



## Elegant Structures: Diagrids take to the Sky

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Terri Meyer Boake, born 1957, teaches and researches in the area of construction, environment and steel design. She has published three important books with Birkhäuser on architectural steel design, diagrids and AESS. She works with the Canadian Institute of Steel Construction to develop learning modules. She is an active board member of the Council on Tall Buildings and Urban Habitat.

### Summary

The word “diagrid” is a blending of the words “diagonal” and “grid” and refers to a structural system that is single thickness in nature and gains its structural integrity through triangulation. Diagrid structural systems have enabled significant transformation in the design of tall buildings. Diagrids are unique in their ability to assume all of the lateral and gravity loading of towers up to at least 50 storeys in height, eliminating the need for traditional columns and cores. Even in Supertall towers it is possible to reduce or eliminate dependence on the core in the top 15% to 30%, allowing for unique spatial opportunities.

Diagrids have created a particular elegance and lightness through efficiency, geometry and form. Where other contemporary structural systems such as megaframes and outriggers are typically repressed in the detailing of the façade and dependent building elements, diagrids are chosen to form the basis of the architectural expression of the building.

The author presents a methodology for the design of diagrid structures based upon the systematic analysis of major buildings constructed from 2004 to the present as documented in her recent book “Diagrid Structures: Systems, Connections, Details” published by Birkhäuser in 2014. The design of diagrid towers will be demonstrated as based upon primary choices in module size, member type, node design, function of the core and the desired expression in the façade system. These translate into additional concerns of constructability and customized fabrication. Fire control systems will impact the ability to architecturally expose or conceal the steel, leading to detailing decisions.

**Keywords:** diagrid; steel; skyscraper; high-rise buildings.

### 1. Introduction

Although the invention of the diagrid system is credited to Vladimir Shukhov (1853-1939) and was used extensively as the support system for hundreds of water towers towards the end of the 1800s, it was really not until the offices of Foster + Partners with Arup re-interpreted the Shukhov system to create the structural system that was suited to a building. This was done for the Swiss Re Tower in London, UK in 2004 where the diagrid system emerged as a contemporary structural methodology. Major structural changes were required to transform the open lattice system that Shukhov had used for his water towers into one capable of supporting floors and cladding systems.

This paper will examine a number of recently constructed diagrid towers to identify a methodology that can be used to approach the detailed design of this new building type. The aesthetic expression of the structure in the architecture, its form and façade requires a better appreciation of the impact of decisions made when conceiving of the building. This includes setting out the overall module, deciding on the precise type of structural elements, designing the nodes and understanding the implications on the façade and fire protection strategies.

The methodology is intended to be applied during the design phase of the project, to be followed by detailed calculations to substantiate decisions in the sizing and particular nature of the members, nodes and floor systems.



## 2. What is a Diagrid?

### 2.1 Definition

The word “diagrid” is a blending of the words “diagonal” and “grid” and refers to a structural system that is single thickness in nature and gains its structural integrity through triangulation. Diagrid structural systems have enabled significant transformation in the design of tall buildings. Diagrids are unique in their ability to assume all of the lateral and gravity loading of towers up to at least 50 storeys in height, eliminating the need for traditional columns and cores. Even in Supertall towers it is possible to reduce or eliminate dependence on the reinforced concrete core in the top 15% to 30%, allowing for unique spatial opportunities.

### 2.2 The Diagrid System

The contemporary diagrid system that is used to structure tower type buildings is comprised of a system of *linear elements* that are connected at *nodes* that are spaced on a predetermined *module*. Although this references the work of Shukhov, the invention of the node is a critical improvement and defining characteristic of the system.



Fig. 6: The Poly Diamond Lantern employs a shallow angle to the diagrid.

## 3. Member, Node and Core Design

Understanding that the size of the module will feed directly into the structural requirements and sizing of the diagrid system, including members and nodes, there are additional factors that will also bear on this decision. The type of member chosen will depend on additional interdependent factors:

- What is the fire protection required for the structure?
- Is/can the structure to be architecturally exposed?
- Will standard structural members suffice (wide flange or HSS most typically chosen)?
- Are custom fabricated sections desired for aesthetic reasons?
- Is there a desire or requirement to cover the structure, noting this can be program directed as a function of interior décor and not fireproofing.
- Are there preferences or differences in expertise based on the skills and practices in the region that will inform or limit the member selection? This feeds into abilities in welding or safety preferences for bolting.

The form of the building will create nodal geometries that will be better served by circular versus rectangular members.

## 4. New Potential Going Forward

As a structural system that can not only provide structure for tall towers, it is showing its capabilities at adapting to a wide range of building shapes and geometries, from curves to faceted crystalline shapes. The applications are indeed quite elegant and this can be quite directly attributed to the aesthetic potential of the diagrid in its form giving qualities that can also be translated through to the design of the façade.