



TRIBHUVAN UNIVERSITY  
INSTITUTE OF ENGINEERING  
PULCHOWK CAMPUS

DEPARTMENT OF CIVIL ENGINEERING

M.Sc. PROGRAM IN STRUCTURAL ENGINEERING

Thesis No: S00110

**STRUCTURAL PERFORMANCE OF REINFORCED  
CONCRETE BEAMS REINFORCED WITH TMT BARS**

**Sidhartha Sagar Shrestha**

JANUARY 2007



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**A Thesis**

**Submitted by:**

**Sidhartha Sagar Shrestha**

*In the partial fulfillment of the requirements for the degree of*

**MASTER OF SCIENCE**

**IN**

**STRUCTURAL ENGINEERING**

**IOE, PULCHOWK CAMPUS**

**JANUARY 2007**

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## **CERTIFICATE**

This is to certify that the thesis entitled “**Structural Performance of Reinforced Concrete Beams Reinforced with TMT Bars**” being submitted by Mr. Sidhartha Sagar Shrestha (061/MSS/116), in partial fulfillment for the award of degree of Master of Science in Structural Engineering at Institute of Engineering, Tribhuvan University, Nepal is as a record of bonafide works carried out by him under my supervision and guidance and that no part of this thesis has been published or submitted for the award of any degree or diploma elsewhere.

---

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January, 2007

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## **ABSTRACT**

TMT (Thermo Mechanically Treated) rebar has been in use in Nepal for last couple of years. There has been a state of confusion among designers to go into TMT or still use CTD (Cold Twisted Deformed) bars. It is the right time to investigate the comparative performance of TMT reinforced structural member and compare its performance to similar CTD counterpart. In this research work, eight reinforced concrete beams of size: 2000 mm × 230 mm × 300 mm. Four of them were reinforced with TMT bars from local market and the other four with CTD bars. The reinforcement detail in all the beams are identical including shear reinforcement; except four had TMT and other four had CTD longitudinal bars. Out of four in each case, two were tested in monotonic loading and the other two were tested in cyclic loading using Universal Testing Machine. The crack propagation pattern in all the eight beams was almost similar. The load deflection curve showed clear system yielding in case of TMT where as it was having smooth path in case of CTD. All the beams showed failure mode as crushing of concrete as designed except one which failed in shear. It was noted that the ratio of deflection of the centre point of the beam at the crushing load to that at the yielding load were more or less similar for both TMT and CTD reinforced beam. TMT reinforced beams showed greater ultimate load which was due to its higher strength. In both the TMT and CTD reinforced beams, the monotonically loaded beams showed greater ultimate load than the corresponding cyclically loaded beam. This investigation showed that the TMT reinforced structural beams behave more or less similar structural performance up to the rupture of tension reinforcement.

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# 1. INTRODUCTION

## 1.1 General

There are various types of structural elements in the structural system like beams, columns, slabs, footings, etc. Among them the beams are the horizontal flexure members which transfer the loads from slabs or walls to the column. The reinforced concrete (RC) beam consists of the composite section of concrete material with steel bars embedded in it. The bond between steel and surrounding concrete ensures strain compatibility; i.e., the strain at any point in the steel is equal to that in the adjoining concrete. The reinforcing steel imparts a property called ductility to the material otherwise it is brittle. The ductility of the material is the property which elongates with sufficient deformation and the section reduces but without the loss of the strength.

Practically the RC beam fails in tension, preceded by large deflections caused by the yielding of steel. Tensile stresses occur either directly, as direction tension or flexural tension or indirectly as in shear, which causes tension along diagonal planes. Temperature or shrinkage effects may also induce tensile stresses. In all such cases, reinforcing steel should be located, in a direction that cuts the principal tensile planes. If insufficient steel is provided, cracks would develop and propagate, and could possibly lead to failure.

During the development of reinforced cement concrete, rebar, one of the vital ingredient materials was also developed in various steps. Initially the mild steel was used; then cold twisted deformed (CTD / TOR) bar were invented. Now a day's thermo mechanical treatment (TMT) rebar is popular. The object of the development of various bars is to increase quality, strength, workability, as well as durability. The use of CTD steel rebar had already stopped in Europe.

TMT bar is the latest type of rebar which is produced with the process of **thermo-mechanical treatment** of steel reinforcement bar. The TMT bar was developed in Europe in the late 60s. It was implemented in 1975 in Belgium. Now it is introduced in Nepal since few years ago. Some companies which produce TMT rebar in Nepal are- Panchakanya steels Pvt. Ltd., Hama Iron and Steel Industries Pvt. Ltd., Himal Iron and Steel Industries Pvt. Ltd., Jagadamba Steels, Pashupati iron and Steels Industries etc.

TMT also called Thermo-processing technology (Thermex) is a research based process developed to produce high strength steel reinforcement bars with a minimum yield point of  $500 \text{ N/mm}^2$ . This bar is manufactured under quenching and tempering technology to obtain steel rebar of unique metallic property. According to the manufacturer the raw material (Billets) are heated in a heating furnace and rolled through a series of rolling stands of various diameters, progressively reduced to the final size and shape of rebar. The hot rolled rebar is rapidly cooled. The section of the TMT Bar has two different cores which can be seen cutting the bar and grinding the section. The finished bar has a microstructure comprising a tough outer layer of tempered Martensite and inner ductile core of ferrite Pearlite (Photo 1). The TOR bar are commercially furnished with helical projection of bit on its surface while the TMT bar are finished with half circle bit projections. The difference can be seen in the Photo 2.

## 1.2 Problems and issues

Many manufacturing companies of TMT bar in Nepal claim that TMT bar is the best rebar for RCC comparing with CTD/TOR steel and other steel bars. It is good quality with high strength, high ductility, high temperature resistance, better weldability, better bendability, and better bondability. But these Physical properties for TMT bars are not based on the research on structural elements. The main Problems are-

### 1) Structural Element Performance

The manufacture Companies claim that TMT bar has high yield strength in tension, over  $500 \text{ N/mm}^2$ . And it has better ductility than TOR steel bar. The ductility they calculated by the elongation percent (strain) which is about 16%. What ever they claim, is based on the tests carried out on bare bars only. But what is the performance of TMT Bar in Structural elements like Beam, Column, Slab, foundation, Shear wall etc., there was no detail research.

### 2) Loading Effect

The effect of Monotonic loading on structural elements how it bears by the TMT bar along with the concrete? And what is the effect of Cyclic loading on structural element reinforced with TMT rebar? Also how it effects the structural element reinforced with TMT rebar by reversal loading?

### 3) Weldability

The TMT rebar is better weldability. For steel, when temperature is increasing the strength is either reducing or increasing. Also by welding the original properties of rebar will be changed. So after welding what will be its performance of TMT bar used in RCC Structures?

### 4) Bending

The bending of rebar is also an important process in the construction site. Sometimes the rebar breaks up while bending. Mostly the TOR bar greater than 20mm diameter break up while it is bent and re-bent. So what will be the performance of TMT bar for bending and re-bending?

### 5) Bonding

Since the surface of TMT bar is projected (rough making), it may assume that the bonding will be similar as that of TOR steel. The manufacture companies claim that TMT bar is better bondability than other bars. But there is no any explanation referring bonding stress ( $\tau_b$ ). So what will be the performance of TMT bar in bonding?

## 1.3 Objectives

### General Objective:

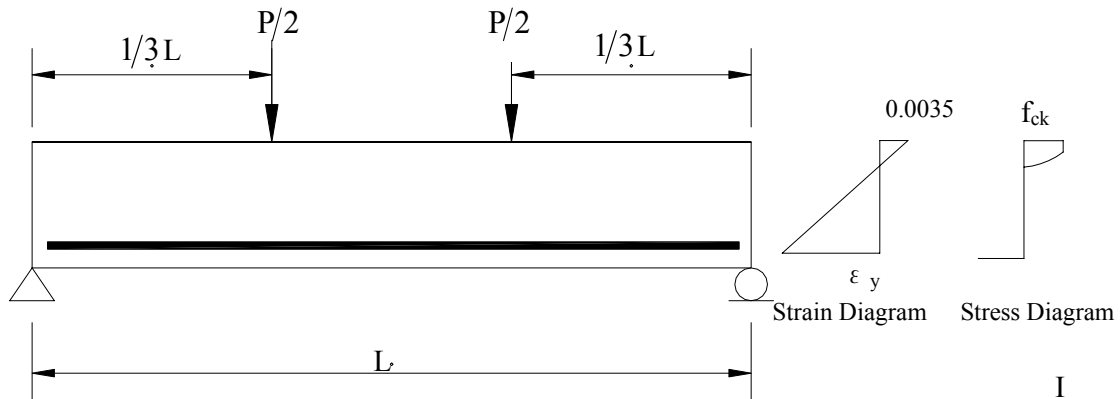
To study the structural performance of TMT rebar in relation to RCC beam and compared to TOR Steel Bar.

**Specific Objective:**

- 1) To study the ductility response of RCC beam reinforced with TMT bar compared to TOR steel bar in monotonic loading case.
- 2) To study the cyclic loading effect in RC beam reinforced with TMT bar compared to TOR Steel bar.
- 3) To understand the ultimate response of TMT reinforced and CTD/TOR bar reinforced similar RC beams (failure mode)
- 4) To study the pattern of crack propagation of RC beam.

**1.4 Preliminary Analysis**

To carry out the study of structural performance of RC beam reinforced with TMT bar and compared to Beam reinforced with TOR steel bar it need to experiment the beams by loading with UTM in the laboratory. For this, specific size beam would be selected reinforced with specified diameter of rebar. So it was analyzed to calculate the bending moment at the center of the beam, corresponding two point load position at one third length of beam. And corresponding deflection at the center was also calculated with various section of beam as well as the various section of rebar. No factor of safety was applied. Also self weight of beam was not considered. Only the effect of external load was considered.



**Fig. 1 Simply supported singly reinforced beam and corresponding strain diagram and stress diagram**

I  
initially  
for

preliminary analysis the concrete was taken as M20. And the yield stress for TMT bar and TOR steel bar were taken as 500 N/mm<sup>2</sup> and 415 N/mm<sup>2</sup> respectively. The effective length of the beam was taken as 1800 mm.

Let us consider the size of beam = b × d × L

Where, b = width of beam

d = effective depth

The cracking Moment of Section is given by,  $M = \frac{I}{y} \sigma_t$  ----- (1)

Where, I = Moment of inertia =  $\frac{bd^3}{12}$

y = 1/2d

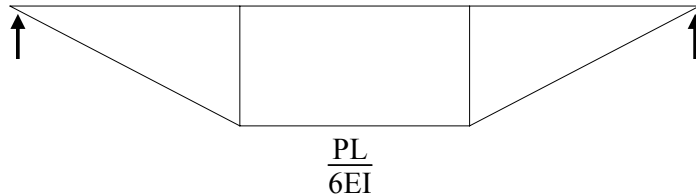
$\sigma_t$  = Allowable tensile stress of concrete. =  $0.7\sqrt{f_{ck}}$

Now, Moment due to external load at one third length of beam,  $M = P/2 \times L/3$  -----

(2)

The cracking load is given by equating equations (1) and (2),

$$\text{i.e. } P_{\text{crack}} = \frac{6I}{L_y} \sigma_t \text{ ----- (3)}$$



**Fig. 2 Conjugate beam**

The cracking deflection of the beam can be calculated by solving the conjugate beam method, shown in figure 2.

$$\text{Reaction at support of conjugate beam, } R = \frac{PL^2}{18EI} \text{ ----- (4)}$$

Where, E = modulus of elasticity =

Now cracking deflection at midspan is given by moment at midspan of conjugate beam,

$$\text{i.e. } \delta_{\text{crack}} = \frac{PL^2}{18EI} \times \frac{L}{2} - \frac{1}{2} \times \frac{L}{3} \times \frac{PL}{6EI} \times \left[ \frac{1}{3} \times \frac{L}{3} + \frac{1}{2} \times \frac{L}{3} \right] - \frac{1}{2} \times \frac{L}{3} \times \frac{PL}{6EI} \times \frac{1}{4} \times \frac{L}{3}$$

$$\delta_{\text{crack}} = \frac{7PL^3}{324EI} \text{ ----- (5)}$$

After yield of the beam, the moment of the section is given by,

$$M_y = f_y A_{st} (d - 0.42 x_u) \text{ ----- (6)}$$

Where,  $f_y$  = yield strength of the rebar

$A_{st}$  = cross sectional area of rebar

$x_u$  = Depth of neutral axis from the top

$$x_u = \frac{f_y A_{st}}{\left( \frac{3}{7} + \frac{2}{3} \times \frac{4}{7} \right) f_{ck} b} \text{ ----- (7)}$$

Again the external yield load is calculated by,

$$\frac{P_y}{2} = \frac{M_y}{L/3} \text{ ----- (8) from which the yield load (} P_y \text{) can be calculated.}$$

Now the deflection after yield of the beam section is again analyzed by conjugate beam method, which is given by,

$$\delta_y = \frac{7P_y L^3}{324 E I_{\text{eff}}} \text{ ----- (9)}$$

Where,  $I_{\text{eff}}$  = effective moment of inertia given by

$$I_{\text{eff}} = \frac{I_r}{1.2 - \frac{M_r}{M} \frac{z}{d} \left[1 - \frac{x}{d}\right] \frac{b_w}{b}} \text{ ----- (10)} \quad [\text{Ref: C-2-1 IS 456: 2000}]$$

Where  $I_r$  = moment of inertia of the cracked section

$$I_r = \frac{bx_u^3}{12} - m A_{st} (d - x_u)^2$$

$$M_r = \text{cracking moment} = \frac{I}{y} \sigma_t$$

$M$  = maximum moment under service load

$b_w = b$  = width of beam section

Depending upon the theory discussed above, many beam sections with verity bar sections were analyzed, which are given in Appendix A. Among them the beam with section (230 X 300 X 1800) mm with 4-12  $\Phi$  bars at the bottom was selected for the experiment in this study (Figure 34).

## 1.5 Scope and Limitation

The research for structural performance of TMT rebar could be done on various structural elements like column, beam, slab, etc. Since the UTM available in the Central Lab in Pulchowk Campus is specially designed for beam, this thesis mainly concentrated on the beam. The loading system for the beam is easy to manage. There is a special table provided on the UTM, to hold the beam, but no such supports for Column or slab. This study dealt with the strength and ductility response of RC beam reinforced with TMT bar and compared to the RC beam reinforced with TOR steel bar. The loading on beams carried out with two categories i) monotonic loading and ii) Cyclic Loading. The Research could also be done on beam with reverse cyclic loading. But for the reverse cyclic loading, it needs UTM with strain control type. The expert for strain control of UTM was not available at the time. And to hold the beams to be tested for reverse cyclic loading, it needs the supports at bottom as well as at the top of the beam. It could not be developed such support system at the lab.

The study could also deal on the performance of weldability in RC beam reinforced with welded TMT rebar. Similarly the bondability and bendability performance of RC elements reinforced with TMT rebar could be studied. But the economy of the study as well as the time available was also concerned, only the ductility and cyclic loading effect on RC Beam reinforced with TMT bar was considered and compared them with the beam reinforced with TOR steel bar. Regarding the economy and time reason, only 12 mm diameter rebar were used in the beam. While it could be studied on the beams using all 12, 14, 16, 18, 20, 22, 25, 28, 32mm, etc. diameter rebar which are available in the market. Also it could include rebar from all manufacturers. But only one brand rebar was used, which was randomly selected from the market.

The cyclic loading on the beam was carried out within three cycles. This was because the deflection was measuring on a dial guage which has maximum deflection of 25 mm. With this guage it can hardly manage to give three cycle of loading. If sensitive strain gauges were available more than three cycles could be loaded. Or, if the strain controlled UTM was available it could be managed to give more cycles of loading and unloading.

## **2. EXPERIMENTAL PROCEDURES**

### **2.1 Material Preparations**

The materials required to cast the beam were aggregate, sand, cement, rebar, binding wire, water and forms. The estimated quantity of aggregate, sand and cement were purchased from market, transported to the Heavy Lab in Pulchowk Campus and stored at appropriate places.

#### **Aggregate**

The aggregate purchased was from Lele area of Lalitpur District. The size of aggregate for concrete was selected of 25mm down. The aggregate was washed in the lab with the normal water to remove the clay, silt, organic material and other harmful salt and minerals (Photo: 3). It was taken care that the fine particles were not washed out. It was then dried at the lab floor to atmospheric condition.

#### **Sand**

The sand available was delivered from the hill mine (not river sand). Since it contains much amount of clay and silt it was also washed with the water available at the Heavy lab. (Photo: 4) The cleaned sand was dried to atmosphere at lab floor.

#### **Cement**

No specific brand cement was aimed to use. But during the study the most renowned Udayapur Cement was available in the market among Nepali Cement. So Udayapur Cement was purchased from the market. It was stored on the timber bed in the Heavy Lab. The cement was covered with plastic sheet while storing to prevent from the moisture. Even it was marked 50 Kg on the bag, it was re-weighed while batching.

#### **Water**

The water used for concreting as well as curing was collected as normal and clean water from the tap in the laboratory. No special treatment was carried out for this normal water. The water was measured with one litter jar while batching. But it was sprayed with pipe everyday while curing both the beam and cube sample.

#### **Rebar**

The rebar was purchased from market randomly. No specified brand was selected. The bar was stored under the ceiling at the heavy lab block. Immediately the bar was used for fabrication next day of purchase.

Two skilled bar benders fabricated the rebar (Photo 5, 6, 7 and 8). Each long piece of bar from the bundle was cut into four pieces for one beam, 6” at the end and 1 meter at the middle of long bar was supposed to exclude. Two pieces of sample for tensile strength test was taken out from each bar of the bundle.

### **2.2 Casting of Beam**

The concrete for the beam was selected as M20. Concrete mix was designed as per IS Code which is shown in Appendix B. The proportion of concrete was as (1:1.6:3.27:0.50). For each beam 72 kg cement, 115 kg sand, 236 kg aggregate and 36 lt. water was calculated for mixing. But the water correction on each day of casting was done. The water content on sand and aggregate was found out by oven drying in the laboratory. The final batching of material were calculated which are shown on Appendix B.

The metal form available at the laboratory was set into the proper size i.e. (230X300X2000) mm. It was fixed with nut bolts. A thin layer of lubricant was applied to the surface inside the form. Aggregate was weighed first properly and laid on the clean floor. Then sand was weighed properly and laid over the aggregate. Similarly cement was weighed and sprayed over the sand. Finally corrected amount of water was measured and poured into the prepared mix of dry concrete. The concrete was hand mixing. Every batch was mixed turning with hand shovel, three times before and three times after the mixing of water.

The fabricated bar was placed into the form with calculated effective depth (270 mm) and effective cover (30 mm) placing the aggregate at the bottom of bar (Photo 9). The concrete was laid into two layers. In each layer the vibrator was applied for compaction (Photo 10). The top of the beam was furnished with trowel. The type of bar used was marked on the beam next day. Five 150mm size cubes were prepared at the same time and same condition (Photo 11) for compressive strength test.

## **2.3 Curing of Beam**

The form of the beam was stripped out next day of casting. The beam was sprayed with normal water at the laboratory. It was covered with jute bag soaked with water. The spraying of water was done three times every day. The curing was done 28 days for each beam. The five cubes were also water curing at the same time and same condition by covering the wet jute bag and spraying with water for 28 days (Photo 11).

## **2.4 Setup**

The Beams cast at Heavy Lab Block were transported to the Central Material Testing Laboratory (CMTL) by means of cart pushed by labor. The beam was put over the supporting rollers of the table of UTM. The supports were put at 900 mm from the center of beam both side, so that the effective length of the beam from support to support became 1800 mm. Marking was done at the center, supports and at one third of effective length for loading points of the beam. At the supports of the beam a layer of the paste of gypsum was applied so that contact between the beam and the supporting roller was uniform throughout the length of roller support. Two rectangular metal solid rods were put at the loading points. Over these metal rods two channels were put with opposite facing. The channels were then made contact to the loading mechanism of UTM which was exactly over the center of the beam. Two deflection measuring dial gauges were put at the edges of center of the beam (Figure 35), (Photo 12).

## **2.5 Loading on Beam**

There were two types of loading for two sets of beam. Each set was consisting of 4 beams, 2 beams cast with TMT bar and 2 beams cast with TOR steel bar.

### **a) Monotonic Loading**

The first set of beams was loaded with monotonic loading. The load was applied continuously till its failure of the beam (Figure 36).

### **b) Cyclic Loading**

Another set of beams was loaded with cyclic loading. The load was applied to the certain deflection after yielding of beam. The beam was unloaded. The beam was

again loaded till the double deflection than before after yielding of the beam. The beam was again unloaded. In this way the beam was loaded till 3 cycles.

## **2.6 Process**

The load was applied on the beam at the rate of 2 ton per minute. In the case of monotonic loading the deflection on both dial gauges was noted at every 500 kg load difference till 10000 kg and after that at the difference of 1000 kg. The load and the deflection were noted up to maximum 25 mm in dial guage. After that both dial gauges were removed and the beam was loaded till it was broken.

In cyclic loading the loading was done similarly as in monotonic loading. While unloading there was no control to UTM machine. The unloading rate varies itself by machine faster at maximum load at just unloading and very slow when the load is decreasing to zero. The deflection was noted at every 2500 kg difference of loading. Finally after 2 cycles it was reloaded till it was broken.

On the same day the five cubes cast with proper beam was tested for compressive strength test at heavy Laboratory (Photo13). Each cube was weighed first. Then it was put centrally on the machine. The load was given by machine till it fails. The failure load was noted.

## 3. EXPERIMENTAL DATA AND ANALYSIS

### 3.1 The tensile strength test of TMT and TOR steel rebar.

In the tensile strength test the bar was tested in the UTM by applying tension load axially to the bar. The elongation of the bar at various value of load was plotted in the graph by the machine itself. Later the stress on the bar was calculated dividing the load by the cross sectional area of the bar. The corresponding elongation was found out from the graph for various values of loads. The strain was calculated again from the elongation dividing by the initial length of the sample bar. The graph was again plotted between the stress and strain. A curve was achieved called stress strain curve. From this curve, the yield strength of the bar was found out. The experimental data, and corresponding yield strength was shown in the tables 1 to 16. The corresponding stress strain curves are shown in figure 3 to 18.

### 3.2 The cube test

The cube sample was prepared simultaneously with the beam sample, 5 nos. of cube for each beam sample. The compression test for the cube was carried out in the compressive strength test machine in the laboratory (Photo 13). The axial load was applied to the cube. The crushing load was noted. This load was modified by applying the modifying equation which was supplied from the laboratory for the machine. It was given by

$$P_{\text{modified}} = 1.5384 \times (0.63 \times P_{\text{observed}} + 6.4158) - 2.8932$$

Where,  $P_{\text{modified}}$  = modified value of the compressive load on the cube

$P_{\text{observed}}$  = Observed value of the compressive load on the cube from compressive testing machine.

The crushing strength of the cube was calculated by dividing the modified load by the sectional area of the cube (i.e.  $150 \times 150$ )  $\text{mm}^2$ . From the five values of strength the maximum one and minimum one are excluded. Other three values were taken for the calculation of the average strength of the concrete. The characteristic strength of the cube was found out by applying the following equation given in the code IS 456 : 2000.

$$f_{\text{ck}} = f_{\text{mean}} - 1.64 \sigma$$

Where,  $f_{\text{ck}}$  = Characteristic strength of the concrete.

$f_{\text{mean}}$  = Average value of strength of concrete.

$\sigma$  = Standard deviation

= 4 for M 20

= 5 for greater than M 30

The experiment data and analysis for characteristic strength are shown in following tables 17 to 24.

**Table 1: Tensile Strength Test of Rebar**

Area of Cross Section of Bar.: 113.097

Sample No. TMT 1A

Length of Bar.: 800

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
1	0	0	0	0.0000	0.00	
2	0.75	0.2	100	0.0009	8.67	
3	2.75	2	1000	0.0034	86.74	
4	4.75	5.2	2600	0.0059	225.52	
5	6.75	9	4500	0.0084	390.33	
6	8.75	13.2	6600	0.0109	572.48	
7	9.78	15	7500	0.0122	650.55	
8	10.75	15.1	7550	0.0134	654.88	
9	12.75	15.15	7575	0.0159	657.05	Yield Stress = 658 N/mm <sup>2</sup> .
10	14.75	15.6	7800	0.0184	676.57	
11	16.75	16	8000	0.0209	693.92	
12	18.75	16.3	8150	0.0234	706.93	
13	20.75	16.4	8200	0.0259	711.26	
14	22.75	16.5	8250	0.0284	715.60	
15	24.75	16.5	8250	0.0309	715.60	
16	26.75	15	7500	0.0334	650.55	
17	28.75	14.8	7400	0.0359	641.87	
18	30.75	11.8	5900	0.0384	511.76	
19	31	0	0	0.0388	0.00	

**Table 2:**

Area of Cross Section of Bar.: 113.097

Sample No. TMT 1B

Length of Bar: 796

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
1	0	0	0	0.0000	0.00	
2	2	1	500	0.0025	43.37	
3	4	3	1500	0.0050	130.11	
4	6	5.7	2850	0.0075	247.21	
5	8	9.4	4700	0.0101	407.68	
6	10	13.1	6550	0.0126	568.14	
7	10.75	14.3	7150	0.0135	620.19	
8	12	14.5	7250	0.0151	628.86	Yield Stress = 626 N/mm <sup>2</sup> .
9	14	14.7	7350	0.0176	637.53	
10	16	15	7500	0.0201	650.55	
11	18	15.4	7700	0.0226	667.89	
12	20	15.6	7800	0.0251	676.57	
13	22	15.9	7950	0.0276	689.58	
14	24	16	8000	0.0302	693.92	
15	26	16	8000	0.0327	693.92	
16	28	16.1	8050	0.0352	698.25	
17	30	16	8000	0.0377	693.92	
18	31	15.8	7900	0.0389	685.24	
19	32	15	7500	0.0402	650.55	
20	33.3	0	0	0.0418	0.00	

Average Yield Strength of the bar =

642 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig 3: Stress-Strain Curve (TMT1A)

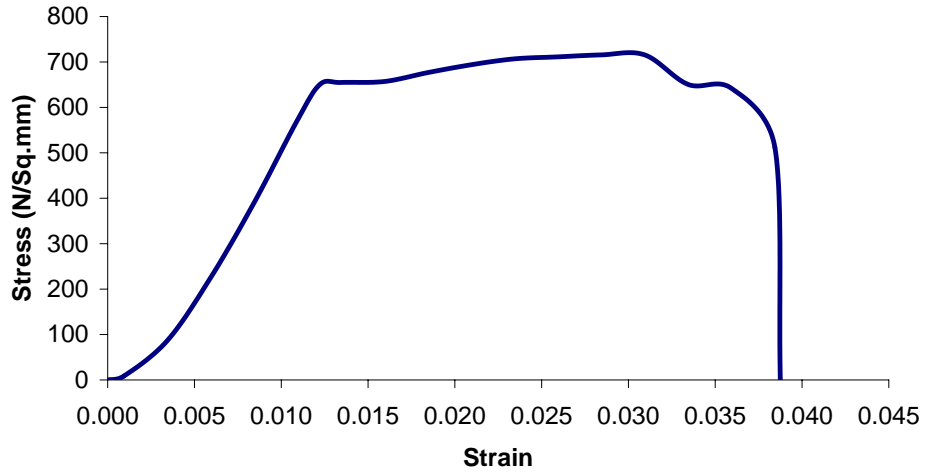
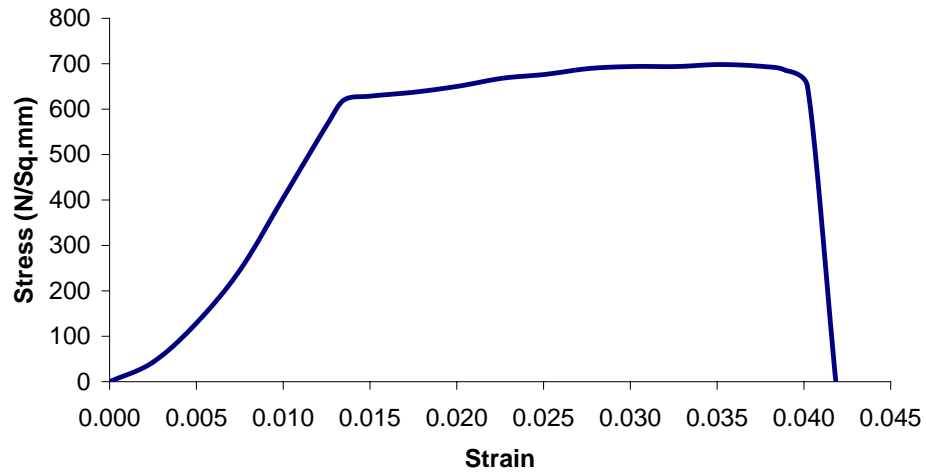


Fig 4 Stress-Strain Curve (TMT1B)



**Table 3: Tensile Strength Test of Rebar**

Area of Cross Section of Bar 113.097 Sample No. TMT 2A

Length of Bar: 903

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
1	0	0	0	0.0000	0.00	
2	2	2.2	1100	0.0022	95.41	
3	4	5	2500	0.0044	216.85	
4	6	8.1	4050	0.0066	351.29	
5	7.5	8.4	4200	0.0083	364.31	
6	8	10.2	5100	0.0089	442.37	
7	10	14	7000	0.0111	607.18	
8	12	14.4	7200	0.0133	624.52	Yield Stress = 615 N/mm <sup>2</sup> .
9	14	14.5	7250	0.0155	628.86	
10	16	15	7500	0.0177	650.55	
11	18	15.2	7600	0.0199	659.22	
12	20	15.4	7700	0.0221	667.89	
13	22	15.6	7800	0.0244	676.57	
14	24	15.7	7850	0.0266	680.90	
15	26	15.8	7900	0.0288	685.24	
16	27	15.7	7850	0.0299	680.90	
17	28	14.8	7400	0.0310	641.87	
18	30	13.4	6700	0.0332	581.15	
19	31.3	0	0	0.0347	0.00	

**Table 4:**

Area of Cross Section of Bar 113.097

Sample No. TMT 2B

Length of Bar: 902

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
1	0	0	0	0.0000	0.00	
2	2	1	500	0.0022	43.37	
3	4	2.7	1350	0.0044	117.10	
4	6	5.4	2700	0.0067	234.20	
5	8	9	4500	0.0089	390.33	
6	10	13.2	6600	0.0111	572.48	
7	10.7	14.2	7100	0.0119	615.85	
8	12	14.5	7250	0.0133	628.86	
9	14	14.6	7300	0.0155	633.20	
10	16	15	7500	0.0177	650.55	Yield Stress = 625 N/mm <sup>2</sup> .
11	18	15.2	7600	0.0200	659.22	
12	20	15.6	7800	0.0222	676.57	
13	22	15.7	7850	0.0244	680.90	
14	24	15.8	7900	0.0266	685.24	
15	26	15.9	7950	0.0288	689.58	
16	27	15.8	7900	0.0299	685.24	
17	28	15	7500	0.0310	650.55	
18	29.2	13.6	6800	0.0324	589.83	
19	29.6	10	5000	0.0328	433.70	
20	29.6	0	0	0.0328	0.00	

Average Yield Strength of the bar = 620 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 5: Stress-Strain Curve (TMT2A)

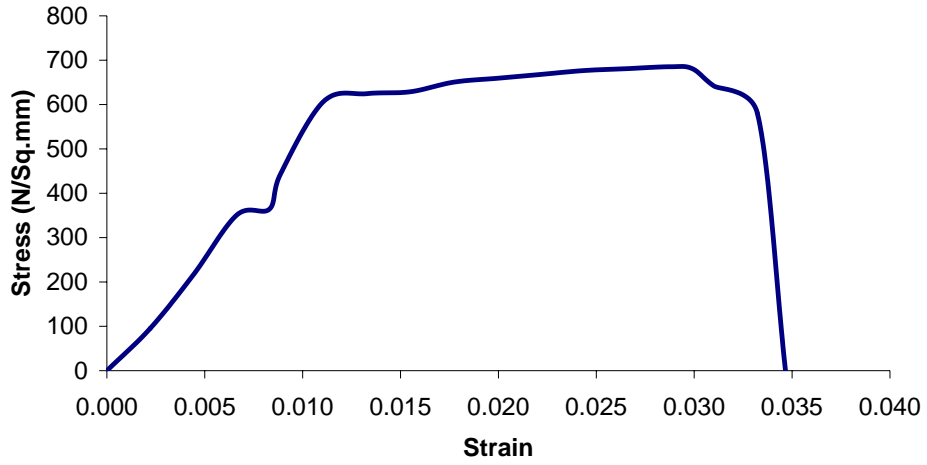
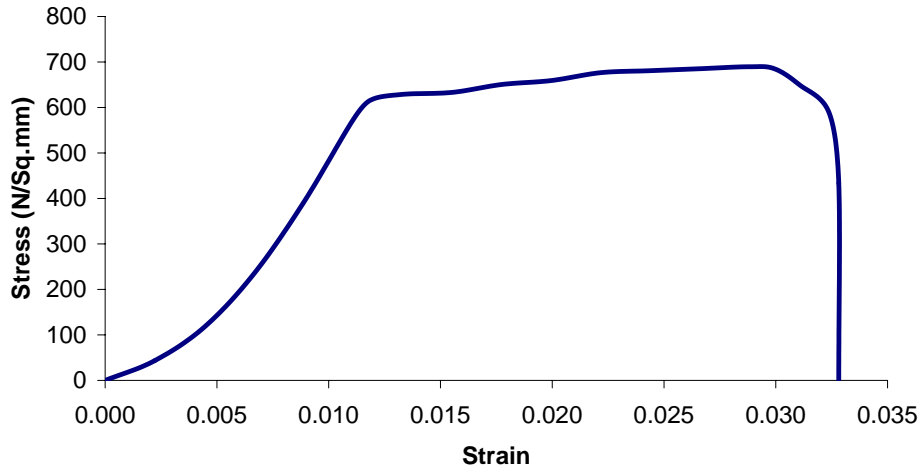


Fig. 6: Stress-Strain Curve (TMT2B)



**Table 5: Tensile Strength Test of Rebar**

Area of Cross Section of Bar 113.097 Sample No. TMT 3A  
 Length of Bar: 895

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
1	0	0	0	0.0000	0.00	
2	2	0.6	300	0.0022	26.02	
3	4	2	1000	0.0045	86.74	
4	6	4.9	2450	0.0067	212.51	
5	8	8.4	4200	0.0089	364.31	
6	10	12.2	6100	0.0112	529.11	
7	11.3	14.4	7200	0.0126	624.52	
8	12	14.5	7250	0.0134	628.86	Yield Stress = 630 N/mm <sup>2</sup> .
9	14	14.6	7300	0.0156	633.20	
10	16	14.8	7400	0.0179	641.87	
11	18	15.2	7600	0.0201	659.22	
12	20	15.6	7800	0.0223	676.57	
13	22	15.7	7850	0.0246	680.90	
14	24	15.8	7900	0.0268	685.24	
15	26	15.8	7900	0.0291	685.24	
16	28	15.8	7900	0.0313	685.24	
17	30	15.8	7900	0.0335	685.24	
18	31.5	15.8	7900	0.0352	685.24	
19	32	15.6	7800	0.0358	676.57	
20	34	13.5	6750	0.0380	585.49	
21	35	0	0	0.0391	0.00	

**Table 6:**

Area of Cross Section of Bar 113.097 Sample No. TMT 3B  
 Length of Bar: 900

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0	0	0	0.0000	0.00	
1	1	0.2	100	0.0011	8.67	
2	3	1.3	650	0.0033	56.38	
3	5	3	1500	0.0056	130.11	
4	7	5.6	2800	0.0078	242.87	
5	9	9.4	4700	0.0100	407.68	
6	11	14.2	7100	0.0122	615.85	
7	11.6	14.9	7450	0.0129	646.21	
8	13	14.9	7450	0.0144	646.21	Yield Stress = 648 N/mm <sup>2</sup> .
9	15	14.8	7400	0.0167	641.87	
10	17	15.3	7650	0.0189	663.56	
11	19	15.5	7750	0.0211	672.23	
12	21	15.6	7800	0.0233	676.57	
13	23	16	8000	0.0256	693.92	
14	25	16	8000	0.0278	693.92	
15	27	16	8000	0.0300	693.92	
16	29	16	8000	0.0322	693.92	
17	30	15.5	7750	0.0333	672.23	
18	31	14.6	7300	0.0344	633.20	
19	33	11.3	5650	0.0367	490.08	
20	33.3	10.5	5250	0.0370	455.38	
	33.3	0	0	0.0370	0.00	

Average Yield Strength of the bar =

639

# Tensile Strength Test of Rebar

Fig. 7: Stress Strain Curve (TMT3A)

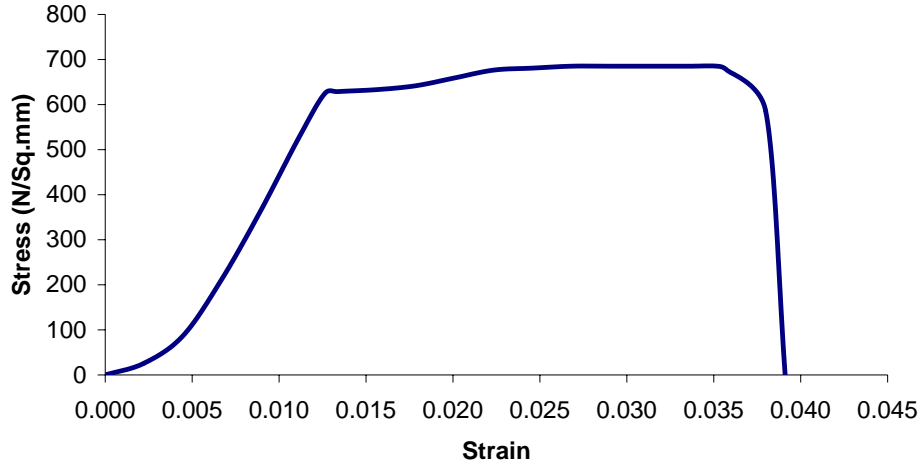
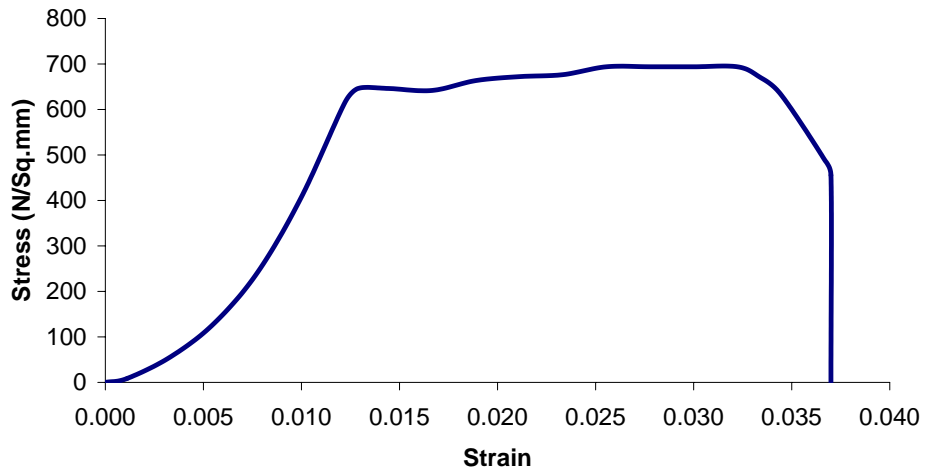


Fig. 8 Stress-Strain Curve (TMT3B)



**Table 7: Tensile Strength Test of Rebar**

Area of Cross Section of Bar 113.097 Sample No. TMT 4A

Length of Bar: 800

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	1.3	1.4	700	0.0016	60.72	
2	3.3	2.8	1400	0.0041	121.44	
3	5.3	5.0	2500	0.0066	216.85	
4	7.3	7.7	3850	0.0091	333.95	
5	9.3	10.9	5450	0.0116	472.73	
6	11.3	14.7	7350	0.0141	637.53	
7	13.3	14.8	7400	0.0166	641.87	Yield Stress = 650 N/mm <sup>2</sup> .
8	15.3	15.0	7500	0.0191	650.55	
9	17.3	15.5	7750	0.0216	672.23	
10	19.3	15.8	7900	0.0241	685.24	
11	21.3	16.0	8000	0.0266	693.92	
12	23.3	16.2	8100	0.0291	702.59	
13	25.3	16.3	8150	0.0316	706.93	
14	27.3	16.2	8100	0.0341	702.59	
15	29.3	15.6	7800	0.0366	676.57	
16	31.3	15.3	7650	0.0391	663.56	
17	33.3	14.1	7050	0.0416	611.51	
18	35.3	0.0	0	0.0441	0.00	

**Table 8:**

Area of Cross Section of Bar 113.097

Sample No. TMT 4B

Length of Bar: 802

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	2.0	1.3	650	0.0025	56.38	
2	4.0	3.3	1650	0.0050	143.12	
3	6.0	6.4	3200	0.0075	277.57	
4	8.0	10.3	5150	0.0100	446.71	
5	8.5	13.0	6500	0.0106	563.81	
6	10.0	13.2	6600	0.0125	572.48	
7	12.0	13.4	6700	0.0150	581.15	Yield Stress = 575 N/mm <sup>2</sup> .
8	14.0	13.5	6750	0.0175	585.49	
9	16.0	14.0	7000	0.0200	607.18	
10	18.0	14.3	7150	0.0224	620.19	
11	20.0	14.6	7300	0.0249	633.20	
12	22.0	14.7	7350	0.0274	637.53	
13	24.0	14.9	7450	0.0299	646.21	
14	25.1	14.9	7450	0.0313	646.21	
15	26.0	14.2	7100	0.0324	615.85	
16	28.0	11.7	5850	0.0349	507.43	
17	28.1	0.0	0	0.0350	0.00	

Average Yield Strength of the bar = 612.5 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 9 Stress-Strain curve (TMT4A)

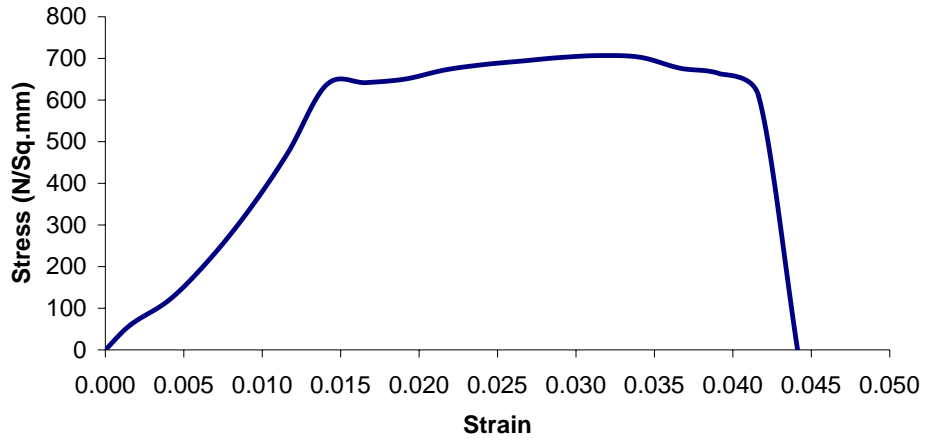
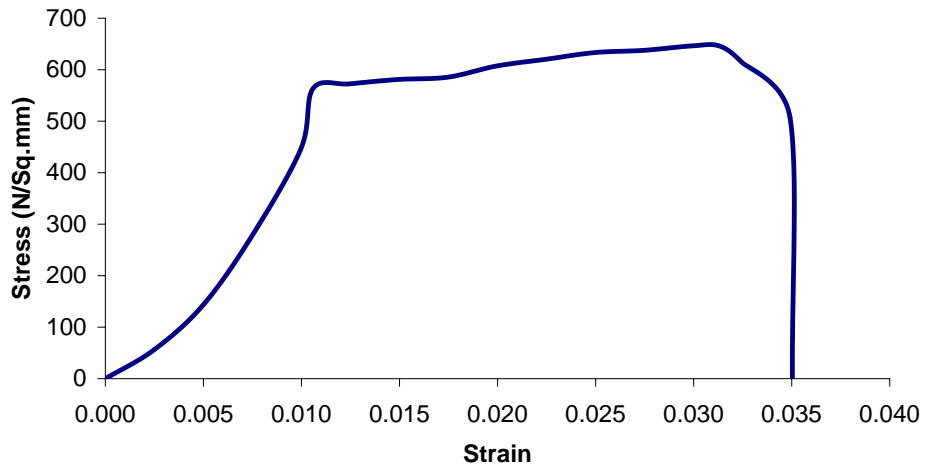


Fig. 10 Stress-Strain Curve (TMT4B)



**Table 9: Tensile Strength Test of Rebar**

Area of Cross Section of Bar 113.097 Sample No. TOR 1A  
 Length of Bar: 1000

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	0.7	0.4	200	0.0007	17.35	
2	2.7	1.5	750	0.0027	65.05	
3	4.7	3.0	1500	0.0047	130.11	
4	6.7	5.2	2600	0.0067	225.52	
5	8.7	7.7	3850	0.0087	333.95	
6	10.7	10.3	5150	0.0107	446.71	
7	12.7	11.8	5900	0.0127	511.76	
8	14.7	12.2	6100	0.0147	529.11	Yield Stress = 527 N/mm <sup>2</sup> .
9	16.7	12.7	6350	0.0167	550.80	
10	18.7	13.0	6500	0.0187	563.81	
11	20.7	13.2	6600	0.0207	572.48	
12	22.7	13.4	6700	0.0227	581.15	
13	24.7	13.4	6700	0.0247	581.15	
14	26.7	13.4	6700	0.0267	581.15	
15	28.7	13.3	6650	0.0287	576.82	
16	30.7	13.2	6600	0.0307	572.48	
17	32.7	11.9	5950	0.0327	516.10	
18	34.7	9.3	4650	0.0347	403.34	
19	34.7	0.0	0	0.0347	0.00	

**Table 10:**

Area of Cross Section of Bar 113.097 Sample No. TOR 1B  
 Length of Bar: 999

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	1.2	0.9	450	0.0012	39.03	
2	3.2	2.0	1000	0.0032	86.74	
3	5.2	3.4	1700	0.0052	147.46	
4	7.2	5.7	2850	0.0072	247.21	
5	9.2	8.4	4200	0.0092	364.31	
6	11.2	10.9	5450	0.0112	472.73	
7	13.2	12.0	6000	0.0132	520.44	
8	15.2	12.5	6250	0.0152	542.12	Yield Stress = 535 N/mm <sup>2</sup> .
9	17.2	12.9	6450	0.0172	559.47	
10	19.2	13.2	6600	0.0192	572.48	
11	21.2	13.4	6700	0.0212	581.15	
12	23.2	13.5	6750	0.0232	585.49	
13	25.2	13.6	6800	0.0252	589.83	
14	27.2	13.5	6750	0.0272	585.49	
15	29.2	13.5	6750	0.0292	585.49	
16	31.2	13.4	6700	0.0312	581.15	
17	33.2	12.0	6000	0.0332	520.44	
18	35.2	9.8	4900	0.0352	425.02	
19	35.2	0.0	0	0.0352	0.00	

Average Yield Strength of the bar = 531 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 11 Stress-Strain Curve (TOR1A)

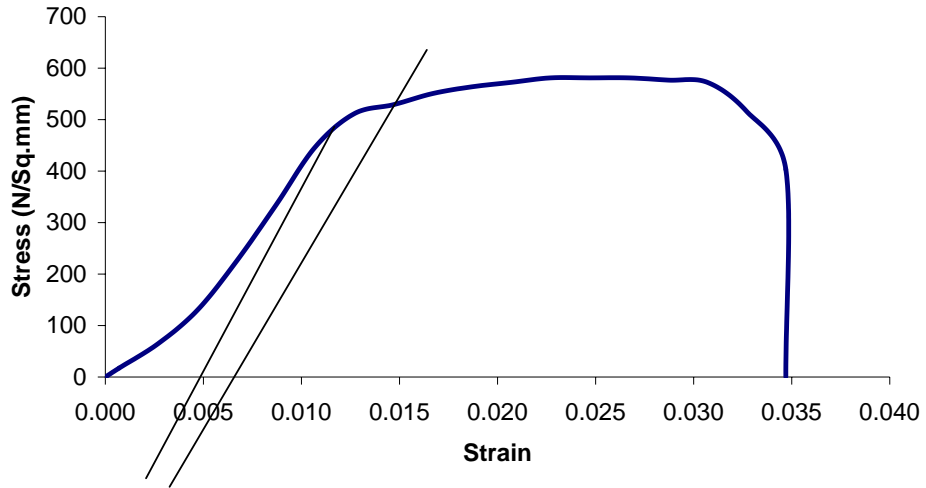
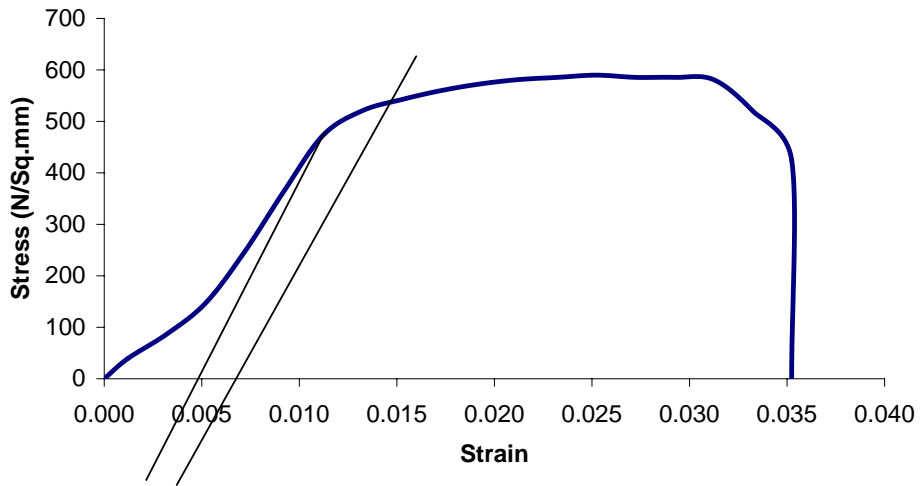


Fig. 12 Stress-Strain Curve (TOR1B)



**Table 11: Tensile Strength Test of Rebar**

Area of Cross Section of Bar 113.097 Sample No. TOR 2A

Length of Bar: 901

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0	0	0	0.0000	0.00	
1	0.9	0.7	350	0.0010	30.36	
2	2.9	2.4	1200	0.0032	104.09	
3	4.9	4.6	2300	0.0054	199.50	
4	6.9	6.5	3250	0.0077	281.90	
5	7.8	7.5	3750	0.0087	325.27	
6	8.9	7.9	3950	0.0099	342.62	
7	10.9	8.5	4250	0.0121	368.64	
8	12.9	9	4500	0.0143	390.33	Yield Stress = 353 N/mm <sup>2</sup> .
9	14.9	9.1	4550	0.0165	394.66	
10	16.9	9.4	4700	0.0188	407.68	
11	18.9	9.6	4800	0.0210	416.35	
12	20.9	9.6	4800	0.0232	416.35	
13	22.9	9.6	4800	0.0254	416.35	
14	24.9	9.5	4750	0.0276	412.01	
15	26.9	9.5	4750	0.0299	412.01	
16	28.9	9.4	4700	0.0321	407.68	
17	30.9	9	4500	0.0343	390.33	
18	32.9	7.9	3950	0.0365	342.62	
19	34.5	5.5	2750	0.0383	238.53	
20	34.5	0	0	0.0383	0.00	

**Table 12:**

Area of Cross Section of Bar 113.097 Sample No. TOR 2B

Length of Bar: 901

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	2.0	0.9	450	0.0022	39.03	
2	4.0	1.9	950	0.0044	82.40	
3	6.0	3.3	1650	0.0067	143.12	
4	8.0	5.0	2500	0.0089	216.85	
5	10.0	7.0	3500	0.0111	303.59	
6	12.0	9.5	4750	0.0133	412.01	
7	13.3	10.7	5350	0.0148	464.06	
8	14.0	10.9	5450	0.0155	472.73	
9	16.0	11.5	5750	0.0178	498.75	Yield Stress = 495 N/mm <sup>2</sup> .
10	18.0	12.0	6000	0.0200	520.44	
11	20.0	12.3	6150	0.0222	533.45	
12	22.0	12.5	6250	0.0244	542.12	
13	24.0	12.6	6300	0.0266	546.46	
14	26.0	12.7	6350	0.0289	550.80	
15	28.0	12.7	6350	0.0311	550.80	
16	30.0	12.7	6350	0.0333	550.80	
17	32.0	12.6	6300	0.0355	546.46	
18	34.0	12.5	6250	0.0377	542.12	
19	35.2	10.8	5400	0.0391	468.39	
20	35.2	0.0	0	0.0391	0.00	

Average Yield Strength of the bar = 424 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 13 Stress-Strain Curve (TOR2A)

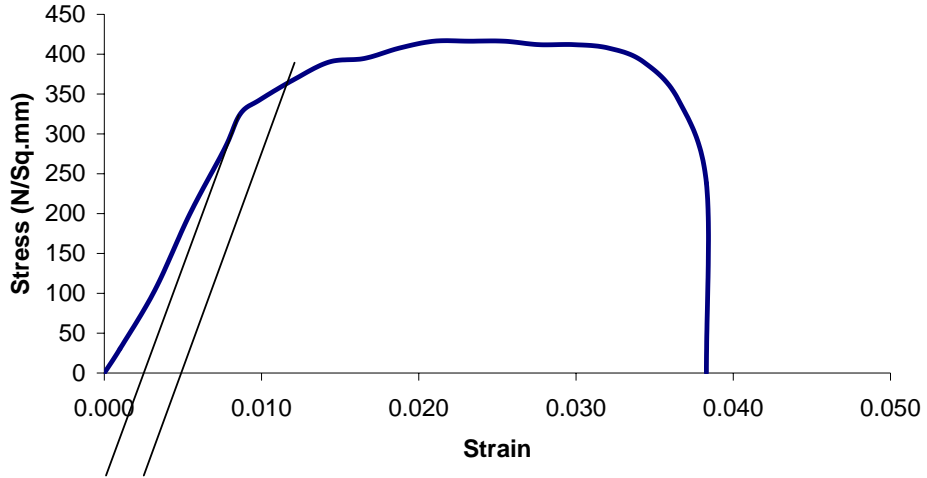
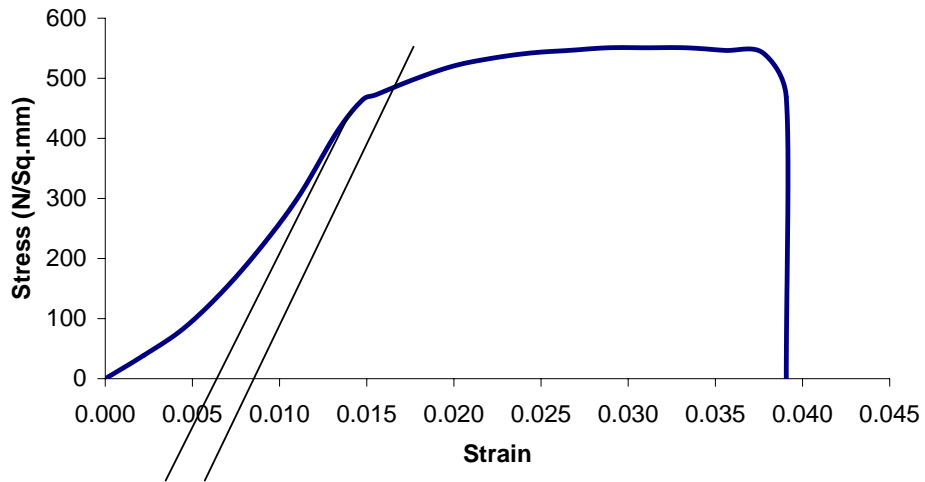


Fig. 14 Stress-Strain Curve (TOR2B)



**Table 13: Tensile Strength Test of Rebar**

Area of Cross Section of Bar: 113.097

Sample No. TOR 3A

Length of Bar: 801

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.00	0.00	0	0.0000	0.00	
1	0.50	0.30	150	0.0006	13.01	
2	2.50	0.76	380	0.0031	32.96	
3	4.50	1.80	900	0.0056	78.07	
4	6.50	3.00	1500	0.0081	130.11	
5	8.50	5.00	2500	0.0106	216.85	
6	10.50	7.00	3500	0.0131	303.59	
7	12.50	9.60	4800	0.0156	416.35	
8	14.50	11.40	5700	0.0181	494.41	
9	16.50	12.30	6150	0.0206	533.45	Yield Stress = 536 N/mm <sup>2</sup> .
10	18.50	12.80	6400	0.0231	555.13	
11	20.50	13.20	6600	0.0256	572.48	
12	22.50	13.50	6750	0.0281	585.49	
13	24.50	13.70	6850	0.0306	594.17	
14	26.50	13.80	6900	0.0331	598.50	
15	28.50	13.80	6900	0.0356	598.50	
16	30.50	13.80	6900	0.0381	598.50	
17	32.50	13.90	6950	0.0406	602.84	
18	34.50	13.70	6850	0.0431	594.17	
19	36.50	12.20	6100	0.0456	529.11	
20	37.80	10.70	5350	0.0472	464.06	
	37.80	0.00	0	0.0472	0	

Area of Cross Section of Bar: 113.097

Sample No. TOR 3B

Length of Bar: 803

**Table 14:**

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	2.0	0.6	300	0.0025	26.02	
2	4.0	1.5	750	0.0050	65.05	
3	6.0	2.8	1400	0.0075	121.44	
4	8.0	4.8	2400	0.0100	208.17	
5	10.0	7.0	3500	0.0125	303.59	
6	12.0	9.2	4600	0.0149	399.00	
7	14.0	11.3	5650	0.0174	490.08	
8	16.0	12.0	6000	0.0199	520.44	
9	18.0	12.5	6250	0.0224	542.12	Yield Stress = 547 N/mm <sup>2</sup> .
10	20.0	12.9	6450	0.0249	559.47	
11	22.0	13.1	6550	0.0274	568.14	
12	24.0	13.3	6650	0.0299	576.82	
13	26.0	13.5	6750	0.0324	585.49	
14	28.0	13.5	6750	0.0349	585.49	
15	30.0	13.5	6750	0.0374	585.49	
16	32.0	13.5	6750	0.0399	585.49	
17	34.0	13.5	6750	0.0423	585.49	
18	36.0	13.5	6750	0.0448	585.49	
19	37.4	13.3	6650	0.0465	576.82	
20	38.0	12.9	6450	0.0473	559.47	
21	40.0	10.8	5400	0.0498	468.39	
22	41.8	5.9	2950	0.0521	255.88	
		41.8	0.0	0	0.0521	

Average Yield Strength of the bar =

541.5 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 15 Stress-Strain Curve (TOR3A)

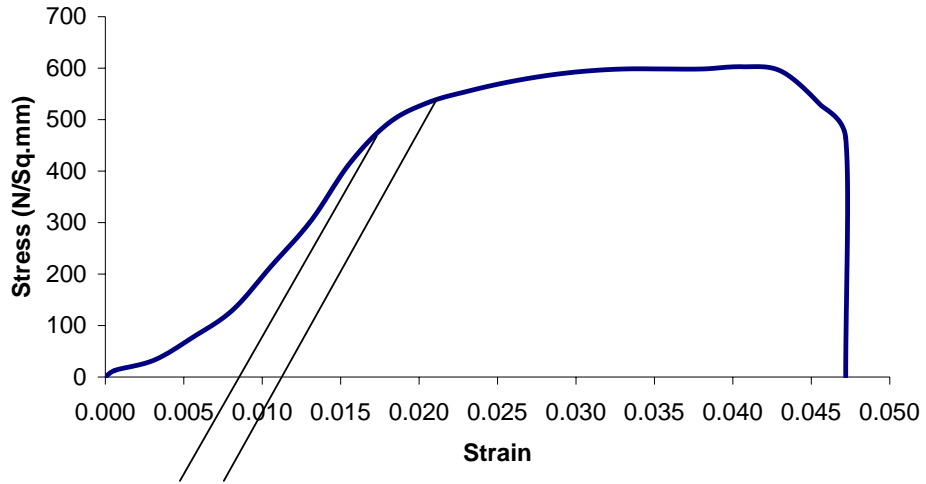
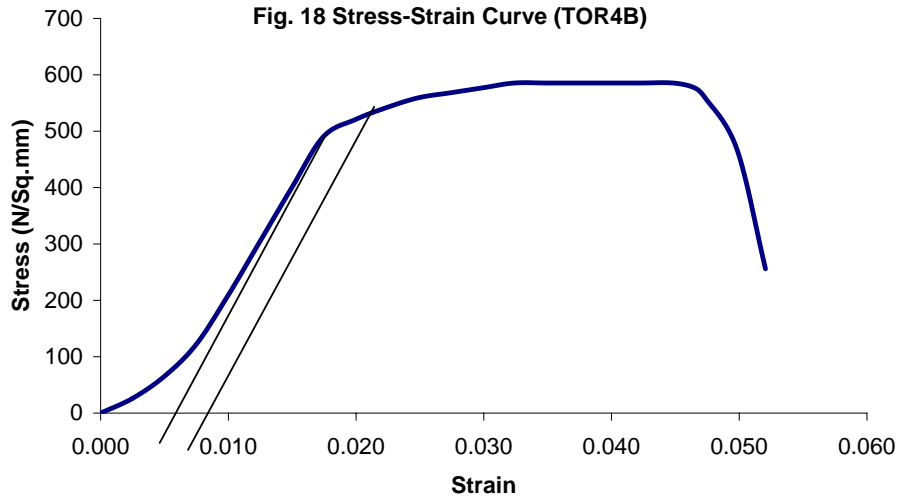


Fig. 18 Stress-Strain Curve (TOR4B)



**Table 15: Tensile Strength Test of Rebar**

Area of Cross Section of Bar: 113.097

Sample No. TOR 4A

Length of Bar: 900

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.00	0.00	0	0.0000	0.00	
1	2.00	1.30	650	0.0022	56.38	
2	4.00	2.66	1330	0.0044	115.36	
3	6.00	4.80	2400	0.0067	208.17	
4	8.00	7.30	3650	0.0089	316.60	
5	10.00	10.30	5150	0.0111	446.71	
6	11.90	12.10	6050	0.0132	524.77	
7	14.00	12.70	6350	0.0156	550.80	
8	16.00	13.00	6500	0.0178	563.81	
9	18.00	13.30	6650	0.0200	576.82	Yield Stress = 531 N/mm <sup>2</sup> .
10	20.00	13.50	6750	0.0222	585.49	
11	22.00	13.60	6800	0.0244	589.83	
12	24.00	13.60	6800	0.0267	589.83	
13	26.00	13.60	6800	0.0289	589.83	
14	28.00	13.60	6800	0.0311	589.83	
15	30.00	13.60	6800	0.0333	589.83	
16	30.80	13.60	6800	0.0342	589.83	
17	32.00	12.95	6475	0.0356	561.64	
18	34.00	11.00	5500	0.0378	477.07	
19	34.40	9.20	4600	0.0382	399.00	
	34.40	0.00	0	0.0382	0.00	

**Table 16:**

Area of Cross Section of Bar: 113.097

Sample No. TOR 4B

Length of Bar: 900

S.No.	Deflection (mm)	scale	Load (Kg)	Strain	Stress (N/mm <sup>2</sup> )	Remarks
0	0.0	0.0	0	0.0000	0.00	
1	2.0	0.9	450	0.0022	39.03	
2	4.0	2.2	1100	0.0044	95.41	
3	6.0	3.9	1950	0.0067	169.14	
4	8.0	6.2	3100	0.0089	268.89	
5	10.0	8.8	4400	0.0111	381.65	
6	12.0	11.3	5650	0.0133	490.08	
7	14.0	12.3	6150	0.0156	533.45	
8	16.0	12.7	6350	0.0178	550.80	
9	18.0	13.1	6550	0.0200	568.14	
10	20.0	13.3	6650	0.0222	576.82	Yield Stress = 543 N/mm <sup>2</sup> .
11	22.0	13.4	6700	0.0244	581.15	
12	24.0	13.5	6750	0.0267	585.49	
13	26.0	13.5	6750	0.0289	585.49	
14	28.0	13.5	6750	0.0311	585.49	
15	30.0	13.4	6700	0.0333	581.15	
16	30.9	13.4	6700	0.0343	581.15	
17	32.0	12.3	6150	0.0356	533.45	
18	33.4	7.5	3750	0.0371	325.27	
	33.4	0.0	0	0.0371	0.00	

Average Yield Strength of the bar =

537 N/mm<sup>2</sup>

# Tensile Strength Test of Rebar

Fig. 17 Stress-Strain Curve (TOR4A)

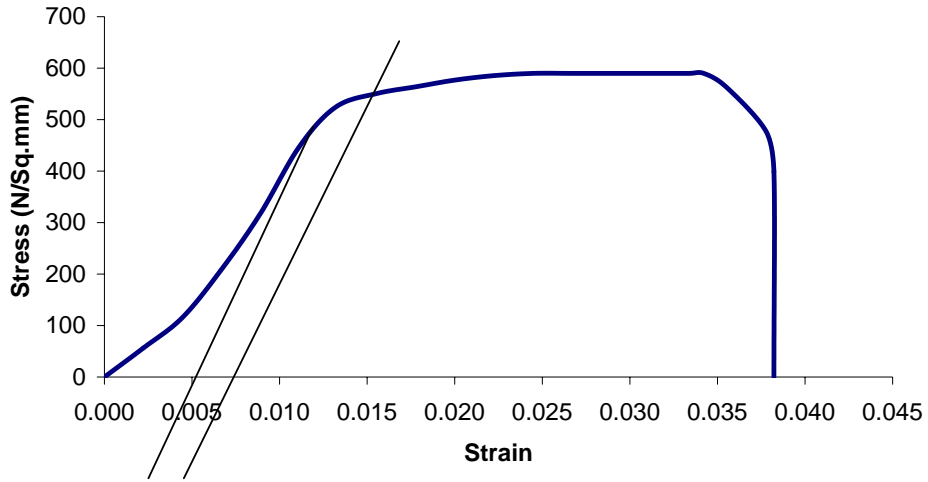
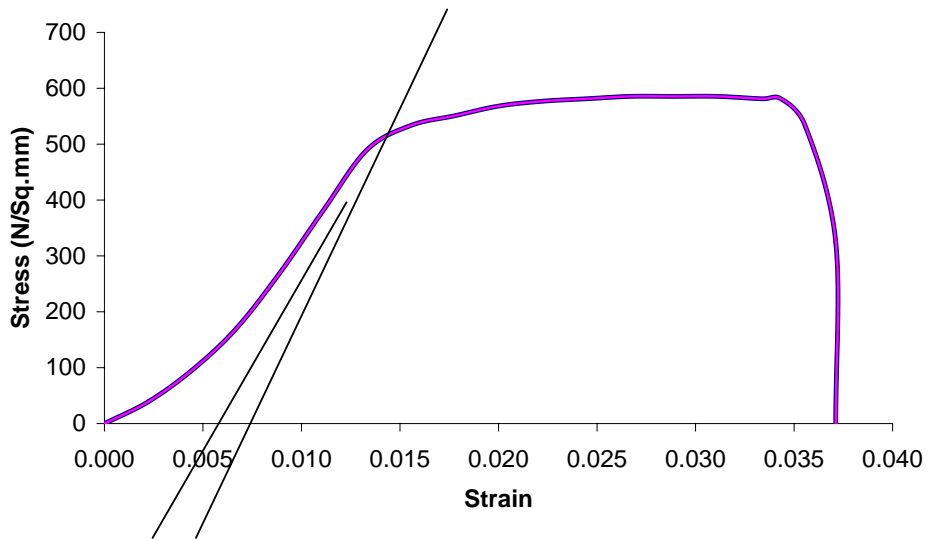


Fig. 18 Stress-Strain Curve (TOR4B)



### Cube Test (Characteristic Strength)

Sample: Beam: M-T-1

**Table 17**

Date of Casting: 2063/5/19

Date of testing: 2063/8/7

80 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-1-A	8.297	980	2458.37	956.79	42.52						
2	C-1-B	8.318	1110	2464.59	1082.78	48.12						
3	C-1-C	8.346	1225	2472.89	1194.24	53.08	46.19		2463.17			Taking all 5 values
4	C-1-D	8.327	920	2467.26	898.63	39.94		45.97		2458.57	37.77	Taking best 3 values Only
5	C-1-E	8.278	1090	2452.74	1063.40	47.26						

Sample: Beam: M-T-2

**Table 18**

Date of Casting: 2063/5/26

Date of testing: 2063/8/11

77 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-3-A	8.25	1010	2444.44	985.86	43.82						
2	C-3-B	8.339	910	2470.81	888.94	39.51						
3	C-3-C	8.386	990	2484.74	966.48	42.95	42.61		2470.99			Taking all 5 values
4	C-3-D	8.409	1060	2491.56	1034.32	45.97		42.52		2464.20	34.32	Taking best 3 values Only
5	C-3-E	8.314	940	2463.41	918.02	40.80						

Sample: Beam: M-C-1

**Table 19**

Date of Casting: 2063/6/3

Date of testing: 2063/8/12

70 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-5-A	8.285	1025	2454.81	1000.40	44.46						
2	C-5-B	8.21	1100	2432.59	1073.09	47.69						
3	C-5-C	8.225	1085	2437.04	1058.55	47.05	47.09		2450.61			Taking all 5 values
4	C-5-D	8.185	1125	2425.19	1097.32	48.77		47.41		2457.68	39.21	Taking best 3 values Only
5	C-5-E	8.449	1095	2503.41	1068.24	47.48						

### Cube Test (Characteristic Strength)

Sample: Beam: M-C-2

**Table 20**

Date of Casting: 2063/6/6

Date of testing: 2063/8/13

68 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-6-A	8.452	1200	2504.30	1170.01	52.00						
2	C-6-B	8.415	1200	2493.33	1170.01	52.00	52.86		2481.24			Taking all 5 values
3	C-6-C	8.349	1250	2473.78	1218.47	54.15		52.00		2487.60	43.80	Taking best 3 values Only
4	C-6-D	8.32	1200	2465.19	1170.01	52.00						
5	C-6-E	8.335	1250	2469.63	1218.47	54.15						

Sample: Beam: C-T-1

**Table 21**

Date of Casting: 2063/5/30

Date of testing: 2063/8/29

91 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-4-A	8.290	1120	2456.30	1092.47	48.55						
2	C-4-B	8.297	1090	2458.37	1063.40	47.26	48.47		2472.30			Taking all 5 values
3	C-4-C	8.449	1135	2503.41	1107.01	49.20		48.34		2472.69	40.14	Taking best 3 values Only
4	C-4-D	8.291	1165	2456.59	1136.09	50.49						
5	C-4-E	8.393	1080	2486.81	1053.70	46.83						

Sample: Beam: C-T-2

**Table 22**

Date of Casting: 2063/5/23

Date of testing: 2063/09/05

103 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-2-A	8.150	1070	2414.81	1044.01	46.40						
2	C-2-B	8.185	1020	2425.19	995.55	44.25	44.03		2425.07			Taking all 5 values
3	C-2-C	8.240	910	2441.48	888.94	39.51		44.75		2423.01	36.55	Taking best 3 values Only
4	C-2-D	8.178	1060	2423.11	1034.32	45.97						
5	C-2-E	8.170	1015	2420.74	990.71	44.03						

### Cube Test (Characteristic Strength)

Sample: Beam: C-C-1

**Table 23**

Date of Casting: 2063/6/8

Date of testing: 2063/09/07

89 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-7-A	8.362	1300	2477.63	1266.93	56.31						
2	C-7-B	8.376	1260	2481.78	1228.16	54.58	51.48		2472.83			Taking all 5 values
3	C-7-C	8.348	1110	2473.48	1082.78	48.12		51.14		2474.57	42.94	Taking best 3 values Only
4	C-7-D	8.331	1170	2468.44	1140.93	50.71						
5	C-7-E	8.312	1100	2462.81	1073.09	47.69						

Sample: Beam: C-C-2

**Table 24**

Date of Casting: 2063/6/10

Date of testing: 2063/09/9

89 days age

S. No.	Sample No.	Weight (Kg)	Load (KN)	Density	Modified Load	Strength	Average Strength		Average Density		Characteristic Strength (N/Sq. mm)	Remarks
1	C-8-A	8.272	900	2450.96	879.25	39.08						
2	C-8-B	8.287	1030	2455.41	1005.24	44.68	44.38		2455.64			Taking all 5 values
3	C-8-C	8.24	1115	2441.48	1087.63	48.34		44.82		2461.93	36.62	Taking best 3 values Only
4	C-8-D	8.287	1040	2455.41	1014.94	45.11						
5	C-8-E	8.353	1030	2474.96	1005.24	44.68						

**Table 24 A: Summary Characteristic Strength of Concrete & Yield Strength of Rebar**

S.No.	Beam Sample No.	Concrete $f_{ck}$ (N/mm <sup>2</sup> )	Rebar $f_y$ (N/mm <sup>2</sup> )	Rebar Sample No.	Remarks
1	M-T-1	37.77	642	TMT 1	
2	M-T-2	34.32	620	TMT 2	
3	M-C-1	39.21	531	TOR 1	
4	M-C-2	43.80	424	TOR 2	
5	C-T-1	40.14	639	TMT 3	
6	C-T-2	36.55	612.5	TMT 4	
7	C-C-1	42.94	541.5	TOR 3	
8	C-C-2	36.62	537	TOR 4	

### **3.3 Analysis of Beam after test of Rebar and Concrete**

Before the experiment of the beam it was designed in the preliminary analysis with the yield strength of rebar as 415 N/mm<sup>2</sup> and the characteristic strength of the concrete as 20 N/mm<sup>2</sup>. After testing the rebar for the tensile strength test and compressive strength test of the concrete the value of yield strain of the bar and the characteristic strength of the concrete from the experiment was used to analyze the beam section finally. The crack load and the cracking deflection of the beam was analyzed depending on the experimental yield strength of rebar and the characteristic strength of the concrete individually for all beams. Similarly the yield load and the yield deflection were also analyzed. Finally the crushing load and the crushing deflection were also analyzed. All these analysis are tabulated in following table.

## Analysis after test of Rebar and Concrete

Width of section = 230 mm  
 Depth of section = 300 mm  
 Effective depth of section = 270 mm  
 Moment of inertia = 377257500 mm<sup>4</sup>.  
 Gross moment of inertia = 517500000 mm<sup>4</sup>.  
 Span L = 1800 mm  
 Load Position (x)= 600 mm  
 Diameter of Bar = 12 mm  
 Number of Bar = 4 nos  
 Area of total bar = 452.39 mm<sup>2</sup>  
 E<sub>s</sub> = 2.0E+05 N/mm<sup>2</sup>

**Table 24B: Cracking Load & Deflection**

S.No.	Sample Number	Concrete		E <sub>c</sub>	Rebar f <sub>y</sub>	m	Moment (M)	Load (P)	P/2	Deflection (δ)	Remarks
		f <sub>ck</sub>	σ <sub>t</sub>								
1	M-T-1	37.77	4.30	30728.65	642	6.51	10819773.16	<b>36065.91</b>	18032.96	<b>0.2347</b>	
2	M-T-2	34.32	4.10	29291.64	620	6.83	10313790.44	<b>34379.30</b>	17189.65	<b>0.2347</b>	
3	M-C-1	39.21	4.38	31308.94	531	6.39	11024098.49	<b>36746.99</b>	18373.50	<b>0.2347</b>	
4	M-C-2	43.80	4.63	33090.78	424	6.04	11651496.76	<b>38838.32</b>	19419.16	<b>0.2347</b>	
5	C-T-1	40.14	4.43	31678.07	639	6.31	11154069.53	<b>37180.23</b>	18590.12	<b>0.2347</b>	
6	C-T-2	36.55	4.23	30228.30	612.5	6.62	10643595.32	<b>35478.65</b>	17739.33	<b>0.2347</b>	
7	C-C-1	42.94	4.59	32764.31	541.5	6.10	11536542.85	<b>38455.14</b>	19227.57	<b>0.2347</b>	
8	C-C-2	36.62	4.24	30257.23	537	6.61	10653782.67	<b>35512.61</b>	17756.30	<b>0.2347</b>	

**Table 24C: Yield Load & Deflection**

Sample No.	Strain ε <sub>y</sub>	Tension T	x	z	Compression 0.8095 f <sub>ck</sub> bx	Yield Moment	Yield Load (P)	P/2	I <sub>r</sub>	I <sub>ef</sub>	Deflection (δ)	Remark
M-T-1	3.210E-03	290433.96	41.30	252.65	290433.96	73379383.57	<b>244597.95</b>	122298.97	159405141.54	147171109.71	<b>5.60</b>	
M-T-2	3.100E-03	280481.39	43.89	251.56	280481.39	70559236.39	<b>235197.45</b>	117598.73	164399071.20	151387500.51	<b>5.49</b>	
M-C-1	2.655E-03	240218.74	32.90	256.18	240218.74	61539284.16	<b>205130.95</b>	102565.47	165181864.82	157204699.79	<b>4.31</b>	
M-C-2	2.120E-03	191813.08	23.52	260.12	191813.08	49894684.84	<b>166315.62</b>	83157.81	167108002.73	168011796.10	<b>3.10</b>	
C-T-1	3.195E-03	289076.79	38.68	253.75	289076.79	73354594.60	<b>244515.32</b>	122257.66	157267964.99	145947602.72	<b>5.47</b>	
C-T-2	3.063E-03	277088.47	40.72	252.90	277088.47	70075382.25	<b>233584.61</b>	116792.30	162527520.66	150601851.17	<b>5.31</b>	
C-C-1	2.708E-03	244968.83	30.64	257.13	244968.83	62989110.30	<b>209963.70</b>	104981.85	160418972.62	153456374.00	<b>4.32</b>	
C-C-2	2.685E-03	242933.08	35.63	255.04	242933.08	61956576.03	<b>206521.92</b>	103260.96	167722733.88	158377112.33	<b>4.46</b>	

### **3.4 The beam test**

The experiment consisted of total eight beam samples. Four beams reinforced with TMT bar and four beams reinforced with TOR steel bar. Two beams reinforced with TMT bar and two beams reinforced with TOR steel bar were tested under monotonic loading. Remaining other four beams was tested under cyclic loading. The designation of beam samples was as following in the table 25. In each experiment the load and corresponding deflection was noted. The graph of load and deflection was plotted from which a curve was achieved called load deflection curve shown in figure 19 to 26. From this curve the yield load on the beam, yield deflection of the beam at its center, the crushing load and the crushing deflection were calculated. All these analysis were shown in the table 26 to 33.

S. No.	Sample	Remarks
1.0	M-T-1	The first letter stands for loading condition (M for monotonic loading and C of cyclic loading). The middle letter stands for bar type used in beam (T for TMT bar and C for cold twisted TOR steel bar). And the last letter stands for specimen number.
2.0	M-T-2	
3.0	M-C-1	
4.0	M-C-2	
5.0	C-T-1	
6.0	C-T-2	
7.0	C-C-1	
8.0	C-C-2	

**Table 25: Sample No. of Specimen Beams**

While testing the beam the development of the crack was observed. When the crack was seen it was marked with the marker and numbered it. It was noted on the note book with appropriate distance from the support, the tentative length of crack and slope. The nearest load at which the crack was seen by naked eyes on the beam was also noted. At the end the crack from which the beam failed was also observed. The tentative crack patterns developed on the beams are shown in following figures 27 to 33.

## Beam Test Load Vs Deflection

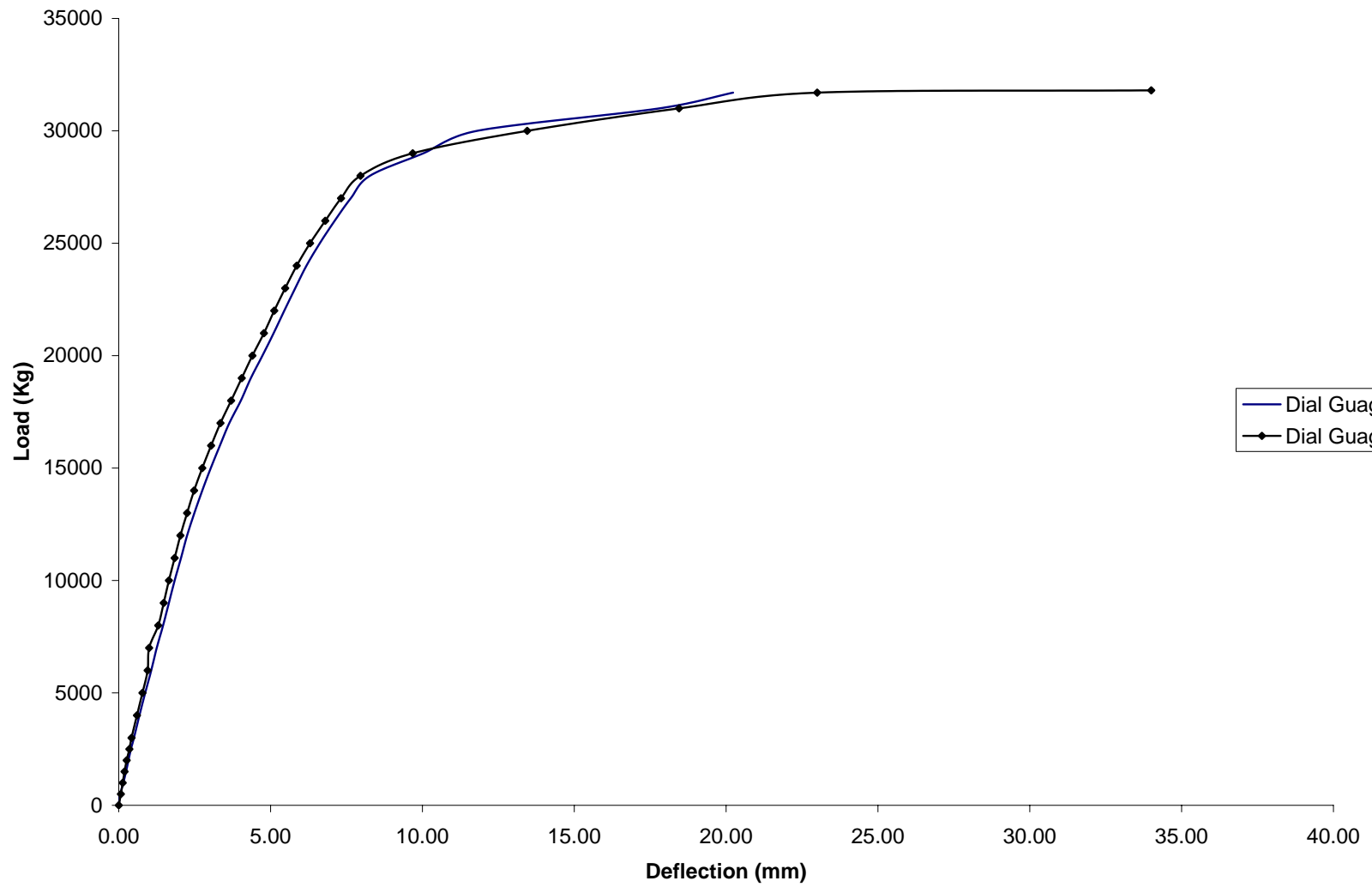
**Table 26**

Beam Sample No: M-T-1  
 Rebar Type: TMT Bar Sample No. : TMT 1  
 Loading Type: Monotonic  
 Date of Casting: 2063/05/19  
 Date of Testing: 2063/8/7  
 Age 80 days  
 Dial Guage Constant = 0.01

S.No.	Load (kg)	Dial Guage Reading		Deflection		Remarks
		Guage 1	Guage 2	Guage 1	Guage 2	
1	0	0	0	0.00	0.00	
2	500	5	7	0.05	0.07	
3	1000	15	13	0.15	0.13	
4	1500	24	19	0.24	0.19	
5	2000	32	26	0.32	0.26	
6	2500	40	35	0.40	0.35	
7	3000	50	42	0.50	0.42	
8	4000	68	60	0.68	0.60	
9	5000	87	78	0.87	0.78	
10	6000	107	95	1.07	0.95	
11	7000	125	100	1.25	1.00	
12	8000	146	130	1.46	1.30	
13	9000	165	148	1.65	1.48	
14	10000	184	165	1.84	1.65	
15	11000	205	184	2.05	1.84	
16	12000	225	203	2.25	2.03	
17	13000	249	225	2.49	2.25	
18	14000	275	248	2.75	2.48	
19	15000	303	275	3.03	2.75	
20	16000	333	304	3.33	3.04	
21	17000	364	335	3.64	3.35	
22	18000	402	370	4.02	3.70	
23	19000	435	405	4.35	4.05	
24	20000	473	440	4.73	4.40	
25	21000	510	478	5.10	4.78	
26	22000	545	512	5.45	5.12	
27	23000	581	548	5.81	5.48	
28	24000	618	586	6.18	5.86	
29	25000	662	630	6.62	6.30	
30	26000	711	680	7.11	6.80	
31	27000	764	732	7.64	7.32	
32	28000	827	796	8.27	7.96	
33	29000	1003	968	10.03	9.68	
34	30000	1180	1345	11.80	13.45	
35	31000	1780	1845	17.80	18.45	
36	31700	2023	2300	20.23	23.00	Tape Measurement (240 mm)
37	31800				34.00	Tape Measurement (229 mm)

Yield Load = 28000 Kg, yeild deflection = 8.12mm

Fig. 19: Load Vs Deflection Curve (M-T-1)



## Beam Test Load Vs Deflection

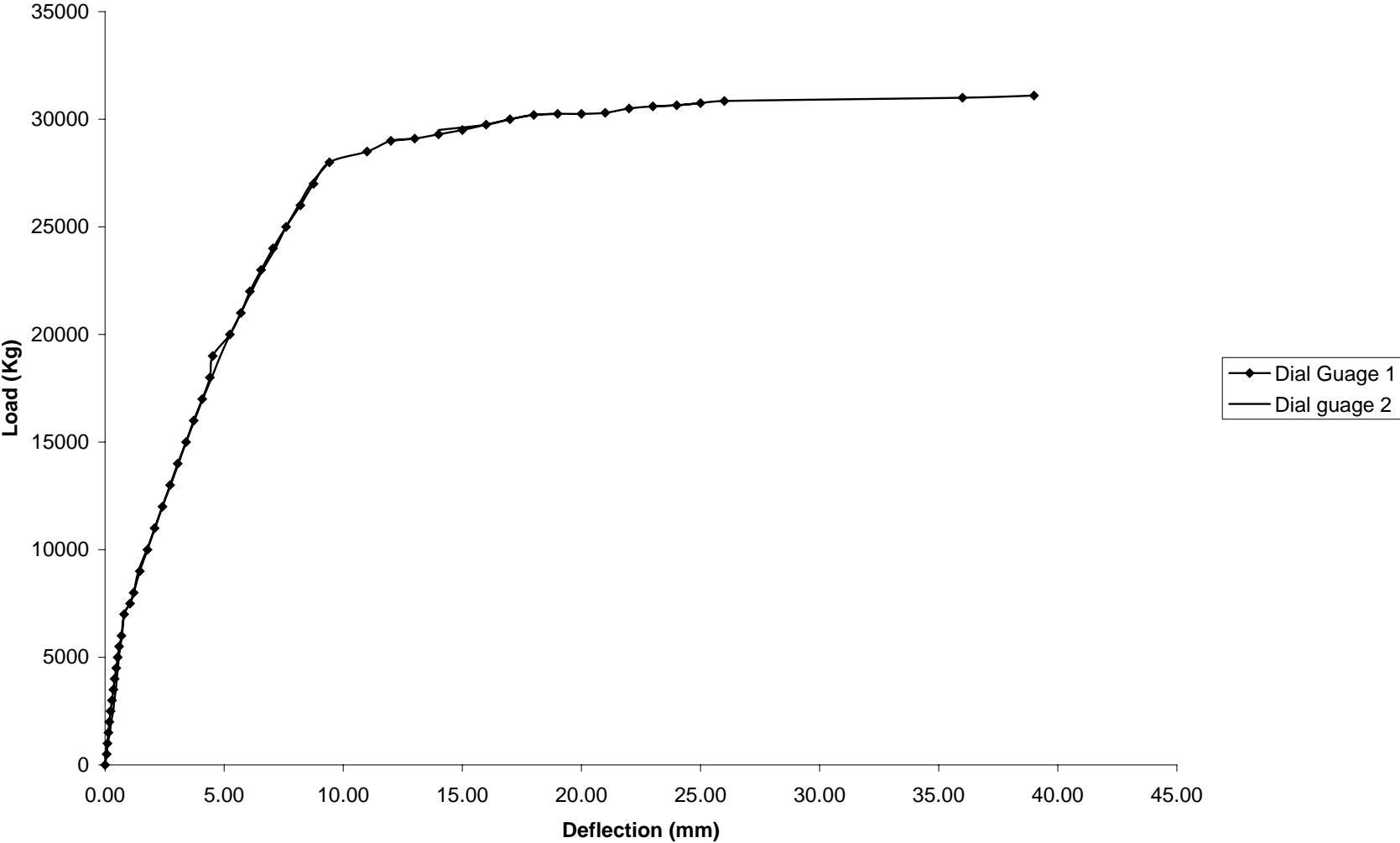
**Table 27**

Beam Sample No: M-T-2  
 Rebar Type: TMT  
 Loading Type: Monotonic  
 Date of Casting: 2063/05/26  
 Date of Testing: 2063/8/11  
 Age: 77 days  
 Dial Guage Constant = 0.01

S.No.	Load (kg)	Dial Guage Reading		Deflection		Remarks
		Guage 1	Guage 2	Guage 1	Guage 2	
1	0	0	100	0.00	0.00	
2	500	7	102	0.07	0.02	
3	1000	10	111	0.10	0.11	
4	1500	14	120	0.14	0.20	
5	2000	18	126	0.18	0.26	
6	2500	23	134	0.23	0.34	
7	3000	29	139	0.29	0.39	
8	3500	35	145	0.35	0.45	
9	4000	40	149	0.40	0.49	
10	4500	47	154	0.47	0.54	
11	5000	53	158	0.53	0.58	
12	5500	59	164	0.59	0.64	
13	6000	69	171	0.69	0.71	
14	7000	80	181	0.80	0.81	
15	7500	105	204	1.05	1.04	
16	8000	120	220	1.20	1.20	
17	9000	146	240	1.46	1.40	
18	10000	178	275	1.78	1.75	
19	11000	208	310	2.08	2.10	
20	12000	241	340	2.41	2.40	
21	13000	273	375	2.73	2.75	
22	14000	305	408	3.05	3.08	
23	15000	340	440	3.40	3.40	
24	16000	372	475	3.72	3.75	
25	17000	408	510	4.08	4.10	
26	18000	440	548	4.40	4.48	
27	19000	452	584	4.52	4.84	
28	20000	524	625	5.24	5.25	
29	21000	570	670	5.70	5.70	
30	22000	608	715	6.08	6.15	
31	23000	655	762	6.55	6.62	
32	24000	705	815	7.05	7.15	
33	25000	760	860	7.60	7.60	
34	26000	820	912	8.20	8.12	
35	27000	875	965	8.75	8.65	
36	28000	942	1040	9.42	9.40	
37	28500	1100		11.00		
38	29000	1200	1300	12.00	12.00	
39	29100	1300	1400	13.00	13.00	
40	29300	1400		14.00		
41	29500	1500	1500	15.00	14.00	
42	29750	1600	1700	16.00	16.00	
43	30000	1700	1800	17.00	17.00	

S.No.	Load (kg)	Dial Guage Reading		Deflection		Remarks
		Guage 1	Guage 2	Guage 1	Guage 2	
44	30200	1800	1900	18.00	18.00	
45	30250	1900	2000	19.00	19.00	
46	30250	2000		20.00		
47	30300	2100	2100	21.00	20.00	
48	30500	2200		22.00		
49	30600	2300	2400	23.00	23.00	
50	30650	2400	2500	24.00	24.00	
51	30750	2500	2600	25.00	25.00	
52	30850	2600		26.00		Tape Measurement 238 mm
53	31000	228		36.00		
54	31100	225		39.00		Beam broken by single rod
55		173		91.00		Break

Fig. 20: Load Vs Deflection Curve (M-T-2)



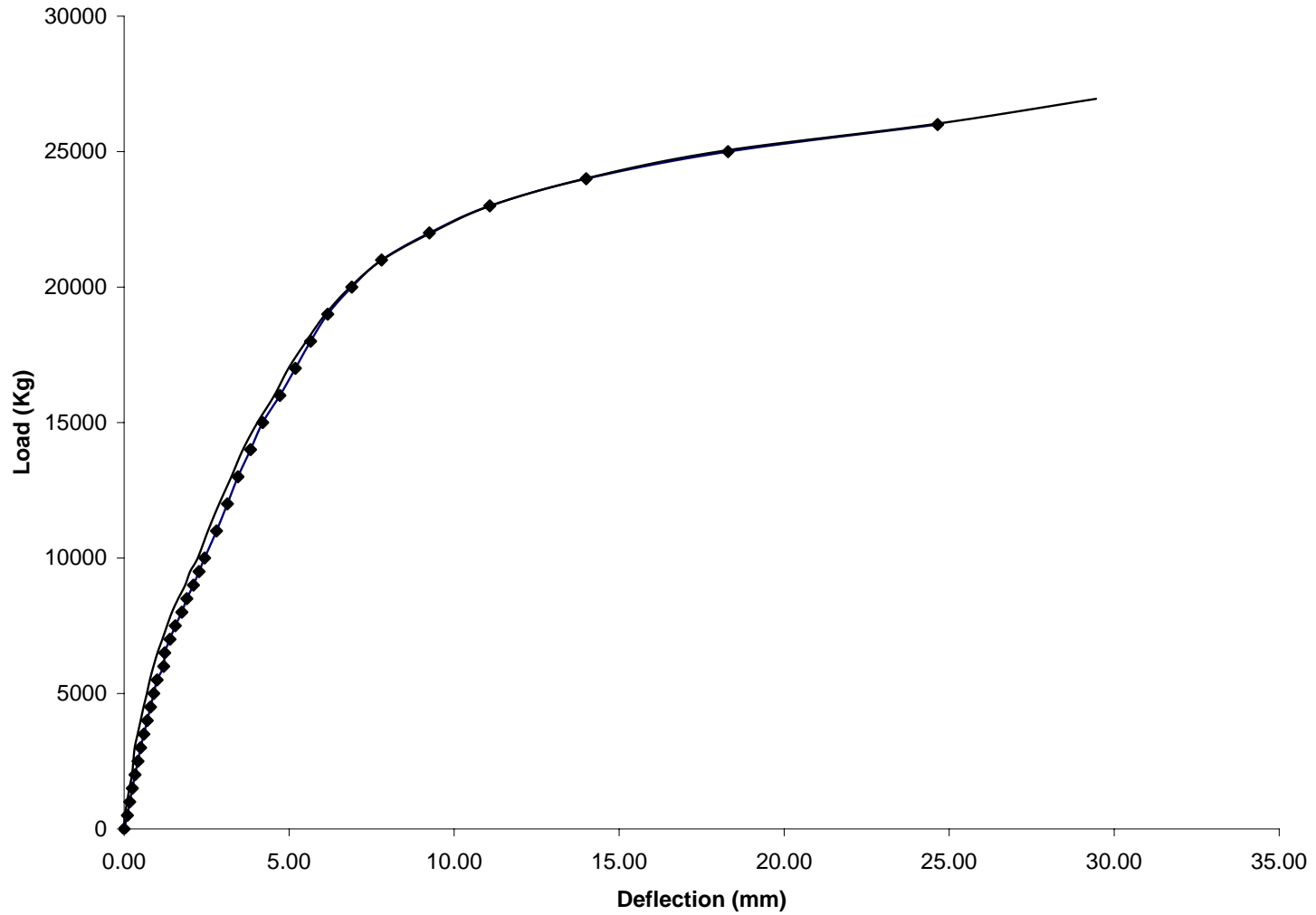
## Beam Test Load Vs Deflection

**Table 28**

Beam Sample No: M-C-1  
 Rebar Type: TOR Steel  
 Loading Type: Monotonic  
 Date of Casting: 2063/06/03  
 Date of Testing: 2063/8/12  
 Age: 70 days  
 Dial Guage Constant = 0.01

S.No.	Load (kg)	Dial Guage Reading		Deflection		Remarks
		Guage 1	Guage 2	Guage 1	Guage 2	
0	0	0	0	0.00	0.00	
1	500	10	2	0.10	0.02	
2	1000	17	9	0.17	0.09	
3	1500	25	16	0.25	0.16	
4	2000	33	24	0.33	0.24	
5	2500	42	28	0.42	0.28	
6	3000	50	32	0.50	0.32	
7	3500	60	41	0.60	0.41	
8	4000	70	50	0.70	0.50	
9	4500	80	59	0.80	0.59	
10	5000	90	69	0.90	0.69	
11	5500	100	78	1.00	0.78	
12	6000	120	89	1.20	0.89	
13	6500	123	101	1.23	1.01	
14	7000	139	116	1.39	1.16	
15	7500	155	130	1.55	1.30	
16	8000	175	145	1.75	1.45	
17	8500	190	164	1.90	1.64	
18	9000	210	185	2.10	1.85	
19	9500	227	200	2.27	2.00	
20	10000	244	223	2.44	2.23	
21	11000	280	254	2.80	2.54	
22	12000	313	288	3.13	2.88	
23	13000	345	325	3.45	3.25	
24	14000	383	360	3.83	3.60	
25	15000	420	404	4.20	4.04	
26	16000	472	455	4.72	4.55	
27	17000	519	498	5.19	4.98	
28	18000	565	552	5.65	5.52	
29	19000	617	610	6.17	6.10	
30	20000	690	685	6.90	6.85	
31	21000	780	782	7.80	7.82	
32	22000	925	930	9.25	9.30	
33	23000	1108	1110	11.08	11.10	
34	24000	1400	1395	14.00	13.95	
35	25000	1830	1800	18.30	18.00	
36	26000	2465	2445	24.65	24.45	Tape Measurement 230 mm
37	26950		225		29.45	Beam Break by Shear failure

Fig. 21 Load Vs Deflection Curve (M-C-1)



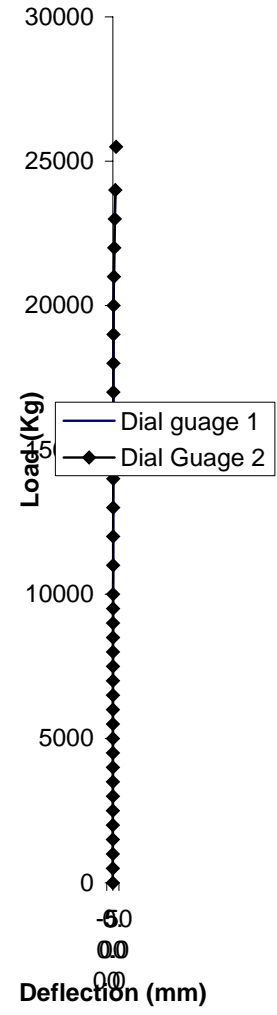
## Beam Test (Load Vs Deflection)

**Table 29**

Beam Sample No: M-C-2  
 Rebar Type: TOR Bar sample no.: TOR 2  
 Loading Type: Monotonic  
 Date of Casting: 2063/06/06  
 Date of Testing: 2063/8/13  
 Age 68 days  
 Dial Guage Constant = 0.01

S.No.	Load (kg)	Dial Guage Reading		Deflection		Remarks
		Guage 1	Guage 2	Guage 1	Guage 2	
1	0	0	0	0.00	0.00	
2	500	6	1	0.06	0.01	
3	1000	14	0	0.14	0.00	
4	1500	20	9	0.20	0.09	
5	2000	30	14	0.30	0.14	
6	2500	38	19	0.38	0.19	
7	3000	45	24	0.45	0.24	
8	3500	51	30	0.51	0.30	
9	4000	60	36	0.60	0.36	
10	4500	67	43	0.67	0.43	
11	5000	78	50	0.78	0.50	
12	5500	85	57	0.85	0.57	
13	6000	95	64	0.95	0.64	
14	6500	105	73	1.05	0.73	
15	7000	115	82	1.15	0.82	
16	7500	129	95	1.29	0.95	
17	8000	143	109	1.43	1.09	
18	8500	158	122	1.58	1.22	
19	9000	175	140	1.75	1.40	
20	9500	195	154	1.95	1.54	
21	10000	209	171	2.09	1.71	
22	11000	245	205	2.45	2.05	
23	12000	278	238	2.78	2.38	
24	13000	310	270	3.10	2.70	
25	14000	344	300	3.44	3.00	
26	15000	380	335	3.80	3.35	
27	16000	415	373	4.15	3.73	
28	17000	465	415	4.65	4.15	
29	18000	515	465	5.15	4.65	
30	19000	572	522	5.72	5.22	
31	20000	650	630	6.50	6.30	
32	21000	930	870	9.30	8.70	
33	22000	1205	1150	12.05	11.50	
34	23000	1660	1600	16.60	16.00	
35	24000	2085	2030	20.85	20.30	
36	25000					Beam broken by all bar rupture
37	25500			27.23	26.75	

Fig. 22: Load Vs Deflection Curve (M-C-2)



## Beam Test (Load Vs Deflection)

**Table 30**

Beam Sample No: C-T-1

Rebar Type: TMT Bar

Steel: TMT 3

Loading Type: Cyclic

Date of Casting: 2063/05/30

Date of Testing: 2063/8/29

Age 91 days

Dial Guage Constant = 0.01

Dial guage No. : 1

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.000		41	20000	441	4.41	
2	500	1.5	0.015		42	20500	462	4.62	
3	1000	5.5	0.055		43	21000	485	4.85	
4	1500	9.5	0.095		44	21500	507	5.07	
5	2000	14	0.140		45	22000	528	5.28	
6	2500	18	0.180		46	22500	553	5.53	
7	3000	24	0.240		47	23000	574	5.74	
8	3500	28	0.280		48	23500	597	5.97	
9	4000	34	0.340		49	24000	620	6.20	
10	4500	38.5	0.385		50	24500	644	6.44	
11	5000	44	0.440		51	25000	668	6.68	
12	5500	50	0.500		52	25500	689	6.89	
13	6000	55	0.550		53	26000	712	7.12	
14	6500	63	0.630		54	26500	738	7.38	
15	7000	71	0.710		55	27000	769	7.69	
16	7500	79	0.790		56	27500	799	7.99	
17	8000	92	0.920		57	28000	835	8.35	
18	8500	97	0.970		58	28500	880	8.80	
19	9000	108.5	1.085		59	29000	980	9.80	
20	9500	119	1.190		60	29200	1120	11.20	
21	10000	131	1.310						
22	10500	143.5	1.435						
23	11000	155	1.550						
24	11500	170	1.700						
25	12000	185	1.850						
26	12500	197	1.970						
27	13000	209	2.090						
28	13500	224	2.240						
29	14000	238.5	2.385						
30	14500	252	2.520						
31	15000	266	2.660						
32	15500	282	2.820						
33	16000	298	2.980						
34	16500	316.5	3.165						
35	17000	331	3.310						
36	17500	345	3.450						
37	18000	363	3.630						
38	18500	379.5	3.795						
39	19000	400	4.000						
40	19500	423	4.230						

## Beam Test (Load Vs Deflection)

Beam Sample No: C-T-1  
 Rebar Type: TMT Bar                      Steel: TMT 3  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/8/29  
 Age                      91 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	1030	10.30		1	500	244	2.44	
2	22500	981	9.81		2	1000	252	2.52	
3	20000	940	9.40		3	1500	262	2.62	
4	17500	882	8.82		4	2000	272	2.72	
5	15000	818	8.18		5	2500	298	2.98	
6	12500	745	7.45		6	3000	305	3.05	
7	10000	680	6.80		7	3500	315	3.15	
8	7500	495	4.95		8	4000	330	3.30	
9	5000	420	4.20		9	4500	342	3.42	
10	2500	335	3.35		10	5000	350	3.50	
11	0	240	2.40		11	5500	362	3.62	
					12	6000	382	3.82	
					13	6500	392	3.92	
					14	7000	405	4.05	
					15	7500	418	4.18	
					16	8000	428	4.28	
					17	8500	436	4.36	
					18	9000	445	4.45	
					19	10000	468	4.68	
					20	11000	490	4.90	
					21	12000	518	5.18	
					22	13000	542	5.42	
					23	14000	570	5.70	
					24	15000	590	5.90	
					25	16000	625	6.25	
					26	17000	652	6.52	
					27	18000	680	6.80	
					28	19000	709	7.09	
					29	20000	738	7.38	
					30	21000	763	7.63	
					31	22000	793	7.93	
					32	23000	820	8.20	
					33	24000	848	8.48	
					34	25000	880	8.80	
					35	26000	907	9.07	
					36	27000	935	9.35	
					37	28000	966	9.66	
					38	29000	1270	12.70	
					39	30000	1790	17.90	
					40	30300	2015	20.15	
					41				

## Beam Test (Load Vs Deflection)

Beam Sample No: C-T-1  
 Rebar Type: TMT Bar                      Steel: TMT 3  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/8/29  
 Age                      91 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	27500	1980	19.80		1	500	1080	10.80	
2	25000	1865	18.65		2	1000	1098	10.98	
3	22500	1820	18.20		3	1500	1112	11.12	
4	20000	1760	17.60		4	2000	1130	11.30	
5	17500	1695	16.95		5	2500	1139	11.39	
6	15000	1620	16.20		6	3000	1150	11.50	
7	12500	1542	15.42		7	3500	1165	11.65	
8	10000	1455	14.55		8	4000	1175	11.75	
9	7500	1368	13.68		9	4500	1188	11.88	
10	5000	1278	12.78		10	5000	1198	11.98	
11	2500	1185	11.85		11	5500	1211	12.11	
12	0	1075	10.75		12	6000	1222	12.22	
					13	6500	1234	12.34	
					14	7000	1248	12.48	
					15	7500	1261	12.61	
					16	8000	1275	12.75	
					17	8500	1289	12.89	
					18	9000	1307	13.07	
					19	9500	1327	13.27	
					20	10000	1338	13.38	
					21	11000	1368	13.68	
					22	12000	1397	13.97	
					23	13000	1428	14.28	
					24	14000	1458	14.58	
					25	15000	1487	14.87	
					26	16000	1518	15.18	
					27	17000	1548	15.48	
					28	18000	1578	15.78	
					29	19000	1609	16.09	
					30	20000	1640	16.40	
					31	21000	1671	16.71	
					32	22000	1701	17.01	
					33	23000	1737	17.37	
					34	24000	1765	17.65	
					35	25000	1794	17.94	
					36	26000	1825	18.25	
					37	27000	1855	18.55	
					38	28000	1992	19.92	
					39	29000	2042	20.42	
					40	30000	2410	24.10	
					41	30400		25.57	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-T-1

Rebar Type: TMT Bar

Steel: TMT 3

Loading Type: Cyclic

Date of Casting: 2063/05/30

Date of Testing: 2063/8/29

Age 91 days

Dial Guage Constant = 0.01

Dial guage No. : 2

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		42	20500	473	4.73	
2	500	0	0.00		43	21000	493	4.93	
3	1000	0	0.00		44	21500	504	5.04	
4	1500	0	0.00		45	22000	536	5.36	
5	2000	1	0.01		46	22500	564	5.64	
6	2500	5	0.05		47	23000	586	5.86	
7	3000	10	0.10		48	23500	609	6.09	
8	3500	15	0.15		49	24000	632	6.32	
9	4000	20	0.20		50	24500	659	6.59	
10	4500	26	0.26		51	25000	683	6.83	
11	5000	32	0.32		52	25500	705	7.05	
12	5500	38	0.38		53	26000	725	7.25	
13	6000	44	0.44		54	26500	753	7.53	
14	6500	51	0.51		55	27000	783	7.83	
15	7000	59	0.59		56	27500	813	8.13	
16	7500	64	0.64		57	28000	850	8.50	
17	8000	82	0.82		58	28500	896	8.96	
18	8500	86	0.86		59	29000	1040	10.40	
19	9000	99	0.99						
20	9500	109	1.09						
21	10000	122	1.22						
22	10500	135	1.35						
23	11000	149	1.49						
24	11500	165	1.65						
25	12000	180	1.80						
26	12500	193	1.93						
27	13000	206	2.06						
28	13500	222	2.22						
29	14000	238	2.38						
30	14500	253	2.53						
31	15000	269	2.69						
32	15500	294	2.94						
33	16000	302	3.02						
34	16500	320	3.20						
35	17000	336	3.36						
36	17500	352	3.52						
37	18000	370	3.70						
38	18500	388	3.88						
39	19000	408	4.08						
40	19500	428	4.28						
41	20000	449	4.49						

## Beam Test (Load Vs Deflection)

Beam Sample No: C-T-1  
 Rebar Type: TMT Bar                      Steel: TMT 3  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/8/29  
 Age                      91 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 2

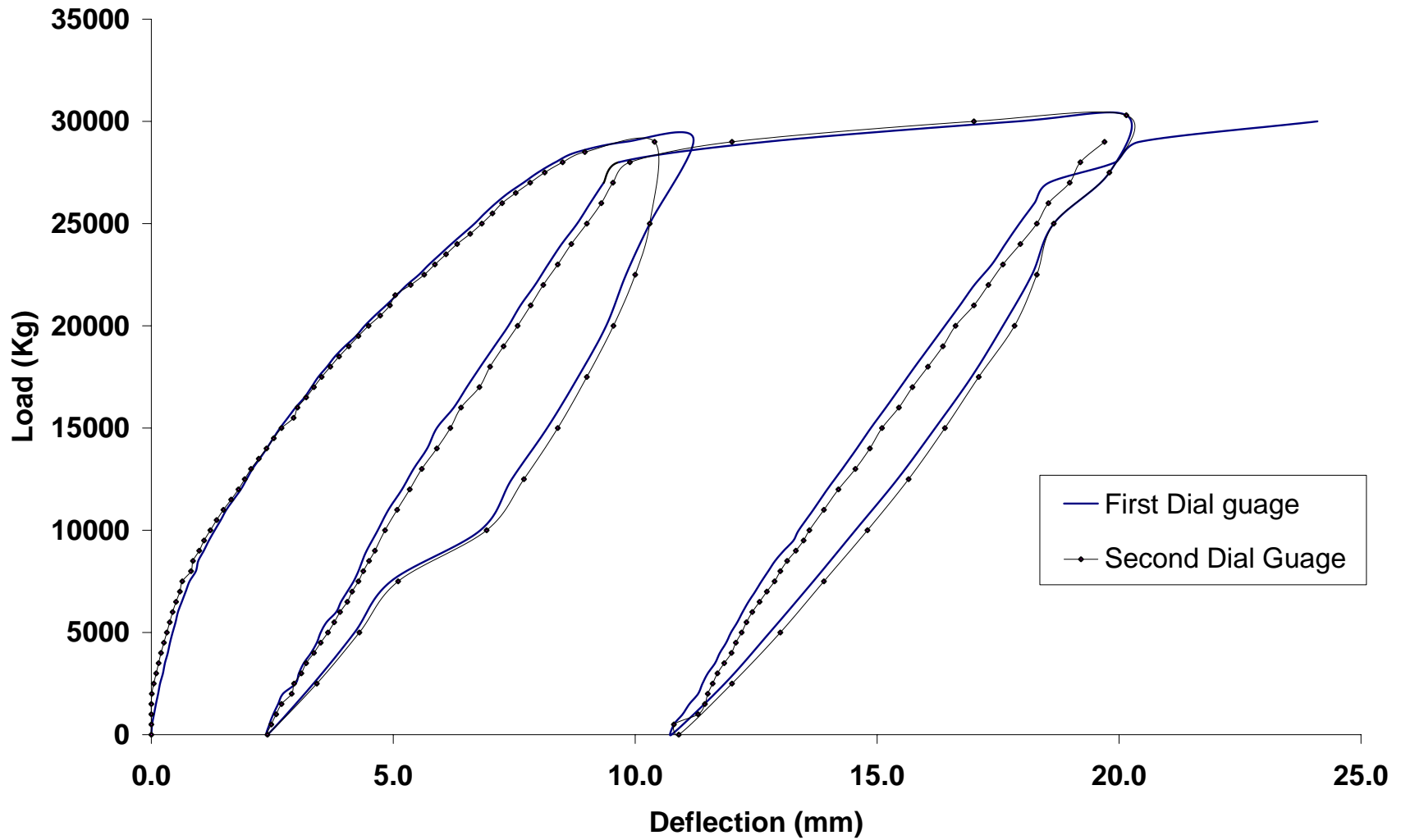
S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	1030	10.30		1	500	248	2.48	
2	22500	1000	10.00		2	1000	258	2.58	
3	20000	955	9.55		3	1500	269	2.69	
4	17500	900	9.00		4	2000	290	2.90	
5	15000	840	8.40		5	2500	295	2.95	
6	12500	770	7.70		6	3000	310	3.10	
7	10000	693	6.93		7	3500	320	3.20	
8	7500	510	5.10		8	4000	336	3.36	
9	5000	430	4.30		9	4500	350	3.50	
10	2500	342	3.42		10	5000	365	3.65	
11	0	240	2.40		11	5500	378	3.78	
					12	6000	390	3.90	
					13	6500	405	4.05	
					14	7000	415	4.15	
					15	7500	428	4.28	
					16	8000	438	4.38	
					17	8500	450	4.50	
					18	9000	462	4.62	
					19	10000	483	4.83	
					20	11000	508	5.08	
					21	12000	534	5.34	
					22	13000	559	5.59	
					23	14000	590	5.90	
					24	15000	618	6.18	
					25	16000	640	6.40	
					26	17000	678	6.78	
					27	18000	700	7.00	
					28	19000	728	7.28	
					29	20000	757	7.57	
					30	21000	784	7.84	
					31	22000	810	8.10	
					32	23000	840	8.40	
					33	24000	868	8.68	
					34	25000	900	9.00	
					35	26000	930	9.30	
					36	27000	954	9.54	
					37	28000	989	9.89	
					38	29000	1200	12.00	
					39	30000	1700	17.00	
					40	30300	2015	20.15	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-T-1  
 Rebar Type: TMT Bar                      Steel: TMT 3  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/8/29  
 Age                      91 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 2

S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	27500	1980	19.80		1	500	1080	10.80	
2	25000	1865	18.65		2	1000	1130	11.30	
3	22500	1830	18.30		3	1500	1144	11.44	
4	20000	1784	17.84		4	2000	1150	11.50	
5	17500	1710	17.10		5	2500	1160	11.60	
6	15000	1640	16.40		6	3000	1170	11.70	
7	12500	1565	15.65		7	3500	1184	11.84	
8	10000	1480	14.80		8	4000	1199	11.99	
9	7500	1390	13.90		9	4500	1208	12.08	
10	5000	1300	13.00		10	5000	1220	12.20	
11	2500	1200	12.00		11	5500	1230	12.30	
12	0	1090	10.90		12	6000	1242	12.42	
					13	6500	1257	12.57	
					14	7000	1272	12.72	
					15	7500	1288	12.88	
					16	8000	1300	13.00	
					17	8500	1314	13.14	
					18	9000	1332	13.32	
					19	9500	1348	13.48	
					20	10000	1360	13.60	
					21	11000	1390	13.90	
					22	12000	1420	14.20	
					23	13000	1455	14.55	
					24	14000	1485	14.85	
					25	15000	1510	15.10	
					26	16000	1545	15.45	
					27	17000	1573	15.73	
					28	18000	1605	16.05	
					29	19000	1636	16.36	
					30	20000	1662	16.62	
					31	21000	1700	17.00	
					32	22000	1730	17.30	
					33	23000	1760	17.60	
					34	24000	1796	17.96	
					35	25000	1830	18.30	
					36	26000	1854	18.54	
					37	27000	1898	18.98	
					38	28000	1920	19.20	
					39	29000	1970	19.70	
					40	30400			

## Cyclic Loading Deflection Curve (C-T-1)



### Beam Test (Load Vs Deflection)

Beam Sample No: C-T-2      **Table 31**  
 Rebar Type: TMT Bar      Steel: TMT4  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30      Date of Testing: 2063/09/05  
 Age: 103 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		28	14000	270	2.70	
2	500	0	0.00		29	14500	284	2.84	
3	1000	1	0.01		30	15000	298	2.98	
4	1500	8	0.08		31	15500	313	3.13	
5	2000	11	0.11		32	16000	327	3.27	
6	2500	16	0.16		33	16500	340	3.40	
7	3000	21	0.21		34	17000	356	3.56	
8	3500	26	0.26		35	17500	372	3.72	
9	4000	32	0.32		36	18000	387	3.87	
10	4500	38	0.38		37	18500	404	4.04	
11	5000	44	0.44		38	19000	420	4.20	
12	5500	51	0.51		39	19500	435	4.35	
13	6000	60	0.60		40	20000	458	4.58	
14	7000	79	0.79		41	20500	475	4.75	
15	7500	90	0.90		42	21000	493	4.93	
16	8000	101	1.01		43	21500	510	5.10	
17	8500	114	1.14		44	22000	528	5.28	
18	9000	130	1.30		45	22500	543	5.43	
19	9500	141	1.41		46	23000	551	5.51	
20	10000	154	1.54		47	23500	580	5.80	
21	10500	169	1.69		48	24000	594	5.94	
22	11000	183	1.83		49	24500	610	6.10	
23	11500	198	1.98		50	25000	630	6.30	
24	12000	210	2.10		51	26000	687	6.87	
25	12500	222	2.22		52	27000	730	7.30	
26	13000	238	2.38		53	29000	1570	15.70	
27	13500	254	2.54						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	1535	15.35	
2	22500	1410	14.10	
3	20000	1350	13.50	
4	17500	1294	12.94	
5	15000	1230	12.30	
6	12500	1162	11.62	
7	10000	1093	10.93	
8	7500	1018	10.18	
9	5000	940	9.40	
10	2500	851	8.51	
11	400	768	7.68	

### Beam Test (Load Vs Deflection)

Beam Sample No: C-T-2

Rebar Type: TMT Bar

Steel: TMT4

Loading Type: Cyclic

Date of Casting: 2063/05/30

Date of Testing: 2063/09/05

Age 103 days

Dial Guage Constant = 0.01

Dial guage No. : 1

S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	400	768	7.68		29	15500	1140	11.40	
2	1000	780	7.80		30	16000	1151	11.51	
3	1500	793	7.93		31	16500	1163	11.63	
4	2000	800	8.00		32	17000	1178	11.78	
5	2500	810	8.10		33	17500	1188	11.88	
6	3500	830	8.30		34	18000	1205	12.05	
7	4000	840	8.40		35	18500	1217	12.17	
8	5000	860	8.60		36	19000	1230	12.30	
9	5500	873	8.73		37	19500	1243	12.43	
10	6000	890	8.90		38	20000	1257	12.57	
11	6500	905	9.05		39	20500	1272	12.72	
12	7000	918	9.18		40	21000	1288	12.88	
13	7500	928	9.28		41	21500	1305	13.05	
14	8000	943	9.43		42	22000	1318	13.18	
15	8500	958	9.58		43	22500	1330	13.30	
16	9000	968	9.68		44	23000	1340	13.40	
17	9500	982	9.82		45	23500	1362	13.62	
18	10000	998	9.98		46	24000	1378	13.78	
19	10500	1010	10.10		47	24500	1390	13.90	
20	11000	1020	10.20		48	25000	1405	14.05	
21	11500	1035	10.35		49	25500	1420	14.20	
22	12000	1047	10.47		50	26000	1440	14.40	
23	12500	1058	10.58		51	26500	1455	14.55	
24	13000	1070	10.70		52	27000	1472	14.72	
25	13500	1088	10.88		53	27500	1490	14.90	
26	14000	1100	11.00		54	28000	1520	15.20	
27	14500	1110	11.10		55	28500	1610	16.10	
28	15000	1122	11.22		56	29500	2130	21.30	

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	2080	20.80	
2	22500	2040	20.40	
3	20000	1990	19.90	
4	17500	1920	19.20	
5	15000	1852	18.52	
6	12500	1770	17.70	
7	10000	1690	16.90	
8	7500	1605	16.05	
9	5000	1516	15.16	
10	2500	1404	14.04	
11	400	1325	13.25	

### Beam Test (Load Vs Deflection)

Beam Sample No: C-T-2  
 Rebar Type: TMT Bar                      Steel: TMT4  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/09/05  
 Age                      103 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	Second Reloading	Dial Guage Reading	De-flection (mm)	Remarks	S.No.	Second Reloading	Dial Guage Reading	De-flection (mm)	Remarks
1	400	1325	13.25		27	14000	1698	16.98	
2	1000	1340	13.40		28	14500	1712	17.12	
3	1500	1360	13.60		29	15000	1725	17.25	
4	2000	1375	13.75		30	15500	1738	17.38	
5	2500	1385	13.85		31	16000	1752	17.52	
6	3000	1395	13.95		32	16500	1768	17.68	
7	3500	1404	14.04		33	17000	1782	17.82	
8	4000	1418	14.18		34	17500	1797	17.97	
9	4500	1428	14.28		35	18000	1810	18.10	
10	5000	1440	14.40		36	18500	1820	18.20	
11	5500	1454	14.54		37	19000	1850	18.50	
12	6000	1470	14.70		38	19500	1870	18.70	
13	6500	1486	14.86		39	20000	1880	18.80	
14	7000	1500	15.00		40	20500	1890	18.90	
15	8000	1520	15.20		41	21000	1910	19.10	
16	8500	1540	15.40		42	21500	1930	19.30	
17	9000	1560	15.60		43	22000	1940	19.40	
18	9500	1572	15.72		44	22500	1955	19.55	
19	10000	1590	15.90		45	23000	1970	19.70	
20	10500	1601	16.01		46	23500	1990	19.90	
21	11000	1618	16.18		47	24000	2000	20.00	
22	11500	1632	16.32		48	26500	2060	20.60	
23	12000	1642	16.42		49	27000	2090	20.90	
24	12500	1652	16.52		50	27500	2110	21.10	
25	13000	1670	16.70		51	28000	2130	21.30	
26	13500	1685	16.85		52	28500	2160	21.60	
					53	29500	2470	24.70	
					54	30000		26.25	

### Beam Test (Load Vs Deflection)

Beam Sample No: C-T-2  
 Rebar Type: TMT Bar                      Steel: TMT4  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/09/05  
 Age                      103 days  
 Dial Guage Constant =                      0.01  
 Dial guage No. : 2

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	De-flection (mm)	Remarks
1	0	0	0.00		28	14000	280	2.80	
2	500	0	0.00		29	14500	293	2.93	
3	1000	0	0.00		30	15000	308	3.08	
4	1500	0	0.00		31	15500	312	3.12	
5	2000	5	0.05		32	16000	340	3.40	
6	2500	11	0.11		33	16500	355	3.55	
7	3000	17	0.17		34	17000	370	3.70	
8	3500	22	0.22		35	17500	388	3.88	
9	4000	29	0.29		36	18000	402	4.02	
10	4500	34	0.34		37	18500	417	4.17	
11	5000	42	0.42		38	19000	438	4.38	
12	5500	49	0.49		39	19500	452	4.52	
13	6000	59	0.59		40	20000	476	4.76	
14	7000	78	0.78		41	20500	494	4.94	
15	7500	91	0.91		42	21000	517	5.17	
16	8000	105	1.05		43	21500	532	5.32	
17	8500	118	1.18		44	22000	552	5.52	
18	9000	135	1.35		45	22500	570	5.70	
19	9500	146	1.46		46	23000	589	5.89	
20	10000	160	1.60		47	23500	608	6.08	
21	10500	175	1.75		48	24000	624	6.24	
22	11000	191	1.91		49	24500	640	6.40	
23	11500	208	2.08		50	25000	648	6.48	
24	12000	220	2.20		51	26000	715	7.15	
25	12500	232	2.32		52	27000	770	7.70	
26	13000	248	2.48		53	29000	1527	15.27	
27	13500	261	2.61						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	27500	1480	14.80	
2	25000	1450	14.50	
3	22500	1435	14.35	
4	20000	1395	13.95	
5	17500	1330	13.30	
6	15000	1267	12.67	
7	12500	1195	11.95	
8	10000	1120	11.20	
9	7500	1040	10.40	
10	5000	955	9.55	
11	2500	862	8.62	
12	400	680	6.80	

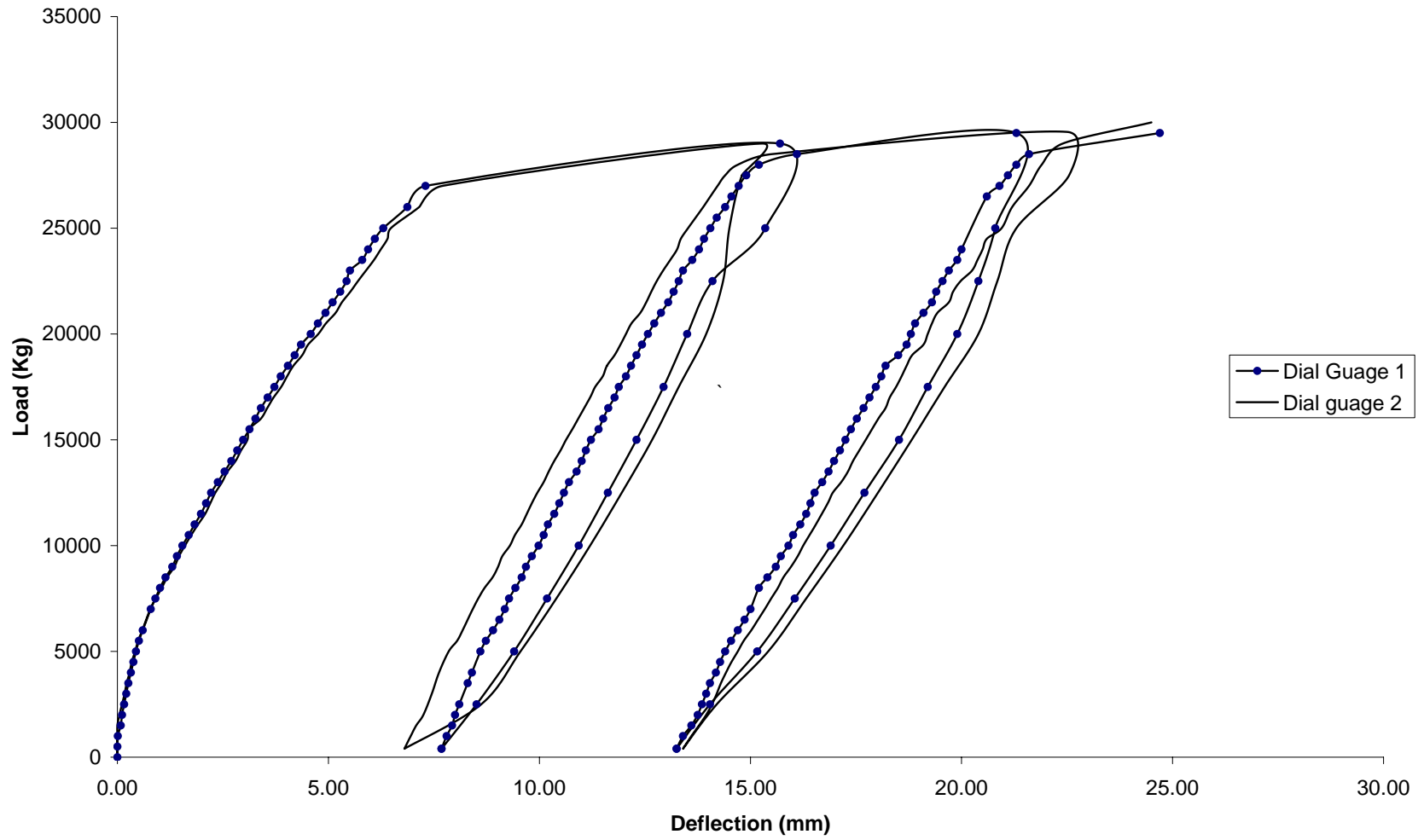


### Beam Test (Load Vs Deflection)

Beam Sample No: C-T-2  
 Rebar Type: TMT Bar                      Steel: TMT4  
 Loading Type: Cyclic  
 Date of Casting: 2063/05/30                      Date of Testing: 2063/09/05  
 Age                      103 days  
 Dial Guage Constant =                      0.01  
 Dial guage No. : 2

S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	400	1340	13.40		28	14500	1758	17.58	
2	1000	1360	13.60		29	15000	1773	17.73	
3	1500	1378	13.78		31	16000	1803	18.03	
4	2000	1395	13.95		32	16500	1820	18.20	
5	2500	1409	14.09		33	17000	1830	18.30	
6	3000	1420	14.20		34	17500	1845	18.45	
7	3500	1430	14.30		35	18000	1858	18.58	
8	4000	1442	14.42		36	18500	1870	18.70	
9	4500	1455	14.55		37	19000	1883	18.83	
10	5000	1470	14.70		38	19500	1910	19.10	
11	5500	1484	14.84		39	20000	1920	19.20	
12	6000	1502	15.02		40	20500	1930	19.30	
13	6500	1518	15.18		41	21000	1943	19.43	
14	7000	1534	15.34		42	21500	1970	19.70	
15	7500	1549	15.49		43	22000	1980	19.80	
16	8000	1565	15.65		44	22500	1998	19.98	
17	8500	1578	15.78		45	23000	2025	20.25	
18	9000	1596	15.96		46	23500	2038	20.38	
19	9500	1612	16.12		47	24000	2050	20.50	
20	10000	1625	16.25		48	24500	2060	20.60	
21	10500	1640	16.40		49	25000	2095	20.95	
22	11000	1655	16.55		50	26000	2120	21.20	
23	12000	1683	16.83		51	27000	2160	21.60	
24	12500	1695	16.95		52	28000	2190	21.90	
25	13000	1715	17.15		53	29000	2240	22.40	
26	13500	1731	17.31		54	30000	2450	24.50	
27	14000	1743	17.43						

**Fig. 24: Cyclic Loading Deflection Curve (C-T-2)**



## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-1      **Table 32**  
 Rebar Type: TOR Steel      Steel: TOR 3  
 Loading Type: Cyclic  
 Date of Casting: 2063/06/08      Date of Testing: 2063/09/07  
 Age      89 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		28	13500	182	1.82	
2	500	0	0.00		29	14000	196	1.96	
3	1000	0	0.00		30	14500	208	2.08	
4	1500	0	0.00		31	15000	224	2.24	
5	2000	0	0.00		32	15500	238	2.38	
6	2500	0	0.00		33	16000	252	2.52	
7	3000	0	0.00		34	16500	267	2.67	
8	3500	0	0.00		35	17000	284	2.84	
9	4000	0	0.00		36	17500	300	3.00	
10	4500	0	0.00		37	18000	315	3.15	
11	5000	0	0.00		38	18500	332	3.32	
12	5500	0	0.00		39	19000	352	3.52	
13	6000	4	0.04		40	19500	370	3.70	
14	6500	12	0.12		41	20000	392	3.92	
15	7000	18	0.18		42	20500	410	4.10	
16	7500	27	0.27		43	21000	430	4.30	
17	8000	37	0.37		44	21500	450	4.50	
18	8500	46	0.46		45	22000	480	4.80	
19	9000	60	0.60		46	22500	542	5.42	
20	9500	71	0.71		47	23000	572	5.72	
21	10000	83	0.83		48	23500	612	6.12	
22	10500	98	0.98		49	24000	662	6.62	
23	11000	111	1.11		50	24500	720	7.20	
24	11500	127	1.27		51	25000	790	7.90	
25	12000	138	1.38		52	25500	880	8.80	
26	12500	152	1.52		53	26000	2100	21.00	
27	13000	162	1.62						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	22500	2060	20.60	
2	20000	2020	20.20	
3	17500	1970	19.70	
4	15000	1910	19.10	
5	12500	1840	18.40	
6	10000	1772	17.72	
7	7500	1696	16.96	
8	5000	1612	16.12	
9	2500	1522	15.22	
10	500	1440	14.40	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-1

Rebar Type: TOR Steel

Steel: TOR 3

Loading Type: Cyclic

Date of Casting: 2063/06/08

Date of Testing: 2063/09/07

Age 89 days

Dial Guage Constant = 0.01

Dial guage No. : 1

S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks
2	1000	1447	14.47		29	14500	1798	17.98	
3	1500	1458	14.58		30	15000	1813	18.13	
4	2000	1468	14.68		31	15500	1828	18.28	
5	2500	1480	14.80		32	16000	1843	18.43	
6	3000	1493	14.93		33	16500	1858	18.58	
7	3500	1506	15.06		34	17000	1872	18.72	
8	4000	1519	15.19		35	17500	1882	18.82	
9	4500	1535	15.35		36	18000	1906	19.06	
10	5000	1548	15.48		37	18500	1920	19.20	
11	5500	1558	15.58		38	19000	1934	19.34	
12	6000	1570	15.70		39	19500	1958	19.58	
13	6500	1585	15.85		40	20000	1963	19.63	
14	7000	1598	15.98		41	20500	1980	19.80	
15	7500	1612	16.12		42	21000	1997	19.97	
16	8000	1625	16.25		43	21500	2010	20.10	
17	8500	1638	16.38		44	22000	2027	20.27	
18	9000	1660	16.60		45	22500	2045	20.45	
19	9500	1665	16.65		46	23000	2060	20.60	
20	10000	1678	16.78		47	23500	2076	20.76	
21	10500	1691	16.91		48	24000	2095	20.95	
22	11000	1708	17.08		49	24500	2114	21.14	
23	11500	1718	17.18		50	25000	2144	21.44	
24	12000	1732	17.32		51	25500	2193	21.93	
25	12500	1744	17.44		52	26000	2320	23.20	
26	13000	1756	17.56		53	26500	2700	27.00	
27	13500	1770	17.70						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
2	20000	2645	26.45	
3	17500	2585	25.85	
4	15000	2510	25.10	
5	12500	2430	24.30	
6	10000	2355	23.55	
7	7500	2260	22.60	
8	5000	2170	21.70	
9	2500	2070	20.70	
10	0	1955	19.55	



## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-1

Rebar Type: TOR Steel

Steel: TOR 3

Loading Type: Cyclic

Date of Casting: 2063/06/08

Date of Testing: 2063/09/07

Age 89 days

Dial Guage Constant = 0.01

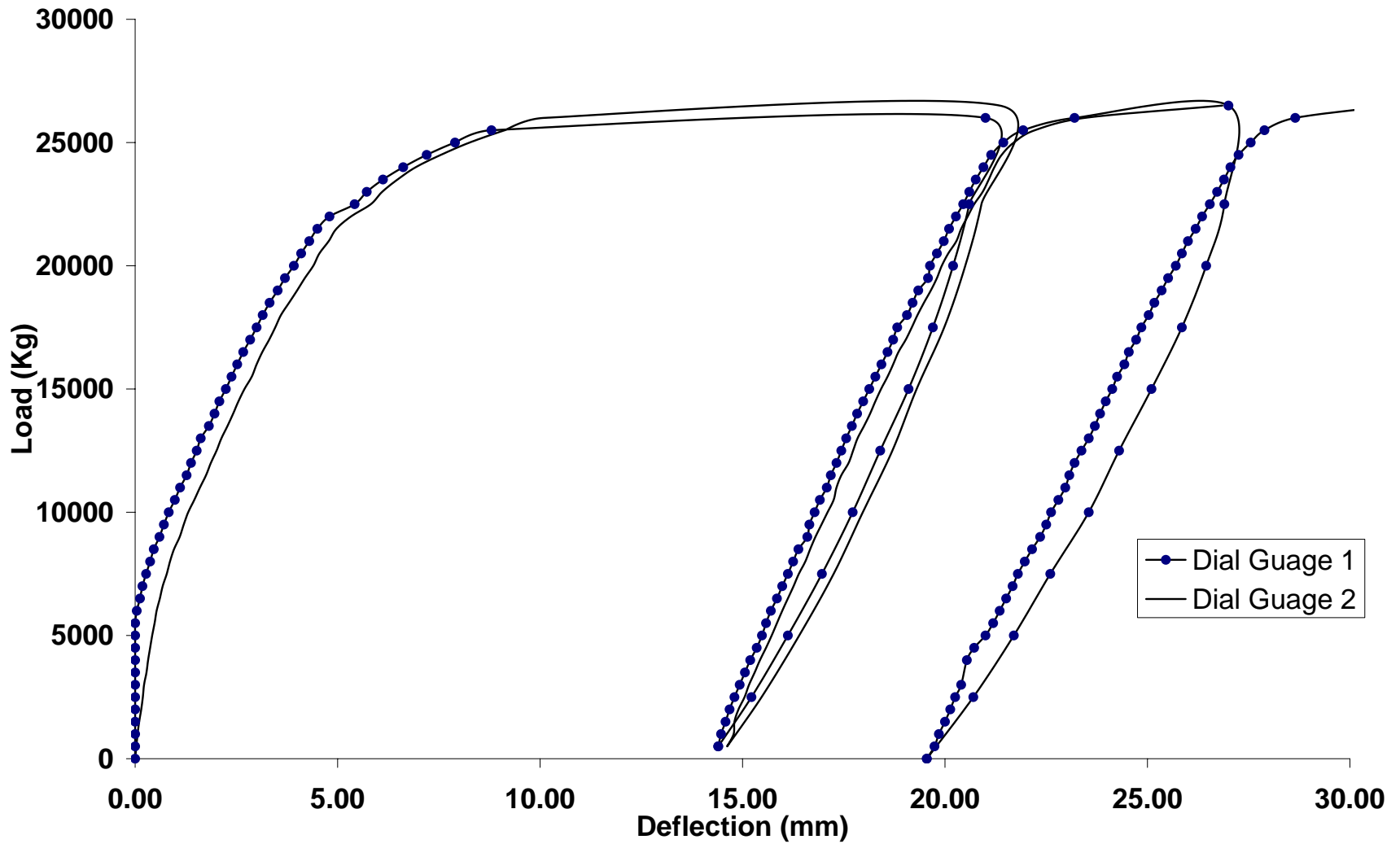
Dial guage No. : 2

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		28	14000	242	2.42	
2	1000	6	0.06		29	14500	255	2.55	
3	1500	10	0.10		30	15000	270	2.70	
4	2000	15	0.15		31	15500	288	2.88	
5	2500	19	0.19		32	16000	300	3.00	
6	3000	22	0.22		33	16500	314	3.14	
7	3500	28	0.28		34	17000	331	3.31	
8	4000	32	0.32		35	17500	346	3.46	
9	4500	37	0.37		36	18000	360	3.60	
10	5000	42	0.42		37	18500	380	3.80	
11	5500	48	0.48		38	19000	400	4.00	
12	6000	53	0.53		39	19500	419	4.19	
13	6500	61	0.61		40	20000	440	4.40	
14	7000	68	0.68		41	20500	455	4.55	
15	7500	78	0.78		42	21000	478	4.78	
16	8000	86	0.86		43	21500	497	4.97	
17	8500	96	0.96		44	22000	533	5.33	
18	9000	110	1.10		45	22500	582	5.82	
19	9500	120	1.20		46	23000	610	6.10	
20	10000	131	1.31		47	23500	648	6.48	
21	10500	146	1.46		48	24000	693	6.93	
22	11000	160	1.60		49	24500	755	7.55	
23	11500	175	1.75		50	25000	826	8.26	
24	12000	187	1.87		51	25500	913	9.13	
25	12500	201	2.01		52	26000	1010	10.10	
26	13000	213	2.13		53	26500	2135	21.35	
27	13500	228	2.28						

S.No.	Un-loading	Dial Guage	Deflection	Remarks
		Reading	(mm)	
1	22500	2090	20.90	
2	20000	2050	20.50	
3	17500	1998	19.98	
4	15000	1930	19.30	
5	12500	1870	18.70	
6	10000	1797	17.97	
7	7500	1725	17.25	
8	5000	1640	16.40	
9	2500	1547	15.47	
10	500	1462	14.62	



## Cyclic Loading Deflection Curve (C-C-1)



## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2      **Table 33**  
 Rebar Type: TOR Steel      Steel: TOR 4  
 Loading Type: Cyclic  
 Date of Casting: 2063/06/10      Date of Testing: 2063/09/09  
 Age: 89 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 1

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		29	14000	282	2.82	
2	500	7	0.07		30	14500	299	2.99	
3	1000	11	0.11		31	15000	312	3.12	
4	1500	17	0.17		32	15500	328	3.28	
5	2000	20	0.20		33	16000	342	3.42	
6	2500	25	0.25		34	16500	357	3.57	
7	3000	31	0.31		35	17000	375	3.75	
8	3500	38	0.38		36	17500	389	3.89	
9	4000	42	0.42		37	18000	405	4.05	
10	4500	48	0.48		38	18500	422	4.22	
11	5000	55	0.55		39	19000	442	4.42	
12	5500	62	0.62		40	19500	459	4.59	
13	6000	71	0.71		41	20000	482	4.82	
14	6500	82	0.82		42	20500	498	4.98	
15	7000	90	0.90		43	21000	528	5.28	
16	7500	104	1.04		44	21500	555	5.55	
17	8000	120	1.20		45	22000	582	5.82	
18	8500	130	1.30		46	22500	612	6.12	
19	9000	144	1.44		47	23000	648	6.48	
20	9500	154	1.54		48	23500	688	6.88	
21	10000	165	1.65		49	24000	730	7.30	
22	10500	180	1.80		50	24500	778	7.78	
23	11000	198	1.98		51	25000	840	8.40	
24	11500	210	2.10		52	25500	930	9.30	
25	12000	226	2.26		53	26000	1028	10.28	
26	12500	238	2.38		54	26500	1170	11.70	
27	13000	250	2.50		55	27000	1373	13.73	
28	13500	263	2.63		56	27500	1688	16.88	

S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	1665	16.65	
2	22500	1622	16.22	
3	20000	1585	15.85	
4	17500	1540	15.40	
5	15000	1488	14.88	
6	12500	1420	14.20	
7	10000	1350	13.50	
8	7500	1268	12.68	
9	5000	1184	11.84	
10	2500	1092	10.92	
11	200	1000	10.00	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2

Rebar Type: TOR Steel

Steel: TOR 4

Loading Type: Cyclic

Date of Casting: 2063/06/10

Date of Testing: 2063/09/09

Age 89 days

Dial Guage Constant = 0.01

Dial guage No. : 1

S.No.	Re-loading	Dial Guage	Deflection	Remarks	S.No.	Re-loading	Dial Guage	Deflection	Remarks
		Reading	(mm)				Reading	(mm)	
1	200	1000	10.00		28	16000	1400	14.00	
2	1000	1010	10.10		29	16500	1412	14.12	
3	2000	1040	10.40		30	17000	1428	14.28	
4	3000	1062	10.62		31	17500	1440	14.40	
5	4000	1082	10.82		32	18000	1456	14.56	
6	5000	1108	11.08		33	18500	1470	14.70	
7	5500	1120	11.20		34	19000	1482	14.82	
8	6000	1132	11.32		35	19500	1497	14.97	
9	6500	1148	11.48		36	20000	1509	15.09	
10	7000	1160	11.60		37	20500	1521	15.21	
11	7500	1170	11.70		38	21000	1535	15.35	
12	8000	1186	11.86		39	21500	1550	15.50	
13	8500	1198	11.98		40	22000	1562	15.62	
14	9000	1212	12.12		41	22500	1578	15.78	
15	9500	1226	12.26		42	23000	1592	15.92	
16	10000	1240	12.40		43	23500	1608	16.08	
17	10500	1250	12.50		44	24000	1626	16.26	
18	11000	1268	12.68		45	24500	1638	16.38	
19	11500	1278	12.78		46	25000	1653	16.53	
20	12000	1290	12.90		47	25500	1671	16.71	
21	12500	1308	13.08		48	26000	1691	16.91	
22	13000	1320	13.20		49	26500	1712	17.12	
23	13500	1330	13.30		50	27000	1760	17.60	
24	14000	1346	13.46		51	27500	1842	18.42	
25	14500	1360	13.60		52	28000	2342	23.42	
26	15000	1375	13.75		53	28250	2492	24.92	
27	15500	1388	13.88						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	2440	24.40	
2	22500	2420	24.20	
3	20000	2370	23.70	
4	17500	2230	22.30	
5	15000	2160	21.60	
6	12500	2087	20.87	
7	10000	2008	20.08	
8	7500	1920	19.20	
9	5000	1825	18.25	
10	2500	1735	17.35	
11	0	1610	16.10	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2

Rebar Type: TOR Steel

Steel: TOR 4

Loading Type: Cyclic

Date of Casting: 2063/06/10

Date of Testing: 2063/09/09

Age 89 days

Dial Guage Constant = 0.01

Dial guage No. : 1

S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	500	1620	16.20		30	15000	2038	20.38	
2	1000	1630	16.30		31	15500	2052	20.52	
3	1500	1638	16.38		32	16000	2068	20.68	
4	2000	1648	16.48		33	16500	2080	20.80	
5	2500	1664	16.64		34	17000	2092	20.92	
6	3000	1678	16.78		35	17500	2107	21.07	
7	3500	1695	16.95		36	18000	2122	21.22	
8	4000	1708	17.08		37	18500	2139	21.39	
9	4500	1720	17.20		38	19000	2150	21.50	
10	5000	1738	17.38		39	19500	2160	21.60	
11	5500	1750	17.50		40	20000	2178	21.78	
12	6000	1768	17.68		41	20500	2192	21.92	
13	6500	1778	17.78		42	21000	2208	22.08	
14	7000	1798	17.98		43	21500	2222	22.22	
15	7500	1810	18.10		44	22000	2235	22.35	
16	8000	1828	18.28		45	22500	2253	22.53	
17	8500	1840	18.40		46	23000	2268	22.68	
18	9000	1856	18.56		47	23500	2280	22.80	
19	9500	1870	18.70		48	24000	2298	22.98	
20	10000	1884	18.84		49	24500	2311	23.11	
21	10500	1900	19.00		50	25000	2329	23.29	
22	11000	1915	19.15		51	25500	2348	23.48	
23	11500	1933	19.33		52	26000	2360	23.60	
24	12000	1948	19.48		53	26500	2378	23.78	
25	12500	1965	19.65		54	27000	2400	24.00	
26	13000	1978	19.78		55	27500	2430	24.30	
27	13500	1995	19.95		56	28000	2550	25.50	
28	14000	2010	20.10		57	28500	2680	26.80	
29	14500	2020	20.20		58	29000	2870	28.70	
					59	29250		29.65	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2  
 Rebar Type: TOR Steel      Steel: TOR 4  
 Loading Type: Cyclic  
 Date of Casting: 2063/06/10      Date of Testing: 2063/09/09  
 Age: 89 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 2

S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	First Load (kg)	Dial Guage Reading	Deflection (mm)	Remarks
1	0	0	0.00		29	14500	342	3.42	
2	1000	10	0.10		30	15000	358	3.58	
3	1500	15	0.15		31	15500	373	3.73	
4	2000	25	0.25		32	16000	389	3.89	
5	2500	32	0.32		33	16500	405	4.05	
6	3000	40	0.40		34	17000	428	4.28	
7	3500	46	0.46		35	17500	440	4.40	
8	4000	55	0.55		36	18000	456	4.56	
9	4500	65	0.65		37	18500	476	4.76	
10	5000	74	0.74		38	19000	496	4.96	
11	5500	83	0.83		39	19500	505	5.05	
12	6000	93	0.93		40	20000	535	5.35	
13	6500	105	1.05		41	20500	563	5.63	
14	7000	110	1.10		42	21000	593	5.93	
15	7500	130	1.30		43	21500	613	6.13	
16	8000	145	1.45		44	22000	642	6.42	
17	8500	155	1.55		45	22500	678	6.78	
18	9000	173	1.73		46	23000	718	7.18	
19	9500	187	1.87		47	23500	752	7.52	
20	10000	202	2.02		48	24000	802	8.02	
21	10500	217	2.17		49	24500	860	8.60	
22	11000	230	2.30		50	25000	918	9.18	
23	11500	248	2.48		51	25500	1002	10.02	
24	12000	263	2.63		52	26000	1112	11.12	
25	12500	278	2.78		53	26500	1258	12.58	
26	13000	293	2.93		54	27000	1480	14.80	
27	13500	309	3.09		55	27500	1805	18.05	
28	14000	325	3.25						

S.No.	Unloading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	1756	17.56	
2	22500	1722	17.22	
3	20000	1698	16.98	
4	17500	1655	16.55	
5	15000	1597	15.97	
6	12500	1520	15.20	
7	10000	1445	14.45	
8	7500	1360	13.60	
9	5000	1269	12.69	
10	2500	1172	11.72	
11	200	1066	10.66	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2

Rebar Type: TOR Steel

Steel: TOR 4

Loading Type: Cyclic

Date of Casting: 2063/06/10

Date of Testing: 2063/09/09

Age 89 days

Dial Guage Constant = 0.01

Dial guage No. : 2

S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Re-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	200	1066	10.66		28	16000	1504	15.04	
2	1000	1080	10.80		29	16500	1518	15.18	
3	2000	1115	11.15		30	17000	1532	15.32	
4	3000	1135	11.35		31	17500	1545	15.45	
5	4000	1160	11.60		32	18000	1561	15.61	
6	5000	1188	11.88		33	18500	1576	15.76	
7	5500	1204	12.04		34	19000	1589	15.89	
8	6000	1216	12.16		35	19500	1604	16.04	
9	6500	1232	12.32		36	20000	1618	16.18	
10	7000	1244	12.44		37	20500	1634	16.34	
11	7500	1267	12.67		38	21000	1648	16.48	
12	8000	1280	12.80		39	21500	1665	16.65	
13	8500	1290	12.90		40	22000	1676	16.76	
14	9000	1307	13.07		41	22500	1693	16.93	
15	9500	1317	13.17		42	23000	1708	17.08	
16	10000	1337	13.37		43	23500	1719	17.19	
17	10500	1352	13.52		44	24000	1738	17.38	
18	11000	1363	13.63		45	24500	1754	17.54	
19	11500	1378	13.78		46	25000	1772	17.72	
20	12000	1389	13.89		47	25500	1791	17.91	
21	12500	1407	14.07		48	26000	1813	18.13	
22	13000	1420	14.20		49	26500	1832	18.32	
23	13500	1433	14.33		50	27000	1887	18.87	
24	14000	1448	14.48		51	27500	2081	20.81	
25	14500	1462	14.62		52	28000	2248	22.48	
26	15000	1478	14.78		53	28250	2552	25.52	
27	15500	1490	14.90						

S.No.	Un-loading	Dial Guage Reading	Deflection (mm)	Remarks
1	25000	2510	25.10	
2	22500	2470	24.70	
3	20000	2428	24.28	
4	17500	2378	23.78	
5	15000	2307	23.07	
6	12500	2221	22.21	
7	10000	2148	21.48	
8	7500	2059	20.59	
9	5000	1958	19.58	
10	2500	1847	18.47	
11	0	1510	15.10	

## Beam Test (Load Vs Deflection)

Beam Sample No: C-C-2  
 Rebar Type: TOR Steel                      Steel: TOR 4  
 Loading Type: Cyclic  
 Date of Casting: 2063/06/10                      Date of Testing: 2063/09/09  
 Age                      89 days  
 Dial Guage Constant = 0.01  
 Dial guage No. : 2

S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks	S.No.	Second Reloading	Dial Guage Reading	Deflection (mm)	Remarks
1	0	1510	15.10		30	15000	1962	19.62	
2	1000	1525	15.25		31	15500	1973	19.73	
3	1500	1544	15.44		32	17000	2027	20.27	
4	2000	1554	15.54		33	17500	2042	20.42	
5	2500	1569	15.69		34	18000	2056	20.56	
6	3000	1587	15.87		35	18500	2067	20.67	
7	3500	1608	16.08		36	19000	2081	20.81	
8	4000	1619	16.19		37	19500	2098	20.98	
9	4500	1634	16.34		38	20000	2121	21.21	
10	5000	1650	16.50		39	20500	2134	21.34	
11	5500	1666	16.66		40	21000	2147	21.47	
12	6000	1682	16.82		41	21500	2162	21.62	
13	6500	1697	16.97		42	22000	2182	21.82	
14	7000	1717	17.17		43	22500	2192	21.92	
15	7500	1727	17.27		44	23000	2208	22.08	
16	8000	1744	17.44		45	23500	2224	22.24	
17	8500	1761	17.61		46	24000	2238	22.38	
18	9000	1774	17.74		47	24500	2253	22.53	
19	9500	1794	17.94		48	25000	2272	22.72	
20	10000	1807	18.07		49	25500	2288	22.88	
21	10500	1827	18.27		50	26000	2308	23.08	
22	11000	1842	18.42		51	26500	2329	23.29	
23	11500	1859	18.59		52	27000	2352	23.52	
24	12000	1872	18.72		53	27500	2388	23.88	
25	12500	1887	18.87		54	28000	2452	24.52	
26	13000	1904	19.04		55	28500	2680	26.80	
27	13500	1922	19.22		56	29000	2920	29.20	
28	14000	1934	19.34		57	29250		30.40	
29	14500	1949	19.49						

Fig. 26: Cyclic Loading Deflection Curve (C-C-2)

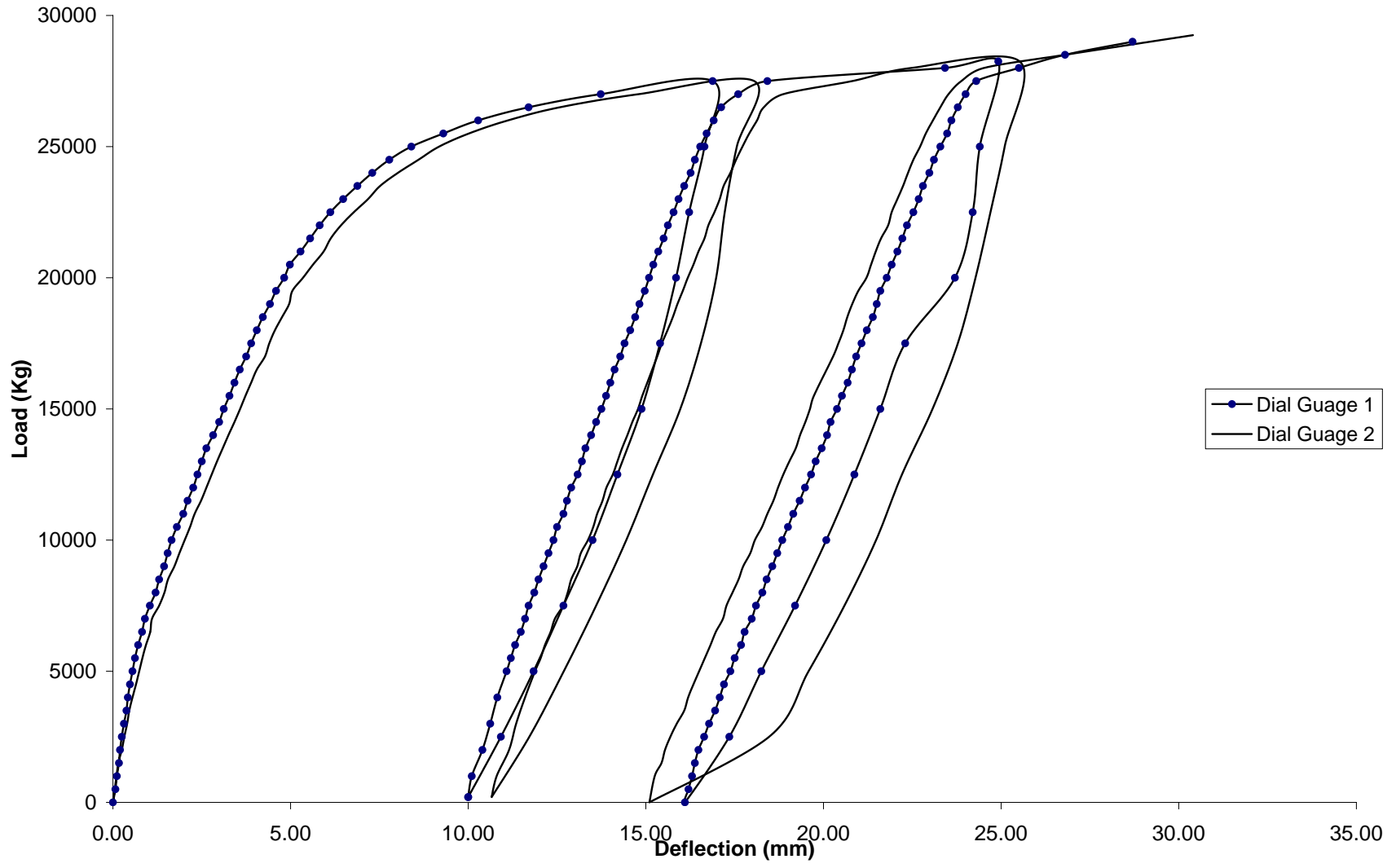
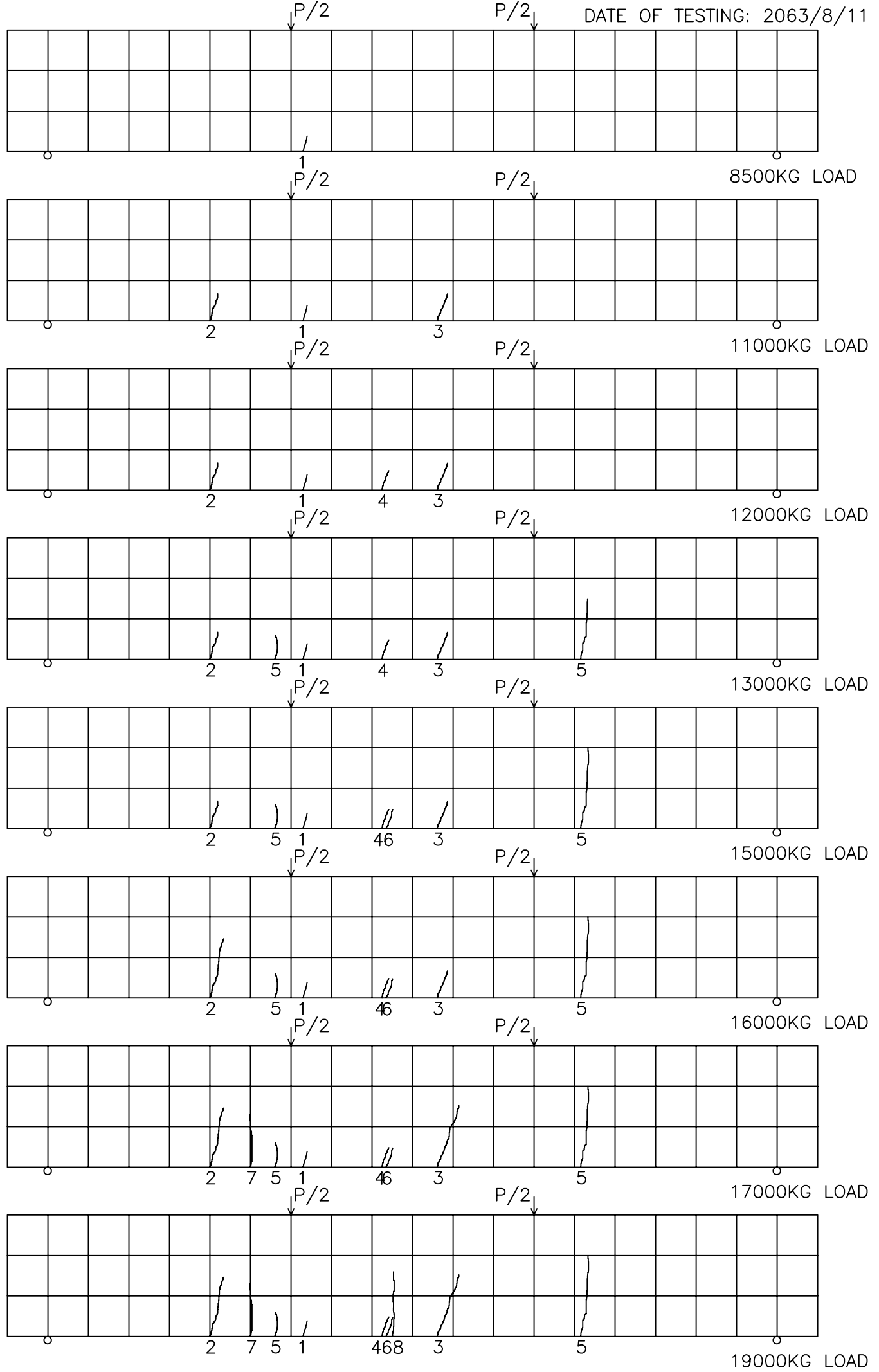


FIG. 27: BEAM SAMPLE: M-T-2

CRACK PATTERN

DATE OF TESTING: 2063/8/11



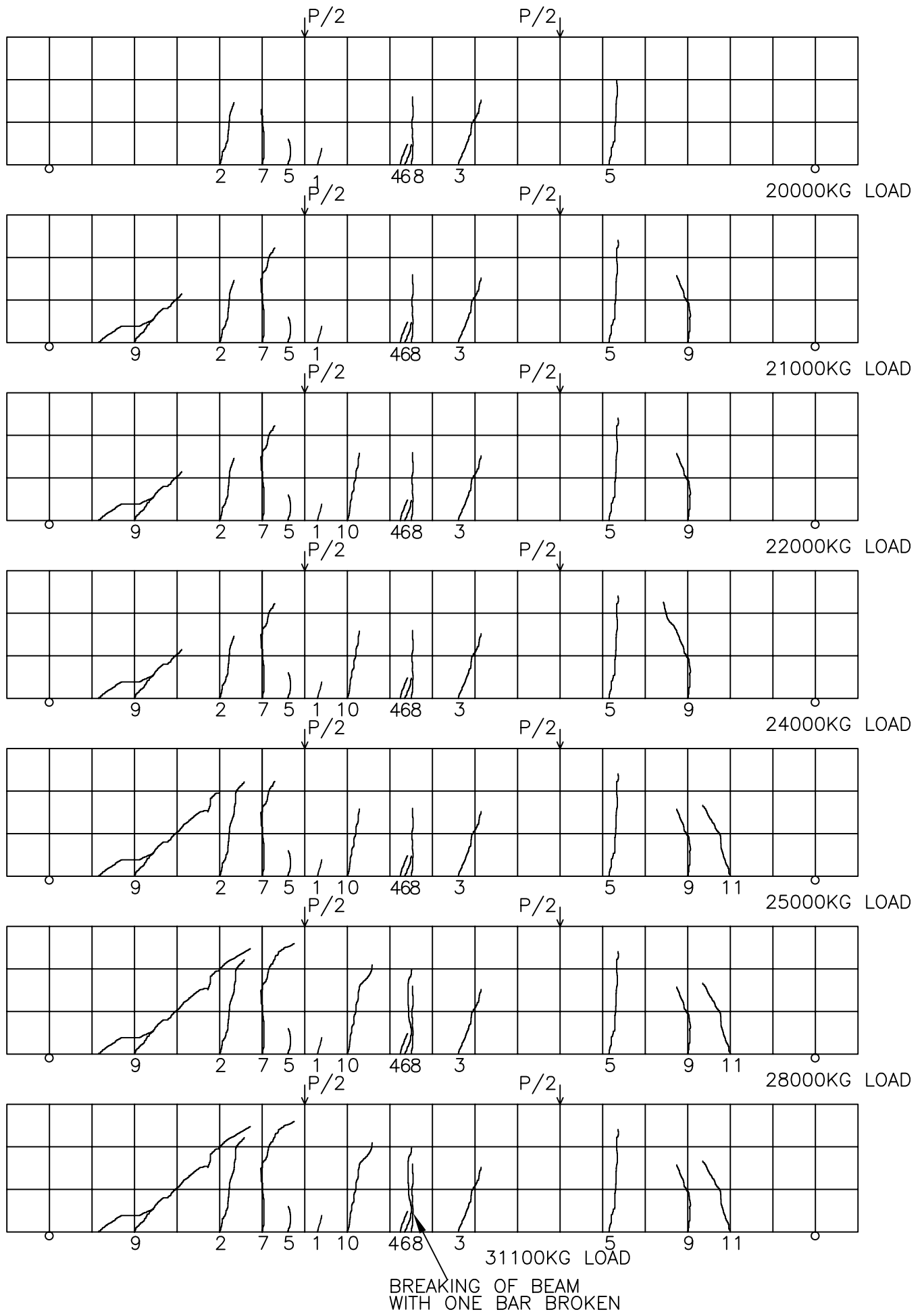
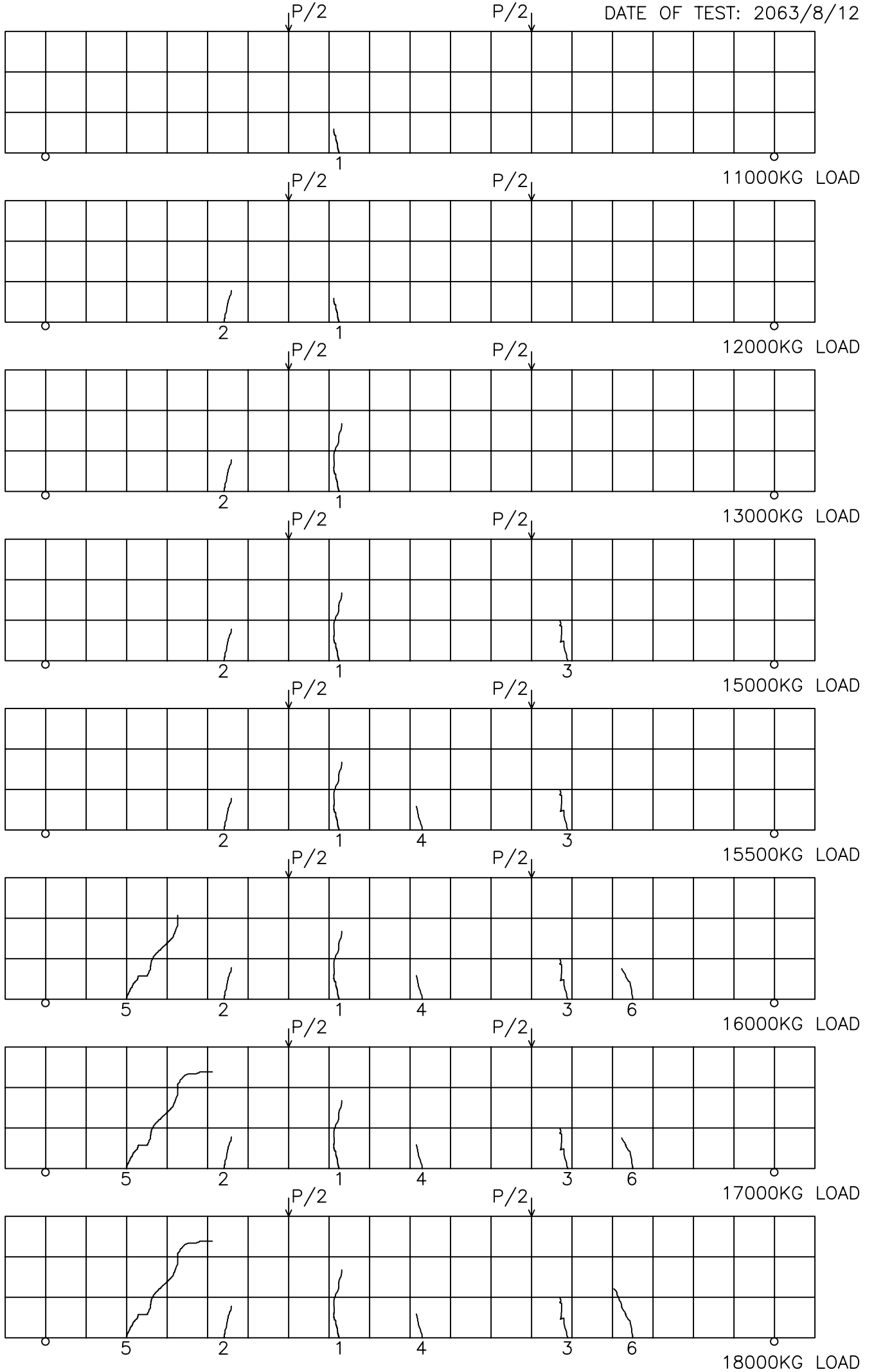
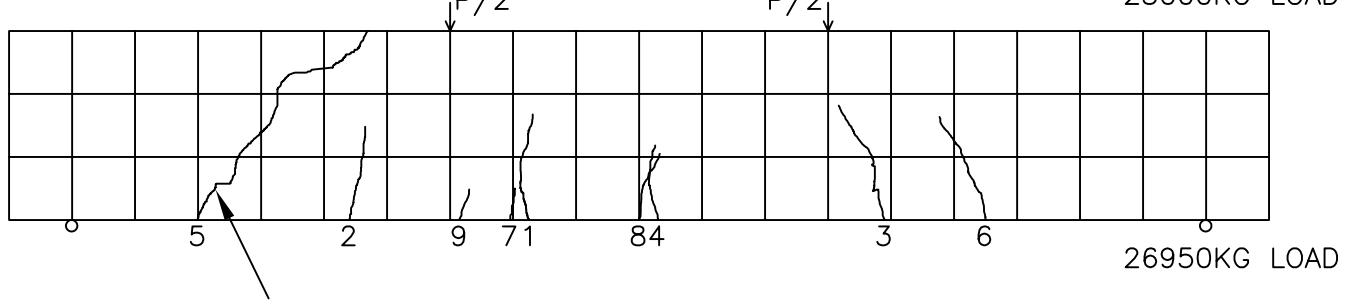
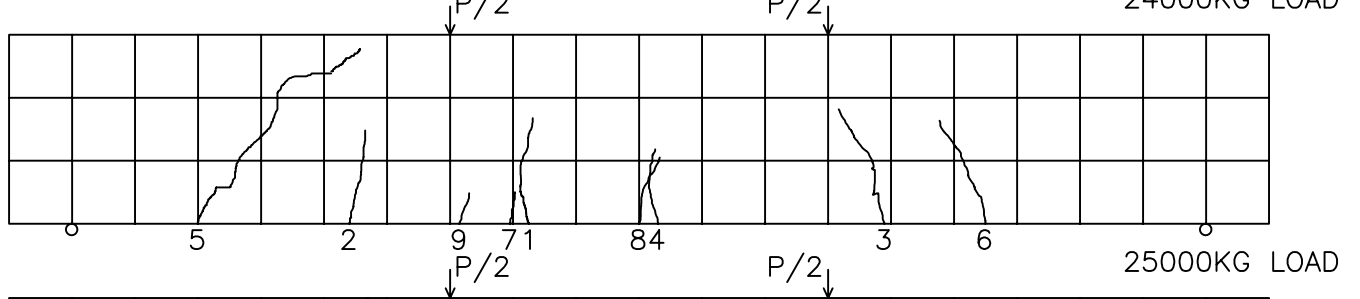
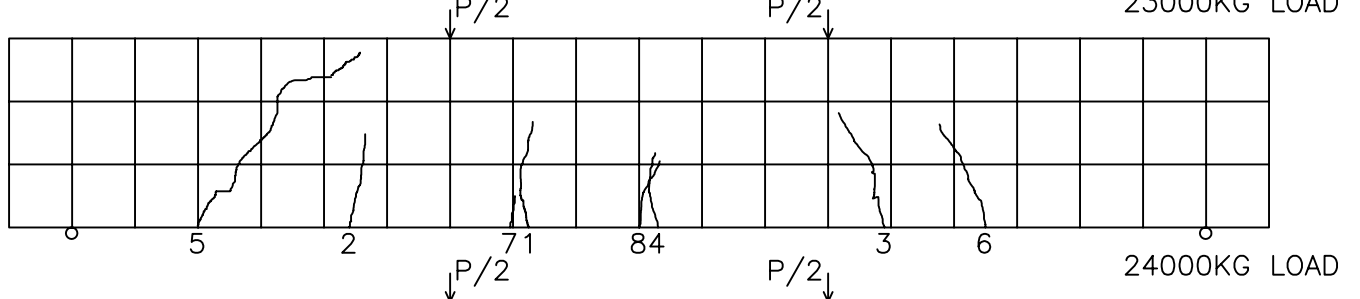
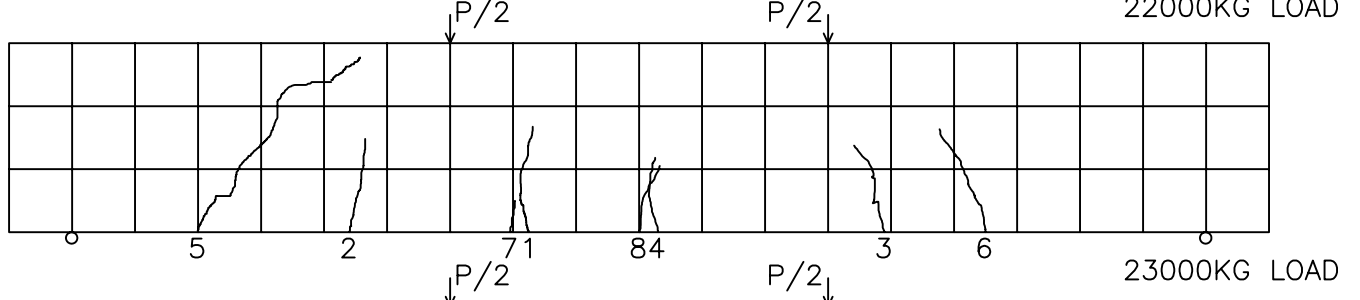
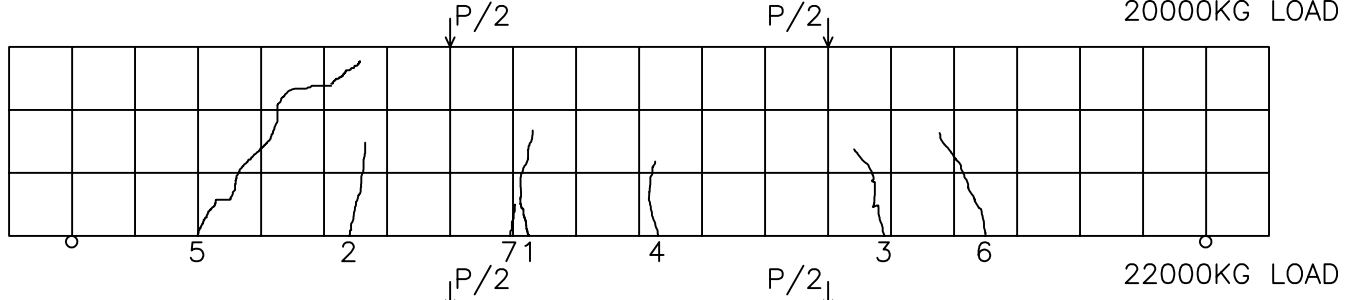
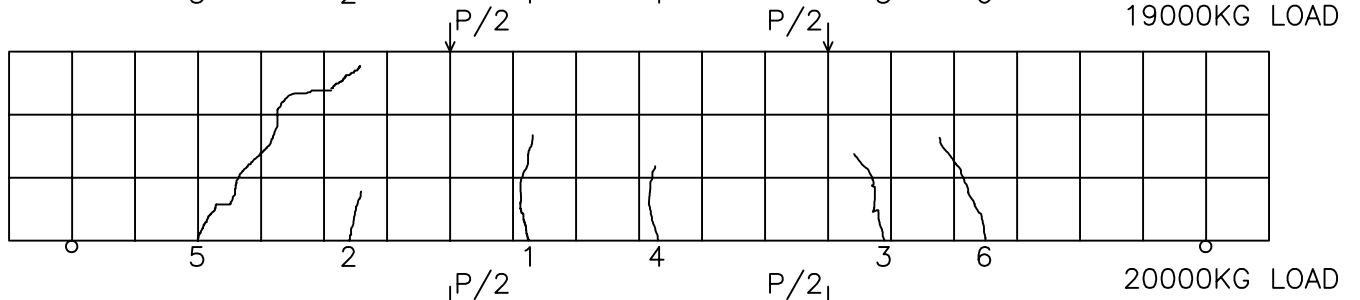
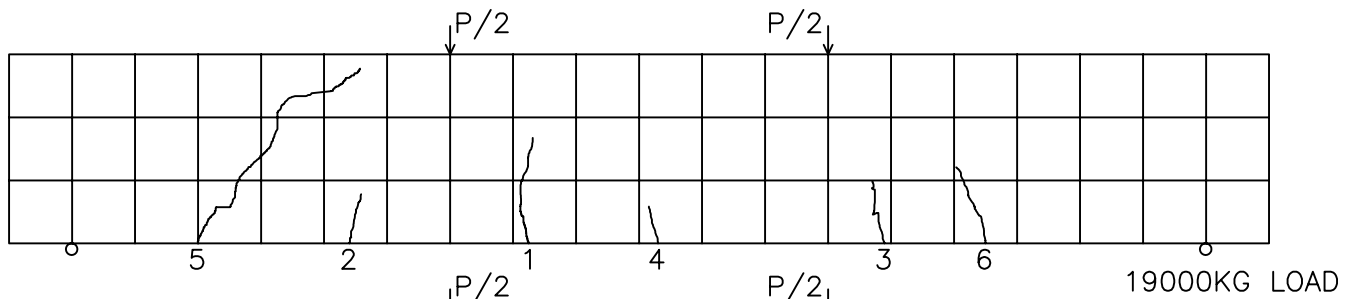


FIG. 28: BEAM SAMPLE: M-C-1

DATE OF TEST: 2063/8/12

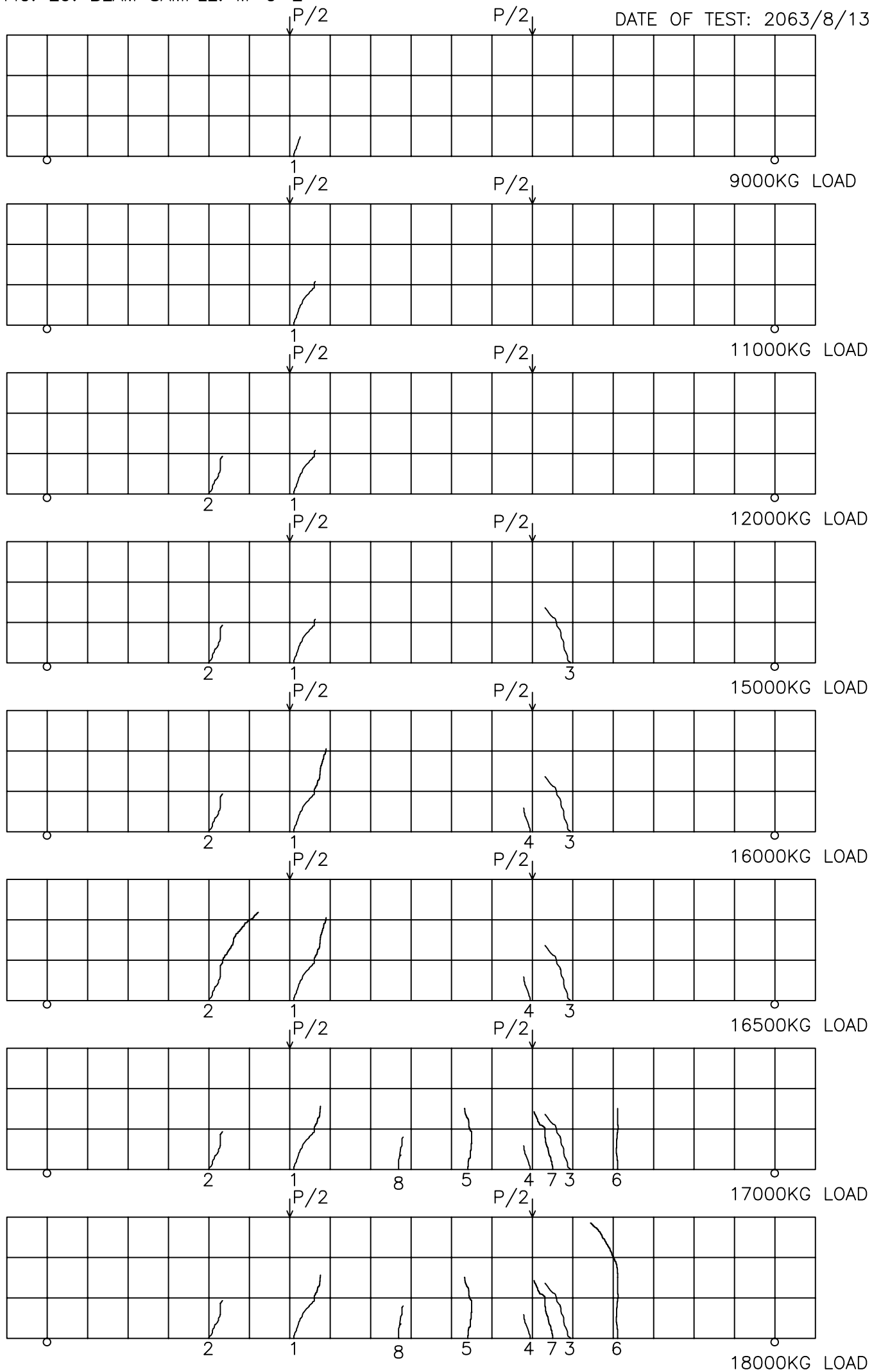


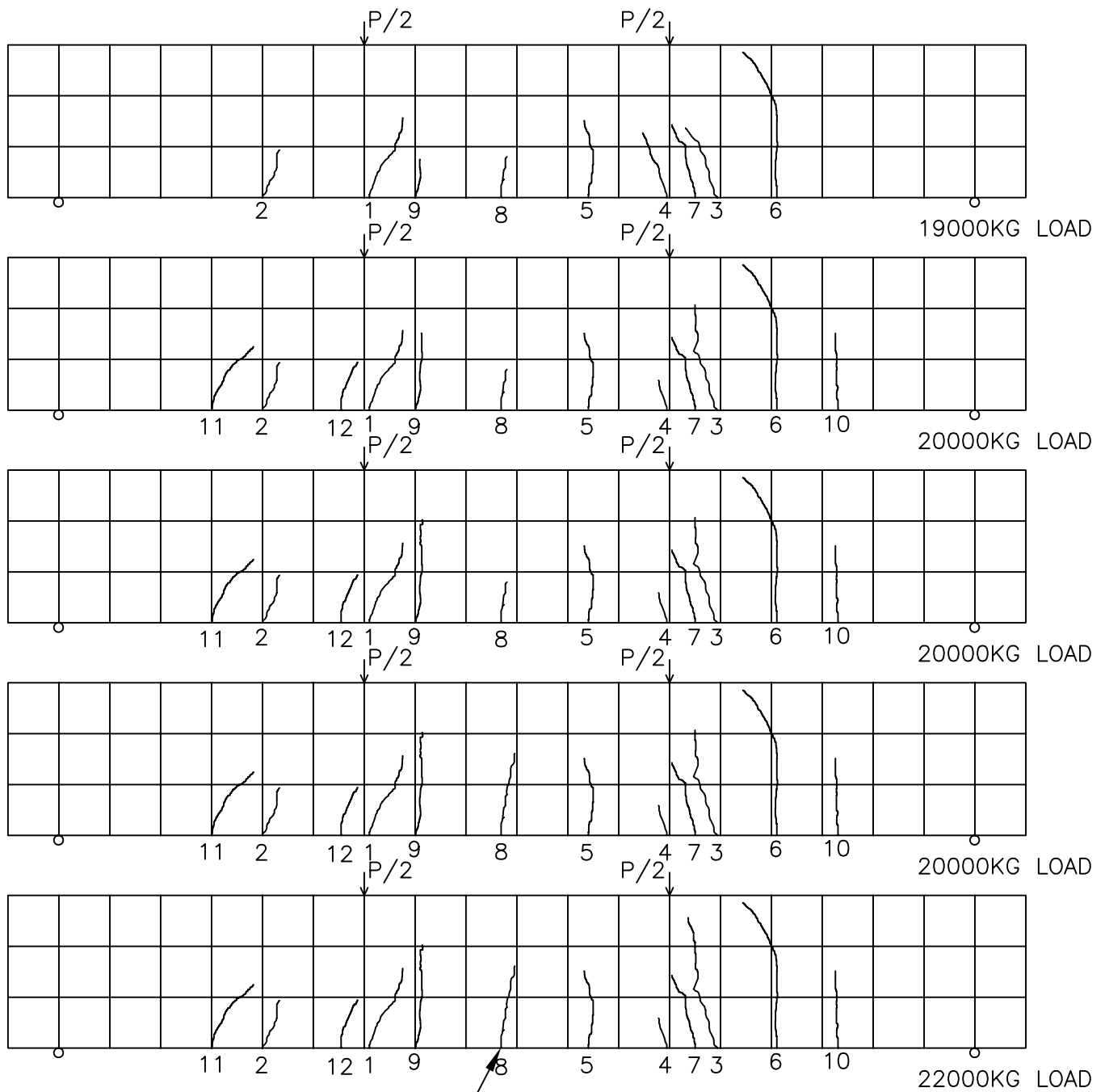


BREAKING OF BEAM (SHEAR FAILURE)  
WITH ALL FOUR BAR BROKEN

FIG. 29: BEAM SAMPLE: M-C-2

DATE OF TEST: 2063/8/13

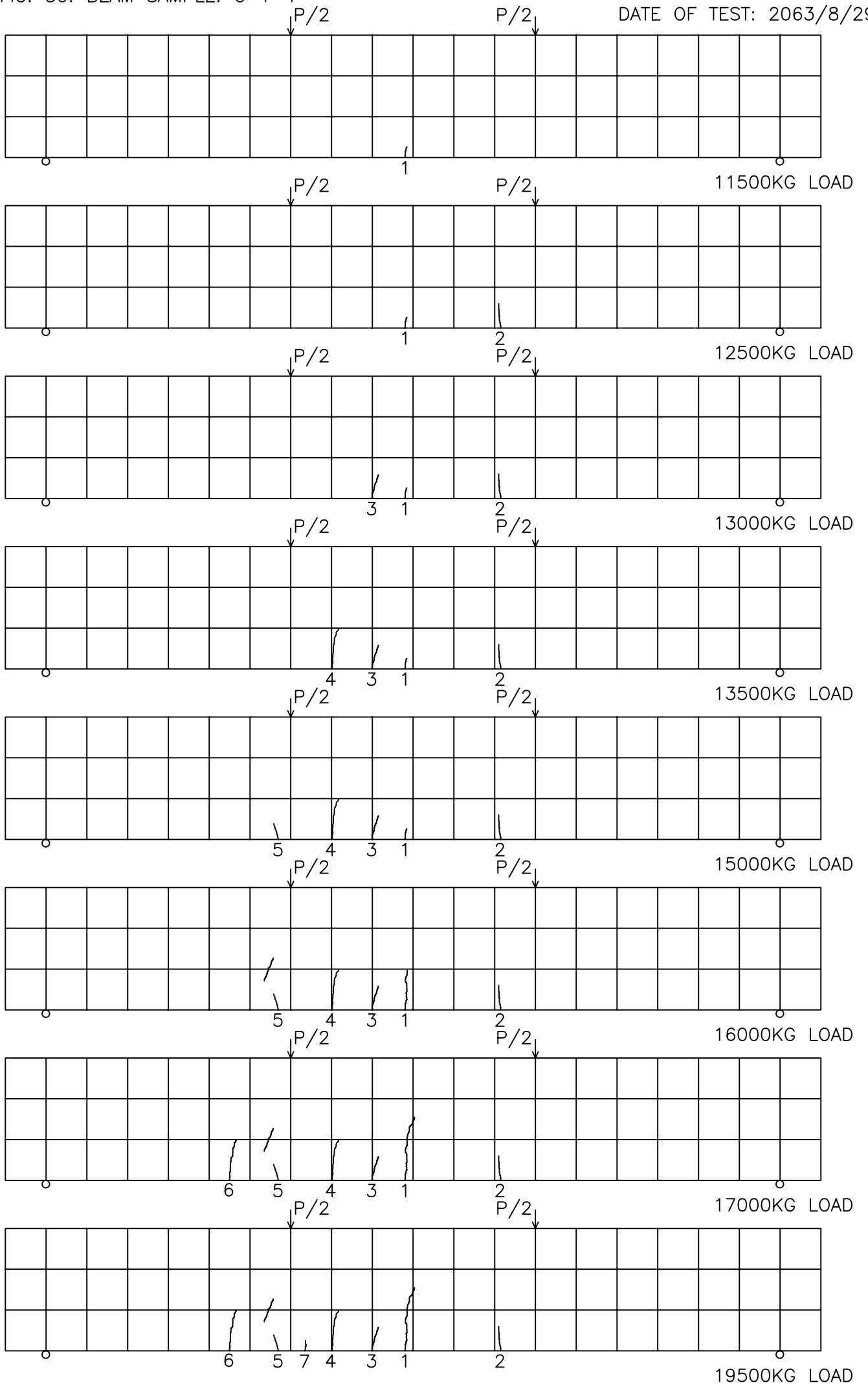


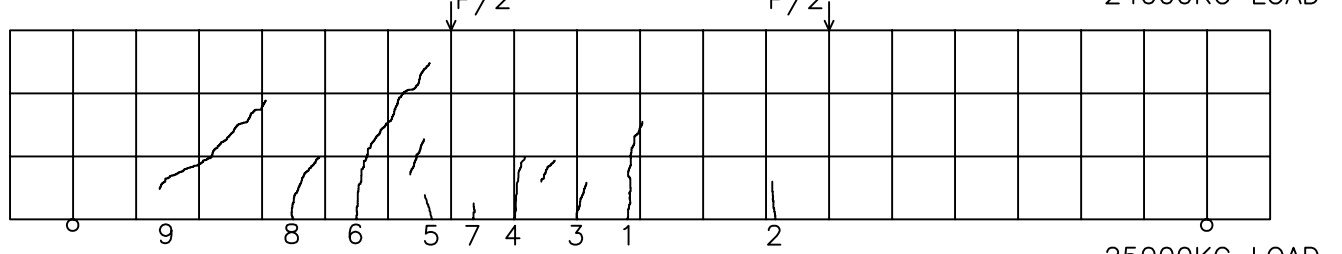
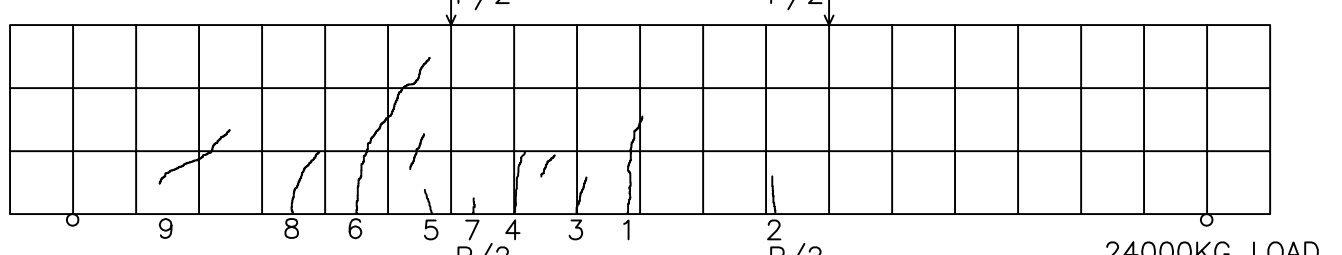
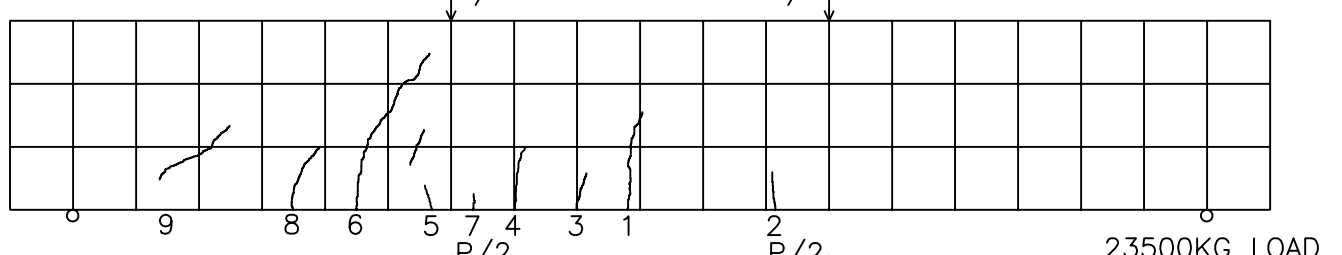
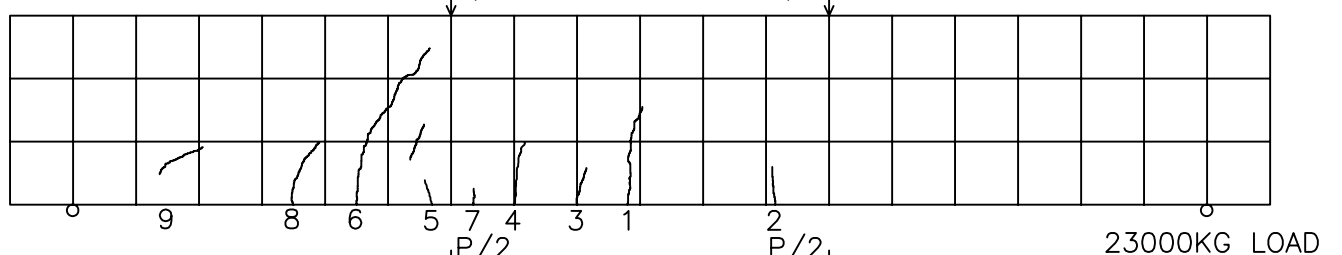
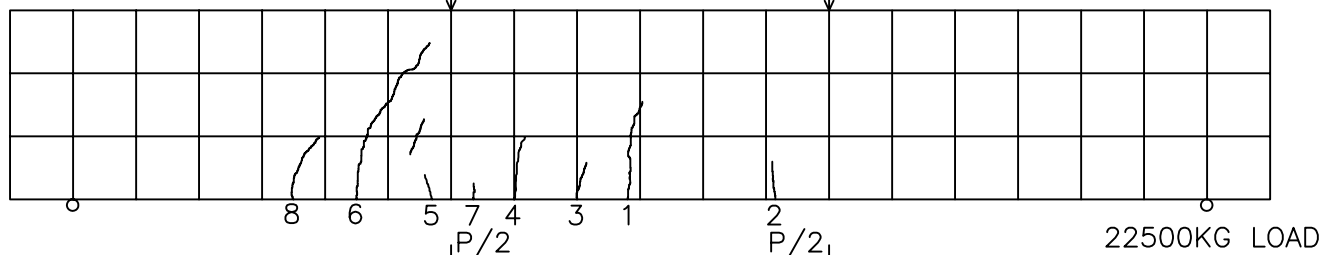
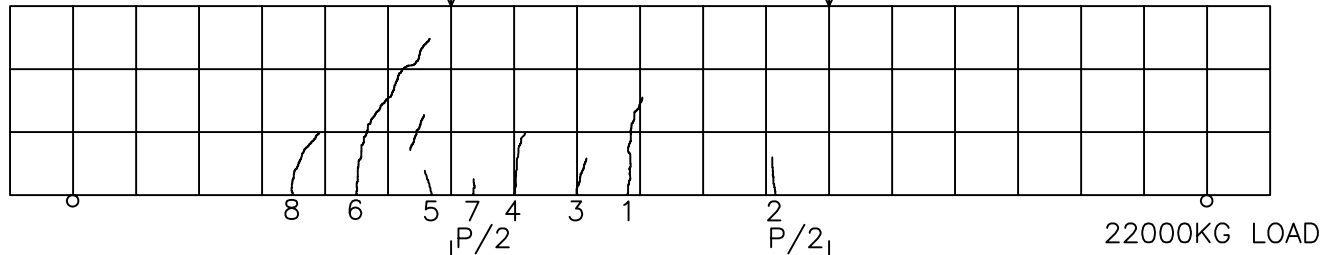
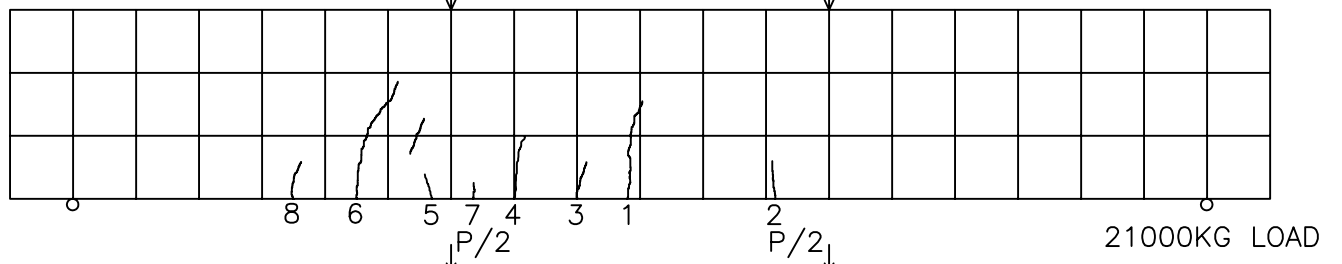
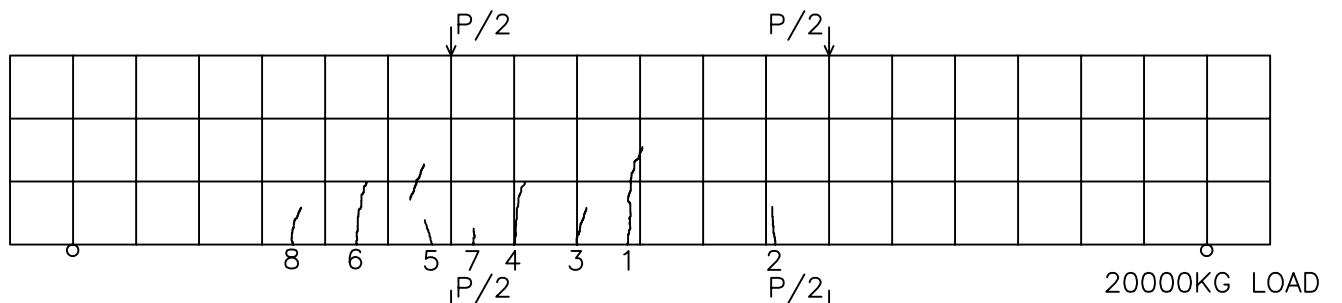


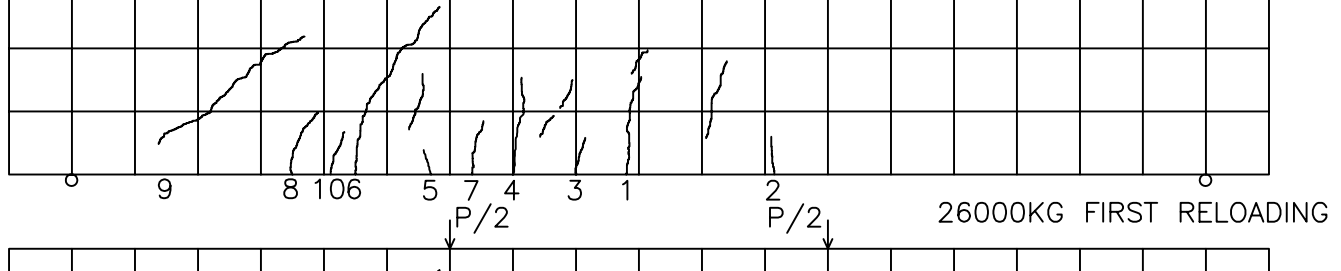
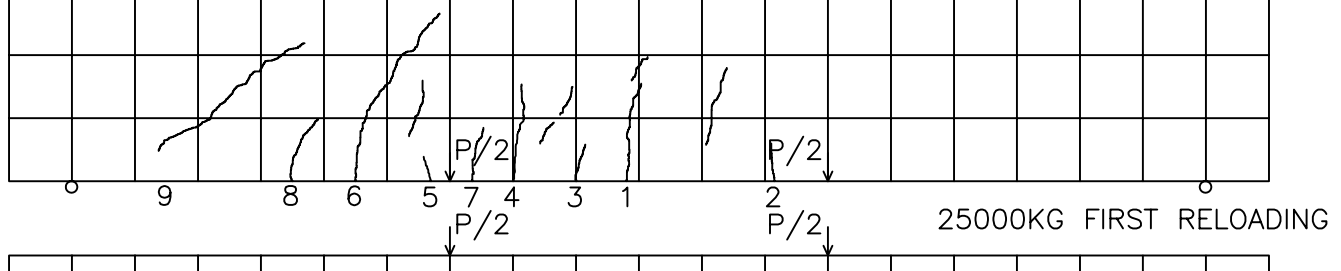
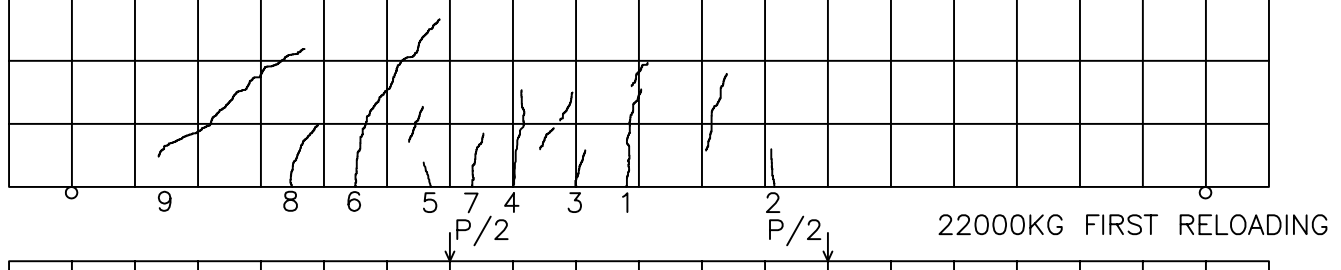
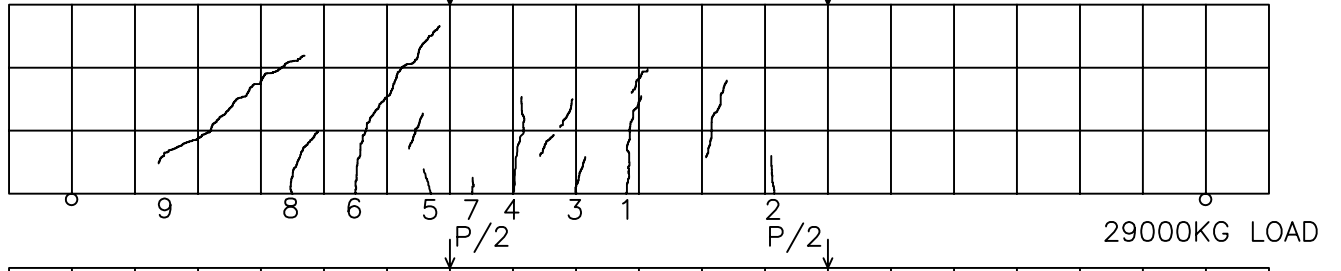
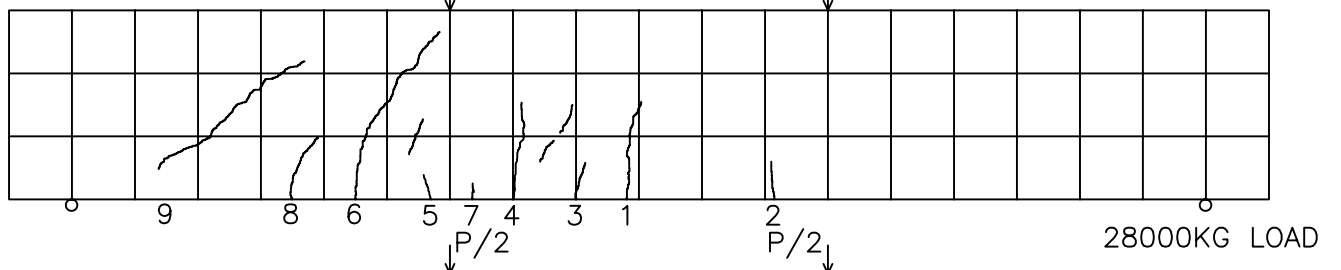
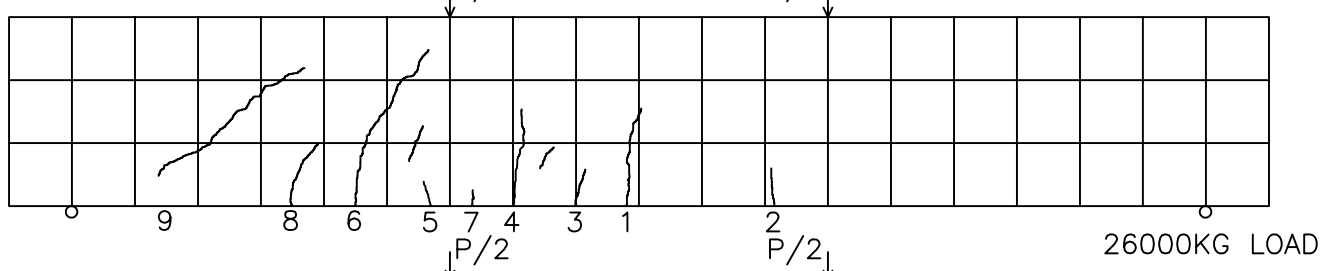
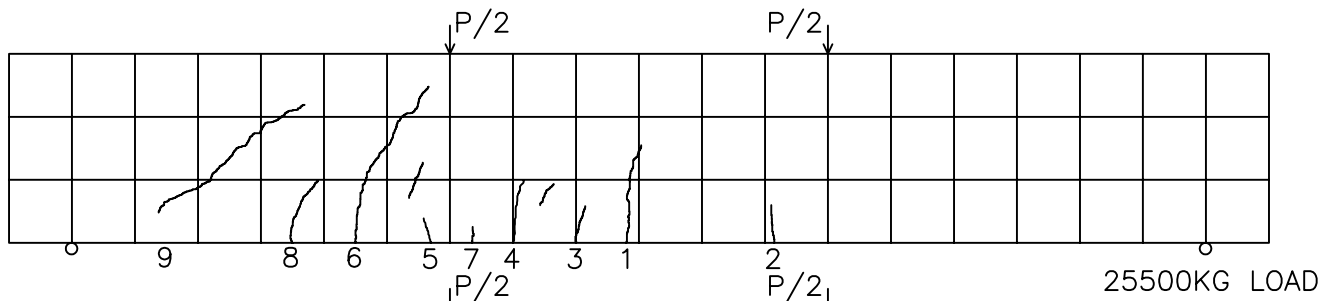
BREAKING OF BEAM (FLEXURE FAILURE)  
WITH ALL FOUR BAR BROKEN

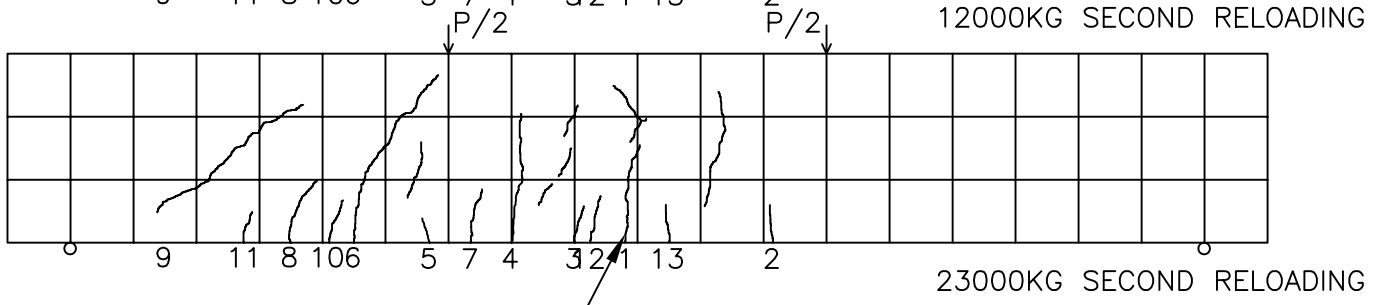
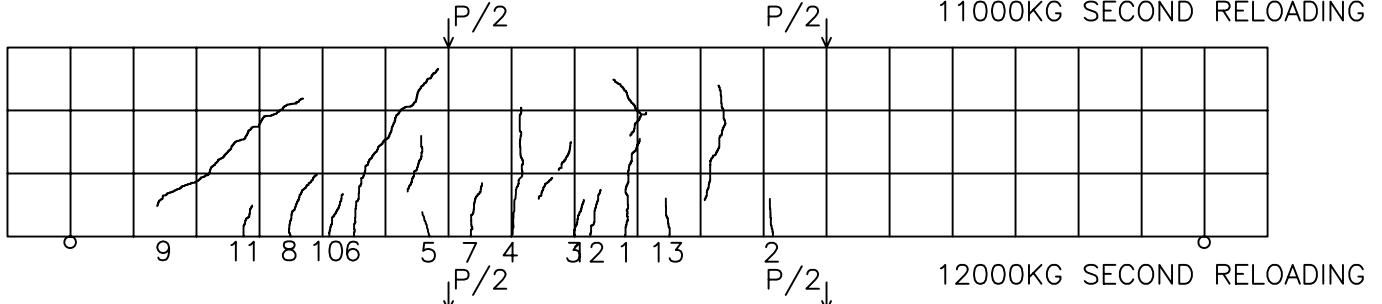
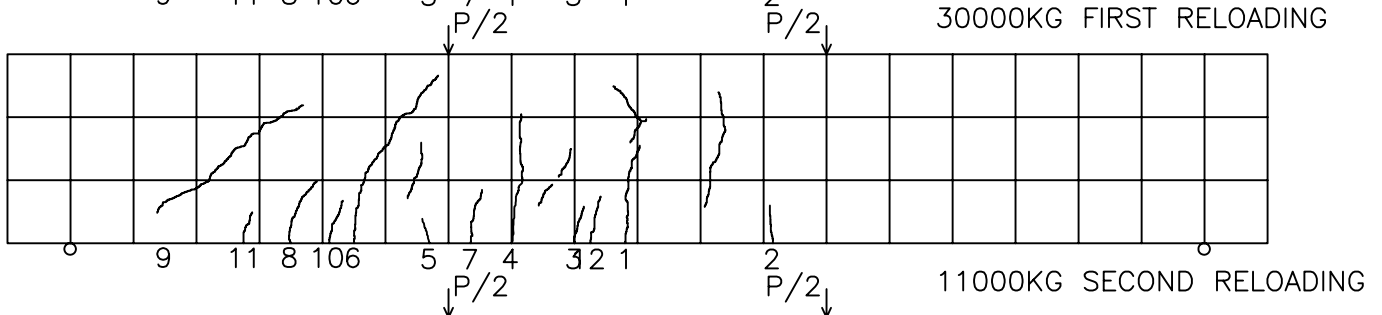
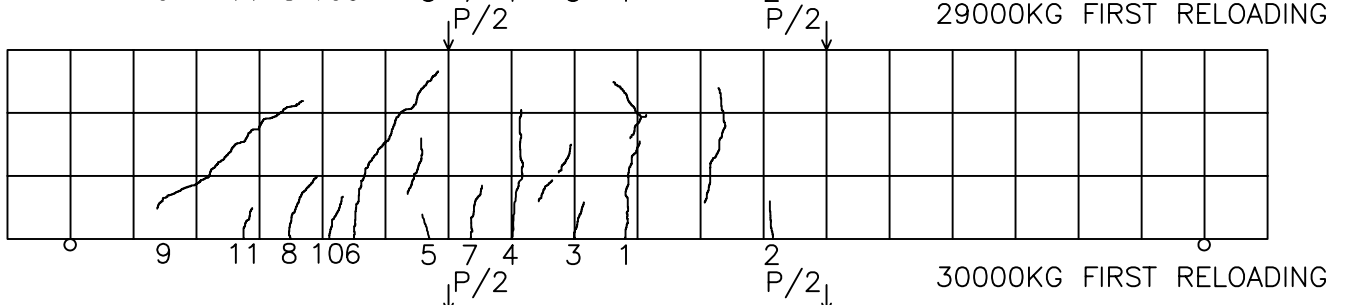
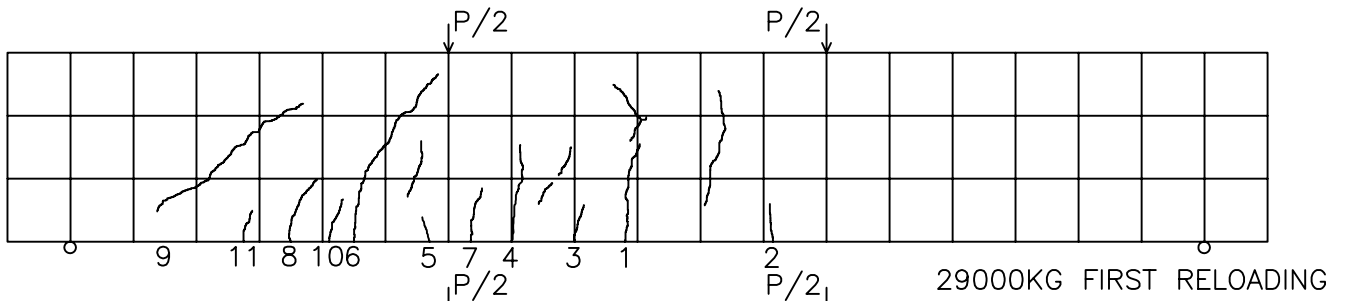
FIG. 30: BEAM SAMPLE: C-T-1

DATE OF TEST: 2063/8/29





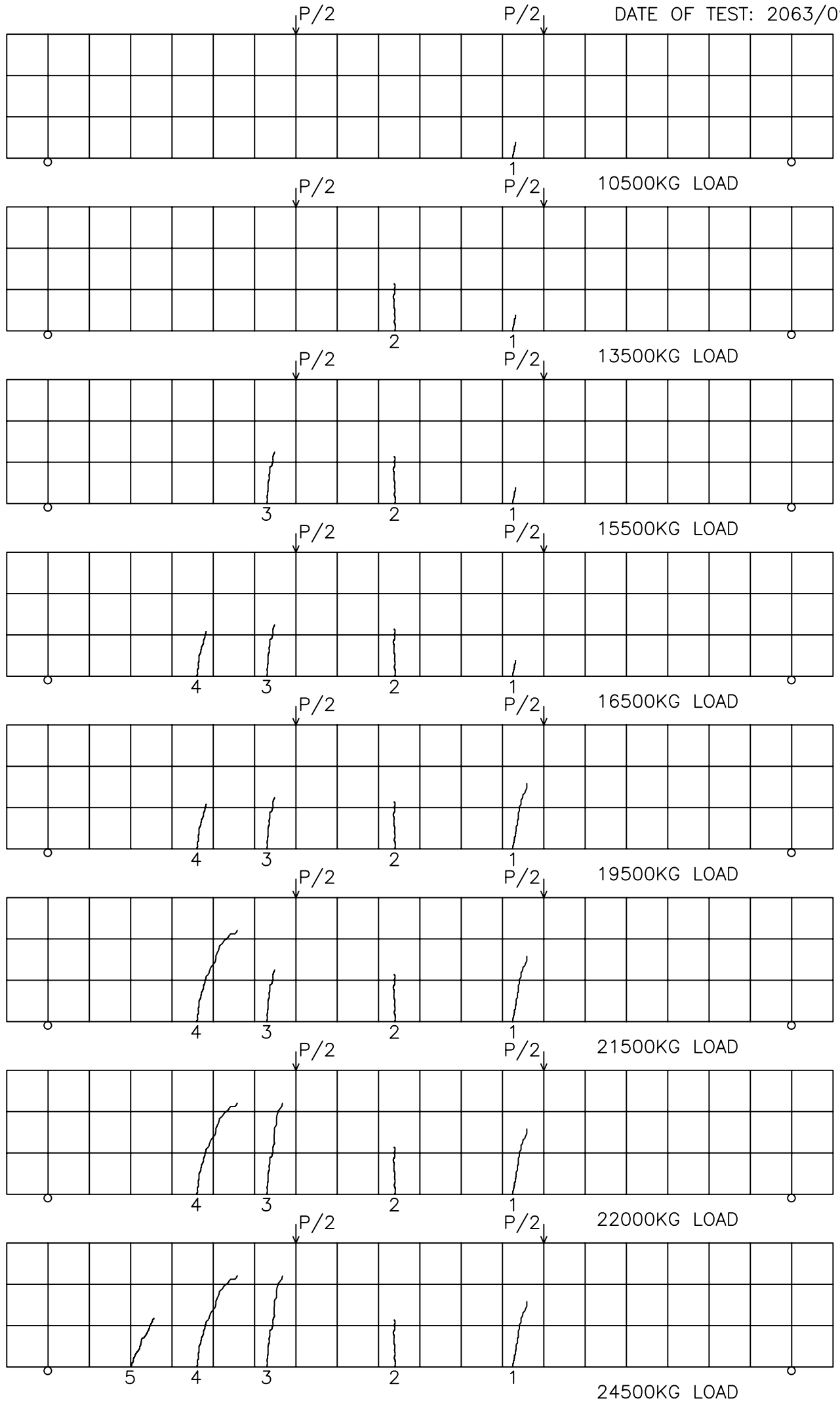


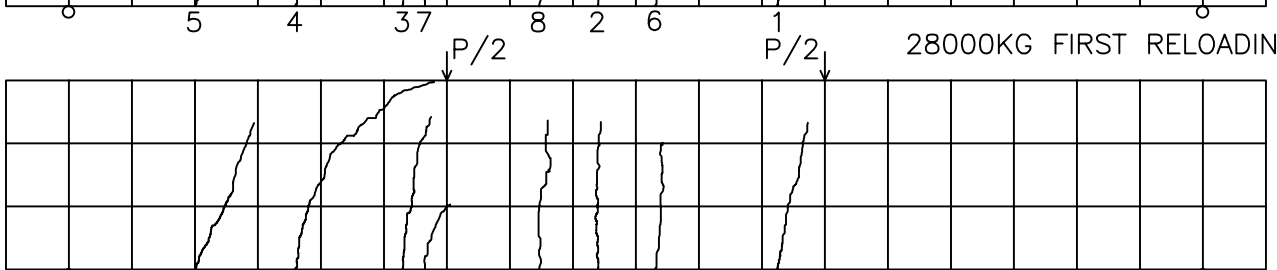
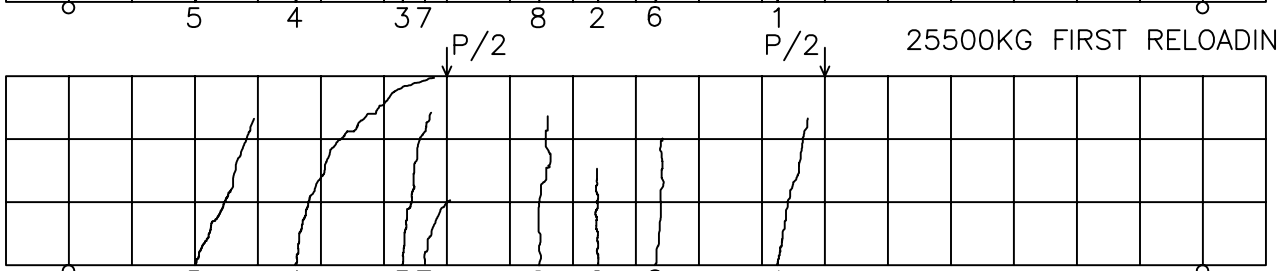
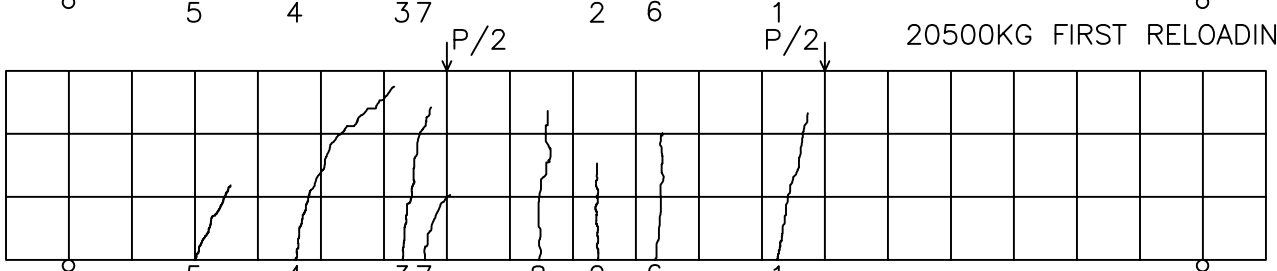
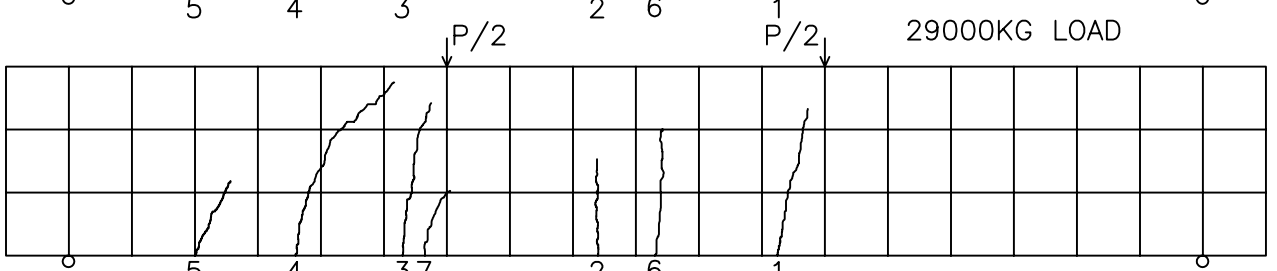
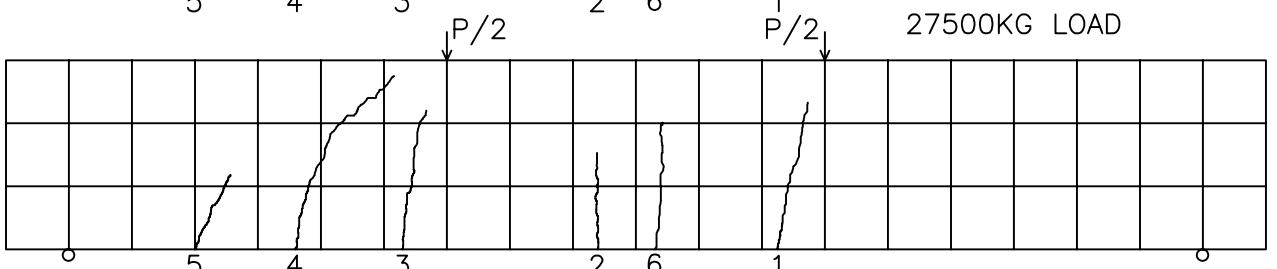
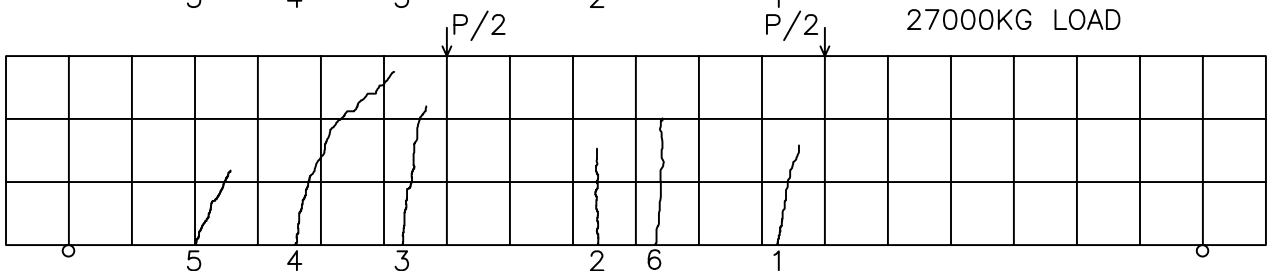
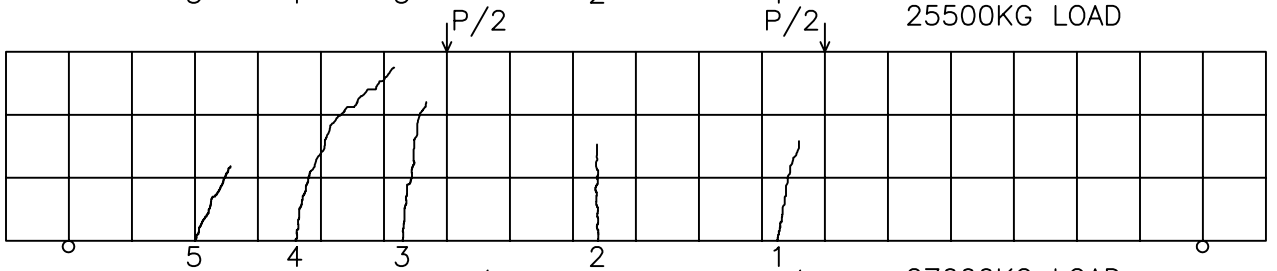
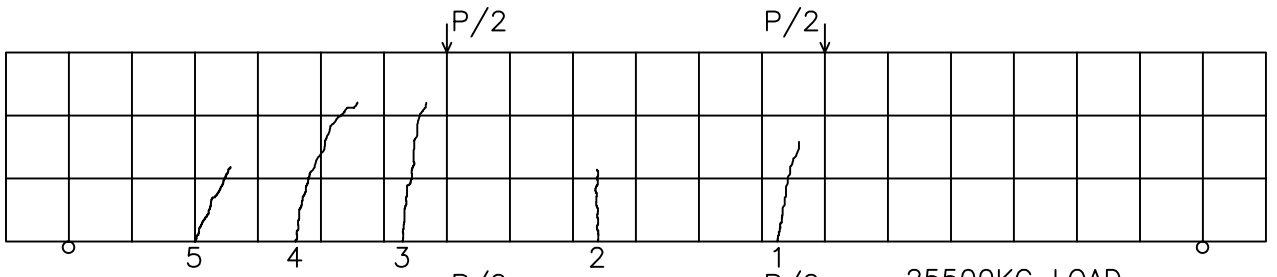


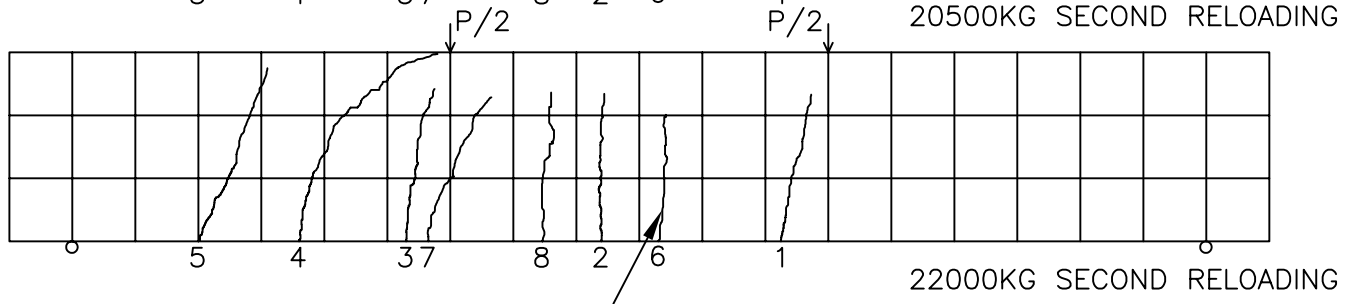
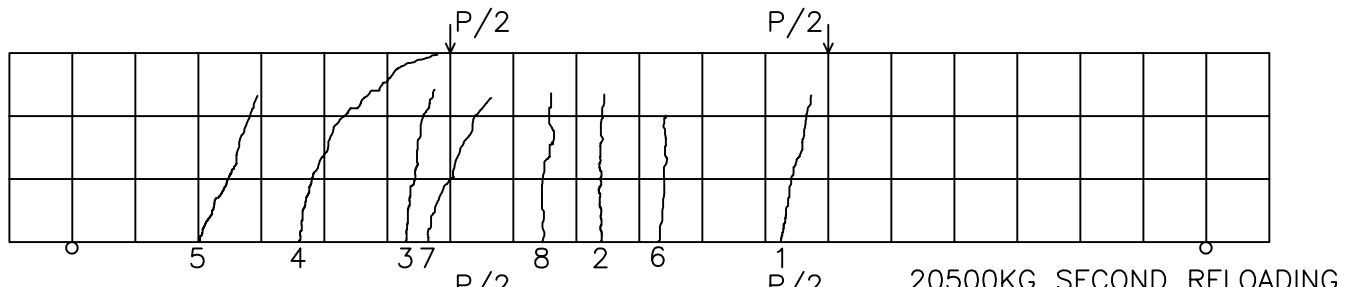
BREAKING OF BEAM (FLEXURE FAILURE)  
WITH ALL FOUR BAR BROKEN

FIG. 31: BEAM SAMPLE: C-T-2

DATE OF TEST: 2063/09/05



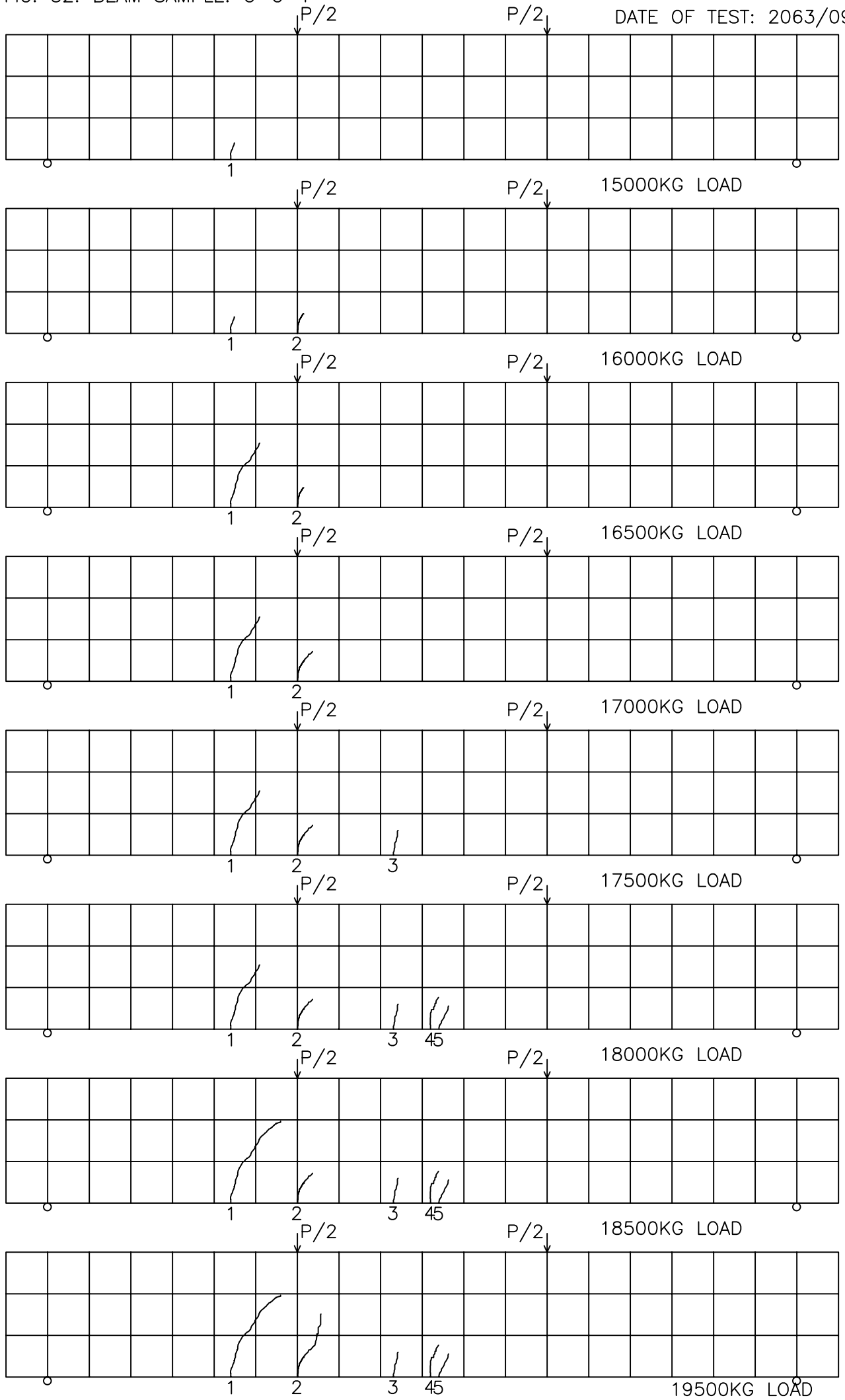


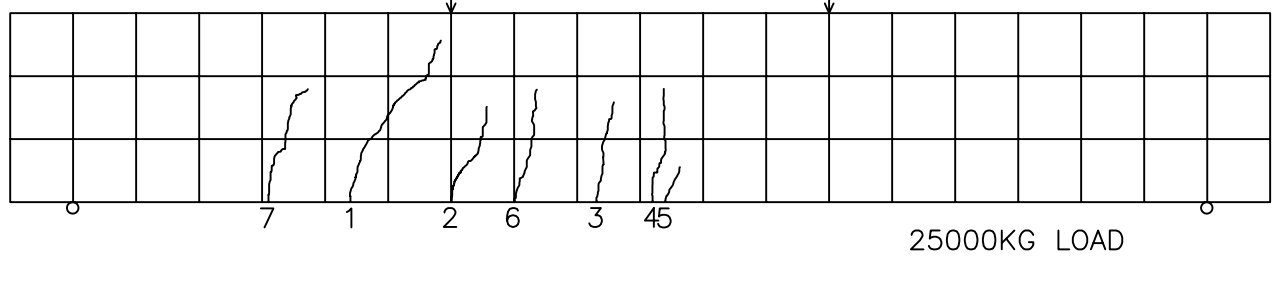
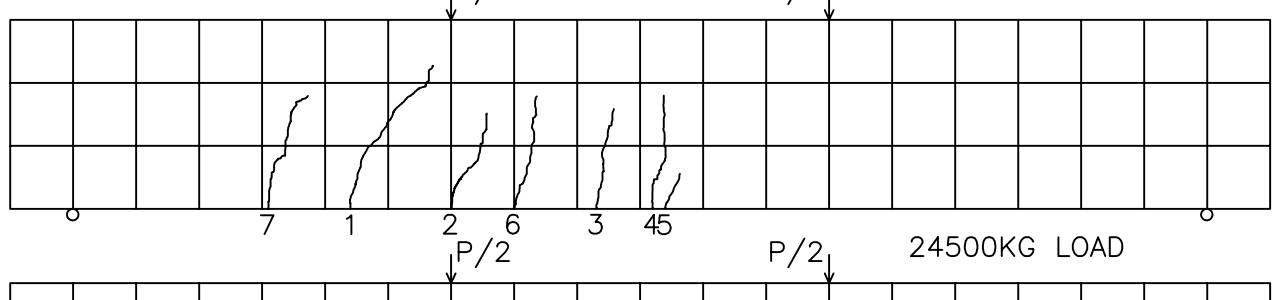
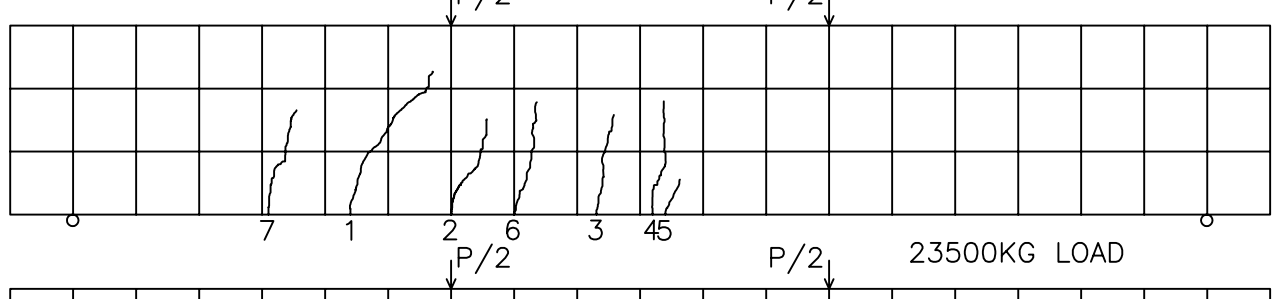
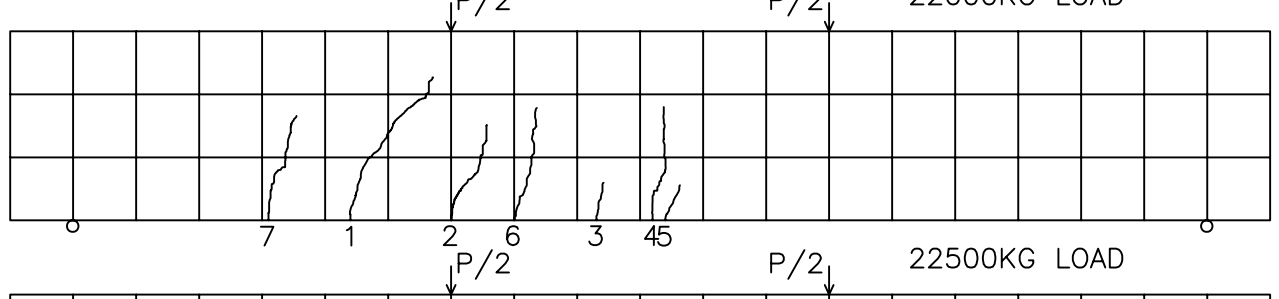
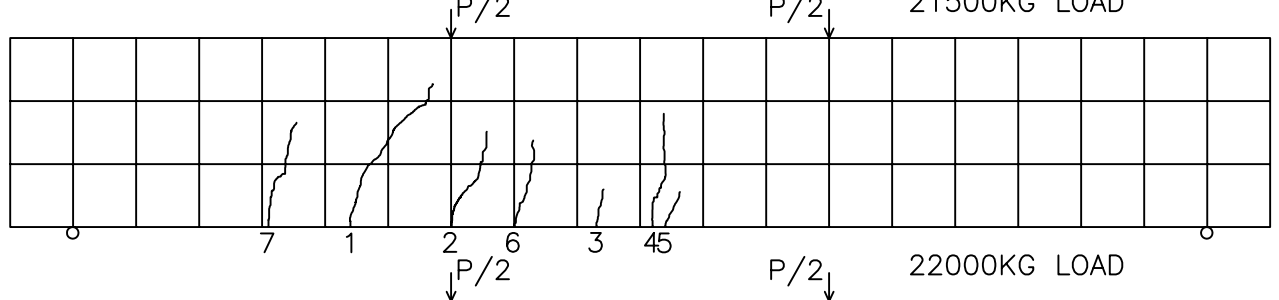
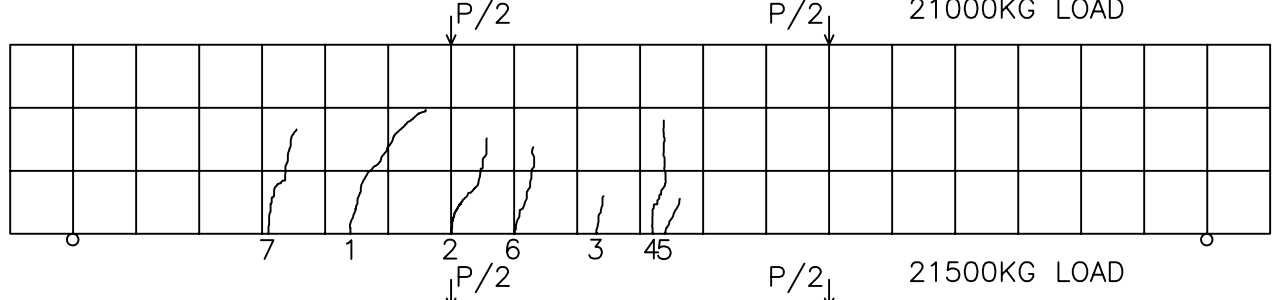
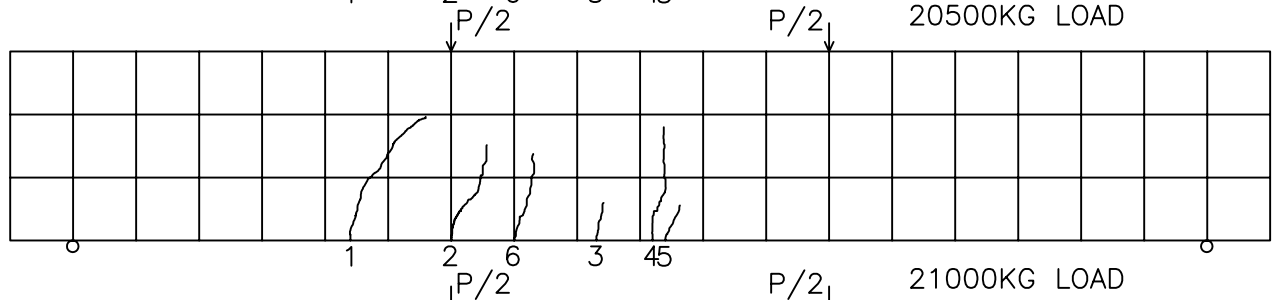
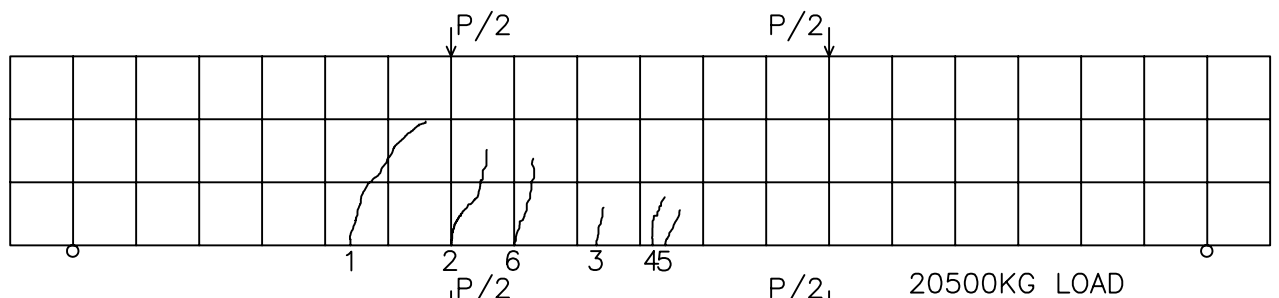


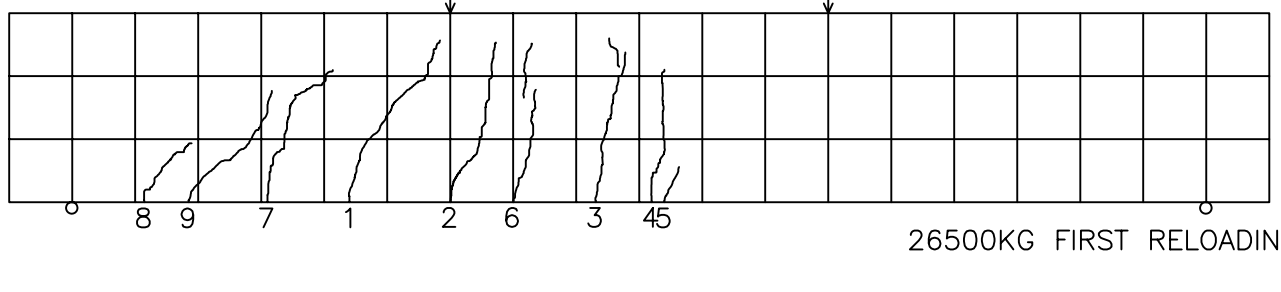
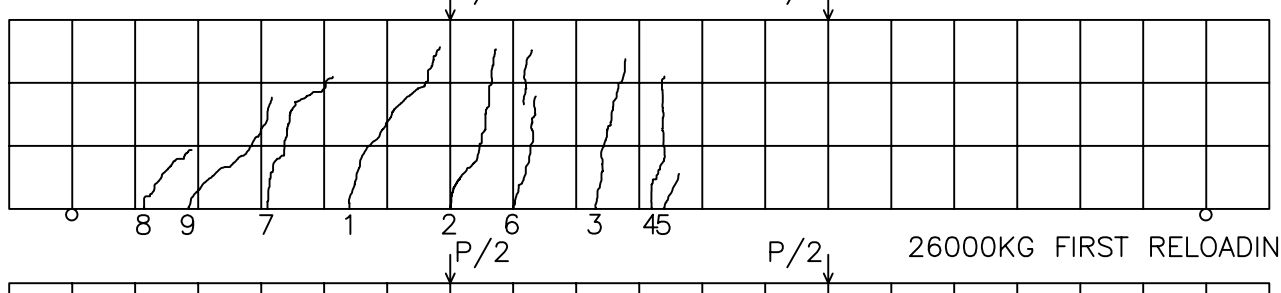
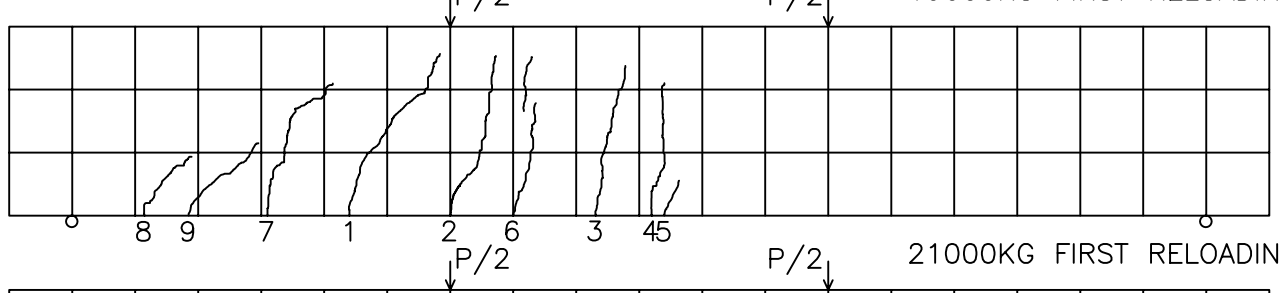
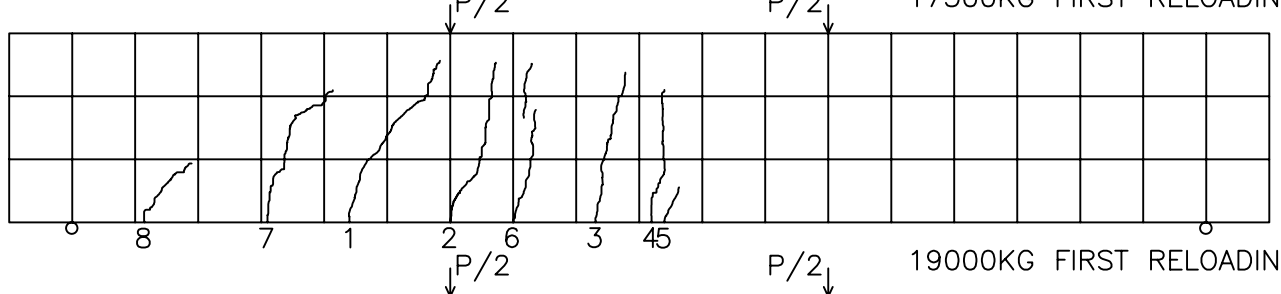
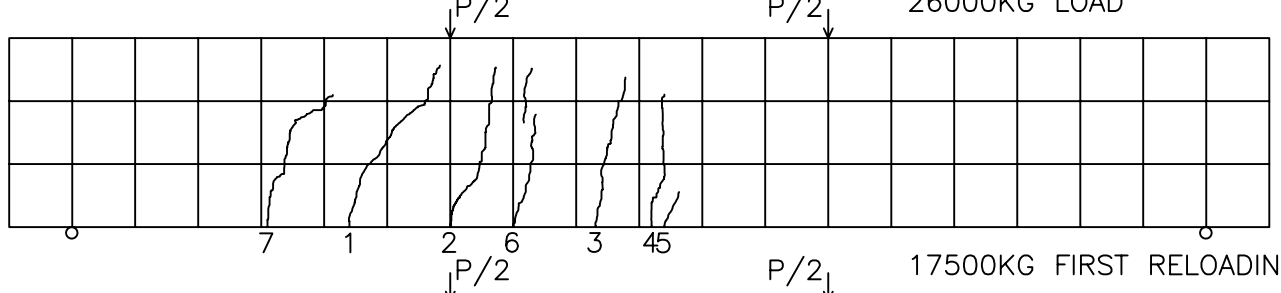
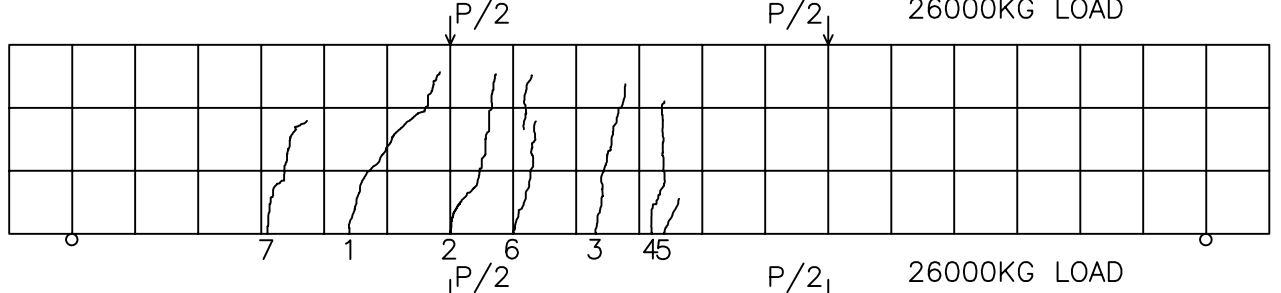
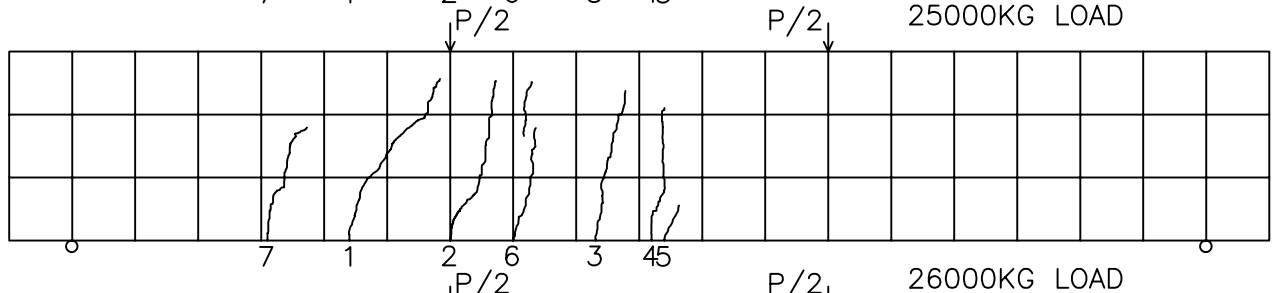
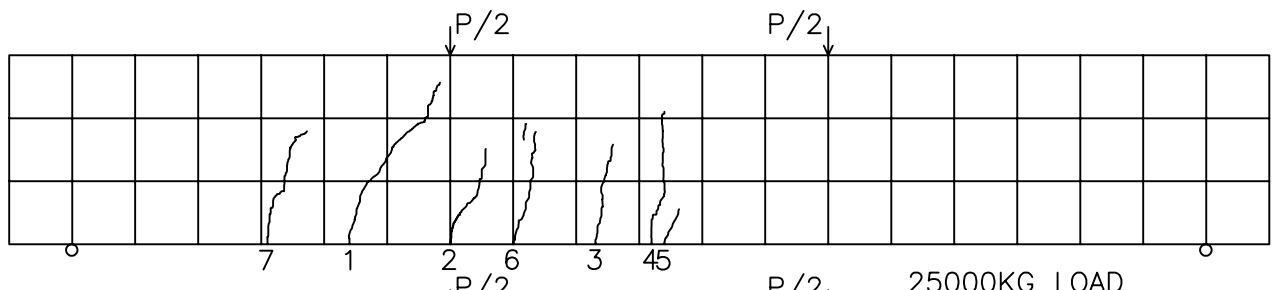
BREAKING OF BEAM (FLEXURE FAILURE)  
WITH ALL FOUR BAR BROKEN

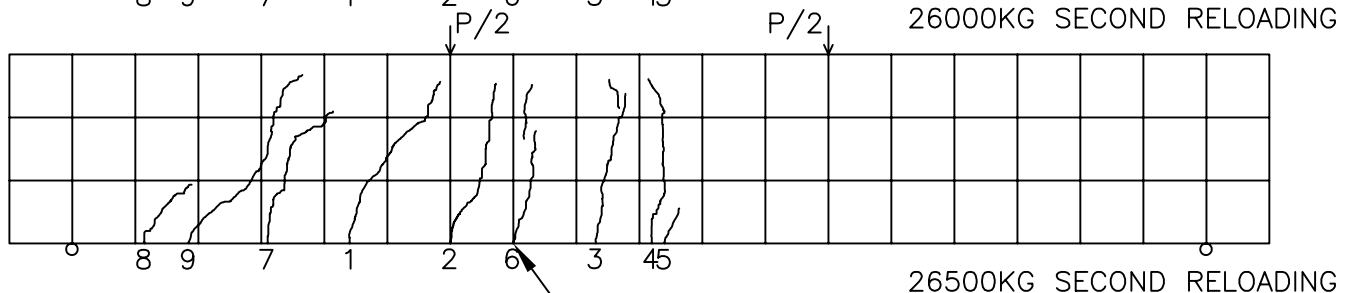
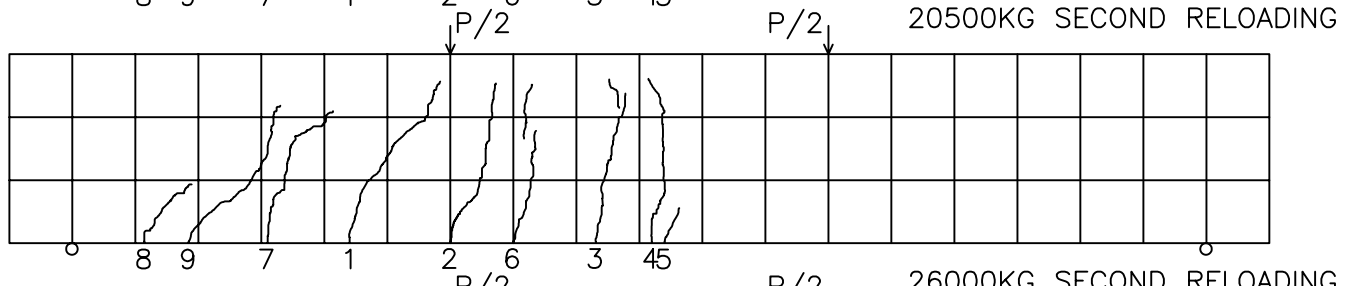
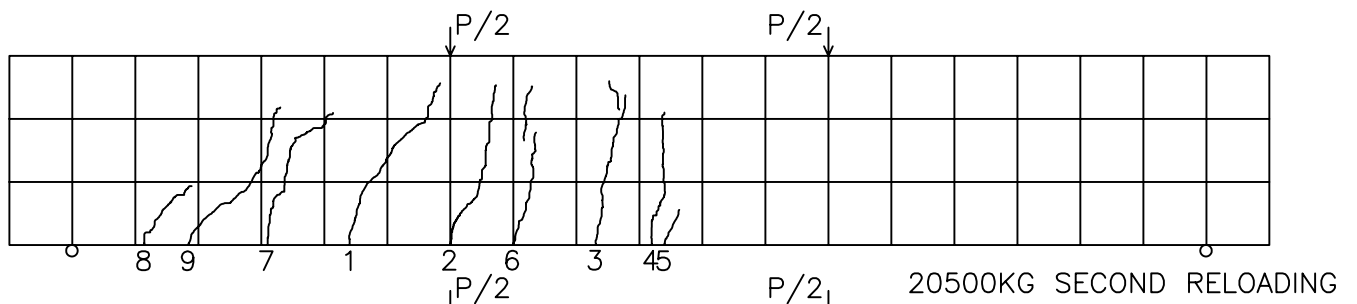
FIG. 32: BEAM SAMPLE: C-C-1

DATE OF TEST: 2063/09/07





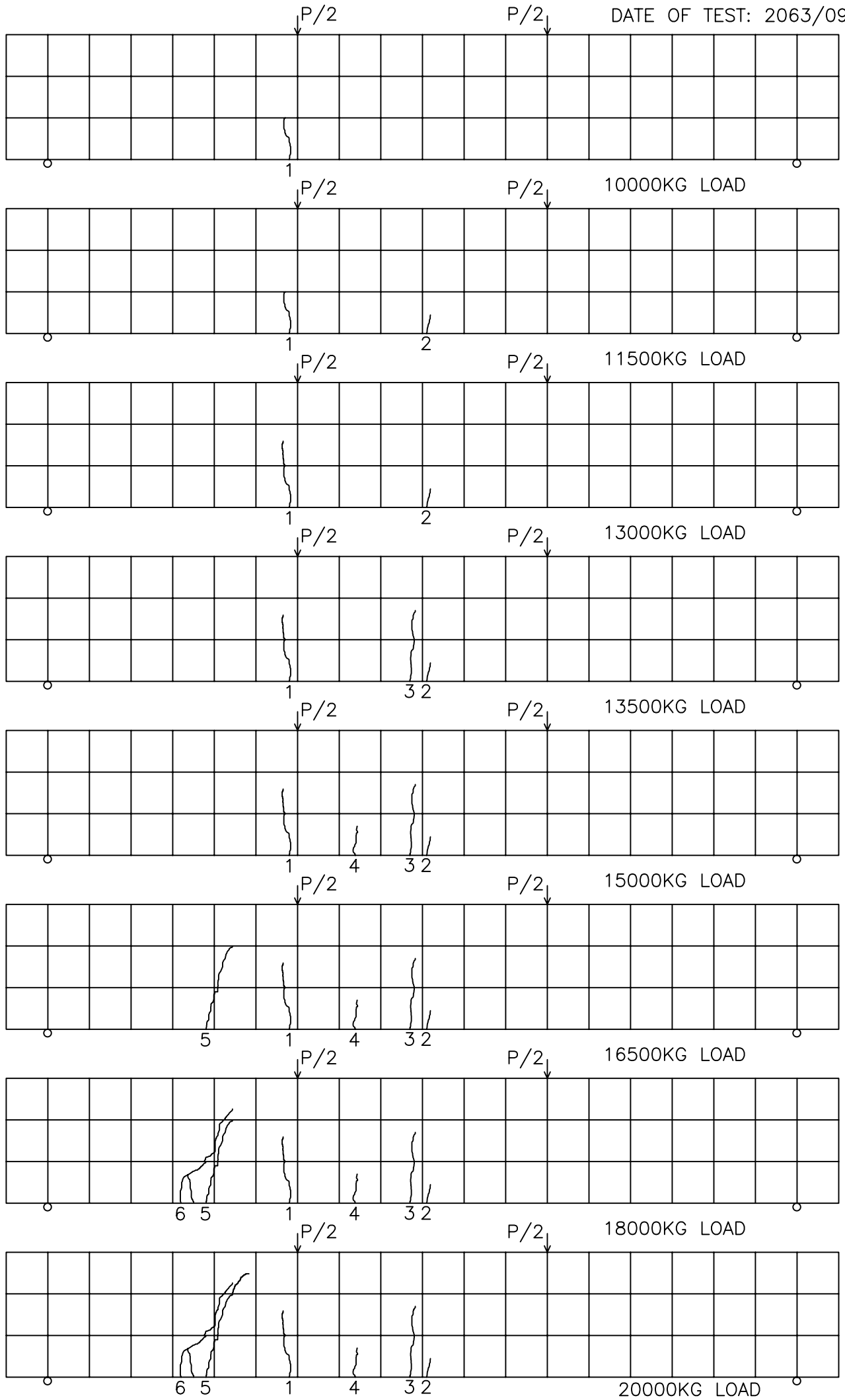


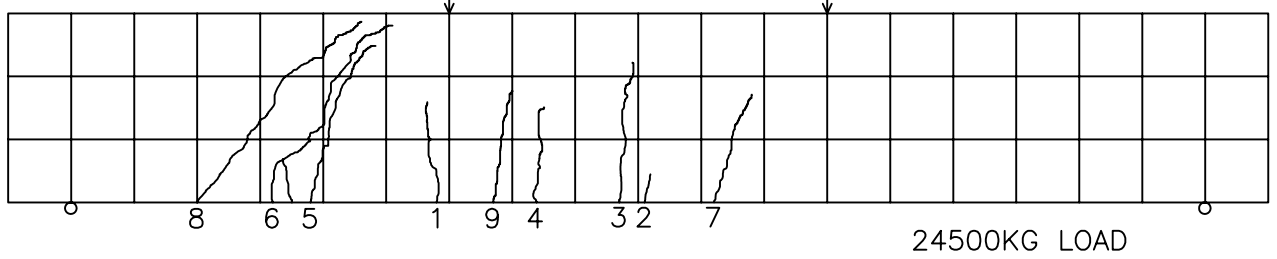
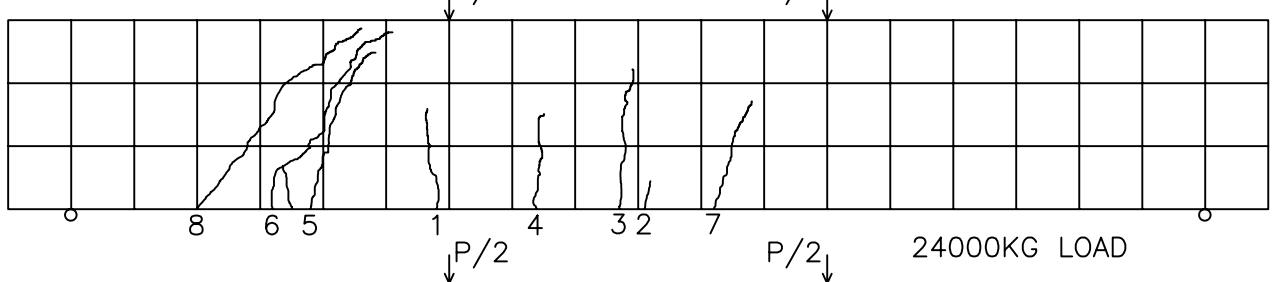
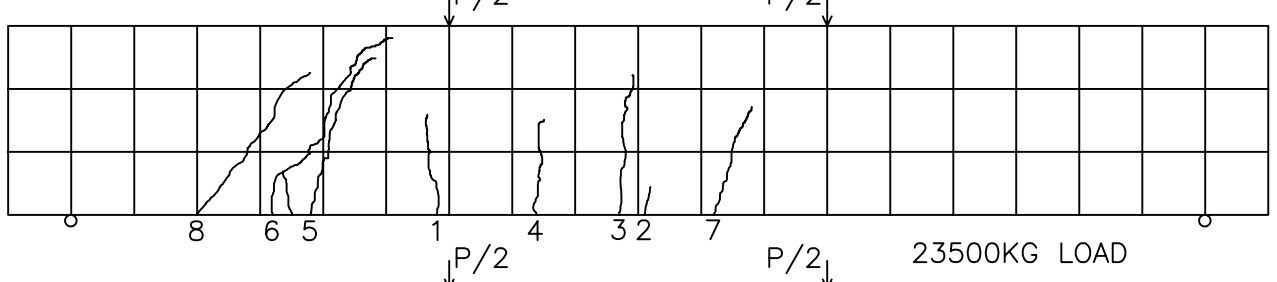
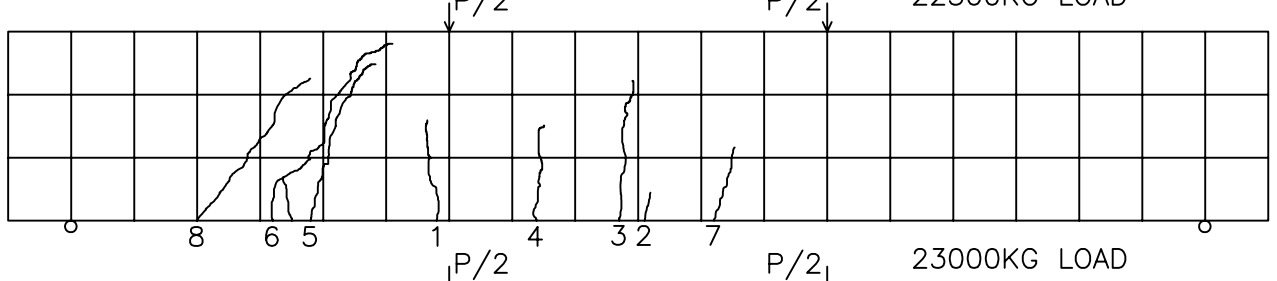
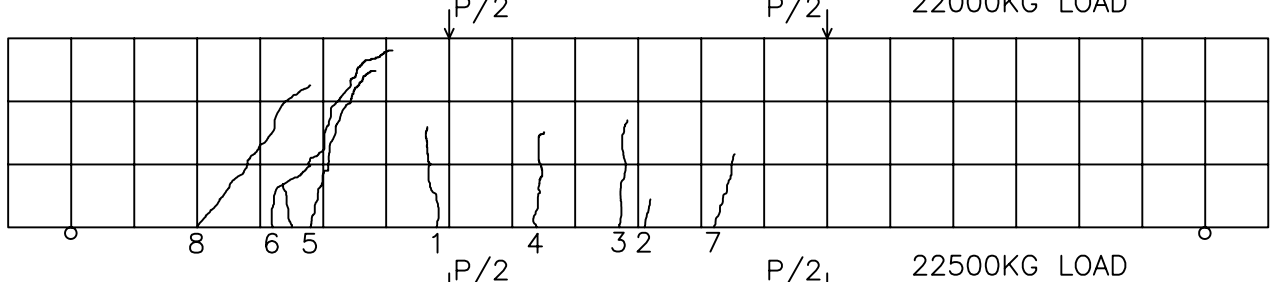
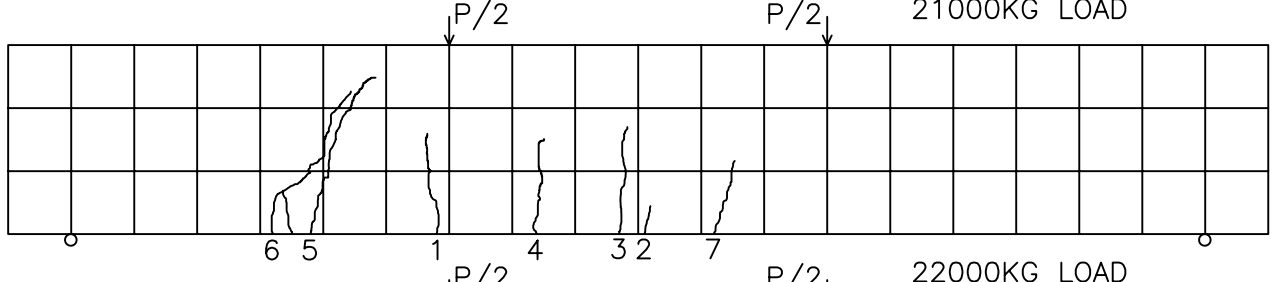
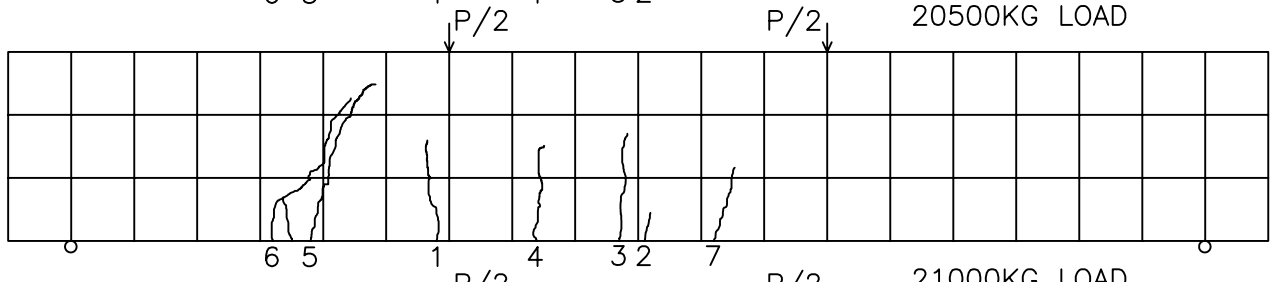
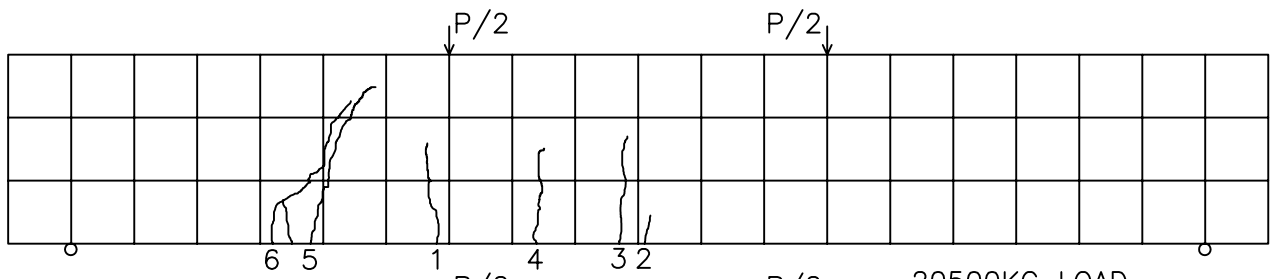


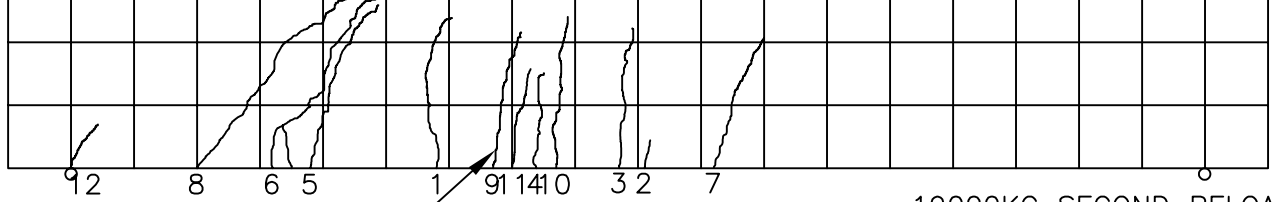
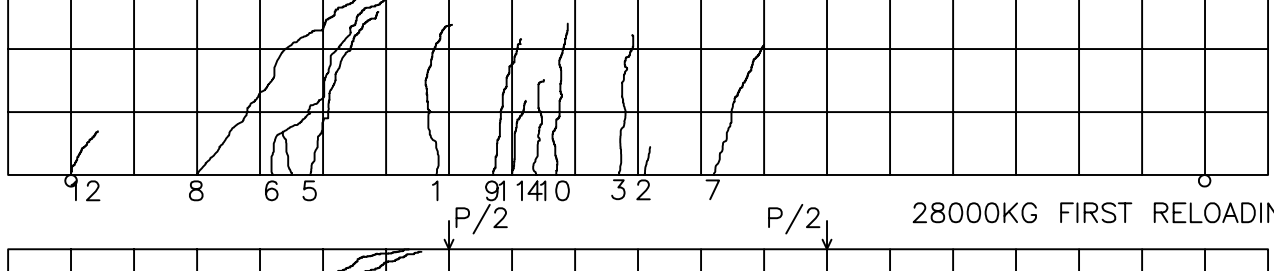
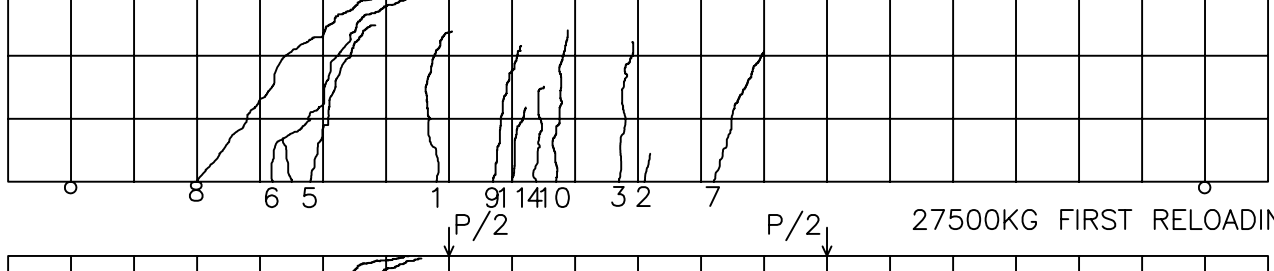
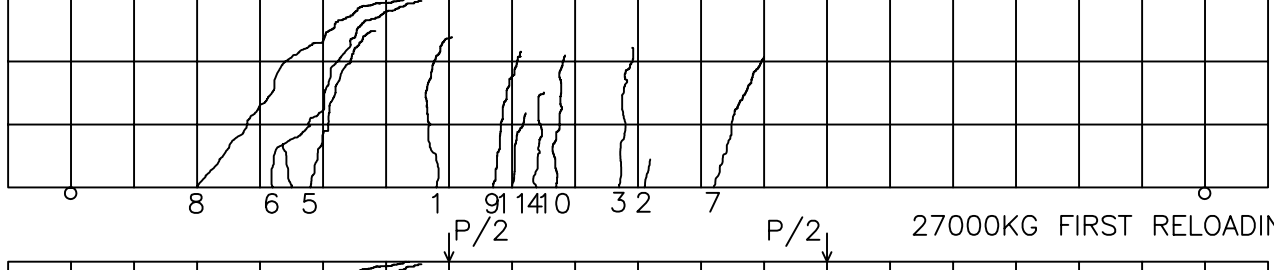
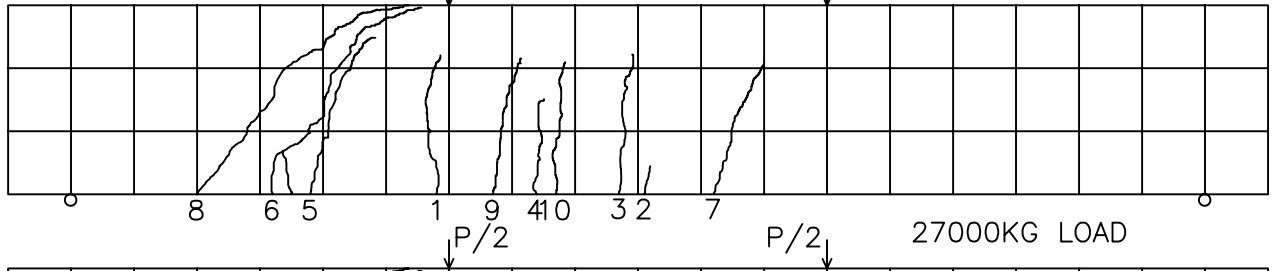
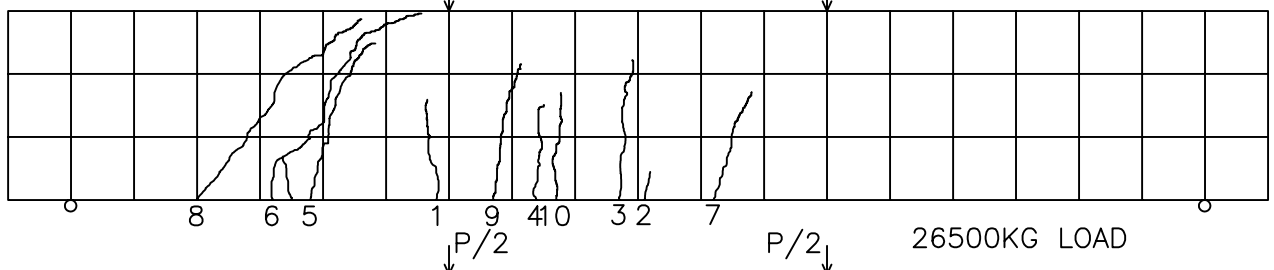
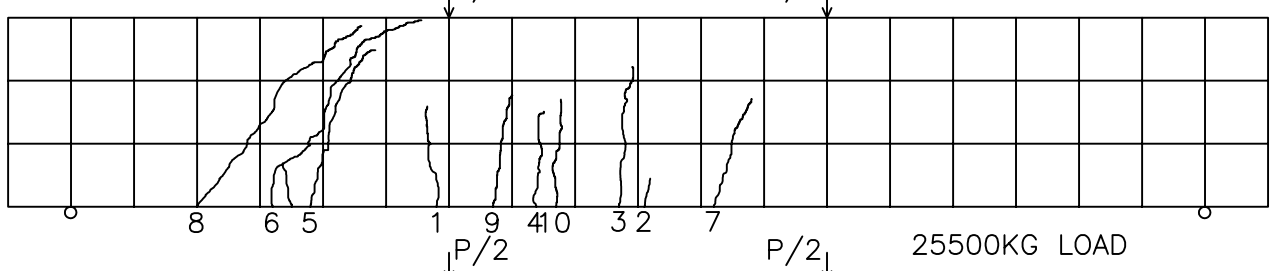
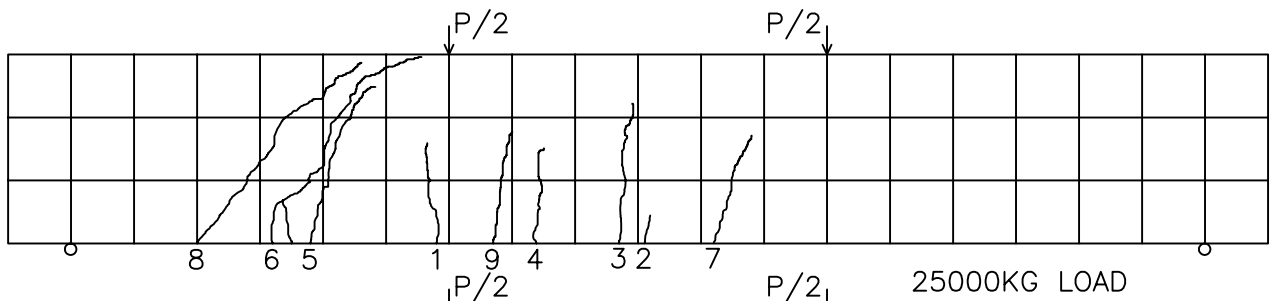
BREAKING OF BEAM (FLEXURE FAILURE)  
WITH ALL FOUR BAR BROKEN

FIG. 33: BEAM SAMPLE: C-C-2

DATE OF TEST: 2063/09/09







BREAKING OF BEAM (FLEXURE FAILURE) WITH ALL FOUR BAR BROKEN

**Table 34 Yield Load and Yield Deflection and Crushing Load and Tentative deflection in Experiment**

S.No.	Sample	Experimental Data								Calculation after testing bar and concrete			
		Yield Load (Kg)	Average Load (Kg)	Yield Deflection (mm)	Average Deflection (mm)	Crushing Load (Kg)	Average Load (Kg)	Crushing Deflection (mm)	Average Deflection (mm)	Yield Load (Kg)	Average Load (Kg)	Yield Deflection (mm)	Average Deflection (mm)
1	M-T-1	28000		8.12		31800		34.80		24933.53		5.60	
2	M-T-2	28000	28000	9.40	8.76	31100	31450	39.00	36.90	23975.28	24454.40	5.49	5.54
3	M-C-1	21000		7.82		26950		29.45		20910.39		4.31	
4	M-C-2	20000	20500	6.50	7.16	25500	26225	26.99	28.22	16953.68	18932.04	3.10	3.70
5	C-T-1	28200		8.65		30400		25.57		24925.11		5.47	
6	C-T-2	27000	27600	7.50	8.08	30000	30200	25.38	25.47	23810.87	24367.99	5.31	5.39
7	C-C-1	25750		9.45		26500		31.05		21403.03		4.32	
8	C-C-2	26000	25875	10.00	9.73	28250	27375	30.03	30.54	21052.18	21227.61	4.46	4.39

# The Crushing deflection in the case of cyclic loading couldn't measure at the experiment, the values are calculated from the load deflection graph prolonging the curve.

**Table 35 Ductility ratio**

S.No.	Sample	Ductility Ratio	Average Ductility	Remarks
1	M-T-1	4.29		
2	M-T-2	4.15	4.22	
3	M-C-1	3.77		
4	M-C-2	4.15	3.96	
5	C-T-1	2.96		
6	C-T-2	3.38	3.17	
7	C-C-1	3.29		
8	C-C-2	3.00	3.14	

**Ductility Ratio = crushing deflection/yield deflection**

## 4.0 DISCUSSION

1) In the case of monotonic loading on the beam cast with TMT bar, the yield load on the beam sample M-T-1 was 28000 kg and the crushing load was 31800 kg. The yield load on the beam M-T-2 was 28000 kg and the crushing load was 31100 kg. The average yield load on beam cast with TMT bar was found 28000 kg and the average crushing load was found 31450 kg in the case of monotonic loading.

2) The yield load in the case of monotonic loading on the beam sample M-C-1 reinforced with TOR steel bar was 21000 kg and the crushing load was 26950 kg. The yield load on the beam M-C-2 was 20000 kg and the crushing load was 25000 kg. So the average yield load was found 20500 kg and the average crushing load was found as 25975 kg in the case of monotonic loading on beams cast with TOR steel bar.

3) Comparing the loads in the case of monotonic loading on beams, the average yield load on beam cast with TMT bar was higher by 26.79% than on the beam cast with TOR steel beam. Similarly the average crushing load on the beam cast with TMT bar was higher by 17.41% than the load on the beam reinforced with TOR steel bar.

4) In the case of cyclic loading, the yield load on the beam C-T-1 was 28200 kg and the crushing load was 30400 kg. The yield load on beam C-T-2 was 27000 kg and the crushing load was 30000 kg. The average yield load was calculated as 27600 kg and the average crushing load was calculated as 30200 kg in the case of cyclic loading on the beams cast with TMT bar.

5) On the beams cast with TOR steel bar in the case of cyclic loading the yield load on beam C-C-1 was 25750 kg and the crushing load was 26500 kg. Similarly the yield load on the beam C-C-2 was 26000 kg and the crushing load was 28250 kg. The average yield load was calculated as 25875 kg and the average crushing load was calculated as 27375 kg.

6) Comparing the loads in the case of cyclic loading, the average yield load on the beams reinforced with TMT bar was higher by 6.25% than the average yield load on the beams reinforced with TOR steel bar. The average crushing load on the beams reinforced with TMT bar was higher by 9.35 % than that in the beams reinforced with TOR steel bar.

7) Comparing the loads between the monotonic loading and cyclic loading in the case of the beam reinforced with TMT bar, the average yield load and crushing load are both are less value in cyclic loading than monotonic loading. The average yield load in the case of monotonic loading was 28000 kg and in the case of cyclic loading was 27600 kg. Similarly the crushing load in the case of monotonic loading was 31450 kg and 30200 kg. The yield load was decreased by 1.43%. And the crushing load was decreased by 3.97%. It is to be noted here that the characteristic strength of the concrete and the yield strength of the TMT bar were in the range of average value respectively in the experiment of material testing.

8) In the case of beam reinforced with TOR steel bar, the average yield load was 20500 kg in monotonic loading and that in cyclic loading was 25875 kg. The crushing load in monotonic loading was 25975 kg and in cyclic loading case it was 27375 kg. Here the loads in the cyclic loading case were higher than in the monotonic loading case. The yield load was higher in cyclic loading case by 26.22% than yield load in the case of cyclic loading. The crushing load was higher in the cyclic loading case by 5.39% than the crushing load in the monotonic loading case. This may

because, the yield strength of the TOR steel bar in monotonic loading case were lesser value in the experiment of tensile test of the bar than that in cyclic loading case. The concrete strength values were in average range.

9) Initially, the flexural crack nearly vertical in the case of monotonic loading was seen near around the centre of the beam. After some number of flexural cracks was seen, and the initial cracks were prolonged, then the shear cracks were seen near the support which was sloped to the base of beam towards the center at top, in all beams cast with TMT bar and TOR steel bar.

In the case of cyclic loading the development of crack in first cycle in all beams were similar as in monotonic case. In second cycle two or three more cracks were seen. In third cycle only one or two cracks were seen in some beams and no more cracks were seen in other beams. In cyclic loading case, when it was loading the opening width of crack was increasing, and was decreasing while it was unloading.

10) Only one bar was ruptured in both beam reinforced with TMT bar in the case of monotonic loading. In the beams reinforced with TOR steel bar all four bars were ruptured at the same time in the case of monotonic loading.

11) In the case of cyclic loading all the bars in all beams were ruptured. On the beams reinforced with TMT bar, one TMT bar was ruptured first and other three bars ruptured immediately. In the same loading case on the beam reinforced with TOR steel bar all four bars ruptured at the same time.

12) The ductility  $[\frac{\delta_u}{\delta_y}]$  ratio was calculated for all beams. The ductility ratio for M-T-1 was 4.29 and for M-T-2 it was 4.15. The average ductility ratio for the beams reinforced with TMT bar in the case of monotonic loading was 4.22.

13) The ductility ratio for beam M-C-1 was 3.77. Similarly the ductility for beam M-C-2 was 4.15. The average ductility ratio for the beams reinforced with TOR steel bar, was 3.96 in the case of monotonic loading.

14) Comparing the average ductility ratio, in the beams reinforced with TMT bar it was higher by 6.12% than the ratio in the beams reinforced with TOR steel bar in the case of monotonic loading.

15) The ductility ratio for the beam C-T-1 was 2.96. And the ductility ratio for beam C-T-2 was 3.38. Average ductility ratio for the beams reinforced with TMT bar was 3.17 in the case of cyclic loading.

16) The ductility ratio for the beam C-C-1 was 3.29 and it was 3 for the beam C-C-2. The average ductility ratio for the beams reinforced with TOR steel bar in the case of cyclic loading was 3.14.

17) Comparing the average ductility ratio, for the beams reinforced with TMT bar it was higher by 0.8% than the ratio in the beams reinforced with TOR steel bar in the case of cyclic loading.

## 5.0 CONCLUSION

Based on the experiment results on simply supported singly reinforced beams, following conclusions were drawn.

- 1) The yield load on the beams reinforced with TMT bar was higher by 26.79% than the yield load on the beams reinforced with TOR steel bar in the case of monotonic loading.
- 2) The crushing load on the beams reinforced with TMT bar was higher by 17.41% than the crushing load on the beams cast with TOR steel bar in the case of monotonic loading.
- 3) The yield load on the beams reinforced with TMT bar was higher by 6.25% than the yield load on the beams reinforced with TOR steel bar in the case of cyclic loading.
- 4) The crushing load on the beams reinforced with TMT bar was 9.35% than the crushing load on the beams reinforced with TOR steel bar in the case of cyclic loading.
- 5) The yield load on beams reinforced with TMT bar, in the case of monotonic loading was 1.43% higher than in the case of cyclic loading.
- 6) The crushing load on the beams reinforced with TMT bar, in the case of monotonic loading was 3.95% higher than in the case of cyclic loading.
- 7) The yield load on the beams reinforced with TOR steel bar, in the case of monotonic loading was 26.22% less than yield load in the case of cyclic loading.
- 8) The crushing load on the beams reinforced with TOR steel bar, in the case of monotonic loading was 5.39% less than crushing load in the case of cyclic loading.
- 9) The development of crack pattern in all the beams in the case of monotonic loading was almost similar. Similarly the development of crack in the cyclic loading case was also similar pattern.
- 10) Only one bar was ruptured in the beams reinforced with TMT bar in the case of monotonic loading. All four bars were ruptured simultaneously in the beams reinforced with TOR steel bar.
- 11) All four bars were ruptured in all the beams both in the case of monotonic loading as well as cyclic loading case.
- 12) The average ductility ratio of the beam reinforced with TMT bar was higher by 6.12% than that of the beam reinforced with TOR steel bar in the case of monotonic loading.
- 13) The average ductility ratio of the beam reinforced with TMT bar was higher by 0.8% than that of the beam reinforced with TOR steel bar in the case of cyclic loading.
- 14) With the experimental study in this research work, TMT bars were found equally effective in terms of resisting monotonic loading and cyclic loading with almost same crack propagation pattern.

**Appendix A**  
**Preliminary Analysis**

















## **Appendix B**

### **Concrete Mix Design**

#### **Final Batching for Concrete Mix**

## Concrete Mix Design

Characteristic Cube Strength : M20  
Size of Coarse Aggregate : 20 mm  
Specific Gravities of :  
Cement ( $S_c$ ) = 3.14  
Sand ( $S_{fa}$ ) = 2.667  
Aggregate ( $S_{ca}$ ) = 2.691  
Type of Exposure : Mild  
Degree of Quality Control : Very Good  
Degree of workability : 0.8

### 1) Target Mean Strength :

Standard Deviation for very good degree of control (s) : 3.6 (IS: 10262-1982)

Percentage of results below the characteristic strength :

5

Value of (t) = 1.65 (Table : 19.1)

Target Mean Strength  $\bar{f}_{ck} = f_{ck} + t_{s}$  = 20 + 1.65 X 3.6  
= 25.94

### 2) Selection of Water Cement Ratio :

The preliminary free w/c ratio by weight corresponding to target mean strength at 28 days for M20 is

w/c = 0.5 (Maximum Value is 0.7) Table 19.3

3) Air Content : 2 % (For Nominal maximum size 20mm aggregate)

### 4) Water Required and fine to total aggregate Ratio :

For maximum size of 20mm aggregate and for concrete grade upto M35 the water content and sand content per cu m of concrete :

Water content per cu m of concrete = 186 Kg Table 19.6

Sand as percent of total aggregate by absolute volume = 35 Kg

### 5) Adjustment of Values in Water Content and Sand Percentage : Table 19.8

Water Content percent = 0

For decrease in w/c ratio (0.6 - 0.5) = 0.1 (Each 0.05 increase or decrease on free w/c ratio)

Percentage sand in total aggregate (p) = 0.1/0.05\*1 = -2 %

Total adjustment :

W/c ratio = 0.5

Water required per  $m^3$  = 186  $Kg/m^3$

Percentage of sand of total aggregate by absolute volume = 35 - 2 = 33 %

### 6) Final Water Content required in Concrete after Adjustments

Water required (W) = 186  $Kg/m^3$

### 7) Cement Required

W/C = 0.5

Cement (C) =  $W/0.5 = 372 \text{ Kg/m}^3$

8) Check for minimum cement content

From Appendix A of IS: 456-2000, the minimum cement content required for durability for plain concrete under mild exposure conditions is 220 kg/m<sup>3</sup>. The value of cement required is greater than this minimum value.

9) Determination of Coarse and Fine Aggregate Content

The fine aggregate (sand) required is calculated as :

$$V = [W + C/S_c + f_a / (p S_{fa})] / 1000$$

$$\text{or, } (1-0.02) = [186 + 372 / 3.14 + f_a / (0.33 \times 2.65)] / 1000 \quad \text{or, } f_a = 594.5395 \text{ Kg/m}^3$$

The Coarse aggregate required is calculated as :

$$V = [W + C/S_c + C_a / \{(1 - p) S_{ca}\}] / 1000$$

$$\text{or, } (1-0.02) = [186 + 372 / 3.14 + C_a / \{(1 - 0.33) \times 2.60\}] / 1000 \quad \text{or, } C_a = 1217.958 \text{ Kg/m}^3$$

10) Total Quantities of Ingredients and Mix Proportions per m<sup>3</sup>

Mix	Cement	Sand	Aggregate	Water
M20	372	594.54	1217.96	186.00
Mix Proportion	1	1.60	3.27	0.50

11) For Each Beam

$$\begin{aligned} \text{Volume of Beam} &= 2.0\text{m} \times 0.23\text{m} \times 0.30\text{m} \\ &= 0.138 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{5Cubes volume} &= 5 \times 0.15 \times 0.15 \times 0.15 \\ &= 0.017 \end{aligned}$$

$$\text{Total volume} = 0.155$$

$$\text{Adding 20\% loss, Total Volume} = 0.194 \text{ m}^3$$

Total Quantities required for each beam :

Mix	Cement	Sand	Aggregate	Water
M20	72.02	115.10	235.79	36.01
Mix Proportion	1	1.60	3.27	0.50

Reference: Design of concrete mixes

- N. Krishna Raju

## Concrete Batching

1) Sample : M-T-1

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

Date of Casting: 2063/5/19

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.70 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 286.70 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 275.52 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(286.7 - 275.52)}{(286.7 - 186.7)} = 0.1118 = 11.18 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.1118 \times 115.1 = 12.87$  Lt.

Net Water Required =  $36 - 12.87 = 23.13$  Lt.

Actual Weight of Sand =  $115.1 - 12.87 = 102.23$

Trial 2

Addition of Sand = 12.87 Kg

Water Content =  $0.1118 \times 12.87 = 1.44$  Lt

Net Water Required =  $23.13 - 1.44 = 21.69$  Lt

Trial 3

Addition of Sand = 1.44

Water Content =  $0.1118 \times 1.44 = 0.16$  Lt

Net Water Required =  $21.69 - 0.16 = 20.25$  Lt

Net Sand Required =  $115.1 + 12.87 + 1.44 = 129.41$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.4 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1700 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1695.5 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{[(\omega_3 - \omega_1) - (\omega_2 - \omega_1)]}{(\omega_2 - \omega_1)} \\ &= \frac{[(1700 - 322.4) - (1695.5 - 322.4)]}{(1700 - 322.4)} = 0.00327 = 0.327 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.00327 \times 235.8$   
= 0.77 Lt.

Net Water Required =  $20.25 - 0.77 = 19.77$  Lt.

Net Aggregate Required =  $235.8 + 0.77 = 236.57$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 129.41 Kg

Weight of Aggregate = 236.57 Kg

Water Cement ratio = 0.50

Volume of water = 19.77 Lt

## Concrete Batching

2) Sample : C-T-2

Date of Casting: 2063/5/23

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.70 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 421.970 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 395.90 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(421.97 - 395.9)}{(421.97 - 186.7)} = 0.1108 = 11.08 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.1108 \times 115.1 = 12.75$  Lt.

Net Water Required =  $36 - 12.75 = 23.25$  Lt.

Actual Weight of Sand =  $115.1 - 12.75 = 102.35$

Trial 2

Addition of Sand = 12.75 Kg

Water Content =  $0.1108 \times 12.75 = 1.41$  Lt

Net Water Required =  $23.25 - 1.41 = 21.84$  Lt

Trial 3

Addition of Sand = 1.41

Water Content =  $0.1108 \times 1.41 = 0.16$  Lt

Net Water Required =  $21.84 - 0.16 = 21.68$  Lt

Net Sand Required =  $115.1 + 12.75 + 1.41 = 129.26$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.4 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1845 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1841.5 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1845 - 1841.5)}{(1845 - 322.4)} = 0.0023 = 0.23 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0023 \times 235.8$   
= 0.54 Lt.

Net Water Required =  $20.54 - 0.54 = 20.00$  Lt.

Net Aggregate Required =  $235.8 + 0.54 = 236.34$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 129.26 Kg

Weight of Aggregate = 236.34 Kg

Water Cement ratio = 0.50

Volume of water = 20 Lt

## Concrete Batching

3) Sample : M-T-2

Date of Casting: 2063/5/26

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.70 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 342.14 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 330.0 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(342.14 - 330.20)}{(342.14 - 186.7)} = 0.0723 = 7.23 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.0723 \times 115.1 = 8.32$  Lt.

Net Water Required =  $36 - 8.32 = 27.68$  Lt.

Actual Weight of Sand =  $115.1 - 8.32 = 106.78$

Trial 2

Addition of Sand = 8.32 Kg

Water Content =  $0.0723 \times 8.32 = 0.60$  Lt

Net Water Required =  $27.68 - 0.6 = 27.08$  Lt

Trial 3

Addition of Sand = 0.6 Kg

Water Content =  $0.0723 \times 0.6 = 0.04$  Lt

Net Water Required =  $27.08 - 0.04 = 27.04$  Lt

Net Sand Required =  $115.1 + 8.32 + 0.6 = 124.02$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.4 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1684.35 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1681.20 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1684.35 - 1681.2)}{(1684.35 - 322.4)} = 0.0023 = 0.23 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0023 \times 235.8$   
= 0.54 Lt.

Net Water Required =  $27.04 - 0.54 = 26.50$  Lt.

Net Aggregate Required =  $235.8 + 0.54 = 236.34$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 124.02 Kg

Weight of Aggregate = 236.34 Kg

Water Cement ratio = 0.50

Volume of water = 26.50 Lt

## Concrete Batching

4) Sample : C-T-1

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

Date of Casting: 2063/5/30

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.84 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 286.81 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 278.85 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(286.81 - 278.85)}{(286.81 - 186.84)} = 0.0796 = 7.96 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.0796 \times 115.1 = 9.16$  Lt.

Net Water Required =  $36 - 9.16 = 26.84$  Lt.

Actual Weight of Sand =  $115.1 - 9.16 = 105.94$

Trial 2

Addition of Sand = 9.16 Kg

Water Content =  $0.0796 \times 9.16 = 0.73$  Lt

Net Water Required =  $26.84 - 0.73 = 26.11$  Lt

Trial 3

Addition of Sand = 0.73 Kg

Water Content =  $0.0796 \times 0.73 = 0.06$  Lt

Net Water Required =  $26.11 - 0.06 = 26.05$  Lt

Net Sand Required =  $115.1 + 9.16 + 0.73 = 124.99$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.4 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1793 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1788.2 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1793 - 1788.2)}{(1793 - 322.4)} = 0.0033 = 0.33 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0033 \times 235.8$   
= 0.78 Lt.

Net Water Required =  $26.05 - 0.78 = 25.27$  Lt.

Net Aggregate Required =  $235.8 + 0.78 = 236.58$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 124.99 Kg

Weight of Aggregate = 236.58 Kg

Water Cement ratio = 0.50

Volume of water = 25.27 Lt

## Concrete Batching

5) Sample : M-C-1

Date of Casting: 2063/6/3

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.69 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 286.69 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 282.17 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(286.69 - 182.17)}{(286.69 - 186.69)} = 0.0452 = 4.52 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.0452 \times 115.1 = 5.20$  Lt.

Net Water Required =  $36 - 5.2 = 30.80$  Lt.

Actual Weight of Sand =  $115.1 - 5.2 = 109.9$  Kg

Trial 2

Addition of Sand = 5.2 Kg

Water Content =  $0.0452 \times 5.2 = 0.24$  Lt

Net Water Required =  $30.8 - 0.24 = 30.56$  Lt

Trial 3

Addition of Sand = 0.24 Kg

Water Content =  $0.0452 \times 0.24 = 0.01$  Lt

Net Water Required =  $30.56 - 0.01 = 30.55$  Lt

Net Sand Required =  $115.1 + 5.2 + 0.24 = 120.54$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.32 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1703.93 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1702.78 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1703.93 - 1702.78)}{(1703.93 - 322.32)} = 0.0008 = 0.08 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0008 \times 235.8$   
= 0.19 Lt.

Net Water Required =  $30.55 - 0.19 = 30.36$  Lt.

Net Aggregate Required =  $235.8 + 0.19 = 235.99$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 120.54 Kg

Weight of Aggregate = 235.99 Kg

Water Cement ratio = 0.50

Volume of water = 30.36 Lt

## Concrete Batching

6) Sample : M-C-2

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

Date of Casting: 2063/6/6

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.65 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 345.05 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 339.99 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(345.05 - 339.99)}{(345.05 - 186.65)} = 0.03195 = 3.2 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.032 \times 115.1 = 3.68$  Lt.

Net Water Required =  $36 - 3.68 = 32.32$  Lt.

Actual Weight of Sand =  $115.1 - 3.68 = 111.42$  Kg

Trial 2

Addition of Sand = 3.68 Kg

Water Content =  $0.032 \times 3.68 = 0.12$  Lt

Net Water Required =  $32.32 - 0.12 = 32.20$  Lt

Trial 3

Addition of Sand = 0.12 Kg

Water Content =  $0.032 \times 0.12 = 0.004$  Lt

Net Water Required = 32.2 Lt

Net Sand Required =  $115.1 + 3.68 + 0.12 = 118.9$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.23 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1489.95 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1476.21 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1489.95 - 1476.21)}{(1489.95 - 322.23)} = 0.0118 = 1.18 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0118 \times 235.8$   
= 2.78 Lt.

Net Water Required =  $32.2 - 2.78 = 29.42$  Lt.

Net Aggregate Required =  $235.8 + 2.78 = 238.58$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 118.90 Kg

Weight of Aggregate = 238.58 Kg

Water Cement ratio = 0.50

Volume of water = 29.42 Lt

## Concrete Batching

7) Sample : C-C-1

Date of Casting: 2063/6/8

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.64 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 286.64 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 283.42 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(286.64 - 283.42)}{(286.64 - 186.64)} = 0.0322 = 3.22 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.0322 \times 115.1 = 3.71$  Lt.

Net Water Required =  $36 - 3.71 = 32.29$  Lt.

Actual Weight of Sand =  $115.1 - 3.71 = 111.39$  Kg

Trial 2

Addition of Sand = 3.71 Kg

Water Content =  $0.0322 \times 3.71 = 0.12$  Lt

Net Water Required =  $32.29 - 0.12 = 32.17$  Lt

Trial 3

Addition of Sand = 0.12 Kg

Water Content =  $0.032 \times 0.12 = 0.004$  Lt

Net Water Required = 32.17 Lt

Net Sand Required =  $115.1 + 3.71 + 0.12 = 118.93$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.24 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1504.69 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1500.70 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1504.69 - 1500.7)}{(1504.69 - 322.24)} = 0.0034 = 3.4 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0034 \times 235.8$   
= 0.80 Lt.

Net Water Required =  $32.17 - 0.80 = 31.37$  Lt.

Net Aggregate Required =  $235.8 + 0.80 = 236.6$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 118.93 Kg

Weight of Aggregate = 236.60 Kg

Water Cement ratio = 0.50

Volume of water = 31.37 Lt

## Concrete Batching

8) Sample : C-C-2

Date of Casting: 2063/6/10

Weight of Cement = 72 Kg

Weight of Sand = 115.1 Kg

Weight of Aggregate = 235.8 Kg

Water Cement ratio = 0.50

Volume of water = 36 Lt

### Water Content in Sand:

Weight of Container ( $w_1$ ) = 186.57 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 286.57 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 280.47 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(286.57 - 280.47)}{(286.57 - 186.57)} = 0.061 = 6.10 \%\end{aligned}$$

Trial 1

Total Weight of Water in Sand =  $0.061 \times 115.1 = 7.02$  Lt.

Net Water Required =  $36 - 7.02 = 28.98$  Lt.

Actual Weight of Sand =  $115.1 - 7.02 = 108.08$  Kg

Trial 2

Addition of Sand = 7.02 Kg

Water Content =  $0.067 \times 7.02 = 0.43$  Lt

Net Water Required =  $28.98 - 0.43 = 28.55$  Lt

Trial 3

Addition of Sand = 0.43 Kg

Water Content =  $0.061 \times 0.43 = 0.03$  Lt

Net Water Required =  $28.55 - 0.03 = 28.52$  Lt

Net Sand Required =  $115.1 + 7.02 + 0.43 = 122.55$  Kg

### Water Content in Aggregate:

Weight of Container ( $w_1$ ) = 322.12 gm

Weight of (Container + Sand Sample) ( $w_2$ ) = 1269.70 gm

Weight of (Container + Dry Sand Sample) ( $w_3$ ) = 1267.75 gm

$$\begin{aligned}\text{Water Content in Sand } (\omega) &= \frac{(\omega_2 - \omega_3)}{(\omega_2 - \omega_1)} \\ &= \frac{(1269.7 - 1267.75)}{(1269.7 - 322.12)} = 0.0021 = 0.21 \%\end{aligned}$$

Trial 1

Total Weight of Water in Aggregate =  $0.0021 \times 235.8$   
= 0.57 Lt.

Net Water Required =  $28.52 - 0.57 = 27.95$  Lt.

Net Aggregate Required =  $235.8 + 0.57 = 236.37$  Kg

### **Final Batching**

Weight of Cement = 72 Kg

Weight of Sand = 122.55 Kg

Weight of Aggregate = 236. Kg

Water Cement ratio = 0.50

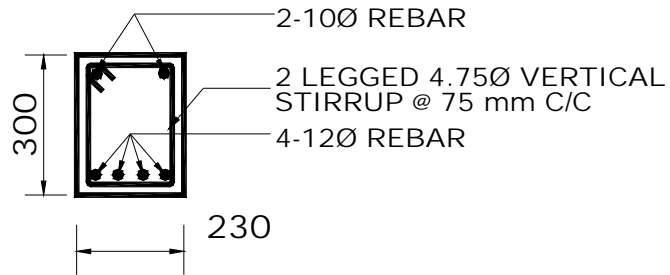
Volume of water = 31.37 Lt

## **Appendix C**

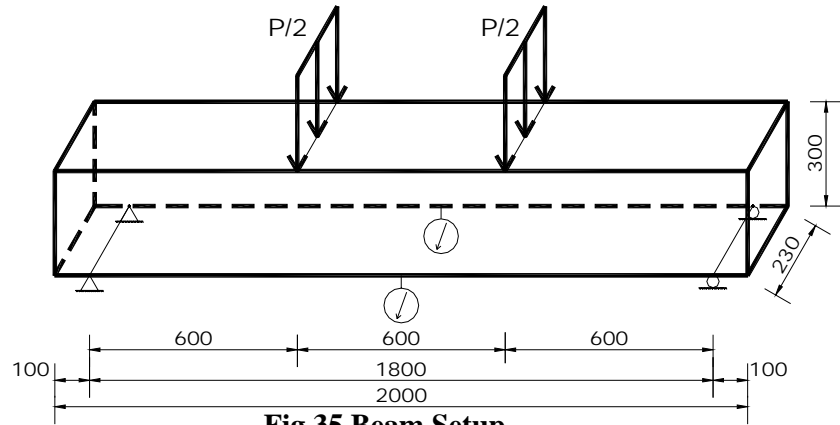
### **Figures**

### **Photographs**

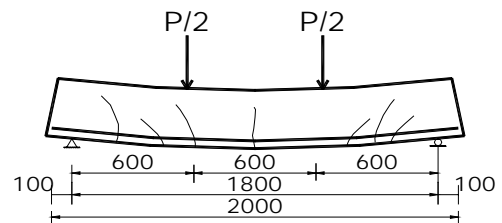
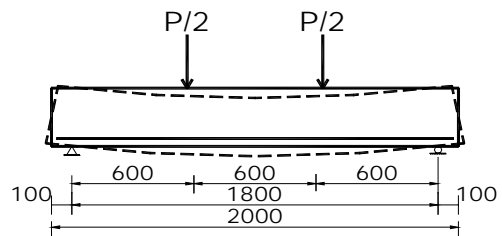
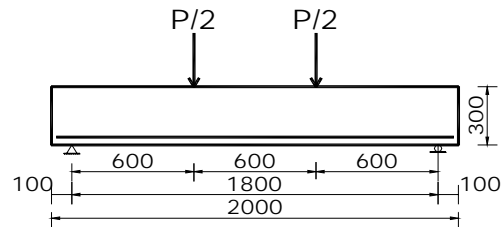
# FIGURES



**Fig 34 Beam Section**

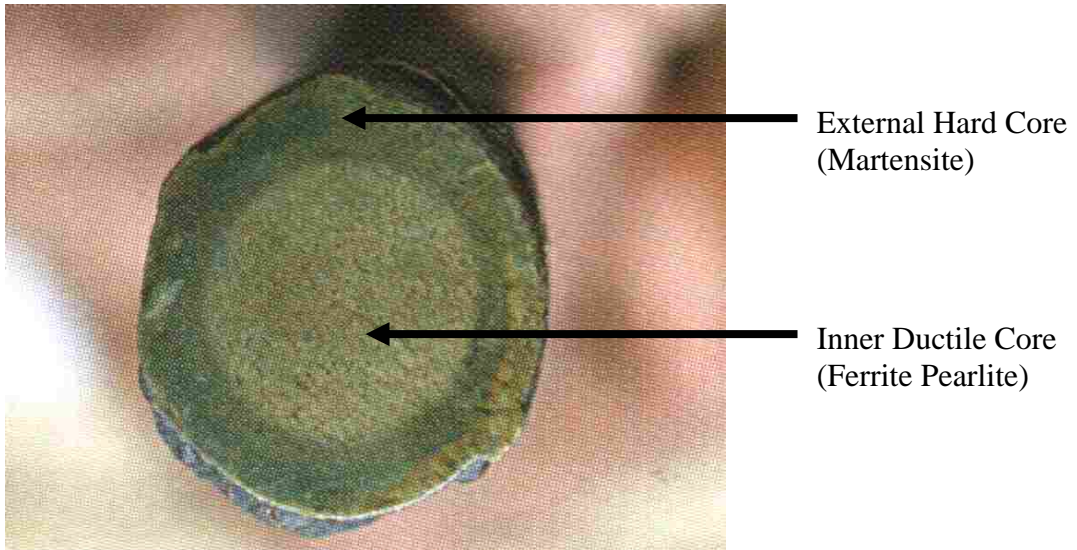


**Fig 35 Beam Setup**



**Fig 36 Loading on Beam**

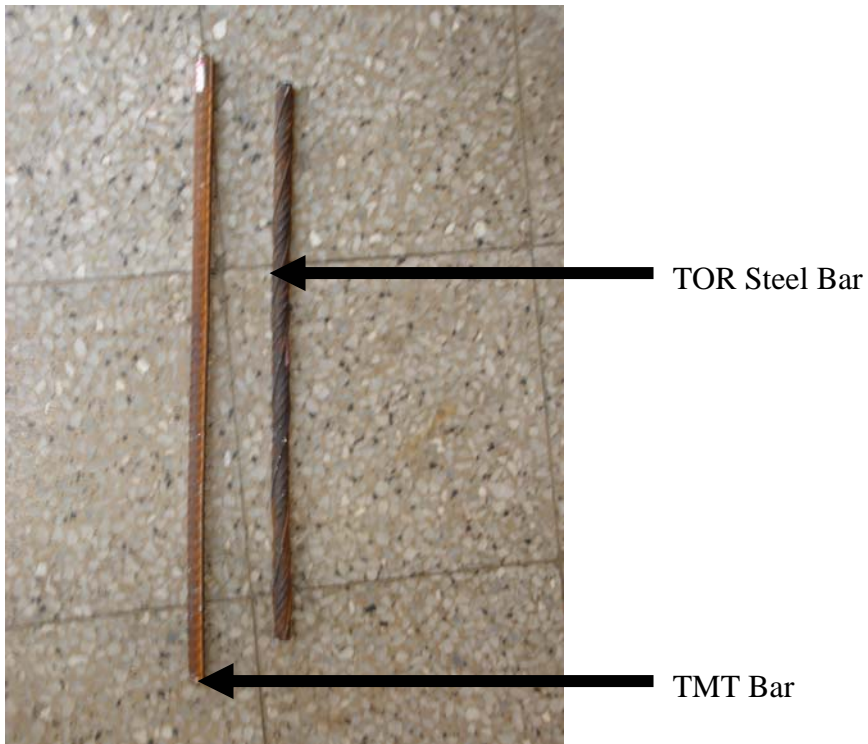
# PHOTOGRAPHS



External Hard Core  
(Martensite)

Inner Ductile Core  
(Ferrite Pearlite)

**Photo 1: Section of TMT Bar**



TOR Steel Bar

TMT Bar

**Photo 2: TMT Bar and TOR steel Bar**



**Photo 3: Aggregate Washing**



**Photo 4: Sand Washing**



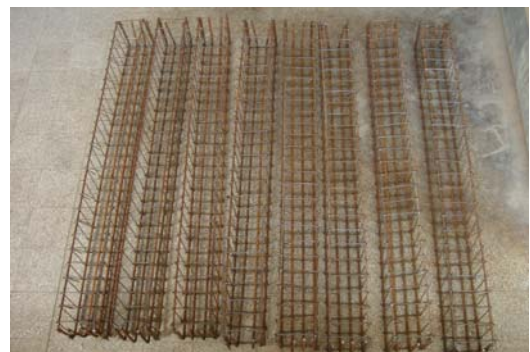
**Photo 5: Rebar Fabrication**



**Photo 6: Shear Rebar Fabrication**



**Photo 7: Rebar Fabrication**



**Photo 8: Fabricated Rebar**



**Photo 9: Rebar in the Form**



**Photo 10: Concrete Vibration**



**Photo 11: Concreting Cube with vibration**



**Photo 12: Curing Beam and Cubes**



**Photo 13: Beam Setup on UTM**



**Photo 14: Compressive Strength test of Cube**



**Photo 15: Loading Beam M-T-1**



**Photo 16: Failure of Beam M-T-1**



**Photo 17: Loading Beam M-T-2**



**Photo 18: Rupture of TMT bar in Beam M-T-2**



**Photo 19: Shear Failure of Beam M-C-1**



**Photo 20: Shear Failure of Beam M-C-1**



**Photo 21: Marking Crack in  
Beam M-C-2**



**Photo 22: Failure of Beam M-C-2**



**Photo 23: Setting Beam C-T-1 on  
UTM table**



**Photo 24: Main Bar Ruptured in  
Beam C-T-1**



**Photo 25: Failure of Beam C-T-2**



**Photo 26: Cube of Beam C-T-2  
Testing for Compressive Strength**



**Photo 27: Loading on Beam C-C-1**



**Photo 28: Bar Ruptured in Beam C-C-1**



**Photo 29: Failure of Beam C-C-2**