BEHAVIOR 0F HIGH STRENGTH CONCRETE BEAMS USING RISEN EPOXY

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ABSTRACT

Reinforced concrete beams for high-strength concrete often exhibit structural and nonstructural cracking due to variety steel reinforcement. Four reinforced concrete beams with dimensions of (120*230*2550)mm were investigated. Beams (1&2) have tensile steel ratio (0.0099), while beams (3&4) have tensile steel ratio (0.018). Deflections were measured at first third, second third and mid span for original repaired beams using dial gauges with accuracy 0.01 mm. The repair strength achieved for risen epoxy injection high-strength reinforced concrete beams was shown similar that original beams, but a little deference. The failure load for repaired beams higher than original beams.

Keywords: compressive strength: concrete: high-strength concrete: risen epoxy: deflection

تصرف الجسور الخرسانية عالية المقاومة باستخدام ايبوكسي الراتنج

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الخلاصة

العتبات الخرسانية المسلحة عالية المقاومة ترسم تشققات إنشائية وغير إنشائية تبعا لتنوع حديد التسليح.أربع عتبات خرسانية مسلحة بأبعاد (120*230*2550 ملم) تم فحصها.العتبات (1 و 2) تمتلك نسبة حديد تسليح في منطقة الشد (0,0099) بينما العتبات (3 و 4) نسبة حديد التسليح في منطقة الشد (0,018). الانحرافات التي قيست في الثلث الأول والثلث الثاني ومنتصف العتبات الأصلية والمصلحة باستخدام مقاييس بدقة 0,01 ملم.مقاومة التصليح لايبوكسي الراتنج المحقون للعتبات الخرسانية المسلحة نفس مقاومة العتبات الأصلية لكن باختلاف قليل.حمل الفشل للعتبات المصلحة اكبر من العتبات الأصلية.

INTRODUCTION:

The cracks may represent the total extent of the damage, or pointing to greater magnitude of problems. Their significance depends on the type of structure, as well as the nature of the cracking. For example, the cracks which acceptable for buildings may not be acceptable in water retaining structures.

The proper repair of cracks depends on knowing the causes and selecting the repair procedures that take these causes into account; except that, the repair may be temporary only. Successful long-term repair procedures must cure causes the cracks as well as the cracks itself. Generally, the kind of the cracks that attack concrete classify according to its stiffening; cracking of plastic concrete and cracking of hardened concrete.

Plastic shrinkage, the crack of plastic concrete occurs when subjected to a very rapid loss of moisture caused by a combination of factors which include air and concrete temperatures, relative humidity and wind velocity at the surface of the concrete.

The another type is the crack of hardened concrete which have many sort; drying shrinkage, thermal stresses, chemical reaction, weathering, construction overloads and errors in design. A common cause of cracking in concrete is restrained drying shrinkage.

1**.** Drying shrinking is caused by the loss of moisture from the cement paste constituent, which can shrink by as much as 1 percent [(1)].

2**.** Thermal stresses**,** which accrue when the temperature differ within the concrete structure.

When the tensile stresses due to the differential volume changes exceed the tensile stress capacity, the concrete will crack.

3. Chemical reaction may cause cracking of concrete. These reactions due to materials used in concrete or materials that come into contact with the concrete after it has hardened (ACI 201.2R).

4. Weather can cause cracking include; freezing and thawing, wetting/drying and heating/cooling[(1)].

5. Construction overloads can often be far more severe than those experienced in service. These conditions may occur at early ages, when the concrete susceptible to damage and they often result in permanent cracks.

6. Errors in design/detailing, these effects range from poor appearance to lack of serviceability to catastrophic failure.

Predication of immediate deflection of reinforced concrete beams after repairing the cracks using injection of Risen Epoxy and studying effecting reinforcement ratio at tension and compression zone on this deflection.

SELECTION OF REPAIR PROCEDURES:-

Based on the careful evaluation of the extent and cause of the cracking, procedures can be selected accomplish one or more of the following objectives:

1. restore and increased strength;
2. restore and increased stiffness;
3. improve functional performance;
4. provide water tightens;
5. improve appearance of the concrete surface;
6. improve durability, and
7. prevent development of corrosive environment at reinforcement.

Depending on the nature of the damage, one or more repair methods may be selection for example, tensile strength may be restored across a crack by injecting it with epoxy or other high strength bonding agent. However, it may be necessary to provide additional strength by adding reinforcement or using post tensioning. Epoxy injection alone can be used to restore flexural stiffness if further cracking is not anticipated (ACI 503 R).

Cracks causing leaks in water-retaining or other storage structures should be repaired unless the leakage is considered minor or there is an indication that the crack is being sealed by autogenously healing. Repairs to stop leaks may be complicated by a need to make the repays while the structures are in service.

Cosmetic considerations may require the repair of cracks in concrete. However, the crack locations may still be visible and it is likely that some from of coating over the entire surface may be required. To minimize future deterioration due to the corrosion of reinforcement, cracks exposed a moist or corrosive environment should be sealed. The key methods of crack repair available to accomplish the objectives outlined are described later. Following the evaluation of the cracked structure, a suitable repair procedure can be selected. Successful repair procedures take into account the cause(s) of the cracking. For example, if the cracking was primarily due to drying shrinkage, then it is likely that after a period of time the cracks will stabilize. On the other hand, if the cracks are due to a continuing foundation settlement, repair will be of no use until the settlement problem is corrected [2].

This article provides a survey of crack repair method, including a summary of the characteristics of the cracks that may be repaired with each procedure the types of structures that have been repaired, and summary of the procedures that are used Readers are also directed to ACI 546.1 R and ACI compilation No-5(1980), which specifically address the subject of concrete repair ( ).

INSTRUMENT USED IN TESTING:-

3.1- Flexural Machine (MFL system) by using two point load mode (capacity = 3000 KN).

3.2- Dial gauges (with accuracy 0.01 mm).

3.3- Srain gages.

All the above instruments are shown in **Fig (1)** during the testing.

Epoxy Injection Implemented In This Work

Cracks are narrow as 0.002 in (0.05 mm) can be bonded by the injection of Risen epoxy. The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surface and injecting the epoxy under pressure.

Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams and other type of concrete structures. However, unless the cause of the cracking has been corrected, it will probably recur near the original crack. If the cause of the cracks cannot be removed than two options are available. One is to rout and seal the crack, thus treating it as a joint or establish a joint that will accommodate the movement and inject the crack with epoxy or other suitable material.

With the exception of certain moisture tolerant epoxies, this technique is not applicable if the cracks are actively leaking and cannot be dried out. Wet cracks can be injected using moisture tolerant materials, bit contaminants in the cracks (including silt and water) cam reduce the effectiveness of die epoxy 10 structurally repair the cracks.

The use of a low-modulus, flexible adhesive in a crack will not allow significant movement of the concrete structure. the effective modulus of elasticity of a flexile adhesive in a crack is substantially the same as mat of a rigid adhesive because of the thin layer of material and high lateral restraint imposed by the surrounding concrete.

Epoxy injection requires a high degree of skill for satisfactory execution and application of the technique may be the limited by the ambient temperature. The general procedures involved in epoxy injection are as follows:-

Clean the cracks, the first step is to clean the cracks that have been contaminated; to the extent this is possible and practical. Contaminants such as oil, grease, din or fine particles of concrete prevent epoxy penetration and bonding and reduce the effectiveness of repairs. Preferably, contamination should be removed by vacuuming or flushing with water or other especially effective cleaning solutions. The solution is then flushed out using compressed air and a neutralizing agent or adequate time provided for air drying it is important. However, to recognize it practical limitations of accomplishing complete crack cleaning. A reasonable evaluation should be made of the extent and necessity of cleaning trail cleaning may be required.

Seal the surfaces, surface cracks should be sealed to keep the epoxy from leaking out before it has gelled the crack face cannot be reached but where there is backfill, or where a slab-on-grade is deign repaired, the backfill material or sublease material is sometimes an adequate seal. However, such a condition can rarely be determined in advance and uncontrolled injection can cause damage such as plugging a drainage system. Extreme caution must therefore be exercised when injection cracks that is not visible on all surfaces. A surface can be sealed by applying an epoxy, polyester or other appropriate sealing material to the surface of the crack and allowing it harden. If a permanent glossy appearance along the crack is objectionable and if high injection pressure is not required a strippable plastic surface sealer may be applied along the face of the crack. When die job is completed, the surface sealer can be stripped away to expose the gloss free surface. Compendious seals can also be used where appearance of the completed work is important. If extremely high injection pressures are needed, the crack can be cut out to a depth of 1/2 in (13 mm) and width of about 3/4 in (20 mm) in a V-shape filled with an epoxy and struck off flush with the surface.

Install the entry and venting pones, three methods are in general use:-

a. Fittings inserted into drilled holes. This method was the first be used and is often used in conjunction with V-grooving of the cracks. The method entails drilling a hole into the crack, approximately 3/4 in (20 mm) in diameter and 1/2:1 in (13 to 25 mm) below the apex of the V-grooving section into which a fining such as a pipe nipple or tire valve stem is usually bonded with an epoxy adhesive. A vacuum chuck and bit or a water-cooled core bit is useful in preventing the cracks from being plugged with drilling dust.
b. Bonded flush fitting. When the cracks are not V-grooved, a method frequently used to provide an entry port is bond a fitting flush with the concrete face over the crack. The flush fitting has an opening at the cop for die adhesive enter and a flange at the bottom chat is bonded to the concrete.
c. Interruption in seal another system of providing facture’s instructions, usually with the use of a mechanical stirrer like a paint mixing paddle. Care must be taken to mix only the amount of adhesive that can be used prior to commencement of gelling of the material. When the adhesive material begins to gel its flow characteristics begin to change and pressure injection becomes more and more difficult. In discontinuous mixing system, the two liquid adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head. The continuous mixing system allows the use of fast setting adhesives that have a short working life.

- Inject the epoxy. Hydraulic pumps, paint pressure pots or air-actuated caulking guns may be used. The pressure used for injection must be selected carefully, increased pressure often dose little accelerate the rate of injection. In face, the use of excessive pressure can propagate the existing cracks causing additional damage.
  If crack is vertical or inclined, the injection process should begin by pumping epoxy into the entry port at the lowest elevation until the epoxy level reaches the entry port above. The lower injection port is then capped and the process is repeated until the crack has been completely filled and all ports have been capped.

For horizontal cracks, the injection should precede from one end of the crack the other in the same manner. The crack is mil if the pressure can be maintained. If the pressure can not be maintained the epoxy is still flowing into unified portions or leaking out or the crack.

- Remove the surface seal, after the injected epoxy has cured, the surface seal should be removed by grinding or other means as appropriate.
- Alternative procedure. for massive structures, an alternate procedure consists of drilling a series of holes [usually 7/3 to 4 in (20 to 100 mm) diameter] chat intercepts the crack at a number of locations. Typically, holes are spaced at 5 ft(1.5m) intervals.

  Another method recently being used is a vacuum or vacuum assist method. her are two techniques: one is to entirely enclose the cracked member with a bag and introduce the liquid adhesive at the bottom and to apply a vacuum at the top. The other technique is to inject the cracks from one side and pull a vacuum from the other. Typically, epoxies are used; however, acrylics and polyester have proven successful.

EXPERIMENTAL WORK:-

Selection of Materials: The production of high –strength concrete requires high quality materials. Moreover, high-strength concrete mix design proportioning is more critical than the design of normal – strength concrete mixtures, therefore special attention must be given to control the water-cement ratio (w/c) in the mix. Usually chemical admixtures (super plasticizers) are employed to obtain a low (w/c) ratio. The following is the detailed description of the materials used:

Cement: the proper selection of the type and source of cement is one of the most important steps in the production of high – strength concrete. OPC type I was used.

Fine Aggregate: the grading and particle shape of fine aggregate are significant factors in the in the production of high –strength concrete. Fine aggregate with a rounded particle shape and smooth texture with a fine ness modulus, specific gravity , and absorption of 2.48 , 2.66 , and 2% , respectively . Natural sand from AL- Rahalia region is used. The sand complies to IQS 45: 1984

Coarse Aggregate: The ideal coarse aggregate should be clean, cubical , angular 100% crushed aggregate with a minimum of flat and elongated particles . Crushed gravel from Al- Nibaee region is used with maximum size of 14 mm. the specific gravity and absorption are 2.66 and 0.66 % , respectively .

Water: tap water is used for both mixing and curing of concrete.

Admixtures: A super plasticizer admixture used in this study is a me lament L–10(melamine for maldehyde condensate). Its properties are listed in **Table (1)**. Because of the capability of more than 12 percent water reduction, this material is classified as type F in ASTM C494.

Reinforcing Steel: - All the reinforcing steels are deferred from the same source. **Table (2)** gives the results of testing 200 mm long sample from size bars (8, 10, 12, and 16 mm).

Concrete Mix:- All reinforced concrete beam have same mix. **Table (3)** shows this mixture.

Type of Epoxy: - Low viscosity epoxy injection resin system uses :-

For injecting into cracks in concrete or masonry to form a permanent bond or seal.

Advantages : -

- Low viscosity allows penetration into the finest cracks.
- Formulated for hot climates.
- Suitable for structural repairs.
- Excellent bond to concrete, brick and masonry.
- Minimum creep under sustained loud.
- Resistant to wide range of chemicals.
- Non-shrink. Adheres with no less of bond.

Description: -

Contexture Epoxy two parts. Solvent – free. low viscosity to resin system is mixed in the proportions supplied to form a strong permanent bond and seal in cracks in concrete and masonry .

Contexture Epoxy is designed to be injected into cracks using suitable resin injection equipment.

Design Criteria: -

Contexture Epoxy is designed to seal and bond cracks in concrete and masonry. crack width of between 0.2 mm and 9 mm can be treated .

Specification:

The epoxy crack injection resin system shall be Contexture Epoxy, a two part solvent – free low viscosity, epoxy, when mixed in the proportions supplied and injected into cracks in concrete the resin shall form a permanent bond and seal in both dry and damp conditions.

Properties:

The following properties were obtained at a temperature of 35c° and at 7 days unless other wise specified in **Table (4).**

Instructions for Use:

Contexture can be applied using either injection packers fixed into holes drilled directly into the crack or drilled diagonally from concrete adjacent to the crash or by the fixing of injection nipples . Bonded to the surface using Nitra or tar (FC) .

Preparation:

Clean the surface and remove any dust, unsound or contaminated material , plaster , oil , paint grease , corrosion deposits or algae , The surface should preferably using high pressure water jetting or light abrasive blasting , following particles by thorough washing to remove dust and remaining particles . Dirt a lone may be removed with wire brushes or similar mechanical means, oil and grease deposits should be removed me steam cleaning detergent scrubbing or the use of a proprietary degreaser the effectiveness of decontamination should be assessed by a pull- off test.

Blow the cracks and treated surface with oil free air to ensure complete removal of all dust and loose particles, Ensure that the surfaces are blown dry . In the presence of running water the flow must be stopped using contexture which produces rapid setting water – stopping foam. When the water is stopped the cracks are re-injected with contexture.

Fixing Injection Packers:

The injection packers shall be in sorted into per- drilled holes at intervals along the length of each crack. The distance between each packer will depend upon the width and depth of the crack. So acing shall be close enough to ensure that the resin will penetrate along the cracks between the packers shall be sealed with a band of Nit mortar (FC) 30 to 40 mm width and 2 to 3 mm thickness . Both sides of any cracks which go all the way through a wall or slab shall be sealed in this way . in the case of a wall or slab cracked all the way through packers shall be located on both sides with those at the back placed at midway points between those at the front .

The Nit mortar FC shall be allowed to cure for 3 hours at 35 c . At low ambient temperatures (5c to 12c) the curing time will be extended and the applicator shall ensure that the surface sealant has adequately cured prior to continuing . One end of the injection hose shall be attached to the lowest packer on vertical cracks or to either end of the horizontal cracks.

Alternative methods of resin injection are currently to use they include the system where injection nipples are bonded to the substrate.

Testing Procedure:-

The beam under test was implying supported over a span of 2550 mm. Two equal point loads, were applied to the third-points of the beam by a part of hydraulic jacks. First, second third and mid-span deflections of the beam were measured with a dial gauges. Loading was increased by small increments until the beam cracked. After each increments of loading, the deflections were recorded and the propagation of crack was examined.

The damaged beam was then repaired by injecting the cracks full depth with a low viscosity, fast-curing, slump-pumping liquid epoxy adhesive after cleaning the surface and remove any dust. The surface should be preferably using high pressure water jetting or light abrasive blasting. Following particles through washing to remove dust and remaining particles.

The perimeter of each cracked section was sealed off with either a rapid-setting epoxy adhesive or temporary seal, leaving several small holes for the subsequent injection and relief of the structural adhesive when the surface seals had cured, the epoxy adhesive was injected into the cracks.

Only the major cracks were treated in this way. The minor cracks, being less than (0.05)mm were too fine for complete penetration of the structural epoxy the crushed concrete in the compression zone of the beam was repaired in a similar manner. The repaired beam was left at ambient temperature for five days and the tested to failure as before. Measurements of deflections are done by dial gauges under 2/3 and 1/3 of span. These dial gauges are with an accuracy of 0.01 mm and strain gauges were located under mid of beams and distributed on the beam's faces. shown in **Figure(1)**, **Figure(2)** and **Table (5)** showed the details of beam sections.

TEST RESULTS

Throughout this testing we can results, the behavior of the repaired beams was similar to that of the pre-crack beams, but a little deference for all beams(B1, B2, B3 and B4) under loading, the repaired cracks did not reopen-instead, new cracks were formed some being ad adjacent to the old ones. At failure concrete crushing occurred away from the epoxy-repaired region. **Figs.(3,4,5,6)** show that load deflection curve relationship for beams B1,B2,B3 and B4. **Plate (1, 2 and 3)** show injection of epoxy and cracks of beams.

CONCLUSION

1- The proper repair of cracks depends on known of the cases and selecting the best repair procedure.
2- In this research show that the compression steel ratio r' =0.0049 or r'=0.0099 for beams 1 and 2 there was no affecting on deflections so as beams 3 and 4 while affecting tensile steel ratio r was greater than r' for all beams.
3- The repair procedure should accomplish one or move of the following objectives increased strength and staffers, improve performance apron cave , water tireless , and durability .
4- Epoxy ejection in found proper method to restore strength of stiffness of the crack number.
5- Load deflection, curves of the repaired its beams were found of similar or improved behavior to those of per-cracked beam.
6- The failure load of the spiciness in general when approaching or any is higher than those of the origins pre-cracked beams.
7- Finally, it may be conclude that the epoxy ejection method of crack repair is found effecting in restoring the original structure and stiffness.

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Table (1) Properties Of The Super Plasticizer*

1	Main action	Concrete
2	Subsidiary effect	Hardening accelerator
3	Appearance	Clear to slightly milky
4	Solid in aqueous solution.	Approx. 20%
5	Density	1.1 g/cm^3
6	Chloride content	Less than 0.005%
7	Sugar content	None
8	Handling	No special precautions
9	PH valve	7-9
10	Frost resistance	Element L-10 with stands any number of frost cycles. It should be thoroughly thawed before use
11	Storage life	At least two years. It should not , however , be exposed to excessive heating

***Properties obtained from product catalogue**

Table (2) Properties Of Reinforcement.*

Nominal Diameter (mm)	Measured Diameter (mm)	Area (mm)	Length (mm)	Elongation %	Modulus of Elasticity (GPa)	Fu MPa	Fu MPa
8	8.01	50.4	200	11.4	213	532.4	602.7
10	10.0	78.5	200	11.9	210	611.9	725.8
12	12.1	114.9	200	14.0	215	534.3	634.5
16	15.97	200.2	200	12.5	204	594.6	784.4

*** Testing was made at the laboratory of materials in Baghdad University, college of Engineering**

Table (3) Concrete Mix Proportions (kg/m^{-3}).

W/C ratio	Water	Cement	Sand	Gravel	S.P *
0.27	162	600	664	996	24

***Super plasticizer**

Table (4) Properties Of Epoxy.

No	Test method	Typical results
1	Compressive strength	70.0 N/mm2 @ 20c
		93.0 N/mm2 @ 35c
2	Tensile strength	26.0 N/mm2 @ 35c
3	Flexural strength	63.0 N/mm2 @ 35c
4	Young’s modulus in compression	16 Gpa.
5	Pot life	90 minutes @ 20 c
		40 minutes @35c
6	Specific gravity	1.04
7	Fixed viscosity	1.0 poise @ 35c

Table (5) Details of beam sections.

Beam No.	Tension Zone		Compression Zone		Dimension			fc′ MPa	fy MPa	fu MPa	Es GPa
	ρ'	Dim. mm	ρ'	Dim. mm	b	d	h				
B1	0.0099	2Ø12	0.0049	1Ø12	120	191	230	71	534	634	125
B2	0.0099	2Ø12	0.0049	2Ø12	120	191	230	69	534	634	125
B3	0.018	2Ø16	0.0	0.0	120	189	230	62	594	784	204
B4	0.018	2Ø16	0.0069	2Ø10	120	189	230	65	594	784	204

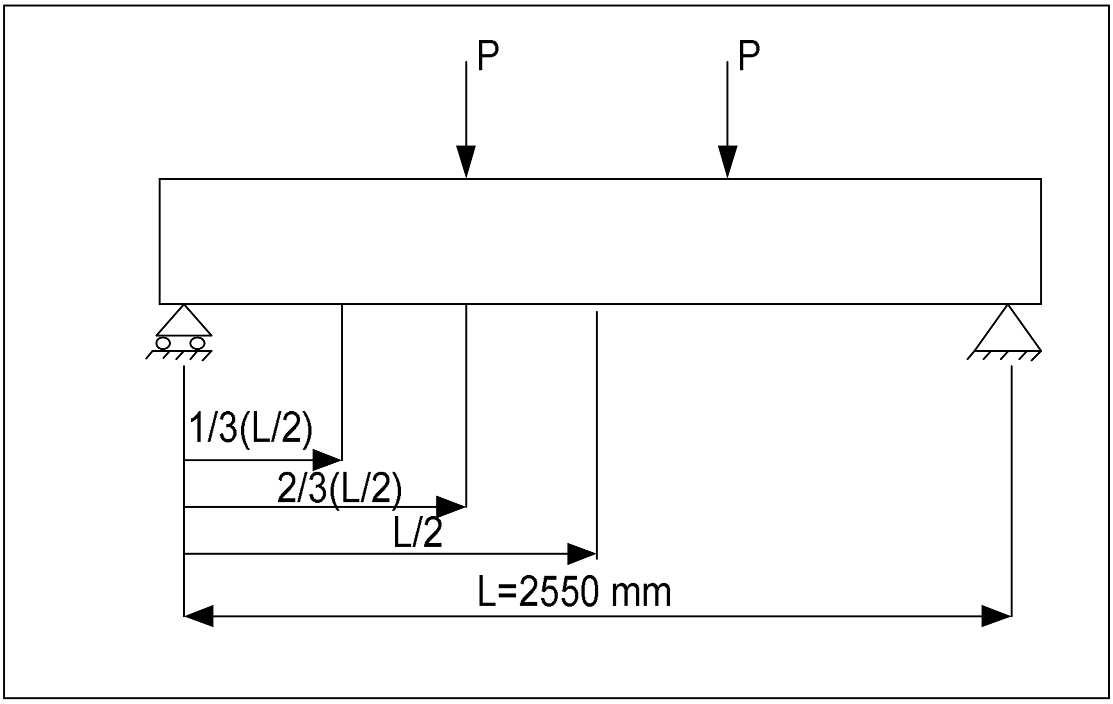

Figure (1): beam specimens test and dial gauges with accuracy 0.01 mm.

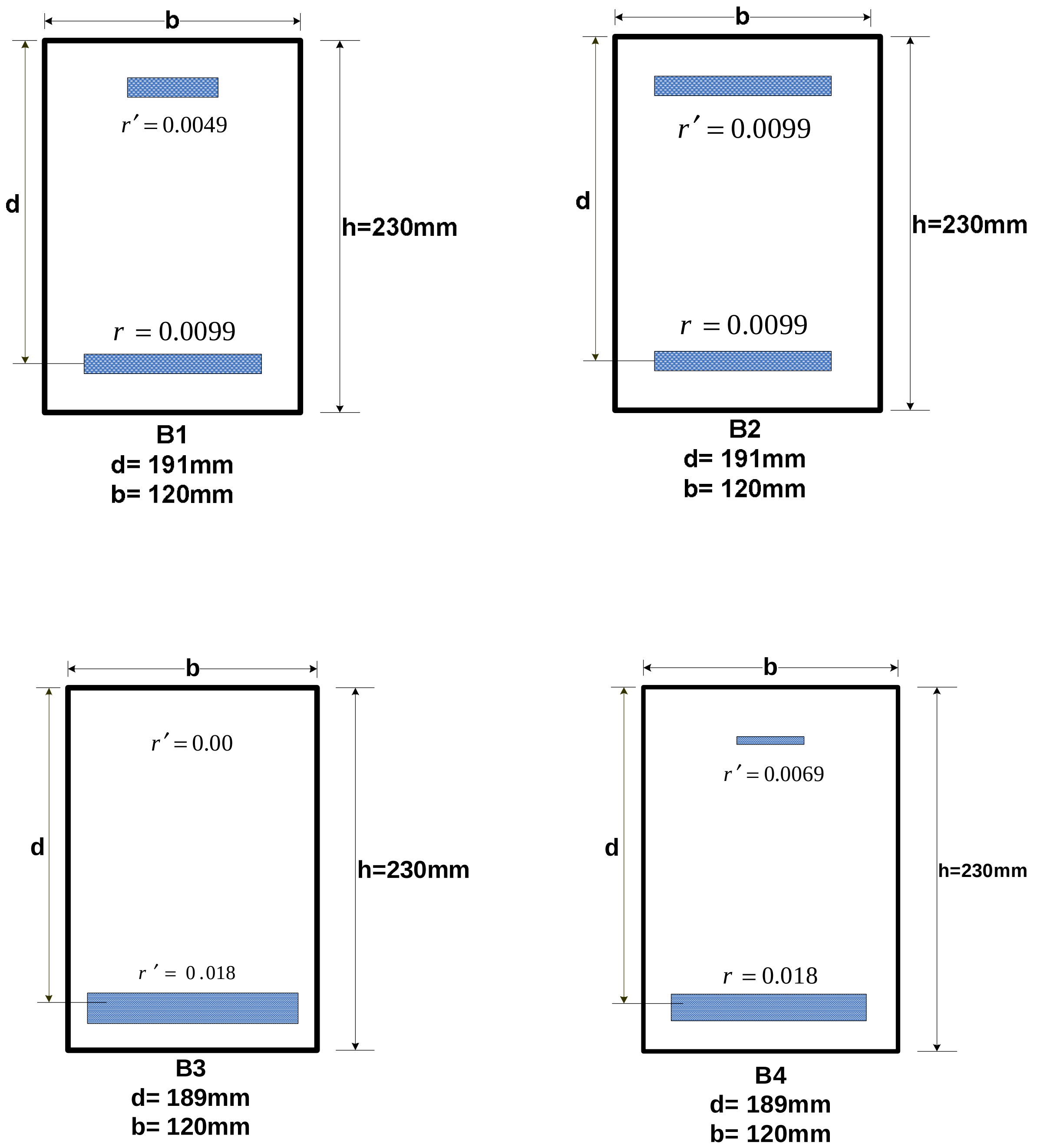

Figure (2): Details Of Beam Section.

Plate (1) Injection Of Epoxy For Beams.

Plate (3) Mish Of Cracks After Loading.

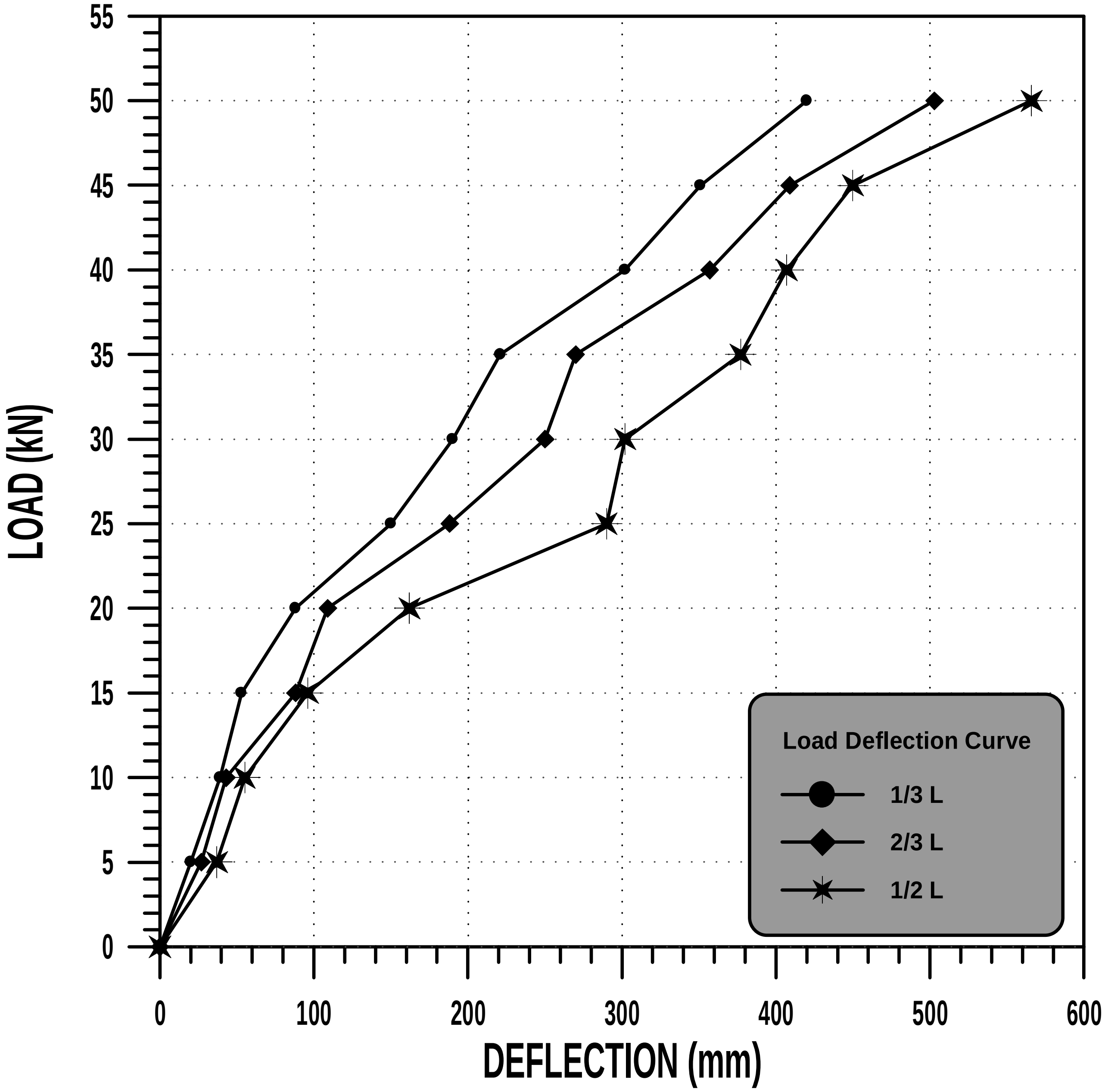

Figure (3) Load-Deflection Relationship B1.

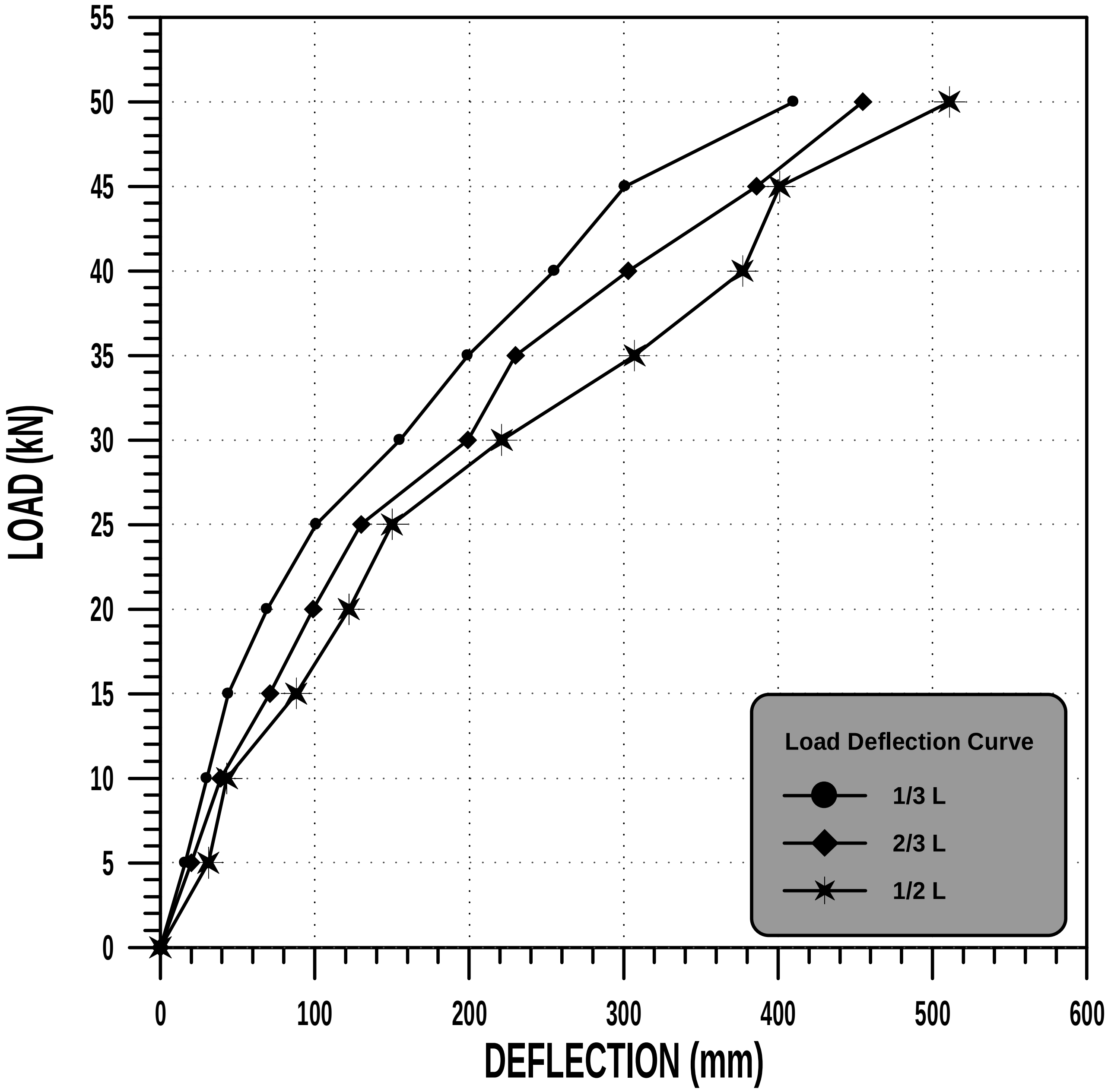

Figure (4) Load-Deflection Relationship B2.

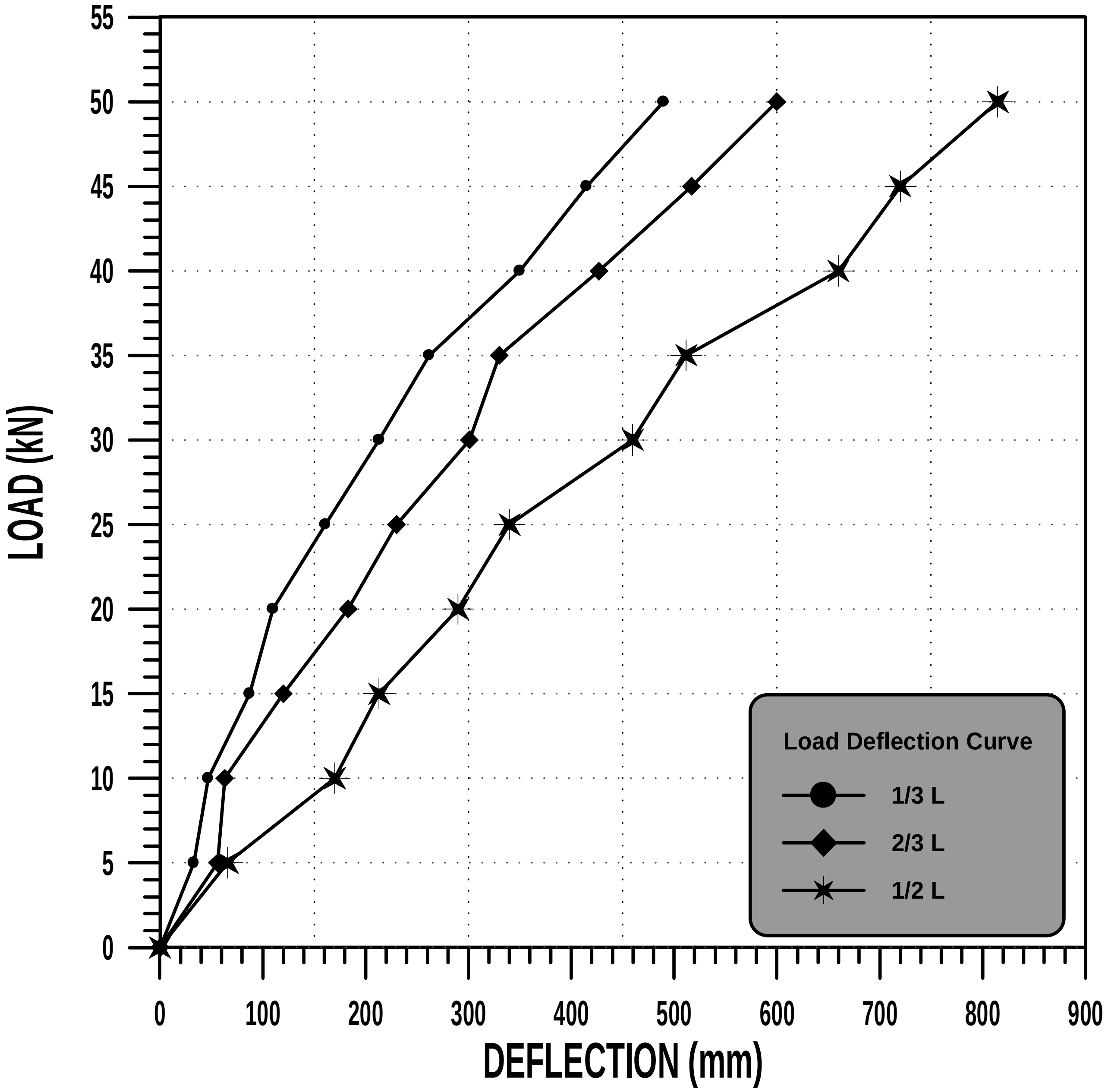

Figure (5) Load-Deflection Relationship B3

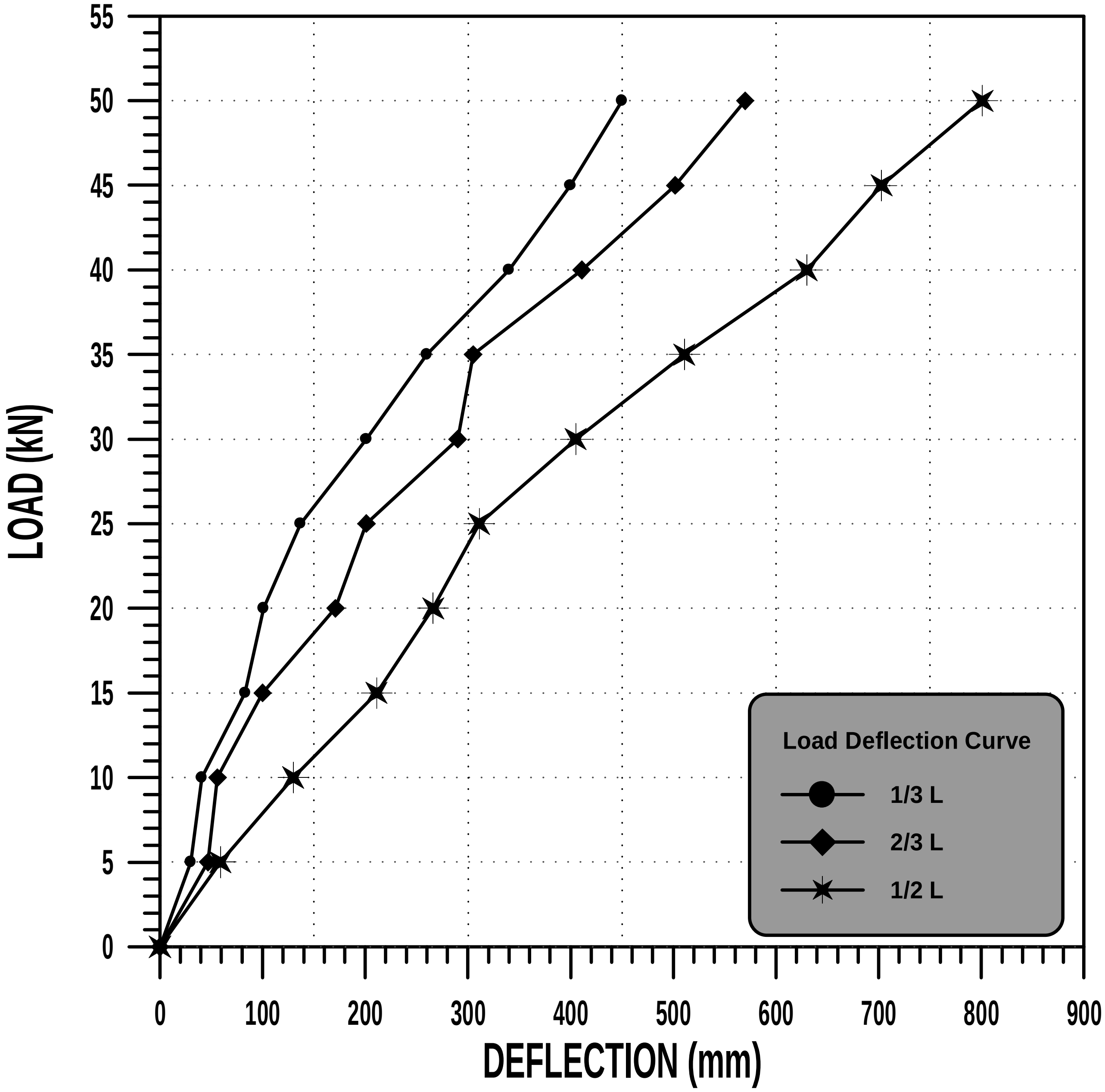

Figure (6) Load-Deflection Relationship B4.