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To cite this article: Fakhruddin *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **419** 012049

IOP Conf. Series: Earth and Environmental Science **419** (2020) 012049 doi:10.1088/1755-1315/419/1/012049

Effect of working method on the strength reduction of reinforced concrete beams

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Abstract. Poor workmanship and improper construction methods often lead to the reduction of the concrete strength. This paper aims to investigate the effect of working methods on the strength reduction of concrete. Nine beams with the dimension of 150 mm wide, 200 mm depth and 3300 mm length were tested with the variation of compaction method and curing method. The variation of compaction methods was by using vibrator (V), tamping rod in the first layer only (1L), and tamping rod in all layers (3L). Meanwhile, the variation of curing methods was by using water (W), wet burlap (K), and room temperature (RT). The results indicated that the beam that was compacted using vibrator and cured in water (V-W) showed the highest flexural capacity. On the other hand, the beam that was compacted with the tamping rod in one layer and curing at the open space (1L-RT) showed the lowest flexural capacity. The experimental results were compared with analytical calculation to obtain strength reduction factor. According to Indonesian Code SNI 2847:2013, the strength reduction factor for the reinforced concrete beams is maximum 0.8. The V-W beam showed the smallest strength reduction factor of 0.93, while 1L-RT beam showed the highest strength reduction factor of 0.75. Therefore, the results indicated that working methods of using one layer tamping road was exceeded the maximum the strength reduction factor specified by Indonesia Code.

1. Introduction

Compacting process of fresh concrete is one of the important stages in concrete casting work. This stage is affect the concrete strength. The purpose of compacting concrete is to remove air cavities and to achieve maximum density. Compaction also guarantees a good attachment between the concrete and the reinforcing steel surface or other means which is casted. Compaction pores are responsible for reductions in compressive strength [1] and the carbonation of concrete [2].

In general, the stage of concrete compaction consists of two, namely internal compacting and external compacting. The two methods of compaction of concrete do have differences. But the goal remains the same, namely compacting fresh concrete to achieve optimal density. Figure 1 shows the pores in concrete caused by poor compaction.

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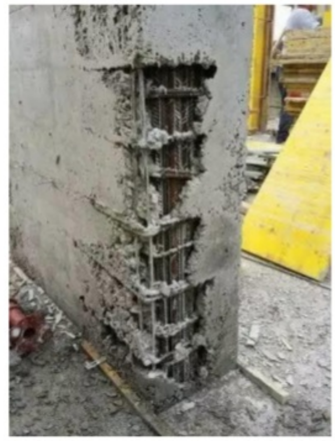
a . Poor compaction at beam-column joint



b. Poor compaction at shear wall

Figure 1. Pores in concrete caused by poor compaction.

After being casted and compacted, then the concrete must go through the treatment / curing process. The process plays a very important role in developing concrete strength and durability. The curing process is carried out as soon as the pouring process is complete. This curing process includes maintenance of humidity and temperature conditions, both in concrete and on the concrete surface in a certain period of time. The curing process on concrete aims to provide sufficient moisture in the advanced hydration process, where overall work methods, compaction methods and maintenance/ curing methods play an important role in producing quality concrete production.

Planning construction work always takes into account the strength reduction factor. The reduction factor is a number that reduces the strength of a material as a safety factor in determining the strength of a plan. The reduction factor is to accommodate the worst conditions in the field, such as differences in material quality. work methods that are not in accordance with the provisions, inaccurate measures and supervision of implementation.

In developing countries, such as Indonesia, concrete work that is not in accordance with applicable standards and regulations is still often found. While the overall work method is very influential on the strength of the concrete produced. When the reduction factor becomes a safety factor in planning, then how much the reduction factor in the strength of the concrete that occurs due to different work methods. In addition, when compared with the reduction factor that has been set by Indonesian National Standard (SNI) [3], whether the reduction in strength that occurs due to poor work methods exceeds or has been in accordance with the reduction in maximum strength set by the SNI.

Therefore, this study aims to investigate the effect of the compaction method and curing method on the strength of reinforced concrete beams. The result of load-displacement, crack pattern and the surface condition of the beams was discussed.

2. Experimental program

2.1. Specimens

Figure 2 shows the detail of specimen. Specimens consist of nine beams with dimension of 3300 mm length, 150 mm width and 200 mm height. The variation of specimens was the vibration method and the curing method. The variation of compaction method was using vibrator (V), tamping rod in the first layer only (1L), and tamping rod in all layers (3L). Meanwhile, the variation of curing methods was using water curing (W), curing with burlap (K), and curing in room temperature (RT). The variation of specimens is summarized in Table 1.

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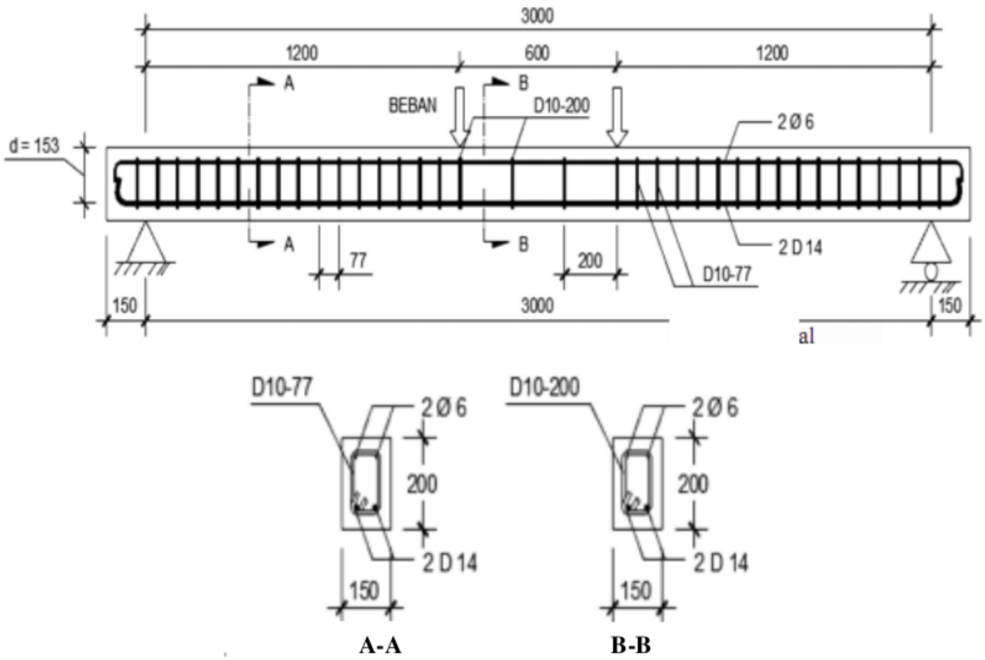

Figure 2. The details of specimen

Table 1. The variation of specimens.

		Curing method		
		Water (W)	Wet burlap (K)	Room temp. (RT)
Compaction method	Vibrator (V)	V-W	V-K	V-RT
	Tamping rod in 1st layer (1L)	1L-W	1L-K	1L-RT
	Tamping rod in all layers (3L)	3L-W	3L-K	3L-RT

2.2. Materials
The design compressive strength of concrete f'_c was 25 MPa. The yield strength of all rebars f_y was 400 MPa. The diameter of tensile rebars was D14 mm while the diameter of compression rebars was 10 mm.

2.3. Compaction and curing process
The compaction process using vibration is shown in figure 3. The water curing, burlap curing and room temperature curing is shown in figure 4 (a), (b) and (c), respectively. The specimens was cured until the day of testing of 28 days.

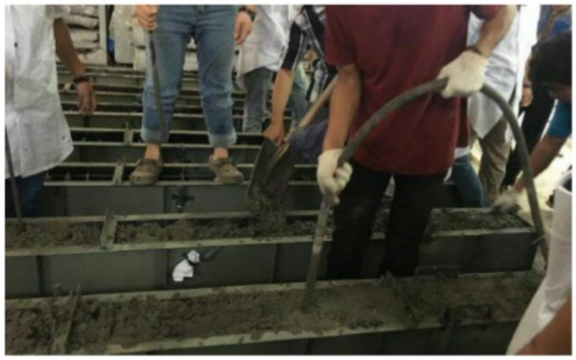

Figure 3. Compaction using vibrator.

a. Water curing

b. Burlap curing

c. Room temperature curing

Figure 4. Curing methods.

2.4. Setup

Figure 3 shows the loading setup. The specimen was loaded using hydraulic jack with capacity of 1500 kN. The measured data was load, displacement, concrete strain, steel strain and crack pattern. The load was measured using load cell capacity of 200 kN. The displacement was measured using Linear Variable Displacement Transducers (LVDT) located under the loading points. The strain of concrete was measured using concrete gauge which was located at the most compression zone of beam. The strain of rebars was measured using strain gauge which was located at the midspan.

Figure 5. Loading setup.

3. Results and discussions

3.1. Ultimate load

Figure 6 shows the ultimate load of specimens with effect of compaction methods. From the figure, it was found that the specimens that were compacted with a vibrator showed the greatest ultimate load compared to other compaction methods. For example in immersion in water, specimens that were compacted with a vibrator (V-W) had an ultimate load of 26.17 kN, compaction with 3-layer tamping rod (3L-W) of 23.67 kN and compaction with 1-layer tamping rod (1L-W) of 22.43 kN. By using V-W as control beam, the ultimate load of 3L-W and 1L-W decreased by 9.6% and 14.3%, respectively. These results indicate that the compaction method is very influential factor on the ultimate load. This is due to the increasing number of pores in the 3L-W and 1L-W beams. These pores could reduced the bonding strength between concrete and steel bars [4]. According to [5-9], the pore structure greatly influences the strength development of concrete. Figure 6 shows the comparison of concrete surfaces on V-W, 3L-W and 1L-W.

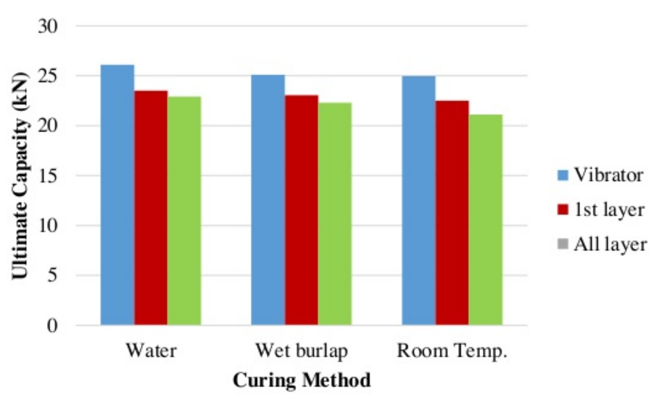

Figure 6. Ultimate load with effect of compaction methods.

(a). V-W

(b). 3L-W

(c). 1L-W

Figure 7. Surface of beams as effect of compaction method.

Figure 8 shows the ultimate load of specimens with effect of curing methods. From the figure, it was found that the specimens that were cured in water showed the largest ultimate load than the other methods. For example the specimens that were compacted with a vibrator and curing in water (V-W) had an ultimate load of 26.17 kN, cured with wet burlap (V-K) was 25.1 and cured in room temperature (V-RT) was 24.87 kN. By using V-W as control beam, the ultimate load of V-K and V-RT decreased by 4.1% and 5.0%, respectively. These results indicate that the curing method is influential on the ultimate load. According to Peter [9], the curing regime has a significant effect on the compressive strength especially in early stages of hardening, which was the most important ones.

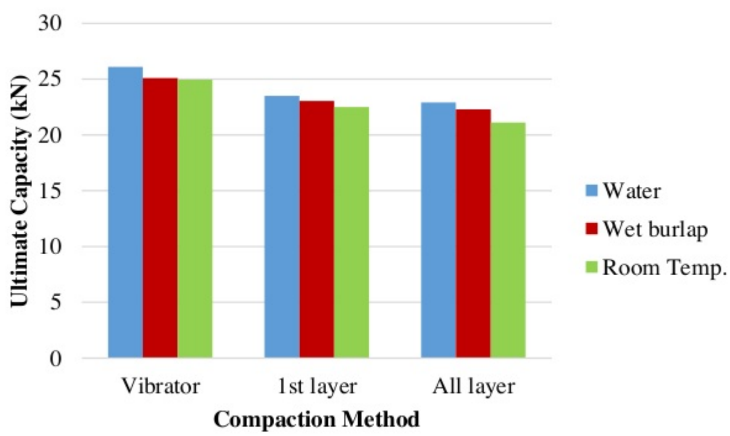

Figure 8. Ultimate load with effect of curing methods.

3.2. Crack pattern

The crack pattern of all beams was typical, where the first crack occurred under the loading point. All the beams failed in flexure. The concrete crushed at the compression zone at the ultimate load. Figure 9 shows the crack patter in V-W specimen.

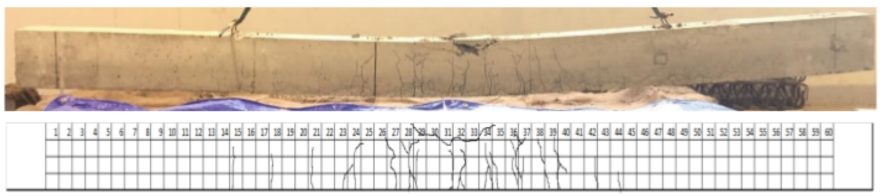

Figure 9. Crack pattern of V-W.

3.3. Comparison experiment and analytical ultimate load

The experimental results were compared with analytical calculation. The moment was calculated according to stress block diagram. The results of calculation are summarized in table 2.

Table 2. Comparison of experiment and analytical calculation.

No	Specimen	Ultimate load (kN)		Moment Ultimate (kNm)		Ratio
		Experiment	Analysis	Experiment	Analysis	Mu_{exp} / Mu_{anals}
1	V-W	26.17		15.78		0.93
2	3L-W	24.63		14.86		0.87
3	1L-W	24.77		14.34		0.84
4	V-K	25.10		15.14		0.89
5	3L-K	23.10	29.23	13.94	17.01	0.82
6	1L-K	22.43		13.54		0.80
7	V-RT	24.87		15.00		0.88
8	3L-RT	22.60		13.64		0.80
9	1L-RT	21.16		12.78		0.75

The ratio of Mu_{exp} / Mu_{anals} in table 2 indicates the strength reduction. Based on table 2, the strength reduction in this study was between 0.75 and 0.93. According to Indonesian Code SNI 2847:2013, the strength reduction factor for the reinforced concrete beams is maximum 0.8. This factor is taken into account the imperfection work method in the field. V-W beam showed the smallest strength reduction factor of 0.93, while 1L-RT beam showed the highest strength reduction factor of 0.75. Therefore, the results indicated that working methods using one layer tamping road was exceed the maximum the strength reduction factor specified by Indonesia Code.

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