San Francisco International Terminal, San Francisco, California.
San Francisco International Terminal
The building integrates all aspects of Architectural Engineering

Functions:- Maintain approach roadway access below terminal in east-west direction
            Simplify flow of airline passengers

Structure:- Seismic, structural spanning

Materials:- Steel, glass, concrete, fabric and aluminium cladding

Aesthetics:- Visual cohesiveness and an iconic identity;
            San Francisco is front door to the world
San Francisco International Terminal

Architect and Structural Engineering Team:- Skidmore, Owings, and Merrill (SOM)

Civil Engineering Team:- AGS, Inc.

Area:- 1.8 million Sq. Ft

Cost:- $ 840 million

Time of Construction:- May 1996- December 2000

Largest base-isolated structure in the world. Required to meet the strictest seismic requirements ever imposed on US airport terminal. The building integrates all aspects of architectural engineering.

Materials used are primarily glass, concrete, steel, fabric, aluminum cladding

The roof’s shape is an organic expression of the actual stress forces its structure must withstand
Skidmore, Owings and Merrill LLP

Founded in 1936, Skidmore
One of the world’s leading architectural, urban design, engineering and
interior architecture firms
Concieved, designed and built projects that include corporate offices,
banking and financial institutions, government buildings, health care facil-
ities, religious buildings, airports, recreational and sports facilities,univer-
sity buildings and residential developments.

Responsible for the design and construction of America’s tallest building,
the 4,600,000 square foot, 109 storey Sear’s Tower in Chicago

Have completed more than 10,000 architecture, engineering, interior
architecture, and planning projects in more than 50 countries around the
world.
**System**
5 sets of trusses 40’ center.
Consist of two of balanced cantilevered trusses supporting a
3rd central truss linked together to create a wing like form
Central truss spans 380 ft

**Two way system**
Central truss system spans existing 10 lane airport entrance
road
Cantilevered trusses span 160’
One way system
Spans overall length of 860’
Tubular truss members range from 12 to 20” diameter
Truss size 35 ft wide, 27 feet high, 140 tons each
Seismic isolation provided the lowest construction cost for achieving the desired seismic performance.

The steel seismic isolators provided the necessary strength and stability to mitigate a magnitude eight earthquake and yet deliver the desired expected performance.

The seismic design are with long spans and tall curtain walls aws accomplished with the use of 267 friction pendulum seismic isolation bearing.
Friction Pendulum
Seismic Isolation Bearing

These Friction Pendulum joints are installed between the superstructure and the foundation.

The function of this joint is to isolate the structure from the earthquake motions by the basic fundamental of a pendulum and reducing the structures natural period.

When hit by an earthquake, the articulated slider moves along the concave surface, causing the structure to move with small pendulum motions.

The dynamic frictional force hence produced helps to generate the required damping to absorb the energy of the earthquake.

The result being that the lateral forces and shaking movements transmitted to the structure is greatly reduced.

This system can accommodate strong earthquake of even magnitude 8.
West Facade- Curtain wall
Laminated glass used
705’ long
210’ wide
83’ high

Glass on the facade plays an important role in seismic and security/safety

Each glass designed to take part of the movement in a repeating unitized curtain wall (like fish scales)

11” allowable displacement between top and bottom of window wall

Breaks overall building moment into smaller components

Flexible
In event of the glass breakage, glass stays in frame/blast resistant
Two floors of conventional beam and column framing

20 slender steel columns used for support

The roof load is transferred to the column through the purlin at the top of the column

The column tapers at the top at the truss connection

It has a pinned support which performs like a fixed support

The support enables some amount of rotation to occur
ROOF SYSTEM

Function: The roof truss diaphragm and supporting box column remain elastic during extreme earthquake motions.

Design: includes both horizontal and vertical response spectra analysis resulting in design spectra shears of 78% horizontal and 100% vertical of main roof structure mass.

Form

Floating Quality

Tripartite roof form suggests flight.

Roof form based on double cantilevered truss concept.

Curving lines of its top and bottom truss chords precisely follow the compressive and tensile forces created by its long span.
Two way System:
Central truss system spans existing 10 lane airport entrance road
Cantilevered trusses span 160’

One way System:
Spans overall length of 860’
tubular truss members range from 12” to 20” diameter
Truss size 35’ wide, 27’ high and 140 tons each

Overview of the Structure Frames showing
Roof Truss- with lateral bracing
3D Space Truss- with skylights

5 sets of trusses at 40’ center
Picture shows one of the bays

Consists of two of balanced cantilevered trusses
supporting a third central truss linked together to
create a wing-form

Central truss spans 380’

Close up of Roof Truss with 2 diagonal tension
cables
Skylight system Responds to truss design. Incorporates very long thin slivers of laminated glass over the double cantilevered truss.

**Material**
Membrane panels give skylight a volume, shape and the illuminated fabric in turn is integral to the wave-form steel trusses that race the length of the terminal.

**Two way System:-**
Central truss system spans existing 10 lane airport entrance road.
**JOINT DETAILS**

- Penetration welds used for all joints
- State of the art steel tubular T-Y-K joint detailing and fabrication (diagram)
- Steel trusses sit on spherical half-joints atop 20 cantilevered steel concrete filled box columns
- Center spans are interconnected by cast steel pinned joined assemblies
- 6” diameter pins
**LOAD TRANSFER DIAGRAM**

**LENTICULAR TRUSS**

Vertical forces due to external loading conditions are transferred down to the columns by vertical supports. The diagonal members are zero-force members and cater only to stabilize the truss under varying loading conditions. The cantilevers that support the central truss are given an uplift by the overhanging cantilevers at the outboard edges of the building.

**BENDING MOMENT DIAGRAM**

Maximum vertical deflections were 4.5" under dead and live loads and 9" peak seismic loading. Frame steel weight of 30 psf and 60 psf including roof construction.

Bending moment is zero at the pinned connections. The columns are based on the FPS isolation bearings. This allows for about 20" of lateral displacement. Friction at the column base enhances structural stability.
The five center span trusses are three chord trusses consisting of two pipe top chords and one pipe bottom chord.

The 182”, 100-ton trusses were shipped on cradles in one piece from the fabrication plant.

They were lifted with a Manitowoc M250 crawler crane using nylon strings at four pick points, and walked into position.

The roof structure purlins and bracing was framed between the football trusses while they were resting on the third floor.
ROOF CONSTRUCTION

The main roof structure, with a total weight of 4,200 tons, includes five sets of trusses at 40’ centers. Each truss incorporated two 320’ long double cantilever one-way sections resting atop spherical bearing and a two-way 180’ long threechord center section.

The tubular truss members range from 12 to 28” in diameter.

All joints were complete penetration welds.
Below the trusses are two floors of conventional beam and column framing.

The 20 tall columns supporting the roof plate are made of 4” square box columns.

Partial penetration weld details are adopted in the fabrication of these box columns while full penetration weld details are adopted at column splice locations.

The connections are designed with pre-Northridge moment connection details for the moment resisting frames since the joints stresses remain elastic with the base isolation for the earthquake.
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