Dubai Festival City – Zone 03F

Peer Reviews on

LadderBlock Due Diligence Structural

Narrative and Package

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1. Introduction:

The objective to this report is to provide a peer review on the LadderBlock Due Diligence Structural Narrative and Package prepared by P.E. Building Systems, Inc. on the feasibility of the LadderBlock System to Zone 03F of Dubai Festival City.

2. Understanding of the System

2.1 LadderBlock System

LadderBlock System is a collection of high precise, engineered concrete components that can be assembled and constructed easily on site to form multi-storey building in a relatively short duration. The components can be designed to suit custom usage and precast off site. Multiple assemble of layers of each component brings a strong part for higher loading usage. Composite construction of column allows heavier loading for Multi-storey buildings if required.

2.2 LadderBlock System Components

LadderBlock System composed of standard module of building parts and each of which can be specially designed and reinforced to fulfill the user's requirement. The standard parts composed of:

1. Double cantilever frame block with 9.4m column centre.
2. Spacer blocks with 8.8m overall frame dimension.
3. Beam blocks
4. Colum blocks
5. Long Floor Block (Double T)

3. General Observations

3.1 Layout

Due to the standardization of the module block, column grids are almost set to a constant grillage of 9.4m x 9m. This standardization module space does not fit very well on the radial spaced car park areas, in addition not particularly well for driveway, ramp and car park space outlined from the original architectural plan.

This configuration faces more challenges when it comes to the southern part of the Offices Tower where the layout is basically a triangular plan area. This irregularity brings random column layout that will interfere the circulation and car parking at basement levels.

The column of the Frame Block tied by space blocks in the perpendicular direction is basically a T-shapes column with dimension larger than that of shown in the Architectual Plan. This may further complicate the car park layout.

Area03 F with its irregular layout and eccentric core arrangement do not seems to work perfectly well with LadderBlock system. Substantiate layout re-configurations will require before successful implementation of the system.

3.2 M&E Consideration

Although there are recesses at top of Frame Blocks to allow for M&E services to go through under the slab without further intruding into the headroom space, vertical ducting system with openings in slab will have to be carefully coordinated to avoid the main spanning beam of the Long Floor Block.

All floor openings must be coordinated before fabrication and no late changes or site modifications are allowed or very difficult to handle at site.

3.3 Future Modification and Addition

The system is so well planned and fabricated before construction, and all details are custom made to suit the design and construction.

Further changes or addition works in the life of building will be very difficult and there may not be lots of leeway to do so.

LadderBlock system, unlike conventional in-situ casting with beams and slab system, allow less flexibility in future changes. All design requirements have to be concisely coordinated during design phase prior to fabrication hence less flexibility for on site changes.

3.4 Hoisting of the module

All of the module and pieces has to be delivered to site, careful planning of the size of the unit and delivery time and route is required. Hoisting the pieces up to the designated level for fabrication required a very detail assessment and the available crane capacity and the height of limit of the operation. Area 03F is a building with 22 levels of floors and approximately 100m tall, and with the size and weight of each components, this becomes a challenge on site. The stability and mobilization of crane operation becomes a very difficult task for contractor especially in this height of building.

The system with almost module in 9m x 9m grid, with quite a size for each unit, the weight of the precast part will be of a concern and delivery to high distance above ground may become problematic, therefore, the system seems to be more suitable for lower rise structure.

4. <u>Technical Observations</u>

4.1 General

This LadderBlock Due Diligence Structural Narrative and Package is intended for the feasibility of applying LadderBlock in Dubai as a protocol trial, not intended for detailed design submission. Therefore, the report illustrates some preliminary design for certain parts only.

4.2 Overall and Stability

4.2.1 Wind Loads

The design of the LadderBlock system relies on the CIS Core system to resist the lateral wind loads. The core system of Area is not symmetric and is not located exactly in the centre of the Tower, will result in eccentric movement. Lateral deflection and inter-storey drift requirement to extreme corner shall be examined in addition to centre of mass deflection. In addition, the Tower is approximately 100m tall with reliance on just core wall group with cross dimension in the weak axis less than one-third of the total depth of the building required a closer look.

Effective transfer of wind loads and integrity under movement rely heavily on the design of Topping slab.

In general, LadderBlock system is very well for gravity load carrying part but may be more suitable for low rise building that lateral load can be more effectively resisted by CIS core system.

4.2.2 Seismic Loads

The design of the LadderBlock system again relies on the CIS Core system to resist the lateral Seismic loads though some deformations required under UBC code were examined in their preliminary assessment to the LadderBlock system. However, the integrity through the inter-locking of each panels and the interfacing anchoring of the topping slab acting as rigid diaphragm required more in-depth study and design assessment.

The Area 03F is a high rise building very susceptible to earthquake. Its behavior and secondary effects to all connecting part under earthquake is very important. We suggest performing a real scale earthquake shaking table test to investigate the effects to the deformation and the maintainability of integrity after seismic condition on various connecting parts.

Once again, with the offset core layout and the height of the building, implementation of LadderBlock system to Area 03F may require further testing and justification.

4.2.3 Rigid Diaphragm

The topping slab plays an important role in the integrity of the building as well as the transfer for loads to the core system.

Proper anchoring to columns, walls and frames is definitely required to make the building intact. Since all pieces are putting together by series of bolts, the robustness of the building in whole will rely heavily on the rigid diaphragm to provide the necessary ties to the periphery, internally and to columns and walls.

Proposed 50mm topping will have to be carefully design to perform the following tasks:

- Acting as Rigid Diaphragm
- Forming internal, periphery and columns/walls ties
- Connecting media for all building parts

Therefore, a thicker topping may be required upon design requirements.

4.2.4 Fire Resistance

All the bolts and connections are generally exposed. The sustainability to fire requires some addition treatment.

Grouting to the pocket or recess with bolts may resolve the problem.

4.2.5 Corrosion Protection

All the bolts and connections are generally exposed though galvanizing can be applied to the bolts.

Corrosion may not be too much of a problem in dry and steady environment but in general, we shall consider a better and maintenance free approach.

Again, grouting to the pocket or recess with bolts may resolve the problem.

4.2.6 Façade

Careful planning and connection details are required for the successful installation of external façade panel.

Area 03F consists of a radial face and many odd angle faces which will make the connection arrangement very difficult, especially with the standard module of straight slab edge.

Greater effort shall be put to the coordination of the joint details and may result even in odd shape or curved edge Long Floor Block parts.

4.3 Component Design and Calculation

4.3.1 Modeling

Only module C with the high rise tower was presented in the calculation package.

The model in general includes all of the component parts, but the effects and simulation of all bolting and composite action of columns required further justifications. The effects of bolts and their deformation under Seismic condition required further study.

There are few ways we would recommend for modeling to further enhance and capture more realistic stiffness are:

- Consider using Spandrel elements for lintel beams at Cores. The stiffness for the joint of connecting spandrel of shell element to wall shell element representing a more rigid connection then line elements to shell element.
- Consider finite meshing the wall panel with connection with the Spandrel Beam mesh.
- Enhancing the E value by accounting the present of reinforcement
- Consider tying the individual cores together by more CIS lintel beams to mobilize the coupling between isolated cores, this is much more effective then tying them just by Rigid Diaphragm.
- Extreme corning deflection shall be reviewed.

4.3.2 Diaphragm Design

The 50mm topping slab is required to tie the building system together, and will provide internal, periphery and columns/walls ties and at the same time acting as rigid diaphragm for the building.

The combined stress with its full function of tying required to be further evaluated in detail design and may require thicker topping in result of the exercise.

The mass from this additional topping will generate more loading under Seismic condition where a review to the overall design of CIS core is required.

4.3.3 3 pins column base connection

The end of each column is connected by the 3-pin connector except the base column.

Simulated stiffness on the geometry and strain of bolts has been considered in the model, but the resulting moment and shear shall be property designed and resisted by these 3 pin bolts.

The bursting forces at the contacted surface of the bolts shall be checked to ensure the rigidity being modeled. See Figure 1.

4.3.4 Columns

The columns are generally very thin in the weak axis direction where bucking is a concern. The Spaced block provided in the other director can provide some stability, but consideration shall be put on the connecting bolts between them.

Furthermore, some areas of columns are sandwiched or even composited with RC column required further reviews on the connecting bolts to develop the necessary internal complimentary shear to hold them together. See figure 2.

4.3.5 Connection of LFB (Long Floor Block)

The Floor Block beam sits on top of the recess of the Frame Block perfectly but some form of connection shall be provided for improved integrity under seismic loads.

The topping at Floor Block is assumed to act as Rigid Diaphragm, however, some form of connection between the toppings to the column of block shall be considered. See figure 3.

4.3.6 Deflection

Vertical deflective limitation due to gravity is limited to Span/240 for immediate loads and Span/480 for long term sustained loads.

This may exceed the limit that can be tolerated by the brittle finishes and partitions.

Special consideration in selection of partitions and façade is required to cope with such deflection limit.

4.3.7 Sandwiches columns and frames

Some of the columns are sandwiched to form a larger and thicker column to resist loads from above but not the frame or beam.

The load path of where these columns are loading from the beam is very important. Otherwise, locally concentrated stress or eccentric moment will result in part of the column piece, but not the whole.

Complementary stress to the connecting bolts required further justification.

4.4 Conclusion

In general, LadderBlock system is technically feasible to be applied in building. The system is unique and easy to build, it also create a very clean construction site environment. Repetition of the system and less labor force requirement makes this system very ideal for fast construction.

However it will be more ideal and suitable to low rise and regular building. Zone 03F seems to be too harsh for the system with the layout being radial and irregular in part of the Tower and a height which is too tall for first implementation. Re-planning in parking space and driveway circulation will require making the system work. For the southern part of the Office Tower with the triangular floor plan may not appears to be very beneficial with LadderBlock system.

The package from P.E. Building Systems, Inc covers only very little of the whole design and those area of concern that are raised in the technical observation can be dealt with in the detail design stage.

5. Recommendation

Our recommendations for the implementation of LadderBlock system in Dubai are:

- Trial project with a low rise and regular building with a central core system to resist all lateral loads;
- Maintain adequate topping for Rigid Diaphragm and integrity ties;
- Perform protocol study and lab testing for taller building and investigate effects under Seismic actions;
- Grout all the pocket and recess to ensure Fire resistance and durability;
- Try to maintain center of load path on sandwiching frames;
- Careful study on the stress to connecting bolts when compositing the columns;
- When enough experience are gain through implementation to low rise and regular building and general acceptance by Local Authority, and with the supporting study, this technique and system can then be extended to taller buildings.