

Transmission Line Foundation Testing

Design Standard

DOCUMENT HIERARCHY

This document resides within the Planning component of Western Power's Asset Management System (AMS).

DOCUMENT DATE

This document was last updated September 2023.

IMPLEMENTATION DATE

This document came into service May 2017

DOCUMENT CONTROL

Record of endorsement, approval, stakeholders, and notification list is provided in EDM# 28935970 appendix

RESPONSIBILITIES

Western Power's Engineering and Design Function is responsible for this document

CONTACT

Western Power welcomes your comments, questions, and feedback on this document, which can be emailed to standards.excellence@westernpower.com.au

DISCLAIMER

This document is published by Western Power for information purposes only. The user must make and rely on their own inquiries as to the quality, currency, accuracy, completeness, and fitness for purpose of any information contained in this document. Western Power does not give any warranty or make any representation concerning the information provided in this document. By using the information in this document, the user acknowledges that they are solely responsible for obtaining independent professional advice prior to commencing any project, activities, or other works. Western Power is not liable in any way for any loss, damage, liability, cost or claim of any kind whatsoever (including responsibility by reason of its negligence) arising from or in connection with the use of or reliance on the information contained in this document. Western Power reserves its rights to modify, supplement or cancel this document or any part thereof at any time and without notice to users.

COPYRIGHT

© Copyright 2022 Electricity Networks Corporation trading as Western Power. All rights reserved. No part of this work may be reproduced or copied in any form or by any means without the written permission of Western Power or unless permitted under the Copyright Act 1968 (Cth). Product or company names are trademarks or registered trademarks of their respective holders

© Western Power
ABN 18540492861



Contents

Contents	2
Revision Details	3
1. Introduction	4
1.1 Purpose and scope	4
1.2 Acronyms	4
1.3 Definitions	5
1.4 References	5
2. Safety in Design	5
3. Compliance	5
4. Functional Requirements	6
5. Foundation Testing Requirements	6
6. Selection of Testing Location	7
7. Test Foundation Installation	8
7.1 Material.....	8
7.2 Test Setup	8
7.3 Instrumentation	9
7.4 Time period Between Installation and Testing	9
8. Test Load	10
8.1 General.....	10
8.2 Test load Application	10
8.3 Loading Steps and Duration	10
9. Test Evaluation	11
9.1 Static foundation test	11
9.2 Dynamic Foundation Test	11
9.3 Pile Integrity Test	11
10. Test Report Format	11
11. Acceptance Criteria	12

Revision Details

Version	Date	Summary of change	Section
0	May 2017	Initial release	
1	May 2018	Amended EDM document categories information	
2	May 2021	Revise to new template	
3	Sept 2023	Change to AMS format	

1. Introduction

Foundation testings are carried out to confirm design adequacy and justify the use of a higher strength reduction factor or to confirm structural integrity or load carrying capacity of existing footing. This standard provides the testing scope for overhead transmission line foundation to comply with relevant Australian and International standards.

1.1 Purpose and scope

The following types of foundation tests are within the scope of this standard:

Table 1-1: Type of Foundation Test Setups

Type of loading on foundation	Foundation type	Foundation test
Axial forces, either in uplift or compression, acting in the direction of the foundation central axis.	Rigid lattice towers with typical individual footings that are: <ul style="list-style-type: none"> - Mass concrete foundations (type C, C1, E, E1, and F) - Bored concrete (type A, B, D) - Steel piles (Type G) 	Test for uplift load Test for compression load
Lateral forces, overturning moments, or a combination of both. This applies to single poles with typical compact foundations.	Pole foundation.	Test for moment
Any	Bored concrete (type A, B, D) Pole foundation	Pile Integrity Test (not a load test)

Refer to Western Power's internal document for test on non-rigid timber pole foundation.

1.2 Acronyms

Acronym	Definition
ϕ_g	Geotechnical strength factor
PIT	Pile Integrity Test

1.3 Definitions

Term	Definition
Design load	Maximum support reaction under the ultimate limit state load
Production foundation	Foundation constructed for the support structure
Instrumentation	Load application, load measuring and deflection measuring parts, blocks, reference beams, reaction piles, equipment essential to carry out a test
Foundation Type	Western Power standard foundation types as per internal document

1.4 References

References which support implementation of this document.

Table 1.2 References

Reference No.	Title
IEC 61773 Ed. 1.0 (1996)	Overhead lines – Testing of Foundations for Structures
AS 2159:2009	Piling - Design and installation
AS/NZS 7000:2016	Overhead line design
	Environmental Protection Act 1986
	Occupational Health and Safety Act 1984

2. Safety in Design

The foundation testing must consider all safety aspects that can arise from the construction, operation, maintenance and decommissioning of the transmission line and other activities within the line corridor.

The Transmission Line Foundation Testing Hazard Management Register (HMR)¹ captures and document what risks have been controlled by this standard, and what residual risks may remain that should be considered at the project design stages and construction.

3. Compliance

The foundation testing shall comply with the following Standards and Acts as applicable:

1. AS 2159 Australian Standard piling – design and installation
2. AS/NZS 7000 Overhead line design – detailed procedure
3. IEC 61773 Overhead lines – testing of foundations for structures
4. Environmental Protection Act 1986
5. Occupational Health and Safety Act 1984

¹ See Western Power internal document

4. Functional Requirements

The objectives of foundation testing are:

1. To assess the geotechnical design parameters with high confidence level
2. To predict the foundation failure load in specified soil condition

5. Foundation Testing Requirements

Static foundation testing categories are described in IEC 61773. AS 2159 specified the dynamic pile testing and pile integrity testing requirements.

Foundation testing is generally not conducted for transmission line support structures unless the conditions in Table 5-1 prevail.

Table 5-1: Foundation testing requirement

When required	Test Category	Frequency and test type ¹	Foundation Type	Sample size and duty of Foundation
If design is based on $\phi_g \geq 0.75$ up to a maximum of 0.9 Test shall be carried out during foundation design stage.	Design test – Full scale	1x Static compression.	All types	3 set of test foundation per geological topography
		1x Static uplift/ moment test.	Type A, B, D or Type G Pole foundation	
		1x Static uplift (cyclic).	Type A, B, D or Type G	
As above & foundation diameter > 1500 mm.	Design test – Reduced scale	1x Static uplift	Type A, B or D Pole foundation	
$\phi_g \geq 0.65$ and where a wide variation in the foundation load-resistance capacity is expected	Proof test – Design	1x Static compression.	Type A, B or D	Initially 5% of relevant production foundation, additional tests to be decided base on the result of initial tests
		1x Static uplift		
		1x Static compression	Type G	
		2x Static uplift (at least one as cyclic test)		
		1x Dynamic compression		

Uncontrolled document when printed

© Copyright 2022 Western Power

When required	Test Category	Frequency and test type ¹	Foundation Type	Sample size and duty of Foundation
Foundation in soil with poor or no supervision.	Proof test – Pile Integrity Test (PIT)	As per AS 2159 clause 8.2.4	Type A, B, D	Initially 15% of relevant production foundation, additional tests to be decided base on the result of initial tests
Mass concrete foundations with poor or no supervision	Proof test – compaction test of backfill	Laboratory compaction test as per AS 1289.3.5. At least 2 samples at mid depth and near the base shall be collected.	Type C, C1, E, E1 and F	Initially 5% of relevant production foundation, additional tests to be decided base on the result of initial tests
Foundations designed with no geotechnical investigation (due to schedule constraint) or with less reliable previous geotechnical data and with assumed medium to good geotechnical parameters	Moment test on direct buried pole foundation	Lateral moment load test at locations where the ratio between ultimate and sustained limit state loading is more than or equal to 2 (no test is required for a lower ration).	Direct buried pole foundations.	

¹ The test method shall be as per IEC 61773 unless otherwise stated.

6. Selection of Testing Location

If a foundation test is required as per clause 5, the foundation test location shall satisfy the requirements stated in Table 6-1.

Table 6-1: Selection of Foundation Test Location

Structure Type	Foundation Design Method	Appropriate Test Location
Tower as well as poles that are not direct buried	Foundation design is based on soil parameters obtained from geotechnical investigation.	A location near the geotechnical investigation site.
Direct buried poles	Foundation design is based on assumed soil parameters without any geotechnical investigation.	A location where the pole is subjected to an ultimate limit state load more than twice the serviceability limit state load and/or additional test location with a soft/weak soil stratum during high water.

7. Test Foundation Installation

7.1 Material

The test foundation material shall be identical to the production foundation.

The material tests shall be as per Table 7-1.

Table 7-1: Test foundation material test

Material	Test
Concrete	Compression strength on cylinder samples (two samples to be tested at 3, 7, 14 and 28 days).
Rebar	Mechanical strength (not required for successful test)
Steel Pile	Mechanical strength (not required for successful test)

7.2 Test Setup

Test foundation (static) setup shall comply with clause 7.2, clause 7.3, clause 7.4 and clause 7.5 of IEC 61773 unless otherwise modified by this standard. If there is any discrepancy between this standard and IEC 61773, this standard shall prevail.

Test setup for the dynamic compression test shall be as per appendix B of AS 2159.

7.3 Instrumentation

All foundation testing instrumentations shall have the following information available before use:

1. The accuracy and sensitivity (the minimum level of accuracy shall not be less than 5%)
2. Valid calibration certificate with a calibration chart and date
3. Maximum range

The load application capacity and deflection measurement range of the foundation testing instrumentations shall comply with Table 7-2.

Table 7-2: Instrumentation range and capacity

Test type	Typical Load application capacity	Typical Displacement measurement range
Static uplift or moment on test foundation	200% of the design load.	Uplift: 0 to 150 mm with at least 1 mm intermediate resolution. Moment: 0 to 10m with at least 5 mm intermediate resolution
Static uplift or moment on production foundation	100% of the design load.	0 to 50 mm with at least 1 mm intermediate resolution.
Static or dynamic Compression on test foundation	150% of the design load.	0 to 150 mm with at least 1 mm intermediate resolution.
Static and dynamic Compression on production foundation	100% of the design load	0 to 50 mm with at least 1 mm intermediate resolution.

7.4 Time period Between Installation and Testing

The minimum time period between the foundation installation and testing shall comply with Table 7-3.

Table 7-3: Minimum time period between foundation installation & testing

Foundation type	Minimum period
Type A, B and D	14 days
Type C, C1, E, E1, F	28 days
Type G in non-cohesive soil	7 days
Type G in cohesive soil	21 days

Clause 6.5 of IEC 61773 shall be followed for foundation types not stated in Table 7-3.

8. Test Load

8.1 General

The test load shall be limited 150% of design load. A test foundation may be subjected to subsequent tests if all previous tests met the acceptance criteria in Section 11. In this case, the test programme should commence with low utilisation foundation tests.

If a production foundation is used for testing and reused for the test load shall not exceed 75% of the ultimate limit state design load or the maximum serviceability limit load.

8.2 Test load Application

The test load application and measurement shall be as per IEC 61773 (for static test) or AS 2159 (for dynamic test) unless otherwise modified by this standard. If there is any discrepancy between this standard and IEC 61773 or AS 2159, this standard shall prevail.

As per clause 6.2b of IEC 61773, foundation uplift test loads can be applied vertically if the leg slope of the tower is less than or equal to 11.5°.

8.3 Loading Steps and Duration

The loading steps and duration for static foundation testing shall be as per Table 8-1.

Table 8-1: Static foundation test: Loading steps and duration.

Test Category and test type	Loading steps in % of design load	Minimum holding period ¹
Design test – Static uplift or moment	Stage 1: 25, 50, 70, 80, 90, 100	for non cohesive soil <70% load, 3 minutes ≥70% load, 10 minutes Final load, 30 minutes
Design test – Static compression	Stage 2: 50, 100, 110, 120, 130, 140, 150	
Proof test on “test” foundation – Static uplift	Stage 1: 25, 50, 70, 80, 90, 100	3 minutes for non cohesive soil Final load, 10 minutes
Proof test on “test” foundation – Static compression	Stage 2: 50, 100, 110, 120, 130, 140, 150	
Proof test on “test” foundation –Static uplift cyclic test	25,35,0; 35,50,0; 50,60,0; 60,70,0; 70,80,0; 80,90,0; 90,100,0	3 minutes for non cohesive soil 100% load, 10 minutes
Proof test on “production” foundation (Static uplift or compression or moment)	25, 35, 45, 50 or 25, 35, 45, 50, 75 (foundation for angle or strain structure)	3 minutes for non cohesive soil Final load, 10 minutes

Test Category and test type	Loading steps in % of design load	Minimum holding period ¹
"Proof" test on "production" foundation (Dynamic compression)	Loading steps and duration for dynamic test shall be as per appendix B of AS 2159.	
¹ The minimum holding period for loading steps $\geq 70\%$ and final load shall be 30 minutes in cohesive soil.		

9. Test Evaluation

9.1 Static foundation test

Static foundation test results shall be evaluated as per clause 9 of IEC 61773 using the following methods:

1. Tangent intersection method
2. Log-log method
3. Parabolic method
4. Hyperbolic model
5. Slope tangent method.

Refers Appendix E of IEC 61773 for the detailed process.

9.2 Dynamic Foundation Test

Test evaluation shall be in accordance with Appendix B of AS 2159.

9.3 Pile Integrity Test

Test evaluation shall be in accordance with Appendix D of AS 2159.

10. Test Report Format

Reports on foundation testing shall include IEC 61773 Annex D records and the following information:

- a) Layout of test equipment and description
- b) Foundation identification, diameter and length
- c) Sketch of soil conditions and ground water location
- d) Valid calibration certificate with a calibration chart and date
- e) Complete records of level, load cell and dial gauge readings against date and time throughout the test in a tabulation
- f) Graphs of load and settlement/heave versus time
- g) Graphs of settlement/heave versus load
- h) Remarks concerning any unusual occurrences during the loading of the pile.

- i) Test reports on integrity testing of piles shall include clear sample diagrams of acceptable signals for comparison purpose, as well as sample graphs indicating defects or doubts on the integrity of the pile.

11. Acceptance Criteria

The acceptance criteria of foundation testing shall be as per following table.

Table 11-1: Foundation testing acceptance criteria

Testing Type	Acceptance criteria
Static test	The test on rigid foundation shall comply with clause 10 of IEC 61773 with the following requirements: <ul style="list-style-type: none"> - The specified design load has been achieved - The maximum temporary deflection is less than 25 mm - The maximum permanent deflection is less than 10 mm - The maximum foundation rotation under moment test shall be less than 2%
	Refer to Wester Power's internal document for test on non-rigid foundation.
Dynamic test	The test foundation shall comply with clause 8.5.2 of AS 2159.
Pile Integrity Test	The test foundation shall comply with clause 8.8.3 of AS 2159.