Use of wider type of steel sheet piles for ERSS applications in Singapore

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ABSTRACT

Steel sheet piles are structural sections that are commonly used to provide lateral support and containment for various types of soil and water. Sheet piles are typically made of steel, which provides strength and durability. The sheets are often interlocked to form a continuous wall, where the interlocking systems allows the sheets to be installed in a sequence to create a barrier against soil or water. Steel sheet piles wall system has been used extensively in Singapore for temporary Earth Retaining or Stabilizing Structures (ERSS) works in the development of many infrastructures involving creation of underground space, drains, rivers, ports, and coastal protection. To optimize the material cost and shorten the construction time, wider type of steel sheet piles wall system has been recently introduced. Design engineers often look for a more robust design with a higher section modulus wall but at the same time, prefer fewer interlocking clutches to avoid water tightness issue. The philosophy of using wider type of steel sheet piles wall system is the current state of art in construction that will eventually reduce the number of sheet piles. This paper demonstrates two case histories in Singapore involving the use of Super Wide 600mm SILENT PILER to install U Type IVw 600mm steel sheet pile materials in replacing the more common use of U Type IV 400mm sheet pile materials.

Key words: *Wider Type, Steel Sheet Piles, ERSS, Press-in Piling, SILENT PILER*

1. Introduction

In Singapore and other ASEAN countries, the use of steel sheet piles has been common in creating a continuous wall for shoring support system using a vertical interlocking system. The walls are often used to retain soil and water, and the performance of a steel sheet pile section relies upon its geometry and the soils it is driven into. Besides the superiority of steel sheet piles in providing the combined strength and versatility, strong emphasis has been carried out to continuously developed new materials and advanced piling technologies to ease the installation effort and provide a cost-effective solution. This further contribute to the evolution of steel sheet piles and maximizing the benefits by using a wider section.

1.1. Historic Overview of Steel Sheet Pile Development

The use of sheet pile-like structures made of wood or timber can be traced back to ancient times, but the adoption of steel as a construction material marked a significant advancement. In the late 19th century, engineers started using steel sheet piles as an alternative to timber for improved strength, durability, and resistance to decay. The early 20th century saw the development of standardized profiles and shapes for steel sheet piles

which enhanced their usability and interchangeability in construction projects.

The idea of interlocking sheet piles to create continuous walls started to gain popularity which provides the water tightness for the stability of constructed walls. Engineers and manufacturers have been working to develop a more efficient interlocking system for steel sheet piles that can ease the pile driving and at the same time, can enhance the structural stability of the wall. Different profiles, such as U-type and Z-type steel sheet piles were introduced, each offering specific advantages for various construction applications. Fig. 1 shows wider type of steel sheet piles which have been introduced.

During the mid-20th century, the construction industry witnessed widespread adoption of steel sheet piles for various applications, including waterfront structures, foundation support, and earth retention projects. The latter part of the 20th century and into the 21st century saw continued innovations in sheet pile technology, including improvements in corrosion resistance, coating technologies, and the introduction of new materials. Advances in manufacturing processes and quality control have contributed to the reliability of steel sheet piles.

Nowadays, steel sheet piles have become a standard solution in construction projects worldwide, employed in diverse applications such as urban development, port, and marine construction. Ongoing research and development continue to enhance the efficiency and sustainability of sheet pile technology.

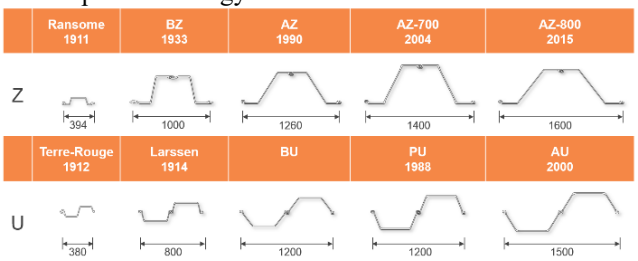

Fig. 1 Historical Overview of Steel Sheet Piles

Japan has had a significant influence on the use and selection of sheet piles in Singapore and other ASEAN countries, particularly in the areas of construction and civil engineering during the introductory period. Through collaborations, partnerships, and projects, Japan has transferred its expertise in adopting more efficient and effective methods for earth retention and water control.

In Japan, steel sheet piles have been first reportedly used for the earth retaining wall during the construction of Mitsui Head Office in 1903 and onwards. Thereafter, large quantities of steel sheet piles were imported from around the world for post-disaster construction and damage repair in the wake of the Great Kanto Earthquake of 1923. In 1929, the former government managed Yawata Works began domestic production of steel sheet piles where it started manufacturing and selling domestic steel sheet piles in 1931.

For almost a century, U-type sheet piles with an effective width of 400mm have been mainly used. In 1997, due to economic woes, reducing construction costs to address the budget cutting of public works in Japan becomes a necessity. As a result, wider type of steel sheet piles (i.e. 600mm width U-type, 900mm width Hat type) as shown in Fig. 2 have been developed, popularized, and progressively replaced the 400mm U-type in the 2000s.

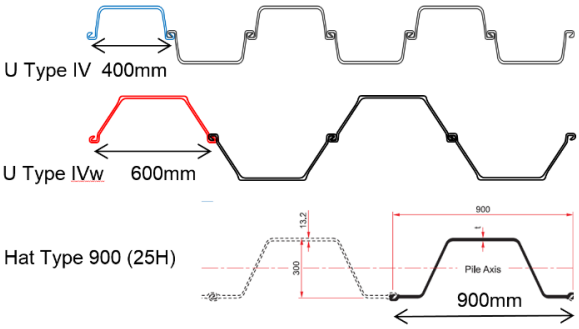

Fig. 2 Wider Type of Steel Sheet Piles (U type & Hat type)

While in Europe and America, the application of Z type sheet piles (i.e. AZ 27-800 as shown in Fig. 3) is prevalently used to provide long-term earth retention support system and creates durable functional structures. These sheet piles are designed to remain in place for extended periods, often serving as integral components of permanent infrastructure.

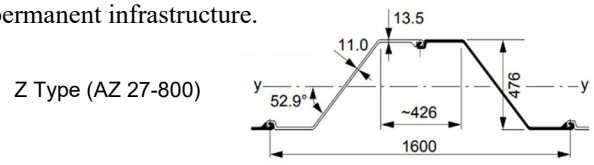

Fig. 3 Wider Type of Steel Sheet Piles (Z type)

1.2. Selection of Steel Sheet Piles

In recent decades, there has been a continued evolution in sheet pile design, with a focus on optimizing materials, shapes, and interlocking mechanisms. Steel sheet piles, especially those made from high-strength steels, remain popular due to their strength and versatility. Modern sheet pile designs have also considered the environmental aspects, with more emphasis on the recyclability and sustainable manufacturing practices.

The selection of sheet piles for a particular project involves careful consideration of various factors to ensure the effectiveness and efficiency of the earth retention support system. Some key considerations in the selection of sheet piles are summarized below.

a) Site Condition

- different sheet pile materials and profiles perform differently in various soil types.
- different sheet pile types may have specific requirements for driving equipment and installation methods.

b) Structural Requirement

- choose the required section modulus and moment of inertia to ensure that the selected sheet piles with adequate strength and durability to withstand the loads.

c) Intended Purpose of Sheet Piles

- depending on the intended service life, function of sheet piles and the associated design considerations, sheet piles can be classified into two main categories: temporary sheet piles and permanent sheet piles.
- temporary sheet piles are employed for short-term construction needs and are designed for easy removal, while permanent sheet piles are integrated into the final structure in providing long-term stability.

d) Environmental Impact

- consider recyclability of the materials, emphasizing on sustainable construction.
- adopting sustainable practices in material sourcing, such as reducing carbon emissions.

e) Cost Consideration

- assess the overall cost of the sheet pile system, including materials re-cyclability, installation, and extraction.

f) Availability and Lead Time

- timely availability of materials is crucial to project scheduling and completion.

2. Wider Steel Sheet Piles for ERSS Applications

2.1. U Type IV 400mm Steel Sheet Piles versus U Type IVw 600mm Steel Sheet Piles

The choice of whether wider steel sheet piles are beneficial depends on the specific requirements and conditions of the construction project as mentioned earlier. The following are some considerations when evaluating the benefits of using wider steel sheet piles.

Table 1. U Type IV 400mm & U Type IVw 600mm Sheet Piles

Section Designation	Section Width (Nominal)		Height of Wall (Nominal)		Thickness				Per 1 m (1 ft) of Wall							
					t_1		t_2*		Sectional Area		Mass		Moment of Inertia		Section Modulus	
Japanese	mm	in	mm	in	mm	in	mm	in	cm²/m	in²/ft	kg/m²	lb/ft²	cm⁴/m	in⁴/ft	cm³/m	in³/ft
II			200	7.9	10.5	0.41	—	—	153.0	7.2	120.0	24.6	8740	64.0	874	16.3
III	400	15.75	250	9.8	13.0	0.51	—	—	191.0	9.0	150.0	30.7	16800	123.0	1340	24.9
IV			340	13.4	15.5	0.61	—	—	242.5	11.5	190.0	38.9	38600	282.7	2270	42.2
VL	500	19.69	400	15.7	24.3	0.96	—	—	267.6	12.6	210.0	43.0	63000	461.3	3150	58.6
VIL			450	17.7	27.6	1.09	—	—	306.0	14.5	240.0	49.2	86000	629.8	3820	71.1
IIw			260	10.2	10.3	0.41	—	—	131.2	6.2	103.0	21.1	13000	95.2	1000	18.6
IIIw	600	23.62	360	14.2	13.4	0.53	—	—	173.2	8.2	136.0	27.9	32400	237.3	1800	33.5
IVw			420	16.5	18.0	0.71	—	—	225.5	10.7	177.0	36.3	56700	415.2	2700	50.2

a) Stability and Strength

- wider steel sheet piles can offer greater stability, especially in applications where higher bending moment capacity and resistance to lateral forces are required.
- wider steel sheet piles have advantageous for deeper excavation in providing a robust structural support to prevent soil or water infiltration.
- moment of inertia and section modulus of U Type IVw 600mm steel sheet piles are much higher than U Type IV 400mm steel sheet piles (as shown in Table 1) although the former U Type IVw has a lighter unit weight.

b) Water Retention and Cutoff Walls

- wider steel sheet piles are more effective in water retention and cutoff wall applications as they provide a broader barrier to control water inflow and prevent seepage.
- wider steel sheet piles will have lesser interlocking clutches, and this will reduce the potential of leakages from these interlocks.

c) Ease of Installation

- wider steel sheet piles reduce the quantity of materials to be handled and installed.

- wider steel sheet piles may be more challenging to drive as compared to narrower ones, but the driving of wider steel sheet piles also depends on specific soil conditions.

d) Cost Consideration

- wider steel sheet piles in the case of U Type IVw 600mm sheet piles have a lighter unit weight as compared to U Type IV 400mm sheet piles (as shown in Table 1).
- wider steel sheet piles provide a faster installation, and it is cheaper to engage piling sub-contractors to carry out the installation and extraction works.

2.2. Damage of Wider Type of Steel Sheet Piles

Sheet piles may experience damage during their service life, and their recycling or disposal decision depends on the extend of the damage level. One common form of damage is corrosion, especially for sheet piles in marine or corrosive environments. Corrosion weakens the structural integrity and leads to replacement.

Overloading and impact during sheet pile driving can cause structural deformation, twisting or bending in sheet piles. Wider steel sheet piles will tend to twist and bend more as compared to narrower ones. Wider steel sheet piles are also heavier and more cumbersome to handle during transportation and installation. So, it is important to assess the damage level of wider steel sheet piles and evaluate its re-cyclability in ensuring the cost-effectiveness of using wider type of sheet piles.

Fig. 4 demonstrates the twisting mechanism during pile driving. Fig. 5 shows the damage condition of wider steel sheet piles.

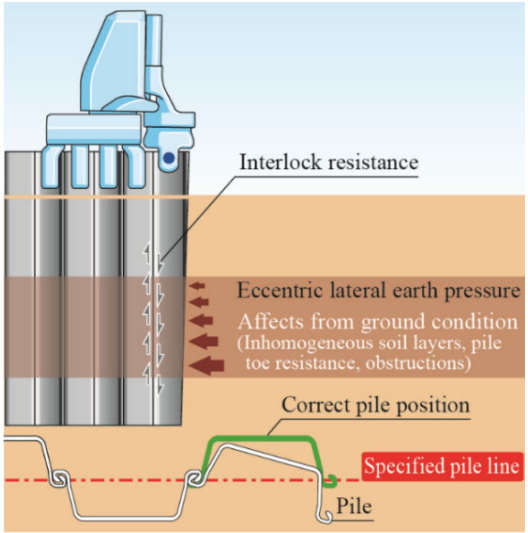

Fig. 4 Sheet Pile Alignment Expected During Pile Driving

Fig. 5 Damage Condition of Wider Steel Sheet Piles

2.3. Recyclability of Wider Type of Sheet Piles

Steel sheet piles are highly recyclable. Even after the end of service life, steel sheet piles can be collected, processed, salvaged, and recycled into new steel products without significant loss of quality.

Wider type of sheet pile is more susceptible to buckling if the sheet pile is relatively thin if compared to narrower ones. Buckling can result in deformations or misalignments, and this compromises their effectiveness in retaining soil or water. Joint failures through de-clutching of interlocks can also lead to misalignment and reduce the stability of the entire sheet pile wall.

2.4. Cost Saving of Recycled or Used Sheet Piles

Recycled or used steel sheet piles are less expensive than newly produced materials and therefore, using recycled or used steel sheet piles can result in cost saving on material procurement. Durable and high-quality recycled or used sheet piles with less potential damage can contribute to long-term cost savings.

2.5. Drivability of Wider Type of Steel Sheet Piles

The type of equipment used for driving wider steel sheet piles plays a significant role. Common installation methods include impact driving with a pile driver, vibratory driving using a vibratory hammer or hydraulic press-in. The tendency of wider steel sheet piles to twist, buckle and bend will be higher if thinner sheet piles are used as compared to narrower sheet piles. Hence, the drivability of wider sections must be carefully assessed.

2.6. Extractability of Wider Type of Sheet Piles

The extractability of wider type of steel sheet piles refers to the ease and efficiency with which these sheet piles can be removed or extracted from the ground after their initial installation. This aspect becomes crucial when the sheet piles need to be retrieved for recycling purpose. Therefore, the extraction process needs to be carefully evaluated if the use of wider sheet piles is for temporary work. It will be very expensive if wider steel sheet piles cannot be extracted and has to be permanently left in inside the ground.

3. Press-in Verification Test

Verification test has been conducted to examine the performance of wider steel sheet piles during the press-in operation (as shown in Fig. 6). Driving different types of wider steel sheet piles into the ground using the SILENT PILER has been conducted to determine the sheet pile drivability (as shown in Fig. 7) and thereafter, the deformation of sheet pile is checked after the extraction process using the same SILENT PILER.

Fig. 6 Press-in Verification Test at GIKEN, Japan

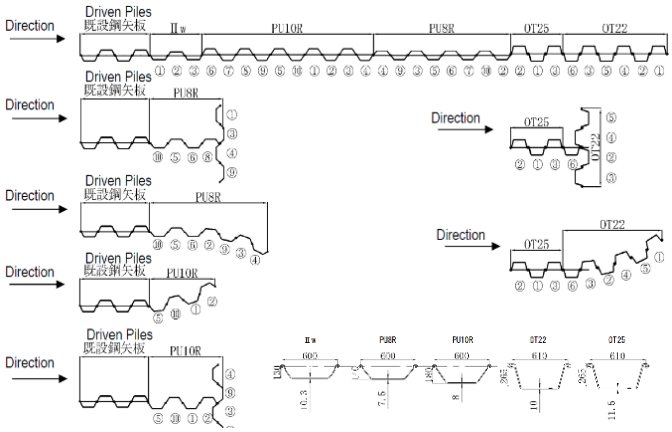

Fig. 7 Sheet Pile Driving Layout for Press-in Verification Test

Drivability and Reusability of wider steel sheet piles by comparing the press-in force and deformation respectively has been performed. However, the results will not be reviewed in this paper.

4. Application of Wider Type of Steel Sheet Piles

Wider steel sheet piles have been initially applied and driven using Super Wide SILENT PILER (SW100) in Singapore (2022). The first project involves a conversion of 380 nos. of 12m U Type IV 400mm Sheet Piles to 254 nos. of 12m U Type IVw 600mm Sheet Piles (please refer to Figs. 8 & 9). Meanwhile, the remaining areas adopted the U Type 400mm Sheet Piles (over 1000 nos.).

In this project, the wider steel sheet piles have proven to be effective, able to shorten the construction time and cost. After the sheet piles have been extracted, the materials are finally inspected, and we discovered the damage level is nominal. However, the soil condition at this jobsite is soft with thick deposition of marine clay.

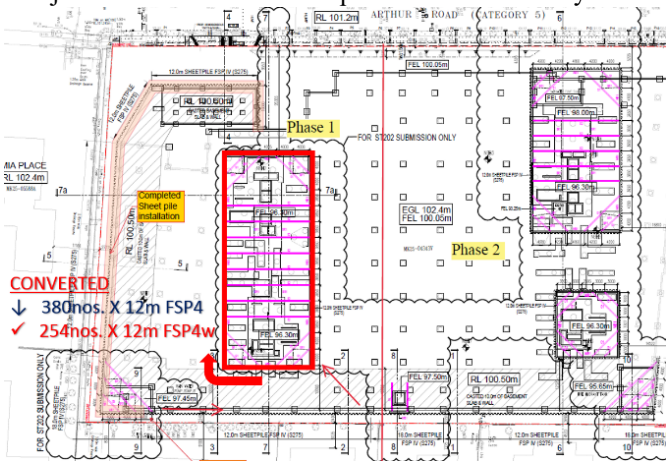

Fig. 8 Use of Wider U Type IVw Steel Sheet Piles at LIV@MB Condominium Development (114A Arthur Road, Singapore)

Fig. 9 Use of Super Wide SILENT PILER (SW100) at LIV@MB Condominium Development (114A Arthur Road, Singapore)

The success story of the first application above using wider steel sheet piles installed by Super Wide SILENT PILER spreads. This increases the confidence level of local main contractors to start using wider steel sheet piles driven by SILENT PILER in other ERSS applications.

The second project in Singapore (2023) involves a conversion of 284 nos. of 12m U Type IV 400mm Sheet Piles to 189 nos. of 12m U Type IVw 600mm Sheet Piles. One side of perimeter wall remains using the U Type IV 400mm Sheet Piles due to presence of sewer pipe at the vicinity of sheet piling line. Please refer to Figs. 10 & 11.

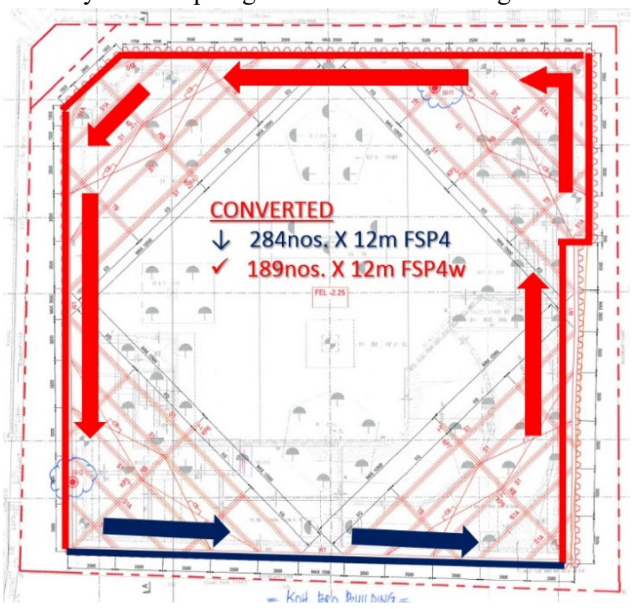

Fig. 10 Use of Wider U Type IVw Steel Sheet Piles at SCAL Building Development (10 Tannery Lane, Singapore)

Fig. 11 Use of Super Wide SILENT PILER (SW100) at SCAL Building Development (10 Tannery Lane, Singapore

The above two case histories are just a snapshot of the success stories in using wider steel sheet piles for ERSS applications in Singapore.

5. Concluding remarks

In conclusion, the decision to use wider steel sheet piles should be based on a thorough analysis of project specific requirements, site conditions, and budget constraints. Engaging with experienced geotechnical and structural engineers during design phase is essential to ensure that the selected sheet pile width aligns with the project goals and offers a cost-effective solution in ensuring the sustainability of construction.

The recyclability and extractability of sheet pile becomes crucial in the event when wider steel sheet pile is employed for temporary purpose in ERSS applications. Wider steel sheet piles require more effort to extract and therefore, they are often used to integrate as a permanent structure, mainly applied for river revetment and marine work applications.

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a) GIKEN LTD. (Japan), the innovator of SILENT PILER.

b) Oriental Sheet Piling Pte. Ltd. (Singapore).

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