METAPOLIS = MATABOLISM + POLIS

HWASUNG, SOUTH KOREA

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METAPOLIS is a mixed-use complex project as a part of the new city development located in the downtown of Hwasung, Korea. The site is located south from Seoul city.

The project has been developed in two phases; Phase 1 includes high-rise residential towers (one 55, one 60 & two 66 stories), retail stores, a shopping mall and entertainment facilities. Phase 2 consists of a 56 story office building, hotel, education facilities and department store.

Phase 1 is recently completed by two general contractors such as POSCO E&C and Shindongah construction co., welcoming new tenants Year 2010 summer.

The recently completed towers, named METAPOLIS (METABOLISM + POLIS) engineered by Thornton Tomasetti, rises to a height of 816 feet (249 m).

The total gross area of phase one is approximately 468,460 m2 (5.04M ft2) and scheduled to be completed in Year 2010.

When this paper is wrote a tallest 66 story 816 feet (249 m) tall residential tower. When completed, it will be the tallest concrete residential tower in Korea.

Structural System

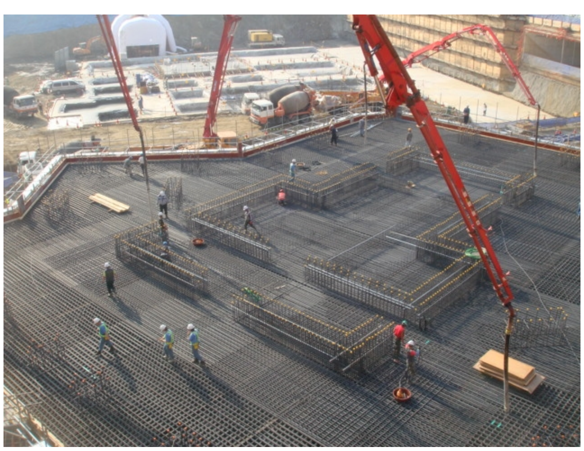
The floor framing system consists of a cast-in place flat plate construction with a slab thickness of 10 in (250 mm) spanning approximately 8m between the columns and central core walls.

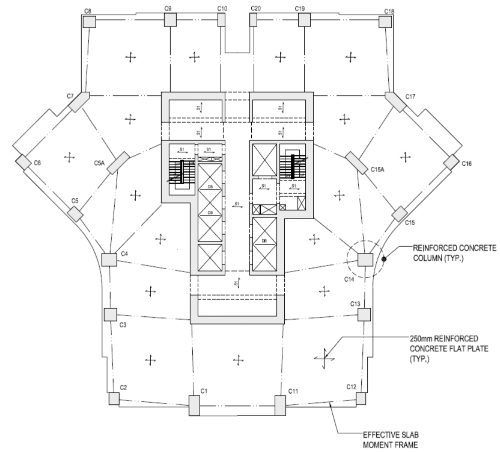
The unique architectural heating system finish radiant floor partition and ceiling. Superimposed dead load includes floor finishes, ceiling, partition walls,

Not only does this type of system reduce the floor to floor height requirements, but it also saves considerable construction cost and allows a short construction cycle. Saving construction time was possible due to the simple flat formwork and shoring as well as repetition of the formwork pattern at every floor.

Foundation system for the 66 story tower is a 3000mm thick reinforced concrete mat supported on a group of 2 meter diameter Reinforced Concrete Drilled Piles (RCD) extended into the underlying sound bedrock. Piles are placed directly underneath a column and a core wall typically spacing on 4 meter o.c. Allowable pile strength was specified as 3450 tonf for compression and 550 tonf for uplift. Uniform spring constant was utilized as 160,000 tonf/m per pile without pile group interaction. It was recommended by geotechnical engineer that when RCD is bearing on underlying bedrock pile group interaction is insignificant.

The tower mat was cast in one day using f'c = 350 kgf/cm^2 (4.26 ksi) concrete. In an effort to lower the heat of hydration of the massive concrete mat, flyash was used as a partial cement replacement in the concrete mixture. Other advantages of using flyash including improvement of both performance and quality of concrete by reducing water demand, segregation, bleeding, permeability, corrosion of reinforcing steel, and alkali aggregate reaction were also realized. Temperature of concrete was regularly monitored in the field during the curing periods.





Lateral stability for the 66 story tower, METAPOLIS is provided by a reinforced concrete core wall and belt wall system.

As a primary material, reinforced concrete in the design of METAPOLIS provides an effective solution to meet both strength and serviceability requirements especially for high-rise building. Especially, inherent structural characteristics of reinforced concrete provides excellent dynamic properties, mitigating building accelerations.

The core is located at the center of the building with overall core dimensions of 17m x 20m in east-west and north-south direction, resulting in high slenderness ratio over 10? In overall height / core dimension. The initial lateral load resisting systems were analyzed as the core wall system alone under the KBC2005-defined wind loads.

Due to the high slenderness ratio, additional lateral stiffness were requested so that two options were conceived by considering a beltwall around perimeter at 33rd floor and an effective slab moment frame. First, two story (7.25m) high belt wall at the mechanical level ties the concrete core wall to perimeter columns, significantly increasing the building lateral stiffness and its resistance to overturning effect due to lateral loads such as wind and seismic load. Second, slab moment frame provides lateral stiffness along top half of building by shear predominant behavior.

Fig. shows a comparison of building drift for four building systems; the core walls plus fin wall alone, core walls plus fin wall up to 6th floor and belt walls, core walls plus fin wall and belt wall with slab moment frame, core walls plus fin wall and slab moment frame. As seen from the figure, the lateral stiffness is achieved significantly by the introduction of the belt wall and slab moment frame. The belt wall has been termed an indirect outrigger system as axial forces in the exterior perimeter columns are induced under lateral loading though the interconnecting action of the floor diaphragms between the core and the exterior at the top and bottom of belt wall floor.

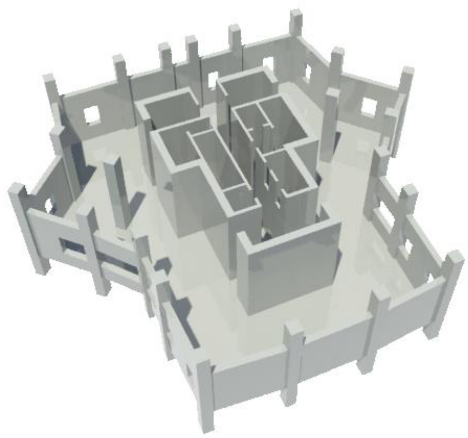


Figure. Isometric View of Belt wall at Mechanic floor

As usual, the belt walls are penetrated at various locations along the building perimeter for air intake and exhaust related to mechanical equipment and the access to the architectural curtain wall installation, maintenance and openings for sky garden requirement. The effective stiffness of the belt wall system was modeled and adjusted in finite element analysis model.

Flat plate participation as a moment frame has also been considered to resist the lateral loads in addition to the core shear wall.

It was found that the belt wall was able to increase approximately 30% in lateral stiffness to the building and also 25% by slab moment frame to meet the serviceability requirements such as overall building drift H/450 ~ H/500 and building acceleration.

In an effort to optimize structural system various concrete strength for the core wall, column and floor slab were used for both strength and stiffness requirements as shown in Figure 10. and building performance summary as shown in Table 5.

Rooftop Elevation	249.15 m
Top of Mat Elevation	-15.2 m
Number of Floors Above Grade	66
Number of Floors Below Grade	4
Typical Floor-to Floor Height	3.1 m
Aspect Ratio (Overall Height / Width)	5.5 in X-Dir 6.6 in Y-Dir
Wind Base Shear (From Wind Tunnel Test)	2,200 Ton in X-Dir 2,150 Ton in Y-Dir
Seismic Base Shear (KBC 2005)	4,290 Ton
Overall Drift Due To Wind Loads	H/475 in X-Dir H/740 in Y-Dir
Inter-story Drift To Seismic Loads	h_{FL}/340 in X-Dir h_{FL}/470 in Y-Dir

Korean building Code 2005 states that the project site is exposed to basic wind speed of V = 30 meter / second (10 minute mean wind velocity), exposure B and Importance factor I = 1.1 for strength design (equivalent to 300 year wind).

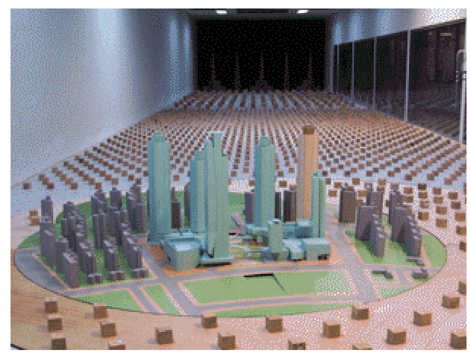


Figure 4. HFFB Wind Tunnel Testing Model

In order to optimize the structural system the high frequency force balance test was performed by TESolution and Western Ontario University. Test model was constructed on scale 1:400 and tested in the presence of all surroundings within full-scale radius of 480m.

In order to predict the full scale structural responses as a function of return period, wind velocity for the wind tunnel data was determined based on combination of a statistical model of the local wind climate and Monte Carlo typhoon simulation. As a result, maximum 10 minute wind speed at 500 meter high was decided in open terrain as follows:

Maximum Wind Speed per Return Period At 500 meter high	
Return Period	Velocity (meter/second)
10	41.29
100	47.98
300	52.35

Table 2. Maximum wind speed at 500 meter high

For wind speed profile, ESDU 84011 was chosen that a simplified method of estimating the variation of design wind speed (mean-hourly or gust values) with height about the ground and with terrain roughness.

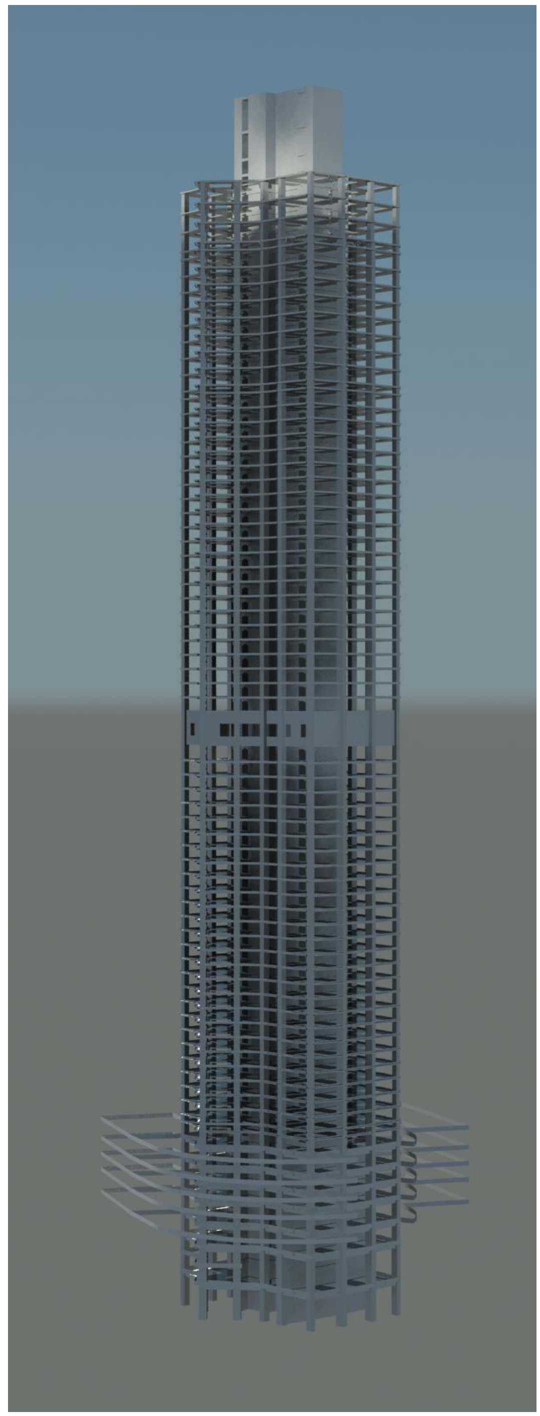
Wind tunnel test provided the design shear and moment with the effects of directionality in the local wind climate based on 3% critical damping and 300 year return period.

Also, wind tunnel testing results showed that the peak building accelerations ranged from 12.3 milli-g for a 10 year return period with 2% critical damping below the acceptable level of 15 ~ 18 milli-g for residential building based on National Canada Code.
An independent wind tunnel study was performed to verify the order of magnitude of wind pressure and to determine the dynamic behavior of the towers due to wind. The wind tunnel study results revealed a substantial reduction in the wind pressures compared with those based in accordance with the Korean Building Code, thus mitigating the concerns regarding the building deflections and accelerations due to wind loads. Consequently, the seismic loads exceeded the wind loads for the tower.

Korean Building Code 2005 states that tower shall resist the static seismic load. Design Load Parameters are listed as follows:

- A = 0.11 Effective Peak Ground acceleration
- Soil Coefficient Sb
- S_{DS} = 0.36575 Spectral Acceleration at short period
- S_{D1} = 0.1463 Spectral Acceleration at 1 second
- I = 1.5 Importance Factor

Constructability



Conclusion

This paper presents an outline of the structural system for the Korea's tallest concrete residential tower construction in Korea when completed in year 2011. This project is currently under construction.

Extensive collaboration and co-operation between the design teams in Korea and the United States was essential to successfully implementing the high-rise residential towers' design and construction.

Developer:	METAPOLIS, Inc.
Architect:	Kunwon Architect and Planner and SKM Design
Structural Engineer:	Thornton Tomasetti Chang Minwoo, MIDAS & Dohwa
CM	HanmiParsons
Contractor:	POSCO E&C, Shingdongah Co.