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TECHNICAL REPORT

POINT LOAD TEST ON PRECAST TUNNEL SEGMENT WITH FIBERGLASS REINFORCEMENT

CUSTOMER:

ATP S.p.A.

January 2014

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PREFACE

The point load test on precast segment with fibreglass reinforcement was carried out in the Laboratory of Materials and Structures of the Civil Engineering Department of the University of Rome Tor Vergata.

Responsible of the tests are Prof. Alberto Meda and Prof. Zila Rinaldi.

1. SEGMENT GEOMETRY

The test is carried out on a precast tunnel segment characterised by a thickness of 250 mm, a length of about 1585 mm and a width of about 1200 mm (Fig. 1).

The segment is reinforced with a fiber glass cage (FGR – fiber glass reinforcement), made of 13+13Ø14 longitudinal bars, 13+13Ø12 straight crossbars and 42Ø14 brackets hoops on the perimeter (Fig. 2) with minimum cover of 15 mm.

The segment was cast with concrete characterized by a cubic strength equal to 61.7 MPa.

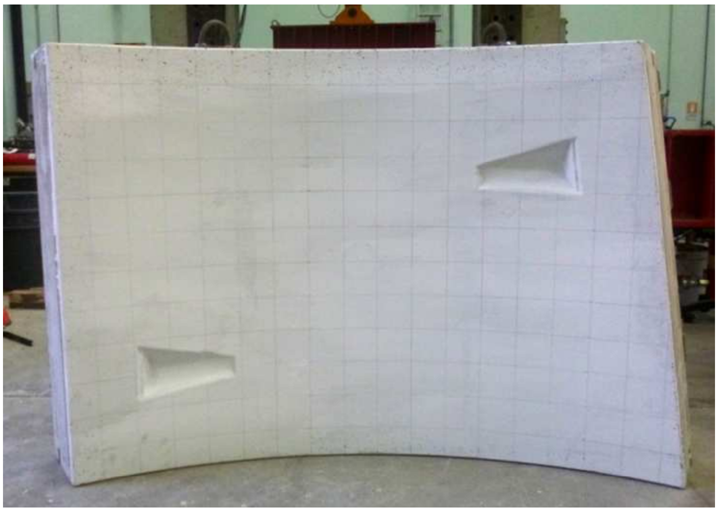


Figure 1. Segment geometry

Figure 2. Fiber Glass cage

2. POINT LOAD SEGMENT TESTING PROCEDURE

The test aims at simulating the TBM thrust. The testing set-up is shown in Figures 3 and 4

The point load test is performed by applying point loads on the segment, by adopting the same steel plates used by the TBM machine. A uniform support is considered, as the segment is placed on a stiff beam suitably designed.

Two 2000 kN jacks are used for every steel plate. The load was continuously measured by pressure transducers. Four wire transducers (two located at the intrados and two at the extrados) measure the shoes displacement, while one LVDT transducer is applied between the load shoes, at the top, in order to measure the crack openings. (Figs. 3 and 4).

The test is usually conducted applying a loading history with loading steps.

Three complete loading – unloading cycles have been carried out, and in particular: .

- first cycle: 0-1130 kN;

- second cycle: 0-2500 kN;

- third cycle: 0-3850 kN (failure load).

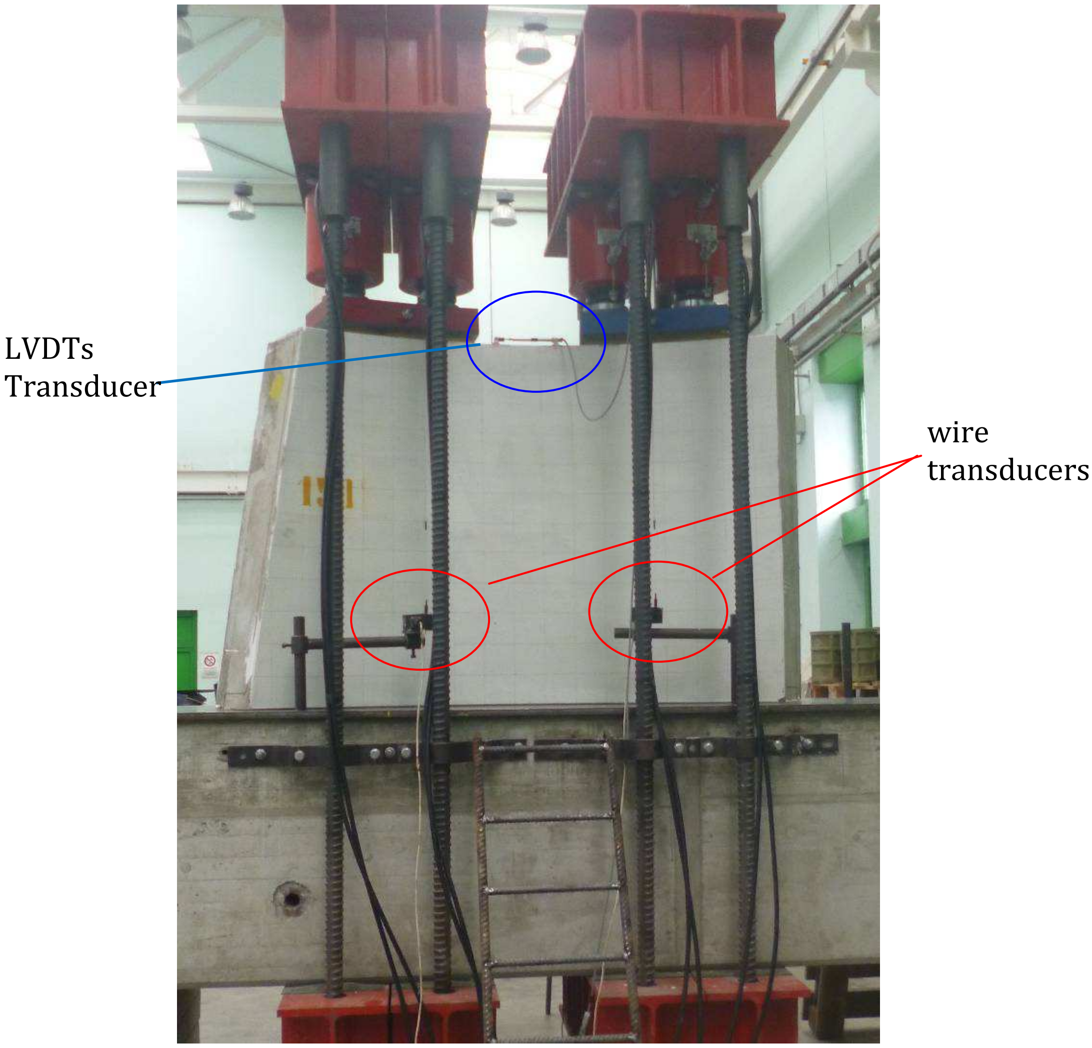


Figure 3. Test set-up. Intrados surface

Figure 4. Test set-up. Extrados surface

3. POINT LOAD TEST: RESULTS

The results of the point load tests carried out the 15/10/2013 on the segment named “150” are summarised in the following. In particular, besides the load history, it will be shown the load-displacement relationships and the evolution of the crack patterns. The displacements are evaluated on the basis of the measures given by the wire transducers located on the intrados and extrados surfaces (Par. 2, Fig. 3 and 4). The crack widths are measured with the LVDT instrument. (Par. 3, Fig. 3).

The upload and unload cycles, performed with the group of two hydraulic jacks (2000 kN each) for each shoes are specified in the following.

The test set-up for the segment, is again highlighted in Figure 5 and Figure 6.

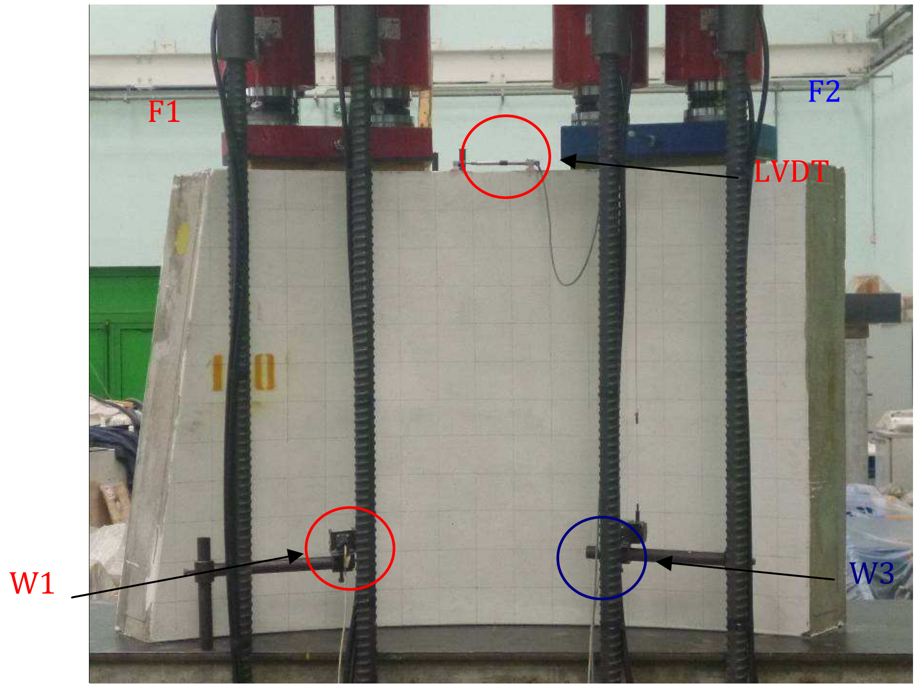


Figure 5. Segment 150: test set-up. Intrados surface.

Figure 6. Segment 150: test set-up. Extrados surface.

The loading process for the segment is summarised in Figure 7 through the load – time diagram. The maximum load is equal to 2850 kN for each shoe and represents the collapse load, as shown in the following.

It is worth remarking that in this report the term load will refer to the single shoe.

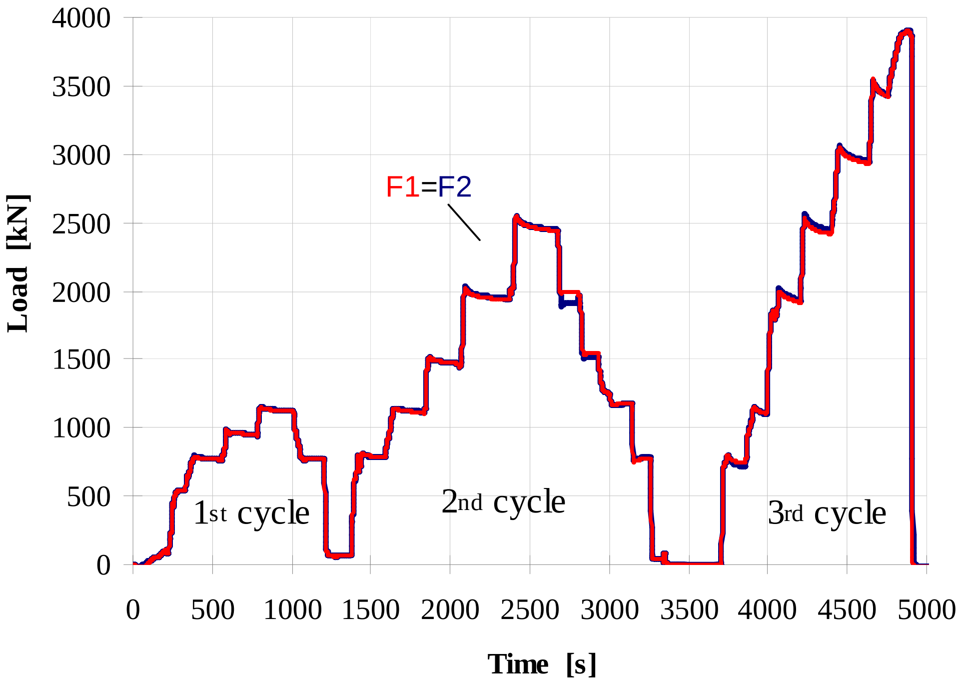


Figure 7. Force-time diagram.

The displacements measured by the four wire transducers (Figs. 5 and 6) are reported versus the force of the single shoe, in Figures 8, 9 and 10. The maximum measured displacement is higher than 200 mm.

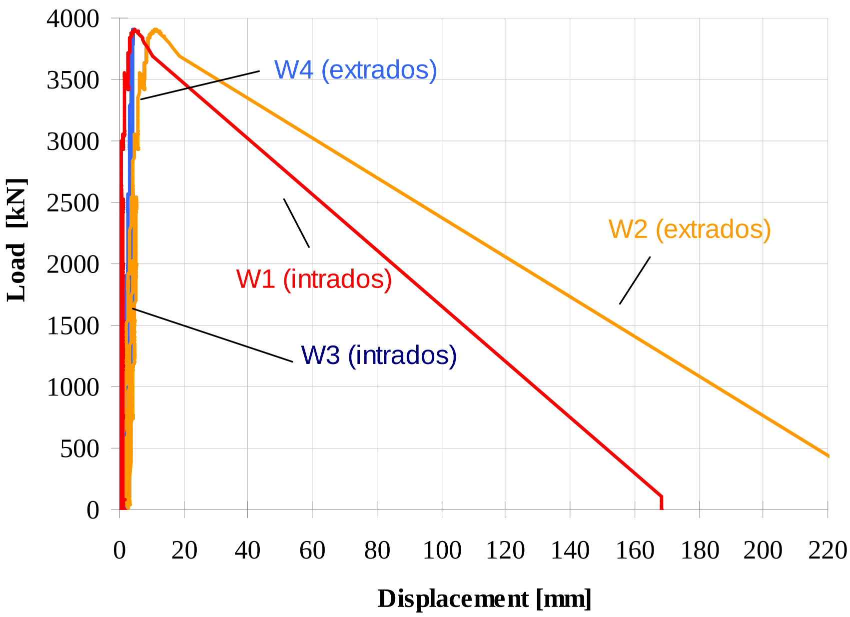


Figure 8. Force-displacement diagrams (Wire transducers). Total graph

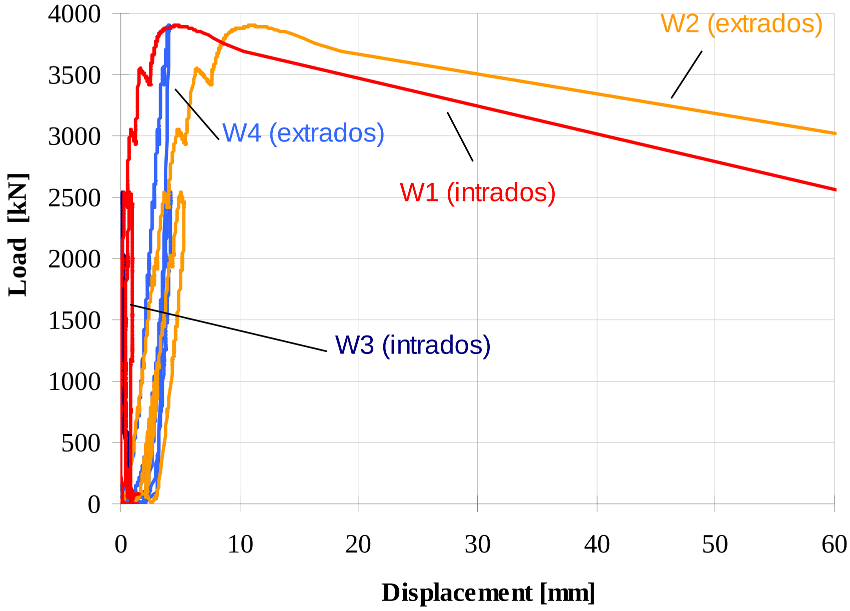


Figure 9. Force-displacement diagrams (Wire transducers). Detail up to 60 mm.

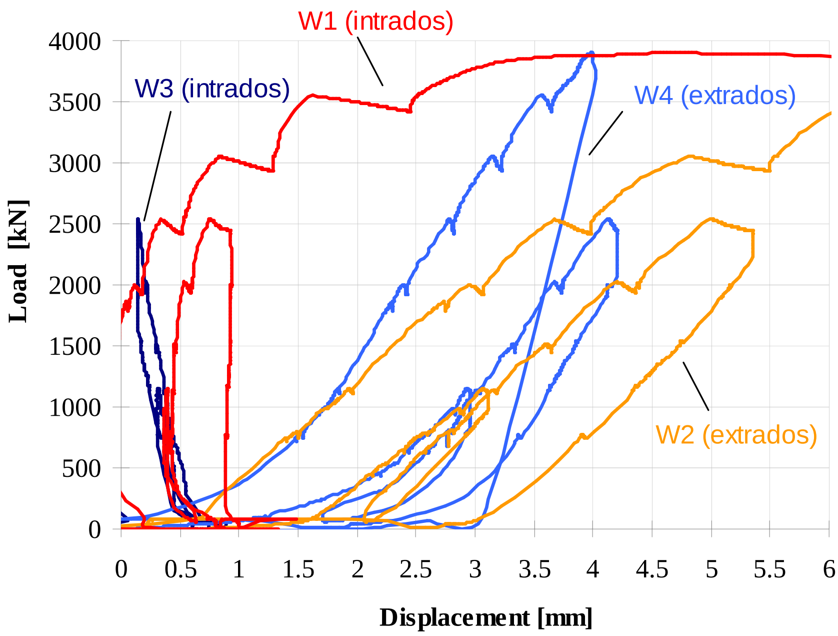
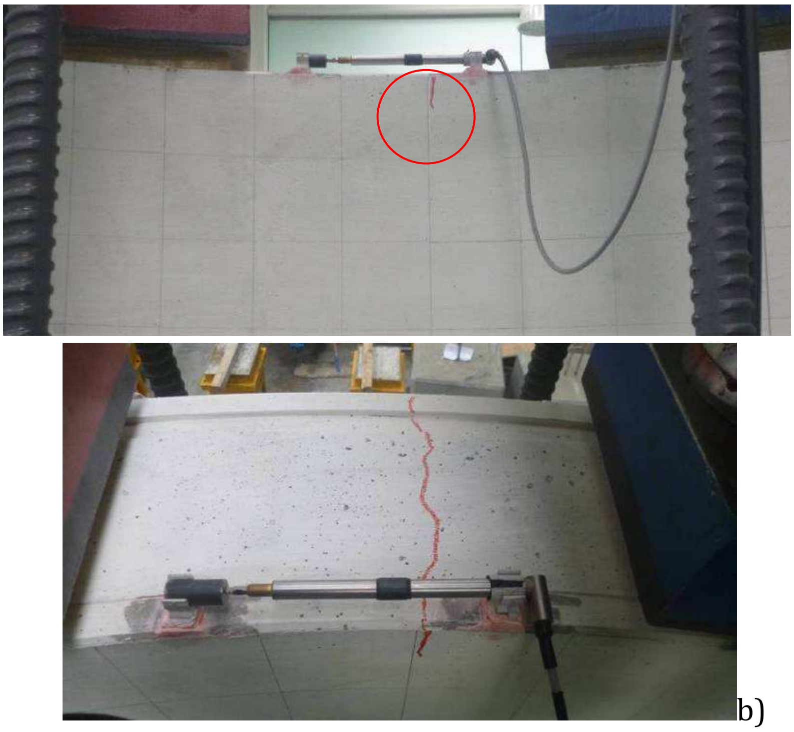


Figure 10. Force-displacement diagrams (Wire transducers). Detail up to 6 mm.

First cycle (0-1130 kN)

The first crack appears at the top of the intrados surface, in the LVDT's length, for a load level of about 785 kN (for each shoe), and passes through the thickness (Fig. 3.6). At the intrados surface its length is about 5 cm .



a)

b)

Figure 11. First cycle. First cracking - 785 kN - (for each shoe); a) intrados, b) top surface.

Up to a load level of about 1130 kN the first crack increases its length and passes through the extrados surfaces (Fig. 12). The maximum crack width is about 0.05 mm. (Fig. 13).

Finally a complete unloading is carried out. When the load is removed the cracks are completely reclosed.

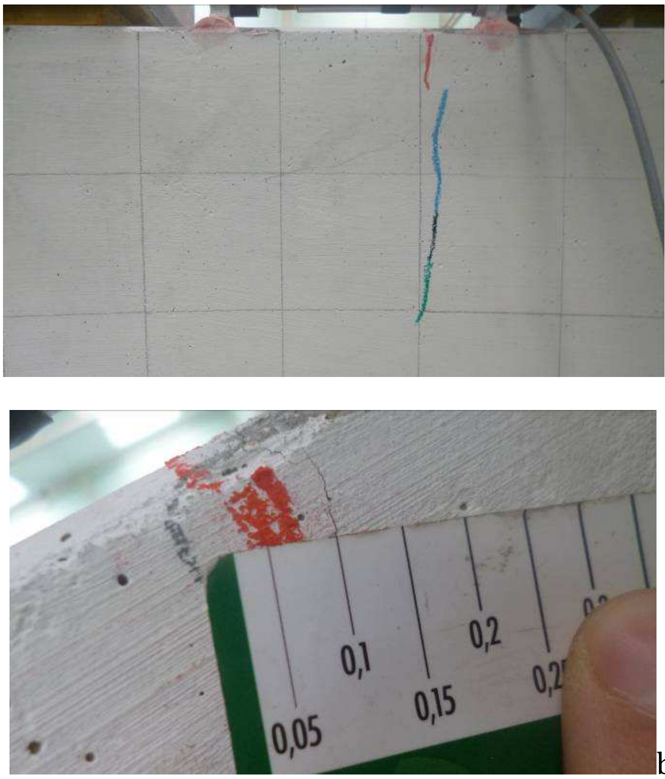
a) b)

Figure 12. First cycle. Load step 1130 kN (for each shoe); a) intrados surface, b) top surface.

Figure 13. First cycle. Maximum crack width (1130 kN).

Second cycle (0-2500 kN)

In the second cycle, the same crack formed during the first cycle opens for a load level of 785 kN. A further increase of its length, with respect to the first cycle, takes place for a load level of about 1130 kN (Fig. 14a in green). The maximum crack width is lower than 0.1 mm (Fig. 14b).



a)

b)

Figure 14. Second cycle. Load level 1130 kN. a) Intrados surface, b)Maximum crack width.

The already formed crack lengthens itself for a load level of 1500 kN, while a new cracks forms at the top surface for a load level of 2000 kN (in blue in Fig. 15).

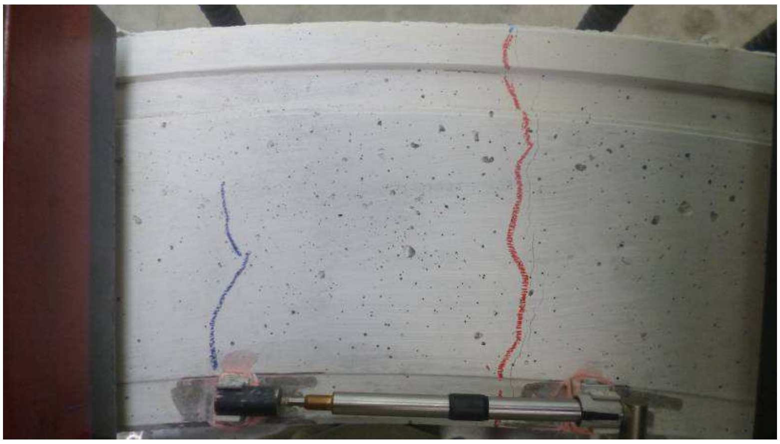


Figure 15. Second cycle. Load level 2000 kN. Top surface.

Further cracks form under to load shoe, at the extrados surface for a load level of 2500 kN, as shown in Figure 16 (in brown). An increase of length of the already formed cracks takes place (brown in Fig. 17). The maximum crack width is equal to about 0.35 mm (Fig. 18).

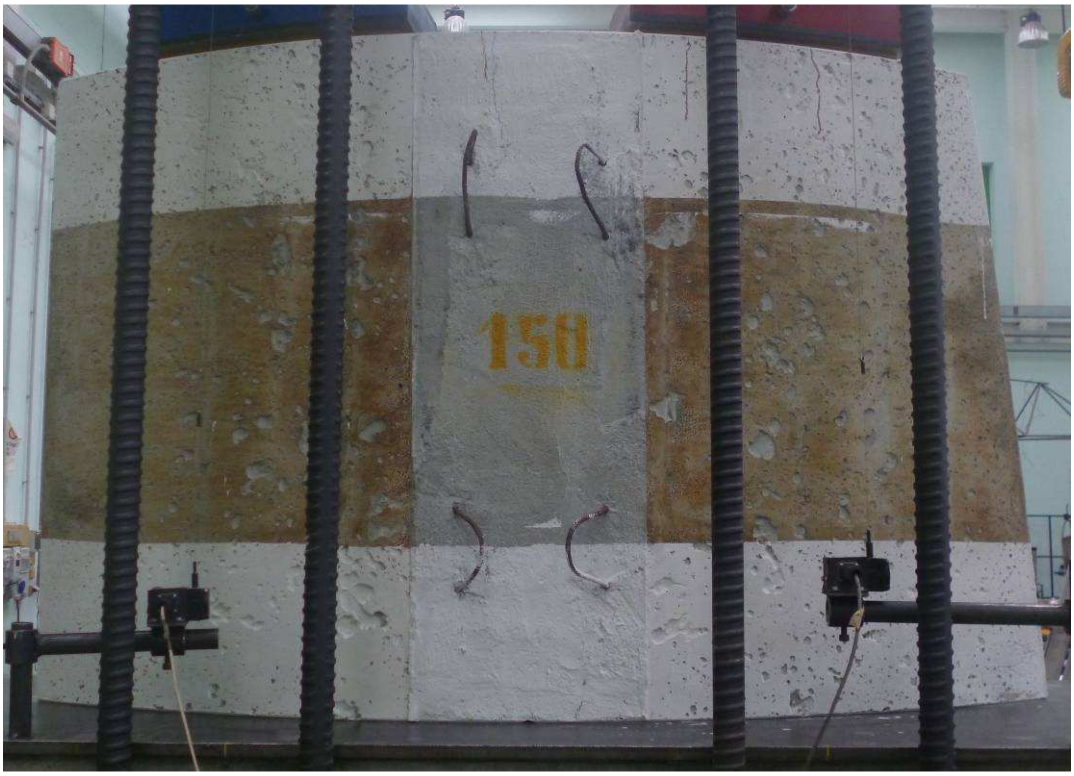
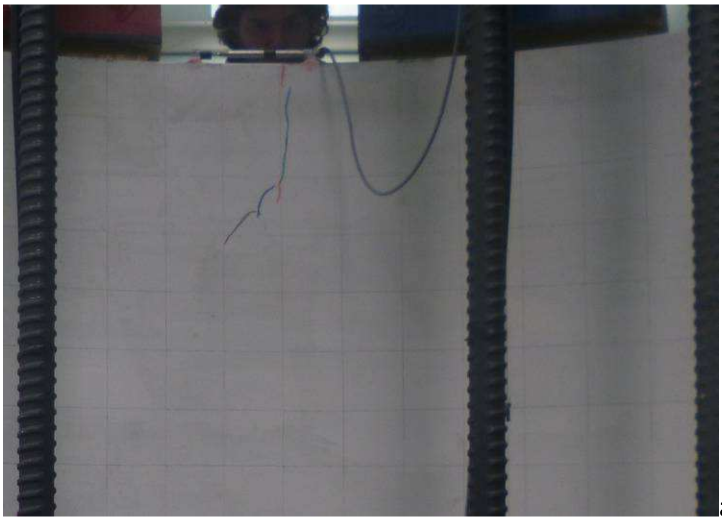
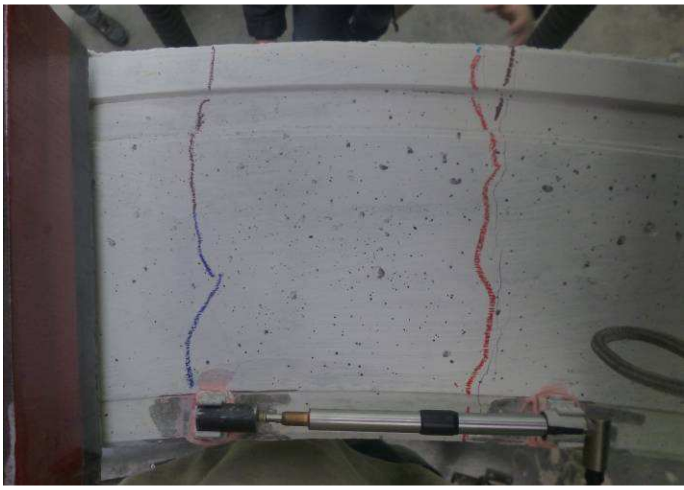


Figure 16. Second cycle. Load level 2500 kN. Extrados face.



a)



b)

Figure 17. Second cycle. Load level 2500 kN. a)Intrados face, b)top surface.

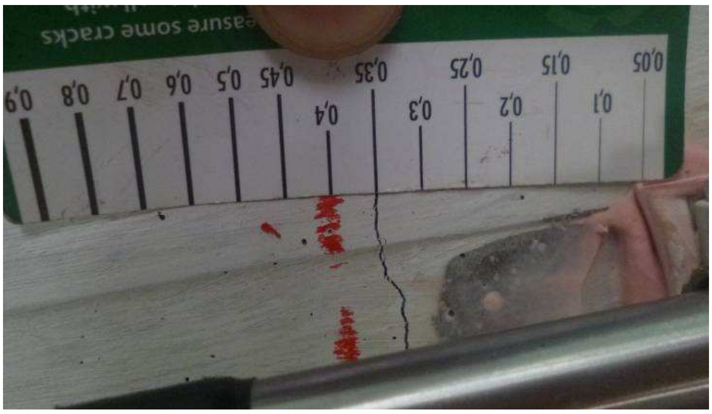


Figure 18. Second cycle. Load level 2500 kN. Maximum crack width.

Finally the unloading phase takes place. The crack width at the end of the second cycle, (load equal to zero) is less than 0.05 mm (Fig. 19).

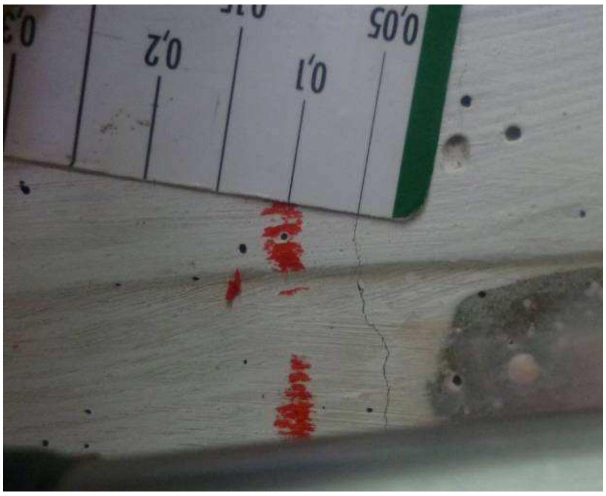


Figure 19. Second cycle. Complete unloading. Maximum crack width.

<u>Third cycle (0-3850 kN)</u>

In the third cycle, the same cracks formed during the second cycle open for a load levels up to 1130 kN. An increase of length, with respect to the second cycle, takes place mainly for the cracks at the extrados surface for a load level of about 2500 kN (Fig. 20 in yellow). The maximum crack width is about 0.35 mm (Fig. 21).

Figure 20. Third cycle. Load level 2500 kN. Extrados surface.

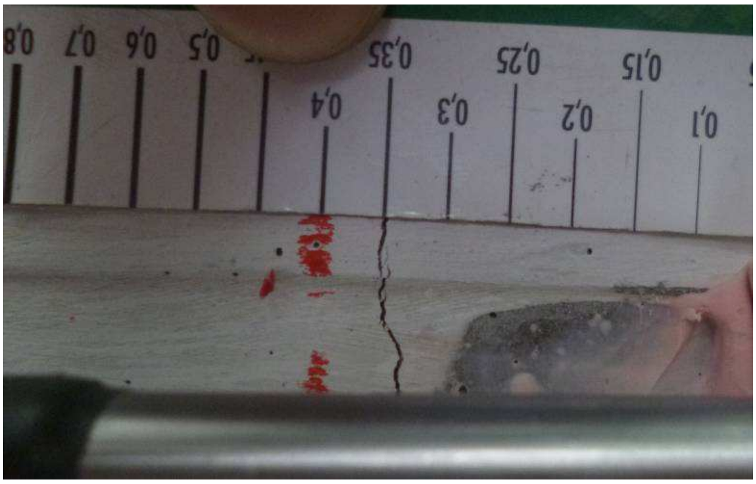


Figure 21. Third cycle. Load level 2500 kN. Maximum crack width.

A new crack forms at the extrados face for a load level of 3000 kN, from the top to the bottom of the element (Fig. 22 in green), passing to the intrados surface (Fig. 23). An increase of length of the crack at the intrados surface also occurs. (Fig. 23)

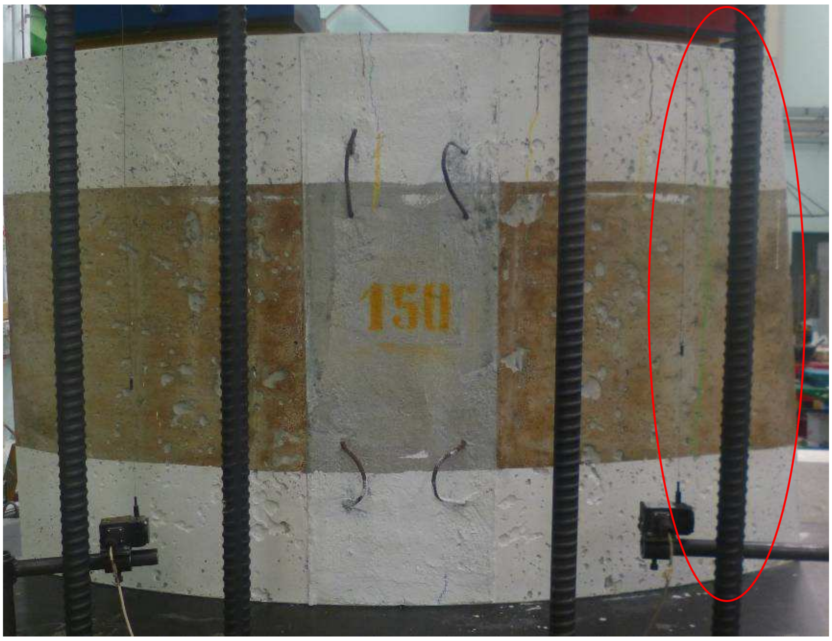


Figure 22. Third cycle. Load level 3000 kN. Extrados surface.

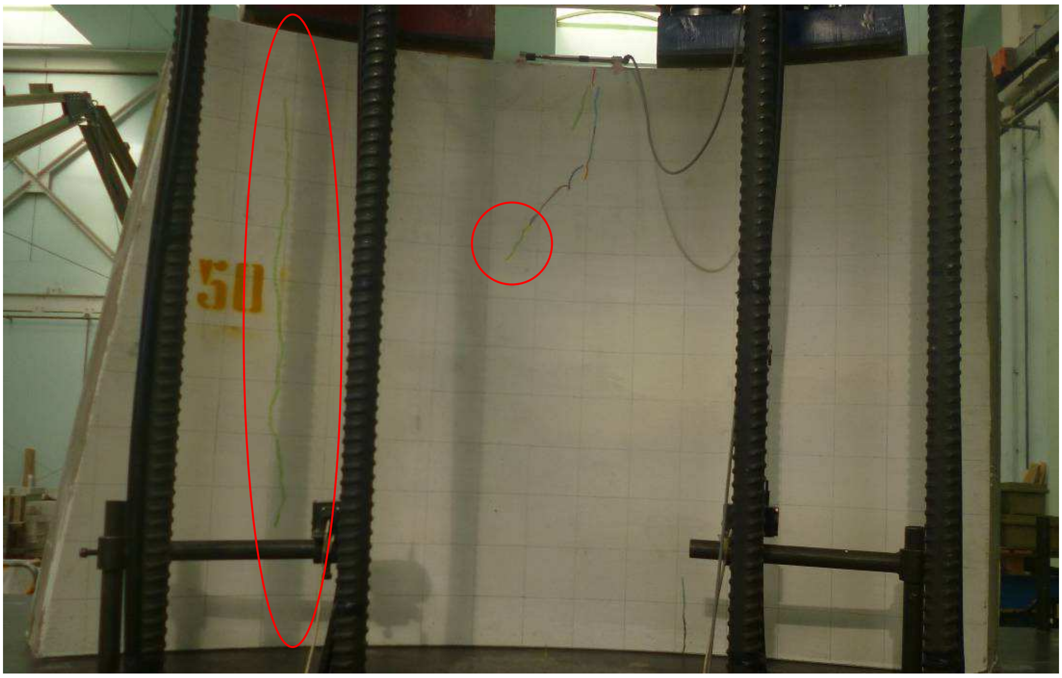


Figure 23. Third cycle. Load level 3000 kN. Intrados surface.

Further cracks open at the intrados surface for a load level of 3500 kN as shown in Figure 24 in pink.

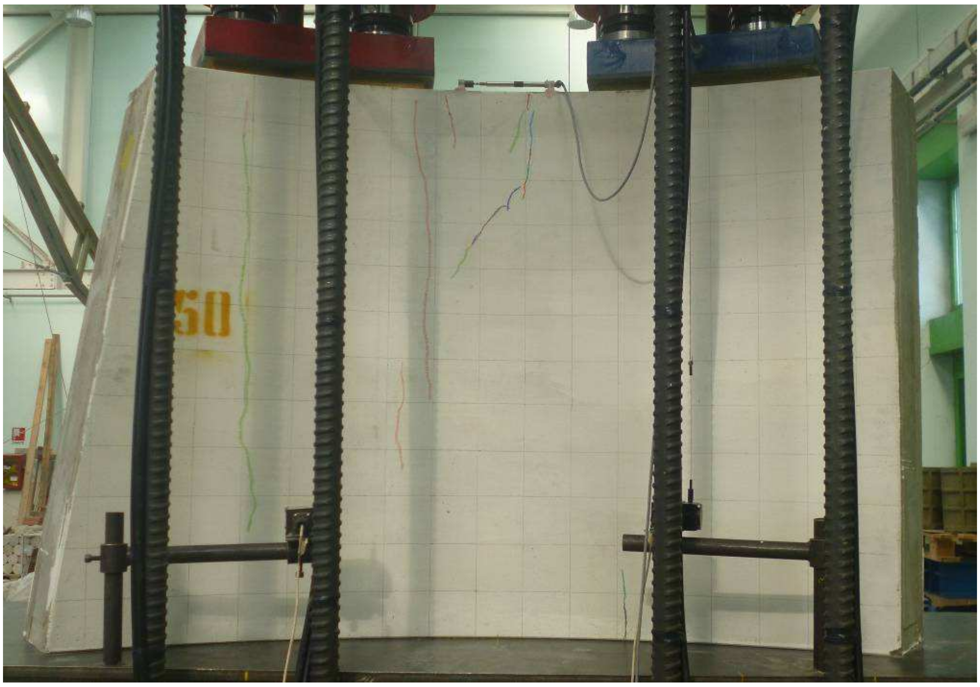


Figure 24. Third cycle. Load level 3500 kN. Intrados surface.

The collapse of the element takes place for a load level of 3850 kN, for a detachment of the concrete cover at the extrados (Fig. 25).

Figure 25. Third cycle. Load level 3850 kN.

The complete final crack pattern is shown in Figure 26.

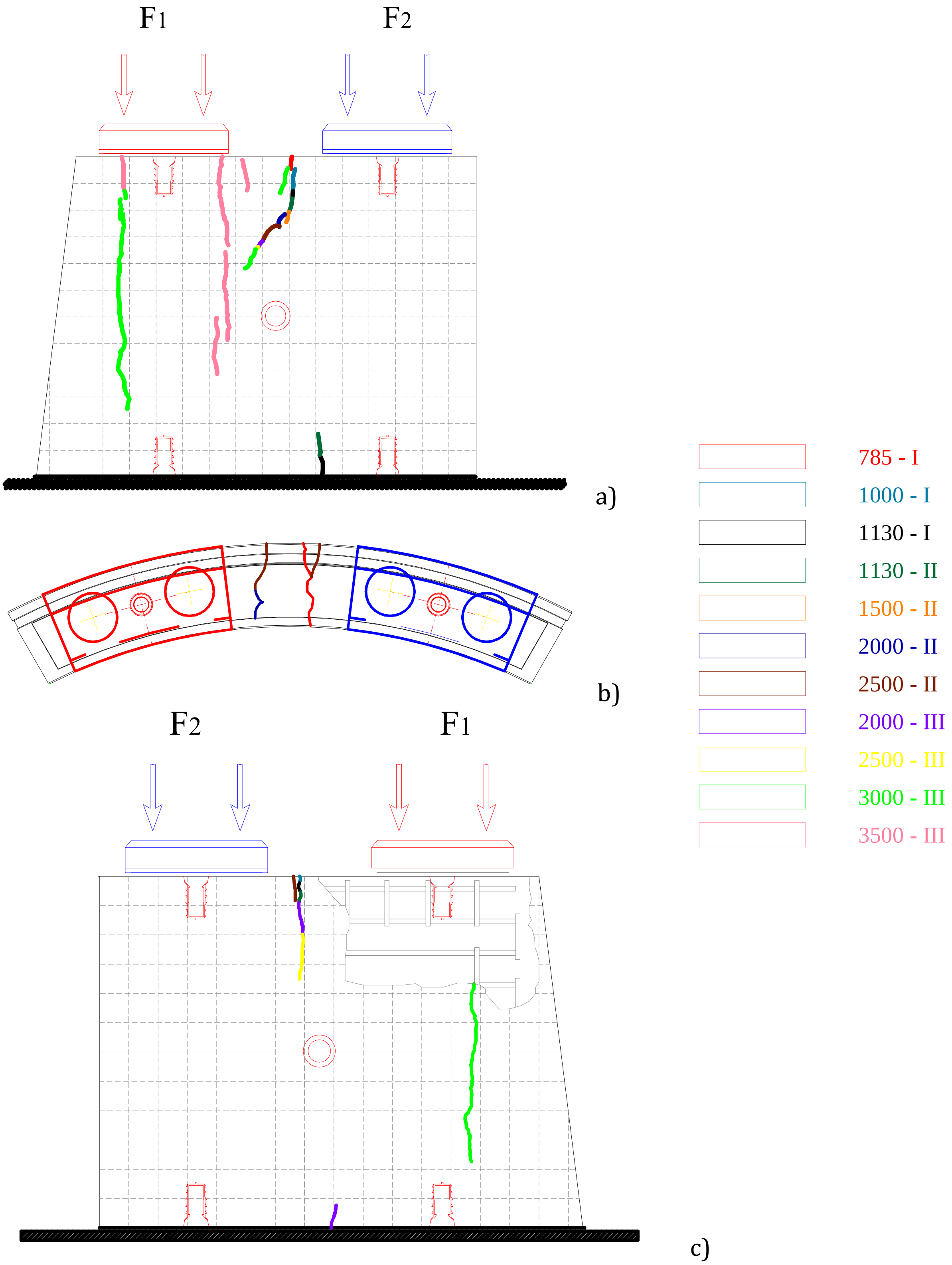


Figure 26. Crack pattern; a) intrados face, b) top face, c) extrados face.

Finally the displacements measured by the LVDT (Fig. 5), related to the one crack opened in the instrument length (Fig. 17) are shown in Figure 27.

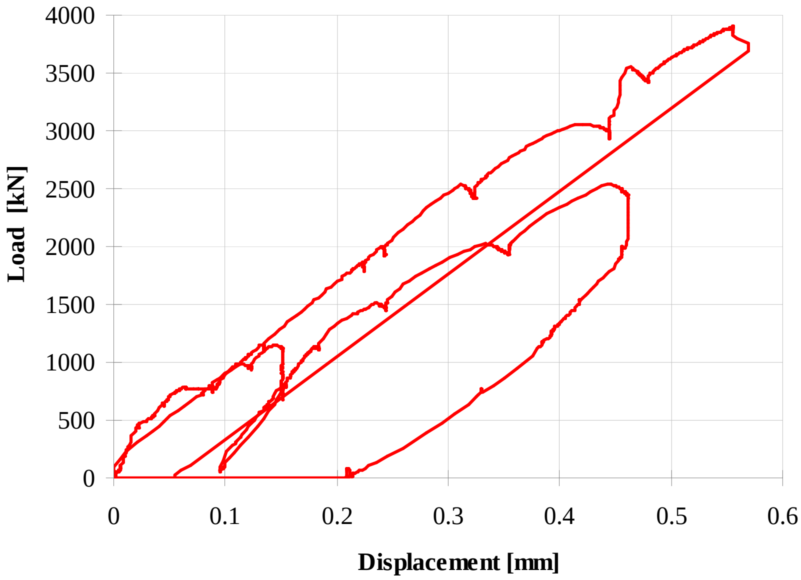


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Figure 27. Load - LVDT displacement.

CONCLUSIONS

The technical report shows the results of a point loads test carried out in the Laboratory of the Rome University “Tor Vergata” on a precast fiber reinforced concrete segment with fiber glass reinforcement.

The load history, the load –displacement diagrams, the load – crack opening and the evolution of the crack pattern are highlighted and pictures related to each cycle of the load history are summarised in this report.

Roma, 08.01.2014

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