Luigia Binda Memorial Workshop on
NDT and Safety Assessment of RC and Masonry Structures
ICACMS 2017 – Chennai Sep 8, 2017 – IIT CLT

Session 3

Development of Methodologies and Combination of Tests

Friday, 8 September 2017 - IIT MADRAS Central Lecture Theatre
Chair: Arun Menon

NDT TESTS ON AN EXISTING R.C. BRIDGE: HOW TO MANAGE DIFFERENT TEST CAMPAIGNS

Samuele Biondi

INGEO Department, University of Chieti-Pescara, Italy

Speaker details

Prof. Samuele Biondi
Associate Professor in Structural Engineering
e.mail: s.biondi@unich.it – skype s.biondi62

Co-authors details

Dr. Nicola Cataldo – Architect Graduate in Structural Engineering
e.mail: nico984@libero.it
Dr. Luigia Zuccarino - Ph.D. in Structural Engineering
e.mail: l.zuccarino@unich.it

University details

Engineering and Geology Department – Ud'A University of Chieti-Pescara
viale Pindaro n. 42 65127 Pescara (Pe) Italy
ph. +39.085.4537.256 - .261 (secr) - .255 (fax)

Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. Previous structural analyses
4. Management of different test campaigns
5. Actual structural analysis
6. Actual experimental analysis
7. Conclusions

The Dragonara Bridge service life

An isostatic (Gerber scheme) prestressed r.c. bridge is considered; this scheme is quite usual for simple bridge

The bridge was built in 1970 as an element of a series of similar bridges; it overpasses the Chieti-Pescara Highway in Dragonara (Chieti Municipality)

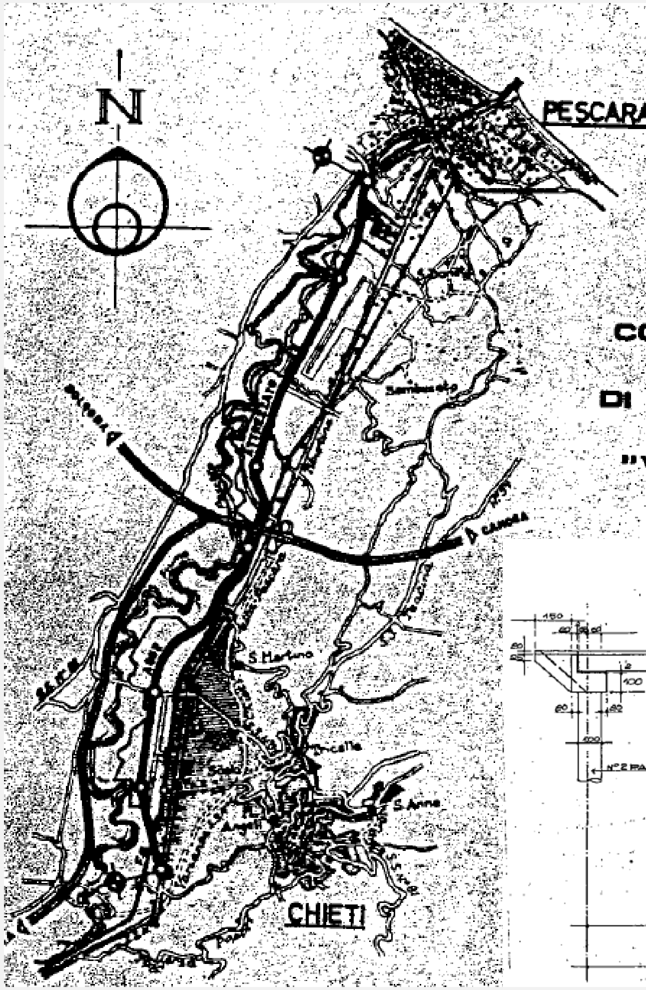
During his service life it suffered poor structural maintenance and it shown transverse and longitudinal displacements that were considered unacceptable for its use

Four series of different structural tests (both non destructive and partially destructive [concrete cores], both static and dynamical load) were carried out

The Dragonara Bridge service life

Nowadays situation from Google Earth

The Dragonara Bridge service life



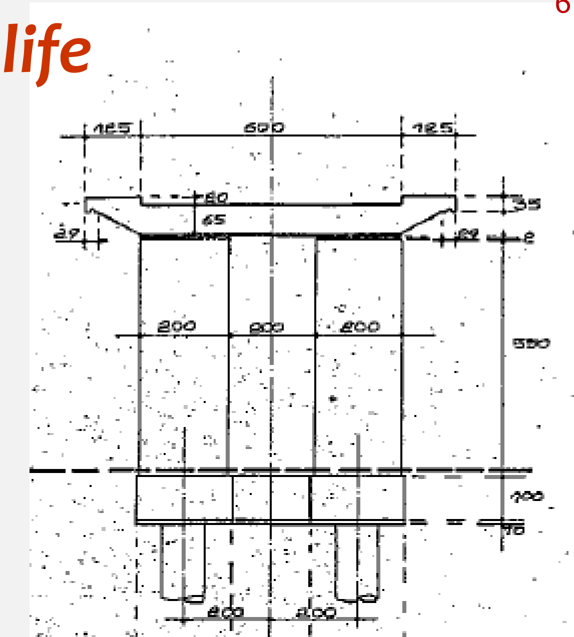
symmetrical configuration

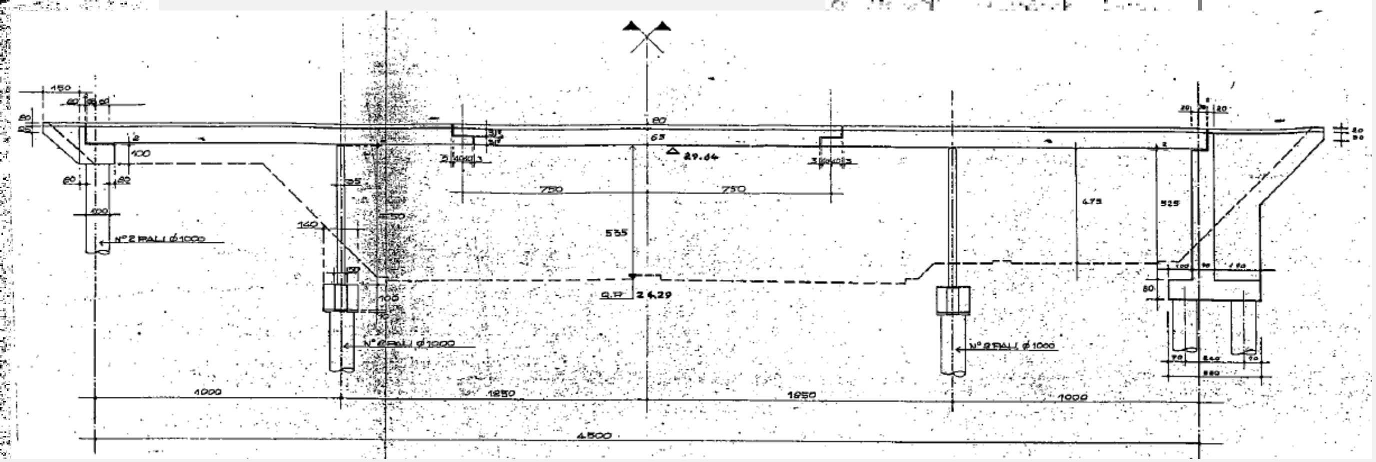
45 m total length

10 m lateral spans

25 m central bay

15 m Gerber's connections distance





The Dragonara Bridge service life

Results of these tests are evaluated independently each other by different Authorities and regardless:

- **real structural scheme**
- **viscous behaviour in concrete**

So wrong conclusions were carried out:

- **in 2012 the bridge was assumed near collapse**
- **traffic over the bridge was forbidden (it serves ONE family)**
- **traffic under the bridge was allowed (it serves thousands people every day)**

In 2013 the Local Authority (Chieti Municipality) ordered a new series of static tests and structural analyses

The Dragonara Bridge service life

Situation in 2012:
lack of maintenance
traffic restricted for the single family that has to use the infrastructure

The Dragonara Bridge service life






no surface and binder bituminous courses on concrete slab
concrete degradation in correspondence of Gerber's connections elements

The Dragonara Bridge service life

From structural point of view, the Dragonara Bridge service life was witness of:

- **seismic classification of Chieti territory (in 1983)**
- **seismic activity in Central Italy until today**
- **different Code approach in terms of load and structural requests for bridges**

The Dragonara Bridge service life experienced too:

- **economical collapse of public-private authority that built it**
- **overlapping of different jurisdictions**
- **necessity to limit the expense for the new tests**

The Dragonara Bridge service life

seismic activity during Dragonara Bridge service life

Presentation Index

1. The Dragonara Bridge service life
2. **Previous experimental activities**
3. Previous structural analyses
4. Management of different test campaigns
5. Actual structural analysis
6. Actual experimental analysis
7. Conclusions

Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- Second experimental series (March 2003)
- Third experimental series (July 2012)
- Fourth experimental series (August 2013)

In green the activity carried out by the Authors

Previous experimental activities

Previous experimental activities are the following:

- **First experimental series (November 1999)**
- Second experimental series (March 2003)
- Third experimental series (July 2012)
- Fourth experimental series (August 2013)

8 NDT tests (Sclerometer & UPV – SonReb)

9 Concrete cores for Carbonation and Compressive tests

2 Load tests by means mobile load (2 phases, 2 trucks every test):

- 1st symmetrical load test in central bay (interrupted after 1st phase)
- 2nd unsymmetrical load test in a lateral bay (interrupted after 1st phase)

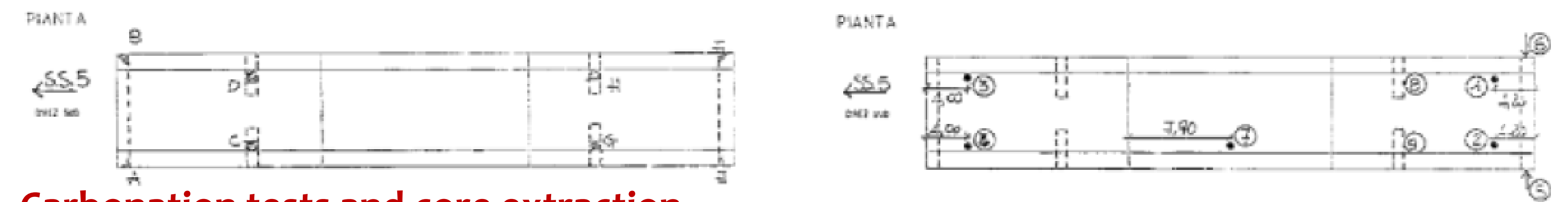
2 Dynamical tests (4 accelerometers – 3 configurations):

- 1st before load tests
- 2nd after load tests

Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)



Carbonation tests and core extraction

NDT tests

Load tests

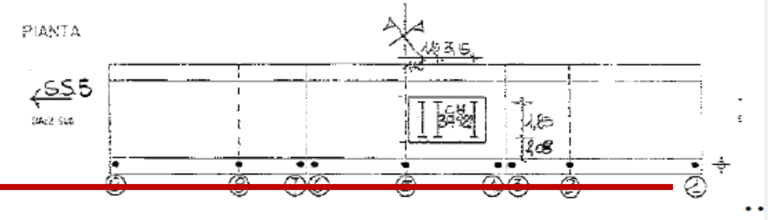
Previous experimental activities

Previous experimental activities are the following:

- **First experimental series (November 1999)**

PROVA N.1 - CAMPATA CENTRALE
Spostamenti verticali rilevati

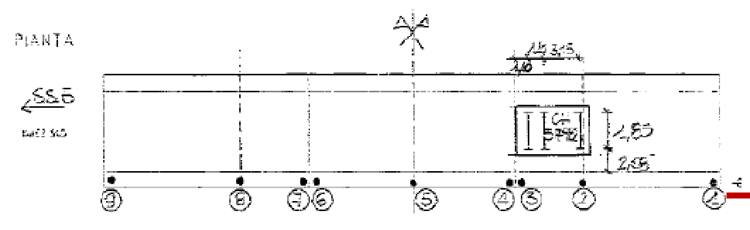
Ora	Carico Fase	Pos.1 (mm)	Pos.2 (mm)	Pos.3 (mm)	Pos.4 (mm)	Pos.5 (mm)	Pos.6 (mm)	Pos.7 (mm)	Pos.8 (mm)	Pos.9 (mm)
05-dic-99										
9.10	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.25	Fase 1	-2.35	0.03	3.82	4.20	5.40	1.72	1.35	0.06	0.12
9.35	"	-2.50	0.05	3.92	4.31	5.72	1.72	1.41	0.07	0.13
9.45	0	-0.11	0.01	0.17	0.15	0.11	-0.06	-0.11	0.03	0.08
9.55	0	-0.10	0.00	0.14	0.13	0.10	-0.05	-0.07	0.03	0.04



PROVA N.2 - SBALZO LATO NORD
Spostamenti verticali rilevati

Due to negative vertical displacements in position 1 these texts were interrupted

Ora	Carico Fase	Pos.1 (mm)	Pos.2 (mm)	Pos.3 (mm)	Pos.4 (mm)	Pos.5 (mm)	Pos.6 (mm)	Pos.7 (mm)	Pos.8 (mm)	Pos.9 (mm)
05-dic-99										
9.55	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.10	Fase 1	-1.24	0.08	2.06	2.17	1.73	0.39	0.43	-0.08	-0.07
10.20	"	-1.30	0.10	2.09	2.21	1.76	0.41	0.43	-0.06	-0.07
10.28	0	-0.05	0.02	-0.04	-0.05	0.04	0.13	0.19	-0.04	-0.02
10.38	0	-0.03	0.02	0.00	-0.02	0.02	0.10	0.15	-0.02	0.00



Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- **Second experimental series (March 2003)**
- Third experimental series (July 2012)
- Fourth experimental series (August 2013)

3 NDT tests (Sclerometer & UPV – SonReb)

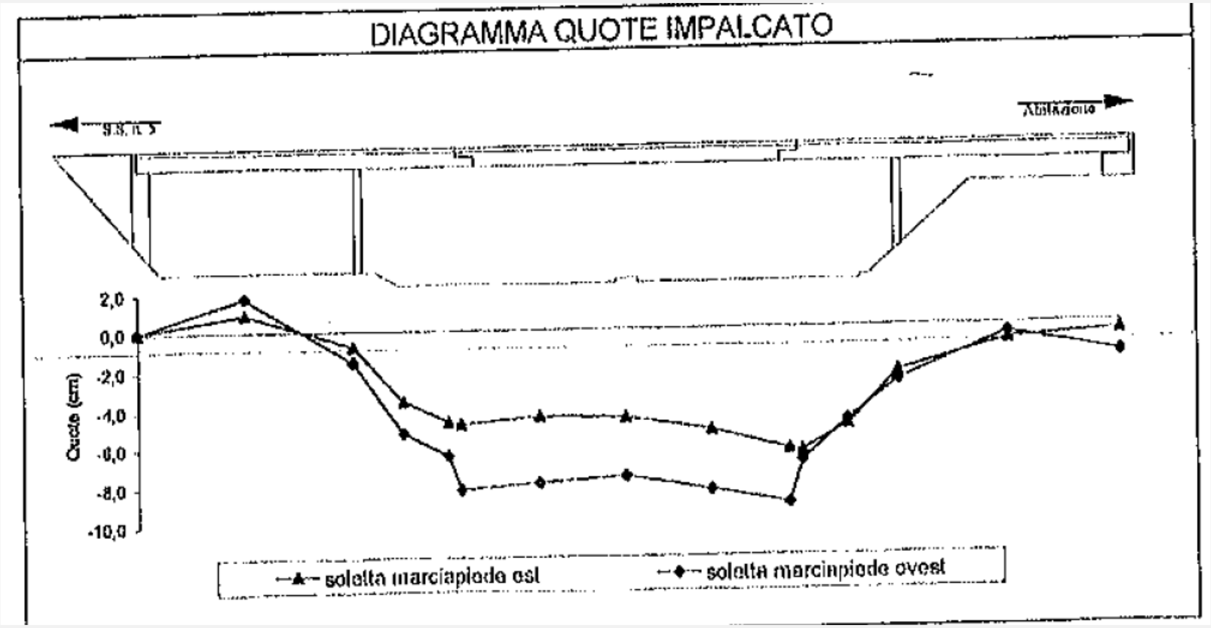
2 Concrete cores for Carbonation (not Compressive) tests

1 High precision topographic leveling

Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- Second experimental series (March 2003)
  - first topographical control of vertical displacements



Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- Second experimental series (March 2003)
- **Third experimental series (July 2012)**
- Fourth experimental series (August 2013)

0 NDT tests (Sclerometer & UPV – SonReb)

1 Concrete cores for Carbonation and Compressive tests

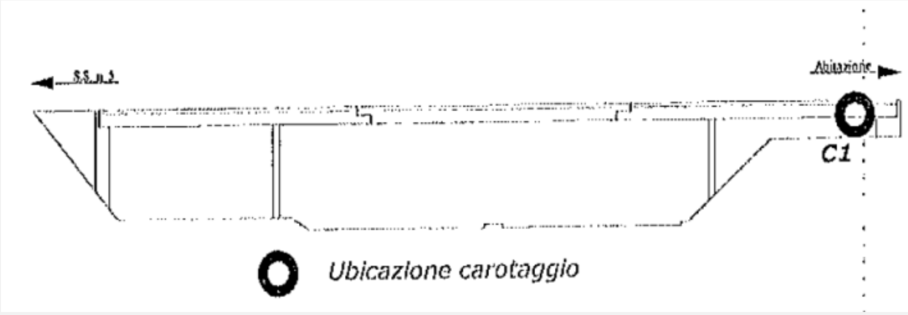
1 High precision topographic leveling

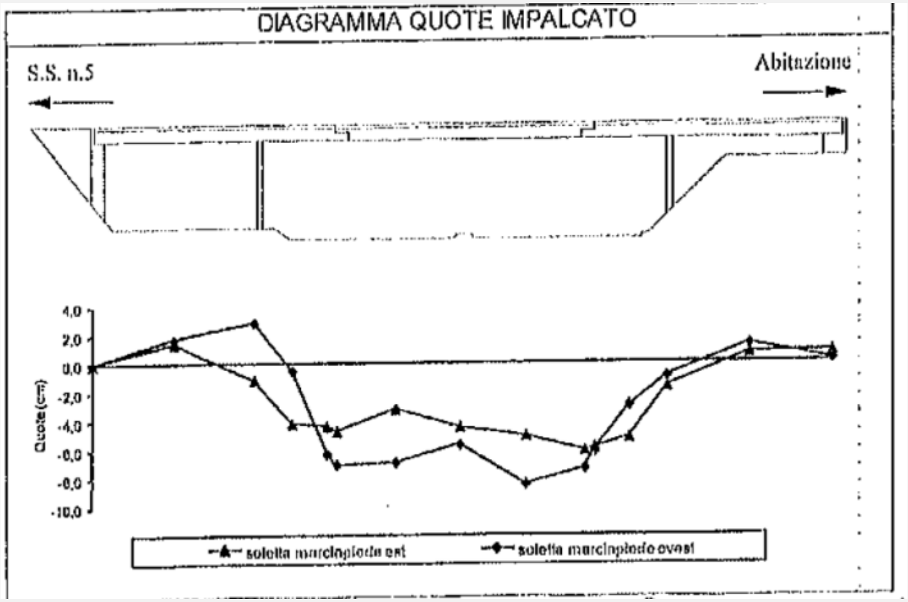
After this poor experimental series they decided that "… structure is near collapse …"

Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- Second experimental series (March 2003)
- Third experimental series (July 2012)
  - Core position on slab
  - Second topographical control of vertical displacements





Previous experimental activities

Previous experimental activities are the following:

- First experimental series (November 1999)
- Second experimental series (March 2003)
- Third experimental series (July 2012)
- **Fourth experimental series (August 2013)**

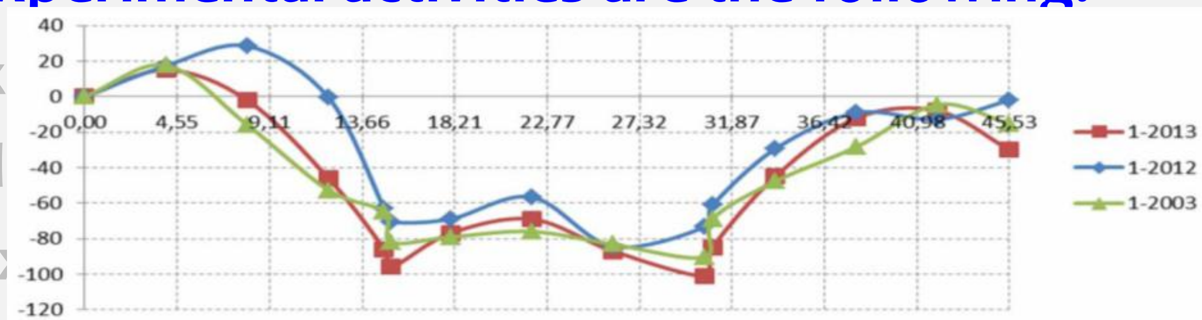
1 Speditive precision topographic leveling in order to control vertical displacement evolution

It is possible to conclude that experimental activities are quite rich but not well organized and not well analyzed

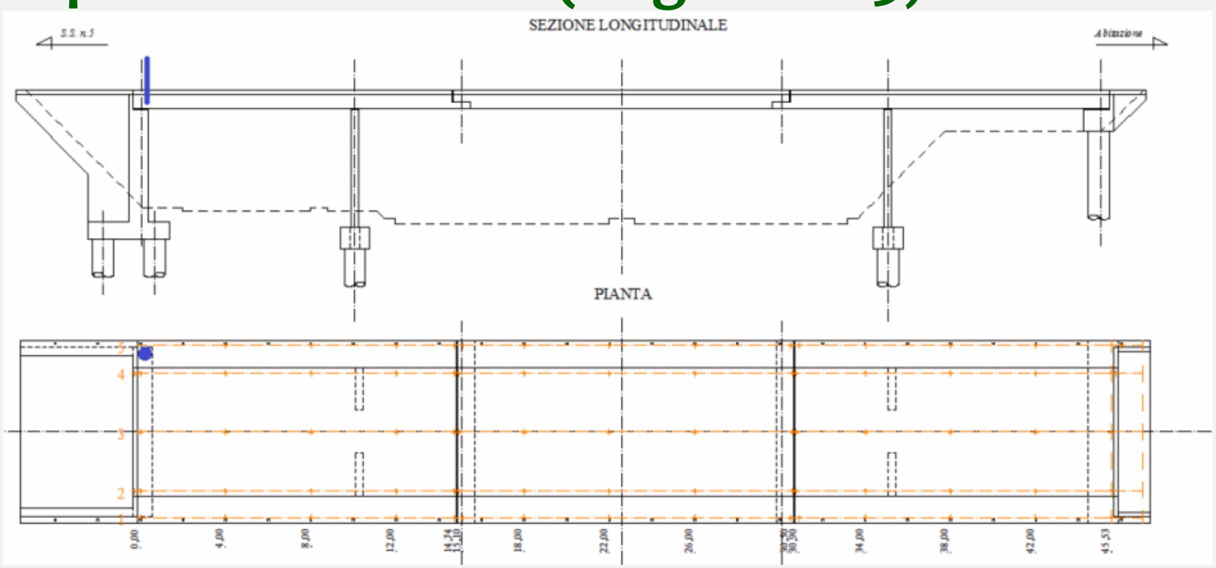
Previous experimental activities

Previous experimental activities are the following:

- First ex
- Second
- Third ex



- **Fourth experimental series (August 2013)**



Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. **Previous structural analyses**
4. Management of different test campaigns
5. Actual structural analysis
6. Actual experimental analysis
7. Conclusions

Previous structural analyses

Previous experimental activities are the following:

- **First structural analysis (May 1999)**
- **Unknown structural analysis (May 1999 – July 2012)**
- **Second structural analysis (July 2012)**
- **Third structural analysis (May 2013)**
- **Fourth structural analysis (November 2013)**

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- Second structural analysis (July 2012)
- Third structural analysis (May 2013)
- Fourth structural analysis (November 2013)

Geometrical and structural survey

- speditive longitudinal deformation evaluation, concrete cover spalling and rebar corrosion mapping, stagnant water and pollution influence

Test campaign proposal (really carried out)

- material characterization, load tests

Local maintenance & restoration work proposal (not carried out)

- concrete cover, corroded rebar, elastomeric bearings, slab waterproofing

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- **Unknown structural analysis (May 1999 – July 2012)**
- Second structural analysis (July 2012)
- Third structural analysis (May 2013)
- Fourth structural analysis (November 2013)

This activity was ordered by Anas (National Road Authority)

- not at disposal but bridge was conserved on duty

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- **Second structural analysis (July 2012)**
- Third structural analysis (May 2013)
- Fourth structural analysis (November 2013)

Comprehensive evaluation of 1st, 2nd and 3rd experimental activities

Structural Certificate of Acceptance refused

- no possibility of maintenance and restoring was detected
- complete demolition of bridge has to be ordered

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- **Second structural analysis (July 2012)**
- Third structural analysis (May 2013)
- Fourth structural analysis (November 2013)

SI CERTIFICA
STRUCTURAL CERTIFICATE
che il Cavalcavia n.5 del Raccordo Autostradale Chieti – Pescara al km 8+000
the No. 5 Bridge of Chieti – Pescara Highway progressive km 8+00
Località Dragonara Chieti Scalo
in Dragonara – Chieti Scalo
NON E' COLLAUDABILE E NON E' STATICAMENTE IDONEO
IS NOT STRUCTURALLY SAFE AND IS NOT ACCEPTABLE

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- Second structural analysis (July 2012)
- **Third structural analysis (May 2013)**
- Fourth structural analysis (November 2013)

Refusing of Structural Certificate of Acceptance confirmed

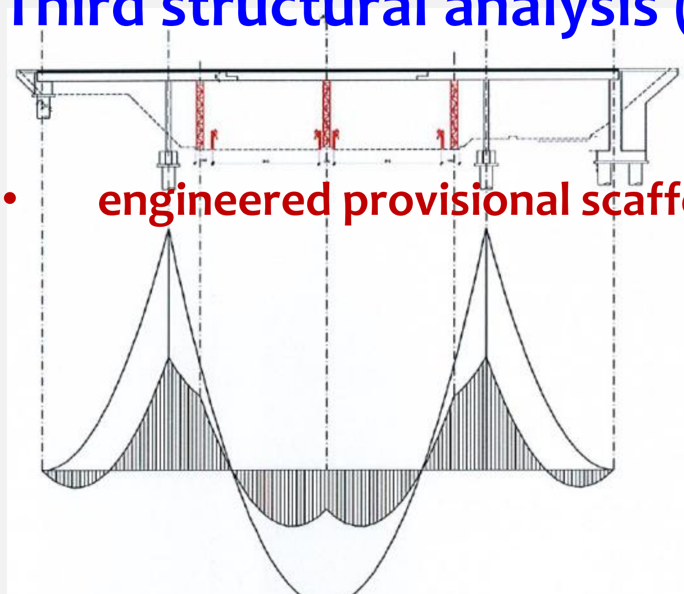
Four different proposals:

- complete demolition
- engineered provisional scaffolding for 2 years operative life
- structural improvement for both substructure (abutment and piers) and superstructure (prestressed r.c. deck)
- substitution of prestressed superstructure with steel girders and deck

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- Second structural analysis (July 2012)
- **Third structural analysis (May 2013)**
    - engineered provisional scaffolding for 2 years operative life



Demolizione totale del manufatto:

	Costo stimato (EURO)	Spese tecniche (EURO)	Tempistica progettazione (gg)	Tempistica realizzazione (gg)
Demolizione totale	130.000,00	30.000,00	20	40
Demolizione del solo impalcato	100.000,00	30.000,00	20	20

Messa in sicurezza provvisoria

	Costo stimato (EURO)	Spese tecniche (EURO)	Tempistica progettazione (gg)	Tempistica realizzazione (gg)
Consolidamento provvisorio con tralicci	70.000,00	30.000,00	30	40

Progetto di consolidamento

	Costo stimato (EURO)	Spese tecniche (EURO)	Tempistica progettazione (gg)	Tempistica realizzazione (gg)
Sostituzione impalcato e consolidamento	550.000,00	45.000,00	60	120

Progetto di demolizione e ricostruzione

	Costo stimato (EURO)	Spese tecniche (EURO)	Tempistica progettazione (gg)	Tempistica realizzazione (gg)
Sostituzione totale	700.000,00	60.000,00	60	180

	Costo stimato (EURO)	Spese tecniche (EURO)	Tempistica progettazione (gg)	Tempistica realizzazione (gg)
Sostituzione con singola carreggiata	350.000,00	60.000,00	50	150

Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- Second structural analysis (July 2012)
- Third structural analysis (May 2013)
- **Fourth structural analysis (November 2013)**

Viscoelastic structural modeling, both static and dynamical FEM analysis, material stresses controlling

Refusing of Structural Certificate of Acceptance NOT confirmed

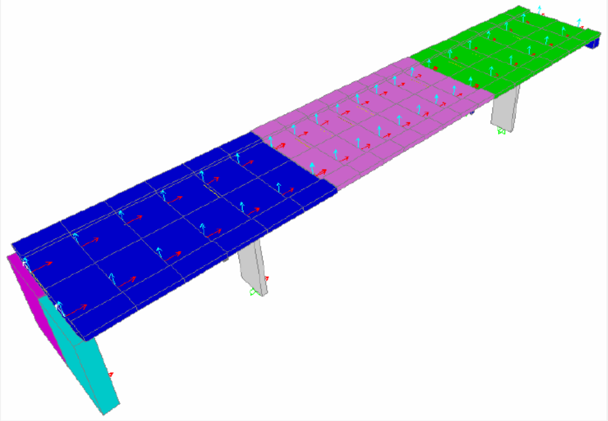
Test activity proposals

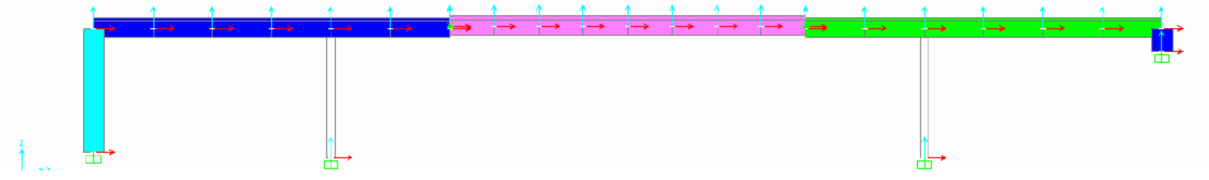
- terrestrial laser scanner surveys
- two phases load test (progressive local loads [no trucks but concrete blocks] supported by high precision topographic leveling and angle measuring)

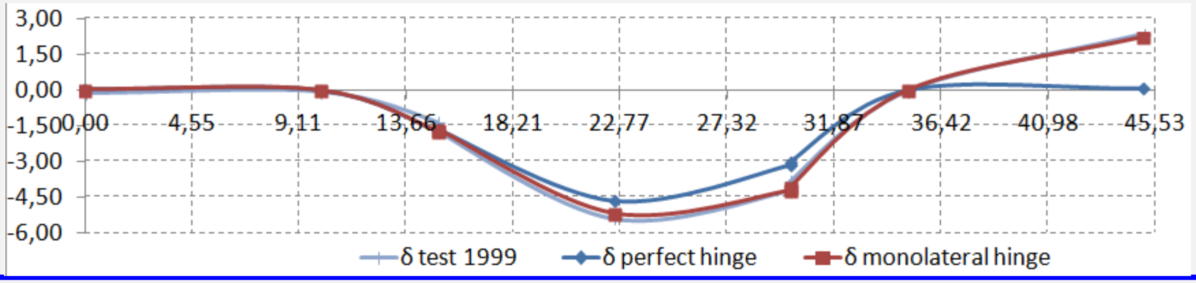
Previous structural analyses

Previous experimental activities are the following:

- First structural analysis (May 1999)
- Unknown structural analysis (May 1999 – July 2012)
- Second structural analysis (July 2012)
- Third structural analysis (May 2013)
- **Fourth structural analysis (November 2013)**







Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. Previous structural analyses
4. **Management of different test campaigns**
5. Actual structural analysis
6. Actual experimental analysis
7. Conclusions

Management of different test campaigns

What they disregarding in terms of structural analysis in different approaches?

- **viscoelastic behaviour of concrete in relation to casting and loading ages**
- **real structural scheme in correspondence of Gerber's connections (elastomeric bearings are monolateral joints and not perfect hinges i.e. negative vertical displacements)**
- **possibility to repeat a progressive load test in order to control real elastic structural behavior**
- **possibility to carried out a system identification via an ambient vibration test approach**

Management of different test campaigns

What we have now in terms of test data for different ages?

- **compressive concrete strength via NDT**
- **carbonation depth evolution**
- **core concrete strength**
- **static self-weight displacements**
- **static load test displacements**
- **dynamical characteristics (at a single age in terms of 1st mode frequency)**

From this point forward every activity was carried out by Authors

Management of different test campaigns

What we have as a common parameter arising from both test results and structural analysis?

If we assume, as we assumed, that the bridge isn't near collapse the concrete elastic modulus E_c is this parameter!

In fact:

- **it was determined as dynamical one via UPV tests**
- **it was determined as static one via core compressive tests**
- **it can be estimated by means of:**
  - **self-weight displacements at different ages**
  - **load test displacements**
  - **dynamical frequencies**

Management of different test campaigns

What we have to define as complementary parameters in order to identify the concrete elastic modulus E_c?

Steel tendons characteristics

- by means of original design drawings
- by means of original design quantity surveying

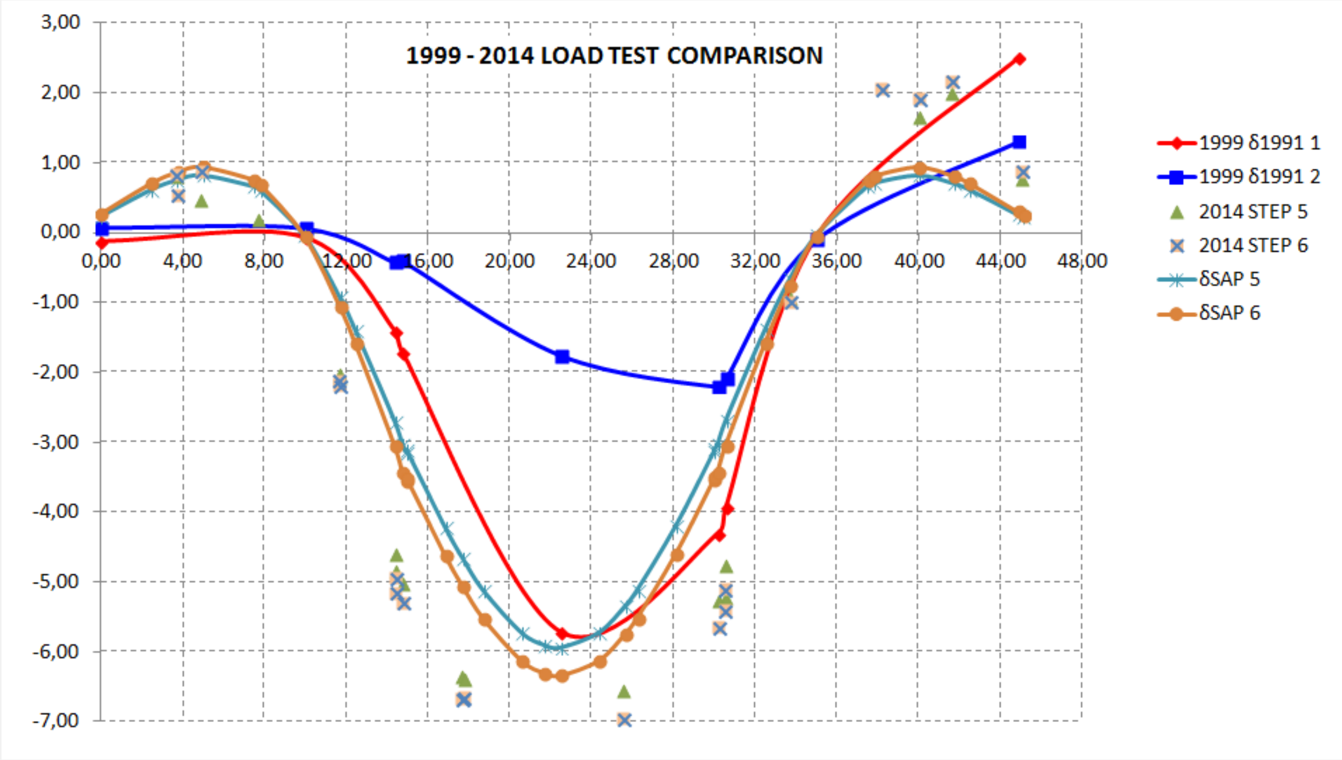
Prestressing loads

- by means of 1970 structural Code provisions
- by means of the engineering practice at that time (allowable stress approach)

Elastomeric bearings characteristics in terms of vertical stiffness

- by means of 1970 product brochure (compressive one)
- by means of tests (extensional one)

Management of different test campaigns



Elastomeric bearings characteristics in terms of vertical stiffness

- by means of 1970 product brochure (compressive one)
- by means of tests (extensional one)

Management of different test campaigns

The concrete elastic modulus E_c is defined as:

$$E_C = E_C(t, \varphi)$$

- t current concrete age
- φ concrete creep coefficient

creep coefficient is defined as (fib Bullettin 55: Model Code 2010):

$$\varphi = \varphi_{RH} \cdot \beta(f_{cm}) \cdot \beta(t_0)$$

- φ_{RH} basic concrete creep coefficient depending relative humidity
- f_{cm} mean compressive strength at the age of 28 days
- t_0 time of load application

Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. Previous structural analyses
4. Management of different test campaigns
5. **Actual structural analysis**
6. Actual experimental analysis
7. Conclusions

Actual structural analysis

Actual structural analysis are, obviously, divided in two phases:

- **before actual experimental tests in order to calibrate them**
- **after actual experimental tests in order to carry out final evaluation of structure safety**

A three-dimensional linear elastic FEM model is used in order to:

- **calibrate E_c as above discussed in relation with:**
  - ❖ **self-weight displacements at different ages**
  - ❖ **load test displacements**
  - ❖ **dynamical frequencies**

According to this FEM model results:

- **NDT results of 2nd text series (March 2003) were disregarded because incoherent with other data**

Actual structural analysis

This decision is crucial in this case-study:

- **an apparently independent parameter (NDT result) is disregarded due to incoherence with a strongly dependent parameter** $E_c = E_c(t, \varphi)$

But you have to note that NDTs estimate not calculate concrete strength i.e. this disregarding is acceptable

According to this FEM model results:

- **NDT results of 2nd text series (March 2003) were disregarded because incoherent with other data**

Actual structural analysis

According to FEM model results:

- elastic stress-strain relationship was defined for lateral slab connection with abutment according to 1999 load tests

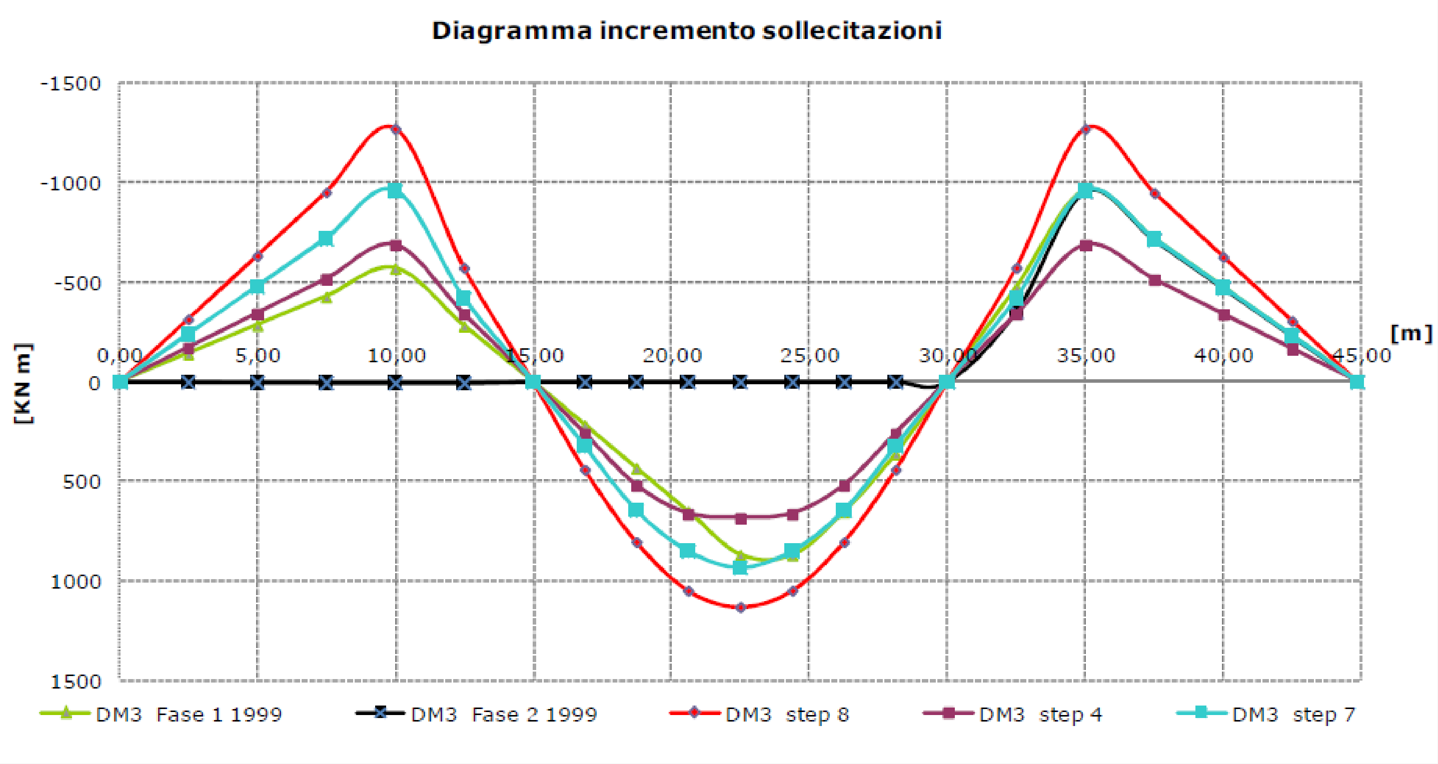
A bi-dimensional simple linear elastic FEM model is now defined in order to:

- define maximum global load assuming that:
  - maximum compressive stress has to be lesser than maximum compressive stress deriving from 1999 load tests
- estimate maximum structural capacity assuming that:
  - maximum stresses have to be a percentage of actual compressive cubic strength R_{ckj}

$$\sigma_c^{max} = -0,38\ R_{ckj} \qquad \sigma_t^{max} = 0,06\ R_{ckj}$$

Actual structural analysis

- **define maximum global load assuming that:**
  - **maximum compressive stress has to be lesser than maximum compressive stress deriving from 1999 load tests**



Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. Previous structural analyses
4. Management of different test campaigns
5. Actual structural analysis
6. **Actual experimental analysis**
7. Conclusions

Actual experimental analysis

A preliminary terrestrial laser scanner activity was carried out

This activity permitted to control:

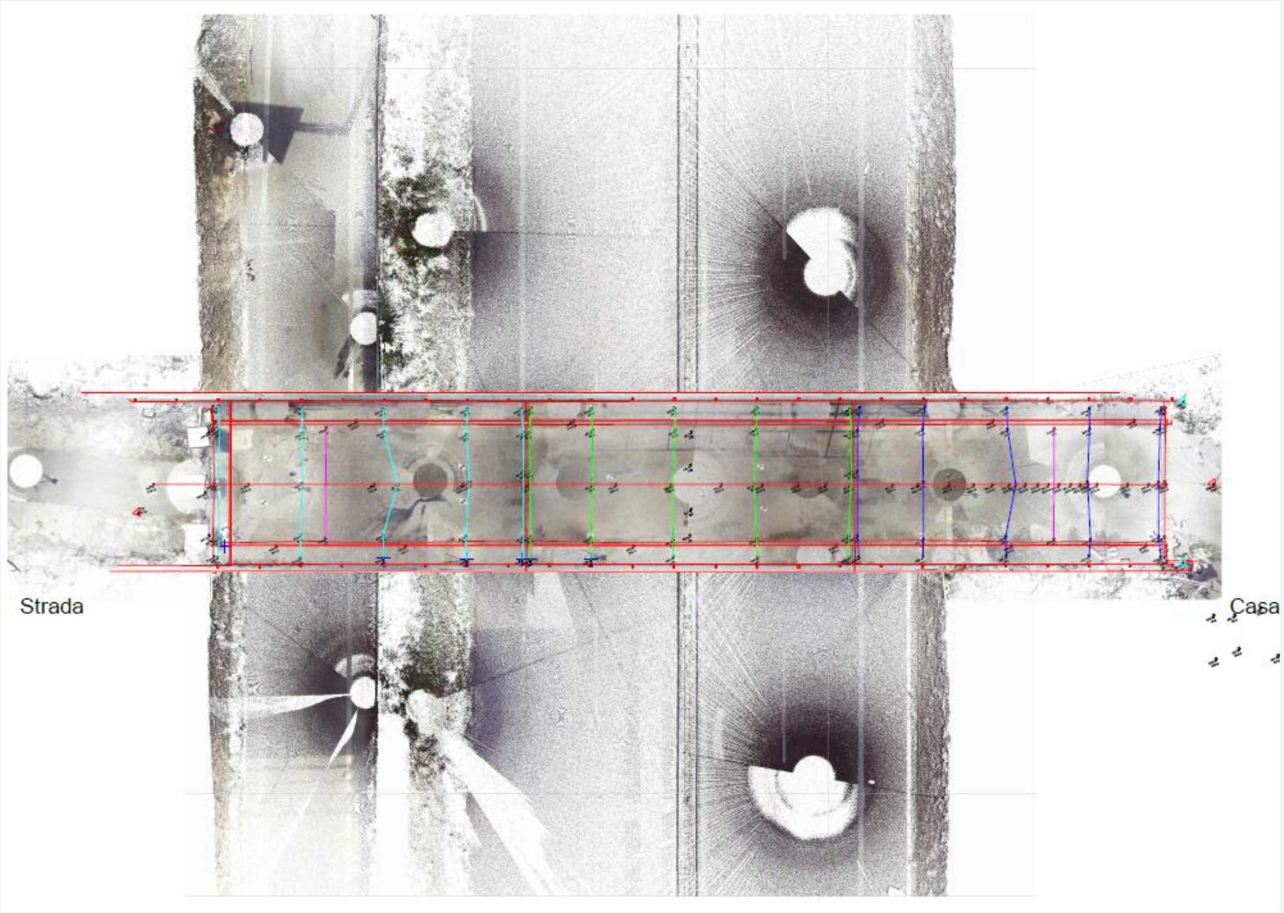
- **geometrical characteristics of the bridge without any impact on under bridge traffic**
- **coherence of vertical displacements between superior and inferior slab faces**
- **three-dimensional linear elastic FEM model correctness**
- **presence of undetected concrete macroscopic defects**

A laser Scanner FARO FOCUS3D 120 was used:

- distance accuracy up to ± 2mm
- range from 0.6m up to 120m
- measurement rate up to 976,000 points/sec

Classical engineering drawings (plan, section, front) are obtained

Actual experimental analysis

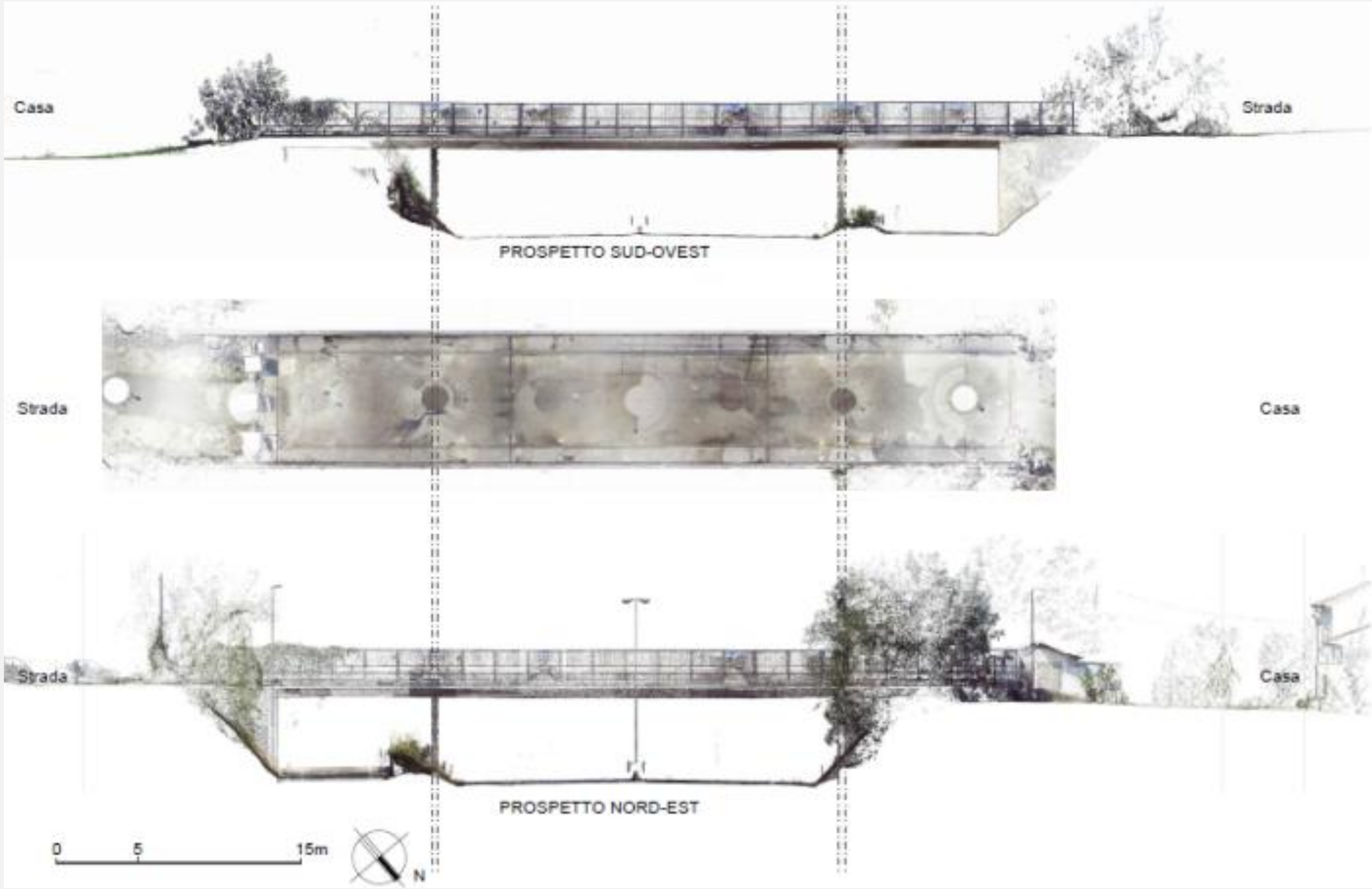


laser scanner plan with georeferenced high precision leveling grid

Actual experimental analysis

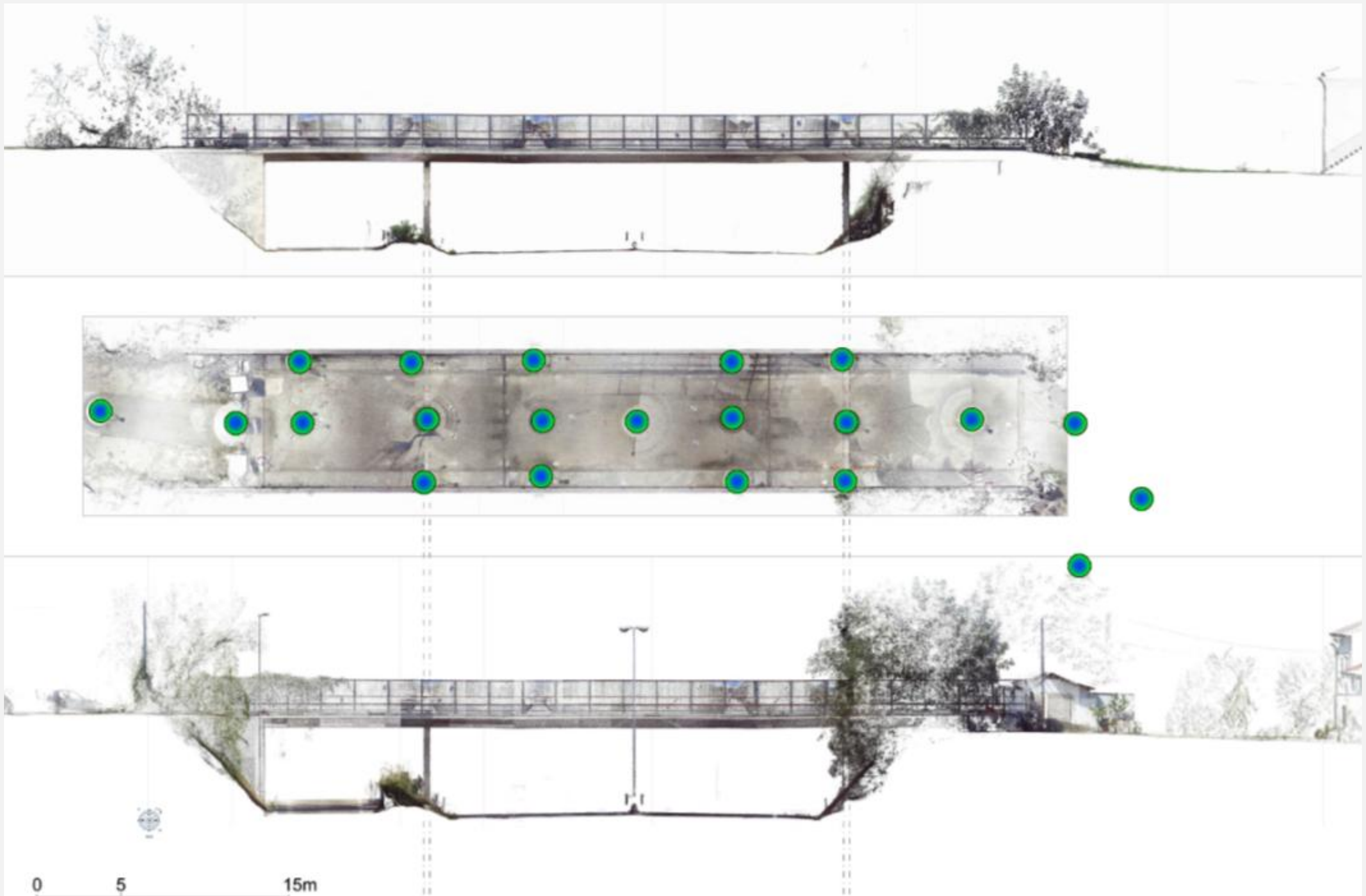
laser scanner sections of slab

Actual experimental analysis



laser scanner plan and fronts: longitudinal displacement can be appreciated

Actual experimental analysis



laser scanner plan and fronts: laser scan stations are pointed out

Actual experimental analysis

laser scanner sections: transversal displacement can be appreciated too

Actual experimental analysis

A preliminary high precision leveling activity, supported by a total station angle measurements activity, was carried out

These activities permitted

- **to define a "level zero" geometry before load test**
- **to estimate expected displacements during load test**
- **to control viscoelastic displacement evolution in comparison with 2013 survey**
- **to obtain a georeferenced grid for the bridge in order to manage future survey activities**

A total station Leica TCR 705 combined with a digital level Leica DNA03 were used:

- **digital level accuracy:** height up to ± 0.3 mm; slope angle ± 10'
- **total station accuracy:** angle measurement up to ± 3"; height up to ± 1.5 mm

Actual experimental analysis

High precision topographic system:
total station for angle measurements
digital level for electronic height measurements

Actual experimental analysis

Total station for angle measurements:
initial activity to measure concrete block position and to define a georeferenced grid of load

Actual experimental analysis


Digital level for electronic height measuring: initial (pre-load) leveling operation

Actual experimental analysis

Actual experimental analysis


Evaluation of influence of the mobile crane weight and activity (it operates by means of a boom tower from the end of which a hook is suspended by wire rope and sheaves)

Actual experimental analysis


Fixed steel stakes on concrete slab: this system is used for high precision leveling height measurements while, due its aim, it is not necessary for total station angle measurements

Actual experimental analysis

18 load steps were carried out

- 8 incremental up to maximum load
- 1 repeated measure at maximum load (the day after)
- 8 decremental up to zero load
- 1 repeated measure at zero load (the day after)

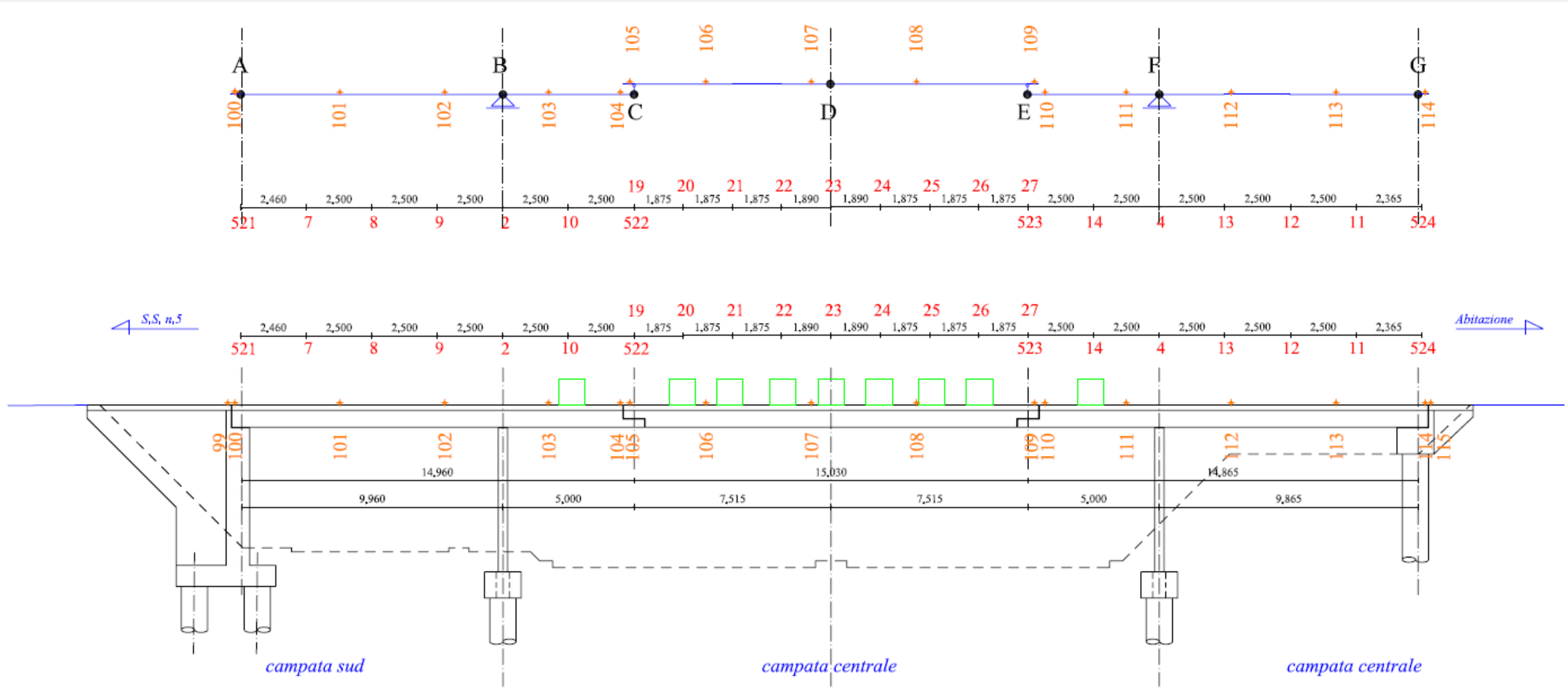
every step had 1 hour of constant load control

at every step high precision leveling was carried out

at every incremental step a comparison with theoretical results was carried out in order to permit the following step

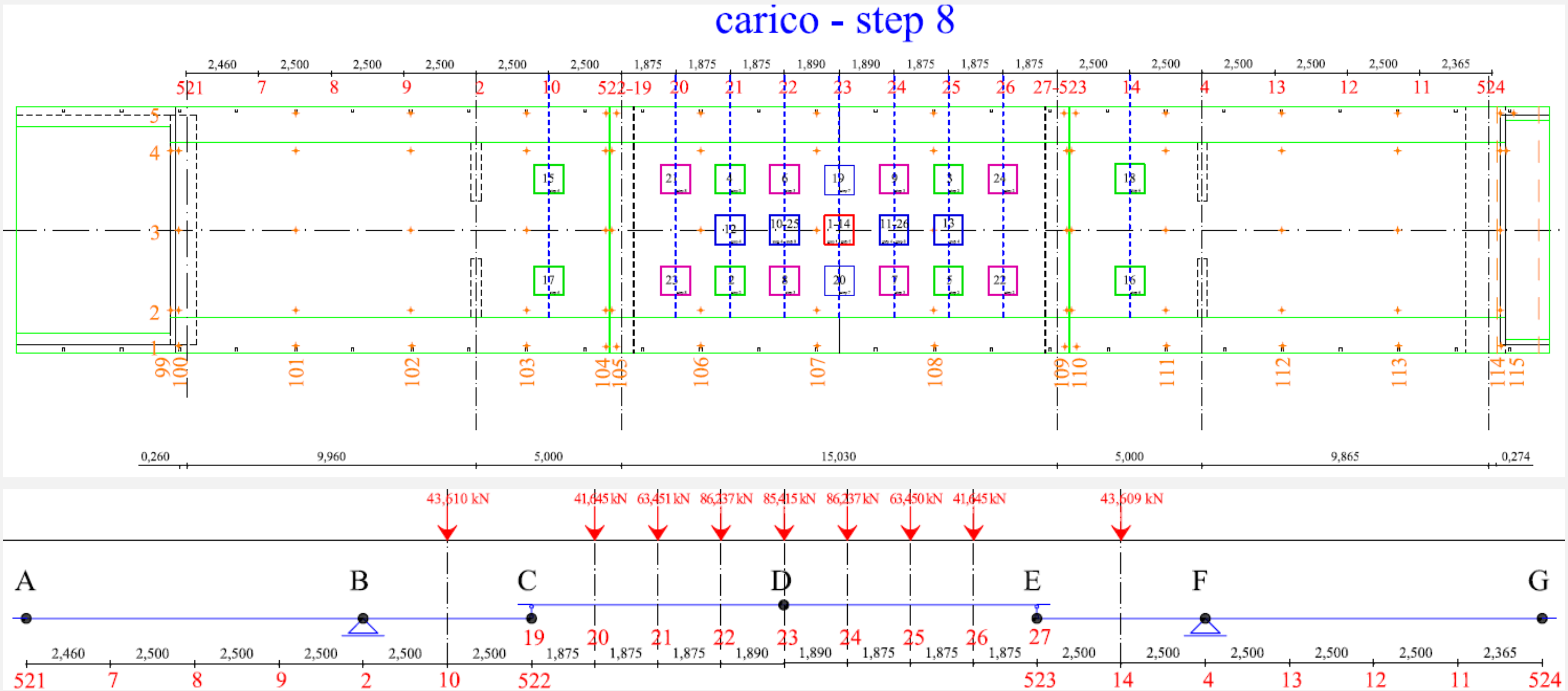
at every decremental step a comparison with theoretical and previous results was carried out

Actual experimental analysis



load test structural scheme: front

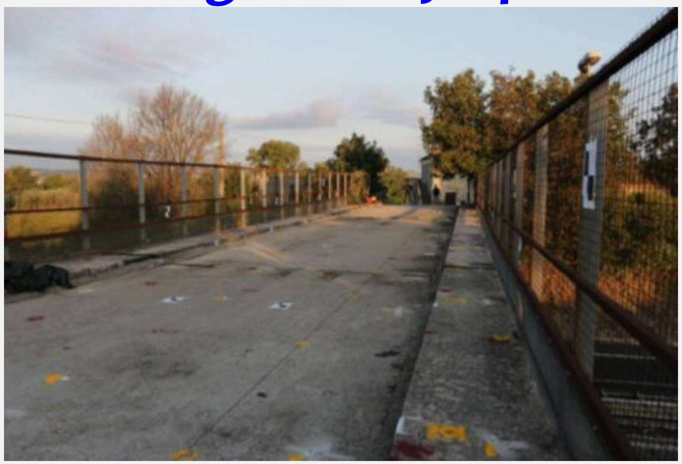
Actual experimental analysis

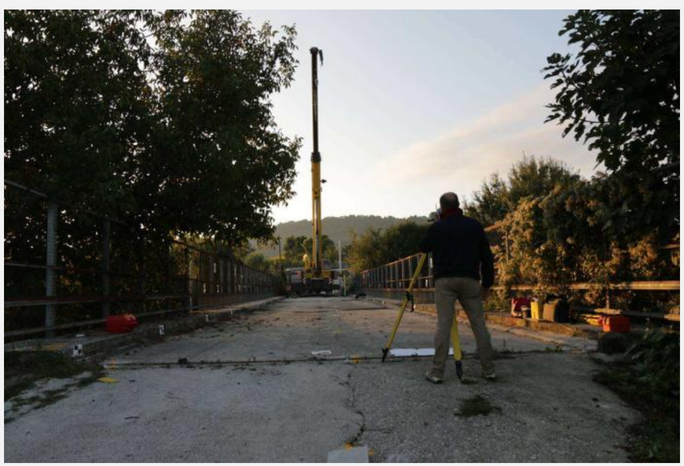


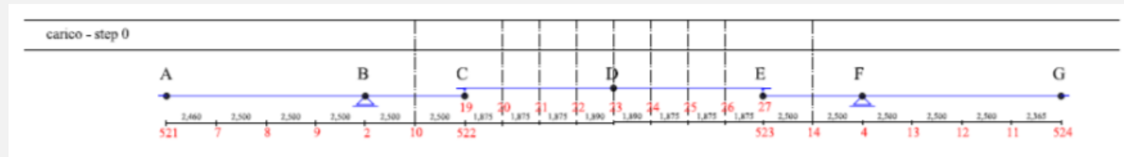
load test structural scheme at maximum load Q_{max} **= 557.37 kN**

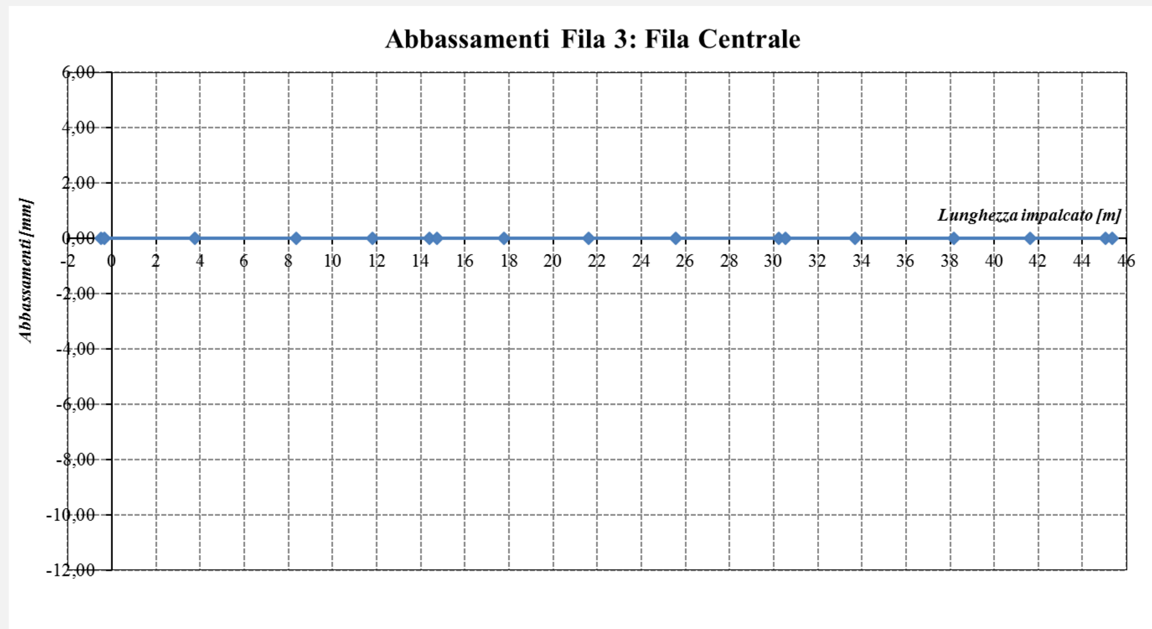
Actual experimental analysis

Starting activity: quite at sun-rise





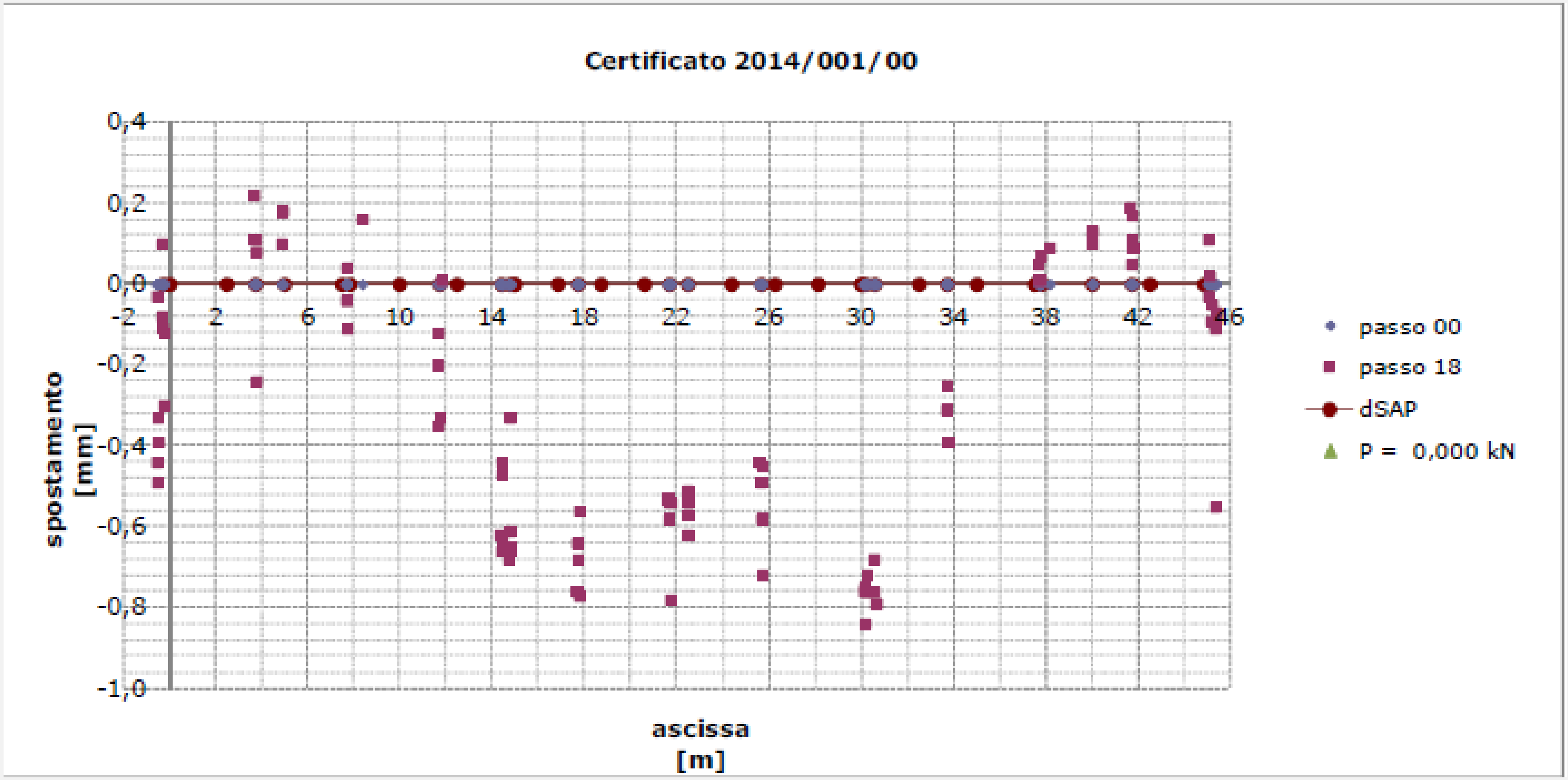




Step 0 – ΔQ_i: 0.00 kN; Q_i: 0.00 kN

Q_{max}: 557.37 kN

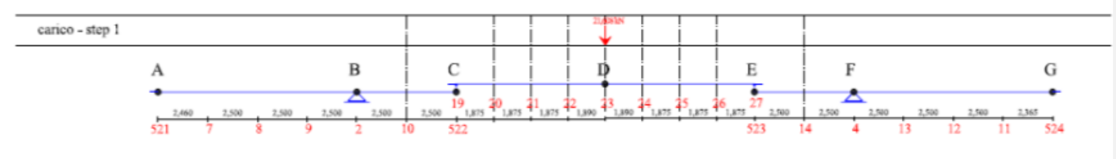
Actual experimental analysis

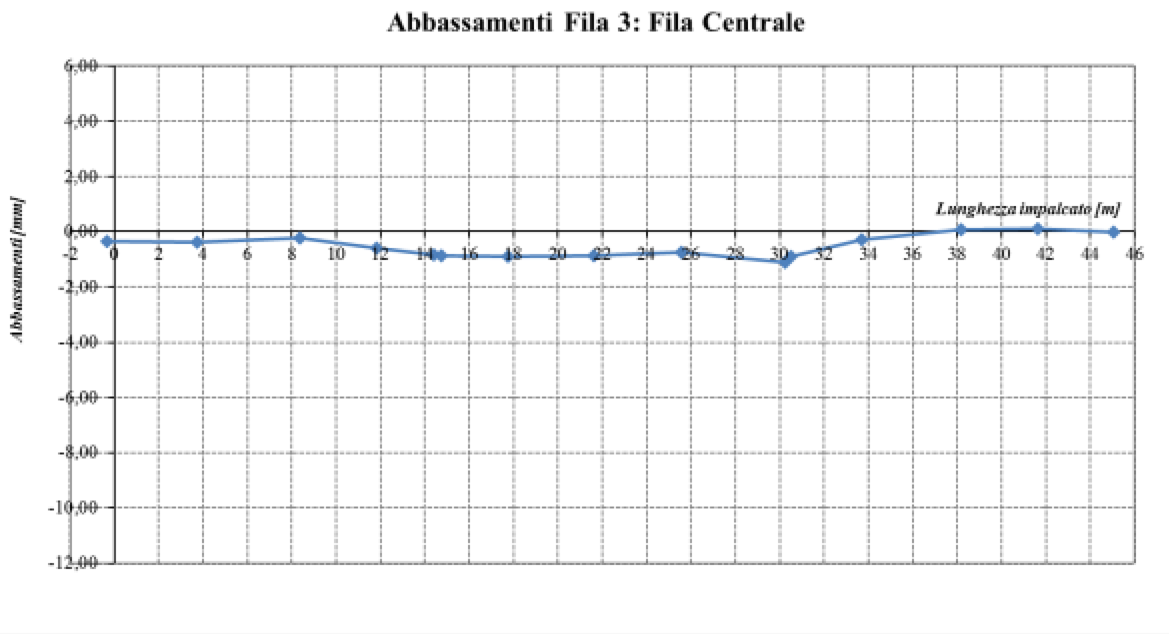


Displacements at load step n. 00 in comparison with theoretical values

Actual experimental analysis

First block posing

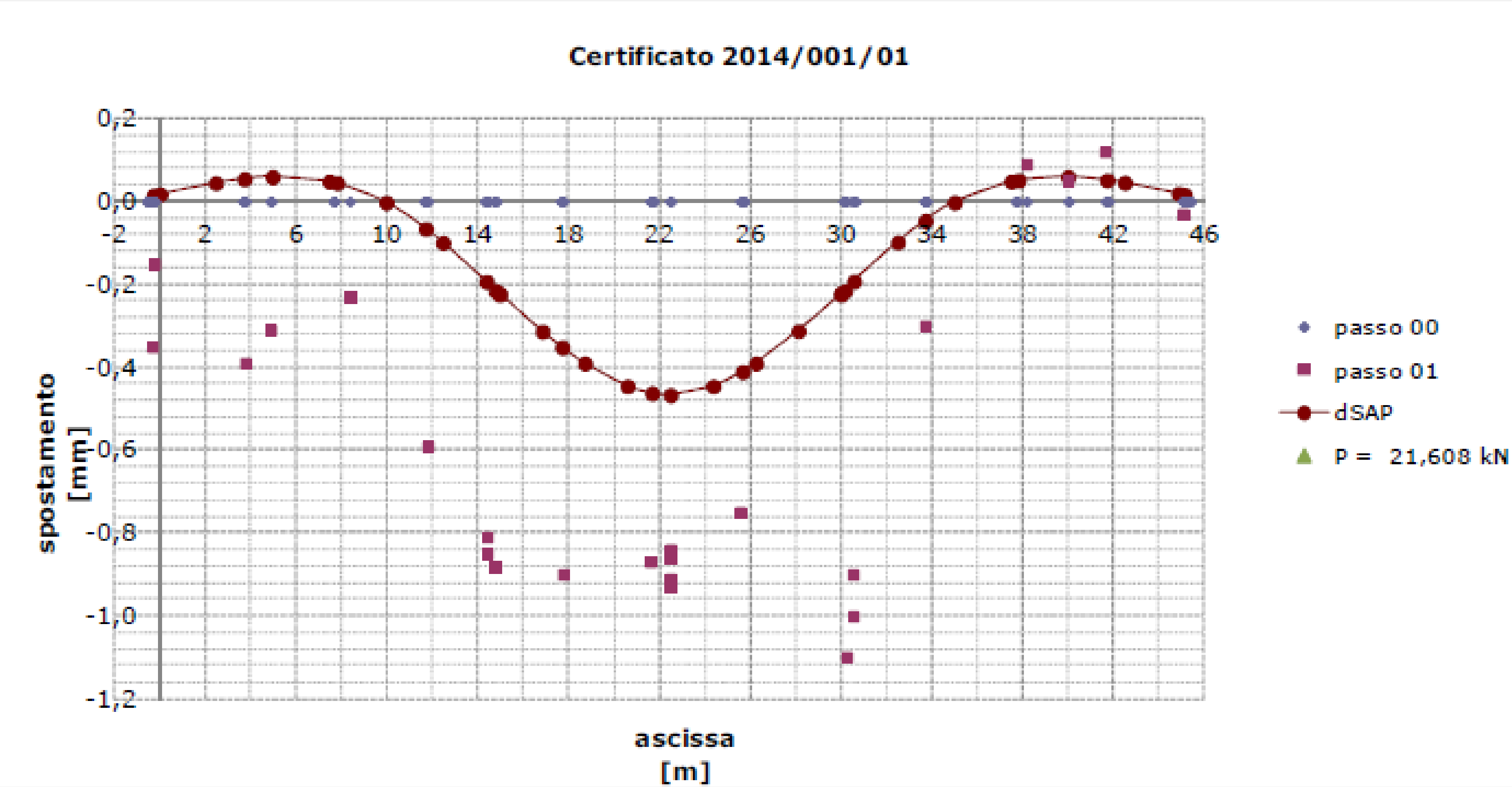




Step 1 – ΔQ_i: 21.61 kN; Q_i: 21.61 kN

Q_{max}: 557.37 kN

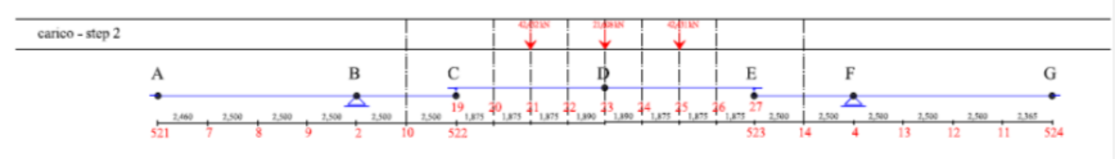
Actual experimental analysis

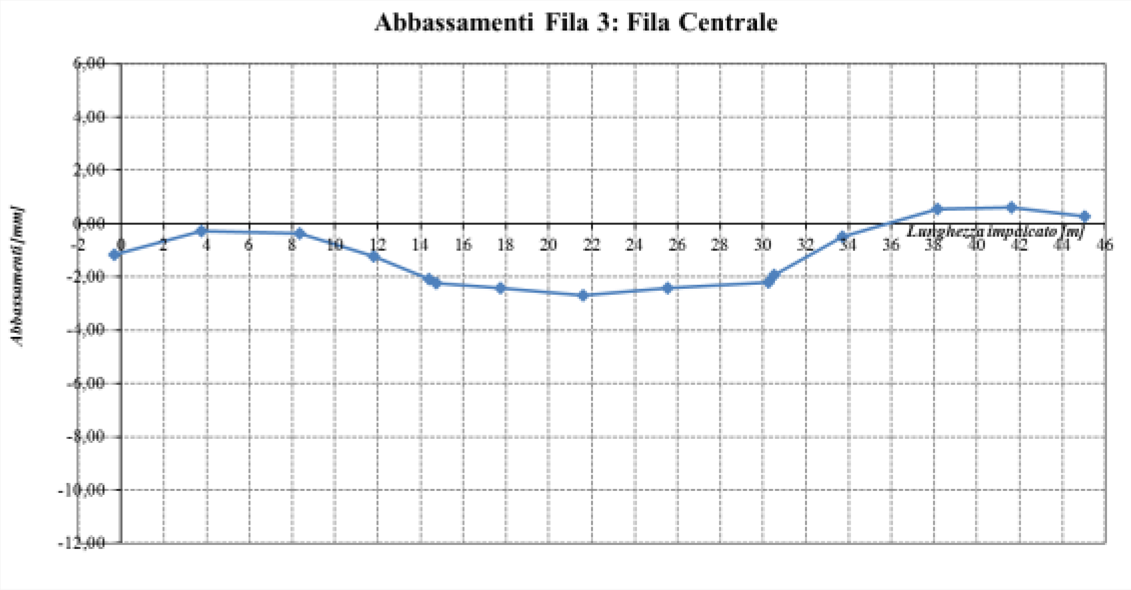


Displacements at load step n. 01 in comparison with theoretical values

Actual experimental analysis

Second blocks posing in symmetrical way

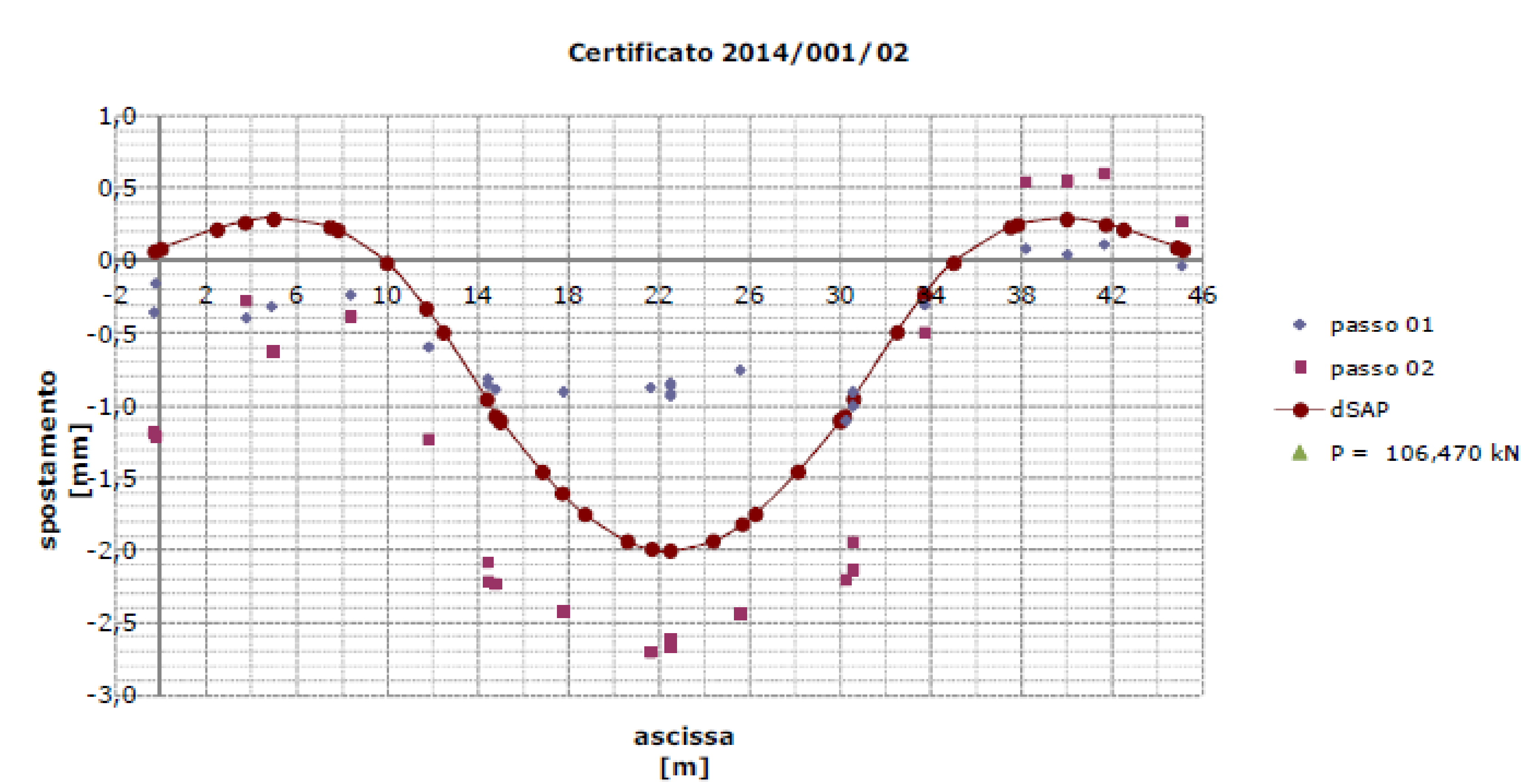




Step 2 – ΔQ_i: 84.86 kN; Q_i: 106.47 kN

Q_{max}: 557.37 kN

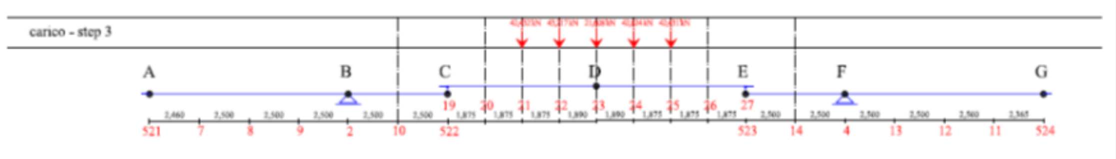
Actual experimental analysis

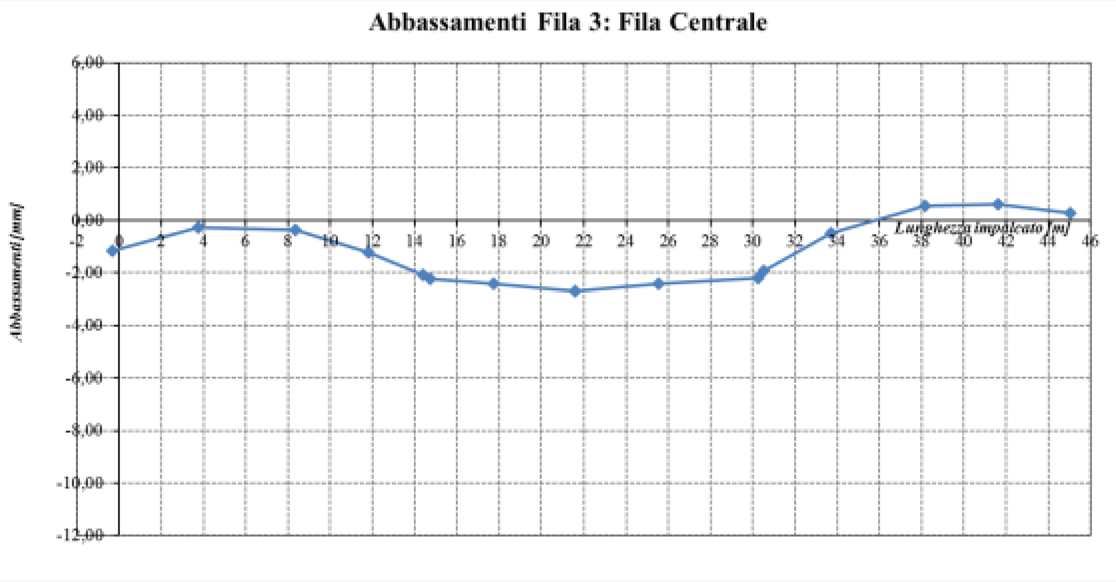


Displacements at load step n. 02 in comparison with theoretical values

Actual experimental analysis

Third blocks posing in symmetrical way

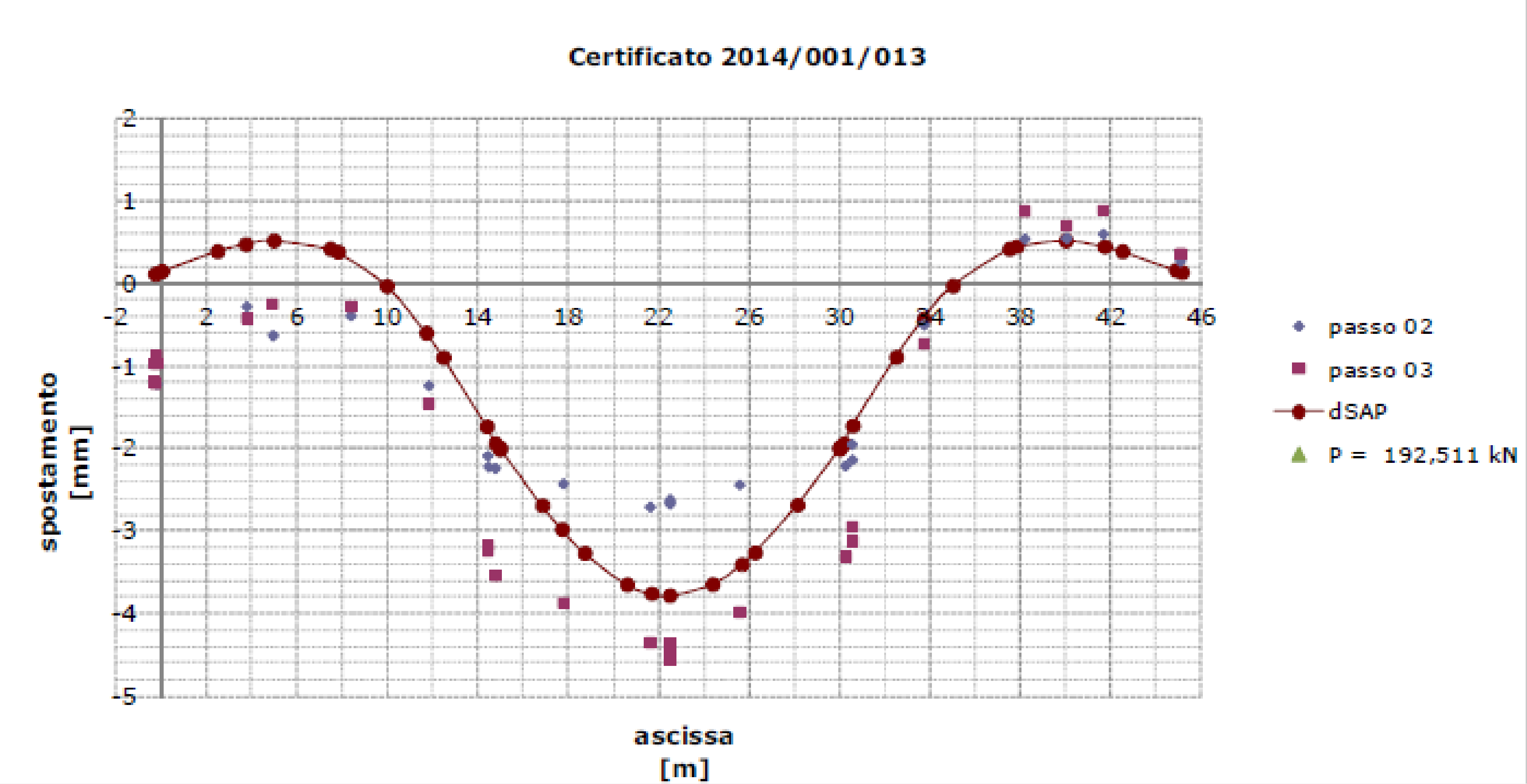




Step 3 – ΔQ_i: 86.04 kN; Q_i: 192.51 kN

Q_{max}: 557.37 kN

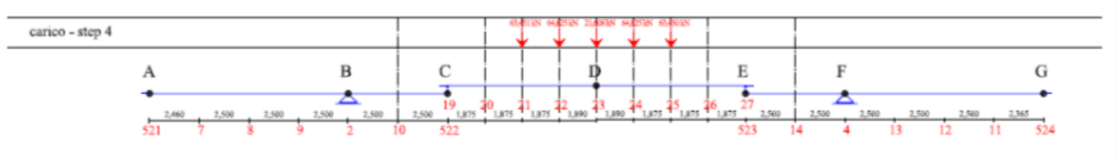
Actual experimental analysis

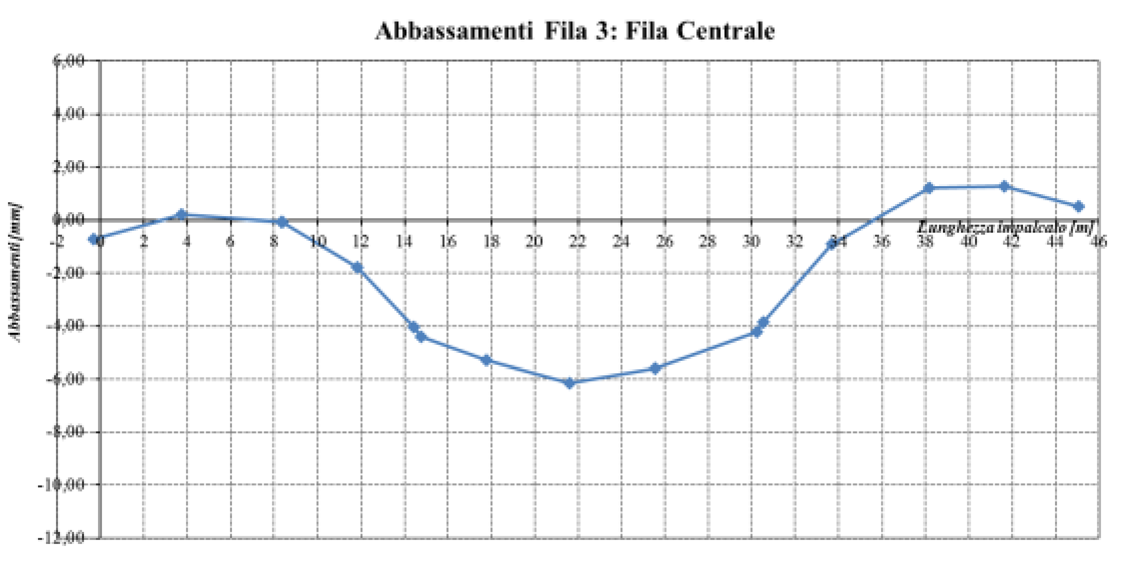


Displacements at load step n. 03 in comparison with theoretical values

Actual experimental analysis

A different response in terms of vertical displacements at the external joint can be noted

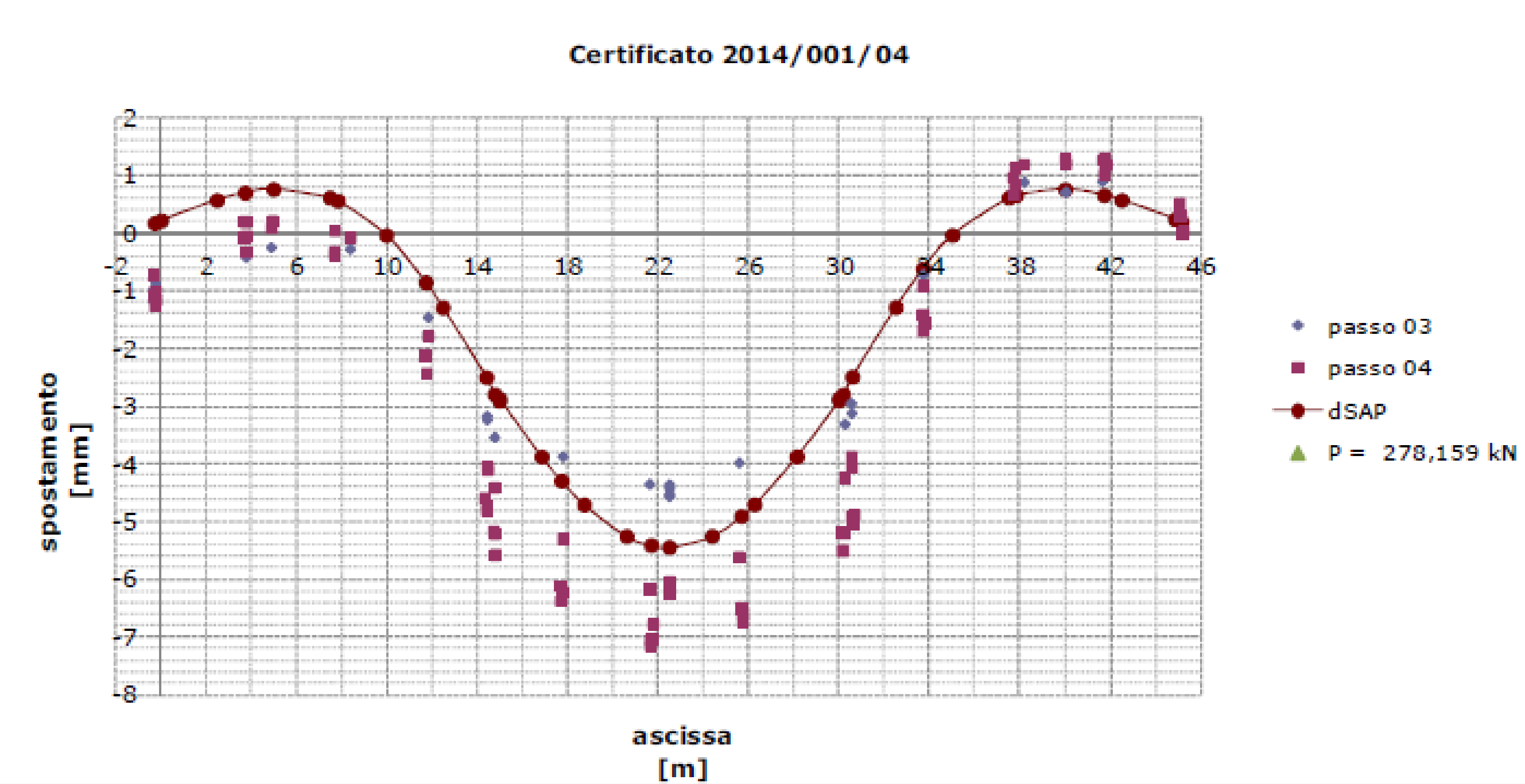




Step 4 – ΔQ_i: 85.65 kN; Q_i: 278.16 kN

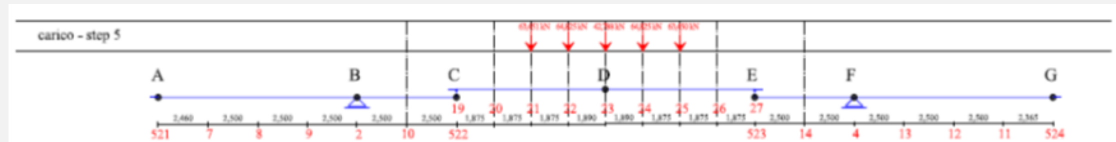
Q_{max}: 557.37 kN

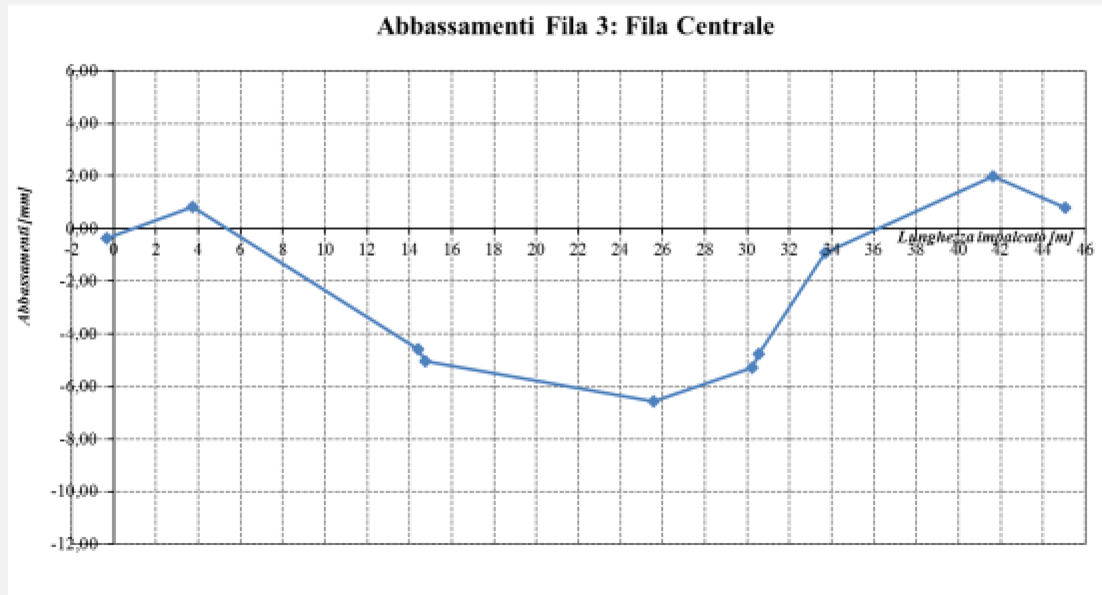
Actual experimental analysis



Displacements at load step n. 04 in comparison with theoretical values

Actual experimental analysis

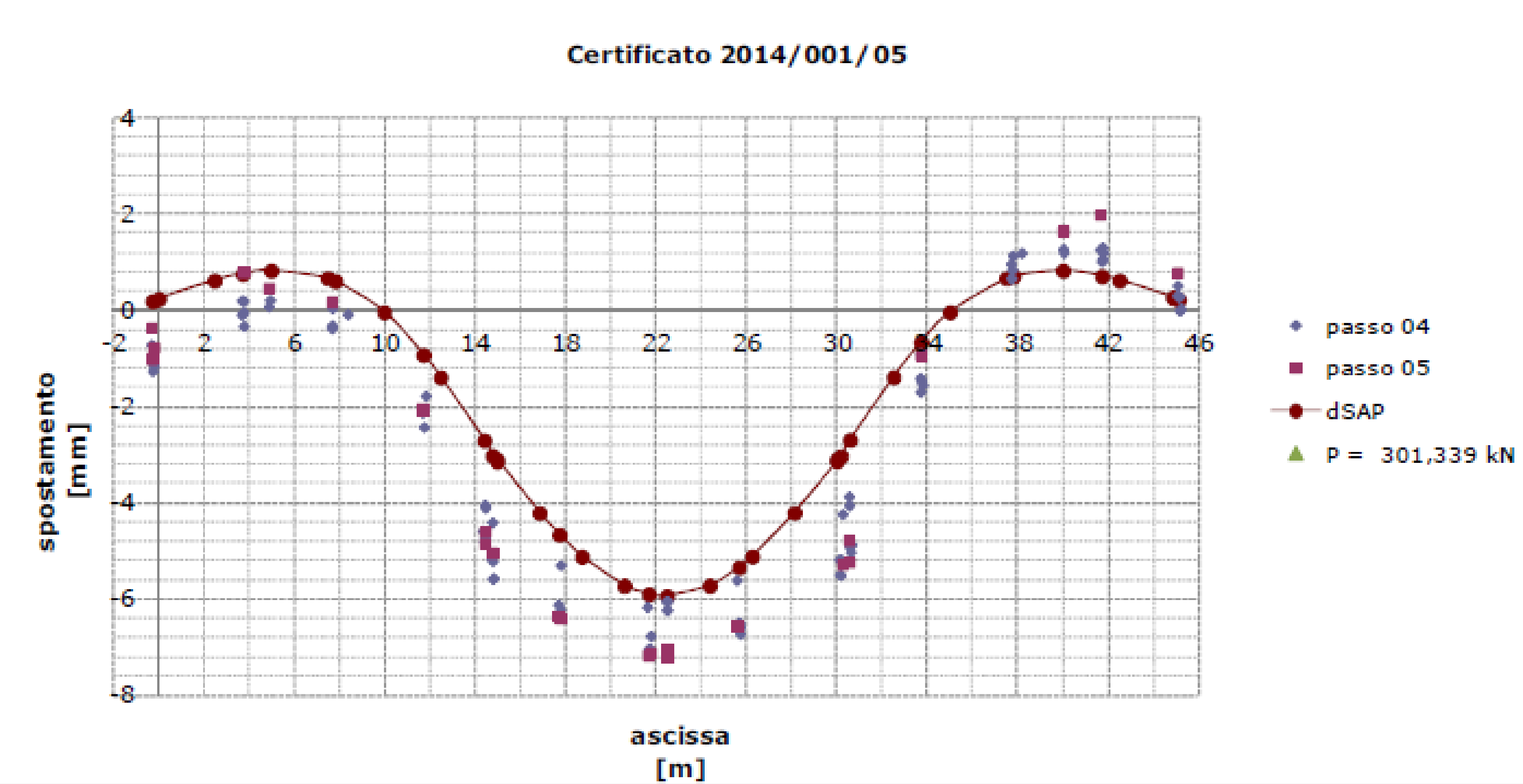




Step 5 – ΔQ_i: 23.18 kN; Q_i: 301.34 kN

Q_{max}: 557.37 kN

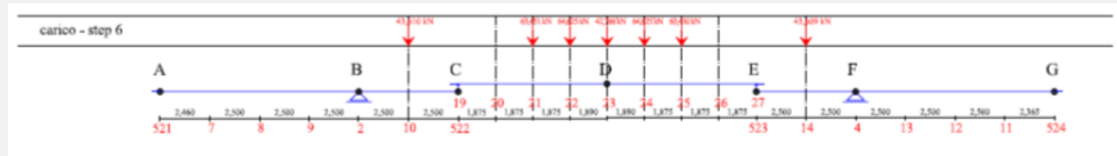
Actual experimental analysis

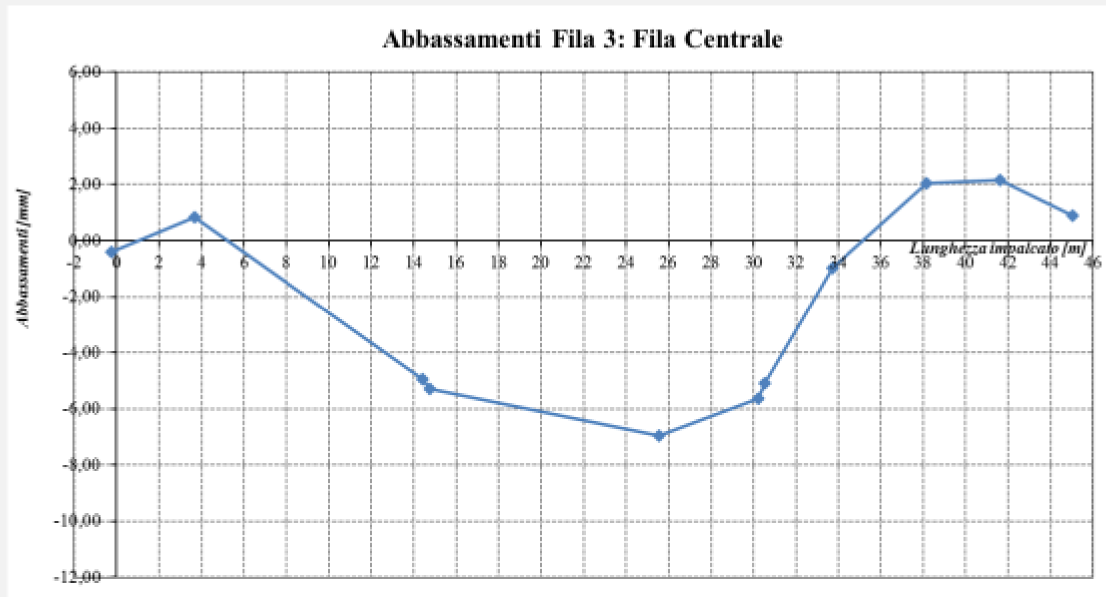


Displacements at load step n. 05 in comparison with theoretical values

Actual experimental analysis

Difficulties in level measurements can be noted due to block view obstruction

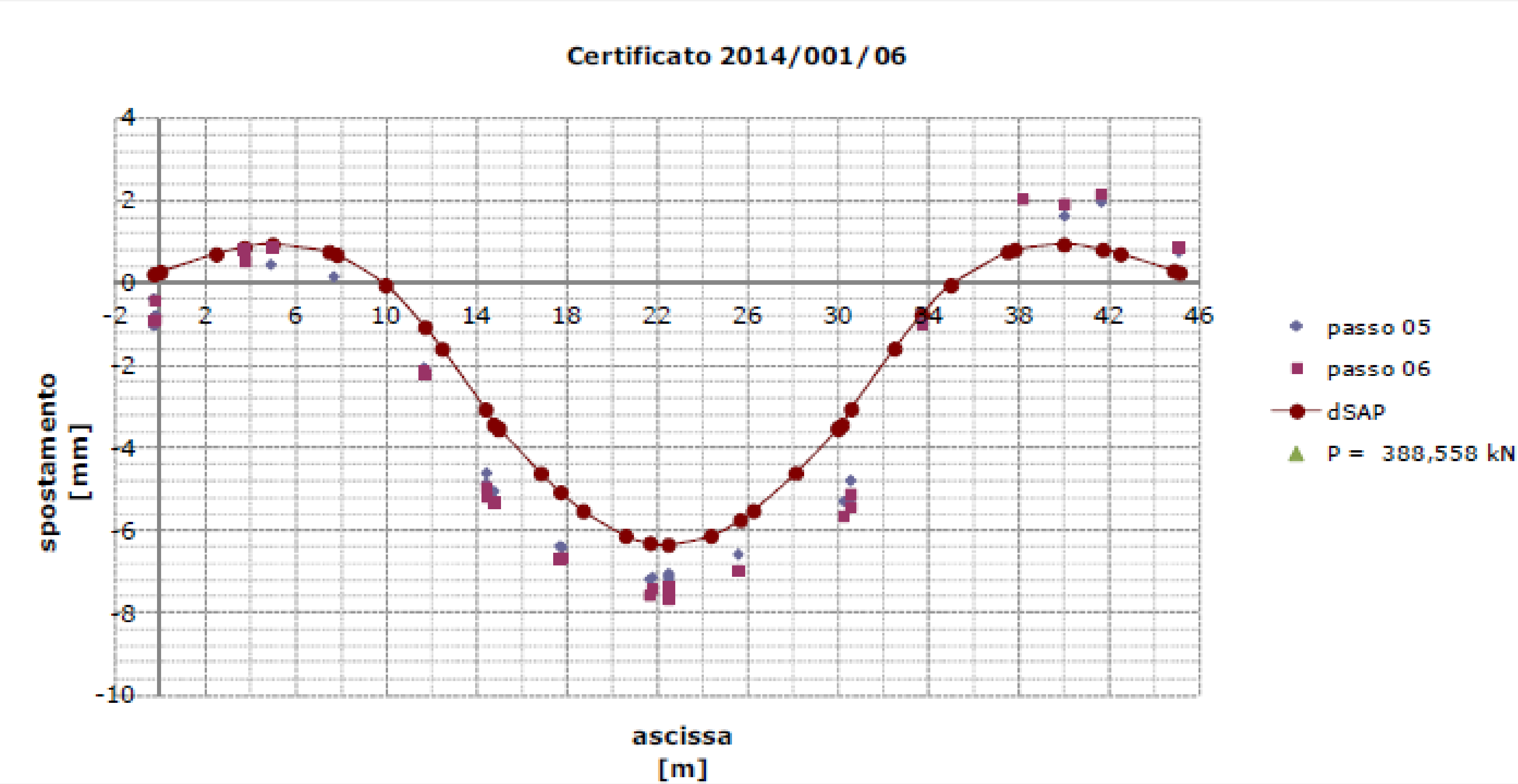




Step 6 – ΔQ_i: 87.22 kN; Q_i: 388.56 kN

Q_{max}: 557.37 kN

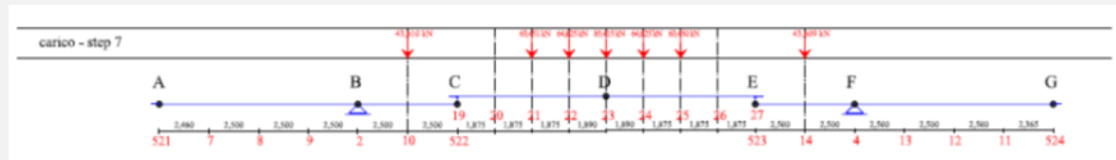
Actual experimental analysis

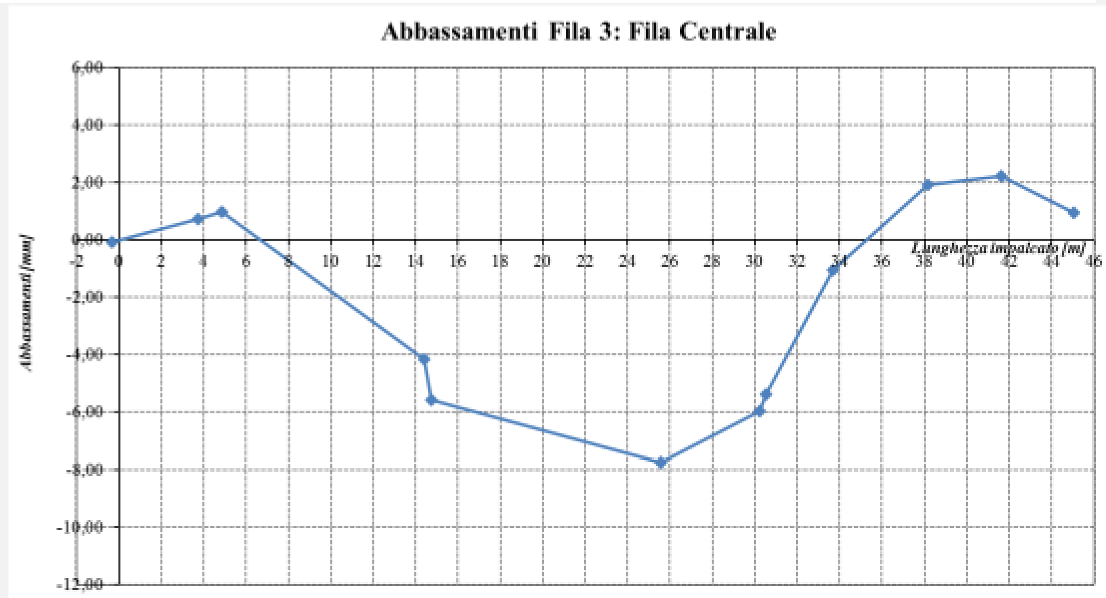


Displacements at load step n. 06 in comparison with theoretical values

Actual experimental analysis

Difficulties in level measurements can be noted due to block view obstruction

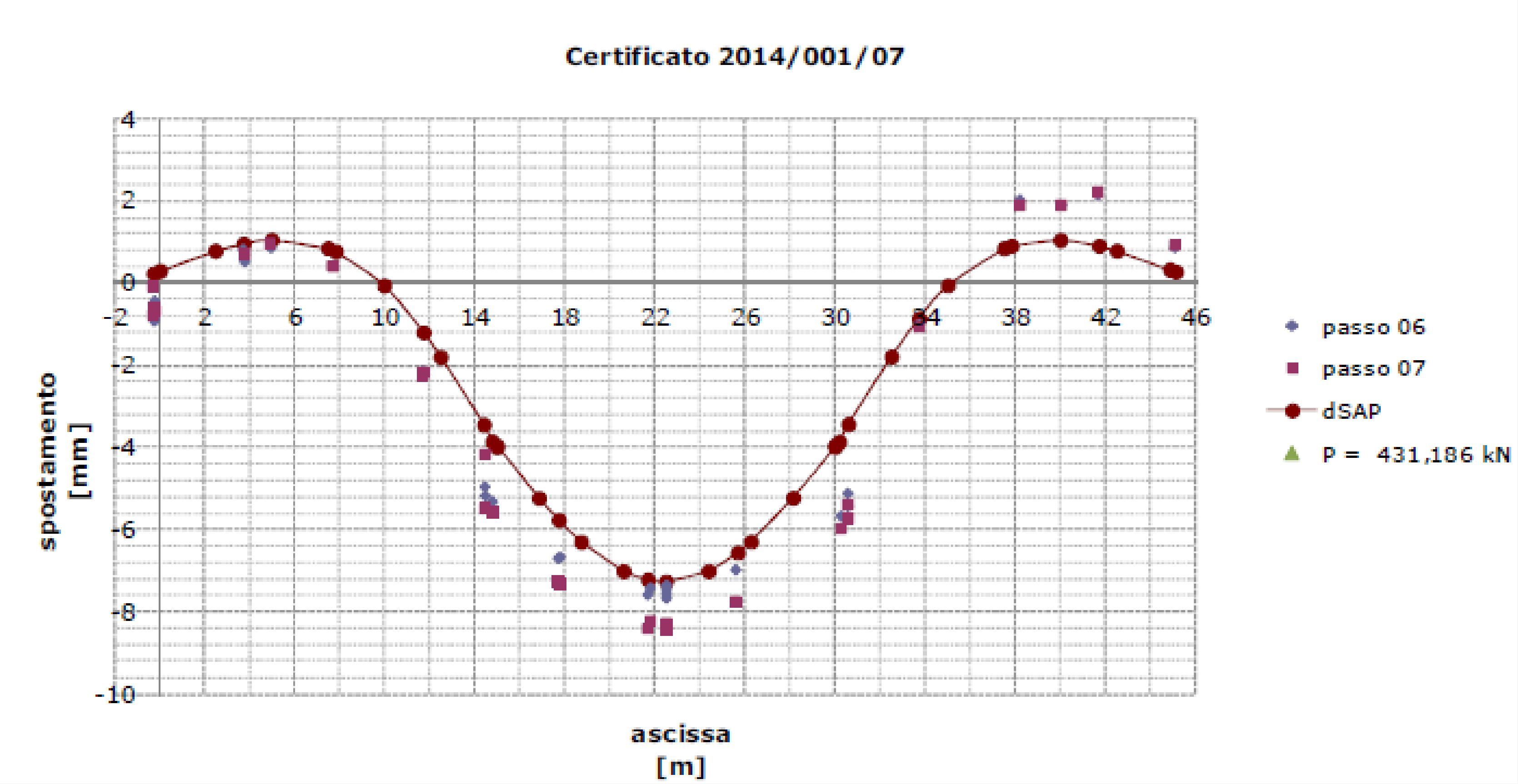




Step 7 – ΔQ_i: 42.63 kN; Q_i: 431.19 kN

Q_{max}: 557.37 kN

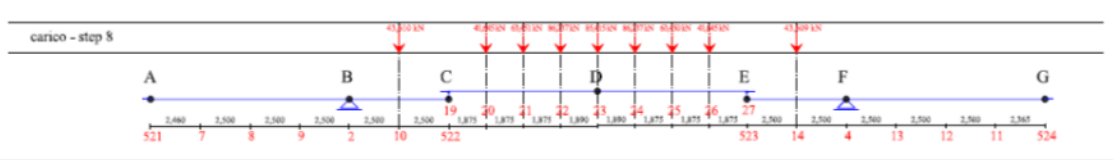
Actual experimental analysis

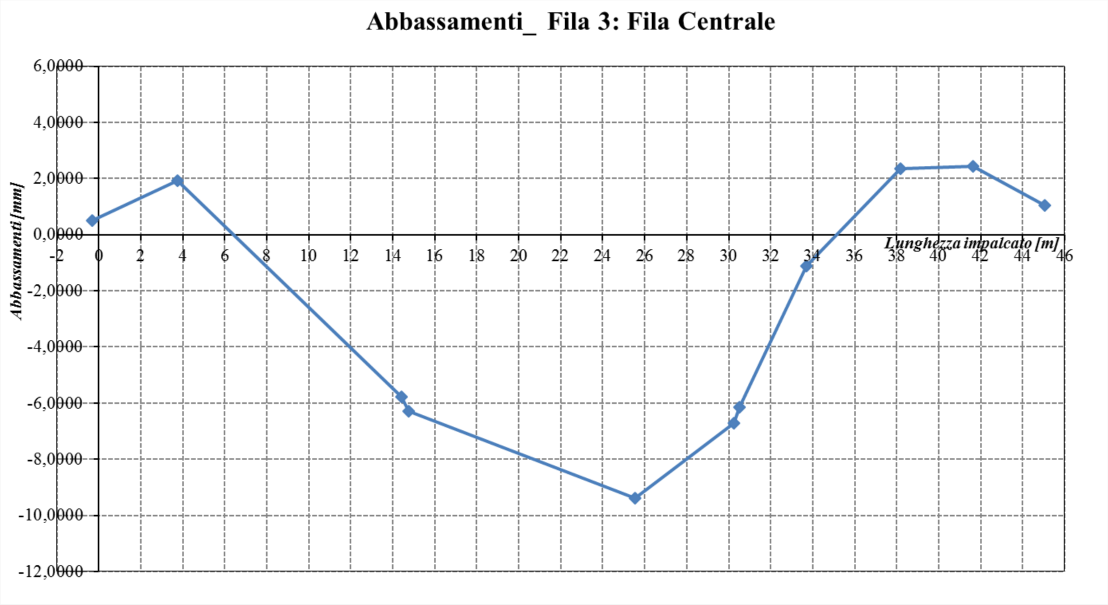


Displacements at load step n. 07 in comparison with theoretical values

Actual experimental analysis

Maximum load step quite at sun-set of test first day

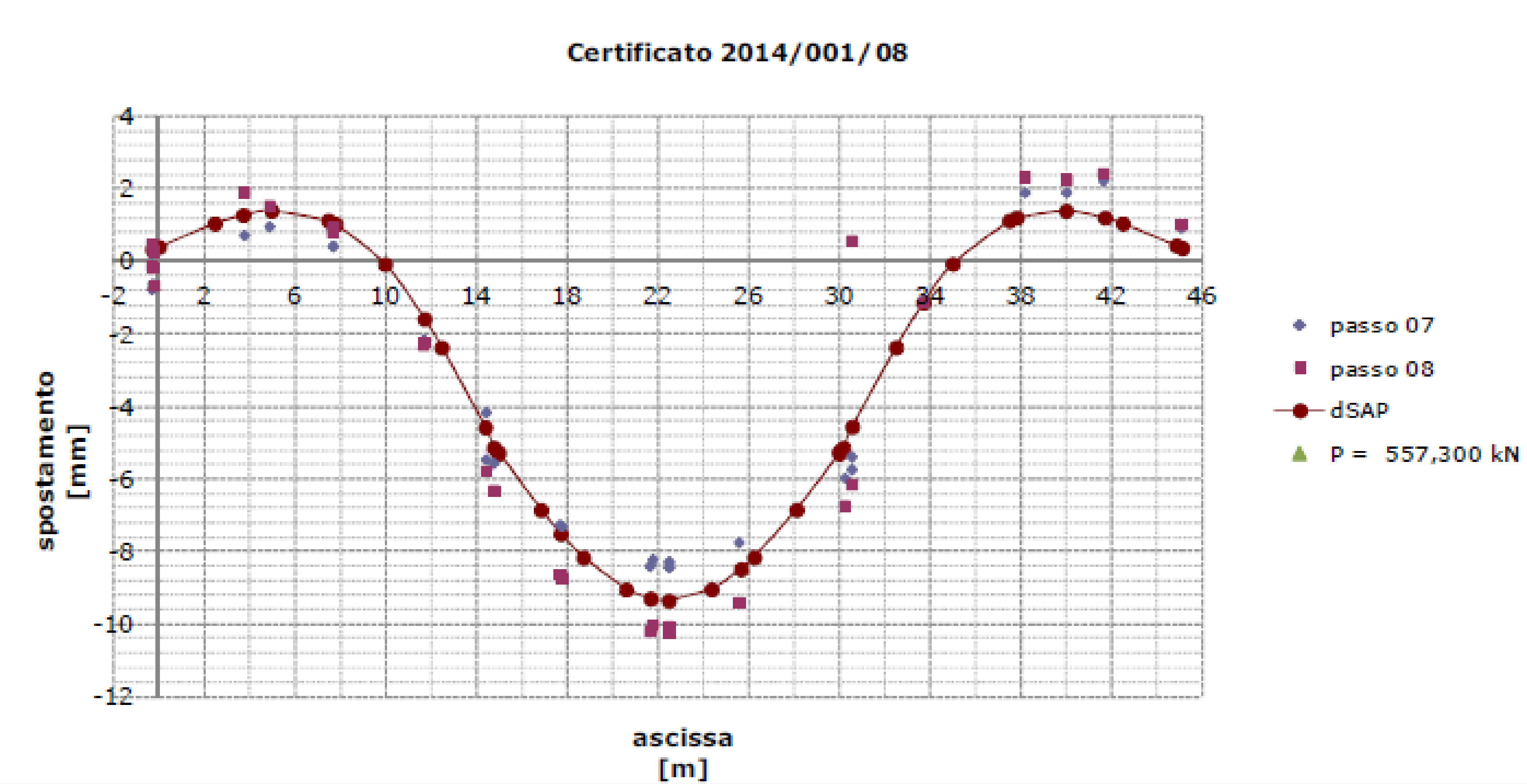




Step 8 – ΔQ_i: 126.11 kN; Q_i: 557.37 kN

Q_{max}: 557.37 kN

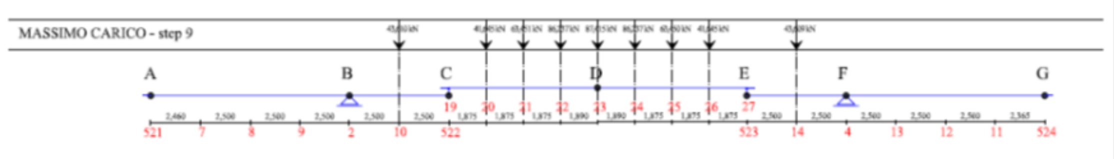
Actual experimental analysis

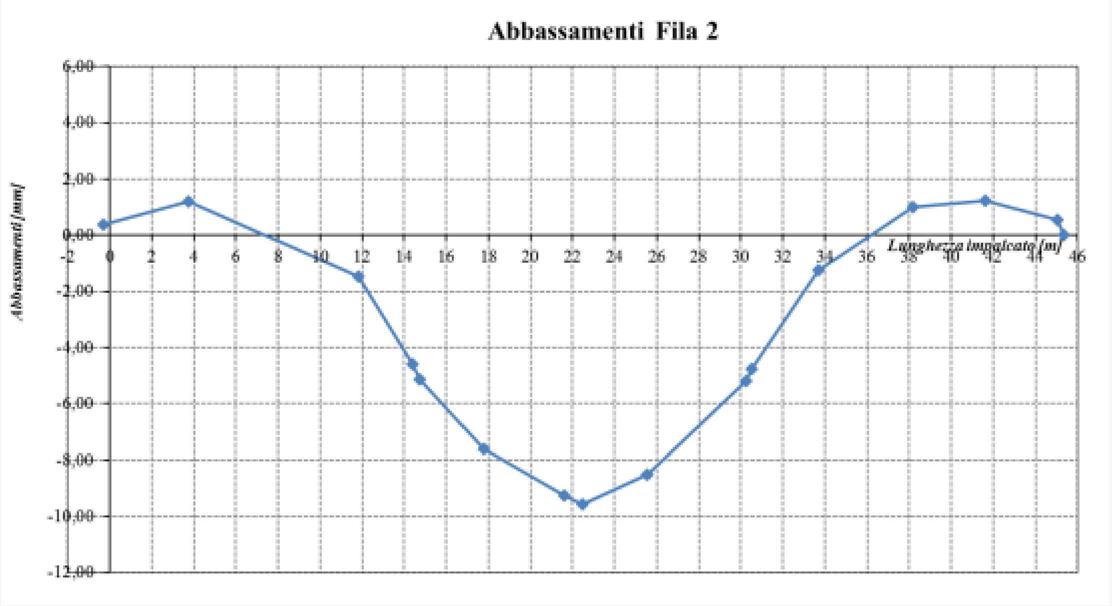


Displacements at load step n. 08 in comparison with theoretical values

Actual experimental analysis

Maximum load step quite at sun-rise of test second day

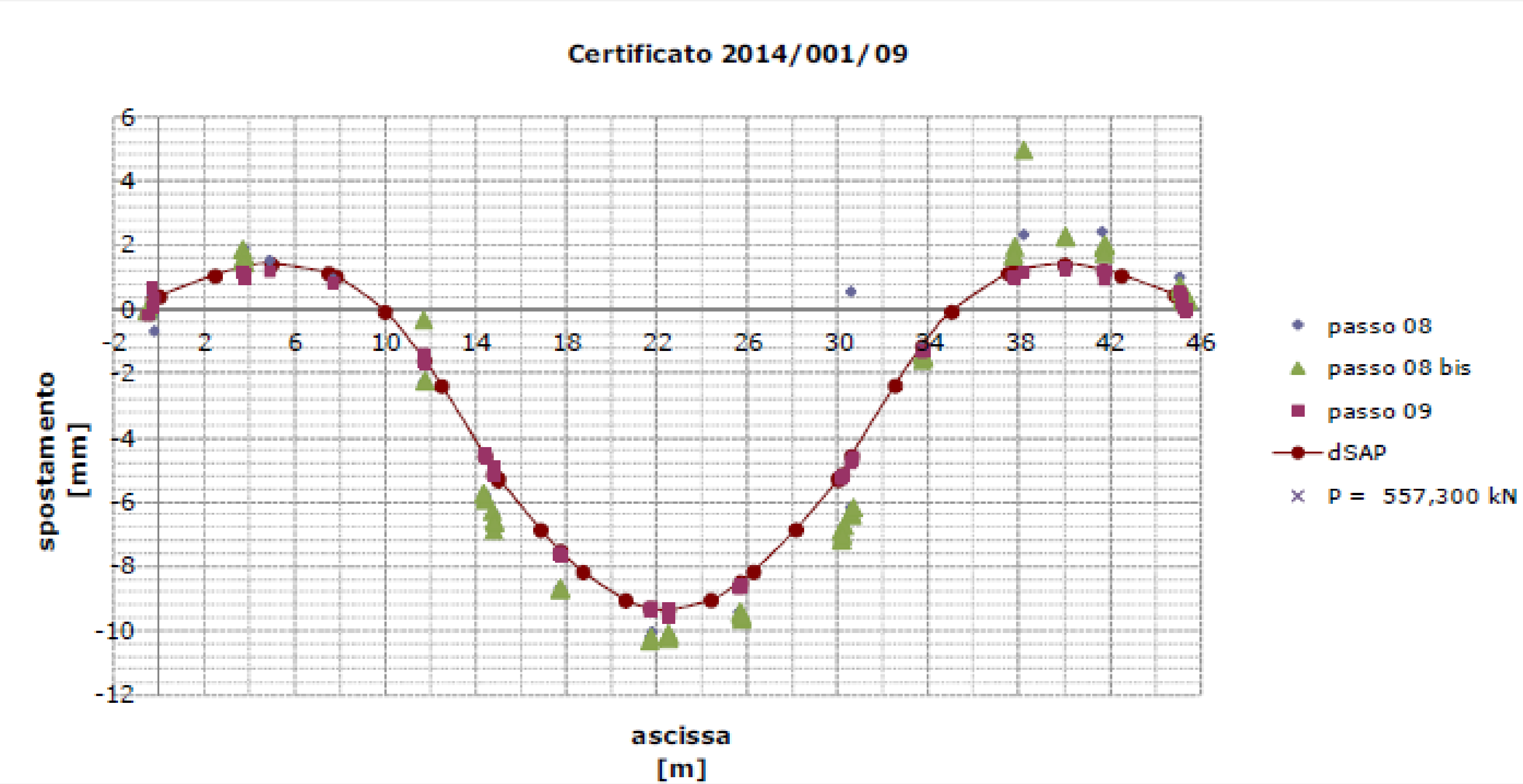




Step 9 – ΔQ_i: 0.00 kN; Q_i: 557.37 kN

Q_{max}: 557.37 kN

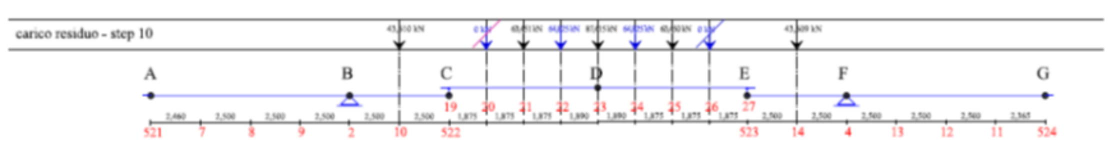
Actual experimental analysis

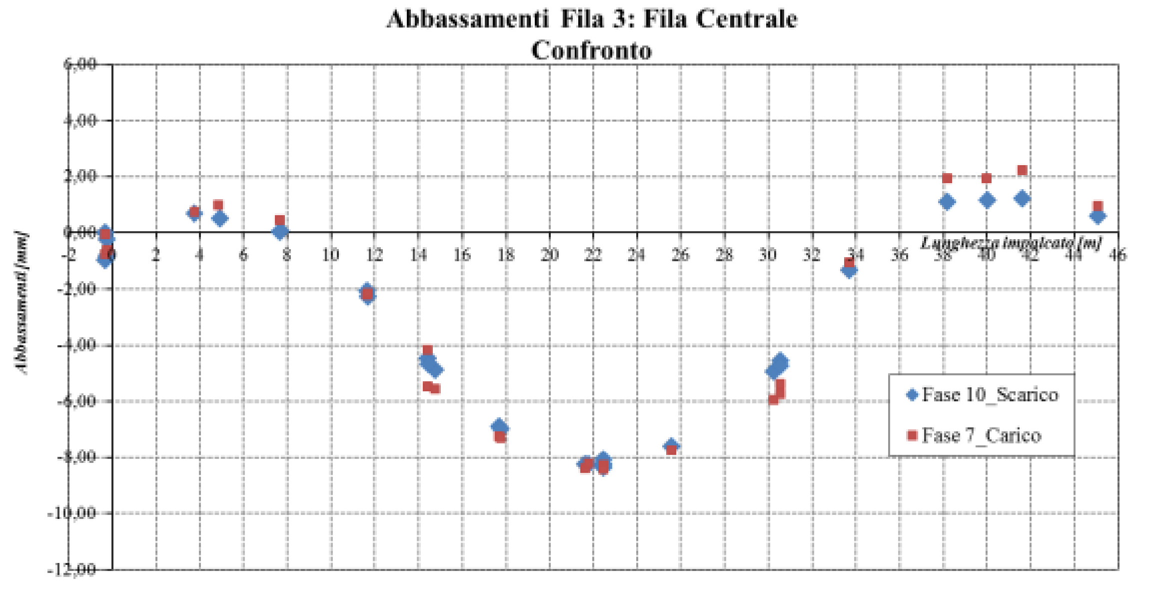


Displacements at load step n. 09 in comparison with theoretical values

Actual experimental analysis

First step of load removing

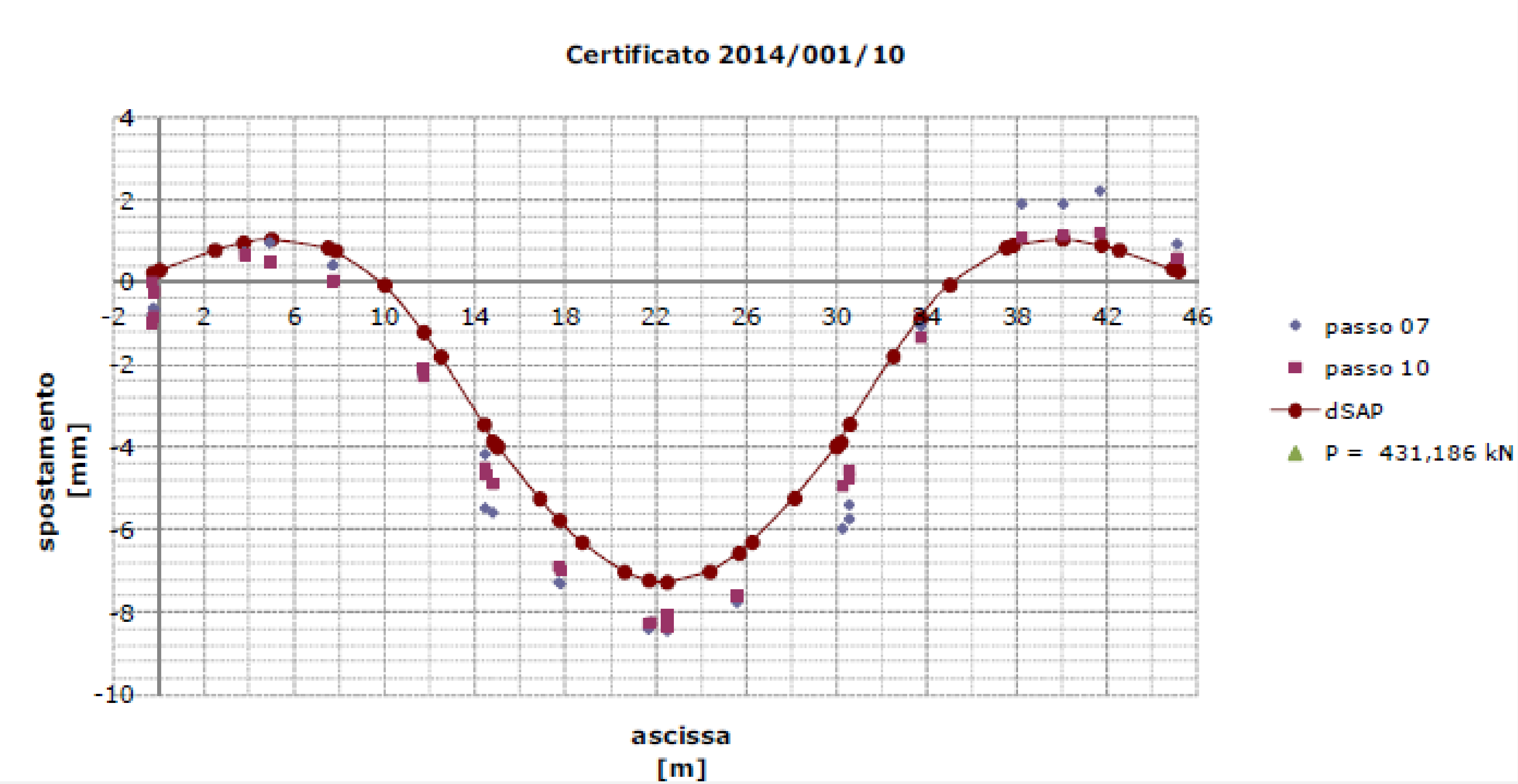




Step 10 – ΔQ_i: -126,11 kN; Q_i: 431.19 kN

Q_{max}: 557.37 kN

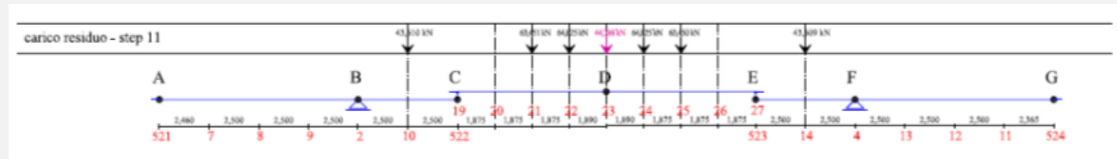
Actual experimental analysis

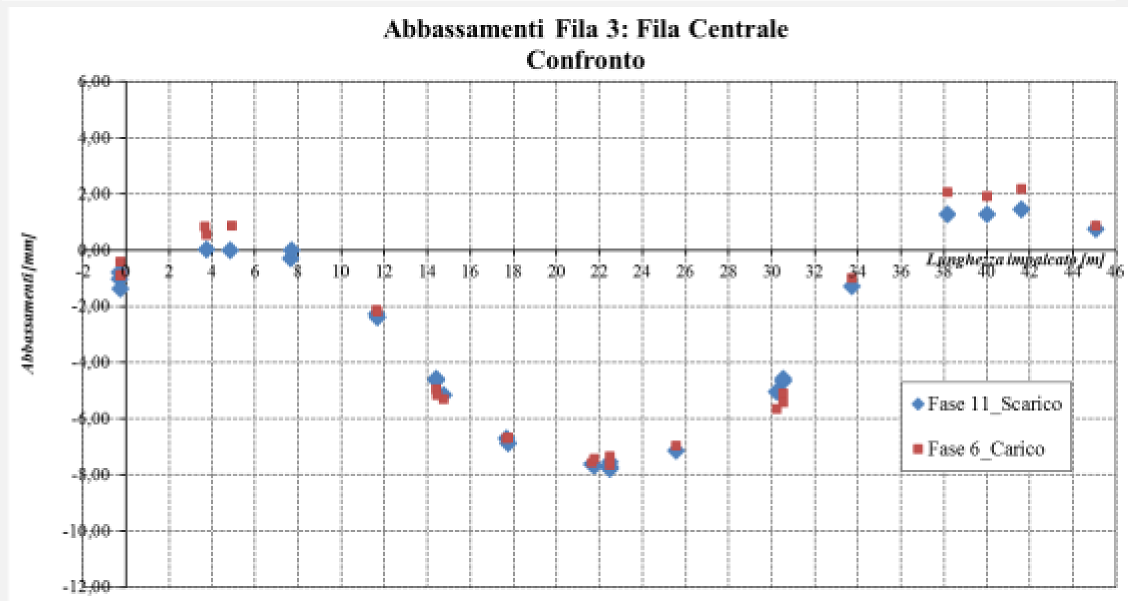


Displacements at load step n. 10 in comparison with theoretical values

Actual experimental analysis

Second step of load removing

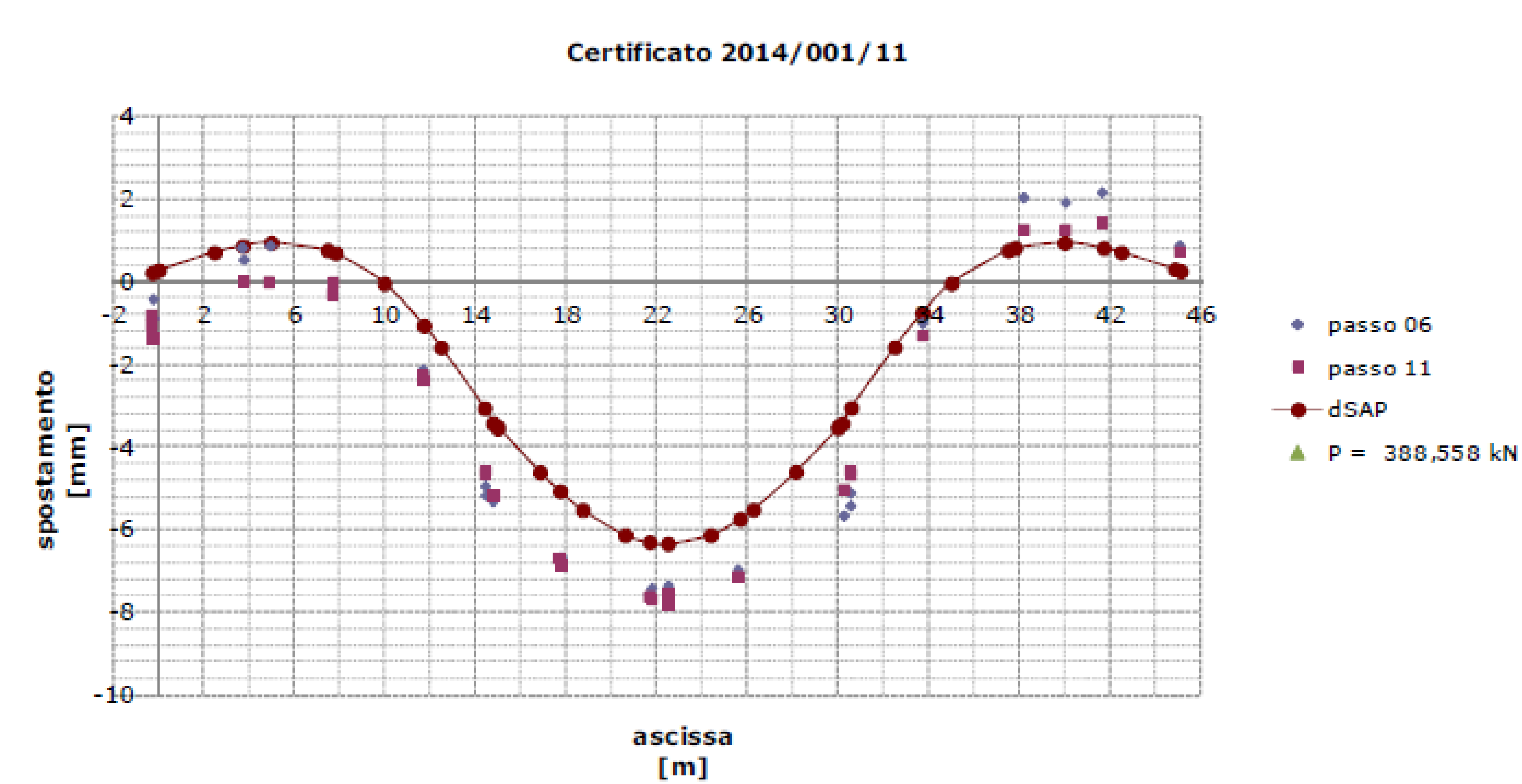




Step 11 – ΔQ_i: -42,63 kN; Q_i: 388.56 kN

Q_{max}: 557.37 kN

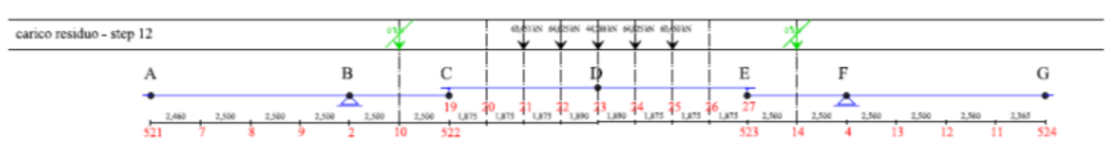
Actual experimental analysis

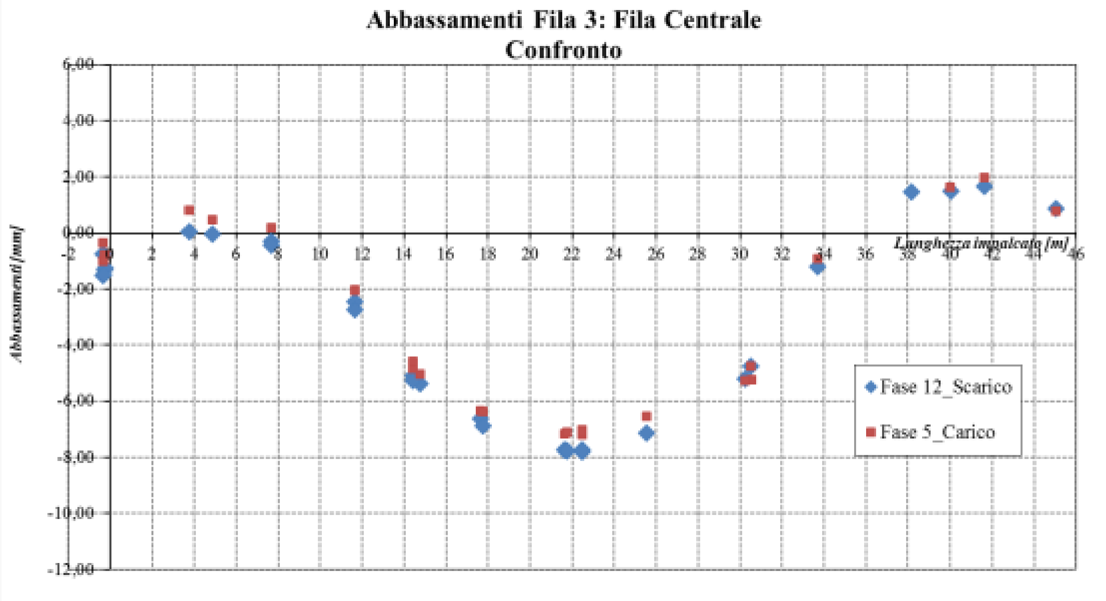


Displacements at load step n. 11 in comparison with theoretical values

Actual experimental analysis

Third step of load removing

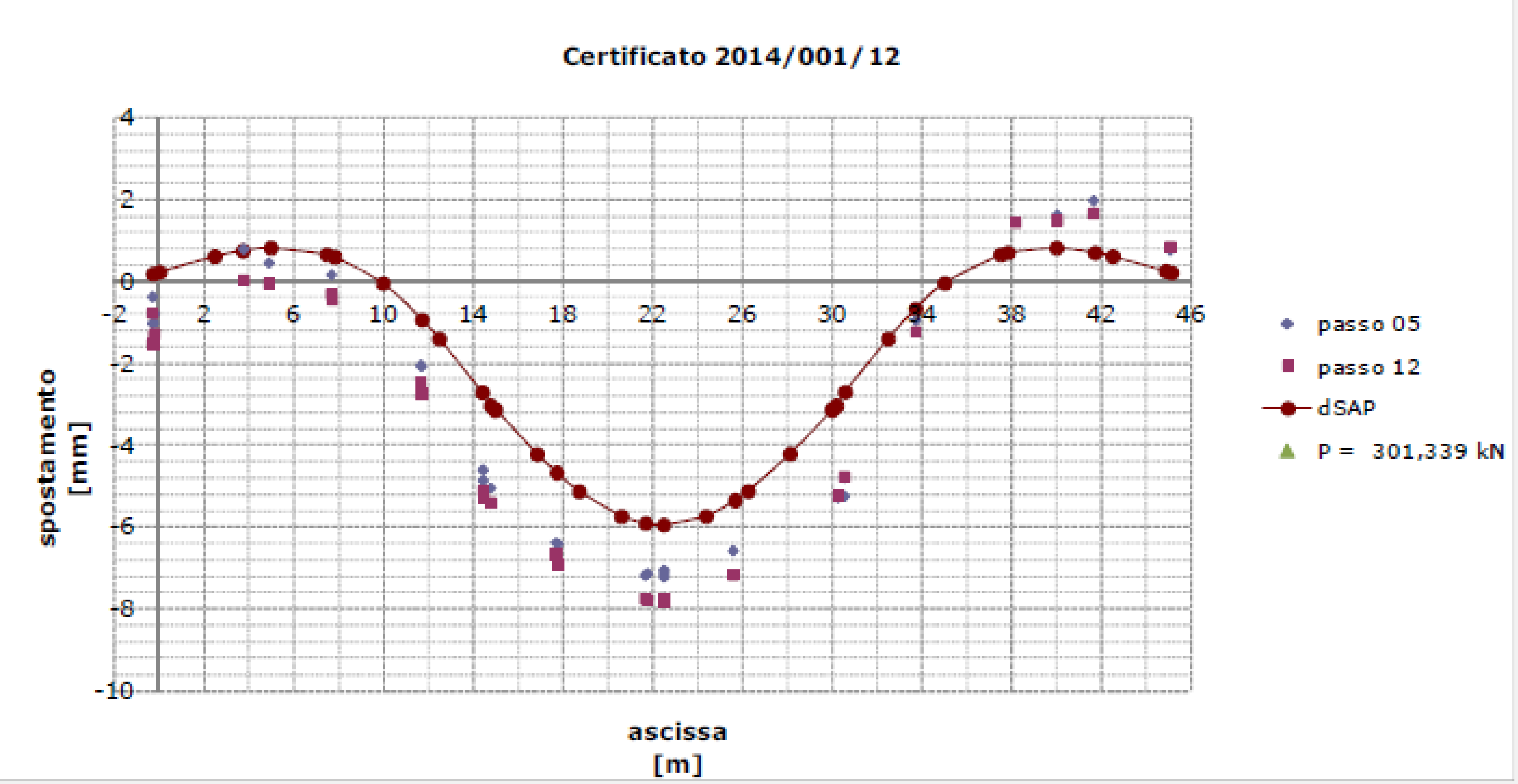




Step 12 – ΔQ_i: -87.22 kN; Q_i: 301.34 kN

Q_{max}: 557.37 kN

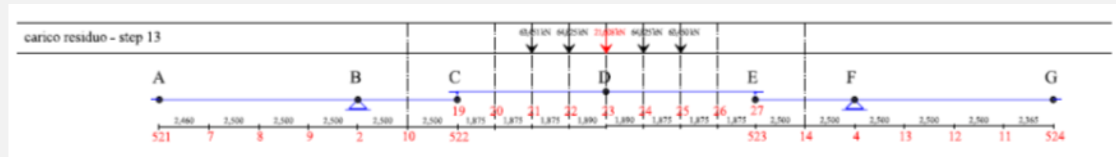
Actual experimental analysis

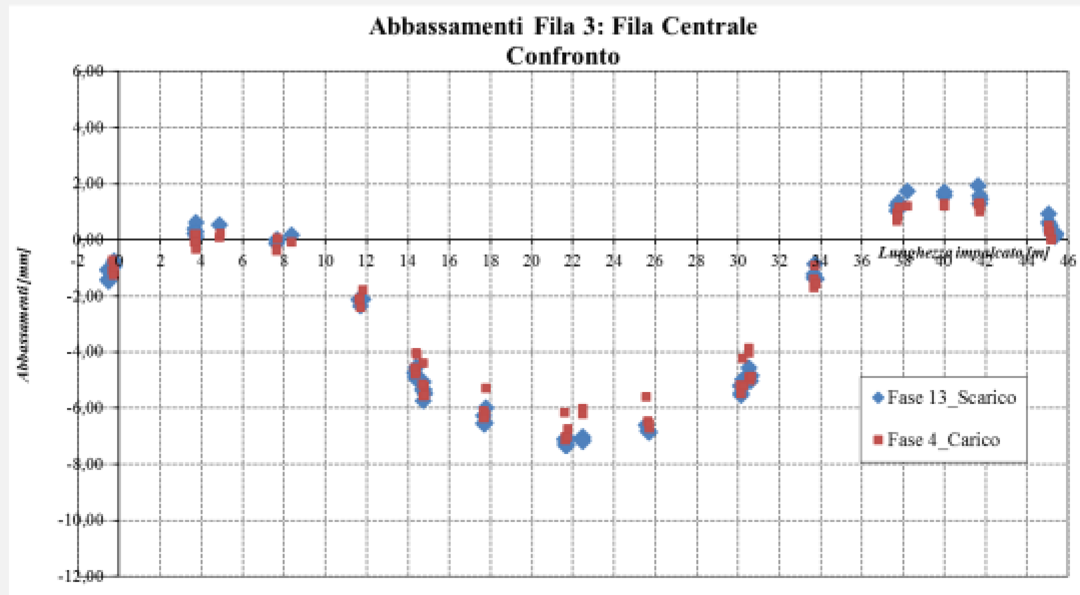


Displacements at load step n. 12 in comparison with theoretical values

Actual experimental analysis

Fourth step of load removing

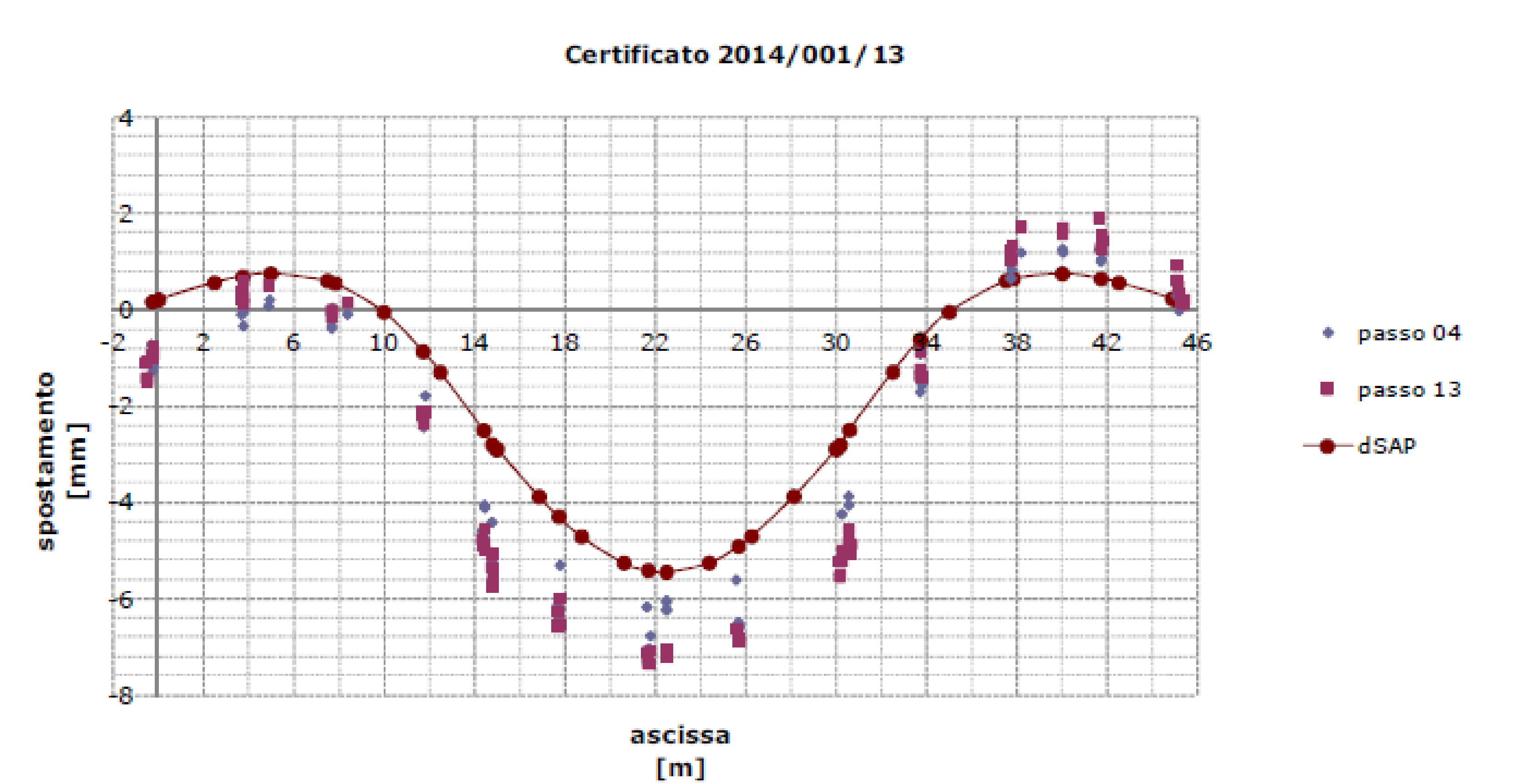




Step 13 – ΔQ_i: -23.18 kN; Q_i: 278.16 kN

Q_{max}: 557.37 kN

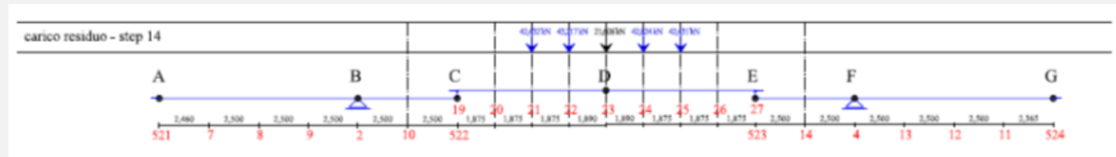
Actual experimental analysis

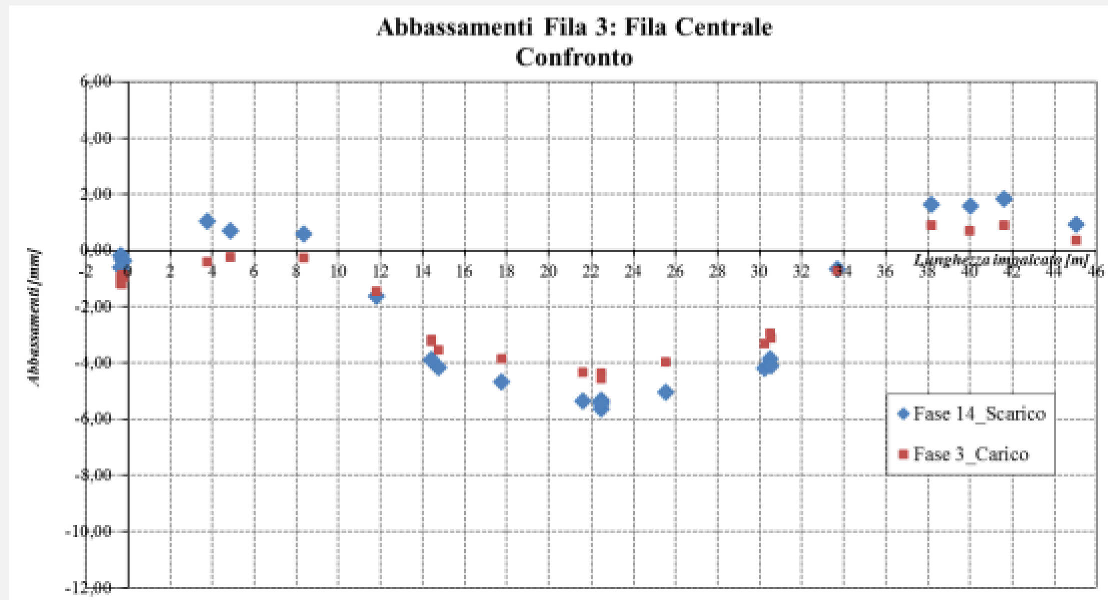


Displacements at load step n. 13 in comparison with theoretical values

Actual experimental analysis

Fifth step of load removing

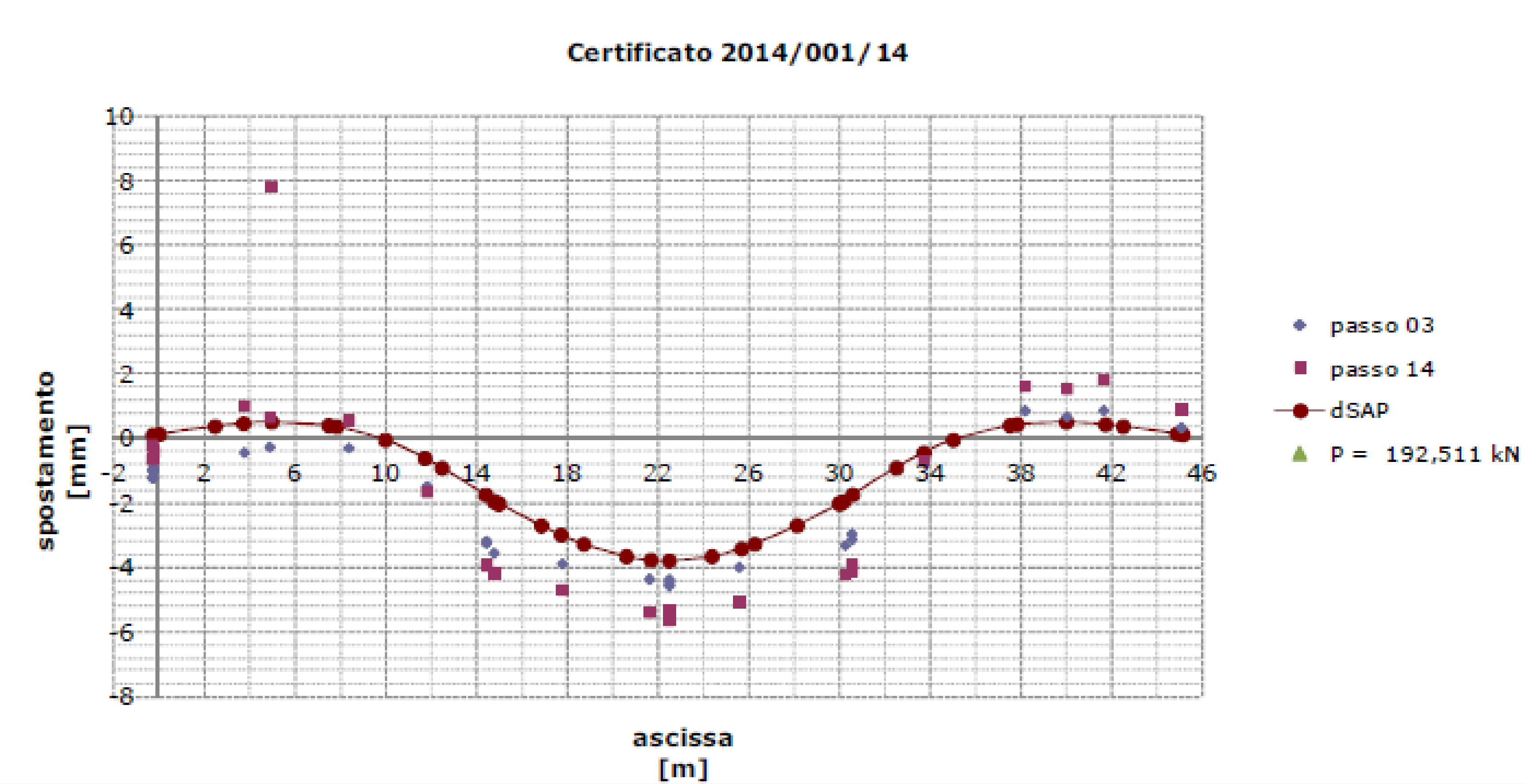




Step 14 – ΔQ_i: -85.65 kN; Q_i: 192.51 kN

Q_{max}: 557.37 kN

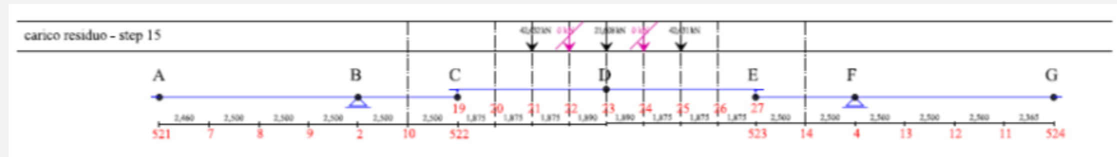
Actual experimental analysis

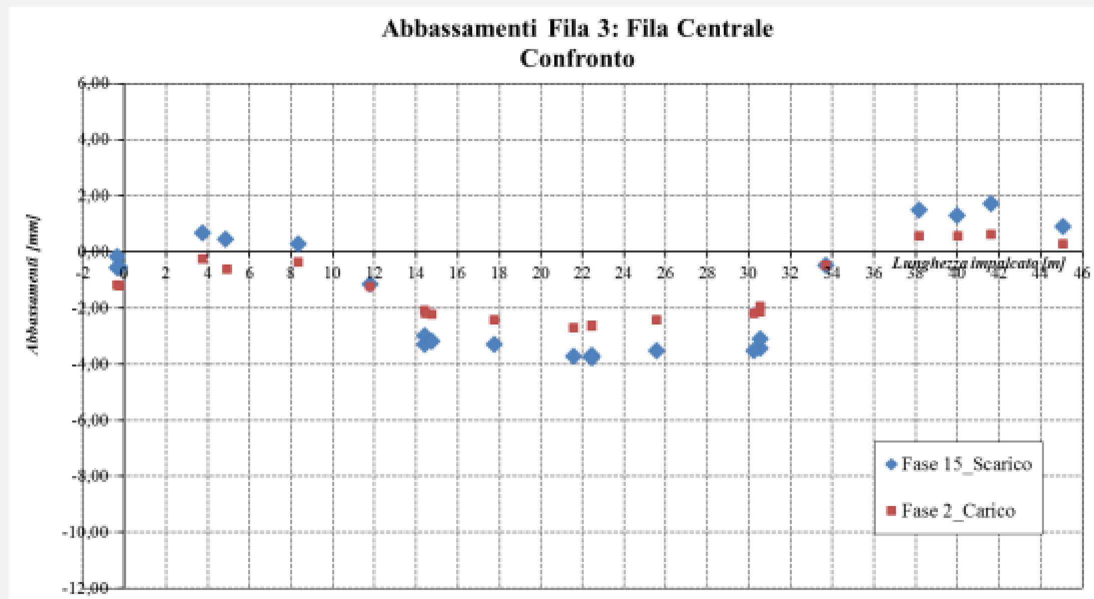


Displacements at load step n. 14 in comparison with theoretical values

Actual experimental analysis

Sixth step of load removing

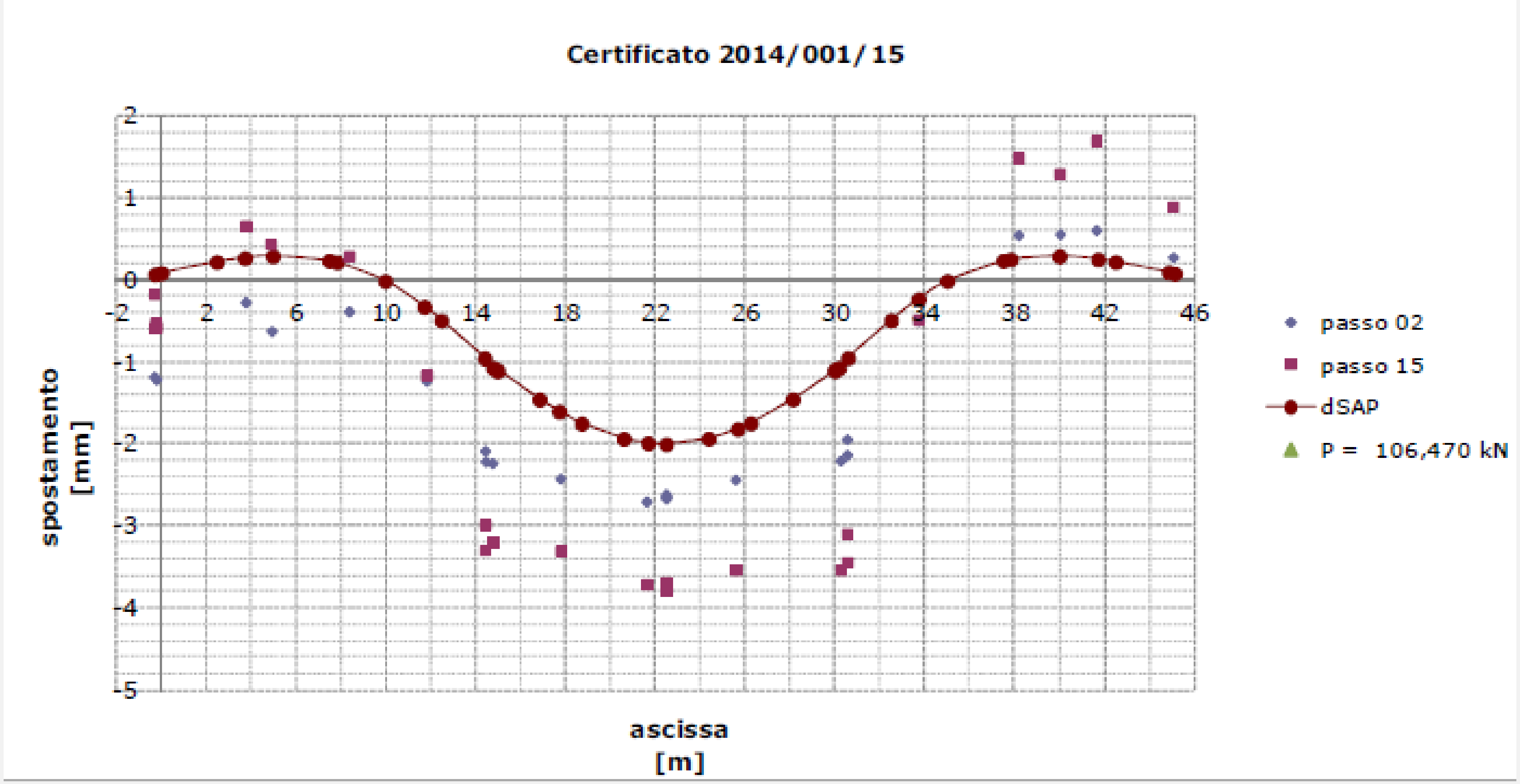




Step 15 – ΔQ_i: -86.04 kN; Q_i: 106.47 kN

Q_{max}: 557.37 kN

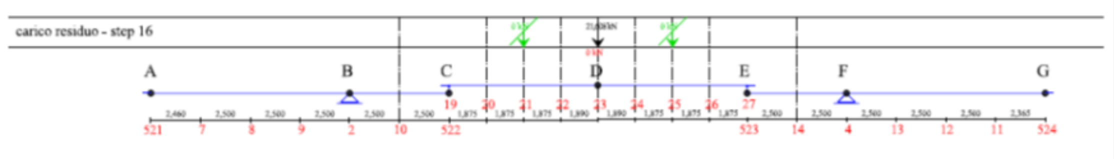
Actual experimental analysis

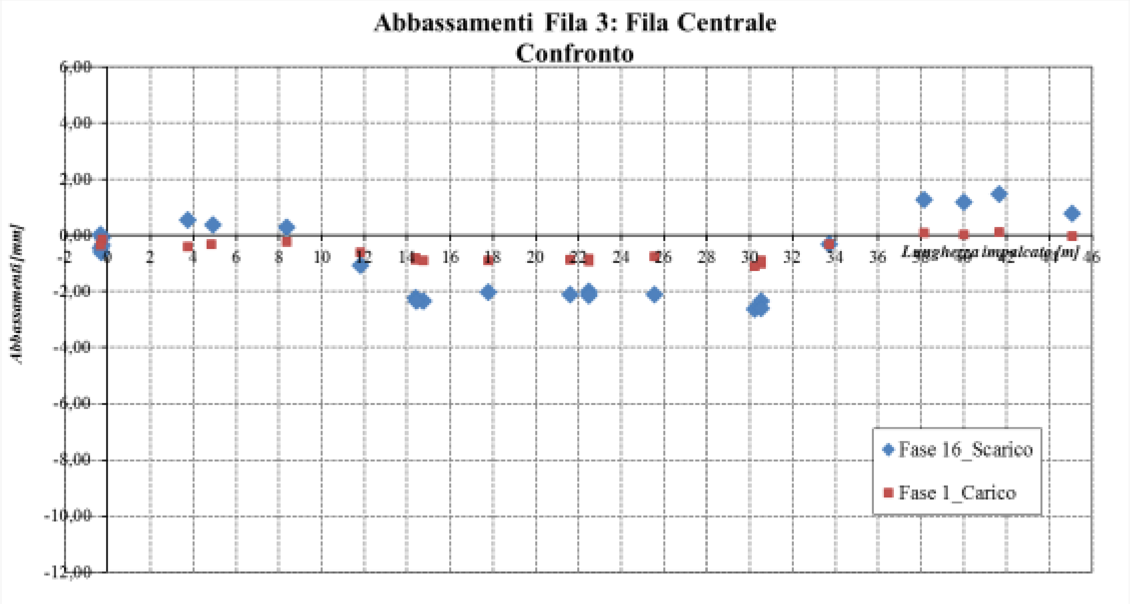


Displacements at load step n. 15 in comparison with theoretical values

Actual experimental analysis

Seventh step of load removing

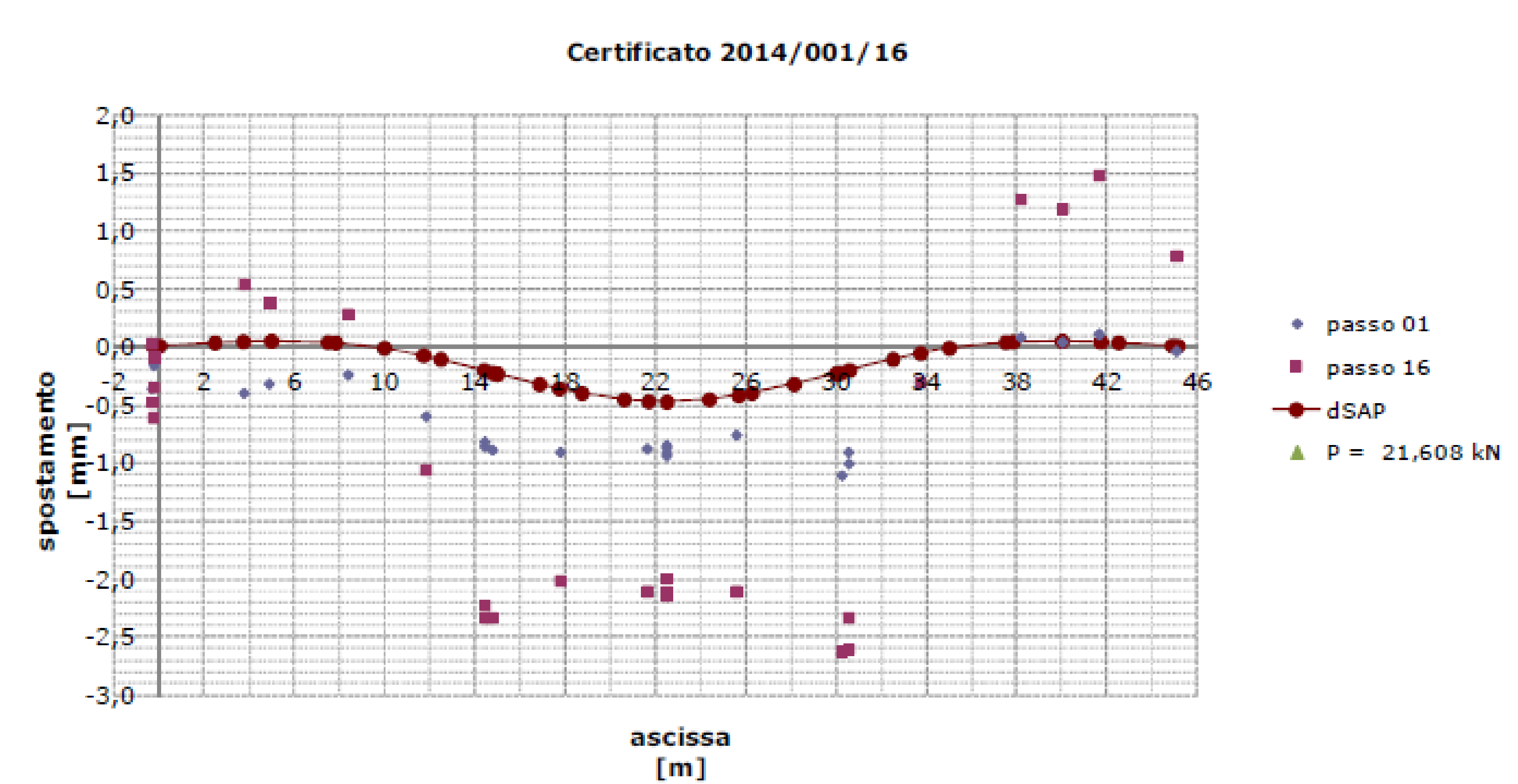




Step 16 – ΔQ_i: -84.86 kN; Q_i: 21.61 kN

Q_{max}: 557.37 kN

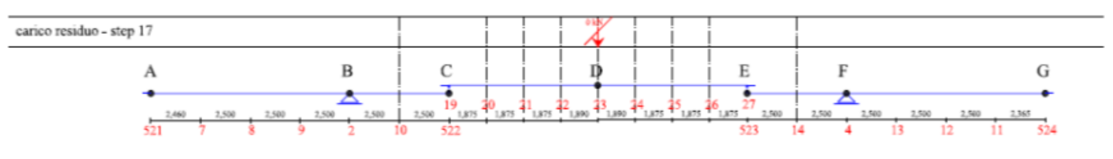
Actual experimental analysis

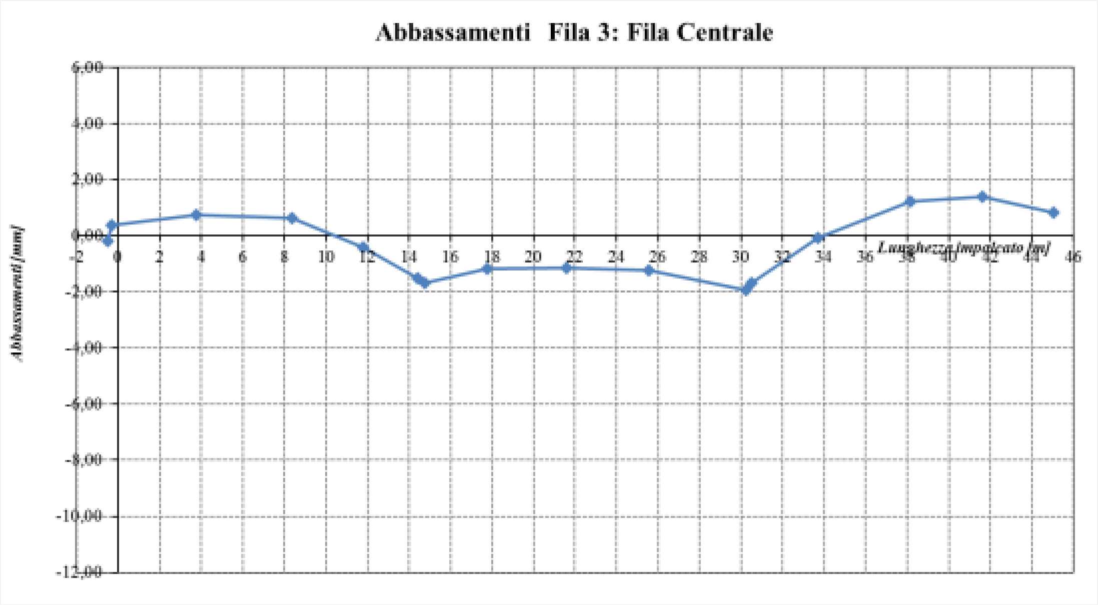


Displacements at load step n. 16 in comparison with theoretical values

Actual experimental analysis

Eighth step of load removing: at sun-set the bridge has no load

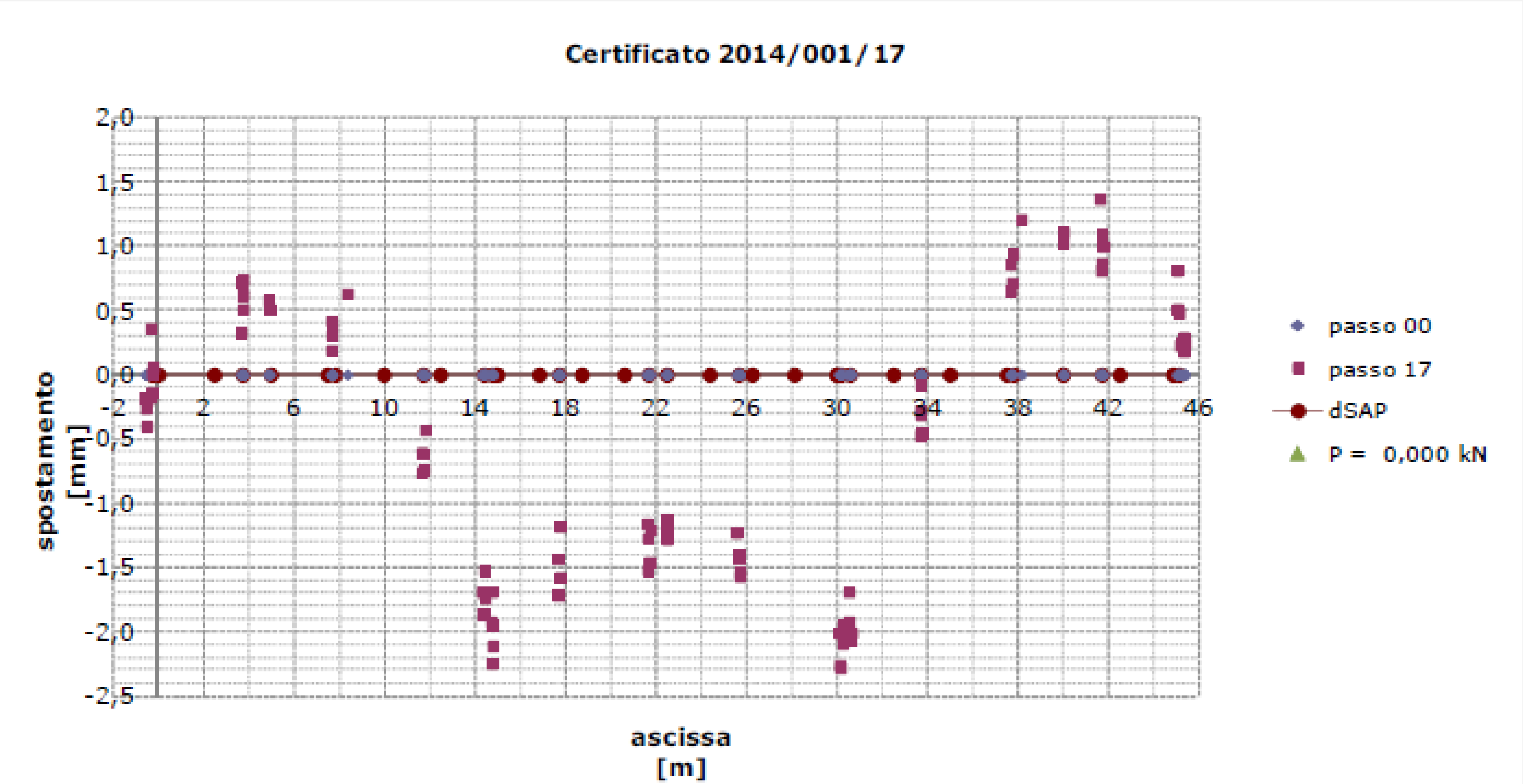




Step 17 – ΔQ_i: -21.61 kN; Q_i: 0.00 kN

Q_{max}: 557.37 kN

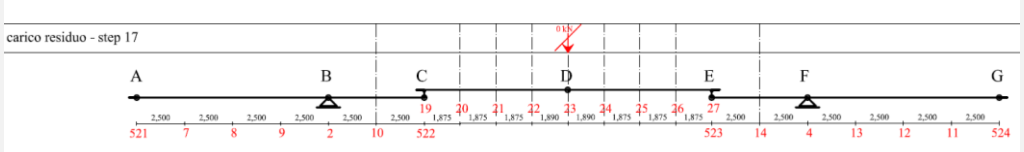
Actual experimental analysis

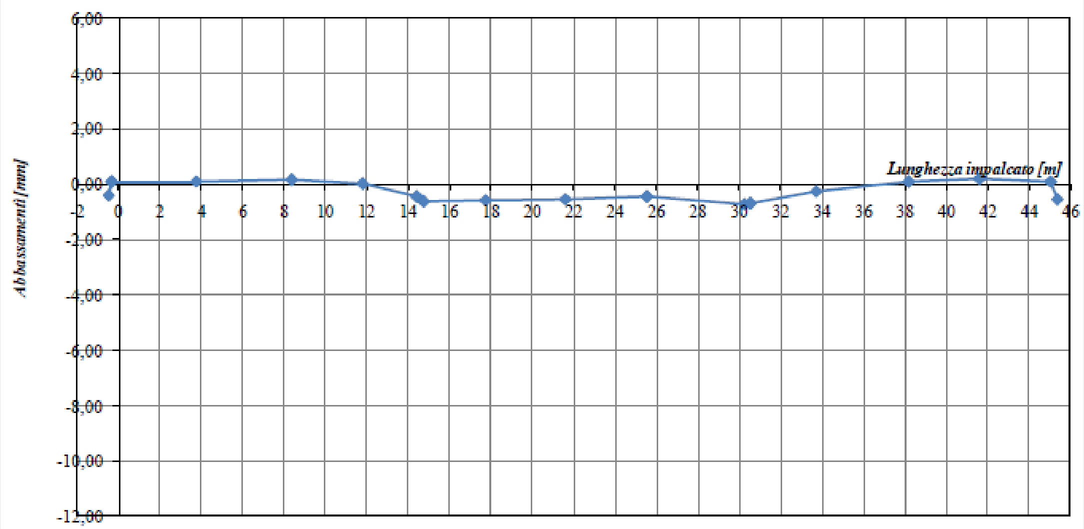


Displacements at load step n. 17 in comparison with theoretical values

Actual experimental analysis

The day after, the elastic displacements were quite completely recovered

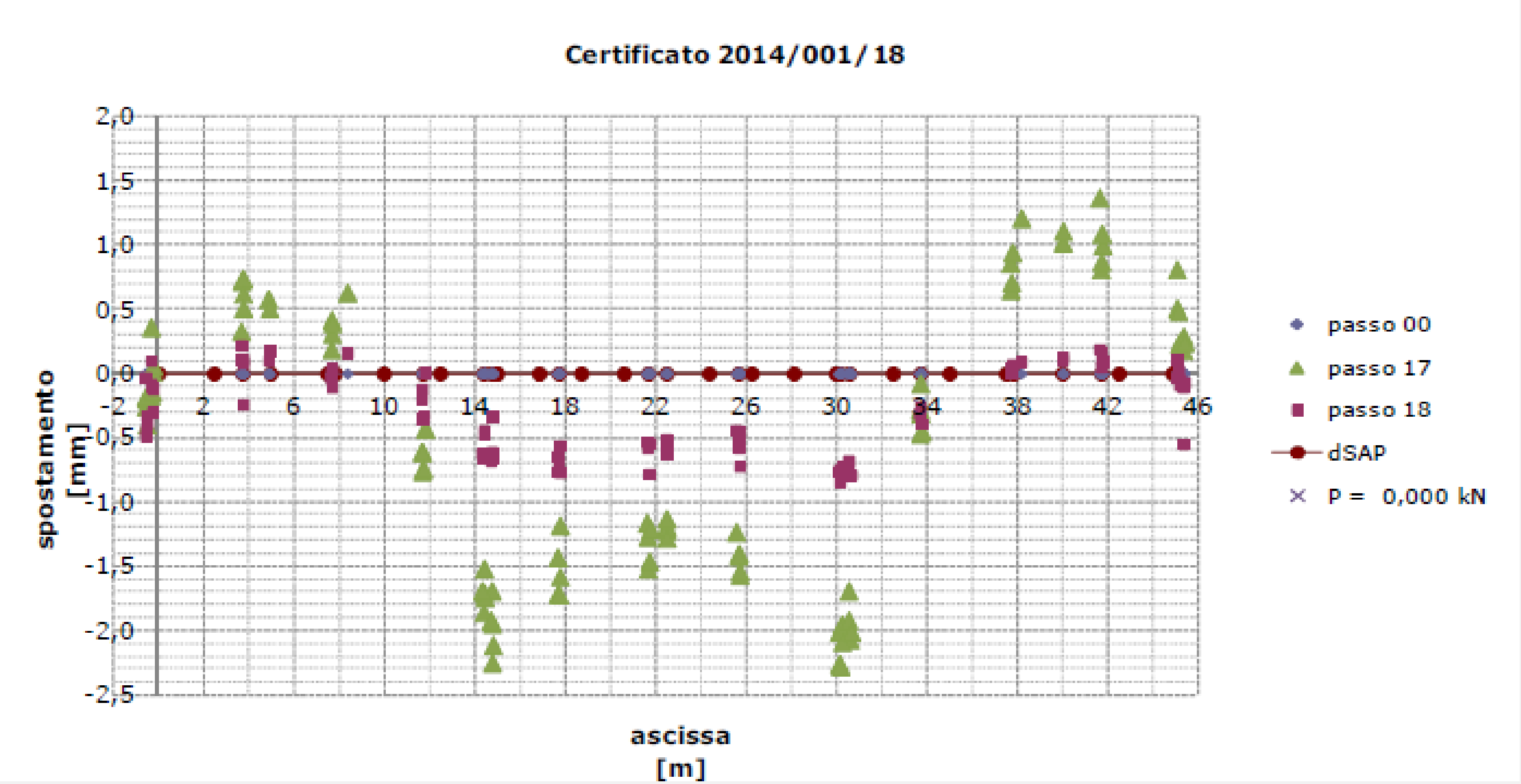




Step 18 – ΔQ_i: 0.00 kN; Q_i: 0.00 kN

Q_{max}: 557.37 kN

Actual experimental analysis



Displacements at load step n. 18 in comparison with theoretical values

Presentation Index

1. The Dragonara Bridge service life
2. Previous experimental activities
3. Previous structural analyses
4. Management of different test campaigns
5. Actual structural analysis
6. Actual experimental analysis
7. **Conclusions**

Conclusions

If viscous response and age of concrete are considered in relation to load time :

- **a correct management of different test campaigns is possible**
- **concrete characteristics (strength and stiffness) are defined**

Due the isostatic configuration, linear elastic stiffness has been assumed as the control parameter

A load test was designed in order to confirm structural material evaluation

Supporting activities of both terrestrial laser scanner surveys and high precision topographic leveling are carried out

Conclusions

A simple (linear) FEM model permits to provide structural response to a load test for the investigated bridge

Previous test data permitted to estimate the real Gerber's connection behavior (no ideal hinges but monolateral attritive hinges)

The efficiency of this provision guarantees the correctness of structural model

The bridge was assumed near collapse while now:

- it is on duty
- a maintenance program will start in the near future