Third International Conference on Sustainable Construction Materials and Technologies http://www.claisse.info/Proceedings.htm

THE STRUCTURAL BEHAVIOUR OF COMPOSITE BEAMS WITH PREFABRICATED REINFORCED CONCRETE PLATE IN POZITIVE MOMENT ZONE

A. Necati YELGIN[1], H. KASAP[2], M.Zeki OZYURT[3] and M. Bora BULUT[4]

[1]*Sakarya University, Sakarya, Turkey*
[2]*Sakarya University, Sakarya, Turkey*
[3]*Sakarya University, Sakarya, Turkey*
[4]*Sakarya University, Sakarya, Turkey*

[1]*Sakarya University, Sakarya - Turkey, yelgin@hotmail.com*
[2]*Sakarya University, Sakarya - Turkey, hkasap@sakarya.edu.tr*
[3]*Sakarya University, Sakarya - Turkey, ozyurt@sakarya.edu.tr*
[4]*Sakarya University, Sakarya - Turkey, Borabulut@gmail.com*

ABSTRACT

The beam which is considered in this study was composed of a prefabricated reinforced concrete plate with dimensions of (3000 x 800 x 100 mm) with a steel profile (INP 120) under the beam. The steel reinforcement which should exist in the positive moment zone of the prefabricated reinforced concrete plate is placed in while the plate is being manufactured. Epoxy resin is used to provide the connection between the prefabricated concrete plate and the steel profile. The sliding and the lifting forces between the prefabricated reinforced concrete plate and the steel profile are transferred by the agglutination property of the epoxy resin. The results which were obtained in this experimental study were in accordance with the results of theoretical computations that were done. In this study of the cooperation between the prefabricated reinforced concrete plate and the steel profile, the effect of concrete quality variation on the bearing strength was researched and certain suggestions are presented.

Keywords. Composite Beams, Reinforced Concrete Plate, Steel Profile, Epoxy Resin, Structural Behaviour.

INTRODUCTION

Composite beams which are composed of reinforced concrete floor plate and steel beams or bridge floor and steel beams are more economical than steel beams that carry reinforced concrete plate freely on their own. In a composite beam the tensile component of the force pair caused by bending is carried by the steel profile while the compressive component that is also due to bending is carried by either reinforced plate or by the reinforced concrete plate and steel profile cooperation system. Therefore, the steel profiles are only partially or not at all subjected to the compressive component of bending. In this way, the reinforced concrete plate carrying the dead load turns out to be a useful element that carries the compressive component. By this cooperation, the lever arm of the force pair becomes greater and thus a good economical factor is constituted by this situation.

Composite beams are always lighter than reinforced concrete beams. In the composite beam, less steel is used than in reinforced concrete beams which have the same height.

In composite beams, a combination material called epoxy resin is used to provide the cooperation between the prefabricated reinforced concrete plate and the steel profile. During the cooperation between the concrete and the steel profile, the sliding and the lifting forced between the two materials are transferred by the help of the epoxy resin.

There are no published research about this subject (Especially regarding composite beams which consist of reinforced concrete plate and t steel profile combined by epoxy resin in the positive moment zone).

Generally in studies with epoxy resin, the cooperation between the steel plate and the reinforced concrete beam is researched.

The main purpose of our study was to research the bearing behavior of reinforced concrete beams and steel elements in the positive moment zone and also how the cooperation by means of the steel profile and plates existing in the reinforced concrete beam (agglutinated with epoxy resin) is materialized (sliding and separation of epoxy resin from the steel etc.).

In the experimental studies which were carried out by R.N. Swamy and R. Jones (Swamy,1987), R.N. Swamy and R. Jones (Swamy, 1989), R.N. Swamy and B. Hobbs (Swamy, 1995), the bearing capacities and the bearing behavior of reinforced concrete beams with steel elements agglutinated by epoxy resin and how the sliding and the separation between the steel element and the reinforced concrete beam is materialized, were researched.

Additionally, in the studies of Dr. T.M. Roberts and H. Haji - Kazemi (Roberts, 1989), certain theoretical model researches were done to determine the distribution of the sliding and the normal strain throughout the coherence surface of beams which are composed of reinforced concrete plate and steel elements agglutinated with epoxy resin. Equations derived from their results were suggested for these kinds of composites.

OBJECTIVE

The objective of the study was to research the influence of the epoxy resin which provides the cooperation of the prefabricated reinforced concrete plate and the steel profile in the positive moment zone on the bearing behavior of the composite beam and also to find out how the additional equipment located in the composite beam affect its bearing behavior. As a result of the deformation of the composite beam under loading, the epoxy resins degree of prevention of rising and sliding of the prefabricated reinforced concrete collaborating with the steel profile was researched. The quality of the reinforcement that was placed in the reinforced concrete plate was BS-1 and that of the steel profile which formed the composite beams was St 37. The quality of the steels which were used is determined exactly by tensile tests.

The results of this experimental study were be compared with that of theoretical computations. The effect of variation of interconnection element distances was researched and certain suggestions are presented.

COMPOSITE BEAMS IN THE POSITIVE MOMENT ZONE

The computations of the composite beams were done according to the plastic theory. In plastic theory, the strain distribution of the concrete and the steel is accepted as the rectangular form (Figure 1). In the positive moment zone, the prefabricated reinforced concrete reacts to the compression and the steel reacts to either the tension completely or sometimes reacts both to tension and partially to compression. In composite beams, concrete always reacts to the compression because the tensile strength of the concrete is so minimal as to be almost zero. The tensile and the compression strength of the steel is so high that it can both react to tension and compression if needed.

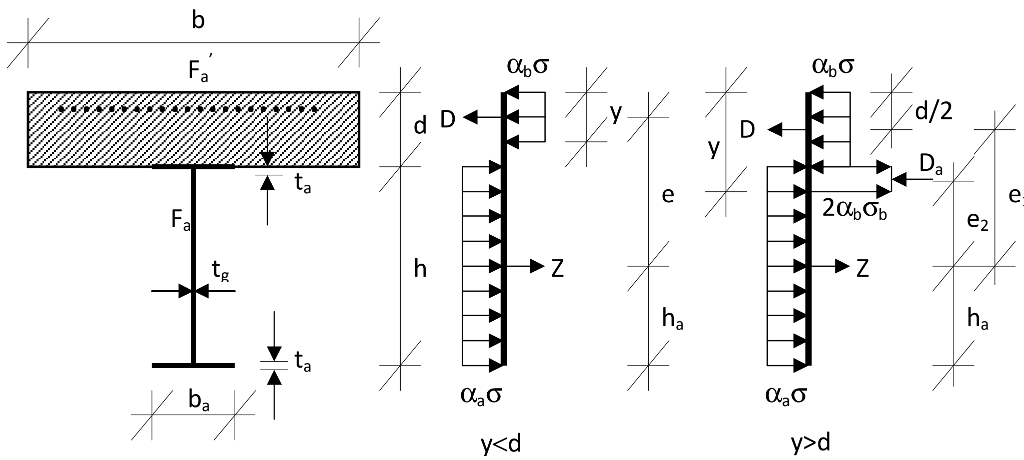

Figure 1. The Behavior of the Composite Beams in the Positive Moment Zone

The location of the objective axis, α_a and α_b are the two variable reducing coefficients changing according to the certain instructions, σ_F is the yield strength of the steel material and σ_b is the cubic strength,

α_c : $\alpha_a = 1$, according to the instructions of European Steel Convention (ECCS). In the English, German and American instructions, $\alpha_a = 0.87 \sim 1.00$

α_b: In the English instructions $\alpha_b = 0.44$, in the German instructions $\alpha_b = 0.60$, in the American Instructions $\alpha_b = 0.74$ and according to the European Steel Convention (ECCS) $\alpha_b = 0.40$

The tensile force which occurs in the steel profile is determined by equation 1;

$$Z = \alpha_a.\sigma_F.F_a \qquad (1)$$

The compression force which occurs in the concrete is determined by equation 2;

$$D = \alpha_b . b . \sigma_b . y \tag{2}$$

Here, y is the distance of the objective axis and is determined by equation 3;.

$$y = \frac{\alpha_a . \sigma_F . F_a}{\alpha_b . b . \sigma_b} \tag{3}$$

In the situation of the double symmetrical cross section the real values of h_o and h_{au} which are taken h / 2 are shown as follows 4,5:

$$h_{ao} = t_{bo} + \frac{\frac{F_a}{2} - b_{ao} . t_b}{t} \tag{4}$$

and

$$h_{au} = h - h_{ao} \tag{5}$$

- If $y \leq d$ then M_u, the bending moment which can be carried by the composite beam is determined by equation 6;

$$M_u = Z.e = Z\left[h_{ao} + d - \frac{y}{2}\right] \tag{6}$$

- If the objective axis of the composite beam is under the reinforced concrete plate (y>d), to determine the location of the objective axis, equations 7 - 10 are used;

$$D_b = \alpha_b . b . d . \sigma_b \tag{7}$$

$$D_a = Z - D_b \tag{8}$$

$$F_{cd} = \frac{D_a}{2 . \alpha_a . \sigma_{Fa}} \tag{9}$$

$$y_c = \frac{F_{ad}}{b_{ao}} \tag{10}$$

- If $y_a \leq t_{bo}$ then $y = d + y_a$ and so M_u, the bending moment which can be carried by the cross section of the composite beam is determined by equation 11;

$$M_u = e_1.D_b + e_2.D_a = D_b\left[h_{ao} + \frac{d}{2}\right] + D_a\left[h_{ao} - \frac{y_a}{2}\right] \tag{11}$$

- If $y_a > t_{bo}$ then M_u is determined by equations 12 - 17;

$$D_{ab} = 2.\alpha_a.b_{ao}.t_{bo}.\sigma_F \tag{12}$$

$$D_{ag} = D_a - D_{ab} \tag{13}$$

$$F_{ag} = D_a/(2\alpha_a.\sigma_F) \tag{14}$$

$$y_{ag} = F_{ag}/t_g \tag{15}$$

$$y = d + t_{bo} + y_{ag} \tag{16}$$

$$M_u = e_1.D_b + e_{2b}.D_{ab} + e_{2g}.D_{ag} =$$

$$D_b\left[h_{ao} + \frac{d}{2}\right] + D_{ab}\left[h_{ao} - \frac{t_b}{2}\right] + D_{ag}\left[h_{ao} - t_b - \frac{y_{ag}}{2}\right] \tag{17}$$

EXPERIMENTAL STUDY

The composite beam was composed of a prefabricated reinforced concrete plate in dimensions of 3000 x 800 x 100 mm and a steel profile. The reinforced concrete plate that formed the compressive headpiece of the composite beam was connected with the steel profile later in the manufacturing process (Figure 2 and Figure 3).

While the composite beam was being prepared, the various elements which provide the connection between the prefabricated reinforced concrete plate and the steel profile were placed in the concrete during the production of the reinforced concrete plate. The connection elements were composed of UNP 80 profile to provide connection between the prefabricated reinforced concrete plate and the steel profile.

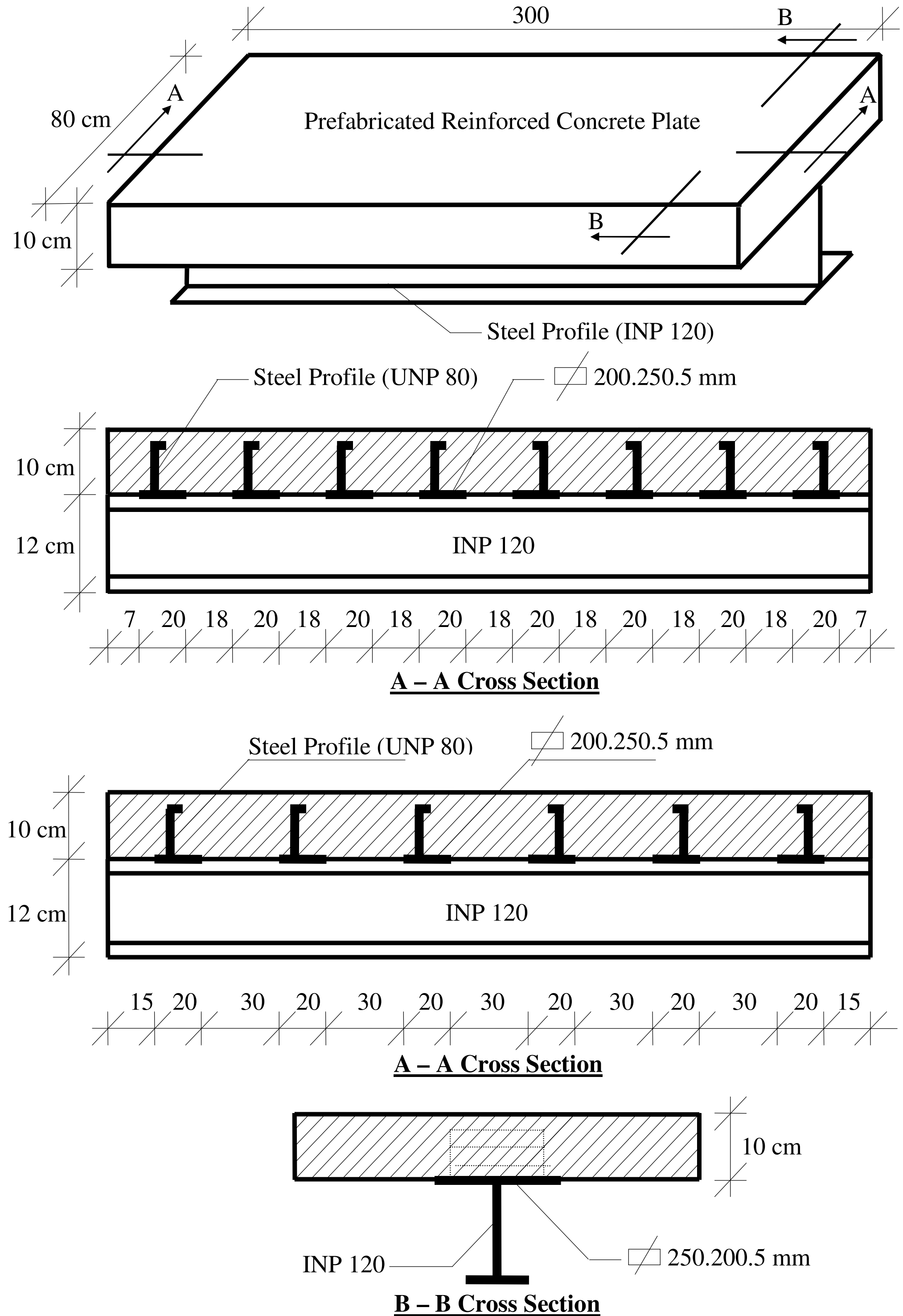

Figure 2. Details of Composite Beams

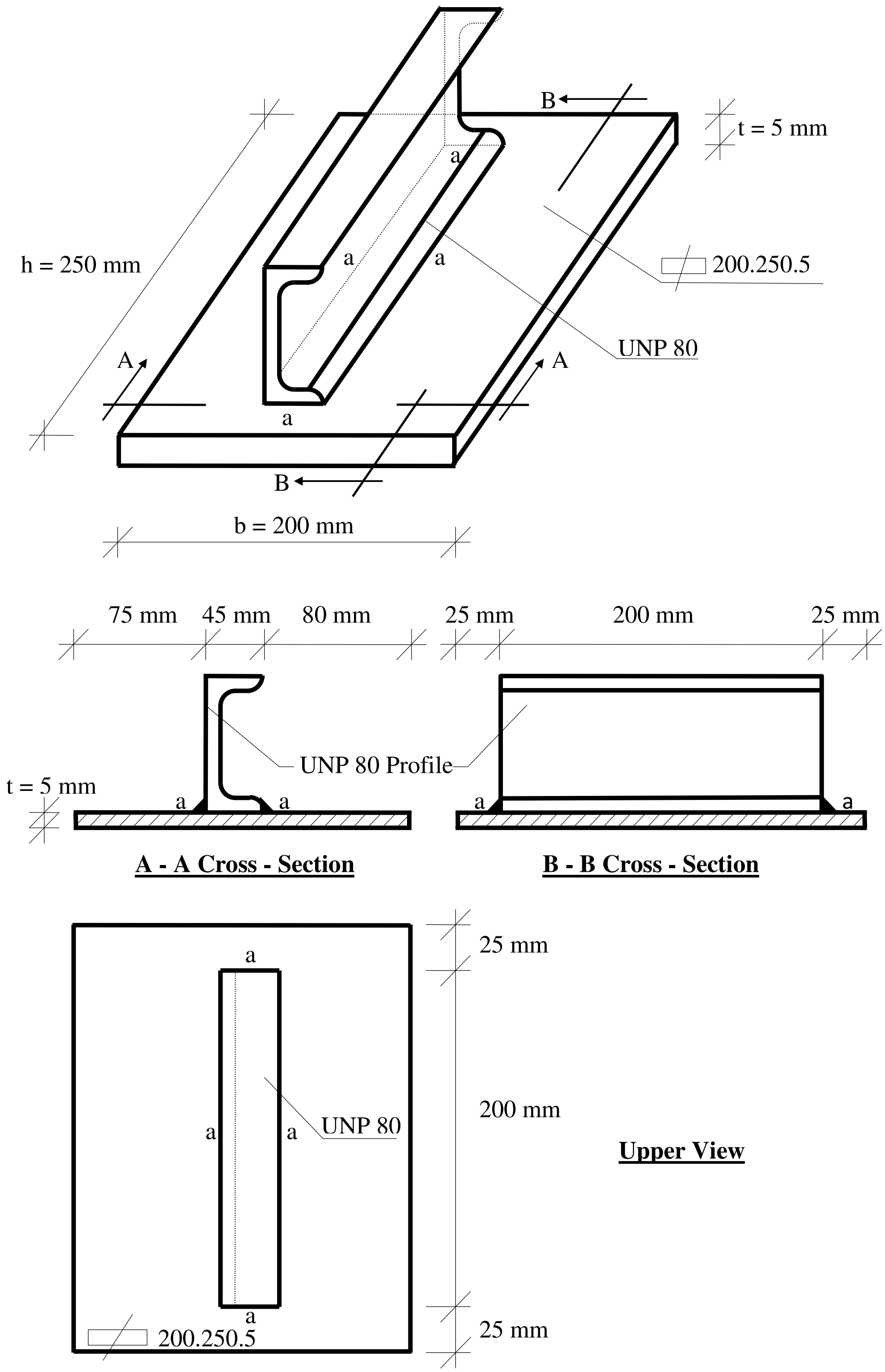

Figure 3. Connection Elements that put into Prepared Concrete Plate

These connection elements were obtained by welding the UNP 80 profile to the steel plate in dimensions of 250 x 200 x 5 mm on its four sides and were located at certain distances when the prefabricated reinforced concrete plate had been prepared by pouring concrete into the mold. The interconnection elements in the prefabricated reinforced concrete were combined to the steel profile by the aid of epoxy resin.

When this composite beam was placed on the experimental frame with joints and supports, a singular force was applied on the center of the beam. The influence of the agglutination with the epoxy resin which was between the steel profile and the steel connection elements and the degree of the epoxy resins assistance in the cooperation of the composite beam was researched. For this purpose, two different kinds of reinforced plates were prepared. In total, 6 prefabricated reinforced concrete plates containing 6 or 8 interconnected prefabricated reinforced concrete plates were prepared. The bearing capacity measurements derived from the composite beam tests are given in Table 1 and the Load - Deformation diagrams are given in Figures 4 - 5.

Table 1. The Values of the Beam Cross Section and the Bearing Capacities

Sample Number	Concrete Dimension (mm)	Steel Profile Number	Interconnect Point	The Rate of The Concrete	Bearing Load (kN)
EPR-1	3000.800.100	INP 120	6	C 30	5,5
EPR-2	3000.800.100	INP 120	6	C 30	5,6
EPR-3	3000.800.100	INP 120	6	C 30	5,8
EPR-4	3000.800.100	INP 120	8	C 30	7,7
EPR-5	3000.800.100	INP 120	8	C 30	7,9
EPR-6	3000.800.100	INP 120	8	C 30	8,0

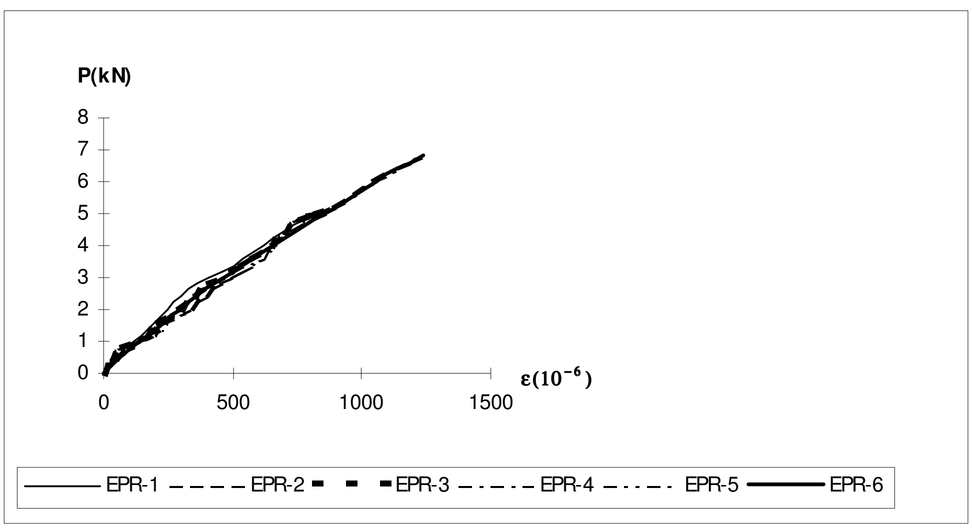

Figure 4. Load - Deformation Diagram (Steel)

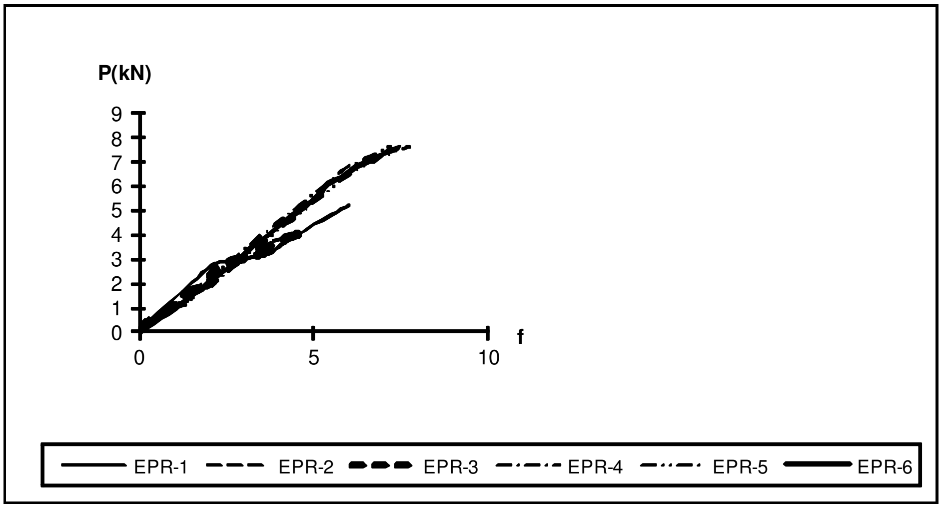

Figure 5. Load - Displacement Diagram (Centre of the Beam)

RESULTS AND DISCUSSION

Results obtained from the study are presented in Figure 4 - 5. One of the points in the structural behavior of composite beam with reinforced concrete plate loaded by a point load is the utilization of the application under the most economic conditions. Therefore, the amount of resin and the number of bonding points between the concrete plate and steel profile which are bonded together by the epoxy resin are important.

Determination of the number of shear connections for the composite beam is one of the main purposes of this study. In the first stage of the study, reinforced concrete plate and steel profile (INP 120) were fixed through 6 points. The loading capacities as well as structural changes formed under loading were determined for the beams. In the second stage, the connection between the plate and the steel profile was performed at 8 points. Ultimate loads attained from 6 experiments are shown in Table 1.

The following results were obtained from the study:

- The connection between the reinforced concrete plate and steel profile was made by joining of steel bars within the concrete plate with steel profile through an epoxy resin. In our previous study, the joining of reinforced concrete plate with steel profile by means of an epoxy resin had been examined. Since, tensile strength of the concrete is close to zero, steel profile was pulled away from the concrete showing the presence of very weak attachment. As a result, the system does not work properly.

- As a result of the reasons given above, in this study steel was bonded to steel by epoxy. It was found that epoxy resin bonds a steel piece to another steel part much tightly than a concrete piece. It was identified that the amount of bonding is 470 % more for the former case. Therefore, in this study an epoxy resin was used to bond steel profiles to steel bars inside the concrete plate.

- The average ultimate load values of the beams fixed through 6 and 8 points were found to be 5.63 kN and 7.86 kN, respectively. The difference between these values originates from the number of connections and therefore the surface area of the epoxy resin between the bonded steel surfaces. The surface area of the connection was 696 cm^2 for the beams fixed by 6 points and it was 928 cm^2 for the beams fixed by 8 points. Accordingly, this condition brought about 40 % more load-bearing capacity for the beams fixed by 8 points. It is obvious that the increase in connection points along the beam opening results in higher ultimate load values. This condition will be investigated later.

To sum up, reinforced concrete plate and steel profile should not be connected directly to obtain a composite beam. It is important to note that during the manufacturing of concrete plate, steel bars should be placed inside so that steel to steel contact is possible while producing composite beam.

REFERENCES

Arda, T.S., Yardimci, N. (1991), "Celik Yapida Karma Elemanlarin Plastik Hesabi".

British Standard Institution, "Composite Construction in Structural Steel and Concrete", CP 117, Part 2.

Commission of the European Communities, (1994), "Common Unified Rules for Composite Steel and Concrete Structures", Eurocode 4, Belgium.

Jones, R., Swamy, R.N., Charif, A., (1988), "Plate Separation and Anchorage of Reinforced Concrete Beams Strengthened by Epoxy - Bonded Steel Plates", The Structural Engineer, 66, No.5, 85 - 94.

Roberts, T.M., Haji - Kazemi, H., (1989), "Strengthening of Under - Reinforced Concrete Beams with Mechanically Attached Steel Plates", The International Journal of Cement Composites and Lightweight Conc..

Roberts, T.M., Haji - Kazemi, H., (1989), "Theoretical Study of the Behavior of Reinforced Concrete Beams Strengthened by Externally Bonded Steel Plates", Proc. Instn Civ. Engrs, Part 2, 39 - 55.

Structures Use of Steelwork for Building, (1990), "Design in Composite Construction", British Standards Inst., B.S. 5950, London - England.

Swamy, R.N., Jones, R., Bloxham, J.W., (1987), "Structural Behavior of Reinforced Concrete Beams Strengthened by Epoxy - Bonded Steel Plates", The Structural Engineer, 65A, No.2, 59 - 68.

Swamy, R.N., Jones, R., Charif, A., (1989), "The Effect of External Plate Reinforcement on the Strengthening of Structurally Damaged RC Beams", The Structural Engineer, 67, No.3, 45 - 54.

Swamy, R.N., Hobbs, B., Robert, M. (1995), "Structural Behaviour of Externally Bonded, Steel Plated RC Beams After Long - Term Exposure", The Structural Engineer, 73, No.16, 255 - 261.