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OPTIMIZATION OF ROLL FORMED BEAMS USED IN CEILING CONSTRUCTION

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
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TUNÇ SAFA ALTUNSARAY

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TUNÇ SAFA ALTUNSARAY

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FOR
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Approval of the Graduate School of Natural and Applied Sciences, Atilim University.

Prof. Dr. Ali Kara
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of **Master of Science in Manufacturing Engineering, Atilim University**.

Prof. Dr. Sadık Engin Kılıç
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This is to certify that we have read the thesis OPTIMIZATION OF ROLL FORMED BEAMS USED IN CEILING CONSTRUCTION submitted by Tunç Safa Altunsaray and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

OPTIMIZATION OF ROLL FORMED BEAMS USED IN CEILING CONSTRUCTION

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In this thesis, the deflections of the C and U beams manufactured by using roll forming of strip material and used in present ceiling constructions in cantilever and simple support modes are calculated by using finite element method. Also, a testing laboratory is developed to check the calculations and to be able to make the real-life measurements and experiments on the profiles. First the elastic deflections of the existing C and U profiles are calculated in the simply supported and cantilever modes. Then experiments are conducted in the developed laboratory to check the theoretical results. Later, new C and U profiles have been developed using thinner material with a more complex design giving deflections not more than the original C and U beams. New designs have been manufactured by roll forming and testing in the simply supported and cantilever modes have been completed. This way, the thicknesses of C and U beams have been reduced by approximately 0.05 mm, resulting in deflections not more than the original designs. Hence, material saving is obtained with an optimal design also saving cost and energy.

Keywords: Ceiling Profile, Simply Supported Test, Cantilever Test, Ceiling Construction Profile

ÖZ

TAVAN KONSTRÜKSİYONUNDA KULLANILAN PROFİLLERİN ENİYİLEŞTİRİLMESİ

Altunsaray, Tunç Safa

Yüksek Lisans, İmalat Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Bilgin Kaftanoğlu

Haziran 2019, 53 sayfa

Bu tezde, şerit malzemenin haddeleme yolu ile üretilen mevcut asma tavan imalatında kullanılan tavan C ve tavan U profillerin ankastre ve basit eğilmedeki sehimleri sonlu elemanlar yöntemi kullanılarak hesaplanmıştır. Aynı zamanda, yapılan hesaplamaların doğruluğunu kontrol etmek ve profillerin gerçek yaşamda oluşan ölçümlerini yapabilmek için bir laboratuvar kurulmuştur. İlk olarak, orjinal tavan C ve tavan U profillerinin elastik bölgedeki sehimleri ankastre ve basit eğilme yöntemi ile bulunmuştur. Ardından teorik sonuçları kontrol etmek için kurulan laboratuvarda deneyler yapılmıştır. Daha sonra, orjinal tavan C ve tavan U profillerine göre daha ince malzeme kullanılarak, karmaşık bir tasarıma sahip , sehim değerleri daha düşük olan yeni tavan C ve tavan U profilleri geliştirilmiştir. Yeni tavan C ve tavan U profilleri ankastre ve basit eğilme modellemeleri tamamlandıktan sonra haddeleme yöntemi ile üretilmiştir. Bu şekilde tavan C ve tavan U profillerin kalınlığı yaklaşık olarak 0.05mm azaltılmıştır. Yeni profillerin sehimlerinin orginal profillere göre daha az olduğu görülmüştür. Bu sayede, en uygun tasarım ile malzeme, maliyet ve enerji tasarrufu sağlanmıştır.

Anahtar Kelimeler: Asma Tavan Profil, Ankastre, Basit Eğilme, Sehim, Sonlu Elemanlar Yöntemi

To My Parents

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LIST OF SYMBOLS/ABBREVIATIONS

UMS	Uğur Metal Company
Y_{max}	Deflection
RFDA	Resonant Frequency and Damping Analyser
E	Young's modules of Elasticity of material (N/m$^{2)}$
I	Area Moment of Inertia (m^2)
X	Distance from one side of the beam (m)
P	Load (N or kN)
L	Distance from one side of the beam
Gr	Gram
Kg	Kilogram
F	Load (N or kN)
FEM	Finite Element Method
CAD	Computer Aided Design

CHAPTER 1

INTRODUCTION

In the construction sector, when manufacturing ceilings of buildings using gypsum board suspending ceiling technology, ceiling-U profile is screwed horizontally to the wall facing its open-end part inside on two opposite walls. Open-end parts of U-profiles are used to support ceiling-C profiles. Figure 1 shows application of ceiling-U and C profiles.

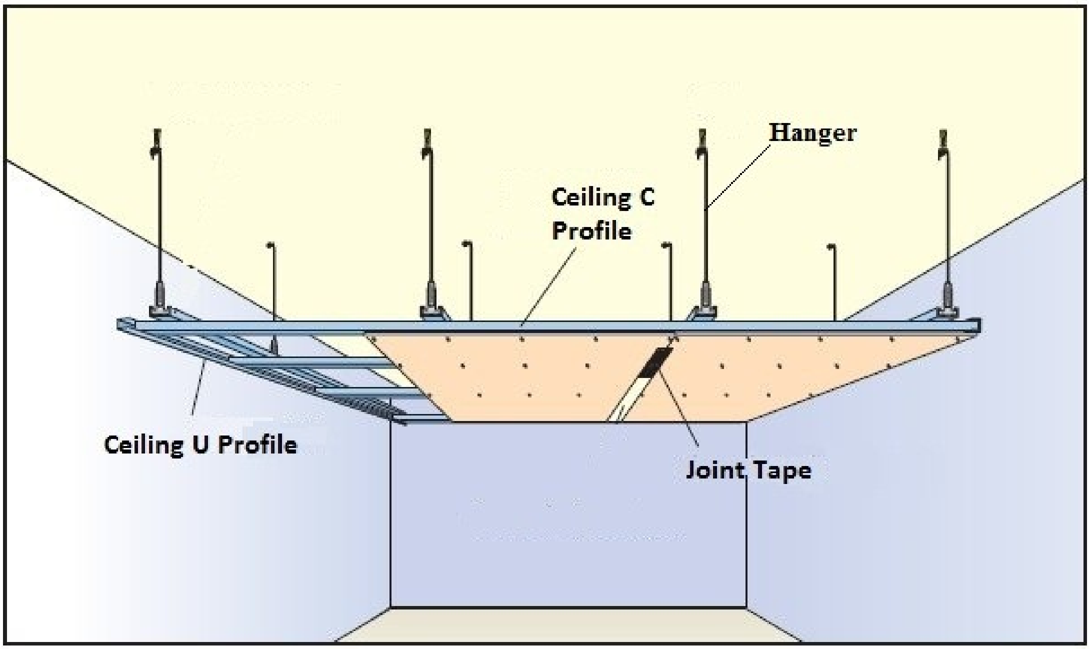

Figure-1: Application of Ceiling U, Ceiling C and Sheet Rocks

Ceiling C profiles are placed between opposing ceiling U profiles leaving sufficient spaces between them. Ceiling C profiles are also fixed to the ceiling with suspension rods. Gypsum boards are then screwed to ceiling C profiles. Moreover, in an area of $1m^2$ Ceiling U Profile 700 mm and Ceiling C Profile 3300 mm are used.

Furthermore, Hanger is attached with Standard 1200 mm spacing, it can also be attached with 1000 mm spacing but it never falls below 1000 mm.

In such a design, decreasing the thickness of the beam material used in the profiles without decreasing its level of strength will lower the load and cost in ceiling construction

Suspended ceilings (sometimes referred to as dropped ceilings or false ceilings) are secondary ceilings suspended from the structural floor slab above, creating a void between the underside of the floor slab and the top of the suspended ceiling. Suspended ceilings systems provide certain advantages. These are, assembly of heating systems, ventilation, air conditioning, wiring systems for construction, speakers, light fittings, wireless antenna, cable-tv, fire and smoke detectors, motion detectors, sprinklers and so on. Due to the weight created by these applications and because of the sheetrocks carried (held) by them, dropped ceilings need to be resistant to bending. To increase its resistance against bending and lower the cost, the second moment of area of ceiling C and ceiling U used in ceiling system installation to minimize bending has to be increased. Figure 2 shows a typical suspended ceilings systems.

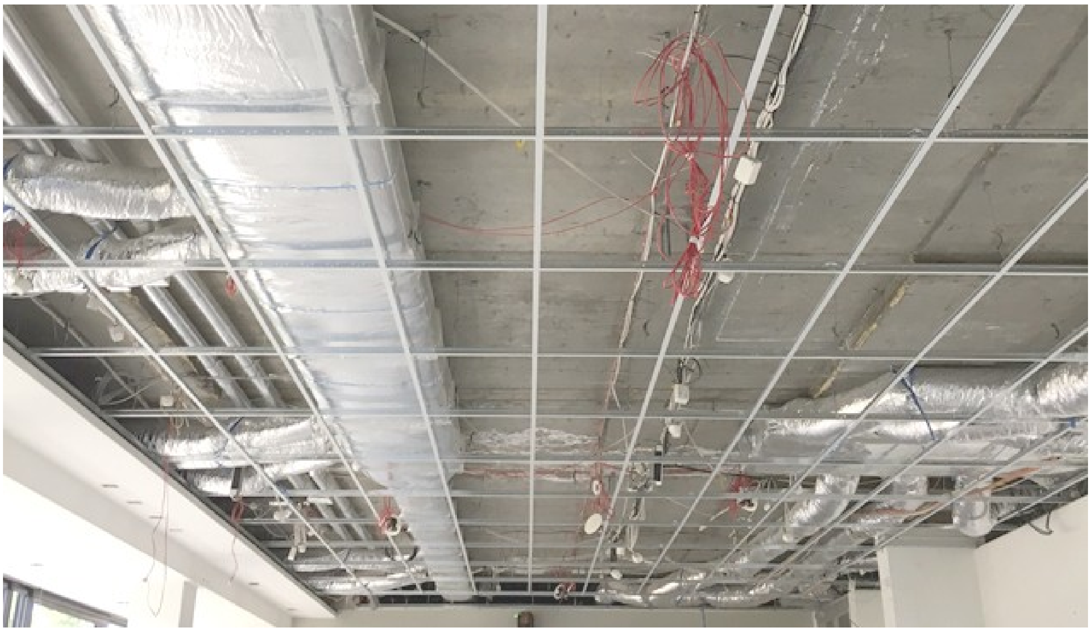

Figure-2: Suspended Ceilings Systems

The purpose of this study is to produce new designs for C and U profiles, to maintain the same or less elastic deflection without changing the outer dimensions, but only decreasing the thickness and modifying the shape of the beams allowed by the standards.

CHAPTER 2

LITERATURE SURVEY

When a literature research is carried on about the optimization of profiles used in present dropped ceiling construction, it is observed that there are only a few studies. In the literature, research carried out especially on the studies on how to improve the second moments of the cross-sectional areas of profiles have been seen [1].For the improvement of the second moment of the cross-sectional area and the design of new profiles for lower deflection, present analytical analyses have been used [2,3]. The analyses given in these publications are valid for simple figures. Although these analyses are used in preliminary investigations in our studies, mainly the finite element [http://www.mscsoftware.com/news/msc-apex-fossa-accelerates-cae-modeling-and-delivers-real-time-results-exploration] analyses have been used [4]. Within the scope of literature research, model and patent search has also been conducted. Rıgıps Saint-Gobain company has worked the most on these profile topics. Their investigation is about C-shaped profiles [5]. The C-shaped profile is made up of two leg sections and a bottom section that interconnects the leg sections. At least one of the leg sections encloses an opening angle exceeding 90º along with the bottom section in the unstressed state of the C-shaped profile. A metal profile for prefabricated walls, ceilings, C-shaped or U-shaped structures and the like which have cross-section are defined [6]. The mentioned profile has U-shaped sections on the surface of at least one of the flanges, which, for example, are bendable towards inside and which can be used as spacers. The Ultra STEEL technology is a patented process of technology that strengthens the base metal which has not yet been formed by cold rolling. Metal meets this hexagonal rough surface which runs through all along the surface as it passes between two cylindrical rollers that contact each other. During this process the effective thickness of the metal is increased twice as much as the original thickness by changing the metal's surface. This technology, which is applied by Rigips Saint-Gobain Company, makes the metal by far much stronger in ceiling C and ceiling U profile [7].

CHAPTER 3

OBJECT OF PRESENT INVESTIGATION

Construction industry is one of the areas Turkey is showing a significant progress. It is estimated to achieve a growth of %3,56 in the world, in 2018, %1,57 in Europe , %2,47 in the USA, %6,12 in China and %9 in Turkey[8].

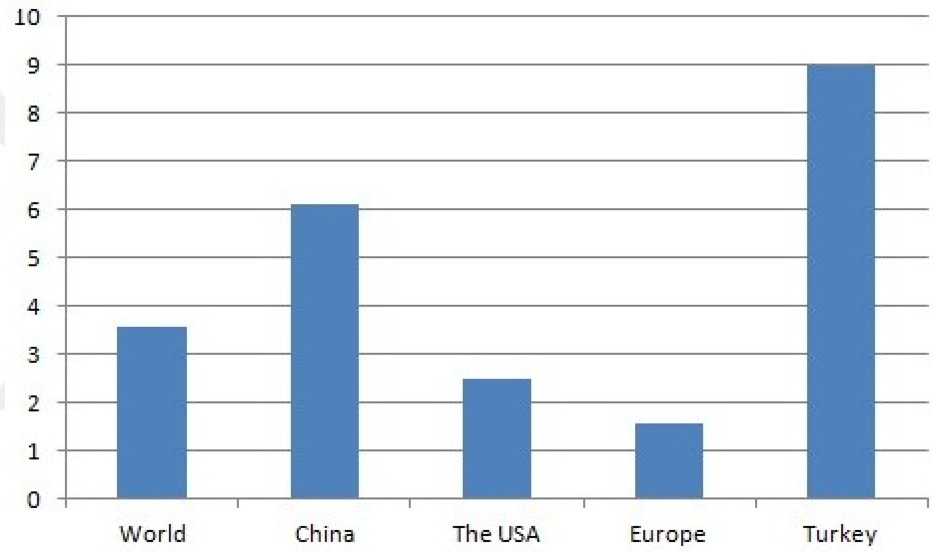

Figure-3: Construction Growth Rate For 2018

In today's houses and skyscrapers dropped ceiling applications are considered as irrevocable for buildings. In the buildings heating systems, ventilation, air conditioning, wiring systems for construction, speakers, light fittings, wireless antenna, cable tv, fire and smoke detectors, motion detectors, sprinklers and so on are all located in dropped ceilings. In order to make it possible to carry such systems and sheetrocks, dropped ceilings need to carry more load. As the load carrying is performed by ceiling C and ceiling U profiles in dropped ceilings, the endurance of these profiles has to be uppermost. The necessities of ceiling C and ceiling U profiles stated above and their applications in all buildings is subject to an important share in industry. There are lots of domestic and foreign ceiling profile manufacturers. As a result of high marketplace demand, the competition level among companies in profile manufacturing is high. Therefore, UMS metal company operating in Ankara applied to Metal Forming Center of Excellence for a research and development project to gain a competitive edge in the sector, to increase the exports and sales of ceiling C and ceiling U profiles, to lower the cost, to put quality certificated products on the market, to increase national and domestic capital and to maximize the carrying capacity of the profiles. Their application was approved and project was started. Within the scope of the project, a contract was signed and design and production of new profiles were given a start in a short time.

The purpose of this study is to produce new designs for C and U profiles, to maintain the same or less elastic deflections without changing the outer dimensions, but only decreasing the thickness and modifying the shape of the beams within allowed limits by the standards.

CHAPTER 4

THEORETICAL ANALYSIS

4.1 Analytical Methods

The calculation of deflections of present ceiling C and ceiling U profiles in cantilever and simply supported modes for simple cross-sections can be done using analytical methods. We have two profiles, these are ceiling C and ceiling U and both of them have different thickness .The thickness values for Ceiling C and ceiling U profiles given below.

Ceiling C: 0,45 mm

Ceiling U: 0,40 mm

4.1.1 Cantilever Beam

The cantilever beam test is used to measure the flexural strength and the deflection of beam. A cantilevered beam is fixed at the one end and the other end is free. Cantilever beam is shown in Figure 4

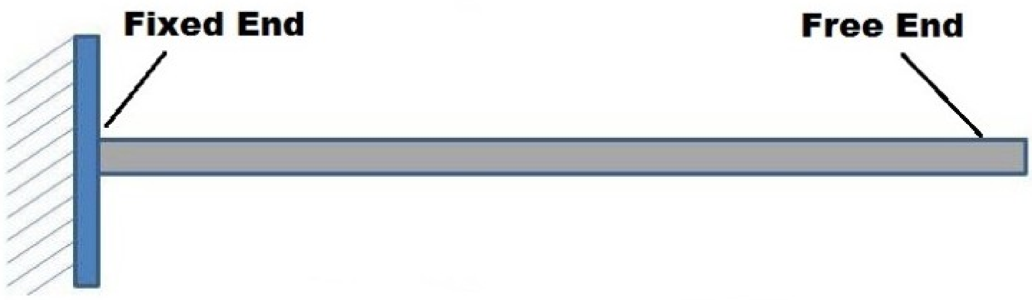

Figure-4: Cantilever Beam

Also we need to use cantilever beam formulas for analytical analysis. Figure 5 shows the nomenclature in cantilever beams.

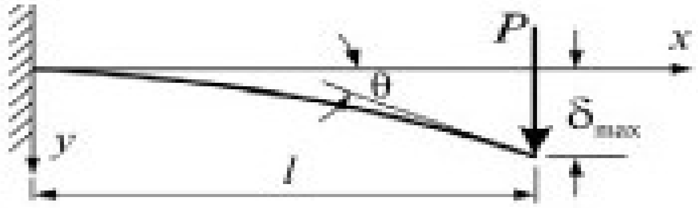

Figure-5: Cantilever Beam Nomenclature

In this case the standard formula for finding deflection y for cantilever is given by:

$$y = -\left(\frac{Px^2}{6EI}\right)(3L - x) \qquad (1)$$

E: Young's modules of Elasticity of material (N/m$^{2)}$

I: Second Moment of Area (m^4)

X: Distance from one side of the beam (m)

P: Load (N or kN)

The maximum deflection occurs at the x=l. Hence, substituting this value in equation (1), we get

$$y_{max} = -\left(\frac{PL^2}{6EI}\right)2L \qquad (2)$$

The maximum deflection $y_{max} = \delta$ is given by:

$$\delta = \frac{PL^3}{3EI} \qquad (3)$$

Cantilever test loading is shown figure 5 for this study. In cantilever loadings in this study, different load are applied on Ceiling U and Ceiling C profiles while profile length is taken as 1000 mm. The reason why it is taken as 1000mm is to be able to calculate the deflections in micron accuracy. The values for this study are given below. Also Young's modules is found by the Resonant Frequency and Damping Analyser (RFDA) method. RFDA process the Young's modulus resonance difference of the sample can be measured precisely through damping analysis.

L=1000 mm

P=Variable

Ceiling U is young's modules E=206,57 GPA

Ceiling C is young's modules E=209,32 GPA

Poisson's Ratio=0.3 (Stainless Steel)

4.1.2 Simply Supported Beam

A simply supported beam is a type of beam that has knife edge supports at both ends. Depending on the load applied, it undergoes shearing and bending. It is the one of the simplest structural elements used. In this study both of the ends are knife edged. Simply Supported beam is shown in Figure 6.

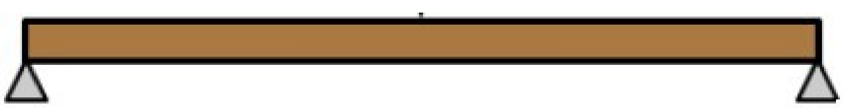

Figure-6: Simply Supported Beam

To carry out the analytical analysis, simply supported beam formulas are reviewed. Figure 7 shows the variables in simply supported beam Nomenclature.

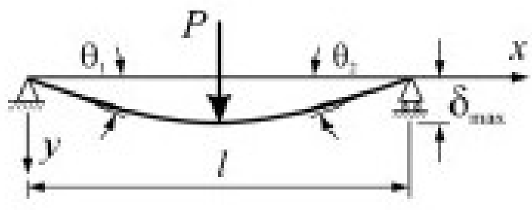

Figure-7: Simply Supported beam Nomenclature

In this case the standard formula for finding deflection y for a concentrated load and knife edge supports is given by:

$$y = \frac{Px}{48EI}(3L^2 - 4x^2) \qquad (4)$$

E: Young's modules of Elasticity of material (N/m^2)

I: Second Moment of Area (m^4)

X: Distance from one side of the beam (m)

P: Load (N or kN)

The maximum deflection occurs at the mid-point so x= L/2. Hence, substituting this value in equation (4), we get

$$y_{max} = \frac{P\,L/2}{48EI}[3L^2 - 4L^4/4] \qquad (5)$$

The maximum deflection $y_{max} = \delta$ at the centre is given by:

$$\delta = \frac{PL^3}{48EI} \qquad (6)$$

Simply supported loading test (Figure 6) shows the deflection occurring in the elastic domain when load is applied on the beam in the middle of its length supported with knife-edge supports at both ends. In simply supported bending tests the length (L) is taken as 1057mm. The reason why length is taken as 1057 mm is that test system built up has knife edges and to be able to calculate the deflections by taking them into account, length is taken as 1057 mm. The values for this study are given below. Also young's modulus is found by RFDA method.

L=1057 mm

P=Variable

Ceiling U is Young's module E=206,57 GPA

Ceiling C is Young's module E=209,32 GPA

Poisson's Ratio=0.3(Stainless Steel)

4.2 Numerical Methods

The above analytical formula can be used for beams with simple cross sections. Ceiling profiles have complex cross sections so we cannot easily find the second moment of area (I) with standard formulas.

However, for complex cross sections finite element method (FEM) can be used. In this study, FEM program used is MSC Apex software. MSC Apex software's home page is shown in Figure 8. MSC Apex modeller is a CAE specific direct modelling and meshing solution that streamlines CAD clean-up, simplification and meshing workflow. The solution features sophisticated and interactive tools that are easy to use and easy to learn.

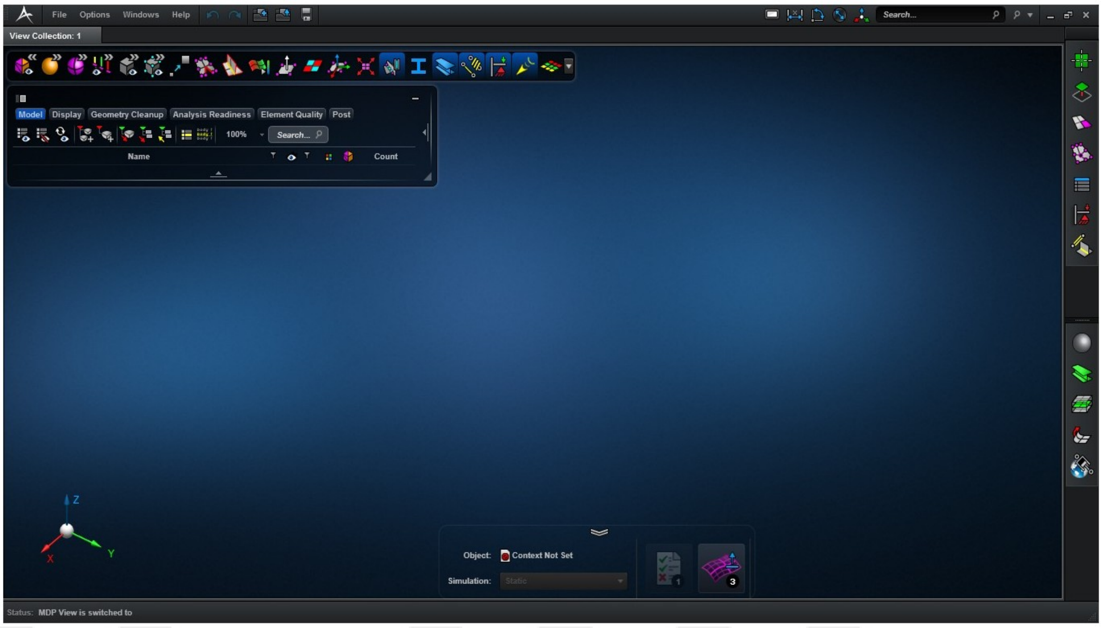

Figure-8: MSC Apex Software's Home Page

To calculate the deflections numerically, first the drawings of present beam profiles are modelled by Computer Aided Design (CAD) techniques using the CatiaV5R20 program. Catia is one of the most common design program in the world. Catia developer Dassault Systems resides in France. IBM is also a Catia marketer. Catia home page is shown in Figure 9.To find the deflections under loading , by numerical calculations a FEM program (Apex) is used using the Catia model.

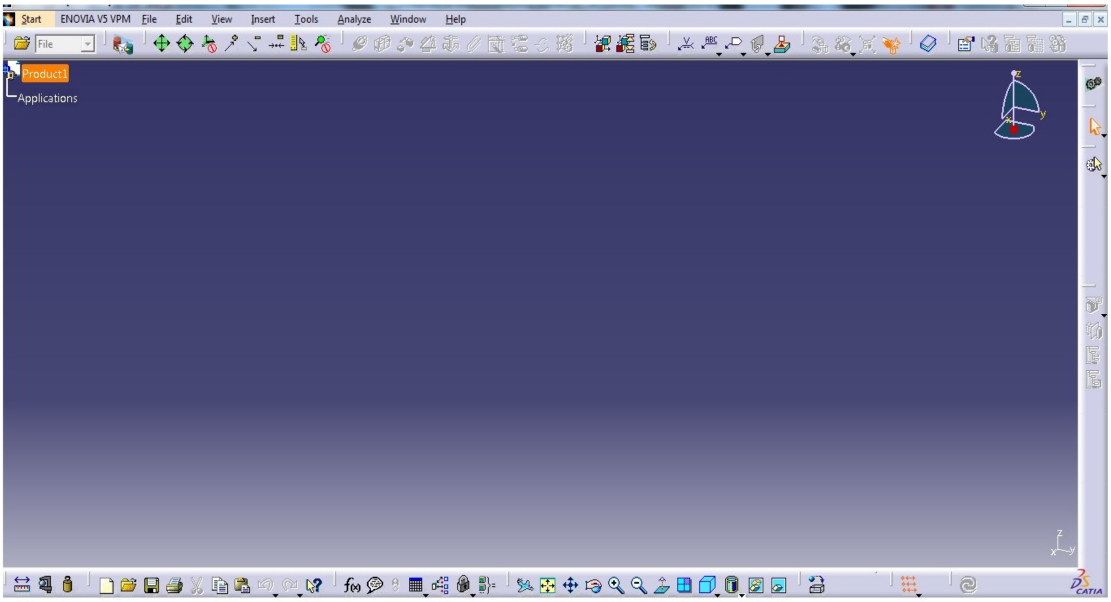

Figure-9: Catia Program's Home Page

4.3 Calculation of Deflections for Existing Profiles

To calculate the deflections numerically, first the drawings of existing beam profiles (Ceiling C and Ceiling U) are modelled by Computer Aided Design (CAD) techniques using the CatiaV5R20 program. Ceiling U and Ceiling C technical drawings are shown in Figure 10 and Figure 11. Then these drawings are used in MSC Apex finite element software. Steps for modelling of cantilever and simple bending loadings of Ceiling U and Ceiling C are;

1. CAD models are opened in MSC Apex Software
2. Meshing is applied
3. Cantilever or Simple bending load is selected
4. Program is executed
5. Solution- numerical results are obtained and plotted

Figure-10: Existing Ceiling U

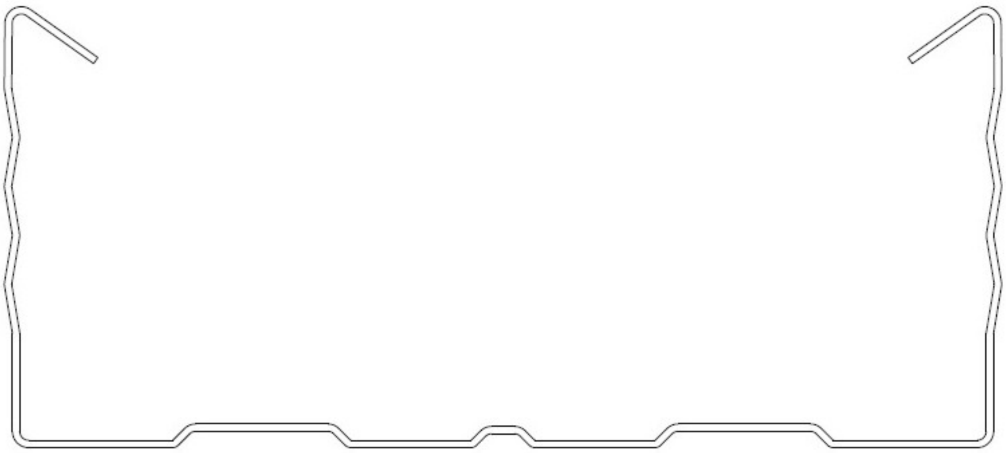

Figure-11: Existing Ceiling C

Detailed modelling of cantilever and simple bending loadings of Ceiling U profile are made using finite element method as shown in Figure 12. Detailed modelling of cantilever and simply supported loadings of Ceiling C profile made using finite element method are shown in Figure 13.

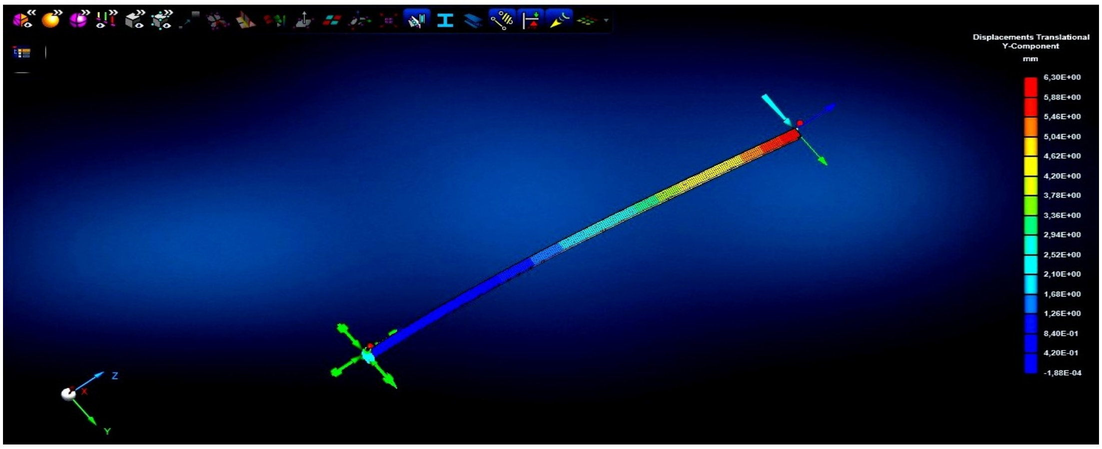

Figure-12a: FEM modelling of Ceiling U profile for Cantilever Loading

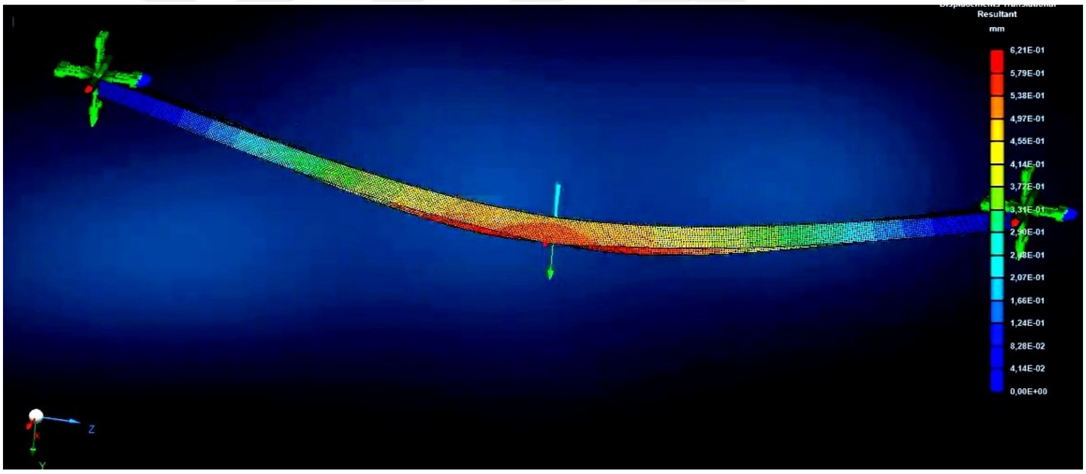

Figure-12b: FEM modelling of Ceiling U profile for Simply Supported Loading

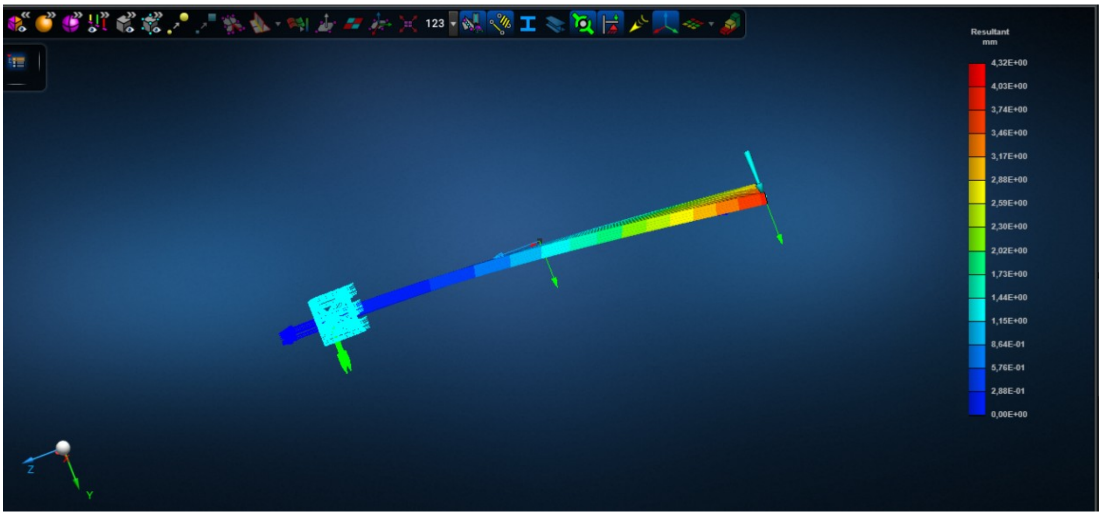

Figure-13a: FEM modelling of Ceiling C profile for Cantilever Loading

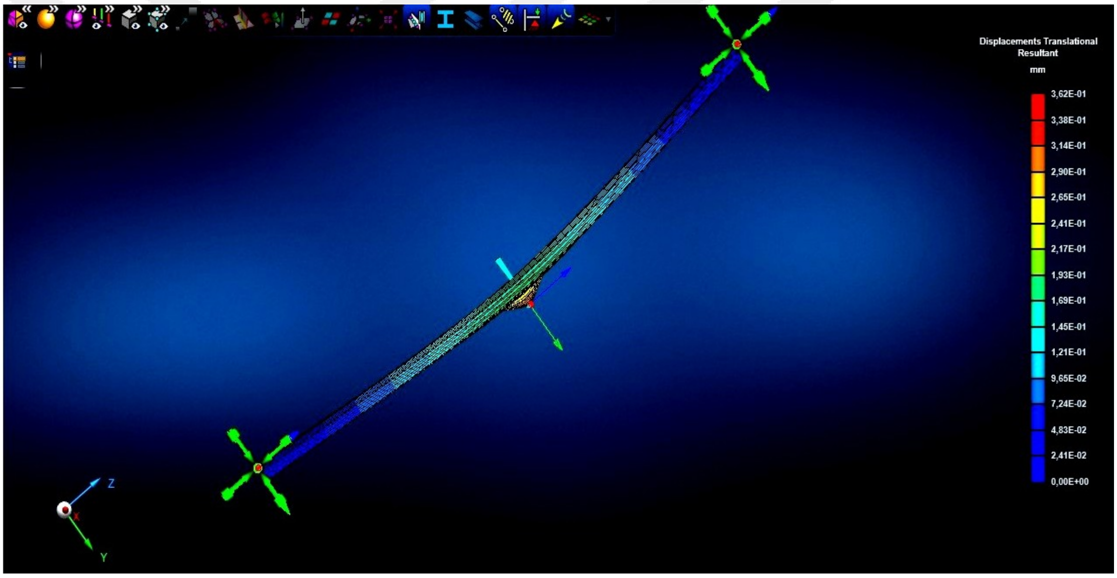

Figure-13b: FEM modelling of Ceiling C profile for Simply Supported Loading

The deflections of Ceiling U and Ceiling C profiles found using the finite element method by making numerical calculations are shown in Table 1 and Table 2.

Table 1: Finite Element Analysis for Cantilever Test

	Thickness	Cantilever	Apex
	Material Thickness (mm)	Load(N)	Deflection(mm)
Existing Ceiling U	0,40	5,31	6,30
Existing Ceiling C	0,42	10,21	4,32

Table 2: Finite Element Analysis for Simply Supported Test

	Thickness	Simply Supported	Apex
	Material Thickness (mm)	Load(N)	Deflection(mm)
Existing Ceiling U	0,40	5,31	0,621
Existing Ceiling C	0,45	10,21	0,362

CHAPTER 5

EXPERIMENTAL INVESTIGATIONS

5.1 Development of Laboratory

There is a need to have a testing laboratory at UMS Company to compare the analyses made by FEM and experimental testing under the same conditions. However; UMS Company did not have a laboratory to make simply supported and cantilever tests of the profiles they produce. Therefore, it is decided to set up a laboratory in the building of the company. Cantilever test system and simply supported test system are principally planned as the necessary equipment for this laboratory. To achieve this, necessary designs for test systems and their manufacturing procedures are started immediately. Manufacturing of the equipment that is going to be used for making experimental measurements are made of the highest quality. Joints of test supports are planned as chrome countersunk bolts. Also, the surface of the platform and all the equipment to be used, the material is ground and manufactured as + -10 micron accuracy. Weights that are going to be used in cantilever and simply supported tests are obtained as 4,905 N (mass is 500 gr), 9,81 N (mass is 1 kg), 19,620 N (mass is 2 kg) and 49,050 N (mass is 5 kg) certified weights. The comparator to be used in tests to measure deflection are set on a magnetic clench (clenching power of 80 kg) and having a dial gauge with the sensitivity of +-10 micron. Sample comparator and the load are shown in Figure 14.

In Figure 15 simply supported laboratory test system is shown. In Figure 16 Cantilever test system is shown. In figure 17 the laboratory built in UMS Company is shown.

Figure-14: Comparator and Loads

Figure-15: Simply Supported Laboratory Test System

Figure-16: Cantilever Laboratory Test System

Figure-17: Ceiling U and C Profiles Test Laboratory

5.2 Experimental Measurements on Existing Profiles

In the developed laboratory experimental measurements are carried out using the cantilever and simply supported test systems. Figure 18 shows Cantilever test sample. And, Figure 19 shows simply supported test sample. Thickness for U profile is taken as 0.40 mm, and for C profile as 0.42 mm and 0.45 mm. Since the company manufactures by strip, the measured values are the measured by the company. These measurements are the original thicknesses measured with calliper gage. As for the applied forces, they are set up as 5,31 N (mass is 500 gr and chain mass is 41 gr) for U profile and 10,21 N (mass is 1 kg and chain mass is 41 gr) for C profile. After the parameters are set up and experiment apparatus is prepared, test process is given a start.

Figure-18: Cantilever Test

Figure-19: Simply Supported test

The cantilever and simply supported bending experiments on Ceiling U and Ceiling C profiles made in the developed laboratory (Figure 16) are presented in Table 3 and Table 4.

Table 3: Laboratory Experiment Analysis for Cantilever Test Results

	Thickness	Cantilever	Laboratory	FEM Analysis Results
	Material Thickness (mm)	Load(N)	Deflection(mm)	Deflection(mm)
Existing Ceiling U	0,40	5,31	6,3	6,30
Existing Ceiling C	0,42	10,21	4,39	4,32

Table 4: Laboratory Analysis for Simply Supported Test

	Thickness	Simply Supported	Laboratory	FEM Analysis Results
	Material Thickness (mm)	Load(N)	Deflection(mm)	Deflection(mm)
Existing Ceiling U	0,40	5,31	0,55	0,621
Existing Ceiling C	0,45	10,21	0,44	0,362

It is observed that the deflection values obtained from numerical calculations using finite element method are in agreement with the results obtained from the experiments made in the laboratory. The differences observed are due to the thicknesses of Ceiling U and Ceiling C profiles used in laboratory experimental environment. The thickness values used in the numerical calculations have been the nominal values such as 0.40 or 0.45 whereas in the real profiles, due to manufacturing tolerances they show variations within the tolerances. Considering this argument, calculations made using finite element method are in agreement with the experimental values obtained in laboratory environment.

5.3 Experimental Measurements of Elastic Modulus

By RFDA process the elastic modulus resonance difference of the sample can be measured precisely through damping analysis. The RFDA machine used is RFDA-HTVP1600.

Figure-20: RFDA-HTVP1600

The equipment of RFDA system and measurement steps can be summarized briefly as in the following figures.

Sample is placed between two supports. As seen in Figure-21 microphone and impingement attachment are placed appropriately and test is given a start.

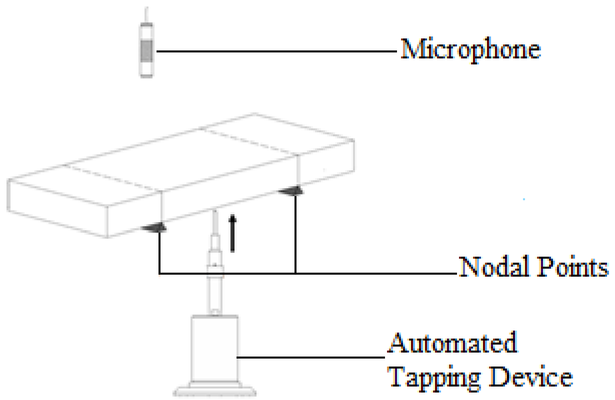

Figure-21: Microphone and Impingement Attachment

By transferring the Vibration signals occurred on the sample to the machine software with the aid of the microphone, measurement is achieved.

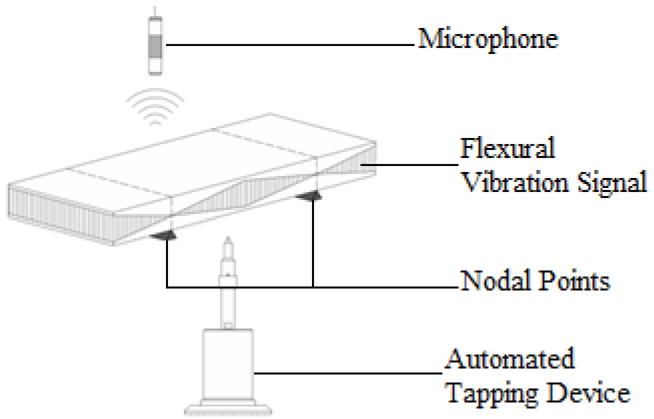

Figure-22: RFDA Test System

The elastic modulus values found are used in the finite element analysis of new and old profiles. The values of elastic modulus found by RFDA method are shown in Table 5 for every thickness of the profiles.

Table 5: Elastic Modulus for Every Thickness of the Profile

Thickness (mm)	Rolling Direction (°)	Average (GPa)	Standard Deviation
0.60	0	195,98	± 7,98 GPa
0.55	0	201,11	± 4,88 GPa
0.50	0	188,12	± 6,04 GPa
0.45	0	209,32	± 28,63 GPa
0.40	0	206,57	± 14,51 GPa

5.4 Experimental Measurements of Tension Test

In these thesis studies, for profiles, macro extensometer tension test is done. The aim of doing this test is to find the flow curves of the profiles and check whether they exceed the flow curve of the analysis made by finite elements method. Macro extensometer tension test is done by ZWICK Z300 machine. The aim of this test is to calculate the flow curve and the anisotropy parameters.

Flow curve test of the tension test sample produced according to ISO 50125 standards is made according to ISO 6892 standards and flow curve is obtained. Anisotropy parameters of the samples of the product in 0 45 90 roll direction are obtained according to ISO10113 standards via tension test data. In the Figure-23 blow tension test machine is shown.

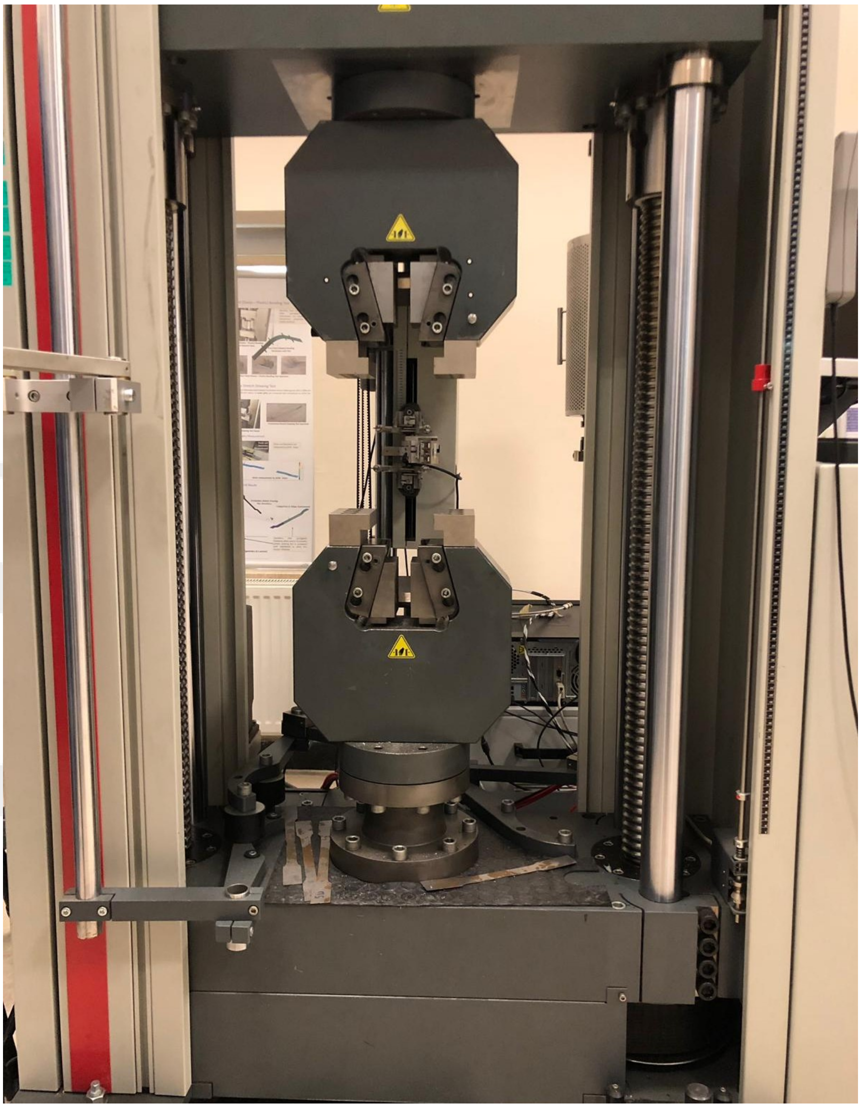

Figure-23: Tension Test Machine

Specimens for tension have a length of 500 mm and their thicknesses vary between 0.40 to 0.50 mm. The experiments conducted for U profiles are designated by 079165u01 and experiments conducted for C profiles are designated by 17100380. The width of the profiles used in the experiments is 20mm.

Flow curves of the profiles found as a result of the tension test are shown in the figure below. Maximum true stress, maximum engineering stress, yield strain and yield stress for tension test are shown in Table 7 and Table 9.

Table 6: Tension Test Variables for Ceiling U Profile

079165u01	U Profile
Specimen thickness	0,40mm
Specimen width	20,03mm

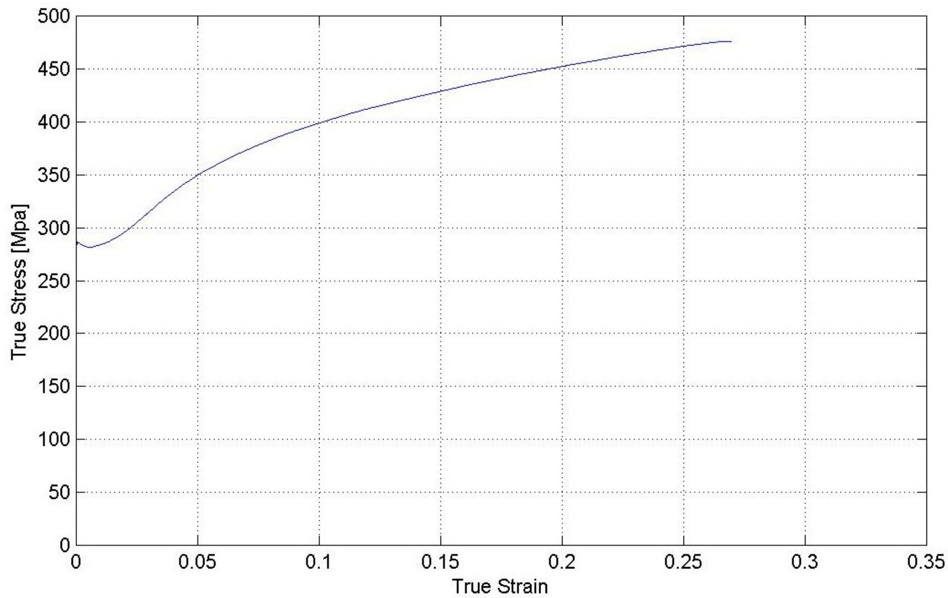

Figure-24: Results of Tension Test for Ceiling U Profile

Table 7: Maximum true stress, maximum engineering stress, yield strain and yield stress

	Max. True Stress (MPa)	Max. Eng Stress (Mpa)	Yield Strain	Yield Stress (MPa)
079165u01	476,45	370,73	0,003	282,02

Table 8: Tension Test Variables for Ceiling C Profile

17100380	C Profile
Specimen thickness	0,51mm
Specimen width	20,04mm

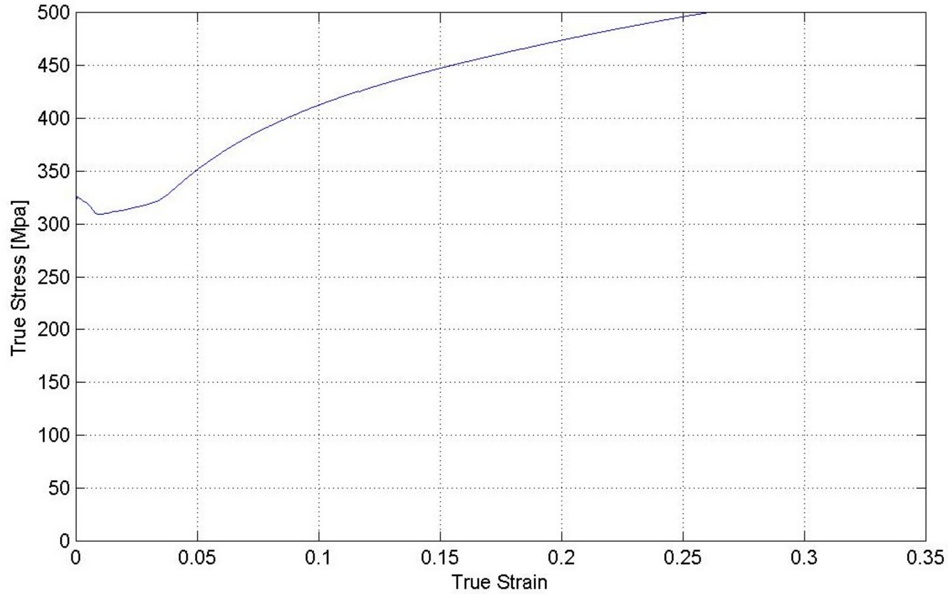

Figure-25: Results of Tension Test for Ceiling C Profile

Table 9: Maximum true stress, maximum engineering stress, yield strain and yield stress

	MaxTrue Stress (MPa)	MaxEng Stress (MPa)	Yield Strain	Yield Stress (MPa)
17100380	505,06	388,07	0,003	320,06

An example of the Von Mises stress distribution found by the finite element method is shown in the Figure below. All remaining values of Von Mises stress can be seen in appendix A.

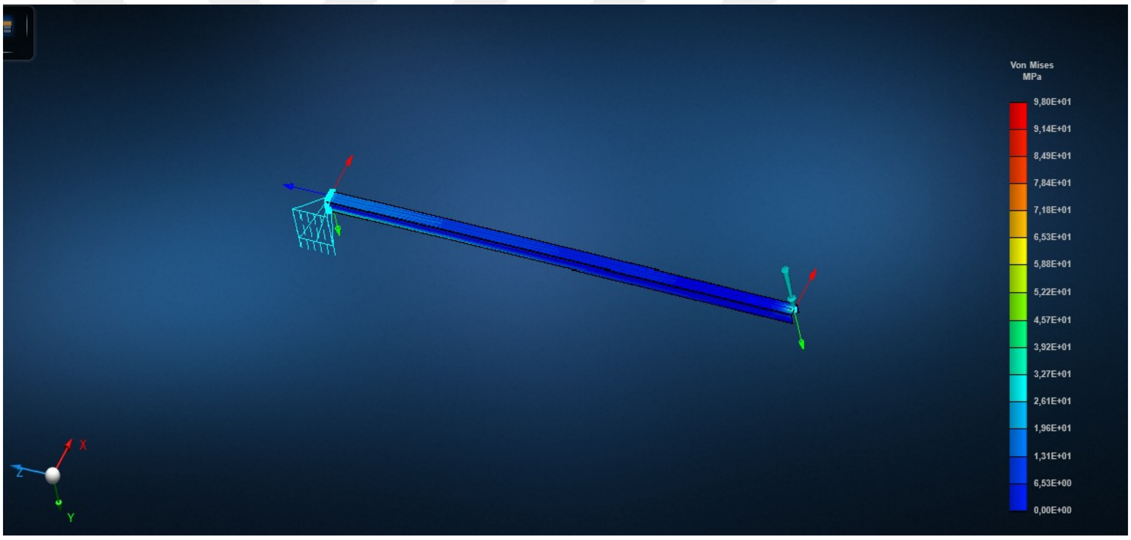

Figure-26: Von Mises Stress

When the analysis are compared with the results of the tension test, it is observed that Von mises stress is smaller than the yield stress obtained in the tension test.

CHAPTER 6

DESIGN OF NEW PROFILES

6.1 Ceiling U Profile

For the cross section of Ceiling U profile, according to the standards, the height of its sides needs to be 22mm, and the width of its base needs to be 28mm. Using these constraints, attempts are made to increase the second moment of area by changing the depth of intrusions on the sides and base. Because of the increase in the second moment of area strength and the stiffness of the beam is increased. Therefore, modifications are made in all existing ceiling U profiles sides allowed by the standards. However, during this process, the manufacturing process, roll-forming have been considered as well. For roll forming from a strip material, sharp edges are not allowed and angles used on the sides of the intrusions are chosen according to the manufacturing parameters. The designs of new Ceiling U profile is developed using the CAD program Catia. Technical drawings of the new Ceiling U profile is shown in Figure 27.

Standards of Ceiling U:

Height: 22 mm

Width: 28 mm

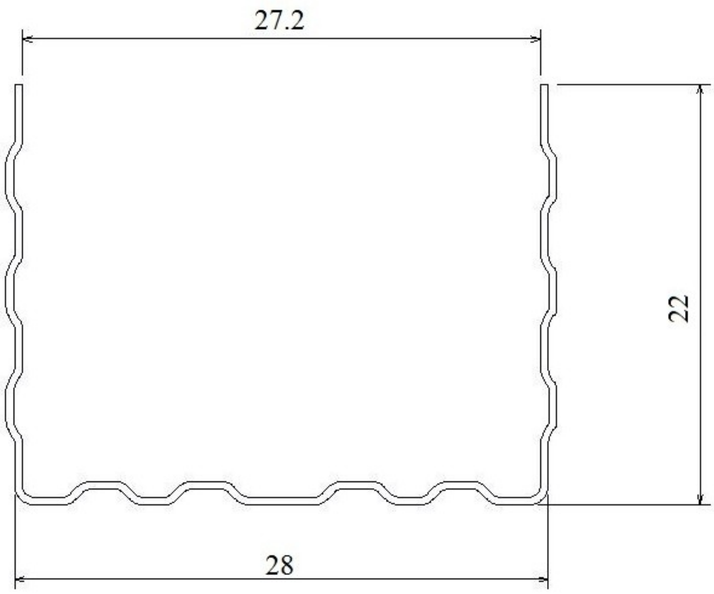

Figure-27: Design of New Ceiling U Profile

6.2 Ceiling C Profile

For the cross section of Ceiling C profile, according to the standards, the height of its side needs to be 27 mm, and the width of its base needs to be 60 mm. Using these constraints, attempts are made to increase the second moment of area by changing the depth of intrusions on the sides and base. Because of the increase the second moment of area, strength and the stiffness of the beam is increased. Therefore, modifications are made in all existing ceiling C profiles sides allowed by the standards. However, during this process, the manufacturing process, roll-forming have been considered as well. For roll forming from a strip material, sharp edges are not allowed and angles used on the sides of the intrusions are chosen according to the manufacturing parameters. The designs of new ceiling C profile is developed using the CAD program Catia. Technical drawings of the new ceiling C profile is shown in Figure 28

Standards of Ceiling C:

Height: 27 mm

Width: 60 mm

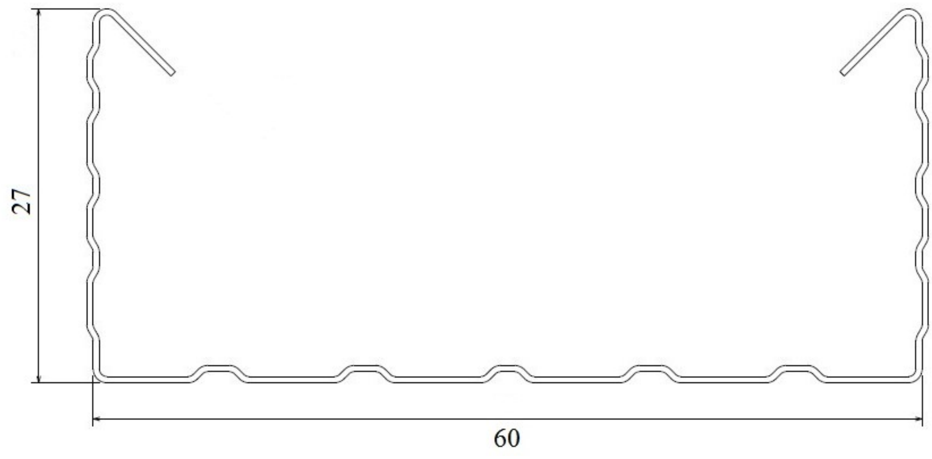

Figure-28: Design of New Ceiling C Profile

CHAPTER 7

DISCUSSION OF RESULTS

7.1 DEFLECTION ANALYSIS of NEW CEILING U and CEILING C PROFILES

Loadings on profiles are shown in Figure 5 and Figure 7. In the cantilever loadings used in this analysis, the length of beam is taken as 1000 mm and different loadings for new Ceiling C and Ceiling U profiles are applied. In simply supported beam test maximum deflection occurs in the middle when the load applied in the middle of its length supported with knife-edges on both of its ends. In simple bending tests the length (l) of beam is taken as 1057mm.

In the developed laboratory, deflections of new profiles have been measured by applying Cantilever and Simply Supported tests (Table 10 and Table 11).

Table 10: Laboratory Experiment Analysis for Cantilever Test Results

	Thickness	Cantilever	Laboratory
	Material Thickness (mm)	Load(N)	Deflection(mm)
New Ceiling U	0,40	5,31	5,91
New Ceiling C	0,45	10,21	3,56

Table 11: Laboratory Experiment Analysis for Simply Supported Test Results

	Thickness	Simply Supported	Laboratory
	Material Thickness (mm)	Load(N)	Deflection(mm)
New Ceiling U	0,40	5,31	0,48
New Ceiling C	0,45	10,21	0,37

7.2 FINITE ELEMENT ANALYSIS of NEW CEILING U and CEILING C PROFILES

Loadings on profiles are shown in Figure 5 and Figure 7. In the cantilever loadings used in this analysis, the length of beam is taken as 1000 mm and different loadings for new Ceiling C and Ceiling U profiles are applied. In simply supported beam test maximum deflection occurs in the middle when the load applied in the middle of its length supported with knife-edges on both of its ends. In simple bending tests the length (l) of beam is taken as 1057 mm.

The calculation of deflections of new Ceiling C and Ceiling U profiles shown in Figures 9 and 10 have been obtained using the finite element method. To find the numerical deflections for both beams, finite elements method (Apex) is used. Detailed modelling of cantilever and simply supported beams of Ceiling U profile made using the finite elements method are shown in Figure 29. Detailed modelling of cantilever and simple bending loadings of Ceiling C profile using finite elements method are shown in Figure 30.

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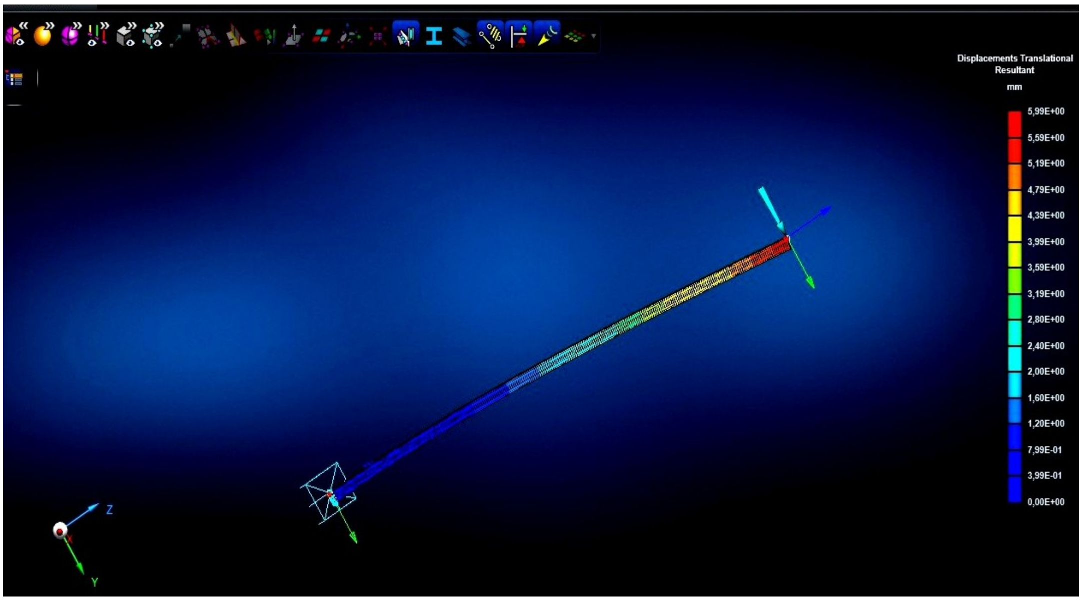

Figure-29a: New Ceiling U Cantilever Loading

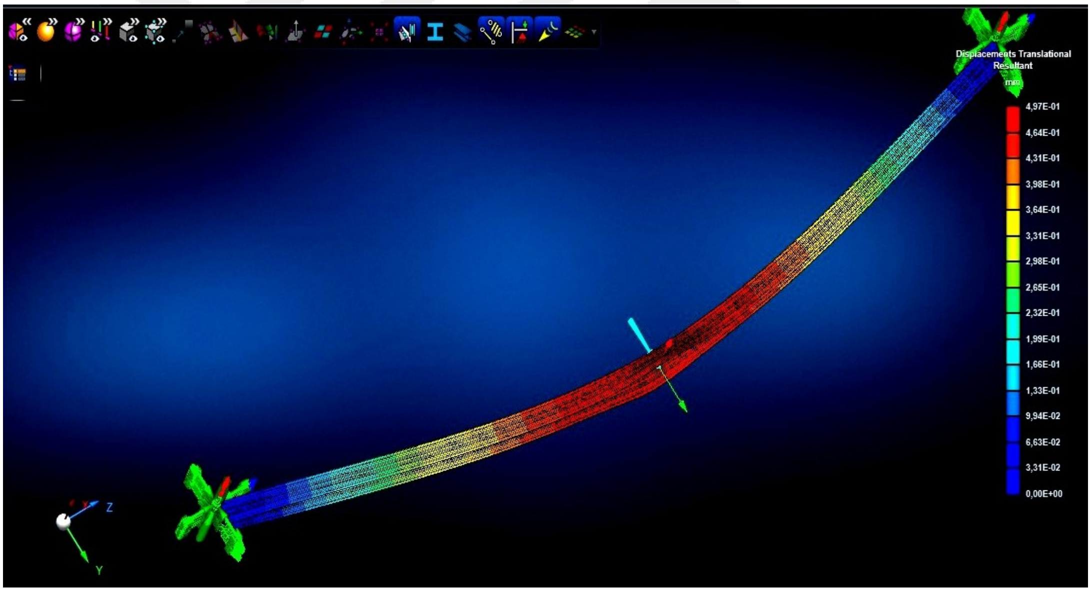

Figure-29b: New Ceiling U Simply Supported Loading

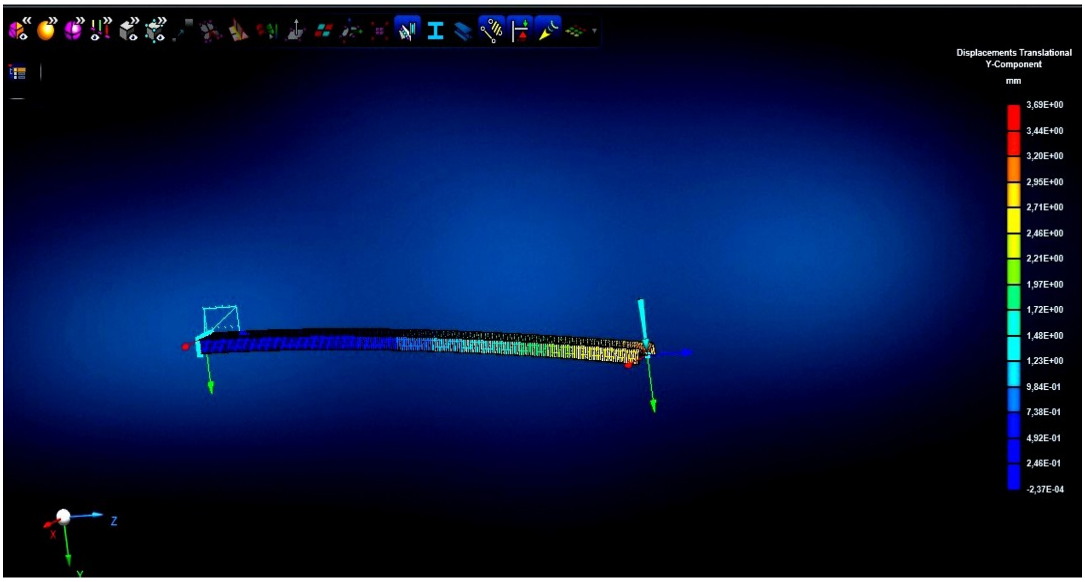

Figure-30a: New Ceiling C Cantilever Loading

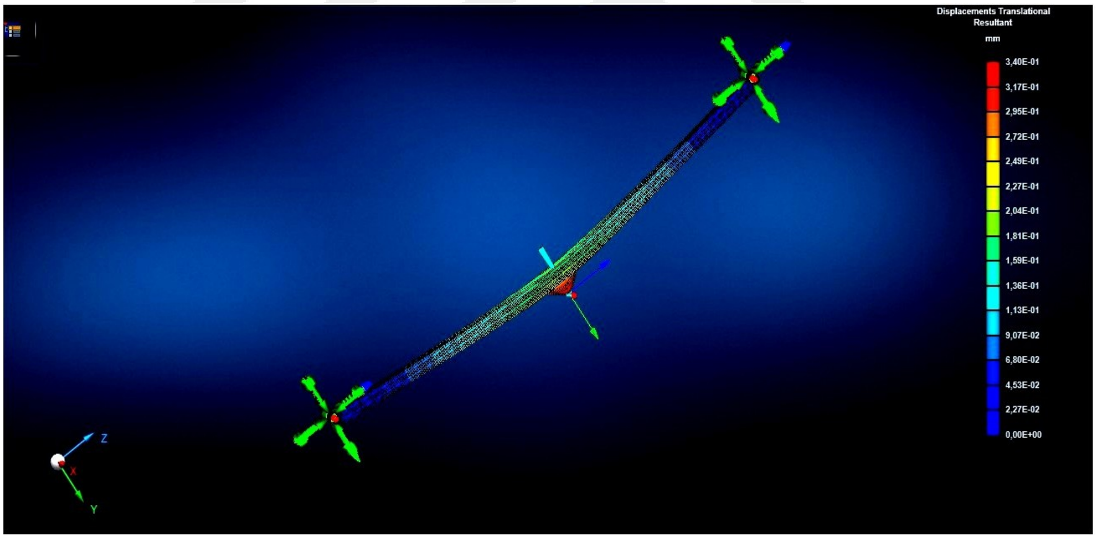

Figure-30b: New Ceiling C Simply Supported Loading

The deflections found using the finite elements method are shown in Table 12 and Table 13. The new profiles that are designed using Catia and numerical calculations of which are made by finite element method have been then manufactured.

Table 12: Finite Element Analysis for Cantilever Test

	Thickness	Cantilever	Apex	Laboratory Experiment Analysis Result
	Material Thickness (mm)	Load(N)	Deflection(mm)	Deflection(mm)
New Ceiling U	0,40	5,31	5,99	5,91
New Ceiling C	0,45	10,21	3,69	3,56

Table 13: Finite Element Analysis for Simply Supported Test Results

	Thickness	Simply Supported	Apex	Laboratory Experiment Analysis Result
	Material Thickness (mm)	Load(N)	Deflection(mm)	Deflection(mm)
New Ceiling U	0,40	5,31	0,50	0,48
New Ceiling C	0,45	10,21	0,34	0,37

In the developed laboratory, deflections of new profiles have been measured by doing Cantilever and Simply Supported tests compared with the deflections obtained by finite elements method. The results found have been seen to be in compliance. Also, as a result of experimental analyses, it has been observed that the strength of profiles in the elastic area has been increased.

7.3 DISCUSSION OF RESULTS

Several tests have been made on existing profiles and new profiles both in FEM environment and in laboratory environment. In the laboratory, on ceiling U profile 2 tests (cantilever and simply supported) for existing ones, and using FEM, 2 analyses (cantilever and simply supported); and for the newly designed ones also the same tests and analyses are carried out. As for ceiling C profile, in the laboratory 2 tests (cantilever and simply supported) for existing ones, and using FEM, 2 analyses (cantilever and simply supported); and for the newly designed ones, the same tests and analyses are also carried out.

When Table 3 and Table 4, Table 10 and Table 11 are examined, the result is; The results of these tests in and analyses show it has been observed that the changes made in the second moment of areas of the profiles increase their strengths. In the results obtained in consequence of the tests and analyses, it is shown which profile is improved to what extent.

-For Ceiling U profiles: Up to % 8 improvement (Cantilever Test)

Up to %15 improvement (Simply Supported Test)

-For Ceiling C profiles: Up to % 15 improvement (Cantilever Test)

Up to %15 improvement (Simply Supported Test)

As a result of laboratory experiments and FEM analysis, the thicknesses of C and U profiles have been reduced by approximately 0.05 mm, resulting in deflections not more than the original designs. In Table 14 the mass changes of the 1000 mm long profiles are given.

Table 14: Mass Change of Profiles

	Length (mm)	Mass (kg)
Existing U Profile	1000	0,029
New U Profile	1000	0,026
Existing C Profile	1000	0,057
New C Profile	1000	0,053

Forming of the C and U profiles can be seen in video:

https://www.youtube.com/watch?v=eNjxP7mEgZQ

The video on the newly developed C and U profiles can be seen at:

https://www.youtube.com/watch?v=3wCor5LzBF4

To protect the new designs of the C and U profiles, an "Useful Model" application to the Turkish Patent Institute has been made as seen in Appendix B.

CHAPTER 8

CONCLUSION

This research was started by the request of UMS Metal Company in OSTİM Ankara producing C and U profiles for the construction industry. The Company wanted to produce C and U profiles with a more competitive design to compete with the other domestic and imported products. They also wanted to develop a better technology for quality control and testing of their products. However, the new products also have to satisfy the requirements of the international standards on the geometry of the profiles.

With these motivations and constraints, research was started on the optimization of the profiles without changing the outside dimensions. The same steel was to be used. However, the thickness of the material, to save weight and cost could be reduced. The only remaining variable left for optimization were the shape of the profiles. Since the criterion for optimization is to maximize the bending strength and stiffness of the beams within the elastic region, second moment of area was maximized by changing the shape considering also the roll-forming constraints for manufacturing. These constraints were mainly the angles of the flutes along the beams given by the manufacturer.

First, the existing C and U profiles were analyzed by finite element method and deflections of the beams were found for cantilever and simply supported conditions. A laboratory was developed to find the deflection of the beams experimentally. A good agreement between theory and experiment was obtained. Then new C and U profiles were designed increasing the second moment of area of the cross sections of the beams. Deflections of the new beams were computed by the finite element method. The beams were then manufactured by the company by roll-forming. Later, experiments to find the deflections for the new beams were conducted. It was found that up to 15 % improvements were obtained.

To protect the design a “Useful Model” application was made to Turkish Patent Institute as shown in Appendix A. Also the results of this research was published in the Mechanical Design and Manufacturing Journal in 2017 [9]. Also, this research was presented in an international conference ICETAS in 2018 [10].

CHAPTER 9

SUGGESTIONS FOR FUTURE WORK

As a result of the studies conducted within the scope of this thesis it has been observed that profiles can be more resistant and it is possible to manufacture more resistant products with a lower cost. In oncoming studies strengthening and manufacturing these profiles at a lower cost is considered to be a follow-up of this thesis study . Concurrently, for all profiles and beams subjected to cantilever and simply supported loads, the studies conducted in this thesis can be used. Moreover, the length was taken as 1000 mm in the laboratory and FEM analysis for cantilever test. These tests can be renewed for more than 1000 mm length in future studies. The length was taken as 1057mm in the laboratory and Fem analyzes for simply supported test. These tests can be renewed for more than 1057 mm length in future studies.

These profiles are not only used in dropped ceiling manufacturing but also used in mezzanine applications. Therefore; in an oncoming study, to increase the resistance of profiles used in the manufacturing of mezzanine and lowering their cost as well can be researched. The modelling done within this thesis and the laboratory environment can be used for the analyses and deflection calculations of profiles with different dimensions for different purposes.

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APPENDIX A

VON MISES STRESS OF ALL ANALYSIS

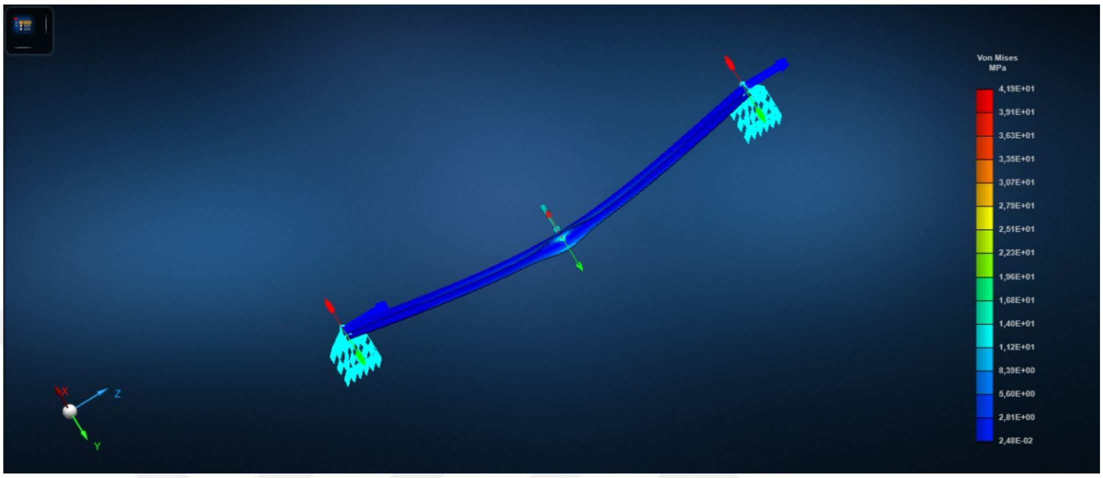

Figure-31: Von Mises Stress Result of Simply Supported Test Analysis for New Ceiling Profile U

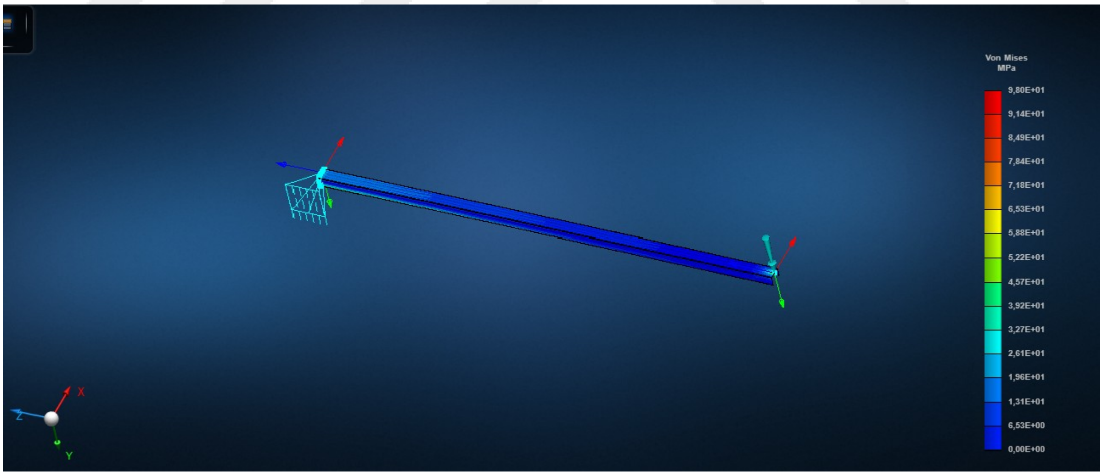

Figure-32: Von Mises Stress Result of Cantilever Test Analysis for New Ceiling Profile U

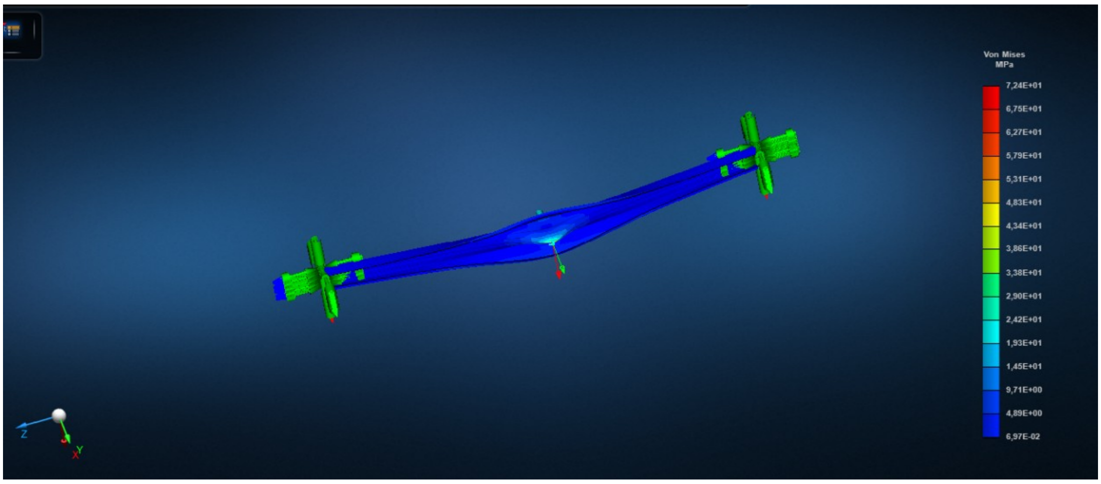

Figure-33: Von Mises Stress Result of Simply Supported Test Analysis for Existing Ceiling Profile C

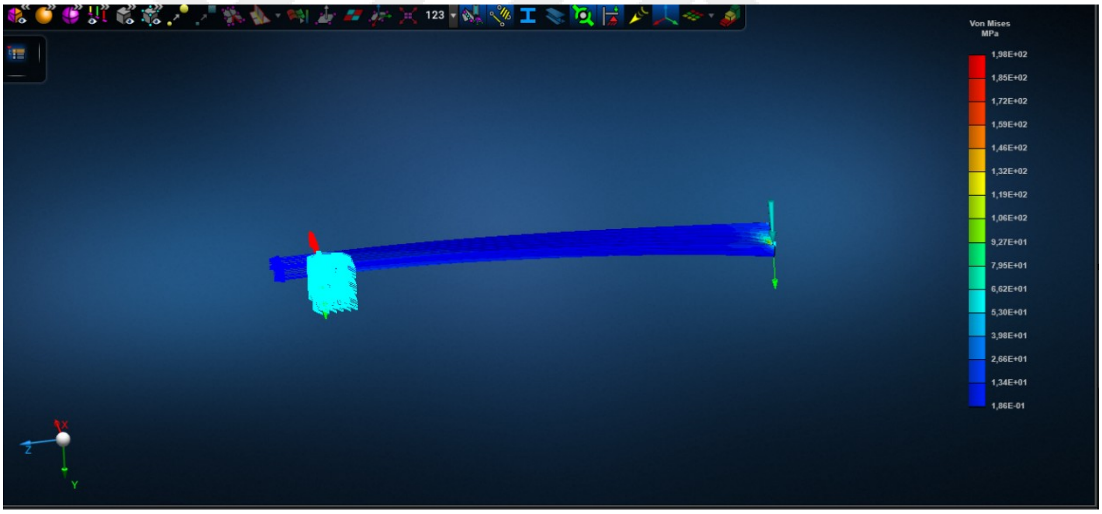

Figure-34: Von Mises Stress Result of Cantilever Test Analysis for Existing Ceiling Profile C

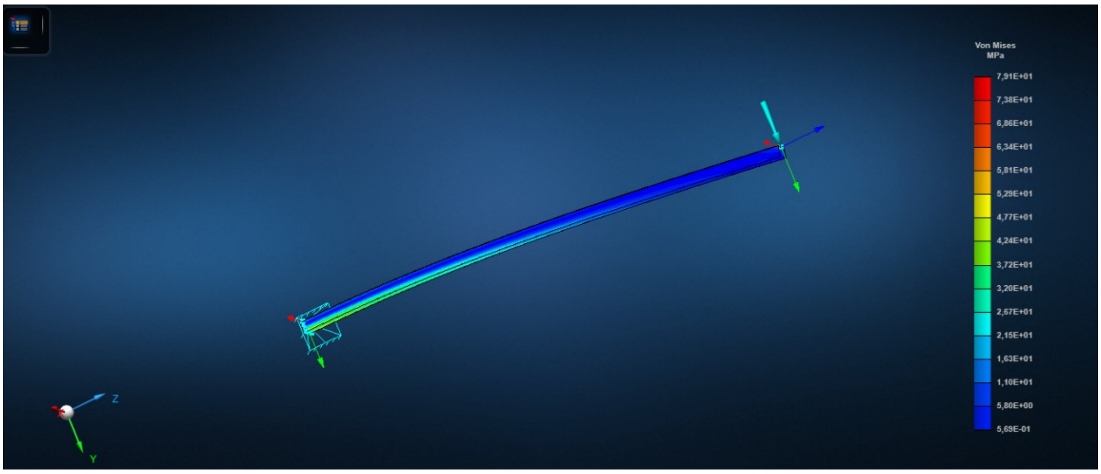

Figure-35: Von Mises Stress Result of Cantilever Test Analysis for Existing Ceiling Profile U

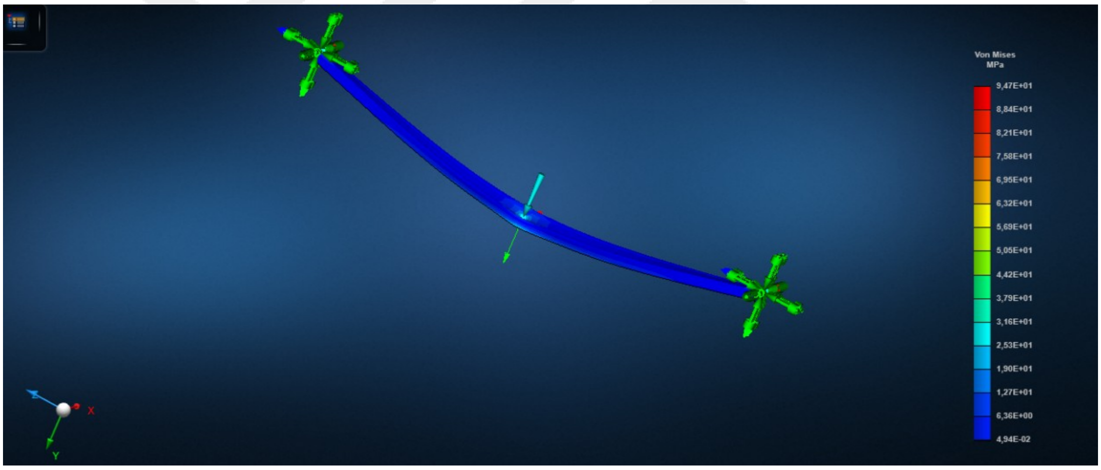

Figure-36: Von Mises Stress Result of Simply Supported Analysis for Existing Ceiling Profile U

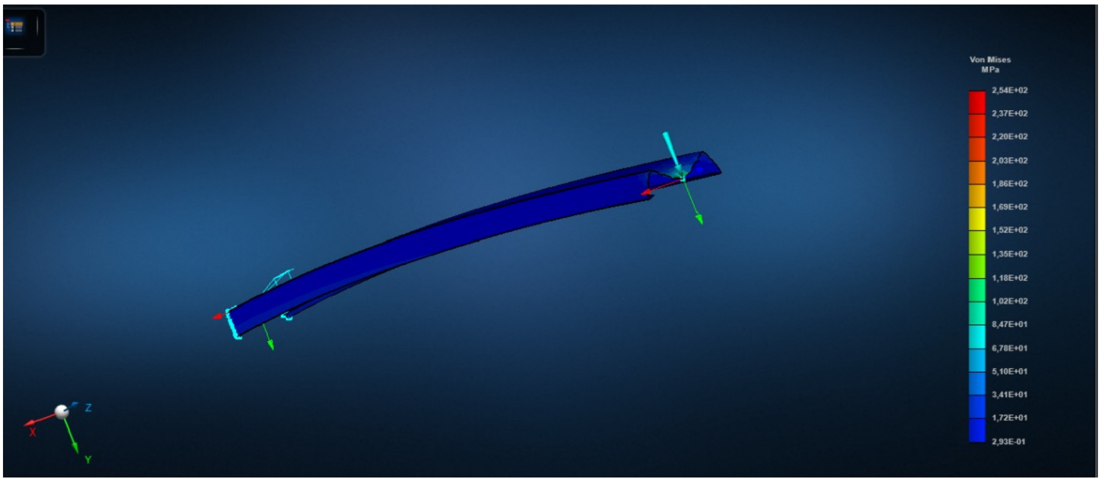

Figure-37: Von Mises Stress Result of Cantilever Analysis for New Ceiling Profile C

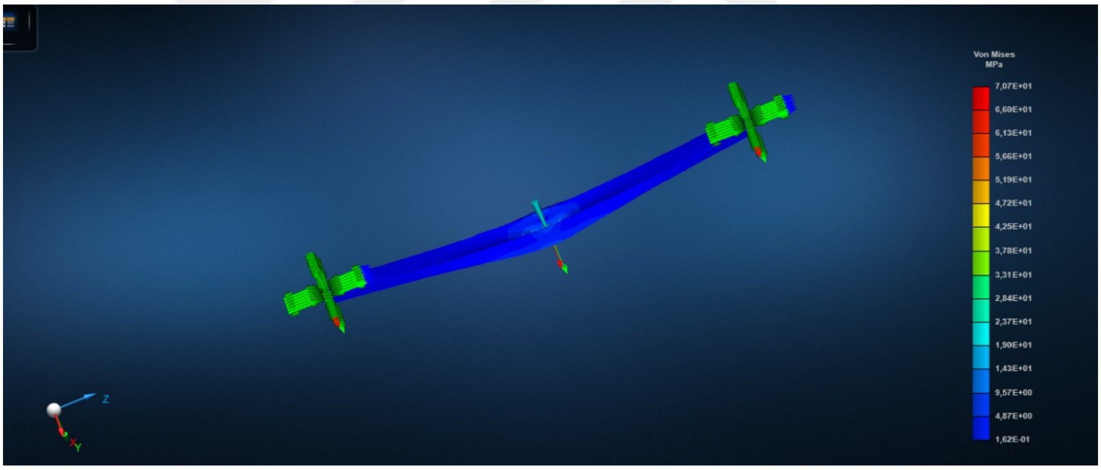

Figure-38: Von Mises Stress Result of Simply Supported Analysis for New Ceiling Profile C

APPENDIX B

USEFUL MODEL

patent araştırma

Yazdır | Dosya Durumu | Sonuç Sayfası | Dokümanlar | Yeni Arama

Başvuru Bilgileri

Başvuru Numarası	: 2017/07263	**Evrak Numarası**	: 2017-GE-196382	**Tescil Numarası**	: 2017 07263
Başvuru Tarihi	: 2017/05/17	**Evrak Tarihi**	: 2017/05/17	**Tescil Tarihi**	: 2019/04/22
Başvuru Şekli	: Ulusal Başvuru	**Koruma Tipi**	: Faydalı Model	**Yayın Tarihi**	:

Başvuru Sahipleri

UMS UĞUR METAL SANAYİ MÜH.İNŞ.NAK İÇVE DIŞ TİC LTD Ş
OSTİM 1208.SK.NO 6 NO:8D-8E Yenimahalle Ankara

Buluşun Tasnif Sınıfları

E04C 3/07
E04B 2/78

Buluş Sahipleri

TUNÇ SAFA ALTUNSARAY
Odabasi Caddesi, Dodurga Mah., Özseçkinköy Sitesi, 13. Parsel 6. Blok No:7 Türkkonut Çayyolu Çankaya Ankara
BİLGİN KAFTANOĞLU
Atılım Üniversitesi Metal Şekillendirme Mükemmeliyet Merkezi İncek Gölbaşı Ankara

Vekil Bilgileri

UĞUR GÜRŞAD YALÇINER (YALÇINER PATENT VE DAN. LTD. ŞTİ.)
Tunus Caddesi No:85/3-4 06680 - ÇANKAYA/ANKARA

Buluş Başlığı

EĞİLMEYE VE BURULMAYA DAYANIKLI TAVAN-U VE TAVAN-C PROFİLLERİ

Buluş Özeti

Bu buluş, her türlü iç mekanın tavanlarında, elektrik ve sıhhi tesisat malzemelerinin kolayca döşenmesini ve ayrıca ses, ısı ve yangın izolasyonu sağlamak üzere alçı levha asma tavanlar için geliştirilen Tavan-U ve Tavan-C adı verilen profiller ile ilgilidir. Bu buluşla eğilme ve burulma dayanıklılığı arttırılmış Tavan-U ve Tavan-C profilleri geliştirilmiştir.

Figure-39: Useful Model

APPENDIX C

SUSPENDED CEILINGS- REQUIREMENTS AND TEST METHODS

TSE.NET Standard Arama Sisteme Giriş

Standard Detayı

TÜRK STANDARDI
(Direktif :89/106/EEC)

TS No :	**TS EN 13964**
Tercüme Tarihi :	3.03.2015
Kabul Tarihi :	29.04.2014
Hazırlık Grubu :	TK10: Yapı Malzemeleri Teknik Komitesi
Doküman Tipi :	ST
Yürürlük Durumu :	U (Yürürlükteki Standard/Standard)
Başlık :	**Asma tavanlar - Gerekler ve deney yöntemleri**
Başlık (İng) :	**Suspended ceilings - Requirements and test methods**
Türü :	Madde-Mamul
Kapsam :	Bu standard, piyasaya sürülmeye hazır asma tavan kaplama bileşenlerini, asma tavan taşıyıcı sistem münferit bileşenlerini, asma tavan taşıyıcı sistem bileşen takımlarını ve asma tavan bileşen takımlarını kapsar. Bu standard, komple bileşen takımı hâlinde satılan asma tavanları, piyasaya bileşen takımı hâlinde sürülen asma tavan taşıyıcı sistemlerini, bu taşıyıcı sistemlere ait münferit bileşenleri (mamulleri) ve asma tavan kaplama bileşenlerini de kapsar. Bu standard, deney ve değerlendirme yöntemlerinin yanı sıra, mamullerin bu standardda verilen gereklere uygunluğunun değerlendirilmesi ve işaretlenmesi ile ilgili hükümleri de kapsar.
Kapsam (İng) :	This European Standard covers membranes, individual substructure components, substructure kits and suspended ceiling kits intended to be placed on the market. It covers suspended ceilings sold as a complete kit, substructures placed on the market as kits, individual components (products) of such substructures, and membrane components. It includes test methods and methods of assessment, as well as provisions for the evaluation of conformity and for the marking of the products to the requirements of this European Standard
Yerini Aldığı :	TS EN 13964 :2004; TS EN 13964/A1 :2007; TS EN 13964 :2008; TS EN 13964/A1 :2008;
Yararlanılan Kaynak :	EN 13964:2014
Uluslararası Karşılıklar :	EN 13964-EQV; DIN EN 13964-EQV; BS EN 13964-EQV; NF P68-204, NF EN 13964-EQV
Tercüme Edildiği STD :	EN 13964
ICS Kodu :	91.060.30 Tavanlar, Zeminler, Merdivenler
Atıf Yapılan STD :	:; TS EN 312 :2012; TS EN 335 :2013; : (TS EN 350 (bütün bölümler));; : (TS EN 351(Bütün bölümler);; TS EN 460 :1997; TS EN 573-3 :2014; : (EN 599 (bütün bölümler));; TS 64-1 EN 622-1 :2005; TS EN 717-2 :1999; :; TS EN 1912 :2001; TS EN 1991-1-4 :2007; TS EN 1995-1-1 :2005; TS EN 1998-1 :2015; TS EN 10143 :2006; TS EN 10152 :2010; TS EN 10169 :2011; TS EN 10346 :2010; TS EN 12600 :2004; TS EN 12664 :2009; TS EN 12667 :2003; TS EN 13162 :2013; TS EN 13171 :2013; TS EN 13245-1 :2011; TS EN 13245-2 :2011; TS EN 13501-1 :2003; TS EN 13501-2 :2008; TS EN 13823 :2010; TS EN ISO 354 :2007; TS EN ISO 717-1 :2014; TS EN ISO 2813 :2014; TS EN ISO 6946 :2012; TS EN ISO 9001 :2009; : (EN ISO 10140 (bütün bölümler));; TS EN ISO 10211 :2009; TS EN ISO 10456 :2009; TS EN ISO 10848-2 :2013; TS EN ISO 11654 :2002; TS EN ISO 11925-2 :2011; TS EN ISO 12944-3 :2004; TS ISO 1006 :2008; :; :;
Cen/Cenelec :	CEN
Dili :	tr
Renk Durumu :	Siyah-Beyaz
Uygulama Durumu :	Yürürlükte
Sayfa Sayısı :	130
Fiyatı :	80,00 TL + %8 Kdv

Figure-40: Requirements and Test methods Standards

According to TS-EN-13964 “Requirements and Test methods Standards”, the maximum deflection in metal dropped ceiling plates in a 28-day-test result should be 0.55 mm according to the “flexural strength” standard.

The maximum deflection of visible carrier system of modular dropped ceiling to be used : According to TS-EN-13964 “Requirements and Test methods Standards”, metal dropped ceiling carrier profiles should be subjected to bending test and load carrying performance should be below 0.2 mm , which is the maximum deflection limit