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RESEARCH ARTICLE

Behavior of Polypropylene Filled Cold Formed Steel Profiles – Part B: Torsion

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Abstract

Torsional behaviors of col- formed steel beams are investigated for the webs which are filled by polypropylene. Four I and U profile beams filled with polypropylene were manufactured and tested. In the study, two specimens U100 and two specimens I100 profiles with 1.5 m length and 1.20 mm thickness and thin-walled cold-formed steel profiles were used. The aim of this study is to investigate the torsional behavior of the composite material formed by pouring the polymer material into the U and I profile molds after homogenous pulping. A total of two groups of samples will be obtained: empty cold-formed steel profiles and waste polymer. In this study, finely ground waste and/or raw PP (polypropylene) was used as filling material. The polypropylene is not only improved the torsional behavior strikingly; but also give a way on environmental profit for waste recycling.

Keywords: Torsional behavior; cold-formed steel; I and U profiles; polypropylene; experimental, waste management

1.Introduction

In recent years, solid wastes have been one of the major causes of environmental pollution. Especially in industrialized countries and cities, the problem of solid waste is increasing day by day. In order to eliminate this problem, many countries and cities implement recycling services. Recycling ensures reusability and prevents environmental pollution. Waste materials are stored as solid waste and have a negative impact on environmental pollution unless recycled. The stored solid wastes must be recycled, and the material must be reused for different purposes through recycling. Waste materials are recycled in many areas and reused. Repeated use of the material is the reason for choosing the material used in many sectors. Storage and separation of disposable wastes ensure that wastes can be used according to the sectors, and it is desired to provide the maximum benefits in material reuse with the separation process. In the construction and civil engineering sector, it is aimed to reduce the use of natural resources, to ensure the recycling of waste materials and to reduce environmental pollution. Reducing the recycling of waste materials and using them as a new material has been the subject of many studies. Polymer based materials are used for many harmful conditions in terms of environment, nature and ecological order, packaging (40%), building materials (22%), electrical devices (10%), agriculture (6%), clothing and footwear (4%), automotive (4%), the other (14%) are used in many independent areas. Therefore, the proportion of plastic wastes increases in the same way [1]. In this study, light steel systems were preferred as molds because it is a high-strength material, the ratio of its own weight to the load is very small, it is light, it is easy to install electrical and plumbing, it has homogeneous, high rigidity and high ductility properties, it prevents the structure to be affected by environmental factors for many years. , the structure is not affected by events such as rain, frost, hot, lightweight and impermeable, recyclable, tensile and compressive strength equals elastic modulus is very high compared to other building materials. It is also a ductile material of light steel and has the property of making deformation under repeated inelastic loading without breaking [2-12]. For example, in an earthquake, loads affecting the building are directly proportional to the weight of the building. The lighter the structure, the less load will be forced in the earthquake. The weight of light steel systems is very small compared to other bearing systems; thus, allowing structures designed to be more resistant to earthquakes and possible external loads. Considering these situations, it was decided to prefer light steel systems in the research. There are many valuable studies in the current literature on waste polymers and light steel profiles, but there are serious shortcomings in the literature on the interoperability of these two materials. With this study, it is aimed to eliminate the deficiencies in the literature. In the current literature studies, there are many experimental studies on the recycling of waste polymers, light steels, I and U profiles and carbon reinforcement. However, there is no experimental study including these three subjects. For this reason, the literature review has been examined in different topics and shown below. Memiş and Örüng [6], worked on the usability of milled waste plastic (PET) additive plasters in agricultural structures. They were used the PETs and converted into plaster material after various processes and their suitability for use in agricultural structures was tried to be determined. Çiçek [7] conducted research on the properties of concrete produced in ground waste pads. In this study, it was observed that unit weight and ultra sound velocity measurement values decreased as the usage amount of waste pet

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increased in concrete. There is also a decrease in compressive strength and bending strength.

As the second part of this research, the purpose is to enhance the torsional behavior by filling the cold formed steel profiles with melted polypropylene. Furthermore, the filling ability, however observed by melted polypropylene, the waste recycling is the another concept of recycling. By this way, the lightness of the profiles is obtained properly, and the relevant strength can be reserved, also.

2. Experimental Work

The experimental setup of the torsional I and U cold-formed steel beams is presented in Fig. 1 [8-11]. The I and U beams are compared with each other by neglecting the frictional forces between the models and the setup. Two steel plates in the form of hollow boxes with a depth of 160 mm were used for both the right and left ends of the beams. As a rigid loading apparatus, 1500 mm HEB160 type steel profile was used in the experiments. The vertical load was applied to the central of HEB160 profile. The three linear variable differential transformers (LVDTs) were used to the measure the deflection and to calculate the rotation of the cross-section of the beams. In this study the specimens were divided into 2 groups: I beam and U beam. The load was applied to the beams through a 900 kN capacity hydraulic pump. The all beam models were placed in all-purpose hydraulic pump, and the load was increased until the failure of the beam. The load was increased gradual rate and was recorded through a data logger. The vertical deflections of the beams are measured at three different points using linear variable displacement transducer (LVDT).

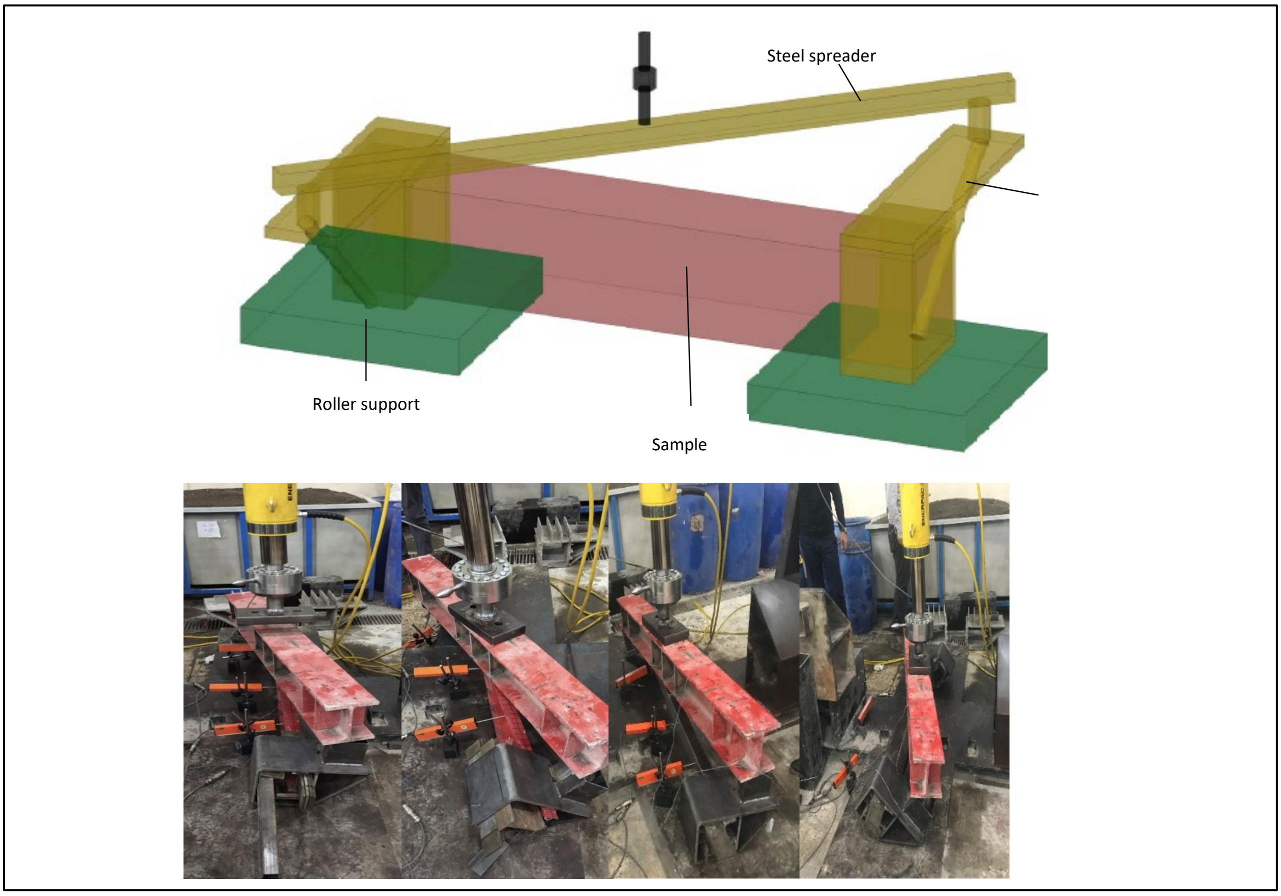

Figure 1. Test setup

3. Results and Discussion

3.1. Torsional behavior for U profile

Figure 2 shows that load- displacements graphic of the Torsional behavior. Figure 2a show that: The displacement of D1 (LVDT at X = 500mm) in the 0-10 KN loading range decreases linearly. D2 (LVDT at X = 750 mm) displacement in the 0-10 KN range showed a linear increase and decrease. D3 (LVDT at X = 1000 mm) displacement increased in the 0-2 KN loading range.110 KN loading range was linearly increased while the displacement remained constant. The displacement values corresponding to the max load value (10 KN) are in the range of D1 = 0-10 mm, in the range of D2 = 10-20 mm, and in the range of D3 = 40-50 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 2b show that: In the loading range 0-1 KN, the vertical deformation S1 increased linearly. 1-10 KN showed a linear increase in loading range. With increasing load value deformation increased. S2 horizontal deformation shows an increase and then a decrease in the 0-10 KN range. Vertical (S1) and horizontal (S2) deformations are different from each other. The vertical deformation S1 (10 KN) corresponding to the max load is between 40-60. The horizontal strain value S2 (10 KN) corresponding to the max load is between 80-100. Compared to vertical deformation (S1) and horizontal deformation (S2) at the same load value, the horizontal deformation (S2) capacity is larger. The vertical deformation S2 is therefore more decisive for the U9 profile (U100 blank profile). Figure 2c show that: The displacement D1 (LVDT at X = 500mm) in the 0-16 KN loading range is constant zero despite the load increase linearly. The displacement of D2 (LVDT at X = 750 mm) in the 0-2 KN range showed a linear increase.2-4 The KN displacement remained constant despite the load increase. Parabolic displacement increased in the range of 2-4 KN. D3 (LVDT at X = 1000 mm) displacement shows a linear increase and decrease in the 0-2 KN loading range. Parabolically increased in the loading range of 2-4 KN. The displacement of 2-16 KN load remained constant. The displacement values corresponding to the max load value (16 KN) are in the range of D1 = 0 mm, in the range of D2 = 20-30 mm, and in the range of D3 = 40-50 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 2d show that: S1 vertical deformation has increased linearly up to 2-3 KN loading.

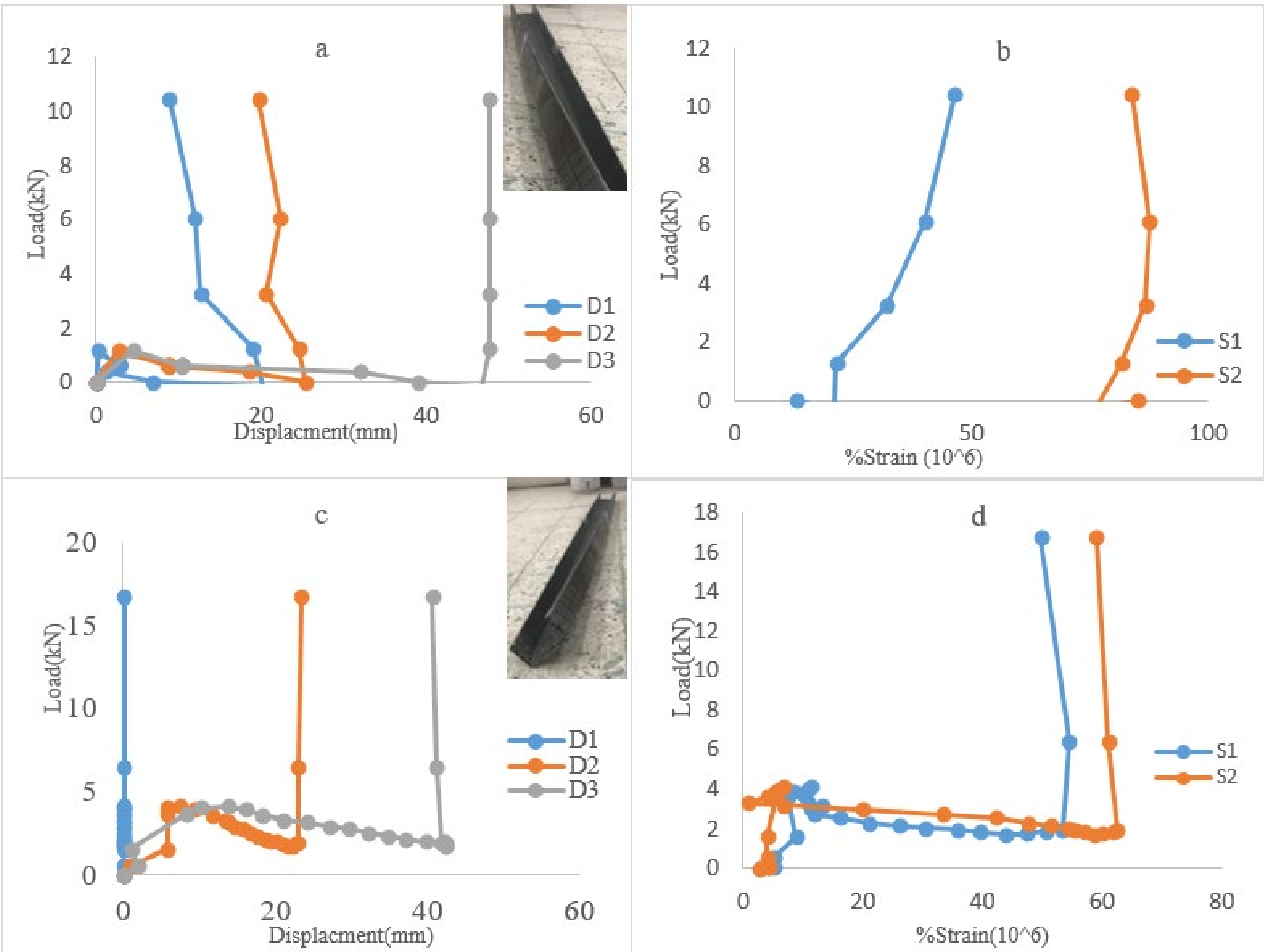

Figure 2. Load-displacement and load- strain for U Profiles (a: without any properties, c: PP)

With increasing load, deformation has increased. 2-16 KN load value shows a linear decrease. 2 Up to 2-3 KN load S2 horizontal deformation increases linearly. 2-16 KN shows a linear decrease in load value. Vertical (S1) and horizontal (S2) deformations are different from each other. The vertical deformation S1 (16 kN) corresponding to the max load is between 50-60. The horizontal deformation value S2 (16 kN) corresponding to the max load is between 50-60. Compared to vertical deformation (S1) and horizontal deformation (S2) at the same load value, the horizontal deformation (S2) capacity is larger. Horizontal deformation S2 is therefore more decisive for U10 profile PP. thus, In the torsion test, the largest displacement occurred at the corner point X = 1000 mm in (Hollow U profile) and (PP) profiles. Also, In the torsion test, the maximum deformation capacity is greater in U9 (Hollow U profile) and U10 (PP) profiles in S2 vertical deformation. Therefore, when S1 (horizontal deformation and S2 (vertical deformation) are compared, S2 is more decisive for U9 (Hollow U profile) and U10 (PP) profiles.

3.2. Torsional behavior for I profile

Figure 3 shows that load- displacements graphic of the Torsional behavior. Figure 3a show that: The displacement at D1 (LVDT at x = 500mm) has been steadily increased until a maximum loading point of 8 KN has been reached and a displacement of approximately 15 mm has occurred. The displacement at D2 (LVDT at x = 750mm) showed a steady increase up to a loading of 12 KN and a displacement of 40 mm occurred. The displacement at D3 (LVDT at x = 1000mm) showed a steady increase up to 8 KN loading and was recorded as 20 mm. The maximum displacement was recorded at point D2 with approximately 40 mm. Figure 3b show that: S1 (vertical) deformation after loading has always shown variable behavior up to 1 KN loading. As load increases, the deformation remains constant from 1KN to maximum load of approximately 9 KN. S2 (horizontal) deformation has always shown variable behavior up to 1 KN loading. As the load increases, the deformation from 1KN to maximum load approximately 9 KN has shown a linear increase. Horizontal and vertical deformations were not the same at any point after loading of 1 KN. It is seen that vertical deformation capacity is higher when vertical and horizontal deformation is compared to maximum loading point. (Strain gauges are placed at two points, X = 500 mm and X = 750 mm). Figure 3c show that: Displacement at D1 (LVDT at x = 500mm) showed variable behavior up to 2 KN loading. After 2 KN, a displacement of approximately 37 mm has been observed, which has increased steadily until reaching the maximum loading point of 11 KN. and a 4 mm displacement occurred. The displacement at D3 (LVDT at x = 1000mm) decreased linearly from 2KN to the maximum load of 11 KN, resulting in a 3 mm displacement. The maximum displacement occurred at D1 with 37 mm. Figure 3d show that: After loading has started, the S1 (vertical) deformation has always been variable, up to 2 KN loading. As load increases, the maximum load from 2 KN to the maximum load point is increased by vertical deformation from approximately 12 KN. S2 (horizontal) deformation has always shown variable behavior up to 2 KN loading. As the loading increased, the deformation from 2KN to the maximum load of about 12 KN showed a linear increase. Horizontal and vertical deformation were not the same at any point after loading started at 2 KN. It is seen that horizontal deformation capacity is higher when vertical and horizontal deformation is compared to maximum loading point. (Strain gauges are placed at two points, X = 500 mm and X = 750 mm). so, In the torsion test, the displacement values were recorded by LVDTs placed at 3 points of X = 500mm, X = 750 mm and X = 1000mm of 1500 mm samples. When the load displacement graph was plotted in 2 samples, the results differed in 2 samples. In the blank I100 profile, the maximum displacement was measured as 20mm at D2, while in PP filled profile 35mm was measured at D1. 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 8 KN, while only polypropylene contains 11 KN.

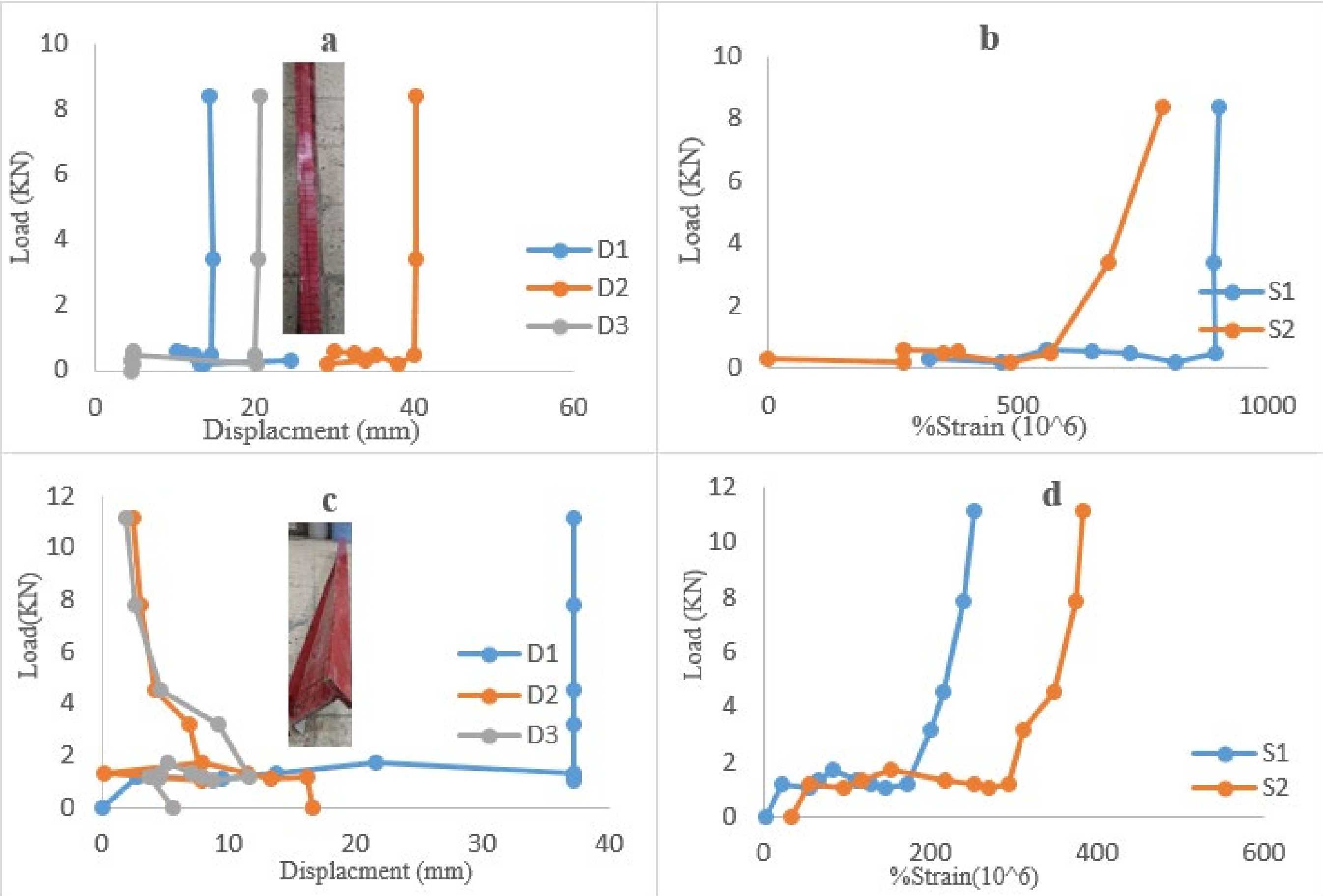

Figure 3. Load-displacement and load- strain for I Profiles (a: without any properties, c: PP)

4. Conclusion

In this study, the behavior of Polypropylene Filled Cold Formed Steel Profiles under pure torsion was investigated. Each beam was analyzed under increasing pure torsion up to failure. The following conclusions were drawn:

1. In the U profile torsion test, the largest displacement occurred at the corner point X = 1000 mm in (Hollow U profile) and (PP) profiles. Also, In the torsion test, the maximum deformation capacity is greater in U9 (Hollow U profile) and U10 (PP) profiles in S2 vertical deformation. Therefore, when S1 (horizontal deformation and S2 (vertical deformation) are compared, S2 is more decisive for U9 (Hollow U profile) and U10 (PP) profiles.

2. In the I profile torsion test, the displacement values were recorded by LVDTs placed at 3 points of X = 500mm, X = 750 mm and X = 1000mm of 1500 mm samples. When the load displacement graph was plotted in 2 samples, the results differed in 2 samples. In the blank I100 profile, the maximum displacement was measured as 20mm at D2, while in PP filled profile 35mm was measured at D1. 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 8 KN, while only polypropylene contains 11 KN.

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Declaration of Conflict of Interests

The authors declare that there is no conflict of interest.

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