Standard codes of practice for Accelerated Curing of Concrete

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Abstract –

The building construction technology is as old as human civilization. Several types of building construction materials were used in ancient times such as e.g. wood , stone, bricks, iron , lime , cement etc. With introduction of concrete technology the use of above materials and labour in any building construction is subdivided as 16% stone in foundation, 22% bricks in superstructure, 16% iron reinforcement in concrete in columns and roof slab, 10% wood in doors and windows, 16% use of other materials in flooring and remaining parts of buildings and 30% labour cost. With advent of concrete technology use of concrete in-situ is widely increased across the world. Therefore researches were carried out to set standard code of practice to facilitate the users for executing safe and durable construction works. Every nation therefore made standard codes of practice to be followed by civil engineers. Strength of concrete in-situ is gained over period of 28 days depending upon the method of curing followed. It is found that warm water curing results into high strength of concrete at early stages , and maximum strength is achieved in 28 days. In this paper comparative study of codes followed by ASTM C 684 – 99, BS 1881:Part112:1983. and I.S 9013-1978, for making, curing and determining the compressive strength of accelerated cured concrete of test specimens is discussed. Recently green building concept has been introduced. The specification for green building concrete in-situ demands that the materials used in construction must be economical (energy saving in mining), eco-friendly (Control of CO_2 level to make living pleasant) time saving (rapidity in construction). The existing concrete code does not provide specifications for green building concrete materials. Therefore authors carried out further study to know the behavior of concrete when demolished waste concrete of buildings is used as coarse aggregate. Determination of early age strength of concrete is useful in determining compressive strength of concrete in construction of heavy structures such as multi-storey buildings , dams , bridges etc, where maximum load is in vertical direction also there is need of determination of early tensile strength of concrete in case of concrete road pavements. Hence suitability of different methods of accelerated curing is being studied which can be implicated at site without much skilled labour and heavy instruments.
Key words- Accelerated curing; Compressive strength; Standard Code of practice for concrete.

Introduction –

ASTM AMERICAN CODE Designation: C 684 – 99

1.1 American code covers four procedures for making, curing, and testing specimens of concrete stored under conditions intended to accelerate the development of strength. The four procedures are: Procedure A—Warm Water Method, Procedure B—Boiling Water Method, Procedure C—Autogenous Curing Method, and Procedure D—High, Temperature and Pressure Method.

Concrete specimens are exposed to accelerated curing conditions that permit the specimens to develop a significant portion of their ultimate strength within a time period ranging from 5 to 49 hrs, depending upon the procedure that is used. Procedures A and B utilize storage of specimens in heated water at elevated curing temperatures without moisture loss. The primary function of the moderately heated water used in Procedure A is to serve as insulation to conserve the heat generated by hydration. The temperature level employed in Procedure B provides thermal acceleration. Procedure C involves storage of specimens in insulated curing containers in which the elevated curing temperature is obtained from heat of hydration of the cement. The sealed containers also prevent moisture loss. Procedure D involves simultaneous application of elevated temperature and pressure to the concrete using special containers. Sampling and testing procedures are the same as for normally cured specimens .

1.2 BS 1881 : Part 112 : 1983

British Standard describes the methods of accelerated curing of concrete test cubes at 35ºC, 55ºC and 82ºC. Strength test results from cubes that have been subjected to accelerated curing can be used for control purposes and it is also possible to use a regime of accelerated strength testing to judge compliance. In addition, the strength of normally cured concrete at later ages can be predicted by the use of correlations appropriate to the method, materials and mix used. While the 35ºC method is the simplest and most convenient of the three, the correlations for a range of different concretes may be somewhat more widely dispersed than for the 55ºC and 82ºC methods. Experience of accelerated curing of concrete has largely been gained from cubes made with ordinary or rapid hardening Portland cement and without admixtures. If other mixes are used caution is required when interpreting accelerated strength test results.

1.3 IS: 9013-1978

Traditionally, concrete quality in construction works is calculated by its 28 days compressive strength. This procedure requires 28 days of moist curing before testing, which is too long a period to be of any value for either concrete construction control or applying timely corrective measures. If after 28 days the quality of concrete is found to be dubious, it would have considerably hardened by that time and also might have been buried by subsequent construction. Thus replacement of the concrete mass of questionable attributes becomes very difficult and often impractical. On the other hand, if the concrete is found to possess of excessive strength than required, it would be too late to prevent wasteful use of cement on uneconomical mix proportioning. **Hence, standard 28 days cube testing of concrete is not feasible for quality control.**

This standard lays down the method for making, curing and testing in compression, specimens of concrete stored under conditions intended to accelerate the development of strength.

Two methods of accelerated curing have been covered in this standard are as follows :

a) Warm-water method, and

b) Boiling-water method.

EXPERIMENTAL SET UP AND SAMPLES TEST PROCEDURE:

2.1 AMERICAN CODE Designation: C 684 – 99

Equipment and small tools for fabricating specimens, measuring slump, and determining air content shall conform to Practice C 31/C 31M.

Moulds: Cylinder moulds for test specimens used in Procedures A, B, and C shall conform to Specification C470. Paper molds are excluded. When specimens are to be tested without capping, use only reusable molds with machined end plates that can be securely connected to both top and bottom of the mold. The end plates shall produce specimens with bearing surfaces that are plane within 0.05 mm (0.002 in.) and whose ends do not depart from perpendicularity to the axis of the cylinder by more than 0.5° (approximately equivalent to 10 mm/m (1⁄8 in. in 12 in.). When assembled, the mold assembly is sufficiently tight to permit the filled mold to be turned from the vertical filling position to a horizontal curing position without loss of mortar or damage to the test specimen.

Cylinder molds for Procedure D shall conform to the following: Made of stainless steel,

Equipped with removable top and bottom metal plugs and O-ring seals, Equipped with a heating element capable of raising the concrete temperature within the mold to 150±3°C(300 ± 5°F) within 30±5 min, and are capable of maintaining this temperature throughout the time required by the test procedure, Equipped with devices to measure the temperature within each mold to ascertain that the temperature of the concrete satisfies the temperature requirements stated herein, and equipped with a companion loading component capable of maintaining a pressure of 10.3 MPa ± 0.2 MPa (1500 ± 25 psi) on the concrete during the curing period.

Curing Apparatus: Accelerated Curing Tank for Procedures A and B:

The tank is of any configuration suitable for the number of cylinders to be tested. Arrange the cylinders in any configuration that provides a clearance of at least 50 mm (2 in.) between the side of each cylinder and the side of the tank, and at least 100 mm (4 in.) between adjacent cylinders. Maintain the water level at least 100 mm (4 in.) above the tops of the cylinders.

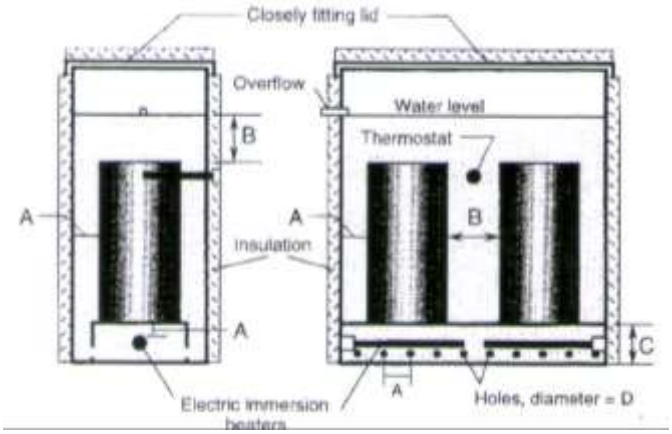


Fig. (1) – Test Apparatus ASTM

2.2 <u>BS 1881 : Part 112 : 1983</u>

Cover plate. A rigid plate, such as a base plate, to cover each mould to isolate the concrete from the water of the curing tank. The material for this cover plate shall be such that it does not react with the concrete or the mould.

Curing tank. A curing tank constructed from any material which is of adequate strength and corrosion resistant, provided with a lid and instruments for continuous recording of the water temperature. The internal dimensions of the tank shall be appropriate for the number and size of the test specimens to be accommodated, shall permit adequate circulation of the water and shall be such that the specimens can be removed easily. In order to provide adequate circulation of the water there shall be at least 30 mm of water above, below and around each specimen and in addition the specimens shall be at least 30 mm above the heating element. The curing tank shall be capable of holding sufficient water and of being controlled so that the temperature of the water at any point within the tank is maintained at 35 ± 2ºC at all times.

Thermometer, suitable for measuring maximum and minimum curing temperatures. *Temperature* recorder. Recording thermograph and probe or similar arrangement fitted in the curing tank to provide a continuous record of the temperature in the curing tank for the whole of the curing cycle.

Making test cubes. Make the test cubes by the method described in BS 1881 : Part 108. Finish the upper surface of the concrete level with the top of the mould and then wipe the mould clean.

Procedure : Thinly coat the cover plate with release agent to prevent adhesion of the concrete and place it in position to form a watertight seal: then immediately lower the specimens gently into the filled curing tank, ensuring that they are adequately spaced. Totally immerse the specimens for a period of 24h±15min, continuously recording the water temperature which shall be maintained at 35±2ºC at all times except for a period not exceeding 15 min immediately after immersion of the specimens. Remove the specimens from the curing tank, de-mould the cubes and clearly and indelibly mark each one with an identification number or code. Testing of the cubes is done as soon as possible after removal from the curing tank.

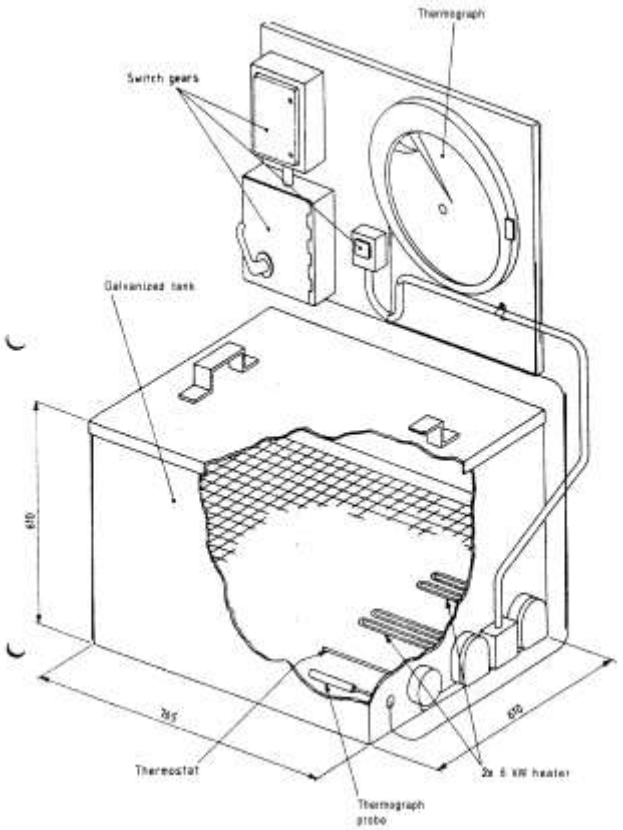


Fig.(2) – Test Apparatus B.S.

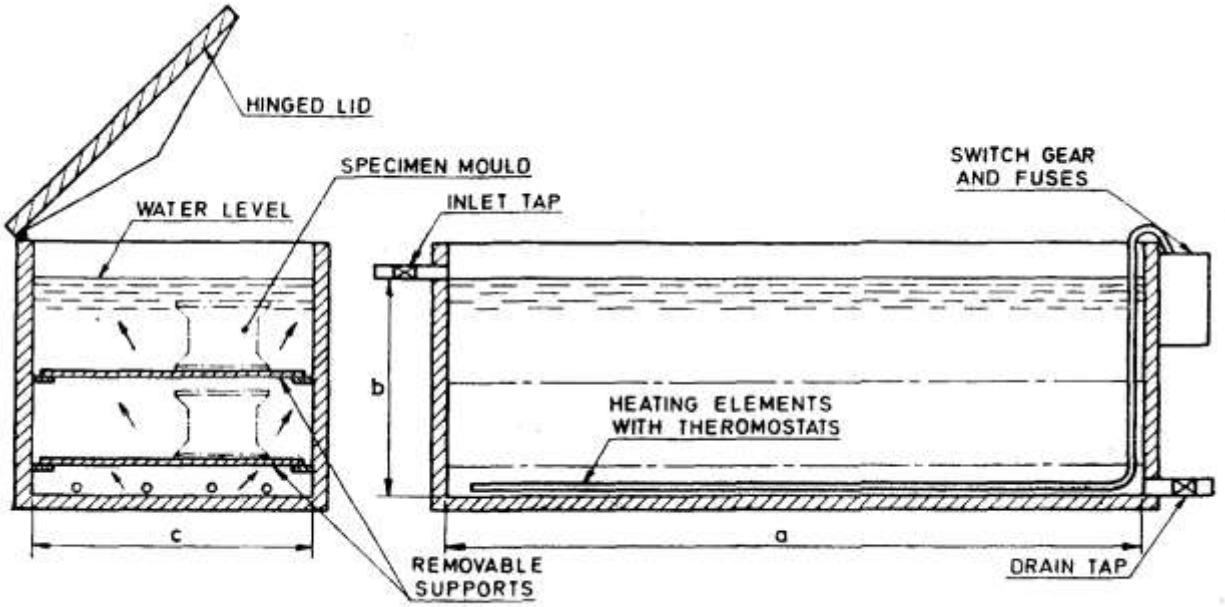
2.3 IS : 516-1959.

Mould Cover Plate - Each mould shall be provided with a flat steel cover plate, rigid enough so as to avoid distortion during use and of dimensions such that the plate completely covers the top edge of the mould.

Curing Tank

The curing tank shall be constructed from any material of suitable strength that will resist the effects of corrosion. The internal dimensions of the tank shall be adequate to accommodate the required number and size of the test specimens such that test specimens can be easily removed.

The tank shall contain sufficient water and be controlled so that the temperature of the water around the specimens immersed in the tank is maintained at the desired level at all times except for a period not exceeding 15 minutes immediately after the immersion of a freshly made specimen into the tank. A typical diagrammatic layout of a tank suitable for accelerated curing of test specimens is given in Fig.(3)



NOTE — The dimensions *a*, *b* and *c* of curing tank suitable for accommodating twelve, 150 mm cubes are 1·60 m, 0·50 m and 0·65 m respectively.

Fig. (3). Test Apparatus I.S.

PREPARATION OF TEST SPECIMENS

The preparation of test specimen including sampling of materials, preparation of materials, proportioning, weighing, mixing, testing for workability, choice of the size of test specimens, compacting, and capping of specimen shall be in accordance with IS: 516-1959*, if tests are intended to draw correlation curve between the results from compressive strength tests on specimens cured by normal curing method and accelerated curing method.

If the tests are intended for control purposes, sampling shall be done in accordance with IS : 1199-1959 and choice of the size of test specimens, compacting and capping of specimen shall be in accordance with IS:516-1959. Immediately after moulding, each specimen shall be covered with a steel plate thinly coated with mould oil to prevent adhesion of concrete.

ACCELERATED CURING BY WARM WATER METHOD

After the specimens have been made, they shall be left to stand undisturbed in their moulds in a place free from vibration at a temperature of 27±2°C for at least one hour, prior to immersion in the curing tank. The time between the addition of water to the ingredients and immersion of the test specimens in the during tank shall be at least 14 hours but shall not exceed 34 hours.

The specimens in their moulds shall be gently lowered into the curing tank and shall remain totally immersed at 55 ± 2°C for a period of not less than 19 hours 50 minutes. The specimens shall then be removed from the water, marked for identification, removed from the mould and immersed in the cooling tank at 27 ± 2°C before the completion of 20 hours 10 minutes from the start of immersion in the curing tank. They shall remain in the cooling tank for a period of not less than one hour.

ACCELERATED CURING BY BOILING WATER METHOD

After the specimens have been made, they shall be stored in a place free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27±2°C for 23 hours ± 15 minute from the time of addition of water to the ingredients.

The specimens shall then be gently lowered into the curing tank and shall remain totally immersed for a period of 3½ hours ± 5 minutes. The temperature of the water in the curing tank shall be at boiling (100°C) at sea level. The temperature of water shall not drop more than 3°C after the specimens are placed and shall return to boiling within 15 minutes.

After curing for 3½hours±5 minutes in the curing tank, the specimen shall be removed from the boiling water, removed from the moulds and cooled by immersing in cooling tank at 27±2°C for 2h.

TESTING

The specimens shall be tested in accordance with IS : 516-1959.

In the warm water method specimens shall be tested while still wet, not more than 2 hours from the time of immersion in the cooling tank.

In the boiling water method, the age at the time of test shall be 28½ hours ± 20 minutes.

3.1 Test Results and Report- ASTM

TABLE 1 Characteristics of Accelerated Curing Procedures

	Procedure	Molds	Source of Strength Acceleration	Accelerated Curing Temperature °C (°F)	Age Accelerated Curing Begins	Duration of Accelerated Curing	Age at Testing
A	Warm Water	reusable or single-use	heat of hydration	35 (95)	immediately after casting	23.5 h ± 30 min	24 h ± 15 min
B	Boiling Water	reusable or single-use	boiling water	Boiling(100^0C)	23 h ± 30 min after casting	3.5 h ± 5 min	28.5 h ± 15 min
C	Autogenous	single-use	heat of hydration	initial concrete temperature augmented by heat of hydration	immediately after casting	48 h ± 15 min	49 h ± 15 min
D	High-Temperature and Pressure	reusable	external heat and pressure	150 (300)	immediately after casting	5 h ± 5 min	5.25 h ± 5 min[A]

3.2 Test Results and Report - B.S.

General. The report shall affirm that the cubes were cured in accordance with this Part of this British Standard. The report shall state whether or not a certificate of sampling and specimen preparation is available. If available, a copy of the certificate shall be provided.

Information to be included in the report

Mandatory information. The following information shall be included in the test report:

(a) identification number or codes of specimens:

(b) method of curing (35 ºC, 55 ºC or 82 ºC method);

(c) maximum and minimum curing temperatures;

(d) certificate that curing has been carried out in accordance with this Part of this standard.

Optional information. If requested the following information shall be included in the test report:

(a) time of adding water to the other materials in the concrete mix;

(b) time of making cubes;

(c) time of immersion of cubes into curing tank;

(d) time of removal of cubes from curing tank;

(e) time when cubes placed in and removed from cooling tank (55 ºC method only);

(f) temperature record during curing.

3.3 Test Results and Report- I.S.

The calculation of compressive strength shall be done in accordance with IS : 516- 1959.

The following information shall be included in the report on each test specimen:

1 Identification mark (including the size and type) of test specimens and date of casting;

2 Date and time of test and age of specimen;

3 Particulars of concrete from which test specimen was made;

4 Method of compaction;

5 Size of specimen;

6 Mass of specimen;

7 Defects, if any, in specimen;

8 Time of adding water to concrete materials;
9 Time of making test specimen;
10 Time of immersion of test specimen into curing tank;
11 Time of removal of test specimen from curing tank;
12Time of immersion of test specimen into cooling tank;
13 Time of removal of test specimen from cooling tank;
14 Thermo graphic record of temperature of water in curing tank;
15 Maximum load at crushing;
16 Compressive strength; and
17 Description of fractured face.

4. Conclusion-

Following conclusions have been drawn:

1.Curing of concrete is very important for the durability of structure. It also controls the compressive strength desired for design conditions of structure. In this review paper it has been found that there are various methods of curing which can be applied for determining compressive strength at initial stages after casting so that quality of concrete can be monitored. Many researchers have developed different methods & formulae which can be applied for predicting early gain of strength in short duration, i,e. 28 days compressive strength can be achieved in 7 to 14 days even more earlier. Much research work is to be done in this field regarding economy of the test and also on the simplicity, so that expenses on testing instruments and experimental setup can be curtailed and monitoring of the concrete strength gain be done economically.

2.Boiling water curing technique is useful in the prefabrication industry, wherein high early age strength enables the removal of the formwork within 24 hours, thereby reducing the cycle time, resulting in cost-saving benefits. Early gain in strength can be explained due to heightened temperatures in curing , the hydration process moves more rapidly and the formation of the Calcium Silicate Hydrate crystals is more rapid. The formation of the gel and colloid is more rapid and the rate of diffusion of the gel is also higher. The reaction being more rapid hence resulting in early gain in strength of concrete .

It has been found after 1^{st} day of casting, concrete gains 16% of its maximum strength but due to different weather conditions the % strength may vary in colder or in hotter climate as hydration process is affected due to weather temperature, also it will be too early to perform testing after 1^{st} day normal concrete curing . After 3 days concrete gains 40% of its max strength , but 3 days will be too late for taking decision about quality of concrete . So, it has been found boiling water curing technique is simple in which accelerated curing is to be done at constant temperature of 100^0C for 3.5 h ± 5 min after 23 h ± 30 min after casting. BWT can be employed any where without much skill supervision. Equipments and labour required are also cheap and testing arrangement can be done in-situ.

3.Accelerated curing gives initial higher values of compressive strength over normal curing method..Therefore it is useful in taking decision about the quality of concrete work well in advance.

Concrete of OPC with different mix proportions and different water cement ratios , gains approx 80% of its 28 days strength by normal curing on 1^{st} day by accelerated curing.

Concrete of PSC Cement with different mix proportions and different water cement ratios , gains approx 55% of its 28 days strength by normal curing on 1^{st} day by accelerated curing.

Concrete of PPC Cement with different mix proportions and different water cement ratios, gains approx 50% of its 28 days strength by normal curing on 1^{st} day by accelerated curing.

4. Early flexural strength of concrete can also be determined on concrete as tensile load is applied in case of concrete road pavements.

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