TEMPORARY MODIFICATION OF THE STRUCTURAL SYSTEM OF EXISTING BRIDGE IN LONDON

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1. SUMMARY

During the "North Wharf – Paddington" project, Erith Contractors have been asked to accomplish the partial demolition and support modification of an existing bridge. Reason for the requested modification has been the pile rig access as close as possible to the bridge abutment and the construction of the designed permanent secant pile wall of the development.

Swanton Consulting – part of Erith Group – designed the structural modification of the bridge frame utilising composite columns, as well as the temporary foundation of the supports.

2. INTRODUCTION

The development site is located on 65 North Wharf road – the bridge itself projects across the Grand Union Canal and the western abutment lies on a pedestrian walkway serving Paddington station (Heathrow Express).

It is a statically independent part of an existing building complex that has been fully demolished.

There have been no archive drawings or any other relevant structural information available– an estimated date of construction between 1960-1970 was provided by ARUP London.

Basic requirement of the developers was that at all stages of the project, the canal traffic and the access to the station could not be obstructed.

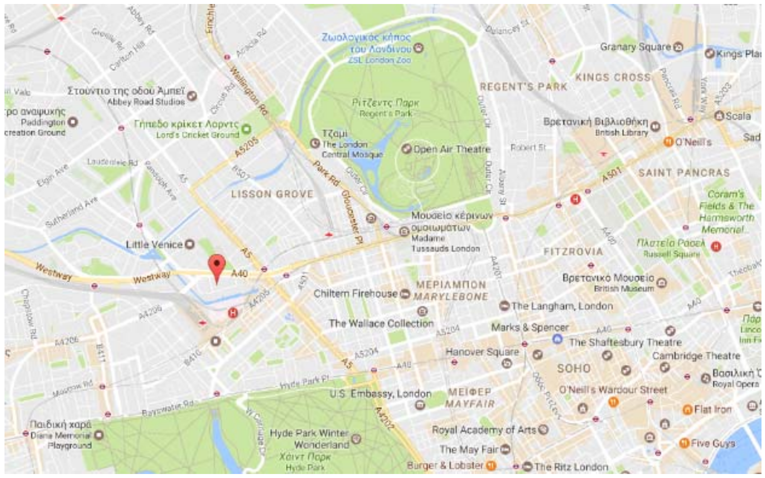


Fig. 1 Map location of the site

3. EXISTING STRUCTURE

The bridge frame was constructed by reinforced concrete, spanning 18,00 m above Grand Union Canal.

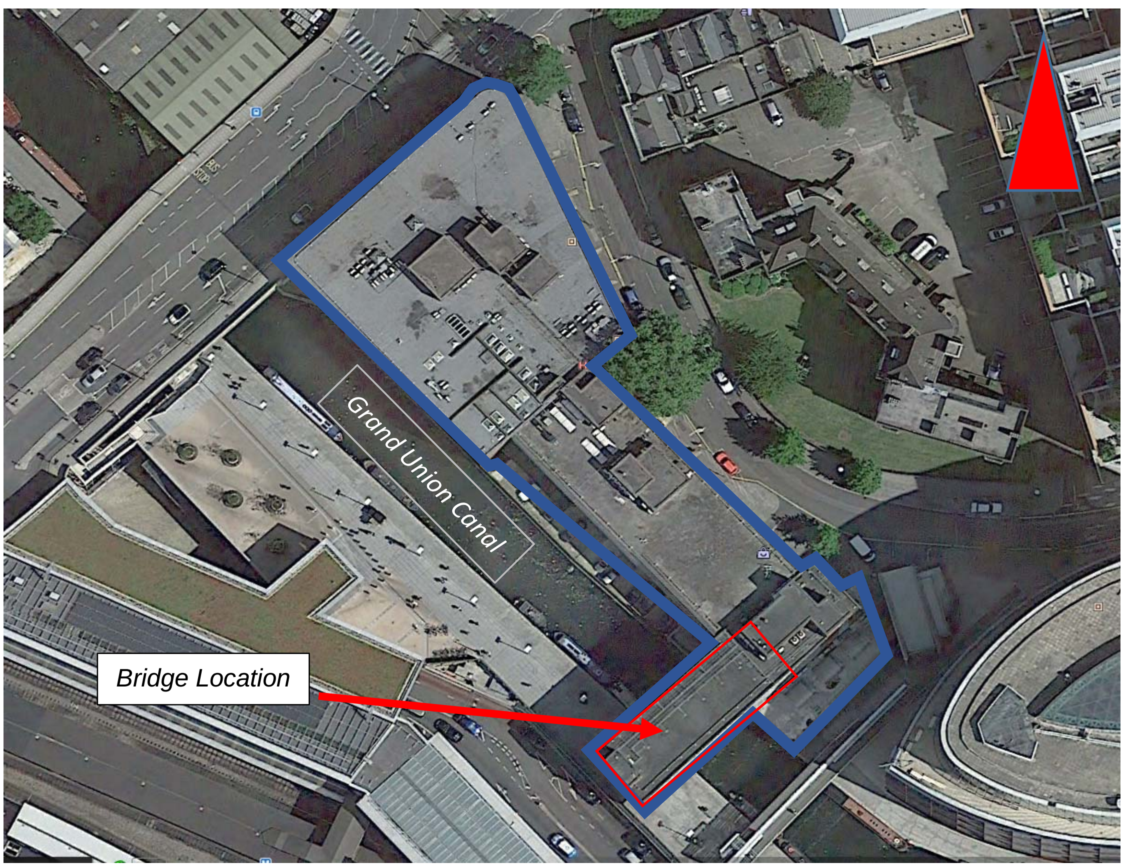


Fig. 2 Aerial View of the Site

Ferro-scanning and site investigations were performed, so as to expose and verify the structural components – without providing sufficient information.
Structural Element description:

Main Beams (2 No): tapered concrete section with unknown steel section encased – no reinforcement present.
Secondary Beams: reinforced concrete sections – fully embedded at the main beams
Bridge deck: pre-cast concrete modular elements laid on the main beams
East side Vertical Supports: Reinforced concrete columns (to remain for the temporary condition). The concrete core that can be seen in Fig.3 had a cold joint with the beams – so pinned connection has been considered.
West side Vertical Supports: Reinforced concrete columns (to be replaced with new support system and demolished afterwards).

- *Storeys to be demolished*
- *Deck, beams and columns to remain and be used as platform to accommodate site office and welfare*

Fig. 3 Existing Structure South Elevation

Purpose of the bridge structure was to support a three (3) storey building for commercial use.

4. DESIGN & CONSTRUCTION SCOPE

As part of the development, the building was to be demolished and a 4-storey welfare village to be installed, for the accommodation of the project offices and facilities.
On the same time, and driven by the tight schedule and a simultaneous task effort, the permanent contiguous wall on the East side was planned to be constructed.

The existing bridge supports as well as the cantilevering part of the deck, were obstructing the access of the pile rigs, not allowing them to operate.
For this obstacle to be removed, it has been decided the supports of the bridge to be "translated" approximately 1,8 m westwards (adjacent to the canal retaining wall) and part of the deck to be demolished.

Hence, the design team had to face:

- Load modification/verification for the bridge transfer structure – 800 tonnes to be supported
- Verification for the adequacy of the existing bridge main and secondary beams, in order to transfer the new loads.
- Bridge structural system alteration
- Provision of new bridge abutment (taking into consideration the modified structural system)
- Safe transfer of the new abutment reactions to the ground. Responsible authority for the canals, Thames water, had instructed the new abutment reactions not to affect the canal wall.

Most importantly, the application of the proposed design had to be done in increased risk Health & Safety circumstances, considering people access to and from the station and boat traffic.

5. DESIGN CONCEPT

The design concept was separated in two interactive components:

- Structural analysis and design of the new support (columns), the stability of the modified structure and demolishing cantilevering part.
- Geotechnical analysis and design for the safe transfer of the "new" support loads to the ground level below the canal and limiting the settlements (in order not to induce additional moments due to relative displacements of the boundaries).

Fig. 4 3D Model of Design Concept

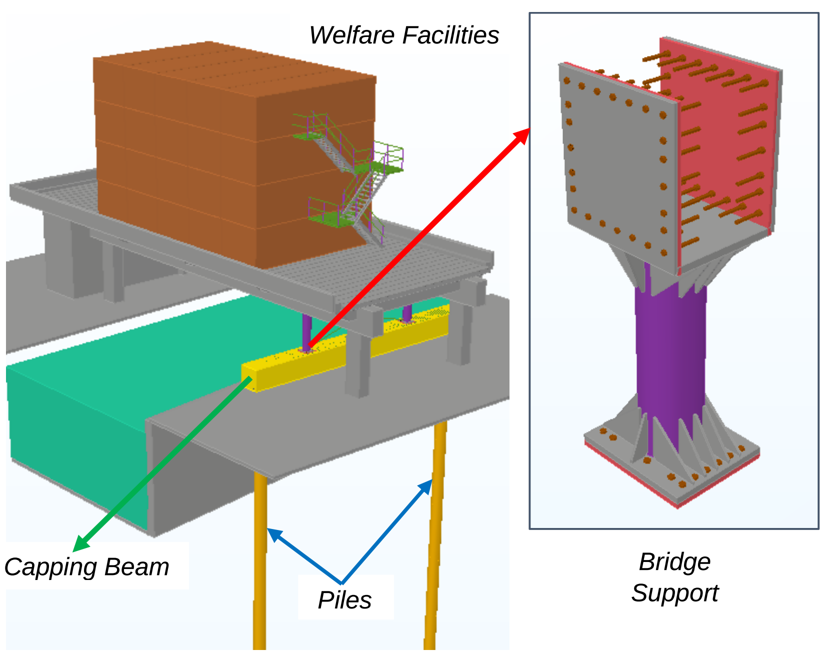
Structural analysis and design

Given the lack of any archive information available – as well as the unsatisfying scanning results, comparative structural analysis has been decided to be performed.

After the verification that the pre- and post- building demolition loading conditions where similar, a Finite Element model of the frame has been created in MIDAS Gen.

Linear analysis has been performed and stress and internal forces envelopes created.

Dealing with a statically indeterminate structure, we created a record of the de-facto



allowable element forces at the most onerous locations.

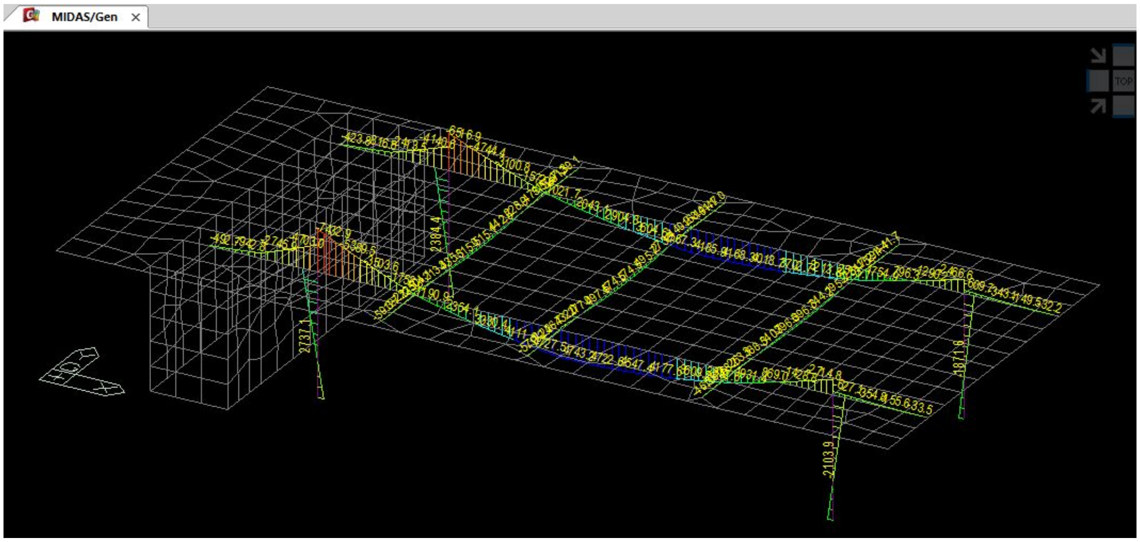


Fig. 5 Moment (Strong Axis) Diagram of Initial Stage

Then, the "modified" bridge frame was analysed and results were compared with the allowable ones – verifying that the sagging and hogging moments of the remaining structure were not exceeding the already operating ones – hence structure was stable and safe.

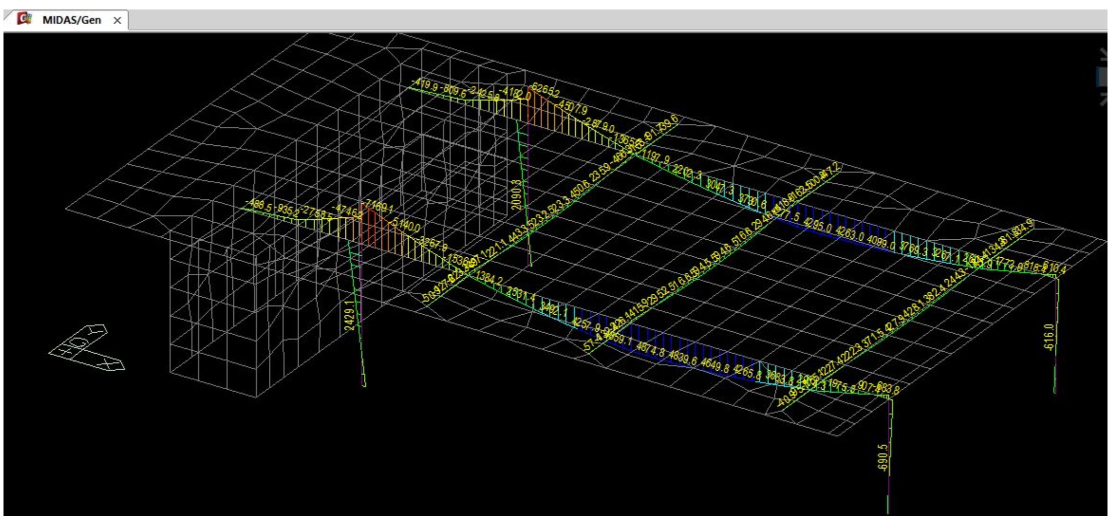
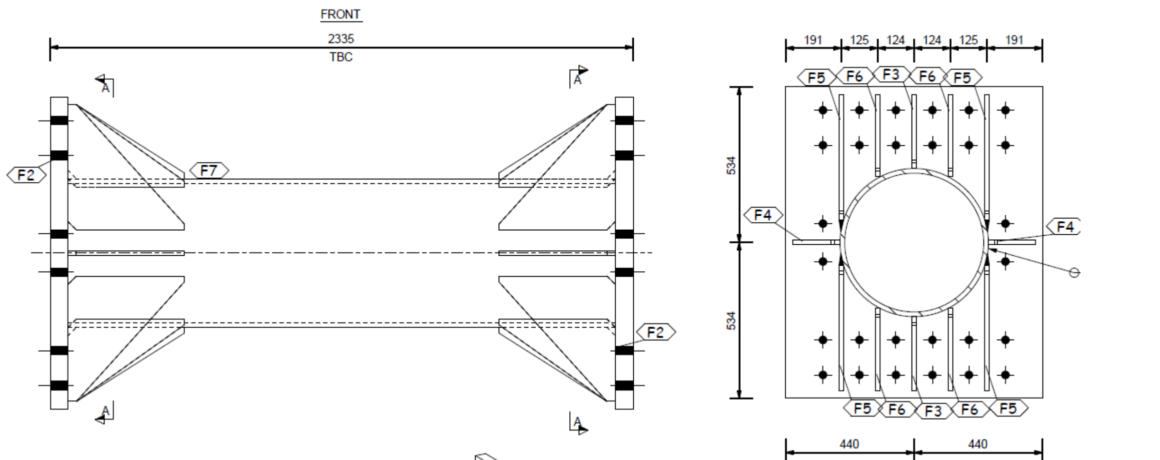
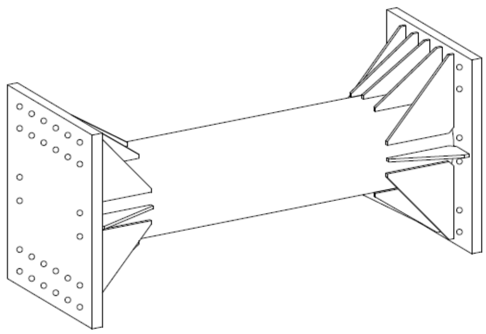


Fig. 6 Moment (Strong Axis) Diagram of Bridge after New Support Installation and Partial Demolition

The new supports were designed as composite columns as an adequate stiffness was required to accommodate the stress redistribution due to the structural system modification.





SHOP MATERIAL LIST FOR 1 ASSEMBLY						
Mark	Size	Grade	No.	Length (mm)	Area $(m)^2$	Weight (kg)
F2	PL880*60	S355	2	1068	4.227	885.3
F3	PLT16*253.8	S355	4	400	0.534	29.0
F4	PLT16*160.8	S355	4	400	0.366	19.0
F5	PLT16*400	S355	8	429	1.709	96.0
F6	PLT16*282.1	S355	8	400	1.171	64.2
F7	CHS508.0*16.0	S355	1	2215	3.557	428.2
				Total	11.564	1521.7

Fig. 7 New Support Composite Column

Geotechnical analysis and Design

The pile design is done as per Eurocode 3 and Eurocode 7 standards.

Due to the fact that the permanent secant piled wall was to be built in close proximity to the temporary piles an additional skin – friction reduction factor based on Converse – Labarre theory which takes into account the pile spacing, the number of rows and the total number of piles.

The selection of the diameter and the pile length design were done according to the loads derived from the structural analysis in ULS Design Combination 1 and in ULS Design Combination 2 as per Design Approach 1 as described in Eurocode 7. It is to be noted that in DC2 an additional 1.3 partial load factor (Υ_Q) was applied in order to compensate for any uncertainties regarding the imposed loading from existing structure and installed cabins and to limit predicted settlements to the lowest boundary by providing longer piles.

Taking into consideration the maximum predicted capping beam deflection at the middle due to imposed loading, the settlement of piles was limited below 12mm something which ultimately dictated the pile length and pile diameter design. The pile settlement analysis was predicted with closed-form solution by two different methods; the Fleming method and the Vardanega method, and the most conservative analysis was chosen mainly because of the sensitivity of the project on imposed settlements and induced strains.

The piles were designed as elements loaded mainly axially with bending moments at the pile head due to the intended moment connection with the capping beam in order to further limit the capping beam settlement at the middle. Additional shear forces and bending moments were induced in the design for the pile vertical and in-plan tolerances as provided by the piling sub-contractors. For the derivation of the design bending moments it was assumed that the top 2.0m of ground was not providing any lateral spring restraint.

6. CONCLUSIONS

With the design applied for the temporary bridge modification and the site based and engineering team coordination, project was completed safely, on time and in budget.
There was no traffic or access disruption for the neighbouring station and for the canal.
Total duration of the project (piles, capping beam, composite columns, wire cutting and demolition): **3 weeks**
Composite columns were loaded 2 days after concrete pouring (after laboratory concrete testing met with the design strength C30/37)

Fig. 8 Wire Cutting part of bridge to be demolished while boat crosses

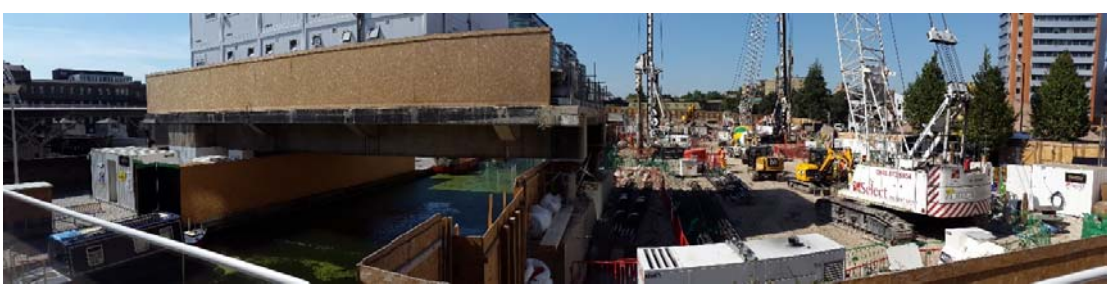


Fig. 9 Panoramic View of the Modified Bridge and The Site Preparing for Piling

ΑΛΛΑΓΗ ΣΤΑΤΙΚΗΣ ΛΕΙΤΟΥΡΓΙΑΣ ΥΦΙΣΤΑΜΕΝΗΣ ΓΕΦΥΡΑΣ

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1. ΠΕΡΙΛΗΨΗ

Κατά τη διάρκεια κατασκευής του έργου «North Wharf – Paddington» στο Λονδίνο, ζητήθηκε από την κατασκευάστρια εταιρεία Erith Group η μελέτη για την αλλαγή στατικού συστήματος υφιστάμενης γέφυρας. Σκοπός ήταν η τμηματική κατεδάφιση της γέφυρας – στήριξη σε όχθη καναλιού – ώστε να εξασφαλιστεί η πρόσβαση διατρητικών μηχανημάτων για την κατασκευή διαφραγματικού τοίχου και την συνέχεια των εργασιών.
Η πλατφόρμα της γέφυρας ήταν τμήμα τριόροφης κατασκευής η οποία κατεδαφίστηκε και στη θέση της οποίας τοποθετήθηκαν οι εργοταξιακές εγκαταστάσεις.
Σημαντικοί περιορισμοί έπρεπε να ληφθούν υπόψιν, όπως η απουσία αρχειακών στοιχείων για τον υφιστάμενο φορέα, το υποκείμενο κανάλι θα παρέμεινε ανοικτό καθ'όλη τη διάρκεια εργασιών, παρακείμενη της παραμένουσας δίοδος πεζών παρέμεινε ανοικτή (σταθμός Paddington εξυπηρετεί το αεροδρόμιο Heathrow) και η έδραση του νέου συστηματος υποστήριξης θα έπρεπε να μεταφέρει τα φορτία σε επίπεδο κατώτερο από τη στάθμη πυθμένα του καναλιού.
Λύση:
Κατασκευή συμμίκτων υποστυλωμάτων κάτω από τις υφιστάμενες κύριες δοκούς.
Ανάλυση και διαστασιολόγηση του νέου στατικού μοντέλου με τροποιημένες ακαμψίες λόγω αλλαγής γεωμετρίας του φορέα. Μελέτη και υλοποίηση συνδέσεων πόδα και κορυφής των νέων συμμίκτων υποστυλωμάτων. Ειδικά για την κεφαλή, μελετήθηκε και εφαρμόσθηκε σύνδεση ειδικού τύπου (clamp connection) λόγω αδυναμίας χημικής αγκύρωσης στο κάτω πέλμα των κυρίων δοκών της γέφυρας.
Κατασκευή δοκού έδρασης των συμμίκτων υποστυλωμάτων πλησίον όχθης καναλιού και έδραση αυτής σε δύο (2) πασσάλους τριβής (βάθος έμπηξης: 38.00 m) για αποφυγή φόρτισης παρειών.