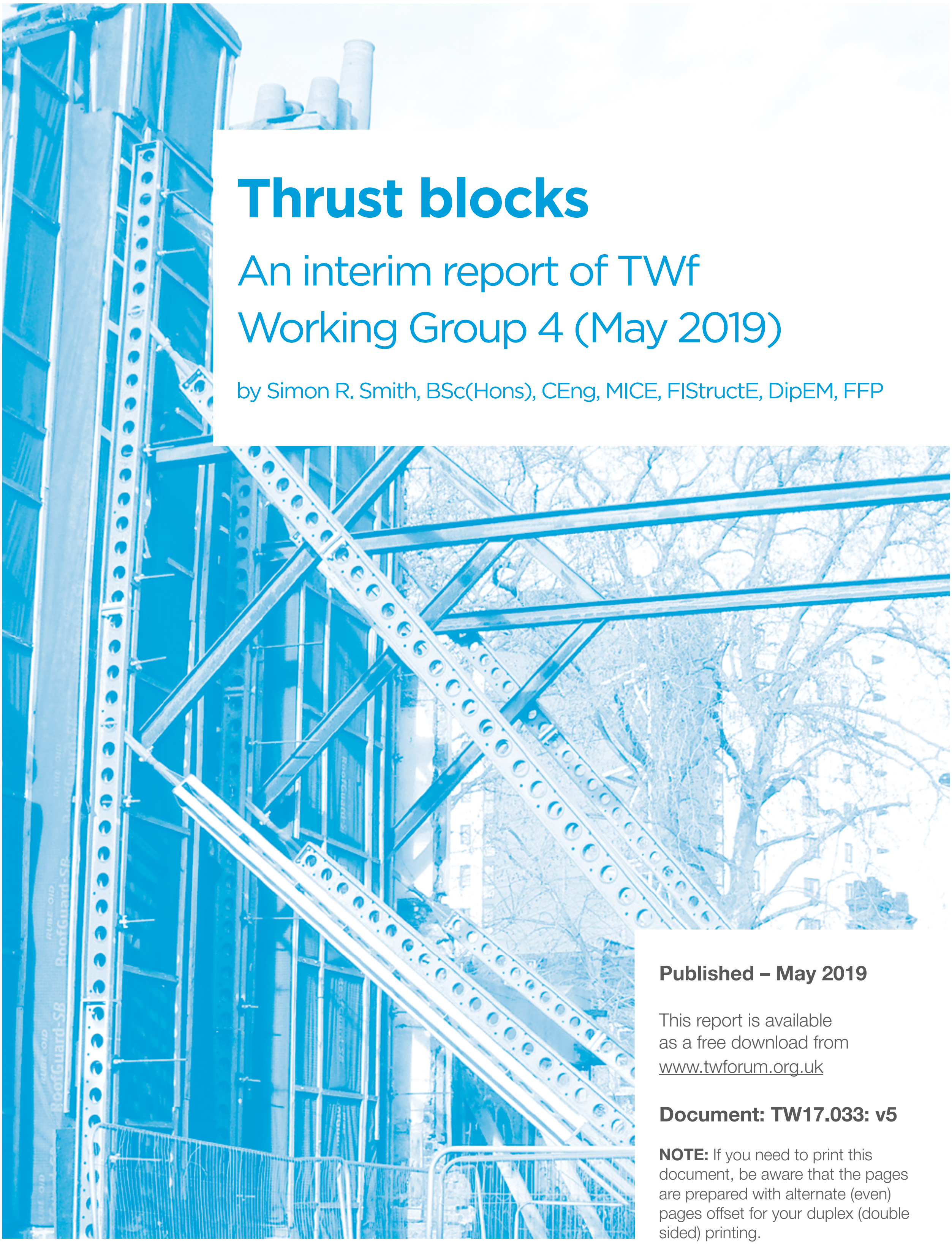

Thrust blocks

An interim report of TWf Working Group 4 (May 2019)

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Temporary Works forum

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Date: 8th May 2019

1.0 Introduction

1.1 Concrete thrust blocks are commonplace structural elements in temporary works. However, their design is often the source of much debate within the engineering fraternity. Under the auspices of the Temporary Works Forum[1] a working group was established with the aim of creating a consistent design approach, together with good practice guidance.

2.0 Background

2.1 Concrete thrust blocks are often used in temporary works to resist forces usually arising from earth and wind forces. They are particularly useful in supporting single-sided excavations where horizontal or corner bracing is impracticable. In such situations, raking props reacting against in-situ concrete blocks cast within the ground can provide a viable temporary works solution (see **Photos 1** and **2**).

2.2 The basic mechanics of how thrust blocks work is understood by most engineers with a rudimentary knowledge of geotechnics, viz. the applied prop load (horizontal and vertical components) are resisted by the ground surrounding the concrete block by a combination of friction and 'passive' earth pressure. However, due to three-dimensional effects, determining the true value of the soil resistance is complicated.

Photo. 1 – Raking props supporting an existing masonry basement retaining wall to a highway via buried concrete thrust blocks (Central London)

[1] *Temporary Works Forum, www.twforum.org.uk*

Photo. 2 – Shoring system providing lateral restraint to a terraced property using buried concrete thrust blocks to allow completion of demolition works (Dalston, London)

2.3 Most current design approaches ignore any load spread beyond the width of the block itself which seems unduly conservative given the well understood load dispersion theory postulated by Boussinesq[2] for foundations. Some designers compensate for this by increasing the width of the block by a factor of 3.0 using the philosophy of Broms[3]. However, this approach is often disputed by checking engineers because it is strictly only applicable to laterally loaded, short, stiff piles.

3.0 Scope

3.1 The aim of the working group was to produce a best practice guide for industry that would cover both design and construction of traditional rectangular or concrete thrust blocks for use in temporary works for both granular and cohesive soil types. This would cover prop forces inclined below 45° to the horizontal: standard foundation design principles incorporating the appropriate inclination factors would be better suited for props at steeper angles.

[2] *Boussinesq, JV, "Applications des potential `a l'ètude de l'equilibre et du movement des solides élastiques" – Gautier-Villars (Paris), 1885*

[3] *Broms, B:*

(i) "The Lateral Resistance of Piles in Cohesionless Soils", Journal of the Soil Mechanics Division, American Society of Civil Engineers, Vol. 90, No. SM3, May 1964, Pages 123 to 156

(ii) "The Lateral Resistance of Piles in Cohesive Soils", Vol. 90, No. SM2, March 1964, Pages 27-63.

4.0 Literature review

4.1 A literature review revealed the following relevant design references relating to thrust block design:

- CIRIA Report 128 (R128)[4]
- CP2:1951[5], also covered in The Piling Handbook[6]
- Washbourne[7]

4.2 R128 deals specifically with thrust block design associated with buried pipelines resisting hydraulic forces at changes in direction. The generous factors of safety recommended for some soil types, coupled with the omission of any allowance for load spread and side friction, makes use of this publication particularly onerous for temporary works situations.

4.3 CP2 was a seminal publication providing invaluable advice for a range of geotechnical issues in civil engineering works. Whilst there is no specific design advice for thrust blocks guidance is offered on the design of deadman anchorages, which are structurally similar.

4.4 The main difference between R128 and CP2 is that the latter includes for an additional resisting force due to shear along the edges of the soil wedge on the compressed or 'pushed' side of the block. However, neither approach makes any allowance for 'load spread' within the compressed soil zone.

4.5 Washbourne recognises and takes cognisance of the load spreading action through the ground behind jacking thrust walls. However, the application of the load in this case is purely horizontal, whereas in practice most temporary props would be inclined. Nevertheless, the principles put forward by Washbourne seem logical and consistent with accepted geotechnical theory.

5.0 Postulated design approach

5.1 Using the basic principles advocated by Washbourne[7], the following design approach was developed. The soil resisting block movement is considered to be wedged shaped with inclined failure planes in plan and cross section (see **Figure 1**).

5.2 Using simple geometry, it is possible to determine the effective width of the resisting soil wedge at the point where the failure planes intersect with the ground surface. It should be noted that this approach would be invalid where thrust block failure wedges overlap.

5.3 For the time being, active pressure acting on the front face together with friction/adhesion acting on the side faces have been ignored in the hypothesis.

5.4 Friction and adhesion on the base of the block is less likely to be influenced by outside factors and hence have been included in determining the overall resisting force.

5.5 Intuitively, inclining the disturbing force should deepen the failure plane increasing the effective width and hence the resisting force. However, for the sake of simplicity, only horizontal applied forces have been considered at this time.

5.6 In order to verify this new approach, a series of site tests were proposed. These were to be undertaken in both granular and clay soil conditions on actual live construction sites. The test arrangements proposed are illustrated in **Figure 2**.

5.7 The aim of the tests was to verify the failure load of the concrete thrust blocks for the various soil types and compare these values to the theoretical values derived using this new postulated design approach.

5.8 To date (May 2019), three tests have been undertaken (**Figure 2**). All have been carried out within the Greater London area in either London Clay or the Claygate Beds.

6.0 Site Tests

6.1 Test 1

6.1.1 The first test site was located in Highgate within the notorious Claygate Beds. Two tests were undertaken: one horizontal and the other inclined at 30° to the horizontal (see **Photo. 3**).

[4] CIRIA Report 128, Thorley, ARD and Atkinson, JH, "Guide to the design of thrust blocks for buried pressure pipelines", CIRIA, London, ISBN 0860173593

[5] Earth Retaining Structures, 1951, Civil Engineering Code of Practice No. 2 (CP2), Institution of Structural Engineers, London

[6] Section 6, "Piling Handbook", 8th Edition, Arcelor Mittal

[7] Washbourne, J, "Three-dimensional passive analysis for jacking walls", Tunnels & Tunnelling, Volume 13, No. 2, March 1981, Pages 13-17

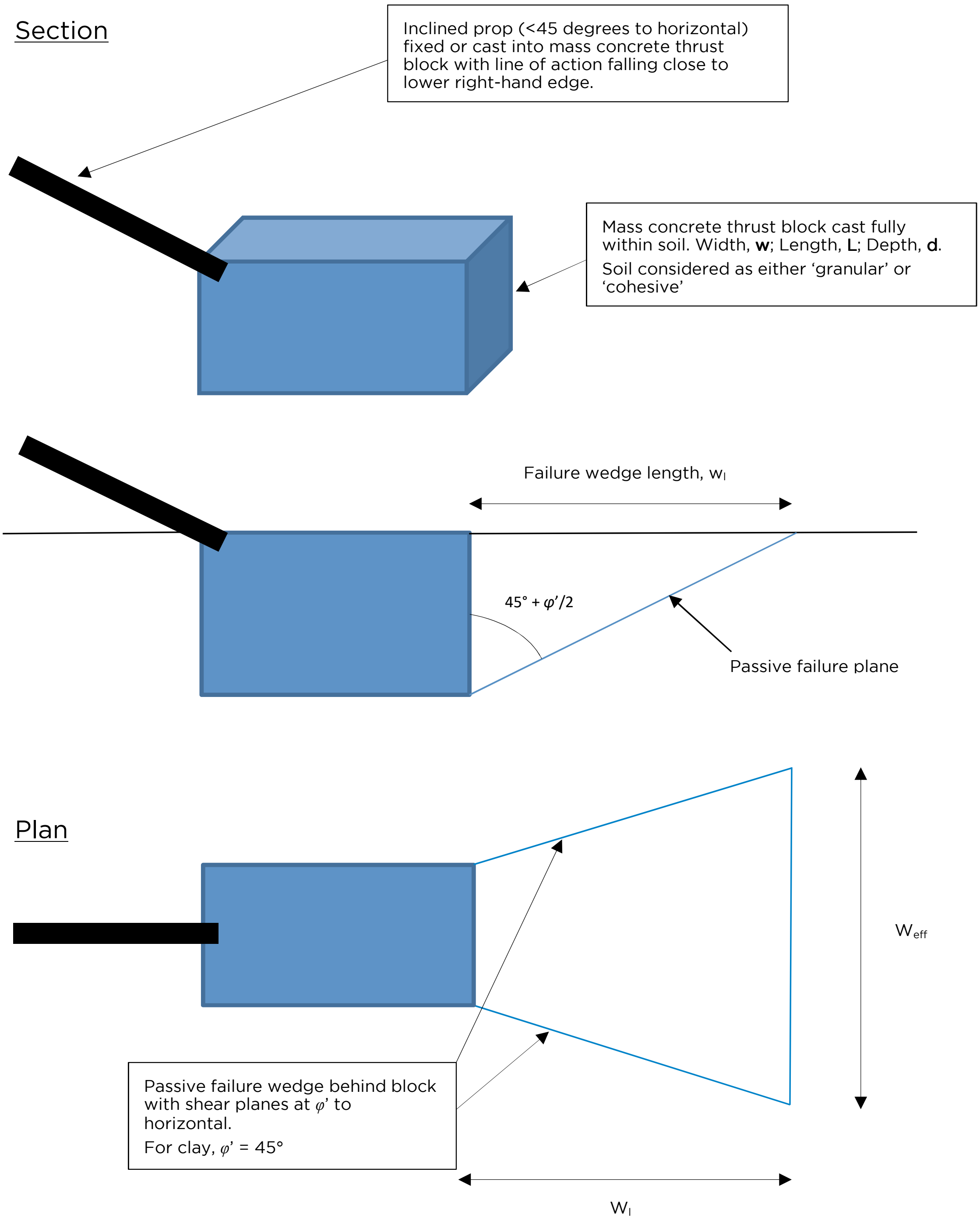

Figure 1 – Typical arrangement

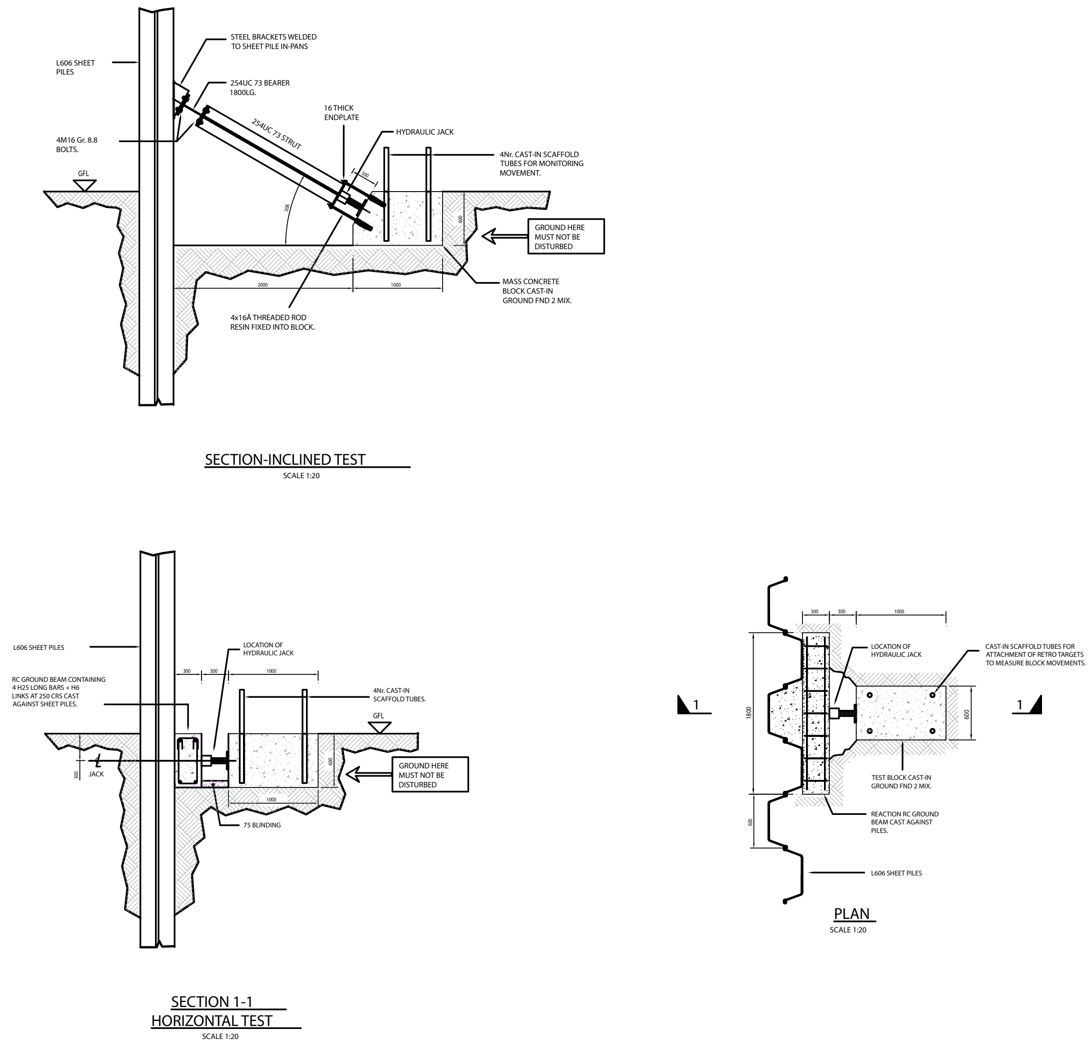

Figure 2 – Thrust block testing details

6.1.2 The strength parameters for the soil surrounding the block based on information presented in the comprehensive site investigation report were taken as follows:

- Density γ = 18kN/m3
- Internal angle of friction, ϕ' = 30°
- Effective cohesion, c' = 5kPa

6.1.3 Block failure was deemed to have occurred when the jack pressure could not be maintained due to movement of the block into the soil.

6.1.4 The failure loads were found to be as follows:

Horizontal: 30kN
Inclined: 50kN

6.1.5 Using the postulated load-spread theory, the corresponding theoretical failure load for the horizontal load case is 33kN which is a close match to the failure load observed.

6.2 Test 2

6.2.1 The location for this test was in the Notting Hill area of London within very stiff London Clay. Unfortunately, due to the very high undrained cohesive strength (>250kPa) and the obvious influence of the blinded formation together with the lower mat of raft reinforcement, failure could not be initiated, even with a 100 Tonne jack (see **Photo 4**).

6.3 Test 3

6.3.1 This test was undertaken on a site close to Regents Park in London within the upper levels of the London Clay stratum which had an undrained shear strength of 80 kPa. This was also verified at the time of the test using a hand penetrometer.

Photo 3 – Test Site 1 (Highgate) - Inclined test using sheet piles for reaction

Photo 4 – Test Site 2 (Notting Hill) – Testing in progress

6.3.2 Due to time constraints, only a horizontal load test was undertaken, the failure load was found to be 240 kN which coincidentally matched the value derived using the new method.

7.0 Interim conclusion (May 2019)

7.1 Based on the tests undertaken to date, there would appear to be a reasonable correlation between actual failure loads (horizontal) and those predicted using the new load spread approach. This is very encouraging.

7.2 The first test in Highgate demonstrated that inclining the applied force through the block increases the resistance, as one would expect. However, the current design approach does not take this into account.

8.0 The Future

8.1 The working group intends to undertake further site tests in different soil types and, hopefully, enlist the services of City, University of London - via a research grant - to enhance their understanding of the actual failure mechanisms.

NOTE: If you think that you might be able to assist in any site testing please contact the TWf Secretary, at secretary@twforum.org.uk

8.2 Through our combined efforts, it is anticipated that some clear, economic design guidance can be prepared.

NOTE: Some TWf members provide a moderate level of funding to support research at City, University of London's Centre of excellence in temporary works and construction method engineering. If your company might be in a position to assist please contact the TWf Secretary, at secretary@twforum.org.uk

A further site test was undertaken by Keltbray at Lille Square. However, this used a triangular shaped concrete block with an inclined prop force. The results for this case have yet to be assessed and may warrant different design guidance.

Temporary Works forum

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