STEEL STRUCTURES FOR ARCHITECTURE IN JAPAN AND ASIA

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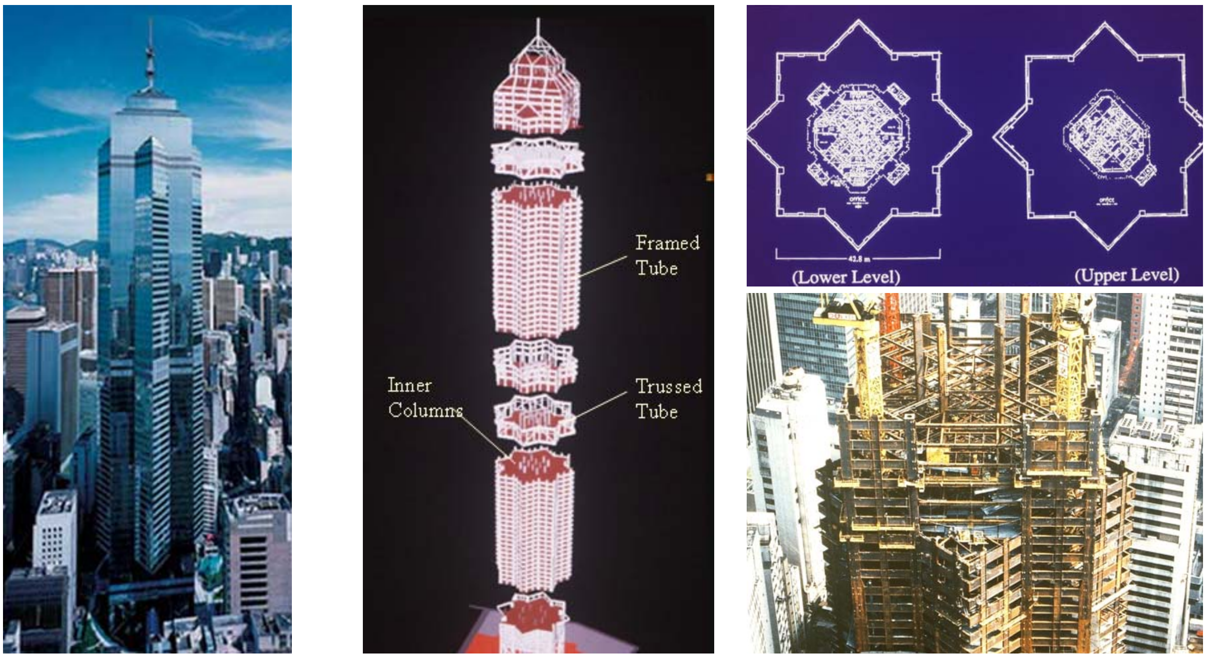
ABSTRACT

According to the development of new concepts of steel materials and members, various applications of steel structures in the field of architecture have been developed in these 20 years in Japan and Asian countries. In this talk, the author discuss on the detailed examples of such recent trends in structural designs.

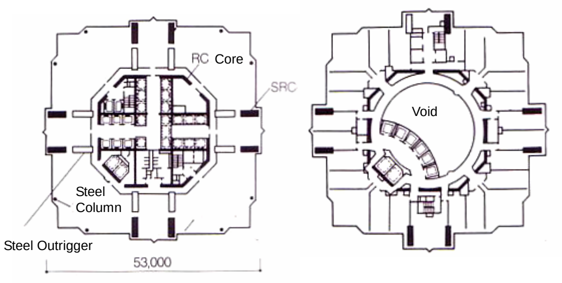
1. STELL STRUCTURES FOR HIGH-RISES

Many countries in Asia including Japan have severe conditions for designing skyscrapers, because of high intensity of earthquake and Typhoon. For achieving economical design against these horizontal loads, the effective structural system providing the horizontal stiffness needs to be provided. Traditional approaches for the structural system in United States in 19th century used various steel structural system as braced frames or tube frames. The structural rationality has been also emphasized, and they have employed simple shapes. However, recent approaches taken place in Asia and Japan is slightly different, and their trend can be expressed as “Diverse requirement for the shape” and “Composite structure”. Fig.1 is “The Center” completed in Hong Kong in 1998, whose height is 350 m including the top mast. Design of this skyscraper emphasizes the traditional Chinese practice of luck “Feng Shui”, which is affect on the rental price of the floor itself. They have a star-shaped symmetry plan with eight corners, with 80-stories, and diagonal braces are carefully avoided. To achieve

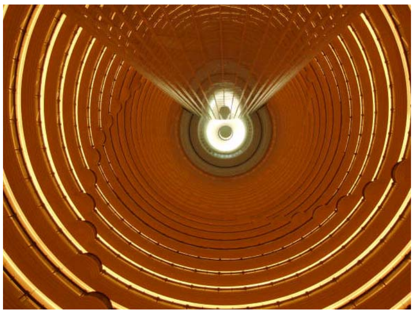


(a) Appearance (b) Structural System (c) Plan and Construction

Fig.1 The Center / Hong Kong



Plan of Lower Office Plan of Upper Hotel



(a) Appearance of the Buildings (b) Plan and Interior / Jin-Mao Bld.

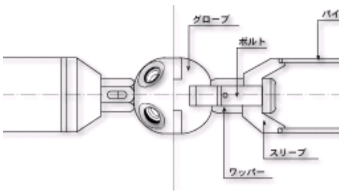
Fig.2 World Financial Ctr. & Jin-Mao Building / Shanghai

Fig.3 Spiral Tower

economical structure for such limited condition, star-shaped framed-tube system with concrete in-filled steel tube column was introduced (Fig.1(c)). In Shanghai, Two skyscrapers over 400m have been constructed (Fig.2(a)). They employ the composite structural system with concrete core walls with steel frames around them. This system is effective to achieve both of the horizontal stiffness and clear space for interior. Jin-Mao building (Fig.2(b)) achieves dramatic interior using the inside space of the core-walls. Free-shaped skyscrapers are also constructed in various cases. Fig 3 is “The Spiral Tower” recently completed in Nagoya, Japan. This building is used for the school of art.

2. STEEL STRUCTURES FOR LONG SPANS

Long-span structures are the fields where the steel materials are mostly appeal its merits of lightness. Traditional approach is truss system, which organizes the steel pipes with triangular units, and systematic joint systems have been developed as in Fig.4. The recent trend can be “Ecological” and again “Free-Shape”. Fig.5 is the “Beans Dome” recently completed in Hyogo, Japan, which covers three tennis courts with planted roof with very light artificial ground. Fig.6 is the national swimming pool gymnasium for Beijing Olympic. They have a space frame of free-formed hexagon layout accommodate with its “Bubble” façade, however fully welded joints are required because of the structures are not composed of triangular units (Fig.6(b)). The main stadium for Beijing Olympic called “Birds Nest” also employs the free-formed structure, however, the traditional truss frames are introduced inside the structure to resolve the structural irrationality (Fig.7). The development of computer-aided shape-creating techniques supports such designs, however, development of systematic joint system for



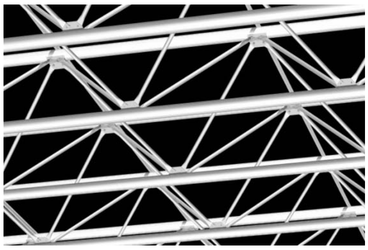


Fig.4 System Truss

Fig.5 Beans Dome / Hyogo

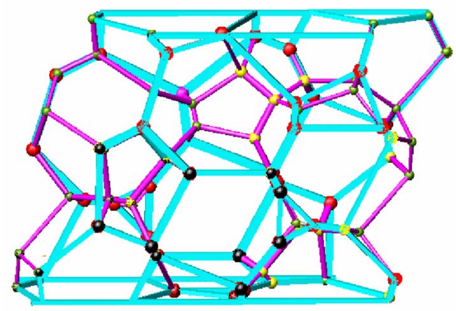


Fig.6 National Swimming Pool Gymnasium / Beijing

Fig.7 National Swimming Pool Gymnasium / Beijing

such free-form structures are desired for practical constructions.

3. STEEL STRUCTURES FOR ELEGANT

Glass skins with steel supporting structures are often used for the entrance hall or atriums of building complexes, and various sash-less grazing systems obtaining high transparency has been developed in these years. Also membrane structures with steel supports are expanding the design fields of light-weight structures. Fig.8 is an early example (completed in 1992 in

Tokyo) of glass boxes supported by high-strength steel rod structures stabilized by pre-tension forces, Japan. The tension structures are one of the most rational structural systems for the steel material comparing to the bending members or compression members, because the section of the member can be fully counted for the strength and stiffness without buckling. For designing such structures, analyses considering geometrical non-linear characteristics are effective to minimize the structural member (Fig.9). With such consideration, structural design with lesser numbers of members are achieved, leads to quite transparent and beautiful structures. Fig.10 is another example of “Glass Service Tower” attached on an ancient palace in Madrid. Such structures are well accommodate with the traditional buildings, and often used for the extension of historical buildings.

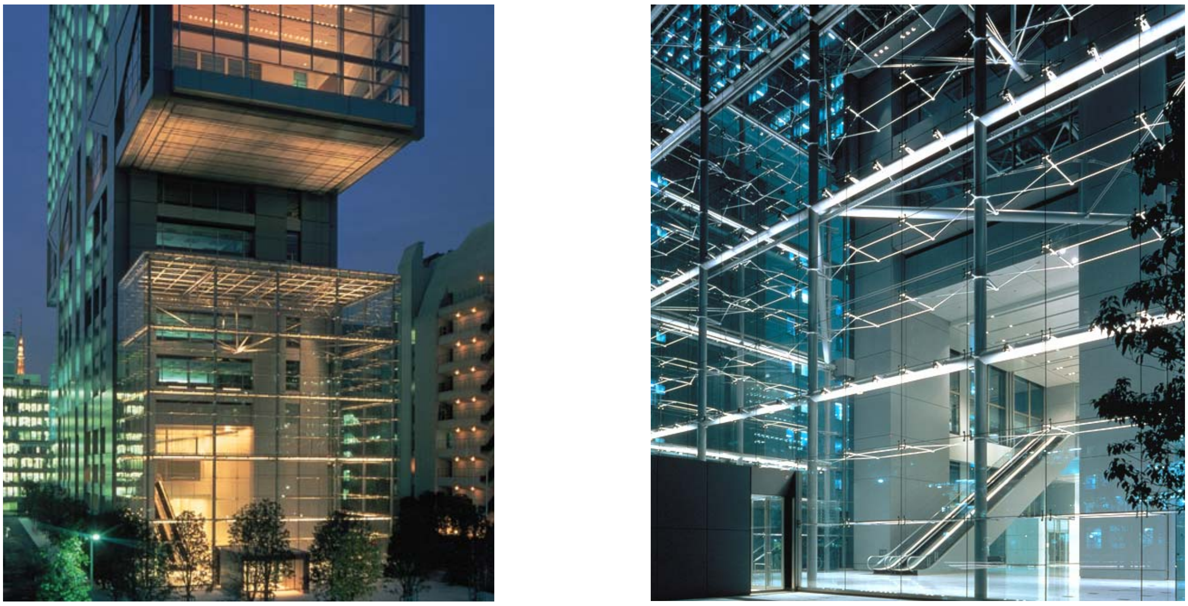


Fig.8 Shinsei Bank Building / Tokyo

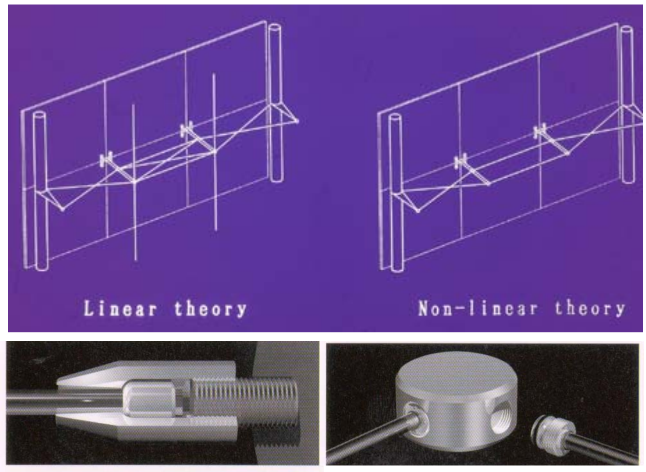


Fig.9 Analysis and Joint for Tension Structures

Fig.10 Glass service Tower / Madrid

4. STEEL STRUCTURES FOR HOUSING

Traditional structural system for housing in Japan has been wooden frames for thousands years. However, there are still disadvantages of weakness against earthquake and organizing

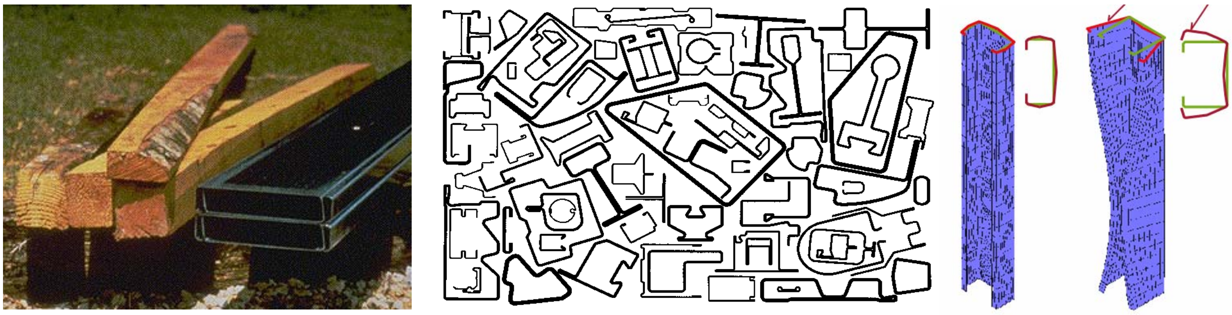


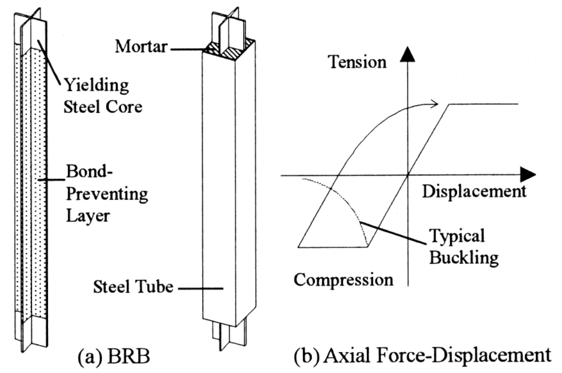
Fig.11 Lightweight Steel Sections

Fig.12 Lightweight Steel Sections

the large interior spaces. On contrary, steel frames have difficulty for site-arrangement by carpenters. Recently housing systems with light-weight steel members are developed and taken into practice (Fig.11). These members can be nailed and cut on site, and composite structures with plywood boards and traditional housing frames can be easily organized (Fig.12). Fig. 11 shows the available member sections and structural system for this “Steel House”. Each member is galvanized in plant, and it is proofed that the corrosion is not expanded even cut or nailed on site. To avoid heat-bridge from outer environments, effective thermal system with outer insulation finishing is also introduced into exterior walls. For designing the light-weight steel sections, various kinds of buckling phenomena become critical as shown in Fig.11. Various analyses and experiments for the effective and economical sections are investigated.

5. STEEL STRUCTURES FOR SAFETY

As aforementioned, many Asian countries including Japan is placed in high-seismic and typhoon zones, and passively vibration control techniques mitigating such disaster using low-yield strength steel dampers have been remarkably developed in these 20 years. One of the most popular elements is “Buckling Restrained Braces (BRB)”, which comprise a steel core plate restrained by a concrete in-filled tube (Fig.13). Developed for practice in the 1980’s in Japan, BRBs have been employed in more than two hundred buildings as ductile bracing members or hysteretic dampers. Distributed in steel frames, these members dissipate the introduced seismic energy, and minimize the damages of main structures and building facilities (Fig.14). Special steel materials having low-strength yield points and high ductility has been developed for the core plates for dissipating the seismic energy effectively. Such devices are introduced to more than 90% of high-rise buildings design in recent Japan.



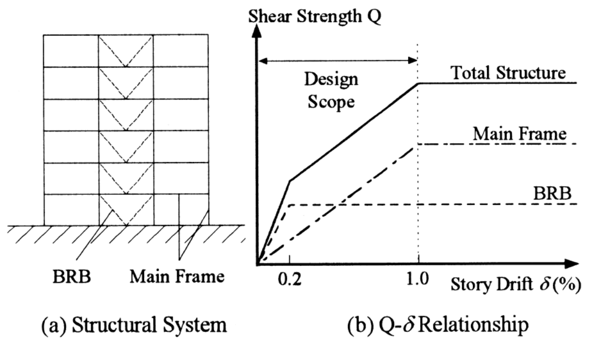


Fig.13 Buckling Retrained Brace

Fig.14 Damage Control Design Concept

Fig.15 Aged Building before Seismic Retrofit

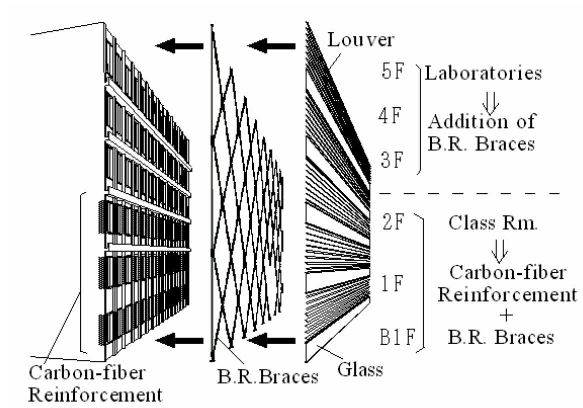


Fig.16 Retrofit Concept

Fig.17 Building Façade after the Retrofit

These techniques are applied for not only new-construction but also retrofit of aged buildings. Fig.15 is the aged building constructed in late 1960's, and found to have very high risks for collapsing in the event of large earthquakes. The BRBs were introduced to retrofit this aged building, designed as part of building façade, improving building appearances and thermal efficiency, not only structural improvements (Fig.16). Different from double-grazing concept in Europe, façade design using louver was investigated for adapting Japanese climates. Fig. 17 is a completed building appearance, which proves this retrofit is effective to renew the design of the building. Comparing the scrap-and build concept, it is estimated the saved production of CO_2 will be 2,000ton for the thermal effect of the façade and avoiding the disposal of concrete scraps. The key word for such design can be defined as integrated approach covers “Sophisticated design”, “Seismic performance”, and “Environmental improvements”.

6. CONCLUSIVE REMARKS

Recent examples of steel structures in Japan and Asian countries are introduced, and their trends are discussed. Different from other industrial products, design of architecture is quite individual depends on the purpose of the building and environment it places. Diverse design concept, hazard risk control, and reduction of environmental impact are generally observed as the key factors of the structural design in each category, and they are supported by individual technologies. The effort to apply such technologies to the condition of each country is expected.

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