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THE FIRST WELDED BRIDGE - PROTOTYPE DEVELOPMENT THROUGH FUSED DEPOSITION MODELLING (FDM)

PRVI ZAVARENI MOST - RAZVOJ PROTOTIPA MODELIRANJEM POSTUPKOM NANOŠENJA U RASTOPLJENIM SLOJEVIMA (FDM)

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- fused deposition modelling (FDM)
- welding
- bridge prototype

Abstract

The first welded bridge in Romania was modelled according to its last technical project. The 3D model used for the expertise was imported into a 3D programme to adjust the structure and prepare it for 3D printing. Only the main elements are preserved on the structure: upper flange, lower flange, struts, side members, lattice beams. Secondary elements as parapet, sidewalk consoles are removed from the 3D structure for an easier layout of the model. The paper presents the process of creating the 3D model of the First Welded Bridge in Romania through the FDM. The model is made of 4 distinct PET segments which are joined together. In order to obtain the components, it was necessary to do FEM remodelling of structural dimensions of the bridge as well as adjusting these dimensions to a scale of 1/25. The resulting model has a size of 1.25 m. The paper shows the printing parameters of the model and the testing of some model components.

Ključne reči
- nanošenje rastopljenog sloja (FDM)
- zavarivanje
- prototip mosta

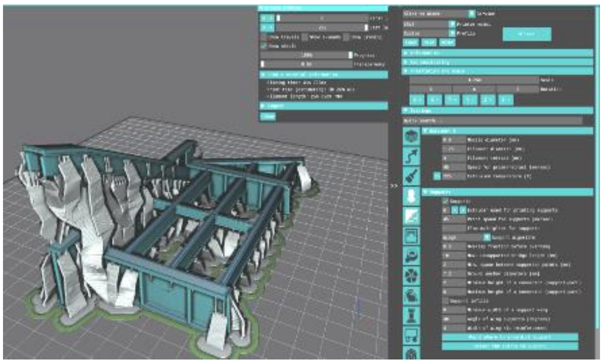
Izvod

Modeliranje prvog zavarenog mosta u Rumuniji urađeno je prema tehničkom projektu izrađenim u poslednjoj ekspertizi konstrukcije. 3D model korišćen za ekspertizu uvezen je u 3D program za prilagođavanje konstrukcije i za pripremu 3D štampanja. Na konstrukciji su očuvani samo glavni elementi: gornji i donji pojasevi nosača, pritisnuti štapovi, bočni elementi, rešetkaste grede. Sekundarni elementi kao što su zaštitni zid, trotoarske konzole su uklonjeni iz 3D strukture kako bi se olakšala izrada modela. U radu je prikazan postupak izrade 3D modela Prvog zavarenog mosta u Rumuniji kroz FDM postupak. Model je sačinjen iz 4 različitih spojenih segmenta od PET materijala. Da bi se kreirale komponente bilo je potrebno FEM remodeliranje konstrukcijskih gabarita mosta kao i prilagođavanje ovih gabarita u razmeri 1/25. Dobijeni model ima dimenziju 1,25 m. U radu su dati parametri štampanja modela i prikazano je ispitivanje nekih komponenata modela.

INTRODUCTION

The paper represents the realization of the prototype of the first welded bridge in Romania, the Vama Bridge, built in Reșița in 1937 by a team led by Acad. Dan Matei Mateescu. In 2013, a team led by Prof. Radu Băncilă performed a technical expertise of this bridge based on direct observations made on-site, the metal deck and the infrastructure survey, as well as in accordance with Technical instructions for establishing the technical condition of an indicative bridge 522: 2002. The technical data for the realisation of the model are taken from the technical expertise in 2013, Fig. 1.

The bridge, classified as a historical monument under CS-II-m-B-10911, /1/, is located over the river Bârzava in the central area of Reşiţa and separates the neighbourhoods of Reşiţa Română from Reşiţa Montană. It is considered the first welded bridge in Romania, being built by the company Uzinele de Fier şi Domeniile Reşiţa -UDR in 1937 under the leadership of former Acad. Dan Mateescu. Once upon a time, in this place there was a custom that delimited the Romanian Resita from Mountain Resita, and the merchants were obliged to pay a toll.



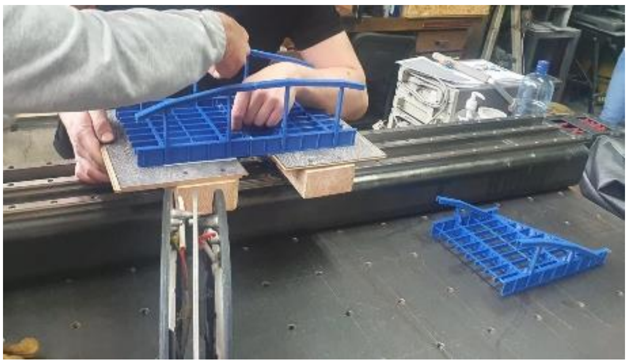


Figure 1. Steps in the process of obtaining the model.

The ‘Customs Bridge’, as it is known in the area, is an oblique road bridge with a single opening, Fig. 2. The angle of obliquity between the axis of the road on the bridge and the obstacle is α = 61-62°. The infrastructure is of stone masonry (springs) and superstructure of welded steel, /1/.

Figure 2. Vierendel parabolic main beam.

DEVELOPMENT OF PRINTING TECHNOLOGY

The realisation of the 3D model of the first welded bridge in Romania was possible within the Polytechnic University of Timisoara in the welding laboratory of the master's specialization Production Welding Procedures in the Protective Gas Environment. To create this 3D model, a Two Trees 3D Sapphire Plus printer is used, Fig. 3, using PET-G filament as raw material with physical properties given in Table 1. The procedure used was FDM - Fused Deposition Modelling.

Figure 3. Two Trees 3D Printer Sapphire Plus.

Table 1. Material specifications.

Specification	Dimension
filament diameter	1.75 mm / 2.85 mm
filament size tolerance	+/- 0.05 mm
tolerance of filament diameter	+/- 0.02 mm
the surface of the material	high gloss
material contraction	low
product weight	1.0 kg net; 1.36 kg brut.
coil material	polycarbonate transparent

The 3D model used takes the data from the technical expertise, so the AutoCAD model from the expertise was imported into a 3D programme to adjust the structure and prepare for 3D printing. Figure 4 shows the adjustment of the drawings from the expertise.

Only the main elements have been preserved on the structure: upper and lower flanges, struts, side members, lattice beams. Secondary elements such as parapet, sidewalk consoles are removed from the 3D structure to make the layout of the model easier, /2/.

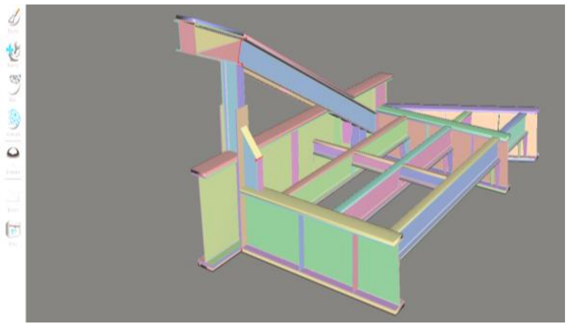


Figure 4. Bridge structure section prepared in the 3D programme for printing. Printing temperature: 195-225 °C. Print speed: 40-80 mm/s.

PET-G (Glycol-modified polyethylene terephthalate) is a co-polyester obtained from a mixture of PET and glycol, developed especially for 3D printing. The PET-G filament combines the advantages of ABS (strength, good temperature behaviour, durability) with those of PLA (easy to print) in a single material. Co-polyesters retain their strength, clarity, and other mechanical properties even when exposed to various chemicals that can affect other materials. Advantages are durability, high impact resistance, flexibility.

The 3D model of the first welded bridge in Romania is made of 4 distinct segments that are then joined together, Fig. 5. To be able to start printing the components, it was necessary to introduce structural dimensions of the bridge and adjust them to a scale of 1/25.

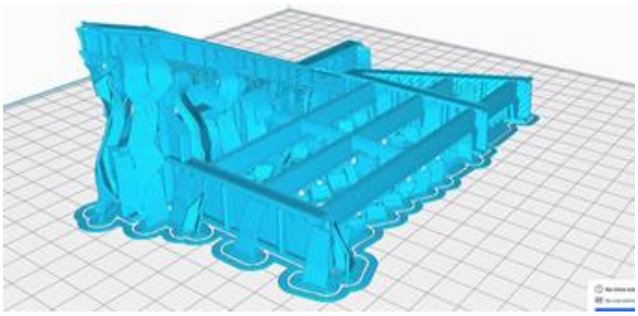


Figure 5. Printing technology simulation.

The printing technology has been adjusted several times to optimize the time and quality of the resulting product. Initially, the first products did not have very good density and printing time was too long, so printing parameters were optimised 3 times (Table 2) to obtain the desired products, Fig. 6, /3-5/.

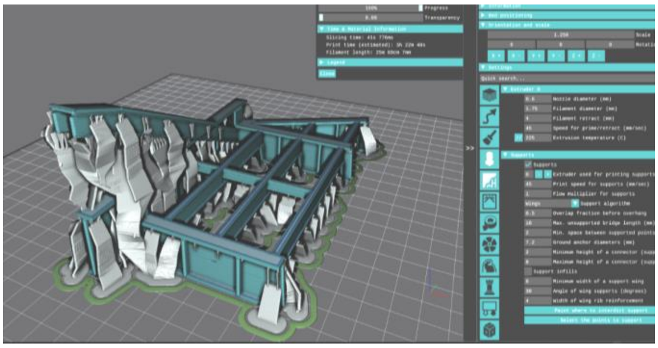


Figure 6. Final image of the printed product.

Table 2. Printing technology.

Layer thickness	0.3 mm
Print speed	75 mm/sec
Perimeter print speed	40 mm/sec
Print speed on the first layer	45 mm/sec
Travel speed	100 mm/sec
Nozzle diameter	0.8 mm
Filament diameter	1.75 mm
Extrusion temperature	230 °C
Heated bed temperature	65 °C
Percentage of cooling fan speed	100 %
Filling percentage	100 %
Support algorithm	wings
Thickening ratio for thin features	1.5
Flow multiplier	1

Printing time was the shortest at the end sections because of their lower complexity and fewer elements to print, while in the central part of the structure there are more elements, and the time interval was larger, Fig. 7.

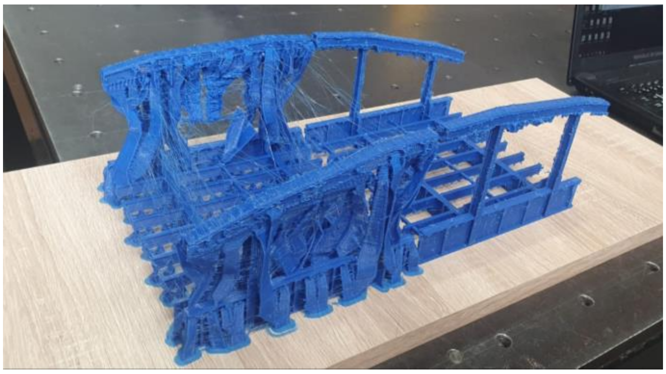


Figure 7. Raw product after 3D printing.

The next phase was joining of these 4 segments. This phase was performed starting from the principle of joining polyethylene pipes by welding, consisted of heating the parts to melting temperature, putting them into contact and maintaining according to the conditions in the welding chart, the principle of butt joint with heating element, Fig. 8, /6-7/.

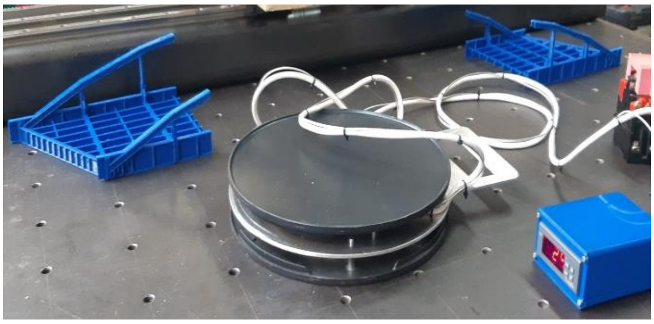


Figure 8. Heating element.

The joining process is performed at 300 °C, the material being heated for a period of 10 s, Fig. 9, after which the two sections were pressed one on top of the other, until a conformal edge was obtained.

Figure 9. The moment when the ends of sections are heated to join.

TESTS AND DISCUSSION

After the 3D model was completed, several specimens of the same material are printed to analyse the mechanical characteristics of the material. Samples are taken on both the Z and XY printing directions, Fig. 10.

Tests show that the highest strength in the XY direction is 45.95 MPa, Fig. 11, about 80 % of the injected PET, since the literature states the limit of 55-75 MPa, /8-9/. Tests in the Z direction provide the lowest strength, 28.80 MPa, about 45 % of the injected PET.

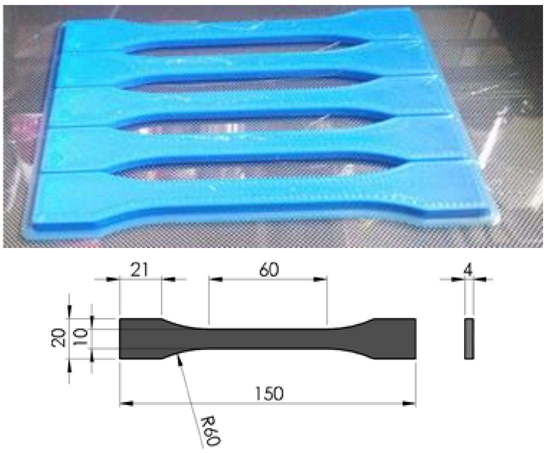


Figure 10. Specimens for mechanical testing.

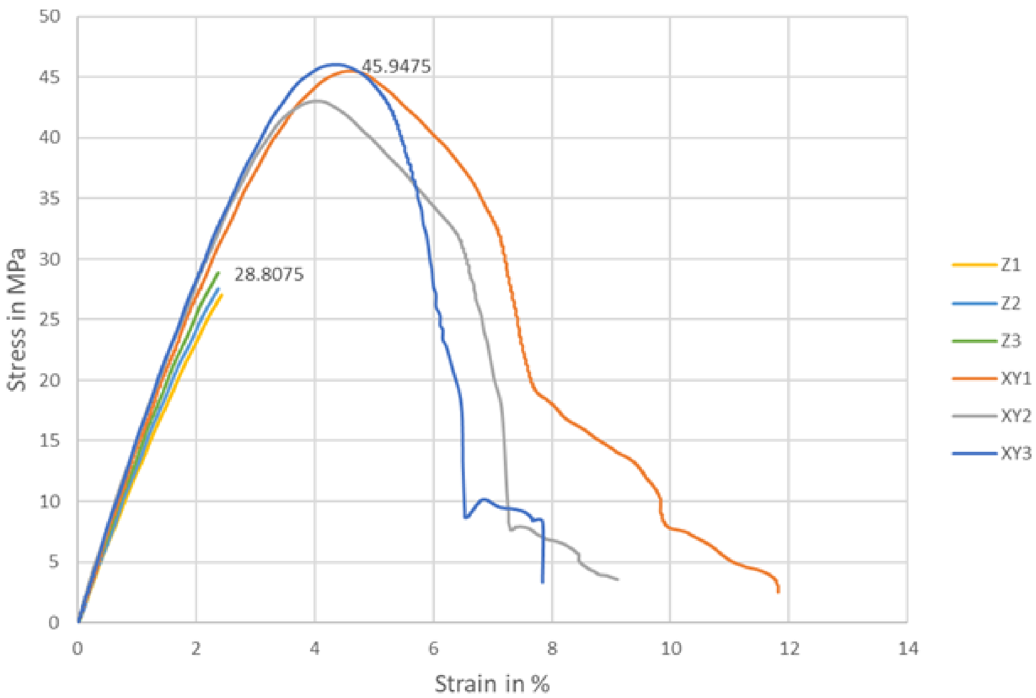


Figure 11. Results of the mechanicals tests.

CONCLUSIONS

The paper started as a model for an exhibition with the students, but obtaining an appreciated product, the research continued.

After the modelling, the material was also checked, so it was concluded that in the XY printing direction the material resistance is about 80 %, and in the Z direction the resistance is 45 %. The research will continue with hardness and compression tests on standardized specimens.

This work also confirmed the ever increasing application of 3D printing, /10-11/.

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