Design, defects and durability

Cyclic Response of a 3D Printed Concrete Shear Wall Made with Concrete Extrusion

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INTRODUCTION

Within this study, the attention is focused on the extrusion process. The proper control of the material properties and of the printing process is essential in view of the printing of low-rise building. The design of a 3D printed concrete wall to be applied in modular constructions of low rising building in seismic prone areas is described. The aim is to identify the main thermal, geometrical, mechanical parameters and investigate its structural performance. A critical discussion of the experimental results is presented. Figure 1 shows a two-storey 3D printed concrete building prototype taken as an example.

Figure 1. Two storey 3D printed concrete building prototype

TEST SPECIMEN

The investigation of the thermal performance of the wall was the starting point. The building was located in the north of Italy and it was designed to comply with the current Italian legislation that set a maximum value for the thermal transmittance U = 0.26 W/m^{2}K. The configuration with inclined diaphragms was chosen as consequence of a parametric study, as it resulted to be the most affecting parameter. An inclination of 37° was adopted to guarantee an integer number of internal diaphragms if a 3 m long shear wall is considered. The external insulation layer was added to avoid the problem of thermal bridges at intersection points (e.g. between floor and wall).

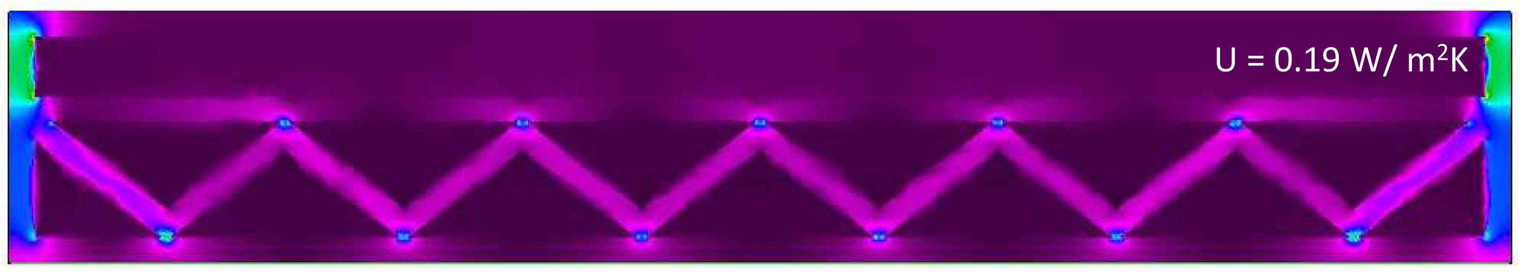

Figure 2. Finite element analysis using the software therm: thermal flux..

The designed wall is characterized by an internal part with inclined diaphragms that has a structural function (in blue in Figure 3), meaning it is the part that withstand the vertical and horizontal load and an external concrete layer with just a thermal and aesthetic function (in orange in Figure 3).

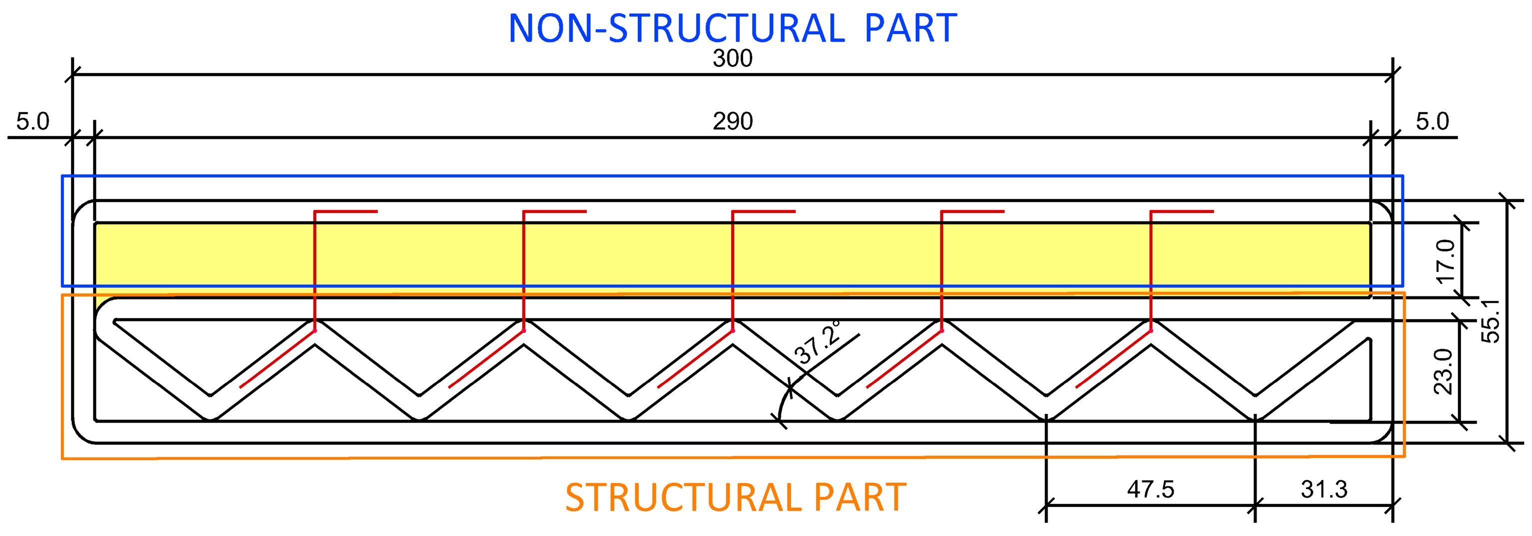

Figure 3. Unreinforced 3DPC wall: plan view.

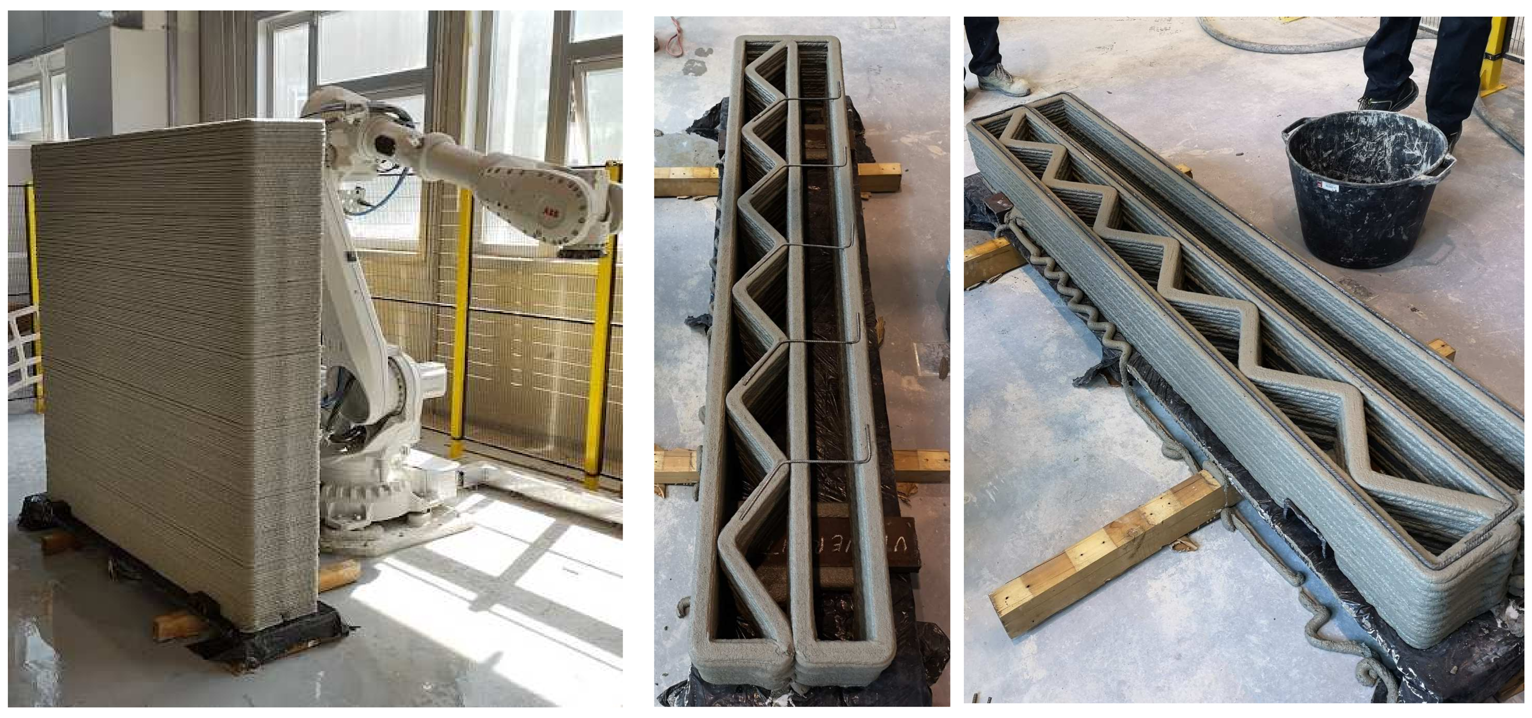

Figure 4. Unreinforced 3DPC wall: printing process.

EXPERIMENTAL CAMPAIGN

In order to assess the structural performance of the unreinforced 3DPC wall made with concrete extrusion, an in-plane quasi-static cyclic test was performed. The designed wall has a height of 3 m, a length of 3 m and a thickness of 55 cm. However, according to the maximum dimensions allowed by the available test setup and by transport operation, the wall dimensions were reduced by a scale factor of 0.70. Therefore, the specimen was 2.10 m high, 2.10 m long and 38 cm thick. To simulate the load of a two-storey building, a vertical load of 200 kN was applied by means of two hydraulic jacks. The horizontal load was applied with an electro-mechanic jack.. The test set-up is shown in Figure 5.

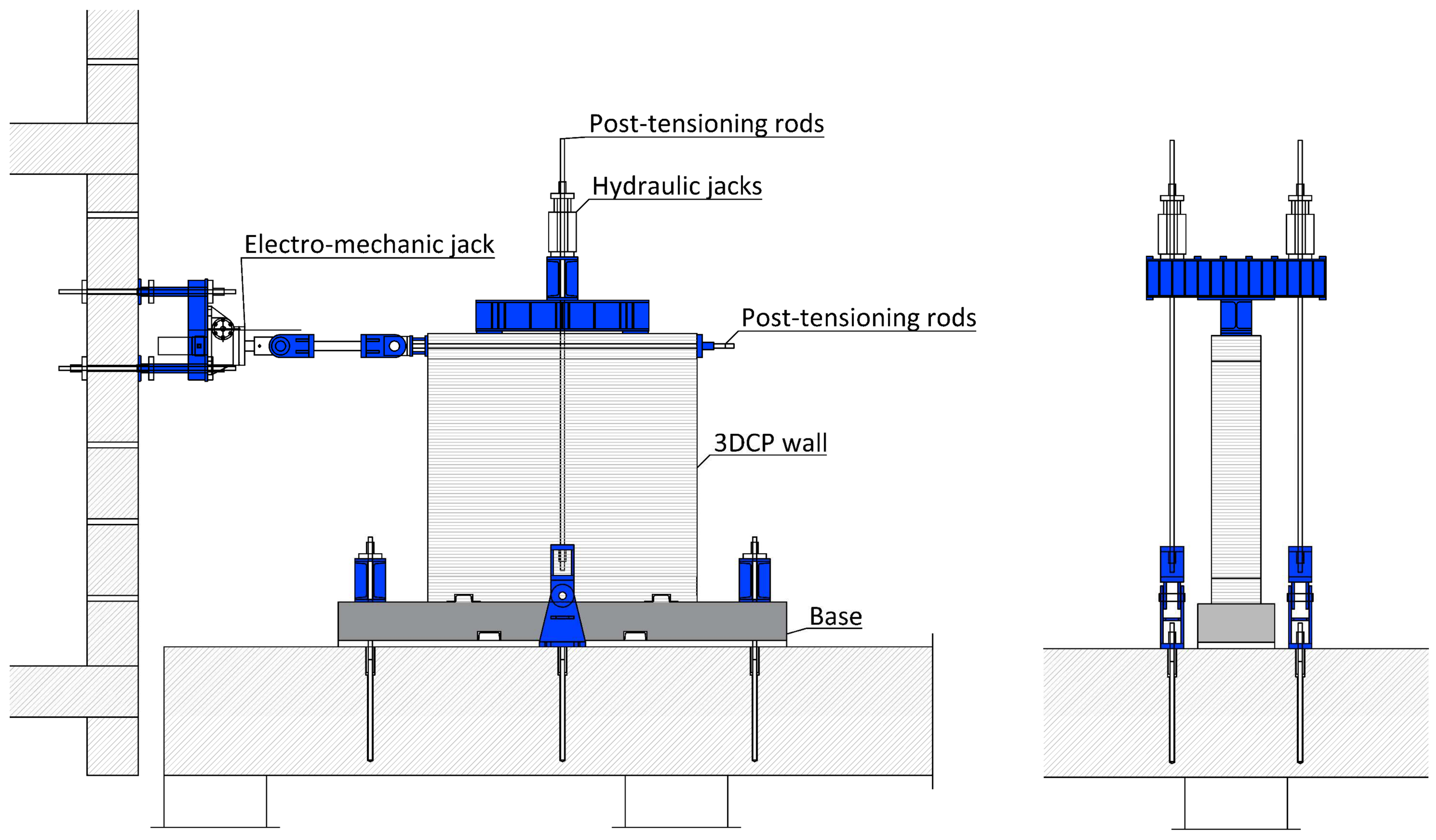

Figure 5. Test setup

RESULTS

Once the maximum tension strength was reached, the wall showed a brittle failure with a horizontal flexural crack running at the interface of two filament layers. First cracking occurred during the push phase (point A$^+$) at a load of 192.6 kN and a drift of 0.8‰. On the reversal of loading, cracking appeared during the pull phase (point A$^-$) at a load of -192.9 kN and a drift of 1‰. A critical crack, then, developed along the entire cross section (points B$^+$ and B$^-$) at a load of -217.5 kN and a drift of -1.6‰. After the cracking, a rocking mechanism followed (points C$^+$ and C$^-$ in Figure 6).

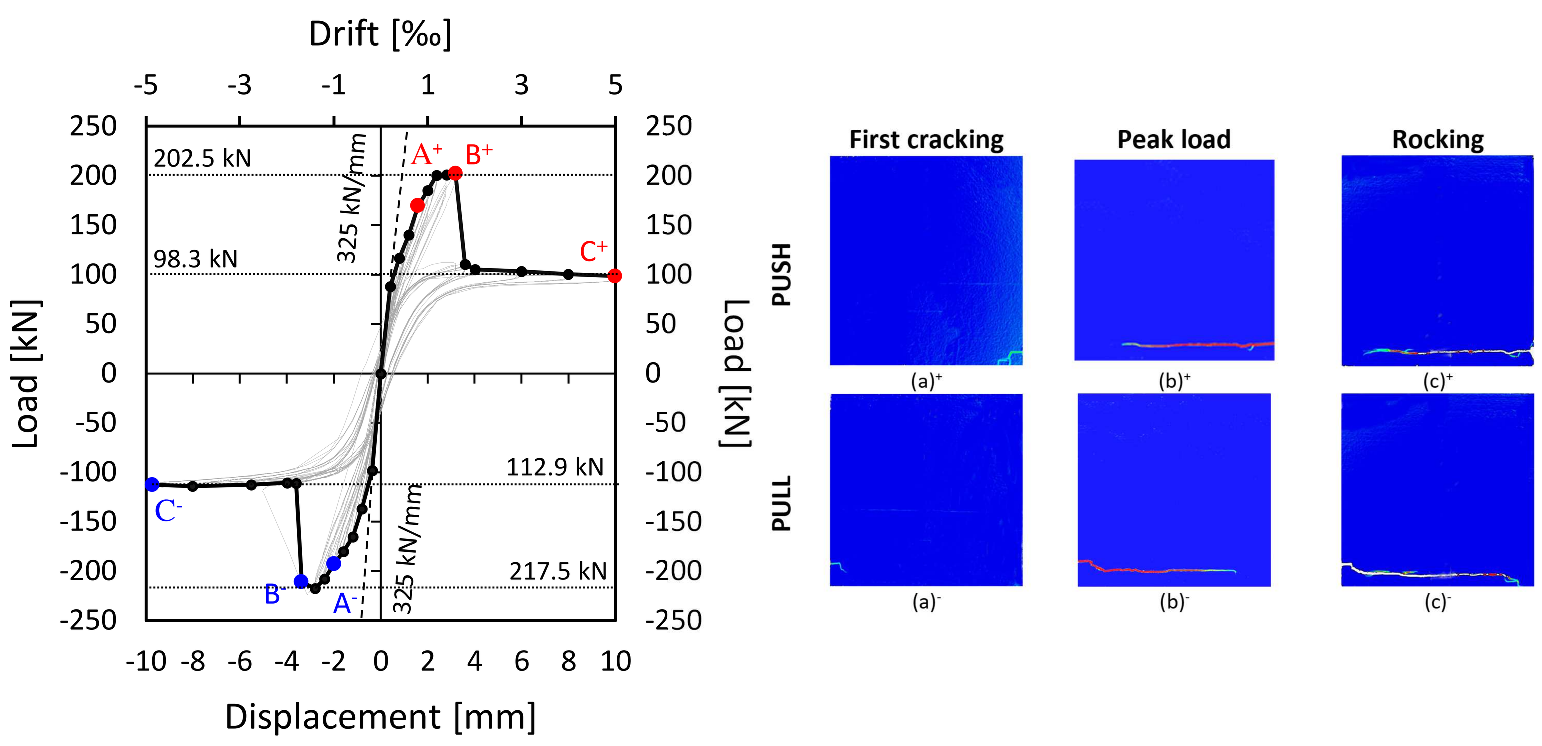

Figure 6. Strain field from DIC: (a) first cracking at 0.8‰ drift; (b) critical cracking (peak load) at 1‰ drift; (c) cracking associated to rocking mechanism up to 5.0‰ drift.

CONCLUSIONS

The structural response of a 3DPC wall under quasi-static horizontal cyclic loading and constant vertical loading is characterized by high initial stiffness and high resistance to horizontal loads. Flexural failure occurred for very limited drift values (1.6‰) when the tensile strength of the material was reached. The wall showed a brittle failure with a horizontal crack occurred at the interface between the layers thus pointing out the weakness of printed structures to interlayer delamination. After cracking, a stable rocking mechanism followed. Eventually, it has to be noted that the friction resistance of the critical section (after failure) was sufficient to guarantee rocking mechanism and prevent the wall sliding.

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