



**Research Article**

**DEVELOPMENT OF DESIGN STRENGTH PROGRAM FOR STEEL PROFILES USING THE NEW TURKISH STEEL CODE**

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**Received: 22.05.2017 Revised: 25.08.2017 Accepted: 20.09.2017**

**ABSTRACT**

In this study, a computer program was developed to calculate the strengths of steel profiles according to the new Turkish Steel Structures Design and Construction Regulations (TSSDCR) to be utilized in steel structures lessons. This program is named as "LETA Steel Strength" and Visual Basic is used as programming language. All the effects specified in the regulations can be calculated within the program. The profile and material properties are determined by the selection menus, and the user cannot interfere with these standard features. This is especially intended to prevent calculation errors in prolonged process. Interfaces are designed on the basis of ease. The program is also suitable for engineering offices to use.

**Keywords:** Steel profile strength calculation, steel structure design, educational software.

**1. INTRODUCTION**

In 2016, comprehensive changes have been taken place in the new regulations [1] which caused the same comprehensive modifications in education. The biggest problems with these changes are a lack of question sources and possible mistakes in solutions. With this developed software, it is aimed that students can check the solutions accordance with the regulations and the software will lead the students in case of errors and they can better understand the solutions and regulations. In the program, the user's intervention is restricted to a large extent, thus the program algorithm is prevented from being corrupted. In order to provide practical calculations by hand, kN and cm are used as a unit. The profile properties given in mm have been subjected to necessary unit conversion operations within the program. Flowchart of the program is given in Figure 1.

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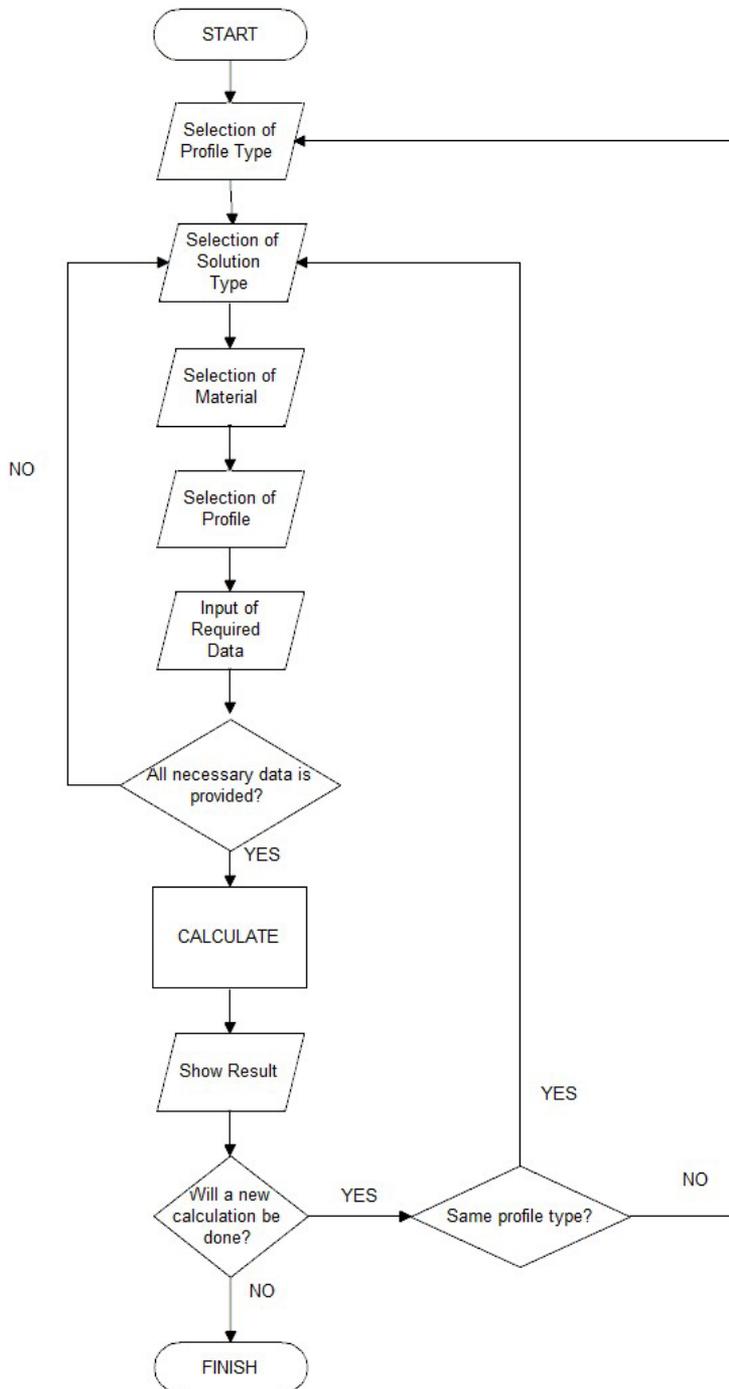


Figure 1. Flowchart

## 2. DESCRIPTION OF THE PROGRAM

This program has been developed to calculate the strength of steel profiles utilized in the steel structure lessons quickly and accurately according to the new regulations. The program is written in the Visual Basic [2] programming language in the integrated development environment of Microsoft Visual Studio Express 2013 for Desktop [3]. After the profile type, solution method, material properties, and profile sizes are selected and the required data is entered, the strength results of the desired profiles can be obtained.

After running the program, the profile type selection menu appears (Figure 2). The buttons on the profile type direct the user to the selected profile's calculation form.



Figure 2. Profile Selection Form

In the present case, the program calculates for the profile types shown above. Calculations of circular, box and cross-section steel structural elements are still being added to the program.

Calculation form appears after the selection of profile type. Only the data boxes which will use for calculation can be displayed in the selected solution method instead of showing all data boxes. By this way, the user will not be deal with unnecessary data for the selected solution method. The general design of the profile form, the calculation form before the solution method selection and the calculation form are shown in Figure 3-5.

Figure 3. Design of the Calculation Form

Figure 4. Calculation Form Before the Solution Method Selection

Figure 5. Calculation Form After Selection of Bending Moment Solution

### 3. A NUMERICAL EXAMPLE

In the example, firstly solution by hand will be described and secondly, the software solution of the same example will be explained step by step with images.

The beam shown in the Figure 6 is a HE-A 260 made of S355 steel. The beam is laterally unbraced along the span. The two concentrated loads on the beam are the service live loads. The weight of the beam is neglected. LRFD specifications in the new Turkish code will be used. According to the specifications,

- a) The flexural strength for the lateral torsional buckling (LTB)
- b) The flexural strength for the local buckling (LB)
- c) The shear strength

calculations are requested for this beam section.

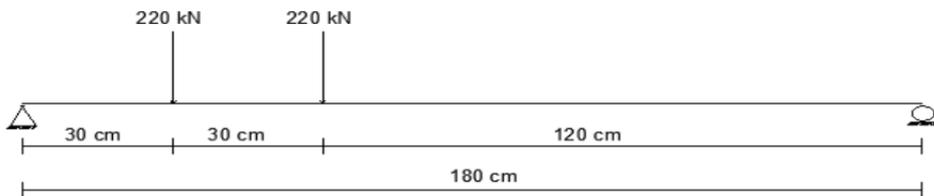


Figure 6. System Dimensions

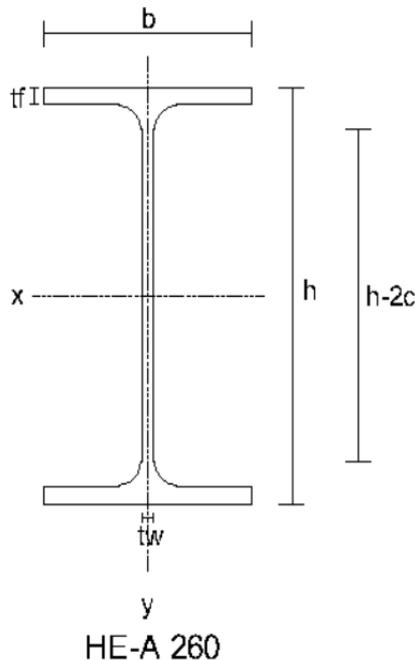


Figure 7. HE-A 260 Profile Section

HE-A 260 İçin:	S355 İçin:
$i_x = 10,97 \text{ cm}$ $I_x = 10450 \text{ cm}^4$	$F_y = 35,5 \text{ kN/cm}^2$
$i_y = 6,50 \text{ cm}$ $I_y = 3668 \text{ cm}^4$	$F_u = 51 \text{ kN/cm}^2$
$A = 86,82 \text{ cm}^2$ $h = 250 \text{ mm}$	$E = 20000 \text{ kN/cm}^2$
$b = 260 \text{ mm}$ $t_w = 7,5 \text{ mm}$	$G = 7720 \text{ kN/cm}^2$
$t_f = 12,5 \text{ mm}$ $h-2c = 177 \text{ mm}$	
$J = 52,37 \text{ cm}^4$ $C_w = 516400 \text{ cm}^6$	
$W_{ex} = 836,4 \text{ cm}^3$ $W_{px} = 919,8 \text{ cm}^3$	
$W = 68,2 \text{ kg/m}$	

**Calculation of the flexural strength for the lateral torsional buckling (LTB)**

First,  $L_p$  and  $L_r$  values must be calculated. The formula of these values is obtained from the new regulations [1].

$$L_p = 1,76 \times i_y \times \sqrt{\frac{E}{F_y}} = 1,76 \times 6,50 \times \sqrt{\frac{20000}{35,5}} = 271,54 \text{ cm}$$

$$L_r = 1,95 \times its \times \frac{E}{0,7 \times F_y} \times \sqrt{\frac{J \times c}{W_{ex} \times ho} + \sqrt{\left(\frac{J \times c}{W_{ex} \times ho}\right)^2 + 6,76 \times \left(\frac{0,7 F_y}{E}\right)^2}}$$

$$its^2 = \frac{\sqrt{I_y \times C_w}}{W_{ex}} = \frac{\sqrt{3668 \times 516400}}{836,4} \rightarrow its = 7,21 \text{ cm}$$

$ho = \text{distance between flange centroids} = h - t_f = 25 - 1,25 = 23,75 \text{ cm}$

for a doubly – symmetric I shape  $c = 1,0$

$$L_r = 1,95 \times 7,21 \times \frac{20000}{0,7 \times 35,5} \times \sqrt{\frac{52,37 \times 1,0}{836,4 \times 23,75} + \sqrt{\left(\frac{52,37 \times 1,0}{836,4 \times 23,75}\right)^2 + 6,76 \times \left(\frac{0,7 \times 35,5}{20000}\right)^2}} = 933,97 \text{ cm}$$

$$\left\{ \begin{array}{l} L_r = 933,97 \text{ cm} \\ L_p = 271,54 \text{ cm} \\ L_b = 180 \text{ cm} \end{array} \right\} \rightarrow L_b < L_p$$

$$M_n = M_p = F_y \times W_{px} = 35,5 \times 919,8 = 32652,9 \text{ kNcm}$$

$$\text{The design strength; } \phi \times M_n = (0,90) \times (32652,9) = 29387,61 \text{ kNcm}$$

$$M_u = M_{max} = 13200 \text{ kNcm} < \phi \times M_n = 29387,61 \text{ kNcm}$$

**Calculation of the Flexural Strength for the Local Buckling**

If  $\lambda \leq \lambda_p$  → compact  
 $\lambda_p < \lambda \leq \lambda_r$  → non-compact  
 $\lambda > \lambda_r$  → slender

For flanges:  $\frac{b}{2t_f} = \frac{260}{2(12,5)} = 10,4 = \lambda$  (Tablo 5.1B TSSDCR 2016)

$$0,38 \times \sqrt{\frac{E}{F_y}} = 0,38 \times \sqrt{\frac{20000}{35,5}} = 9,02 = \lambda_p$$

$$1,00 \times \sqrt{\frac{E}{F_y}} = 1,00 \times \sqrt{\frac{20000}{35,5}} = 23,74 = \lambda_r$$

$$\lambda_p < \lambda \leq \lambda_r \rightarrow \text{Non - compact}$$

For web:  $\frac{h-2c}{t_w} = \frac{177}{7,5} = 23,26 = \lambda$  (Tablo 5.1B TSSDCR 2016)

$$3,76 \times \sqrt{\frac{E}{F_y}} = 3,76 \times \sqrt{\frac{20000}{35,5}} = 89,25 = \lambda_p$$

$$5,70 \times \sqrt{\frac{E}{F_y}} = 5,70 \times \sqrt{\frac{20000}{35,5}} = 135,29 = \lambda_r$$

$$\lambda \leq \lambda_p \rightarrow \text{Compact}$$

Because the flange is non-compact, the Local Buckling must be controlled according to the Chapter 9.3.2 (a) of the TSSDCR regulation, the local buckling bending moment strength ( $M_n$ ) of profiles which fulfill the conditions of compact web and non-compact flanges will be calculated with the formula [1] given below.

$$M_n = M_p - (M_p - 0,7 F_y W_{ex}) \left( \frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}} \right)$$

$$\lambda = \frac{b}{2t_f} = \frac{260}{2(12,5)} = 10,4$$

$$\lambda_{pf} = 0,38 \times \sqrt{\frac{E}{F_y}} = 0,38 \times \sqrt{\frac{20000}{35,5}} = 9,02$$

$$\lambda_{rf} = 1,00 \times \sqrt{\frac{E}{F_y}} = 1,00 \times \sqrt{\frac{20000}{35,5}} = 23,74$$

$$M_p = F_y * W_{px} = 35,5 \times 919,8 = 32652,9 \text{ kNcm}$$

$$M_n = 32652,9 - (32652,9 - 0,7 \times 35,5 \times 836,4) \left( \frac{10,4 - 9,02}{23,74 - 9,02} \right)$$

$$M_n = 31539,58 \text{ kNcm}$$

The design strength;  $\phi \times M_n = (0,90) \times (31539,58) = 28385,62 \text{ kNcm}$

$$M_u = M_{max} = 13200 \text{ kNcm} < \phi \times M_n = 28385,62 \text{ kNcm}$$

**Calculation of Shear Strength**

According to the Chapter 10. 2.1 of the TSSDCR regulations, the nominal shear strength,  $V_n$ , of unstiffened or stiffened webs according to the limit states of shear yielding and shear buckling will be calculated with formula [1] given below.

$$V_n = 0,6 \times F_y \times A_w \times C_{v1}$$

According to the Chapter 10.2.1 (a) of the regulations, in the web of hot-rolled I profiles if

$$\phi_v = 1,00 \text{ (YDKT)} \text{ or } \Omega_v = 1,50 \text{ (GKT)}$$

and  $C_{v1} = 1,0$  will be used.

$$\frac{h}{tw} = \frac{177}{7,5} = 23,6 \leq 2,24 \sqrt{\frac{E}{F_y}} = 2,24 \sqrt{\frac{20000}{35,5}} = 53,17$$

$$A_w = d \times tw \rightarrow A_w = 25 \times 0,75 = 18,75 \text{ cm}^2$$

$$V_n = 0,6 \times 35,5 \times 18,75 \times 1,0 \rightarrow V_n = 399,38 \text{ kN}$$

$$\phi_v \times V_n = (1,00) \times 399,38 = 399,38 \text{ kN}$$

**Calculation with the Program**

After the running program, press the “HE-HL” button on the profile type selection page and go to the HE calculation form. (Figure 8)



**Figure 8.** HE-HL Profile Selection Form

Then, the solution method is firstly selected in the calculation form. (Figure 9)

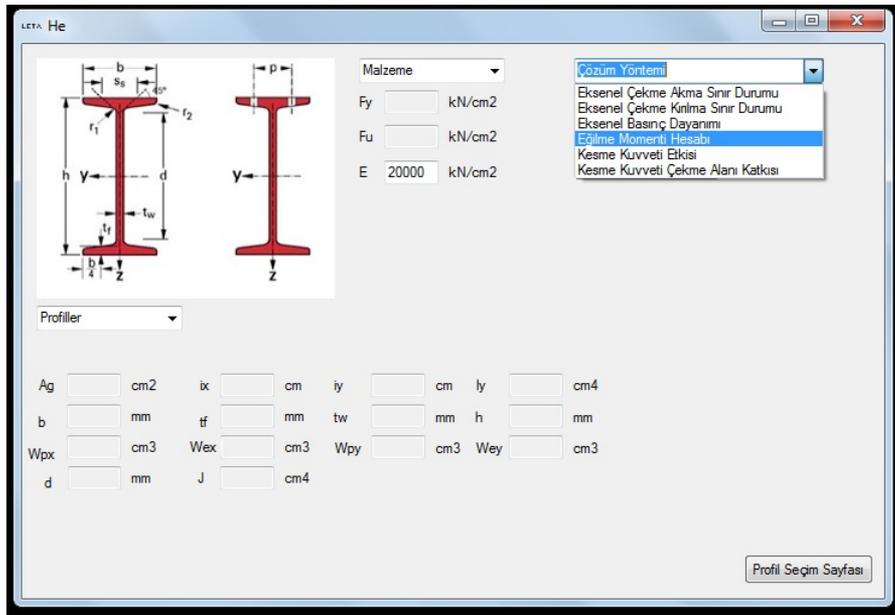


Figure 9. Selection of Solution Method

After the selection of LRFD (YDKT in Turkish) as a design method, the S355 class material is selected from the material type combo box as shown in Figure 10. These material properties are taken from Table 2.1.A and Table 2.1.B in the regulations.

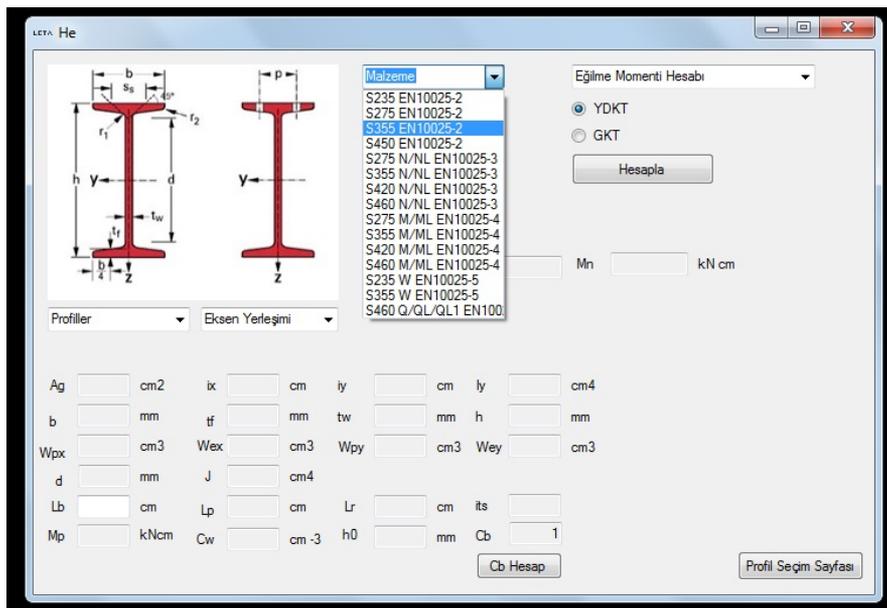


Figure 10. Selection of Material Type

In the given system, it is seen that the calculations are made on the strong axis of the profile. Therefore “Strong Axis” (Kuvvetli Eksen in Turkish) is selected from the axis placement box. (Figure 11).

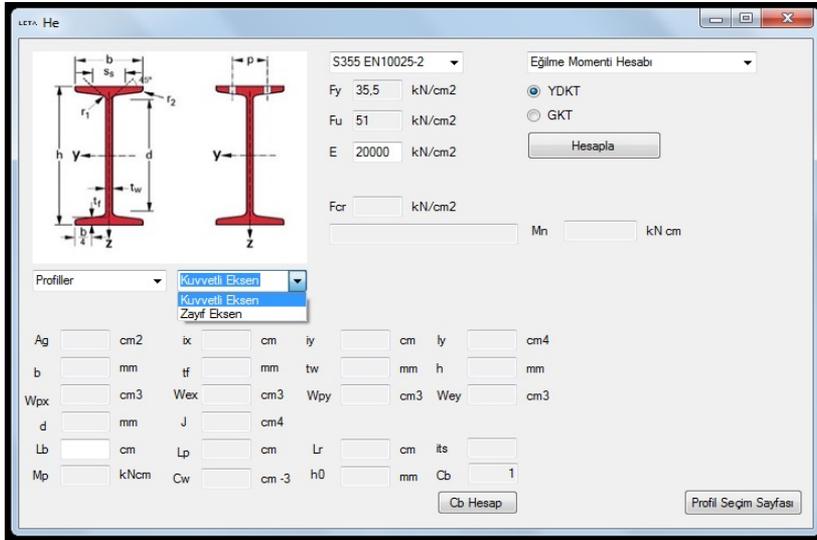


Figure 11. Axis Placement

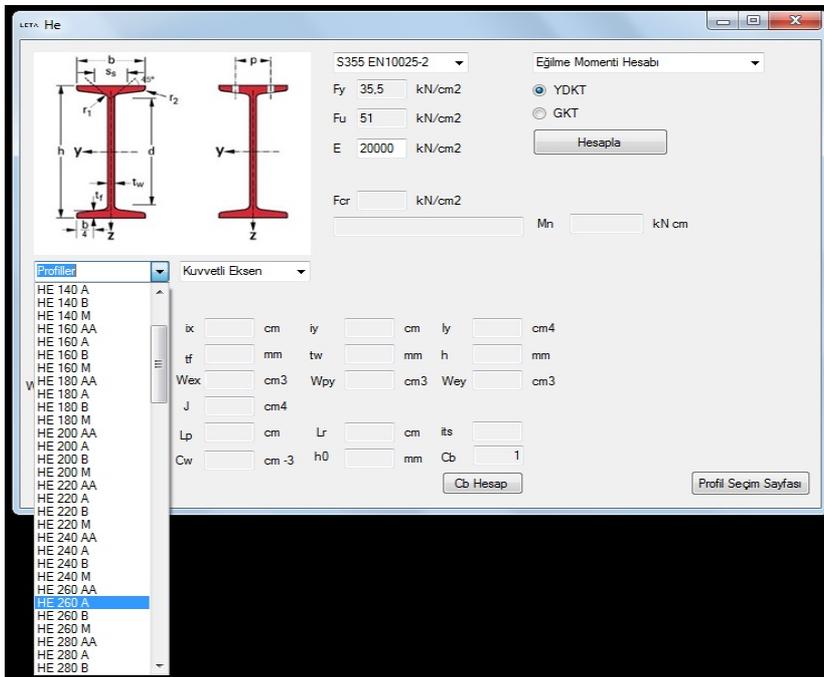


Figure 12. Selection of Profile

Then the profile type is selected from profile selection box (Figure 12). Profile properties are constant and they are taken from published Excel tables produced by manufactures. Program users can't interfere with these standard profile properties.

After the profile selection, if " $L_b$ " value is necessary, this value is expected from a user as an input. (Figure 13). If the value of  $L_b$  is not a numerical value, the program warns the user.  $L_b$  value is given as 180 cm in the example.

The screenshot shows the LETA He software interface. On the left, there are two diagrams of an HE 260 A profile with dimensions labeled. The main area contains input fields for material properties: S355 EN10025-2,  $F_y = 35.5$  kN/cm<sup>2</sup>,  $F_u = 51$  kN/cm<sup>2</sup>,  $E = 20000$  kN/cm<sup>2</sup>, and  $F_{cr}$  kN/cm<sup>2</sup>. There are also radio buttons for 'Eğilme Momenti Hesabi' with 'YDKT' selected and 'GKT' unselected. A 'Hesapla' button is present. Below these are fields for  $M_n$  kN cm. At the bottom, there is a grid of section properties:  $A_g = 86.82$  cm<sup>2</sup>,  $i_x = 10.97$  cm,  $i_y = 6.5$  cm,  $I_y = 3668$  cm<sup>4</sup>,  $b = 260$  mm,  $t_f = 12.5$  mm,  $t_w = 7.5$  mm,  $h = 250$  mm,  $W_{px} = 919.8$  cm<sup>3</sup>,  $W_{ex} = 836.4$  cm<sup>3</sup>,  $W_{py} = 430.2$  cm<sup>3</sup>,  $W_{ey} = 282.1$  cm<sup>3</sup>,  $d = 177$  mm,  $J = 52.37$  cm<sup>4</sup>,  $L_b = 180$  cm,  $L_p$  cm,  $L_r$  cm,  $i_{ts}$  cm,  $M_p$  kNcm,  $C_w = 516.4$  cm<sup>-3</sup>,  $h_0$  mm,  $C_b = 1$ . There are 'Cb Hesap' and 'Profil Seçim Sayfası' buttons.

Figure 13. Input value for  $L_b$

After all the necessary data is provided, the results of the example are obtained via pressing "Hesapla" (Calculate in English) button. Under the bending moment effect, calculations are made for more than one limit state. According to the regulations, the design moment strength of these limit states is the lowest design moment value in the states [1]. In the program, all calculated moments are shown with a message box and the lowest design moment strength is shown in result box (Figure 14). In addition, other calculated data (like  $L_p$ ,  $L_r$  compact or non-compact) are shown on the calculation form as shown below.

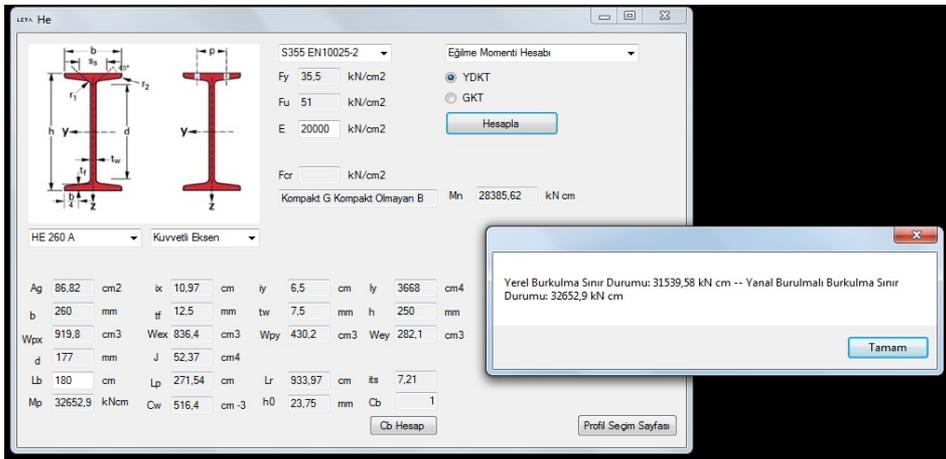


Figure 14. Result of Bending Moment Effect Calculations

Another calculation asked in the example is the shear strength calculation. Firstly, the solution method is renewed as “Kesme Kuvveti Etkisi” (Effect of Shear in English) to calculate the shear strength of the profile selected (Figure 15).

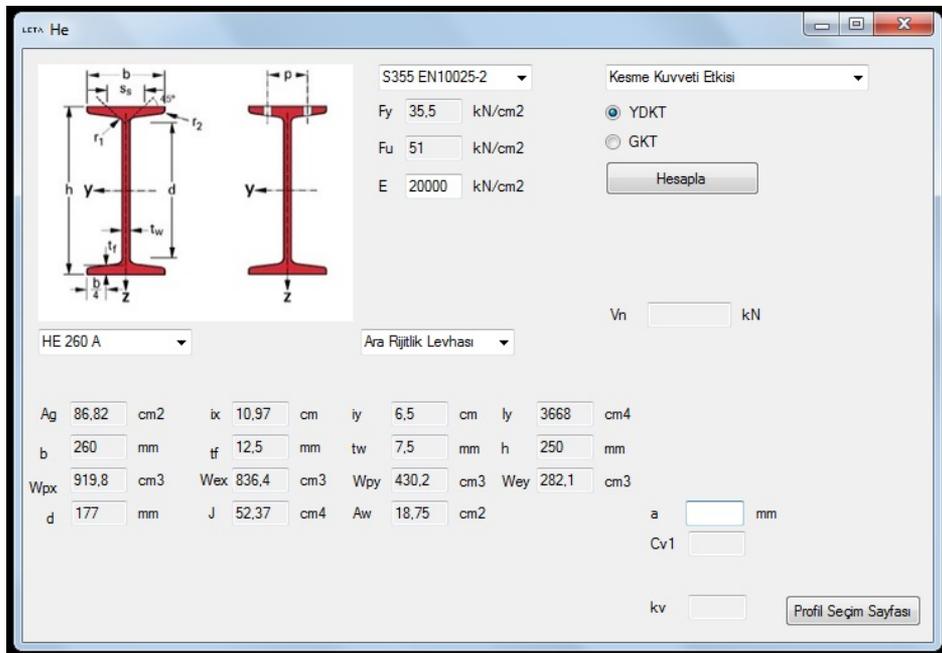


Figure 15. Selection of Shear Strength Solution Method

As it is seen in Figure 15, when the solution method is changed, the view of the form is changed. There is not any stiffener used in the beam hence “Kullanılmıyor” (Not Used in English)

option is selected from stiffener selection box (Figure 16). Therefore, there is no need to give any input “a” value in the solution form. The result of the shear strength calculation is obtained via pressing the “Hesapla” (Calculate in English) button (Figure 17).

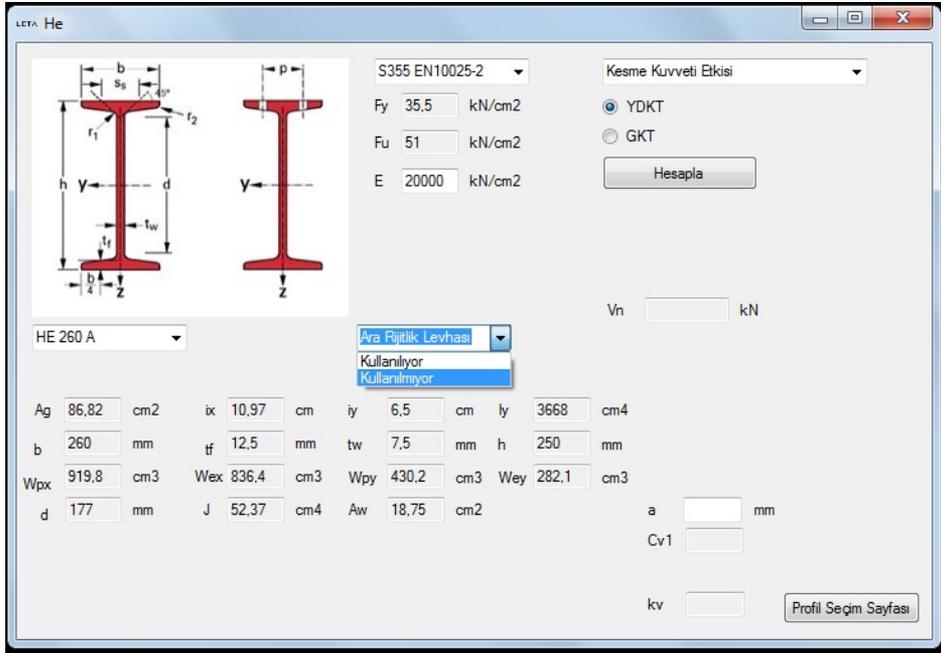


Figure 16. Selection of Stiffener Usage

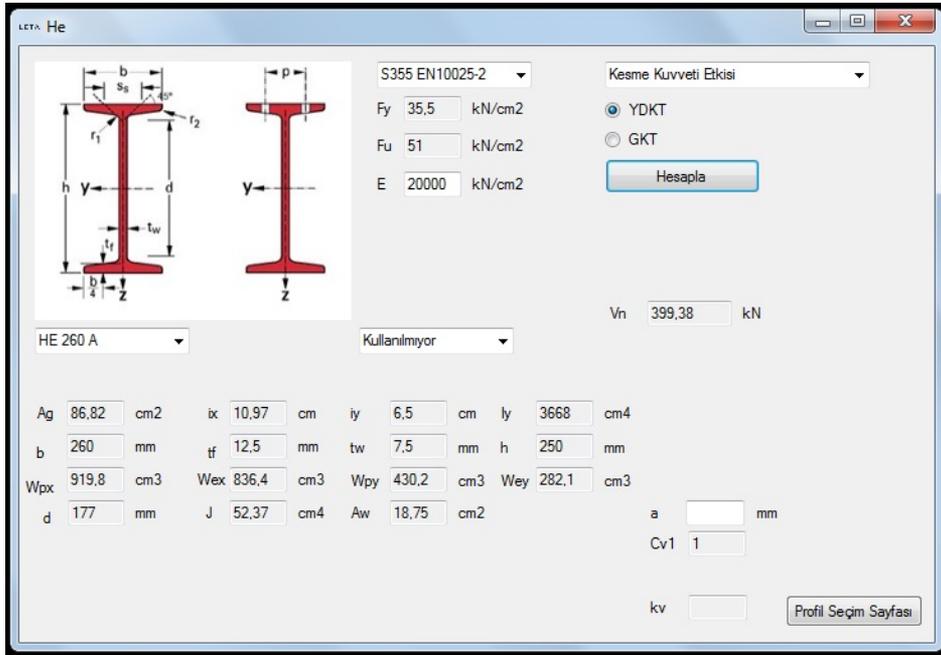


Figure 17. Result of Shear Strength Calculation

As it can be seen in Figure 17, the program gives the same results with the hand calculation.

#### 4. RESULTS

In this study, a new software is developed in order to assist lessons related to steel structures. This program is named as "LETA Steel Strength". After the input necessary data is provided, the strength calculation results of profiles can be obtained according to the new steel structures regulations. This program will provide to check the solution of the questions in steel structures lessons and the users spend lesser time for calculations in steel structure design lessons. More effective education is purposed by showing all calculated data in the calculation forms. Most important feature of this program is to give the correct answers to the users in a very short time with very easy interface.

#### REFERENCES

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