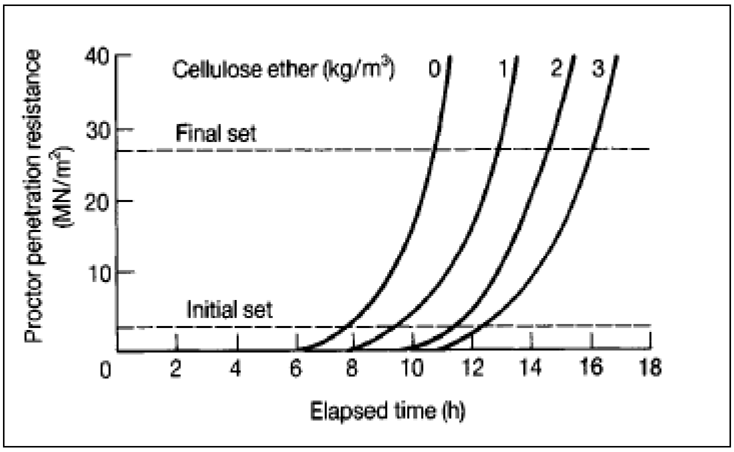

Figure 2.8 : Influence of cellulose ether on setting time [14]

2.5.5 Strength and Durability

Strength and durability are essential qualities and methods of measuring the effectiveness of non-dispersible concrete admixtures at maintaining strength following free fall through water are important. Much ingenuity has been used to develop such tests. Production of cubes by dropping concrete into moulds placed in water tanks is the most common approach but does not readily simulate practical conditions. A better approach is to produce 300mm diameter castings in moulds which include simulated reinforcement. These need to be sufficiently large to enable 100 mm diameter cores to be cut to provide the test specimens. The long-term durability of concrete containing the normal range of admixtures is well established. Less direct evidence is available for non-dispersible admixtures, particularly in terms of synergistic effects. However, the addition of micro silica to enhance the strength and durability of concrete has become established practice. There is over 15 years of evidence of the durability of non-dispersible concretes containing cellulose ether, and acrylic latex has been used to enhance the properties of hydraulic cement concretes (at much higher proportions than are used in non-dispersible concretes) for well over 10 years. The long-term durability is not therefore likely to be reduced by the use of these admixtures and, in view of the more reliable quality achieved, durability is likely to be enhanced.

2.5.6 Full Scale Test

Laboratory tests rarely reflect practical conditions. Unless first-hand experience of the actual placing conditions is available, it is good practice to cast trial sections of projects under the prevailing conditions. Sampling the newly cast and/or hardened concrete will enable the proposed process and materials to be assessed. The costs involved are justified in view of the financial and safety implications of failure.

2.6 History of Underwater Concrete

There is evidences that 2000 years ago, were applied by Romans. Romans knew how to make massive concrete placements underwater. At the long-abandoned sunken harbor in Caesarea, Israel, archaeological divers found massive concrete blocks, some as large as l3x10x108 m.[18] Henri Khayat made several studies of underwater concrete. Most anti-washout admixtures are water-soluble polymers that modify the rheological properties of fresh concrete. Such admixtures have been incor-porated into concrete intended for underwater placements and repairs, and implemented in production of extremely workable and flowing concrete. They have also been used to enhance resistance to sagging of shotcrete and produce bleed-free cement grouts for filling post-tensioning ducts. This paper presents results from a study aimed at better understanding of the effects of antiwashout admixtures on concrete properties. It will highlight benefits and limitations of employing such admixtures in concrete. Fresh properties of low-, medium-, and high-strength concretes made using two types of antiwashout admixtures, a microbial polysaccharide and cellulose derivative, were evaluated. Fresh properties are compared with those of similar concretes made without antiwashout admixtures. Among the parameters evaluated are fluidity, bleeding, water dilution, segregation, setting time, and air content. Test results show that incorporation of an antiwashout admixture can greatly reduce external bleeding and significantly enhance resistance of concrete to water dilution and segregation. However; there is a signijcant increase in water demand, and a high-range water-reducing admixture is needed to maintain a desired level of fluidity without excess addition of water. The combined additions of an antiwashout admixture and high-range water-reducing admixture delay setting time, especially at high concentrations of high-range water-reducing admixture. Viscous concretes containing antiwashout admixtures show a greater demand for air-entraining admixture. However; once enough air is entrained, proper air-void parameters needed to insure good freeze-thaw resistance can be obtained.[17]

3.EXPERIMENTAL STUDIES

3.1 Materials and Method:

There is 6 different material types are used in this study. These are aggregate (includes stone powder), Portland cement, water, fly ash, anti-washout admixture and superplasticizer. There are for concrete types that have applied for the experiments. Type III is defined as Type II+ fly ash. Type IV is defined as Type II without anti-washout admixture.

3.1.1 Aggregate

The extraction of alluvial materials can be carried out with the help of a loader or excavator, if the area is dry, thanks to multibucket excavators. If the area contains water, a dredge connected to floating conveyors. From a bench or massive rocks, extraction requires the use of explosives. Blasting breaks down the materials, which are then brought to a handling facility. Transferring aggregates to handling facilities is generally carried out by means of belt conveyors. When belt conveyors are not feasible, the transfers are carried out by haul trucks or barges if waterway is available. Aggregates are reduced in size by crushing. Then they are sorted using wire mesh screens. Afterwards the aggregates are often washed, as some uses require the material to be perfectly clean. The materials are stored in piles, in bins or silos, where they are sorted according to different categories. There are sands, gravel and rocks of various sizes. Each category of aggregate meets specific criteria based on its intended uses. All materials that leave the quarry are weighed with truck scales. Delivery is performed by trucks, barges and trains.

3.1.1.1 Stone Powder

Stone powder produced from stone crushing zones appears as a problem for effective disposal. Sand is a common fine aggregate used in construction work as a fine aggregate. In this study, the main concern is to find an alternative of sand. Substitution of normal sand by stone powder will serve both solid waste minimization and waste recovery. From laboratory experiments, it was revealed that concrete made of stone powder and stone chip gained about 15% higher strength than that of the concrete made of normal sand and brick chip.[19] Concrete of stone powder and brick chip gained about 10% higher strength than that of the concrete normal sand and stone chip, shows that better mortar can be prepared by the stone powder. On the other hand, concrete from brick chip and stone powder produce higher compressive value from that of brick chip and normal sand concrete.

3.1.2 Portland Cement

Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It usually originates from limestone. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulfate and up to 5% minor constituents as allowed by various standards such as the European Standard EN 197-1.

Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates (3 $CaO·SiO_2$ and 2 CaO·SiO2), the remainder consisting of aluminium- and iron-containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0% by mass.

ASTM C150 defines Portland cement as "hydraulic cement (cement that not only hardens by reacting with water but also forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an inter ground addition." Clinkers are nodules (diameters, 0.2–1.0 inch [5–25 mm]) of a sintered material that is produced when a raw mixture of predetermined composition is heated to high temperature. The low cost and widespread availability of the limestone, shales, and other naturally occurring materials make Portland cement one of the lowest-cost materials widely used over the last century throughout the world. Concrete is one of the most versatile construction materials available in the world. Portland cement clinker is made by heating, in a kiln, a homogeneous mixture of raw materials to a calcining temperature, which is about 1450°C for modern cements. The aluminium oxide and iron oxide are present as a flux and contribute little to the strength. For special cements, such as Low Heat (LH) and Sulfate Resistant (SR) types, it is necessary to limit the amount of tricalcium aluminate ($3\,CaO \cdot Al_2O_3$) formed. The major raw material for the clinker-making is usually limestone ($CaCO_3$) mixed with a second material containing clay as source of alumino-silicate. Normally, an impure limestone which contains clay or SiO_2 is used. The $CaCO_3$ content of these limestones can be as low as 80%. Secondary raw materials (materials in the rawmix other than limestone) depend on the purity of the limestone. Some of the materials used are clay, shale, sand, iron ore, bauxite, fly ash, and slag. When a cement kiln is fired by coal, the ash of the coal acts as a secondary raw material.

OPC 42.5 was used in Underwater Concrete mix design.

3.1.3 Water

Combining water with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more freely.Less water in the cement paste will yield a stronger, more durable concrete; more water will give an free-flowing concrete with a higher slump.hnpure water used to make concrete can cause problems when setting or in causing premature failure of the structure.Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles, and other components of the concrete, to form a solid mass. In thıs study , municipal water was used.

3.1.4 Fly Ash

Fly ash is a product of burning finely ground coal in a boiler to produce electricity. It is removed from the plant exhaust gases primarily by electrostatic precipitators, or baghouses and secondarily by scrubber systems. Physically, fly ash is a very fine, powdery material, composed mostly of silica nearly all particles are spherical in shape. Fly ash is generally light tan in color and consists mostly of silt-sized and clay-sized glassy spheres.

3.1.5 Admixtures

3.1.5.1 Anti-washout Admixture:

Viscobeton is a powder product formulated for non-water-soluble and non-segregable concrete for underwater structures. This product increases the viscosity of the cement mix and makes it resistant to wash-out and water penetration, both during the fresh and hardening stages. Viscobeton is chloride-free used for both freshwater and saltwater concrete casts, Viscobeton prevents leaching in fresh concrete and aggregate segregation. The pictures of admixtures are shown at Figure 3.1, 3.2. Concrete with the Viscobeton additive offers the following advantages:

- Consistently uniform and compact, with better mechanical properties and impermeability;
- No bleed;
- No segregation.

Figure 3.1: Anti-washout admixture.

3.1.5.2.Superplasticizer

Superplasticizers are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation, and to improve the flow characteristics of suspensions such as in concrete applications.

Figure 3.2: Superplasticizer

3.2 Mix Proportion

The compositions used to prepare underwater concrete in this study consisted of coarse aggregates, fine aggregates, stone powder, ordinary Portland cement, water, anti-washout admixture and superplasticizer. However, admixtures such as fly ash was also used in some of the mixes to produce a strength variation. Three groups of samples were developed. The mixture proportions for each were summarized in Table 3.1. The first group was produced with of coarse aggregates, fine aggregates, stone powder, ordinary Portland cement, water, anti-washout admixture and superplasticizer. The second group was made with the same recipe with first group (coarse aggregates, fine aggregates, stone powder, ordinary Portland cement, water, anti-washout admixture and superplasticizer) but rising the ratio of fine aggregate (stone powder). The third group was made like the second group but the fly ash was used as admixture with 10 % weight of cement . The forth group have the same recipe with second group without anti-washout admixture. In all groups, the water to cement ratio was 0,41. In this way, samples of different strength and other applied experiment results were obtained.

Table 3.1: Mix Proportions of Specimens

Materials	**Aggregate**	**(kg/m^3)**	**Cement**	**Water**	**Fly Ash**	**Anti-washout admixture**	**Superplasticizer**
Type IV	16-31.5 mm	18					
	4-16 mm	674	425	175	50	-	4.25
	0-4 mm	1039					
Type III	16-31.5 mm	18					
	4-16 mm	674	425	175	50	4.25	4.25
	0-4 mm	1039					
Type II	16-31.5 mm	18					
	4-16 mm	674	425	175	-	4.25	4.25
	0-4 mm	1089					
Type I	16-31.5 mm	18					
	4-16 mm	833	425	175	-	4.25	4.25
	0-4 mm	931					

3.3.Sieve Analysis:

Sieve analysis is used for determining size of aggregate. When this analysis is applied, the largest sieve is at the top and the sieve size is getting smaller by going downward direction. A pan is placed at the bottom of the sieve series to avoid any spilling of fine particles passing through the smallest sieve. Total pass rate of aggregates are shown of Figure 3.3.

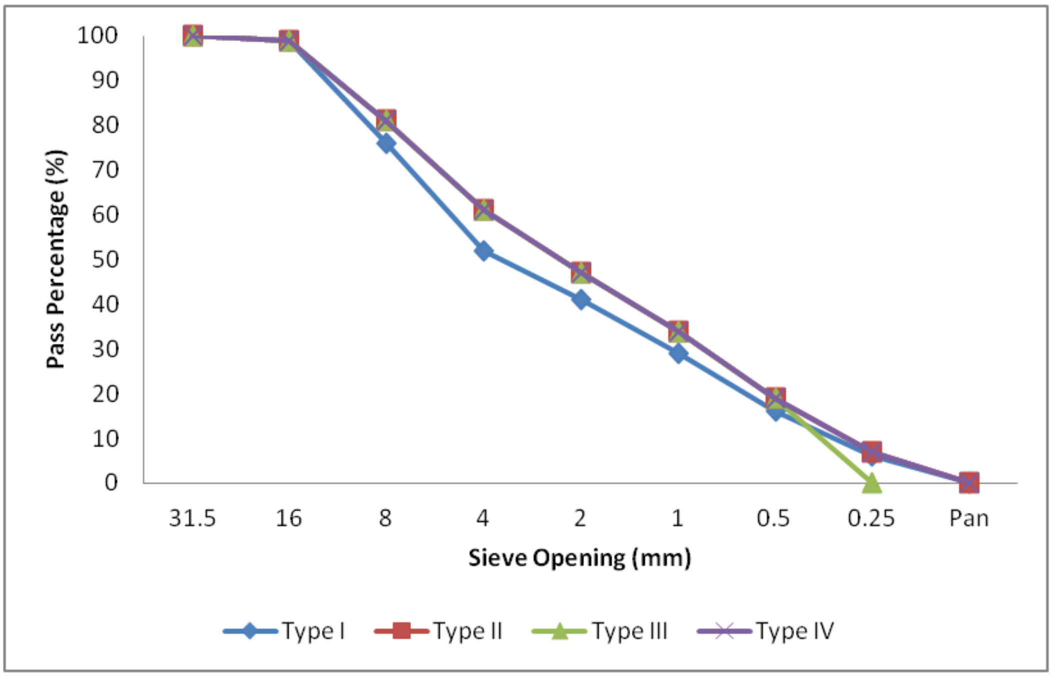

Figure 3.3: Gradation of aggregate mixtures..

3.4 Unit Weight Test

The unit weight, or density, of concrete varies with the amount and density of the aggregate, the amount ofentrapped or entrained air, and the water and cement contents.

To determine the unit weight of freshly mixedconcrete, you will need a cubic metal measure(container) which has 15 cm diameter, 15 cm height, and 15 cm width.. If necessary, you should calibrate the measure before performing the test procedures. To calibrate the measure, you first determine the tare weight of the measure, and then fill the measure with water at room temperature. Then determine the temperature, density, and weight (in pounds) of the water.

Procedure

Fill the measure with fresh concrete consolidated in three layers, as described for theair-content test. After each layer is rodded, tap the sidesof the container 10 to 15 times with a rubber or rawhidemallet to remove any air pockets. After filling and consolidating, strike off the topsurface, taking care to leave the measure level full. Clean all excess concrete from the exterior of the measure. Then weigh it and determine the net weight of the concrete inside the measure by subtracting the tare weight of the measure from the gross weight of the measure and concrete. Calculate the unit weight by multiplying the net weight of the concrete by the calibration factor for the measure.

3.5 Slump Test

The concrete slump test is an empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness.

Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It is also used to determine consistency between individual batches.

Procedure

1. The mold for the slump test is a frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm (4 in).
2. The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested .

3. Each layer is temped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end.
4. When the mold is completely filled with concrete, the top surface is struck off (leveled with mould top opening) by means of screening and rolling motion of the temping rod.
5. The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mould.
6. Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump.
7. The decrease in the height of the center of the slumped concrete is called slump.
8. The slump is measured by placing the cone just besides the slump concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete.
9. The decrease in height of concrete to that of mould is noted with scale. (usually measured to the nearest 5 mm (1/4 in).

Figure 3.4: Slump cone and testing.

European classes of slump shown at Table 3.6:

Table 3.6: European classes of slump

Slump class	**Slump in mm**
S1	10 – 40
S2	50 – 90
S3	100 – 150
S4	160-210
S5	≥220

3.6 Pulse Velocity Test

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time T of the pulse to be measured.

Longitudinal pulse velocity (in km/s or m/s) is given by:

$$v = L / T$$

Where;

v is the longitudinal pulse velocity,
L is the path length,

T is the time taken by the pulse to traverse that length.

Procedure

Where possible the direct transmission arrangement should be used since the transfer of energy between transducers is at its maximum and the accuracy of velocity determination is therefore governed principally by the accuracy of the path length measurement. The couplant used should be spread as thinly as possible to avoid any end effects resulting from thedifferent velocities in couplant and concrete.

Figure 3.5: Application of pulse velocity test.

Figure 3.6: Apparatus of pulse velocity test.

3.7 Compression Test

Compression test determines the strength of concrete under standard conditions. This method describes the procedure for making and curing compression test specimens from fresh concrete and for determining the compressive strength of the specimens.

Procedure

- Place the mold on a firm, level surface. Form the test sample by placing concrete in the mold in three layers of approximately equal volume.
- Move the scoop around the top edge of the mold to ensure a symmetrical distribution of the concrete within the mold.
- Rod each layer with 25 strokes of the tamping rod. For layers 2 and 3, the rod shall penetrate about 25 mm into the underlying layer. Distribute the strokes uniformly over the cross-section of the mold.
- Close the voids left by the tamping rod by lightly tapping the sides of the mold. After the top layer has been rodded, the surface will be struck off with a trowel and covered with saran wrap to prevent evaporation.
- Store the specimen undisturbed for 24 hours in such a way as to prevent moisture loss and to maintain the specimen within a temperature range of 15^{o} C to 27^{o} C.
- Remove the test specimen from the mold between 20 and 48 hours and transfer carefully to the place of curing and testing. If molds are being shipped it is permissible to leave specimen in cardboard mold during transit.
- Place the specimen in the water bath and store for the curing period designated in the contract.

Figure 3.7: Apparatus of compression test.

Operate the machine at a constant rate within the range of 680 kgf per second for cubic specimens.

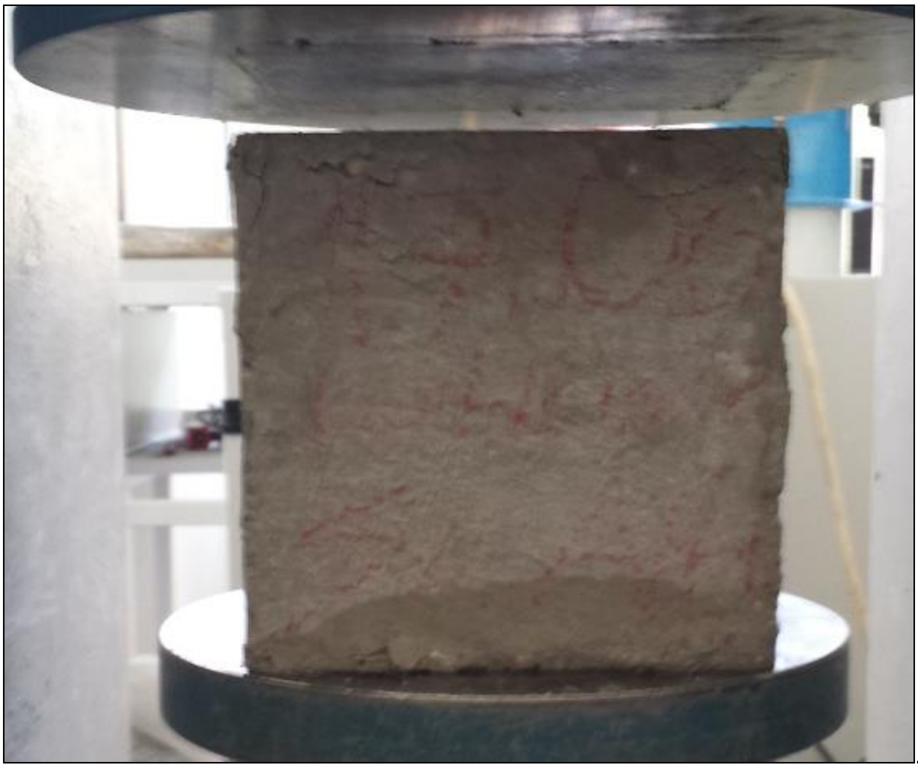

Figure 3.8: Cubic specimen.

Figure 3.9: Application of compressive strength test.

3.8.Underwater Concrete Application

One of the old curing pool was used for application of underwater concrete. The specimens placed into the pool and the underwater concrete applied by follwing materials. The materials that have been used are pipe, trowel, hand truck, showel.

Figure 3.10: Pouring of underwater concrete

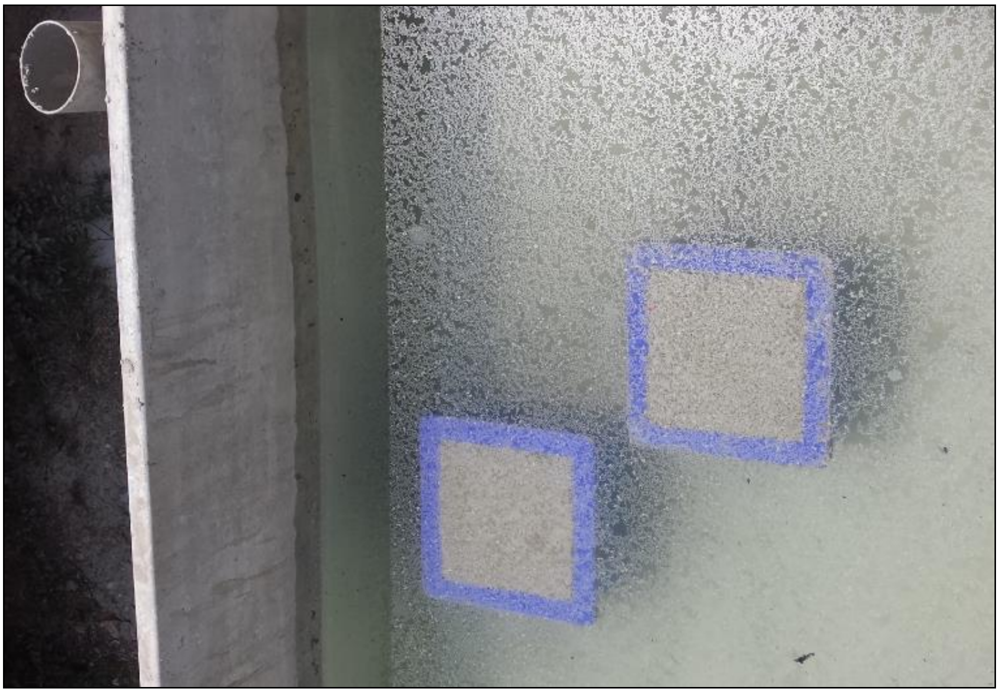

Figure 3.11: Placed underwater concrete

4.RESULTS

4.1 Unit Weight Test

Results of unit weight experiment given in Table 4.1:

Table 4.1: Results of unit weight experiment**.**

Type	Unit weight in air (t/m^3)	Unit weight in water (t/m^3)
Type I	2.47	2.46
Type II	2.38	2.37
Type III	2.39	2.38
Type IV	2.34	2.35

Because the fineness of the mixture is increasing from type I to type IV, it is expected that the unit weigth of the specimen will decrease.

4.2 Slump Test

According to slump experiment the results are given below in Table 4.2:

Table 4.2: Results of slump experiment.

Concrete Type	Slump in mm	Slump Class
Type I	62	S2
Type II	71	S2
Type III	73	S2
Type IV	69	S2

Figure 4.1: Mesure of slump.

4.3 Ultrasound Pulse Velocity Test

The results of pulse velocity test given the tables. To compare results of pulse velocity test and determined that specimens' voids. The specimens that poured traditionally is named as reference concrete. On the other hand the concrete which is poured in water is named as underwater concrete in Figures 4.2, and 4.3. The major result that have been observed is the rise of the voids into the concrete which shown in Figures itself as the decrease of velocity from type I to type IV.

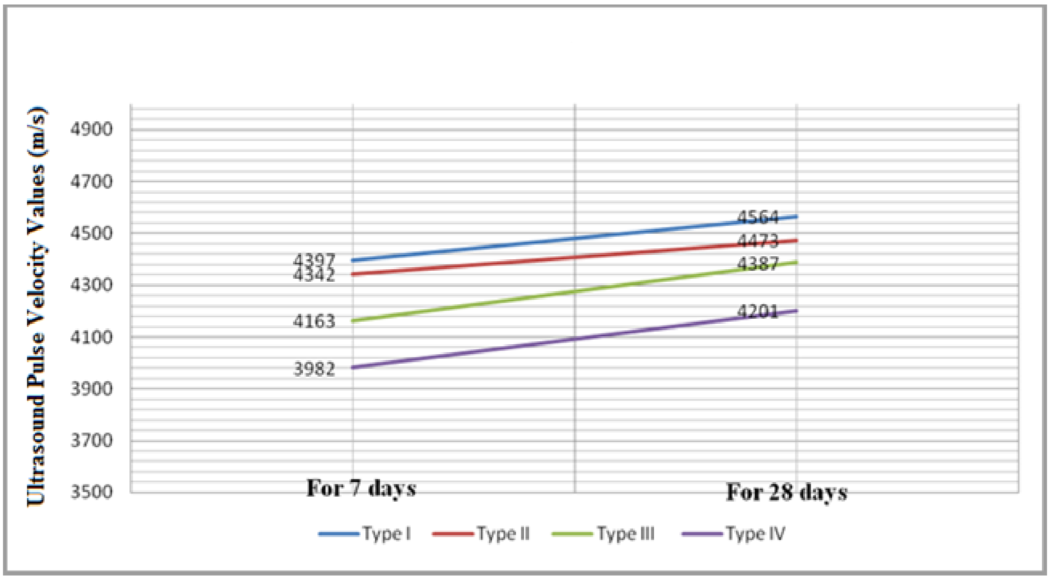

Figure 4.2: Comparison of ultrasound pulse velocity tests for reference concrete.

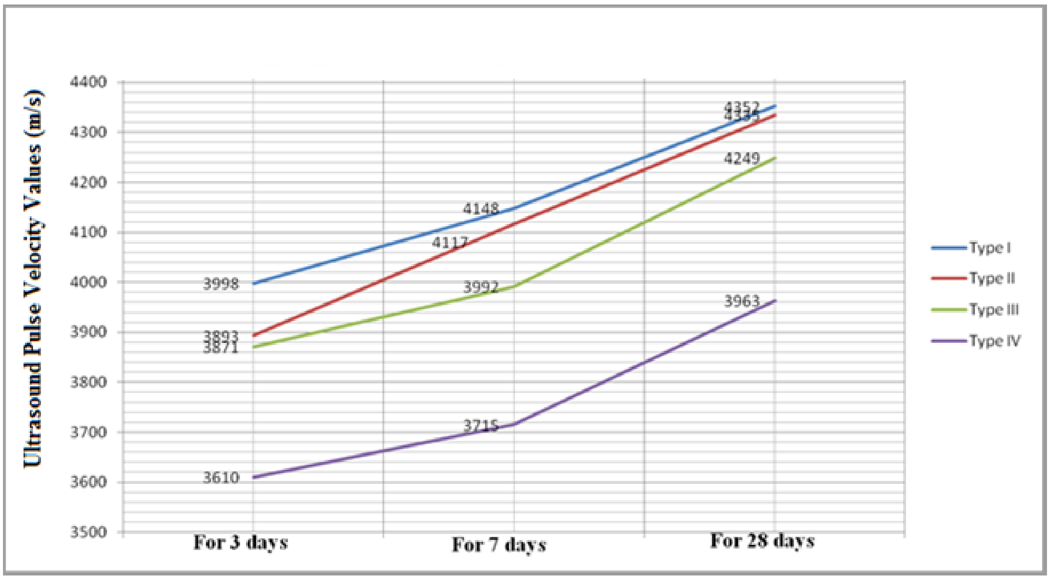

Figure 4.3: Comparison of ultrasound pulse velocity tests resulst for underwater concrete.

According to Figure 4.2, 4.3; first type of underwater concrete mixture has the highest value for reference and underwater concrete. Because first type mixture has the higher ratio of coarse aggregates than others, the void ratio of

Type I is the lowest. It is shown by this experiment that fine aggregate increase the ratio of void. Increase of the void ratio causes lower Ultrasound pulse velocity. Reference concrete has higher value of velocity which means that pouring the concrete in water increases voids.

4.4 Compressive Strength Test:

Results of Type I , Type II, Type III and Type IV:

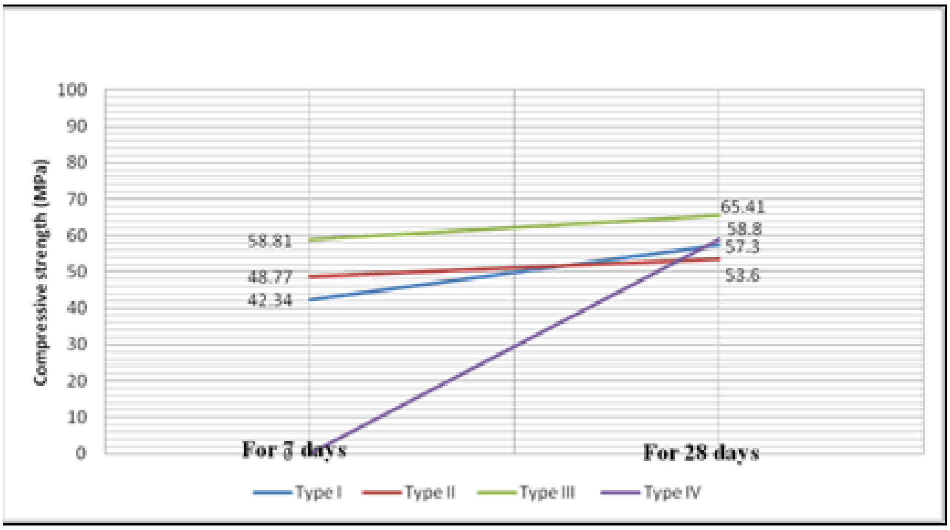

Figure 4.4: Comparison of compressive strength for reference concrete.

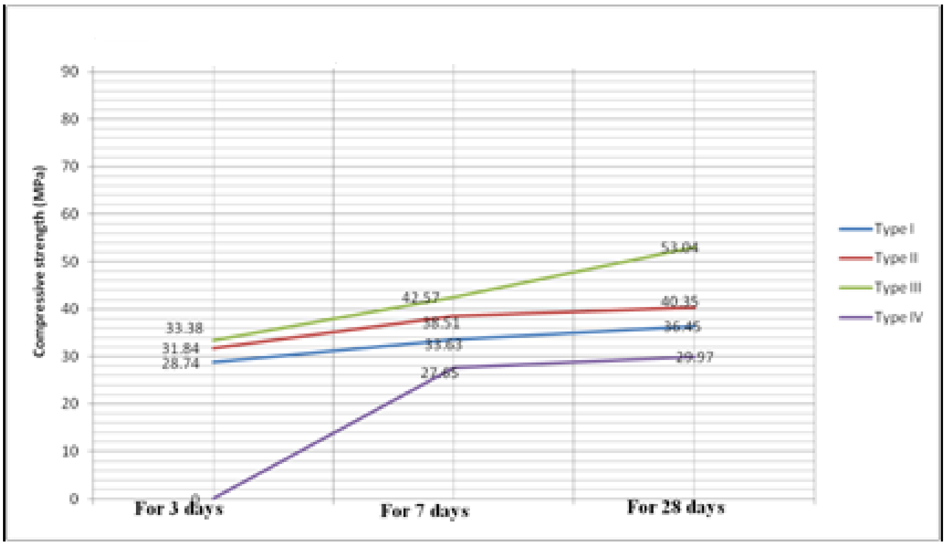

Figure 4.5: Comparison of compressive strength for underwater concrete.

The specimens that poured traditionally is named as reference concrete. On the other hand, the concrete which is poured in water is named as underwater concrete in Figures 4.4, 4.5. It is observed from the experiment that the most cohesive, strength type of mixture is type III. It is also observed that beside the anti-wash-out admixture, fly ash has an remarkable role in the mixture that affects the strength of the same recipe of concrete by the strength value as 32%. Because anti-washout admixture bond the cement, it is observed that anti-washout admixture has an significant role in mixture as increasing the value of strength 76%. On the other hand, the underwater type III specimen has 82% of the reference type III specimen that is observed although anti-washout admixture minimize the cement dispersion and increase the value of strength 76% when the concrete is poured in water, it still can not prevent the dispersion of the cement which causes the low of the strength value up to 18%.

5.Conclusion:

First of all, for underwater concrete the mix proportions are determined. According to these mix proportions, ingredients of concrete which are fine aggregate, coarse aggregate, water, cement, anti-washout admixture, superplasticizer, and fly ash are ready for mixing. Prepared mixtures are placed into three molds for each type. These specimens are located in water batch for 3, 7, and 28 days.

The compressive strength, pulse velocity and unit weight tests are applied for these specimens. The tests which are performed are compared to concrete development day by day. Each tests are examined for 3, 7, and 28 days.

One of the benefitial results is that plastic vicosity and yield value of fresh concrete increase by using antiwashout admixture. Thus, decomposition of concrete is prevented by minimizing washout of fresh concrete during casting underwater. Therefore, yield value of concrete is made decreased by using superplasticizers. As a conclusion, superplasticizer has positive effects on compressive and flexural strength, ultrasonic pulse velocity on the concretes which were cast in both water and air.

There is an another result that have observed is the decrease of the compressive strentgh associated with poured concrete in air. Even the anti-washout admixture minimize the washout loss, because of the washout loss of the concrete which is poured in water.

According to tests results, Type III(Type II + fly ash) is most strong as compressively, also Type II is higher strength than only Type I. Because of these results, fly ash is improving the compressive strength of concrete similarly normal concrete. In addition, fineness of the underwater concrete is increasing the compressive strength. Type II includes much more fine aggregate ratio than Type I. Therefore, the strength of Type III mix has highest strength.

The other result is that, the w/c ratio is constant, but the fineness modulus is increased, pulse velocity results are decreased because the void ratio increases, pulse velocity values decreases.

According to study aim, different mixture types are applicable for underwater concrete design. Fineness of the mixture is increasing the value of compressive strentgh of the concrete. Also fly ash has benefits for underwater concrete design. Without anti-washout admixture, compressive strentgh of the concrete which is poured in water is considerably low because of the washout loss. Type III is the most efficient mixture type because, has the biggest value of compressive strength, most cohesive concrete mixture.

Suggestions that have determined during the study are classified below.

• With a constant amount of anti-washout admixture, the concrete behaviour might be observed by changing the amount of superplasticizer for underwater concrete mix design.

• Cylindirical specimens may be used for pouring concrete in water to have healthier results.

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