



## HIGH EARLY STRENGTH OF CONCRETE PROPERTIES

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### ABSTRACT

High early strength concrete is one of the type in high performance concrete. A high early strength concrete means that the compressive strength of the concrete at the first 24 hours after site-pouring could achieve structural concrete quality (compressive strength > 21 MPa). There are 4 (four) important factors that must be considered in the making process, those factors including: portland cement type, cement content, water to cement ratio, and admixture. In accordance with its high performance, the production cost is estimated to be 25 to 30% higher than conventional concrete. One effort to cut the production cost is to utilize local materials. This paper will also explain about the local materials which were abundantly available, cheap, and located in strategic coast area of East Java Province, that is: Gresik, Tuban and Bojonegoro city. In addition, the application of this study is not limited only to a large building project, but also for a small scale building which has one to three-story. The performance of this concrete was apparently able to achieve the quality of compressive strength of 27 MPa at the age of 24 hours, which qualified enough to support building structurally

### INTRODUCTION

High early strength concrete was created to solve the setting time problems that occur in the world of buildings and infrastructures construction. Generally, it takes 7 to 14 days to achieve the full concrete hardening and reach the minimum compressive strength of 0.7 to 0.85 fc'. This setting time generated on concrete was generally not fast enough to achieve the minimum quality required. This circumstances might concern public on cost production, time spent and efficiency [8]. To solve this problem, some research on concrete technology were conducted to produce high strength concrete in early age with several approach, such as: use several types of cement (type I cement, type III cement, rapid set cement); high cement content (410 to 740 kg/m<sup>3</sup>); use several types of admixture (calcium chloride and polycarboxylate ether-PCE); low water to cement ratio (0.2 to 0.4). Thus, the result of compressive strength may reach 39 to 66 MPa at 24 hours [1,2,3,8]. In accordance with its high performance, the production cost is estimated to be 25 to 30% higher than conventional concrete. One effort to cut the production cost is to utilize local materials. With these innovations, the cost of making high early strength concrete can be cheaper, so people do not have to worry about spending a lot of of 1234567890 ICASIE IOP Publishing IOP Conf. Series: Materials Science and Engineering 267 (2017) 012004 doi:10.1088/1757-899X/267 money to buy it. Then, another benefit is to improve the community economy around the area of materials resources .

## 2. DEFINITION

High early strength concrete is one of the type in high performance concrete. A high early strength concrete means that the compressive strength of the concrete at the first 24 hours after site-pouring

could achieve structural concrete quality (compressive strength > 21 MPa) [4]. Furthermore, high early strength concrete is a concrete that is capable of reaching 50%  $f_c'$  at 24 hours of age, with water to cement ratio ranging from 0.3 to 0.4 [1].

3. Previous research on high early strength concrete

The following are brief data from some previous research:

3.1 High Early Strength Concrete by Strategic Highway Research Program (1993) In 1993, Strategic Highway Research Program provided some data on material specifications, mix designs, and mechanical properties from 4 (four) different regions origin of concrete aggregates in America: Crushed Granite (CG), Marina Marl (MM), Rounded Gravel (RG), and Dense Crushed Limestone (DL) [1]. Its composition and strength properties are presented in the (Tab.1) below:

Table 1. High Early Strength Concrete Mix Designs by Strategic Highway Research Program [1].

Materials	CG Lilington	MM Lilington	RG Memphis	DL Van Buren
Type III Cement (Kg/m <sup>3</sup> )	522	522	522	522
Coarse Aggregate (Kg/m <sup>3</sup> )	1032	942	990	1008
Fine Aggregate (Kg/m <sup>3</sup> )	576	588	540	618
W/C Ratio	0.32	0.32	0.34	0.34
HRWR (Naphtalene Based) (mL/100 Kg) cementitious materials	26	26	26	16
Calcium Nitrite (gr/m <sup>3</sup> )	2.4	2.4	2.4	2.4
Air Entraining Agent (mL/100 Kg) cementitious materials	9	1	1	4
Slump (cm)	2.54	17.2	17.8	7.7
Compressive strength-1day (MPa)	37	38.7	39	36.5

3.2 High Early Strength Concrete by Federal Highway Administration (2001) In 2001, Federal highway administration has conducted various experiments in making high early strength concrete with several types of mix designs [2]. Its composition and other information are presented in the (Tab.2) below: Table 2. High Early Strength Concrete Mix Designs by Federal Highway Administration [2].

Materials	Type I (GADOT)	Type III (Fast Track I)	Type III (Fast Track II)	RSPC	Rapid
Set Cement					
Cement (Kg/m <sup>3</sup> )	450	400	450	350	400

Fly ash (Kg/m <sup>3</sup> )	-	45	50	-	-
Coarse Aggregate (Kg/m <sup>3</sup> )	1070	830	780	1010	1070
Fine Aggregate (Kg/m <sup>3</sup> )	610	810	780	830	600
W/C Ratio	0.4	0.4-0.48	0.4-0.48	0.41	0.45
Water Reducer	-	Use	Use	-	-
Air Entraining Agent	6 ±2%				

• **Factors to be considered in making high early strength concrete**

From some of the studies described in the previous chapter, there are several factors that influence the high initial strength mechanisms in concrete:

4.1 Types of Portland Cement

The following are some types of portland cement commonly used in making high early strength concrete:

4.1.1 Portland cement type III

This type of portland cement quickly hardened, commonly used in the application of concrete structures that require high initial strength and also concretion at low temperatures. The mechanism in the cement which can accelerate the hydration process, followed by acceleration of hardening and strength development are: C3S and C3A content of a higher portland cement type I, and also the finess value with the blaine tool which is higher than portland cement type I [1,2]. The following are some of compressive strength results on high early strength concrete in previous research that used portland cement type III:

Table 3. Compressive strength and the age test of highearly strength concrete using portland cement type III

Researcher	Compressive strength	Age
SHRP 1993	36.5 MPa – 39 MPa	24 hours
FHWA 2001	Min. 13.5 MPa	24 hours

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• **Portland cement type I (Ordinary Portland Cement)**

This type of cement is a hydraulic cement. It widely used for general construction, such as building construction that do not require special requirements for: sulphate resistance, hydration heat, and high initial strength [2,3]. The following are the compressive strength results on high early strength concrete in previous research that used portland cement type I: Table 5. Compressive strength and the age test of high early strength concrete using portland cement type I [2,3].

Researcher	Compressive strength	Age
FHWA 2001	Min. 13.5 MPa	4 hours

Research of Product	18.35 MPa – 25.56	8 hours
Application Department	59.37 MPa – 66.39 MPa	24 hours

PT. Semen Indonesia

**• Rapid Set Cement (RSC)**

This type is a type of hydraulic cement or hydraulic blend cement that has a rapid strength advantage over the first 24 hours during the hydration process. The cement has been simultaneously milled specifically with non-chloride accelerator materials, so it is safe for reinforced concrete structures. This type has a very fast final setting time of 15 to 35 minute, and can achieve structural strength within 1 hour. In its application, rapid set cement is used for: improvement and creation of structural elements. The concrete price is more expensive than other type of cement [2]. The following are some of compressive strength results on high early strength concrete in previous research that use rapid set cement:

Compressive strength and the age test of high early strength concrete using rapid set cement [2].

Researcher	Compressive strength	Age
FHWA 2001 Min.	13,5 MPa	4 to 6 hours

**• Cement Content**

Each concrete grade has different cement content levels. The following are the cluster of cement content based on it levels and applications:

Several type of content cement based on levels and applications [5].

Content cement (Kg/m <sup>3</sup> )	Levels	Application
200 – 400	Medium cement content	Normal concrete
> 400 – 600	High cement content	High strength concrete
> 600	Very high Cement Content	Very high strength concrete

According to above, it can be seen that in the manufacture of high strength concrete, the cement content used ranges from 400 Kg/m<sup>3</sup> to 600 Kg/m<sup>3</sup>. For very high strength concrete, it used more than 600 Kg/m<sup>3</sup>. But, in application of high strength concrete in field, high and very high strength concrete do not use more than 600 Kg/m<sup>3</sup> of cement content. The following table is previous research data of cement content that used in high strength concrete, very high strength concrete and high early strength concrete:

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**Water to Cement Ratio**

By reducing the water to cement ratio, it reduces the volume of the air cavity and increases the density of the concrete. This transformation contributes significantly to the strength and durability of the concrete [5]. The following table is classifications of water to cement ratio levels and several results from the concrete.

Classifications of water to cement ratio [5].

Water to cement ratio	Classification
> 0.45	Conventional Concrete

0.45 – 0.30  
< 0.3

High Strength Concrete  
Very High Strength Concrete

- **Classifications of water to cement ratio of high early strength concrete in several past research .**

Researcher	Water to cement ratio	Classification
SHRP 1993	0.32	High Strength
FHWA 2001	0.40	High Strength
Research of Product Application Department PT. Semen Indonesia 2015	0.20	Very High Strength

According to above, the water to cement ratio used in ranges 0.2 to 0.4 (high to very high strength classification).

- **Types of Admixtures**

In high early strength concrete manufacturing, there are several types of admixture used for different purposes: accelerating and water reducing admixture and high range water reducing admixture. The following table is several types of chemical admixture that used in making high early strength concrete:

**Typical of chemical admixture in making high early strength concrete.**

Admixture types	Function	Based on	Type
Accelerating	1. Accelerate cement hydration process	Calcium Chloride	E (1st Generation)
Admixture and Water Reducing	2. Reducing water content by 5 to 10%.	Sodium Sulphate Aluminum Sulphate Calcium Nitrite Ligno Sulphonate	
High Range Water Reducing	1. Accelerate cement hydration process.	Gluconate Naphtalene	F (2 <sup>nd</sup> Generation)
	2. Reducing water content by 20% (generation 2)	Sulphonate Melamine	

3. Reducing water content Vinyl Copolymers F(3<sup>rd</sup> Generation)  
by 40%

(generation

### **High early strength concrete using local materials**

In some areas in northern coast (Pantura) of east java province, namely: Tuban, Bojonegoro, and Gresik proved to have a potential source of high early strength concrete materials. These materials are: kethak (calcite) stone in Merakurak-Tuban and Ujung Pangkah-Gresik, then Bengawan Solo river sand in Bojonegoro. With the formation of the strategic material source location, the concrete can be implemented. In 2016, Institut Teknologi Sepuluh Nopember (ITS) and PT. Semen Indonesia has conducted research on high early strength concrete with utilizing the local materials [8]. The following

table is brief several specifications of the material and the performance of the concrete:

5.1 Specification of "kethak" (calcite) stone and Bengawan Solo river sand

### **CONCLUSIONS**

From some of the explanations in this paper, we can get a conclusion:

- a) High early strength concrete was created to solve the setting time problems that occur in the world of buildings and infrastructures construction. Generally, it takes 7 to 14 days to achieve the full concrete hardening and reach the minimum compressive strength of 0.7 to 0.85 fc'. High early strength concrete means that the compressive strength of the concrete at the first 24 hours after site-pouring could achieve structural concrete quality (compressive strength > 21 MPa)
- b) There are 4 (four) important factors that must be considered, those factors including: portland cement type, cement content, water to cement ratio, and admixture type.
- c) The performance of high early strength concrete with local materials (kethak or calcite stone from Merakurak-Tuban and Ujung Pangkah-Gresik, then Bengawan Solo river sand from Bojonegoro) was apparently able to achieve the quality of compressive strength of 27MPa at the age of 24 hours, which qualified enough for the structural compressive strength > 210 MPa.

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