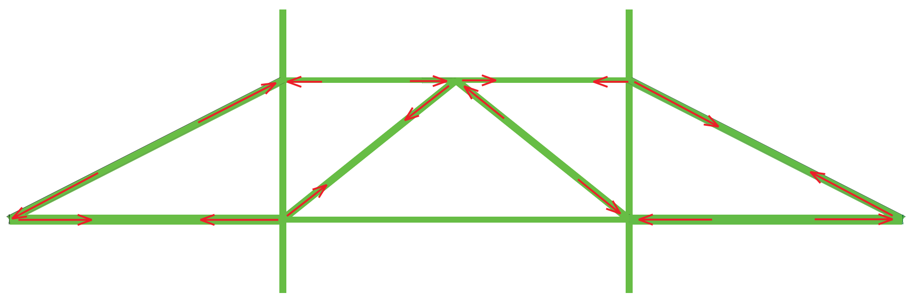
4. 1. 3 伸臂桁架与腰桁架 Outrigger and Belt Truss

风和地震引起的倾覆力矩单独由41层以上的核心筒来抵抗，然后通过伸臂桁架转移到外周边的腰桁架和钢柱体系。该体系是非常高效的。它可最大程度地抵抗侧向荷载、减小剪力滞后效应、提高加强层整体刚度、同时让所有竖向构件来承载重力和横向力。

Overturning moment in the system due to wind and seismic loading is resisted by the core alone above level 41 but then in transferred out to the outer columns uniformly through the steel truss system. The system is efficient in that it maximizes the footprint of the structure used to resist lateral loads, decreases shear lagging effects, and increases stiffness at strengthened levels while engaging all the vertical load carrying elements in the gravity and lateral system.

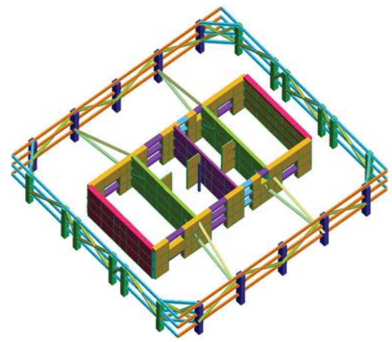
伸臂桁架的大量内力在水平荷载作用下传递大量平面剪力至核心筒墙体。结构钢构件预埋入核心筒墙体中以帮助抵抗这些平面剪力。右图说明在重力和横向荷载的作用下，伸臂桁架和平面板的载荷路径。加强层的楼板的假设为弹性模（非刚性板），在伸臂桁架的内力计算中不考虑楼板效果。

The large forces in the outriggers under lateral loading induce large panel zone shear forces into the core walls. Structural steel members are embedded in the core walls to assist in resisting these panel zone shears. The figures on the right illustrate the outrigger and panel zone load paths under gravity and lateral loading. At outrigger level, the floor stiffness is assumed to be elastic (not rigid). The force at the outrigger diagonal is calculated with no slab contribution.



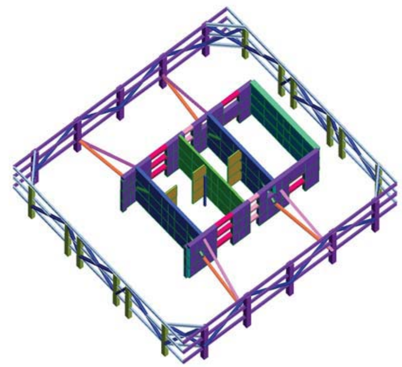
水平力流程
Lateral Load Flow

图 4. 1. 3-1
Fig. 4.1.3-2



下部设备层伸臂和腰桁架
UBB Outriggers and Belt Truss at Lower Mechanical Level

图 4. 1. 3-2
Fig. 4.1.3-2



上部设备层伸臂和腰桁架
UBB Outriggers and Belt Truss at Upper Mechanical Level

图 4. 1. 3-3
Fig. 4.1.3-3

屈曲约束支撑 Buckling Restrained Braces

采用屈曲约束支撑作为加强层的伸臂桁架，可为整体结构提供额外的阻尼能耗作用，减轻罕遇地震作用下主体结构，特别是加强层附近的楼层受到破坏的程度，改善结构的抗震性能。

By applying UBB as outriggers at strengthened levels, supplemental damping is provided to dissipate additional energy. Thus reduces structural response under rare earthquake. More specifically, it enhances the structural seismic performance and reduces damages around strengthened levels.

屈曲约束支撑的原理，即在核心支撑的外面套一个约束构件，使核心支撑在受压的情况下不发生失稳和屈曲，而仅使芯材达到屈服状态，通过芯材的往复拉压变形耗散地震能量。在钢-砼组合框架中采用该支撑时，可以增加刚度，提高抗震能力。下图阐述了屈曲约束支撑的构成原理。

The principle of UBB is to case the diagonal core with a confining sleeve, which prevent buckling of core under compression. In contrast, the core will only yield similar to it is in tension, so the reciprocating T-C behavior will dissipate more energy from the structure comparing to a conventional outrigger. By applying this type of brace, it increases the lateral stiffness of structure and improves the behavior in resisting seismic loads. Figure below indicates the configuration of the UBB.

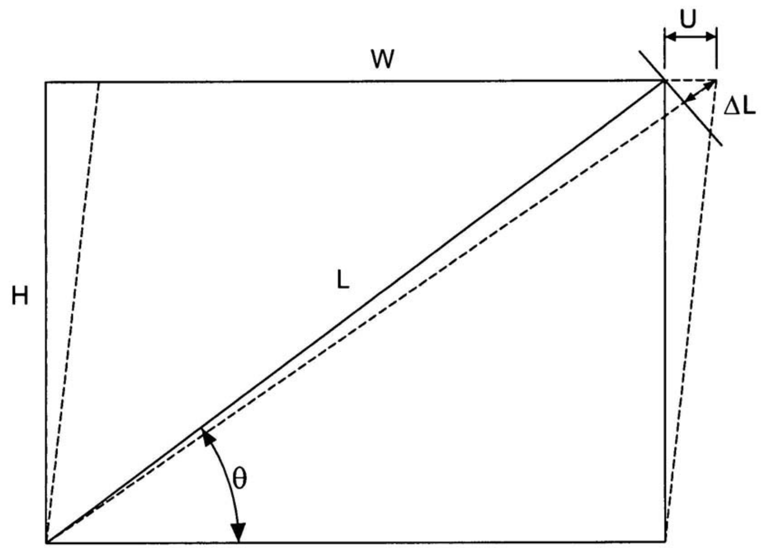


图 4.1.3-4 屈曲约束支撑位移图解
Fig. 4.1.3-4 UBB Deflection Illustration

在纵向构造上，如下图所示，UBB由(1)无约束非屈服段、(2)约束非屈服段、(3)带无粘结涂层和屈曲约束机构的约束屈服段组成。约束屈服段在反复荷载下屈服，是主要耗能部位；约束非屈服段在套管和砂浆内，是约束屈服段的延伸部分，作为过渡；无约束非屈服段是支撑与框架连接的部分，通常采用螺栓连接或焊接；无粘结材料可有效确保芯材上的轴力不传递至砂浆和套管上；屈曲约束机构主要有砂浆和中空套管组成，用以共同防止支撑的屈曲。

The UBB length-wise consists of defined sections which are (1) an unrestrained non-yielding segment (UNS), (2) a restrained non-yielding segment (RNS), and (3) a restrained yielding segment (RYS) with debonding material and restraining element. The RYS yields under hysteretic loading which dissipates the majority of energy. The RNS the portion of the brace is a transitional extension between UNS and RYS. The UNS portion of the brace is to connect UBB element to the perimeter frame with bolted or welded connections. The debonding material is to ensure the axial force from core will not be transferred to the steel tube. The restraining element consists of a steel tube and mortar, which in combination is to prevent the core from buckling.

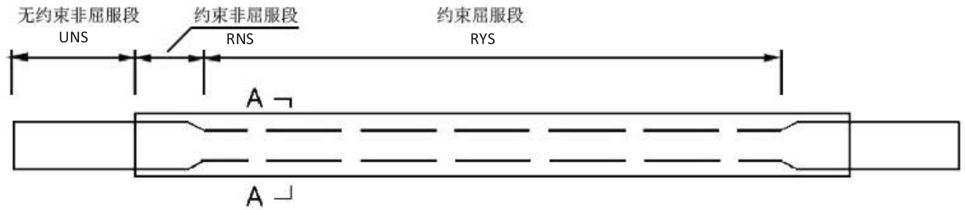


图 4.1.3-5 屈曲约束支撑纵向构成示意图
Fig. 4.1.3-5 UBB Longitudinal Configuration

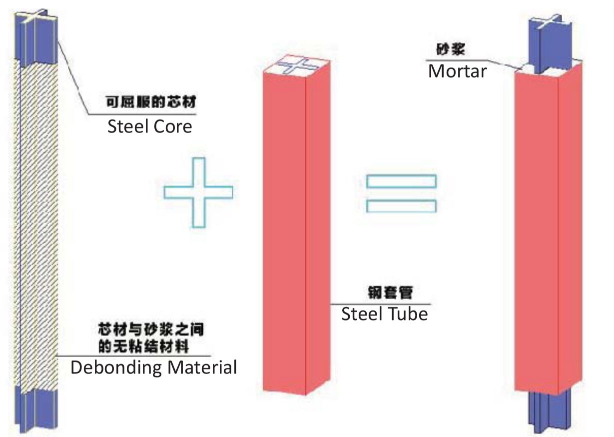


图 4.1.3-6 屈曲约束支撑典型构成
Fig. 4.1.3-6 Typical UBB Components

三星中国总部大楼采用的屈曲约束支撑参数如下表：

The table below indicates the proposed UBB design parameters for Samsung China Headquarters Building.

型号 Model	内芯等效面积 Core Area	有效刚度 Effective Stiffness	屈服承载力 Yielding Capacity	构件长度 Member Length
JY-SD-20000	0.0504 m^2	715,355 kN/m	20,000 kN	15.5m

与普通钢支撑相比，屈曲约束支撑主要的优点在于：

1).承载能力高，且拉压对称不屈曲；容许变形大，在大震下依然可以提供可靠支撑；设计时不用考虑长细比限值；设计简单，安装方便；在结构中充当“保险丝”的作用。

2).当屈曲约束支撑屈服以后，进入塑性阶段，从而消耗地震作用下的能量，为结构提供附加阻尼。下图阐述了屈曲约束支撑和普通支撑结的在拉压情况下的性能对比。

Comparing to conventional steel braces, the advantages of UBB are:

1). The stress-strain relationship is symmetrical under tension and compression. It allows for larger deformation limit due to its unbuckled behavior which provides for reliable bracing even under rare earthquake. Slenderness limit is unnecessary for this type of bracing system, so it simplifies design work and installation.

2). After yielding, the diagonal will get into plastic behavior, which dissipates energy under earthquake and provides supplemental damping to the structure.

The figure below contrasts a typical stress-strain curve between a UBB and a conventional brace.

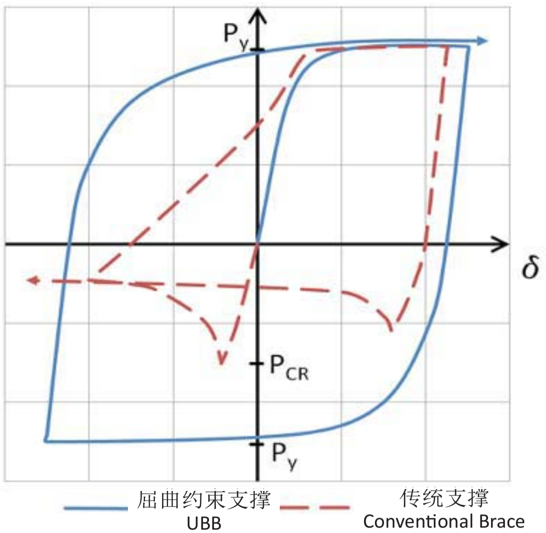


图 4.1.3-7　屈曲约束支撑与普通支撑性能对比
Fig. 4.1.3-7　Performance Comparison between UBB and Conventional Brace

4.1.4　抗震设计等级 Seismic Design Grade

地面以上和地下一层的剪力墙、钢骨混凝土柱、UBB连接杆件、框架梁和连梁为特一级，其余部位为一级。

Shear wall, SRC column, UBB connecting diagonal member, framed beam and link beam of all floors above ground and one floor below ground are classified as Special Grade-1. The elements at other basement levels are classified as Grade-1.

4.1.5　塔楼嵌固 Tower Support

塔楼的水平支撑位于1层除了在底层基础上的嵌固之外。结构计算满足高规（JGJ3-2010）的相关要求，包括第5.3.7节规定的横向刚度要求。楼层侧向刚度比按第3.5.2条第二款公式计算，γ_2=5.99（X向)及γ_2=3.06（Y向)。

The tower is considered to be supported against lateral loads at level 1 in addition to the foundation. The associated requirements from the Concrete Tall Building Code (JGJ3-2010) have been met, including lateral stiffness requirement of section 5.3.7. Based on section 3.5.2-2, γ_2=5.99 in X direction and 3.06 in Y direction in consideration of the adjacent basement walls.