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4 Effects of vibration time on compressive strength and corrosion resistance of steel bars in concrete

M A Caronge¹, M W Tjaronge¹, R Irmawaty¹, B Bakri¹ and S Hamuddin¹

¹Department of Civil Engineering, Faculty of Engineering, Universitas Hasanuddin, Makassar, Indonesia

Email: ma-caronge@unhas.ac.id

Abstract. In this paper, effects of vibration time (0, 10 and 20 seconds) on compressive strength and corrosion resistance of steel bar in concrete are experimentally investigated. Compressive strength of concrete was performed on cylindrical specimens of Ø100x200 mm with water cement ratio (w/c) 0.52 after 28 days curing in tap water. Cylindrical specimens of Ø100x200 mm having 16 mm diameter of steel bar are considered for corrosion study. The specimens were subjected to cyclic wetting and drying regime up to 15 cycles. In wet cycle the specimens are immersed in sea water for 3 days, while in dry cycle the specimens were placed in open air for 4 days. The corrosion activity is monitored by measuring the copper/copper sulphate (CSE) half-cell potential according to ASTM C-876. The chloride penetration depths of concretes are also measured after 28 days immersed in 10% NaCl solution. Results show that compressive strength, chloride penetration depths and corrosion of steel bars is significantly affected by vibration time.

1. Introduction

Concrete is composite material generally used in construction defined as composed of aggregate, water, cement and sometimes chemical and/or additives. The quality and durability of normal concrete directly depends on the number and the shape of voids, so, in order to produce durable concrete, it is necessary to reduce the amount of air that trapped inside the concrete, which is usually done by vibrating the concrete in the mixing stage or the casting stage.

Concrete strengths have deviations for each production, since it is composite material. During production, placing and curing of concrete required attention should be paid to have desired properties. For this reason compressive strength which is one of the most important properties of concrete depends on material qualities and its proportion. However, fresh concrete produced according to desired properties is placed either more or less, because of unsuitable vibration applications. As a result compressive strength differences occur even if concrete is produced appropriately [1].

In addition, corrosion resistance of steel bars in concrete may affect by vibration time, which provide voids in the Interfacial Transition Zone (ITZ) of concrete. Thus, it can lead the chlorides easily penetrate to the concrete and reach the steel bar [2]. In this paper, effects of vibration time of 0, 10 and 20 seconds on compressive strength and corrosion resistance of steel bar in concrete are experimentally investigated on Portland Composite Cement (PCC).



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2. Experimental procedures

2.1. Materials and Mix Proportion ²²

Portland Composite Cement (PCC), river sand and crushed stone aggregate were used for concrete mixes. The chemical compositions of PCC are shown in table 1. Further, the physical properties of materials are presented in table 2.

Concrete with water to cement ratio (w/c) of 0.52 was used for all concrete specimens. The Mix proportion of concrete used is presented in table 3. After 24 h casting, the concrete specimens were cured in tap water with constant temperature of $20 \pm 2^\circ\text{C}$ until 28 days.

Table 1. Chemical composition of PCC [3].

Item	MgO	SO ₃	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	LOI	Free Lime
Value, %	0.99	1.81	18.39	5.15	3.41	4.61	1.56

Table 2. Physical properties of materials.

Material	Description
Cement	Portland Composite Cement (PPC)
	Density = 3.08 g/cm ³
	Bulk density = 1.10 kg/l
Sand	River sand
	SSD density = 2.58 g/cm ³
	F.M = 2.35
Gravel	Crushed stone
	SSD density = 2.70 g/cm ³
	MSA = 20 mm

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Table 3. Mix proportion of concrete.

w/c	Water (kg/m ³)	Cement (kg/m ³)	Sand (kg/m ³)	Gravel (kg/m ³)	Slump (cm)
0.52	215	413	681	1021	8.5

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2.2. Compressive Strength ¹⁰

Cylindrical concrete specimens of $\varnothing 100$ mm x 200 mm were made to measure compressive strength and stress-strain curve. The tests were done at the age 28 days after curing in tap water in accordance with ASTM C39 [4]. Three samples were used for each test.

2.3. Chloride Penetration ⁷

For testing chloride penetration, 100 mm in diameter and 200 mm in height cylindrical specimens were prepared in accordance with ISCE-G572 [5]. The demoulding was done at the age of 24 h. They were cured in tap water until 28 days. They were then cut into 50 mm thick slices and the 25 mm was cut from each end of specimen. The 50 mm center slices were epoxy coated around the cylinder.

Specimens were immersed in 10% NaCl at constant room temperature of $20 \pm 2^\circ\text{C}$. At 28 days immersed in 10% NaCl solution, specimens were split and the freshly split surfaces were soon sprayed with 0.1 N silver nitrate (AgNO₃) solution. The depths of chloride penetration were indicated by the boundary of color change. Three samples were tested for each set of results.

2.4. Corrosion potential

Cylindrical specimens of $\varnothing 100 \times 200$ mm having 16 mm diameter of steel bar were used for corrosion study. The specimens were subjected to cyclic wetting and drying regime up to 15 cycles. In wet cycle the specimens were immersed in sea water for 3 days, while in dry cycle the specimens were placed in open air for 4 days.

The half-cell potential method was used in order to assess the relative probability of corrosion activity of steel bar in concrete by electrochemical means. The test was conducted in accordance with ASTM C 876 [6]. A high impedance voltmeter was connected between the steel bar and a copper-copper sulfate (CSE) reference electrode on the concrete surface where the measurement could be made for the half-cell potential. The configuration of half-cell potential measurement is shown in figure 1.

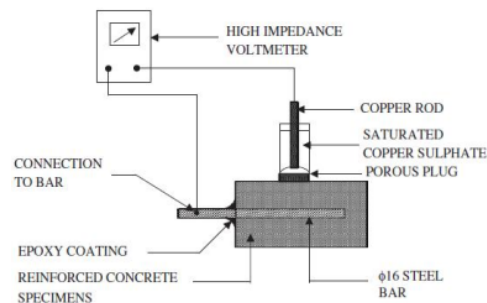


Figure 1. Test configuration of half-cell potential measurements [6].

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3. Results and Discussion

3.1. Compressive Strength

Average cylinder strengths and typical stress-strain curves of concrete specimens with vibration time of 0 (V-0), 10 (V-10) and 20 (V-20) seconds are shown in figure 2. It is clearly seen that strength properties of concrete affected by vibration time. Vibration time increases the compressive strength as well as the young modulus of concrete. Average compressive strengths for V-0, V-10 and V-20 were 30.10, 40.45 and 45.31 MPa, respectively. The results indicate that an appropriate vibration time and its application are important to obtain a good quality of concrete.

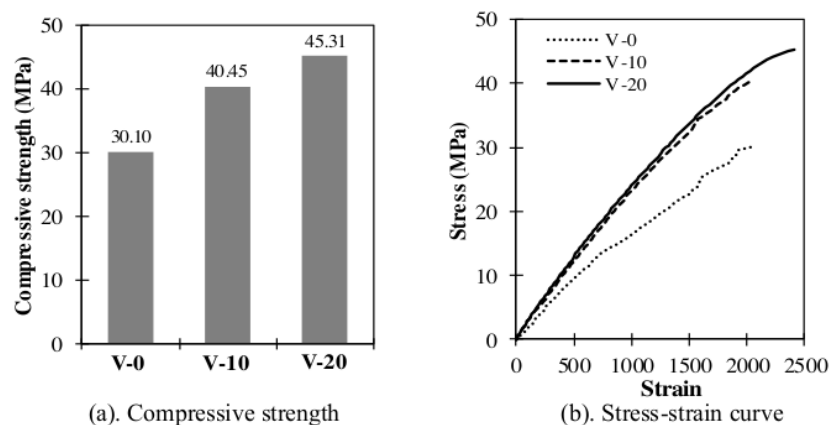


Figure 2. Compressive strength and stress-strain curve of concrete specimens.

3.2. Chloride Penetration Depths

Figure 3 shows chloride penetration depths of concrete after 28 days immersed in 10% NaCl solution. An average chloride ion penetration is presented in figure 4. The chloride penetration of concrete decreased with an increase in vibration time. It is found that chloride penetration depth of the specimen without vibration (V-0) was 26.78 mm. This value is higher compare to V-10 and V-20 about 21.61 and 20.51 mm, respectively. It is due to the larger number of voids in concrete without vibration (V-0) and as a result, chloride ions easily transport into concrete.

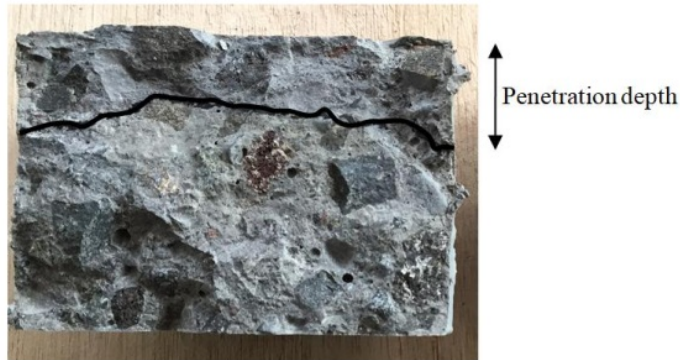


Figure 3. Chloride penetration depth after sprayed AgNO_3 0.1 N.

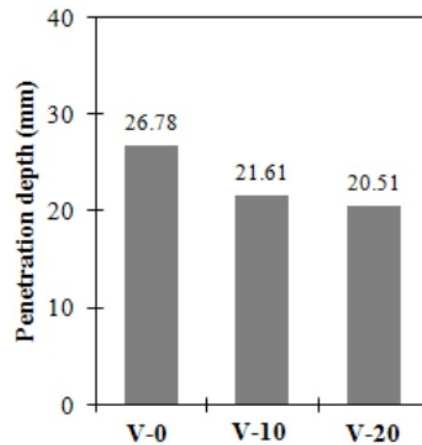


Figure 4. Chloride ion penetration depths of concrete.

3.3. Corrosion Potential

Figure 5 represents time-dependent changes of the half-cell potential of steel bars versus time. It shows that V-0 reached the potential value around -340 mV at the early age, while V-10 and V-20 were about 275 and 200 mV. After eight cycles, the potential value of V-0 shifts to -355 mV and categorized of 90% of corrosion probability per ASTM C 876 [5]. While for specimen V-10 and V-20, it is observed that the potential value shifts to the 90% probability of corrosion after 11 and 13 cycles, respectively. The results indicate that vibration time could increase the resistance of concrete against chloride.

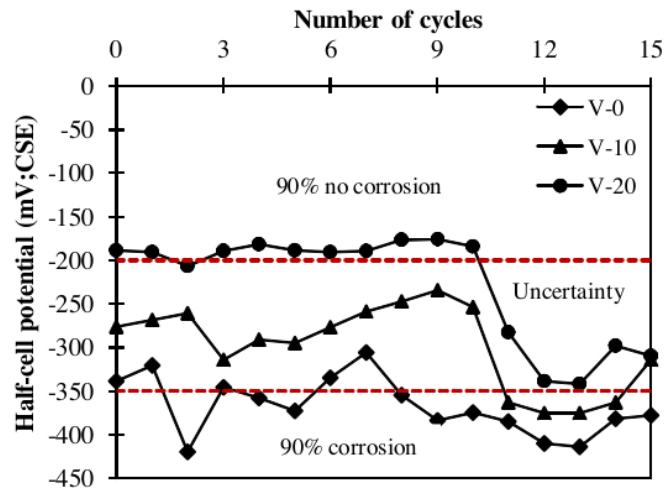


Figure 5. Time-dependent changes of the half-cell potential with time

4. Conclusion

This investigation presents the effects of vibration time on compressive strength and corrosion resistance of steel bar in concrete. From the test results strong correlation between vibration times, compressive strength and corrosion resistance of steel bar in concrete is found. An appropriate vibration time and its application are important to obtain a good quality of concrete and durability against chloride as well.

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