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Experimental Study on Compressive Strength of Concrete Under Simple Curing and Encased in Steel Mould

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Abstract: This paper presents a comparison and analysis of compressive strength development of normal concrete under three typical simple curing methods: air curing, water immersion curing, plastic film cover curing, and maintained in steel mould. Portland cement with 30% fly ash was used, concrete cubic compressive strength at 28 days and 60 days were tested. The comparison of experimental results shows that concrete samples applied 7-day water immersion curing and samples maintained in steel moulds up to testing date displayed excellent compressive strength development compared with concrete samples under air curing. This implies core concrete in steel tubular members might develop a higher strength than design assumption based on standard curing procedure. Wrapping concrete with plastic film for more than 7 days as a curing method might delay the concrete strength development in early stage. Water immersion curing for long period may not accelerate concrete compressive strength gain.
Keywords: Concrete compressive strength; Air curing; Water immersion curing; Plastic film cover curing; Maintaining concrete in steel mould; Comparison.

1. Introduction

Concrete is one of the most used construction materials in construction engineering practice. Unlike many other construction materials, concrete may be mixed onsite as a soft composite material and then placed in formworks with desired shapes of structures. Although the raw materials and mix proportion of concrete dominate the mechanical characteristics of hardened concrete, the curing method and environment applied to the fresh concrete in early stage play an important role on the concrete properties, such as compressive strength, durability and permeability etc. Neville [1] describes curing as “procedures used for promoting the hydration of cement, and consists of a control of temperature and of the moisture movement from and into the concrete”, “More specifically, the object of curing is to keep concrete saturated, or as nearly saturated as possible, until the originally water-filled space in the fresh cement paste has been filled to the desired extent by the products of hydration of cement.” The British standards BS8110-1:1997 [2] describes curing as “the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime”. So simply speaking curing is a process of maintaining satisfactory moisture content and environment to maximise the hydration process of concrete in early stage.

As curing significantly impacts the development of strength and durability characteristics of concrete, so after fresh concrete made, it is usually carefully maintained, or cured, during the early stage to ensure effective hydration process. However, in practice, what curing method to be adopted depends on the construction environment, construction structure itself and the available curing method. In construction practice, there are various curing methods to maintain the presence of maxing water throughout the early stage of concrete hardening. They are also beneficial to concrete in hot weather conditions as they provide cooling through the evaporation of water. Such methods include ponding or immersion, spraying or fogging, and saturated wet covering etc. In addition, there are various curing methods that may be implemented to decrease the level of water lost which belongs to the concrete surface, such as putting a layer of impervious paper, plastic sheeting or membrane on the concrete to cover it. In concrete material laboratory, accelerate strength gain methods supply the concrete with heat and additional moisture by applying live steam, coils that are subject to heating, or pads that have been warmed electrically. The following lists some simple but practical curing methods. Water Curing: which involves wetting concrete to keep it moist or immersed in water; Moist Curing: which uses plastic sheets or wet burlaps to prevent concrete moisture loss at the concrete surface; Sealed Curing: sealing concrete using impermeable membranes or sealants to prevent moisture escape from surface, in particular used in hot weather; Air Curing: also known as natural curing, which lets concrete cure naturally under ambient circumstances, relying on the concrete mixture and environmental wetness, air curing is the most cost-effective and easy process; Steam Curing: which accelerates concrete hydration process and strength gaining; Autogenous Curing: using internal water reservoirs in concrete cause autogenous curing. In addition, accelerated curing techniques may be adopted for expediting the strength development in concrete, such as the utilization of calcium chloride or other chemical admixtures, can be implemented.

Many researchers carried out investigations to explore the effect of various curing methods and curing environments to the concrete properties. The outcomes helped a better understanding of curing methods and their application in construction practice. Ramezanianpour [3] investigated the performance of slag, fry ash, and silica fume concretes under four different curing regimes: moist curing, curing at room temperature after demoulding, curing at room temperature after two days of moist curing, and curing at 38°C with 65% relative humidity. It was found that the reduction of moist-curing period resulted in concrete strength decrease, porosity and permeability increase. Bushlaibi & Alshamsi [4] studied the effect of curing methods on compressive strength development of high-strength concrete at different environments and evaluated the efficiency of existing concrete curing practices. They found that the effect of curing regimes on concrete strength is highly influenced by the exposure environment. The curing methods affected strength of indoor concrete samples differently from strength of the outdoor samples. Husem & Gozutok [5] investigated effect of low curing temperature on the concrete strength. They cured specimens for 7 days at temperatures of 23+/-2ºC, 10, 5, 0, and -5 ºC, and found that the compressive strength of the specimens at 10 ºC and less than 10 ºC during 7 days was lower than that of the specimens at 23+/-2 ºC curing. At the end of 28th days the compressive strength of concrete specimens cured at low temperatures were much lower than that of specimens cured at 23+/-2 ºC. Atis et al [6] explored the influence of dry and wet curing conditions on compressive strength of silica fume concrete. It was found that the compressive strength of silica fume concrete cured at 65% relative humidity was influenced more than that of Portland cement concrete. Chen et al [7] conducted an experimental study to evaluate the effect of curing conditions on the strength, porosity, and chloride ingress characteristics of concretes made with high slag blast furnace cement and ordinary Portland cement. The effects of two curing conditions, or seawater immersion and marine atmospheric exposure during curing at 4, 7, 28, 90, 180, and 360 days intervals considered. It was found that seawater-cured specimens showed a slightly higher early strength, but a lower ultimate strength as compared with air-cured specimens. Bingöl & Tohumcu investigated the effect of air curing, water curing and steam curing on the compressive strength of self-compacting concrete. They found water curing giving highest strength and air curing giving lower compressive strength. Ibrahim et al [9] tested the effect of four types of curing compounds, namely water-, acrylic-, and bitumen-based and coal tar epoxy to the concrete compressive strength, water absorption and chloride permeability. It was observed that the strength and durability characteristics of both ordinary Portland cement and silica fume cement concrete specimens cured by applying the selected curing compounds were similar or better than that of concrete specimens cured by covering with wet burlap. Among the selected curing compounds, the performance of bitumen-based curing compound was generally better than that of other curing compounds, followed by coal tar epoxy, and acrylic and water-based curing compounds in the decreasing order. Usman & Isa [10] studied the effect of four curing methods: immersion, sprinkling, polythene sheeting and sharp sand coating. It found that water immersion curing method as well as sprinkling (spraying) methods of curing, provided better results than membrane (polythene sheeting) method of curing. While sharp sand giving least strength. Princy & John [11] studied the effect of various curing periods and various curing methods (dry curing, immersion technique, liquid membrane curing compound, and water proofing compound) to the concrete compressive strength. The results indicated that conventional water curing is the most efficient method of curing as compared to membrane curing, 7day, 14day water curing and dry air curing methods. Using wax based curing compound and acrylic resin based curing compound can achieve 99% and 96% of compressive strength compared to conventional curing method. Tang et al [12] studied the effect of higher curing temperatures, or temperature from normal, 40◦C, 60◦C, 75◦C, and 90◦C, to the concrete strength and durability behaviours. Their experimental results revealed that the hot temperature curing environment may benefit early-stage strength development but reduce the long-term strength. It proved that 60∘C is a critical temperature point. At above 60∘C, the strength of the concrete material and its resistance to chloride ion permeability showed a decreasing trend; however, in the appropriate temperature range, the frost resistance properties of the concrete were improved with increasing temperature. Odeyemi et al [13] adopted four different curing methods (immersion, sprinkling, wet-curing and open-air) to cure concrete with Palm Kernel Shell (PKS) aggregate. They found that water immersion method of curing gave the highest compressive strength, followed by the sprinkling method of curing. Suresh & AGM-R&D [14] investigated the effect of different early curing conditions on long-term strength and durability properties of Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) concretes, and the effect of different curing methods (Wet sand curing, immersing in water, Water spraying, Apply curing compound and No curing) on the concrete strength and durability. The results showed that concrete durability increases with increase initial water curing for all type concretes. At later period, in all curing conditions, concrete with PPC and PSC attained higher strengths and durability than OPC concrete. Also ascertained that concrete attained higher strength and durability with Wet sand curing method than other curing methods (Immersing in water, Water spraying, apply curing compound and No curing) and immersing in water curing concrete properties closer to Wet sand curing concrete properties. Zuo et al [15] investigated the effect of curing regimes (standard and steam curing) on the mechanical strength, hydration, and microstructure of ecological ultrahigh-performance concrete (EUHPC). The test results showed that the compressive strength of EUHPC under steam curing was increased considerably compared to that under standard curing, while the flexural strength was mildly decreased. Anwar et al [16] tested the compressive strength of concrete under four curing techniques (air curing, water-submerged curing, polythene curing, curing by boiling) at 3, 7, 14, 21 and 28 days, they found that concrete specimens produced using the water-submergence technique of curing had the maximum 28-day compressive strength. Suryawanshi & Shastri [17] reviewed references and found initial curing is more effective for concrete with higher cement content. A minimum curing time of 3 days is sufficient for concentrated mixes in hot weather, and a minimum curing time of 7 days for thinner mixes (lower cement content) will suffice. Increasing the curing time after delayed curing from 3 to 7 days increased the compressive strength of the concrete but did not compensate for the decrease in strength caused by the delayed curing. Hamada et al [18] had a comprehensive review to explore the different effects of curing methods on the strength development of normal concrete and ultra-high-performance concrete. The reviewed curing methods includes microwave curing, autoclave curing, carbon curing, and steam curing, electric curing, ambient and air curing and watering. They found that all these curing methods achieved satisfactory values of compressive strength, however, it is not practical to specify the peak curing regimes for concrete or ultra-high-performance concrete since the best results need critical monitoring of curing parameters.

Currently when determine the mechanical properties of a concrete, the concrete is usually sampled from fresh concrete in site and then cured and tested in laboratories where standardised curing procedures are adopted. However, in engineering practices, curing in the construction sites after the placing of concrete might be different from the laboratory criteria, this include some standard curing methods adopted in laboratory can't be applied on site and sometimes contractor compromises the curing methods in order to reduce construction costs etc. Obviously, the difference of curing methods adopted in laboratory from construction site might over or underestimate the real concrete properties.

In the recent two decades, concrete filled steel tubular members have been extensively used in construction engineering practice. Concrete-filled steel tubular composite member comprises a combination of steel and concrete and utilise the most favourable properties of both constituent materials. It is well recognized that the confinement interaction between the steel hollow section and concrete core makes the composite members perform better structurally than individual constituent members. However, the better curing environment the steel tube provides to the inside concrete is not considered, which might increase the strength of concrete core inside the steel tube. The research presented in this paper will explore the effect of typical simple curing methods and maintaining concrete in steel moulds to the concrete compressive strength development.

2. Experimental programme

In normal weigh concrete, the aggregates may consist of 60-80% of the concrete. It is generally believed that the strength of hardened concrete is governed by the hardened cement paste strength and bonding strength between hardened cement paste and aggregates. It is recognized that the strength development of the hardened cement paste is dominated by the hydration process after the cement is mixed with water. Before the concrete sets, the liquid cement paste likes a "lubricant" wrapping the aggregates and filling the space between aggregates, after the concrete setting, the cement paste acts as a binder to glue aggregates together to form the hardened concrete. For normal concrete cured in open air environment, the compressive strength might reach 40~60% of the final strength in 7 days, 70~90% in 28 days. The hydration reaction progress has never stopped in concrete, however different curing methods and environments might change the speed of hydration process finally led to the change of concrete strength development. The intention of this experimental study is to detect the effect of four curing procedures, open air curing, water immersion curing, plastic film cover curing and maintaining concrete in steel mould (mould curing), to the concrete strength development. The "mould curing" is expected to reflect a curing environment of concrete filled in the steel tube hollow sections. A series of experiments was carried out at the University of Bradford, with which the aforementioned curing methods were applied to concrete cube samples to find their impact to the concrete compressive strength.

2.1 Concrete raw materials

General purpose cement CEM II/B-V 32.5R type of Portland-fly ash cement (PC) complied with EN 197:2011 from LAFARGE was used for concrete in this research. The cement consists of 30% fly ash and its loss of ignition of the cement is less than 7%. Natural river sand and siliceous gravel with a maximum size of 20 mm, as shown in Figure 1, were adopted as fine and coarse aggregates for the concrete specimens.

Figure 1. cement and aggregates used for concrete specimens

2.2 Concrete mix specification

Three concrete mix proportions were considered to produce deferent graded concrete, it is expected the hardened concrete cubic compressive strength in the range of 30~45 MPa. This range represents normal strength concrete and broadly used as structural concrete. Table 1 gives the concrete mix proportions with target cubic compressive strength grade C30, C38 and C45 at 28 days by open air curing.

Table 1. Proportions of the concrete mixtures (kg/m3)

Concrete grade	Cement	Water	Fine aggregate	10 mm coarse aggregate	20 mm coarse aggregate
C30	346	180	739	369	738
C38	406	195	640	380	760
C45	473	180	516	404	830

2.3 Concrete mixing, casting and curing procedures

Using the above designed mix specifications, three batches of concrete with different target compressive strengths were created in the laboratory. Cubic specimens were then casted in steel moulds (100 x 100 x 100 mm) and compacted via a vibration table. In total 122 cube specimens were made, in which 20 specimens for C30 concrete, 82 specimens for C38 concrete and 20 specimens for C45 concrete. All specimens were de-moulded after 24 hours (except the specimens applied mould curing), then all specimens were kept in laboratory and applied the following curing procedures as given in Table 2.

Table 2. Summary of curing procedures adopted in this research

Curing procedures	ID	Curing procedure description
Air curing	AC	after de-mould, the concrete cubic specimens were maintained in open air until the testing date
Water immersion curing	WC-A	after de-mould, concrete cubic specimens were immersed in the water until the testing date
	WC-B	after de-mould, concrete cubic specimens were immersed in the water for 7 days, then maintained in open air until the testing date
Plastic film cover curing	PC-A	after de-mould, concrete cubic specimens were wrapped in plastic film until the testing date
	PC-B	after de-mould, concrete cubic specimens were wrapped in plastic film for 7 days, then maintained in open air until the testing date
Steel mould curing	MC-A	concrete cubic specimens were maintained in the steel mould until the testing date
	MC-B	concrete cubic specimens were maintained in the steel mould for 7 days before de-mould, after de-mould the specimens were maintained in open air until the testing date.

Figure 2 shows the four curing methods mentioned above and adopted in this research. Concrete cube compressive strength on 28 days and 60 days after casting were tested to analyse the strength development of concrete with different curing procedures.

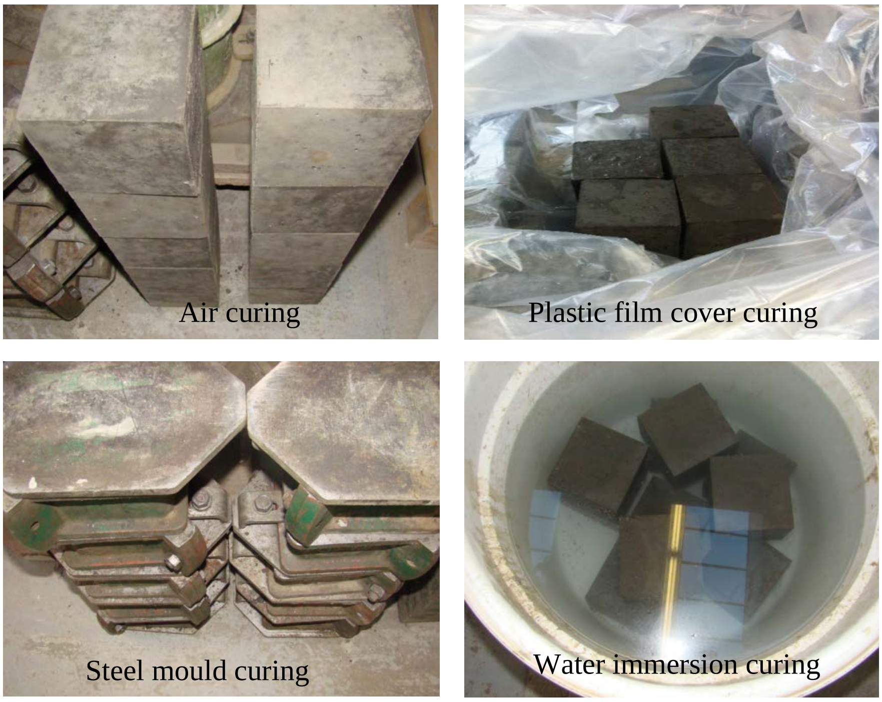

Figure 2. Curing procedures adopted in the research

3. Experimental results and discussion

3.1 Experimental results

Table 3 shows the measured cubic compressive strength of concrete at 28 days and 60 days. The average cubic compressive strength of concrete applied air curing procedure at 28 days is 37.9MPa. The value is very close to the target compressive strength C38 at 28 days, however, from Table 3, it can be seen that for cubic specimens applied other curing procedures, their measured compressive strengths are very different.

1) When samples were applied PC-A procedure, it appears the strength development was slower. The measured concrete strength at 28 day is just about 76% of the measured strength of samples applied AC procedure. It took about 60 days when the compressive strength of concrete reached the target strength 38MPa, but this is only 87.4% of the measured strength of samples applied AC procedure at 60 days.

2) When samples were applied WC-A procedure, the speed of strength gain was quicker than that of samples applied AC. Although at 28 days, the measured compressive strength is just about 4% higher than the measured compressive strength of concrete applied AC procedure, but at 60 days, the measured concrete compressive strength was 29% higher than the 28-day strength of concrete applied AC procedure and 12% higher than the 60-day strength of concrete with AC procedure.

3) Comparing with concrete applied AC procedure, there was a dramatic change when samples were applied MC-A procedure. The strength development of concrete with MC-A procedure was much quicker than that of concrete with AC procedure. At 28 days, the measure compressive strength of concrete was 14.4% higher than measured strength of concrete in AC procedure. At 60 days, the measured concrete compressive strength is 35.3% higher than the 28-day concrete strength applied AC procedure and 17.4% higher than the 60-day concrete strength applied AC procedure.

Table 4 and Table 5 show the 28-day cube compressive strength of concrete with different curing procedures. For these two batches of concrete specimens, the curing duration was much shorter than the C38 concrete specimens given in Table 3. For specimens showed in Table 4 and Table 5, after de-mould, the curing duration applied to each sample was 7 days, then all samples were applied AC procedure, or maintained in air. The measured average 28-day compressive strengths of concretes with AC procedure are 31.1MPa and 44.3MPa respectively. They are very close to the target strength C30 and C45. As well the curing procedures affected the concrete compressive strength development significantly.

1) When samples were applied PC-B method, the measured 28-day compressive strength was slightly higher than measured strength of concrete applied AC procedure (1% higher for C30 concrete and 3.9% higher for C45 concrete).

2) When samples were applied WC-B method, the measured 28-day compressive strength of concrete was much higher than that of samples applied AC method after de-mould. It can be found, the compressive strength 29.1% higher for C30 concrete and 30.1 higher % for C45 concrete.

3) When samples were applied MC-B method, the 28-day measured compressive strength is 15.6% higher for C30 concrete applied AC and 10.9% higher for C45 concrete with AC.

The above comparison clearly shows the effect of different curing procedures on the concrete compressive strength. Maintaining the concrete in steel mould no doubt provided a good curing environment which led to the higher concrete strength. Water immersion curing also promoted the concrete strength, however being immersed in water for too long time in early stage will not benefit the strength development. Plastic film wrapping curing appears not help the early strength development.

Table 3. Strength development of C38 concrete applied different curing procedures

Curing methods / Specimen No.	28-day compressive strength				60-day compressive strength			
	AC	PC-A	MC-A	WC-A	AC	PC-A	MC-A	WC-A
1	38.2	28.4	43.2	38.9	43.7	39.0	52.4	49.3
2	37.2	29.6	44.4	39.2	44.7	38.7	51.4	47.2
3	36.8	28.7	42.6	40.5	42.0	36.4	48.7	46.8
4	39.9	28.4	41.8	41.0	41.3	37.2	51.2	50.4
5	38.1	29.5	43.9	38.5	45.5	39.3	52.1	51.1
6	37.0	27.8	41.9	37.2	43.5		49.8	48.3
7	38.7	29.5	42.2	39.8	45.1		54.3	45.1
8	37.0	27.9	43.4	40.9	43.3		49.5	50.7
9	36.9		43.8	40.6	43.4		51.6	49.3
10	37.0		44.4	41.7	43.3		52.0	50.2
11	38.3		44.8	39.7				
12	37.0		42.8	37.0				
13	40.8		43.5	39.0				
Average strength	37.9	28.7	43.3	39.6	43.6	38.1	51.3	48.8
Ratio of average strength to 28-day average strength applied AC	1.000	0.758	1.142	1.044	1.149	1.005	1.353	1.288
Ratio of average strength to 60-day average strength applied AC					1.000	0.874	1.176	1.119
Ratio of average strength at 60 days to average strength at 28 days					1.150	1.328	1.185	1.232

Table 4. Strength development of C30 concrete applied different curing procedures

Curing methods / Specimen No.	28-day compressive strength			
	AC	PC-B	MC-B	WC-B
1	31.5	29.6	37.2	40.3
2	30.0	30.9	35.4	39.5
3	31.4	32.0	35.4	41.1
4	30.6	33.0	35.8	40.2
5	32.0	31.6	36.0	39.7
Average strength	31.1	31.4	36.0	40.2
Ratio of average strength to 28-day average strength with AC	1.000	1.010	1.156	1.291

Table 5. Strength development of C45 concrete applied different curing procedures

Curing methods / Specimen No.	28-day compressive strength			
	AC	PC-B	MC-B	WC-B
1	43.7	45.1	50.1	58.5
2	42.5	46.4	48.3	56.0
3	46.1	43.8	49.8	57.3
4	45.3	46.1	50.0	59.3
5	44.1	49.0	47.7	57.4
Average strength	44.3	46.1	49.2	57.7
Ratio of average strength to 28-day average strength with AC	1.000	1.039	1.109	1.301

3.2 Effect of curing methods to strength development

3.2.1 Air curing

Opening air curing is the most used curing procedure for concrete infrastructures, such as for road concrete, pavement etc. However in many cases, spraying and surface covering etc. are adopted for a couple days after concrete placing to reduce shrinkage and cracking. From Table 3 to Table 5, it can be seen that for the three batches of concrete, the measured 28-day average compressive strength of concrete applied air curing is very close the 28 day target strength. For the C38 concrete its measured concrete strength at 60 days is about 15% higher than its 28-day compressive strength.

3.2.2 Water immersion curing

As described in the previous sections, the water immersion curing procedure applied to the tested concrete cube samples was sorted out into WC-A and WC-B for different curing durations. The WC-A means the curing time up to the testing date, the WC-B means the water immersion time is only 7 days after de-mould, and then AC procedure was applied. From Table 3, it can be seen that for samples with WC-A curing, the 28-day measured average compressive strength is 39.6 MPa, 4.4% higher than the 28 day measured strength of samples applied AC procedure after de-mould. However the 60 day measured compressive strength is 48.8MPa, which is 28.8% higher than 28 day measured strength of samples applied AC procedure and 11.9% higher than 60 day measured strength of samples applied AC procedure. From Table 4 and Table 5, it can be seen that the 28 day measured compressive strength of concrete applied WC-B procedure is much higher than that of samples directly applied AC method after de-mould, the strength increment up to 29.1% for C30 concrete and 30.1% for C45 concrete. The above comparison shows that a long duration of water immersion curing did not benefit the early concrete strength development, inversely the 7-day water immersion cured specimens provided a higher measured strength. The observation indicated that the increase of water immersion curing duration does not result in a quick compressive strength development.

3.2.3 Plastic film cover curing

As well from Table 3, it can be seen that the 28 days measured compressive strength of concrete applied PC-A procedure is just 75.8% of the measured strength of concrete with AC method. Although the 60-day measured compressive strength of concrete applied PC-A procedure is 0.5% higher than the measured 28 day strength of concrete with AC method, it is still just 87.4% of the 60 day measured compressive strength of concrete applied AC procedure. Obviously, for concrete samples applied plastic film cover curing procedure for long duration, the compressive strength development is relatively slow. From Table 4 and Table 5, it can be seen that the 28 day measured compressive strength of concrete applied PC-B procedure is 1.0% higher than that of samples applied AC procedure for C30 concrete and 3.9% higher for C45 concrete. The above observation shows that the long-term plastic film cover curing might slow down the concrete strength development. It might a good practice that applying the plastic film covering to concrete surface not over 7 days if using the plastic film to control the fresh concrete shrinkage and cracking.

3.2.4 Maintaining concrete in steel mould

As shown in Table 3, the 28-day measured compressive strength of concrete applied MC-A procedure is 43.3 MPa, 14.2% higher than 28 day measured strength of samples with AC method. The 60-day measured compressive strength of concrete applied MC-A procedure is 35.3% higher than the 28 day measured strength of samples with AC method and 17.6% higher than the 60 day measured strength of samples with AC method. From Table 4 and

Table 5, it can be seen that the 28 day measured compressive strength of concrete applied MC-B procedure is 15.6% higher than that of samples applied AC procedure after de-mould for C30 concrete and 10.9% for C45 concrete. The above observation showed that maintaining the concrete in the steel mould eusured the concrete strength development in early stage.

4. Conclusions

This paper presents an experimental study to explore the effect of different curing methods/ procedures to the concrete compressive strength. Based on the comparison and analysis of results, the following conclusions can be drawn:

1) The four different curing procedures showed different effects to the compressive strength development of concrete. Short period of water immersion curing in early stage and maintaining concrete in steel mould until test date resulted in higher concrete strength development.

2) Plastic film wrapping fresh concrete for more than 7 days reduced the concrete strength development at early stage. If adopt plastic film to reduce fresh concrete shrinkage or prevent cracking, it is suggested that the curing duration should be not over 7 days.

3) Water immersion curing is an effective curing method. It considerably accelerated the concrete strength development, however long period of immersion curing, such as over 7 days, appears did not benefit concrete compressive strength gain.

4) Steel mould provided an excellent curing environment for concrete inside, this implies that the core concrete in a concrete-filled steel tube member may develop a higher strength than that adopted in design.

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6. References

[1] Neville AM. Properties of Concrete. Fourth Edition. Pearson. 2006.
[2] BS8110-1: 1997. Structural use of concrete - Part 1: Code of practice for design and construction. The British Standard.
[3] Ramezanianpour AA. Effect of Curing on the Compressive Strength, Resistance to Chloride-Ion Penetration and Porosity of Concretes Incorporating Slag, Fly Ash or Silica Fume. Cement & Concrete Composites. 1995; 17:125-133.
[4] Bushlaibi AH, Alshamsi AM. Efficiency of curing on partially exposed high-strength concrete in hot climate. Cement and Concrete Research. 2002; 32: 949-953.
[5] Husem M, Gozutok S. The effects of low temperature curing on the compressive strength of ordinary and high performance concrete. Construction and Building Materials. 2005; 19: 49-53.
[6] Atis CD, Zcan FO, Kılıc A, Karahan O, Bilim C, Severcan MH. Influence of dry and wet curing conditions on compressive strength of silica fume concrete. Building and Environment. 2005; 40: 1678-1683.
[7] Chen HJ, Huang SS, Tang CW, Malek MA, Ean LW. Effect of curing environments on strength, porosity and chloride ingress resistance of blast furnace slag cement concretes: A construction site study. Construction and Building Materials. 2012; 35: 1063-1070.
[8] Bingöl AF, Tohumcu I. Effects of different curing regimes on the compressive strength properties of self compacting concrete incorporating fly ash and silica fume. Materials and Design. 2013; 51: 12-18.
[9] Ibrahim M, Shameem M, Al-Mehthel M, Maslehuddin M. Effect of curing methods on strength and durability of concrete under hot weather conditions. Cement & Concrete Composites. 2013; 41: 60-69.
[10] Usman N, Isa MN. Curing Methods and Their Effects on The Strength of Concrete. Int. Journal of Engineering Research and Application. 2015; 5(7): 107-110.
[11] Princy KP, John E. Study on the Effectiveness of Various Curing Methods on the Properties of Concrete. International Journal of Engineering Research & Technology (IJERT). 2015; 4(11).
[12] Tang Y, Su H, Huang S, Qu CL, Yang JQ. Effect of Curing Temperature on the Durability of Concrete under Highly Geothermal Environment. Advances in Materials Science and Engineering. 2017; 5.
[13] Odeyemi SO, Abdulwahab R, Anifowose MA, Atoyebi OD. Effect of Curing Methods on the Compressive Strengths of Palm Kernel Shell Concrete. Civil Engineering and Architecture. 2021; 9(7): 2286-2291.
[14] Suresh GAB, AGM-R&D. The Effect of Curing Methods and Periods on the Strength and Durability of Concrete. International Research Journal of Engineering and Technology (IRJET). 2021; 8(7).

[15] Zuo ZW, Zhang JC, Li BX, Shen CQ, Xin GF, Chen X. Effect of Curing Regime on the Mechanical Strength, Hydration, and Microstructure of Ecological Ultrahigh-Performance Concrete (EUHPC). Materials. 2022; 15.
[16] Anwar A, Tariq H, Adil A, Iftikhar MA. Effect of curing techniques on compressive strength of concrete. World Journal of Advanced Research and Reviews. 2022; 16(3): 694-710.
[17] Suryawanshi A, Shastri SS. The Effect of Curing Period and Curing Delay on Properties of Hardened Concrete- Review. Journal of Algebraic Statistics. 2022; 13(3): 2289-2292.
[18] Hamada H, Alattar A, Tayeh B, Yahaya F, Almeshal I. Influence of different curing methods on the compressive strength of ultra-high-performance concrete: A comprehensive review. Case Studies in Construction Materials. 2022; 17.