STATE-OF-THE-ART TECHNOLOGY OF Y-JACK IN BI-DIRECTIONAL PILE TEST

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ABSTRACT: The innovative pile testing that is categorized as a bi-directional test method (BD) obtained worldwide popularity for very large pile load design. For pile load design exceeded test load of 30,000kN, BD is a practical and an economical type of static load test method (SL). Presently, the most popular BD technology is using O-cell which was introduced by Prof Osterberg in 1989. O-cell or mechanically called as O-Jack is a piston type hydraulic jack which is embedded in the test pile for static load test. Load is applied bi-directionally from the jack to simulate static load test using the top load method. In year 2007, Y-Jack is an innovative jack specially designed for BD static load test. It is invented and named by Engineer Yu. Technically, Y-Jack is conceptually different in design compared to O-Jack with more advantages. Functionality, both jacks are the same, i.e. to conduct BD pile test. The type of Y-Jack is a capsule hydraulic jack, instead of piston hydraulic jack. This technical paper will introduce Y-Jack technology and its installations and some comparisons to O-Jack.

Keywords: pile test, load test, pile load test, hydraulic jack, piston jack, capsule jack, static pile test, dynamic pile test

THE PILING AND TESTING DEVELOPMENT

Pile foundation has been widely used worldwide since thousands years ago. In convention, piling is a terminology used in pile foundation for piles installed by pile driving hammers. Since last century, piling included cast in-situ and injection piles.

For driven piles installed by pile driving hammers, the piling industry already gone through four (4) major development (Wai, 2003), i.e.:-.

- Development 1: pile as rigid body
- Development 2: impulse-momentum theory (1930s)
- Development 3: wave mechanics theory (1960s)
- Development 4: impact load theory (2000s)

For cast in-situ piles such as bored piles and caissons, the trend of pile design became bigger and higher load since three (3) decades ago with following pile design classifications:-

- Small piles: test load less than 30,000kN
- Large piles: test load more than 30,000kN

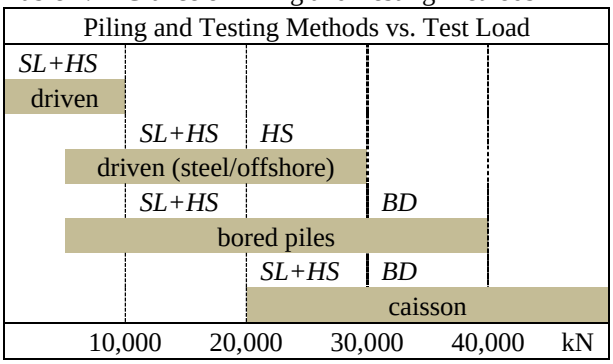
INTRODUCTION OF BI-DIRECTIONAL PILE TEST

For test load less than 30,000kN, the pile can be tested either using static load test (SL) or dynamic load test based on high-strain method (HS). However, for test load more than 30,000kN, the test using SL or HS method is almost impossible due to technical constraints and economical considerations.

In order to solve pile testing problem on large cast in-situ piles, a new technology was introduced in three (3) decades ago by installing a hydraulic jack embedded in the pile to conduct the pile load test. This new test method is named as bi-directional pile load test (BD).

Table 1 is a glance on piling and testing methods.

Table 1. A Glance on Piling and Testing Methods



For large pile testing, the BD pile test has unmatchable advantages.

- Unlimited test load, higher load lower unit cost
- Small work area, small headroom required
- Improved safety, no reaction system required
- Friction and end bearing ratio computed

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WHAT IS BD PILE TEST

A sacrificial and embedded hydraulic jack is cast within the pile body.

Upon application of load, the pile is separated into two sections and load is applied to both sections simultaneously and reacting against each other in two directions; upward against upper skin friction and downward against base end bearing and lower skin friction as illustrated in Figure 1.

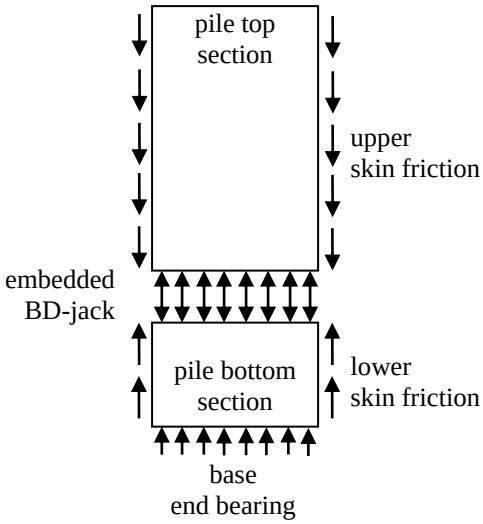


Figure 1. BD Loading Mechanism

Practically, the BD pile test does not require reaction beams, anchor piles or Kendledge during load applying. However, technically BD is equivalent to SL test method. In other words, BD simulates the SL results.

Figure 2. Analogy of SL to be BD Test

With the analogy, as illustrated in Figure 2, if the SL reaction system (either Kentledge or anchor piles) covered by soil and apply loading, the system becomes bi-directional (BD). The hydraulic jack in SL test becomes BD-jack.

The load applying on BD is exactly same as SL test method with designated loading steps. The BD test results and the simulated SL test results will be illustrated in Figure 3(A) and 3(B).

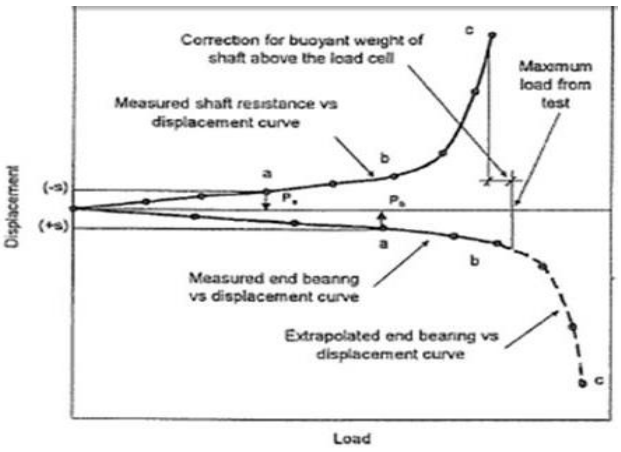


Figure 3(A). BD Load-Displacement Plot (Singapore Standard CP4: 2003)

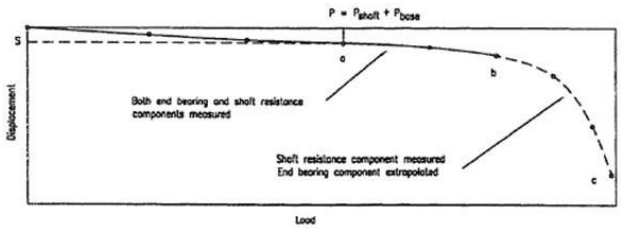


Figure 3(B). Simulated SL Load-Displacement Plot (Singapore Standard CP4: 2003)

THE HISTORY OF BD PILE TEST

The BD is the test method used to conduct SL pile load test. The hydraulic jack embedded in the pile to conduct BD test is called as BD-jack.

Since the introduction of BD pile test in three (3) decades ago, there are three (3) types of BD-jack:-

(1) Tomer Method (www.tomer-systems.com)
This is patented technology in Europe in the year 1978. However, this method is less popular worldwide.

(2) Osterberg Method, O-Jack (Osterberg 1989)
This is patented technology in the USA in the year 1989. Since then, it becomes worldwide popularity. It is using friction sealing components such as commonly used in hydraulic jack.

(3) Yu Method, Y-Jack (Yu 2007)
This is patented technology in China in the year 2007. Since then, it has become very popular in China due to many advantages and cost effective. It is using flexible capsule for sealing with a mechanism similar to basketball bladder.

WHAT IS Y-JACK

Y-Jack is a special jack designed for BD pile test. It is invented and named by Engineer Yu.

Presently, there are two (2) types of jacking and sealing methods.

(A) Friction Sealing

Use friction sealing components (sealing ring, piston ring and etc.) to ensure the sealing performance, such as commonly used hydraulic cylinder and jack. The main advantage is long product life (thousands of time in applying load). But the disadvantage is needed to be precisely produced, hence cost relatively high.

(B) Bladder Sealing

Use flexible capsule for sealing. The mechanism is similar to basketball bladder. The advantages are excellent sealing performance with low production cost. The disadvantage is relatively short product life (few times in applying load).

Professional Y-Jack adopts capsule sealing technology. That gives a more reasonable product value which avoids too wasteful long life of normal sacrificed test jacks. Meanwhile it offers lower height, larger loading area, lower oil pressure and safer loading results.

The cross-section details of Y-Jack are illustrated in the Figure 4.

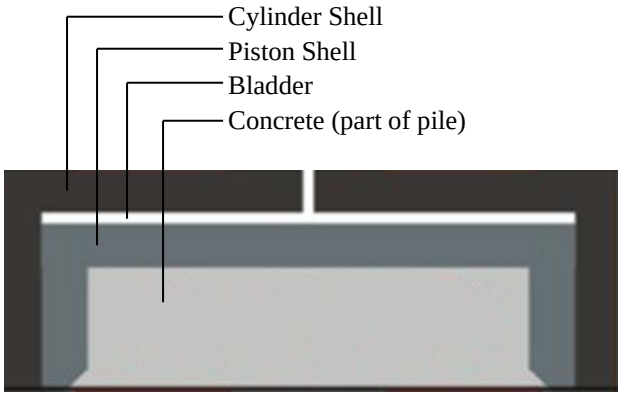


Figure 4. Y-Jack Cross-Section Details

THE Y-JACK LOADING MECHANISM

Y-Jack is designed to load low pressure (20-30MPa) onto pile body to ensure the pressure applied on the pile is less than the pile structural capacity.

In practice, many piles were designed as a high concrete material, but the pile actual strength usually does not meet the designed value due to the complex positions of the BD-jack and low flow-ability of sediments. Therefore, the safe loading is essential in BD testing to avoid pile damage caused by overloading on to the pile material.

In practice, many testing organizations fix 20-30mm thick steel plates on top and bottom of BD-jacks in order to enlarge the applied force bearing area.

However if the steel plates are too thin, the plates will deform during load applied to BD-jack and over-stress the concrete.

Appropriate steel plate thickness should be calculated as per area ratio as illustrated in the Figure 5.

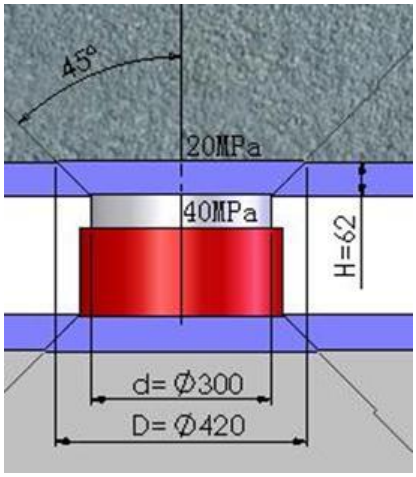


Figure 5. Steel Plate Thickness in BD Test

For a piston diameter of 300mm, for a loading delivery pressure of 40MPa, the steel plate should be thicker than H＝0.212*d＝62mm to ensure the bearing strength of the plate to the pile is less than 20MPa.

Due to Y-Jack mechanical design is a capsule type of hydraulic jack instead of piston type, the large surface of cylinder shell will ensure a low bearing stress on to the pile.

The Y-Jack has the following loading mechanism as illustrated in Figure 6.

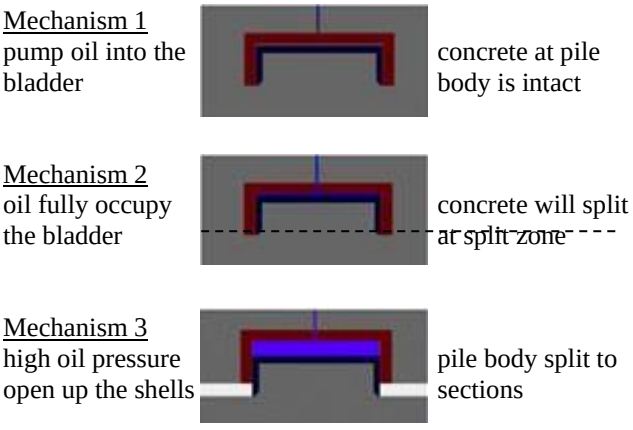


Figure 6. Y-Jack Loading Mechanism

THE ADVANTAGES OF Y-JACK

Due to many advantages since the introduction of Y-Jack in year 2007, it gains popularity very quickly. The advantages are:-

Flexible Assembly and Low Cost:

Y-Jack adopts standardized and serialized manufacturing mode. Y-Jacks are mass productions, hence lower the unit costs. Users select appropriate specification of Y-Jack under various situations and weld them to freely form up different combinations and sizes of Y-Jack as shown in Figure 7.

Figure 7. Flexible Assemble of Y-Jack

Bigger Space for Concrete to Flow:

In order to provide more free spaces for concrete flowing throughout the Y-Jack and to reduce cavities, Y-Jack enables abandoning top and bottom steel plates. As the result, the concrete flows fluently through the Y-Jack without sediments clogging. Sediments will form low stress concrete.

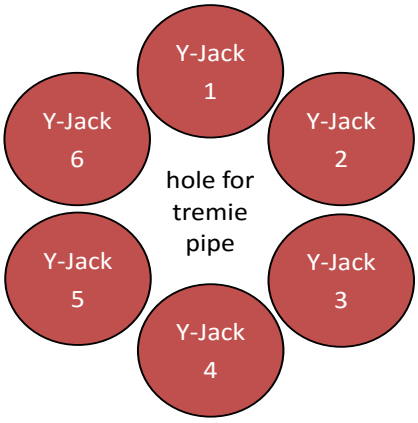


Figure 8. Bigger Space for Concrete to Flow

Pile Body & Y-Jack Intact Together

After concreting and before the loading, the pile body will be intact together with Y-Jack. The Y-Jack cylinder shell and piston shell rigidly connect upper and lower parts of the pile body. In other words, the Y-Jack is “embedded” in the pile body. Obviously, there are no spaces or cavities generating within the Y-Jack after concreting (before loading).

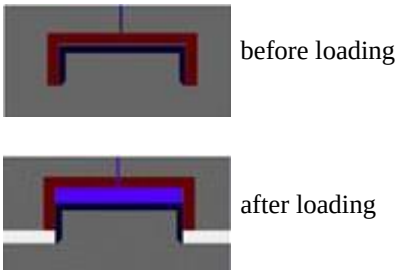


Figure 9: Pile Body & Y-Jack Intact Before Loading

Low Apply Load Limited to 30MPa:

Y-Jack uses low-medium pressure to meet the testing requirement, i.e. not over-stress the pile material with loading that is usually not higher than 30MPa. It will reduce the risk of unexpected crush at the contact faces of the pile during loading. Thus, the safety and the success rate can be enhanced.

In summary, the advantages are:

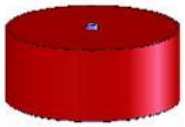
- ✓ Y-Jacks are easy handling and very mobility in remote area
- ✓ Y-Jacks can be calibrated at the factory prior to mobilize to project site
- ✓ Assembly at the site is relatively easy and simple
- ✓ Multiple Y-Jacks can achieve very high load (unlimited)
- ✓ Y-Jacks are mass productions, hence lower the costs per unit test load
- ✓ Manufactured in a factory and pass QA/QC to maintain consistent quality
- ✓ Y-Jack is a closed form super press jack that no hydraulic leakage (no oil seal ring)
- ✓ The pressure of Y-Jack is limited to 20MPa (for high bearing design pile, limited to 30MPa)
- ✓ The Y-Jack location only occupies < 50% pile section area for the concrete to flow fluently
- ✓ Y-Jack is “embedded” in the top and bottom pile sections to form the whole intact pile (not separated)

THE DIFFERENT OF Y-JACK AND O-JACK

Technically, Y-Jack is conceptually different in design compared to O-Jack with more advantages. Functionally, both jacks are the same, i.e. to conduct BD pile test.

The Y-Jack and O-Jack have three (3) major differences:-

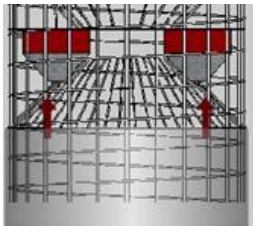
(1) Mechanical Design



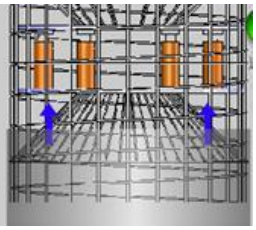
The loads are applied by using hydraulic capsule units

The loads are applied by using hydraulic jack units

(2) Top and Bottom Steel Plates

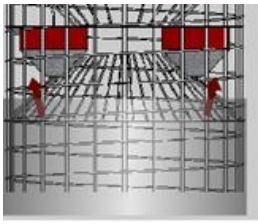


No steel plates and the Y-Jack only occupy relatively small cross-section, hence the concrete can flow upward fluently

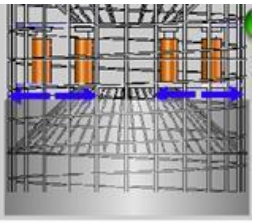


Steel plates located at bottom & top of the O-Jack which occupy most of the cross-section, hence block the concrete to flow

(3) Concrete Fluently Flow



Due to concrete can flow upward easily, hence the contact points at bottom are 100% intact. Accurate measurement.



Due to difficulty of concrete to flow, the bottom of the cells may not fully intact. Measurement may not accurate.

THE Y-JACK SELECTION EXAMPLE

The following will demonstrate an example to install Y-Jack:-

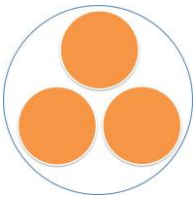
- Pile Type: cast in-situ bored pile
- Pile Length: 54.0m
- Pile Diameter: 1200mm
- BD Location: 35m from top
- Working Load: 8,000kN (800T)
- Test Load (ult.): 16,000kN (1,600T)
- Factor of Safety: 2.0

Y-Jacks are produced in standardized mass production. Table 2 is the sample specification table of Y-Jack.

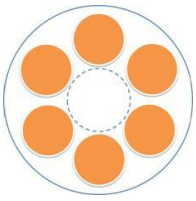
Table 2. Y-Jack Specification

Y-Jack Model	Rated Pressure (MPa)	Nominal Force (T)	External Diameter (mm)
YJ2D300	≈ 20	135	330
YJ2D300s	≈ 25	165	
YJ3D300	≈ 30	200	
YJ2D400	≈ 20	235	430
YJ2D400s	≈ 23	260	
YJ3D400	≈ 27	300	
YJ2D500	≈ 20	310	500
YJ2D500s	≈ 28	405	
YJ3D500	≈ 34	495	

From the Y-Jack specification table, select model YJ2D500. Apply Load 310T on Y-Jack will generate a bi-directional load = 310*2 = 620T. Quantity Y-Jack required = 1,600/620 = 3nos.



Model: YJ2D500



Model: YJ2D300

By referring the above diagram for model YJ2D500, the Y-Jack orientation in 1,200mm diameter pile will be very congested in the pile center for allowing the concrete tremie pipe to lower down to pile bottom for concreting. Hence the selection of model YJ2D500 is not appropriate.

By re-select model YJ2D300. Apply Load 135T on Y-Jack will generate a bi-directional load = 135*2 = 270T. Quantity Y-Jack required = 1,600/270 = 6nos.

By selecting model YJ2D300, the Y-Jack orientation in 1,200mm diameter pile will have sufficient space for concrete tremie pipe.

CONCLUSION

The innovative design of Y-Jack with mass production in a factory allows the cost of BD pile test reduces substantially. The implementation of Y-Jack BD pile test enables the pile design for large diameter pile become possible to carry out the pile load test. For pile load design exceeded test load of 30,000kN, BD is a practical and an economical type of static load test method.

After three (3) decades of development, BD tests obtained worldwide acceptance especially in developed and rich countries such as United States, Europe, Middle East and Singapore. These countries adopting BD tests because many of their skyscraper buildings are using large pile designs.

Without BD test method, to verify pile bearing capacity with high design load is almost impossible due to technical constraints and economical considerations in conducting pile load test.

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