ISS

Institute of Steel Structures

Newsletter

January 2021

National Technical University of Athens
School of Civil Engineering

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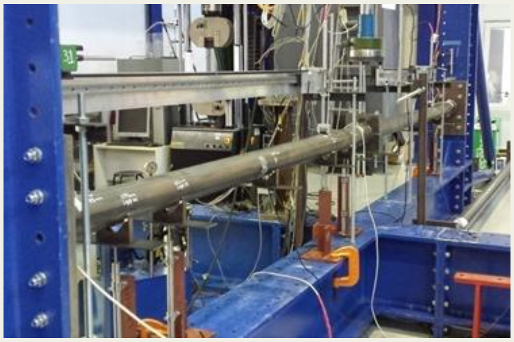
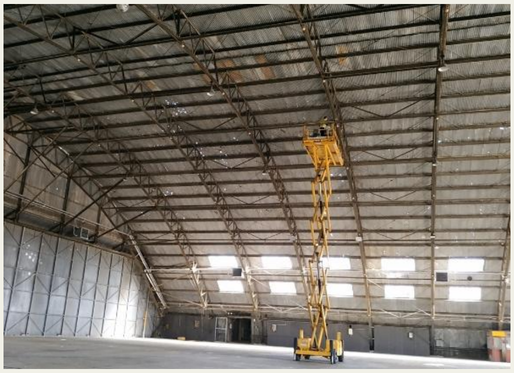
Institute of Steel Structures - NTUA / January 2021

Designed & formatted by: **Aikaterini Michaltsou**

Front cover: **Connection test in the Laboratory of ISS-NTUA**

Welcome to the Newsletter of ISS-NTUA!





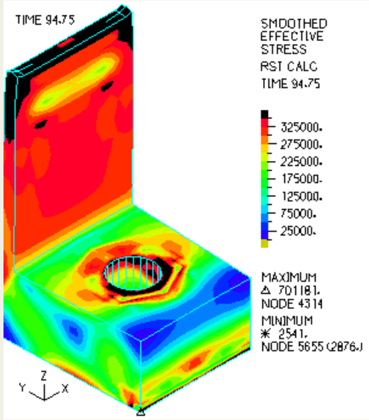
Dear students, colleagues, alumni and friends,

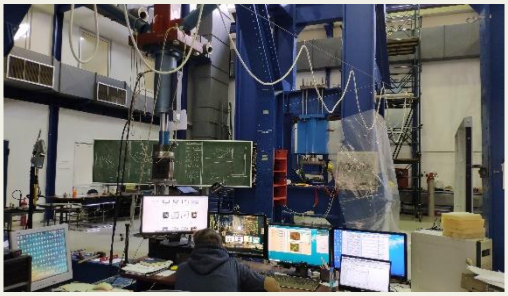
Aim of this new effort of our Institute of Steel Structures at the National Technical University of Athens is to provide a forum for communicating with you and sharing our news with the Greek and international steel structures community. We hope to make this a bi-yearly publication, each time including a sample of our recent activities. The language will be English, so that we can also address our international friends and colleagues.

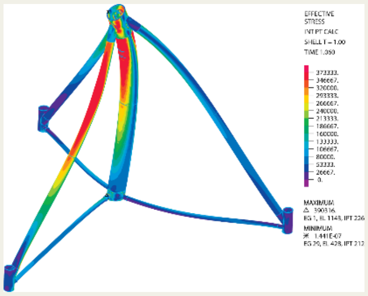
At ISS-NTUA we firmly believe in balance between theory and practice, and between education, research and service to the structural engineering community. The contents of this first issue of our Newsletter demonstrate this balance, including examples of field measurements, laboratory tests, advanced numerical analyses, participation of our faculty in Greek and European code committees, student term projects and theses, as well as the three doctoral theses completed at ISS in 2020.

In this year marked by the pandemic the members of our Institute have managed to remain healthy and at the same time to be productive and resourceful. We look forward to a year with fewer difficulties and more challenges and wish you all the same.

Charis Gantes







Measurements of the dynamic response of an arch bridge under pedestrian loading

In summer 2020 the Institute of Steel Structures conducted dynamic tests on a new 45m span pedestrian arch bridge overpassing an expressway road at the seafront of Athens (Fig 1). The hollow section arch and stiffening girder are eccentric to the bridge deck, which is supported by I-section beams cantilevering from the stiffening girder with a concrete topping to act compositely with the cantilever beams. The overall width of the bridge is 4 m, while the net width is 3 m.

The measuring program included the determination of the main vibration modes and subsequently vibration measurements during passage of various numbers of persons at various frequencies and modes (Table 1). The tact was given by a beeper and transferred through loudspeakers.

Accelerations of the deck in three directions (x,y,z) were recorded by three sensors positioned at the cantilever edge, where the largest accelerations were expected, at ¼ and ½ of the bridge span, plus a fourth sensor near the arch at mid-span (Fig. 2). The signals were transferred through cables to the recording equipment that was placed at the end of the bridge.

The power density spectra of the measurements indicate the fundamental frequencies of the bridge (Fig. 3). Maximum power density values are achieved at the passage frequency and main fundamental frequencies of the bridge, which appear to be 3,6/7,3 Hz in the vertical and 2,8/4,9 Hz in the horizontal transverse direction. These values are in the low risk frequency range as provided by SETRA [1].

Statistical evaluation of the recorded accelerations indicated low probability of violation of required comfort levels of the bridge (Fig. 4). Indeed, mean values for vertical accelerations are below 0,5 m/s^2, indicating maximum comfort to vertical vibrations, while the same happens for horizontal vibrations, which are below 0,05 m/s^2. However, 95% fractiles exhibit larger values, so that unproper use should be prohibited.

As a conclusion, it was decided not to install dampers under the bridge. The complete report (in Greek) may be found in [2]

REFERENCES

1. Assessment of vibrational behavior of footbridges under pedestrian load, SETRA, 2006.
2. Vayas I., Pelekis P., Technical Report. Pedestrain Bridge Poseidonos & Kalamaki. Dynamic tests after completion of construction, 2020.

by Ioannis Vayas

Fig. 1 - Arch bridge during measurements

Table 1 - Measuring program			
Type of walk	1 person	12 persons in a group	Crowd (45 persons = 0,35 p/m^2)
Slow walk 1,7Hz	x		x
Normal walk 2.0Hz	x		
Fast walk 2,3Hz			x
Running 3,0Hz	x		
Random walk	x	x	x
Jumping		x	
Fundamental bridge frequency		x	
Remarks	5 different persons 3 transits per person	5 transits	5 transits

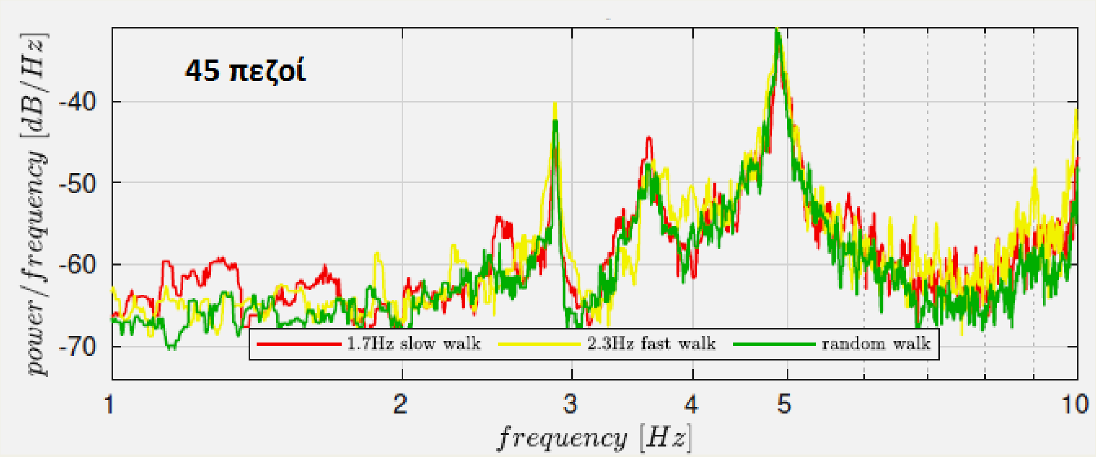


Fig. 3 - Power density spectra of horizontal vibrations for passage of 45 persons

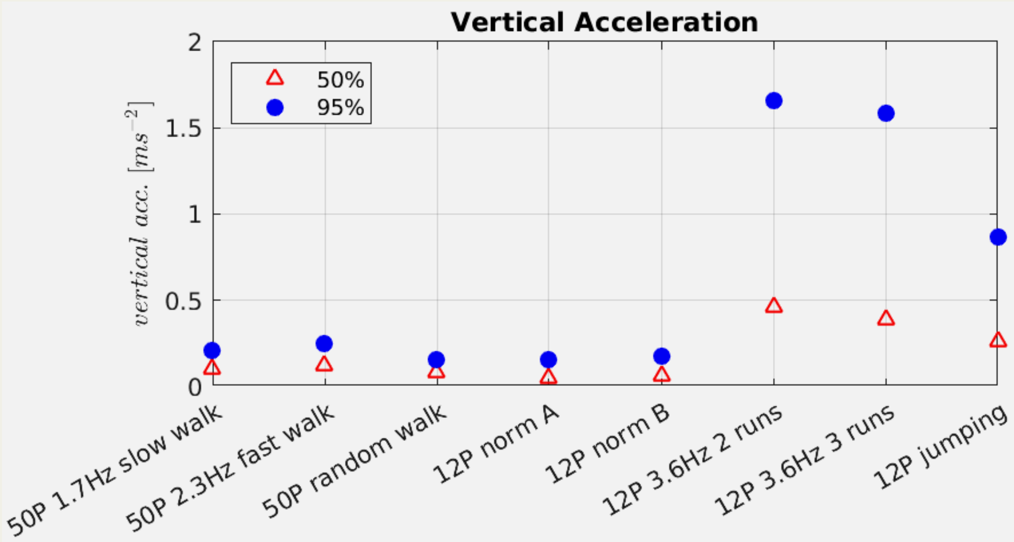


Fig. 4 - Mean values and 95%-fractiles of vertical accelerations

Fig. 2 - Position, numbering and cabling of sensors

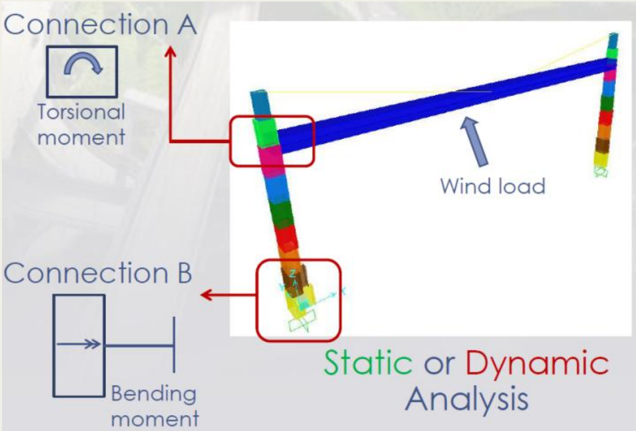
The PANOPTIS project

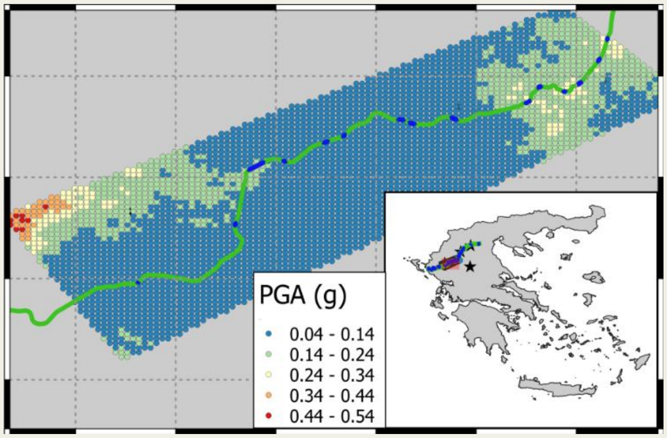
The PANOPTIS Horizon 2020 project started in June 2018 comprising 14 partners from the industry and academia. It aims to improve the resilience (ability to adapt) of road infrastructures and ensure reliable network availability under unfavorable conditions, such as extreme weather, landslides, and earthquakes. It combines down-scaled climate change scenarios, structural and geotechnical simulation tools, and online data from sensors (terrestrial and airborne) to provide the operators with an integrated tool able to support effective management of their infrastructures at the planning, maintenance and operation level. The following technologies are implemented in the PANOPTIS tool:

– Reliable quantification of climatic, hydrological and atmospheric stressors
– Multi-Hazard vulnerability modules and assessment toolkit
– Development of a forecasting module to provide high-resolution tailored weather and precipitation forecasts
– Improved assessment of structural and geotechnical safety risk
– Improved multi-temporal, multi-sensor observations with robust spectral analysis, computer vision and machine-learning damage diagnostics for diverse road infrastructure systems
– Detailed and wide area transport asset mapping, integrating state-of-the-art mobile mapping and making use of UAV technology
– Design of a Holistic Resilience Assessment Platform
– Design of a Common Operational Picture including a Decision Support System, an enhanced visualization interface and an Incident Management System.

ISS participates in PANOPTIS with doctoral candidates Akrivi Chatzidaki, Katerina Ntaifoti, Zacharias Fasoulakis, Dimitrios Bilionis, and faculty members Dr. D. Vamvatsikos and Dr. C. Gantes.

by Dimitrios Vamvatsikos





PANOPTiS

Contributions to code development

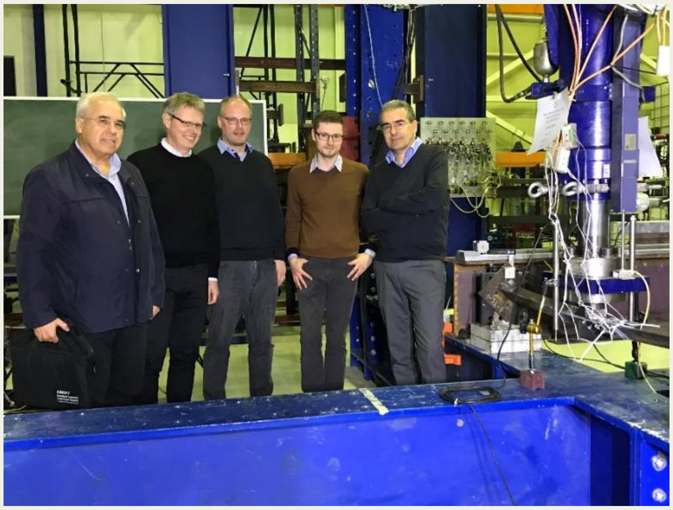
In 1975, the Commission of the European Community decided on an action program in the field of construction based on Article 95 of the Treaty of Rome. The objective of the program was the elimination of technical obstacles to trade and the harmonization of technical specifications. For 15 years, the Commission, with the help of a steering committee containing representatives of EU member states, oversaw the development of the Eurocodes program, which led to the publication of an initial set of European codes in the 1980s.

The Structural Eurocodes were first available as European pre-standards (ENVs) and then converted to the full European standards (ENs). Publication of each of the various EN Eurocode Parts started in 2002 and was completed in 2006, for adoption by the CEN members. Full implementation of this first generation of EN Eurocodes took place in 2010.

In December 2012, through Mandate M/515, the European Commission initiated the development of the so-called 2nd generation of Eurocodes. The revised standards incorporate new performance requirements and design methods, introduce a more user-friendly approach, represent an increased level of international consensus, and are accompanied by a series of background documents.

In December 2015, the European Commission confirmed funding for Phase 1 of the CEN/TC 250 work program under Mandate M/515. In January 2017 and January 2018, the European Commission confirmed funding for Phase 2 and Phases 3 and 4, respectively. Through an open call for experts, Project Teams were established to undertake the specific tasks in M/515 Phases 1 to 4. Their work is on-going.

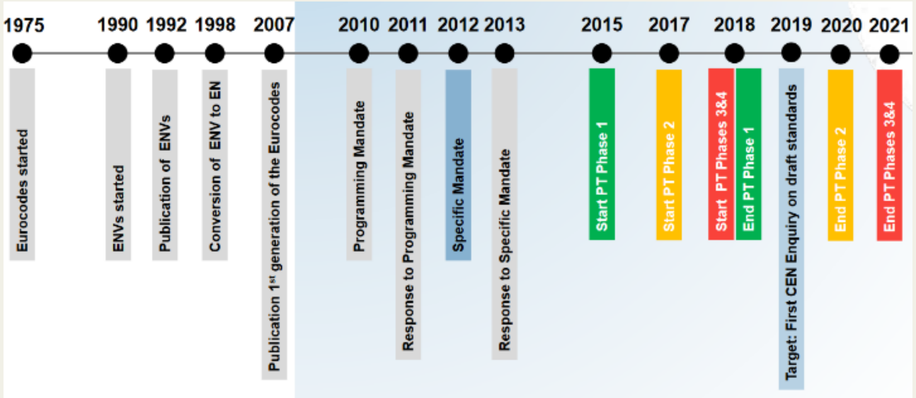
NTUA's Institute of Steel Structures is actively involved in this process, at a European as well as a national level. Prof. Gantes participated in Project Team SC3/T1 of EN1993-1-1 (Part 1-1 of Eurocode 3), General rules and rules for buildings. He is now member of Project Team SC3/T11 of EN1993-3 (Part 3 of Eurocode 3), Masts, towers and chimneys - Consolidation and rationalisation of EN 1993-3. Prof. Vamvatsikos is member of Project Team SC8/T5 of EN1998-4 and EN1998-6 (Parts 4 and 6 of Eurocode 8), Silos, tanks and pipelines - Towers, masts and chimneys.



Project team SC3-T11 meeting at ISS-NTUA

Professors Vayas, Gantes and Thanopoulos are members of the Greek mirror Committee of CEN/TC250, ELOT/TE67 Committee on "Eurocodes". Prof. Gantes is Coordinator of this mirror Committee and representative of Greece in Committee CEN/TC250/SC3 for Eurocode 3 of the European Committee for Standardization, CEN.

by Charis Gantes



Time frame for development of 2nd generation of Eurocodes

Student term projects

Every year, the 7th semester structural engineering students undertake a group design project as part of the Steel Structures II course.

For 2020-2021 this regards the design of a 4-floor steel building, used as car parking facility. The building is situated in a 40 m by 30 m site in Athens. Because of limited space, elevators are used to move vehicles among floors. The goal is to provide a safe structure that maximizes parking spots.

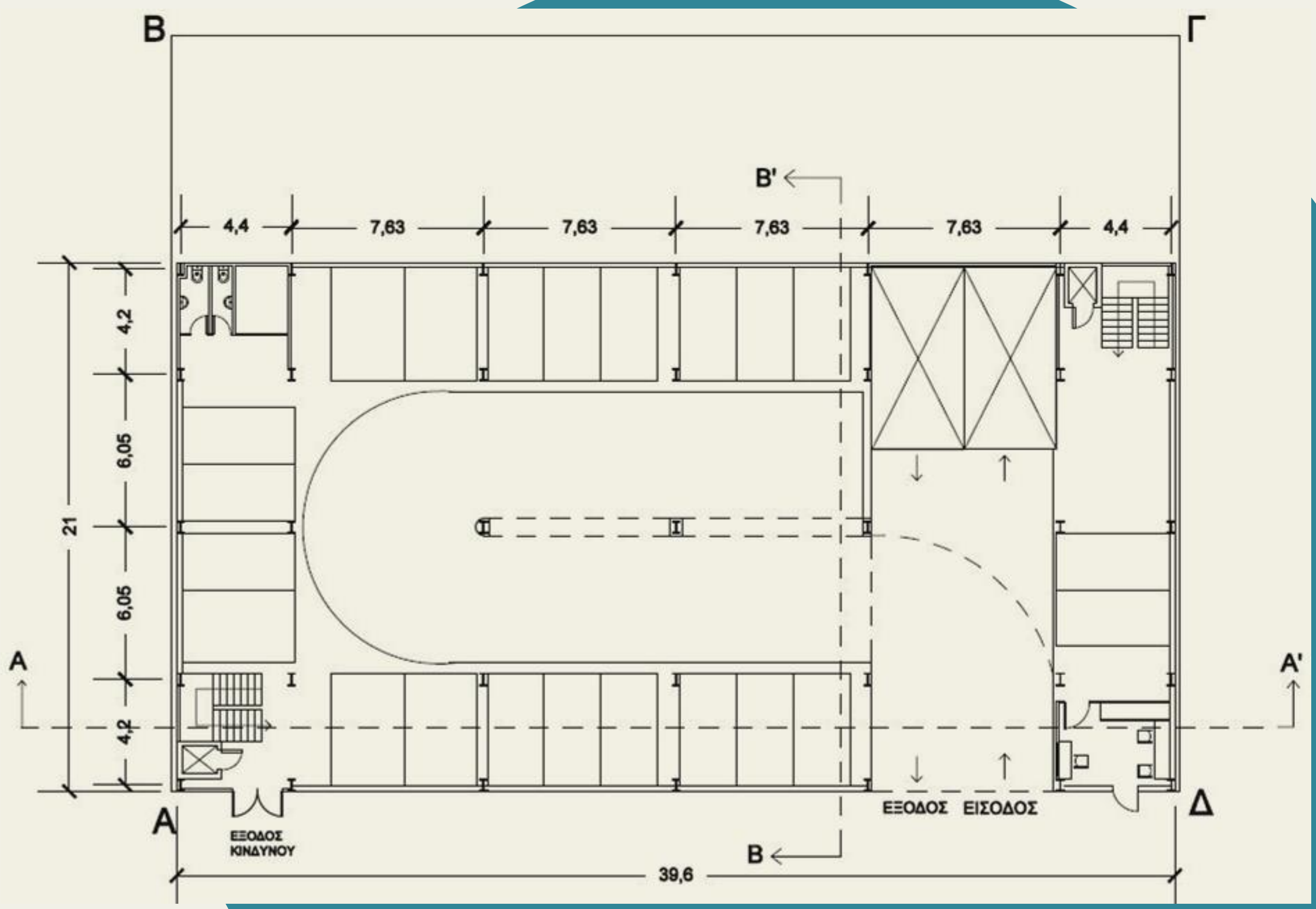
Each team presents its own proposal on the architectural and structural design of the facility, designating car parking spots, car circulation corridors, car elevators, staircases, transit office space, common areas and sizing beams, columns braces, typical connections etc.

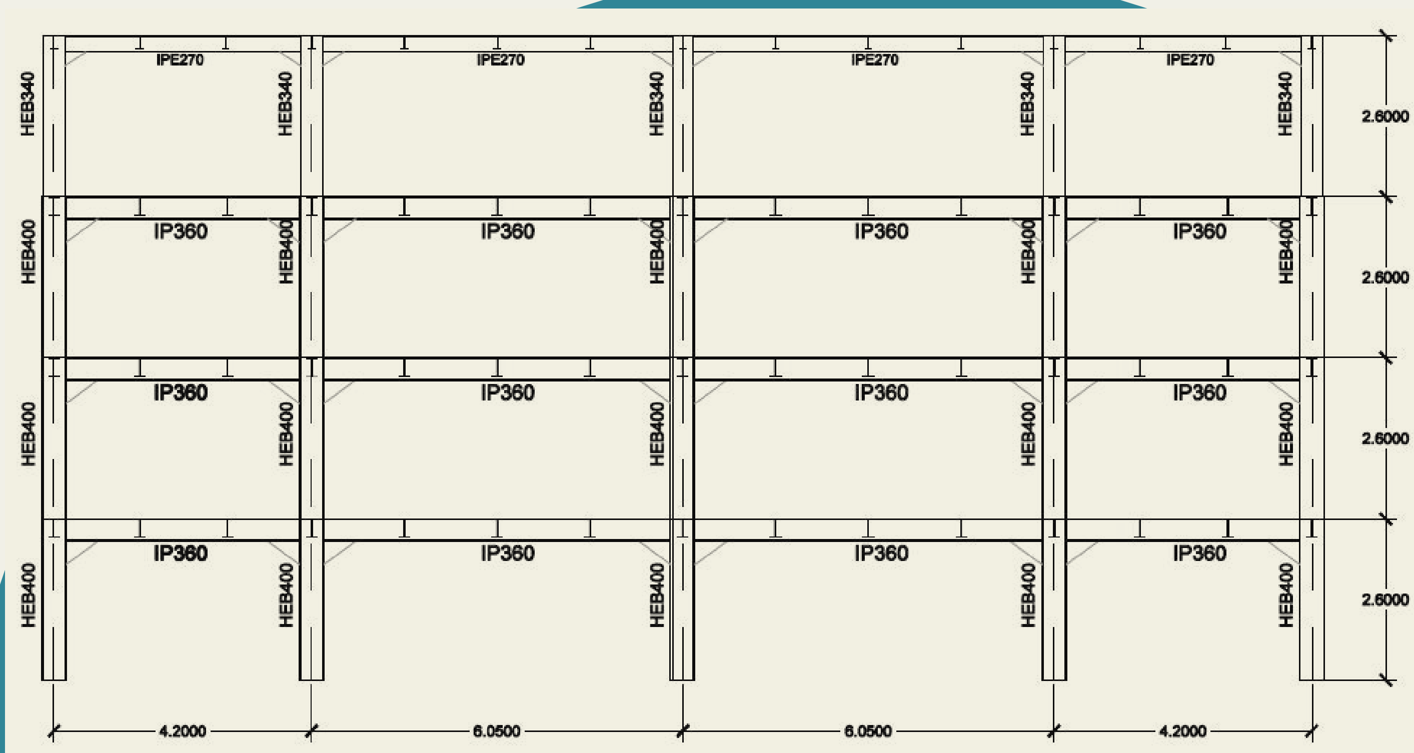
Each team shall deliver the following:

1. Architectural plans (layout, elevation, sections)
2. Structural models with appropriate loads and boundary conditions for the analysis and dimensioning of the main parts of the structure
3. Deflection plots, axial force, shear force and bending moment diagrams
4. Selection and verification of sections for main structural members
5. Design of main connections
6. General structural plans (layout, sections)
7. Typical detail plans

Some characteristic drawings by Anastasia Panopoulou and Vassiliki Panou are shown as an example of the level of the students' work.

by Tassos Avraam

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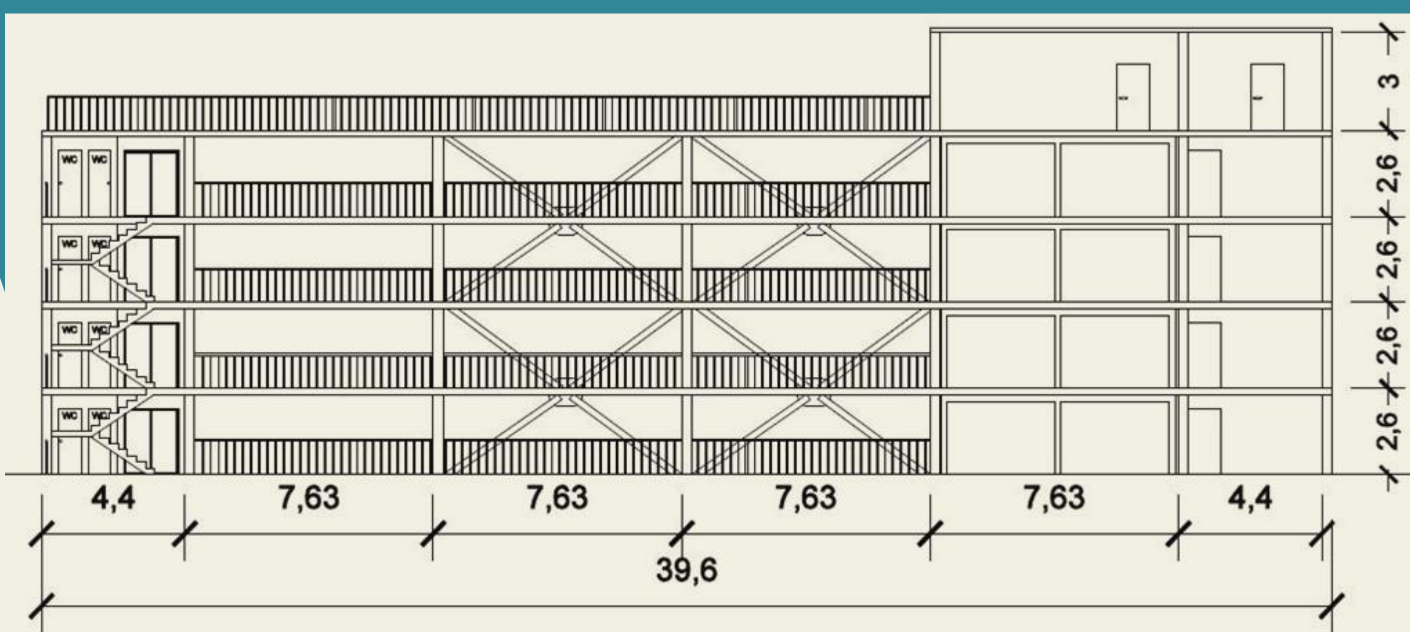
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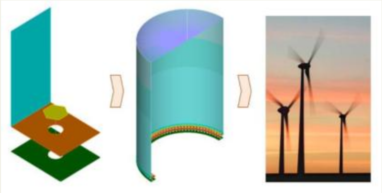
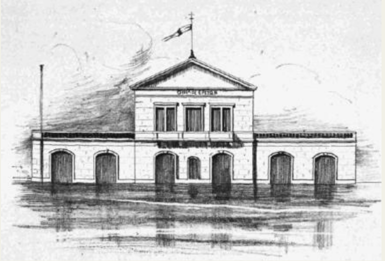
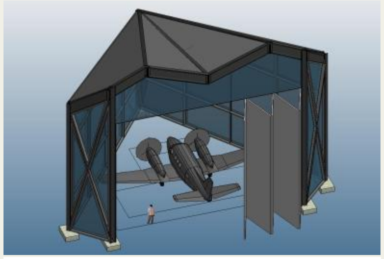
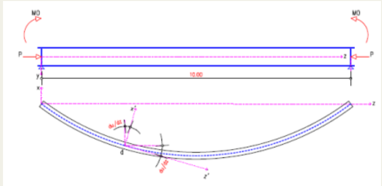
Recently completed diploma and graduate theses

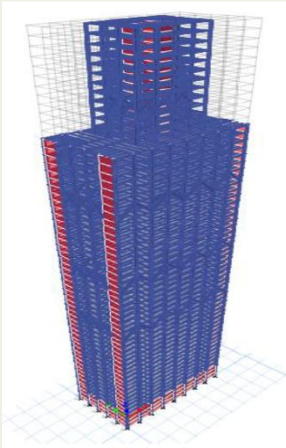
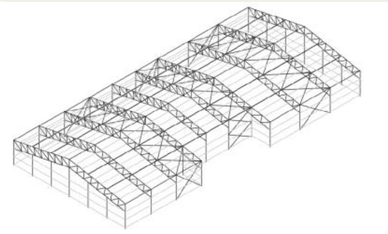



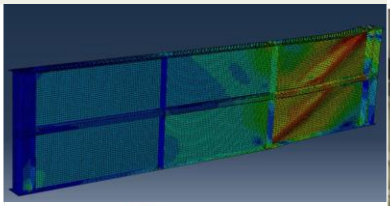
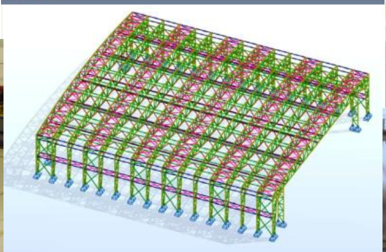
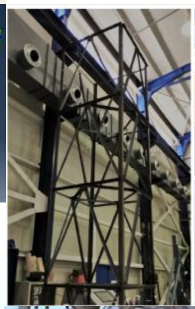
More than 40 diploma and graduate theses have been completed in 2020, ranking the Institute of Steel Structures among the top choices of graduate and post-graduate students in the School of Civil Engineering. Despite the restrictions enforced due to the COVID-19 pandemic, the supervision and examination of the theses were carried out with cheering success. The theses were of great quality and originality, covering a vast range of topics:

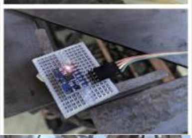

- Design and seismic risk assessment according to the Eurocodes
- Design of energy efficient buildings
- Design of industrial buildings or large-span roofs
- Design of pedestrian and road bridges
- Design of residential and office buildings
- Design of tall buildings
- Design of warehouse with cold formed steel sections
- Experimental and numerical investigation of steel members' and joints' behaviour
- Experimental estimation of eigenfrequencies
- Investigation of connections in tubular wind turbine towers
- Lateral bucking of bending beams by numerical methods
- Assessment, strengthening and rehabilitation of existing buildings
- Buckling design through Finite Element Analysis
- Modern surveying methods in BIM technology environment
- Response of steel panels under blast loading

by Pavlos Thanopoulos

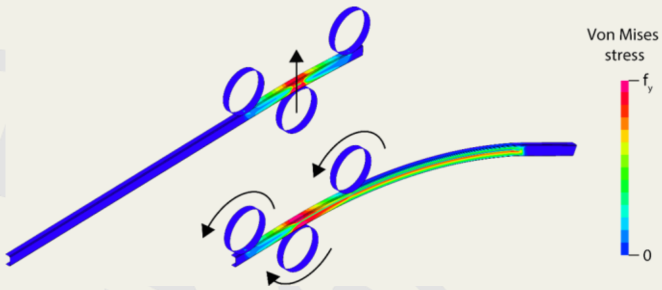





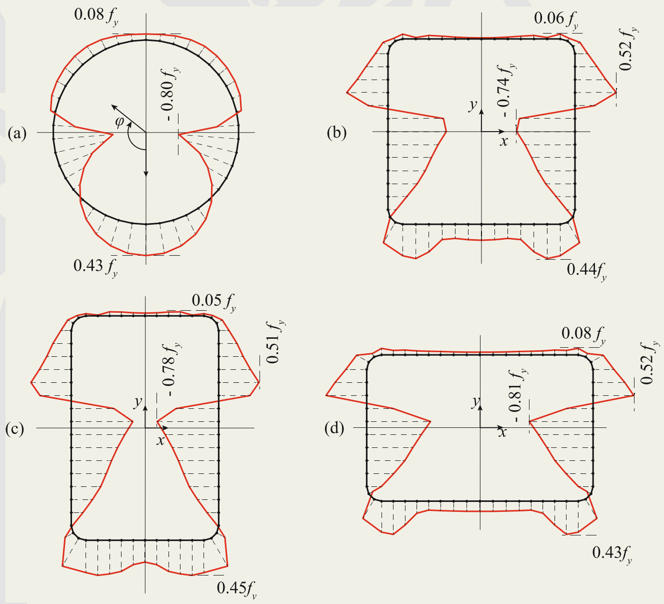

PhD Defense of Ilias Thanasoulas

Gaining insight into the structural stability of steel arches has been objective of the Institute's research efforts throughout recent years. In the beginning of 2020, **Ilias Thanasoulas** successfully defended his PhD dissertation "**Stability Criteria for Hollow-Section Steel Arches"**. In this work a combined experimental, numerical, and analytical approach was implemented to assess the behavior of roller-bent arches.



Numerical modeling of roller bending process

Steel arches are typically manufactured from initially straight members. The roller-bending process is the most commonly used fabrication method for curving constructional steel members. It is a cold-forming process, in which a workpiece is passed iteratively through a three-roller-bending machine. Residual stresses along with significant plastic deformations are induced during cold-forming, affecting the structural behavior.



Residual stress distributions

The contribution of this work to the advancement of engineering science included the presentation of experimental and numerical results on steel arches, the development of sophisticated numerical models of the cold-curving process, the proposal of residual stress models for roller-bent hollow sections, and the formulation of proposed design rules in terms of appropriate buckling curves for hollow-section steel arches. The proposed residual stress distributions are very useful for analysts in the constructional steel research, while, the proposed buckling curves can be reliably implemented in the structural design practice, in compliance with modern structural design standards. Findings also revealed that the "*Bauschinger*" and "*Strain Aging"* effects significantly affect the structural behavior of roller-bent arches.

Shortly after defending his thesis, Ilias started as industrial postdoc researcher in Copenhagen, Denmark, working in collaboration with the Danish Institute of Fire and Security Technology (GTS Institute) and the Denmark Technical University (DTU).

PhD Defense of Stella Avgerinou

In June 2020, Stella Avgerinou successfully defended her PhD dissertation **"Investigation of the Application of High-Strength Steel in Dissipative Elements**".

Production of HSS is the result of significant improvements in steel making technologies regarding metallurgy, rolling and heat treatment processes, achieved in the last decades. The structural application of HSS may reduce member sizes and workload of transportation and construction, thus providing significant economic, environmental and architectural advantages. However, its application is still limited, while its relevance to seismic design is currently under discussion.

This thesis investigated experimentally and numerically the possible application of HSS in the dissipative elements of the innovative FUSEIS system. FUSEIS consists of a pair of closely spaced strong columns rigidly connected via multiple dissipative links which may be beams or pins. An important advantage of FUSEIS is repairability: in case of a strong earthquake damage is concentrated in the replaceable links, protecting the rest structural members.

The experimental investigations included large-scale cyclic tests on FUSEIS systems consisting of different types of links (HEA beams, SHS beams and circular pins) and steel grades (S355, S500, S700), conducted at the National Technical University of Athens. The tested systems were simulated via different models with increasing complexity and suggestions were given in order to approximate their response.

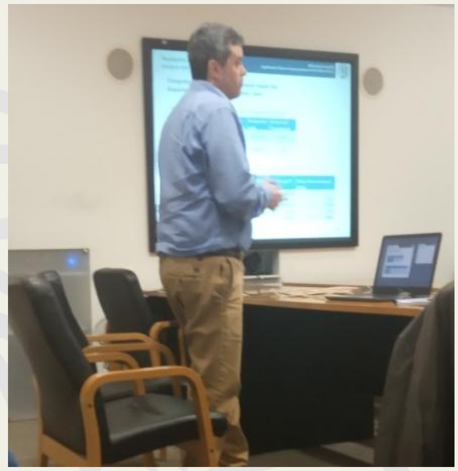
Eventually, two building case studies including FUSEIS systems with S700 beam links were designed to comply with Eurocode's requirements, although the application of HSS in dissipative members is not currently allowed. The case studies were subjected to performance-based evaluation via Incremental Dynamic Analysis, while considering the response of their most critical components. Simulation of material non-linearity in the dissipative elements was based on the aforementioned test calibration. Given that the seismic design of buildings is governed by stiffness demands, the specific application of HSS could not fully benefit from the material's advantages. Finally, the models were assessed at two limit states following two different methodologies, both of which result in the acceptance of their design q-factor (equal to 3.5).

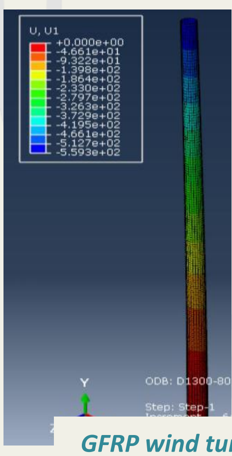
Overall, the objective of this study was to explore whether the hysteretic behavior of HSS can be sufficient for dissipative zones, rather than comparing it to conventional steels. Experimental and numerical investigations provided encouraging results although further investigations is required. The tested systems exhibited satisfactory response, although their ductility decreased with yield strength. However, it should be noted that the specific application of HSS in FUSEIS dissipative members did not seem to provide financial incentives. Viable applications of HSS in seismic resistant systems would probably have to involve a combination of conventional and high-strength steel subsystems to account for stiffness demands or be established in low-seismicity regions.

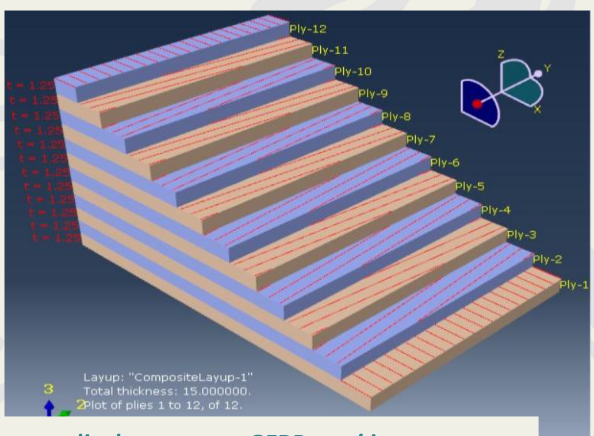
PhD Defense of Thomas Altanopoulos

in February 2020 Thomas Altanopoulos successfully defended his PhD Thesis **“Design of Wind Turbine Towers Made of Composite Materials**”. Objective of the dissertation was to investigate the structural behavior and to develop a design approach for wind turbine towers made of GFRP. In order to achieve this goal, the following procedures were executed: a) Experimental investigation of the mechanical properties of GFRP materials and comparison between experimental and analytical results; b) Experimental investigation of the structural behavior of tapered GFRP poles and calibration of a FEA model; c) Parametric analyses regarding the geometry of GFRP towers and the stacking sequence of the composite material; d) Design of a GFRP tower to support a 30kW wind turbine and comparison with an equivalent steel tower.

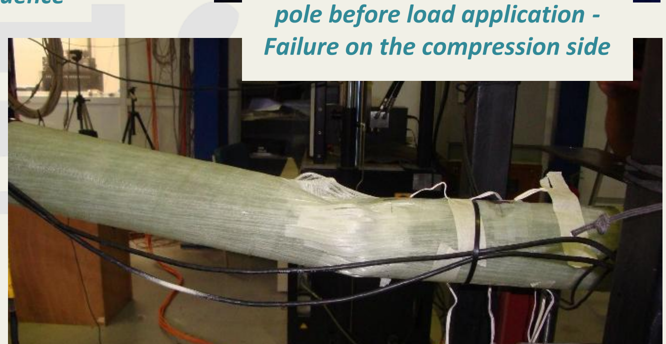
The dissertation offered ample evidence that mechanics-based approach for composite materials is a viable alternative to testing of GFRP specimens. Still, the influence of the geometry of a GFRP tapered tower was shown to be crucial, affecting its mass and critical tip deflection. Actually, an increase in the number of layers with fibers oriented along the longitudinal direction leads to a reduction of the tip deflection, while circumferentially oriented layers help avoid local failures. Finally, the comparison between the towers made of steel and GFRP showed that composite materials can be an excellent and fairly cost-effective alternative.



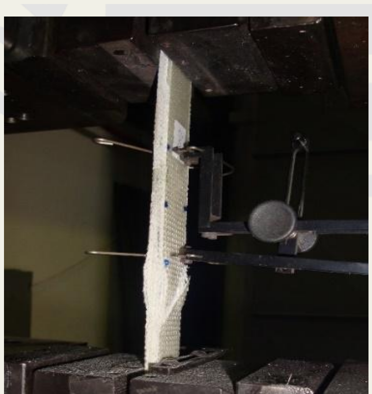




GFRP wind turbine tower displacements - GFRP stacking sequence



Experimental GFRP pole before load application - Failure on the compression side



Coupon with+/-45° fiber orientation before and after testing

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