FY2023
ENII01
26 Feb (Mon) AM

*<Lecture>*

# Overview of Steel Structures in the Japanese Construction Market

Mr. Masahiro NAGATA

*Ministry of Economy, Trade and Industry*

AOTS

The Association for Overseas Technical Cooperation and Sustainable Partnerships

# Overview of Steel Structures in the Japanese Construction Market

1. Problems in Developing Steel Structures

2. Economic Growth and Steel Market
   - 1-1. Economic Growth and Steel Consumption
   - 1-2. Steel Demand for Construction Market
   - 1-3. Steel Production in Major Countries

2. Advantages of Steel Structures
   - 2-1. Advantages of Steel Structures
   - 2-2. Structures Applied the Advantage of Steel

3. Historical Development of Steel Structures in Japan
   - 3-1. High Economic Growth from 1960s to 1970s
   - 3-2. Economic Bubble around 1990
   - 3-3. Post Bubble and Current Steel Construction Market

February 26, 2024

**Masahiro NAGATA**



# Answer to Questionnaire for Participants

## Results of Questionnaire to Participants

- Many of the opinions were right on target.
- First of my lecture, I would like to present them.
- Please practice "trainer's training".
- In other words, I would like the content of today's lecture to be shared within the office after the participants return to home, rather than being confined to one person.

# Problems and issues in adopting steel structures (1/6)

| Questionnaire | Answer |
|---|---|
| • Higher initial cost compared to conventional materials<br>• Lack of awareness of life cycle costs of steel and concrete structures | 1. Structural cost is about 30% (30% for housing complexes, 25% for office buildings, 20% for data centers), and interior/exterior, fixtures, and equipment work largely determine the overall construction cost<br>2. Invisible cost competitiveness (short construction period and early capital recovery, large effective area for rooms, high building asset value, easy post-construction remodeling such as reconstruction and change of use)<br>3. Life cycle costs of steel structures are lower than those of RC structures<br>4. Looking to the future, soaring labor costs will become an issue as a result of rapid economic growth. In contrast to RC construction, which is labor-intensive and requires rebar and formwork workers, demand for steel structures is expected to increase due to their short construction period, high production efficiency, and ability to utilize high-density land. |



# Problems and issues in adopting steel structures (2/6)

| Questionnaire | Answer |
|---|---|
| • Cultural resistance to using steel as a construction material<br>• Cultural and architectural preferences influence choice of materials for residential and commercial buildings<br>• Many examples in industrial facilities, but not adopted in general buildings, where the benefits of steel construction are not well known<br>• Powerful influence of the cement industry<br>• Familiarity with traditional RC construction and unwillingness to take risks with the new construction method of steel construction | 1. Steel frame construction allows for a variety of exterior design expressions, ranging from robust and massive expressions using concrete-based materials (Pre-cast and ALC) to simple and sharp expressions using metal-based panels.<br>2. Although the exterior of the National Diet Building is made of stone, it is a steel-frame structure using 9,800 tons of steel. Quality control from design to fabrication and construction, as well as maintenance that takes durability into consideration, enable the building to have a long service life.<br>3. Proposal of mixed structure such as RC columns and Steel beams to mitigate resistance for steel structure |

# Problems and issues in adopting steel structures (3/6)

| Questionnaire | Answer |
|---|---|
| • Limited understanding of steel use among architects, engineers, and general public<br>• Lack of knowledge among decision makers on building projects and academics<br>• Insufficient technical materials for engineers to learn and employ steel structures<br>• Insufficient opportunities for engineers to learn steel structures even after graduation<br>• Lack of design assistance guidebooks and software for Indian standards<br>• Detailed design of steel construction is more complicated than RC<br>• Design firms have engineers familiar with RC design, but only a few engineers are familiar with steel construction design, fabrication, and construction | 1. Seminars for the general public to explain the case studies, attractiveness, and benefits of steel structures in an easy-to-understand manner<br>2. Educational materials related to steel structures, visiting lectures, site tours<br>3. Publish detailed design manuals and guidebooks for roofs, walls, floors, etc.<br>4. Standard design of small and med-sized buildings (frame, joint, roof, wall, floor, etc.) , obtained technical evaluation<br>5. Distribution of magazines introducing steel structures (information on new technologies and projects, SCT&T etc.)<br>6. Awards for achievements in steel structures, including projects and researches |



# Problems and issues in adopting steel structures (4/6)

| Questionnaire | Answer |
|---|---|
| • Design standards need to be updated and harmonized with international standards<br>• Ensure consistent quality in steel production and construction processes<br>• Need skilled welding labor for proper construction of steel frames | 1. Construction standards and criteria, institutional design (building permit, technical evaluation system), engineer qualification and certification system of fabrication plants (CPD & renewal), human resource development and education programs<br>All of the above are important issues in the materials, design, manufacturing, and construction processes, and can be accomplished through collaboration among government, industry, academia, and the organizations leading the entire process. **(this afternoon, a Japanese case study will be explained in detail)** |

| | |
|---|---|
| • Limited financial support and incentives for steel construction projects<br>• Lack of life cycle assessment in public works & bidding projects<br>• Lack of adequate understanding of the long-term service life of infrastructure assets | 1. Data creation through industry collaboration<br>2. Lobbying from industry to government agencies (MLIT, METI, etc.) |

# Problems and issues in adopting steel structures (5/6)

| Questionnaire | Answer |
|---|---|
| • Corrosion is a serious problem in most parts of India due to high temperatures and the surrounding environment<br>• Expensive protection methods to prevent corrosion of steel structures and lack of knowledge about fire protection are obstacles to steel frame design | 1. Corrosion is a problem for civil structures, but buildings are covered by interior and exterior surfaces, and a general paint is sufficient for buildings<br>2. Overcoming weaknesses in steel construction. High-performance steel materials such as fire-resistant steel, weather-resistant steel, stainless steel (PR for additional benefits, reduced maintenance costs and improved construction environment) |
| • Lack of quality university faculty<br>• University curricula focus more on concrete compared to steel structures | 1. Research grants, scholarships, and other mechanisms in place<br>2. Establishment of academic associations related to steel structures, publication of technical information journals and collections of papers |



# Problems and issues in adopting steel structures (6/6)

| Questionnaire | Answer |
|---|---|
| • Availability of steel is a concern, and ensuring a smooth and reliable supply chain is important<br>• Not easy to obtain the thick and extra-thick steel needed for the project<br>• Dependence on imported steel and potential disruption | 1. Development of domestic standards for steel materials dedicated to construction applications that reflect user needs (not accepting overseas standards as they are and preventing imports of inferior overseas steel materials)<br>2. Frequent communication between design, fabrication, and construction companies and steel manufacturers; committee, association, and group activities |

# Suggestions to promote steel structure development (1/2)

| Questionnaire | Answer |
|---|---|
| • Indian economy is growing rapidly and the construction industry has a significant impact on GDP growth | Yes |
| • Infrastructure development has time constraints and steel structures are more preferable | Yes, short construction period, mass production and supply |
| • The quality of steel materials also determines the quality of steel structures in terms of durability | Yes, corrosion protection, weather resistance, stainless steel |
| • On site, bolted joints are more risk-reducing than welded joints | utilization of industrialized products, downward welding position in the plant, useful in terms of quality control |
| • Develop standards that allow structures to be repaired in a short period of time and that can respond to natural disasters | short construction time is an advantage of steel construction, can be expanded to standardization, prefabrication, and seismic retrofitting |
| • Propose lightweight, economical steel structures in earthquake-prone areas | same as above |

# Suggestions to promote steel structure development (2/2)

| Questionnaire | Answer |
|---|---|
| • Increase awareness and availability of earthquake, weather, and fire resistant products | high strength and earthquake resistant steel, weather resistant steel, fire resistant steel, also reduced maintenance work and environment during construction |
| • Cultivate skilled workers throughout Japan who can fabricate at least 500 tons of steel frames per month | fabricators were initially located only available near major cities in case of Japan, but as steel structures became more widespread, they are located throughout Japan, and quality was improved through qualified engineers and fabrication plant certification systems |
| • Shift to off-site construction such as prefabrication and precast that can use inexpensive labor | Steel structure has the advantage of factory fabrication, but it requires the training and education of skilled technicians such as welders. |
| • Provide quality steel fabricators and solutions | steel fabrication plant certification system |

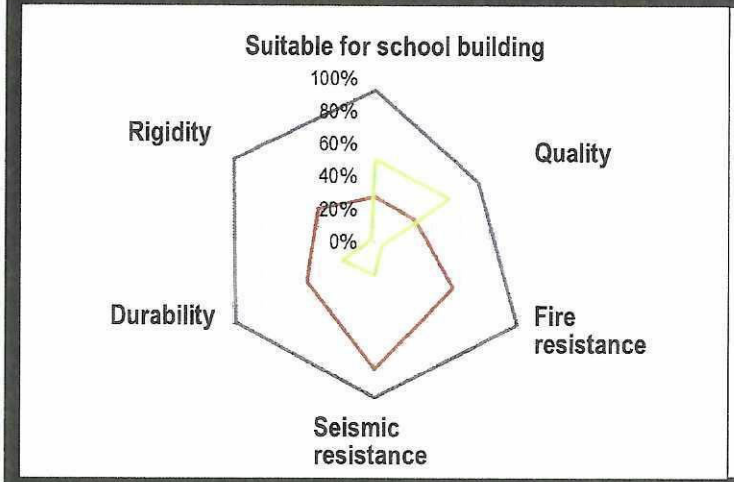
# Image survey of structural materials (1/2)

**Survey on the Image of Structural Materials Used in School Buildings**

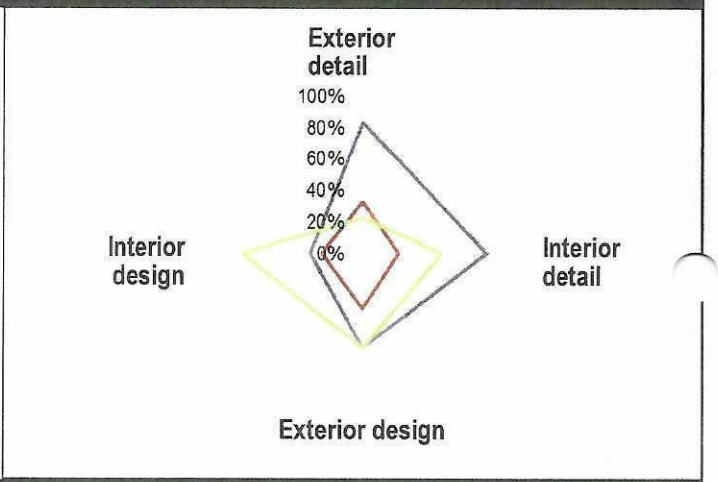
- Commissioned by the Kozai Club to the Research Institute of Educational Facilities
- Survey year: 1986-87
- Survey target: 40 architectural engineers from Boards of Education across Japan.
- Percentage of positive ratings (very suitable, fairly suitable, and somewhat suitable) on a 7-point scale is shown in a pie chart

RC
Steel
Wood

(a) School quality, fire resistance, seismic resistance, durability, rigidity




(b) Exterior/interior detail and design

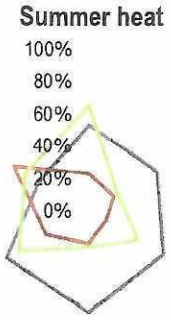





# Image survey of structural materials (2/2)

(c) Thermal and sound environment, maintenance & management, changeability

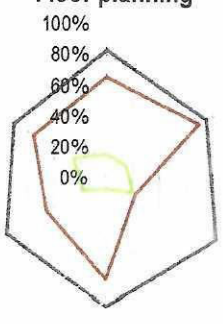
RC
Steel
Wood



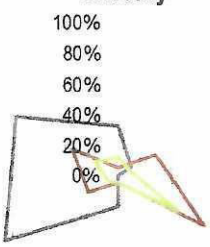

- Misunderstanding of Steel Construction
- Now technically solved

Materials should be selected according to the functional requirements

(d) Ease of planning, design, construction management, and on-site construction




(e) Subsidies, costs, construction schedule, procedures



# Constraints and challenges hindering the widespread use of steel structures (1)

**Challenges in promoting steel structures are not unique to Japan, but common to all countries. The following challenges need to be overcome.**

## 1. Dispelling misconceptions and raising awareness about steel structures

The general public has the misconception that RC structures are safer than steel structures because they have thicker walls. It is important to dispel these misconceptions and promote the advantages of steel construction in an easy-to-understand manner.

## 2. Lack of technical skills related to building materials that make up steel structures, such as finishing, thermal insulation, acoustic insulation, and waterproofing

Although the supply of steel materials is not a problem, there are concerns about product performance and procurement due to a lack of technical capabilities related to peripheral construction materials such as finishing materials, heat insulation, sound insulation, and waterproofing.



# Constraints and challenges hindering the widespread use of steel structures (2)

## 3. Improvement of technical level of skilled workers engaged in steel construction

While RC construction can be handled by form and reinforce workers, steel structures require workers with a high technical level, so it is necessary to create an education and training system to improve the technical level.

## 4. Dissemination of Structural Design Programs for Steel Structures

Structural design programs for RC (Reinforced concrete) are widely used, but there are only a few structural design programs for steel structures, so design firms do not incorporate them into their drawings.

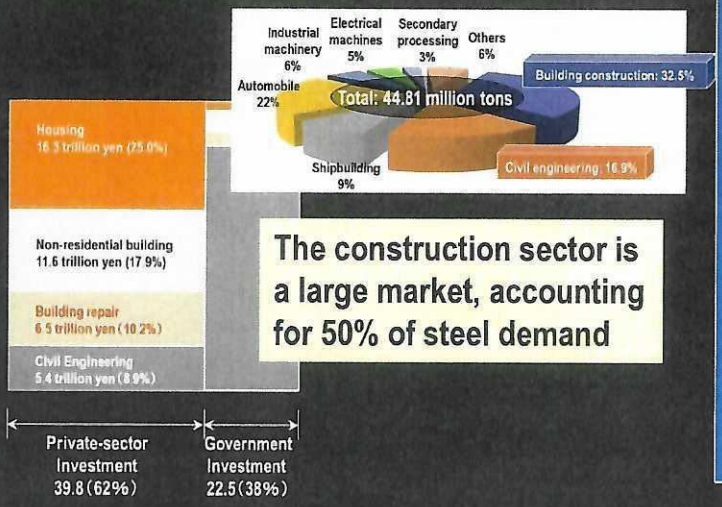
## 5. Establishment of a supply chain for steel structures and promotion of dialogue between users and manufacturers

Supply chain for steel structures has not been established. It is important to discuss ideas and measures to promote steel structures, including steel manufacturers, fabricators, building materials manufacturers, general contractors, and other related companies, and to create a common awareness among all parties involved.

# In today's lecture, we will focus on the Building Market. Why?

## Civil Engineering Market

The steel structure market also includes road, rail, and other civil engineering structures, but although the scale of each project in the civil engineering field is large, it is necessary to approach each client (government) individually to promote the market.




**The construction sector is a large market, accounting for 50% of steel demand**

## Building Market

- The construction sector, although smaller in scale per project, has a large number of projects and a potential market that is approximately twice the size of the civil engineering sector in terms of steel consumption and construction investment, and the market is expected to expand under the technology policy.
- The building sector has a wide range of companies that receive orders for materials (steel), steel frame fabrication, various building materials manufacturing, design and construction, etc.
- It is necessary to work on a wide variety of comprehensive promotion such as legislation, standards and guidelines, quality assurance, and human resource development, but once realized, the steel structure market is expected to expand in a chain reaction.



# 1. Economic Growth and Steel Market

1-1. Economic Growth and Steel Consumption
1-2. Steel Demand for Construction Market
1-3. Steel Production in Major Countries

# GDP and Steel Consumption in Asian Countries & the U.S.

**With Economic Growth, Steel Consumption will be increased.**

| | Capita (million) | | GDP per capita (US$) | | Apparent Steel Use per capita (kg) | |
|---|---|---|---|---|---|---|
| | 2010 | 2022 | 2010 | 2022 | 2010 | 2022 |
| **India** | 1,240 | 1,417 | 1,377 | 2,392 | 54.9 | 82.0 |
| **China** | 1,341 | 1,412 | 4,500 | 12,670 | 427.4 | 649.2 |
| Indonesia | 237.6 | 275.5 | 3,178 | 4,798 | 37.3 | 60.3 |
| **Japan** | 127.6 | 125.1 | 45,136 | 33,854 | 500.9 | 443.6 |
| Vietnam | 87.9 | 98.2 | 1,628 | 4,087 | 139.8 | 226.4 |
| Thailand | 67.2 | 71.7 | 5,076 | 7,070 | 211.0 | 324.4 |
| Korea | 49.6 | 51.6 | 23,077 | 32,418 | 1077.2 | 990.0 |
| Malaysia | 28.6 | 33.9 | 9,047 | 12,466 | 315.8 | 221.4 |
| Taiwan | 23.2 | 23.3 | 19,181 | 32,687 | 771.8 | 728.1 |
| **United States** | 309.7 | 333.3 | 48,586 | 76,343 | 267.3 | 279.4 |

Source: World Steel "Steel Statistical Yearbook" & IMF "World Economic Outlook Database"



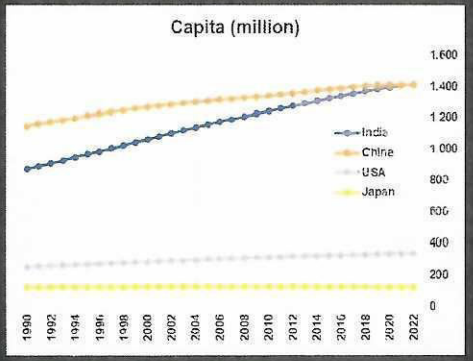
# GDP and Steel Consumption

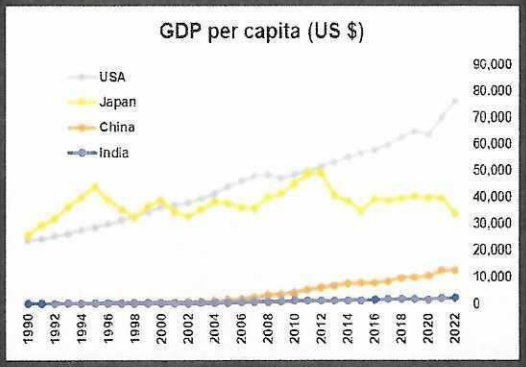
| | Capita (million) | GDP (trillion US$) | per capita GDP (US$) | Steel production (mil. tons) | Steel consumption (mil. tons) | Per-capita steel consumption (kg) |
|---|---|---|---|---|---|---|
| India | 14.17 | 3.39 | 2,392 | 125.3 | 114.9 | 82.0 |
| China | 14.12 | 17.9 | 12,670 | 1018.0 | 920.9 | 649.2 |
| Japan | 1.27 | 4.24 | 33,854 | 89.2 | 55.0 | 443.6 |
| USA | 3.31 | 25.5 | 76,343 | 80.5 | 94.5 | 279.4 |

Source: World Steel "Steel Statistical Yearbook" & IMF "World Economic Outlook Database"

**Indian government plans to raise steel production to 300 million tons by 2030.**
**Demand for steel in India is expected to grow 8.6% y/y in 2023 and 7.7% y/y in 2024 due to robust construction of buildings, bridges and railroads.**

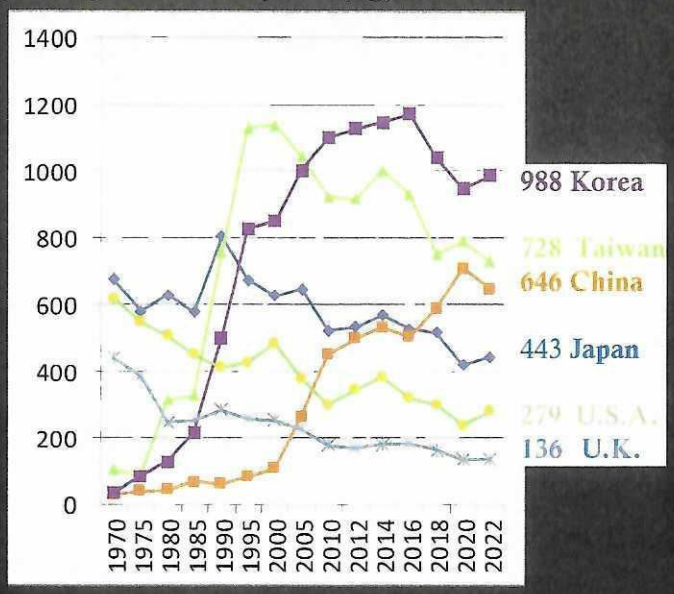
**Considering India's large population, there is significant potential for future growth in both GDP and steel consumption.**



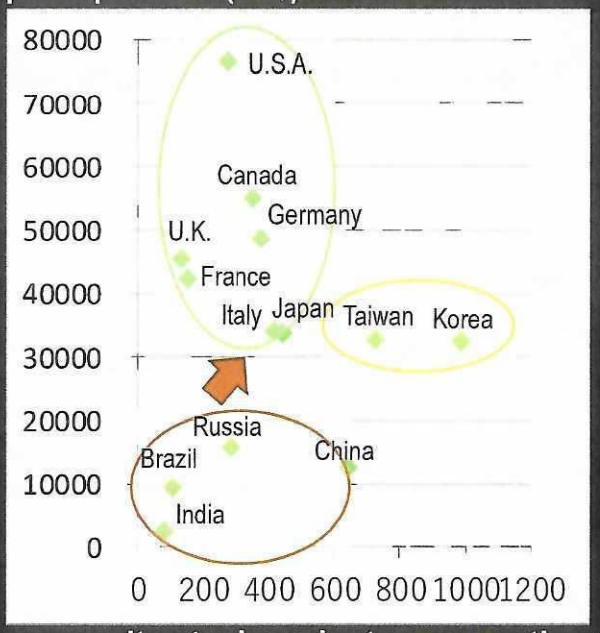
# Steel Consumption in Major Countries

per-capita consumption (kg)




Apparent per-capita steel consumption

per-capita GDP (US$)




per-capita GDP & Steel Consumption in 2022

Souse: World Steel "Steel Statistical Yearbook"

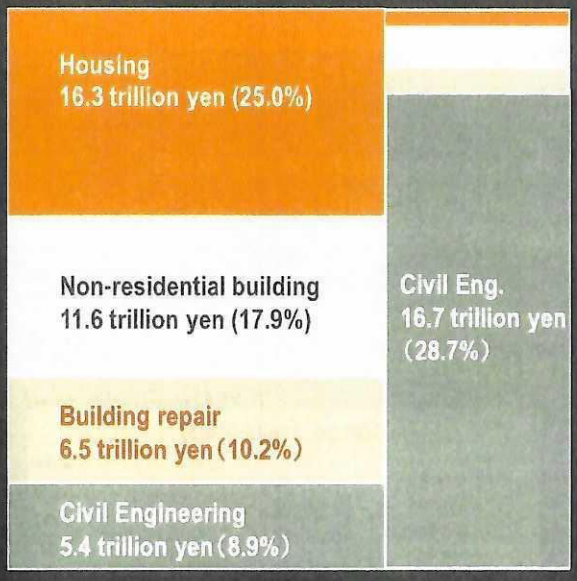
Source: World Steel "Steel Statistical Yearbook"
IMF " World Economic Outlook"





# Composition of Construction Investment

【2019FY】

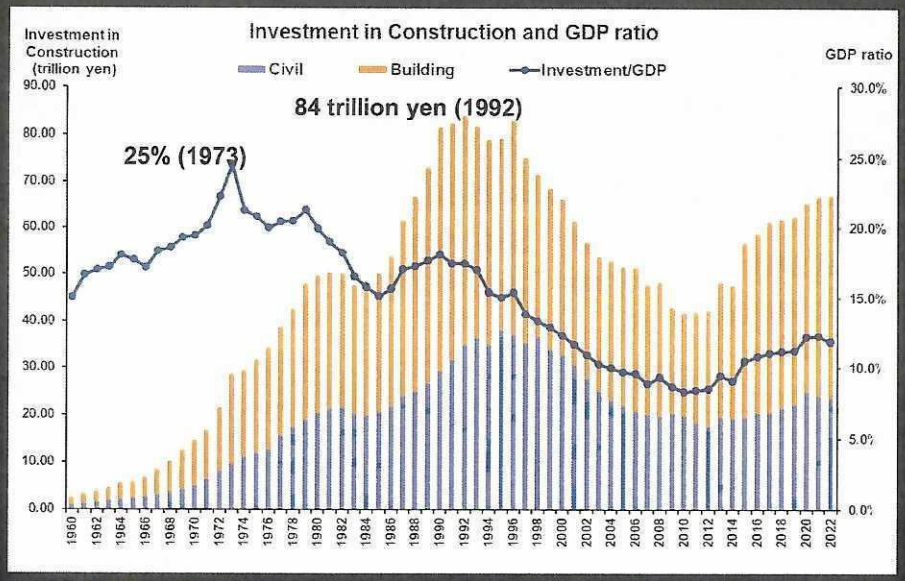



Housing 0.4 trillion yen (1.0%)
Non-residential 3.9 trillion yen (6.2%)
Building repair 1.4 trillion yen (2.1%)

- Private-sector investment accounts for 62% of total construction investment (62.3 trillion yen per year), government 38%.
- Building 62.4%, civil engineering 37.6%
- Most of civil engineering is government investment (75%), most of building is private investment (85%)
- Both government and private-sector investment in renovation increased, including renewal of existing stock and urban renewal

( ) is the composition ratio when the total investment amount is 100, Source: MLIT

# Investment in Construction and GDP ratio



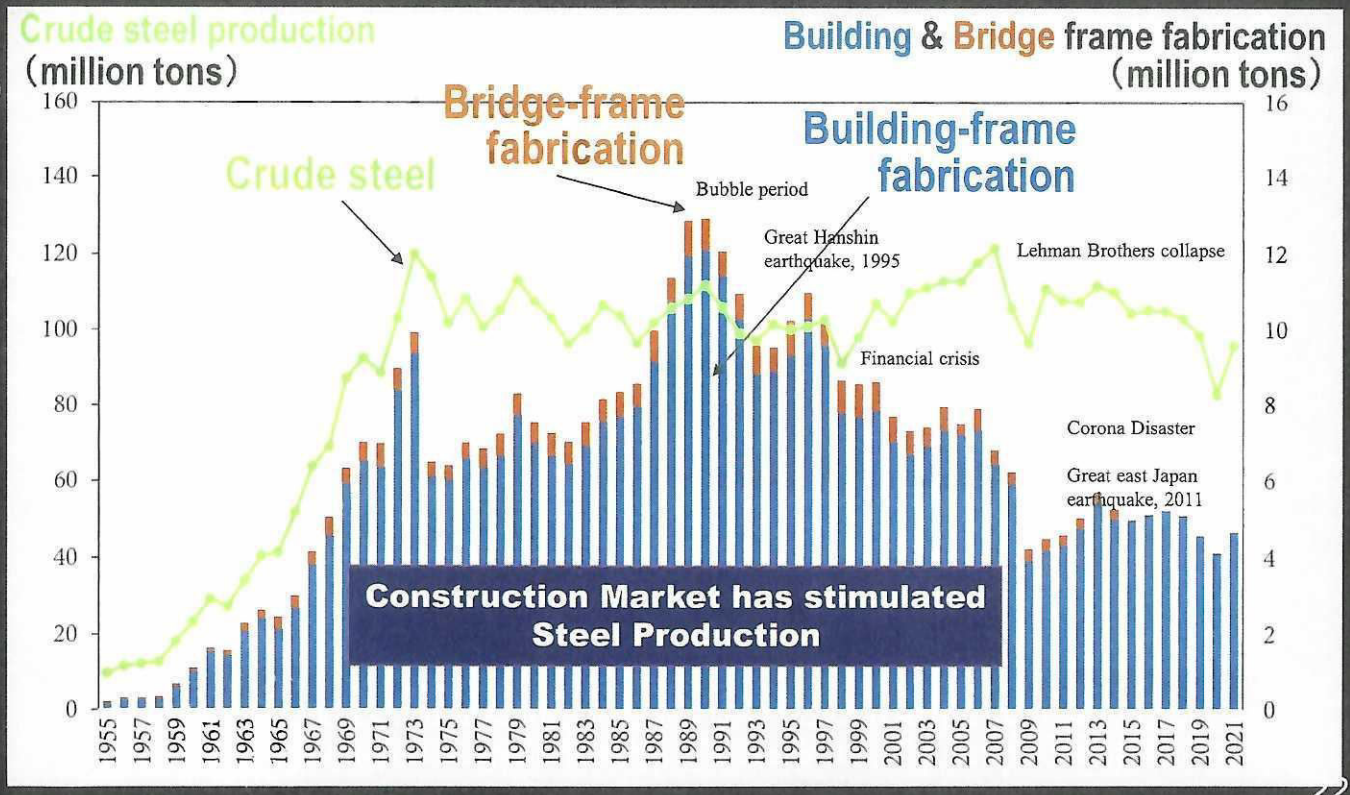

- After peaking at 84 trillion yen in 1992, construction investment continued to decline, temporarily halving to the 40 trillion yen level. Currently, it has recovered to the 60 trillion yen level, backed by reconstruction demand from the Great East Japan Earthquake, active private-sector investment, and the expansion of the repair market.
- Construction investment as a percentage of GDP was 25% in the 1970s, 18% in the 1990s during the bubble period, and then began to decline, dropping after the Lehman Shock, but has recently recovered to the 10% level.

The relationship between GDP and construction investment was meaningful during the high-growth period when the emphasis was on infrastructure development such as housing, public facilities, commercial facilities, factories, warehouses, roads, railroads and etc..



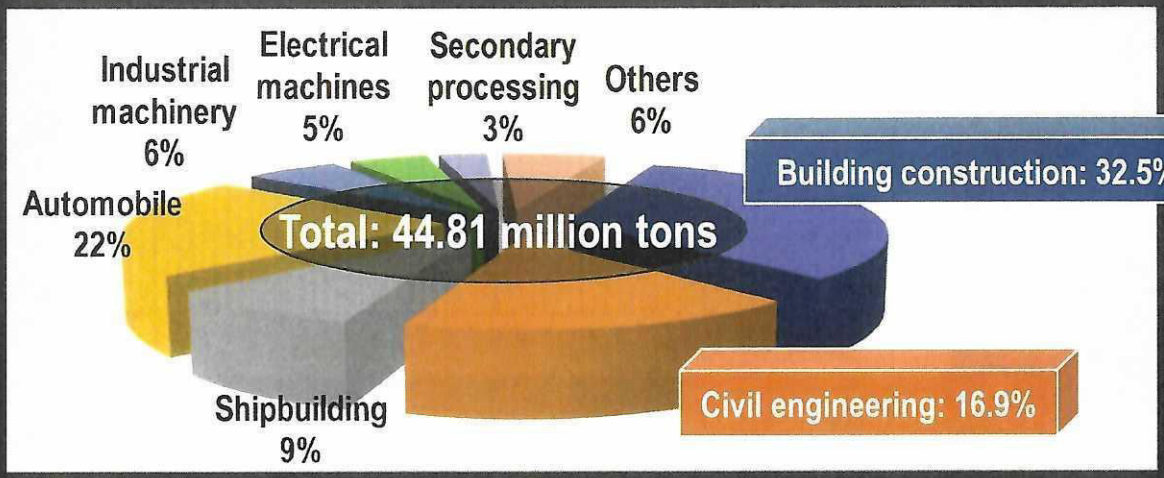


# Crude Steel Production and Steel-frame Fabrication in Japan



# Domestic Demand for Steel Products for Construction in Japan

Domestic demand for ordinary steel products in FY2018 (Before the Corona Disaster)



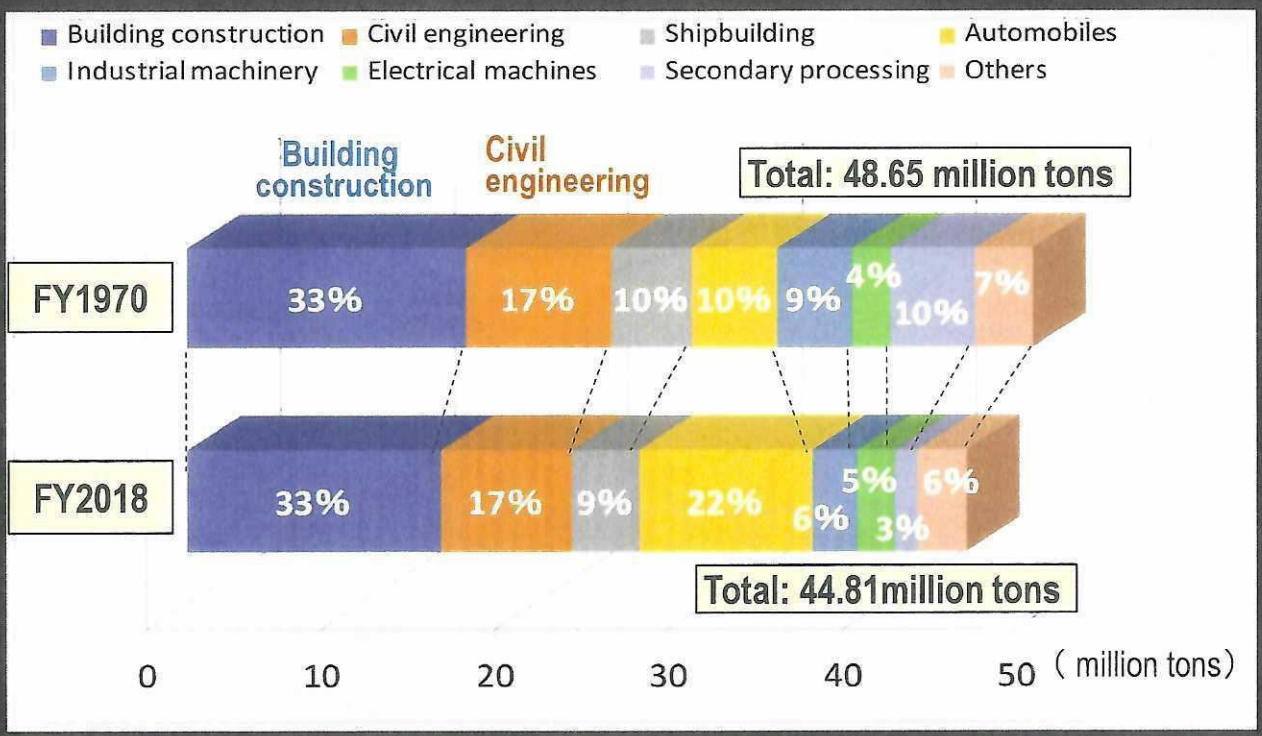

**Share of Construction (Civil engineering & Building construction) in total domestic demand: about 50%**

Source: Estimated Consumption of Ordinary Steel Products by Consuming Industry, Iron and Steel Statistical Handbook 2023





# Domestic Demand for Steel Products in Japan



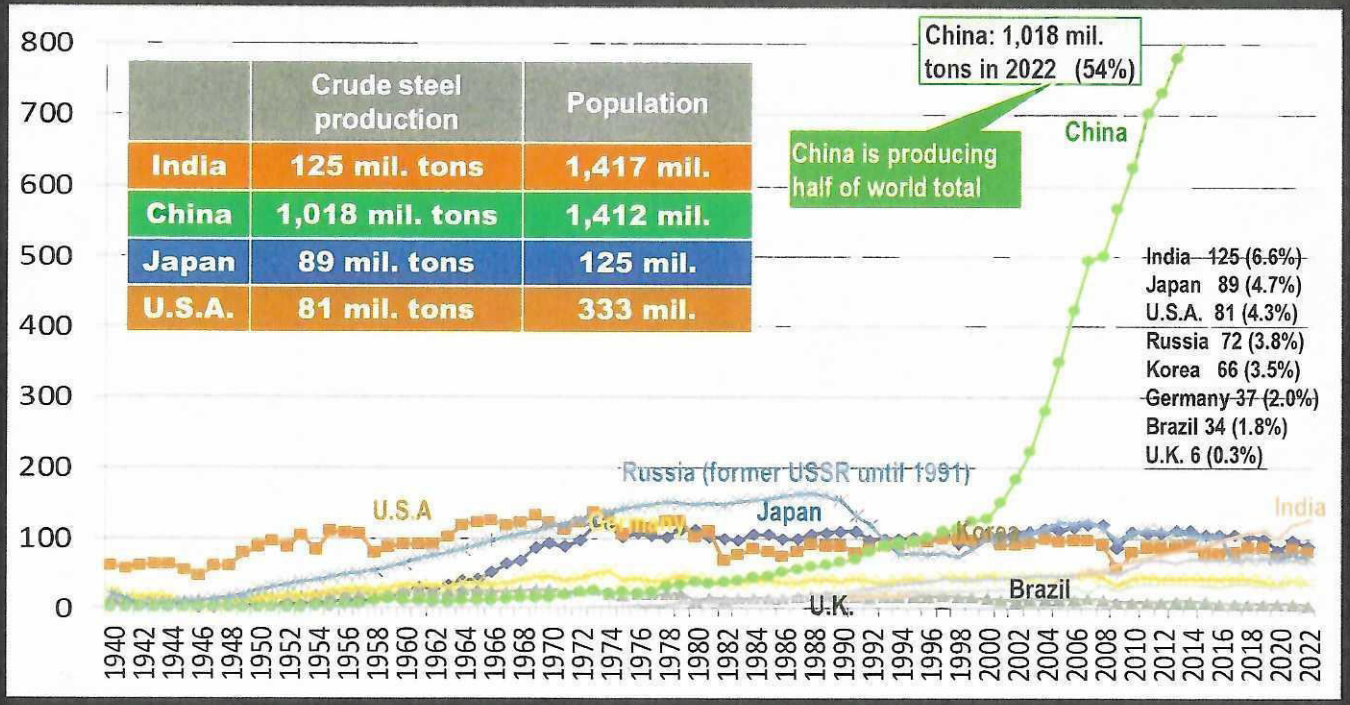

**As there were the Greatest Needs for Infrastructures during Economic Growth, Share of Construction (Civil & Building) in total domestic demand reaches 50%.**

Source: Estimated Consumption of Ordinary Steel Products by Consuming Industry, Iron and Steel Statistical Handbook (1970/2018)

# Steel Production in Major Countries

Crude Steel Production (million tons)

**World total in 2022: 1,888 million tons**




| | Crude steel production | Population |
|---|---|---|
| India | 125 mil. tons | 1,417 mil. |
| China | 1,018 mil. tons | 1,412 mil. |
| Japan | 89 mil. tons | 125 mil. |
| U.S.A. | 81 mil. tons | 333 mil. |



# Top Steel-Producing Companies

**(Looking Back Half a Century, in million tons)**

| | 1970 | 1980 | 1990 | 2000 | 2010 | 2019 | 2022 |
|---|---|---|---|---|---|---|---|
| | World total: 595 | 716.4 | 770.4 | 850.0 | 1435.3 | 1878.5 | 1887.9 |
| 1 | Nippon Steel (Japan, 34.6) | Nippon Steel (Japan, 32.9) | Nippon Steel (Japan, 28.8) | Nippon Steel (Japan, 28.4) | Arcelor Mittal (Euro, 98.2) | Arcelor Mittal (Euro, 97.3) | Baosteel Gr. (China, 131.8) |
| 2 | US Steel (US, 28.5) | US Steel (US, 21.1) | Usinor (Euro, 23.8) | POSCO (Korea, 27.7) | Baosteel Gr. (China, 37.0) | Baosteel Gr. (China, 95.5) | Arcelor Mittal (Euro, 68.9) |
| 3 | British Steel (Euro, 25.6) | NKK (Japan, 14.0) | POSCO (Korea, 16.2) | Arbed (Euro, 24.1) | POSCO Korea, 35.4) | Nippon Steel (Japan, 51.7) | Ansteel Group (China, 55.7) |
| 4 | Bethlehem Steel (US, 18.7) | Finsider (Euro, 13.7) | British Steel (Euro, 13.8) | LNM (Euro, 22.4) | Nippon Steel (Japan, 35.0) | HBIS Group (China, 46.7) | Nippon Steel (Japan, 44.4) |
| 5 | NKK (Japan, 12.9) | Bethlehem Steel (US, 13.6) | USX (US, 12.4) | Usinor (Euro, 21.0) | JFE Steel (Japan, 31.1) | POSCO (Korea, 43.1) | Shagang Gr. (China, 41.5) |
| 6 | Thyssen (Euro, 12.2) | Sumitomo M. (Japan, 12.7) | NKK (Japan, 12.1) | Corus (Euro, 20.0) | Shagang Gr. (China, 23.2) | Shagang Gr. (China, 41.1) | HBIS Group (China, 41.0) |
| 7 | Sumitomo M. (Japan, 11.2) | Kawasaki St. (Japan, 12.7) | ILVA (Euro, 11.5) | Thyssen Krupp (Euro, 17.7) | Tata Steel (India, 23.2) | Ansteel Group (China, 39.2) | POSCO (Korea, 38.6) |
| 8 | Kawasaki St. (Japan, 11.0) | Thyssen (Euro, 12.4) | Thyssen (Euro, 11.1) | Baosteel (China, 17.7) | US Steel (US, 22.3) | Jianlong Gr. (China, 31.2) | Jianlong Gr. (China, 36.6) |
| 9 | Finsider (Euro, 9.7) | Usinor (Euro, 9.2) | Sumitomo M. (Japan, 11.1) | NKK (Japan, 16.0) | Ansteel (China, 22.1) | Tata Steel (India, 30.2) | Shougang Gr. (China, 33.8) |
| 10 | Republic Steel (US, 8.7) | J&L (US, 8.6) | Kawasaki St. (Japan, 11.1) | Riva (Euro, 15.6) | Gerdau (Brazil, 18.7) | Shougang Gr. (China, 29.3) | Tata Steel (India, 30.2) |

**The ranking of top 10 has changed significantly over the past half century, with Chinese companies dominating the list since 2000.**

# 2. Advantages of Steel Structures

2-1. Advantages of Steel Structures
2-2. Structures Applied the Advantage of Steel



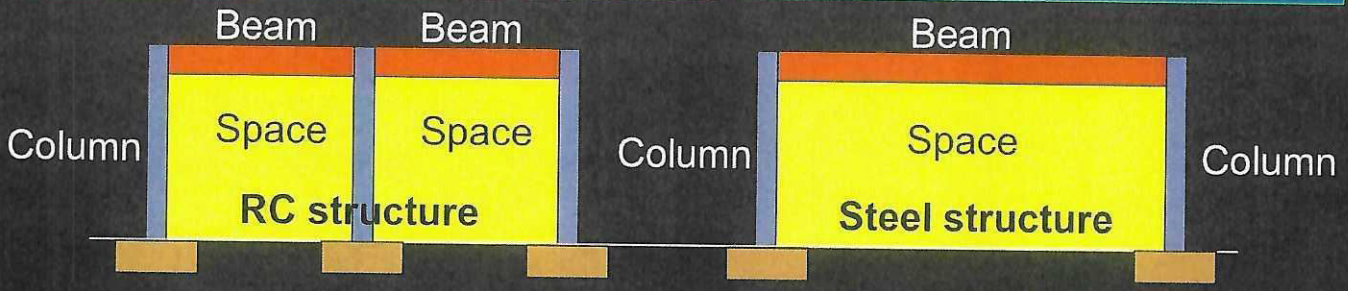


## How Strong is Steel ?

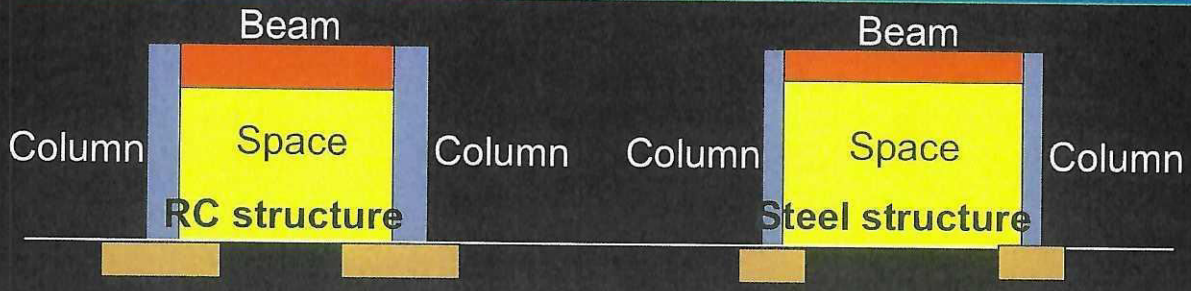
| items | unit | | force | Steel | Concrete |
|---|---|---|---|---|---|
| Specific Gravity | ($t/m^3$) | A | | 7.85 | 2.30 |
| Strength | ($N/mm^2$) | B | Tension | 400 | 2.7 |
| | | C | Compression | 400 | 18 |
| Young's Modulus | ($N/mm^2$) | | | $2.05 \times 10^5$ | $2.1 \times 10^4$ |
| Specific Strength | ($kN \cdot m/kg$) | B/A | Tension | 51.0 | 1.2 |
| | | C/A | Compression | 51.0 | 7.8 |

- Specific Strength is strength-to-weight ratio, the physical quantity indication of the strength per unit weight.
- Steel has higher strength than concrete.

- Steel structures will achieve Long-span Beams than RC, under the condition of same member sizes.




- Steel structures will achieve Small-size Members than RC, under the condition of same span.
- The weight of steel structure can be reduced. Cost reduction can be achieved because foundation and piling works are reduced.



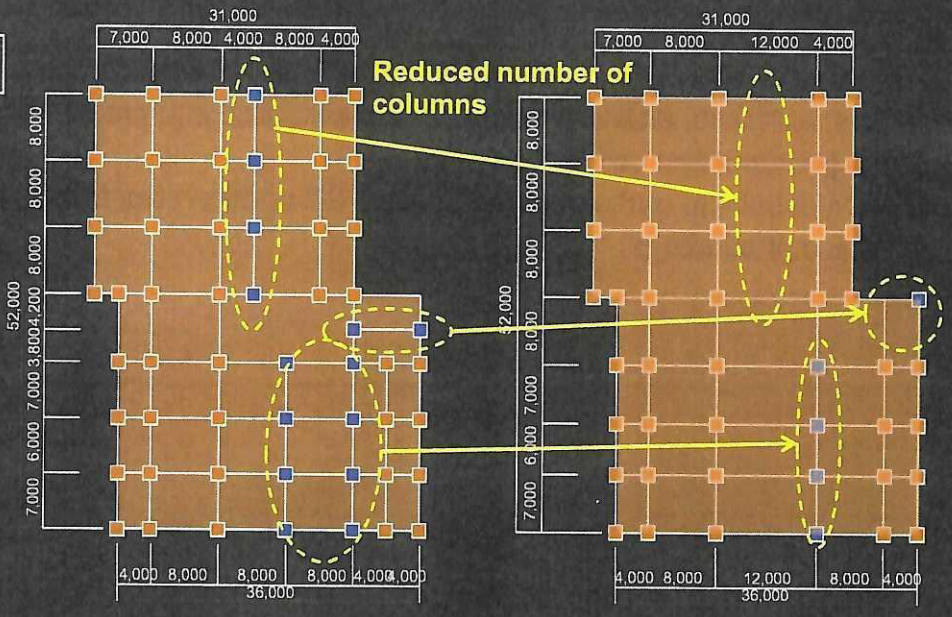





# Comparative Design between Steel and RC Structures (1/4)

- 4-story School Buildings (Junior High & Elementary School)
- Total Floor Area: 6,700m²

Typical Floor Plan




RC structure

Steel structure

# Comparative Design between Steel and RC Structures (2/4)

| | RC structure | Steel Structure |
|---|---|---|
| Column Size | Min. □ - 750 × 750<br>Max. □ - 800 × 1000 | Min. □ - 400 × 400 × 12<br>Max. □ - 400 × 400 × 22<br>(BCR295) |
| Beam Size | Max. □ - 1000 × 600 | Max. H - 700 × 300 × 12 × 22<br>(SN490B) |
| Number of Columns | 55 | 46 |
| Max. Span | 8 meter | 12 meter |

Minimized member sizes

Reduced number of column

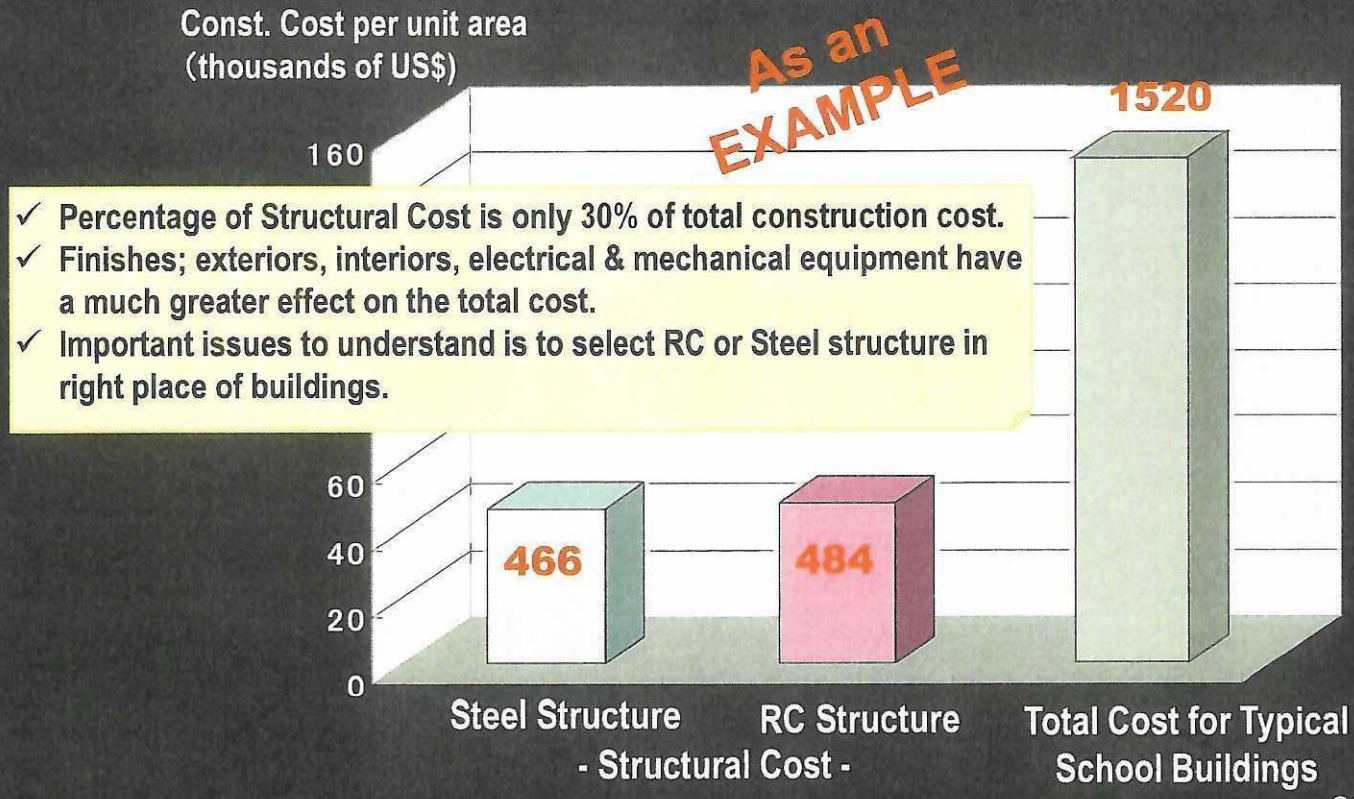
Long span

- Reduced number of column and weight saving at steel structure lead to a cost down of foundation work and piling
- Maximize internal space by minimizing member sizes





# Comparative Design between Steel and RC Structures (3/4)



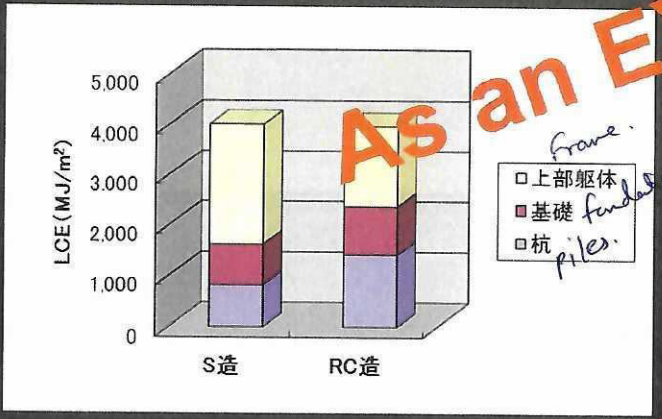

- ✓ Percentage of Structural Cost is only 30% of total construction cost.
- ✓ Finishes; exteriors, interiors, electrical & mechanical equipment have a much greater effect on the total cost.
- ✓ Important issues to understand is to select RC or Steel structure in right place of buildings.

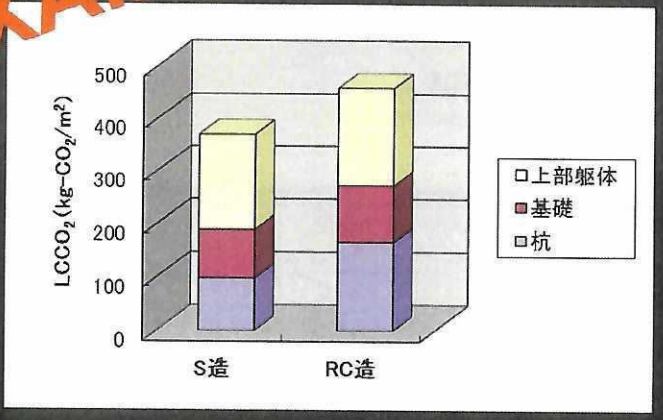
(Cost simulation based on 2005FY data)

# Comparative Design between Steel and RC Structures (4/4)

## Comparison of LCA between RC and Steel Structure during Construction

As an EXAMPLE




- ✓ Comparison contains none of ordinary use, abolishment and re-use.
- ✓ Recycle will give a more advantages of Life Cycle Assessment to Steel Structure.





# Advantage of Steel Structures

### 1. Earthquake and Disaster-resistance Buildings

- Excellent in earthquake resistance, as disaster-prevention & emergency evacuation centers
- Reduced vibration & improved habitability by use of CFT columns and vibration control devices

### 2. Attractive Design

- Light-weight design of slender structural members
- Curved structural design by steel's workability
- New steel-structure design matching with wooden, glass, metallic and stone materials
- Fire-resistance by use of FR steel

### 3. Flexibility of Planning

- Flexibly for future application changes due to large column-free space
- Wall-free structures with large opening
- Free layout in room space due to movable partitions

### 4. Stable Quality and Short Construction Period

- Stable quality; shop production, less on-site work, no need for special technology and skilled workers
- Shorter construction period by use of steel's excellent workability

### 5. Eco-friendly Structure

- Resource saving through recycling use in all stages from demolition to re-assembly
- Lower environmental burdens due to improved durability
- Reduced construction waste through recycling use, sustainable structural materials

## 2-2. Structures Applied the Advantage of Steel

| Application Examples | High-strength, High-ductility | Large span, column-free space | Short construction Period |
|---|---|---|---|
| 1. High-rise Building (Rentable area, Mega-structure) | ✓ | ✓ | |
| 2. Space Frame (Airport, Stadium, Station etc.) | | ✓ | |

- **Steel Structures are excellent in seismic resistance.**
- **The strength of steel per weight is higher than concrete.**

***1. For high-rise buildings,*** ***the column section that support heavy load from upper stories becomes large.***

- ***It is an advantage of steel structures that smaller column section saves the space, in the other words, increases asset values of buildings.***

***2. For airports, stadiums, stations, and other large-scale*** ***facilities that require large space,***

- ***The weight of members can be reduced by using steel structures. This allows long span and the space with small number of columns and walls.***

## 2-2. Structures Applied the Advantage of Steel

| Application Examples | High-strength, High-ductility | Large span, column-free space | Short construction Period |
|---|---|---|---|
| 3. Commercial Building (Shopping Mall etc.) | | ✓ | ✓ |
| 4. Factory, Warehouse | | ✓ | ✓ |
| 5. Plant structure (supported heavy machines) | ✓ | | ✓ |

- **Steel Structures are excellent in seismic resistance.**
- **The strength of steel per weight is higher than concrete.**

***3-4. For Commercial Buildings, Factories and Warehouses,*** ***Steel Structures also have an advantage because these buildings also require large space and reduction in construction period.***

***5. For Plant structures,*** ***steel structures are necessary to support heavy machines and flexibly deal with a design change.***

# Advantage of Steel Structures (Summary)

Although reinforced concrete (RC) construction is currently used in many countries, rapid economic growth will increase the need for infrastructure development. In the near future, steel construction is expected to increase due to the following advantages;

## 1) Infrastructures securing public safety & economic activity

- **Seismic resistant buildings** increase in asset value with long-term use
- **Securing BCP and supply chain** against natural disasters

## 2) Buildings applied the advantage of steel structures

- **High-rise & Space frames**; High-strength, ductility & large span
- **Commercial buildings, Factories & Warehouses**; large span, short construction period and quick recovery of investment

## 3) Changes in market mechanism & progress of urbanization

- **Shortage of skilled workers and cost surge in labor market**; departure from labor-intensive industry to high-labor productivity, from on-site construction to pre-fabrication in the factory
- **Needs for advanced land utilization & short construction period** with progress of urbanization





# Steel Structure Construction Costs and Future Prospects

As economic growth and rapid urbanization fuel construction demand, soaring labor costs will become an urgent issue. In the future, the construction industry is expected to shift from a labor-intensive industry to an industry with high labor productivity through mechanization and IT. As a result, demand is expected to increase for steel structures, which offer short construction periods, high production efficiency, and advanced land utilization through high-rise construction.

## 1. Cost of the structural frame

The cost of the structural frame is 25-30% of the total construction cost. The construction cost is largely determined by the selection of specifications for equipment, interior and exterior, and fixture work, rather than by the structural differences between RC and steel frame construction.

## 2. Cost advantages of steel-frame construction

- Short construction period and early recovery of funds
- Larger effective area for rooms and higher asset value of the building
- Post-construction remodeling, such as reconstruction or change of use, is easy.

## 3. Life cycle cost evaluation taking into account energy and $CO_2$

Steel frame construction has an advantage over RC construction in terms of life cycle energy and $CO_2$ emissions. Furthermore, when considering disposal and re-use, the cost of RC construction is higher at the disposal stage, while steel frame construction is recycled, which widens the gap.

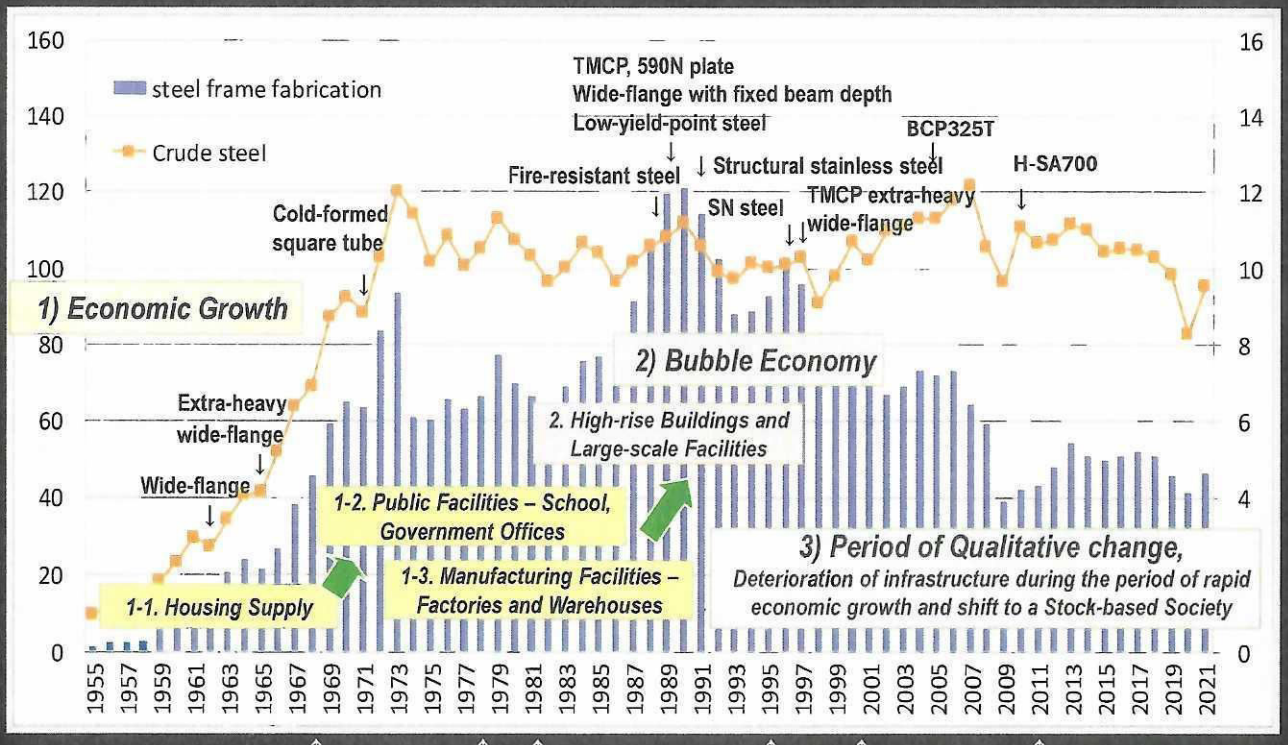
# 3. Historical Development of Steel Structures in Japan

3-1. High Economic Growth from 1960s to 1970s
3-2. Economic Bubble around 1990
3-3. Post Bubble and Current Steel Construction Market in Japan





Demand for steel structures, characterized by **short construction periods and mass supply** is dramatically increased during economic growth.



# Historical Development of Steel Structures

The demand for steel structures, characterized by short construction period and mass supply, has dramatically increased in high economic growth and infrastructure development began in the 1960s. Currently, the share of steel structures in non-residential buildings exceeds 70%.

## 1) High economic growth from 1960s to 1970s

- Housing; wooden for single-family housing, RC for multi-family apartment
- Public facilities such as schools and hospitals; mainly RC
- Construction of commercial facilities and production facilities such as factories and warehouses; mainly steel structures

## 2) Bubble Economy period around 1990

- High-rise buildings; High-strength, Heavy thickness and large section steels
- Space structures such as airport, stadium and station; large span

## 3) Post Bubble and Current Steel Construction Market

- Increase of stock; shift from construction to maintenance & management
- Infrastructure restructuring for urban revitalization
- Aging workers; lack of skilled workers such as formwork & reinforcement work for RC construction



# Historical Development of Steel Structures

## (1) High economic growth from 1960s to 1970s

### (1) High Economic Growth period from 1960s to 1970s

Steel structures became the preferred choice for mass supply and short construction periods due to their efficiency. As demand for steel structures grew, steel production also increased rapidly, exceeding 100 million tons annually by 1972.

- To address the significant housing shortage caused by the war and postwar baby boom, the government initiated housing improvements. This involved constructing detached wooden houses and mass-producing RC housing complexes in the suburbs through the Japan Housing Corporation.
- Additionally, public facilities such as schools and government buildings were built using fire-resistant RC, which could be handled by local construction companies. At the time, there were few steel fabrication plants for steel frame construction, and the use of steel frames had not yet become widespread.

However, with the rise of mass construction of commercial facilities, factories, and warehouses, steel fabrication plants were established nationwide and production capacity increased. As a result, many steel-framed structures were constructed, which excelled in mass supply and short construction periods.

# Historical Development of Steel Structures
## (2) Bubble Economy period around 1990

### (2) Bubble Economy period around 1990

Japan's economy peaked during the bubble period, and urbanization proceeded throughout the country, with the construction of many high-rise buildings and large facilities, as well as roads and railroads to create an inter-city transportation network.

1988: Great Seto Bridge (10 bridges)
1991: Tokyo Metropolitan Government Building (height: 243m)
1993: MM21 Yokohama Landmark Tower (height: 296m)
1994: Kansai International Airport
1998: Akashi Kaikyo Bridge (total length: 3,911m, center span: 1,991m, longest suspension bridge in the world)
1999: Setouchi-Shimanami Sea Route (three routes of the Honshi-Shimanami Viaduct were completed)

- At the time, the annual production volume of building steel frames and bridges reached 12 million and 900,000 tons, respectively, both all-time highs.
- Demand for the construction of skyscrapers and long-span bridges increased, and steel manufacturers began to develop and commercialize high-performance steel materials with high strength, extra-thickness, large cross-sections, and improved weldability.



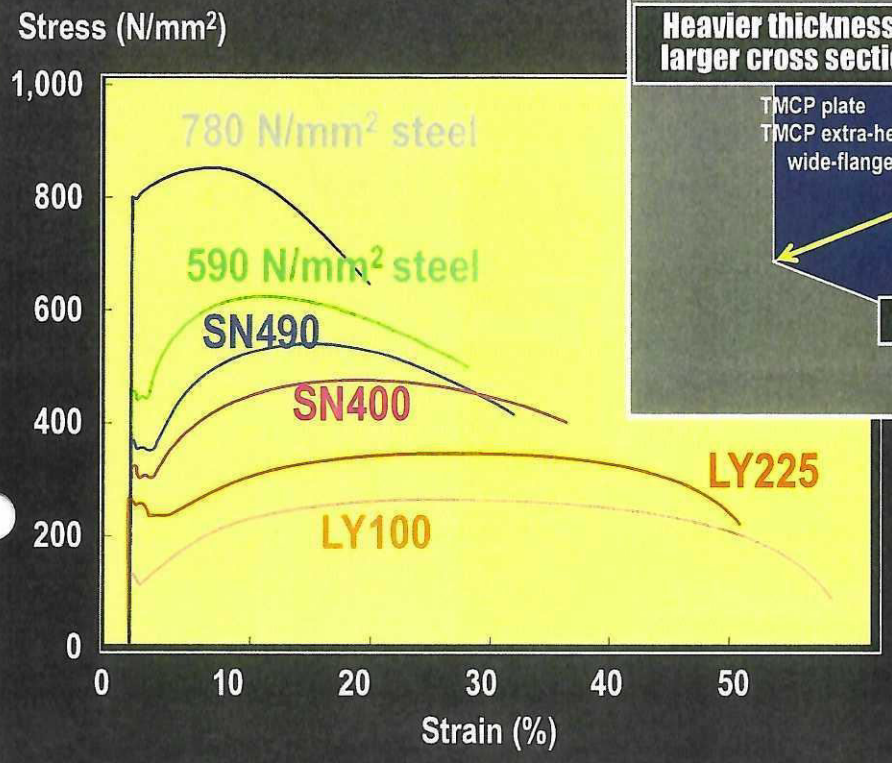
# Historical Development of Steel Structures
## (2) Bubble Economy period around 1990

Design, fabrication, and construction methods that construct many high-rise buildings and large facilities, along with the development of new steel products to support these methods.

1. Developing high strength and ultra-thickness and its joining technology to support large-scale structures, ensuring seismic resistance and weldability as exemplified by SN steel, and development of CFT columns to complement buckling strength.
2. Overcoming weak points such as fire resistance and rust by making the building attractive not only in terms of structure but also in terms of environment and building design;
   - Fire resistance, aesthetics and construction environment (fire-resistant steel)
   - Corrosion resistance, aesthetics and maintenance costs (weather-resistant steel, stainless steel)

# New Steel Products for Building Structures

**Conventional Steel**
- 400 N/mm² steel (SS400)
- 490 N/mm² steel (SM490)




**< Directions of Development >**

**Higher strength**
- 590N/mm² steel
- 780N/mm² steel

**Heavier thickness & larger cross section**
- TMCP plate
- TMCP extra-heavy wide-flange

**Higher performance**
- SN, BCR, BCP
- Weldability
- Lower yield ratio, narrow-range yield point
- Higher dimensional accuracy

**Lower yield point**
- LY100, LY225

**New performance**

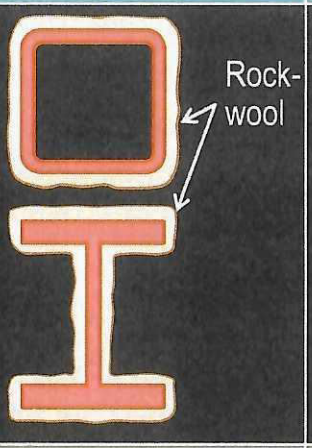
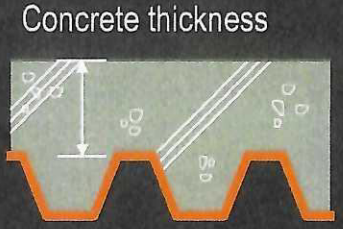
**High-temperature property**
- Fire-resistant steel

**Durability**
- Weathering steel
- Stainless steel

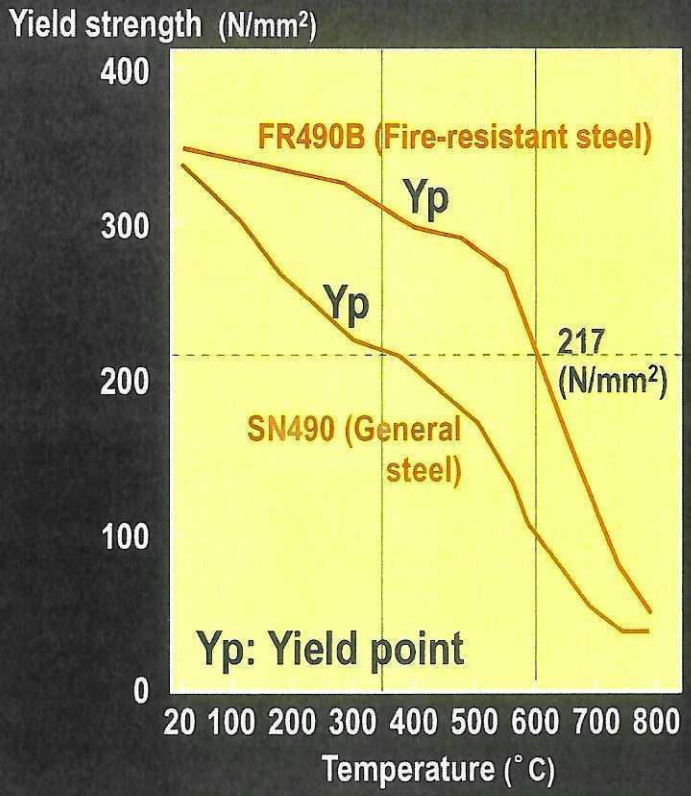


# Fire Protection Specifications for Main Structural Sections

## (General specifications in building standard of Japan)

| | Column | Beam | Floor |
|---|---|---|---|
| Fire duration |   |   |   |
| 1 hour | Rock-wool 30 mm | Rock-wool 30 mm | Concrete thickness ≧80 mm |
| 2 hours | Rock-wool 45 mm | Rock-wool 45 mm | Concrete thickness ≧ 95mm |

# Comparison of High-temperature Strength between Fire-resistant Steel & Normal Steel




**< Products >**

- Plate
- Shape
- Tube
- Box column

**< Joining material >**

- High-strength bolt
- Welding material



# Multi-storied Parking Building without Fire Protection, Using Fire-resistant Steel

Conventional parking building with fire protection (Rock-Wool)

**(Obtainment of general approval of Ministry of Land, Infrastructure, Transport and Tourism)**

Total floor area≦50,000㎡
Up to 14th floor from the topmost floor

# Application Examples for Weathering Steel

## ■ Weathering steel

**One of the weak point for steel is rust.** When the frame is exposed, the painting is most popular answer to prevent rust. But the painting will be deteriorate and we need re-painting many times.

In recent years, there are lots of application examples for weathering steel, growing need for **weather resistance based on the concept Life-Cycle-Costs (LCC)** and rising repainting and other maintenance cost.

- Reversed concept that Cr, Ni, Cu and other elements are added to ordinary steel to form stabilized rust on the steel product surface with which rust development is prevented
- Coating of treatment liquid having a color similar to that of rust aiming at earlier formation of stabilized rust
- Change of red-brown color surface to chocolate-color appearance with lapse of time



# Application Examples for Stainless Steel

- **The features of stainless steel are rustproof, durability, and architectural design. Stainless steel is generally used as materials for finishes, kitchens and dishes.**
- **In Japan, stainless steels have been standardized as the structural members for buildings and their design and construction methods have been developed.**

Office Entrance

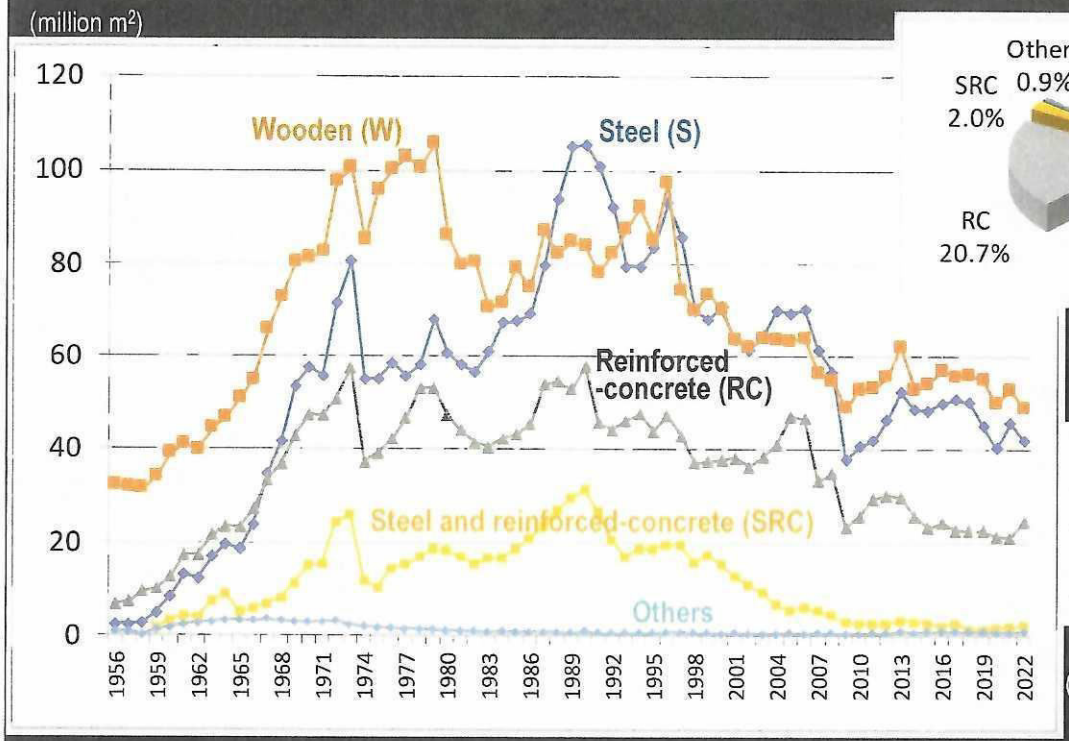
Display Space

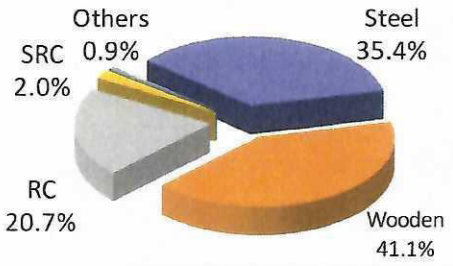
Swimming facility

- **Stainless steels (SUS304A, 316A, 304N2A specified in JIS G4321) are applicable to all buildings up to 60m-high in Building Standard Law as a building construction material.**

# Total Floor Area of Building Construction by Structural Type in Japan

**Share of Steel & SRC structure in total building construction: 37%**




**Total (FY2022): 119 million m²**

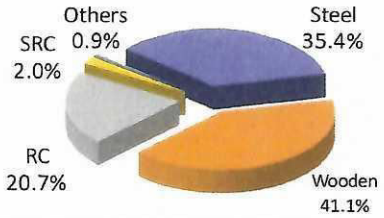
- S: 42 million m² (35.4%)
- W: 49 million m² (41.1%)
- RC: 25 million m² (20.7%)
- SRC: 2 million m² (2.0%)
- Others: 1 million m² (0.9%)

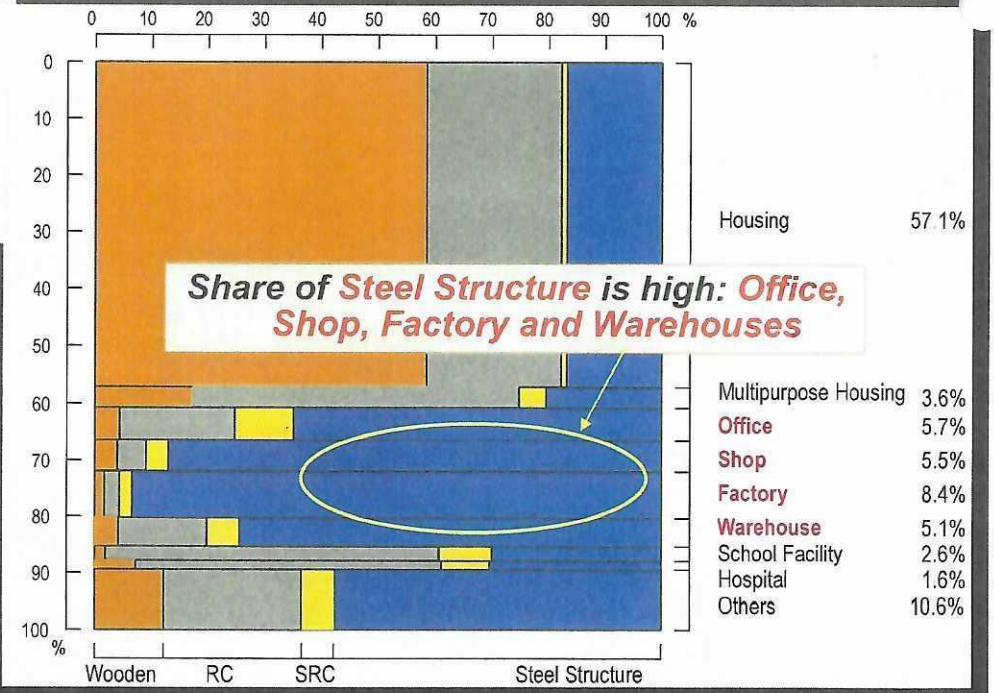




# Share of Steel Structures by Building Use

***Share of Steel Structure in total building construction: 35.4%***
***Share of Steel structure in the field of non-residential : 70%***



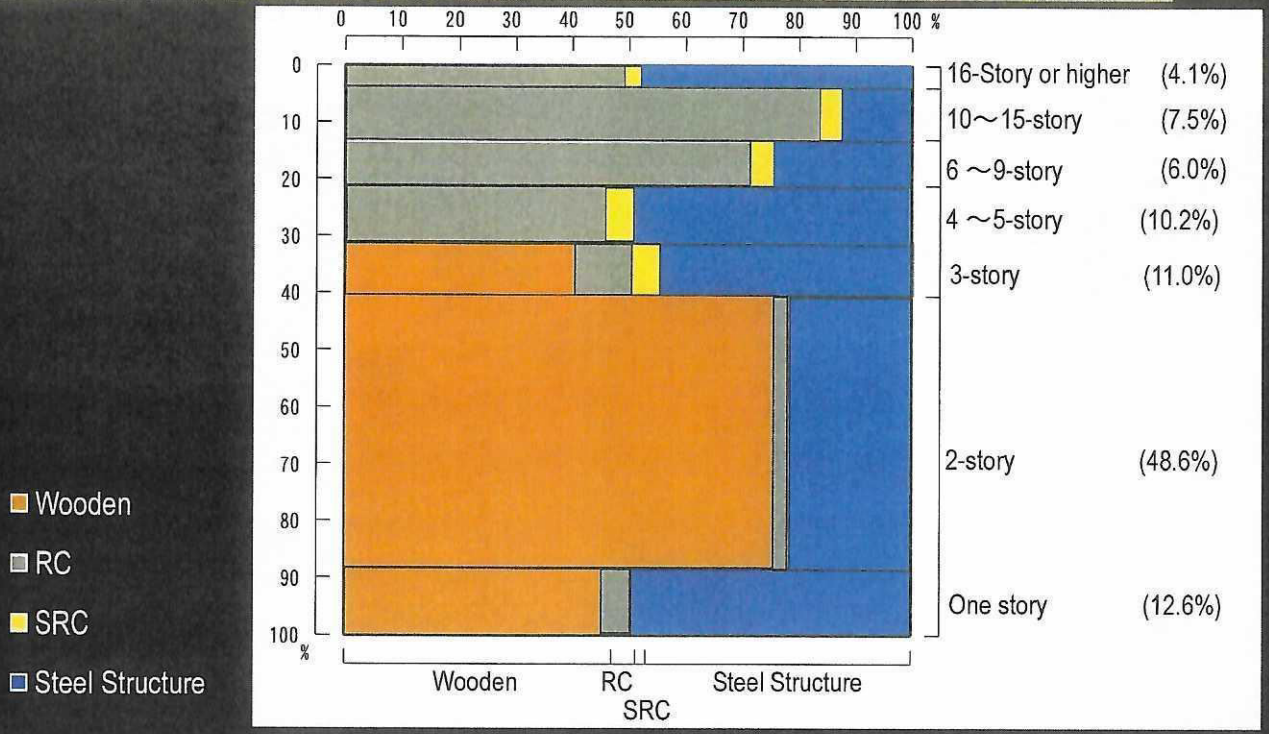




***Share of Steel Structure is high: Office, Shop, Factory and Warehouses***

Source: Building Construction Starts by MLIT

# Share of Steel Structures by Number of Stories

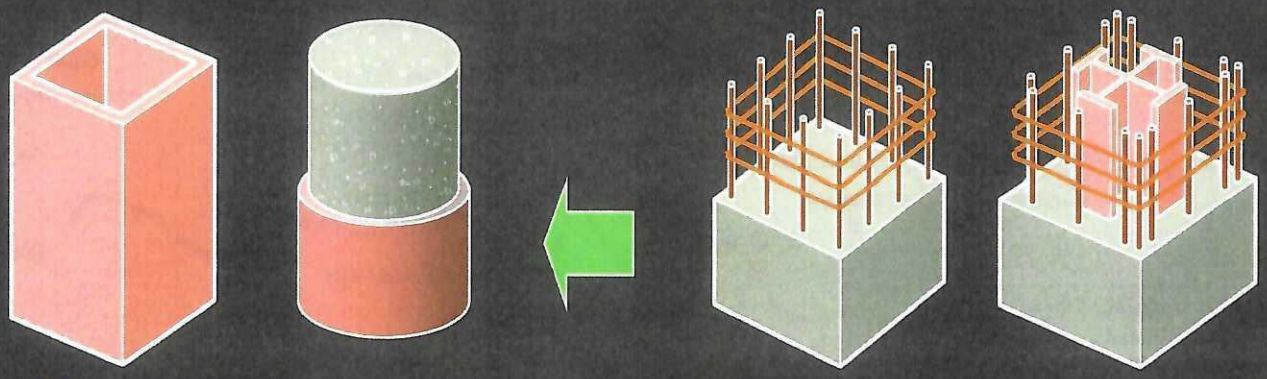
***Mid- to low-rise buildings** of nine stories or less account for almost **90% of the market.***




Source: Building Construction Starts by MLIT







Steel (S) structure

Mixed & Composite structure, i.e. Concrete-filled steel tube (CFT) structure

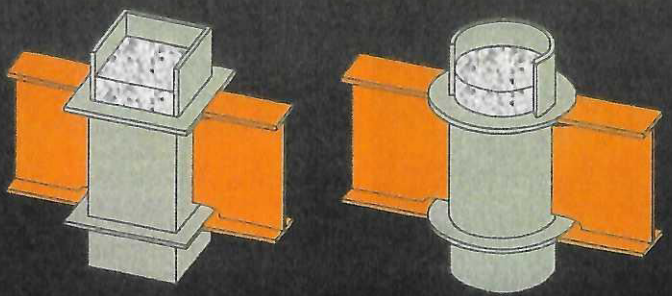
Reinforced-concrete (RC) structure

Steel and Reinforced Concrete (SRC) structure

- ***Labor Cost** will go up with **Economic Growth**.*
- ***Steel Structures** have advantages in not only seismic resistance but also **higher labor productivity and shorter construction period** than **labor-intensive RC structures**.*

# CFT (Concrete Filled Steel Tube)

- *The CFT structure is filled with concrete in steel tube.*
- *It compensates for the weakness of the RC structure and Steel structure, and has high earthquake resistance and fire resistance.*



Square Tube Type　　Circular Tube Type

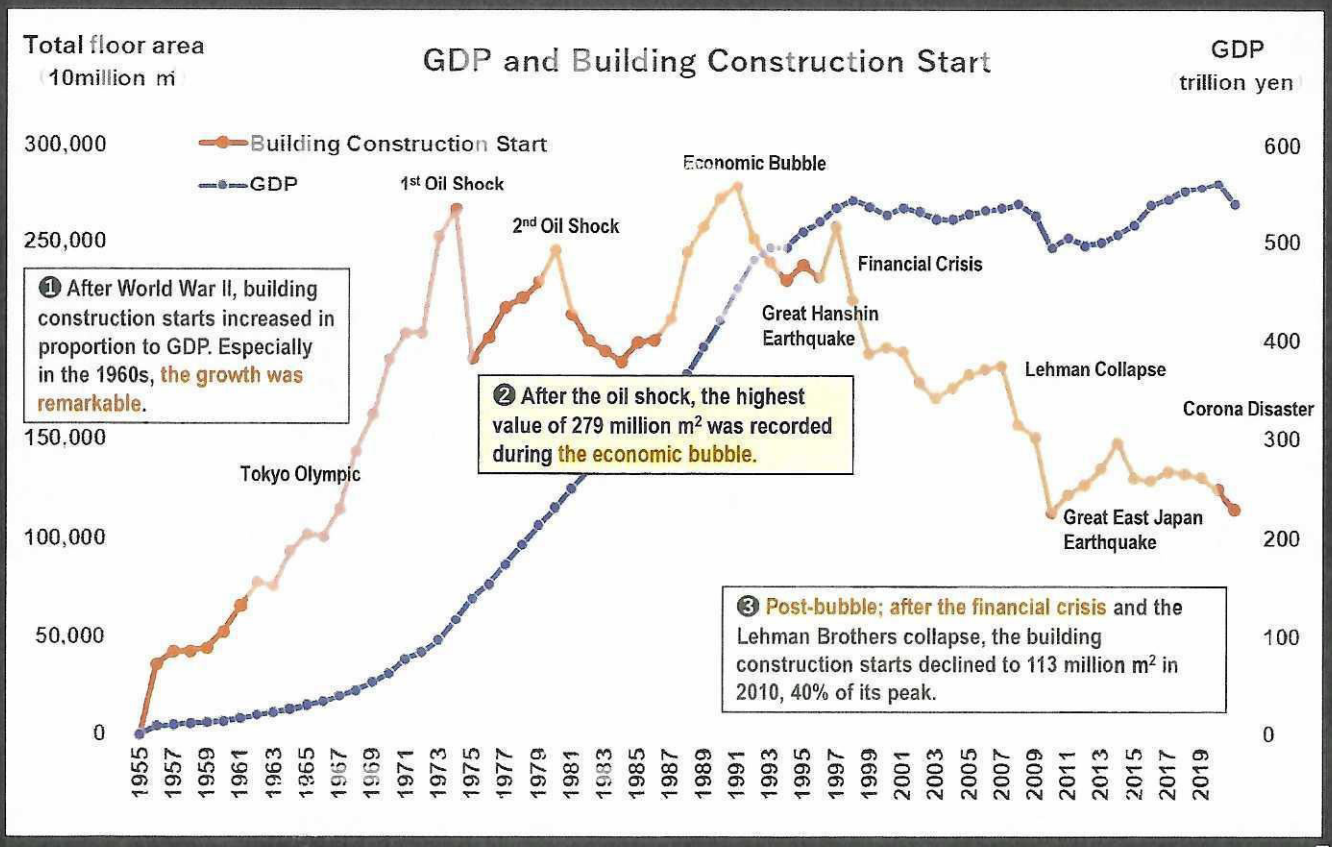
- *Confined Effect of Steel Tube & Concrete*
- *No fieldwork for reinforcing bar assembly and concrete form arrangement*
- *High Heat Capacity of Concrete*

1. *Increase of Strength and Ductility*
2. *Short Construction Period*
3. *Superior resistance to Fire, No Fireproof Covering*

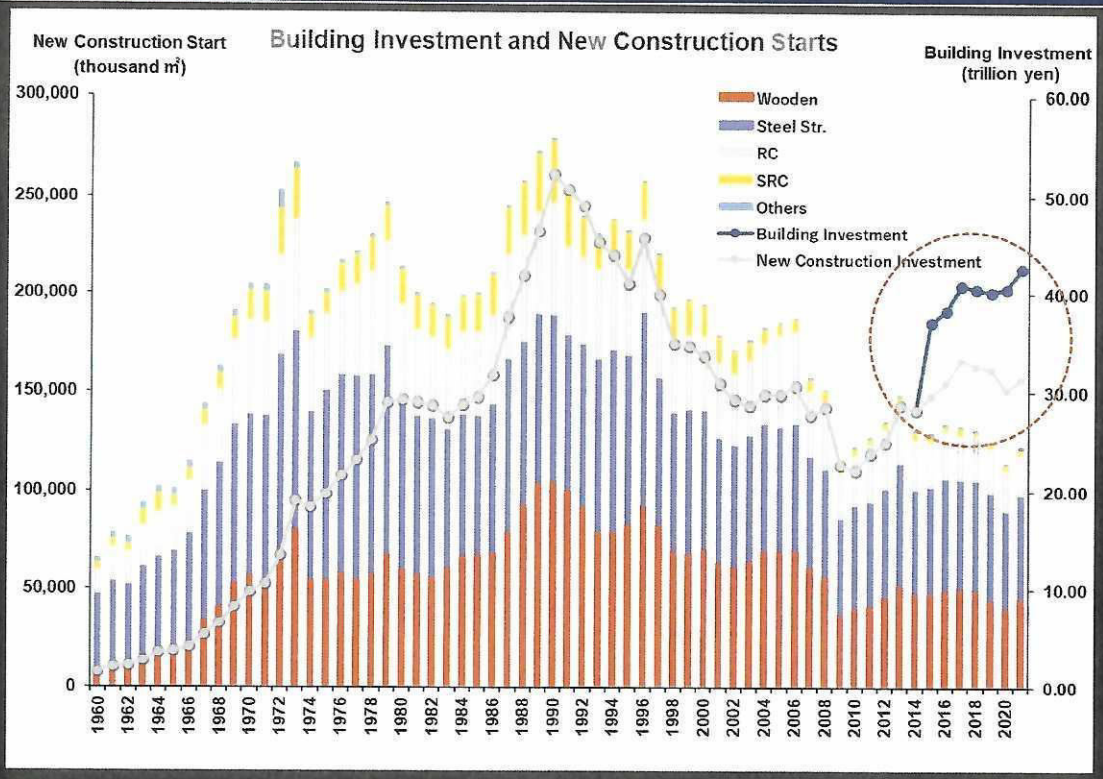




# GDP and Building Construction Start



# Building Investment and New Construction Starts




- Building investment and new construction floor area are proportional to each other.
- Repairs have been included in construction investment since 2015, accounting for 25% of the total.


57

# Historical Development of Steel Structures

## (3) Post Bubble and Current Steel Construction Market)

### (3) Post Bubble and Current situation in Japan

The MLIT's survey of building starts shows that steel and wood-framed structures each account for approximately 40% of the total floor area of new construction starts, while RC structures account for about 20%.

- In the non-residential buildings, such as offices, stores, factories, and warehouses, steel frame construction accounts for over 70%, demonstrating the advantages of steel structures; produced in factories and assembled onsite, resulting in high labor productivity, short construction periods, and quality assurance.
- Steel construction is widely used in high-rise buildings, large facilities, commercial facilities, factories and production facilities due to its high strength, large spans, and short construction periods.
- In residential applications, wooden construction accounts for approximately 60%, while steel and RC each account for about 20%. Wooden construction is typically used for detached houses, RC for medium- and high-rise apartment buildings, and steel structure, mainly by industrialized housing manufacturers, for detached houses and medium- and low-rise apartment buildings.
- RC construction has decreased in recent years due to the aging of construction workers and the shortage of skilled workers, such as form workers and reinforce workers.

The infrastructure constructed during the high-growth period has been in service for more than half a century, and the construction market is undergoing a paradigm shift from a "new construction to a stock-type society" and a "sustainable society" that requires a response to "demand for maintenance, management, and renewal".