Civil Engineering Beyond Limits 2 (2020) 1-6

Civil Engineering Beyond Limits

www.acapublishing.com

RESEARCH ARTICLE

Behavior of Polypropylene Filled Cold Formed Steel Profiles – Part A: Bending & Shear

Mahyar Maali[1], Mahmut Kılıç[2], Barış Bayrak[2], Elif Mete[3], Kübra Çebi[3], A. Cüneyt AYDIN[2]

[1] *Erzurum Technical University, Engineering and Architecture Faculty, Dep. of Civil Engineering, Erzurum, TURKEY*

[2] *Ataturk University, Engineering Faculty, Department of Civil Engineering, 25030, Erzurum, TURKEY*

[3] *Erzincan Binali Yildirim University, Engineering Faculty, Department of Civil Engineering, Erzincan, TURKEY*

Abstract

Plastic waste is one of the most important problems that have occurred with modernization in the world and in our country. The use of plastics, which makes our daily life easier at many points, is also increasing day by day. The recycling and re-usability of these waste materials after use are of great importance and meaning when evaluated in terms of ecological order. In this study, finely ground waste polypropylene, which became waste, were poured into cold formed I100 and U100 steel profile molds. Carbon and glass fibers were used as reinforcement within the 16 samples. After melting, the behavior of I100and U100 molds filled with polypropylene will be observed after bending and shear tests on the samples. In the study, eight specimens for I100 and eight specimens for U100 profiles were produced. The main purpose of the cold formed steel in the production of I100 and U100 models is to enhance the bending and shear behavior of the models. As a result, the melted polypropylene within the cold formed I and U type models are presented a stunning performance.

Keywords: Polypropylene; cold-formed steel; experimental; bending; shear

1.Introduction

There are certain criteria for the realization of a construction technology. Technical performance, environmental benefit, improved seismic response, economy, robustness, architectural and functional flexibility and comfort are of paramount importance to this criterion. To summarize, the main purpose of an engineer in a building is to design safe, economic and aesthetic structures. At the same time, the structures and bearing elements must provide sufficient strength and stiffness values to perform their functions. Different structural design possibilities, if there is a choice to be made between construction technology, lightweight steel construction system are that they have advantageous aspects, and Turkey should be considered the applicability of the most common conditions in the preferred construction technology. When the current studies are examined, light steel systems have been used in the world for many years and ensure successful results. In the following literature, some studies on these issues are summarized. Akçaözoğlu (2008) [1]. Waste Pet bottle fractures in the study of the usability of lightweight concrete aggregate pet, pet with sand aggregate examined two groups of samples. In this study, it was shown that waste pet bottle fractures can be used as an earthquake resistant structure design carrier lightweight concrete aggregate. Çinar (2016) [2]. conducted a research on the properties of concrete produced in ground waste pads. In this study, as the amount of use of Waste Pet in concrete increased, unit weight and ultrasound velocity measurement values decreased. There is also a decrease in compressive strength and bending strength. Gureı et al (2004) [3] In his study on the use of waste pet aggregate in blast furnace slag and metakaolin mortars activated by alkalis, unit weight, compressive strength, bending strength, ultrasound transition rate, water absorption and void ratio tests were performed. And also high temperature resistances are studied. As a result of the experiments it was concluded that the use of waste pet aggregates is appropriate. Tama [4] investigated the behavior of four different cross-section beams produced from thin-walled steel plate elements by cold forming method under bending effect, as the end non-rigid channel section beam element, the end rigid channel section beam member, the end non-rigid sigma section beam element, and the end rigidized sigma section beam element.

The aim of this study is to investigate the bending and shear behavior of I and U type cold formed self-produced models. The main concept is not only the forming I and U type models with cold-formed steel idea, but also to enhance the cross-sectional behavior with melted polypropylene and fiber usage within the sections. The usage of waste and raw polypropylene (PP) is also an environment friendly concept. Furthermore, to use the conventional steel profiles for manufacturing of inside empty cold-formed members is another innovative concept by using melted polypropylene and fiber based reinforcements.

2.Experimental Setup

All the all profiles made of mild steel, and they are produced in Erzurum, simultaneously. The length of these profiles is 1500 mm and the thickness is 1.22 mm. The profiles were filled with finely ground waste polypropylene and melted. Polypropylene is used because of its many advantages (low density, chemical resistance, high-tensile strength, environmental resistance and chemical resistance). As

*Corresponding Author: mahyar.maali@gmail.com (M.Maali)

Received 30 Dec 2019 Revised 30 Dec 2019 Accepted 30 Dec 2019
Civil Enginering Beyond Limits 2 (2020) 1-6

https://doi.org/10.36937/cebel.2020.002.001

reinforcement, glass and carbon fiber reinforcements were added to the four samples in the I and U profiles. The diameter of these bars was chosen as 1 mm as a result of the calculations since the profile should not exceed the wall thickness. In order to perform the melting of waste polymers, a resistive waste polymer melting apparatus was designed and the melting of the molds was carried out on this system. The bending, and shear tests were carried out in the existing laboratory. In the experiments, the load from the loading cell was distributed to two points of the sample with two apparatus and one plate. The displacements of the experiment were measured by LVDT's placed at certain points and the deformations were measured by strain gauges and the results were recorded by data-logger device. Load-displacement graphs were drawn and results were interpreted within the collected data.

There is no system for melting polypropylene material in I and U molds at the Ataturk University, Engineering Faculty, Department of Civil Engineering, Structural, Building Materials and Applied Mechanical Laboratory, a new test setup was created in order to realize this process. Heating of this test apparatus is provided by several resistances, and the temperature can be reached up to about 500 degrees. However, for the used material within this research, the used maximum temperature was not more than 170 ^{0}C. Figure.1 shows the melting system.

Figure 1. Fine grinding waste and polypropylene melting system

After the melting process, samples were taken from the system and allowed to cool, then the painted samples were divided into 20 mm squares in order to better observe the deformations.

A universal testing with maximum capacity 900 kN were used during the test program [5, 6]. The experimental setups are shown in Figure 2 and 3. The experimental setup for all tests is a commonly used in literature. Linear variable differential transformers (LVDTs) were used to measure displacements at different locations of the tested beams, as shown in Figure 2. the test set-up to applied bending moment are shown in Figure 3. The test set-up is consisted of two different type of loading, namely four-point bending (Figure 3a) and bending with cantilever (Figure 3b) for shear.

3.Results

Four-Point Bending for U Profiles

Figure 4 shows that load- displacements graphic of the four-point bending. Figure 4a show that: Displacement of D1 (LVDT at X = 500mm) increased linearly up to 10 KN loading. The displacement increased with increasing load. The displacement of D2 (LVDT at X = 750 mm) up to 10 KN loading showed a linear increase. D3 (LVDT at X = 1000 mm) displacement showed a 10 KN linear increase. The displacement values corresponding to the max load value (10 KN) are D1 = 12 mm, D2 = 12 mm, D3 = 16 mm. The maximum displacement D2 (LVDT at X = 1000 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the midpoint of the profile. Figure 4b show that: The displacement of D1 (LVDT at X = 500mm) up to 7 KN loading increased linearly up to 0-3 KN loading and increased parabolic ally in the 3-7 KN load range.

Figure 2. Test setup for bending

The displacement increased with increasing load. D2 (LVDT at X = 750 mm) increased linearly in the 0-3 KN loading range and increased parabolic ally in the 3-7 KN load range. D3 (LVDT at X = 1000 mm) displacement increased linearly at 0-3 KN loading and showed a parabolic increase in the 3-7 KN load range. The displacement values corresponding to the max load value (7 KN) are in the range of D1 = 8-10 mm, in the range of D2 = 10-12 mm, and in the range of D3 = 10-12 mm. The maximum displacement D3 (LVDT at X = 1000 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the corner point of the profile at X = 1000 mm. Figure 4c show that: At 14 KN loading, the displacement of D1 (LVDT at X = 500mm) increased linearly. The displacement increased with increasing load. The displacement of D2 (LVDT at X = 750 mm) up to 14 KN loading showed a linear increase. D3 (LVDT at X = 1000 mm) displacement showed a linear increase in 14 KN loading. The displacement values corresponding to the max load value (10 KN) are in the range D1 = 8-10 mm, D2 = 10-12 mm, D3 = 8-10 mm. The maximum displacement D2 (LVDT at X = 750 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the midpoint of the profile. Figure 4d show that: The displacement of D1 (LVDT at X = 500mm) increased linearly in the 10-12 KN loading range. The displacement increased with increasing load. Displacement of D2 (LVDT at X = 750 mm) up to 10-12 KN loading showed a linear increase. D3 (X = LVDT at 1000 mm) displacement showed a linear increase in the loading range of 10-12 KN. The displacement values corresponding to the max load value (10-12 KN range) are in D1 = 6-7 mm range, D2 = 7-8 mm range, D3 = 5-6 mm range. The maximum displacement D2 (LVDT at X = 750 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the midpoint of the profile (X = 750mm).

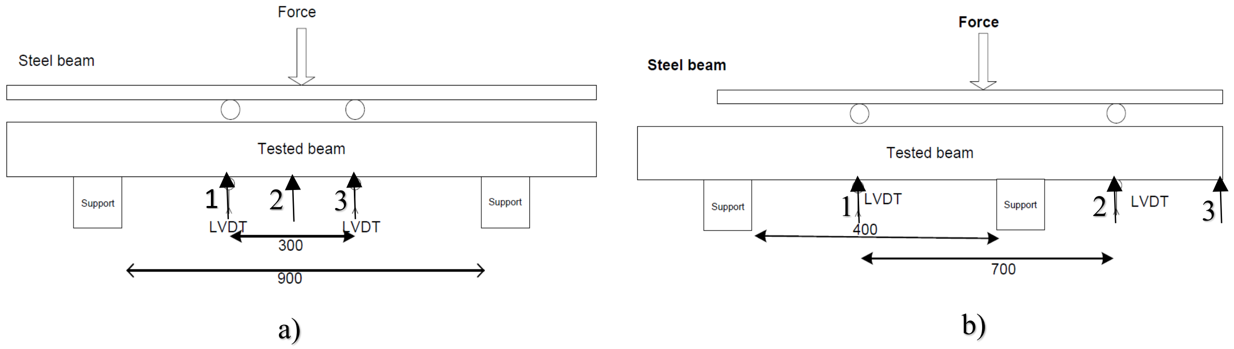

Figure 3. Test setups, a) four-point bending b) Bending with cantilever, for shear

Four-Point Bending for I Profile

Figure 5 shows that load- displacements graphic of the four-point bending. Figure 5a show that: D1, D2 and D3 increased linearly up to the maximum loading point (6KN). At D1, there is a displacement of approximately 7 mm at maximum loading, at about 11 mm at maximum loading at D2, and at about 10 mm at maximum loading at D3. Maximum displacement was 110 mm in LVDTs placed at the midpoint (750 mm). Figure 5b show that: D1, D2 and D3 increased linearly up to the maximum loading point (20KN). At D1 (x = 500mm) the maximum loading was approximately 6 mm, at D2 (x = 750mm) the maximum loading was 9 mm, and at D3 (x = 1000mm) the maximum loading was approximately 6 mm. Maximum displacement was 90 mm in LVDTs placed at the midpoint (750 mm). Figure 5c show that: D1, D2 and D3 increased linearly up to the maximum loading point (12 KN). Approx. 3.5 mm at maximum loading at D1 (LVDT placed at x = 500mm), approx. 3.6 mm at maximum loading at D2 (LVDT placed at x = 750mm), approx. 3 at maximum loading at D3 (x = 1000mm) , 1 mm displacement occurred. The maximum displacement was 3.6 mm in LVDTs placed at the midpoint (LVDT placed at x = 750mm). Figure 5d show that: D1, D2 and D3 increased linearly up to the maximum loading point (14 KN). Behavior at D1 and D3 progressed almost the same way. Approximately 3.9 mm at maximum loading at D1 (LVDT placed at x = 500mm), approximately 4.6 mm at maximum loading at D2 (x = 750mm placed at maximum point), approximately 3 at maximum load at D3 (x = 1000mm placed at LVDT) , 1 mm displacement occurred. Maximum displacement was 3.6 mm in LVDTs placed at the midpoint (LVDT placed at x = 750mm).

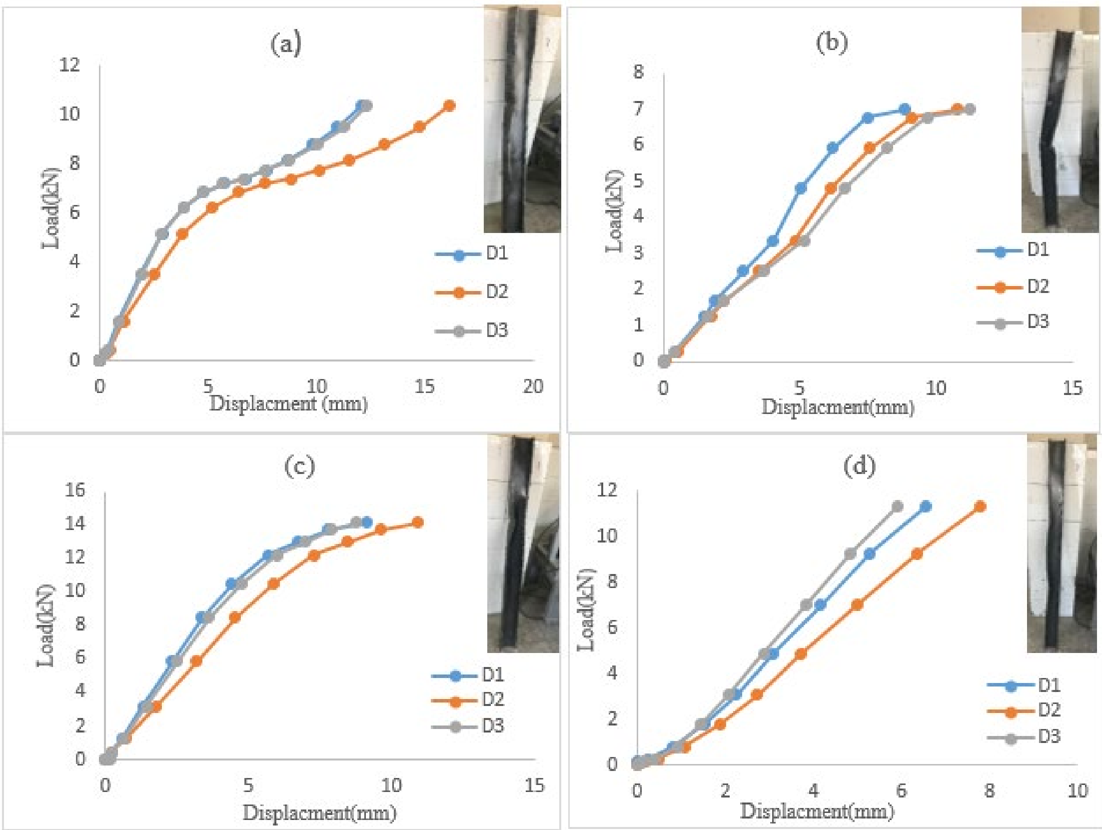

Figure 4. load-displacement for U Profiles (a: empty model, b: PP filled model, c: PP + Glass Fiber and d: PP + Carbon Fiber)

Shear with Cantilever For U Profile

Figure 6 shows that load- displacements graphic of bending with cantilever. Figure 6a show that: The displacement of D1 (LVDT at X = 500mm) in the 0-10 KN loading range showed a linear increase and decrease. The displacement of D2 (LVDT at X = 750mm) up to 2 KN loading showed a linear increase and decrease. There was a linear increase in the 2-9 KN range and a parabolic increase in the 9-10 KN range. The displacement increased with increasing load. D3 (LVDT at X = 1000 mm) displacement showed a linear increase and decrease in the 0-3 KN range. A linear increase in the 3-8 KN interval and a parabolic increase in the 8-10 KN interval was observed. The displacement values corresponding to the max load value (10 KN) are in the range of D1 = 0-1 mm, in the range of D2 = 1-2 mm, and in the range of D3 = 4-5 mm. The maximum displacement D3 (LVDT at X = 1000 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the corner point of the profile (X = 1000 mm). Figure 6b show that: D1 (LVDT at X = 500 mm) displacement was observed to increase linearly in the 0-3 KN loading range. The displacement increased with increasing load. A linear increase in the loading range of 3-6 KN and a linear decrease in the 6-12 KN range were observed.

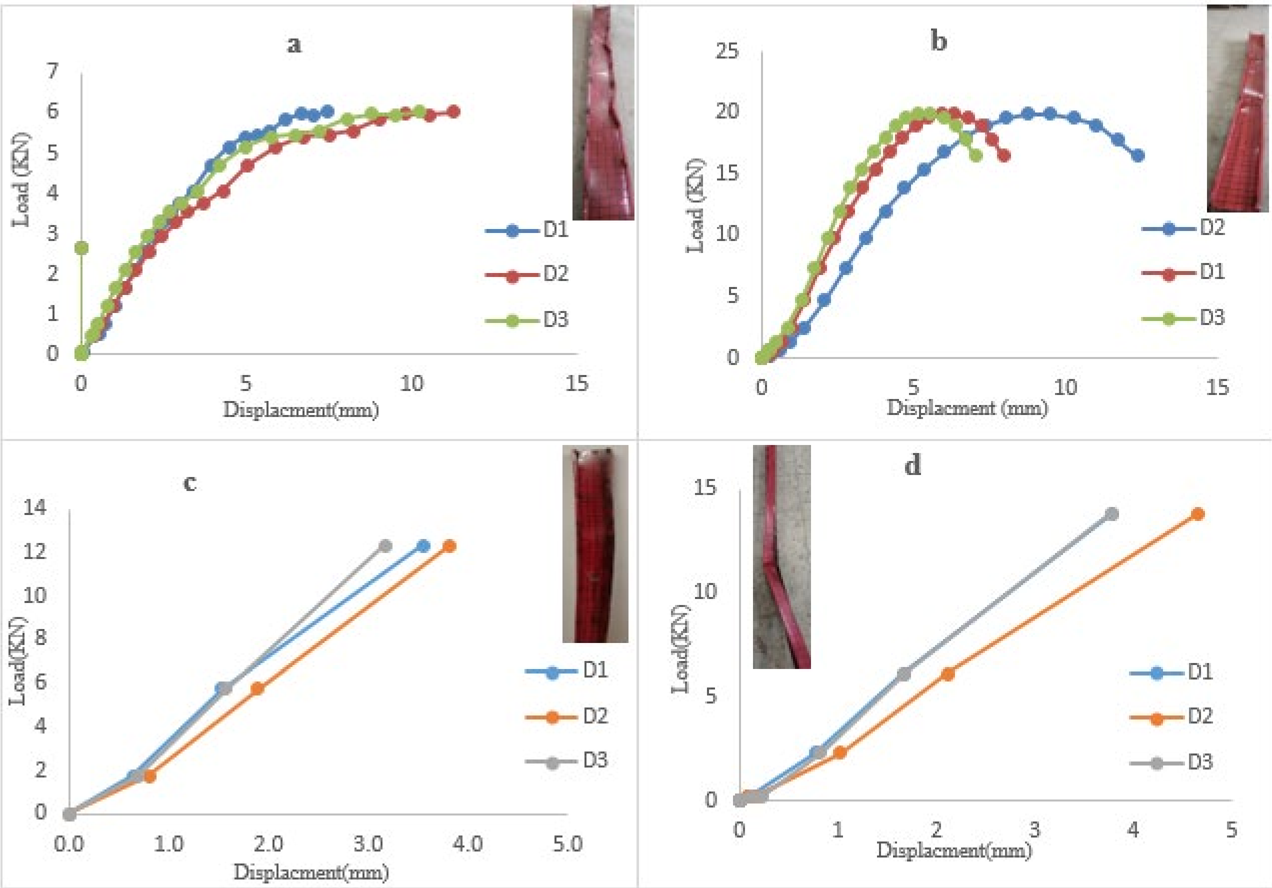

Figure 5. load-displacement for I Profiles (a: empty model, b: PPfilled model, c: PP + Glass Fiber and d: PP + Carbon Fiber)

D2 (LVDT at X = 750 mm) displacement showed a linear increase in the range of 0-6 KN and 6-12 KN. The displacement of D3 (LVDT at X = 1000 mm) showed a linear decrease in the loading range of 0-1 KN. In the range 1-12 KN, linear increase and decrease were observed respectively. The displacement values corresponding to the max load value (12 KN) are in the range of D1 = 3-4 mm, in the range of D2 = 1-2 mm, and in the range of D3 = 4-5 mm. The maximum displacement D3 (LVDT at X = 1000 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the corner point (X = 1000mm) of the profile. Figure 6c show that: The displacement of D1 (LVDT at X = 500mm) in the loading range 0-1 KN increased slightly in a linear manner. The displacement of D2 (LVDT at X = 750 mm) up to 0-1 KN loading showed a slight increase linearly. The displacement in the 1-9 KN range is constant and showed a linear decrease in the 9-12 KN range. D3 (LVDT at X = 1000 mm) displacement showed a minimal linear increase in the loading range of 0-1 KN. 1-9 KN is a linear increase and 9-12 KN is a linear decrease. The displacement values corresponding to the max load value (12 KN) are in the range of D1 = 2.5-3 mm, D2 = in the range 1 mm, D3 = in the range 2.5-3 mm. The maximum displacement D1 (LVDT at X = 500mm) and D3 (LVDT at X = 1000 mm) were also produced at the same load value. That is, the maximum displacement at the same load value occurred at the corner points of the profile (X = 500mm, X = 1000mm). Figure 6d show that: The displacement of D1 (LVDT at X = 500mm) shows a linear increase and decrease in the loading range of 0-2 KN. The displacement of D2 (LVDT at X = 750 mm) between 0-2 KN and 2-10 KN showed a linear increase. The displacement of D3 (LVDT at X = 1000 mm) showed a linear increase in the loading range of 0-2 KN and 2-10KN. The displacement values corresponding to the max load value (10 KN) are in the range of D1 = 0-1 mm, in the range of D2 = 2-3 mm, and in the range of D3 = 5-6 mm. The maximum displacement D3 (LVDT at X = 1000 mm) occurred at the same load value. That is, the maximum displacement at the same load value occurred at the corner point (X = 1000mm) of the profile.

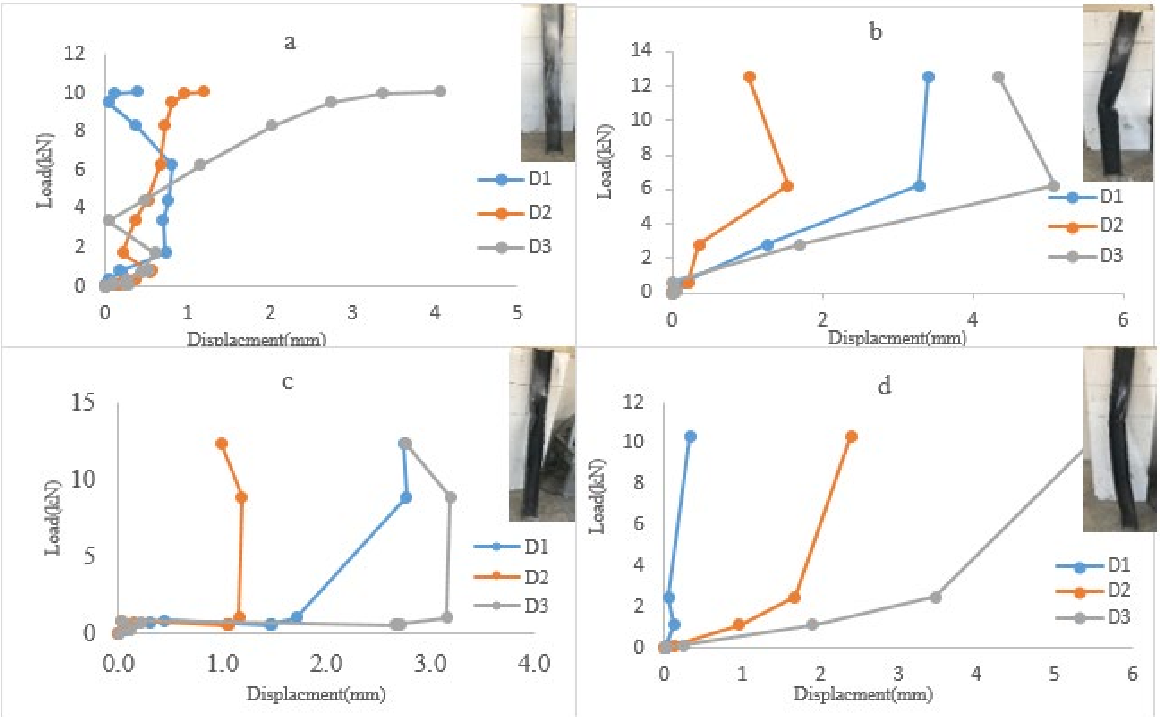

Figure 6. load-displacement U Profiles (a: empty model, b: PP filled, c: PP + Glass Fiber and d: PP + Carbon Fiber)

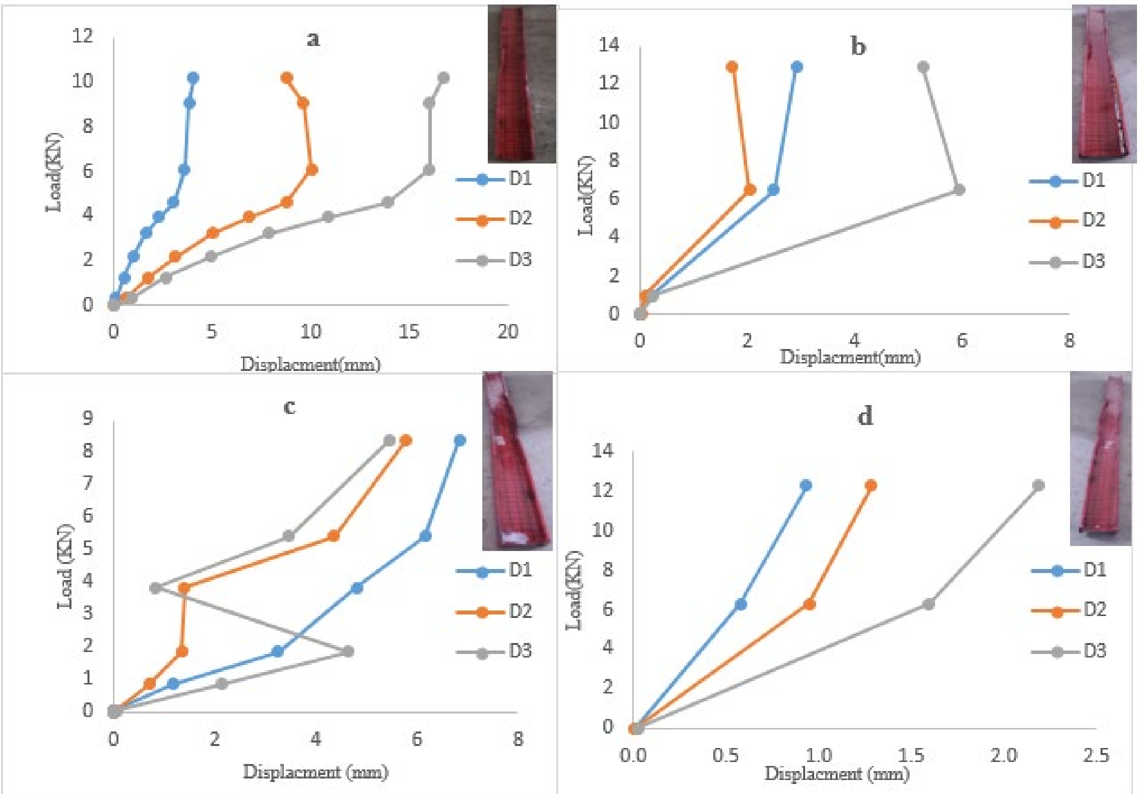

Figure 7. load-displacement I Profiles (a: empty model, b: PP filled, c: PP + Glass Fiber and d: PP + Carbon Fiber)

Figure 7 shows that load- displacements graphic of bending with cantilever. Figure 7a show that:

The displacement at D1 (LVDT at x = 500mm) increased parabolically up to 4.2 KN loading and recorded as 3 mm. In the 4 to 6 KN loading, there was a linear increase. The displacement at D2 (LVDT at x = 750mm) showed a parabolic increase up to 4.2 KN loading and recorded as 8.3 mm. In the 4 to 6 KN loading, there was a linear increase. The displacement at D3 (LVDT at x = 1000mm) increased parabolically up to 4.2 KN loading and recorded as 14 mm. In the 4 to 6 KN loading, there was a linear increase. The displacement between 6 KN and 9 KN remained constant and finally reached the maximum point with a slight increase. Figure 7b show that: The displacement at D1 (LVDT at x = 500mm) showed a linear increase up to a load of 6.1 KN, then decreased to a maximum, reaching a maximum point. linear increase and recorded as 2 mm. A linear decrease was observed in the continuation of the 6 KN loading. The displacement at D3 (LVDT at x = 1000mm) increased linearly up to a loading of 6 KN and recorded as 6 mm. Afterwards, it decreased linearly and reached its maximum point. The maximum displacement was observed at D3 with 6mm. Figure 7c show that: The displacement at D1 (LVDT at x = 500mm) increased linearly until a maximum loading point of 8 KN reached a displacement of about 7 mm. The displacement at D2 (LVDT at x = 750mm) showed a linear increase up to 2 KN loading and recorded as 1.3 mm. The displacement at D3 (LVDT at x = 1000mm) increased linearly up to a loading of 2 KN and was recorded as 4.7 mm. Afterwards, it decreased linearly between 2 KN and 4 KN. After 4 KN, it continued to increase linearly and reached 5.3 mm when it reached maximum load. The maximum displacement was observed at D1 with approximately 70mm. Figure 7d show that: The displacement at D1 (LVDT at x = 500mm) showed a linear increase until a maximum loading point of 12 KN reached a displacement of approximately 1 mm. The displacement at D2 (LVDT at x = 750mm) showed a linear increase up to a loading of 12 KN and a displacement of 1.3 mm occurred. The displacement at D3 (LVDT at x = 1000mm) increased linearly up to a loading of 12 KN and was recorded as 2.2 mm. The maximum displacement was recorded at point D3 with approximately 2.2 cm.

4. Conclusion

In this research, 4-point bending test was applied to the test samples first. The load-displacement graphs of the profiles were drawn as a result of the 4-point bending test performed on the hollow I100 and U100 profile, the I100 and U100 profile filled with pp, the profile containing pp and carbonn reinforcement and the I100 and U100 profile containing pp and glass reinforcement. In the 4-point bending I 100 test, the displacement values were recorded by LVDTs placed at 3 points of 150 cm samples at X = 50mm x = 75mm X = 100mm. At the same time, the maximum load that all samples can afford and the displacement corresponding to this load is examined and it is seen that only the sample containing polypropylene performs well. The maximum load is 10 KN, pp and carbon 12 KN, pp and glass up to 14 KN, while only polypropylene contains up to 20 KN. In the 4-point bending test, the largest displacement in the test without any thing, PP glass and PP carbon reinforced profiles were in the midpoint (X = 750 mm), while the largest displacement in the PP profile corner points (X = 1000 mm).

Acknowledgment

The research is part of the Ataturk University Projects **FYL-2019-7353** and **FYL-2019-7354**. The authors would like to thank to Ataturk University for funding the projects.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest.

References

[1] P Akçaözoğlu, S. (2008)" Atik Pet Şişe Kiriklarinin Hafif Beton Agregasi Olarak Kullanilabilirliği", Doktora Tezi, Çukurova Üniversitesi Fen Bilimleri Enstitüsü, Adana,5-15.

[2] ÇINAR, M,E. (2016)"Atık Pet ve Mermer Tozunun Kompozit Malzeme Üretiminde Değerlendirilmesi", Yüksek Lisans Tezi, Fırat Üniversitesi Fen Bilimleri Enstitüsü, Elazığ,5-39.

[3] Gureı, C. Akbulut H. ve Kurklu, G.(2004)" İnşaat Endüstrisinde Geri Dönüşüm ve Bir Hammadde Kaynağı Olarak Farklı Yapı Malzemelerinin Yeniden Değerlendirilmesi", 5 Endüstriyel Hammaddeler Sempozyumu, Afyon,28-32.

[4] Tama, Y,S.(2002)"Soğuk Şekillendirilmiş Açık Kesitli Çelik Kirişlerin İncelenmesi", Doktora Tezi, Pamukkale Üniversitesi Fen Bilimleri Enstitüsü, Denizli, 26-32.

[5] Korucuk, F.M.A., et al., Experimental analysis of the effect of dent variation on the buckling capacity of thin-walled cylindrical shells. Thin-Walled Structures, 2019. 143: p. 106259.

[6] Maali, M., et al., Buckling and post-buckling behavior of various dented cylindrical shells experimental data. Thin-Walled Structures, 2019. 137: p. 29-39.