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# Analysis on Fire Resistance Performance of New Chemical Bar-planting Concrete Anchorage Connection

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This paper gives a contrastive analysis on high temperature fire resistance performance of organic and inorganic adhesive bar-planting concrete, and researches the influence of different anchorage depth and bar-planting adhesive on mechanical performance of chemical planting bar of concrete with laboratory test method. The research conclusions indicate that component surface shows plenty of water vapor during high temperature heating of organic and inorganic adhesive concretes. During high temperature heating of organic adhesive concrete specimen, concrete shows peeling, steel bar shows slipping failure, and cohesive force reduces obviously; during inorganic adhesive concrete test, deflection of planting bar increases gradually, concrete also shows peeling, while steel bar shows no slipping failure. When the external fire temperature is the same, temperature of steel bar beam is basically the same at different measuring points in the same section, and temperature of different section shall increase gradually along with increment of heating time. Regardless of organic adhesive or inorganic adhesive concrete, the shallower the bar planting is, the earlier the time of showing cracking and slipping failure is, and the weaker the ductility is. Organic adhesive concrete shows greater deformation in high temperature, and specimen shows brittle failure finally after suffering tensile stress and compressive stress repeatedly; strength of inorganic adhesive concrete decreases after suffering high temperature effect, and cohesive action of inorganic adhesive declines, while inorganic adhesive does not lose effect fully. When adopting chemical bar-planting anchorage technology, one shall increase anchorage depth in high temperature environment, to promote safety stock of concrete.

## 1. Introduction

Chemical bar-planting method of concrete is also known as post-anchorage technology, and it is the method of drilling in concrete poured, inserting in steel bar, and bonding the two with bar-planting adhesive. In engineering, chemical bar-planting technology is usually used in connecting the newly increased building components with original concrete structure, and it is also used in transformation of old building. Chemical bar-planting method has such advantages as simple construction, false design, low cost and high safety (Pinoteau et al., 2011; Eligehausen et al., 2006; Epackachi et al., 2015; Upadhyaya and Kumar, 2015).
Presently, the domestic and overseas researchers have given more analyses to mechanical characteristics of chemical bar-planting method in normal temperature (Han et al., 2003; Kodur et al., 2008; Tan et al., 2004; Subramanian and Cook, 2002), and it states that curing temperature of chemical bar planting is -5°C-40°C in normal temperature and the operating temperature is less than 65°C. However, seldom research is given to the change of various indicators of the concrete after bar planting in such harsh environment as high temperature and fire hazard (Cook 1995; Gesoğlu et al., 2014; Silva and Biscaia, 2011). Actually, caking property and slipping property of concrete shall all show obvious change when adopting chemical bar-planting method in high temperature environment (Barnaf et al., 2012).
Bar-planting adhesive is an important component of chemical bar-planting method, and it is mainly composed of such chemical materials as synthetic resin and chemical compound. The traditional bar-planting adhesive is organic adhesive as ordinary, and it may lose effect in high temperature environment. Inorganic adhesive is a new bar-planting adhesive, and it has high temperature resistance property. However, being as chemical bar-

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planting bonding agent, mechanical mechanism of the inorganic adhesive in high temperature shall be researched and analyzed further (Güneyisi et al., 2016; Mutsumi et al., 2016; Yilmaz et al., 2013; Speare et al., 1996).
This paper gives contrastive analysis to fire resistance performance of organic adhesive and inorganic adhesive bar-planting concretes in high temperature, adopts laboratory test method, and researches influence of different anchorage depth and bar-planting adhesive on mechanical performance of chemical planting bar of concrete.

## 2. Chemical bar-planting test program of inorganic adhesive

The traditional chemical planting bar of concrete adopts organic bar-planting adhesive as ordinary, and bearing capacity of planting bar and connection performance of concrete can be ensure in normal temperature. However, in fire hazard or under exposure in high temperature, cohesive force of organic adhesive shall be wear off, and then bearing capacity of planting bar shall decline. As indicated by researches, organic adhesive shall lose effect in the environment with temperature above 200°C. Thus, chemical bar-planting method of inorganic adhesive is used in replacing the traditional organic adhesive in this paper. Main component of inorganic adhesive is improved silicate which possesses favorable high temperature resistance performance. Research shall be given to bonding and anchorage of the inorganic adhesive to concrete for being as chemical bar-planting adhesive.
Figure 1 refers to conditions of reinforcement and concreting of specimen making. Stirrup is HPB235, strength of the concrete poured is C30, and standard test block of concreting shall be given static force test simultaneously, and curing shall be given to specimen and test block for 28d in the same environment.

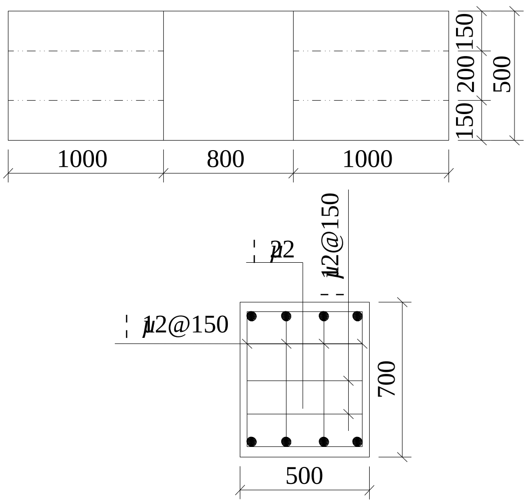


*Figure 1: Basic parameters of specimen*

There are two bar-planting beams contained in specimen. To verify high temperature resistance performance of the inorganic adhesive planting bar, specimen shall be divided into the two groups of organic adhesive planting bar and inorganic adhesive planting bar. Table 1 shows relevant parameters of the two groups, and d refers to embedded depth.

*Table 1: Embedded depth and anchoring adhesive type of specimens*

| Specimen | Embedded depth | Type | Beam number |
|---|---|---|---|
| O-15d | 15d | Organic adhesive | B1, B2 |
| O-20d | 20d | Organic adhesive | B3, B4 |
| O-30d | 30d | Organic adhesive | B5, B6 |
| I-15d | 15d | Inorganic adhesive | B7, B8 |
| I-20d | 20d | Inorganic adhesive | B9, B10 |
| I-30d | 30d | Inorganic adhesive | B11, B12 |

Figure 2 is schematic diagram of weight loading program of inorganic adhesive panting bar specimen. Weight loading can reduce the phenomena of greater deflection and early unloading of the bar-planting beam caused by fire hazard, and can strengthen stability of vertical load. Load is set as 65% of the ultimate load.

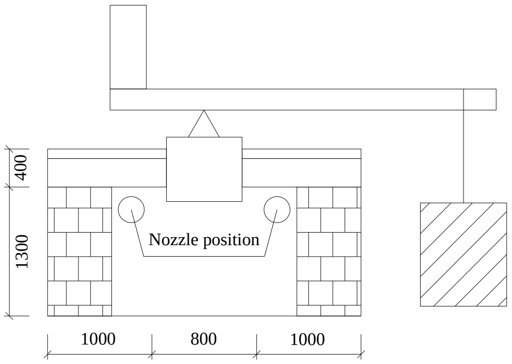


*Figure 2: Schematic arrangement of weight drop loading*

Temperature shall rise gradually in test process, and extent of temperature rising shall be calculated by adopting Formula 1:

$$T = 345\lg(8t+1) + T_0 \tag{1}$$

t refers to total test time; $T_0$ and $T$ refer to furnace temperatures in beginning and at ending of test.
There are several thermal monitors installed in furnace, to record temperature change curves of inorganic adhesive planting bar and organic adhesive planting bar in the whole test process, as shown in Figure 3. It can be seen from figure that temperature change curves of inorganic adhesive and organic adhesive are basically same as the standard temperature rising curve.

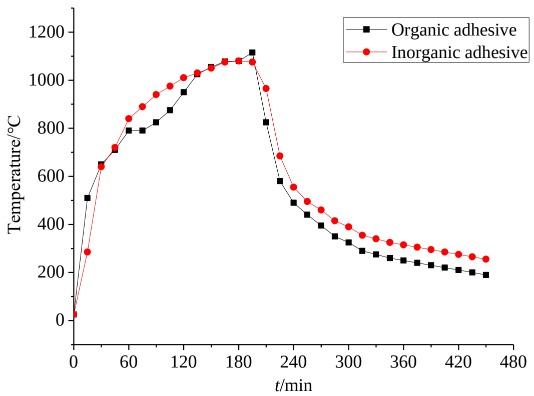


*Figure 3: Temperature change curve of organic adhesive and inorganic adhesive*

The main indicators tested in the test are heated furnace temperature, steel bar and concrete temperature, deflection and high temperature strain of bar-planting beam, etc. High temperature strain is measured by strain gage.

## 3. Test results and analysis

### 3.1 Test phenomena

High temperature tests shall be given to organic adhesive bar-planting concrete and inorganic adhesive bar-planting concrete respectively. During test process, water vapor shall show on surface of organic adhesive concrete component after 26min nearly, and it shall increase gradually afterwards. At the time of 70min, the component with chemical bar-planting depth 15d shows obvious change in vertical displacement, and it shows failure phenomena at 95min, mainly including bar slipping failure and concrete peeling; the components with bar-planting depths 20d and 30d show destroy at 113min and 125min respectively. Steel bars of the three specimens are extracted wholly, so the cohesive force declines obviously.
Water vapor shows on surface of inorganic adhesive concrete component at 35min, and plenty of water vapor shows around the component at 58min. The component with chemical bar-planting depth 15d shows the

phenomenon of excessive deflection of bar-planting beam at 137min, and the components with bar-planting depths 20d and 30d show failure at 150min and 158min. Failure form of inorganic adhesive concrete component is mainly concrete peeling, and it shows no phenomenon of slipping failure of steel bar.

### 3.2 Distribution characteristics of section temperatures of concrete

Figure 4 gives statistics to temperature change curve of inorganic adhesive chemical bar-planting concrete specimen in different sections, and the sections selected are those having distances of 80mm, 160mm and 320mm away from bottom of beam. It can be seen from figure that temperature of each section of concrete basically shows no change and is about 45°C from beginning of test to 30min, for moisture evaporation of specimen takes away a part of heat, and then internal and external environment temperatures of specimen reach balance; during 30min-120min, concrete temperature at 80mm section shows rapid increment, while that at 160mm and 320mm sections keep at 100°C around, for water vapor on surface of concrete is evaporated fully, and there is still moisture in the interior of concrete. It can also be seen from test results that: when the external fire temperature is same, temperature of steel bar beam is basically same at different measuring points in a same section, and temperature in different section increases gradually along with increment of heating time.

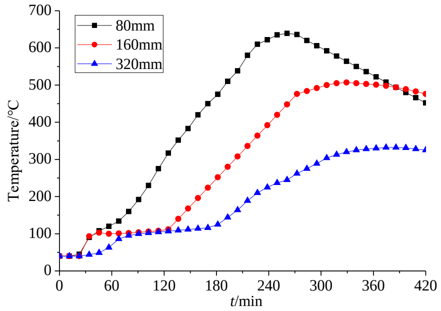


*Figure 4: Temperature-time curves of inorganic adhesive concrete with different sections*

### 3.3 Displacement and strain of bar-planting component in high temperature effect

Figure 5 shows beam mid-span deflection and displacement curve of organic adhesive bar-planting concrete and inorganic adhesive bar-planting concrete specimens in high temperature. As indicated in the figure, mid-span displacement of all specimens increases slowly since from beginning of the test to 90min, and it rises obviously during 120min—180min. By this time, bar-planting beam shows failure, deflection is greater, and organic adhesive bar-planting concrete shows the characteristic of brittle failure; displacement of inorganic adhesive bar-planting concrete specimen increases slowly, and fire endurance is greater. It can be seen from figure that: whether organic adhesive or inorganic adhesive, the shallower the bar planting is, the earlier the time of showing cracking and slipping failure is, and the weaker the ductility is.

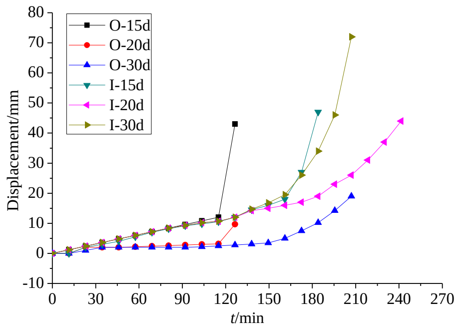


*Figure 5: Mid-span displacement of the chemically-planted steel bar specimen*

After being heated in high temperature, chemical bar-planting concrete specimen shall be cooled in indoor temperature environment. During cooling, organic adhesive bar-planting concrete specimens all show slipping failure, while inorganic adhesive bar-planting concrete specimens show no slipping failure. Figure 6 shows strain condition of O-30d steel bar in high temperature, and O-450, O-250 and O-50 in the figure refers to the measuring points having distances of 450mm, 250mm and 50mm away from old-new concrete joint face respectively. It can be seen from figure that: the three curves all show declining trend before 10min when suffering high temperature, and concrete suffers pressure stress at this time; afterwards, stresses of O-450 and O-250 show rising, concrete stress also changes from pressure stress to tensile stress, for cohesive force of chemical planting bar is wear off gradually after suffering high temperature, and stress shows redistribution. When increasing the heating time further, strain curve shall be stable basically, for the measuring strain gage and organic adhesive all lose effect.

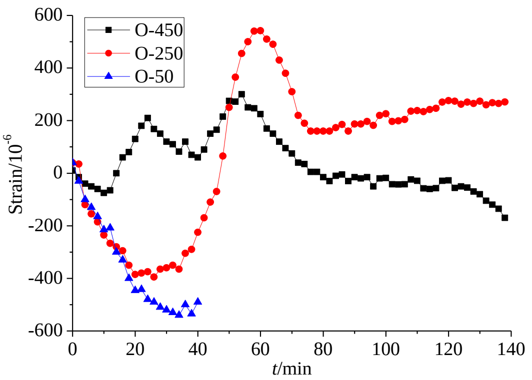


*Figure 6: High temperature strain curve of organic adhesive concrete specimen*

Figure 7 shows strain condition of I-30d steel bar in high temperature, and I-450, I-250 and I-50 refer to the measuring points having distances of 450mm, 250mm and 50mm away from old-new concrete joint face respectively. Comparing with very obvious strain change of organic adhesive chemical bar-planting concrete, strain change of inorganic adhesive concrete is smaller along with increment of heating time, it shows gradually increasing trend as a whole, and concrete suffers pressure stress all the time, for strength of concrete decreases after suffering high temperature effect, and cohesive action of inorganic adhesive declines, while inorganic adhesive does not lose effect fully. Thus, it does not show slipping failure and brittle failure during test process.

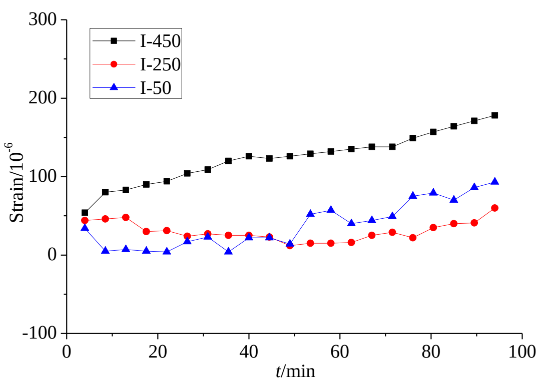


*Figure 7: High temperature strain curve of inorganic adhesive concrete specimen*

## 4. Conclusions

This paper gives contrastive analysis to fire resistance performance of organic adhesive and inorganic adhesive bar-planting concretes in high temperature, adopts laboratory test method, and researches influence of different anchorage depth and bar-planting adhesive on mechanical performance of chemical planting bar of concrete. The research conclusions are as follows:

(1) Component surface shows plenty of water vapor during high temperature heating of organic and inorganic adhesive concretes. During high temperature heating of organic adhesive concrete specimen, concrete shows peeling, steel bar shows slipping failure, and cohesive force reduces obviously; during inorganic adhesive concrete test, deflection of planting bar increases gradually, concrete also shows peeling, while steel bar shows no slipping failure.

(2) When the external fire temperature is same, temperature of steel bar beam is basically same at different measuring points in a same section, and temperature in different section increases gradually along with

increment of heating time. Whether organic adhesive or inorganic adhesive concrete, the shallower the bar planting is, the earlier the time of showing cracking and slipping failure is, and the weaker the ductility is.
(3) Organic adhesive concrete shows greater deformation in high temperature, and specimen shows brittle failure finally after suffering tensile stress and compressive stress repeatedly; strength of inorganic adhesive concrete decreases after suffering high temperature effect, and cohesive action of inorganic adhesive declines, while inorganic adhesive does not lose effect fully. When adopting chemical bar-planting anchorage technology, one shall increase anchorage depth in high temperature environment, to promote safety stock of concrete.

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