Infrastructure Projects

Network Rail's In-Service Experience of the ORE Method

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Contents

1. Introduction

The foundations of overhead line equipment (OLE) support structures have traditionally been designed using empirical formulae derived from full scale field tests carried out in the 1950s under the auspices of the Office for Research and Experiments (ORE) of the International Union of Railways (UIC) [1].

The UIC-ORE method described in Reference [1], which will be referred to as the ORE Method in this report, is based on a series of formulae initially derived from the results of reduced scale model tests of square, rectangular and circular section foundations in dry sand carried out and reported by Ramelot and Vandeperre [4] and subsequently modified following a series of full scale field tests. It is purely empirical (based on observation), and does not explicitly distinguish between effective stress ("drained") and total stress ("undrained") conditions [2].

The full scale tests carried out under the auspices of the ORE investigated the effect of three different configurations of ground (in a cutting; on the level; and on an embankment) and three different degrees of support from the track (close to the track with pull towards the track; further from the track with pull towards the track; and pull in the direction away from the track) [2].

The method is entirely empirical, in that the limiting moment equation is determined directly from experimental results in a range of terrain types and is not built up or derived by considering either a limiting or an in-service ("working") stress distribution – something that is extremely difficult to address in sloping terrain such as an embankment [2]. The authority of the method derives from the extensive, international research that went into developing it, together with the fact that it has been used extensively and successfully in railway administrations in Europe for decades – including British Rail (BR), Société nationale des chemins de fer français (SNCF) and High Speed 1 (HS1) [1, 2, and 3].

This report addresses BR's (and subsequently after privatisation - Network Rail's) in-service experience of the ORE Method based on data from the Anglian routes and on East Coast Main Line (ECML), and the timeline of the method.

1.1 ORE Method: Benefits and Caveats from the ORE Report

References [1 and 2], identified the following benefits and limitations about the ORE Method:

- It easily deals with sloping terrain – No other methods deal with this issue explicitly [2]
- Restrictions on soil type (not peat, not where the water table is high, not alluvium, not chalk)
- Original tests had a maximum moment at ground level of 470 kNm and a maximum foundation length of 3m [1]
- Original tests were on concrete foundations
- Maximum disturbed depth (Non-effective depth) was 0.5 m – However based on 1976 practice this was increased to 0.9 m – Refer to drawing No. 1/098/805/A2 in Reference [6]

- The effect of foundation / mast weight and weight distribution may not be fully reflected in the formulae

2. Purpose

The original UIC-ORE report [1] excludes the implementation of ORE foundations in the following ground types (geology): alluvium, peat, turf, chalk, rock, or quicksand.

The purpose of this report is to explore the possibility of extending the application of the ORE Method beyond the original 1957 report in terms of foundation type and geology, based on experience post publication of the original UIC-ORE report in 1957 [1] and to highlight the UIC-ORE Method's compliance with current European design standards. Achieving this will introduce considerable cost efficiencies in comparison with recent experiences associated with the Great Western Main Line Electrification scheme where an alternative design approach was developed [2].

3. Definitions and Abbreviations

BR	British Rail
CTRL	Channel Tunnel Rail Link
EC7	Eurocode 7
ECML	East Coast Main Line
HS1	High Speed 1
MK 3B	Mark 3B 25Kv ac OLE System Design
OLE	Overhead Line Equipment
ORE	Office for Research and Experiments
PAN	Project Advice Note
PAS	Publicly Available Specification
RAM	Route Asset Manager
SNCF	Société nationale des chemins de fer français
UIC	International Union of Railways

4. ORE Method: Compliance with Eurocode 7

BS EN 1997-1: Geotechnical Design Reference [14], usually referred to as Eurocode 7 (EC7), gives guidance and actions for geotechnical design of building and civil engineering works and also allows the use of empirical methods in designs. Reference [2] outlines the rationale behind the compliance of the ORE Method with EC7. This is summarised as follows:

- Foundations act as laterally loaded ("side-bearing") piles
- EC7 (paragraph 7.7.2) allows the design of laterally loaded piles on the basis of load tests not taken to failure
- As the ORE method is based on the synthesis of a large number of full scale load tests, it meets this requirement for conditions within the range covered by the tests
- Serviceability considerations are addressed explicitly through the application of a factor of 3 to the pile moment resistance (the avoidance of excessive deflection is given as the reason for choosing this value in UIC-ORE, 1957)
- The ORE method is therefore EC7 compliant

5. Time Line of ORE Foundations in the UK

Concrete OLE foundations allocated from the ORE Method were first installed in Anglia from 1984 on the route sections between Colchester, and Norwich and Manningtree and Harwich.

Following a set of laboratory tests, the application of the ORE Method was extended to include foundations in the form of 610-mm diameter tubular steel piles [7 and 8], which in 1984 were implemented for the first time in Anglia East between Wickford and Southminster. These 610mm piles were developed so as to extend the ORE range of foundations to cater for sites where construction programmes are extremely tightly scheduled [7] and complete electrification work *i.e.* installation of foundation, structure and wires must be completed in the same possession.

East Coast Main Line (ECML) electrification, constructed in the years 1986 to 1992, saw the biggest ORE foundation roll out on any single electrification programme to this date. On this programme, both concrete and 610 mm diameter steel pile foundations were implemented between Hitchin and Carstairs. Allocation of these foundations was via a computer programme called OSD by Computer.

The timeline of the implementation of the ORE method of foundation design in the UK is given in Figure 1.

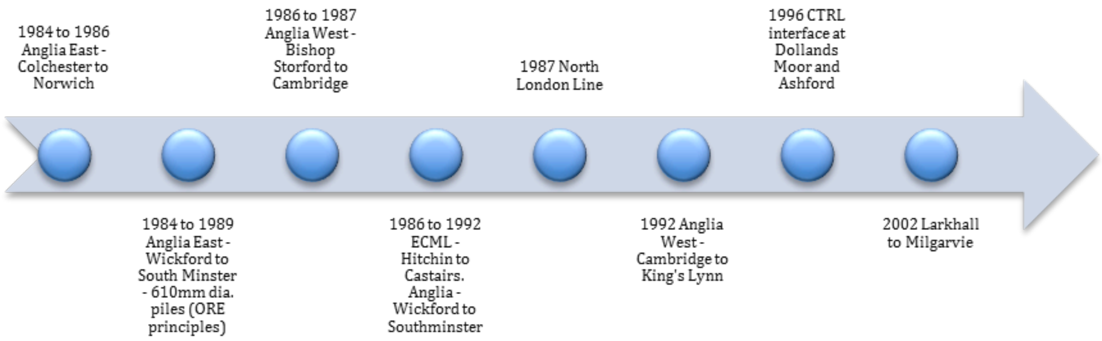

Figure 1: Timeline of the implementation of ORE foundations in the UK

Historically, the ORE method of foundation design was used only for the Mark 3B (MK 3B) 25kV AC OLE System Design until 2013 when it was included as part of the Series 2 design with the publication of PAN/E&P/EE/CS/101 (PAN101) [6]. More recently, it has also been included as part of the UK Master Series [13]. The geographical distribution of the implementation of MK 3B foundation design using the ORE method is given in Figure 2 of Appendix A.

6. Mark 3B Structures and Foundations and Associated Geology

There is no evidence of any catastrophic failures of MK3B OLE structures and/or foundations or train delays attributable to foundations allocated through the ORE Method being inadequate, or any inadequacy of an ORE-designed foundation being the root cause of renewal works for masts or foundations where earthworks are stable. Issues pertaining to these foundations and structures are essentially in the form of leaning structures and foundations due to unstable earthworks. This is not unexpected, as these foundations are not meant to stabilise earthworks.

OLE structures and foundations are inspected at 4-weekly or 6-weekly intervals [10], depending on OLE line category, by foot patrollers. This activity would normally identify foundations and structures that are leaning and require close monitoring. Remote monitoring of contact wire height and stagger is also undertaken every 6 months. If deemed necessary, minor maintenance intervention such as adjustments to the OLE are then executed. In cases where the structures are deemed to have the potential of causing a dewirement, the structures and foundations would then be renewed. The number of structures and foundations that need to be renewed is very small relative to the overall population of structures and foundations on the network (typically less than 0.1%). These types of intervention are an expectation of the business and are well understood and executed, and are acceptable performance criteria for OLE structures and foundations. Also, OLE structures are a good indicator for the stability of earthworks.

A sample of Mark 3B OLE structures and foundations was analysed based on information from as-built cross section drawings for ECML and Anglia combined with geological data for earthworks obtained from the Network Rail Route Asset Managers (RAM) for geotechnics. The findings of the analyses are presented in Sections 5.1 and 5.2.

6.1 Experience of different types of structures founded on different types of foundations

The experience of different types of structures founded on particular types of foundations is summarised in Table 1. The grabbed and hand-dug concrete foundations and the steel pile foundations were specified on the basis of the ORE design principles. Hand-dug foundations were installed in sensitive areas where it was felt that the installation of grabbed foundations could have caused damage to buried services. Concrete gravity pads were bespoke foundation designs in ground types where a side bearing pile foundation could not be implemented, irrespective of the design method. This was generally associated with particular categories of peat geology.

Structure Types	Concrete Grabbed	Concrete Hand-Dug	Concrete Gravity Pad	Steel Piles
Single Track Cantilever (STC)	✓	✓	✓	✓
Two Track Cantilever (TTC)	✓	✓	×	×
Twin Track Cantilever	✓	✓	×	✓
Portal	✓	✓	×	×
Anchored – STC	✓	✓	×	✓
Anchored – TTC	✓	✓	×	Limited
Anchored – Portal	✓	✓	✓	×
Balanced Weight Anchor	✓	×	✓	✓
Headspans	✓	✓	×	×
Hinged Portal	×	×	✓	×

Table 1: Experience of different types of structures founded on particular types of foundations designed using the ORE method

It is clear from Table 1 that NR has good experience of concrete ORE-designed foundations in relation to nearly all types of OLE structures apart from hinged portals that do not need to be founded on side bearing types of foundations due to the pinned connection at their bases in the cross-track direction. Therefore, hinged portals require a bespoke type of foundation design such as concrete gravity pads. Gravity pads have also been implemented in poor ground conditions such as certain categories of peat.

Steel pile foundations, designed based on ORE principles, in the form of 610 mm diameter tubes were found to have performed well in conjunction with STCs, Twin Track Cantilevers and Balanced Weight Anchors, which are relatively lightly loaded compared to the other structures listed in Table 1. It is also clear that historically no reliable experience is available for 610mm piles designed based on ORE principles in relation to highly loaded structures. However, the comparative study that was carried out by the University of Southampton [2], shows convergence between the ORE method and the Fleming et al (1994) [10 and 11] limit equilibrium approach at higher loads in flat ground. This therefore suggests that 610mm piles based on ORE principles could be used in relation to more highly loaded type of structures *e.g.* TTCs, *etc*. However, confirmation should be sought by way of in-situ tests in difficult terrains.

6.2 Experience of different types of foundation in different types of Geology

Geology	Grabbed side-bearing foundation	Hand-Dug side-bearing foundation	610 mm dia. steel pile foundation
Alluvium / Estuarine Deposits	✓	✓	✓
Alluvium / Estuarine Deposits, Granular Glacial Till / Terrace Deposits / Blown Sand	✓	✗	✓
Alluvium / Estuarine Deposits, Sand and Gravel	✓	✗	✓
Chalk	✓	✓	✗
Coal Measures	✓	✓	✓
Granular Glacial Till / Terrace Deposits / Blown Sand	✓	✓	✓
Interbedded Limestone and Mudstone	✓	✗	✓
Interbedded Limestone and Mudstone, Uncemented Sands	✓	✗	✗
Limestone	✓	✗	✗
Made Ground / Head Deposits	✓	✗	✓
Made Ground / Head Deposits, Alluvium / Estuarine Deposits	✓	✗	✓
Made Ground / Head Deposits, Granular Glacial Till / Terrace Deposits / Blown Sand	✓	✗	✓
Made Ground / Head Deposits, Peat	✗	✗	✓
Made Ground / Head Deposits, Alluvium / Estuarine Deposits, Sand and Gravel	✓	✗	✗
Made Ground / Head Deposits, Sand and Gravel	✓	✗	✗
Metamorphic Sandstone	✓	✗	✗
Overconsolidated Clay	✓	✗	✗
Peat	✓	✗	✓

Peat, Granular Glacial Till / Terrace Deposits / Blown Sand	✗	✗	✓
Sand and Gravel	✓	✗	✓
Sandstone	✓	✓	✗
Siltstone / Sandstone	✓	✗	✓
Uncemented Sands	✓	✓	✓

Table 2: Foundation type in different types of geology

The experience of the different types of ORE foundations in different types of geology is summarised in Table 2. It is clear and not surprising that there is good experience in allowable geology that are not excluded for the implementation of ORE foundations, as per the original ORE report [1].

Interestingly, historical records show good experience of ORE foundations in geology such as alluvium, chalk, and certain categories of peat, which are some of the excluded geology in [1].

The reason for the exclusion of chalk from the original report [1] could be because that a lot less was known about chalk as an engineering material in the 1950s, as most of the research related to chalk as an engineering material occurred place post 1970s. Thus UIC-ORE may have taken a conservative approach in excluding chalk. However, with the 30 plus years of good performance of concrete ORE foundations in chalk on the UK rail network, there are no reasons why chalk should remain as an excluded ground type. ORE method-designed foundations were also widely implemented in chalk on HS1 [3]. Thus there are no known reasons why 610 mm piles should be excluded.

It is clear from the records that ORE-designed foundations in alluvium have performed well. Records for alluvium show that it tends to occur in combination with various deposits, e.g. sand and gravel on earthworks such as embankments, and it is unlikely that an embankment will be made entirely of alluvium. In this case, alluvium in combination with other ground types as shown above can be allowable ground type for the implementation of ORE-designed foundations. However, some in-situ site tests or ground investigations would be useful.

The experience with peat is not as clear cut as in other ground types. Although it is possible that ORE-designed foundations could work in some forms or types of peat, it would be advisable for appropriate ground investigation to be carried out where peat is present in order to decide if an ORE foundation design could be implemented. If the ORE design method is inappropriate, a single side-bearing foundation pile is unlikely to be a suitable solution and an alternative bespoke type of foundation, such as a gravity pad or multi-piles, should be adopted.

7. Conclusions

Based on historical evidence it is clear that tubular steel piles can be included as part of the ORE-designed range of foundations and that the allowable ground type for implementation of ORE foundations should include chalk and alluvium for railway applications.

Peat can also possibly be included as an allowable ground type. However, confirmation should be sought by way of a ground investigation. If a side-bearing pile or concrete foundation is found to be inappropriate, then a bespoke foundation type should be implemented. Note this is not a function of the design method, but of the pile type.

The ORE method could potentially be used for the design of highly loaded tubular steel piles. However, confirmation should be sought by way of in-situ tests in difficult terrains.

8. Further Work

Currently the author is in the process of mapping out a way forward with the Chairman of TC250/SC7 (the Eurocode 7 committee) in terms of bringing the ORE method to a wider audience. In the first instance, it is envisaged for the ORE Method to be published as a Publicly Available Specification (PAS) with a view of upgrading the PAS into an Informative Annexe within EC7. Ultimately, the plan is to include the ORE Method in the Geotechnical Construction part of the revised version of EC7 which is planned to be published in the year 2020.

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Appendix A