DUCTILE DESIGN OF BEAM COLUMN JOINT

A Major thesis submitted towards the partial fulfillment of requirements for the awards of the degree

OF

MASTER OF ENGINEERING

IN

STRUCTURAL ENGINEERING

BY

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Place : **Roll No. 08/Str/09**

CANDIDATE'S DECLARATION

I hereby certify that the work presented in this dissertation entitled "DUCTILE DESIGN OF BEAM COLUMN JOINTS" in partial fulfillment of the requirement for the award of degree of Master of Engineering in Civil Engineering, with specialization in structural Engineering, submitted to the department of Civil and Environmental Engineering , Delhi Technological University, Delhi is an authentic record of my own work, under the supervision of Associate Prof. Awadhesh Kumar, Department of Civil Engineering, Delhi Technological University, Delhi

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Date :

Gulam Sarwar

Place :

CERTIFICATE

This is certify that the above statement made by the candidate is correct to the best of our knowledge.

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Abstract:

The beam column joints in reinforced concrete frame building is the most critical part of the structure as the time when seismic forces act on the building, A large amount of forces attracted at beam column joints. Mostly, failure of structure is shear failure at joint and it is brittle nature. This type of failure not required as earthquake resistance design.

For avoiding shear failure of joints IS Codes and different countries codes also, gives recommendation of beam and column joints in ductile frames that the joints must have adequate shear strength and ductility to facilitate the development of large inelastic reversible rotation in the event at the time of severe earthquake by providing this special confining reinforcement (hoops). This confining reinforcement near the column end should be extended in the join as well. Development length requirement for flexural reinforcement within the joint is also required. It is desirable to use high strength concrete mix in the joint region and shall achieve good compaction of concrete.

The main problem at beam column joints is diagonal cracking and crushing of concrete.

In the joint resign concrete may controlled by two means by providing large column sizes and closely spaced steel ties around column bar in the joint region. Ties are to hold the joint together and also resist the shear forces thereby reducing the cracking and crushing of concrete.

We study Corner (knee) joint with the help of SAP and Staad model as finite Element Member and note the failure load, moments and deflection for two conditions, opening joint and closing joint. In another model we increased the area of concrete by providing 45 degree angle in the concrete fillet and provide nominal reinforcement. It is found that the moment, axial force and deflection are reduced. In third model, we increased concrete area by providing two fillet surfaces and again found moment, axial force and deflection are reduced. Fourth specimen same as third specimen, but we have provided extra reinforcement at tension side of opening joints. We have also verified experimentally by making four types of specimen and tested in the lab and found same results.

1. Introduction

There are verities of method recommended by different research scholar for beam column confinement, such as conventional joint with shear reinforcement, Incasing concrete column in the steel tube and Confinement of core using extra ties.

We have used Sap 2000 and Staad pro to study beam column joints theoretically and later same types of sixteen specimens have been made. The sizes of specimen i.e. beam and column are same 0.2 meter width, 0.2 meter depth and 0.9 meter in length and the cover of column and beam is considered 40 mm and 25 mm respectively. These all specimen have been tested in laboratory and obtained results are compared with software result and tabulated in in Table no 4 and 5.

1.1 Types of Specimen

Specimen –A

In this study, we first used Sap 2000 and Staad -04 for analysis. The behavior of beam column connection (At corner joint) was observed, in which we make corner joint using finite element method (as member). The sizes of specimen is 0.2mX0.2m and length of beam and column is 0.9 meter, we designed it as per ductile design and it is as per IS: 13920. We apply a load of different intensity like 15 KN, 25 KN, 35KN and 45 KN in both cases for opening joint and closing joint and note down the failure axial load, failure moment and maximum deflection.

Same specimen used in lab as experimentally to verify failure loads and moments of theoretically found from Sap 2000 and Staad -04.

Specimen –B

In this study, we first used Sap 2000 and Staad -04 for analysis. The behavior of beam column connection (At corner joint) was observed, in which we make corner joint using finite element method (as member). The sizes of specimen are 0.2mX0.2m and length of beam and column is 0.9 meter, but we increase concrete area at 45 degree angle and provide nominal reinforcement with ties (As concrete fillet at corner). We designed it as per ductile design and it is as per IS: 13920. We apply a load of different intensity like 15 KN, 25 KN, 35KN and 45 KN in both cases for opening joint and closing joint and note down the failure axial load, failure moment and maximum deflection.

Same specimen used in lab as experimentally to verify failure loads and moments of theoretically found from Sap 2000 and Staad -04.

Specimen –C

In this study we first used Sap 2000 and Staad -04 for analysis. The behavior of beam column connection (At corner joint) was observed, in which we make corner joint using finite element method (as member). The sizes of specimen is 0.2mX0.2m and length of beam and column is 0.9 meter, but both fillet corner and increase concrete area at 45 degree angle and provided nominal reinforcement with ties (As concrete fillet at corner). We designed it as per ductile design and it is as per IS: 13920. We apply a load of different intensity like 15 KN, 25 KN, 35KN, 45 KN of in both cases for opening joint and closing joint and note down failure axial load, failure moment and maximum deflection.

Same specimen used in lab as experimentally to verify failure loads and moments of theoretically found from Sap 2000 and Staad -04.

Specimen –D

In this study, we first used Sap 2000 and Staad-04 the behavior of beam column connection (At corner joint) was observed in which at beam column joint we make corner joint using finite element method (as member) the sizes of specimen is 0.2mX0.2m and length of beam and column is 0.9 meter, but both corner fillet increase concrete area at 45 degree angle and provided nominal reinforcement with ties (As concrete fillet at corner and extra reinforcement its opposite sides). We designed it as per ductile design and it is as per IS: 13920. We apply a load of different intensity like 15 KN, 25 KN, 35KN ,45 KN of in both cases for opening joint and closing joint and note down failure axial load and failure moment and maximum deflection.

Same specimen used in lab as experimentally to verify failure loads and moments of theoretically found from Sap 2000 and Staad -04.

This results shows that details of connection affect and beam column joint rigidity.

1.2 Research Objective

This study aspire is good understand the behavior of reinforcement concrete beam column joints. We made four types of model in Sap 2000 and Staad -04 and same types of specimen made for experimentally verify the results first type is beam column joint at corner. in second model by increasing the concrete area diagonally such as fillet and in another model by providing fillet at both sides of corner surface with providing nominal reinforcements at fillet portion . Fourth types of model are the same as third types but providing extra reinforcement at other side at fillet. After that we see failure loads and note down the failure axial forces and moments of beam column joints.

The results of numerical analysis of non linear finite element method verified by using experimental results of deferent specimens.

Therefore objective of this research are

(a) To conduct numerical analysis using finite element method (Using Sap 2000 and Staad -) and experimental analysis for a beam column joint with a applied Axial load (15 KN, 25 KN, 35KN ,45 KN) of in both cases for opening joint and closing joint and note down failure axial load and failure moment.

(b) For the four types of beam column joints specimen of opening joint and closing joint condition

(c) To understand behavior of beam column joint with defferent detailing.

(d) To verify numerical analysis results with experimental test of specimen.

(e) To experimentally observe of beam column joints including crack pattern, damage of specimen, plastic hinge formation, load displacement relatiomship strength and stiffness degradation ductility etc.

1.3 Types of Joint in Frame Structure

The joint is defined as the portion of the column within the depth of the deepest beam that frames into the column.

In a moment resisting frame, three types of joints can be identified as .interior joint (Fig.A), exterior joint (Fig.B)and corner joint (Fig.C)

(i) **Interior Joints:** When four beam of a frame connected to vertical face of column are called as interior joint

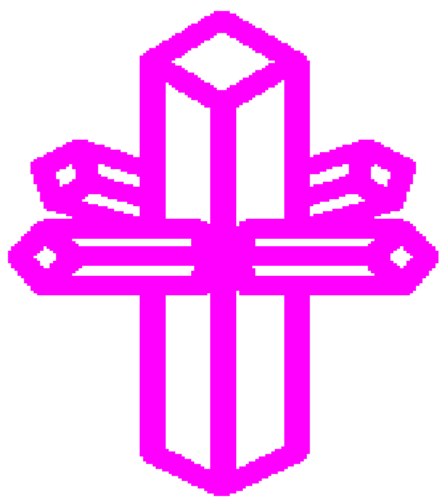

Figure A: Interior Joint

(ii) **Exterior Joint** : When one beam joint frame into the vertical face of column called exterior joint

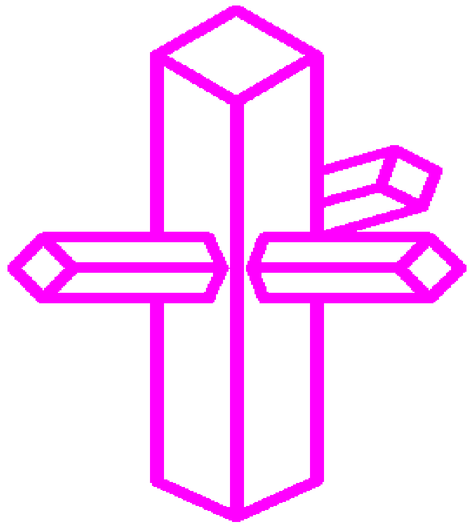

Figure B: Exterior Joints

(iii) **Corner Joints :** When a beam each frame into two adjacent vertical faces of column , then the joint is called as a corner joint.

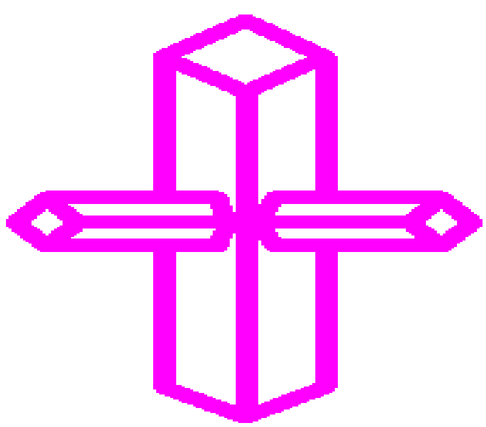

Figure C: Corner Joint

2.0 Literature review

2.1 Force directly acting on joint

1. Figure 1 gives the forces that can be assumed to act on a joint. There should be sufficient anchorge of steel to meet these forces. The moments from the beams on both sides of the column can be equal or opposite in sign under gravity and wind loads. We have already seen that the moments considered at the failure condition should be due to the yield stress fy .

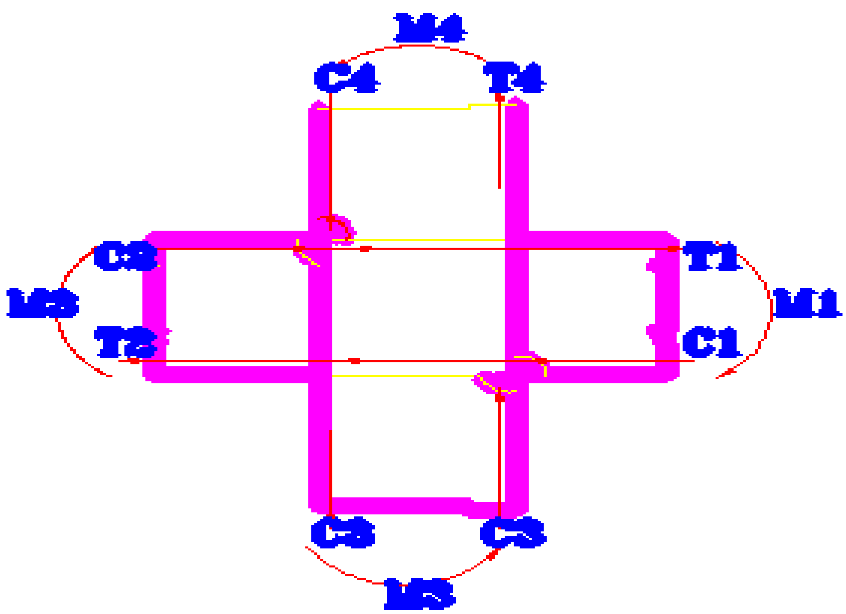

Fig 1:Force acting on joints

Class 1 joint and that due to strain hardening strees (1.25fy) for class to joints. The resultant shear on the joints as seen in fig 1.0will be the following

Vu= Ti+C2-Vcol

Vcol = Shear in Column

Also, T_1= c_1, T_2=C_2

In type 1 joint there may be no joint degradations but in type 2 joints, after a large number of reversals, the joint resistance has been found more by the formation of a mechanism, as shown in fig. 2.0, inside the joint. After the elastic action, we can get the diagonal compression mechanism, I e. the strut mechanism to carry the loads, further deterioration of the joint can lead to a truss mechanism for equilibrium of forces [2]

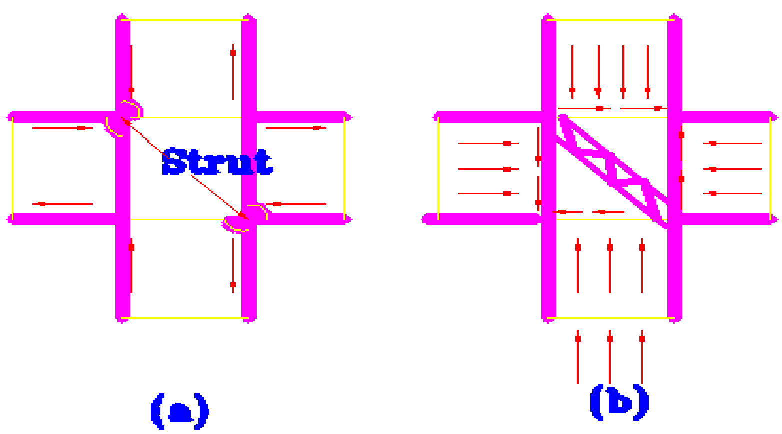

Fig. 2: Struts and Truss Mechanism Resisting Forces in Joints: (a) Strut Mechanism; and (b) Truss Mechanism

In the strut of diagonal compression mechanism, the shear in the joint will be a component off the strut compression (P). Thus

$$\mathbf{V = P \cos \alpha}$$

The cross – sectional area of the effective strut will depend on factors such as point confinement, compression that acts on the core of the joint, the amount of vertical steel, and the column size.

In the truss mechanism, there will be intensive cracking and the absolute necessity of horizontal and vertical steel can be easily seen for its proper action. Even though initially the horizontal confinement may bar assumed to be provided by the side beams framing in to the column, reversal of the load can reduce this action.

Hence, in type 2 joints for the safety of the joints, it is more sensible to depend on confinement of concrete by steel specially provided for this purpose. In type 1 joint, these steel have to be provided only if there are no beams to confine to joints. Thus confinement of the joint is an important factor for good performance of joints.

2.2 Design of joints for strength

As seen from the above discussion, there are three main factors considered in design of joints, in addition to the strength requirement of column 1.0. These are the following:

1. Anchorage of main reinforcement of beams

2. Confinement of the core of the joint

3. Shear strength of the joint

.

2.3 Anchorage

First, we shell consider the anchorage requirements given in ACI and IS codes. These are based on different concepts in the two codes.

2.3A Anchorage Requirements in ACI 318

The requirement specified for anchorage in ACI 318 and IS 456 are not the same. The method of providing the development length, as shown in fig. 3 in Indian practice, and

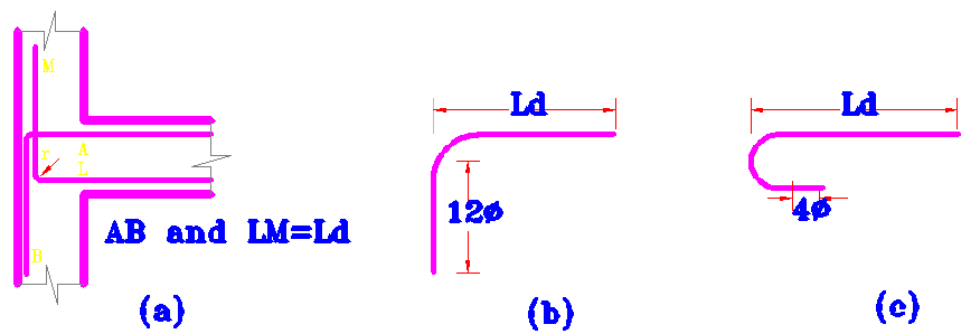

Fig 3: Development length according to (a) Is 456 (b)ACI standard bend(c) ACI standard hook

Described in IS 13920 Clause 6.25, is not accepted by the ACI code. The ACI requirements for the development length can be summarized as follows:

1. The basic development length is tension of a straight HYD bar up to 32 mm (11bar)

   Given in ACI 318 (83) clause 12.2 is as follows:

   $$Ld = 0.02AbFy/ \sqrt{Fck} \text{ (in Si units)}$$

   Where Ab is the area of steel.

   Modification factors; of 0.7 for good cover 0.8 for the presence for confirming stirrups can also be applied to third formula. Larger diameter of bar will have larger bond and the factor corresponding to 0:02 above increases correspondingly.

2. The development length of HYD bars in tension ending in an ACI standard bend or hook is given by ACI 318 clause 12.5.1. using the relation f'c=0.8 fck, it can be expressed as

3.

   $$\mathbf{Ldh = (0.27Qfy)\backslash(\sqrt{Fck})}$$

   Where Q is the diameter of the reinforcement rod.

   For joints with load reversals where the bend should end in confined concrete ACI 318 (1983) clause 21.6.4.1 gives the following formula. The end should have the ACI standard hook and bend

   $$\mathbf{Ldh = (QFy)\backslash(65\sqrt{F'c}) \text{ in psi}}$$

   Converting it into SI units. Hence,

   $$\mathbf{Ldh=(0.20qfy)/ \sqrt{Fck} \text{ ----(E)}}$$

   Where Ld should also not less than 8# or 150 mm. therefore,

   Ld = straight length to tangent point + bend radius 4# + diameter of bar

2.4 Anchorage Requirements in IS 456

The anchorage IS 456 and BS 8110 steel continue to be the same as used from the early days of reinforced concrete. The length required depends on the bond strength between steel and concrete. For every 45 degree of the bend or hook, the increase in the development length from tangiest point is assumed as 4ǿ with such bending no stress is assumed to be transmitted to the end of the bend. Alternately, the rod can be bent in an easy curve, and the development length provide can be as shown in fig. 3(a). the bearing strength at the bend should also be checked by the following equation derived from IS 456 clause 26.2.2.5:

$$R \geq 0.456Fy/Fck\ (1+2q/a)\ Q \quad \text{(see page 179 of reference [3]) (f)}$$

where

Q = Diameter of the rod

r = Radius of the bend 0.87fy in the bar

a = centre-to-centre distance between bars or the cover plus bar size for a bar adjacent to the face of the member.

2.5 Anchorage Requirements for Joints

The anchorage provided for the tension bars in external joints should satisfy the above code requirements. The anchorage of bars in the internal joints is not a problem if the beam bars are made continuous through the column and adequately spliced outside the column core as usually done. The bond stress developed in the bar has to compensate only for the stress in the bar which can be tension on one side compression on the other, thus making the forces cumulative.

The following empirical rule is also usually recommended to satisfy the bond requirements [1] in column bars:

Total depth of column/diameter of beam bar > 20,

Total depth of beam/diameter of a column bar > 20 (20.10)

2.6 Confinement of Core of Joint

The second item to be considered is the confinement of joints. Laboratory tests have shown conclusively the necessity of confining the concrete inside a joint subjected to horizontal forces. The confinement can be by spirals (laterals) placed inside the joints, in type 1 joints, the presence of beams of dimensions extending to at least $3/4^{th}$ the size of the column (on the side of the column) in the direction of the shear forces can be taken as providing the necessary confinement. According to the ACI-ASCE joints committee report, type 1 joints which are not confined as above, should be provided with the specified confining steel in the form of hoops or laterals in the direction of shear, whereas joints which are properly confined by beams need to be provide only with one-half the specified steel. In type 2 joints, confining steel in the concrete is to be provided, whether or not side-confinement is provide by beams.

The principal for providing spirals or circular hooks for confining joints is based on the assumption that the load taken by spirals should fully compensate the loss of ***strength*** due to the spelling of the cover**.** The per unit volume of the spirals is also assumed to be twice as effective as the equivalent longitudinal steel [2]. Let

Ash= Area of spirals used

S = Pitch of the spirals (not more than ¼ dimension of column or 100 mm but not less than 75 mm)

Ag = Gross area of column

Ag = Area of the concrete core from outside to outside of the spirals

D = Diameter of the core

Equating forces according to the above assumptions, we get

$$2Ash\pi D(0.85fy)/S = 0.63fck\ (Ag\text{-}Ak)$$

This reduce to the expression given in IS 13920 clause 7.4.7 for the area of spirals.

$$Ash = 0.09SDk(Ag/Ak\text{-}1)\ fck/fy \qquad \text{(h)}$$

Since rectangular hoops are considered only half effective, as spirals we require double the steel. The formula for rectangular hoops as given in IS 13920 clause 7.4.3 is the following:

$$Ash = 0.18SH\ (As/Ak - 1)\ F\ ck\ /Fy \qquad \text{(h-1)}$$

Where

S = spacing of hoops

H = The larger dimension of the confining hoop measured to its outer faces. In addition, if it exceeds 300 mm, it should be subdivided by additional ties as shown in fig. 3a.

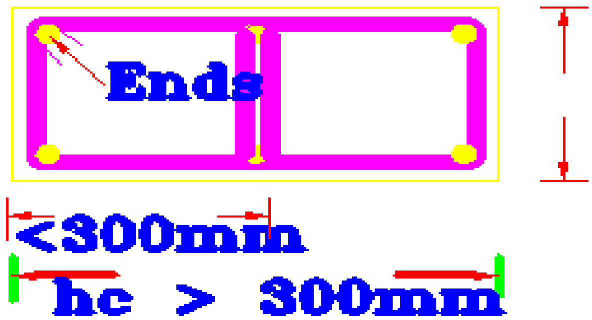

Fig 3A: Confining hook (distance between longitudinal bar should not exceeds 300 mm)

These tied should be closed hoops which end in standard 145digree hook and 10 Q extension (but not less than 75 mm) with ends embedded inside confined concrete. These confining steel in type 1 and in type 2 joints should be continued beyond the joint for a length not less than the following:

1. The largest lateral dimension of the member, or

2. 1/6th of the clear span, or

3. 450 mm

2.7 Shear Strength of the Joint

Thirdly we shall examine the requirement for shear strength of the joint depends on the probable forces that will be transmitted from the beams to the columns. The shear acting on the joint is given by the following equation with reference to fig. 1.0considering the maximum forces that can be developed in the beams at failure conditions, we have

$$\mathbf{V = C + T - V\ col} \qquad \text{(i)}$$

Where ,

T = As1 (steel stress)

W = As2 (steel stress)

As1, As2 Areas of tension and compression steels

Vcol = sum of moments in the beams/storey height

(The steel stress is Fy for type 1 joints and 1.25Fy for type 2 joints.)

2.8 ACI- ASCE Committee Method

The ACI- Committee's observation on design of joints for shear need special mention The committee 318 made the recommendation based *on tests on joints that the shear strength of the joint is to be considered* as a function of the cross –sectional area of concrete Ai only provided the required minimum amount of transverse steel is already provided (see Fig. 3b)

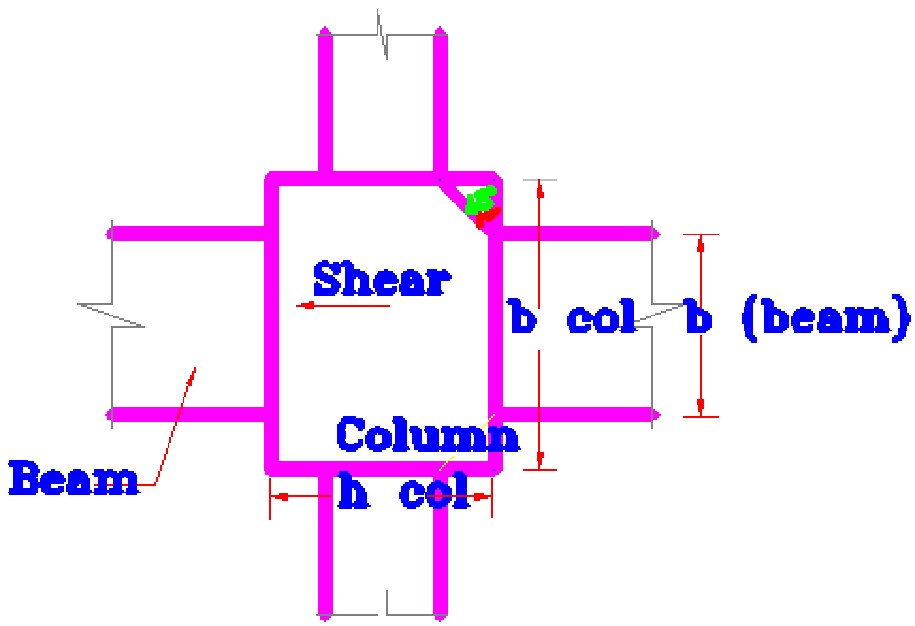

Fig 3B: Plan view of beam column joint in shear

The shear strength of the joint is given by the following equation:

$Vn= \gamma \sqrt{f'c}\, hbj$ (in psi units)

Where;

γ = 20 for internal joints, 15 for external and for corner joints

h= depth of column as show in fig. 3B

bj= effective joint width = ½ (b beam+ b col) but ≤ b beam + (1+2) [1/2h

col}

converting the above equation into SI units, and with reduction factor 0.85 and f'C = 0.8f ck,

we get,

vn= 0.063 γ hbj √ fek (in SI units) (j)

when the factored shear in the joint exceeds the shear strength of joint as the given by Eq. (j) we can either increase the column size or increase the depth of the beam. The former increasing the shear capacity and the latter will reduce the amount of steel and hence the shear to be transmitted to the joint

2.9 Corner (Knee) Joint

These joints occur commonly in construction and require special consideration. As shown in Fig. 4.0, it can be a closing or an opening corner joint.

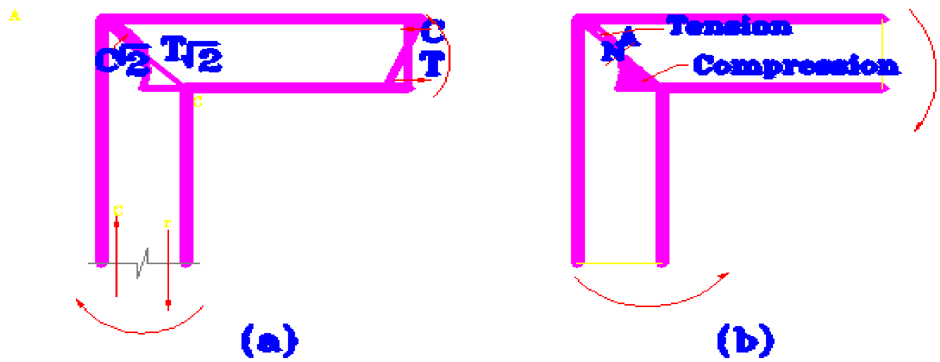

Fig 4: Distribution of stress in corner in opening and closing joints

The neutral axis and the stress distribution in both the arms at sections away from the junction in these joints are as in the case of ordinary beams. However, at the corner, the stress distribution is different and is as shown in fig. 4, with zero stress at A and neutral axis at nearly a third point along AC from the inside joint C. there is also a stress concentration at C. in an opening joint at C (Fig. 4a), we have tension stress concentration and since the Concrete in weak in tension,

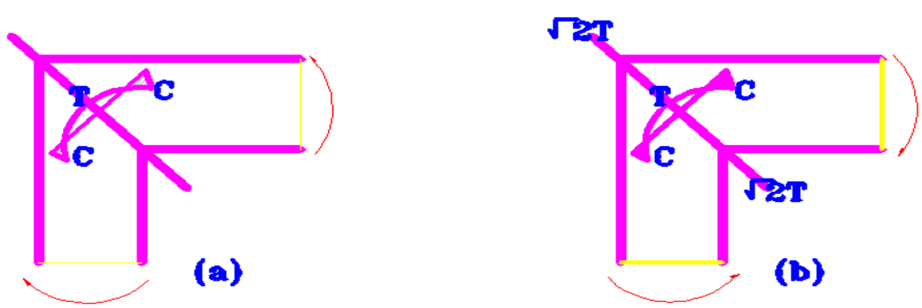

Fig 4A: Distribution of stress in corner in opening and closing joints; (a) Opening joint (b) closing joint and there will be a tendency of premature cracking unless special steel is provided at this place. If the stress concentration is compressive, it does not pose any problem as the concrete is strong in compression. In general, two types of cracking can occur in these joints as discussed below:

If the shear in the core is high, it can cause cracking due to diagonal tension. If T is the tension in steel transmitted to the joint, then

Diagonal tension = shear = v

$$V = T/bd = Asfy/bd$$

Assuming a maximum shear strength = $0.8\sqrt{Fck}$ we have

$$As/bd = 0.8\sqrt{Fck}/fy = p$$

With Fck = 25 and Fy = 415, we get p = 0.0096.

Thus, if the tension steel is more than 1%, then the diagonal steel has to be provided to limit the growth of tension cracks due to shear.

2.0 Cracking can occur due to stress concentration at the joint if it is an opening joint. The total tension in diagonal AC = $\sqrt{2}$ T as shown in fig. 4.0. if this tension acts on a small area, then cracking will occur.

IS publication SP 34 (1987) [4] p. 110 gives the method of detailing of 90 degree opening corners as shown in fig. 5.0 splay-bars of an area equal to one-half the main stell in the beams at The joints are recommended.

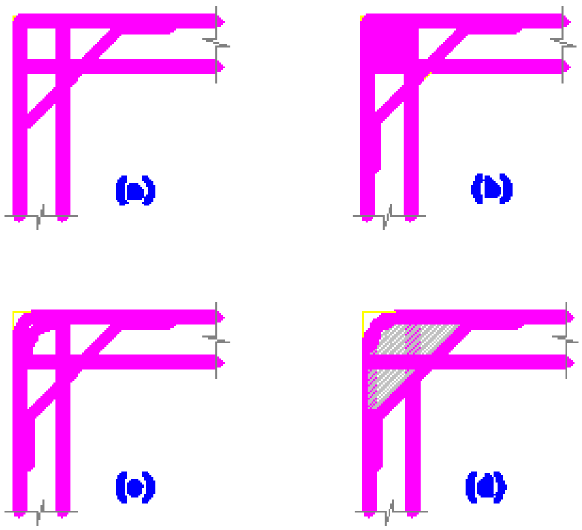

Fig. 5: Detailing of knee joints: (a) 90 degree opening corners of members with percentage of steel < 1 : splay to be 50% of main steel; (b) joints under alternating loads; (c) alternative to (a); and (d) members with more than 1% steel (SP 34 pages 110).

Additional diagonal steel is provided in the opening corners for stress concentration when the percentage of tension steel is more than 1%. The area of the steel is

$$As = \sqrt{2}T/0.87Fy \qquad (k)$$

However, for joints under a alternating loads (type 2 joints), provision of the secondary steel as vertical and horizontal bars is better than the diagonal bars, see Fig. 5(b)

2.10 Detailing for anchorage in exterior beam column joint

In this three-member joint (item to in fig. x), the tension from a beam is transferred to the joint core by anchorage of bars. Since these anchorage are under cycle loads in type 2 structures, they have a tendency to straighten up, their hooked ends should be placed always along the column bars and restrained by stirrups. IS 13920 (93) clause 6.2.5 requires that In external joints, both the top and bottom bars of the beam shall be provided with anchorage length beyond the face of the column equal to the development length in tension plus 10α minus The allowance for 90 degree bend.

2.11. Procedure for design of joints

The various steps in design of joint can be summarized as follows:

Step 1: check the capacity of column to take the vertical load as well the maximum probable moments from the beams joining the column, Eq. (A).

Step 2: check the capacity of column in shear produced by the maximum probable moments beams from the beams joining the column, Eq. (B). (the beam capacities assumed should be 1.2M

For type 1 joints and 1.4M for type 2 joints.)

Step 3: check the anchorage requirement of tension bars in the beam inside the core of the columns.

Step 4: check the confinement of the joint and provide steel for the confinement it found necessary.

Step 5: check the shear. Calculate the ultimate shear acting on the joint and check the capacity of the joint to withstand the shear.

Step 6 : check the detailing of the steel at the joint. Table 20.1 gives the procedure for checking anchorage, confinement and shear in joints by various methods.

2.12. In the beam column joint the two type of forces act on it

(a) Opening the joints

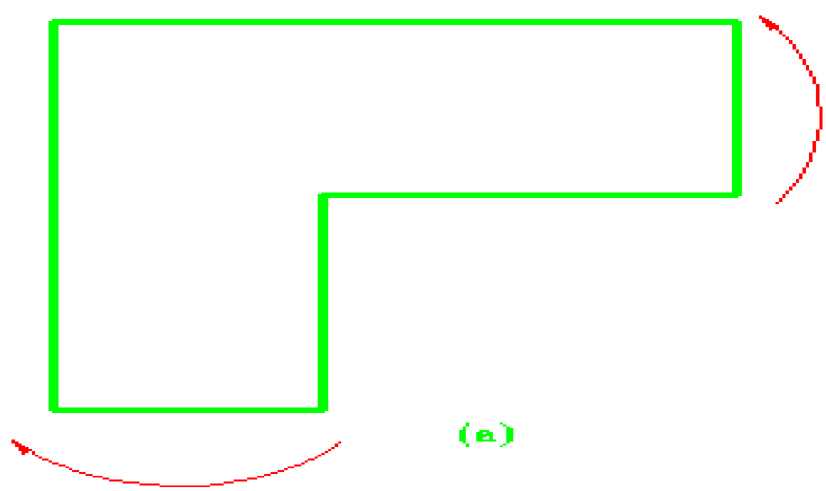

Figure 6: Opening of Joints

(b) Closing joint of beam column joint

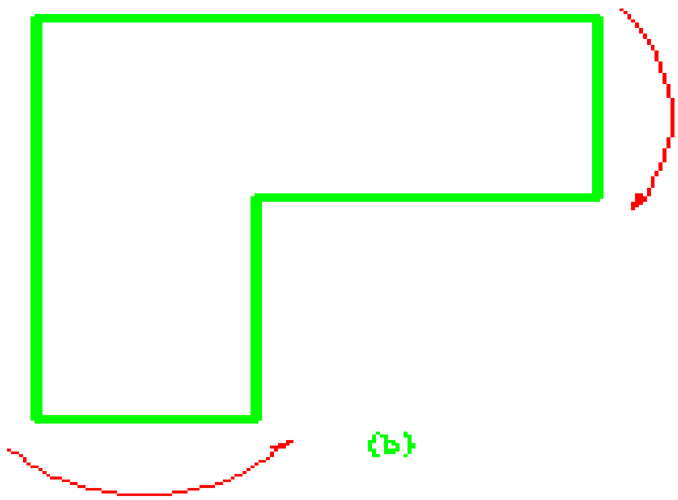

Figure 7: Closing of Joints

3.0. Analytical Analysis

3.1. Analysis Using Sap 2000

Type 1. (As Per IS:13920 Beam Column Joints) (Sap2000 -Specimen –A) For A Load Considered At Cantilever Portion 15 Kn –Open Joint

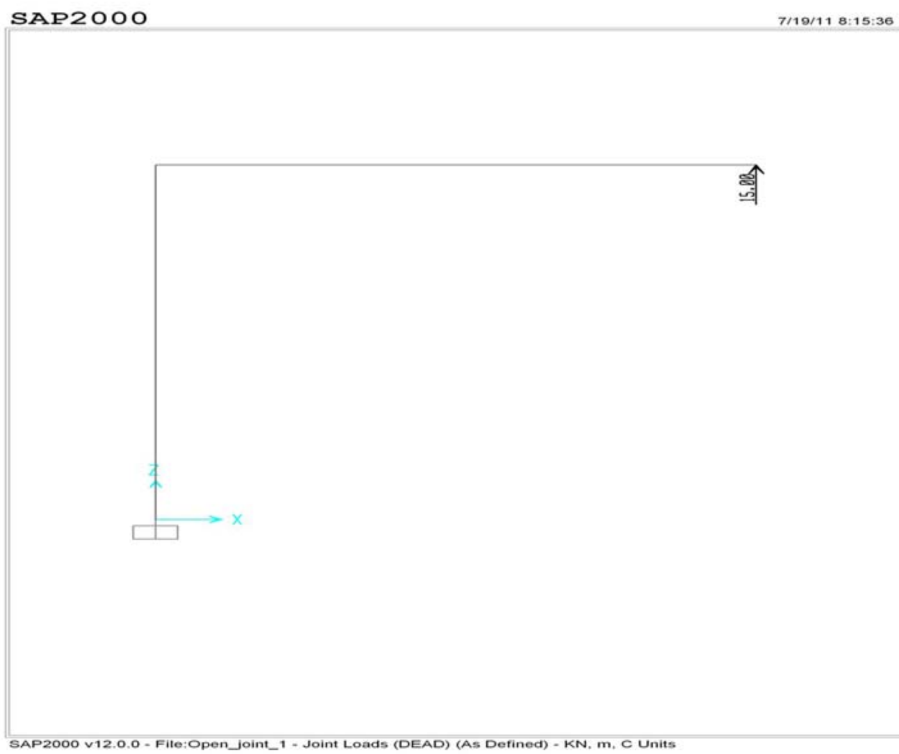

Figure 8: Beam column joint –for specimen-A as per Sap (Open joints)

AXIAL FORCE FOR SPECIMEN –A –OPEN JOINT

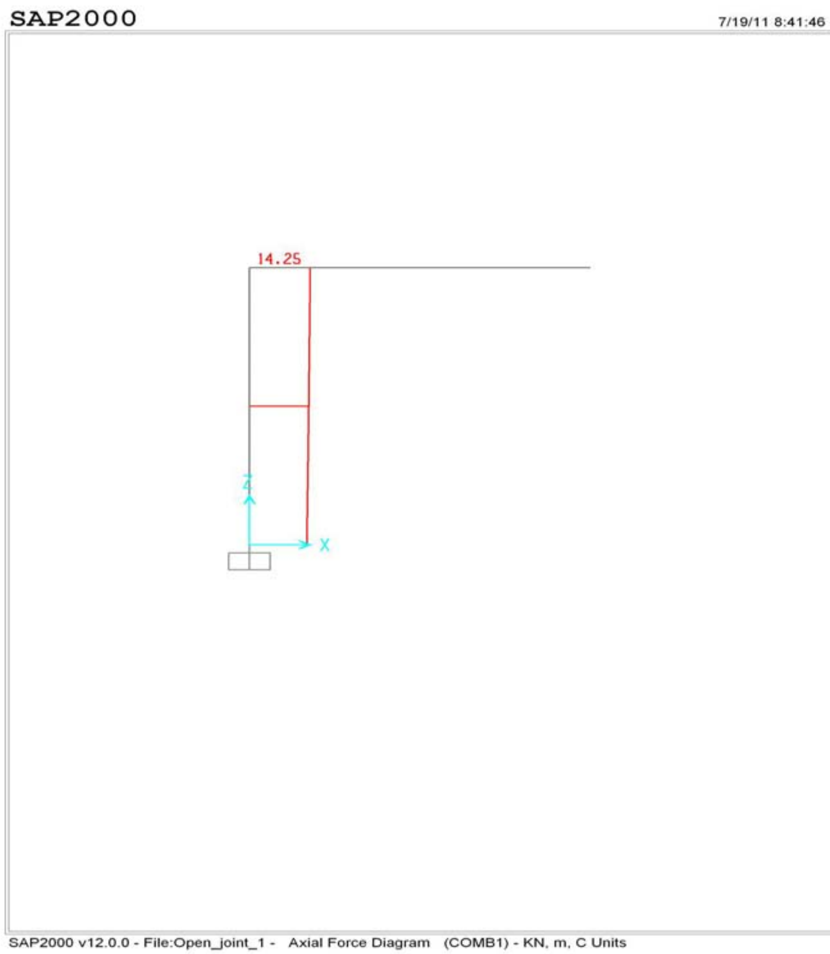

Figure 9: Axial force for specimen-A –for open joints – (Sap 2000)

BEDING MOMENT FOR SPECIMEN –A –OPEN JOINT

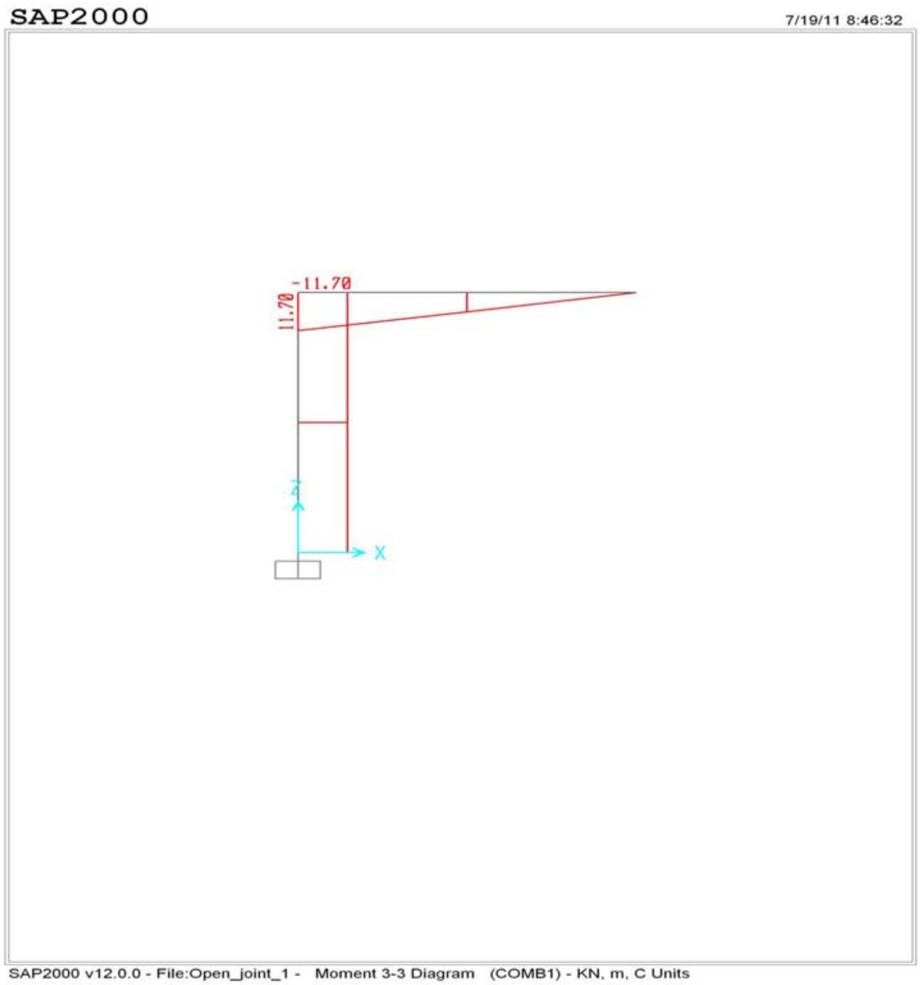

Figure 10: Bending moment for specimen-A –for open joints – (Sap 2000)

DESIGN RESULTS OF (SPECIMEN) A BEAM COLUMN JOINT AS PER SAP -2000–OPEN JOINT

SAP2000 Concrete Design

Project

Job Number

Engineer

```
Indian IS 456-2000 COLUMN SECTION DESIGN  Type: Ductile Frame  Units: KN, m, C  (Summary)

L=0.800
Element      : 1                    B=0.200         D=0.200         dc=0.043
Station Loc  : 0.800                E=24855578.3    fc=27579.032    Lt.Wt. Fac.=1.000
Section ID   : COL                  fy=413685.473   fys=413685.473
Combo ID     : COMB1                RLLF=1.000

Gamma(Concrete): 1.500
Gamma(Steel)   : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3
            Capacity     Design      Design      Design    Factored    Factored
               Ratio         Pu          M2          M3          M2          M3
               0.674    -14.246       0.285     -11.698       0.000     -11.698

AXIAL FORCE & BIAXIAL MOMENT FACTORS
                             K           L     Initial  Additional     Minimum
                        Factor      Length      Moment      Moment      Moment
   Major Bending(M3)     1.000       0.800     -11.698       0.000       0.285
   Minor Bending(M2)     1.000       0.800       0.000       0.000       0.285

SHEAR DESIGN FOR V2,V3
                        Design       Shear       Shear       Shear       Shear
                         Rebar          Vu          Vc          Vs          Vp
   Major Shear(V2)       0.000       0.000      22.314       0.000       0.000
   Minor Shear(V3)       0.000       0.000      22.314       0.000       0.000

JOINT SHEAR DESIGN (Informative only)
                   Joint Shear       Shear       Shear       Shear       Joint
                         Ratio       VuTop       VuTot     phi*Vc        Area
   Major Shear(V2)         N/A         N/A         N/A         N/A         N/A
   Minor Shear(V3)         N/A         N/A         N/A         N/A         N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)
                         Major       Minor
                         Ratio       Ratio
                           N/A         N/A


Notes:
   N/A: Not Applicable
   N/C: Not Calculated
   N/N: Not Needed
```

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\Open joint FOR 15 KN\Open_joint_1 July 30, 2011 18:38

TYPE 2. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –B) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN–OPEN JOINT

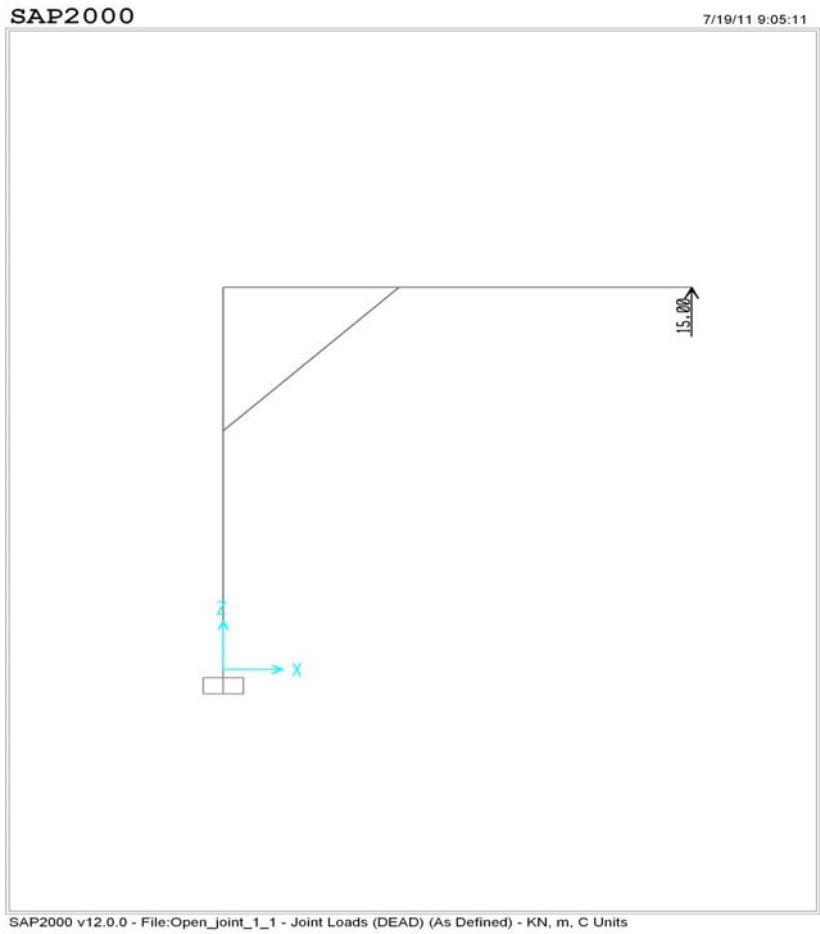

Figure 11: Beam column joint –for specimen-B as per Sap (Open joints)

AXIAL FORCE FOR SPECIMEN –B –OPEN JOINT

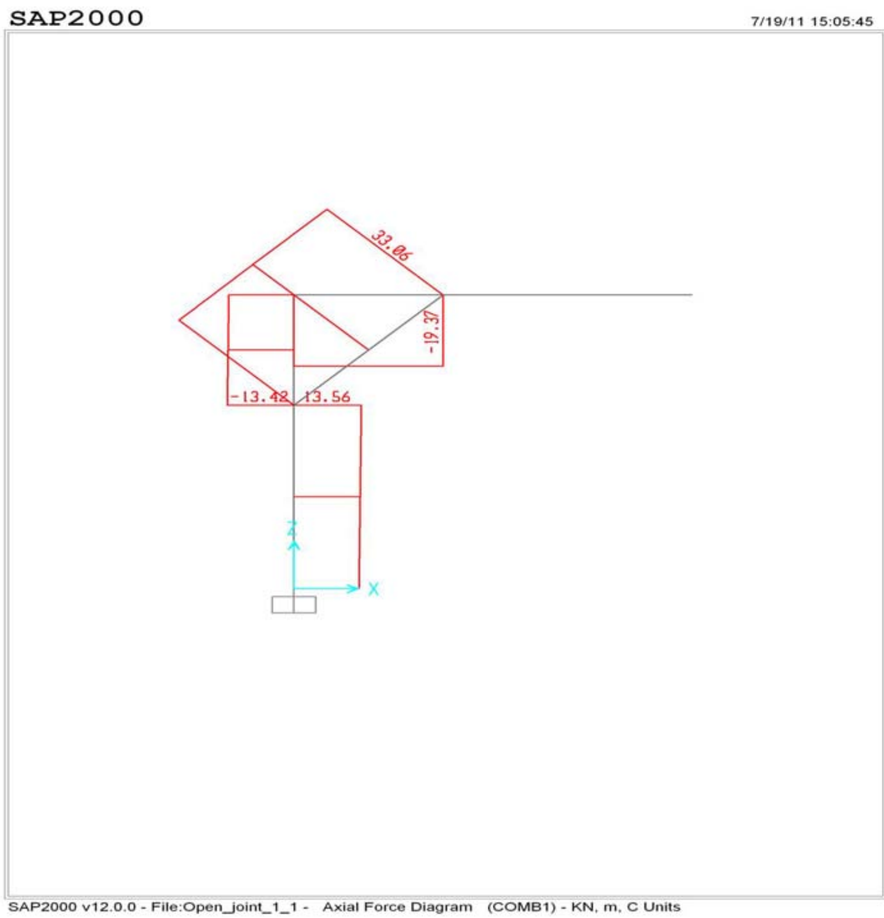

Figure 12: Axial force for specimen-A –for open joints – (Sap 2000)

BENDING MOMENT FOR SPECIMEN –B –OPEN JOINT

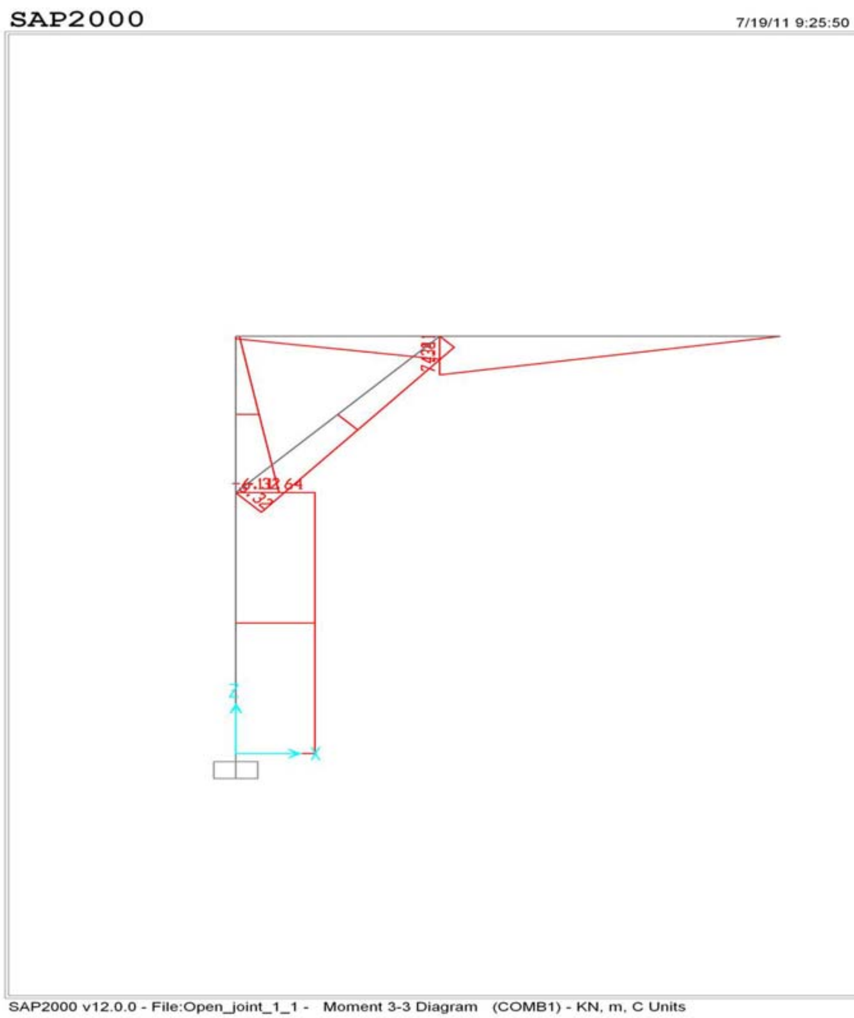

Figure 13: Axial force for specimen-A –for open joints – (Sap 2000)

DESIGN RESULTS OF(SPECIMEN-B) BEAM COLUMN JOINT AS PER SAP -2000–OPEN JOINT

SAP2000 Concrete Design

Project ______

Job Number ______

Engineer ______

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summa

L=0.300

Element	: 4	B=0.200	D=0.200	dc=0.043
Station Loc	: 0.000	E=24855578.3	fc=27579.032	Lt.Wt. Fac.=1.000
Section ID	: COL	fy=413685.473	fys=413685.473	
Combo ID	: COMB1	RLLF=1.000		

Gamma(Concrete) : 1.500
Gamma(Steel) : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.300	13.420	0.268	-6.323	0.000	-6.320

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.300	-3.995	0.003	0.268
Minor Bending(M2)	1.000	0.300	0.000	0.003	0.268

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	2.224E-04	19.372	23.128	12.560	0.000
Minor Shear(V3)	0.000	0.000	23.128	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:
- N/A: Not Applicable
- N/C: Not Calculated
- N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\Open joint FOR 15 KN\Open_joint_1 July 30, 2011 18:48

TYPE 3. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –C) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN–OPEN JOINT

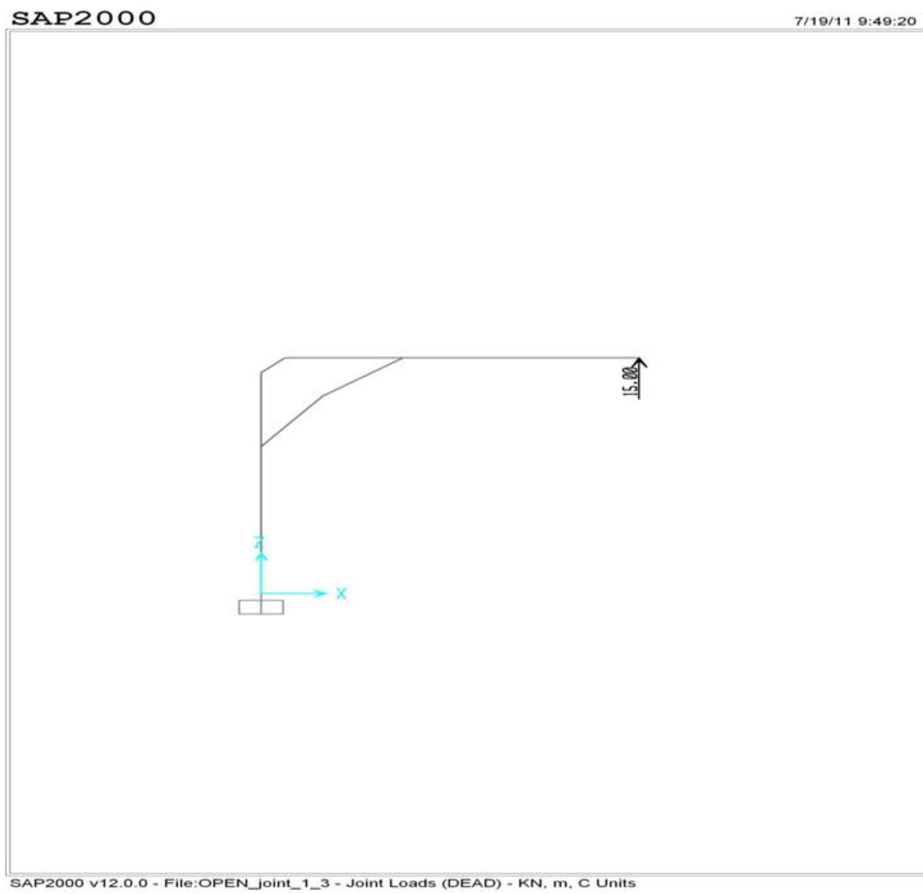

Figure 14: Beam column joint –for specimen-C as per Staad (Open joints)

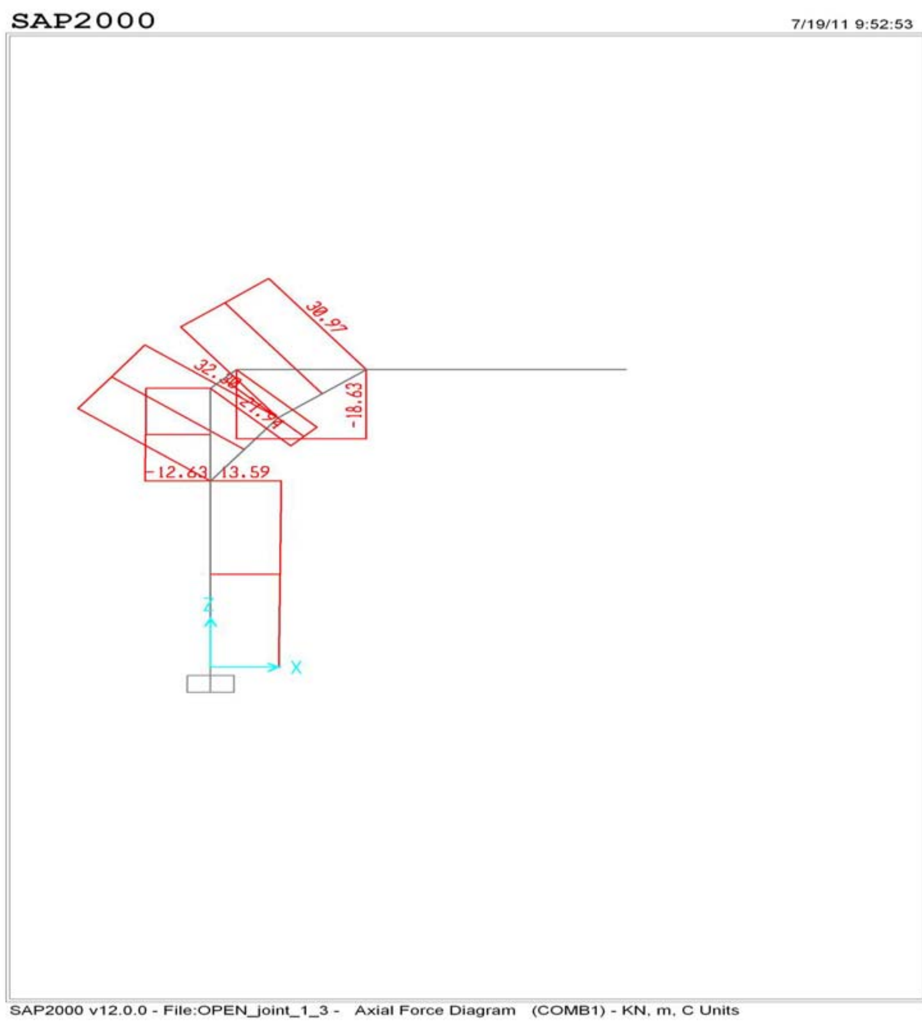

Figure 15: Axial force for specimen-C –for open joints – (Sap 2000))

BENDING MOMENT FOR SPECIMEN –C –OPEN JOINT

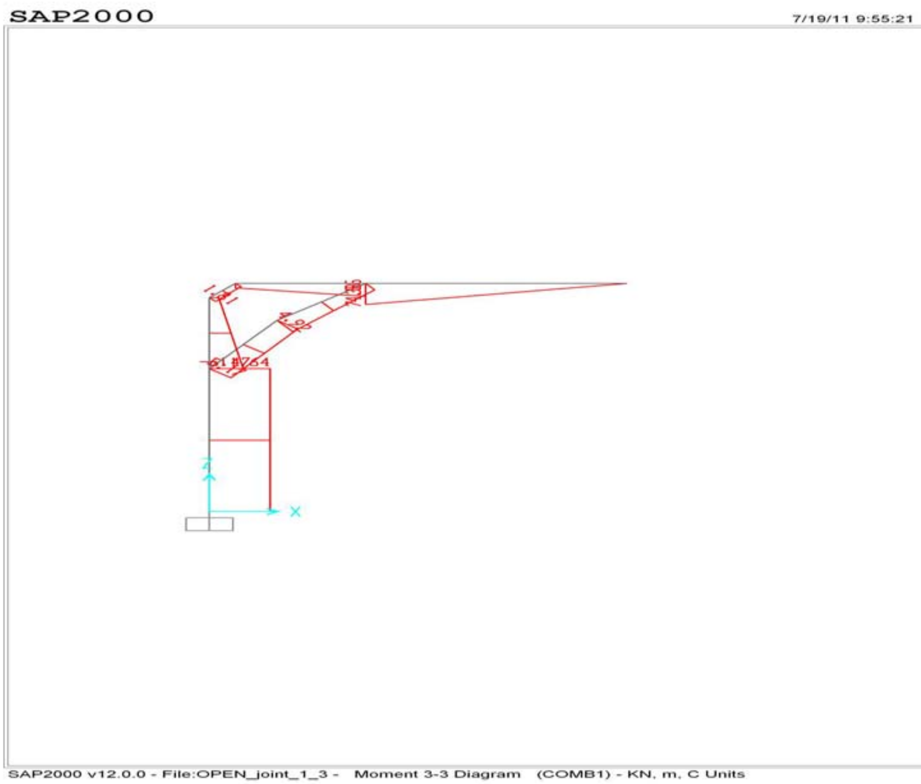

Figure 16: Bending moment for specimen-C –for open joints – (Sap 2000)

DESIGN RESULTS OF (SPECIMEN-C) BEAM COLUMN JOINT AS PER SAP -2000–OPEN JOINT

SAP2000 Concrete Design

Project

Job Number

Engineer

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summ

L=0.250

Element : 9	B=0.200	D=0.200	dc=0.043
Station Loc : 0.000	E=24855578.3	fc=27579.032	Lt.Wt. Fac.=1.000
Section ID : COL	fy=413685.473	fys=413685.473	
Combo ID : COMB1	RLLF=1.000		

Gamma(Concrete) : 1.500

Gamma(Steel) : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.310	12.634	0.253	-6.471	0.000	-6.469

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.250	-4.606	0.002	0.253
Minor Bending(M2)	1.000	0.250	0.000	0.002	0.253

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	2.224E-04	18.627	23.080	12.560	0.000
Minor Shear(V3)	0.000	0.000	23.080	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:

N/A: Not Applicable

N/C: Not Calculated

N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\Open joint FOR 15 KN\OPEN_joint_July 30, 2011 18:49

TYPE 4. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –D) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN–OPEN JOINT

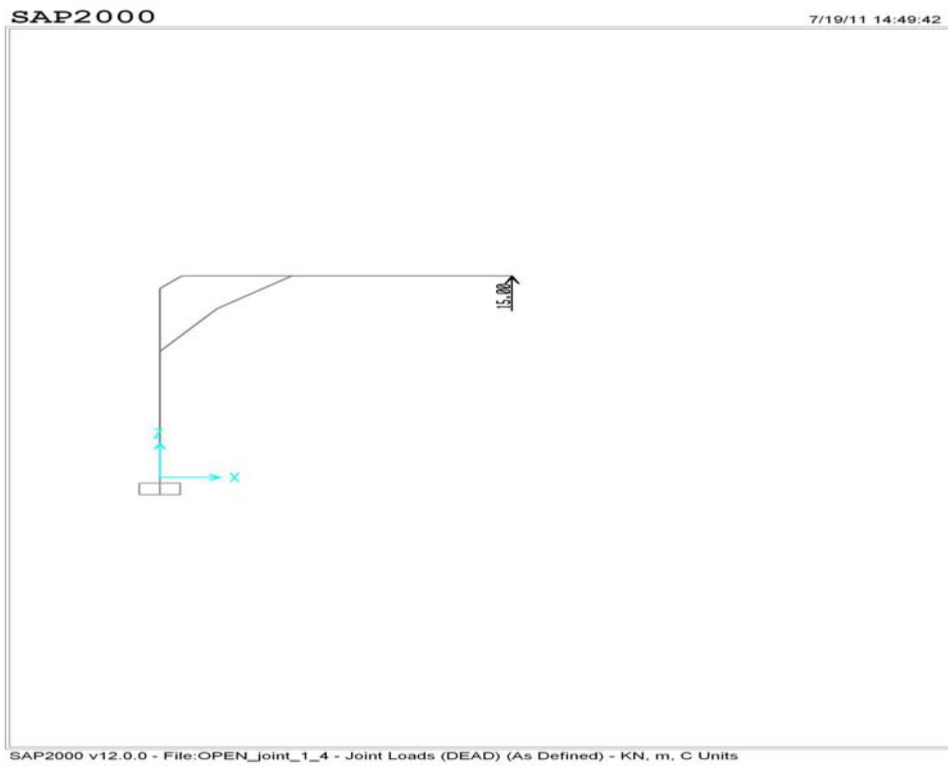

Figure 17: Beam column joint –for specimen-D as per Sap (Open joints)

AXIAL FORCE FOR SPECIMEN –D –OPEN JOINT

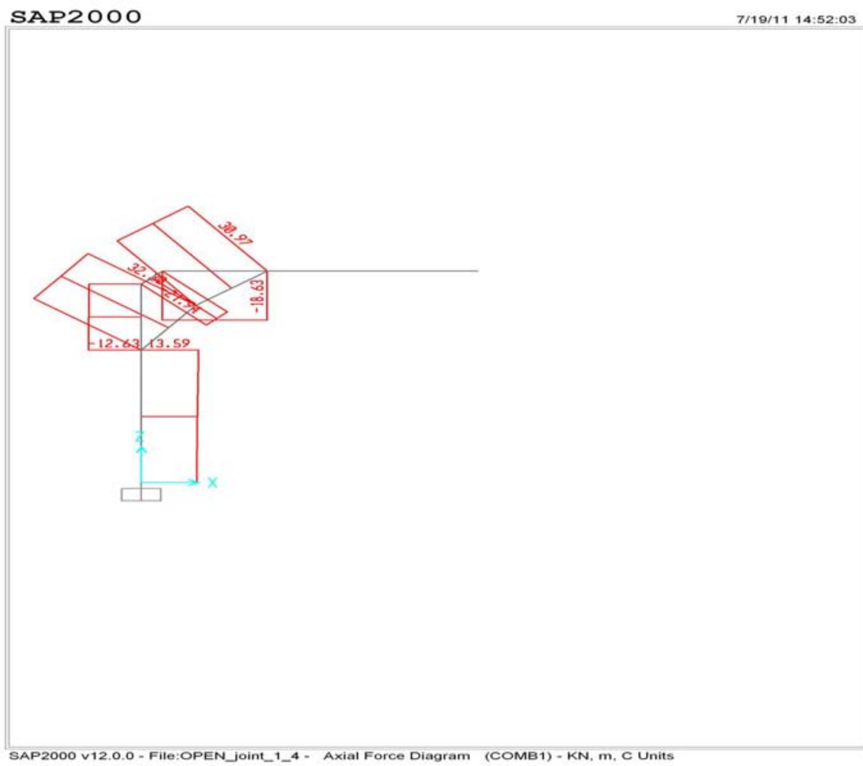

Figure 18: Axial force for specimen-D –for open joints – (Sap 2000)

BENDING MOMENT FOR SPECIMEN –D –OPEN JOINT

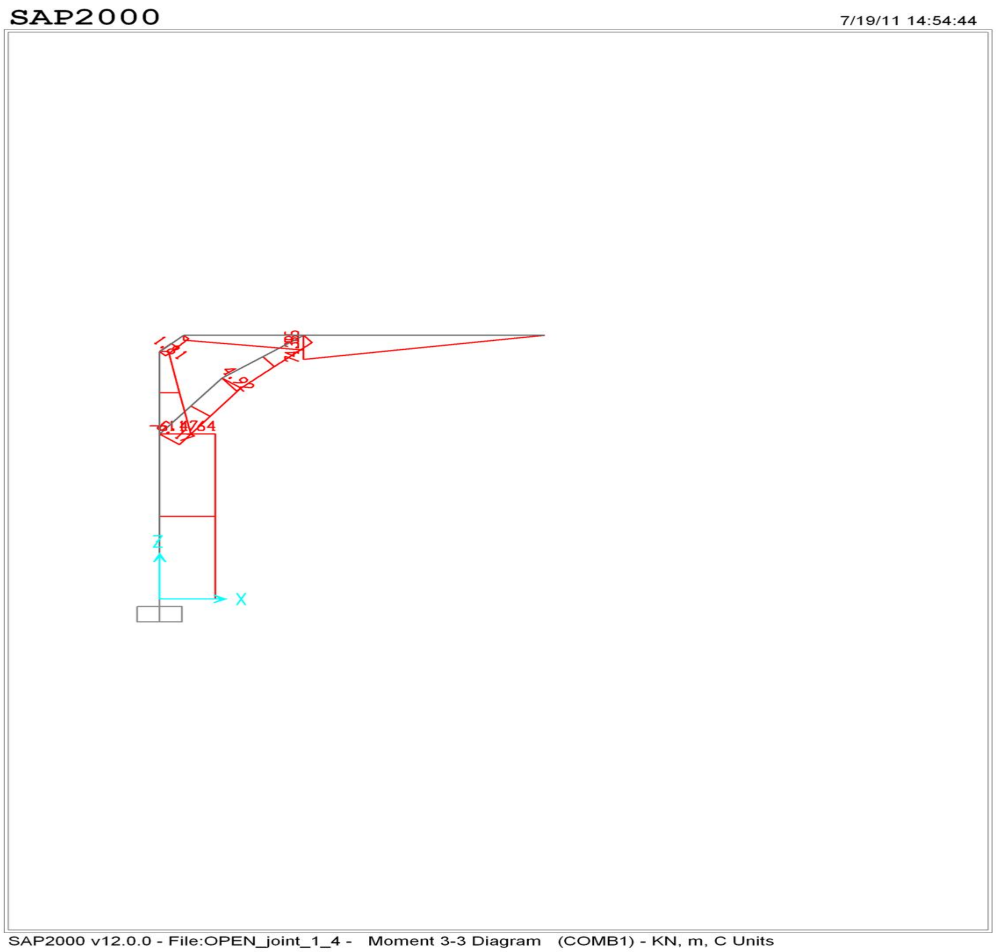

Figure 19: Bending moment for specimen-D –for open joints – (Sap 2000)

DESIGN RESULTS OF(SPECIMEN-D) BEAM COLUMN JOINT AS PER SAP -2000–OPEN JOINT

SAP2000 Concrete Design

Project

Job Number

Engineer

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summary)

L=0.250

Element : 9	B=0.200	D=0.200	dc=0.043
Station Loc : 0.000	E=24855578.3	fc=27579.032	Lt.Wt. Fac.=1.000
Section ID : COL	fy=413685.473	fys=413685.473	
Combo ID : COMB1	RLLF=1.000		

Gamma(Concrete) : 1.500
Gamma(Steel) : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.310	12.634	0.253	-6.471	0.000	-6.469

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.250	-4.606	0.002	0.253
Minor Bending(M2)	1.000	0.250	0.000	0.002	0.253

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	2.224E-04	18.627	23.080	12.560	0.000
Minor Shear(V3)	0.000	0.000	23.080	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:
N/A: Not Applicable
N/C: Not Calculated
N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\Open joint FOR 15 KN\OPEN_joint_1_4 July 30, 2011 18:51

TYPE 1. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –A) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN– CLOSED JOINT

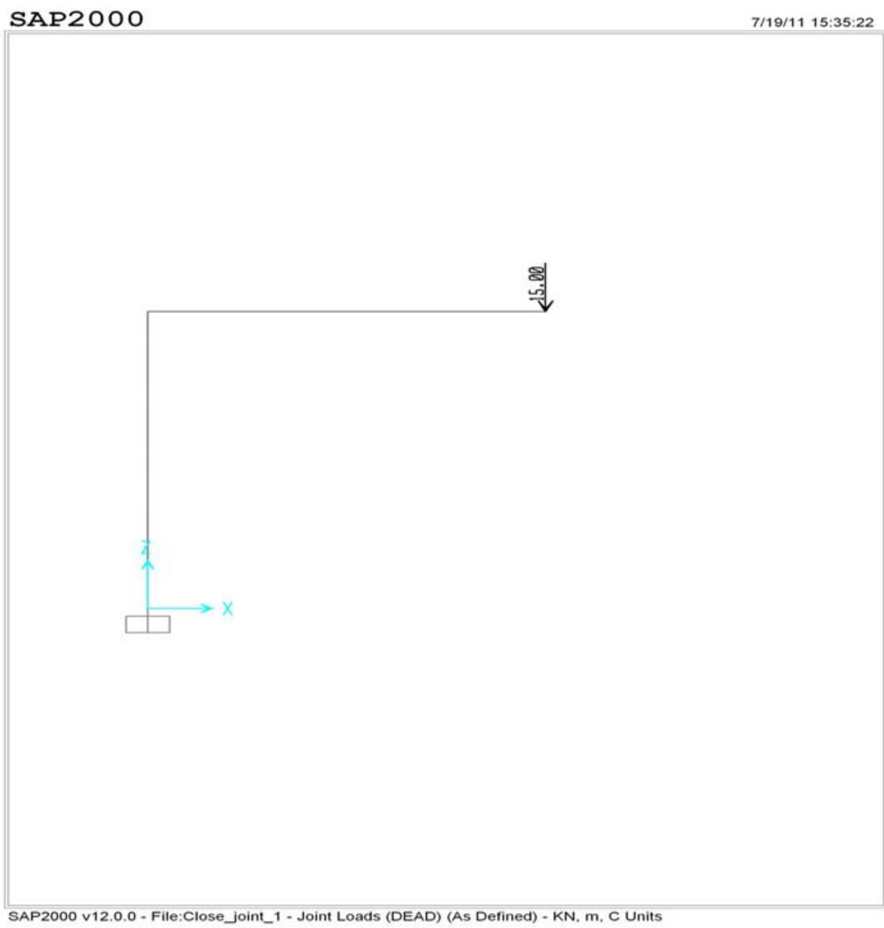

Figure 20: Beam column joint –for specimen-A as per Sap(Closed joints)

AXIAL FORCE FOR SPECIMEN –A- CLOSED JOINT

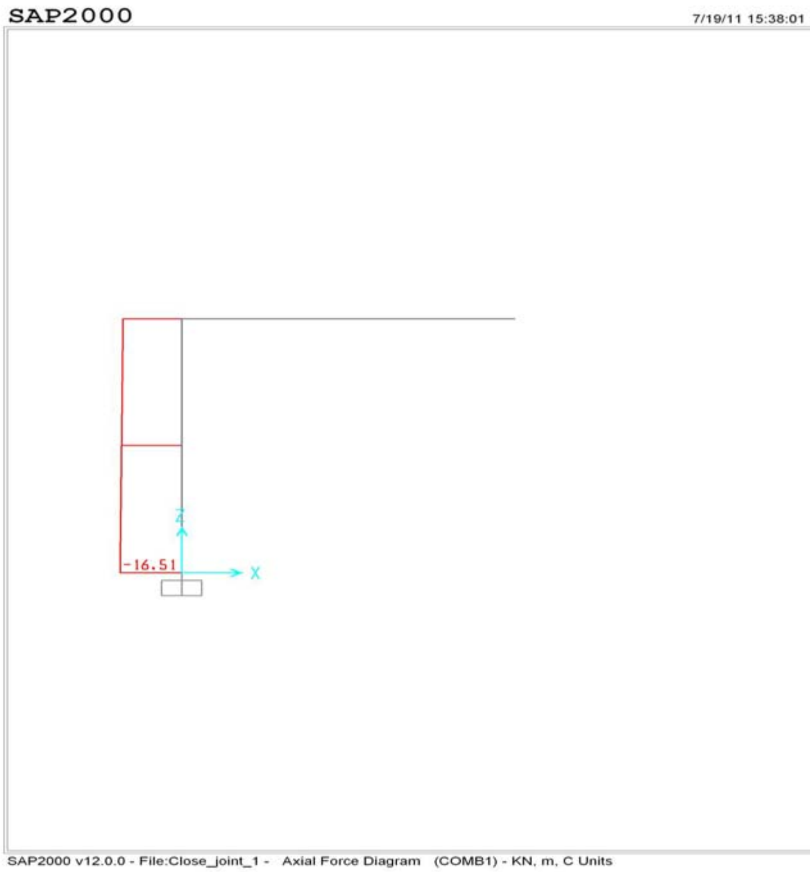

Figure 21: Axial force for specimen-A –for Closed joints – (Sap 2000)

BENDING MOMENT FOR SPECIMEN – A- CLOSED JOINT

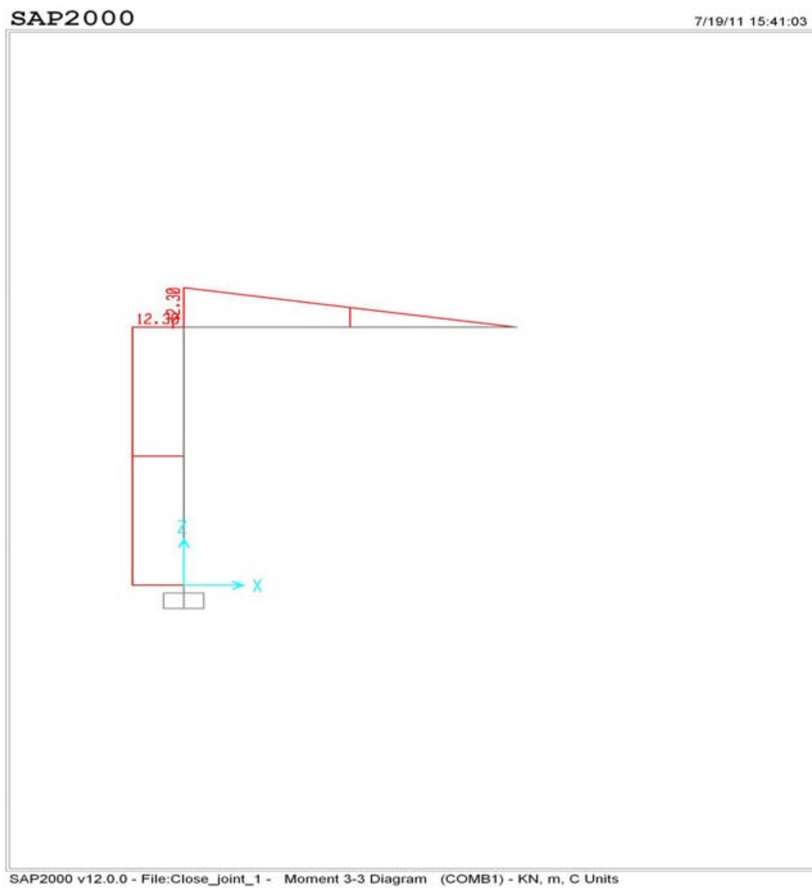

Figure 22: Axial force for specimen-A –for open joints – (Sap 2000)

DESIGN RESULTS OF (SPECIMEN-A) BEAM COLUMN JOINT AS PER SAP -2000– CLOSED JOINT

SAP2000 Concrete Design

Project ______
Job Number ______
Engineer ______

```
Indian IS 456-2000 COLUMN SECTION DESIGN   Type: Ductile Frame   Units: KN, m, C   (Sum

L=0.800
Element      : 1              B=0.200          D=0.200          dc=0.043
Station Loc  : 0.800          E=24855578.3     fc=27579.032     Lt.Wt. Fac.=1.000
Section ID   : COL            fy=413685.473    fys=413685.473
Combo ID     : COMB1          RLLF=1.000

Gamma(Concrete): 1.500
Gamma(Steel)   : 1.150
```

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.615	15.754	0.315	12.327	0.000	12.302

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.800	12.302	0.025	0.315
Minor Bending(M2)	1.000	0.800	0.000	0.025	0.315

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	0.000	0.000	23.270	0.000	0.000
Minor Shear(V3)	0.000	0.000	23.270	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:
N/A: Not Applicable
N/C: Not Calculated
N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\CLOSE JOINT FOR15 KN\Close_joint July 30, 2011 18:54

TYPE 2. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –B) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN– CLOSED JOINT

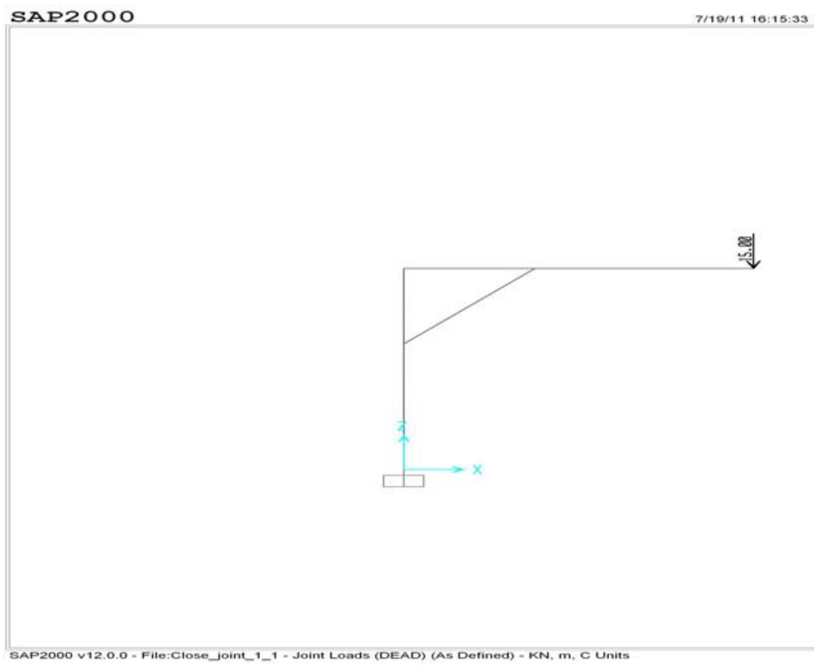

Figure 23: Beam column joint –for specimen-B as per Sap(Closed joints)

AXIAL FORCE FOR SPECIMEN –B- CLOSED JOINT

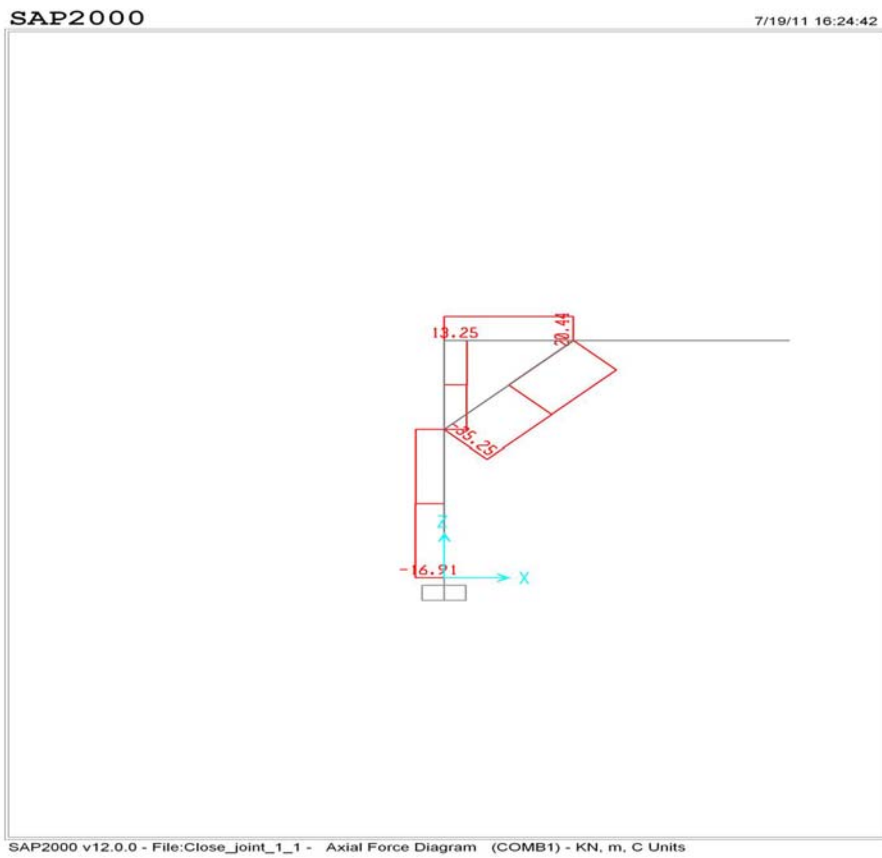

Figure 24: Axial force for specimen-A –for open joints – (Sap 2000)

BENDING MOMENT FOR SPECIMEN – B- CLOSED JOINT

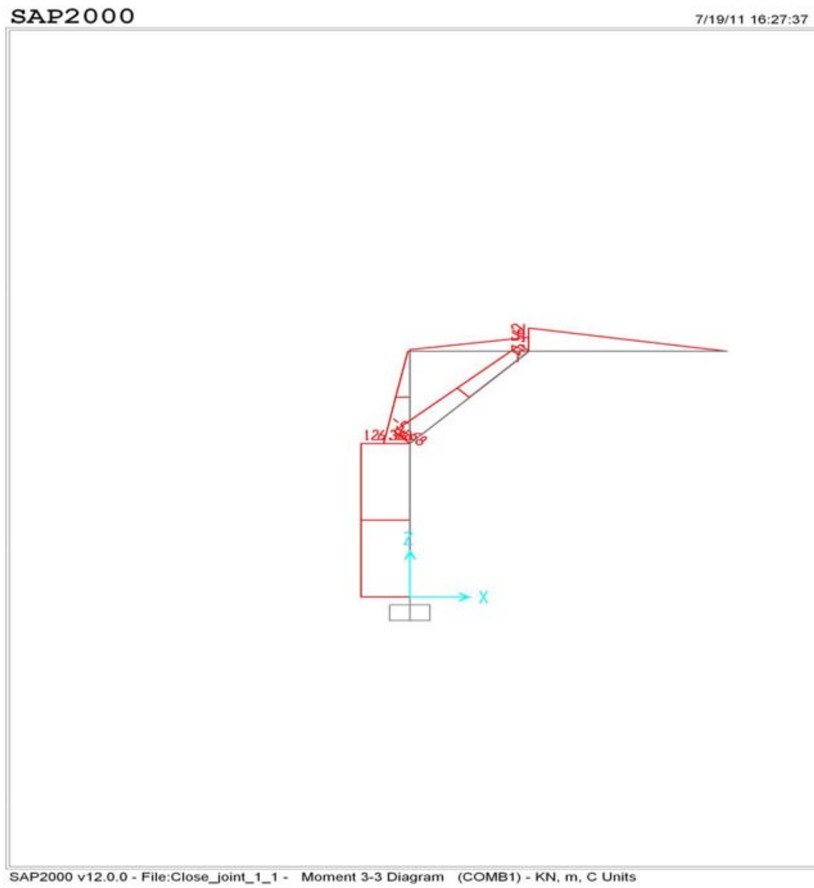

Figure 25: Bending moment for specimen-B –for Closed joints – (Sap 2000)

DESIGN RESULTS OF (SPECIMEN-B) BEAM COLUMN JOINT AS PER SAP -2000– CLOSED JOINT

SAP2000 Concrete Design

Project ______________________

Job Number ______________________

Engineer ______________________

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summ

L=0.300			
Element : 4	B=0.200	D=0.200	dc=0.043
Station Loc : 0.300	E=24855578.3	fc=27579.032	Lt.Wt. Fac.=1.000
Section ID : COL	fy=413685.473	fys=413685.473	
Combo ID : COMB1	RLLF=1.000		

Gamma(Concrete) : 1.500
Gamma(Steel) : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.074	-13.248	0.265	0.547	0.000	0.547

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.300	4.227	0.000	0.265
Minor Bending(M2)	1.000	0.300	0.000	0.000	0.265

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	2.224E-04	20.442	22.314	12.560	0.000
Minor Shear(V3)	0.000	0.000	22.314	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:
- N/A: Not Applicable
- N/C: Not Calculated
- N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\CLOSE JOINT FOR15 KN\Close_joint_1 July 30, 2011 18:56

TYPE 3. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –C) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN– CLOSED JOINT

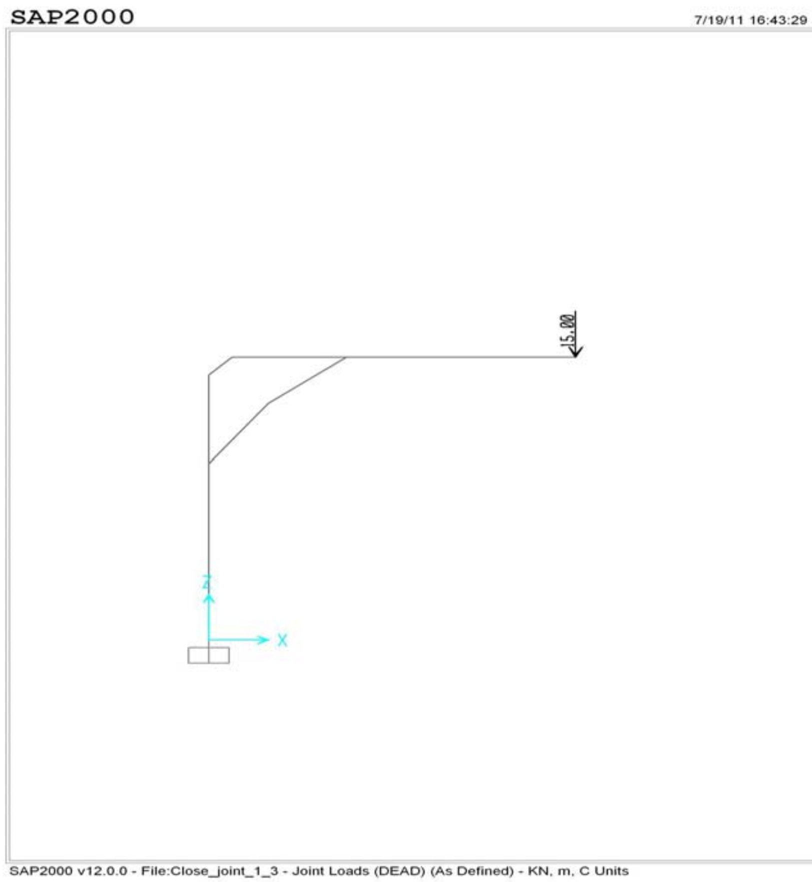

Figure 26: Beam column joint –for specimen-C as per Sap 2000 (Closed joints)

AXIAL FORCE FOR SPECIMEN –C- CLOSED JOINT

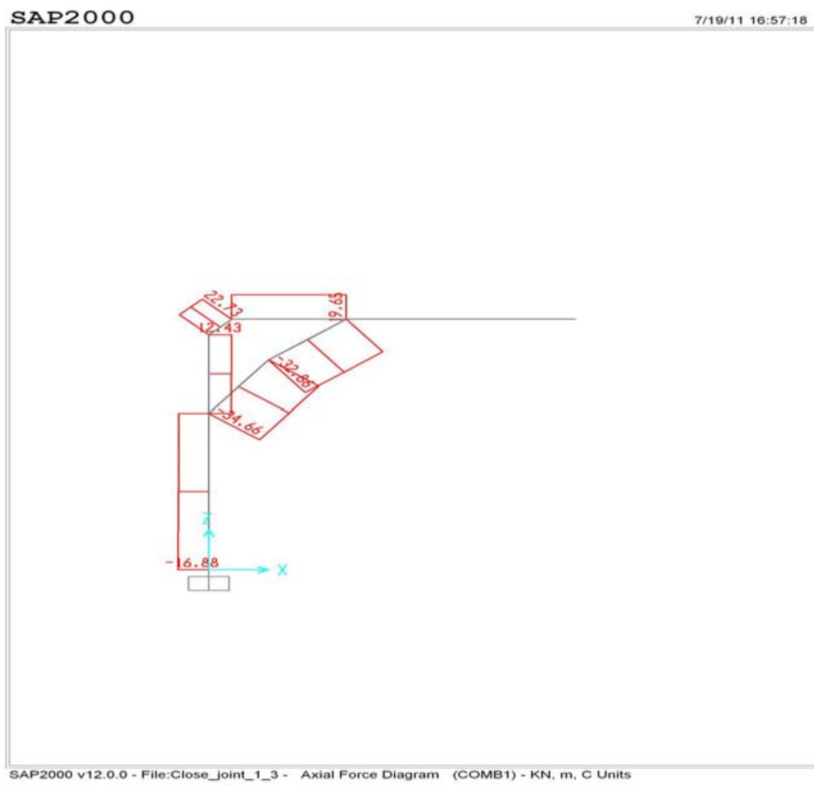

Figure 27: Axial force for specimen-C –for Closed joints – (Sap)

BEDING MOMENT FOR SPECIMEN – C- CLOSED JOINT

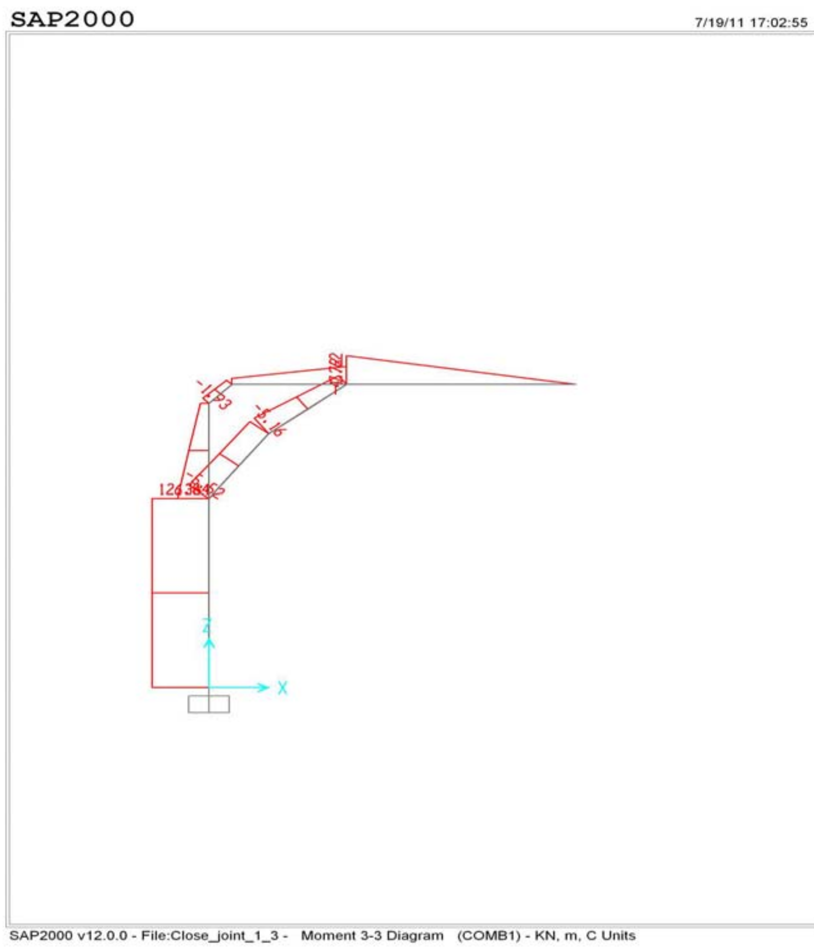

Figure 28: Bending moment for specimen-C –for closed joints – (Sap)

DESIGN RESULTS OF (SPECIMEN-C) BEAM COLUMN JOINT AS PER SAP -2000– CLOSED JOINT

SAP2000 Concrete Design

Project ______

Job Number ______

Engineer ______

Indian IS 456-2000 COLUMN SECTION DESIGN Type: Ductile Frame Units: KN, m, C (Summa

L=0.250

Element : 9	B=0.200	D=0.200	dc=0.043
Station Loc : 0.250	E=24855578.3	fc=27579.032	Lt.Wt. Fac.=1.000
Section ID : COL	fy=413685.473	fys=413685.473	
Combo ID : COMB1	RLLF=1.000		

Gamma(Concrete) : 1.500
Gamma(Steel) : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3

Capacity Ratio	Design Pu	Design M2	Design M3	Factored M2	Factored M3
0.144	-12.429	0.249	1.925	0.000	1.925

AXIAL FORCE & BIAXIAL MOMENT FACTORS

	K Factor	L Length	Initial Moment	Additional Moment	Minimum Moment
Major Bending(M3)	1.000	0.250	4.873	0.000	0.249
Minor Bending(M2)	1.000	0.250	0.000	0.000	0.249

SHEAR DESIGN FOR V2,V3

	Design Rebar	Shear Vu	Shear Vc	Shear Vs	Shear Vp
Major Shear(V2)	2.224E-04	19.649	22.314	12.560	0.000
Minor Shear(V3)	0.000	0.000	22.314	0.000	0.000

JOINT SHEAR DESIGN (Informative only)

	Joint Shear Ratio	Shear VuTop	Shear VuTot	Shear phi*Vc	Joint Area
Major Shear(V2)	N/A	N/A	N/A	N/A	N/A
Minor Shear(V3)	N/A	N/A	N/A	N/A	N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)

Major Ratio	Minor Ratio
N/A	N/A

Notes:
- N/A: Not Applicable
- N/C: Not Calculated
- N/N: Not Needed

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\CLOSE JOINT FOR15 KN\Close_joint_3 July 13, 2011 18:58

TYPE 4. (AS PER IS:13920 BEAM COLUMN JOINTS) (SAP2000 -SPECIMEN –D) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN– CLOSED JOINT

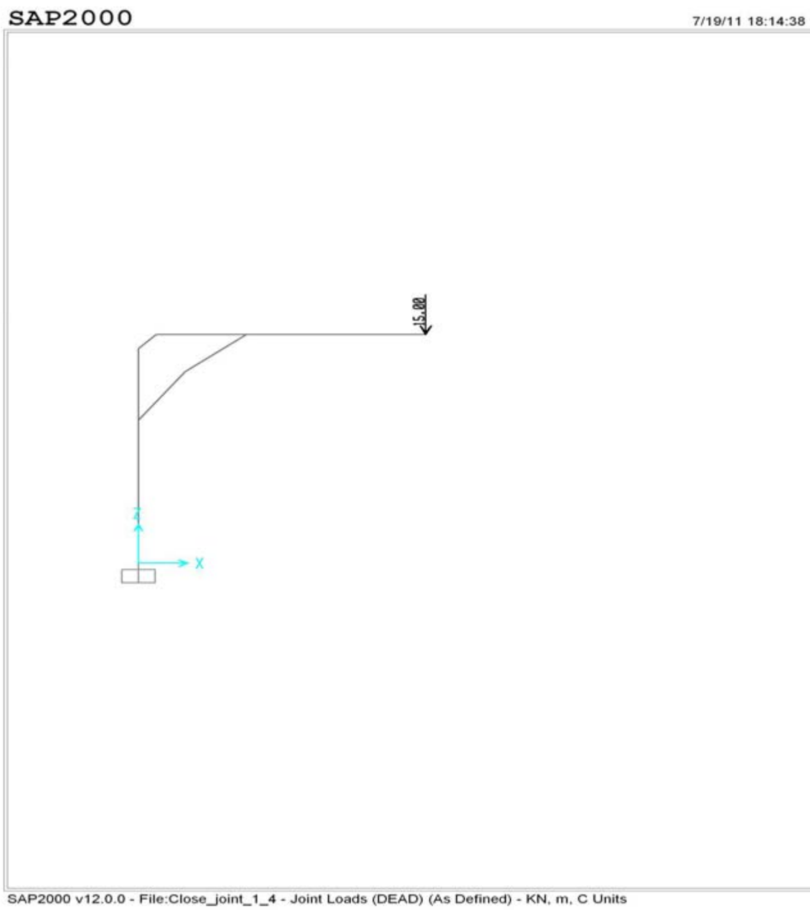

Figure 29: Beam column joint –for specimen-D as per Sap 2000 (Closed joints)

AXIAL FORCE FOR SPECIMEN –D – CLOSED JOINT

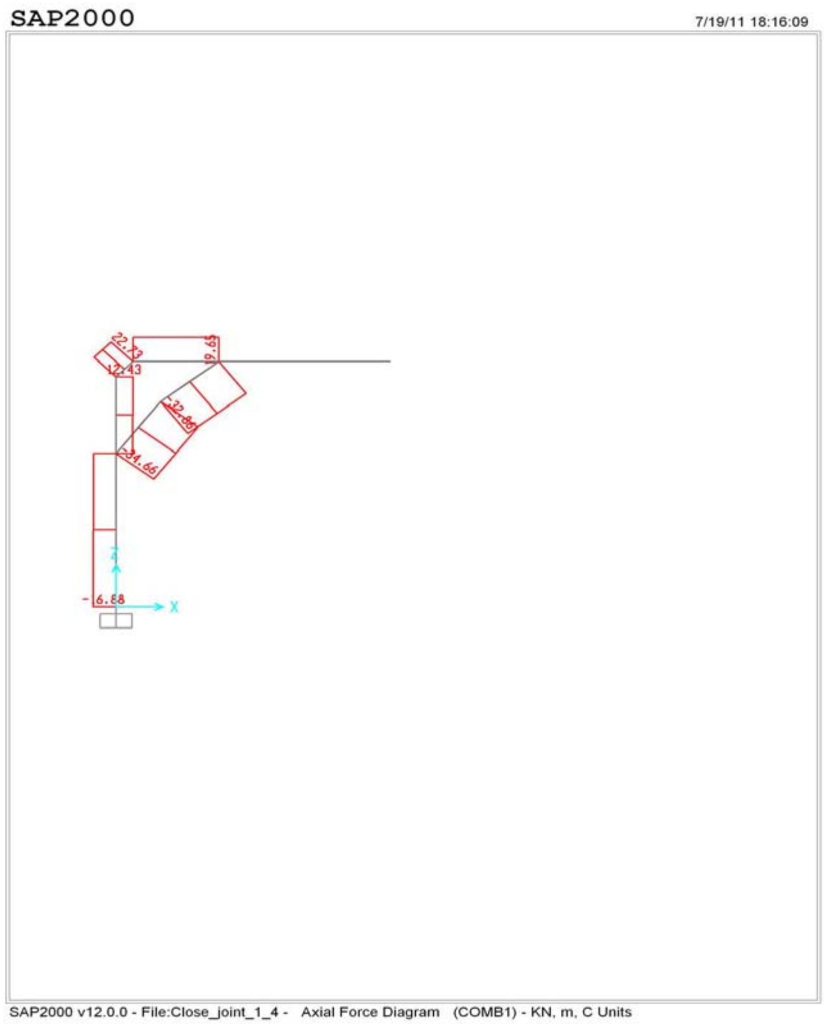

Figure 30: Axial force for specimen-D –for closed joints – (Sap 2000)

BENDING MOMENT FOR SPECIMEN –D – CLOSED JOINT

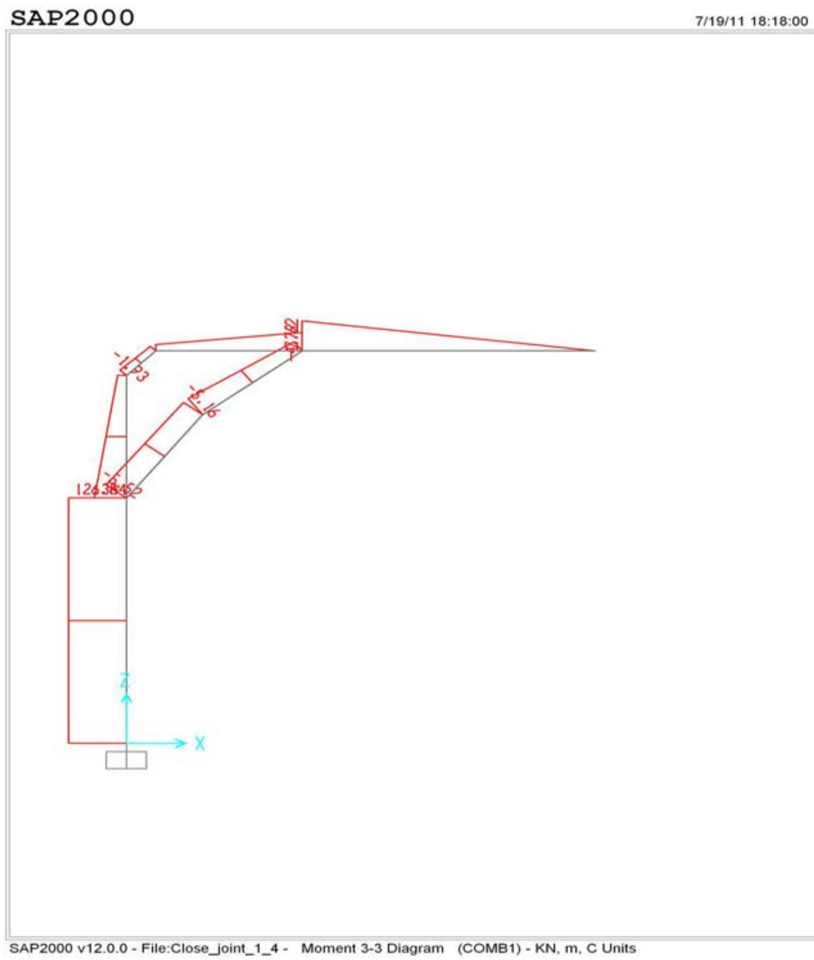

Figure 31: Bending moment for specimen-D –for closed joints – (Sap 2000)

DESIGN RESULTS OF (SPECIMEN-D) BEAM COLUMN JOINT AS PER SAP -2000– CLOSED JOINT

SAP2000 Concrete Design

Project ______

Job Number ______

Engineer ______

```
Indian IS 456-2000 COLUMN SECTION DESIGN   Type: Ductile Frame   Units: KN, m, C   (Summa

L=0.250
Element      : 9                  B=0.200            D=0.200           dc=0.043
Station Loc  : 0.125              E=24855578.3       fc=27579.032      Lt.Wt. Fac.=1.000
Section ID   : COL                fy=413685.473      fys=413685.473
Combo ID     : COMB1              RLLF=1.000

Gamma(Concrete): 1.500
Gamma(Steel)   : 1.150

AXIAL FORCE & BIAXIAL MOMENT CHECK FOR PU, M2, M3
              Capacity     Design      Design      Design     Factored    Factored
                 Ratio         Pu          M2          M3           M2          M3
                 0.275    -12.311       0.246       4.381       0.000       4.381

AXIAL FORCE & BIAXIAL MOMENT FACTORS
                                K           L     Initial  Additional     Minimum
                           Factor      Length      Moment      Moment      Moment
   Major Bending(M3)        1.000       0.250       4.873       0.000       0.246
   Minor Bending(M2)        1.000       0.250       0.000       0.000       0.246

SHEAR DESIGN FOR V2,V3
                           Design       Shear       Shear       Shear       Shear
                            Rebar          Vu          Vc          Vs          Vp
   Major Shear(V2)      2.224E-04      19.649      22.314      12.560       0.000
   Minor Shear(V3)          0.000       0.000      22.314       0.000       0.000

JOINT SHEAR DESIGN (Informative only)
                      Joint Shear       Shear       Shear       Shear       Joint
                            Ratio       VuTop       VuTot     phi*Vc        Area
   Major Shear(V2)            N/A         N/A         N/A         N/A         N/A
   Minor Shear(V3)            N/A         N/A         N/A         N/A         N/A

(1.1) BEAM/COLUMN CAPACITY RATIOS (Informative only)
                            Major       Minor
                            Ratio       Ratio
                              N/A         N/A


Notes:
   N/A: Not Applicable
   N/C: Not Calculated
   N/N: Not Needed
```

SAP2000 v12.0.0 - File:D:\sarwar\SAP-MODEL\open joint\CLOSE JOINT FOR15 KN\Close_joint_04 July 30, 2011 19:03

3.2 Analysis using Staad 2004

TYPE 1. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – A) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN –OPEN JOINT

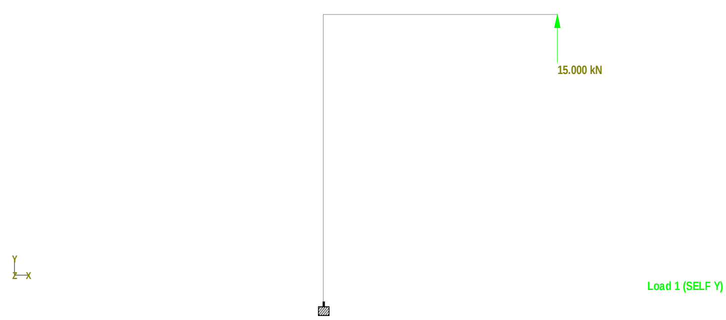

Figure 32 : Beam column joint –for specimen-A as per Staad (Open joints)

AXIAL FORCE FOR SPECIMEN –A- OPEN JOINT-(IN STAAD)

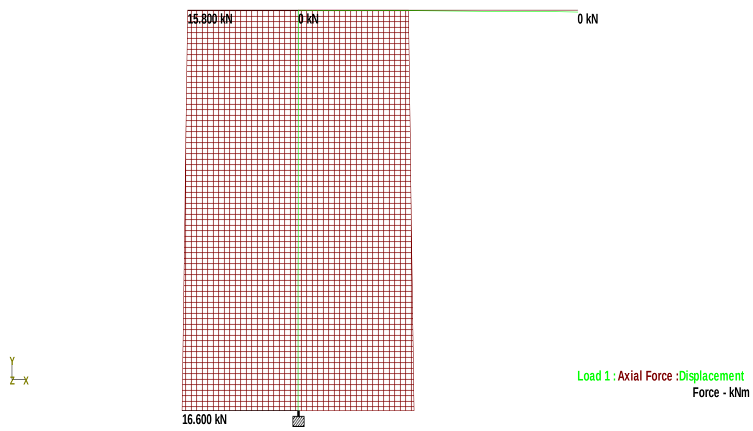

Figure 33 : Axial force for specimen-A –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –A – OPEN JOINT-(IN STAAD)

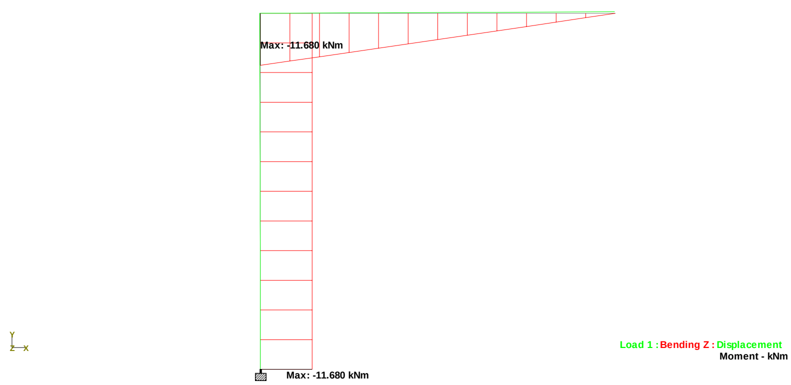

Figure 34 : Bending moment for specimen-A –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-A) BEAM COLUMN JOINT AS PER STAAD -2000– OPEN JOINT

C O L U M N N O. 1 D E S I G N R E S U L T S

M25 Fe500 (Main) Fe500 (Sec.)

LENGTH: 800.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 1 END JOINT: 9 SHORT COLUMN

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : -14.2

		About Z	About Y
INITIAL MOMENTS	:	11.68	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.28	0.28
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	11.68	0.28

REQD. STEEL AREA : 480.00 Sq.mm.

MAIN REINFORCEMENT : Provide 4 - 16 dia. (2.01%, 804.25 Sq.mm.)
(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 200 mm c/c

TYPE 2. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – B) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN –OPEN JOINT

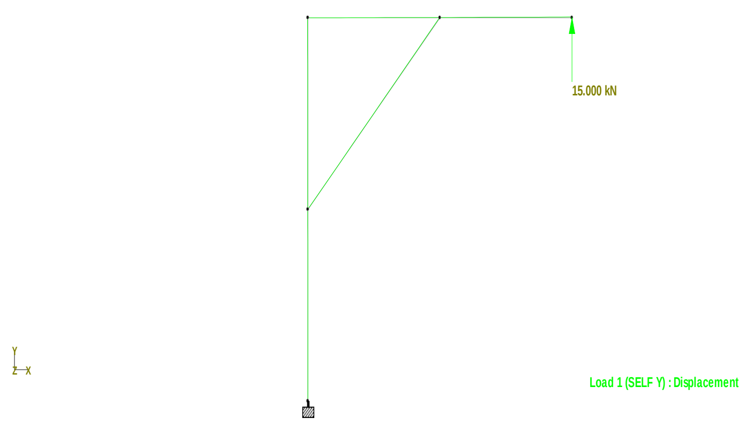

Figure 35 : Open joint as per Staad-specimen B(Staad)

AXIAL FORCE FOR SPECIMEN –B- OPEN JOINT-(IN STAAD)

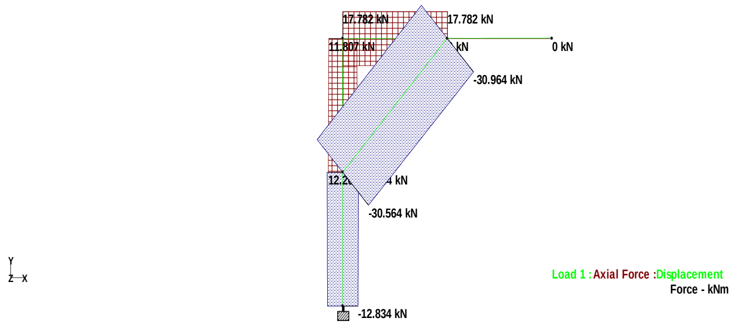

Figure 36 : Axial force for specimen-B –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –B – OPEN JOINT-(IN STAAD)

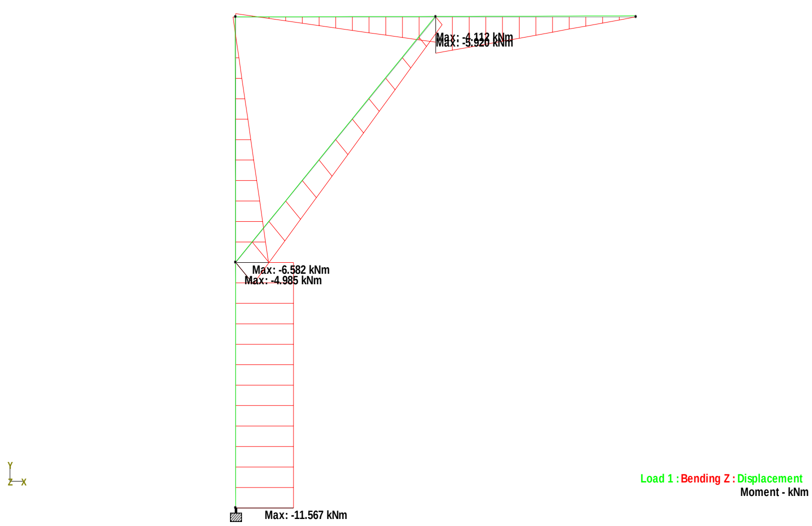

Figure 37 : Bending moments for specimen-B –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-B) BEAM COLUMN JOINT AS PER STAAD -2000– OPEN JOINT

==

C O L U M N N O.   3 D E S I G N R E S U L T S

M30   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 400.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 1 END JOINT: 5 SHORT COLUMN

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : 12.2

		About Z	About Y
INITIAL MOMENTS	:	6.58	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.24	0.24
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	6.58	0.24

REQD. STEEL AREA : 196.34 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 598.46 Muz1 : 6.83 Muy1 : 6.83

INTERACTION RATIO: 1.00 (as per Cl. 39.6, IS456:2000)

TYPE 3. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – C) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN –OPEN JOINT

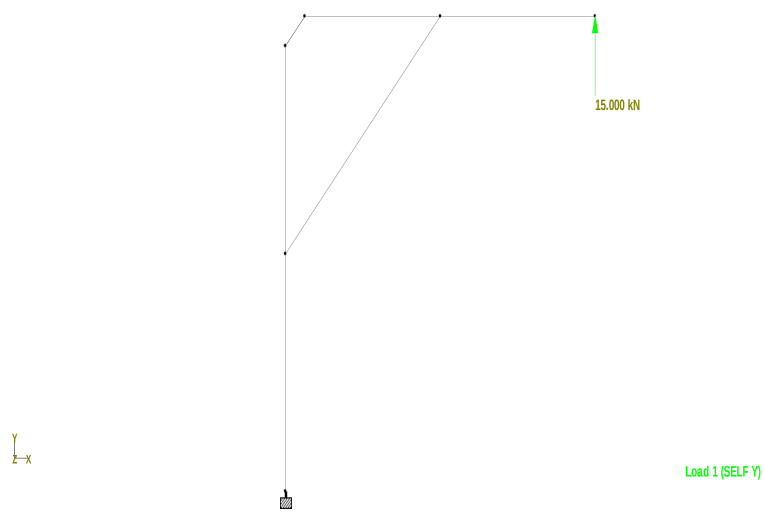

Figure 38 : Specimen B in open joints as per staad

AXIAL FORCE FOR SPECIMEN –C- OPEN JOINT-(IN STAAD)

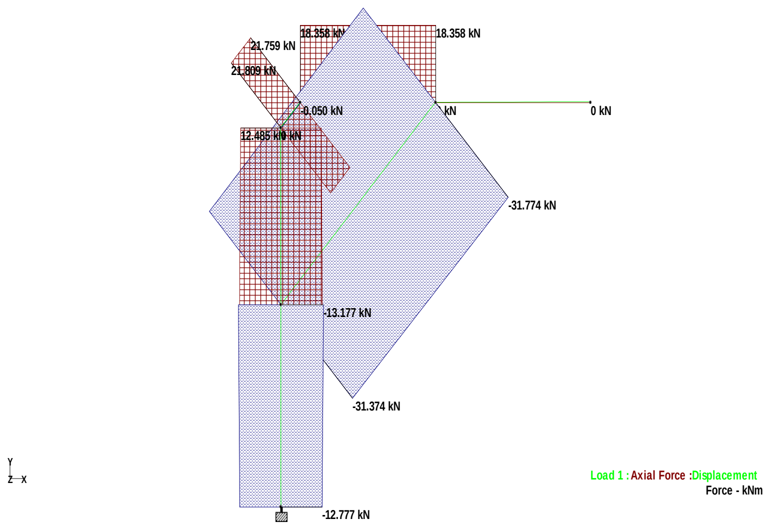

Figure 39 : Axial force for specimen-C –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –C – OPEN JOINT-(IN STAAD)

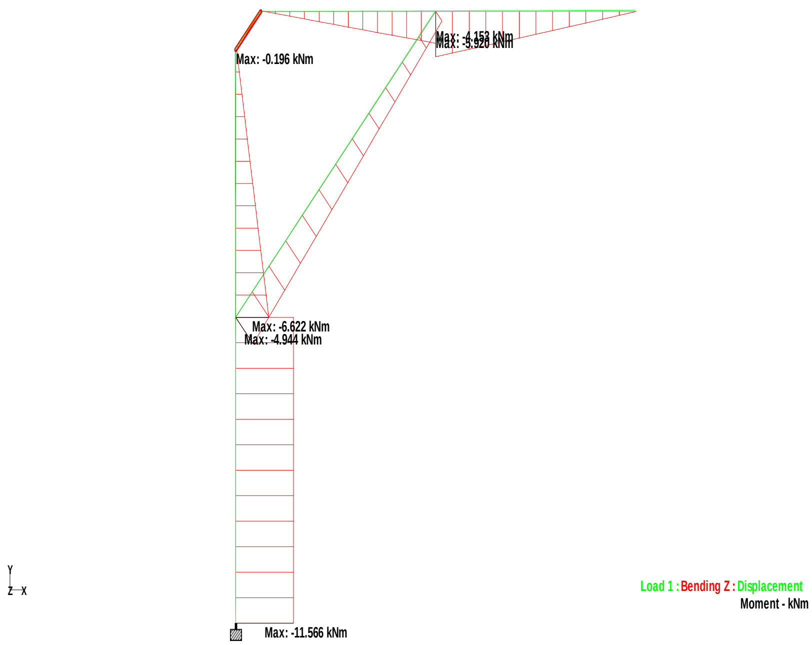

Figure 40 : Bending moments for specimen-C –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-C) BEAM COLUMN JOINT AS PER STAAD -2000– CLOSED JOINT

C O L U M N N O.   3 D E S I G N R E S U L T S

M25   Fe500 (Main)   Fe500 (Sec.)

LENGTH: 350.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

**** GUIDING LOAD CASE: 1 END JOINT: 5 SHORT COLUMN**

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : 12.8

		About Z	About Y
INITIAL MOMENTS	:	6.62	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.26	0.26
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	6.62	0.26

REQD. STEEL AREA : 172.99 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 512.92 Muz1 : 6.88 Muy1 : 6.88

INTERACTION RATIO: 1.00 (as per Cl. 39.6, IS456:2000)

TYPE 4. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN –D) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN –OPEN JOINT

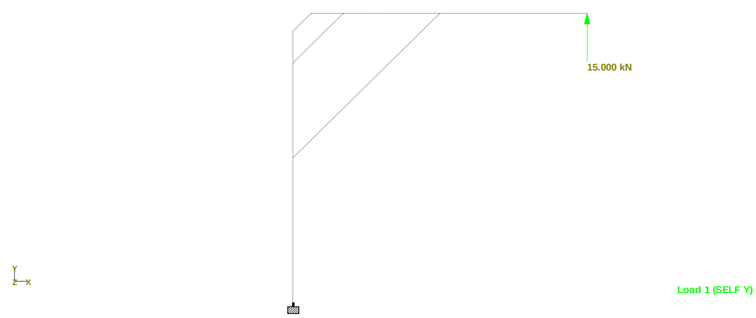

Figure 41 : Specimen –D beam column joints for open joints (In Staad)

AXIAL FORCE FOR SPECIMEN –D- OPEN JOINT-(IN STAAD)

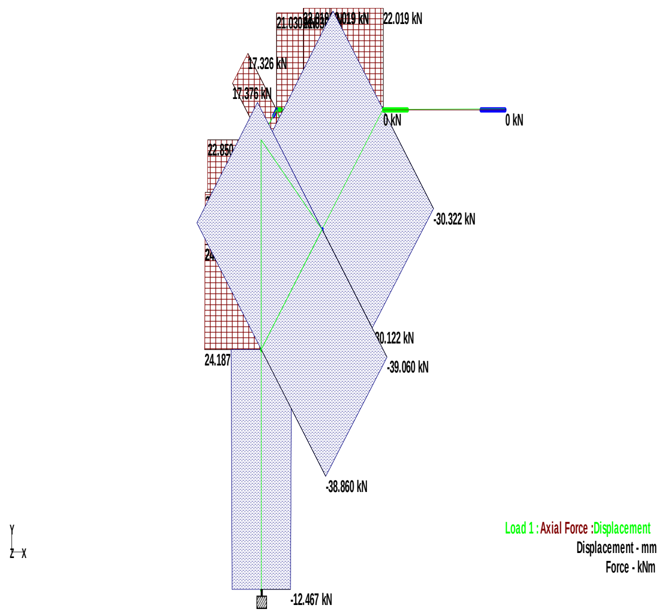

Figure 42 : Axial force for specimen-D –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –D – OPEN JOINT-(IN STAAD)

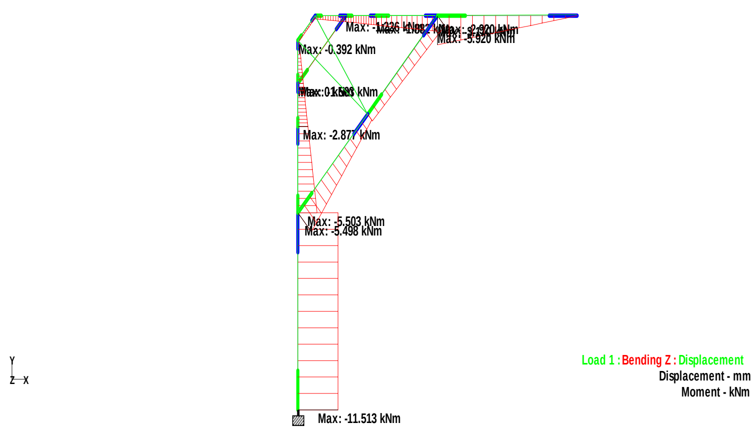

Figure 43: Bending moments for specimen-D –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-D) BEAM COLUMN JOINT AS PER STAAD -2000– OPEN JOINT

C O L U M N N O. 3 D E S I G N R E S U L T S

M25 Fe500 (Main) Fe500 (Sec.)

LENGTH: 175.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

**** GUIDING LOAD CASE: 1 END JOINT: 5 SHORT COLUMN**

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : 13.0

		About Z	About Y
INITIAL MOMENTS	:	6.63	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.26	0.26
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	6.63	0.26

REQD. STEEL AREA : 173.05 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 512.95 Muz1 : 6.90 Muy1 : 6.90

INTERACTION RATIO: 1.00 (as per Cl. 39.6, IS456:2000)

TYPE **1. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – A) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN – CLOSED JOINT**

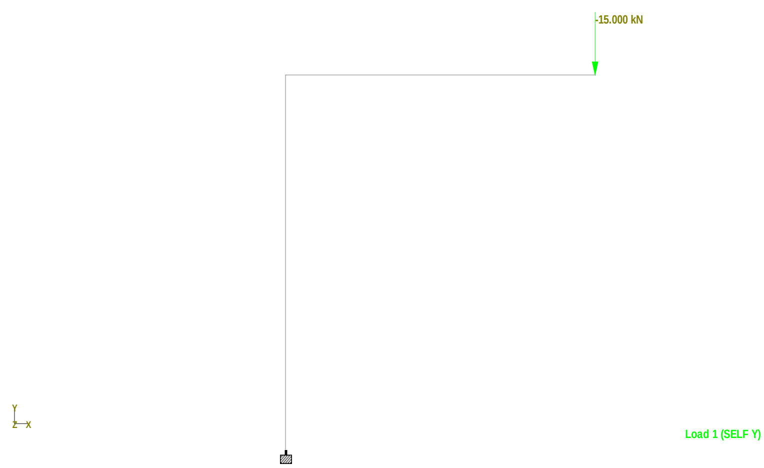

Figure 44 : Specimen –A beam column joints for closed joints (In Staad)

AXIAL FORCE FOR SPECIMEN –A- CLOSD JOINT-(IN STAAD)

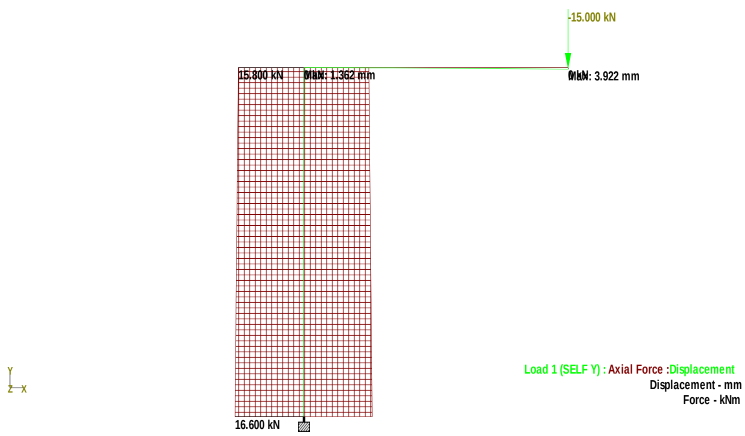

Figure 45 : Axial force for specimen-D –for open joints – (Staad)

(73)

BENDING MOMENT FOR SPECIMEN –A – CLOSED JOINT-(IN STAAD)

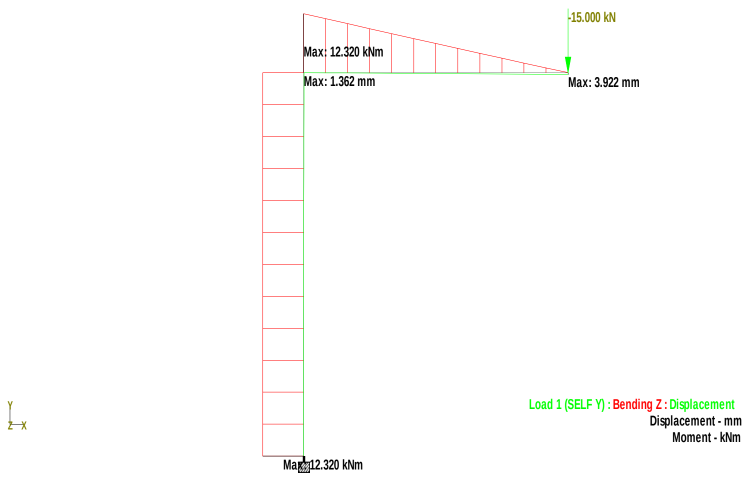

Figure 46 : Bending moments for specimen-D –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-A) BEAM COLUMN JOINT AS PER STAAD -2000– CLOSED JOINT

C O L U M N N O. 1 D E S I G N R E S U L T S

M25 Fe500 (Main) Fe500 (Sec.)

LENGTH: 800.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 1 END JOINT: 9 SHORT COLUMN

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : 15.8

		About Z	About Y
INITIAL MOMENTS	:	12.32	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.32	0.32
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	12.32	0.32

REQD. STEEL AREA : 416.04 Sq.mm.

MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

TYPE 2. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – B) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN – CLOSED JOINT

)

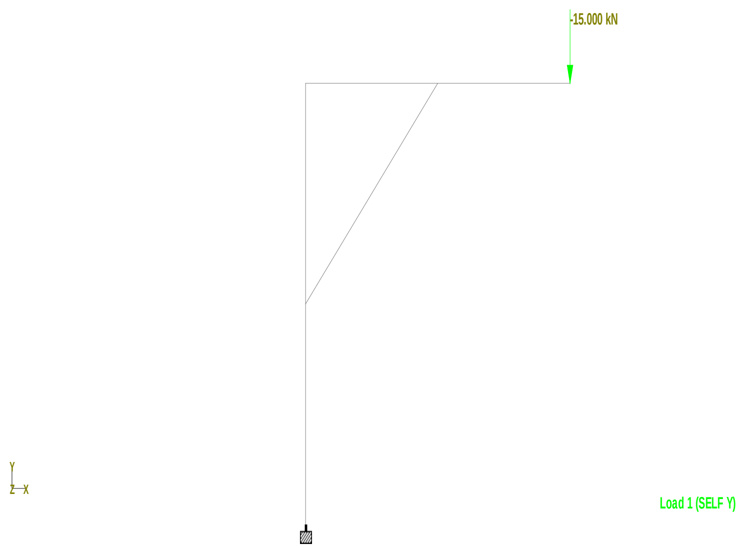

Figure 47 Specimen –A beam column joints for closed joints (In Staad)

AXIAL FORCE FOR SPECIMEN –B- CLOSED JOINT-(IN STAAD)

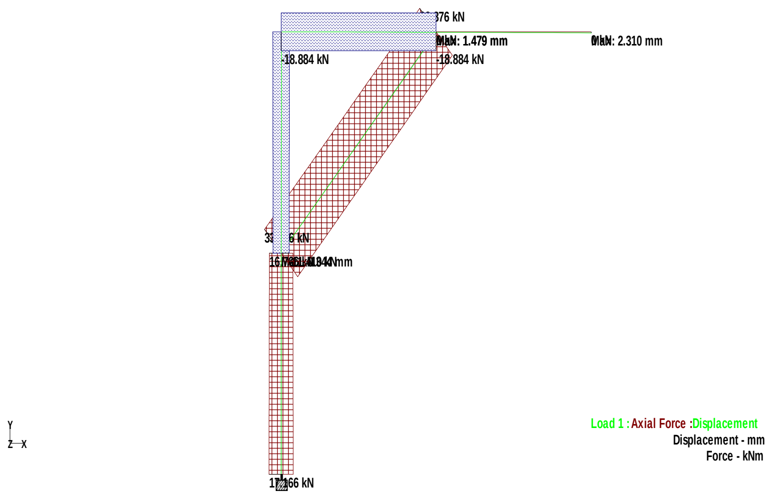

Figure 48 Axial force for specimen-D –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –B – CLOSED JOINT-(IN STAAD)

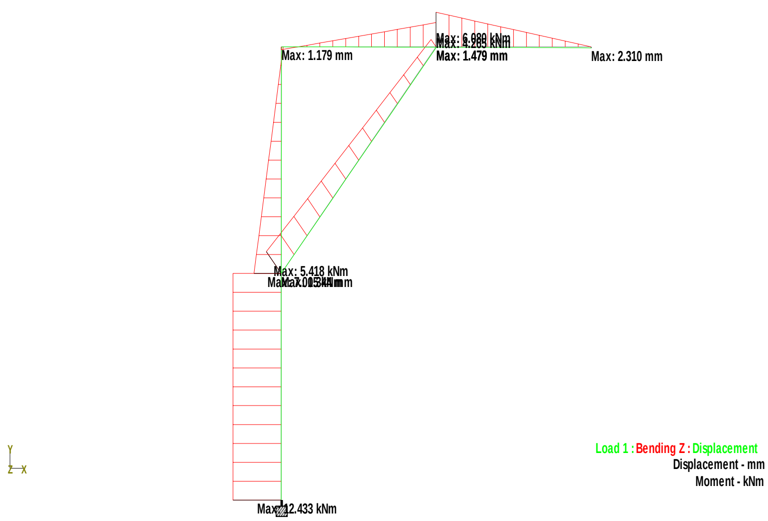

Figure 49 : Axial force for specimen-D –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-B) BEAM COLUMN JOINT AS PER STAAD -2000– CLOSED JOINT

===

C O L U M N N O. 3 D E S I G N R E S U L T S

M30 Fe500 (Main) Fe500 (Sec.)

LENGTH: 400.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 1 END JOINT: 3 SHORT COLUMN

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : -11.8

		About Z	About Y
INITIAL MOMENTS	:	0.54	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.24	0.24
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	0.54	0.24

REQD. STEEL AREA : 320.00 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 655.68 Muz1 : 9.53 Muy1 : 9.53

INTERACTION RATIO: 0.08 (as per Cl. 39.6, IS456:2000)

TYPE 3. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – C) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN – CLOSED JOINT

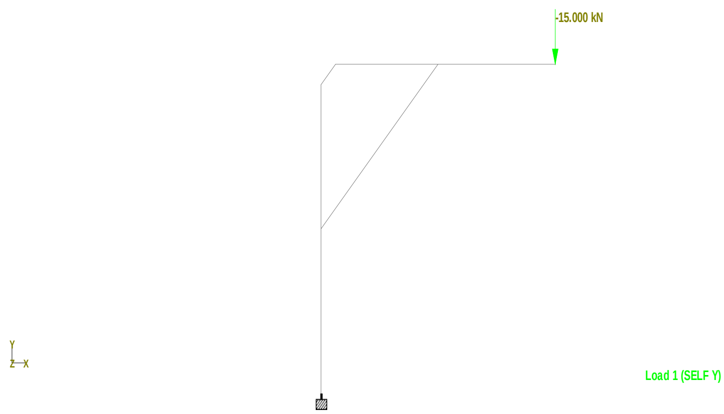

Figure 50 : Beam column joint as per Staad

AXIAL FORCE FOR SPECIMEN –C- CLOSED JOINT-(IN STAAD)

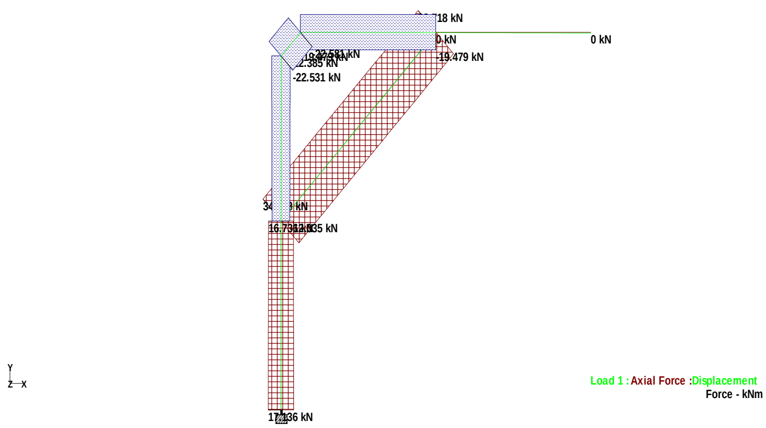

Figure 51 : Bending for specimen-C –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –C – CLOSED JOINT-(IN STAAD)

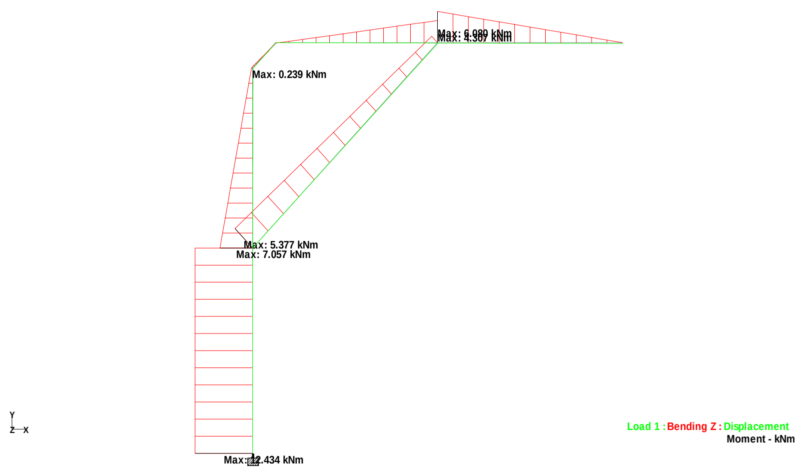

Figure 52 : Axial force for specimen-C –for Closed joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-C) BEAM COLUMN JOINT AS PER STAAD -2000– CLOSED JOINT

C O L U M N N O. 3 D E S I G N R E S U L T S

M25 Fe500 (Main) Fe500 (Sec.)

LENGTH: 350.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 1 END JOINT: 9 SHORT COLUMN

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : -12.4

		About Z	About Y
INITIAL MOMENTS	:	0.24	0.00
MOMENTS DUE TO MINIMUM ECC.	:	0.25	0.25
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	0.25	0.25

REQD. STEEL AREA : 320.00 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 566.40 Muz1 : 9.11 Muy1 : 9.11

INTERACTION RATIO: 0.05 (as per Cl. 39.6, IS456:2000)

TYPE 4. (AS PER IS:13920 BEAM COLUMN JOINTS) STAAD -SPECIMEN – D) FOR A LOAD CONSIDERED AT CANTILIVER PORTION 15 KN – CLOSED JOINT

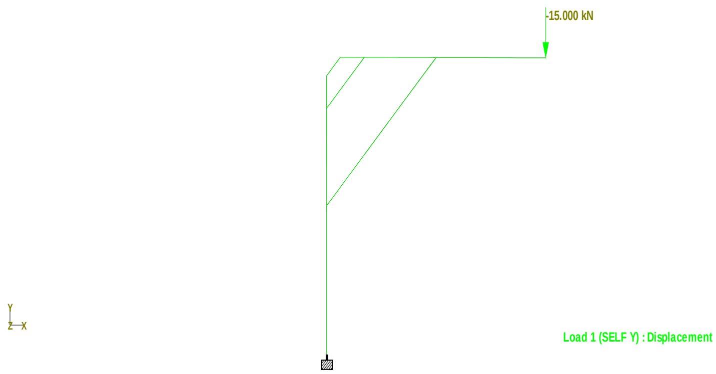

Figure 53 : Beam column joint as per Staad

AXIAL FORCE FOR SPECIMEN –D- CLOSED JOINT-(IN STAAD)

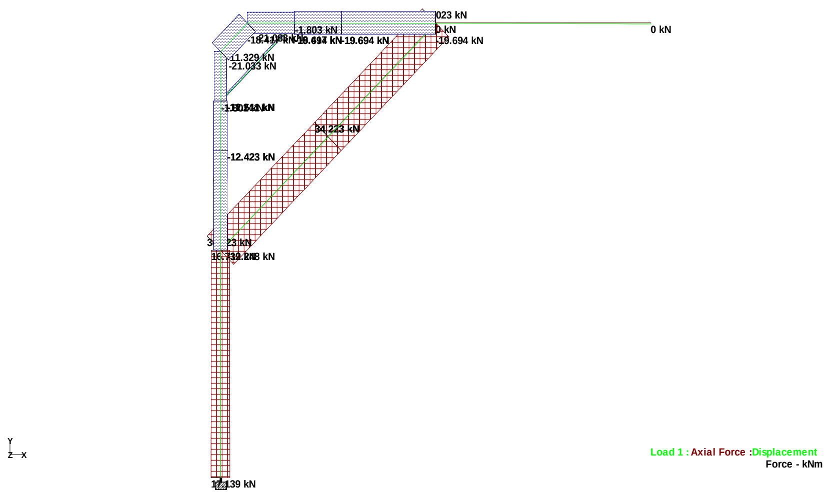

Figure 54 : Axial force for specimen-D –for open joints – (Staad)

BENDING MOMENT FOR SPECIMEN –D – CLOSED JOINT-(IN STAAD)

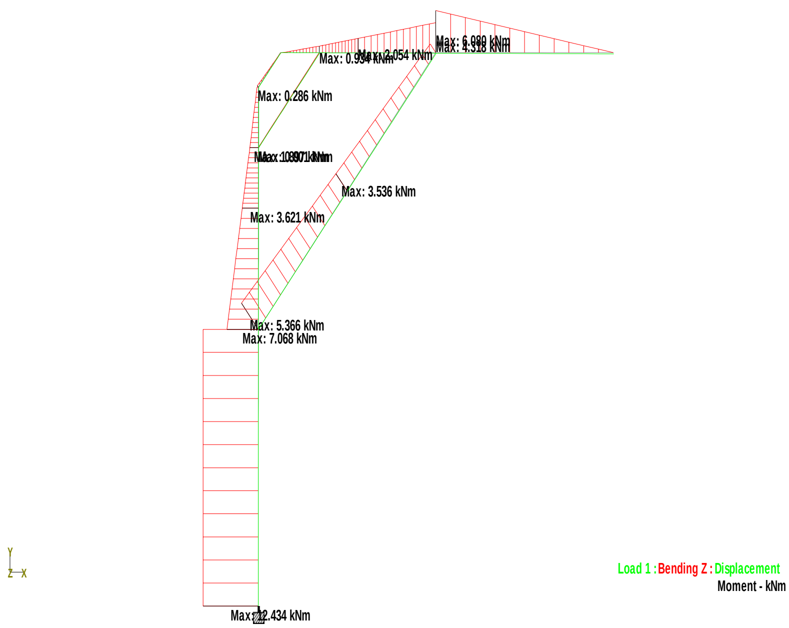

Figure 55 : Axial force for specimen-D –for open joints – (Staad)

DESIGN RESULTS OF (SPECIMEN-D) BEAM COLUMN JOINT AS PER STAAD -2000– CLOSED JOINT

C O L U M N   N O.   3 D E S I G N   R E S U L T S

M25   Fe500 (Main)   Fe500 (Sec.)

LENGTH: 175.0 mm CROSS SECTION: 200.0 mm X 200.0 mm COVER: 40.0 mm

**** GUIDING LOAD CASE: 1 END JOINT: 11 SHORT COLUMN**

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu) : -12.4

		About Z	About Y
INITIAL MOMENTS	:	**3.62**	**0.00**
MOMENTS DUE TO MINIMUM ECC.	:	**0.25**	**0.25**
SLENDERNESS RATIOS	:	-	-
MOMENTS DUE TO SLENDERNESS EFFECT	:	-	-
MOMENT REDUCTION FACTORS	:	-	-
ADDITION MOMENTS (Maz and May)	:	-	-
TOTAL DESIGN MOMENTS	:	**3.62**	**0.25**

REQD. STEEL AREA : 320.00 Sq.mm.
MAIN REINFORCEMENT : Provide 4 - 12 dia. (1.13%, 452.39 Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY (KNS-MET)

Puz : 566.40 Muz1 : 9.10 Muy1 : 9.10
39.6, IS456:2000)

4.0. EXPERIMENTAL WORKS
(Casting and testing of specimen)

4.1. TEST OF SPECIMES MADE FOR EXPERIMENTAL ANALYSIS

The four types of specimen made of beam column joints. Sizes of beam column joints are 0.2 mx0.2m and height of each specimen is 0.9 m. The specimen is designed as per IS-13920.

Specimen –A

The sizes of specimen is 0.2mX0.2m and length of beam and column is 0.9 meter. The sizes of beam as well as column are 0.2x0.2m and 0.90 meter long. We designed as per ductile design by using recommendation of Indian standard codes Is: 13920.

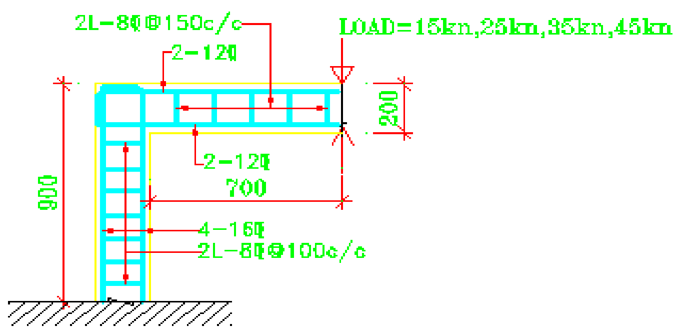

Figure 56 : Specimen A-For open and closed joints

Specimen –B

The sizes of beam and column are same as specimen – A, but in specimen-B we increased concrete area at 45 degree angle and provide nominal reinforcement with ties (As concrete fillet at corner).

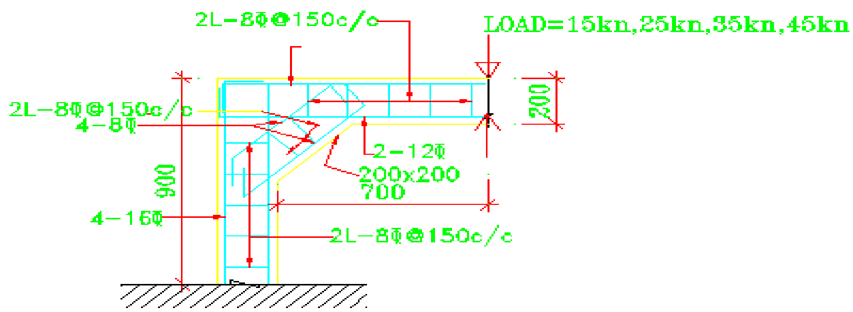

Figure 57 : Specimen B-For open and closed joints

Specimen –C

The sizes of beam and column are same as specimen –A, but in specimen-C both corners fillet and concrete area increased at 45 degree angle and nominal reinforcement are provided with ties (As concrete fillet at corner).

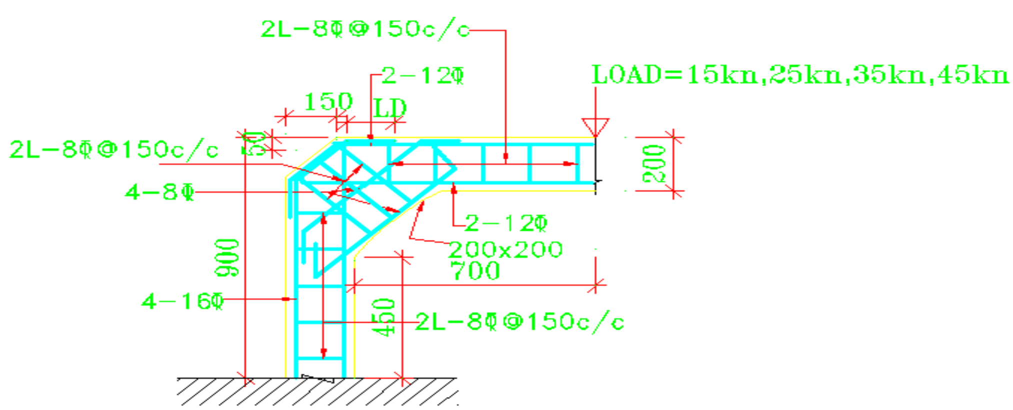

Figure 58: Specimen C-For open and closed joints

Specimen –D

The sizes of beam and column are same as specimen –A, but in specimen-D, both corner fillet concrete area increased at 45 degree angle and nominal reinforcement are provided with ties (As concrete fillet at corner and extra reinforcement its opposite sides).

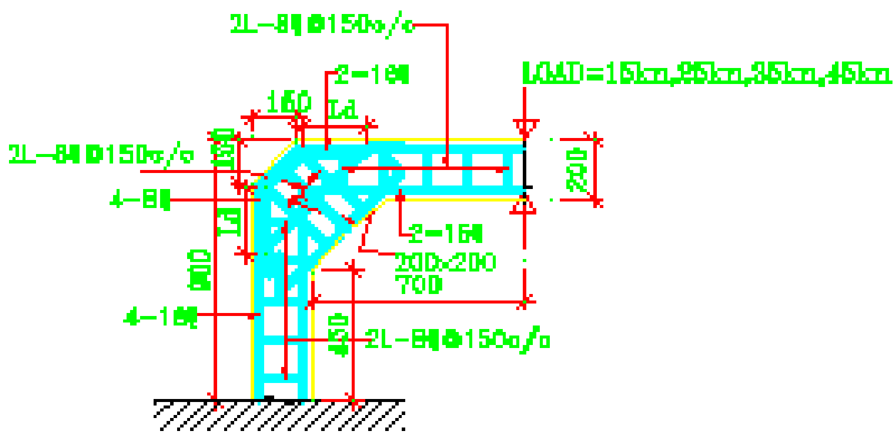

Figure 59 : Specimen D-For open and closed joints

Specimen	Structural Elements	Width (b) (mm)	Width (b) (mm)	Length (L) (mm)	Concrete Cover	Reinforcement		
						Longit udinal	Trans -verse	Fillet (At 45 degree)
A	Beam	200	200	900	25	4-12#	5-8#	0
	Column	200	200	900	25	4-16#	5-8#	
B	Beam	200	200	900	25	4-12#	5-8#	4-8#
	Column	200	200	900	25	4-16#	5-8#	
C	Beam	200	200	900	25	4-12#	5-8#	4-8#
	Column	200	200	900	25	4-16#	5-8#	
D	Beam	200	200	900	25	4-16#	5-8#	4-8# +Extra 1-16# at opposit e side of f fillet
	Column	200	200	900	25	4-16#	5-8#	

Table 1: Dimension and Reinforcement of Specimens

4.2. Details of concrete and Reinforcement are used

The grade of steel are used Fe-500 and the grade of concrete are used M-25 design mix.

In columns 4 numbers main longitudinal reinforcement of 16 dia and transverse reinforcement of column are 5 number of 8 dia are used.

For beam main longitudinal reinforcement 4 numbers of 12 dia and transverse reinforcement of beam (Shear reinforcement) are 5 number of 8 dia are used.

For inclined member 4 numbers of 8 dia are used as main reinforcement and 3 number of ties 8 dia are used.

4.3. Casting and curing :

For the casting of beam column joints are made using wooden mould. Before casting, mould are oiled to prevents the wooden mould to absorbing water from concrete. For good compaction of concrete we used temping rod of 16 mm of diameter and 650 meter length.

The mould of beam column joints are removed after 24 hours of casting .for each times when concreting is done of beam column joints, cube is filled for testing of strength .
For curing gunny bag are used and continuous water are put on the gunny bag so that gunny bag get wet all the times.

Continuous curing is done for 28 days. After 28 days of curing, the specimen are dried and send for testing.

Figure 60: Curing of specimen

4.4. Casting of specimen

4.4A. Specimen before casting and after casting

TYPE 1. (AS PER IS:13920 BEAM COLUMN JOINTS) (BEFORE CASTING-SPECIMEN –A)

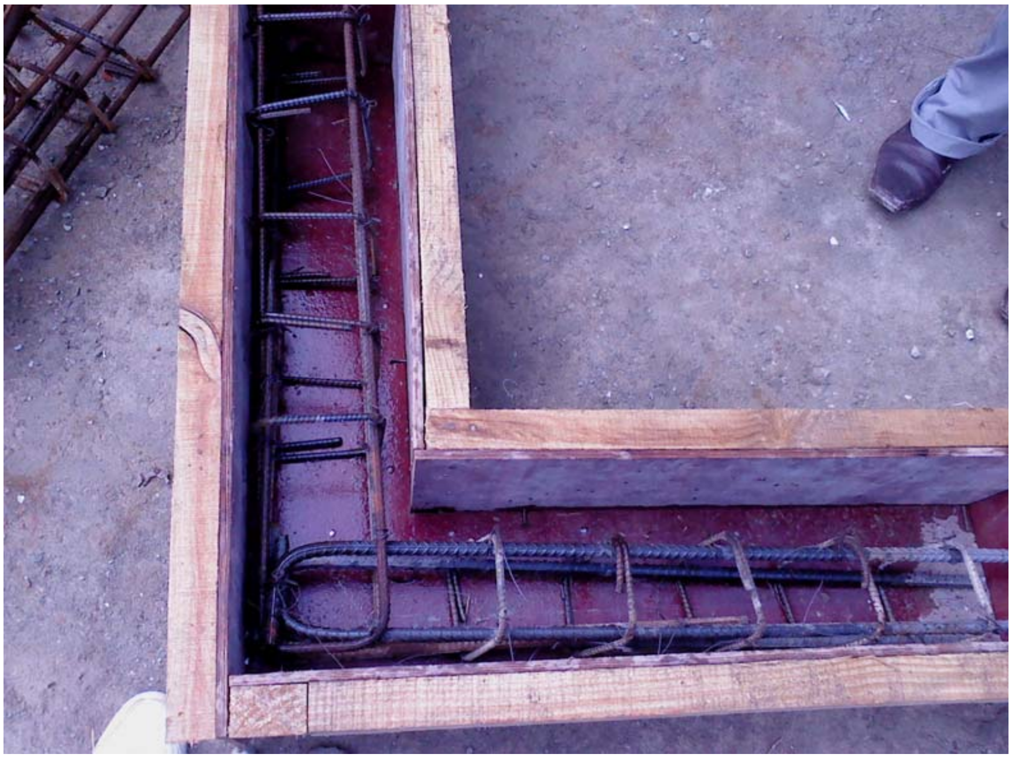

Figure 61: Specimen A before casting

TYPE 1. (AS PER IS:13920 BEAM COLUMN JOINTS) (AFTER CASTING-SPECIMEN –B)

Figure 62: Specimen A-after casting

TYPE 2. FILLET AT CORNER (BEFORE CASTING-SPECIMEN –B)

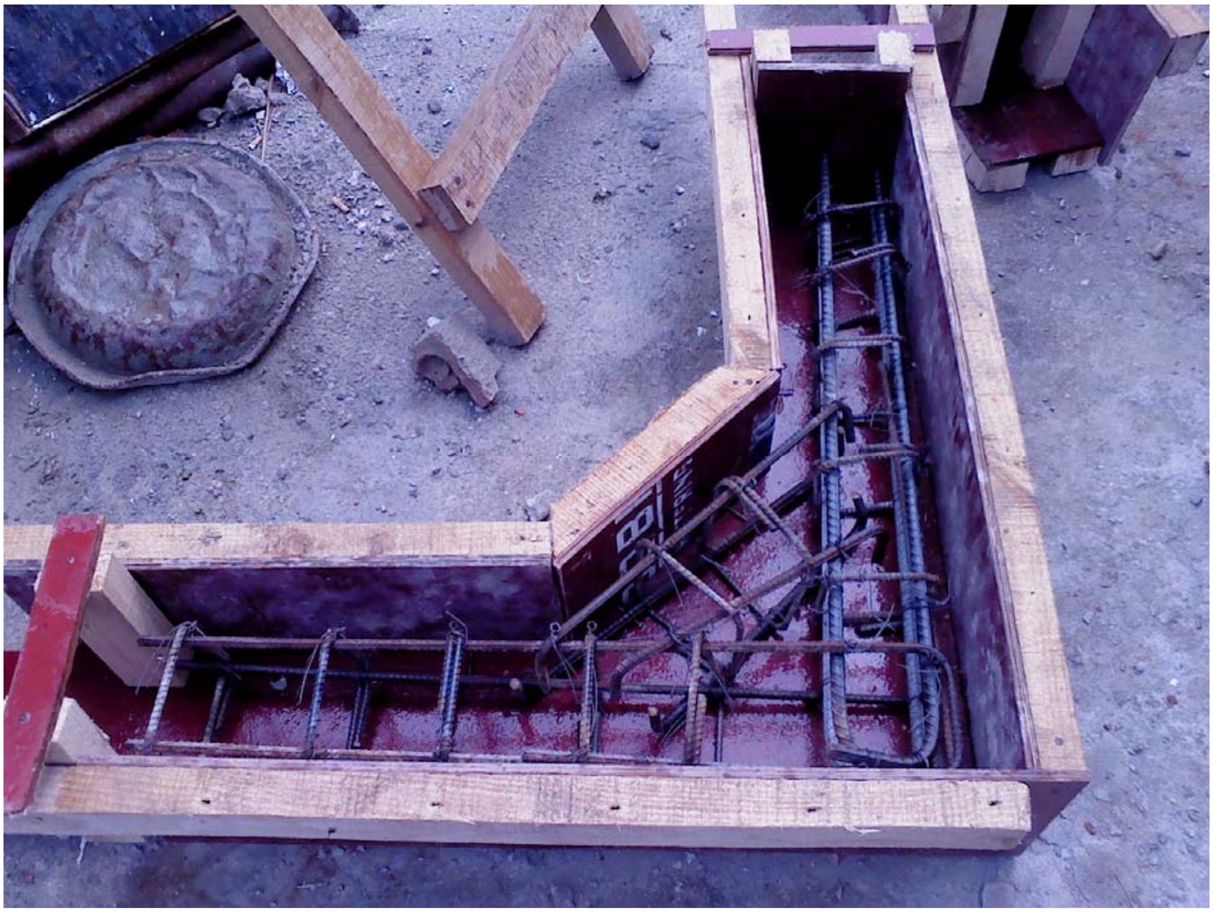

Figure 63: Specimen B before casting

TYPE 2. FILLET AT CORNER (AFTER CASTING-SPECIMEN –B)

Figure 64: Specimen B after casting

TYPE 3. FILLET AT BOTH CORNERS (BEFORE CASTING-SPECIMEN –C)

Figure 65: Specimen C before casting

TYPE 3. FILLET AT BOTH CORNER (AFTER CASTING-SPECIMEN –C)

Figure 66: Specimen C after casting

TYPE 4. FILLET AT BOTH CORNER WITH SAME R/F CONTINOU and EXTRA R/F AT TOP (BEFORE CASTING-SPECIMEN –D)

Figure 67: Specimen C before casting

TYPE 4. FILLET AT BOTH CORNER WITH SAME R/F CONTINOU and EXTRA R/F AT TOP (AFTER CASTING-SPECIMEN –D)

Figure 68: Specimen D after casting

4.5 Testing of Cubes and Reinforcements:

(a) Cubes : Before test

Figure 69: Cubes before testing

(b) Cubes : After test

Figure 70: Cubes after testing

Sample (Concrete Cubes) Test for Compressive Strength 25N/mm2 for Design Mix M-25.

Sample (Concrete Cubes) after Test we get Compressive Strength 29 N/mm2 for Design Mix M-25

4.6 Instrumentation and test setup

(a) Loading frame with load capacity of 100 KN

(b) Proving ring capacity 200 KN

(c) Hydraulic jack capacity 1000 KN

Specimen fix with loading frame , after fixing it using proving ring above hydraulic jack and load applied by using hydraulic jack . At load continuous increasing at a time come the specimens failed at deferent fashion. We noted down failure loads and compare these loads from analytical results and found those loads are almost same.

Figure 71 : Test setup -1

Figure 72 : Final Test setup -2

4.7 Transportation of Specimen

(a) Step- 1

Figure 73 : Transportation of specimen stage-1

(b) Step- 2

Figure 74: Transportation of specimen stage-2

(c) Step- 3

Figure 75: Transportation of specimen stage-3 – (Lifting using Crane)

(d) Step- 4

Figure 76: Transportation of specimen final stage-4

4.8 Test Results

4.8A. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A1- SPECIMEN- FOR CLOSE JOINT

(a) Up to 2 Mton no crack appear

FIGURE 77: TYPE –A-SPECIMEN AFTER TEST-CLOSE JOINT

4.8A. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A1- SPECIMEN- FOR CLOSE JOINT

(b) At 2.5 Mton crack appear at joints

FIGURE 78: TYPE –A-SPECIMEN AFTER TEST-OPEN JOINT

4.8B. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A2-SPECIMEN-IN CLOSED JOINT

(a) At 2.5 Mton first crack appear at joints

FIGURE 79: TYPE –A2--SPECIMEN AFTER TEST

4.8B. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A2- SPECIMEN-IN CLOSE JOINT

(b) At 4 Mton crack progress at joints

FIGURE 80: TYPE –A2-SPECIMEN AFTER TEST

4.8C. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A3-SPECIMEN-IN OPEN JOINT

(a) Up to 2.o Mton no crack appear

FIGURE 81: TYPE –A2--SPECIMEN AFTER TEST-OPEN JOINT

4.8C. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A3- SPECIMEN-IN OPEN JOINT

(b) At 2.0 Mton first crack appear at joints

FIGURE 82: TYPE –A3 - SPECIMEN AFTER TEST-OPEN JOINT

4.8D. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –A4-SPECIMEN-IN OPEN JOINT

FIGURE 83: TYPE –A4-SPECIMEN AFTER TEST-OPEN JOINT

4.8E. AFTER THE TEST FAILURE PATTERN OF SAMPLE- TYPE –BI- SPECIMEN-IN OPEN JOINT

FIGURE 84: TYPE –B - SPECIMEN AFTER TEST-CLOSE JOINT

5.0 Results

5.1 Load and Deflection Relationship

Forces on Close Joint

S. No.	Specimen	Load (in Kn)	Axial Force (in Kn)	Moment (in Kn)		Shear Force (in Km)	Maximum Deflection (in mm)
		(P)	(Fx)	(Mz)	(Mx)	(V)	**(δ)**
1	A	15 Kn	15.8	12.23		15.8	3.922
	B	15 Kn	11.4	0.54		18.8	2.31
	C	15 Kn	12.03	0.24		19.479	2.31
	D	15 Kn	11.34	0.29		19.7	2.31
2	A	25 Kn	25.8	20.32		25.8	6.472
	B	25 Kn	19.28	0.9		31.1	3.799
	C	25 Kn	20.649	0.38		32.1	3.791
	D	25 Kn	18.9	0.45		30.3	3.789
3	A	35 Kn	35.8	28.3		35.8	9.023
	B	35 Kn	27.55	1.252		43.3	5.29
	C	35 Kn	28.563	0.53		44.74	5.28
	D	35 Kn	26.47	0.64		42.25	5.275
4	A	45 Kn	45.8	36.32		45.8	11.573
	B	45 Kn	35.43	1.7		55.51	6.778
	C	45 Kn	37.12	0.67		57.31	6.769
	D	45 Kn	34.044	0.81		54.16	6.76

Table 2: Forces on Close Joint

We seen that from above results the maximum deflection are reduced, as we compare with Specimen – A and found that the around 40% deflection are reduced in specimen B C and D .

Forces on Open Joint

S. No.	Specimen	Load (in Kn)	Axial Force (in Kn)	Moment (in Kn)		Shear Force (in Km)	Maximum Deflection (in mm)
		(P)	(Fx)	(Mz)	(Mx)	(V)	**(δ)**
1	A	15 Kn	13.4	11.61		15	3.728
	B	15 Kn	11.8	0.53		0.53	2.159
	C	15 Kn	12.4	0.196		0.19	2.154
	D	15 Kn	11.1	0.39		0.39	2.153
2	A	25 Kn	23.4	19.68		24.20	6.278
	B	25 Kn	19.68	0.90		30.00	3.649
	C	25 Kn	20.67	0.34		30.97	3.64
	D	25 Kn	18.959	0.42		29.25	3.639
3	A	35 Kn	34.2	27.68		35	8.82
	B	35 Kn	27.52	1.24		42	5.13
	C	35 Kn	28.9	0.49		43.5	5.13
	D	35 Kn	26.53	0.59		41.2	5.12
4	A	45 Kn	44-2	35.68		45	11.38
	B	45 Kn	35.4	1.6		54.5	6.63
	C	45 Kn	37.2	0.63		56.2	5.13
	D	45 Kn	34.12	0.77		56.83	5.12

Table 3: Forces on Open Joint

5.2. Graph of Load and Deflection Relationship

For Close Joint Specimen - A

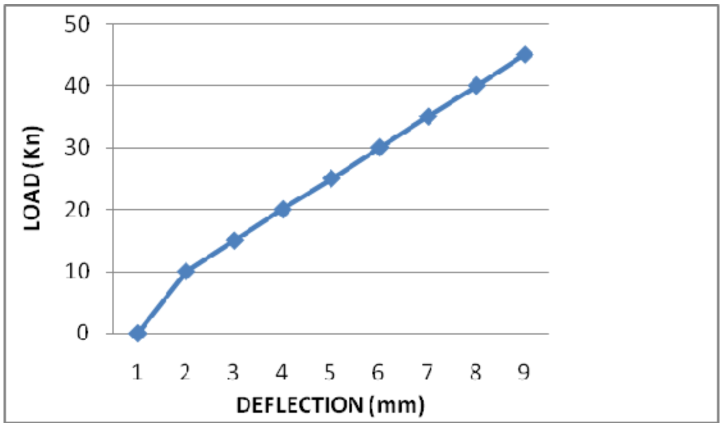

Figure 85: Load deflection curve for closed joints – (Specimen-A)

For Close Joint Specimen B

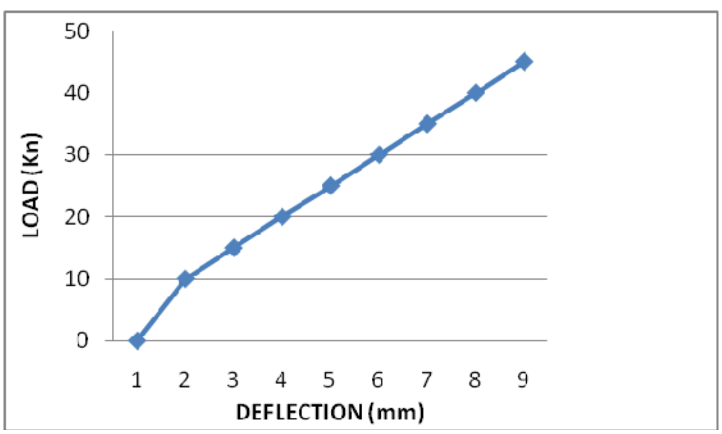

Figure 86: Load deflection curve for closed joints –(Specimen-B)

For Close Joint Specimen C

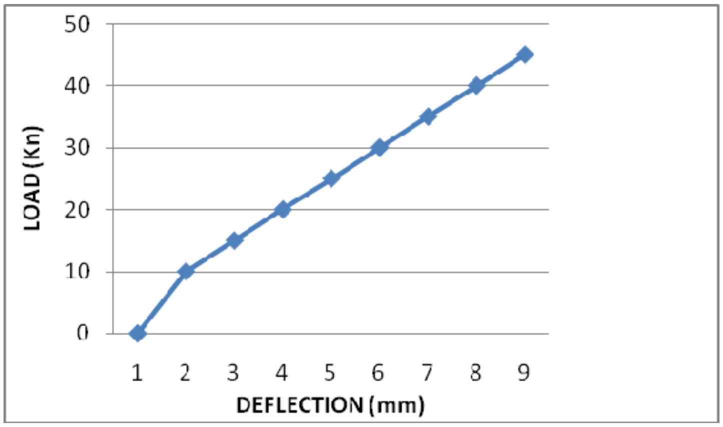

Figure 87: Load deflection curve for closed joints –(Specimen-C)

For Close Joint Specimen D

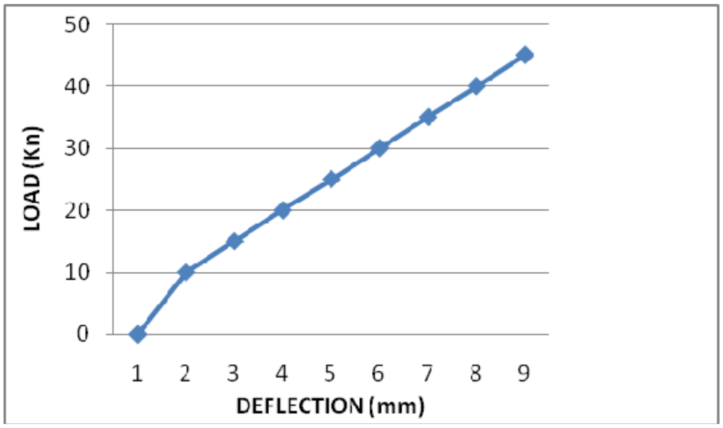

Figure 88: Load deflection curve for closed joints –(Specimen-D)

For Open Joint Specimen A

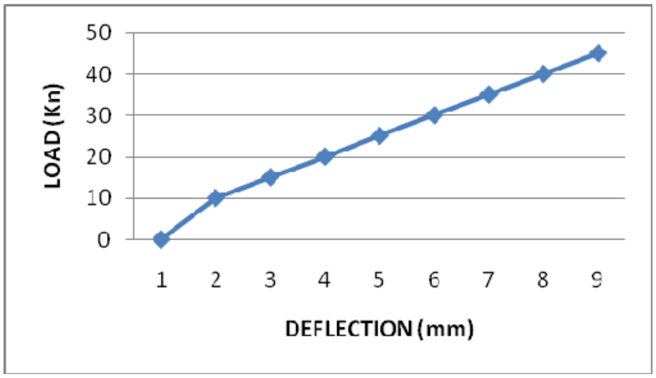

Figure 89: Load deflection curve for open joints –(Specimen-A)

For Open Joint Specimen B

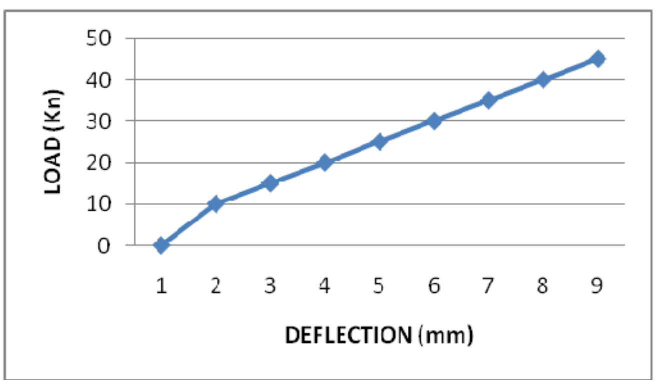

Figure 90: Load deflection curve for open joints –(Specimen-B)

For Open Joint Specimen C

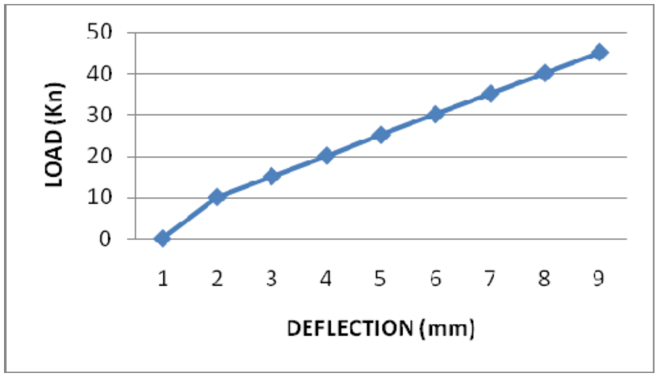

Figure 91: Load deflection curve for open joints –(Specimen-C)

For Open Joint Specimen D

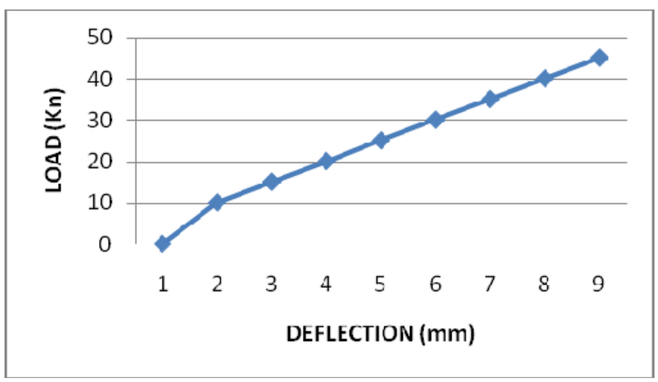

Figure 92: Load deflection curve for open joints –(Specimen-D)

5.3 Failure load in Specimen

For opening joints

S.N.	TYPES OF SPICEMEN	FAILURE LOAD(Analytical)	FAILURE LOAD(Experimental)
1	A	25 KN	25 KN
2	B	45 KN	100 KN (Not fail)
3	C	45 KN	100 KN (Not fail)
4	D	50 KN	100 KN (Not fail)

Table 4: Failure load in Specimen (For opening joints)

FOR OPEN JOINTS FAILURE LOAD

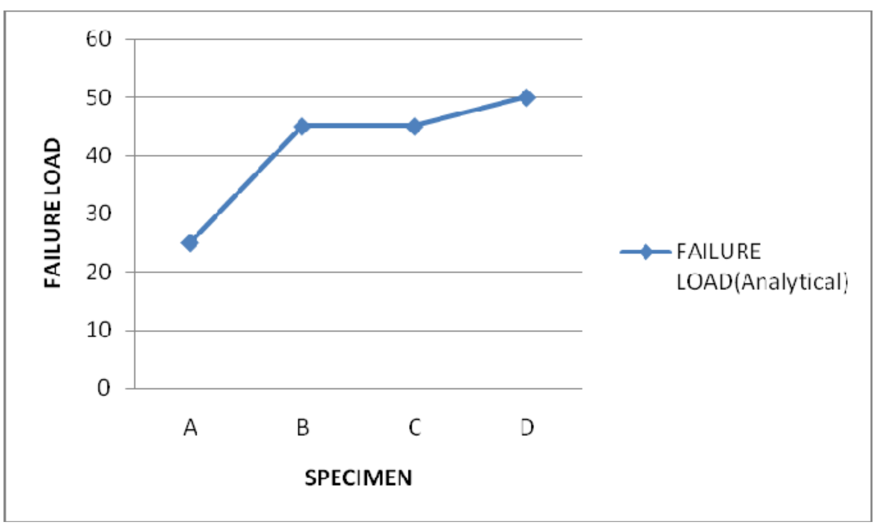

Figure 93: Load deflection curve for open joints (Specimen-D)

For closing joints

S.N.	TYPES OF SPICEMEN	FAILURE LOAD(Analytical)	FAILURE LOAD(Experimental)
1	A	28 KN	20 KN
2	B	45 KN	100 KN (Not fail)
3	C	45 KN	100 KN (Not fail)
4	D	50 KN	100 KN (Not fail)

Table 5: Failure load in Specimen (For closing joints)

FOR CLOSED JOINTS FAILURE LOADS

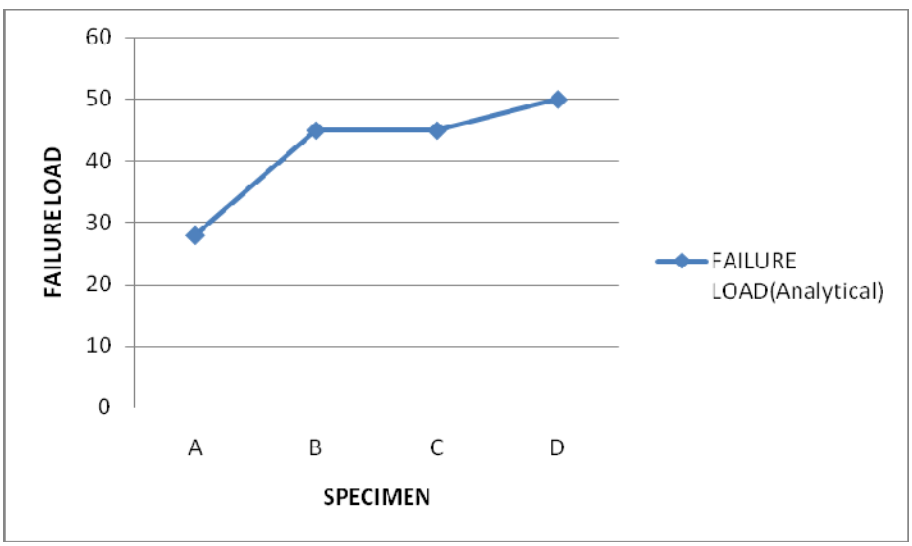

Figure 94: Load deflection curve for closed joints –(Specimen-D)

5.4 Crack pattern

As we seen in experimental results and failure pattern for specimen A1 and A2 for closed joints the failure occurs at tension face of the section and it is outer sides of the joints.

As we seen in experimental results and failure pattern for specimen A3 and A4 for open joints the failure occurs at tension face of the section and it is inner sides of the joints.

For specimen A the failure pattern is joints failure.

For specimen B, C and D are unable to fail and the loading frame exceeds its maximum capacity.

CONCLUSIONS

1. **The failure load of specimen –D are much higher than all other specimen, the failure load are 100% more than specimen –A for both cases of open joints and closed joints. That means we can say that the beam column joint are stronger if we used specimen -D.**

2. **The failure load of specimen B and C are also increased around 80% for open joints and 60% for closed joints. As compare to specimen –A.**

3. **The maximum deflection reduced around 40%, if we used any one of the specimen B, C and D. If we reduced such a great amount of deflection, it will very good for serviceability points of view.**

4. **Since reinforcement is 60 times costlier than concrete, so we can economies the structure by increasing the concrete area and by reducing the reinforcement as joints capacity increased.**

5. **We also use fillet at corner and give curved finishing at corner at beam column joint, it may leads to architectural aesthetic/appearance and reduced the overall cost of Structure.**

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