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Common Mistakes in Execution of Plane Load Test

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ABSTRACT Shallow foundation is the preferred foundation whenever possible, as it is economically more feasible compared to deep foundation. The design method for shallow foundation has long been established by Terzaghi. The Terzaghi's bearing capacity equation requires soil strength parameters for its calculation. To obtain accurate results, undisturbed sample for laboratory testing is necessary. However, depending on the accuracy of soil sampling and laboratory testing, the results can have large inaccuracy. The in-situ determination of shallow foundation can be carried out by plate loading test. It is a well-established test which was standardized by British Standards in 1990 and American Society for Testing and Materials in 1994. The testing method is simple, and the standards provide flexibility in the execution of the test. Unfortunately, this flexibility can cause mistakes in the execution of the test, as practitioners can be selective in choosing the test procedure to minimize the test duration and/or cost. These mistakes can cause the plate load test results to be unusable or lead to erroneous results. This paper aims to address common mistakes in execution of plate load test.

KEYWORDS Shallow Foundation; Plate Load Test; Bearing Capacity; Field Test

1 INTRODUCTION

Shallow foundation is often preferred over deep foundation. This is mainly because shallow foundation is cheaper to construct than deep foundation. The bearing capacity of shallow foundation can be calculated with the well-established Terzaghi's bearing capacity (1943), or the general bearing capacity equation by Meyerhof (1951), or Vesić (1973). All the aforementioned analytical methods require soil strength parameters to calculate, which means laboratory testing. Laboratory testing requires soil sampling, and the results are highly affected by sample quality. The quality of the sample is highly affected by soil type, sampling technique, transportation of samples as well as sample extrusion for laboratory testing (La Rochelle et al., 1981; Santagata and Germaine, 2002; Tanaka et al. 1996). All these factors can disturb the soil, altering the soil's behaviour and thus affecting the accuracy of the parameters obtained. Therefore, it is ideal to conduct direct measurement on site whenever possible to minimize disturbance. Fortunately, bearing capacity of shallow foundation can be obtained directly and inexpensively via plate loading test.

Plate loading test is a test method to obtain bearing capacity of shallow foundation, as the name implies, the test involves loading a plate. The method has been established since 1990s by the British Standards (1990) and American Society for Testing and Materials (1994; 1997). Both standards laid out the required apparatus, test execution, measurement as well as termination. There is no hard rule on the apparatus used for testing, as well as execution and termination procedure, i.e., the standards give flexibility to practitioner on how to carry out the test. Although this flexibility allows engineers to modify the test in accordance with design necessity, this flexibility also opens up room for practitioners to make mistakes. Especially when the tests are conducted by technician without supervision from an experienced engineer (Özyurt, 2012).

This paper aims to address common mistakes that can be found when executing plate loading test. This paper starts by introducing the required apparatus and test setup based on British Standards Chapter 4 (BS 1337 – 9) and American Society for Testing and Materials (ASTM 1194 – 94 &

ASTM 1196 – 93). Thereafter, the test procedures based on the two standards are described. Thirdly, examples of mistakes from case studies are presented. Finally, the paper is concluded with the author's remark on plate load test.

It should be noted that both ASTM 1194 – 94 and ASTM 1196 – 93 laid out the standard procedure for plate load test (For simplicity, from here onwards the two ASTMs are called ASTM 1194 and ASTM 1196). The former is aimed for the interpretation of spread footing, while the latter is for soils and flexible pavement. While both standards are highly similar, ASTM 1196 is more detailed, and ASTM 1194 has been withdrawn since 2003. In this paper, both ASTM and the differences between the two are presented.

2 PLATE LOADING TEST APPARATUS AND TEST ASSEMBLY

2.1 Plate/Loading Plate

The British Standards do not specify the shape, dimension, or material of the bearing plate. British Standards simply state that the plate shall be as large as practically possible while considering soil properties and load to be applied. When testing fissured clays, the diameter of the plate needs to be at least 300 mm and 5 times the average spacing between fissures. When testing on granular soil, the plate diameter must be at least 5 times the nominal size of the largest soil particle. Other than that, the British Standards commented that the plate has to be rigid and flat on the underside. The plate also has to have a guide for locating the loading column (center of plate). The contact of loading column to the plate has to be arranged so that tilt is resisted. A ball seating is not allowed.

In ASTM 1194 and 1196, the dimensions of the plates are determined. In ASTM 1194, three circular bearing plates with a minimum thickness of 1 inch (25 mm), are stacked in pyramid fashion. The base plate has a diameter of 30 inches (762 mm), while the top plate has a diameter of 12 inches (305 mm). The middle plate can be of any size between the base plate and the top plate. The three circular steel plates can be replaced by square steel plates of equivalent area. The steel plates can also be replaced by concrete footings with the same or larger dimensions than that specified for steel plates. In ASTM 1196, it is recommended to use four circular plates with the top and bottom plates having the same size requirement as ASTM 1194. The adjacent plates should not differ by more than 152 mm in diameter, i.e., the plates are to have a diameter of 762 mm, 610 mm, 458 mm, and 305 mm. Additional note is given by ASTM 1196 that the plate requirements are not a strict one. Single plate of any size can be used to evaluate bearing index.

2.2 Reaction Loading Systems

British Standards listed a few possible reaction loading systems that can be used for plate load test, such as kentledge, tension piles, or jacking against an existing structure. BS states that when tension piles are to be used, they should be pre-installed before excavation of test area. Whereas ASTM 1194 only states loading platform or bins of sufficient capacity can be used. In ASTM 1196, more devices are listed as possible reaction sources, such as truck, trailer as well as tractor-trailer.

As for the supports of reaction loading system, the British Standards state that the supports have to be located sufficiently far from the plate load test. In the case of reaction by tension piles, the center-to-center distance from the loading plate to the tension pile has to be at least 3 times the plate diameter. The distance when kentledge reaction is used is not specified in the British Standards. In ASTM, the recommended distance between the support of loading system to the loading plate is no less than 2.4 m. In ASTM 1194, it is not stated whether this distance is the clear distance or the center-to-center distance. This is clarified in ASTM 1196, that the 2.4 m is the clear distance, i.e., the distance from the circumference of the largest plate to the reaction support.

2.3 Hydraulic Jack/Calibrated Force Measurement System

For the hydraulic jack, the British Standards only commented that it should have sufficient accuracy and load capacity. British Standards also state that additional force measuring device(s) may be necessary to cover the load range desired.

ASTM 1194 and 1196 have the same statement as British Standards that the hydraulic jack has to have sufficient capacity and an accurately calibrated gage to measure the load. However, in ASTM 1194, more specifications are given, i.e., the hydraulic jack has to have a minimum capacity of 440 kN, and the force measuring device has to have an accuracy of ± 2% of the load increment.

2.4 Settlement Recording Device

The British Standards require the settlement measuring device to have an accuracy of ± 0.05 mm, while ASTM 1194 and 1196 require an accuracy of ± 0.25 mm, and ± 0.01 mm respectively. Both BS and ASTM require the measurement to be independent from the influence of other apparatus/loading, i.e., soil deformation around the plate or support for loading platform. This can be achieved by using a reference beam. The British Standard does not specify the required distance for the footing of reference beam, but the reference beam needs to be referred to a stable benchmark clear of the load site. Whereas both ASTM 1194 and 1196 recommend the footing of reference beam to be placed a minimum of 2.4 m away. Again, in ASTM 1194 it is not specified whether the 2.4 m is the clear distance or center-to-center distance, but ASTM 1196 clarifies that the 2.4 m required is the clear distance.

2.5 Miscellaneous Apparatus

In addition to the aforementioned apparatus, BS and ASTM 1194 list excavating equipment and leveling tools which are required for the preparation of test pit. British Standards further list a few more apparatus such as quick setting plater (if necessary), dry density test apparatus, containers to collect disturbed/undisturbed samples as well as thermo-couple if drastic temperature change during the execution of test is expected. The British Standards commented that significant temperature change can affect the deformation measuring system. ASTM 1196 does not have any remark on miscellaneous apparatus.

2.6 Test Pit Preparation (if Test is Below Original Ground Level)

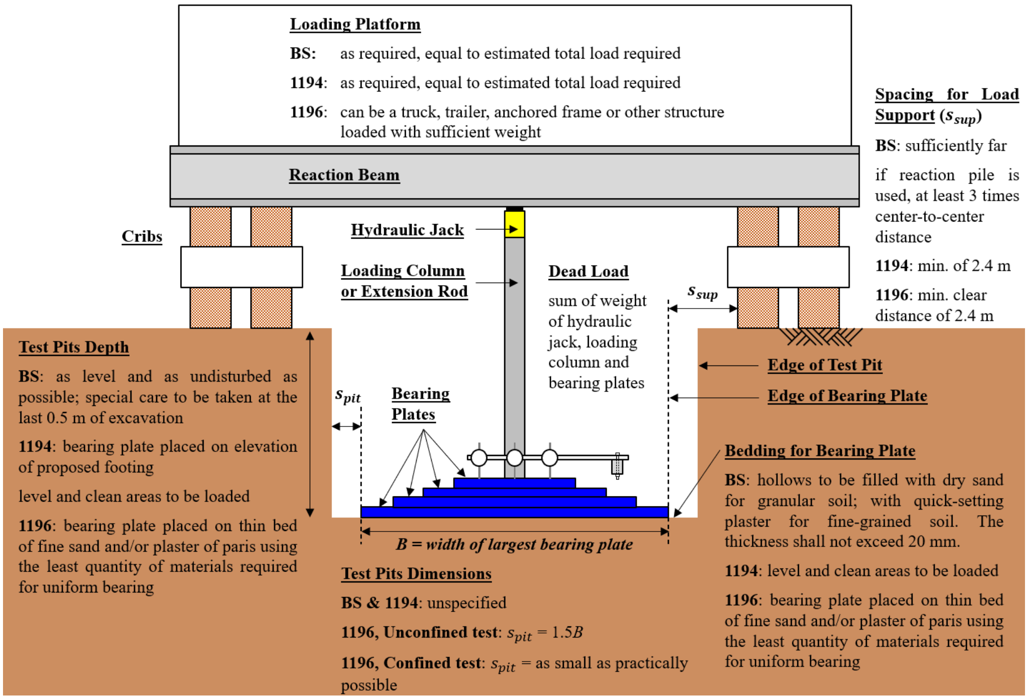
The British standards do not state the length or width required for the test pit. Instead, BS state that excavation within 0.5 m of test level has to be done carefully to minimize disturbance. All loose materials and embedded fragments are to be carefully trimmed off and removed so that the bearing plate is laid on level ground and as undisturbed as possible. Often, the surface of soil is not flat, nor smooth. In this case, bedding can be provided before the bearing plate is placed. On fine-grained soils, the recommended bedding is quick-setting plaster of 15-20 mm thick. Immediately after the paste is spread, bed the plate. For granular soils, hollows are to be filled with clean dry sand to produce a level surface for bedding the plate. The test area is to be protected from moisture changes to the best possible. This means protecting test area from sunlight and adverse weather changes.

ASTM 1194 is similar to BS in regard to test pit preparation. ASTM 1194 also does not state the required length or width of test pit, but states that the test area should be on undisturbed soil which is cleaned and leveled. However, ASTM 1194 does not mention the process to be taken to ensure low degree of disturbance, as well as the process of cleaning, leveling nor bedding materials.

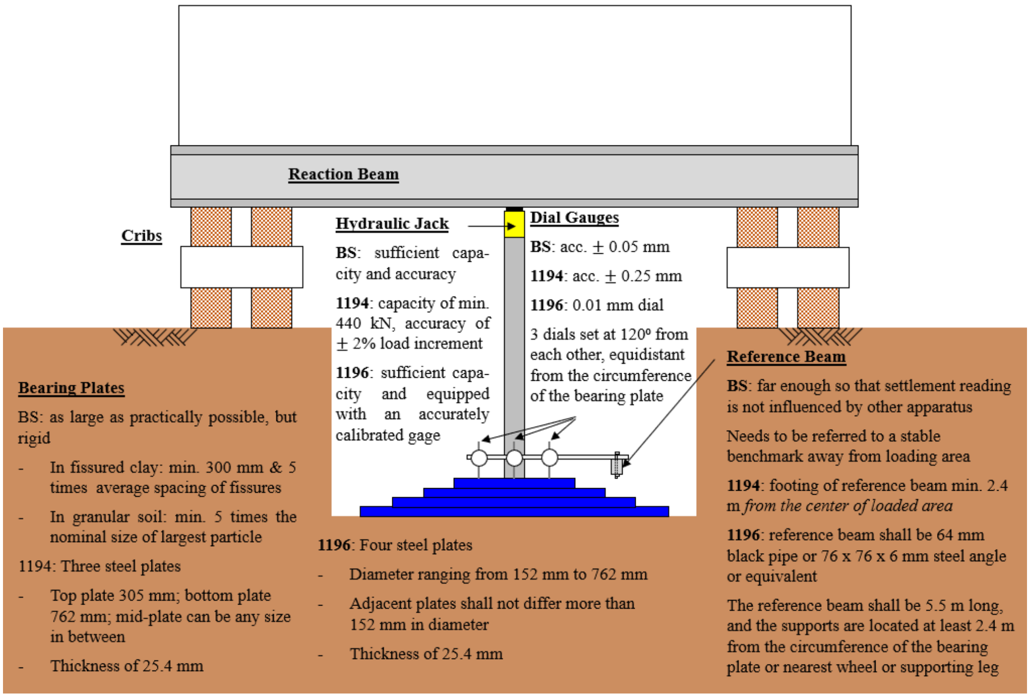
Similar to ASTM 1194, ASTM 1196 also does not state any precautions on the excavation process of test pit. However, more details on the bedding of bearing plates are given. Plates are to be placed on a thin bed of fine sand and/or plaster of Paris using the least quantity needed to provide a uniform level. In addition, ASTM 1196 covers the specification for width and length of test pit. For unconfined test, the distance of test pit to edge of bearing plate is to be at least 1.5 times bearing plate diameters. For confined test, the width of test pit should be just enough to place the selected bearing plate.

Regarding moisture, similar to the BS, ASTM 1194 also states to protect test pits and areas against moisture changes. The only exception is additional information regarding wetting of soil. When the soil is expected to get wet in the future, the pit can be pre-wet to a depth of at least two times the diameter of largest bearing plate. ASTM 1196 gives more detailed precautions on protection against moisture loss, i.e., the exposed subgrade to a distance of 1.8 m from the circumference of the bearing plate is to be covered with a tarpaulin or waterproof paper.

The test setup for plate load test is summarized in Figure 1.



(a)



(b)

Figure 1. Setup of plate load test: (a) details of test pit and reaction loading system; (b) details of bearing plates, hydraulic jack, dial gauges, and reference beam (Modified from ASTM D1194 – 94).

2.7 Comments on Test Apparatus and Test Assembly

Both British Standards (Clause 4.1.3.1) and ASTM 1194 (Note 1) commented that the apparatus and test assemblies are not fixed and can vary widely depending on job conditions, testing and precision requirements, as well as equipment available. ASTM 1194 further states that the variation from the standards has to be approved by a supervising engineer. ASTM 1196 (Note 1) only commented on the flexibility of bearing plate size. It is not written whether the spacing requirement for load support as well as reference beam support changes according to the bearing plate size used.

3 TEST AND MEASUREMENT PROCEDURE

The test procedure of plate load test consists of three main steps, i.e., loading, termination criteria, and unloading. After the apparatus has been assembled, the loading can be initiated. There are two methods for loading, that is load-controlled, or strain-controlled. BS suggests using load-controlled and strain-controlled when drained and undrained loading are expected, respectively. In ASTM 1194, both procedures are given but it is not specified when each procedure should be used. ASTM 1196, however, only covers the load-controlled method. This section discusses the load-controlled test and the strain-controlled test separately.

3.1 Load-Controlled Test

3.1.1 Seating load (zero-load)

When plate load test is initially setup, the hydraulic jack is not in contact with the reaction load yet. Therefore, an initial load has to be applied before the hydraulic jack will come into contact with the reaction load. This initial load is defined as seating load. BS and ASTM 1194 do not describe what needs to be done in terms of this seating load. Although BS and ASTM 1194 do not describe the seating load, BS and ASTM 1194 noted that the dead loads (weight of plate, loading column, hydraulic jack, etc.) applied on the ground prior to application of load have to be recorded. In BS, the dead loads are considered in the calculation of bearing capacity, while in ASTM 1194 it is not written on how the dead loads should be used in interpretation of results. However, the deformation during placement of bearing plate(s), loading column, and hydraulic jack will be difficult to record, especially the bearing plate(s) prior to placement of settlement recording dial gage. The author assumes that the dead loads are assumed to have a deformation of zero, while the first load applied on hydraulic jack is the first deformation recorded. Likewise, the author also assumes that ASTM 1194 has the same intention as the BS regarding the dead loads.

In ASTM 1196, the application procedure for seating load is given. Firstly, apply a load to produce a deflection of more than 0.25 mm, but less than 0.51 mm (this deformation excludes deformation produced by dead loads). Unload the hydraulic jack and reapply the recorded load (that produces deformation of 0.25-to-0.51 mm) multiplied by 1.5. Re-zero the deformation measuring devices. This shall be the ‘zero-seating load’. ASTM 1196 further notes that this zero-deflection point has to be corrected, considering both the seating load, as well as the dead loads when interpreting the load-settlement curve.

3.1.2 Loading step (load increment)

In load-controlled test, prior to loading, the load increment has to be predetermined. The load increment is based on estimated ultimate bearing capacity. In ASTM 1194, the load increment used is 1/10th of the estimated bearing capacity but not more than 95 kPa per load increment. Whereas the BS use load increment of 1/5th of the bearing capacity with no maximum load increment specified. The BS also provides an alternative, instead of using ultimate bearing capacity, one can use the design pressure. When the design pressure is used, also use 1/5th as the load increment. The BS allows for unloading and reloading cycle to be done in between loading steps. No specification is given on how to carry out the unloading and reloading cycle. The ASTM 1194 does not comment on cyclic loading.

Different from the two aforementioned standards, in ASTM 1196, no loading increment value is specified. Instead, ASTM 1196 simply states that the load increment has to be small enough so that at least 6 points in the load-settlement curve can be recorded.

3.1.3 Loading step (loading duration and guideline for measurement)

In ASTM 1194, each load increment is to be maintained for at least 15 minutes. Longer time can be maintained until the settlement rate has ceased or becomes uniform. When longer time intervals are used, each load increment has to use this longer interval. A minimum of six readings should be taken per load increment at equal time intervals. The first and last readings should include reading before and after the application of each loading increment. This means the readings should be taken every 3 minutes starting from 0 minute up to 15 minutes. In ASTM 1196, the minimum duration requirement is no longer stated. Instead, the load is to be maintained until rate of deflection is less than 0.03 mm per minute for 3 consecutive minutes. The time intervals are not stated in ASTM 1196, but from the rate of deflection criteria, it can be assumed that measurement is to be taken every minute.

Similar to ASTM 1196, the BS does not specify the duration that has to be maintained for each load increment. However, the BS suggests maintaining the load until the penetration rate has stopped. If the duration required to reach zero penetration rate is too long, the load should at least be maintained until primary consolidation is complete. This can be evaluated using settlement versus log time plot. The BS also does not specify the required time intervals for measuring the settlement. The BS only suggest taking frequent measurements at the beginning of loading, the time interval between measurement can be increased when settlement rate starts to decrease.

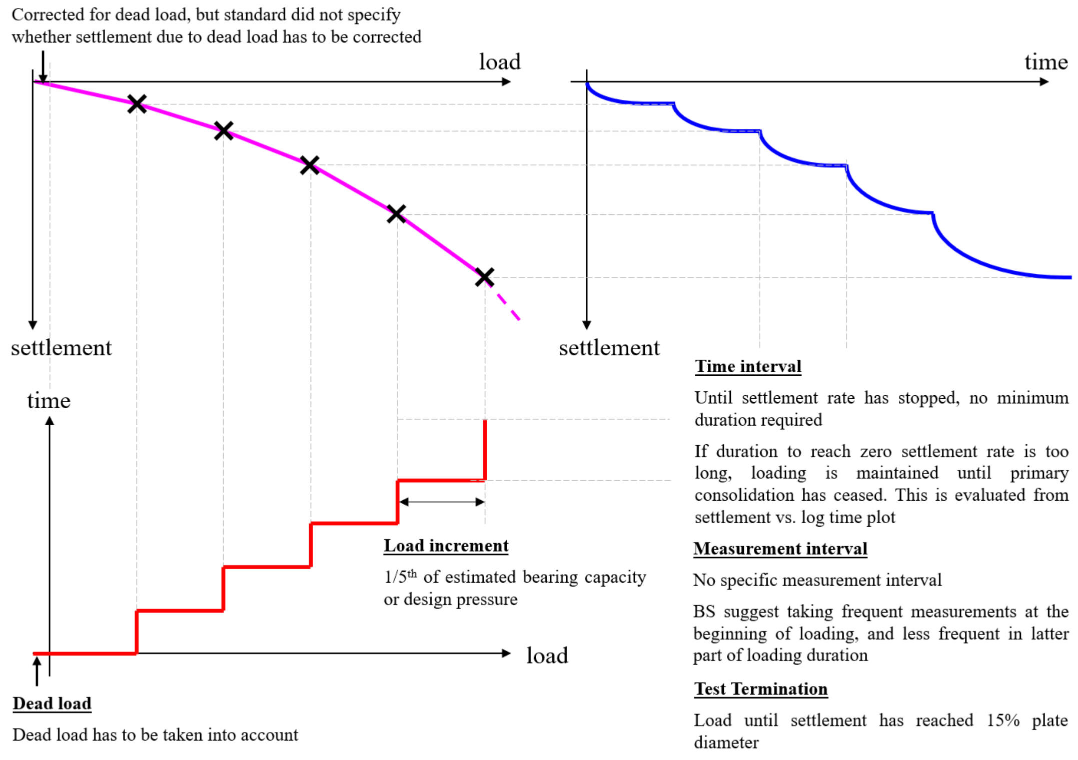
3.1.4 Termination criteria and unloading

In ASTM 1194, loading is continued until a peak load is reached, a well-defined failure load is observed or at least 10% of the plate diameter. Thereafter unload in three equal decrements. For each unloading step, the rebound/heave should be recorded until it stops or for a period equal to the duration of each loading step.

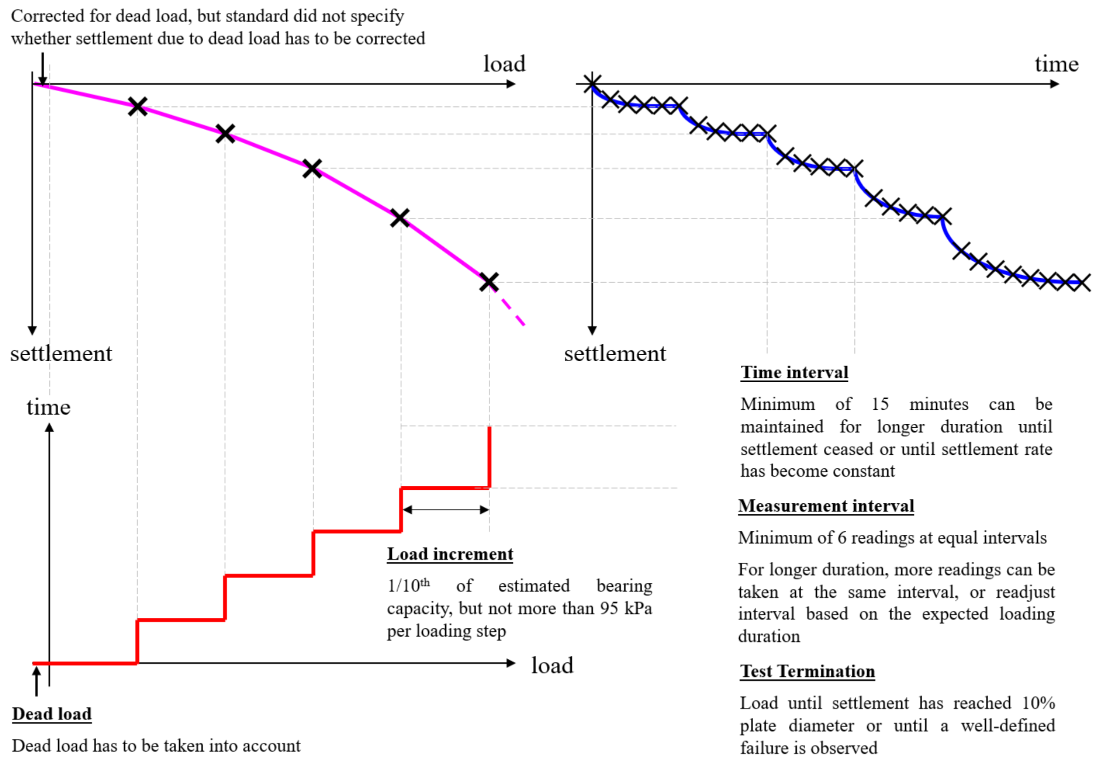
Different from ASTM 1194, ASTM 1196 does not state any termination criteria. ASTM 1196 simply states, load the plate until ‘selected deflection’ is obtained, or until the capacity of hydraulic jack is reached, whichever happens first. Unloading is done in one single step to the zero-seating load. The zero-seating load is maintained until the heaving rate does not exceed 0.03 mm per minute for 3 consecutive minutes.

In the BS, the termination criteria specified is for strain-controlled test, but not stress-controlled. Therefore, it is assumed the termination criteria is the same as strain-controlled. The BS specified 15% of the plate diameter as termination criteria. There is no unloading criterion stated in the BS.

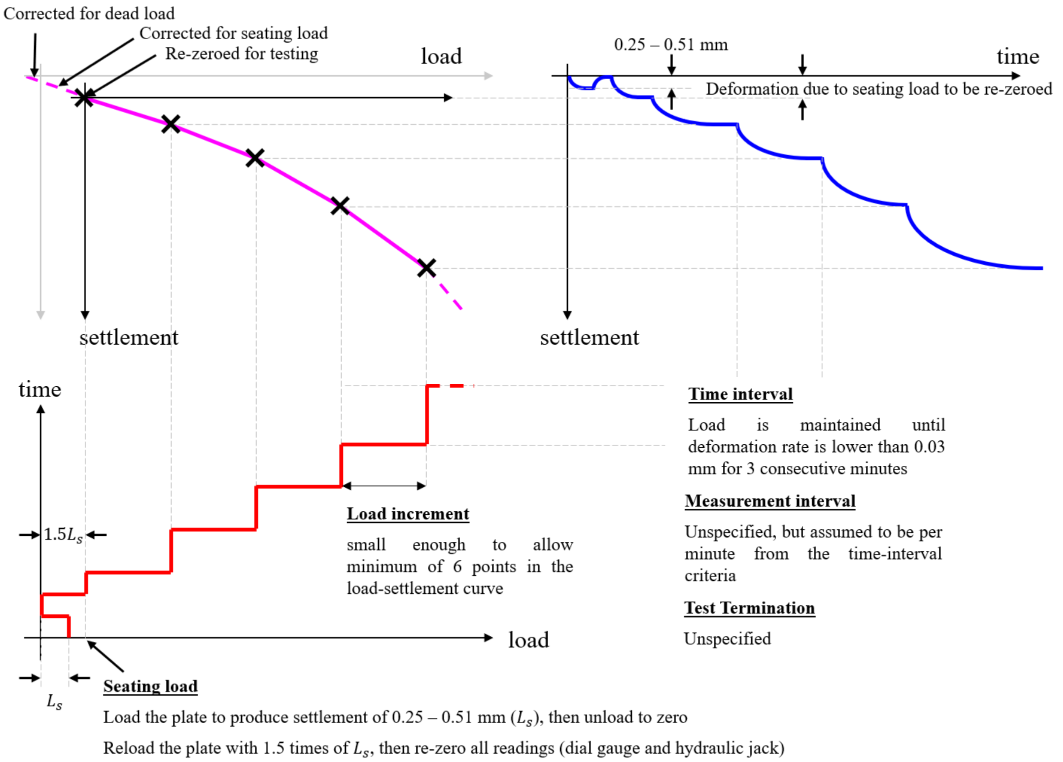
The test and measurement procedure are summarized in Figure 2.


Corrected for dead load, but standard did not specify whether settlement due to dead load has to be corrected
load
time
settlement
settlement
time
load
Time interval
Until settlement rate has stopped, no minimum duration required
If duration to reach zero settlement rate is too long, loading is maintained until primary consolidation has ceased. This is evaluated from settlement vs. log time plot
Load increment
1/5th of estimated bearing capacity or design pressure
Measurement interval
No specific measurement interval
BS suggest taking frequent measurements at the beginning of loading, and less frequent in latter part of loading duration
Dead load
Dead load has to be taken into account
Test Termination
Load until settlement has reached 15% plate diameter

(a)


Corrected for dead load, but standard did not specify whether settlement due to dead load has to be corrected
load
time
settlement
settlement
time
Time interval
Minimum of 15 minutes can be maintained for longer duration until settlement ceased or until settlement rate has become constant
Measurement interval
Minimum of 6 readings at equal intervals
For longer duration, more readings can be taken at the same interval, or readjust interval based on the expected loading duration
Load increment
1/10th of estimated bearing capacity, but not more than 95 kPa per loading step
load
Dead load
Dead load has to be taken into account
Test Termination
Load until settlement has reached 10% plate diameter or until a well-defined failure is observed

(b)



(c)

Figure 2: Test and Measurement Procedure: (a) British Standards; (b) ASTM 1194; (c) ASTM 1196.

3.2 Strain-Controlled Test

For strain-controlled testing. ASTM 1194 suggests loading every 0.5% plate diameter settlement. After the settlement is reached, the load is to be measured at fixed time intervals. The suggested time intervals are 30 seconds, 1 minute, 2 minutes, 4 minutes, 8 minutes, and 15 minutes. The measurement is continued until the variation of load shows no further change or until the variation of load against log time (log *t*) is linear. The termination and unloading criteria are the same as load-controlled test. Essentially, the strain-controlled testing described in ASTM 1194 is still load-controlled but using strain-increment instead of load-increment to determine the loading step. ASTM 1196 does not provide any guidance on strain-controlled test.

Different from ASTM 1194, the BS specifies that the plate is to be loaded with a constant and continuous penetration rate. The load applied is to be continuously monitored. The BS does not specify the rate of penetration. At any point during the test, unloading and reloading can be conducted to obtain the irreversible deformation. The loading is continued until the plate has settled by 15% of plate diameter. The ultimate bearing capacity is taken at the well-defined failure. If no clear-defined failure is observed, ultimate bearing capacity is taken at the load corresponding to 15% plate diameter settlement. Similar to the load-controlled test, there is no specification for the unloading in strain-controlled test.

4 COMMON MISTAKES IN EXECUTION OF PLATE LOAD TEST

As shown in section 2 and 3, despite the seemingly simple plate load test, there are many specifications and utmost care is necessary when executing plate load test. In this section, the common mistakes are categorized to showcase that there are many room for errors when conducting plate loading test.

4.1 Choice of Reaction Loading System

For convenience, excavator which is used to excavate the test pit is often reused as the reaction loading system. Figure 3 shows an example of a small excavator being used as reaction loading system. In this case, the excavator used LiuGong Model 908 E (LiuGong, 2022). This model has a clearance of 1.3 m between the track shoes, and track gauge (the distance between center of track shoes) are 1.75 m. This is clearly insufficient to meet the ASTM requirement of 2.4 m from the edge of bearing plate. If BS requirement of 3 times diameter from the center of bearing plate to the edge of track shoes are used, this allows bearing plate smaller than 215 mm diameter to be used. If the BS requirement is taken more leniently, i.e., 3 times diameter from the center of bearing plate to the center of track shoes, this allows bearing plate up to 292 mm diameter to be used. In the example shown (Figure 3), the plate used was 450 mm in diameter, not conforming to any of the three Standards.

Figure 3. Excavator being used as reaction loading system for plate load test.

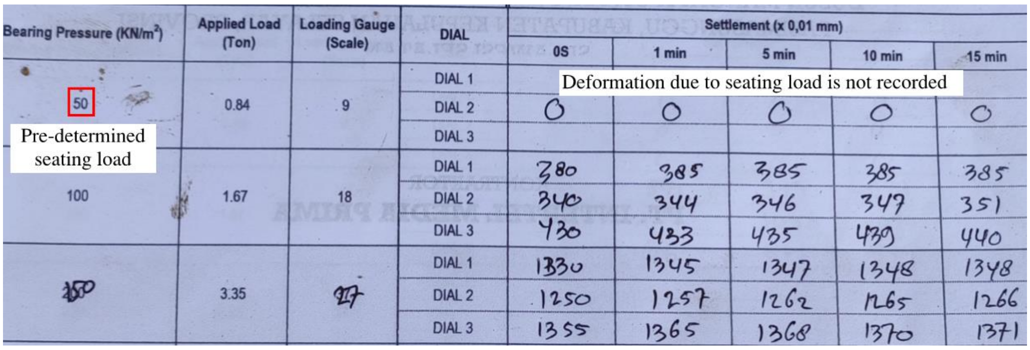
4.2 Reference Beam Support

Similar to the distance requirement of bearing plate to reaction loading system, distance requirement of bearing plate to reference beam support is also often an issue. Figure 4 shows a photograph of reference beam being used for plate load test. The reference beam used partially fulfilled the requirement of ASTM 1196, i.e., black pipe of the correct diameter. However, the reference beam used clearly does not meet the length requirement of 5.5 m, nor the support distance of 2.4 m. The clear distance of reference beam support to the bearing plate is less than one time the plate diameter used. The reference beam support is highly likely to be within the influence zone of loaded bearing plate, thus affecting the plate load test results.

Figure 4. Reference beam used for plate load test is too near the bearing plate.

4.3 Seating Load

The requirement of ASTM 1196 in terms of seating load can be quite difficult to fulfill. To avoid the difficulty in determining the seating load, some practitioners simply use the first load increment as seating load, as shown in Figure 5. Worsening the mistake, the deformation from the seating load/first load increment is ignored. This mistake might be due to the mixed interpretation of BS and ASTM 1196.



Bearing Pressure (KN/m²)	Applied Load (Ton)	Loading Gauge (Scale)	DIAL	Settlement (x 0,01 mm) 0S	1 min	5 min	10 min	15 min
50	0.84	9	DIAL 1	Deformation due to seating load is not recorded				
			DIAL 2	0	0	0	0	0
Pre-determined seating load			DIAL 3					
100	1.67	18	DIAL 1	380	385	385	385	385
			DIAL 2	340	344	346	347	351
			DIAL 3	430	433	435	439	440
150	3.35	27	DIAL 1	1330	1345	1347	1348	1348
			DIAL 2	1250	1257	1262	1265	1266
			DIAL 3	1355	1365	1368	1370	1371

Figure 5. Record of plate load test.

4.4 Choice of Load Increment

Load increment chosen should be small enough so that a proper load-settlement curve can be obtained. However, the smaller the load increment, the more loading steps required to reach the termination criteria. This leads to longer test duration. Economically speaking, longer test duration will be more expensive than short ones. Hence, to minimize cost, large load increment tend to be used.

Figure 6 shows four plate load tests which use a load increment of 1/4th of design pressure. As the tests were terminated at the design pressure, and the first loading step is taken as seating load, the load-settlement curve essentially only has 3 data points. The tests shown defy the BS requirement of 1/5th of design pressure, as well as ASTM 1196 standards which require at least 6 data points. Due to the lack of data points, the failure load cannot be clearly defined. For test 1 and 2, the failure load could lie between 100 to 150 kPa; But for test 3 and 4, the failure load is less clear. Determination of failure load is made more difficult as the deformation from the first load increment (50 kPa) is unaccounted for. These tests show the importance of using a small enough load increment when executing plate load test.

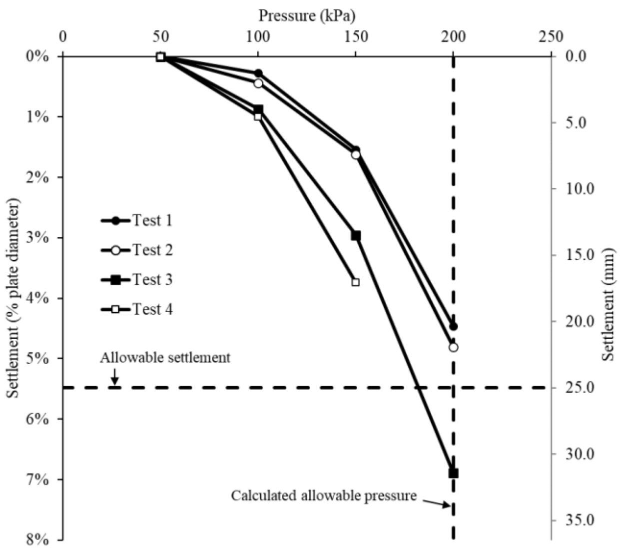


Figure 6. Example of plate load tests with load increment which is too large.

4.5 Termination of Test and Unloading

The termination of plate load test is determined by a settlement criterion. It can be 10% or 15% plate diameter as advised by ASTM 1194 or BS, respectively. It can also be the allowable settlement, as advised by ASTM 1196. A common mistake in interpretation of the standard is to equalize allowable settlement as calculated allowable pressure. This mistake could have risen from misinterpretation of the British Standards load increment criterion. As BS requires load increment of 1/5th of design pressure, practitioner may misinterpret that test is completed when 100% design pressure is reached.

Figure 7 shows four plate load tests which use calculated allowable pressure as termination criteria. As shown in the figure, all tests are terminated at the calculated allowable pressure (200 kPa), prior to reaching the allowable settlement (25 mm). With the exception of test 8, the other 3 tests have not shown any sign of failure. These tests show that the preliminary calculation of bearing capacity is overconservative. However, as the plate is not loaded to failure, how much more conservative cannot be evaluated. Furthermore, the unloading step is not recorded.

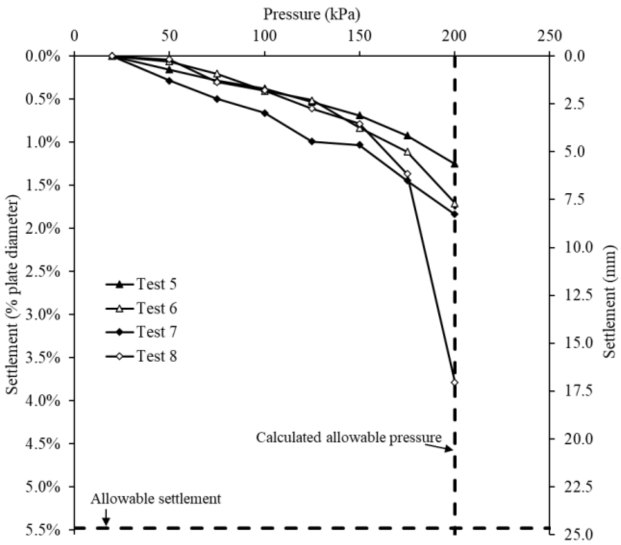


Figure 7. Example of plate load tests with early termination.

4.6 Other Sources of Errors

Other than the errors listed in this paper, another source of error is the choice of bedding. This topic has been extensively discussed by Barnard (2013; 2019), and thus is not further discussed in this paper. In addition to errors in test execution, there can also be errors in interpretation as well. One can refer to a paper from Anyang et al. (2018) for this topic.

5 SUGGESTION FOR EXECUTION OF PLATE LOAD TEST

5.1 Choice of Reaction Loading System

The ASTM standards of 2.4 m clear distance between plate to load support are made with consideration that 0.762 m diameter plate is being used. This still gives a clear distance of more than 3 times the plate diameter. The British standards have a more lenient requirement of clear distance equal to 2.5 times the plate diameter. It is recommended to abide at least the British Standards. Figure 8 shows the plate diameter that can be used for a given track gauge of an excavator. The shaded area is the plate diameter for any given track gauge with track width ranging from 0.45 to 0.90 m. The line if the British Standard requirement is taken as center-to-center distance is also shown in the figure, however it is not recommended to use this value.

To allow for bigger plates, it is better to use a truck or trailer. However, when using a truck/trailer, care should be taken when placing the reference beam support. The reference beam support also has to abide the minimum clear distance from the wheel of the truck/trailer.

If the clear distance requirement cannot be met, one can conduct a 3D finite element analysis to back analyze the results while considering the weight from reaction load. The engineer can then calibrate the soil properties, and then evaluate the bearing capacity of shallow foundation in the conditions expected in the final design. To allow better calibration, the deformation of soil near the bearing plate can also be measured.

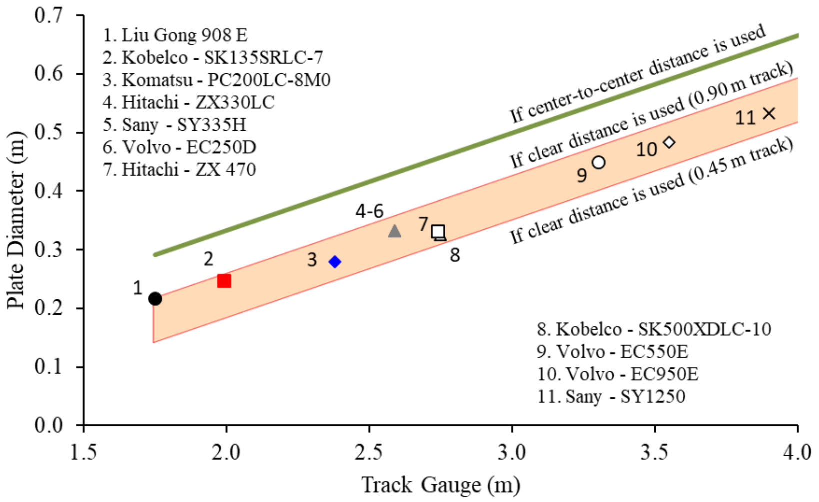


Figure 8. Usable plate diameter with track gauge of excavator (based on British Standards).

5.2 Reference Beam Support

The criteria made by ASTM should be taken as the first minimum. Reference beam support should be 2.4 m away from the edge of plate diameter, as well as the support of reaction system. However, if the reference beam is too short, a clear distance of 3 times the plate diameter should still be maintained. If both requirements cannot be met, the reference beam has to be surveyed at the end of each loading step to measure the deformation experienced by the reference beam support. The net settlement of the bearing plate can then be calculated.

5.3 Seating Load

As aforementioned, doing a proper seating load is not easy. To make it easier, one can use a very small seating load, Patel (2019) recommends 7 kPa. The settlement due to the seating load, as well as the dead loads can be ignored. The test can then be started with the first load increment. Similar to the recommendation in Section 5.1, the engineer can conduct a back analysis with 3D finite element modelling with consideration for the dead loads as well as the seating load.

5.4 Load Increment

Load increment has to be small enough to allow a well-defined load-settlement curve to be produced. Load increment and termination criteria (discussed later) have to be agreed upon before execution of test. To allow fairness for both the owner and contractor of the plate load test, the cost of plate load test can be adjusted in accordance with the test duration.

5.5 Termination of Test and Unloading

Termination of test should be based on the objective of plate load test. There are two main objectives when conducting plate load test. The first is to verify whether the dimension of footing is adequate for a given design load. The second is to find out the ultimate bearing capacity, which can then be used to optimize the dimension of footing. For the first case, one can terminate the test once the allowable settlement is reached. For the latter case, one must load the plate until failure, i.e., 10% plate diameter following ASTM, or 15% plate diameter following British Standards. The author recommends loading to at least 10% plate diameter. Similar to load increment, the cost of plate load test can be adjusted to the test duration instead of lump sum.

6 CONCLUDING REMARKS

In the field of geotechnical engineering, mistakes during testing can be made consciously or unconsciously. Mistakes include taking shortcuts in testing procedures or defying test apparatus requirements. This paper laid out some of the common mistakes found in terms of test execution, i.e., choice of reaction system, reference beam support, seating load, load increment, and termination of test and unloading. Of course, there are other sources of errors which have not been included in this paper. One example is the choice of bedding for plate load test. In cases where some requirements cannot be fulfilled, a complete 3D finite element back analysis can be carried out. The back analysis should consider effects of excavation of test pit, pressure from support of reaction system, dead loads from test apparatus, and seating-load.

Mistakes in test execution can lead to erroneous interpretation, potentially endangering lives. Care must be taken when conducting any test, including plate load tests. Hopefully, with this paper, there can be more awareness in the proper execution of plate load tests.

DISCLAIMER

The author has no competing interests to declare that are relevant to the content of this article.

AVAILABILITY OF DATA AND MATERIALS

All data are available from the author.

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