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PRECAST TUNNEL SEGMENTS REINFORCED WITH FIBER GLASS BARS

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Name of Presenter, Job Title / Affiliation

Simone Spagnuolo,Ph.D. Student, Italy

- Born in 1986.
- Graduate(cum laude) in Civil Engineering at the University of Rome “Tor Vergata”(2011) with the thesis “Structural behavior of innovative fiber-reinforced concrete Containing Municipal Solid Waste Fly Ash with lightweight aggregates”.
- Currently PhD student at the Department of Civil Engineering of the University of Rome “Tor Vergata”, focused on the behaviour of structures reinforced with fiber glass bars (with particular reference to precast tunnel segments and skin reinforcement) .
- Assistant with the chairs of "Structural Analysis and Design".
- Collaboration for tests: Bending & TBM jack thrust for hydroelectric plant(Panama); flat jacks in Tunnel(Francie); prestressing cables of a bridge (Italy).

The Fourth International *fib* Congress 2014, Mumbai

February 10 – February 14, 2014

PRECAST TUNNEL SEGMENTS REINFORCED WITH FIBER GLASS BARS

(Alberto MEDA, Zila RINALDI, Simone SPAGNUOLO)

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The use of fiber glass rebars in substitution of traditional steel reinforcement allows a series of advantages and it could be an innovative solution in some applications but it is not suitable for all the applications for two main reasons:

1) The **cost** of the fiber glass reinforcement is generally higher respect to the traditional steel;

2) The problem related to **static fatigue** when the bar is subjected to a constant **tensile load** over time

The use of GFRP is suggested in:

2.1) Structures that are mainly in **compression** under the serviceability load conditions
(deep tunnels, tunnels excavated in rock);

2.2) In **temporary structures** (also subject to tension).

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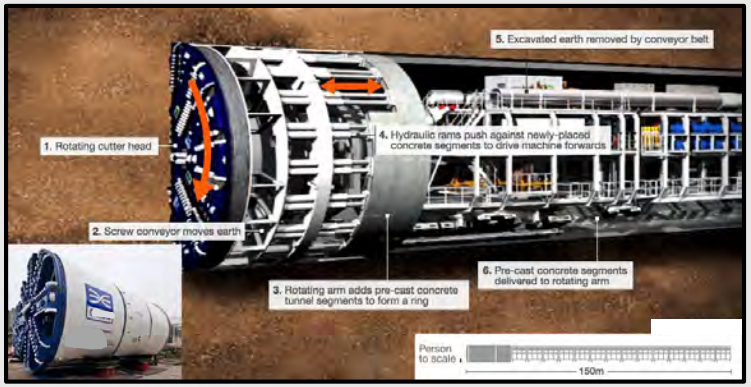
Introduction

Our research is focused on the possibility of use GFRP in:

PRECAST TUNNEL SEGMENTS

Precast segments are traditionally used for the lining of tunnels excavated with a Tunnel Boring Machine (TBM) and they are used as reaction elements from the TBM during the excavation.



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The use of GFRP bars in tunnel segments allows several advantages:

1) NO corrosion

Steel bars subject to corrosion

Fiber Glass bars are not subject to corrosion

2) Durability aspects

In reference to the structures that are in **compression**

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The use of GFRP bars in tunnel segments allows several advantages:

1) NO corrosion

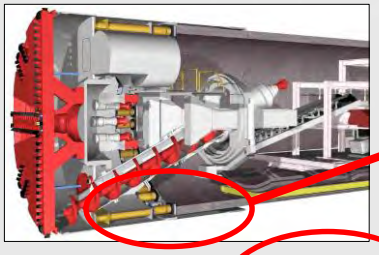
2) Durability aspects

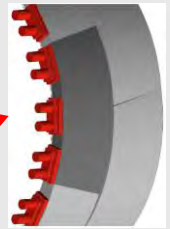
The possibility of reducing the concrete cover that is usually a weak point for this kind of structures

Concrete cover can crash during:

1) Handling of the segments

2) TBM thrusts





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The use of GFRP bars in tunnel segments allows several advantages:

3) In case of TBM excavation where it will be necessary later to demolish or remove the precast segments, it is convenient to utilize GFRP reinforcement instead of the traditional steel.

Some of the most common applications:

- Segments to be demolished for realization of fire-safety niches.

The cutting of the reinforcement bars (GFRP) is useless.

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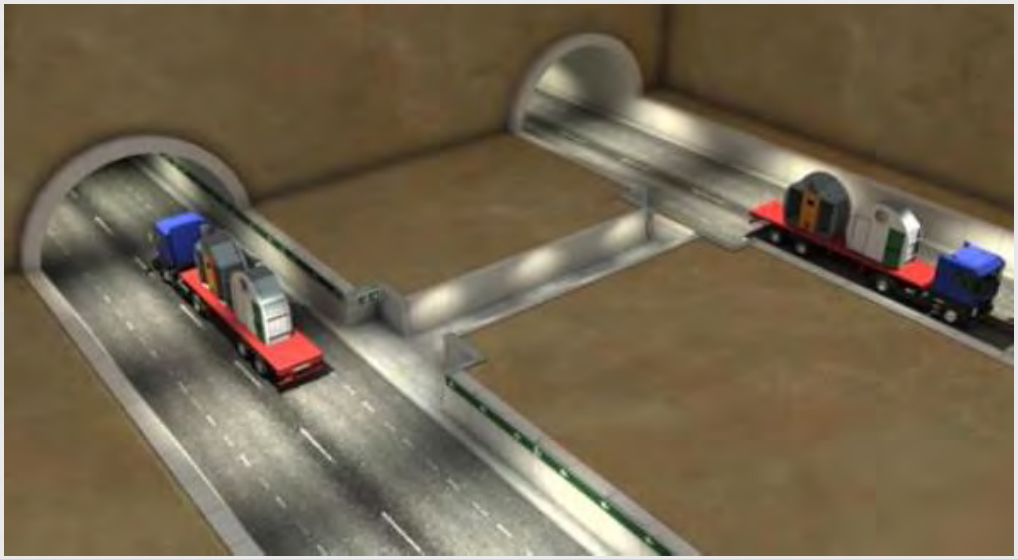
Some of the most common applications:

- Construction of by-pass tunnels for access to adjacent tunnels or for realization of escape or vent channels.



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Some of the most common applications:

- Full section channels for transfer of TBM

Metro stations where for sake of time the TBM will cross an area to be later excavated, the utilization of segments with GFRP rebar reinforcements will facilitate the excavation.

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The use of GFRP bars in tunnel segments allows several advantages:

4) Easy disposal

concrete + steel

the two materials must be separated to a different destination, in relation to their different ability to be recycled

concrete + GFRP

does not require this type of separation can be crushed and recycled or brought to the landfill

5) Create a dielectric joint in the tunnel for the new driverless metro system

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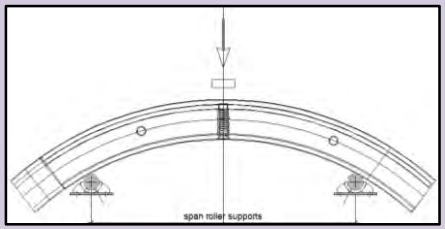
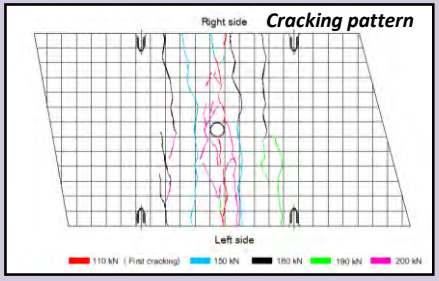
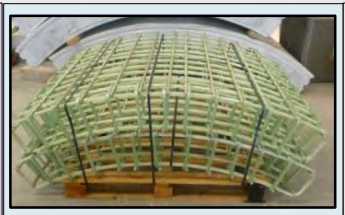
Experimental program

FULL SCALE TEST:

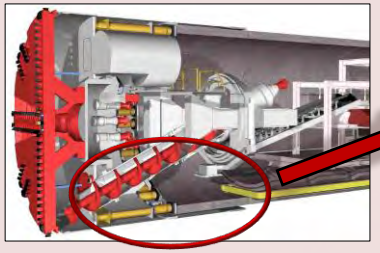
1) BENDING TEST

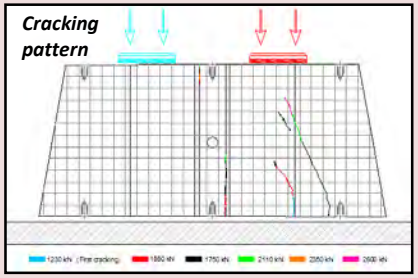






2) TBM JACK THRUST TEST





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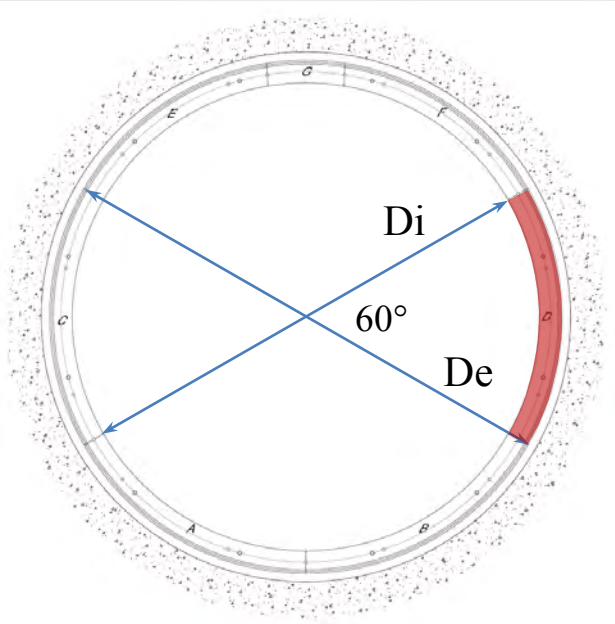
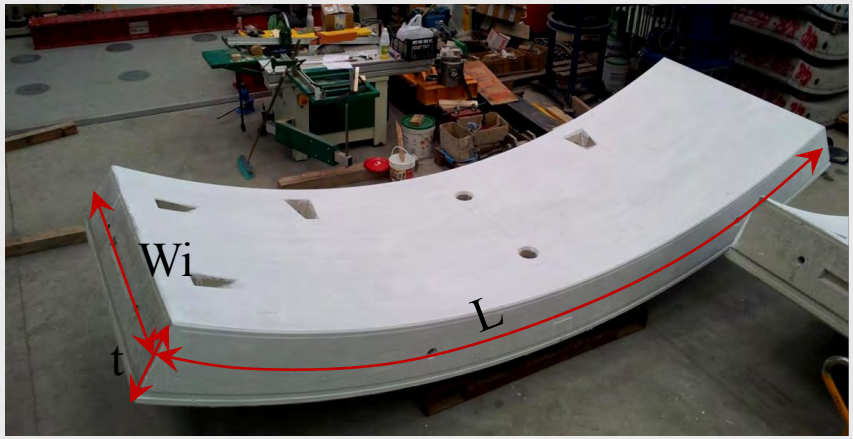
GEOMETRY of the segment





D_i = 8.30 m

D_e = 9.10 m

Length = 4150 mm

Width = 1500 mm

thickness = 400 mm

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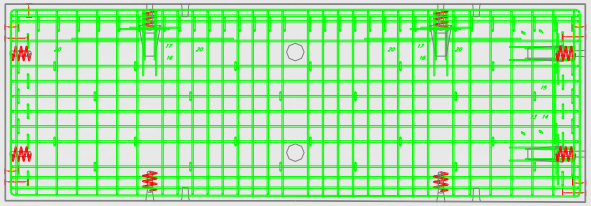
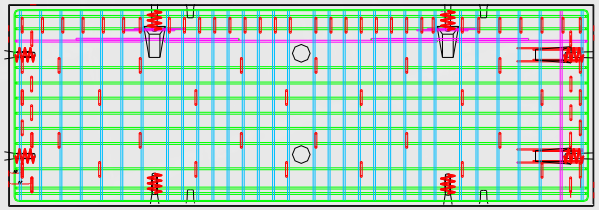
REINFORCEMENT of the segments

Traditional steel cage for the reference segment (SR)



12Φ12 bars intrados surface
12Φ12 bars extrados surface

Fiber Glass cage (FGR)



12Φ14 bars intrados surface
12Φ12 bars extrados surface

- In these tests, it was considered the same concrete cover(minimum) of 50mm
- The reinforcements were designed in order to have the same bending resistence
- The concrete is characterized by a cubic strength equal to 61 MPa

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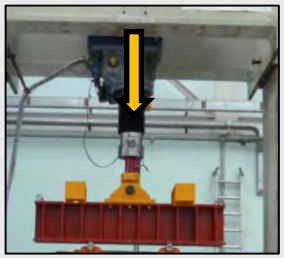
FULL SCALE BENDING TEST

The segment was loaded by means of a electromechanical close loop jacket having a maximum capacity of 1000 kN.

1) Portal frame
2) Load jack
3) Load sharing system
4) Roller supports
5) Constraint system

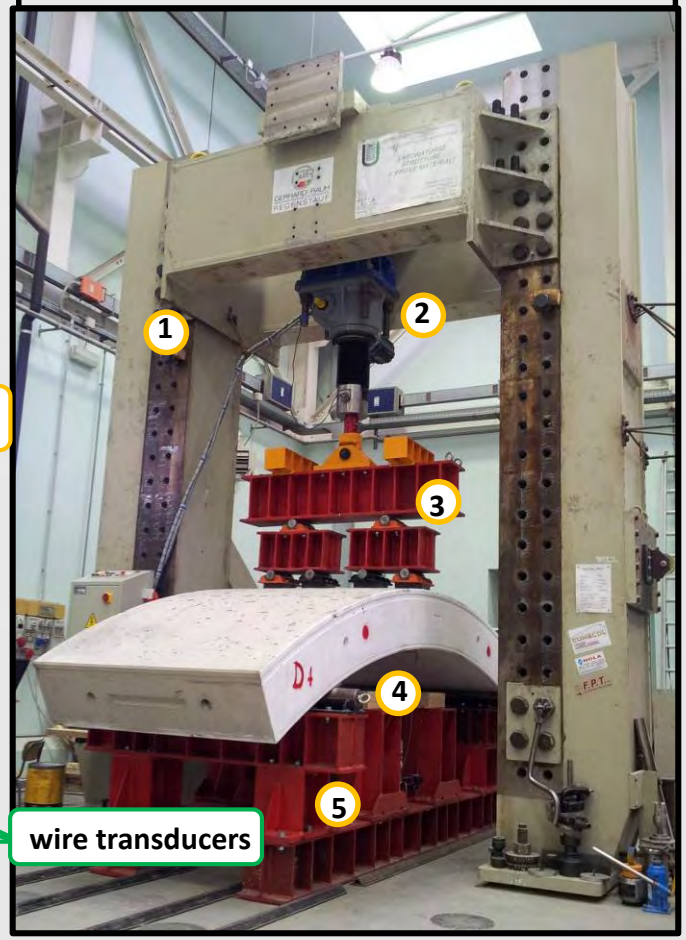
During the test, the following measures were continuously registered:



• the load measured by means of a 1000kN load cell with a precision of 0.2%;

• the midspan displacement measured by means of three potentiometer wire transducers placed along the transverse line;

• the crack opening at midspan, measured by means of two LVDTs.



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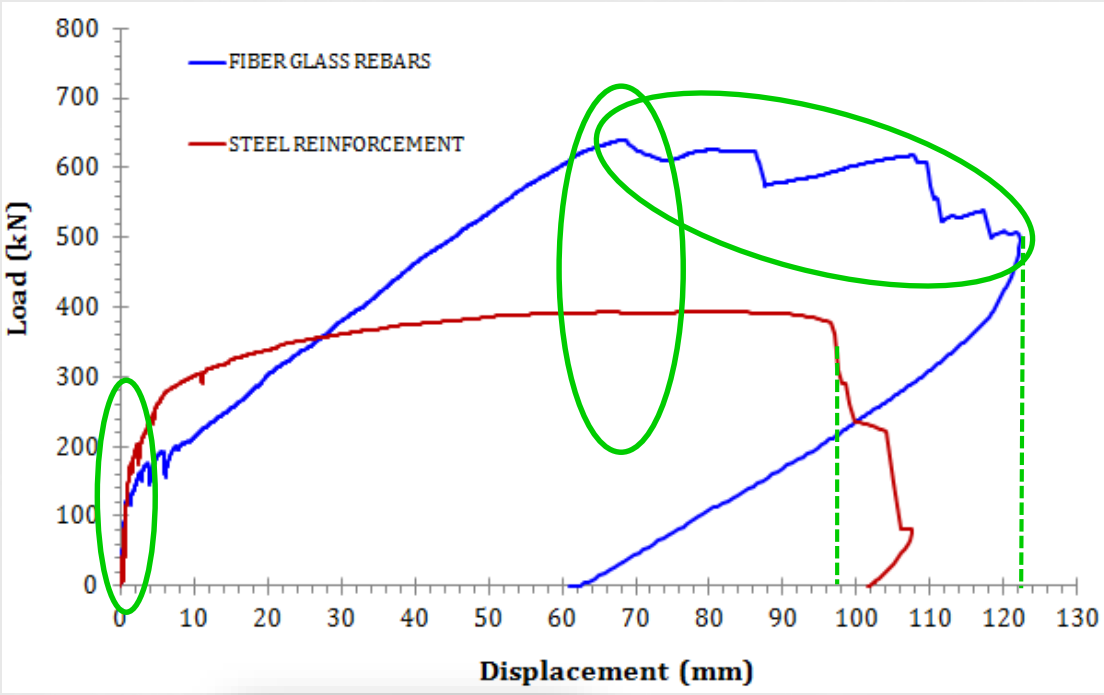
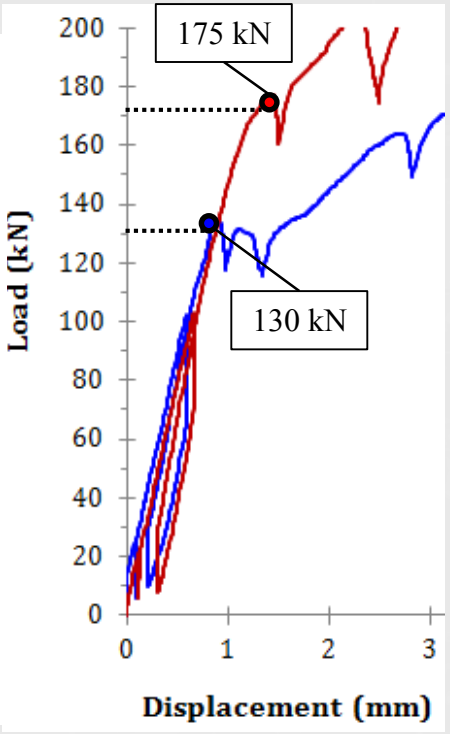
LOAD Vs MIDSPAN DISPLACEMENT CURVES





	Steel Reinforcement (SR)	Fiber Glass Reinforcement (FGR)
Load at the First Crack	175 kN	130 kN
Maximum bearing capacity	396 kN	640 kN
Safety coefficient [γ]	1.15	1.5

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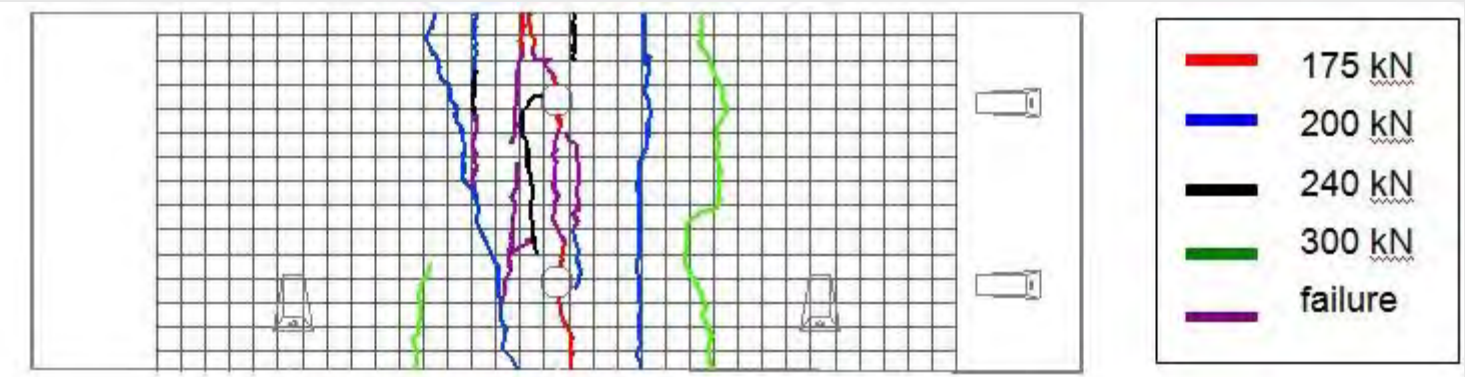
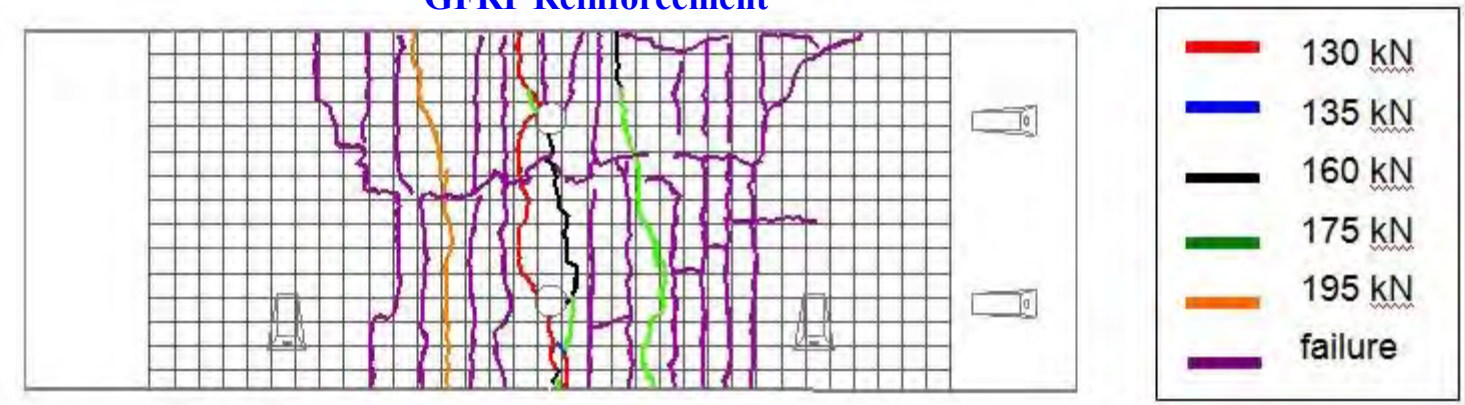
THE CRACK PATTERN FOR DIFFERENT LOAD LEVEL

Furthermore, the crack pattern was recorded at different step, with the help of a grid plotted on the intrados surface (100x100mm).

STEEL Reinforcement



GFRP Reinforcement



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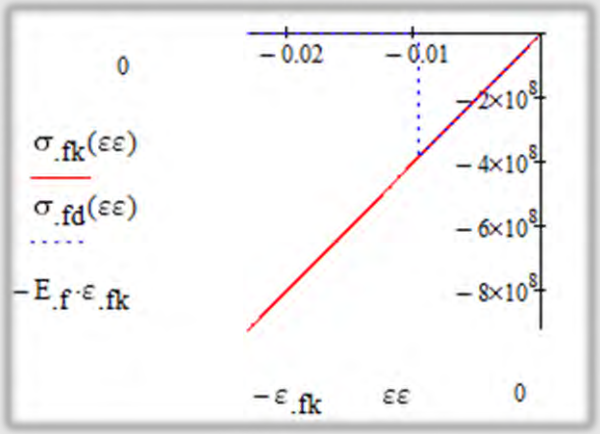
BENDING MOMENT Vs AXIAL FORCE ENVELOPE

Some considerations have to be done on the design aspect compared to the use of fiber glass rebars compared to the traditional reinforcement:

1. Design guidelines for fiber glass rebars (*fib* bulletin 40, ACI 440, CNR DT203) suggest to use:

   - ELASTO-BRITTLE behavior for the fiber glass rebars in tension
   - NO RESISTANCE IN COMPRESSION



2. The material safety coefficient is usually taken as 1.5 (CNR DT203) compared to 1.15 for the steel

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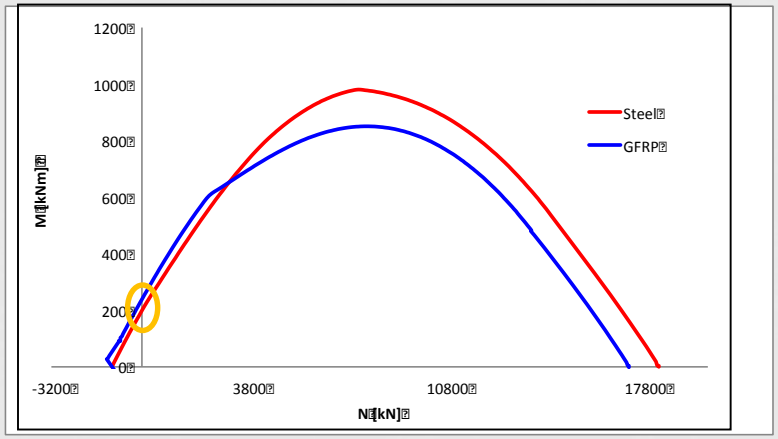
BENDING MOMENT Vs AXIAL FORCE ENVELOPE

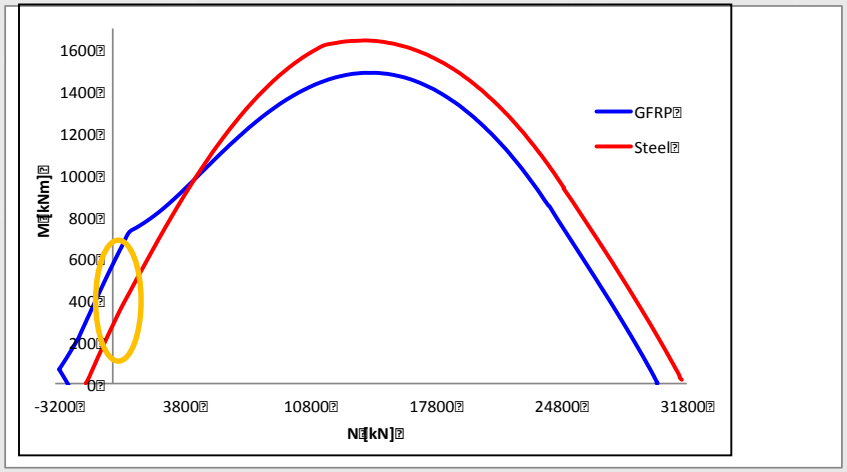
Some considerations have to be done on the design aspect related to the use of fiber glass rebars respect to the traditional reinforcement:

3. The reinforcement detail in the specimens was defined in order to have the same design bearing capacity for the two segments, at least in pure bending



DESIGN STRENGTH OF THE MATERIAL

4. If the average values of the material strength are considered, it is clear the higher bearing capacity exhibited by the segment with fiber glass rebars.



AVERAGE STRENGTH OF THE MATERIAL

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Conclusion

1. Fiber glass rebars can be a solution in some problems that can arise in the segmental lining construction.

2. From the point of view of the structural behavior, there are not significant differences when the steel reinforcement is substituted with a fiber glass reinforcement. In fact, despite the brittleness of the fiber glass rebars, the structural behavior exhibited not only a significant strength but also adequate post peak displacements.

3. Flexural tests showed spreading of cracks in the intrados surface

4. On the base of the obtained results, fiber glass rebars can substitute the steel reinforcement in this kind of application.

Referring to the problems of durability of these structures, we are studying the use of GFRP as **skin reinforcement**

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