COLD JOINT FORMATION OF CONCRETE IN HOT WEATHER CONDITIONS

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1. INTRODUCTION

Cold joints are formed primarily between two layers of concrete when the second layer is placed after the vibration limit (initial setting time) of the first layer, which is 3.5 N/mm^2 penetration resistance in the setting time test. The cold joint is likely to form due to lack of intermixing of layers and it forms undesirable void structure between two surfaces. The major parameters that affect the occurrence of cold joints are setting of the underlying layer, the placement interval, and any treatment applied between the two layers [1].

The presence of a cold joint in concrete structure may cause deterioration, strength reduction and destroys the esthetic appearance of the concrete surface. In hot weather condition, the formation of cold joint becomes more severe issue due to more excessive evaporation and rapid setting behavior of concrete. However, cold joint formation at high temperature conditions, over 35ºC has not been fully understood. Under high temperature conditions, concrete sets quickly with different pore structural arrangement, or rate of bleeding is different and these would affect the cold joint formation process. In this research, the effect of ambient and mixing temperatures on setting time and slump loss of fresh concrete and the effect of placement interval on joint flexural strength under extreme temperature conditions, over 35ºC are examined.

2. METHODOLOGY

2.1 Setting time test

Setting times of concrete are determined using methods specified in ASTM C403/C403M. This experiment was conducted to investigate the effect of mixing and ambient temperature on setting time of concrete. Setting behavior was studied with mixing temperatures of 25 and 30ºC and ambient temperatures of 25; 35 and 45ºC were maintained in the fresh state to measure the penetration resistance after each mixing.

2.2 Workability test

This experiment was designed to investigate the placing limit of overlay by examining the unworkable state of fresh concrete with its setting. Slump test was carried out to find the relationship of slump loss with penetration resistance of fresh concrete and the value of penetration resistance that fresh concrete is still workable. Re-vibration test was done to obtain unworkable setting stage with respect to the porker vibrator by visually observing the trace in the samples due to the vibrator.

2.3 Flexural strength test

In order to investigate the relationship between cold joint formation and setting behavior of concrete under different ambient temperatures: 25ºC to 45ºC, 100×100×400mm concrete beams were casted. To investigate the effect from the consolidation method, experiment was carried out with two different vibration procedures by poker vibrator as given in Fig. 1, case (a) recommended by JSCE [2] and case (b) represents the worst field condition. Flexural strength of concrete at an age of 7 days was determined using methods specified in ASTM C78/C78M.

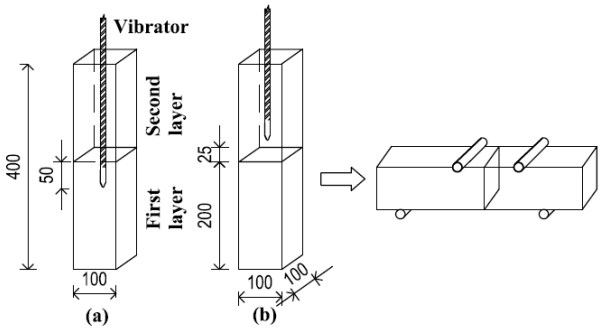


Fig. 1 Beam preparation for bending test

3. RESULT AND DISCUSSION

3.1 Setting time of concrete

The effect of ambient and concrete mixing temperatures on setting time is given in the Fig. 2. It is concluded from the results that both mixing and ambient temperatures affect significantly the setting time. The setting time of concrete decreases with a rise in the temperatures. At high temperature, setting time is accelerated.

The acceleration effect is more pronounced with mixing temperature than ambient temperature, it can be evidenced by the results of the initial setting time of the concrete with ambient temperature of 35ºC and mixing temperature of 30ºC is similar to the initial setting time of the concrete with

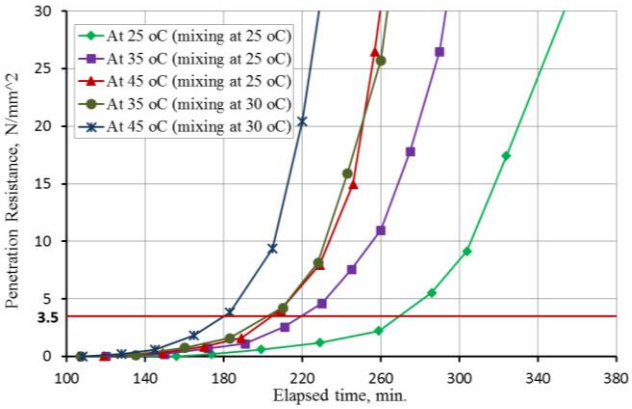


Fig. 2 Effect of temperature on setting time of concrete

ambient temperature of 45ºC and mixing temperature of 25ºC; the difference of 5ºC in mixing temperature gives the same effect as the difference of 10ºC in ambient temperature. Therefore, initial temperature of concrete is more dominant factor compared to ambient temperature in cold joint formation.

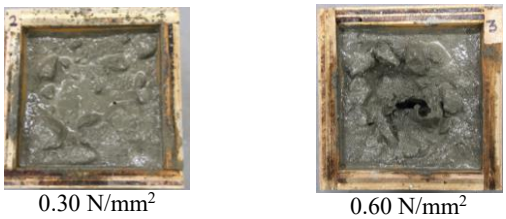
3.2 Workability test results

Table 1 shows the relationship of elapsed time; penetration resistance and slump of fresh concrete. The experimental results show that slump of concrete is zero when penetration resistance is higher than 0.60 N/mm^2. Fresh concrete even become very stiff when penetration resistance is 0.5 N/mm^2 (slump is 10 mm). Therefore, when penetration resistance is higher than 0.5 N/mm^2 the poker vibrator is not suitable to consolidate at this stage.

Even when the resistance is less than 0.5 N/mm^2, the consolidation may be not easy but be dependent on the vibration method because the workability can be greatly reduced just for 10 minutes from the resistance of 0.30 N/mm^2 to 0.50 N/mm^2.

Table 1 Slump loss of concrete

Elapsed time, min.	*Resistance, N/mm^2*	*Slump, mm*
0	0.00	200
160	0.30	15
170	0.50	10
180	0.60	0



0.30 N/mm^2 0.60 N/mm^2

Fig. 3 Trace of the vibrator

3.3 Flexural strength test results

Fig. 4 shows the results for the through vibration method (case a). For the case ambient temperature of 25ºC, the flexural strength at cold joint start to reduce when the placement interval is longer than 350 minutes, this value is much longer than initial setting time of concrete (270 minutes). Furthermore, the cold joint appear when placement interval is longer than 210 minutes (Fig. 6), however the formation of cold joint is irrespective of strength reduction when placement interval is shorter than 350 minute. Further investigating the damageability of the substrate due to the vibrator and cross sectional observation at cold joint, it was found that, the reason for higher joint strength even after initial setting time is owing to growth of surface roughness due to the damages caused by vibrator of substrate, overlay on rough surface leads to good bondage between concrete layers (Fig. 3). For the case ambient temperature of 45ºC, when the placement interval is longer than 159 minutes, the flexural strength at cold joint start to reduce. For case (a), workability of the first concrete layer greatly affects the joint strength. High temperature (45ºC) cause quickly increasing of penetration resistance, therefore the reduction of strength happen earlier and more serious.

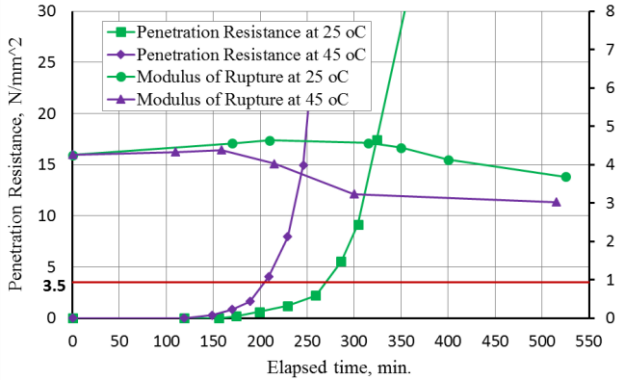


Fig. 4 Flexural strength at cold joint of case (a)

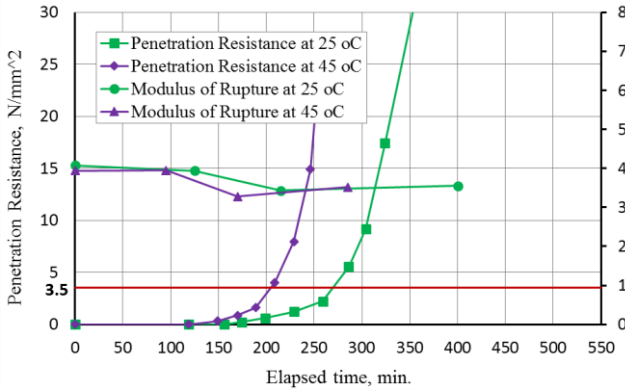


Fig. 5 Flexural strength at cold joint of case (b)

Fig. 5 shows the results for vibration method case (b) at both ambient temperature conditions (25 and 45ºC), flexural strength reduction was observed when the placement interval is longer than 125 minutes and 95 minutes respectively. Furthermore, cold joint started to be visually observed when the placement interval is 215 and 95 minutes respectively (Fig. 6). The appearance of strength reduction in case (b) is earlier than case (a). However, the effect of temperature on strength reduction in case (b) is less than case (a), the strength reduction at 25ºC and 45ºC are not much difference.

At 25ºC At 45ºC

Fig.6 The formation of cold joint before initial setting time

4. CONCLUSION

In conclusion, cold joint forms at placement interval less than the initial setting time (3.5 N/mm^2 penetration resistance, vibration limit). Furthermore, the initial setting time as the placement interval is not applicable in hot weather conditions. Placing temperature of concrete is more dominant in reducing the second layer placement time than ambient temperature.

REFERENCES

[1] JSCE Concrete Committee, "Japan's Concrete Technology", 2014.
[2] JSCE Concrete Committee, "Cold Joint Problem of Concrete Structure and Measures", Concrete library, Vol. 103, 2000.