Underwater concreting with Rescon T

Introduction

Since the 1980s, admixtures that increase the cohesion of the concrete and allow direct contact with water possible without significantly changing the properties of the concrete, have been developed and widely used.

The anti washout admixtures, e.g. Rescon T and similar products, have certain properties that influence the fresh concrete, the setting and hardening of the concrete, and the hardened concrete. Knowledge about these properties is crucial for all parties involved.

1. Different Methods of Underwater Concreting

Traditional methods with normal underwater concrete:

1.1 Bucket Concreting

The simplest way of placing underwater concrete in a formwork under water is to lower the concrete through the water in an open bucket to a diver who will carefully place the concrete in the formworks. Bucket concreting should only be used for very minor and temporary work.

1.2 Sack Concreting

This method is used in minor permanent works and repair works. The concrete is placed in porous sacks of woven materials and lowered down through the water to the diver. Since the sacks are only filled between 50 to 70 % full of concrete, the diver can push the sacks into shape to give them a good contact area with each other, either side by side and/or upon each other. Since the cement paste will be squeezed out through the woven sacks, a certain cementation will occur between the sacks. The opening of one sack should always be turned in towards another sack. To provide a stronger and a better result, the diver can drive reinforced steel bars through the sacks. The sacks are usually lain ind bond similar to block walling.

1.3 Container Concreting

The concrete is lowered down through the water in a closed bag or skip in one of the following ways:

- The bag method. Where small amounts of concrete are required, for example in repair work, a convas bag, about 2 m long and about 0,5 m in diameter is a useful method for placing concrete under water. The canvas bag, which is

reuseable, is filled with concrete and lowered to the specified location after the bag has been closed at both ends. Just above the casting spot, the bottom of the bag is slowly opened, letting the concrete slowly flow out of the bag into the form.

- The steel container or skip method. In this method a cylindrical steel container or skip is used with a top and bottom lid. This method is more effective than the bag method since it is possible to bury the bottom or the mouth of the skip in previously laid concrete and in this way prevent or reduce the possibility of wash-out of the cement as much as possible. When loaded, the skip should be full and a flexible cover or lid should be placed over the top opening. This will reduce the wash-out of cement during lowering and during discharging. The flexibile cover will follow the top of the concrete down during pouring. To allow free flow of concrete through the skip, the skip should always be vertical during discharge of the concrete. The weight of the skip with the concrete will be sufficient to ensure that it sinks into the concrete surface. To reduce the possibility of wash-out, the skip should be provided with a skirt. During pouring the skip should be slowly raised.

1.4 Tremie Pipe Concreting

The concrete is transported and poured through the water by means of a rigid pipe that dips into the fresh concrete already placed. When the concreting starts, the first batch is passed through the pipe under the control of a sliding valve. Plastic pipe should not be used. The pipe and hopper are suspended from a staging and mounted so that the steel pipe and hopper can be smoothly lifted and lowered vertically and independently of waves and tidal variations.

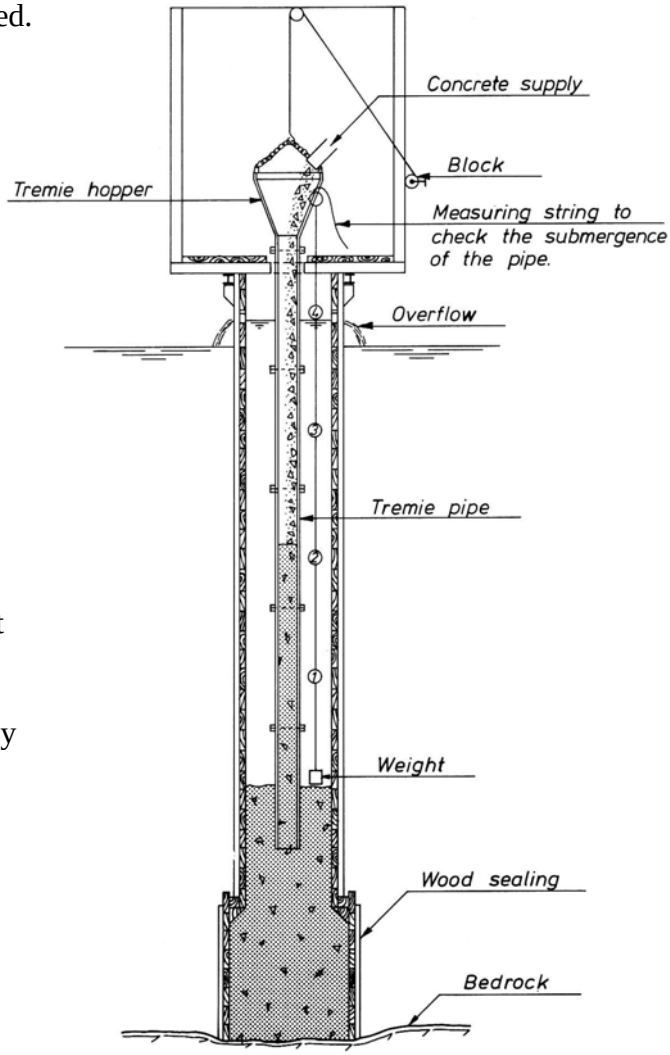


Fig. 5.1.3.1.A Tremie pipe method

1.5 Hydrovalve conreting

This method is a refinement of the tremie method, or it can be said to be a cross between the skip metnod and the tremie pipe method. Instead of using a rigid pipe, the concrete slides down a collapsible tube which is kept closed by wqater pressure until the weight of the concrete in the tube overcomes the hydrostatic pressure and the tube skin frfriction. The concrete plug will then slide slowly through the tube, and the tube will be sealed behind each plug by the water pressure. A valve at the bottom end of the tube controls the concrete discharge

1.6 Pump Concreting

Pump concreting method can also be said to be an extension of the tremie pipe method. Instead of delivering the concrete into the formwork by falling through a pipe or a tube, the concrete is placed into the formwork by hydraulic pumps.

1.7 Injection

In this method the formwork is first filled with specially washed coarse graded aggregate. The voids in the aggregate are then filled by injection with a mortar or grout consisting of cement, sand and then expanding and stabilizing material. This method can be especially useful in flowing water and in areas inaccessible to skips, tremie, hydrovalve or pump concreting sunch as undercuts for example under a foundation.

For traditional underwater casting, several problems may occur – as listed in the figure below.

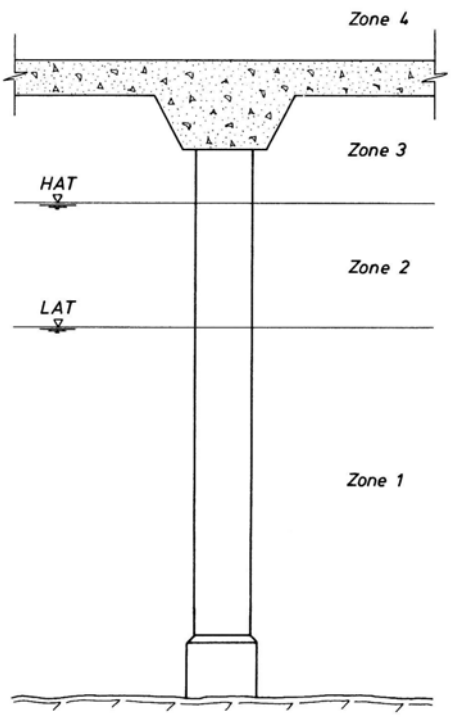


Fig. 5.2.1.A Zonal division

Zone:	Deterioration caused by:	Deterioration occurring immediately	Deterioration occurring after some years
Zone 1	Faulty formwork	X	
	Faulty pouring	X	X
	Corrosion		X
	Chemical reactions		X
	Erosion		X
Zone 2	Faulty pouring	X	X
	Freezing and thawing	X	X
	Physical actions	X	X
	Corrosion		X
	Chemical reactions		X
	Erosion		X
Zone 3	Freezing and thawing	X	X
	Corrosion		X
	Chemical reactions		X
Zone 4	Corrosion		X

Fig. 5.2.1.B Deterioration to be expected in the different zones

An alternative method of casting underwater concrete involves principally the material, and not so much the method (as discussed in 2.5 Placing/Casting methods)

1.8 T-Concreting

T-concrete is a special underwater concrete with an anti washout agent added. The agent is a formulation of a stabilizer, high range water reducer (superplasticiser), special fillers and additives. The superplasticiser ensures that the cement flocks are adequately dispersed. The stabilizer encapsulates the cement grains, which prevents the cement of being washed out, even when in close contact with water. The properties and possibilities and limitations are discussed in chapter 2

2. The T-concrete method

2.1 General

When adding anti washout agents, such as Rescon T, the concrete's properties are radically altered. T-concrete makes the diver's work more efficient; the visibility makes it possible to control and correct during casting.

With a correct mix design, the T-concrete is very flowable. The yield stress is extremely low, allowing the concrete to flow to a nearly even surface (self-levelling). It can pass obstacles, surround any reinforcement and fill the form completely. In situ core tests reveal perfect self-compacting abilities. The flow through water is relatively slow, due to its high viscosity. T-concrete retains its slump for a substantial period of time, increasing as the dosage increases. This allows for longer transport and casting over several hours. Adjustment of slump flow can be done on site in a sufficiently efficient truck mixer.

2.2 Mix design consequences

It is the dosage of admixture rather than the sand – stone ratio, or the cement content, that is decisive for the T-concrete's water demand. The higher the amount of anti washout agent, the more mixing water is needed. Compared to ordinary underwater concrete, an increase of 40 to 70 litres of water is not unusual.

As opposed to traditional underwater concrete, the amount of coarse aggregates must not be reduced in T-concrete. Equal amounts of coarse (> 8 mm) and fine (< 8 mm) aggregates can be chosen. The aggregates should be well graded with a maximum size of 22 to 26 mm. Rounded particles are always preferable, but crushed stones that are not too flaky or elongated are highly acceptable.

Dependent on casting methods and type of cement used, the addition of 5 to 10 % of condensed silica fumes, by weight of cement, is advantageous. The fine particle shape, the fineness, and its pozzolanic efficiency both improves the flow and inner cohesion in fresh concrete, as well as the long term compression strength, the permeability and the durability of the hardened concrete are all improved. The addition of silica also reduces the retarding effect of the anti washout agent.

As in ordinary concrete, the final strength of T-concrete is decided by the water to cement ratio, and the adding of silica contributes positively in this connection. The influence of the cement type is as for concrete in general, with the normal differences in early strength development. The anti-washout agents have a noticeable retarding effect, which becomes significant at lower temperatures (e.g. below 10 degrees Celsius). Using cement with higher Blaine and adding silica reduces this retardation of setting.

Deriving from this discussion, these are two examples of mix designs for T-concrete:

Compressive strength class (sylinder/cube)	**C 45/55**	**C 35/45**
Water/ cement ratio (i.e. water/binder ratio)	**0,40**	**0,53**
Rescon T	5	5
Total water	212*	216*
CEM I – 42,5 R	465	370
Silica (CSF)	35	20
Sand 0- 8 mm	820	860
Coarse aggregates 8-22/26 mm	820	860
Superplasticiser	2- 4	

* Roughly changes of 1 kg of Rescon T results in 6,5 liter change in water demand

2. 3 Mixing procedure

Anti-washout agents can be added into a central mixer or directly into a truck mixer, providing this has a sufficiently efficient mixing capacity.

When added into the mixer of a ready-mix plant, the addition can be done either on the aggregate scales or at the same time as the aggregates into the mixer, but it can also be added after the ordinary concrete is mixed. The correct amount of water should be added at once, since adjusting flow by water after the introduction of the anti washout agent is both time consuming and extremely difficult because of the anti washout properties! Parts of the concrete will stick to the sides of the mixer, especially if the water content is too low; thereby it is more difficult to empty the mixer.

The best method is to add the powder directly into the truck mixer. The efficiency of the mixer must be verified on beforehand, but most automixers are perfectly capable of mixing T-concrete. The addition can be done in two ways; either by adding the powder into the concrete flow as the batch is poured into the truck mixer, or – by placing the powder in the truck prior to the fresh concrete. In both cases the rapid rotation of the mixer is essential.

And; both methods require a thorough mixing at full rotation speed of the mixer. The minimum time of mixing at full speed, while the truck is at a stand still, is 15 minutes. During transport, the mixer is normally slowly rotating, but the general stability of the T-concrete makes it even possible to transport T-concrete without rotation.

If, on the arrival at the construction site, one finds that the flow is not high enough, it is possible to adjust the flow by adding a high range water reducer/superplasticiser. Again, one will experience the need of a somewhat prolonged mixing time. Both superplastisicers based on melamine and the new co-polymers can be used. Sulphonated naphthalene MUST NOT BE USED.

It is essential that this adjustment is done in co-operation with the diver, who is able to verify the actual flow into the form. In this way, the corrections can be communicated to the ready-mix plant to ensure the correct mixing of the following batches.

2.4 Casting procedures

Many problems resulting in damaged constructions in ordinary underwater concrete constructions occur as a result of bad craftsmanship, lack of knowledge or bad planning.

The introduction of an anti washout agent into a sound concrete, does not make these parameters superfluous: it is still essential to execute the casting according to codes and good craftsmanship, and indeed it is absolutely necessary to do a fair deal of planning prior to the concreting. Deviation from the ideal plan, unforeseen problems can occur, and must be handled accordingly. The better the planning, the more adequately these problems can be solved. A saying goes like this: Plan ahead, and you won't go wrong! Here is a short list of crucial questions that must be included in the planning:

- Do we have the necessary equipment and does it work?
- What is the backup plan if we have a breakdown?
- When executing the casting; is the progress realistic?
- What is the logical sequence of the casting?
- Do we have sufficient pipes and valves?
- What happens if a plug occurs?
- Is the concrete liable to fall freely through water? Is the proper amount of anti washout agent prescribed to tolerate deviations?
- Is the pumping equipment suitable for the job?
- What are the conditions for inspections?
- Do we have backup divers?

2.5 Placing / Casting methods

T-concrete can be cast in most ways, often reducing the need for costly and complicated rigs.

Both new constructions and repair works at smaller depths have been successfully carried out with a crane and skip. If the concrete should sustain a substantial free fall through water, it is advisable to prescribe maximum dosage of admixture (with Rescon T, up to 7,5 kg pr m^3), but just an introduction of a slope to reduce the direct free fall reduces the danger of washout dramatically.

For smaller works it is also possible to use buckets and simply pour the concrete into the form.

When executing larger works, and with larger sea depths, pumping of the concrete is normal. In contrast to traditional underwater casting, the necessity of a constant submerged pipe can be waived. Even with dosages as low as 4 - 5 kg pr m^3, the anti

washout effect is high enough to tolerate a casting pipe placed above the surface of the concrete.

When pumping T-concrete, it is essential to give the concrete time to flow slowly through the pipe. Trying to increase the speed only results in higher pumping pressure and a rising temperature in the hydraulic oil, and thus increased wear on the equipment. The high viscosity prevents fast pumping, so the only measures to be taken to increase rate of casting, are either to increase the diameter of the pipes (a minimum should be 4”) or to use more pumps.

2.6 Formwork consequences

T-concrete has extreme flowing abilities, ensuring that the form is completely filled without any additional compaction energy needed. The active flow is also followed by a penetrating quality that enables the T-concrete to find its way out through even apparently small holes. It is therefore paramount to ensure absolutely tight forms. Especially the transition zone between rock/ground and formwork is important. A leakage here can have serious consequences.

Because of the retarding effect of the anti washout agent, the formwork must be dimensioned to tolerate the loads of a fresh concrete pillar from bottom to top of the form. Again the zone between formwork and foundation is essential; a good anchoring either by bolting or by sand bags is absolutely necessary.

T-concrete is practically self-levelling if correctly designed and mixed; it is therefore not possible to obtain slanting surfaces without an overform.

2.7 Combination

It is possible to combine T-concrete and traditional underwater concrete in the same construction. If one can guarantee that the concrete is cast through a permanently submerged pipe, the start of the casting – that is when the concrete is most exposed to washing out – can be done with a concrete into which an anti washout agent is added. The amount of this “start” is relative to the possible exposure to water; leaner constructions with smaller cross-sections have reduced surfaces compared to massive constructions. The subsequent casting is continued with a pipe always submerged approximately 70 cm. The mix is then an ordinary well-designed underwater concrete

with the appropriate water to cement ratio. The initial T-concrete will function partly as a buffer with primary contact with water. The possibility of the normal concrete to be exposed to water cannot be ruled out, especially with complex forms and currents in the sea, but more often than not, this method has radically improved the final result.

2.8 Hardened concrete

For traditional underwater concrete, the reduced quality of the concrete that is in contact with water has resulted in a designed reduction of the effective cross-section of the construction. The outer 10 cm in leaner constructions cannot be considered as carrying loads. For massive constructions the outer 20 cm must be excluded. In accordance with the improved performance of concrete with anti washout agents, the Norwegian Concrete Association's Publication no. 5 (Guidelines for The Design and Construction of Underwater Concreting) has allowed the full cross-section to be accounted for as carrying loads. This makes for leaner constructions and a reduced quantity of concrete.

Also, exposed surfaces with traditional underwater concrete are normally very porous, often leaving larger depths with "concrete" with an extremely high water to cement ratio. With T-concrete, practical applications show none or only very thin layers with reduced quality, thus ensuring the high quality of the concrete cover which is so essential for the durability of concrete.

All concrete follow the "law" of slow starters: in the end the strength is higher than it is for the "false starters". The T-concrete is normally a slow starter; and the surroundings of underwater constructions can also be unfriendly in terms of temperature. On the other hand, underwater concrete has always sufficient water to ensure complete hydration of the cement. It is therefore not surprising that the development of strength measured in situ constructions, show a markedly growth after 28 days. The addition of silica also adds to this development.

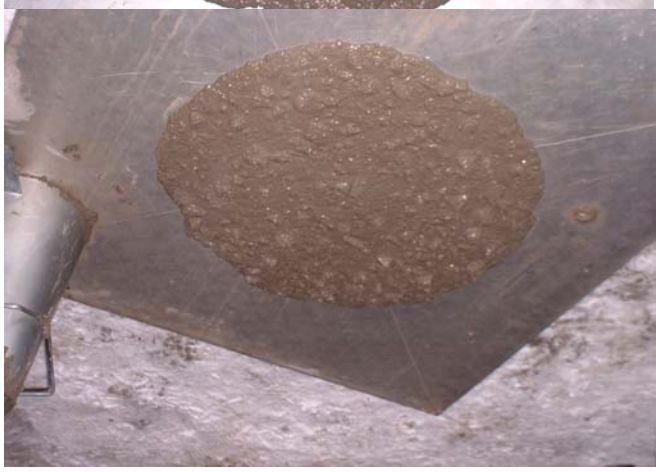
Concrete totally submerged in water, does not freeze, but in tidal zones, the cycles of freezing and thawing can deteriorate the concrete from within. T-concrete is not susceptible to air entraining agents, and is therefore not considered as frost resistant. Reports from tests made in Sweden do show T-concrete resisting high numbers of freezing-thawing cycles with a minimum of spalling. Nevertheless, the normal

procedure is to stop using T-concrete approximately 0.5 meters below the tidal zone and then continue the concreting with air entrained frost resistant concrete in the tidal zone and into the construction above sea level.

3. Concluding remarks

By using the admixture Rescon T it is now possible to avoid the unnecessary suspension normally connected with traditional underwater concrete. The concrete will be sound and safe and lasting for years and years.

But, as always, any admixture cannot and should not make knowledge and good craftmanship superfluous. And, if necessary, technical personel from Rescon Mapei will assist whenever Rescon T is used.



Methods of Repair

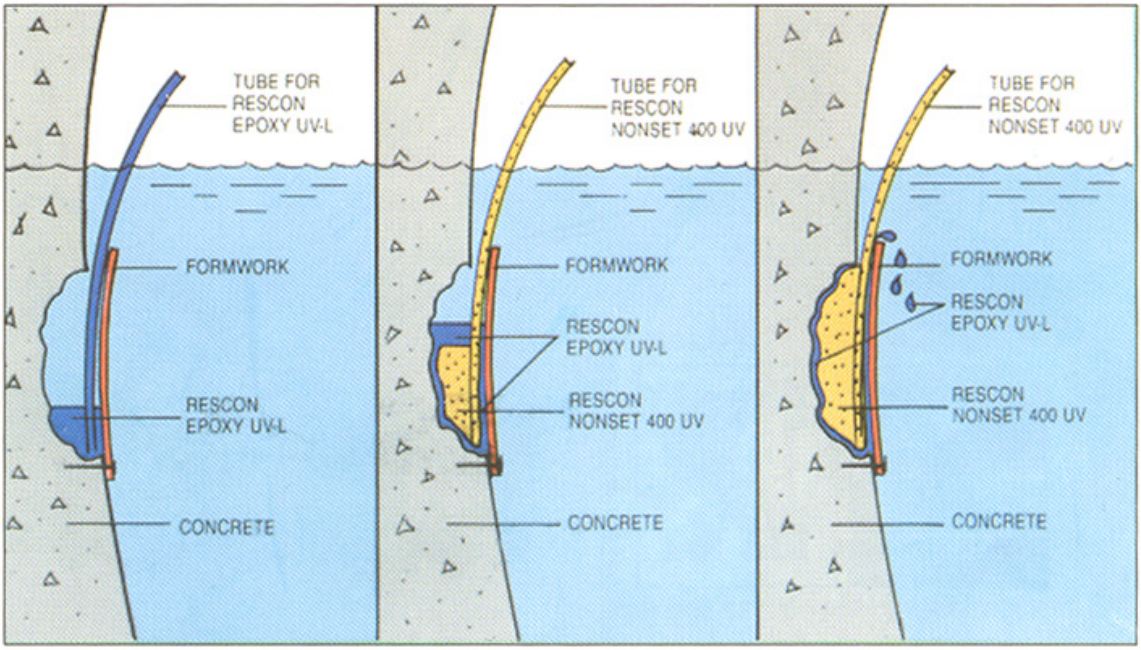
Cement and epoxy resin products have been used in underwater repair, but used alone both have drawbacks. For example, in contact with water, cement can be leached out from the repair grout, leaving a low strength product. Also, epoxy resin mortars are limited by high cost and mechanical properties, which differ substantially from those of concrete. The Rescon Method combines both repair materials and utilises their best properties. For example:

- The E-modulus and thermal coefficient of expansion of the cement grout is similar to that of concrete.
- The repair is more economic in material costs when compared to an equivalent volume of epoxy mortar
- Cement washout is eliminated by the epoxy resin in the Rescon Method
- The epoxy resin ensures good adhesion between the repair grout and the parent concrete (up to 2.5 MPa)

Procedure

- Remove the damaged or eroded area, leaving only sound material and prepare a suitable bonding surface using grit blasting or water jetting
- Construct shuttering using smooth, preferable transparent, sheets. Make tight at the base and side, using foam strips, mechanical fixing and underwater putty. The shuttering is positioned slanting away from the structure at the top to allow access for the hose down which the repair materials are pumped from the surface.
- The epoxy resin is mixed at the surface and pumped into the base of the mould to an approximate depth of 10-20 cm down the hose, which reaches into the lowest part of the mould (figure 1).
- Immediately, the epoxy is followed by an expanding cement grout, which displaces the epoxy resin from the base of the mould. This action coats the structure with epoxy improving the adhesion, coating the shuttering and ultimately giving a protective epoxy coating to the grout whilst maintaining a layer of epoxy on the surface of the rising grout, preventing cement leaching (figure 2and 3)
- When the epoxy and grout have finally cured (the increase in temperature of the curing cement also helps to cure the epoxy), strip the shuttering for reuse.

THE RESCON METHOD



The patented Rescon method is a well-known concept for repairing underwater structures. It has been used to vey good effect through the years to repair wharfs and bridges.