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Dear Sir / Madam

JOINT BCA / IES / ACES / GEOSS CIRCULAR 2021

GUIDELINES ON ADOPTION OF RAPID LOAD TESTS FOR FOUNDATION PILES

Since the issuance of the joint circular¹ in September 2016, there has been an increasing trend in the adoption of rapid load tests (RLT) for foundation piles. RLT can be carried out within a much shorter duration with much lesser manpower requirements than conventional maintained static load tests (SLT) that use either kentledge blocks, steel plates or ground anchors to provide the reaction load.

2. To steer the industry's transformation drive towards sustainable construction in the built environment sector without compromising safety, BCA has taken the initiative to form an industry working group comprising academia, government agencies, practitioners and members from *Institution of Engineers Singapore (IES)*, *Association of Consulting Engineers Singapore (ACES)* and *Geotechnical Society of Singapore (GeoSS)*, to jointly formulate the guidelines and requirements on RLT. The guidelines aim to provide guidance to the industry with greater clarity on the usage of RLT for verification of pile capacity so that the industry can stand to benefit from this innovative testing method without compromising on the reliability of the test results.

3. The joint industry workgroup has consulted local RLT specialists, reviewed current practices overseas and reviewed the test results in local ground conditions before finalising the guidelines as described in [Annex A](#) (Replacement of SLT with RLT) and [Annex B](#) (RLT technical requirements).


Note 1: Joint BCA / IES / ACES / GeoSS Circular on "Requirements on Ground Investigation, Load Test and Quality Control Test for Foundations" issued on 22 September 2016

4. These guidelines shall be complied with in structural plan submissions to the Commissioner of Building Control, which include the use of RLT for verification of capacity and serviceability of foundation piles. This Circular should be read in conjunction with the joint circular¹ of September 2016.

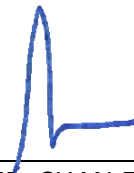
5. **Notwithstanding the guidelines provided in this Circular, all qualified persons must continue to exercise their engineering judgment and evaluation, and take all reasonable steps and due diligence to ensure that the adoption of RLT methods will fulfil the objectives and performance requirements as stipulated in the Fifth Schedule of the Building Control Regulations 2003 and comply with all relevant standards and codes of practice.**

6. Please disseminate the contents of this circular to your members. If you need any clarification, please contact Er. Ben Tan Tuang Ho at tel. 1800 3425 222 or submit your enquiry through BCA's Online Feedback Form at <https://www.bca.gov.sg/feedbackform/>. Thank you.

Yours faithfully



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JOINT BCA / IES / ACES / GEOSS CIRCULAR GUIDELINES ON ADOPTION OF RAPID LOAD TESTS FOR FOUNDATION PILES



ANNEX A

In Collaboration With



DATE OF ISSUANCE: 01 SEP 2021

ANNEX A - REPLACEMENT OF MAINTAINED STATIC LOAD TESTS (SLT) WITH RLT

1. With reference to the joint circular¹ issued on 22 September 2016, QPs may consider replacing a higher percentage of the required SLT with RLT, provided that site-specific correlation tests were carried out to establish the reliability of RLT in accordance to Annex B of this document. [Table 1](#) shows the maximum RLT replacement schedule for foundations of building works.

Table 1: Maximum RLT replacement schedule for foundation of building works

Type of verification tests	Maximum replacement percentage
Working load test (WLT) - to verify safe working load and serviceability limit state of production pile	Up to 100% replacement of SLT with RLT*
Ultimate load test (ULT) - to verify ultimate geotechnical capacity of preliminary pile	On case-by-case basis, subject to specific requirements; pre-consultation required**

* RLT shall be correlated with SLT in accordance to Annex B

** Specific requirements for ULT replacement in accordance to Annex B

2. To ensure that RLT is carried out by competent specialists, QPs, builders and/or developers should review the track record of the specialist firms, the experience and competency of personnel involved in conducting the tests and interpreting the data from RLT tests. RLT specialist firms shall comply with the requirements on testing equipment, test procedures, recording of test results and reporting format in accordance with *BS EN ISO 22477-10* or equivalent internationally recognised standards.
3. QPs who adopt RLT for pile verification should be competent and conversant in the subject matter, with full awareness of the limitations of RLT and address them adequately in the application of RLT results to pile design. QPs shall review the results and determine the suitable pile design parameters to be used.

Note 1: Joint BCA / IES / ACES / GeoSS Circular on "Requirements on Ground Investigation, Load Test and Quality Control Test for Foundations" issued on 22 September 2016

4. QPs shall prepare and submit the factual test and interpretation reports of RLT in accordance to Section 6 of Annex B as part of the plan submission for review and approval.
5. BCA will require, in due course, that the QPs attend and pass a certifying course.

JOINT BCA / IES / ACES / GEOSSE CIRCULAR GUIDELINES ON ADOPTION OF RAPID LOAD TESTS FOR FOUNDATION PILES



ANNEX B

In Collaboration With



DATE OF ISSUANCE: 01 SEP 2021

ANNEX B – TECHNICAL REQUIREMENTS OF RLT

1. Introduction

- 1.1 Rapid Load Test (RLT) is a category of pile load testing method in which the loading on pile is brief but quasi-static, allowing the entire pile length to move with the same velocity range and the pile-soil interaction to be modelled as a single mass-spring-damper system.
- 1.2 Local experience with RLT and the analysis of RLT data using suitable methods like Unloading Point Method (UPM) for piles terminated in competent soil or rock stratum with good end-bearing resistance ($SPT \geq 100$) has been reported to yield consistent results. Engineers shall conduct additional studies and tests to justify the reliability and accuracy of RLTs in other pile embedment conditions.
- 1.3 Engineers adopting RLT as an alternative pile load testing method should have full understanding of its limitations. These limitations include pile creep behaviour under sustained compression loading and loading rate effect. Due engineering allowance are to be made to account for these limitations.

2. Objective

- 2.1 These guidelines are applicable for the testing of foundation piles using RLT in Singapore. The purpose of these guidelines is to provide guidance to assist Qualified Persons (QPs), builders and developers involved in the testing of foundation piles to fulfil the objectives and performance requirements stipulated in the *Fifth Schedule of Building Control Regulations 2003*, while complying with *BS EN ISO 22477-10*.

3. Salient features of RLT

- 3.1 The proper conduct and evaluation of RLT requires special knowledge and experience on the use of the test. The specialist firm conducting the RLT should have suitably qualified and experienced personnel to supervise the acquisition of field data and interpretation of test results. The testing equipment, test procedures, recording of test results and reporting format shall comply with the requirements spelt out in *BS EN ISO 22477-10*.

- 3.2 Some of the key features of RLT that shall be complied with include the following:
- a) The load applied at the pile head during testing shall have a duration t_f which fulfils the formula:

$$10 < t_f \times C_p/L \leq 1,000$$

where

t_f = duration of rapid load application

C_p = velocity of stress wave in test pile ($\approx 4,000\text{m/s}$ for concrete pile; $5,100\text{m/s}$ for steel pile)

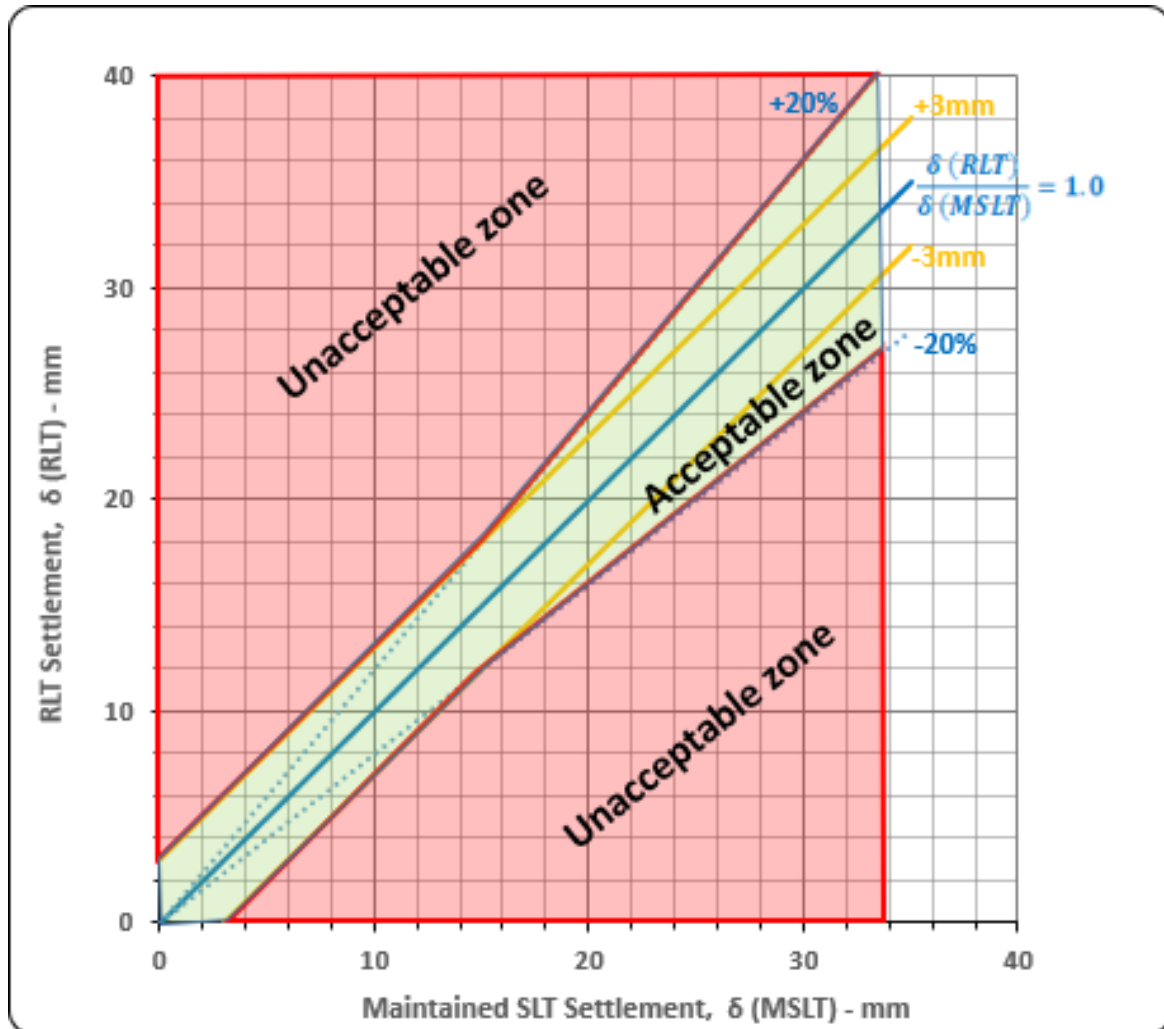
L = length of pile

- b) All the transducers including load cells, displacement and acceleration transducers, strain gauges and data acquisition system shall be calibrated by accredited laboratories registered with Singapore Accreditation Council (SAC) or overseas laboratories registered under ILAC Mutual Recognition Agreement scheme or equivalent, and capable of acquiring the data at a minimum sampling rate of 4,000 samples per second.
- c) Before and after each load cycle, the level of pile head shall be determined by optical levelling and recorded in the field data sheet.
- d) All measured test results shall be made available immediately after testing for checking by QP's representatives at site.
- e) If the pile integrity is in doubt after conduct of the RLT load test, non-destructive test (NDT) should be carried out on the pile.

4. Correlation and validation of RLT test results

- 4.1 Correlation should be carried out to compare the load versus settlement characteristics and load transfer behaviour of piles obtained from SLT and RLT. The aim of the correlation test is to validate the RLT results so that it can be adopted as a replacement test method for maintained static load test (SLT) for a project site. The correlation test results shall be prepared by the QP to: (a) establish the validated settlement range of RLT; and (b) determine the required correlation or load reduction factors for assessment of subsequent RLT results performed in the same site with similar geological and pile embedment condition, instrumentation and test method.
- 4.2 Each correlation test should be planned in such a way that maximum pile settlement occurs in the correlated RLT test, so that it can substantiate and validate the range of settlements for all subsequent RLTs conducted in the site. Pile settlements obtained from subsequent RLTs which exceed the validated range from correlation test will not be considered conclusive.
- 4.3 To ensure the reliability and effective correlation of RLT settlement, the correlation result that shows RLT settlement differing from SLT settlement by more than 20% or 3mm (whichever is greater) is deemed to be unacceptable and needs to be redone. Borderline results can be considered on case-by-case basis. [Figure 1](#) shows the acceptable and unacceptable zones of the correlation test results.

Figure 1: Acceptable and unacceptable zones of correlation test results



4.4 Even though the loading of a pile in a RLT test is brief, the same pile subsequently loaded via SLT after subjected to an earlier RLT loading could be behaving in the reloading state depending on the magnitude of the RLT load. It is therefore recommended that QPs to consider the following:

For RLT to replace WLT

- a) If QP decides to adopt RLT for both WLT and ULT, the correlation test on WLT is to be carried out separately from correlation test on ULT. This is because the correlation test results of the pile at WLT loads of up to 2 times working load would normally fall within the elastic range, whereas the correlation test on ULT of up to 3 times working load would likely go into the inelastic or non-linear range; and
- b) If correlation test on WLT is conducted on the same pile, conducting RLT first followed by SLT is preferable as the preloading effect of RLT is much less as compared to SLT. RLT results should not be corrected if the RLT indicates a more onerous response (i.e. higher settlement) than SLT under the same load.

For RLT to replace ULT

- c) The correlation test should be conducted on two adjacent piles of similar length and size, installed in similar geological condition and with similar method of construction and workmanship control; and
 - d) QP shall arrange for a pre-consultation with BCA, as expert advice may be necessary for a proper interpretation of the RLT test results to achieve the desired outcome.
- 4.5 Correlation or load reduction factors to the correlation test results should be assessed with caution and could be applied via a single factor or in multiple steps as determined by the QP.

5. Application of RLT results to foundation design in accordance to SS EN 1997-1

- 5.1 The lower model factor in accordance to *NA to SS EN 1997-1* may be used in the geotechnical design of the piles, when the ULT conducted using RLT has been correlated with maintained SLT and proven reliable and yield similar results as maintained SLT.
- 5.2 The lower partial resistance factors R4, i.e. R4 with explicit verification of SLS in accordance to *NA to SS EN 1997-1* may be used in the geotechnical design of the piles, when: (a) minimum 1% of working piles are subjected to WLT not less than 1.5 times the representative load to verify their serviceability; and (b) WLT conducted using RLT has been correlated with maintained SLT and proven reliable and yield similar results as maintained SLT.
- 5.3 For adoption of lower model factor and partial resistance factors R4 as described in sections 5.1 and 5.2, at least one correlation test shall be carried out for each type of geological formation, and for each different type of pile embedment conditions. Piles socketed in rock and piles founded in soil should be considered as different embedment conditions. Engineers shall exercise due diligence in the selection of model factor and R4 factors in the geotechnical design of the foundation piles.

6. Factual test and interpretation reports²

- 6.1 Engineers shall prepare and submit the factual test and interpretation reports of RLT. The reports shall contain the following:
- a) reference to all relevant standards;
 - b) information concerning the test site and test programme;
 - c) information concerning the ground conditions;
 - d) specification of the test pile(s);
 - e) specification of the test(s);
 - f) test(s) results;
 - g) interpretation of the measured test(s) results³

Note 2: Recommended report format as proposed in BS EN ISO 22477-10. Please refer to the document for more details

Note 3: Interpretation to be carried out by a competent QP

7. References

- a) SS EN 1997-1, Eurocode 7: Geotechnical Design – Part 1: General rules
- b) NA to SS EN 1997-1, Singapore National Annex to Eurocode 7: Geotechnical design – Part 1: General rules
- c) BS EN ISO 22477–10, Geotechnical investigation and testing — Testing of geotechnical structures, Part 10: Testing of piles: rapid load testing
- d) ASTM D7383-19, Standard Test Methods for Axial Rapid Load (Compressive Force Pulse) Testing of Deep Foundations
- e) “Rapid Load Testing on Piles”, CRC Press (2009), ISBN: 978-0-415-48297-4; 978-0-203-88289-4
- f) “Rapid load test of pile”, International Press-In Association (IPA) Newsletter, Volume 4, 2 June 2019