Heavy Lifts / PPVC Modules Lifting Frame & Anchor

Min Po

Planning & Methods Manager

(United Tec Construction Pte. Ltd.)

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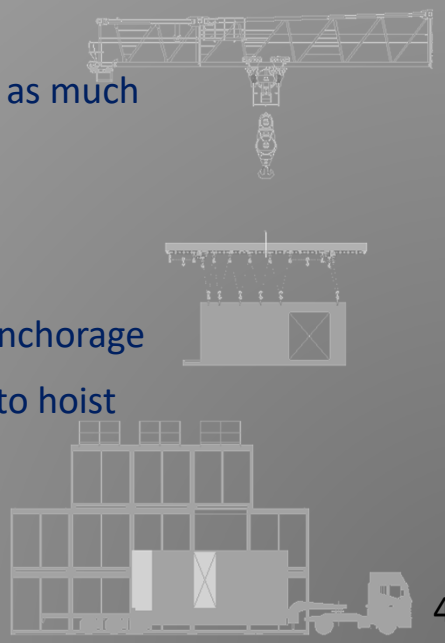
1. Introduction

1.1 Introduction

- The increased adoption of DfMA in Singapore Construction Industry, 70% of construction work off-site and PPVC methods leads to the creation of a safer and greener working environment.
- Prefabricated Pre-finished Volumetric Construction (PPVC) is a game-changing construction technology and it comes with its own set of unavoidabe issues and challenges.
- Lifting Frame with higher capacity is required, with concrete PPVC Module weighting as much as 20.0T ~ 35.0T. Lifting Frame plays an important role for PPVC Module installation.
- The use of Lifting Frame requires more headroom than a normal lifting.
- The Lifting Anchor Points must be strategically positioned such that sufficient bond anchorage can be developed and the load distribution to all lifting points is reasonably uniform to hoist the entire PPVC Module safely.



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2. Purposes of PPVC Module Lifting Frame

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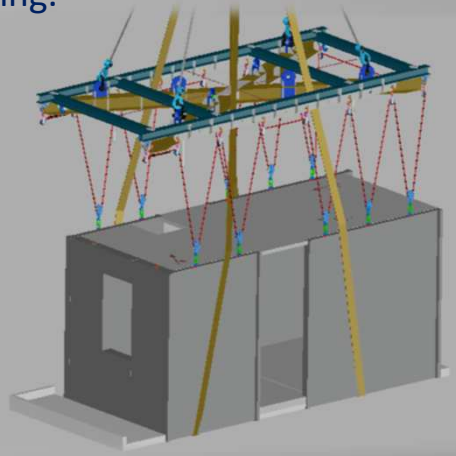
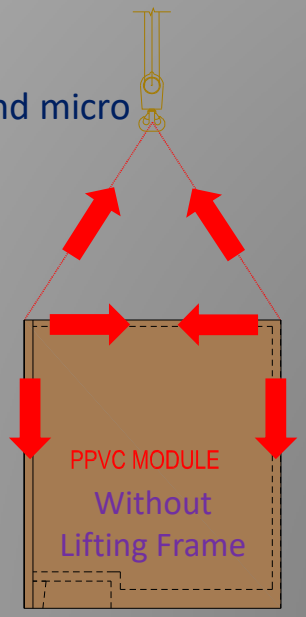
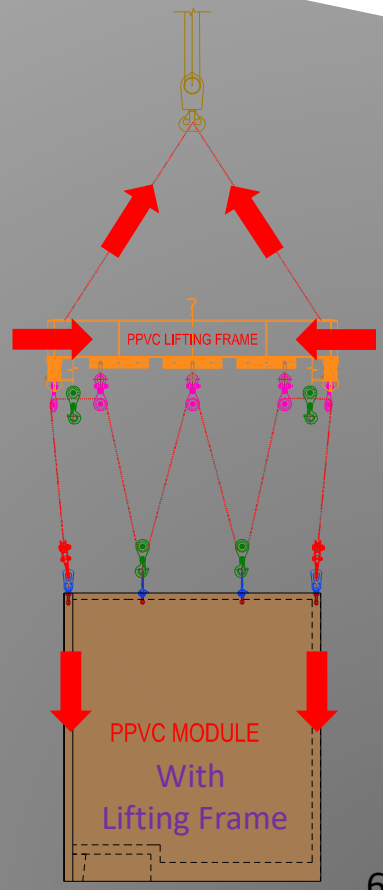
2.1 Purposes of PPVC Module Lifting Frame

- The use of Lifting Frame is to transfer the compressive force in PPVC Module to the Lifting Frame.
- Lifting Frame and multiple lifting anchorage points prevent excessive deformation of PPVC Module.
- Specially designed Lifting Frame allows safe lifting, self-balancing and micro positioning during launching.







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3. Lifting Frame Assembly & Planning

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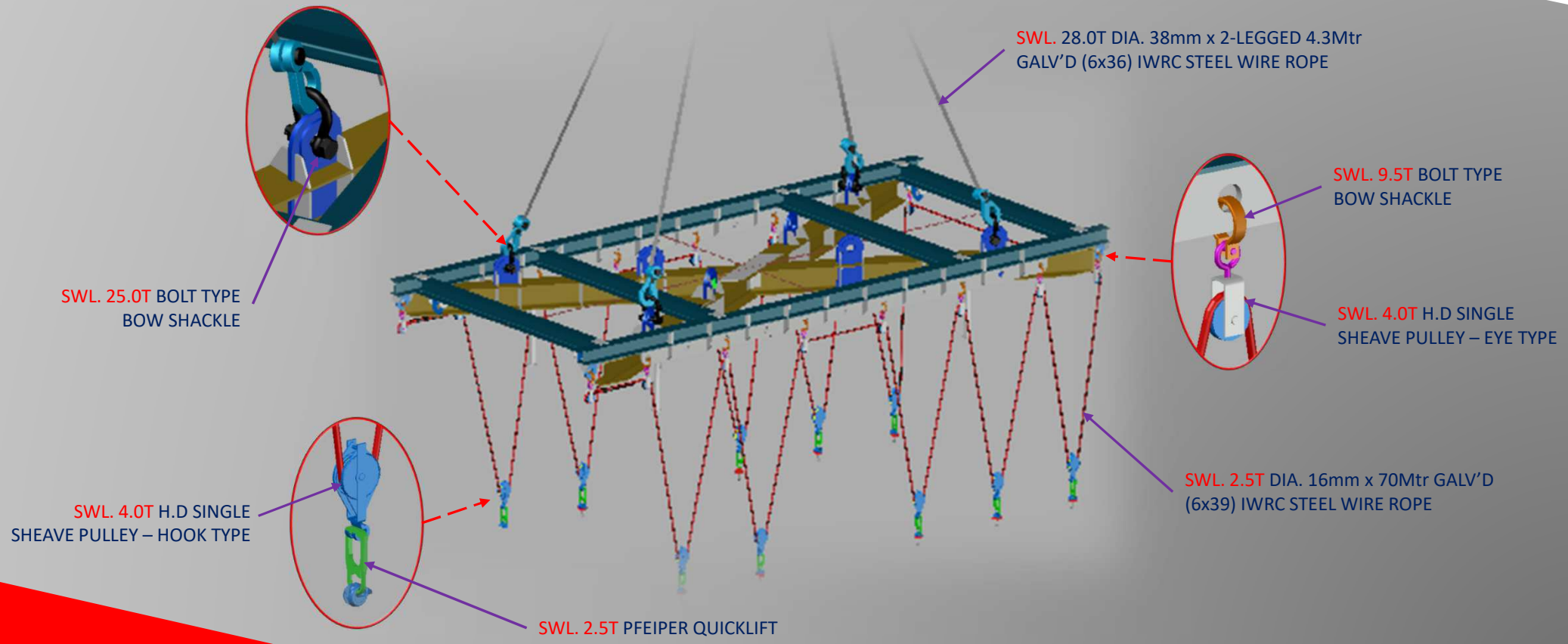
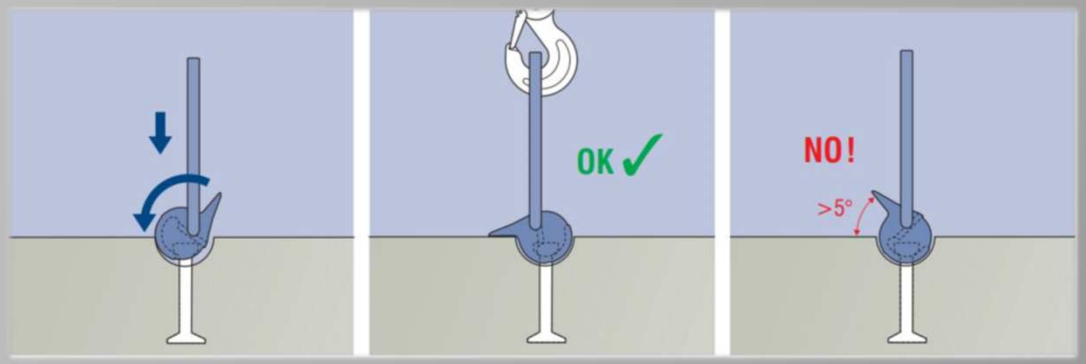
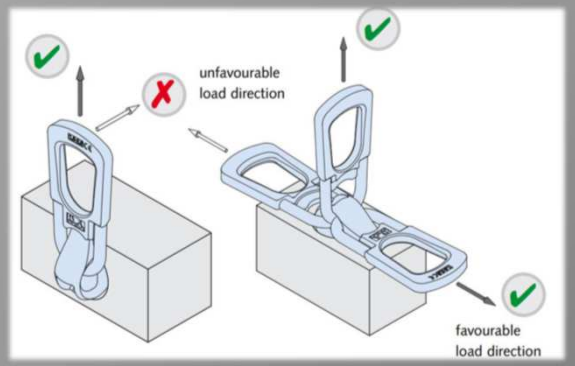
3.1 Lifting Frame Assembly

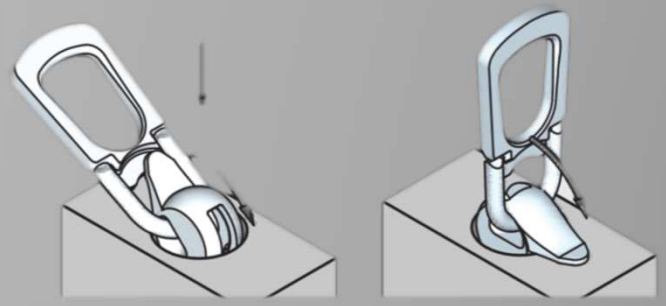


3.2 PPVC Module Safe Rigging Arrangement

- **Improper Attaching of Universal Lifting Clutch** is a risk of the PPVC Module falling and causing a hazard to life and limb. It must always be fully inserted until the lip is seated in position.



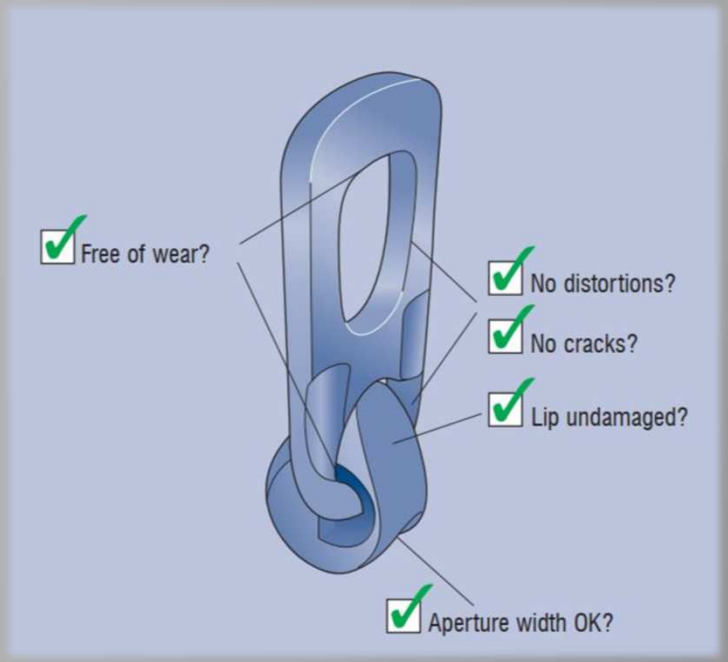




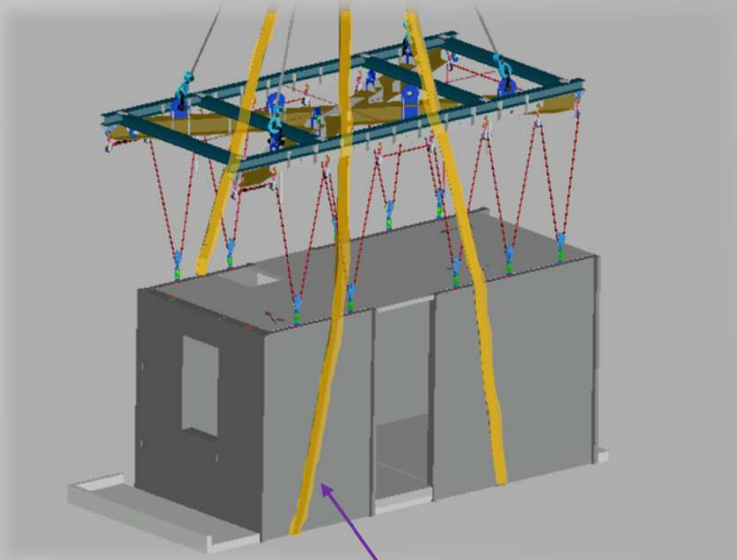
Universal Lifting Clutch

3.2 PPVC Module Safe Rigging Arrangement

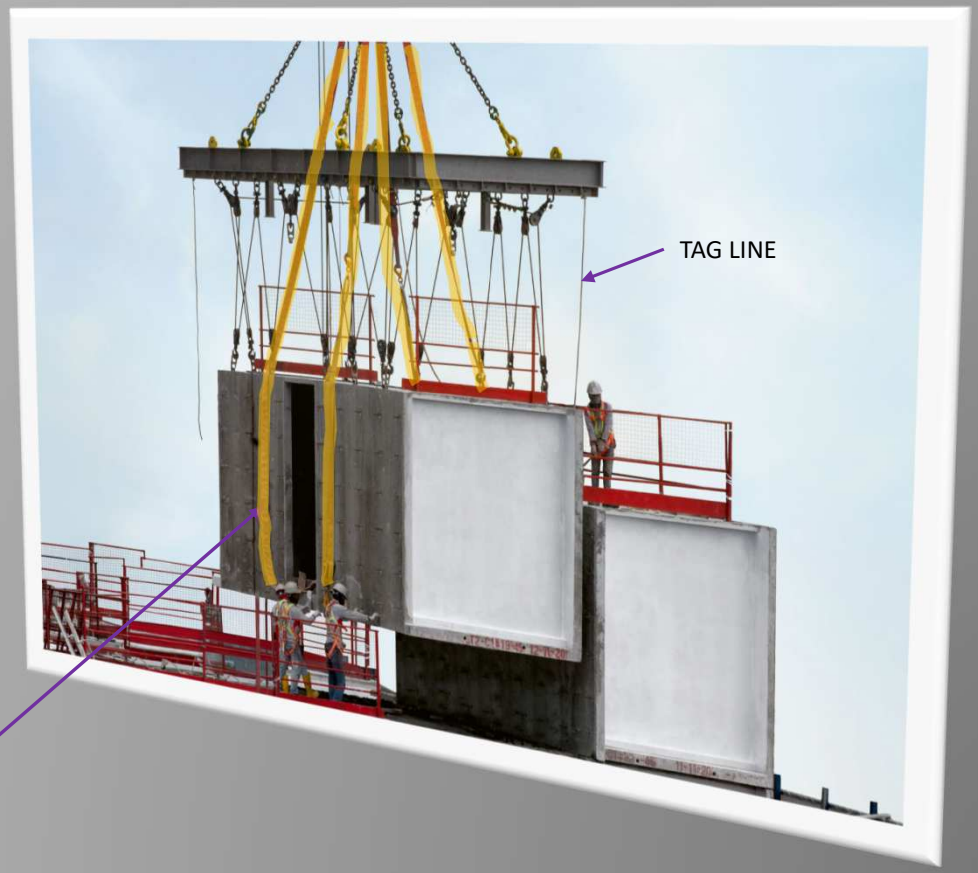
- **Before each use visually check** all lifting equipment for correct application and damage-free condition.



3.3 PPVC Module Lifting Additional Safety

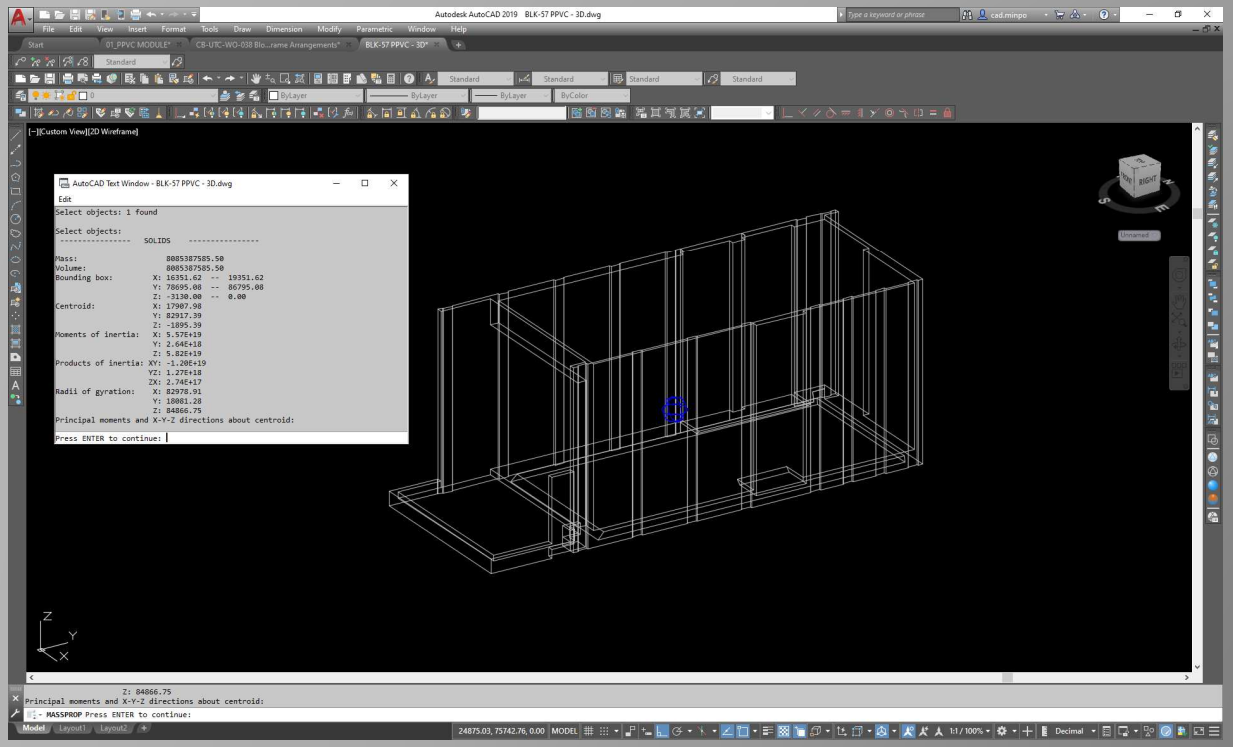


100mm x 5m LASHING BELT c/w RACHET SYSTEM (BREAKING LOAD 20.0T)



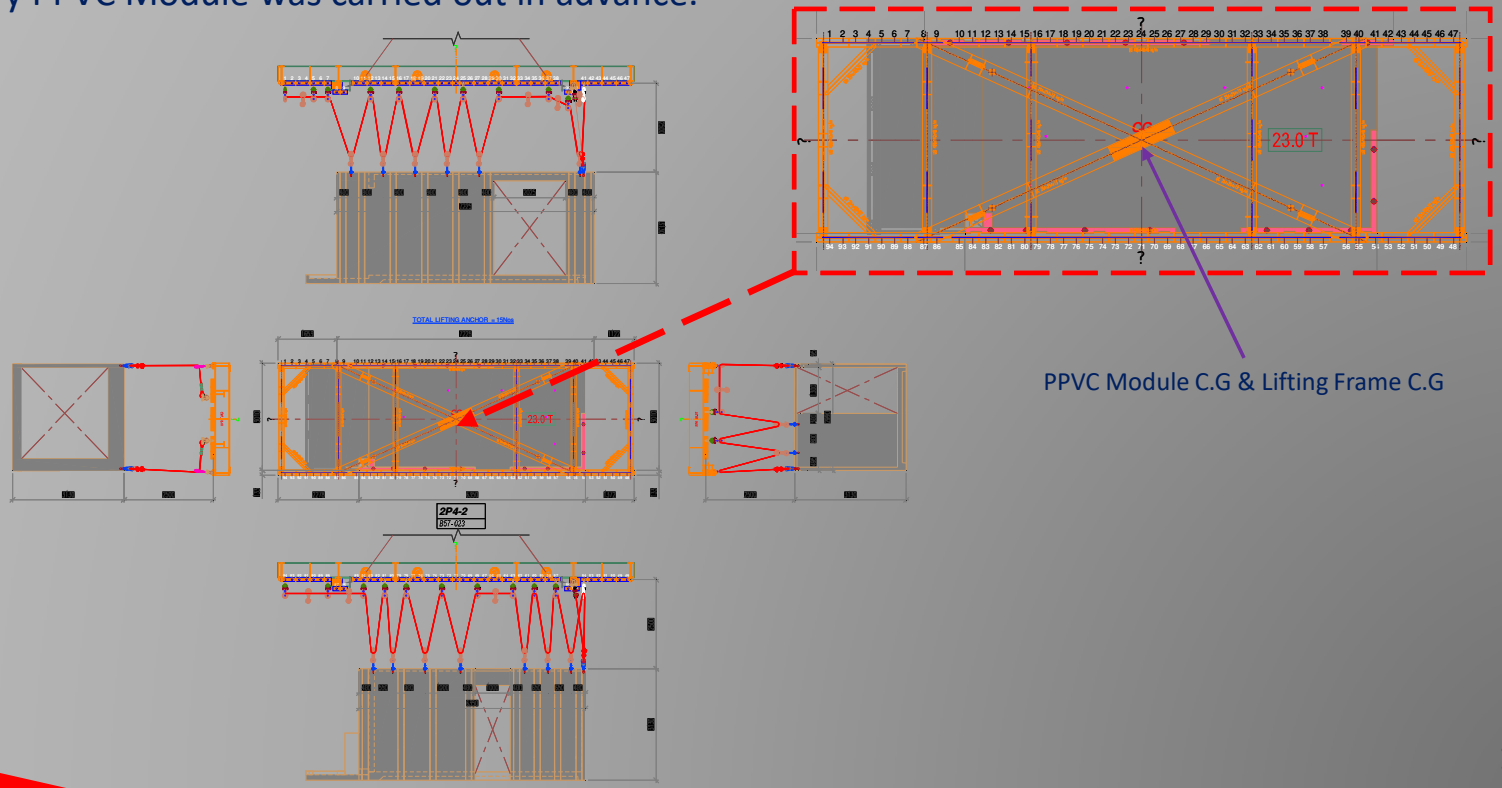
3.4 PPVC Module Lifting Planning

- With the aid of BIM software, every PPVC Module CG was predetermined.



3.4 PPVC Module Lifting Planning

- Based on Module specific CG, Lifting Anchor Location and Lifting Frame arrangement for each and every PPVC Module was carried out in advance.



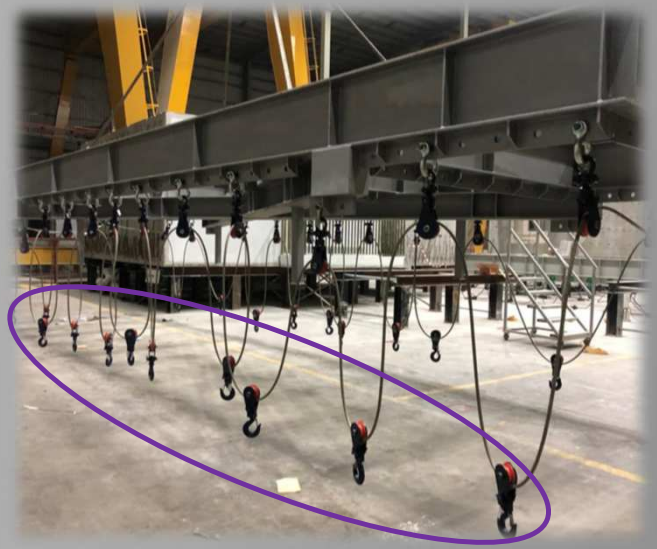
4. Lifting Frame & Anchor Design Consideration for Safety Aspects

4.1 Lifting Frame Design Consideration

- **PPVC Module's Weight** governs the **Lifting Frame capacity** and needs to cater for the worst-case scenario of the heaviest module.
- **PPVC Module's Size** defines the **Lifting Frame overall length & width** which has to be suitable for both smallest module and biggest one. Also taken into account of site conditions and avoid clashing with adjacent temporary / permanent structures, such as formwork, safety screen and lift-shaft wall, etc.

4.1 Lifting Frame Design Consideration

- **Self-weight of Lifting Frame** will add on to the final lifting weight of PPVC Module and it'll affect the crane capacity. It's better to control the self-weight of the Lifting Frame without affecting its integrity.
- **Nos. of provided lifting anchor points** are set based on the module weight with safety factor 3. And that will determine the total length of Lifting Frame wire rope and nos. of pulley hooks.

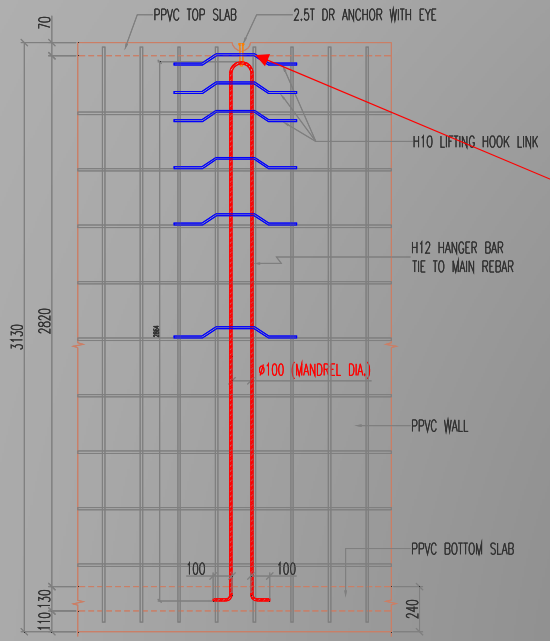


4.1 Lifting Frame Design Consideration

- Due to the rush hoisting (eg. unloading from trailer) or improper adjustment of the pulley hook positions, Lifting Frame can be out of plane and will over stress. Lifting Frame hook points and connection joints have to be designed taking into consideration such accidental cases.

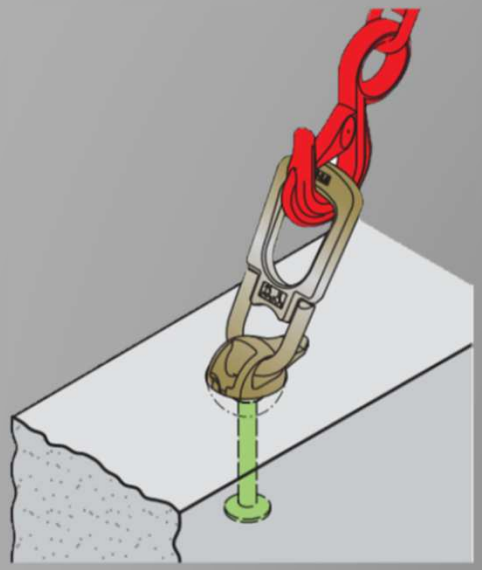
4.2 Lifting Anchor Design Consideration

- **Lifting Eye Anchors with Hanger Bar** are widely used in PPVC Module lifting and ideally suited for thin and heavy panels. It's designed to transfer the entire anchor load through the reinforcement into concrete.



4.3 Lifting Anchor Design Consideration

- **Design of Lifting Anchor (Safe Working Load)** has to be given to assess each load case including Demoulding, Storage, Transportation and Launching. In addition to the Global Safety Factor, the following factors need to be taken into account for design consideration.
  - Suction Force
  - Sling Angle Factor
  - Dynamic Factor



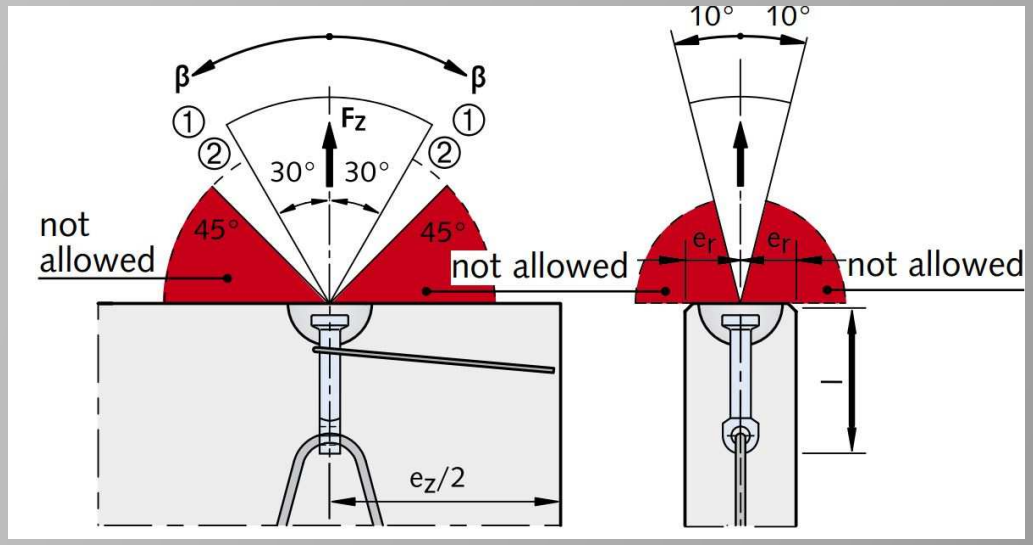
4.3 Lifting Anchor Design Consideration

- Suction Force between concrete element and the formwork can vary depending on the material and geometry of the casting bed.

Adhesion to the formwork	
Lubricated steel formwork	≥ 1kN/m²
Vanished timber formwork	≥ 2kN/m²
Rough formwork	≥ 3kN/m²

4.3 Lifting Anchor Design Consideration

- Sling Angle Factor for the rigging also affects the amplitude of the service load on the anchor.



Spread angle factors		
Cable angle ß=30	Spread angle	Factor z
0°	-	1.00
7.5°	15°	1.01
15°	30°	1.04
22.5°	45°	1.08
30°	60°	1.16

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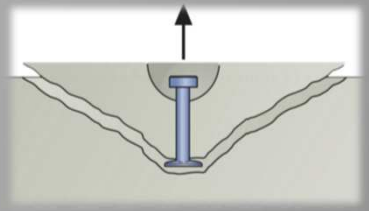
4.3 Lifting Anchor Key Design for Safety Aspects

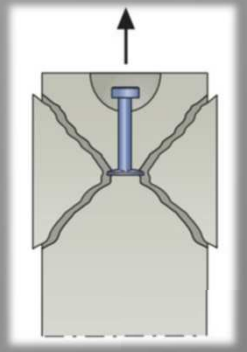
- Dynamic Factor has a great impact on the lifting anchor and it can be varied based on the type of crane and ground conditions.

Dynamic-factors Ψdyn*	
Lifting Unit	Shock factors Ψdyn*
Stationary crane, swing-boom crane, rail crane	1.2
Lifting and moving on level terrain	2.5
Lifting and moving on uneven terrain	≥ 4.0

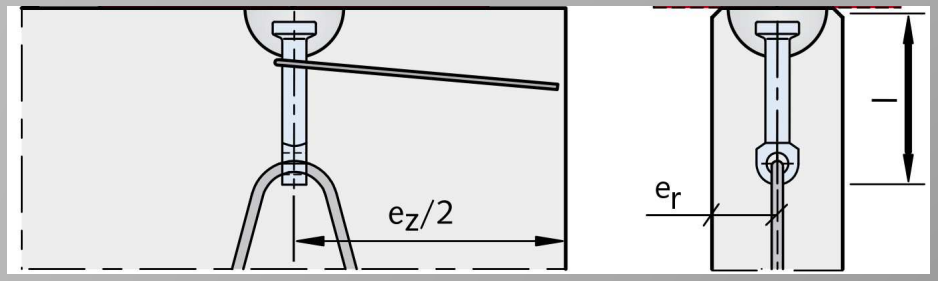
4.4 Lifting Anchor Allocation & Installation

- **Allocation & Installation of Lifting Anchor** have to be carried out based on the PPVC Module C.G and depending on the load tributary area. Improper Installation of Lifting Anchor can lead to potential danger of concrete failure mechanisms such as Concrete Cone and Blow-Out Failure. Following safety precautions have to be implemented as per manufacturer's guidelines.
  - Min. Hoist Element Thickness (mm)
  - Anchor Edge Distance (mm)
  - Anchor Axial Spacing (mm)
  - Min. Concrete Cube Strength at the time of Lifting (N/mm2)
  - Min. Steel Reinforcement (mm2 / m)





4.4 Lifting Anchor Allocation & Installation



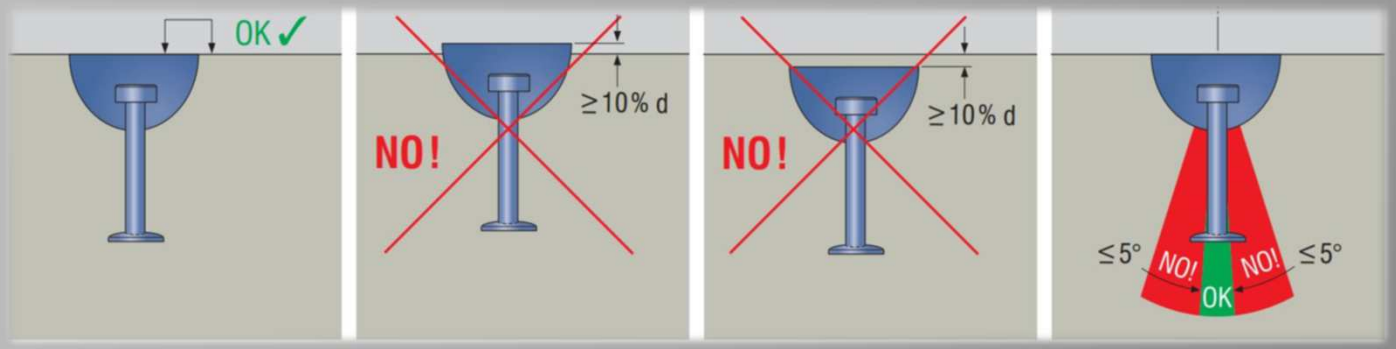
Load capacity and reinforcement for the spherical head eye anchor

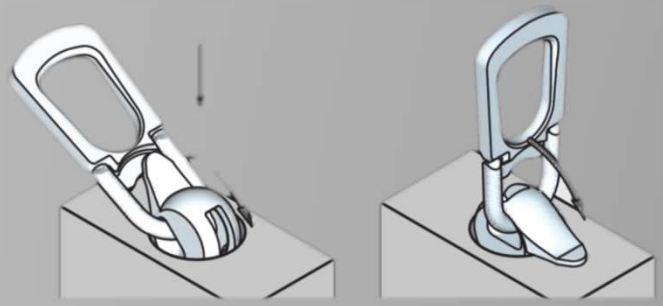
Load class	Article number	Min. element thickness $2 \times e_r$ [mm]	Axial spacing of anchors e_z [mm]	Square mesh reinforcement both sides [mm²/m]	Additional reinforcement d_{s3} [mm]	Concrete strength f_{ci} 15 N/mm² l_{s3} [mm]	25 N/mm² l_{s3} [mm]	35 N/mm² l_{s3} [mm]	Load capacity (kN) for **Axial pull** up to 30° [β] concrete strength f_{ci} 15 N/mm²	**Diagonal pull** up to 45° [β] concrete strength f_{ci} 15 N/mm²	**Axial** and **diagonal pull** up to 45° [β] concrete strength f_{ci} ≥ 25 N/mm²
1,3	6001-1,3-0065	80	500	60	8	650	510	420	13.0	10.2	13.0
2,5	6001-2,5-0090	80	600	100	12	1000	800	650	25.0	20.0	25.0
5,0	6001-5,0-0120	100	750	140	16	1700	1350	1100	50.0	40.0	50.0
10,0	6001-10,0-0180	140	1200	180	20	2000	1600	1300	100.0	80.0	100.0
20,0	6001-20,0-0250	180	1500	240	32	3000	2400	1950	200.0	160.0	200.0

f_{ci} = concrete cube strength at time of lifting

4.4 Lifting Anchor Allocation & Installation

- **Fixing and Forming of Recess Former with Lifting Anchor** play an important role for the proper seating in and locking of Lifting Clutch for safe lifting.





Universal Lifting Clutch

Rubber Recess Former

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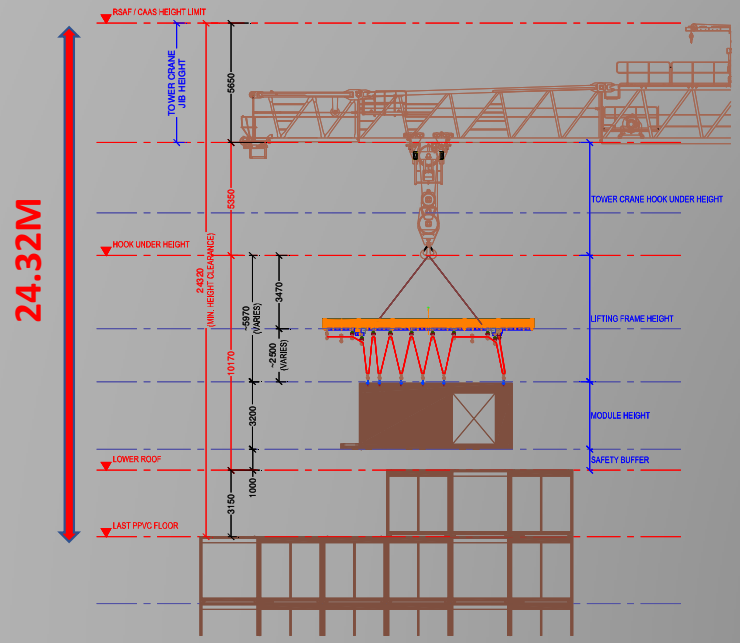
5. ISSUES & CHALLENGES ON-SITE

5.1 ISSUES & CHALLENGES ON-SITE

- **For safer lifting, more headroom height** will be required once we use the Lifting Frame to install the PPVC Modules. That will determine the overall building height due to the RSAF and CAAS high restriction. Min. 24.32m clearance height required from the last PPVC floor to the RSAF / CAAS Height Limit.



5.2 ISSUES & CHALLENGES ON-SITE

- **PPVC Module CG** can be off-centre due to uneven weight distribution caused by interior finishing. As a result, Lifting Frame can be out of plane and on-site adjustment of pulley-hook positions are required which is time-consuming, labour-intensive and leading to human errors for unsafe lifting.

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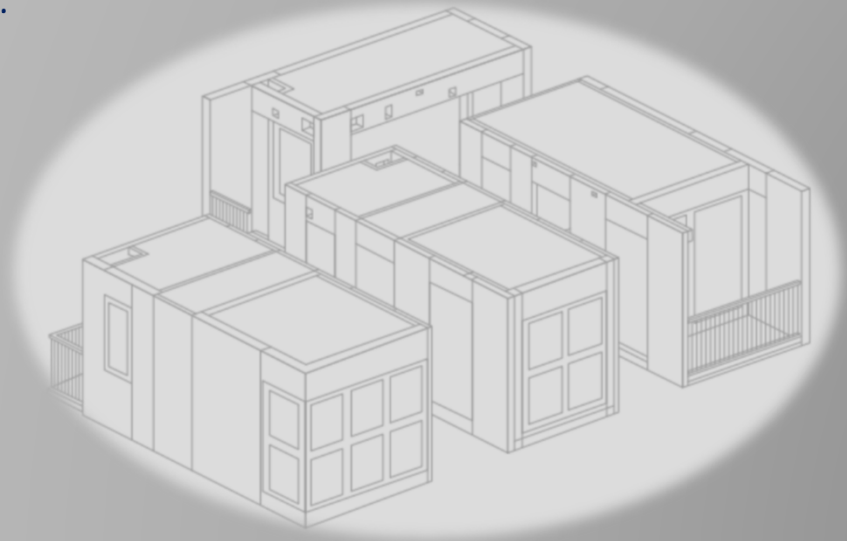
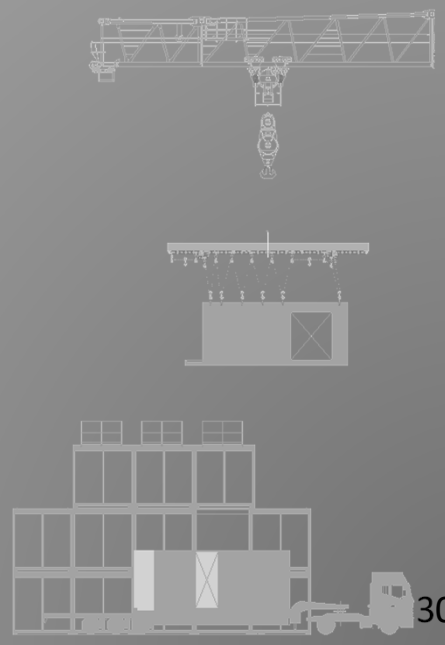
6. CONCLUSION

6.1 CONCLUSION

- **Standardizing the PPVC Module's size / unit type at design stage** will minimize the different configurations of Lifting Frame arrangement of pulley-hook positions. That will not only improve productivity and cost savings but also eliminate human errors and create a safer working environment.





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Thank you ..!