Kipoi Compressor Station – Case Study

Kipoi Compressor Station, Support Steelwork (30m tall flue support for critical infrastructure in a seismic region). Located in Kipoi, Evros region, Greece - part of the Trans-Adriatic Pipeline

Client: Cullum Detuners

Cost: £2,000,000.

The Trans-Adriatic Pipeline (TAP) is a natural gas pipeline nearly 900km long, currently under construction in southern Europe. GCA Consulting was engaged by Cullum Detuners to undertake the design of five structures at the Kipoi Compressor in Northern Greece, a key part of the pipeline's route into Europe. These structures support a ventilation exhaust, a runway beam and an oil coalescer, as well as a combustion intake filter, a ventilation intake filter and a combustion exhaust flue. The flue offered the most significant challenge, as it comprised a slender structure at over 30m high with a 4x4m footprint.

Seismic forces were calculated to exert lateral loads on the tower of 50 tonnes, and as part of critical national infrastructure the tower had to withstand such loads whilst still meeting serviceability requirements (with limited permitted deflections). The design was complicated by the requirement for open zones along its height for heat recovery and maintenance access. This interrupted the diagonal bracing system and required Vierendeel action. A detailed assessment of the dynamic behaviour of the combined steelwork and flue was required to capture its response to seismic loads.

Due the international nature of the project and its high importance as a critical energy project, the design specification was set at a very high level, and prompt delivery was of paramount importance. GCA operated within a demanding framework to develop and deliver a structural design that was both interesting (being outside the conventional UK scope) and challenging due to its complexity, the coordination required and level of scrutiny that was subjected to.

Coventry and Solihull Waste Disposal Company (CSWDC)

Fin Fan Coolers

- **Alterations to an existing industrial building**
- **Tight timescales and budgets**
- **£1.1 million project cost**

CSWDC required three new 20 ton Fin Fan Coolers to be located on top of the fragile, lightly loaded roof of the existing Furnace Hall at their site in Coventry. The tight timescales and budget, complex existing structure, and coordination of multiple stakeholders made this an exciting engineering challenge.

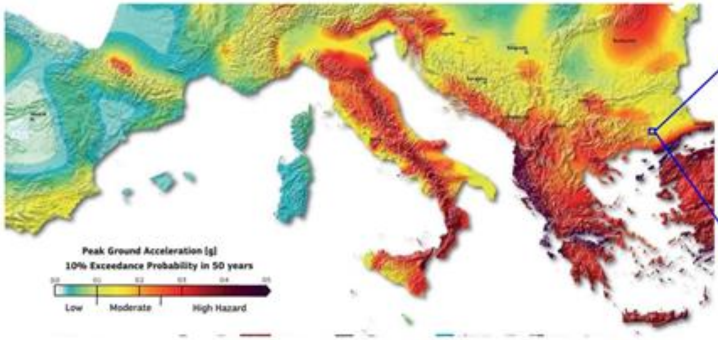
GCA undertook a rigorous options appraisal considering time constraints, construction cost, safety, and available space on site. It was determined that the most viable solution was to prove that the existing substructure and superstructure had sufficient capacity to support the new plant on the roof of the Furnace Hall, and carry out the design of a new steel subframe to transfer the loads to the Furnace Hall. This proposal was approved by the client.

GCA collaborated closely with the client, geotechnical engineer, and steel fabricator to produce a design which took into account the projects many constraints and requirements.

With GCA's rigorous attention to detail and considered risk mitigation a solution was provided at half the original predicted cost whilst keeping to the original program. The final scheme also significantly reduced the additional steelwork required in comparison to constructing an entirely new frame supported from ground level, making it an environmentally conscious solution.

For more details of the project, see our winning IStructE Midland Counties award entry.

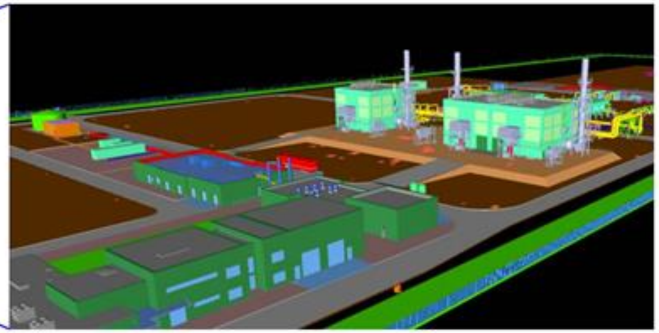
The Kipoi Station



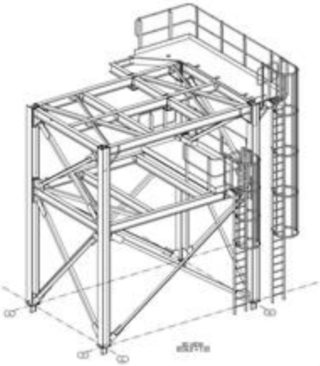
Ground Acceleration Map

Code requirement: 0.16g
Design requirement: 0.52g

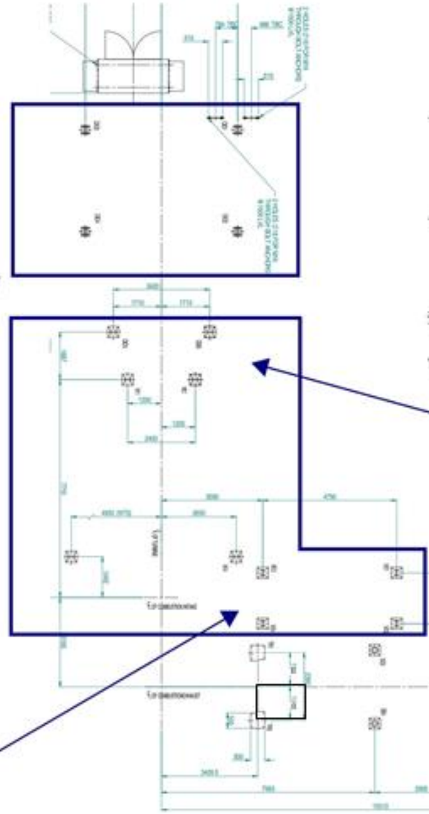
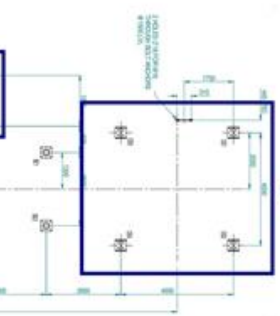
Location of the Kipoi Station site



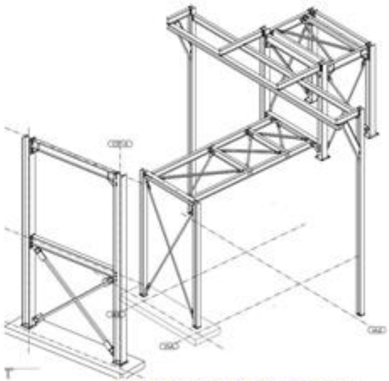
Kipoi Station render view showing the three flues



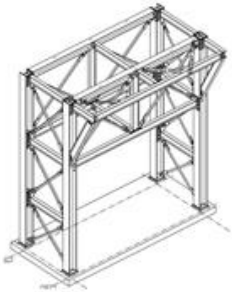
Combustion Intake Steelwork (outdoors)

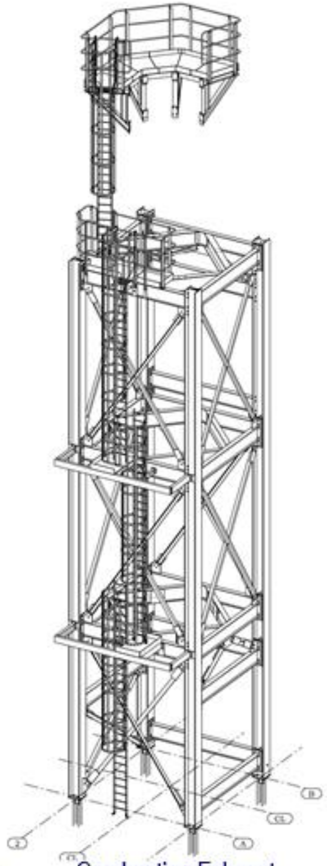
Plan layout showing location of steel structures



Combustion Intake Portal and Ventilation Intake Portal (indoors)



Combustion Exhaust Steelwork (indoors)



Combustion Exhaust Steelwork (outdoors)

Kipoi Compressor Station – Design Challenges

The Kipoi site lies within a high-seismicity region. The brief required the structure to be able to withstand a 2475-year return seismic event, which corresponds to a ground acceleration of 0.52g (3 times larger than the value stated in the Greek National Annex).

GCA rapidly developed our understanding of the requirements for seismic analysis and design within the time constraints given and delivered a structural design which met both the client's requirements and the supply chain's rigorous checking processes. GCA undertook thorough research into local codes and design methods, translated the Greek National Annexes in-house and developed expertise in the relevant 3D dynamic analysis methods. The acquired knowledge was directed towards producing a rigorous design, supporting the client and resolving efficiently issues that appeared during the design and construction phase.

GCA performed two methods of analysis, escalating as the project progressed from the static Lateral Force Method to full dynamic Modal Response Spectrum Analysis (MRSA) to capture the complex behaviour of the flue support towers. This enhanced the client's confidence and ensured approval through the checking process. In addition, GCA developed a detailed analysis scope describing the methodology, assumptions and parameters used in the calculations.

This statement was issued through the supply chain to the checking engineers early in the design process to ensure the parameters for design were agreed before detailed work was undertaken, This sped up the review and checking process at the later, time- critical parts of the project.

In addition to the seismic loads the outdoor structures were required to resist winds of up to 60mph and temperatures down to - 20°C. GCA undertook detailed calculations of the wind effects on the unclad structures, the exposed ducting and the cylindrical flues and determined appropriate steel sub-grades for the given design temperatures.

GCA worked with numerous international stakeholders, and engaged with all involved team members to:

1. Design a significant structure to support critical infrastructure in a seismically active region.
2. Eliminate areas of ambiguity in the design brief e.g. the definition of the Importance Factor for seismic analysis.
3. Work with the full team to agree practical conclusions for the correct consequence and execution classes.
4. Be proactive in pushing the programme forward by providing options and solutions during the design and construction phase (e.g. anchoring options for the flue tower and temporary support design for installation).

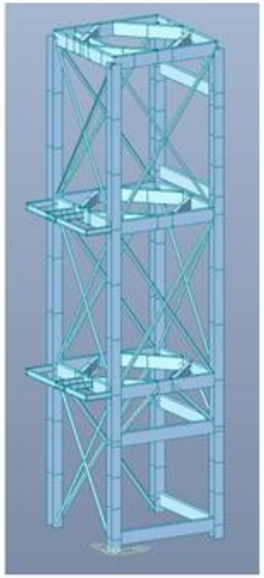
Kipoi Compressor Station – Conclusions

Following approval of the Kipoi station steelwork the design was used as a 'blueprint' for another TAP compressor station in western Albania. The construction of the Kipoi station is in progress and the first flue support tower has been successfully installed on site.

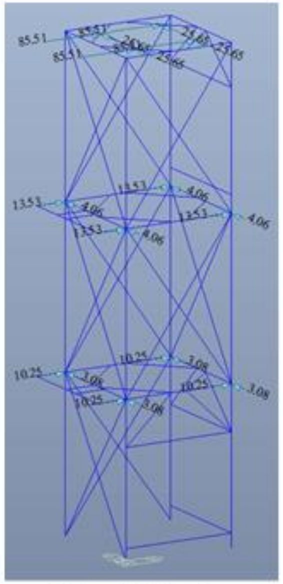
The Analysis

Lateral Force Method

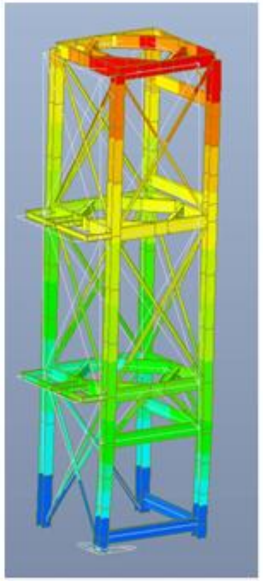
Initial analysis of the flue support tower was performed by the Lateral Force Method. The seismic loads were calculated separately and applied as static point loads at nodes.



Model



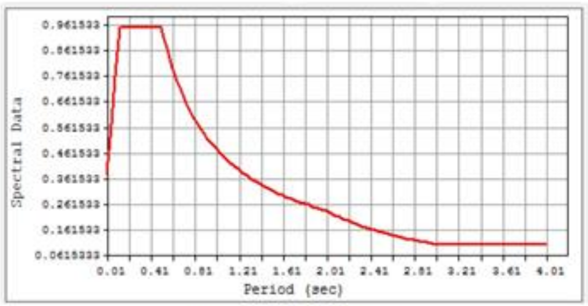
Seismic X: Loads



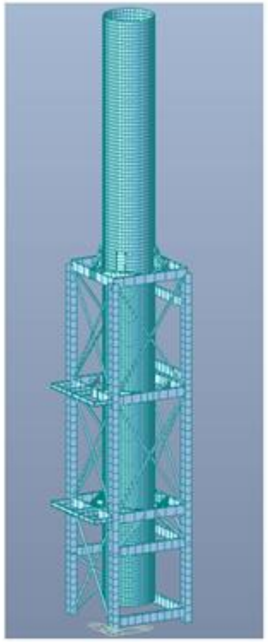
Seismic X: Deformation

Modal Response Spectrum Analysis Method

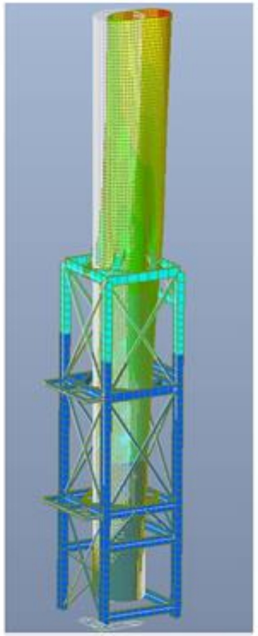
Flue support tower modelled for the Modal Response Spectrum Analysis method. A combined system was used for the steelwork and the flue. The method captures the complex response of the structure due to dynamic loads and statistically sums the peak responses. The 20 first modes of vibration was considered in the analysis. The flue was modelled as a 6mm thick shell comprising plate elements and its mass adjusted to equates the combined mass of the exhaust (outer steel, insulation, inner liner)



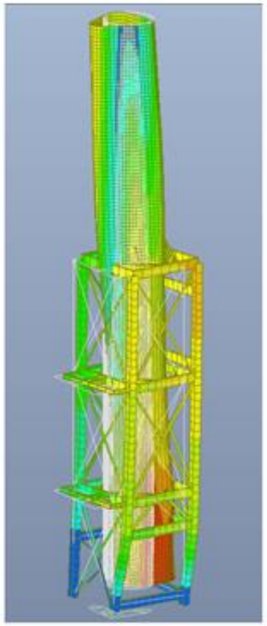
Design Spectrum Graph



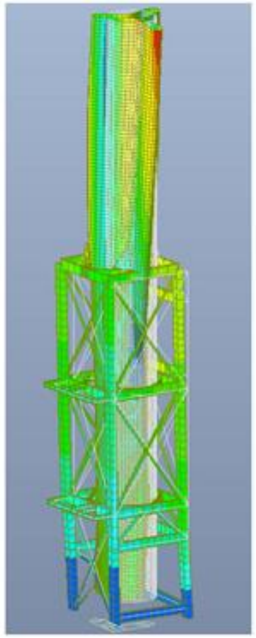
Model



Mode 1

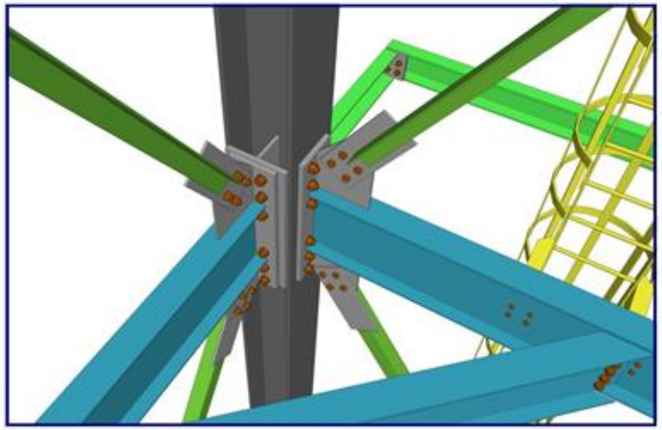


Mode 6

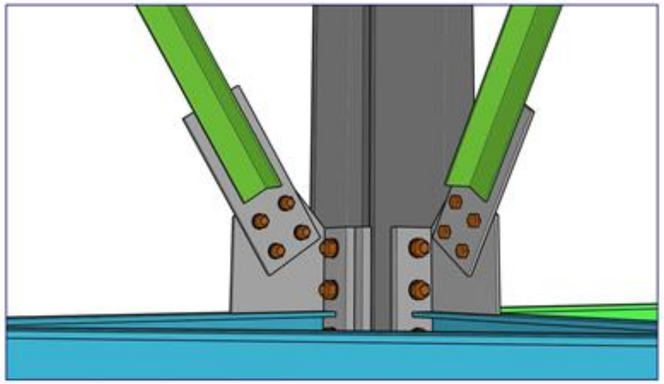


Mode 7

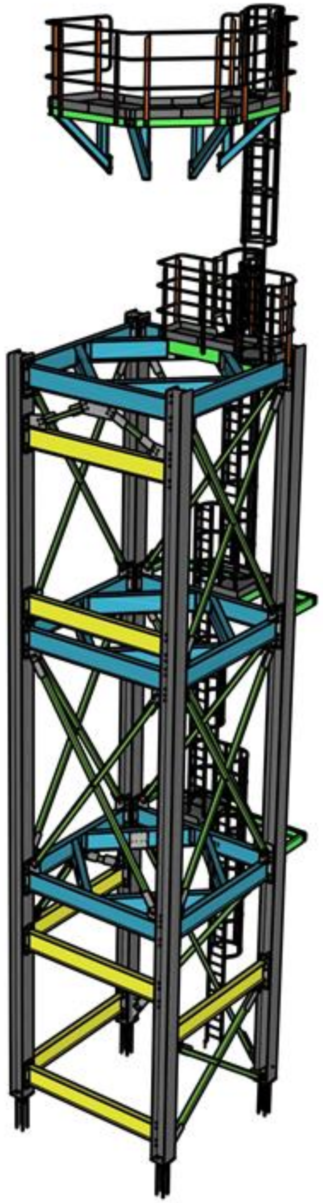
The Design

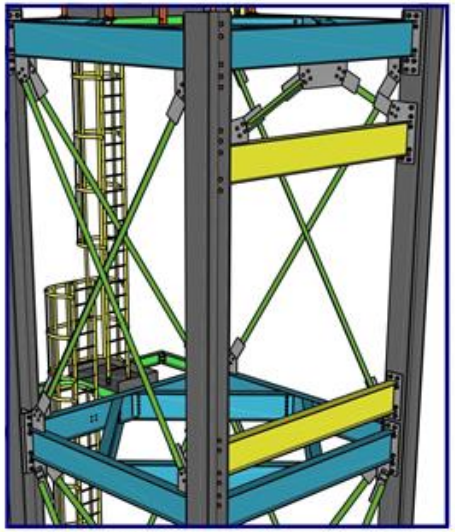


A combined system of moment resisting connections and diagonal bracing was used to provide the required stiffness to the structure and reduce lateral deformations

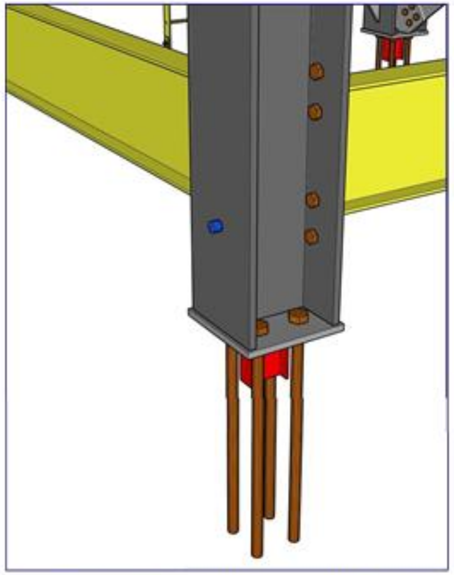


Welded steel plates to RSAs were specified to benefit from full tensile capacity of the bracing. The central axis of the RSAs was aligned with the of that of the plates to eliminate eccentricities.





A number of open zones were required for future heat recovery, and maintenance access. Moment frame beams were added to introduce Vierendeel action and restore the stiffness of the bays.



Column base plates designed as nominally pinned to be consistent to the analysis model. Shear keys were added to resist base shear

The Installation