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# REZULTATI ISPITIVANJA OŠTEĆENIH GREDA T-PRESJEKA

# TEST RESULTS OF THE DAMAGED T-SECTION BEAMS

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Pregledni rad

***Sažetak:*** *Cilj ovog rada je eksperimentalno određivanje zaostale (rezidualne) nosivosti greda sa oštećenom pločom. Ispitivanja su provedena kako bi se odredio utjecaj oštećenja grede na njezinu preostalu nosivost.*

***Ključne riječi:*** *betonske grede, oštećenja, uništenje, nosivost.*

Review article

***Abstract:*** *The aim of the paper is the experimental determination of residual bearing capacity of beams with damaged flange. Tests were conducted to study the effect of beam damage on its residual load bearing capacity.*

***Key words:*** *concrete beams, damage, destruction, bearing capacity*

## 1. INTRODUCTION

Reinforced concrete T-structures are used in the construction of individual structures - typical beams and flange in stock - monolithic and prefabricated ribbed panel. Due to the location of the slabs in the upper zone, the height of the beams under the ceiling is reduced, making them more comfortable when used in the construction of public buildings, shopping and entertainment centers. T-section beams are proven to be more economical and of higher efficiency compared to rectangular beams.

There are two schemes of bending elements destruction:

1) – the achievement of stretched armature calculated resistance at yield point;

2) – the destruction of compression zone before the tension zone when there is a colossal damage in the top zone or when there is a design flaw.

## 2. ANALYSIS OF THE PREVIOUS STUDIES

Concrete T-beams are damaged in the ribs and in the flange when they are in service (i.e. during operation when it is under load).

The most common damage in ribs of the beams are normal and slanted cracks, spilling of the protective layer of concrete stretched zone.

The most common damage in flange of the beams is the destruction of compressed concrete layer in the zone of pure bending and at the point of the concentrated load application.

A major contribution to the study of defects and damages of bending elements was given by Adhikary B. [1], Al-Bayati N. [2], Constantin E. Chalioris and Constantin N. Pourzitidis [3], Hassan A. [4], J.Jayaprakash [5], Smith Roger W.[6], Wu Hao [7] and others.

## 3. THE RELEVANCE OF THE WORK

Unfortunately, the possibility of determining the residual bearing capacity of damaged reinforced concrete T-beams is not considered by the current regulations of Ukraine [8], although it could significantly reduce the costs of strengthening. Study of the stress-strain state of such structures would analyze their future work in conjunction with the construction of strengthening. Therefore, the determination of the residual bearing capacity is a very important task.

## 4. EXPERIMENTAL SET-UP OF DAMAGED T-BEAMS STUDY

To solve this problem at the Department of Building Structures The Odessa State Academy of Building and Architecture has performed a series of experiments (15 samples of T-beams with damaged flange and an equal number of prisms and cubes) using the mathematical theory of experiment planning.

The variation factors are the following:

- damaged part of the flange, as expressed by the ratio ($b_{eff1}/b_{eff2}$), where $b_{eff1}$ - the width of the damage; $b_{eff2}$ - value overhangs the flange;
- depth of damage $a_1$ in terms of the ratio of the depth of damage to the rack flange thickness ($a_1/h_f^{/}$);
- angle of the damage $\beta$, expressed in terms of the ratio of the angle of damage to the flange angle equal to $90^0$.

Level and range of variation of these factors are given in Table 1.

**Table 1.** Factors of variation for the model experiment planning

| The investigated Factors of Y Series | | Levels of variation | | | The variation interval |
|---|---|---|---|---|---|
| Subsistence value | Cod | «-1» | «0» | «+1» | |
| Angle of the damage $\beta/90^0$ | $X_1$ | $0^0/90^0$= 0 | $22.5^0/90^0$= 0.25 | $45^0/90^0$= 0.5 | 0.25 |
| Depth of the damage $a_1/h_f^/$, mm | $X_2$ | 0/60=0 | 30/60=0.5 | 60/60=1 | 0.5 |
| The damaged part of the flange $b_{eff1}/b_{eff2}$, mm | $X_3$ | 0/165=0 | 82.5/165=0.5 | 165/165=1 | 0.5 |

To produce prototype beams, cubes and prisms, ordinary heavy concrete class was used for the project C30/35 prefabrication.

Reinforcement of prototype beams was made by single Ø16A500C (operating armature) and Ø6A240C (transverse and mounting armature). For pure bending moment test the reinforcement in the upper zone was removed to test the resistance of the concrete to compression. Tests were carried out on a hydraulic press P-125. The load is transferred to the beam by two traverse parts to distribute the load through the socket joints.

During the test, values of deflections were recorded using indicators such as the clock with a scale division of 0.05 mm, located on both sides of the beams at the bottom, and the transverse and longitudinal deformation of concrete and armature through strain gauges with a 5cm base for concrete and 2cm for armature with resistance 200 Ohm.

The first cracks appeared in the zone of pure bending at the level of loading (0.25 ... 0.3). By increasing the load in the span, shear oblique cracks began to appear (evolved to the level of the flange and often crossed it). Moreover, in samples with wide flange (400mm) shortly before the destruction, vertical longitudinal cracks at the site abutting ribs overhung to the flange were formed. Normal cracks were also formed along the entire height of the ribs to the flange when applied load was increased (Fig.1).

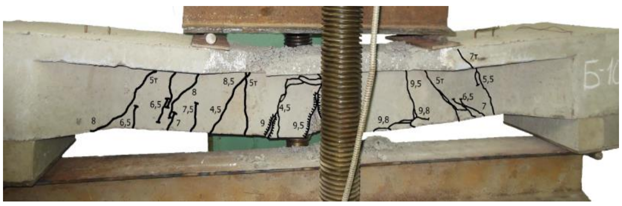

**Figure1.** The destruction of the beam B10

Fracture of beams corresponds to the case 2 when stretched armature voltage has not reached its yield strength and fracture was due to the fragmentation of concrete compressed zone of the prevailing bending moment.

In conducting the experimental studies fixed values of the external load were obtained corresponding to the appearance of the first normal cracks in the zone of pure bending specimens, and the inclined cracks in the shear span of beams and the destruction of beams (Table 2).

**Table 2.** The values of the external load corresponding to the first appearance of normal, oblique fractures and fracture of beams

| Marks of beams | $F_{w,ult\perp}$, kN | $F_{w,ult\,/}$, kN | $F_{ULS}$, kN | *M,kNm.* |
|---|---|---|---|---|
| B1 | 55 | 35 | 80 | 20 |
| B2 | 40 | 35 | 40 | 10 |
| B3 | 40 | 50 | 130 | 32.5 |
| B4 | 20 | 40 | 105 | 26.25 |
| B5 | 30 | 25 | 95 | 23.75 |
| B6 | 30 | 50 | 130 | 32.5 |
| B7 | 30 | 35 | 110 | 27.5 |
| B8 | 30 | 25 | 75 | 18.75 |
| B9 | 30 | 20 | 95 | 23.75 |
| B10 | 25 | 50 | 98 | 24.5 |
| B11 | 20 | 30 | 90 | 22.5 |
| B12 | 30 | 50 | 118 | 29.5 |
| B13 | 25 | 30 | 90 | 22.5 |
| B14 | 30 | 50 | 105 | 26.25 |
| B15 | 20 | 40 | 110 | 27.5 |

From the pre-analysis of the experimentally obtained data it is concluded that the beams which collapsed due to greater loads had less damage prior to the test and the beams which failed due to smaller loads were with width of damaged slab of $b_{eff}$=70mm.

Before the formation of the first crack deflection of beams was observed. The appearance of the first normal and then oblique cracks was accompanied by a substantial increase in the deflection. The relationship between load and deflection was proportional until after the formation of these cracks when the deflection increased substantially and was not proportional to the increase of the external load. With the exhaustion of the bearing capacity of the beam deflection increased even with a small increment of the external load (Figure 2).

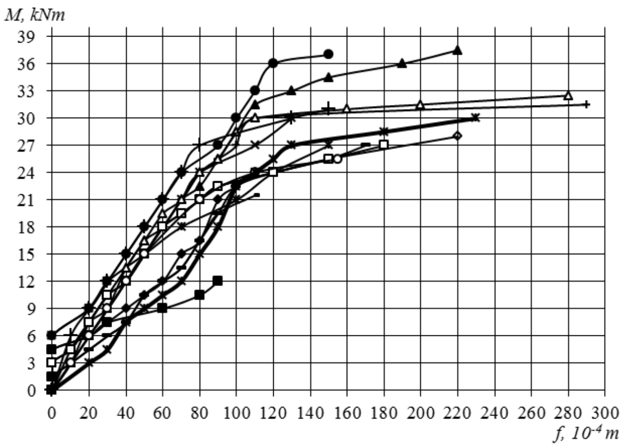


**Figure 2.** The growth of deflection before the destruction of beams under load level ($0.95F_{ULS}$)

Table 3 shows the average value of deflections experienced by the beams at points of measurement on the operational ($0.67F_{ULS}$) level of loading, and before the destruction (0.95 $F_{ULS}$).

Pre-analysis of the obtained values of deflections is an evidence that the greatest deflection received beams are B7, B12, B14, a distinctive feature of which is the angle of damage $\beta = 22.5^0$. The smallest deflections were recorded in beams B1, B2, B8 with damaged flange $b_{eff}$ = 70cm.

**Table 3.** The average values of deflection of beams on the operational ($0.67F_{ULS}$) level of loading and before the destruction($0.95\ F_{ULS}$).

| Marks of beams | $f$ under $0.67F_{ULS}$, cm | $f$ under $0.95F_{ULS}$, cm | Subsistence value of the factors | | |
|---|---|---|---|---|---|
| | | | $\beta/90^0$, ($\beta$,$^0$) | $a_1/h_f^{/}$, ($a_1$, mm) | $b_{eff1}/b_{eff2}$, ($b_{eff}$,mm) |
| B1 | 0.8 | 1.1 | 0.5 ($45^0$) | 1 (60) | 1 (70) |
| B2 | 0.6 | 0.9 | 0 ($0^0$) | 1 (60) | 1 (70) |
| B3 | 0.9 | 2.2 | 0.5 ($45^0$) | 1 (60) | 0 (400) |
| B4 | 0.7 | 1.3 | 0.5 ($45^0$) | 1 (60) | 0.5 (235) |
| B5 | 0.8 | 1.5 | 0 ($0^0$) | 0 (0) | 1 (70) |
| B6 | 0.8 | 1.5 | 0 ($0^0$) | 0 (0) | 0 (400) |
| B7 | 0.8 | 2.9 | 0.25 ($22.5^0$) | 0.5 (30) | 0.5 (235) |
| B8 | 0.8 | 1.1 | 0.25 ($22.5^0$) | 1 (60) | 1 (70) |
| B9 | 0,9 | 1.7 | 0.5 ($45^0$) | 0.5 (30) | 1 (70) |
| B10 | 0.7 | 2.2 | 0.5 ($45^0$) | 0.5 (30) | 0.5 (235) |
| B11 | 0.6 | 1.5 | 0 ($0^0$) | 0.5 (30) | 0.5 (235) |
| B12 | 0,8 | 2,8 | 0.25 ($22.5^0$) | 0.5 (30) | 0 (400) |
| B13 | 0,7 | 1,55 | 0 ($0^0$) | 0.5 (30) | 0 (400) |
| B14 | 0,9 | 2,3 | 0,25 ($22.5^0$) | 1 (60) | 0.5 (235) |
| B15 | 0,65 | 1,5 | 0 ($0^0$) | 0 (0) | 0.5 (235) |

## 5. CONCLUSION

The article raises the question of further operation of damaged reinforced concrete T-beams. An important task for the future is the mathematical definition of the residual load-bearing capacity of beams for the type of damage. It is proven that the type of damage affects the residual load-bearing capacity, the nature of the occurrence and the further development of cracks and the beam deflection.

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