A study on interrelations of structural systems and main planning considerations in contemporary supertall buildings

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Abstract

Purpose – The aim of the study is to provide a comprehensive understanding of interrelations of structural systems and main planning considerations in supertall buildings (≥300 m).

Design/methodology/approach – Data were collected from 140 contemporary supertall towers using the case study method to analyze structural systems in the light of the key design considerations to contribute to the creation of more viable supertall building projects.

Findings – Central core typology, outriggered frame system, composite material and tapered prismatic and free forms were the most preferred features in supertall building design. Shear walled frame and tube systems occurred mostly in the 300–400 m height range, while outriggered frame systems were in the range of 300–600 m in height. Asia, the Middle East and North America mainly preferred outriggered frame systems, followed by tube systems. Considering the building function and form, the most preferred structural system in each of these groups was outriggered frame system, while mixed-use function stood out in all structural systems except in shear walled frame system.

Originality/value – To date, there has been no comprehensive study in the literature of the interrelations of structural systems and important planning considerations in the design of contemporary supertall towers through a large set of study samples. This critical issue was multidimensionally explored in this paper in light of 140 detailed case studies of supertall buildings around the world.

Keywords Supertall building, Interrelations, Structural system, Building height, Building form, Core planning, Structural material

Paper type Research paper

1. Introduction

The increasing rate of urbanization in recent years, along with the race to win the title of the tallest building, has seen an accelerating trend in the construction of supertall buildings around the world, especially in developing economies (Al-Kodmany, 2012, 2018a; Gabel, 2016; Gerges et al., 2017; Ilgin, 2021a). The world continues to witness an explosion of growth in the number of skyscrapers above 200 m with record-breaking completions for three consecutive years (2014–2016), and an over 400% increase in the total number of such towers in the 21st century (Gabel, 2018; Khallaf and Khallaf, 2021). According to the Council on Tall Buildings and Urban Habitat (CTBUH) database (CTBUH, 2022), the number of supertall buildings under construction and completed in the last decade is close to 250. The rapidly increasing global
demand for supertall buildings in the world brings up the parameters that play a critical role in the design and implementation of these giant projects as in the cases of Burj Khalifa (Dubai, 828 m) (Figure 1a) (Abdelrazaq, 2010), Merdeka PNB118 (Kuala Lumpur, under construction) (Figure 1b) (Fender et al., 2016), Shanghai Tower (Shanghai, 2015) (Figure 1c) (Wu et al., 2019) and One Vanderbilt Avenue (New York, 2020) (Figure 1d) (Klemperer, 2015).

Since a supertall building is feasible by the structure itself, the structural system is the most important design parameter, and many planning criteria depend on the structural

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**Figure 1.** Contemporary supertall building examples

**Note(s):** (a) Burj Khalifa (source: Wikipedia); (b) Merdeka PNB118 (source: Wikipedia); (c) Shanghai Tower (source: Wikipedia); (d) One Vanderbilt Avenue (source: Percival Kestreltail/Wikipedia)
system in terms of its performance (Ilgın, 2018). The selection of an optimal building structural system is also critical to improving building construction (Chakraborty et al., 2020; Zhong et al., 2022). Structural systems play a key role in determining a cost-effective supertall building form. Moreover, the structural cost of tall buildings can constitute approximately 30% of the total construction cost, and this cost increases as the building rises (Almusharaf and Elnimeiri, 2010; Wang et al., 2017; Mubarek et al., 2019; Elmousalami, 2019). Due to the current trend of the pluralistic architectural style, the structural systems have become more diverse and have somehow lost their natural logic, adapting to the formatting predetermined by the architect (Ali and Al-Kodmany, 2012). The style and aesthetics of the buildings are integrally related to the horizontal and vertical configurations.

It should be noted here that many studies in the literature raise concerns about the sustainability and ecological dimensions of construction projects (e.g. Chakraborty et al., 2016; Swei et al., 2017; Kumar and Gururaj, 2019; Opoku, 2019; Elhegazy et al., 2021a) including supertall towers (e.g. Yeang, 2008; Al-Kodmany, 2018b, c; Borrallo-Jiménez et al., 2020; Zhang, 2020). According to Al-Kodmany (2018b, c), these buildings have elements that threaten their social, economic and environmental sustainability. In this sense, from a social perspective, supertall buildings can cause social isolation due to their vertical composition and therefore are generally not assessed suitable for raising children and family life. They are also thought to be self-referential and vertically stratified objects devoid of cultural and social references to their surroundings (Scheeren, 2014; Henn and Fleischmann, 2015; Safarik, 2016). From an economic point of view, supertall towers are costly to build due to their complex structure and their mechanical and electrical systems (DeJong and Wamelink, 2008). In addition, far greater amounts of materials and energy, and far greater amounts of embodied energy, must be involved in their construction and operation than in low-rise buildings (Ali and Al-Kodmany, 2012). From an environmental perspective, the construction and maintenance of supertall buildings generate large amounts of carbon dioxide emissions (Dong et al., 2015; Gan et al., 2017). It should also be underlined here that building management, evaluating its performance and assessing tenant satisfaction are key components of achieving more sustainable skyscrapers (Safarik et al., 2016).

Although there are many studies on tall and supertall building structural systems in the literature (e.g. Ali and Moon, 2007; Taranath, 2016; Ali and Moon, 2018; Fu, 2018), limited studies examine the relationship between the structural system and other design parameters. Among these studies, Sev and Özgen (2009) analyzed the space efficiency in 10 high-rise office buildings from Turkey and the world in the light of various parameters such as leasing depth, gross and net floor areas, core integrity, structural material, floor-to-floor height and structural system. Elnimeiri and Almusaraf (2010) scrutinized the historical development of the relationship between the structural system and tall building form. Alaghmandan et al. (2014) examined architectural and structural trends in the design of tall buildings through 73 case studies. Ilgın (2021b) focused on space efficiency in 44 contemporary supertall office buildings with the main architectural and structural parameters (i.e. core planning, building form, structural system and structural material), while Ilgın (2021c) studied space efficiency in 27 contemporary supertall residential buildings with the same parameters. On the other hand, Ilgın et al. (2021) analyzed the contemporary trends in main architectural and structural design considerations and several corresponding interrelations through 93 case studies.

To date, there has been no comprehensive study in the literature of the interrelations of structural systems and important planning considerations in the design of contemporary supertall towers through a large set of study samples. This critical issue was multidimensionally explored in this paper in light of 140 detailed case studies of supertall buildings around the world.

In this study, besides giving general information (building name, country and city, height, number of stories, completion date, function), key planning considerations (core design,
building forms, structural systems and structural materials) and interrelations of the structural system and main design considerations including building height, location, function, building form and structural material were analyzed. By doing so, this paper, which reveals the current state of the art of supertall applications, is believed to provide insight into making more viable design decisions for future supertall towers.

The remainder of this paper was structured as follows. First, an explanation of the materials and methods used in the study was provided. This was followed by results of interrelations of structural system and main planning considerations. Finally, discussion and conclusions were presented, with research limitations and suggestions for future studies.

2. Materials and methods
In this study, the case study method was employed to collect and consolidate information about contemporary supertall buildings to examine the interrelationships of structural systems and major planning considerations. This method is a widely used approach in built environment assessments, where projects are identified and documented for quantitative and qualitative data through in-depth literature review (Kuzmanovska et al., 2018).

In this paper, the following parameters, which have an important role in the planning of supertall buildings and are associated with the structural system, were discussed: (1) building height, (2) location, (3) building function, (4) building form and (5) structural material.

Cases which included 140 supertall buildings in a variety of countries [78 from Asia (58 from China), 31 from the Middle East (22 from Dubai, the United Arab Emirates), 20 from North America (14 from the United States), 7 from Russia, 2 from Australia, 1 from South America (Chile), 1 from Europe (UK)]. Appendices 1 and 2 show detailed information of 140 contemporary supertall towers.

Functionally supertall buildings are divided into single-use or mixed-use. In supertall tower design, hotels, residential buildings and offices are considered as the primary functions in this paper.

Based on the CTBUH database (CTBUH, 2022), a single-use building is considered a building where 85% or more of its total height is devoted to a single function, whereas a mixed-use building is assumed to contain two or more functions, occupying a significant part of the total area of the tower in this study. It was also assumed that a supertall building is equal to and higher than a 300 m building (CTBUH, 2022). Additionally, the following core classification of Ilgin et al. (2021) was used because of its more comprehensive structure in the literature (e.g. Trabucco, 2010; Oldfield and Doherty, 2019): (1) central core (central and central split), (2) atrium core (atrium and atrium split), (3) external core (attached, detached, partial split and full split) and (4) peripheral core (partial peripheral, full peripheral, partial split and full split).

Furthermore, compared to other studies in the literature (e.g. Al-Kodmany and Ali, 2016; Szolomicki and Golasz-Szolomicka, 2019), the following forms of classification were used in this study (Ilgin et al., 2021): (1) prismatic, (2) setback, (3) tapered, (4) twisted, (5) leaning/tilted and (6) free forms.

Since it is more comprehensive than the existing structural system classification in the literature (e.g. Gunel and Ilgn, 2007; Gunel and Ilgn, 2014a, b; Taranath, 2016; Ali and Moon, 2018), the author used the following classification for supertall buildings (Ilgin et al., 2021):

(1) shear-frame system consisting of shear wall/truss and frame with subsets of shear trussed frame and shear walled frame;

(2) mega core system consisting of a mega core with much larger cross-sections than normal, running continuously along the height of the building as a main load-bearing element;
(3) mega column system consisting of mega columns or shear walls with much larger cross-sections than normal, running continuously along the height of the building as main load-bearing elements;

(4) outriggered frame system consisting of at least one-story deep outriggers added to shear-frame system;

(5) tube system:
   - framed-tube system consisting of closely spaced exterior columns with spandrel beams at the facade,
   - trussed-tube system consisting of exterior columns with exterior multistory braces,
   - bundled-tube system consisting of a combination of more than one tube; and

(6) buttressed core system, an advanced “shear wall system,” consisting of shear walls directly supporting the central core.

In this article, the following classification was used for structural materials for supertall building construction: (1) steel, (2) reinforced concrete and (3) composite. Considering vertical structural members – columns, beams, shear trusses, shear walls and outriggers – as the main structural elements, “composite” referred to the buildings in which some structural elements were made of reinforced concrete and other structural elements were made of steel, or to those in which some structural elements were made of both structural steel and concrete together or to both the first and the second categories (e.g. Chen, 2021; Elhegazy et al., 2021b).

3. Results

Figure 2 shows the relationship between the building height and the number of stories of supertall towers examined. As seen in the red trendline in Figure 2, it can be said that there is a directly proportional relationship between the height of the building and the number of stories.

It is worth noting here that a building can also have symbolic functions besides its main function(s), which is divided into regular floors with typical floor heights. This could make the building an outlier, as in the case of the 36-story, 300 m high Aspire Tower (see Figure 2) comprising both hotel and office functions. The tower, which resembles a hand holding a flaming torch, became the most important symbol of the 15th Asian Games held in Qatar in 2006 (Chikaher and Hirst, 2007; Gunel and Ilgin, 2014b). Similarly, as in the 62-story, 427 m high One Vanderbilt Avenue in New York, a part of a supertall building may have been designed not for purely human occupation in the form of an office, hotel or residence, but for other purposes, such as an observation deck on the upper floors (Klemperer, 2015). This approach can also make the building an outlier (see Figure 2).

Additionally, in Figures 3–5, the bars demonstrate the total number of supertall buildings (right axis of the chart) by function, form and structural material, respectively, while dots correspond to the heights of supertall buildings (left axis of the chart) by function, form and structural material, respectively. As seen in Figure 3, building functions other than hotel either reached the level of megatall buildings (≥600 m) or were very close to it, while megatall building limit exceeded in all building forms as shown in Figure 4. Considering the wind loads that become more critical as the building height increases (e.g. Wang and Ni, 2022), the aerodynamic efficiency of the tapered, setback, free and twisted forms may have contributed to the skyscrapers built with these forms to break through the megatall height limits (Ilgın and Günel, 2007; Sharma et al., 2018; Ilgün and Gunel, 2021; Li et al., 2022; Mandal et al., 2022).

As highlighted in Figure 5, many composite buildings were built beyond the megatall building height. This can be explained by the superiority of composite structure, which
combines the advantages of both materials, such as the high strength of steel and the rigidity and fire resistance of reinforced concrete (e.g., Du et al., 2022). Megatall limit was exceeded only with the Burj Khalifa (Figure 1a) as reinforced concrete, and these structures were generally built in the range of 300–600 m. At the Burj Khalifa, high-performance, high-strength concrete with strengths of up to 80 MPa may have contributed significantly to the tower’s attainment of this extraordinary height (Weismantle et al., 2007; Aldred, 2010). On the other hand, the tallest building in steel was 435 m in the study sample.

3.1 Interrelations of structural system and main planning considerations
Interrelations of structural system and main planning considerations associated with it, such as building height, location, building function, building form and structural material, were

![Figure 2. Interrelation of the building height and the number of stories](image1.png)

![Figure 3. Interrelation of building height and function](image2.png)
examined in this section. Since the most used core typology by a wide margin (>96%) in the study sample was the central core, no analysis was made on this issue.

3.1.1 Interrelation of structural system and building height. In Figure 6, the bars demonstrate the total number of supertall buildings (right axis of the chart) by structural system, while dots correspond to the heights of supertall buildings (left axis of the chart) with such a structural system.

Shear walled frame systems occurred 92% in the 300–400 m height range, and only Al Hamra Tower, whose height exceeds 400 m, was built with this system. According to the study example, buttressed core systems were rarely preferred in supertall building construction, but Burj Khalifa (Figure 1a), the world’s tallest completed building, was built with a buttressed core system. Outriggered frame systems with a ratio of 95% were in the height range of 300–600 m, while only 5 of them can be called megatall towers (>600 m). By January 2022, 9 of the 10 tallest buildings completed in the CTBUH database (CTBUH, 2022) used an outriggered frame system: Shanghai Tower with 128-stories and 632 m height (Figure 1c), Makkah Royal Clock Tower with 120-stories and 601 m height, Ping An Finance Center with 115-stories and 599 m height, Lotte World Tower with 123-stories and 554 m height, One World Trade Center with 94-stories and 541 m height, Guangzhou CTF Finance Centre with 111-stories and 530 m height, Tianjin CTF Finance Centre with 97-stories and 530 m height, CITIC Tower with 109-stories and 528 m height and Taipei 101 with 101-stories and 508 m height. Tube systems, which occurred at a rate of 59%, were in the height range of 300–400 m; only 4 of them exceed 500 meters. In the sample group, while framed-tube system

![Figure 4. Interrelation of building height and building form](image1)

![Figure 5. Interrelation of building height and structural material](image2)
was preferred most (63%) among tube systems, trussed-tube system was employed in Goldin Finance 117 with 596 m height, the tallest building in which the tube system was used.

3.1.2 Interrelation of structural system and location. Figures 7 and 8 show the interrelation of structural system and location. Asia preferred outriggered frame system in a wide margin (76%), followed by tube system with a ratio of 18%. Similarly, the Middle East and North America utilized outriggered frame systems mostly, with ratios of 48 and 65%, respectively. As the number of supertall buildings in the sample group was relatively small in Russia (7 cases) and the remaining locations (4 cases), it was difficult to establish a scientific relationship between structural system and location.

3.1.3 Interrelation of structural system and building function. Figure 9 compares the use of alternative structural systems for a given building function. Although outrigger frame system was the most preferred structural system in all building functions, followed by tube system apart from hotel function, outrigger frame system’s dominance became more pronounced (>70%) especially in mixed-use development. On the other hand, Figure 10 compares the use of alternative functions for a given structural system. While mixed-use function stood out in all structural systems except shear walled frame, this situation became even more evident in outriggered frame systems. Since the number of buildings with buttressed core system and hotel function was very few, deriving a correlation between structural system and building function of those buildings was likely to be inaccurate.
3.1.4 Interrelation of structural system and building form. Figure 11 compares the use of alternative structural systems for a given building form. Even though outrigger frame system was the most used structural system in all building forms, followed by tube system
apart from free form, outrigger frame system’s dominance became more pronounced especially in tapered and free forms (>70%). On the other hand, Figure 12 compares the use of alternative building forms for a given structural system. While tapered, free and prismatic forms were preferred in outriggered frame systems; prismatic, tapered and setback forms were employed in tube systems according to the order of frequent use. Since the number of buildings with twisted form and buttressed core was very low, it did not seem possible to establish a relationship between the building form and structural system of those buildings.

3.1.5 Interrelation of structural system and structural material. Figures 13 and 14 show the interrelation of structural system and structural material. As seen in Figure 13, composite was the most preferred material, followed by reinforced concrete, in all types of structural systems except buttressed core system. When the subject was considered in terms of structural material classification, outriggered frame system was the most preferred structural system in terms of all types of materials, followed by tube system. Since the number of buildings made of steel and with buttressed core system was very few, deriving a correlation between structural systems and structural materials of those buildings was likely to be inaccurate.

4. Discussion and conclusions
The results obtained in this study showed similarities and dissimilarities with other studies in the literature (e.g. Oldfield and Doherty, 2019; Ilgın et al., 2021). In this paper, central core arrangement was the most used typology, as noted in similar studies (Oldfield and Doherty, 2019; Ilgın, 2021b, c; Ilgın et al., 2021). Among the 140 supertall towers, tapered, prismatic and free forms were the most frequent, and this finding was verified by the findings in the studies of Ilgın et al. (2021) on 93 supertall towers, Ilgın (2021b) on 44 supertall office buildings and Ilgın (2021c) on 27 supertall residential towers. In terms of structural systems, outriggered frame system was mainly used in supertall buildings, which confirmed the findings of other studies such as Ilgın et al. (2021), Ilgın (2021b) and Ilgın (2021c), while the use of composite
was more prevalent than steel and reinforced concrete as in the studies of Ilgın et al. (2021) and Ilgın (2021b).

Regarding the interrelations of the structural system and the main planning considerations associated with it, this study analyzed building height, location, building function, building form and structural material to provide an introductory design guide for key construction professionals in supertall building projects. Shear walled frame and tube systems mostly occurred in the 300–400 m height range, while outriggered frame systems were primarily in the height range of 300–600 m. Asia, the Middle East and North America mainly preferred outriggered frame systems, followed by tube systems, in supertall building construction. Similarly, considering building function and building form, outrigger frame system was the most prevalent structural system in all building function and form groups. Additionally, mixed-use function came to the fore in all structural systems except shear walled frame. On the other hand, while tapered, free and prismatic forms were preferred in outriggered frame systems, prismatic, tapered and setback forms were employed in tube systems according to the order of frequent use. In terms of the interrelation of the structural system and structural material, composite was the most used material, followed by reinforced concrete, in all structural systems except buttressed core system.

It is also worth noting that supertall buildings have come under serious criticism that they are unsustainable in many ways, including social, financial and ecological considerations.
Solutions to these important issues should be considered from the initial planning phase of supertall towers. In this context, architects should be aware that the design of these gigantic projects, like many other complex structures, is a multidimensional issue that requires interdisciplinary collaboration and high-level teamwork.

In this paper, through 140 supertall cases, main design considerations (i.e. core planning, building forms, structural systems and structural materials) and interrelations of structural system and main design considerations (i.e. building height, location, building function, building form and structural material) were analyzed.

In conclusion, the results obtained in this study on interrelations of structural systems and main planning considerations in contemporary supertall buildings are expected to provide design guidelines for key professional stakeholders such as architects, engineers and developers.

The empirical data presented in this paper are limited to buildings taller than or equal to 300 meters. Additional categorization levels for 140 supertall buildings in the study sample set especially relatively may give biased results for a small number of building groups such as hotel function buildings and steel buildings; it was emphasized that, where appropriate, it would probably be inaccurate to extract correlations from these building groups. However, considering the significantly increasing number of buildings in the scope of this study in the last decade, it can be foreseen that there will be a sufficient number of buildings in subcategories in the near future.

In addition, buildings below 300 m can also be included in the study sample to create a sufficient number of subcategories. On the other hand, as innovative structural systems are developed for the next generation of sustainable, ultra-tall buildings and megastructures, the relationships between the structural system and other design parameters may change, which will require further research. In particular, future research should delve deeper into the structural system-sustainability relationship of supertall towers, and in this context, supertall timber building projects may come to the fore (Johnson et al., 2014; Foster and Ramage, 2017; Ramage et al., 2017).

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### Table A1.
Contemporary supertall buildings considered in this study

| #  | Building name                  | Country | City         | Height (meters) | # of storeys | Completion date | Function |
|----|-------------------------------|---------|--------------|-----------------|--------------|-----------------|----------|
| 1  | Nakheel Tower                 | UAE     | Dubai        | 1,000           | 200          | NC              | M (H/R/O) |
| 2  | Burj Khalifa                  | UAE     | Dubai        | 828             | 163          | 2010            | M (H/R/O) |
| 3  | Suzhou Zhongnan Center        | China   | Suzhou       | 729             | 137          | NC              | M (H/R/O) |
| 4  | Merdeka PNB118                | Malaysia| Kuala Lumpur | 644             | 118          | UC              | M (H/O)   |
| 5  | Shanghai Tower                | China   | Shanghai     | 632             | 128          | 2015            | M (H/O)   |
| 6  | Chicago Spire                 | USA     | Chicago      | 609             | 150          | NC              | R        |
| 7  | Makkah Royal Clock Tower      | Saudi   | Mecca        | 601             | 120          | 2012            | M (H/R)   |
| 8  | Pingan Finance Center         | China   | Shenzhen     | 599             | 115          | 2017            | O        |
| 9  | Goldin Finance 117            | China   | Tianjin      | 596             | 128          | OH              | M (H/O)   |
| 10 | Entisar Tower                 | UAE     | Dubai        | 577             | 122          | OH              | M (H/R)   |
| 11 | Lotte World Tower             | South Korea | Seoul | 554             | 123          | 2017            | M (H/R/O) |
| 12 | One World Trade Center        | USA     | New York     | 541             | 94           | 2014            | O        |
| 13 | Guangzhou CTF Finance Centre  | China   | Guangzhou    | 530             | 111          | 2016            | M (H/R/O) |
| 14 | Tianjin CTF Finance Centre    | China   | Tianjin      | 530             | 97           | 2019            | M (H/O)   |
| 15 | CIFIC Tower                   | China   | Beijing      | 528             | 108          | 2018            | O        |
| 16 | Evergrande Hefei Center 1     | China   | Hefei        | 518             | 112          | OH              | M (H/R/O) |
| 17 | Pentominium Tower             | UAE     | Dubai        | 515             | 122          | OH              | R        |

(continued)
| #  | Building name                               | Country     | City           | Height (meters) | # of storeys | Completion date | Function |
|----|---------------------------------------------|-------------|----------------|----------------|--------------|----------------|----------|
| 18 | Busan Lotte Town Tower                      | South Korea | Busan          | 510            | 107          | NC             | M (H/R/O) |
| 19 | TAIPEI 101                                  | Taiwan      | Taipei         | 508            | 101          | 2004          | O        |
| 20 | Greenland Jinmao International Financial Center | China     | Nanjing        | 499            | 102          | UC             | M (H/O)  |
| 21 | Shanghai World Financial Center             | China       | Shanghai       | 492            | 101          | 2008          | M (H/O)  |
| 22 | International Commerce Centre               | China       | Hong Kong      | 484            | 108          | 2010          | M (H/O)  |
| 23 | Wuhan Greenland Center                      | China       | Wuhan          | 475            | 97           | UC             | M (H/R/O) |
| 24 | Central Park Tower                          | USA         | New York       | 472            | 98           | 2020          | R        |
| 25 | Chengdu Greenland Tower                     | China       | Chengdu        | 468            | 101          | UC             | M (H/O)  |
| 26 | R&F Guangdong Building                      | China       | Tianjin        | 468            | 91           | OH             | M (H/R/O) |
| 27 | Lakhta Center                               | Russia      | St. Petersburg | 462            | 87           | 2019          | O        |
| 28 | Vincom Landmark 81                          | Vietnam     | Ho Chi Minh City | 461          | 81           | 2018          | M (H/R)  |
| 29 | Changsha IFS Tower T1                       | China       | Changsha       | 452            | 94           | 2018          | M (H/O)  |
| 30 | Petronas Twin Tower 1                        | Malaysia    | Kuala Lumpur   | 452            | 88           | 1998          | O        |
| 31 | Petronas Twin Tower 2                        | Malaysia    | Kuala Lumpur   | 452            | 88           | 1998          | O        |
| 32 | Zifeng Tower                                | China       | Nanjing        | 450            | 66           | 2010          | M (H/O)  |
| 33 | The Exchange 106                             | Malaysia    | Kuala Lumpur   | 446            | 95           | 2019          | O        |
| 34 | Marina 106                                  | UAE         | Dubai          | 445            | 104          | OH             | R        |
| 35 | World One                                   | Mumbai      | India          | 442            | 117          | NC             | R        |
| 36 | KK 100                                      | China       | Shenzhen       | 441            | 98           | 2011          | M (H/O)  |
| 37 | Guangzhou International Finance Center      | China       | Guangzhou      | 438            | 103          | 2010          | M (H/O)  |
| 38 | Multifunctional Highrise Complex–Akhmat Tower | Russia   | Grozny         | 435            | 102          | OH             | M (R/O)  |
| 39 | 111 West 57th Street                         | USA         | New York       | 435            | 84           | UC             | R        |
| 40 | Chongqing Tall Tower                         | China       | Chongqing      | 431            | 101          | OH             | M (H/R/O) |
| 41 | Haikou Tower 1                               | China       | Haikou         | 428            | 94           | OH             | M (H/R/O) |
| 42 | One Vanderbilt Avenue                        | USA         | New York       | 427            | 62           | 2020          | O        |
| 43 | Marina 101                                  | UAE         | Dubai          | 425            | 101          | 2017          | M (H/R)  |
| 44 | 432 Park Avenue                              | USA         | New York       | 425            | 85           | 2015          | R        |
| 45 | Trump International Hotel and Tower          | USA         | Chicago        | 423            | 98           | 2009          | M (H/R)  |
| 46 | Al Hamra Tower                               | Kuwait      | Kuwait City    | 413            | 80           | 2011          | O        |
| 47 | Princess Tower                               | UAE         | Dubai          | 413            | 101          | 2012          | R        |

(continued)
| #  | Building name                  | Country     | City          | Height (meters) | # of storeys | Completion date | Function |
|----|--------------------------------|-------------|---------------|----------------|--------------|----------------|----------|
| 48 | Two International Finance Center | China       | Hong Kong     | 412            | 88           | 2003           | O        |
| 49 | LCT The Sharp Landmark Tower   | South Korea | Busan         | 411            | 101          | 2019           | M (H/R)  |
| 50 | Guangxi China Resources Tower  | China       | Nanning       | 402            | 86           | 2020           | M (H/O)  |
| 51 | China Resources Tower          | China       | Shenzhen      | 393            | 68           | 2018           | O        |
| 52 | 23 Marina                      | UAE         | Dubai         | 392            | 88           | 2012           | R        |
| 53 | CITIC Plaza                    | China       | Guangzhou     | 390            | 80           | 1996           | O        |
| 54 | Dynamic Tower                  | UAE         | Dubai         | 388            | 80           | NC             | M (H/R)  |
| 55 | Shum Yip Upperrhills Tower 1   | China       | Shenzhen      | 388            | 80           | 2020           | M (H/O)  |
| 56 | 30 Hudson Yards                | USA         | New York      | 387            | 73           | 2019           | O        |
| 57 | PIF Tower                      | Saudi Arabia| Riyadh       | 385            | 72           | ATO            | O        |
| 58 | Shun Hing Square Tower         | China       | Shenzhen      | 384            | 69           | 1996           | O        |
| 59 | Autograph Tower                | Indonesia   | Jakarta       | 382            | 75           | UC             | M (H/O)  |
| 60 | Burj Mohammed Bin Rashid Tower | UAE         | Abu Dhabi     | 381            | 88           | 2014           | R        |
| 61 | Guiyang World Trade Center     | China       | Guiyang       | 380            | 92           | UC             | M (H/O)  |
| 62 | Elite residence                | UAE         | Dubai         | 380            | 87           | 2012           | R        |
| 63 | Central Plaza                  | China       | Hong Kong     | 374            | 78           | 1992           | O        |
| 64 | Federation Tower               | Russia      | Moscow        | 373            | 93           | 2016           | M (R/O)  |
| 65 | Golden Eagle Tiandi Tower A    | China       | Nanjing       | 368            | 77           | 2019           | M (H/O)  |
| 66 | Bank of China Tower            | China       | Hong Kong     | 367            | 72           | 1990           | O        |
| 67 | St. Regis Chicago              | USA         | Chicago       | 362            | 101          | 2020           | M (H/R)  |
| 68 | Almas Tower                    | UAE         | Dubai         | 360            | 68           | 2008           | O        |
| 69 | Hanking Center                 | China       | Shenzhen      | 359            | 65           | 2018           | O        |
| 70 | Greenland Group Tower          | China       | Suzhou        | 358            | 77           | UC             | M (H/O)  |
| 71 | Sino Steel International Plaza | China       | Tianjin       | 358            | 83           | OH             | O        |
| 72 | II Primo Tower 1               | UAE         | Dubai         | 356            | 79           | UC             | R        |
| 73 | Emirates Tower One             | UAE         | Dubai         | 355            | 54           | 2000           | O        |
| 74 | OKO-Residential Tower          | Russia      | Moscow        | 354            | 90           | 2015           | M (H/R)  |
| 75 | Raffles City                   | China       | Chongqing     | 354            | 74           | 2019           | M (H/O)  |
| 76 | The Torch                      | UAE         | Dubai         | 352            | 86           | 2011           | R        |
| 77 | Spring City 66                 | China       | Kunming       | 349            | 61           | 2019           | O        |
| 78 | The Center                     | China       | Hong Kong     | 346            | 73           | 1998           | O        |
| 79 | Neva Towers 2                  | Russia      | Moscow        | 345            | 79           | 2020           | R        |
| 80 | ADNOC Headquarters             | UAE         | Abu Dhabi     | 342            | 65           | 2015           | O        |
| 81 | One Shenzhen Bay Tower 7       | China       | Shenzhen      | 341            | 78           | 2018           | M (H/R/O) |

Table A1. (continued)
| #   | Building name                                      | Country   | City           | Height (meters) | # of storeys | Completion date | Function |
|-----|---------------------------------------------------|-----------|----------------|-----------------|--------------|-----------------|----------|
| 82  | Comcast Technology Center                         | USA       | Philadelphia   | 339             | 59           | 2018            | M (H/O)  |
| 83  | LCT The Sharp Residential Tower A                 | Korea     | Busan          | 339             | 85           | 2019            | R        |
| 84  | Mercury City Tower                                 | Russia    | Moscow         | 338             | 75           | 2013            | M (R/O)  |
| 85  | Hengqin International Finance Center              | China     | Zhuhai         | 337             | 69           | 2020            | M (R/O)  |
| 86  | Tianjin World Financial Center                    | China     | Tianjin        | 337             | 75           | 2011            | O        |
| 87  | Wilshire Grand Center                             | USA       | Los Angeles    | 335             | 62           | 2017            | M (H/O)  |
| 88  | DAMAC heights                                     | UAE       | Dubai          | 335             | 88           | 2018            | R        |
| 89  | Shimao International Plaza                        | China     | Shanghai       | 333             | 60           | 2006            | M (H/O)  |
| 90  | LCT The Sharp Residential Tower B                 | Korea     | Busan          | 333             | 85           | 2019            | R        |
| 91  | China World Tower                                 | China     | Beijing        | 330             | 74           | 2010            | M (H/O)  |
| 92  | Hon Kwok City Center                              | China     | Shenzhen       | 329             | 80           | 2017            | M (R/O)  |
| 93  | 3 World Trade Center                             | USA       | New York       | 329             | 69           | 2018            | O        |
| 94  | Keangnam Landmark Tower                           | Vietnam   | Hanoi          | 328             | 72           | 2012            | M (H/R/O) |
| 95  | Golden Eagle Tiandi Tower B                       | China     | Nanjing        | 328             | 68           | 2019            | O        |
| 96  | Salesforce Tower                                  | USA       | San Francisco  | 326             | 61           | 2018            | O        |
| 97  | Deji Plaza                                        | China     | Nanjing        | 324             | 62           | 2013            | M (H/O)  |
| 98  | Q1 Tower                                          | Australia | Gold Coast     | 322             | 78           | 2005            | R        |
| 99  | Burj Al Arab                                      | UAE       | Dubai          | 321             | 56           | 1999            | H        |
| 100 | Nina Tower                                        | China     | Hong Kong      | 320             | 80           | 2006            | M (H/O)  |
| 101 | Sinar Mas Center 1                                | China     | Shenzhen       | 320             | 65           | 2017            | O        |
| 102 | Palace Royale                                     | Mumbai    | India          | 320             | 88           | OH              | R        |
| 103 | 53 West 53                                        | USA       | New York       | 320             | 77           | 2019            | R        |
| 104 | New York Times Tower                              | USA       | New York       | 319             | 52           | 2007            | O        |
| 105 | Chongqing IFS T1                                  | China     | Chongqing      | 316             | 63           | 2016            | M (H/O)  |
| 106 | Australia 108                                     | Australia | Melbourne      | 316             | 100          | 2020            | R        |
| 107 | Mahanakhon                                        | China     | Bangkok        | 314             | 79           | 2016            | M (H/R)  |
| 108 | CITIC Financial Center Tower 1                    | China     | Shenzhen       | 312             | –            | UC              | M (R/O)  |
| 109 | Bank of America Plaza                             | USA       | Atlanta        | 312             | 55           | 1992            | O        |
| 110 | Shenzhen Bay Innovation and Technology Centre     | China     | Shenzhen       | 311             | 69           | 2020            | O        |
| 111 | Menara TM                                         | Malaysia  | Kuala Lumpur   | 310             | 55           | 2001            | O        |
| 112 | Ocean Heights                                     | UAE       | Dubai          | 310             | 83           | 2010            | R        |
| 113 | Pearl River Tower                                 | China     | Guangzhou      | 309             | 71           | 2013            | O        |
| 114 | Fortune Center                                    | China     | Guangzhou      | 309             | 68           | 2015            | O        |
| 115 | Emirates Tower Two                                | UAE       | Dubai          | 309             | 56           | 2000            | H        |

(continued)
| #   | Building name                      | Country     | City        | Height (meters) | # of storeys | Completion date | Function |
|-----|------------------------------------|-------------|-------------|----------------|--------------|-----------------|----------|
| 116 | Guangfa Securities Headquarters   | China       | Guangzhou   | 308            | 60           | 2018            | O        |
| 117 | The One                            | Canada      | Toronto     | 308            | 85           | UC              | R        |
| 118 | Burj Rafal                          | Saudi Arabia | Riyadh     | 307            | 68           | 2014            | M (H/R) |
| 119 | Amna Tower                          | UAE         | Dubai       | 307            | 75           | 2020            | R        |
| 120 | Noora Tower                         | UAE         | Dubai       | 307            | 75           | 2019            | R        |
| 121 | The Shard                           | UK          | London      | 306            | 73           | 2013            | M (H/R/ O)|
| 122 | Cayan Tower                          | UAE         | Dubai       | 306            | 73           | 2013            | R        |
| 123 | Northeast Asia Trade Tower          | South Korea | Incheon   | 305            | 68           | 2011            | M (H/R/ O)|
| 124 | 35 Hudson Yards                     | USA         | New York City | 304       | 72           | 2019            | M (H/R) |
| 125 | Baiyoke Tower II                    | Thailand    | Bangkok     | 304            | 85           | 1997            | H        |
| 126 | One Manhattan West                  | USA         | San Francisco | 303       | 67           | 2019            | O        |
| 127 | Two Prudential Plaza                | USA         | Chicago     | 303            | 64           | 1990            | O        |
| 128 | Jiangxi Nanchang Greenland Central Plaza, Parcel A | China | Nanchang | 303            | 59           | 2015            | O        |
| 129 | Jiangxi Nanchang Greenland Central Plaza, Parcel B | China | Nanchang | 303            | 59           | 2015            | O        |
| 130 | Leatop Plaza                        | China       | Guangzhou   | 303            | 64           | 2012            | O        |
| 131 | Capital City Moscow Tower           | Russia      | Moscow      | 301            | 76           | 2010            | R        |
| 132 | Kingdom Centre                      | Saudi Arabia | Riyadh    | 302            | 41           | 2002            | M (H/R/ O)|
| 133 | Supernova Spira                     | India       | Noida       | 300            | 80           | UC              | M (H/R) |
| 134 | Al Wafi Tower                       | UAE         | Dubai       | 300            | 64           | UC              | M (H/R/ O)|
| 135 | Shimao Riverside Block D2b          | China       | Wuhan       | 300            | 53           | UC              | M (H/O) |
| 136 | Aspire Tower                        | Qatar       | Doha        | 300            | 36           | 2007            | M (H/O) |
| 137 | NBK Tower                           | Kuwait      | Kuwait City | 300            | 61           | 2019            | O        |
| 138 | Golden Eagle Tiandi Tower C         | China       | Nanjing     | 300            | 60           | 2019            | O        |

**Note(s):** “M” indicates mixed-use; “H” indicates hotel use; “R” indicates residential use; “O” indicates office use; “UAE” indicates the United Arab Emirates; “UC” indicates under construction; “NC” indicates never completed; “OH” indicates on hold.

Table A1.
## Appendix 2

### Table A2
Supertall buildings by core type, building form, structural system and structural material

| #  | Building name                  | Core type | Building form | Structural system                           | Structural material |
|----|--------------------------------|-----------|---------------|---------------------------------------------|---------------------|
| 1  | Nakheel Tower                  | Central   | Free          | Mega column                                 | Composite           |
| 2  | Burj Khalifa                   | Central   | Setback       | Buttressed core                             | RC                  |
| 3  | Suzhou Zhongnan Center          | Central   | Tapered       | Outrigged frame                             | Composite           |
| 4  | Merdeka PNB118                  | Central   | Free          | Outrigged frame                             | Composite           |
| 5  | Shanghai Tower                  | Central   | Twisted       | Outrigged frame                             | Composite           |
| 6  | Chicago Spire                   | Central   | Twisted       | Outrigged frame                             | RC                  |
| 7  | Makkah Royal Clock Tower        | Central   | Prismatic     | Outrigged frame                             | Composite           |
| 8  | Ping an Finance Center          | Central   | Tapered       | Outrigged frame                             | Composite           |
| 9  | Goldin Finance 117              | Central   | Tapered       | Trussed-tube                                | Composite           |
|10  | Entisar Tower                   | Central   | Setback       | Framed-tube                                 | RC                  |
|11  | LoTe World Tower                | Central   | Tapered       | Outrigged frame                             | Composite           |
|12  | One World Trade Center          | Central   | Tapered       | Outrigged frame                             | Composite           |
|13  | Guangzhou CTF Finance Centre    | Central   | Setback       | Outrigged frame                             | Composite           |
|14  | Tianjin CTF Finance Centre      | Central   | Tapered       | Framed-tube                                 | Composite           |
|15  | CITIC Tower                     | Central   | Free          | Trussed-tube                                | Composite           |
|16  | Evergrande Hefei Center 1       | Central   | Free          | Outrigged frame                             | Composite           |
|17  | Pentominium Hefei Tower          | Central   | Free          | Outrigged frame                             | RC                  |
|18  | Busan LoTe Town Tower           | Central   | Free          | Outrigged frame                             | Composite           |
|19  | TAIPEI 101                      | Central   | Free          | Outrigged frame                             | Composite           |
|20  | Greenland Jinmao International Financial Center | Central   | Tapered       | Outrigged frame                             | Composite           |
|21  | Shanghai World Financial Center  | Central   | Tapered       | Outrigged frame                             | Composite           |
|22  | International Commerce Centre   | Central   | Tapered       | Outrigged frame                             | Composite           |
|23  | Wuhan Greenland Center          | Central   | Tapered       | Buttressed core                             | Composite           |
|24  | Central Park Tower              | Central   | Setback       | Outrigged frame                             | RC                  |
|25  | Chengdu Greenland Tower         | Central   | Tapered       | Outrigged frame                             | Composite           |
|26  | R&F Guangdong building          | Central   | Setback       | Outrigged frame                             | Composite           |
|27  | Lakhta Center                   | Central   | Twisted       | Outrigged frame                             | Composite           |
|28  | Vincom Landmark 81              | Central   | Setback       | Bundled-tube                                | Composite           |

(continued)
| #  | Building name                                | Core type | Building form | Structural system     | Structural material |
|----|---------------------------------------------|-----------|---------------|-----------------------|---------------------|
| 29 | Changsha IFS Tower T1                       | Central   | Prismatic     | Outtriggered frame    | Composite           |
| 30 | Petronas Twin Tower 1                       | Central   | Setback       | Outtriggered frame    | RC                  |
| 31 | Petronas Twin Tower 2                       | Central   | Setback       | Outtriggered frame    | RC                  |
| 32 | Zifeng Tower                                | Central   | Free          | Outtriggered frame    | Composite           |
| 33 | The Exchange 106                            | Central   | Tapered       | Outtriggered frame    | Composite           |
| 34 | Marina 106                                  | Central   | Prismatic     | Framed-tube frame     | RC                  |
| 35 | World one                                   | Central   | Setback       | Buttressed core       | RC                  |
| 36 | KK 100                                      | Central   | Free          | Framed-tube core      | Composite           |
| 37 | Guangzhou International Finance Center      | Central   | Tapered       | Outtriggered frame    | Composite           |
| 38 | Multifunctional Highrise Complex – Akmat Tower | Central   | Tapered       | Framed-tube frame     | Steel               |
| 39 | 111 West 57th Street                        | Peripheral| Setback       | Outtriggered frame    | RC                  |
| 40 | Chongqing Tall Tower                        | Central   | Tapered       | Outtriggered frame    | Composite           |
| 41 | Haikou Tower 1                              | Central   | Tapered       | Outtriggered frame    | Composite           |
| 42 | One Vanderbilt Avenue                       | Central   | Tapered       | Outtriggered frame    | Composite           |
| 43 | Marina 101                                  | Central   | Prismatic     | Framed-tube frame     | RC                  |
| 44 | 432 Park Avenue                             | Central   | Prismatic     | Framed-tube frame     | RC                  |
| 45 | Trump International Hotel and Tower         | Central   | Setback       | Outtriggered frame    | RC                  |
| 46 | Al Hamra Tower                              | Central   | Free          | Shear walled frame    | Composite           |
| 47 | Princess Tower                              | Central   | Prismatic     | Framed-tube frame     | RC                  |
| 48 | Two International Finance Center            | Central   | Setback       | Outtriggered frame    | Composite           |
| 49 | LCT The Sharp Landmark Tower                | Central   | Prismatic     | Outtriggered frame    | RC                  |
| 50 | Guangxi China Resources Tower               | Central   | Tapered       | Outtriggered frame    | Composite           |
| 51 | China Resources Tower                       | Central   | Tapered       | Framed-tube core      | Composite           |
| 52 | 23 Marina                                   | Central   | Prismatic     | Outtriggered frame    | RC                  |
| 53 | CITIC Plaza                                 | Central   | Prismatic     | Shear walled frame    | RC                  |
| 54 | Dynamic Tower                               | Central   | Free          | Mega core frame       | RC                  |
| 55 | Shum Yip Upperhills Tower 1                 | Central   | Prismatic     | Outtriggered frame    | Composite           |
| 56 | 30 Hudson Yards                             | Central   | Tapered       | Outtriggered frame    | Steel               |
| 57 | PIF Tower                                   | Central   | Free          | Trussed tube frame     | Composite           |
| 58 | Shun Hing Square                            | Central   | Free          | Outtriggered frame    | Composite           |
| 59 | Autograph Tower                             | Central   | Prismatic     | Outtriggered frame    | Composite           |

Table A2. (continued)
| #   | Building name                                      | Core type            | Building form | Structural system                  | Structural material |
|-----|---------------------------------------------------|----------------------|---------------|------------------------------------|---------------------|
| 60  | Burj Mohammed Bin Rashid                          | Central              | Free          | Outriggared frame                  | RC                  |
| 61  | Guiyang World Trade Center Landmark Tower         | Central              | Tapered       | Framed-tube                         | Composite           |
| 62  | Elite Residence                                   | Central              | Prismatic     | Framed-tube                         | RC                  |
| 63  | Central Plaza                                     | Central              | Prismatic     | Trussed-tube                        | Composite           |
| 64  | Federation Tower                                   | Central              | Free          | Outriggared frame                  | Composite           |
| 65  | Golden Eagle Tiandi Tower A                       | Central              | Tapered       | Outriggared frame                  | Composite           |
| 66  | Bank of China Tower                                | Central              | Setback       | Trussed-tube                        | Composite           |
| 67  | St. Regis Chicago                                 | Central              | Free          | Outriggared frame                  | RC                  |
| 68  | Almas Tower                                       | Central              | Free          | Outriggared frame                  | Composite           |
| 69  | Hanking Center Tower                              | External             | Tapered       | Trussed-tube                        | Steel               |
| 70  | Greenland Group Suzhou Center                     | Central              | Free          | Outriggared frame                  | Composite           |
| 71  | Sino Steel International Plaza T2                 | Central              | Prismatic     | Framed-tube                         | Composite           |
| 72  | II Primo Tower 1                                  | Central              | Prismatic     | Outriggared frame                  | RC                  |
| 73  | Emirates Tower One                                | Central              | Prismatic     | Mega column                         | Composite           |
| 74  | OKO-Residential Tower                             | Central              | Free          | Outriggared frame                  | RC                  |
| 75  | Raffles City Chongqing T4N                        | Central              | Tapered       | Outriggared frame                  | Composite           |
| 76  | The Torch                                         | Central              | Prismatic     | Outriggared frame                  | RC                  |
| 77  | Spring City 66                                    | Central              | Free          | Outriggared frame                  | Composite           |
| 78  | The Center                                        | Central              | Prismatic     | Mega column                         | Composite           |
| 79  | NEVA TOWERS 2                                     | Central              | Prismatic     | Outriggared frame                  | RC                  |
| 80  | ADNOC Headquarters                                | External             | Prismatic     | Shear walled frame                 | RC                  |
| 81  | One Shenzhen Bay Tower 7                          | Central              | Tapered       | Outriggared frame                  | Composite           |
| 82  | Comcast Technology Center                         | Central              | Setback       | Trussed-tube                        | Composite           |
| 83  | LCT The Sharp Residential Tower A                 | Central              | Prismatic     | Outriggared frame                  | RC                  |
| 84  | Mercury City Tower                                | Central              | Setback       | Framed-tube                         | RC                  |
| 85  | Hengqin International Finance Center              | Central              | Free          | Outriggared frame                  | Composite           |
| 86  | Tianjin World Financial Center                    | Central              | Tapered       | Outriggared frame                  | Composite           |
| 87  | Wilshire Grand Center                             | Central              | Tapered       | Outriggared frame                  | Composite           |
| 88  | DAMC Heights                                      | Central              | Tapered       | Outriggared frame                  | RC                  |
| 89  | Shimao International Plaza                        | Central              | Free          | Mega column                         | Composite           |
| 90  | LCT The Sharp Residential Tower B                 | Central              | Prismatic     | Outriggared frame                  | RC                  |

(continued)
| #  | Building name                  | Core type | Building form | Structural system        | Structural material |
|----|--------------------------------|-----------|---------------|--------------------------|---------------------|
| 91 | China World Tower             | Central   | Tapered       | Outriggered frame        | Composite           |
| 92 | Hon Kwok City Center          | Central   | Prismatic     | Outriggered frame        | Composite           |
| 93 | 3 World Trade Center          | Central   | Setback       | Trussed-tube frame       | Composite           |
| 94 | Keangnam Hanoi Landmark Tower | Central   | Setback       | Outriggered frame        | RC                  |
| 95 | Golden Eagle Tiandi Tower B   | Central   | Tapered       | Outriggered frame        | Composite           |
| 96 | Salesforce Tower              | Central   | Tapered       | Shear walled frame       | Composite           |
| 97 | Deji Plaza                    | Central   | Prismatic     | Outriggered frame        | Composite           |
| 98 | Q1 Tower                      | Central   | Prismatic     | Outriggered frame        | RC                  |
| 99 | Burj Al Arab                  | Central   | Free          | Shear walled frame       | Composite           |
|100 | Nina Tower                    | Central   | Prismatic     | Outriggered frame        | RC                  |
|101 | Sinar Mas Center 1            | Central   | Free          | Outriggered frame        | Composite           |
|102 | Palace Royale                 | Central   | Prismatic     | Outriggered frame        | RC                  |
|103 | 53 West 53                    | Peripheral| Tapered       | Framed-tube frame        | RC                  |
|104 | New York Times Tower          | Central   | Prismatic     | Outriggered frame        | Steel               |
|105 | Chongqing IFS T1              | Central   | Prismatic     | Outriggered frame        | Composite           |
|106 | Australia 108                 | Central   | Free          | Outriggered frame        | RC                  |
|107 | Mahanakhon                    | Central   | Prismatic     | Outriggered frame        | RC                  |
|108 | CITIC Financial Center Tower 1| Central   | Tapered       | Framed-tube frame        | Composite           |
|109 | Bank of America Plaza         | Central   | Setback       | Mega column              | Composite           |
|110 | Shenzhen Bay Innovation and   | Central   | Prismatic     | Framed-tube frame        | Composite           |
|   | Technology Centre Tower 1     |           |               |                          |                     |
|111 | Menara TM                     | Central   | Free          | Outriggered frame        | RC                  |
|112 | Ocean Heights                 | Central   | Tapered       | Outriggered frame        | RC                  |
|113 | Pearl River Tower             | Central   | Free          | Outriggered frame        | Composite           |
|114 | Fortune Center                | Central   | Free          | Outriggered frame        | Composite           |
|115 | Emirates Tower Two            | Atrium    | Prismatic     | Outriggered frame        | RC                  |
|116 | Guangfa Securities Headquarters| Central   | Tapered       | Outriggered frame        | Composite           |
|117 | The One                       | Central   | Prismatic     | Outriggered frame        | Composite           |
|118 | Burj Rafal                    | Central   | Prismatic     | Outriggered frame        | Composite           |

Table A2. (continued)
| #  | Building name                                      | Core type   | Building form | Structural system       | Structural material |
|----|---------------------------------------------------|-------------|---------------|-------------------------|---------------------|
| 119| Amna Tower                                        | Central     | Prismatic     | Outrigged frame         | RC                  |
| 120| Noora Tower                                       | Central     | Prismatic     | Outrigged frame         | RC                  |
| 121| The Shard                                         | Central     | Tapered       | Shear walled frame      | Composite           |
| 122| Cayan Tower                                       | Central     | Twisted       | Framed-tube frame       | RC                  |
| 123| Northeast Asia Trade Tower                        | Central     | Tapered       | Outrigged frame         | Composite           |
| 124| 35 Hudson Yards                                   | Central     | Setback       | Outrigged frame         | RC                  |
| 125| Baiyoke Tower II                                  | Central     | Setback       | Outrigged frame         | RC                  |
| 126| One ManhaTan West                                 | Central     | Tapered       | Shear walled frame      | Composite           |
| 127| Two Prudential Plaza                              | Central     | Setback       | Outrigged frame         | RC                  |
| 128| Jiangxi Nanchang Greenland Central Plaza, Parcel A| Central     | Free          | Outrigged frame         | Composite           |
| 129| Jiangxi Nanchang Greenland Central Plaza, Parcel B| Central     | Free          | Outrigged frame         | Composite           |
| 130| Leatop Plaza                                      | Central     | Prismatic     | Trussed-tube frame      | Composite           |
| 131| Kingdom Centre                                    | Central     | Free          | Shear walled frame      | RC                  |
| 132| Capital City Moscow Tower                         | Central     | Free          | Outrigged frame         | RC                  |
| 133| Supernova Spira                                   | Central     | Prismatic     | Outrigged frame         | RC                  |
| 134| Al Wasl Tower                                     | Central     | Free          | Outrigged frame         | Composite           |
| 135| Torre Costanera                                   | Central     | Tapered       | Outrigged frame         | RC                  |
| 136| Abeno Harukas                                     | Central     | Setback       | Outrigged frame         | Composite           |
| 137| Shimao Riverside Block D2b                        | Central     | Tapered       | Outrigged frame         | Composite           |
| 138| Aspire Tower                                      | Central     | Free          | Mega core               | RC                  |
| 139| NBK Tower                                         | Central     | Free          | Outrigged frame         | Composite           |
| 140| Golden Eagle Tiandi Tower C                        | Central     | Tapered       | Outrigged frame         | Composite           |

**Note(s):** “RC” indicates reinforced concrete

Table A2.