Standard Test of Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

الفحص القياسي لمقاومة الإنثناء للخرسانة

1- Scope: To measure the flexural strength of concrete specimens by the use of a simple beam (or prism) with center-point loading to estimate in direct tensile strength of concrete.

الغرض من الفحص: لقياس مقاومة الإنثناء للخرسانة بإستخدام عتب او موشور تحت إسناد بسيطو محمل بنقطة تحميل مركزية وذلك اتخمين مقاومة الشد الغير مباشرة للخرشانة.

2- Apparatus

1- Standard prism (or beam) molds.

2- Steel floats: Two plasterer's steel floats (mallets).

3-Scoop

4-Sampling tray, 1.2 m x 1.2 m x 50 mm deep made from minimum 1.6 mm thick non-corrodible metal.

5- Square mouthed shovel,

6-Tamping rod, made out of straight steel bar of circular cross section, 16 mm diameter, 600 mm long with both ends hemispherical.

الأجهزة والأدوات:

1- قوالب عتب او موشور قياسية.

2-مالجين

3-مغرفة بحجم مناسب.

4- وعاء كبير بأبعاد 120*120*5 سم

5- مقلابة (كرك) ذو مقطع مربع.

6- عصا رص مدورة النهاية بقطر 16 ملم وطول لايقل 60 سم.

3-Procedure

1- The moulds must be lightly coated in a mould release agent. This ensures that the concrete does not stick to the mould and makes it easier to remove the specimen.

2- Concrete Mixing:

Hand Mixing— are not applicable to air-entrained concrete or concrete with no measurable slump. Hand mixing should be limited to batches of 0.007 m3 [1⁄4 ft3] volume or less. **Machine Mixing**—Prior to starting rotation of the mixer add the coarse aggregate, some of the mixing water, and the solution of admixture, when required. When feasible, disperse the admixture in the mixing water before addition. Start the mixer, then add the fine aggregate, cement, and water with the mixer running. If it is impractical for a particular mixer or for a particular test to add the fine aggregate, cement, and water while the mixer is running, these components may be added to the stopped mixer after permitting it to turn a few revolutions following charging with coarse aggregate and some of the water. Mix the concrete, after all ingredients are in the mixer, for 3 min followed by a 3-min rest, followed by a 2-min final mixing. Cover the open end or top of the mixer to prevent evaporation during the rest period. Take precautions to compensate for mortar retained by the mixer so that the discharged batch, as used, will be correctly proportioned. To eliminate segregation, deposit machine-mixed concrete in the clean, damp mixing pan and remix by shovel or trowel until it appears to be uniform.

3- Consolidation or Compaction:

Base the selection of the Consolidation method on the slump. Rod or vibrate concrete with slump greater than or equal to 25 mm [1 in.]. Vibrate concrete with slump less than 25 mm [1 in.]. Do not use internal vibration for cylinders

with a diameter less than 100 mm [4 in.], and for beams or prisms with breadth or depth less than 100 mm [4 in.].

Hand Compaction Place the concrete in the mold, in the required number of layers of approximately equal volume. Rod each layer with the rounded end of the rod using the number of strokes and size of rod specified in Table 2. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate through the layer being rodded and into the layer below about 25 mm [1 in.]. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single-use molds which are susceptible to damage if tapped with a mallet.

Mechanical Compaction (Vibration)—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete. Fill the molds and vibrate in the required number of approximately equal layers (Table 2). Place all the concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than 6 mm [1⁄4 in.]. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about 3 mm [1⁄8 in.], work it into the surface and then strike it off. It is very important not to over vibrate the layers as it may lead to segregation / disruption of the concrete mix.

4- Once complete, the concrete is levelled off using a concrete float or trowel to give a smooth surface flush with the top of the mould.

5- Labelling: It's very important to uniquely identify each of the cubes (and moulds) and to record where they have come from.

6- Initial Curing—To prevent evaporation of water from unhardened concrete, cover the specimens immediately after finishing, preferably with a non-absorptive, nonreactive plate or a sheet of tough, durable impervious plastic. Record the maximum and minimum ambient temperatures during the initial curing.

7- Removal from Molds—Remove the specimens from the molds 24 ± 8 h after casting. For concrete with prolonged setting time, molds shall not be removed until 20 ± 4 h after final set.

8- Curing Environment—Unless otherwise specified all specimens shall be moist cured at 23.0 6 2.0°C [73.5 6 3.5°F] from the time of molding until the moment of test. Storage during the first 48 h of curing shall be in a vibration free environment.

9- Specimens are generally tested at 7 & 28 days unless specific early tests are required, for example to remove a concrete shutter safely prior to 7 days.

10- The specimens are removed from the curing tank, dried and grit removed. Do not dry the faces of the prism or beam.

11- The specimens are tested using a calibrated compression machine. The compression machine exerts a constant progressing force on the specimens till they fail. Apply the load so that the maximum stress on the tension face increases at a rate between 0.9 and 1.2 MPa/min. The reading at failure is the maximum strength of the concrete.

طريقة العمل

1- تدهن الاسطح الداخلية للقوالب لمنع التصاق الخرسانة بالقالب.

2- عملية الخلط:

يمكن إستخدام الخلط اليدوي عندما لا يتجاوز حجم الخلطة على 0.007 متر مكعب ولا يمكن إستخدام الخلط اليدوي عندما تحوي الخرسانة على مضافات تسبب فقاعات هوائية أو عندما لا يعمل فحص الهطول للخلطة مسبقا. أما في الخلط الآلي فيضاف الركام الخشن أولا وجزء من ماء الخلط واي محلول مضاف مراد إستخدامه الى الخلاط ثم يضاف الرمل والسمنت وباقي الماء (اما اذا تعذر ذلك بسبب الحجم المحدود للخلاط عندها يمزج السمنت والرمل ويضاف مزيج السمنت والرمل وباقي ماء الخلط) بعد اضافة جميع مكونات الخرسانة في الخلاط تترك لتمزج لمدة 3 دقائق ثم فترة استراحة حيث يتم ايقاف الخلاط لمدة 3 دقائق ويجب تغطية الخلاط لمنع التبخر في هذه الفترة ثم يعاد تشغيل الخلاط لفترة 2 دقيقة. يجب الانتباه الى عدم ترك المونة الملتصقة في جدران الخلاط للحفاظ على نسب الخلطة المطلوبة. ولمنع الانعزال تفرغ الخرسانة في وعاء رطب ويعاد خلطها قليلا بواسطة المغرفة لضمان التجانس.

3- عملية الرص:

تحدد طريقة الرص المناسبة (يدوية ام آلية) بإعتماد مقدار الهطول للخلطة أذا كان الهطول أكثر أو مساوي 2.5 سم يمكن الرص آاليا أو يدويا اما إذا كان الهطول أقل من 2.5 سم فيتم إستخدام الرص الآلي. يملئ القالب بعدد من الطبقات المتساوية الحجم وحسب جدول رقم(1) وترص كل طبقة بعدد من الضربات كما موضح في جدول رقم (2).

في الرص اليدوي يتم إستخدام عصا الرص القياسية بحيث عصا الرص تخترق الطبقة المراد رصها ويمكن أن تخترق الطبقة التي تحتها (إن وجدت) بعمق 2.5 سم وبعد رص كل طبقة يدق القالب بواسطة

المالج بعدد 10-15 ضربة خفيفة لأخراج الفقاعات الهوائية المحصورة. أما في حالة الرص الالي فإن الهزاز الكهربائي يستخدم للرص لكل طبقة حتى تنتهي الفقاعات من السطح. عند رص الطبقة الاخيرة يجب ان يراعى ملئ القالب بالخرسانة حتى تعلو حافة القالب لكن ليس اكثر من 6 ملم.

4- يعدل سطح القالب بالمالج ويضاف مونة إسمنت بسمك قليل تقريبا 3 ملم ويعدل السطح لحين الحصول على سطح أملس.

5- توضع علامات على النماذج لبيان تاريخ الصب وغيرها من المعلومات المهمة لتمييز النماذج.

6- الإنضاج الإبتدائي: مباشرة بعد اكمال تحضير النماذج يغطى السطح العلوي بأي مادة مانعة لتبخر الماء ويوضع القالب في مكان بعيد عن الاهتزازات ويترك لمدة 8±24 ساعة أما إذا كانت الخرسانة من النوع البطيئة التصلب فتترك لمدة 20±4 ساعة من وقت التماسك النهائي. بعد ذلك تفتح القوالب.

7- بيئة الإنضاج : توضع النماذج في الماء لغرض الانضاج في درجة حرارة 2±23 درجة مئوية وبعيدا عن الاهتزازات ويجب ان تغمر كليا بالماء لحين يوم الفحص.

8- تفحص عادة في عمر 7 أيام وعمر 28 يوم.

9- تزال النماذج من خزان الماء وتنظف من اي شوائب. يجب أن لا تنشف أوجه العتب أو الموشور من الماء قبل الفحص.

10- تفحص النماذج بوضعها في الجهاز الخاص لهذا الفحص. يجب ان يكون معدل التحميل منتظم بحيث يحقق زيادة في الاجهاد الاقصى للشد بمعدل MPa/min(0.9 ~1.2).

4-Calculations:

$$R = \frac{3\ PL}{2\,bd^2}$$

where: R = modulus of rupture, MPa [psi],

P = maximum applied load indicated by the testing machine, N [lbf],

L = span length, mm [in.], b = average width of specimen, at the fracture, mm [in.], and

d = average depth of specimen, at the fracture, mm [in.].

5-Discussion:

- (Direct tension < Splitting Tension < Flexure Tension) because of two reasons: First, the usual size of laboratory specimens contains a fewer weak elements than the real volume of concrete structural members meaning more chances to failure to occur. Second, Splitting and Flexure tests involve non-uniform stress distribution (not direct tension) that can impede crack propagation.
- The flexural strength of concrete at 28 day-age is about 10% to 20% of compressive strength, thus the flexural strength should not be less than 2.5 MPa for structural use.
- The flexural strength depends on water content and the physical characteristics of aggregate, like the aggregate texture, the grading of aggregate.
- The type of the aggregate can affect the flexural strength more than the direct tension and splitting strengths. The flexural strength is higher when the crashed angular aggregate is used than with rounded natural aggregate this is because increasing the bond strength which hold the materials together to sustain more load before failure.

- The moisture condition of concrete influences the relation between the flexural and the compressive strength of the concrete. Flexural strength of continuously wet stored concrete than that of concrete cured wet and then stored in a dry environment. This is because flexural strength is more affected by the shrinkage cracks.
- Flexural strength of concrete is used for pavement design since the pavement design depends on a theory based on flexural strength while very few use flexural testing for structural concrete.

TABLE 1 Number of Layers Required for Specimens

Specimen Type and Size	Mode of Consolidation	Numbers of Layers of Approximate Equal Depth
Cylinders: Diameter, mm [in.]		
75 to 100 [3 or 4]	rodding	2
150 [6]	rodding	3
225 [9]	rodding	4
up to 225 [9]	vibration	2
Prisms and horizontal creep Cylinders: Depth, mm [in.]		
up to 200 [8]	rodding	2
over 200 [8]	rodding	3 or more

TABLE 2 Diameter of Rod and Number of Roddings to be Used in Molding Test Specimens

Cylinders		
Diameter of Cylinder, mm [in.]	Diameter of Rod mm [in.]	Number of Strokes/Layer
75 [3] to < 150 [6]	10 ± 2 [⅜ ± 1/16]	25
150 [6]	16 ± 2 [⅝ ± 1/16]	25
200 [8]	16 ± 2 [⅝ ± 1/16]	50
250 [10]	16 ± 2 [⅝ ± 1/16]	75
Beams and Prisms		
Top Surface Area of Specimen, cm^2 [$in.^2$]	Diameter of Rod mm [in.]	Number of Roddings/Layer
160 [25] or less	10 ± 2 [⅜ ± 1/16]	25
165 to 310 [26 to 49]	10 ± 2 [⅜ ± 1/16]	one for each 7 cm^2 [1 $in.^2$] of surface
320 [50] or more	16 ± 2 [⅝ ± 1/16]	one for each 14 cm^2 [2 $in.^2$] of surface
Horizontal Creep Cylinders		
Diameter of Cylinder mm [in.]	Diameter of Rod mm [in.]	Number of Roddings/Layer
150 [6]	16 ± 2 [⅝ ± 1/16]	50 total, 25 along both sides of axis

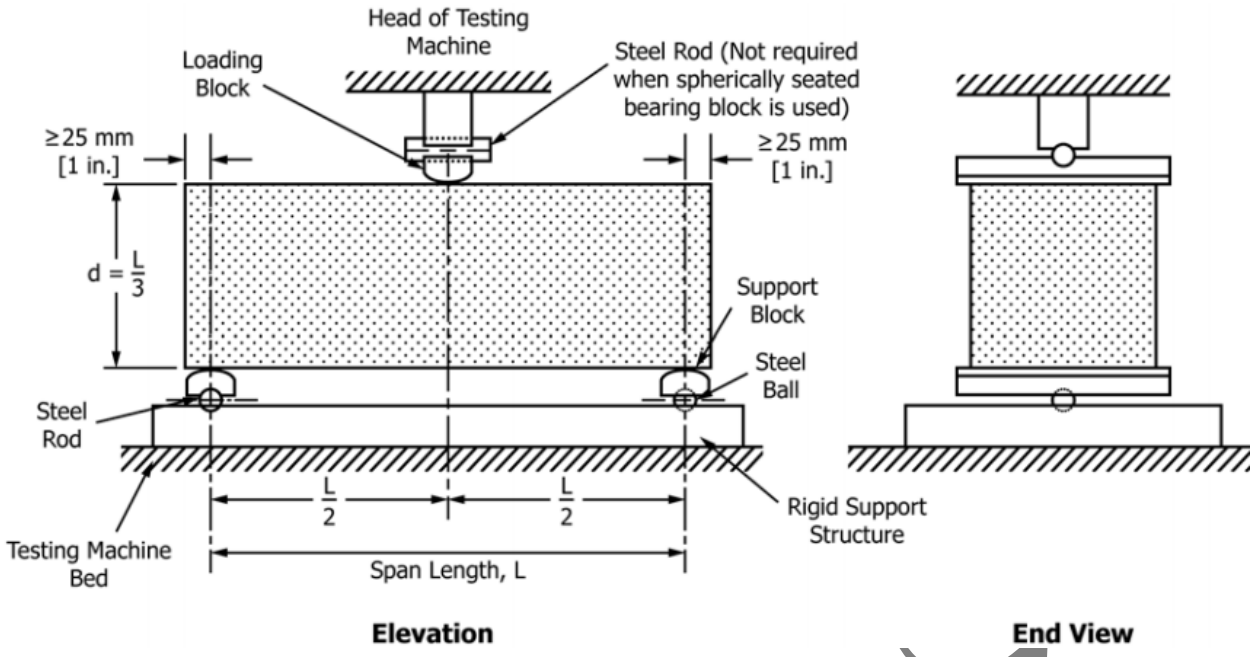

Figure (1): Specimen Setup

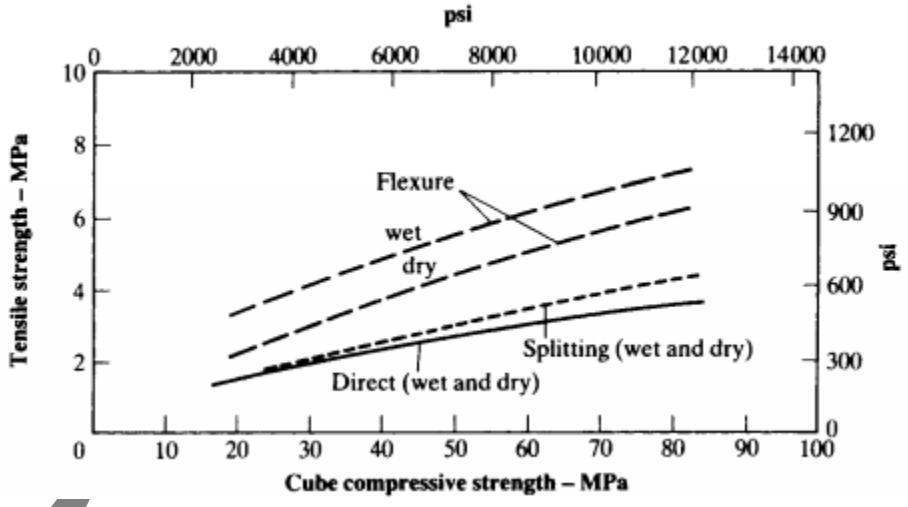

Figure (2): Relation between Moisture Conditions and Compressive Strength versus Tensile Strength

References:

1- C293/C293M − 16 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

2-Concrete Technology Book by A.M. Neville, J.J. Brooks

3- C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

4- ACI 318 Building Code Requirements for Structural Concrete and Commentary

5-ACI 213R-03 Guide for Structural Lightweight-Aggregate Concrete