High-speed Construction Method for PC LNG Tanks Using Precast Forms
— Ishikari LNG Terminal, PC LNG Tanks —

プレキャスト型枠を用いたPCLNG貯槽の高速施工方法
— 石狩LNG基地PCLNG貯槽 —




* Yuki KOBAYASHI, P.E.Jp: Taisei Corporation.
小林　祐樹，技術士（総合技術監理部門，建設部門）：大成建設（株）
** Haruhiko KAYAMA, P.E.Jp: Taisei Corporation.
香山　治彦，技術士（建設部門）：大成建設（株）
*** Gyo NISHINOMIYA: Taisei Corporation.
西宮　暁：大成建設（株）
**** Masato NIIDA: Taisei Corporation.
仁井田　将人：大成建設（株）
Contact: kbyyuk00@pub.taisei.co.jp
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Synopsis

The Ishikari LNG Terminal (**Fig.1**) is the first large liquefied natural gas (hereinafter referred to as LNG) regasification terminal in Hokkaido. This terminal contributes to the establishment of a stable gas supply system in Hokkaido and the realization of a low-carbon society. The No.1 tank was constructed in initial terminal development work from 2009 to 2012, and the No.2 tank was constructed in expansion work from 2013 to 2016.

For these tanks, the Dual prestressed concrete (hereinafter referred to as PC) wall system was adopted, developed originally by the Taisei Corporation to rationalize the structure. This wall system has many applications in Japan[1].

In addition, the Dual PC Speed Erection hereinafter referred to as (DPSE) method using precast concrete (hereinafter referred to as PCa) forms was newly developed and adopted for the design and construction of the No.2 tank[2]. DPSE was developed in response to the need for rapid construction, the shortage of skilled workers, and the lack of equipment and materials after the Great East Japan Earthquake.

Structural Data

Structure: LNG storage tank
Gross Capacity: 180,000kL (No.1), 200,000kL (No.2)
Structural Type: Full-containment LNG tank
Outer Wall Type: PC
Inner Wall Diameter: 80.0m (No.1), 83.2m (No.2)
Height of Wall: 40.2m (No.1), 43.1m (No.2)
Client: Hokkaido Gas Co., Ltd.
Principal Contractor: Tokyo Gas Engineering Solutions Corporation
Design/Construction: Taisei Corporation

Fig.1 Ishikari LNG Terminal

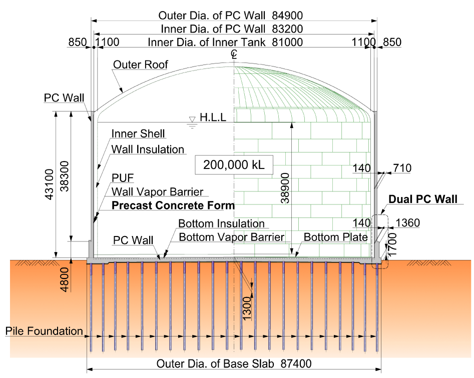


Fig.2 General drawing (No.2 tank)

1. Introduction

The tanks at the Ishikari LNG Terminal are above-ground PC LNG tanks comprising an inner shell and an outer PC wall. Made from 9% nickel steel, the inner shell contains the LNG at −164°C during normal service. The outer PC wall is a prestressed concrete structure that holds LNG if the inner tank leaks (**Fig.2**).
The Dual PC wall system was adopted for the wall design and construction of the No.1 and No.2 tanks. This wall system is an innovative solution to (i) have a thicker section at the bottom of the PC wall where the stress is greatest and (ii) to arrange vertical post-tensioning (hereinafter referred to as PT) tendons rationally. Thus, high quality and significant economic benefits were achieved.
The DPSE method using PCa forms was newly developed and adopted for the wall design and construction of the No.2 tank. This method allows the mechanical contractor to begin constructing the tank earlier than would be the case for a conventional tank, thereby shortening the total construction period.
The Dual PC wall system and DPSE method as used at the Ishikari LNG Terminal are summarized in the following sections.

2. PC Wall Structure

The Dual PC wall system was adopted for the wall design and construction of the No.1 and No.2 tanks.
The features of Dual PC Wall are (i) to enable placement of one or two types of PT tendons to resist large vertical bending moments near the bottom, (ii) to minimize the size of the PT tendons to resist only small vertical bending moments near the top, and (iii) to optimize the wall thickness (i.e., the section is thicker near the bottom and thinner near the top).
Long and short PT strands were placed in the Dual PC wall of the No.1 tank (**Fig.3**). This resulted in economic benefits over using conventional PC walls (**Fig.3**). In the Dual PC wall of the No.2 tank, for further rationalization, vertical PT tendons were installed in three separate areas according to the magnitude of the bending moment. PT strands capable of introducing a large prestressing force were placed at the thicker portion near the bottom. To facilitate tensioning work, PT bars were placed only where necessary near the top (**Fig.3**). Consequently, an easier and more economical construction design was realized for the No.2 tank.

3. Construction of No.2 tank

(1) Development of New Method

The No.2 tank was constructed to prepare the facility for future increases in demand for LNG, to stabilize further supply, and to realize efficient transportation. The work was carried out during a shortage of skilled workers, equipment, and materials due to recovery work following the 2011 Great East Japan Earthquake. In addition, the construction yard was narrow because the existing LNG terminal was being expanded. Furthermore, a revision of the Gas Business Act allowed for larger LNG tanks. Accordingly, the capacity of the No.2 tank was increased from the 180,000kL planned initially to 200,000kL.
Under those conditions, use of the same conventional method adopted for the PC wall of the No.1 tank would have required a construction period of 46 months, exceeding the target construction period by 8 months. Also, because the conventional method requires the installation of temporary scaffolding on both sides of the PC wall, the mechanical contractor would have to wait until the interior scaffolding was removed.
Therefore, a PC wall construction method was sought to shorten the construction period drastically. The new DPSE construction method (**Fig.4**) was developed, avoiding the need for temporary scaffolding inside the PC wall.

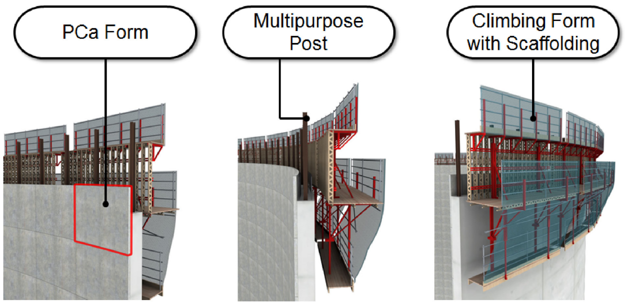


Fig.4 Dual PC speed erection method

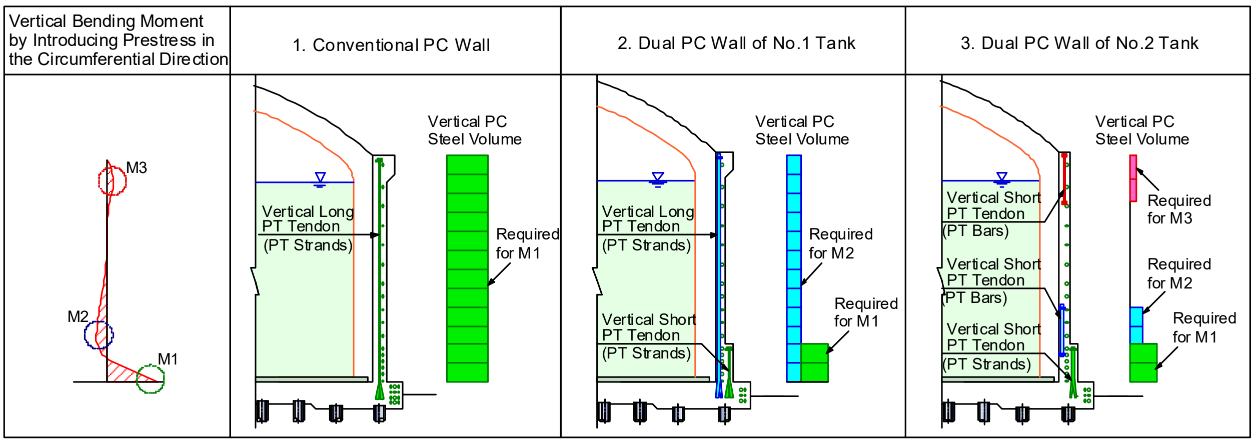


Fig.3 Comparison with conventional PC wall and Dual PC Wall

(2) Summary of DPSE Method

A PC wall constructed by the DPSE method has PCa forms placed inside the wall and multipurpose post for temporarily fixing the PCa forms in the center of the wall at the time of construction (**Fig.4**). Accordingly, it becomes unnecessary to install and remove the inner forms and the temporary inside scaffolding that are necessary in the conventional method.

In the conventional method, after constructing the base slab, its upper surface is unavailable to the mechanical contractor until the temporary scaffolding on the base slab has been removed. By contrast, the DPSE method does not require temporary scaffolding on the inside of the PC wall, making the upper surface of the base slab available to the mechanical contractor immediately after its construction (**Fig.5**). This shortens the total construction period by around 4 months.

When constructing the upper part of the PC wall, it is possible to clearly distinguish work spaces between civil and mechanical constructions by the precast forms. Accordingly, workability and safety are greatly improved (**Fig.6**).

In addition, having a “climbing form with scaffolding” on the outside of the PC wall reduces the risk of work being interrupted by strong wind, simplifies the construction work, and reduces the size of the construction yard. Moreover, manufacturing the PCa forms in a factory simplified the construction procedure and improved construction accuracy and quality.

(3) Comparison of Construction of the No.1 and No.2 Tanks

1) Constructing the Lower Part of the PC Wall

Fig.7 compares the construction of the No.1 tank (conventional method) with that of the No.2 tank (DPSE method). Both photographs were taken 4 months after completion of the base slab. In the construction of the No. 1 tank, the use of bracket-supported scaffolding made the upper surface of the base slab available to only the mechanical contractor at that stage. By contrast, in the construction of the No. 2 tank, the bottom vapor barrier had already been installed and construction of the outer roof had been started.

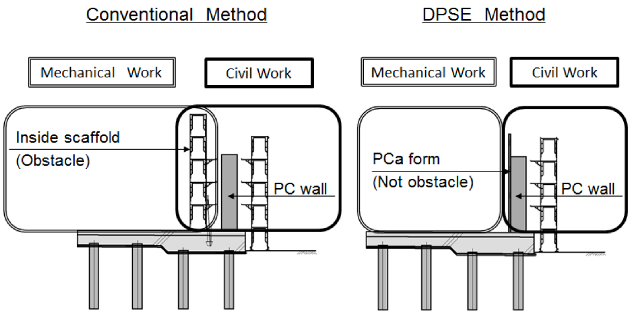


Fig.5 Benefits of adopting DPSE method (shortened construction period)

2) Constructing the Upper Part of the PC Wall

Fig.8 shows the construction of the upper parts of the PC walls of the No.1 tank (conventional method) and the No.2 tank (DPSE method). For the No.1 tank, the mechanical contractor had to work under the temporary scaffolding inside the PC wall. By contrast, for the No.2 tank, there was no scaffolding on the inside of the PC wall, and the work spaces for civil and mechanical construction could be distinguished clearly. Accordingly, there was no interference when materials were loaded for mechanical construction, and vertical work was greatly lessened, thereby improving workability and safety greatly.

(4) Shortening the Construction Period

Fig.9 compares the construction schedules. The DPSE method made the base slab available to the mechanical contractor immediately after it was constructed. With that method, the mechanical contractor was able to begin construction 4 months sooner than would have been the case with the conventional method. Also, it was possible to raise the roof before the second winter season, making it possible to build the inner tank throughout the year. The construction period of the No.2 tank achieved the target 38 months, shortening the construction period by 8 months compared with the conventional method.

4. Conclusion

When developing the Ishikari LNG Terminal, the Dual PC wall system was used to rationalizing the structure of the PC walls of the LNG tanks. In addition, the DPSE method using PCa forms was newly developed and used for construction of the PC wall of the No.2 tank.

The DPSE method allowed the mechanical contractor to begin construction sooner and shortened the construction period. The technology discussed herein can be applied not only to LNG tanks but also to other construction work.

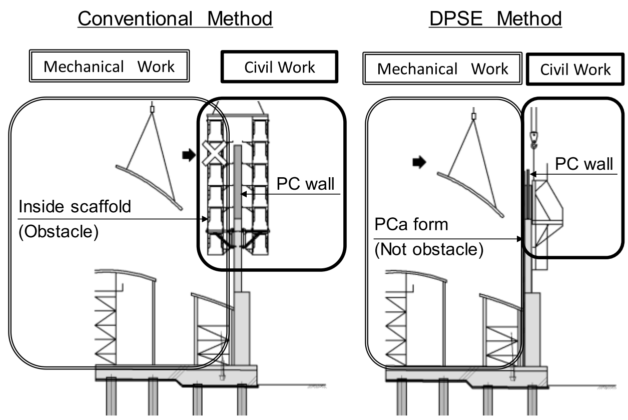
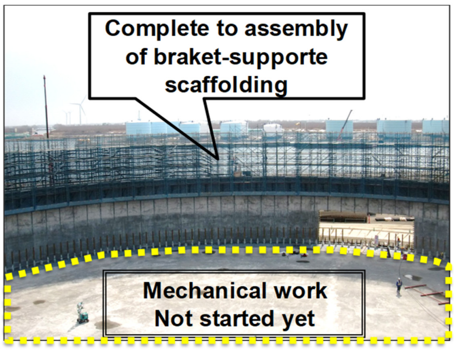
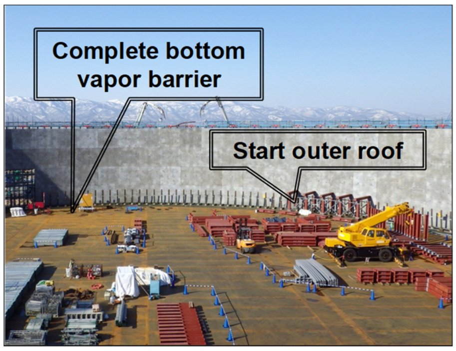


Fig.6 Benefits of adopting DPSE method (improved workability and safety)

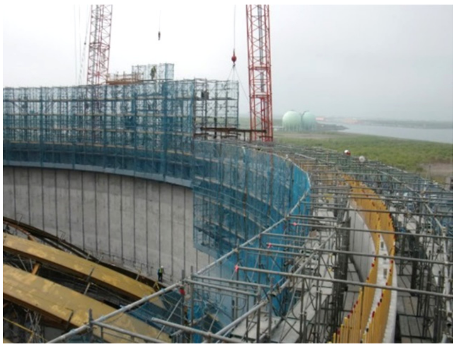


No.1 tank (conventional method)

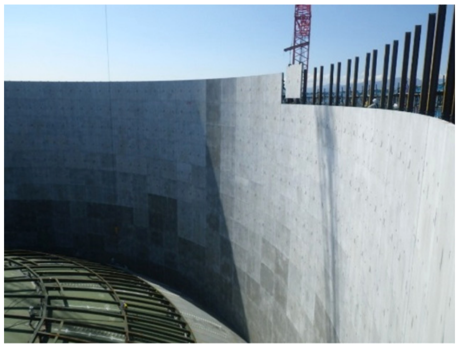


No.2 tank (DPSE method)

Fig.7 Constructing lower parts of PC walls (4 months after constructing the base slab)



No.1 tank (conventional method)



No.2 tank (DPSE method)

Fig.8 Constructing the upper parts of the PC walls

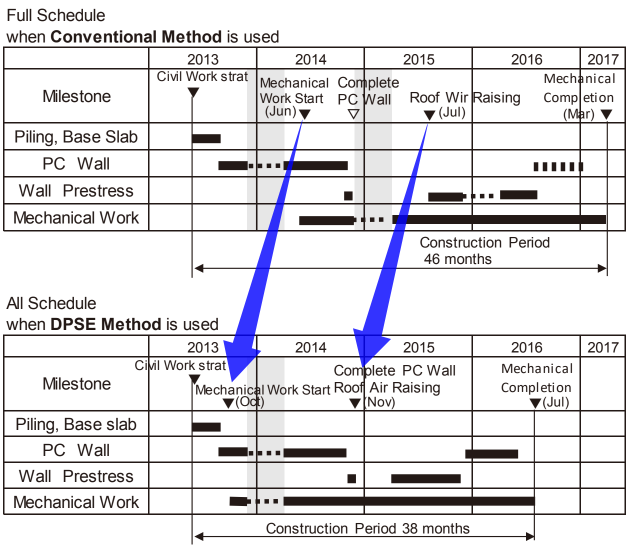


Fig.9 Shortening of the construction period

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[1] Ichinami, K. et al.: Design and Construction of Dual PC Wall -Sakaide LNG Terminal, 180,000kL PC LNG Tank-, National Report, The Third fib Congress 2010, Japan Prestressed Concrete Engineering Association, 2010.

[2] Kayama, H. et al.: Development of the Construction Period Shortening Method for Prestressed Concrete LNG Storage Tank using precast concrete form, Journal of prestressed concrete, Vol.58 No.1, Japan Prestressed Concrete Engineering Association, 2016. (in Japanese)

概　要

石狩 LNG 基地は，北海道初の輸入 LNG を受け入れる大型基地として，北海道全域のエネルギー安定供給体制の確立および低炭素社会の実現に貢献するものである。

本基地の主要構造物である PCLNG 貯槽は，金属製の内槽タンク，保冷材，RC 構造の基礎版および PC 防液堤からなる円筒形構造物である。No.1タンク（180,000kL）は2009年～2012年，No.2タンク（180,000kL）は2013年～2016年に建設した。これらのタンクでは，PC 防液堤の構造の合理化を目的として開発され，日本国内にて多くの施工実績のある変断面 PC 防液堤（Dual PC 防液堤）を採用した。さらに，No.2タンクでは，東日本震災以降の建設ニーズの急速な高まり，技能労働者不足，資機材不足に対応するため，埋設型プレキャスト型枠を使用した新しい PC 防液堤の構築方法「Dual PC Speed Erection 工法」を開発して採用することで，全体工期を大幅に短縮した。