THE REVOLUTION AND ADVANTAGE OF CHEMICAL ADMIXTURE IN CONCRETE

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SUMMARY

"CONCRETE", a most widely used construction material, usually means a mixture of cement, aggregate, sand, and water. However concrete is more complicated than 15 years ago. The research on each raw material has made new concrete designs and applications possible, for example Slag cement and Fly-ash cement are produced because more Pozzolan materials have been used. Researchers changed their concrete study from traditional macroscopic discussions to microscopic investigations.

Concrete design has been more complicated in recent years because of new factors, for example: resource conservation ($CaCO_3$), waste recovering (Slag & Flyash), and durability increase. Concrete industry has put lots of efforts for researches of concrete durability improvements. It's been confirmed the necessary raw materials in concrete, Cement and Water, contribute major damages to the durability of concrete.

The nature of cement to cause concrete a number of problems: Hydration, Creeping, Shrinkage, Alkali-Aggregate-Reaction, etc. Although cement cannot be fully eliminated in the concrete, Pozzolans have been employed to lower cement consumption in the concrete. Many industrial by-products, e.g. Slag, Flyash, and Silica Fume are most popular Pozzolans used by concrete industry. Pozzolans offer strength by Pozzolan Reaction,which is different from the CHS gel strength by Portland Reaction, and change many characteristics of concrete. In addition, Pozzolans are no longer considered as environmental nuisance. There was a Chinese saying, "the boat is supported and capsized by Water". It's same situation happen to concrete. Water is needed to help concrete setting, but too much water also hurts concrete. Too much water causes too much Hydration heat, reduces concrete strength and conducts cracking problem. A Too much water also increases total capillary pores of the hardened concrete that conducts more serious permeability problems and reduces the durability of concrete.

Except those raw material parameters, construction procedures are also important impacts to concrete durability. It's often that concrete failure problem was not because of raw materials, but it's caused by construction procedures, e.g. too much water added in pumping, incorrect vibration, incorrect pouring process, etc. Many raw materials of concrete have been adopted for

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automatic operations to make the construction more efficient and more effective. Self-Compacting Concrete (S.C.C.) is an important application for this purpose.

Many kinds of High-performance Concrete (HPC) were also developed. For example:

(1) High Early Strength Concrete – Slump of 14~20cm; 24hrs strength achieves 4000psi; Steam is not needed
   (i) Super Retard Concrete – Retarding for 7~8 hours, 24 hrs strength is acceptable.
   (ii) Light Weight Concrete - The concrete weight is only 1,600kg/m^3 with acceptable strength
   (iii) Controlled Low Strength Concrete – 12 hrs Strength achieves 7kg/cm^2 and 28 days Strength is less than 90kg/cm^2
(2) Admixture" makes above varied concrete possible. It is like the magic potion in concrete. The admixture is one of the most important factors to accelerate Concrete evolution.

INTRODUCTION

Accompanying by sophistication for concrete, the revolution of chemical admixture had improved a lot. The chemical admixture we mention in this article was the most important factor for concrete. We also introduced the chemical knowledge principle and application of these 3 systems. Owing to the research and development of concrete should depend on chemical admixture. Therefore, more developed of chemical admixture will bring more powerful result for concrete development.

THE APPLICATION OF CONCRETE AND ADMIXTURE IN EACH STEP

Normal Concrete

In early stage, normal concrete is composed of water, cement, fine aggregate, sand, coarse aggregate and boulder. It can cast in any shape of container as a plastic viscosity. When water and cement finish chemical reaction, concrete will curing and harden by time. The strength for 28 days is about 1000-2000 psi, density is about 1950-2500 kg/m^3.

In early stage, the inside of concrete is full of void, this effect cause low durability, easy to rip by wind and low strength, usually not fit for modern high-rising building. The solution for this effect is to promote cement content for increasing strength and durability.
However, the high cement content will bring high cost and easy to produce cracking for high cement reaction heat.

Workability Concrete

The more research result of concrete show that the strength is proportional to concrete W/C . Moreover, the workability is also related to water content and aggregate proportion. Therefore,

we can limit W/C and S/A to control the strength and slump of concrete. However, the large scale using machinery for construction to save cost and time, therefore, we need good concrete workability to maintain longer time. For this purpose, scientist tries to improve concrete workability by using chemical admixture. The most popular admixture and still using today is LSA (Lignin sulfonate acid). It can retard the curing time, bring more workability, less water consumption, low down W/C and increase strength.

High Strength Concrete

The limitation of land in developed modern city cause high rising building and high rising viaduct. For efficient using of structure area, the huge demand of increase structure strength is necessary, consequently, the demand of high strength cement is naturally. However, the low W/C for high strength concrete can't achieve by LSA, therefore, the R&D of high efficient water reducing agent is developed. The major product can categorized by 4 group: sulfonated melamine-formaldehyde condensates; sulfonated naphthalene-formaldehyde condensates; modified lignosulfonated ; and others such as sulfonic-acid esters and carbohydrate esters.

The application of high efficient dispersing agent will bring a lot of benefit for society economy. This agent had huge water reducing function which can produce HSC with low W/C. We can save up to 10% W/C and achieve same workability and strength or we can produce high flow ability with same cement and water content.

High Performance Concrete

The most popular benefit of PNS is high water reduction and little effect for concrete curing time. But the defect is it will loss workability very fast and cause difficult in construction. Some area add twice to overcome slump loss problem but some time twice adding will cause over using of admixture. Therefore, many company add PNS into LAS try to keep both high efficient of water reduction and low slump loss benefit. For the time being, this kind of admixture can produce excellent quality concrete and using in whole world.

Along with the ability of admixture, the characteristics of concrete is diverse, for example, water tide concrete, high flow ability concrete, early strength concrete, water pouring concrete, shot concrete and a lot of different HPC had been developed.The natural limitation of admixture for LAS and PNS can't promote concrete performance to high level. However, PCA (ploycarboxylic acid)using very successful in HPC, the best evidence is self-compaction concrete.

Mineral Admixture Concrete

For research discover recently, the higher cement using in concrete, the lower durability for concrete. It will also cause cracking, Alkali-Aggregate-reaction. Therefore, the trade of using low cement and mineral admixture is popular. This procedure can environment protection and energy saving.

Before 1960s, many research find out that the mixture will cause naturalization in concrete and bring poor durability. The reason is the poor technical of mineral production will cause low durability of concrete when we add admixture into high W/C content concrete. After 1970s, owing to the improvement of technology, the vase research result show that W/C is the key factor for durability. If we use high efficient water reduction agent and good mineral

admixture can good workability concrete, the mineral admixture can bring more pozzolan CSH gel and block void, improve the anti-rust ability for rebar. Therefore, the high efficient water reduction and good quality of mineral admixture cause save energy and fit green earth environment protection low down cement cost, improve workability, eliminate breeding, diverse, lower water reaction heat and decrease the possibility of shrinkage cracking happen.

High Fluidity Concrete

Due to the slump for normal concrete(8-18cm) can't satisfy the demand of the modern building, more and more admixture can increase slump reach 20-26 cm and flow like water. The flow mobilized agent is different than normal agent. The high disperse for cement molecule can ensure solid particle don't slag together.

In this case, it can pump without compaction and get the benefit of save energy, save man power and low down noise.The normal concrete placing need large scale of compaction, honey cone will happen if the compaction is not enough. However, the partial over compaction will cause aggregate sink and breeding. When the uncertainty of the construction increase, the unreliable of strength also increase. This cause the different of real capacity than design in element. For ensure the safety of structure, we have to increase design value and design capacity. This cause the cost of construction increase. Therefore, the quality and uncertainty of concrete is the crucial for all construction project.

The compaction of high slump concrete is based on appropriate ration design , adjustment and using of chemical admixture to reach this capacity, ratio should be appropriate adjust to reach balance between flow ability and viscosity. The main purpose is don't get diverse and breeding while under very high flow ability. Meantime, the aggregate distance can self-adjust without compaction and keep homogenous of material.

The quality audit of normal concrete is based on concrete compression test; however, the whole construction quality can't depend on a few sample test. Moreover, if these sample fail in test, it is very difficult to remedy the whole structure, nevertheless, this is the natural limitation of concrete.

The biggest benefit of high flow ability concrete is can reach any corner of rebar and firm fit to reach good embed bonding. Any qualify high slump concrete can self-compact to any corner of formwork and rebar without consider any defect come form poor compaction. Moreover, the qualify of high slump concrete is easy to test before construction to prevent any remedy procedure.

When we add high efficient water reduction agent, the bio-molecule long bond is suction stage on the cement particle surface. Different suction stage is based on different water reduction agent. It direct affect the oxygen value for slump change when we add this kind of agent. Traditional Naphthalene water reduction is bad bond. Because of flat suction, the static exclusion is weak, this result the electrical potential drop very fast and static bawlance had been destroy by this procedure. The result is slump drop too fast and water transport is poor owing to water reduction agent's exclusion. If concrete need high air content we should add air mixture to reach this construction demand.

The suction stage on the cement particle surface for Polycarboxylic Acid is crown type, this kind of water reduction agent not only have good dispersing for cement particle but also can

keep slump stable. The one of the reasons is this kind of poly-molecule had a lot of carboxylic and it can obstacle the static aggregation. The second reason is the long bond for tree type poly-molecule gradual break out and release a lot of carboxylic and repeat the form procedure. The third reason is the value of the electrical potential for poly-molecule is lower than Naphthalene serial water reduction agent.

Therefore, the charge amount to get the same dispersing stage is lower, in other word, when the amount of agent is same, PCA had better dispersing effect. Moreover, because PCA had better dispersing and air transport effect than PNS, therefore, PCA had better performance than PNS in air transport. If concrete need low air content, we should add air reduction agent to reach this construction demand.

The most popular using of high slump concrete is Type I cement. However, owing to PCA had very good dispersing effect and it can low down the cement usage in concrete. We can low down cost and water reaction hear by using mineral admixture.

THREE MAJOR ADMIXTURE TYPES

There were so many chemicals tried over last 20-30 years to develop new admixtures. There are only three types have been massive employed to date:

(i) Lignin sulfonate acid
(ii) Naphthalene sulfonate acid (PNS)
(iii) Polycarboxylic acid (PCA)

Please refer to Fig. 6, Fig.7., Fig.8

A,B,C stand for different chemical groups that produce diverse effects in concretes. All of the PCA manufacturers developed their own PCA with different A,B,C materials for concrete demands. In the meantime, they must control another important factor: COST.

WATER REDUCTIO THEORY OF ADMIXTURE

Admixtures actually act as “dispersing agent” in concretes. They perfectly disperse cementing materials to create great concrete workability without surplus water, which reduces the water/cement ratio (w/c ratio).

In accordance to the chemical structures of above three admixture types (I, II, III), we understand both of Lignin sulfonate acid & Naphthalene Sulfonate Acid (I &II) mainly use SO_3^- functional group for dispersing. Although they only have a two-dimensional dispersion effect, both types, especially Naphthalene sulfonate acid, have good water reduction effect due to the strong polarity of SO_3^- groups.

However Polycarboxylic acid (PCA) is different. PCA has a three-dimensional structure.

Not only SO_3^- groups on the main chain for dispersing, but also the side chains contribute to increase dispersion effects because of the steric repulsive force. Many high performance concretes have been developed result from PCA because its special structure performs much better characteristics on water reduction, workability and slump loss control. Please refer to Fig. 9 & Fig.10

Case Reference

To feel the importance of the breakthroughs to above characteristics, we need a few examples to study the different mix designs and to understand the consequence.

(1)SCC is one of perfect workability goal concrete, it should fit as followings:
(i) Slump flow:55-70 cm, maintain for 1.5 hr
(ii) No breeding
(iii) Pass V type test
(iv) Pass U type test
Please refer to Fig. 11, Fig.12., Fig.13

From the sample take form Taiwan subway 100 cubic metric test (Please refer to table 1), we found out for satisfy concrete characteristics ,water reduction of this agent should satisfy not lower than 23% and flow ability should maintain longer than 2 hours. That is the unique from other chemical agent and that is the reason shy SCC is popular all world wide today and everybody is discussion.

(2)Low water content, high density and good work ability concrete

As the matter of fact, for low water content, high density and good workability concrete in other word is good durability concrete. However, owing to the discussion of the good durability is too wide and we can't cover by low water content and high density. The reason we discuss about good work ability concrete (slump=18-20 cm) is there were some case for (slump=8-12 cm) problem. As matter of fact that, the problem is slump too small. First of all, put water in pump can cause diverse for concrete. Secondly, honey cone will happen when concrete harden. For more control factor to reach concrete durability for more easy to control this goal.

The reason we mention low water content, high density is for protect rebar. In other word, to protect the integrity of whole structure. If there is only very small void in concrete, it can block the rebar to contact air; consequently, bring no rebar rust problem and more good durability for concrete.

Table 2 is the ratio for 100 years assurance in column using in Taiwan High Speed Rail project. The original demand is total gel should lower than 345 kg/m3, slag no bigger than 25%, flyash lower than10%, cement alkali-content lower than 0.6%, W/C smaller than 0.5, slump maintain over 3 hours. That prove the goal of Taiwan High Speed Rail project is low water content and high density for concrete.

Table 3 is the ratio for public construction for Taiwan public work. We can easy to find out that Table 3 is 30 kg/m3 more than Table 2. You can image the void made from this extra water when it vaporized. It is far from high density concrete. Therefore, the idea of the low water content bring low cement content and low water reaction heat . At last, the age of the

different mineral admixture concrete is coming.

(3) Controlled Low Strength Material(CLSM)

As matter of fact, CLSM is low strength, early curing and flow ability concrete, it should fit as followings:

(i) it can reach 7 kg/cm2 after 12 hours
(ii) flow ability reach 50 cm
(iii) 28 days' strength lower than 90 kg/ cm2
(iv) coarse aggregate small than 400 kg/m3
(v) unit weight range from 1800-2000 kg/m3

The main purpose of this concrete is try to overcome the problem of the pipe fill-back compaction and can fit about easy to chip out. Table 4 can easy to confused by a lot of functions conflict concrete design. The chemical admixture already had a very significant advantage in today's concrete business.

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Table 1 Taiwan subway 100 cubic metric concrete mix design

Concrete Class	Cement	Slag	Flyash	S.P.	W/C	S/A
(psi)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(%)	(%)
5000	230	110	110	6	36	53

Table 2 Taiwan High Speed Rail project. concrete mix design

Concrete Class	Cement	Slag	Water	S.P.	W/C	Slump
(psi)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(%)	(%)	(cm)
4000	230	115	170	0.9	50	15

Table 3 Taiwan public work's concrete mix design

Concrete Class	Cement	Slag	Water	W/C	Slump
(psi)	(kg/m^3)	(kg/m^3)	(kg/m^3)	(%)	(cm)
4000	400	0	200	50	8~12

Table 4 CLSM Mix design

CLSM	Cement	W/C	Accelerating Admixture	Air-entrained Admixture	Flow
	(kg/m^3)	(%)	(%)	(%)	(cm)
4000	170	60	3	1	50

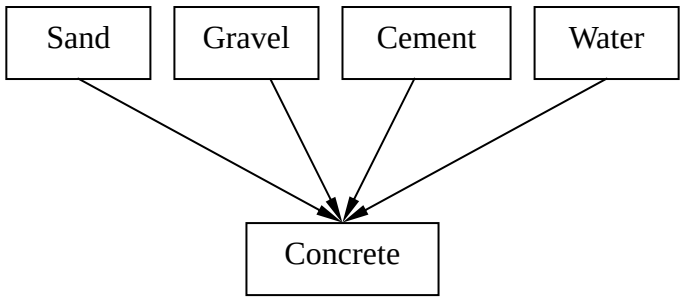

Figure 1 Normal Concrete

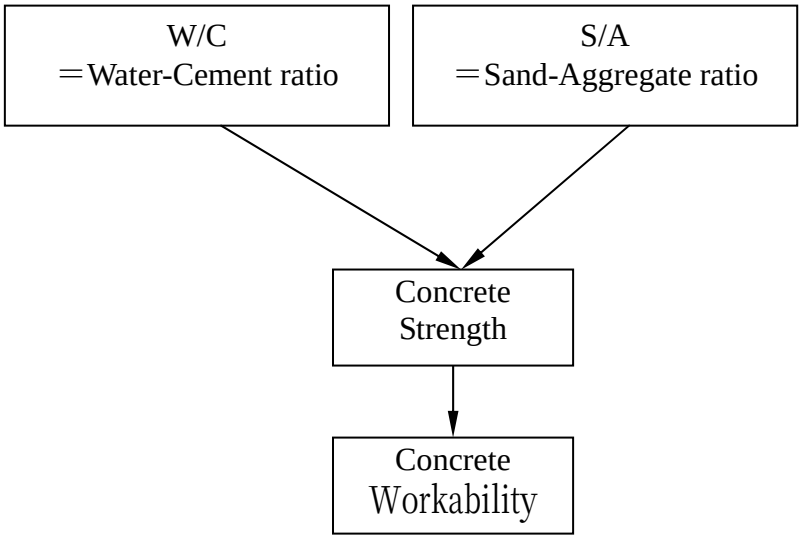

Figure 2　Workability Concrete

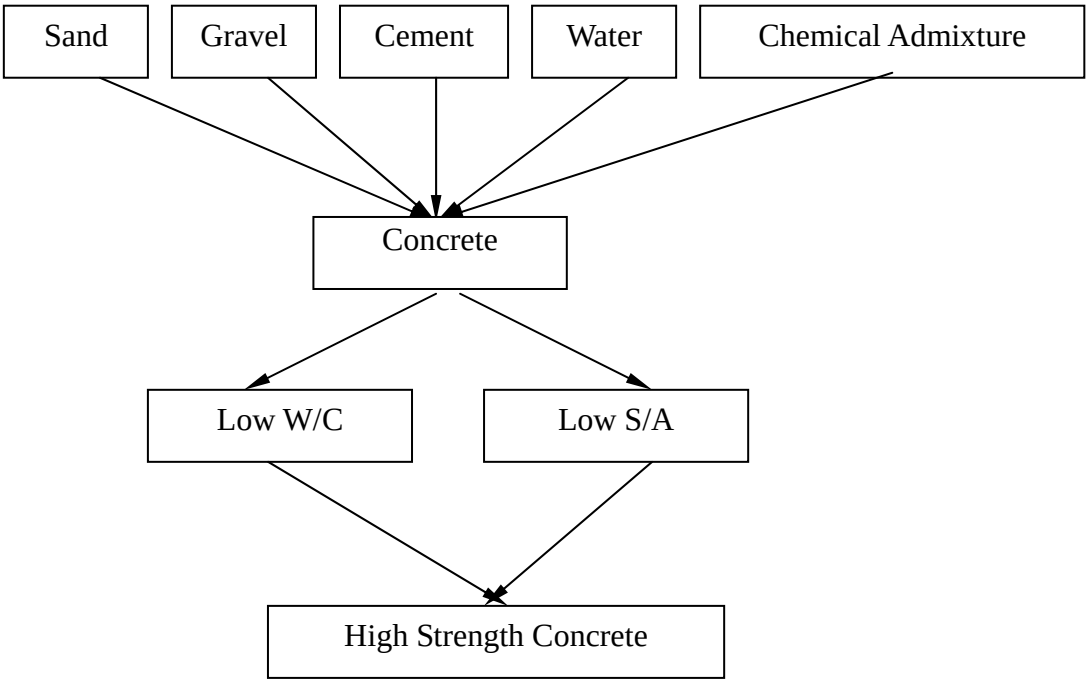

Figure 3　High Strength Concrete

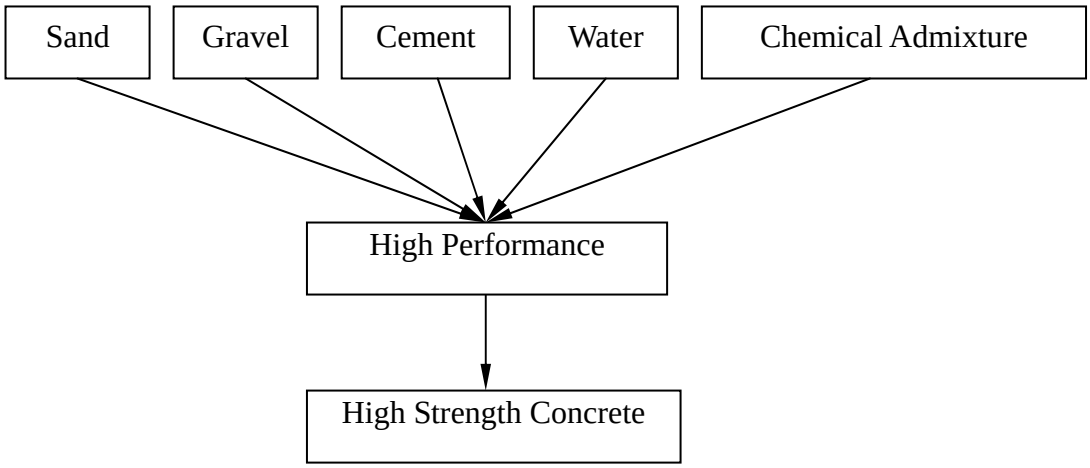

Figure 4 High Performance Concrete

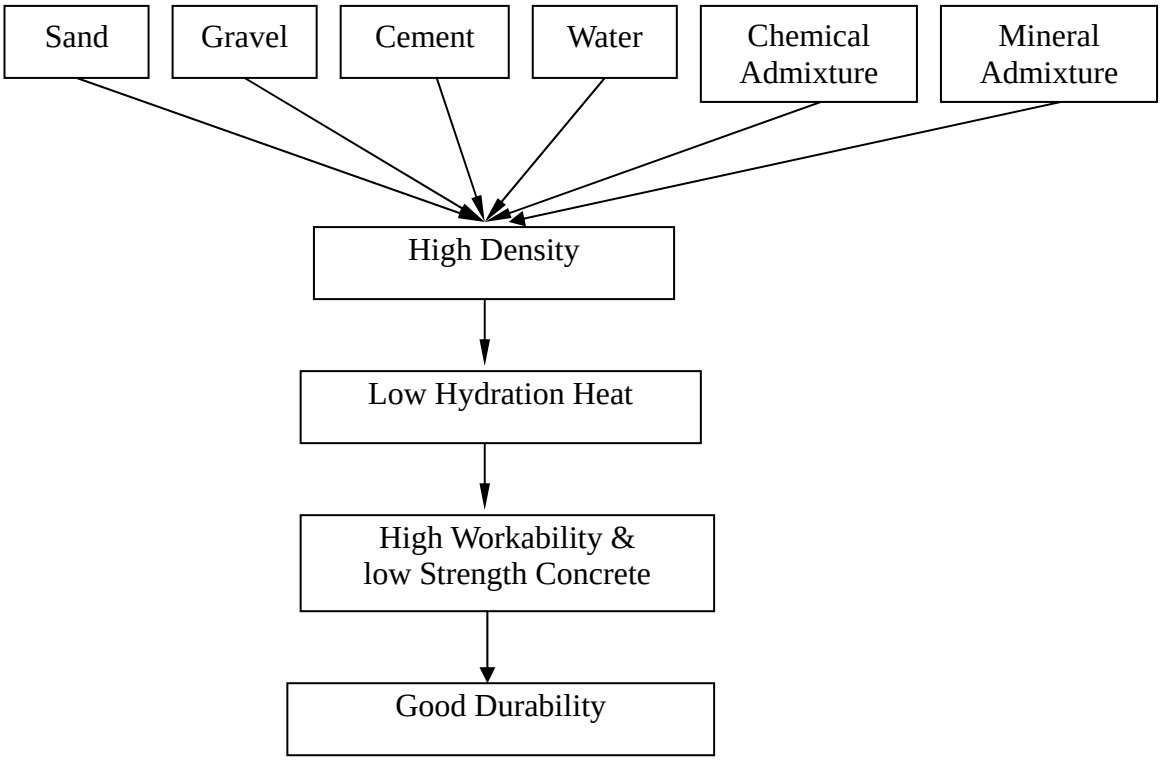

Figure 5 High Fluidity Concrete

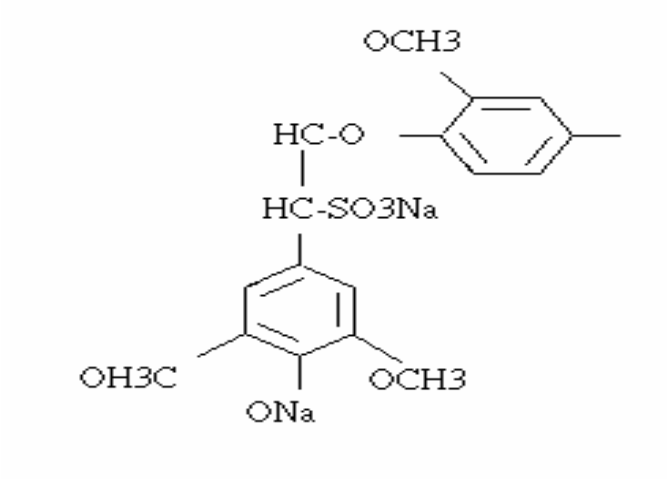

Figure 6 Lignin sulfonate acid

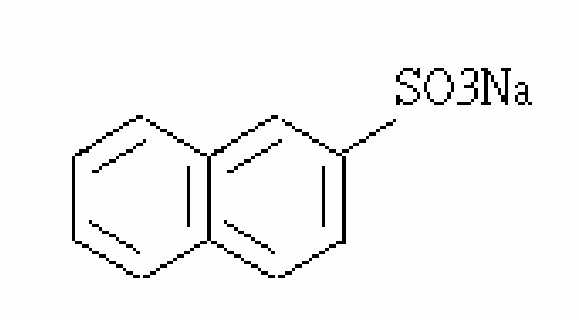

Figure Naphthalene sulfonate acid (PNS)

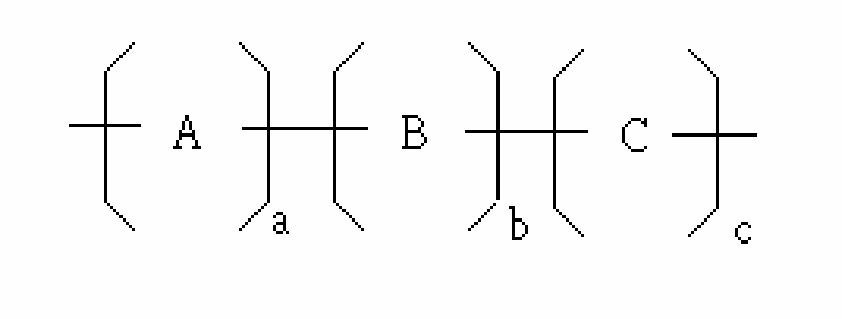

Figure 8 Polycarboxylic acid (PCA)

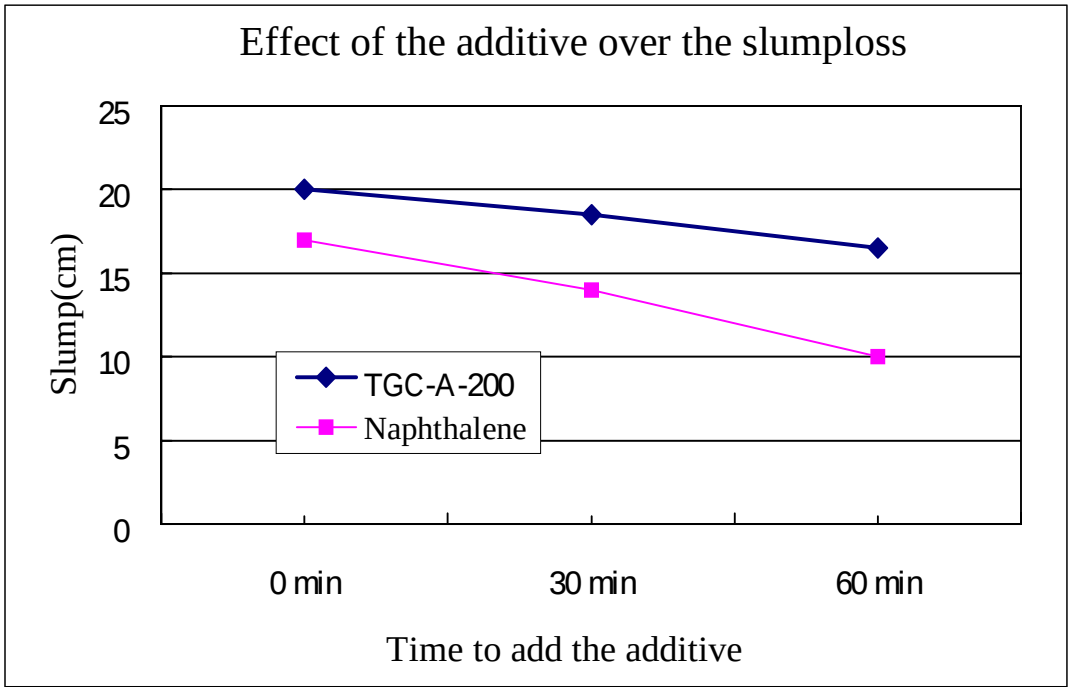

Figure 9 Effect of the additive over the slumploss

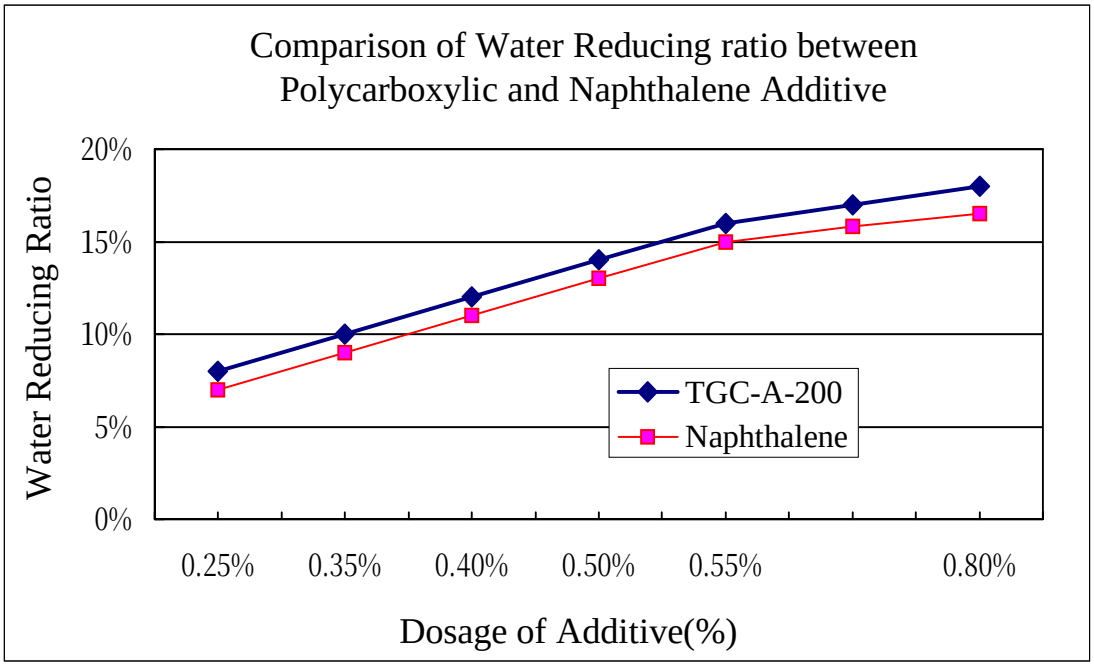

Figure 10 Comparison of Water Reducing ratio between Polycarboxylic and Naphthalene Additive

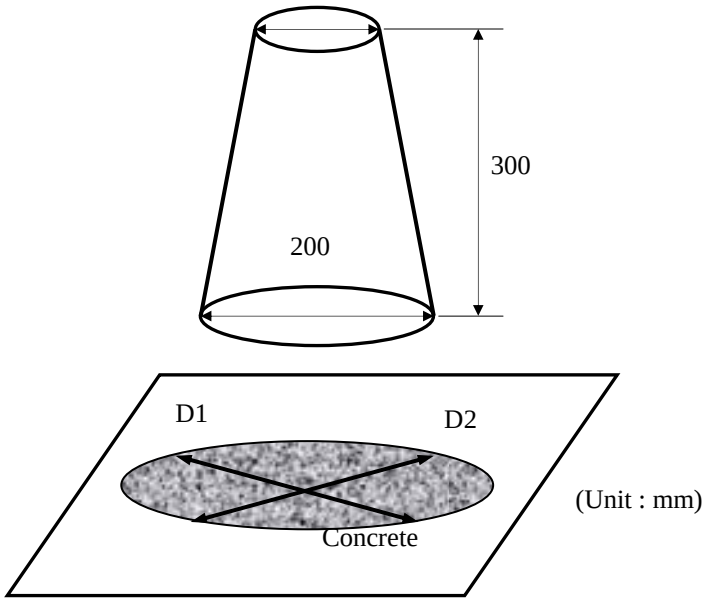

Figure 11 Slump flow test

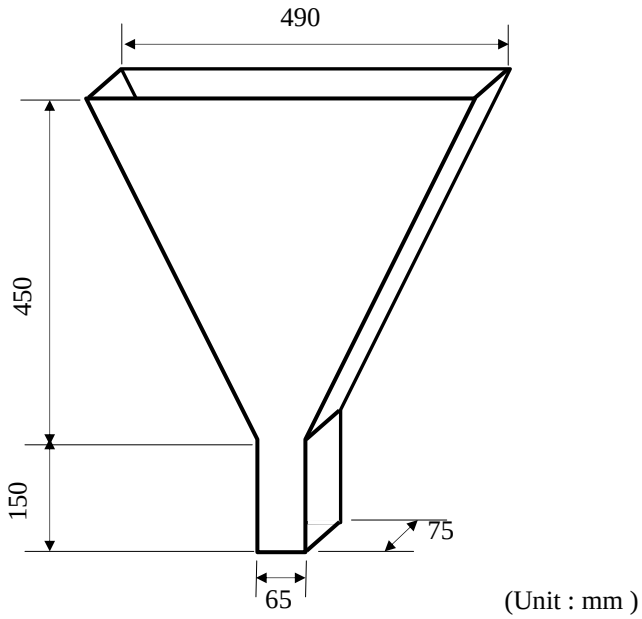

Figure 12 Pass V type test

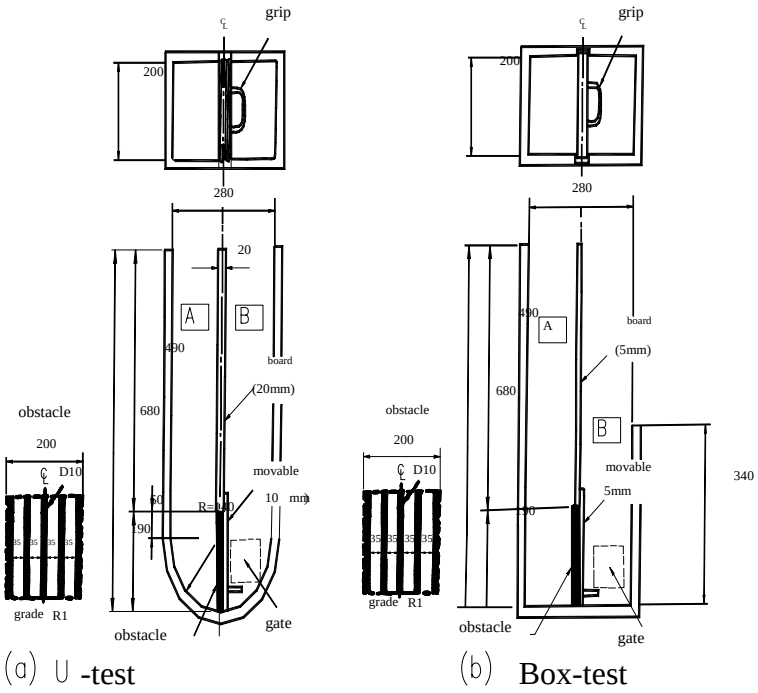

Figure 13 Pass U type test