ABSTRACT: The Peak@Sudirman is a super-tall Residential Building located at the golden triangle central business district of Jakarta. This development consists of two 30-storey towers and two 50-storey, on top of a 3-level basement. The 50-storey towers have a slenderness ratio of 1:8, making them the one of the most slender and tallest building in Indonesia.

The lateral system for this 50-storey tower is reinforced-concrete corewall and outriggers. The outriggers have a depth of two full stories, connecting the corewall to the outrigger columns, and located at three different levels along the height of the building. By linking the outrigger columns and core, it enables the full width of the building to act in resisting lateral forces. These outriggers convert the overturning bending moment in the corewall into tension-compression couple forces in the outrigger columns, and help in achieving the required stiffness of the structure.

The structure is designed to withstand lateral wind force and earthquake. For wind effect on structure, 100-year wind of 40 m/sec is adopted for strength criteria, while 10-year wind is used for the human perception criteria. The building model has undergone wind tunnel testing at RWDI Canada to determine the static and dynamic behavior of the building.

For seismic load, the building is designed to take 500-year earthquake with a 10% probability of exceedance during the 50-year life time

The Peak@Sudirman sits on bored pile foundation and uses 55 MPa concrete to achieve the required stiffness in order to meet the occupant comfort criterion for the building. The foundation work was completed in 4 months and the structure took another 17 months. Progress of work for the typical floor is 7 days per floor.

This paper describes the design and construction of the Peak@Sudirman, currently the tallest residential building in Jakarta.
several clusters of lift shafts to provide the private lifts to each unit. The shaft contained two lifts, with RC walls surrounding them, but the size of these individual corewalls were too small to provide the required stiffness of the structure. The structural engineer then proposed a central RC corewall of decent size, and to put all the lifts within the corewall. With the new configuration and wall thickness of 700 mm, the fundamental period of the structural was around 7.0 second, and this was considered too flexible for this building. By putting double-story outriggers at three locations along the height of the building, the required stiffness can be achieved.

Reinforced concrete is used as the main structural elements, as the raw materials for concrete are in abundance in Indonesia. Furthermore, the RC slab suits very well to the irregular architectural plan and grids, and is able to minimize the floor to floor height. The familiarity of local contractors with the system is another consideration taken into account. Over the past decade or so, engineers and ready mix concrete producers have researched and developed higher and higher strength of concrete. Before 1990, the common grade is $f'c = 20 \text{ MPa} – 30 \text{ MPa}$. During the design of the 52-storey Amartapura residential apartment tower in 1994, a high-strength concrete of grade 60 MPa was developed and used, successfully.

**SUB STRUCTURE**

The Peak@Sudirman has a common basement, 3 levels with excavation reaching 10 m from the surface. The building sits on bored-pile foundation, diameter 1 m and 1.2 m with effective length of 24 m to 28 m and allowable load of 470 m.tons to 660 m.tons. Contiguous bored pile is used for the retaining structure, with one or two rows of ground anchors. The foundation work was completed in four months. Excavation of soil took another two months, and then the mat foundation was completed in one and a half months. The structural system for the basement slab is flat slab with drop panel.

**SUPER STRUCTURE**

The gravity system for this building is flat slab with drop panel, which allow the architect to make use of the available space to obtain a ceiling height of 3.00 m. Because of the irregularity of the plan, the slab cannot be analyzed by simple method. A finite-element analysis is used to analyze the forces and the deformation in the slab, especially to calculate the long term deflection of the slab. The slab thickness is then determined, which is generally 180 mm thick with 120 mm thick drop panel.

The corewall has a thickness of 650 mm on East and West side and 550 mm on North and South side. Double story outrigger beams are put at Level 10 to Level 12, Level 21 to Level 23 and Level 23 to Level 34. These outrigger beams connect the central corewall to the outrigger columns at the edge of the building, thus making use of the whole width of the building to resist the lateral load. Figure 1 shows the Peak@Sudirman in the near completion stage. Figure 2 shows the cross-section of the building and the plan. The concrete grade used in the project is of grade 55 MPa in the bottom part of the building, and subsequently reduced to 25 MPa as the structure get higher.

![Figure 1. The Peak@Sudirman, Jakarta](image1)

![Figure 2. The cross section of the building and the plan.](image2)
The structure is analyzed as a 3-D model using ETABS software. The dynamic characteristic of the structure is presented in Table 1 below:

<table>
<thead>
<tr>
<th>Mode</th>
<th>T (sec)</th>
<th>Modal Participating Mass Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X-Trans</td>
</tr>
<tr>
<td>1</td>
<td>4.536</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4.162</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>2.368</td>
<td>0</td>
</tr>
</tbody>
</table>

The outrigger system helps significantly in stiffening the structure. However, it also attracts huge forces from the lateral load. The outrigger beams are penetrated by door openings, one opening on each floor for each beam. The openings are 1200 mm by 2300 mm. They do not affect the stiffness of the outrigger beams, but the shear forces in the link beam is so huge it necessitates the installation of the steel beam to resist it.

**WIND-EFFECT**

Indonesia has not developed a map of wind speed for using in the design of tall buildings. For the Peak@Sudirman, we used the study of wind climate model developed by Lythe, G.R and Isyumov, N [1], which was previously used for the 52-storey Amartapura apartment building designed by us in 1995. The model is based on the daily record of wind speed during 20 years, from the Halim Airport. Since the building is very slender with 1:8 aspect ratio, we decided to use 100-year wind, 40 m/sec (fastest one mile speed) for strength criteria. For the human perception criteria we use 1-year, 5-year and 10-year wind. Rowan Williams Davies & Irwin, Inc. Canada is the wind consultant in this project. They performed wind-effect studies on the structure, established the cladding pressure and the comfort level of pedestrian around the building. A high-frequency force balance model with a scale of 1:300 was used to study the generated forces in the building and the peak acceleration at Level 50. Figure 3 shows the force balance model in the wind tunnel test. Figure 4 shows the rigid body model, made from plexiglass with 419 pressure taps, to determine the wind pressure for the design of the cladding system. The design damping ratio is taken as 1.5% to 2.0% of critical damping.

![Figure 3. The force balance model in the wind tunnel test.](image)

![Figure 4. The rigid body model](image)

The result of the force balance model shows the total wind force acting on the building in the x and y direction is 479 m.tons and 980 m.tons respectively. The acceleration at the top floor is well below the ISO criteria for 1-year, 5-year and 10-year wind. The 10-year wind acceleration is 9.0 – 10.4 m.g, well below the 16.0 m.g limit. See Table 2 below.

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>Peak Total Acceleration (milli-g)</th>
<th>ISO Criteria (milli-g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D=2.0%</td>
<td>D=1.5%</td>
</tr>
<tr>
<td>1</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>5</td>
<td>7.2</td>
<td>8.4</td>
</tr>
<tr>
<td>10</td>
<td>9.0</td>
<td>10.4</td>
</tr>
</tbody>
</table>

**SEISMIC-EFFECT**

The Peak@Sudirman is designed to take 500-year earthquake with 10% probability of exceedance during its 50-year life time, as per Indonesian Seismic Code. The seismic response modification factor is taken as R = 5.5, and the importance factor I = 1.0. The outrigger beams and columns are designed to resist the elastic...
seismic force but not bigger than the sum of the shear yield capacity of the steel link beams. In this way, we make sure that the energy dissipation take place either in the steel link beams or in the corewall. The design Peak Ground Acceleration is 150 milli-g. This gives the value of base shear in the x and y direction as 1210 m.tons and 1125 m.tons respectively.

Figure-5 and Figure-6 present the comparison of the ultimate story-shear for axis-X and axis-Y for wind and earthquake load, while Figure-7 and Figure-8 show the ultimate overturning moment. In the X-direction the ultimate overturning moment due to earthquake is bigger than the wind, while on the Y-direction it is the other way around.

The shape of the building is rectangular, with 1:8 aspect ratio on one axis but not so slender in the other axis. The North and South elevation has much bigger frontal area than the East and West. This explains the above description.

Figure-9 shows the 3-D computer model of the structure, with the corewall and the double story outriggers at three locations. Figure-10 shows the steel link beam, with thick web plate and thin flange plates. Figure-11 shows the installation of the link beam during construction.
Figure 8. The ultimate overturning moment for axis-Y

Figure 9. The 3-D computer model of the structure showing the corewall and the double story outriggers at three locations

Figure 10. The steel link beam, with thick web plate and thin flange plates.

Figure 11. The installation of the link beam during construction.

CONSTRUCTION ASPECTS

The basement construction was completed in two months. The super structure took another twelve months. Flying form system was used to achieve a speed of seven days per floor. Special precaution was exercised on the exposed corner columns, which need extra care on the construction practice. The outriggers were not allowed to be cast until the topping-off, in order to transfer all the load directly to the columns as per their tributary area. The requirement for the confinement of the boundary elements in the corewall has created some congestion problems in rebar.
installation, which was then solved by rearrangement of the stirrups diameter and spacing. See Figure-12. The installation of the steel link beams did not create any problem, but the construction cycle for the related floor was two days longer. Figure-13 shows the construction of the super structure with one shored plus two reshored formwork.

![Figure 12](image)

The concrete grade used is $f_{c'} = 25$ MPa up to 55 MPa, delivered to the site by trucks from different plans within 45 minutes drive to the site. The steel rebar is of grade BJTS-40, minimum yield strength is 400 MPa. Topping-off was conducted in November 2005 and the building was completed at the end of 2006.

**REFERENCES**

Lythe, G.R; and Isyumov N,“A Study of Wind Effects for Amartapura the Residential Palace, Jakarta, Indonesia”, BLWT-5523-1995