30 St Mary Axe, London
Norman Foster

Assignment 1: Structural and Cost Analysis

Course: Construction Technology 4 ARBE4100

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1. Introduction

30 St Mary Axe, better known as the Gherkin because is floor plan resembled a sliced pickle, is located in the heart of London's insurance district. It was originally the site of the Baltic Exchange since 1903 but was obliterated in April 1992 by the IRA. The site went under many discussions on what was to be done with it including restoring the Baltic Exchange and the proposal of an 84 storey Millennium Tower. In 1997 insurance giants Swiss Re acquired the site and commissioned Foster and Partners to design the building.

London's first environmentally sustainable tall building stands 180m high and consists of 40 storeys. The building consumes about half the energy of most skyscrapers this size. The building gradually widens at each floor plan until it reaches the 16th where it then diminishes until it reaches its apex. This distinctive form responds to the constraints of the site: the building appears more slender than a rectangular block of equivalent size; reflections are reduced and transparency is improved; (Foster+Parnters.com). The sliming of the building at ground floor maximises the public space at ground level. It helps maintain pedestrian comfort at street level as the profile reduces the amount of wind deflected to the ground compared with a rectilinear tower of similar size.

The following has been taken from Dominic Munro's report titled Swiss Re's Building, London.

1.1 Facts and Figures

Dimensions

Height to top of dome:	179.8 m
Height to highest occupied floor level:	167.1 m
Number of floors above ground:	40
Number of basement levels:	single basement across whole site
Largest floor external diameter (lvl 17):	56.15 m
Site area:	0.57 hectares (1.4 acres)
Net accommodations areas:	
➢Office	46,450 m2
➢Retail	1,400 m2
Office floor-floor:	4.15 m
Gross superstructure floor area (incl. lightwells):	74,300 m2
Tower Structural Steelwork	
Total weight of steel (from Arup Xsteel model):	8,358 tonnes
of which:	
➢ 29% is in the diagrid	
➢ 24% core columns	
➢ 47% beams.	
Total number of primary steel pieces:	8 348
Total length:	54.56 km
Diagrid column sizes:	
➢ Ground – level2:	508mm f, 40mm thick
➢ Level 36–38:	273mm f, 12.5mm thick
Hoop design tension at level 2:	7 116 kN
Perimeter column maximum design load:	15,460 kN
Core column maximum design load:	33,266 kN
Foundations	
750mm diameter straight-shafted piles into London Clay	
Number of piles:	333
Total length of piles:	9 km
Total design capacity:	117,000 Tonnes

Credits

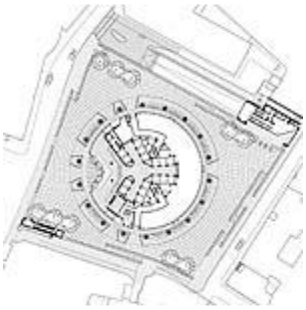
Client: Swiss Re
Project Manager: RWG Associates
Architect: Foster and Partners
Structural Engineer: Arup
Building Services Engineer: Hilson Moran Partnership
Cost consultant: Gardiner & Theobold
Fire Engineering: Arup Fire
Main Contractor: Skanska
Structural Steel sub-contractor:
Victor Buyck – Hollandia
Dome sub-contractor: Waagner-Biro

2. Structural System

2.1 Structural Form

30 St Mary Axe consists of two primary structural systems. The first being the core, which takes most of the load, and the other a diagonal braced structure 'diagrid'. The perimeter steel structural solution was developed specifically for this building in order to address the issues generated by the unusual geometry. This diagrid consists of intersecting tubular steel sections spiralling in different directions, that connect together at 360 different nodes. Each one of these nodes consists of three steel plates welded together at different angles. Each connection is up to 2m high and they link the 2,500 tonnes of steel in the diagrid. (APTA) this is an extremely strong and stiff frame, which required 20% less steel than a conventional structure and is rigid enough to require no mass damper.

2.2 Footprint

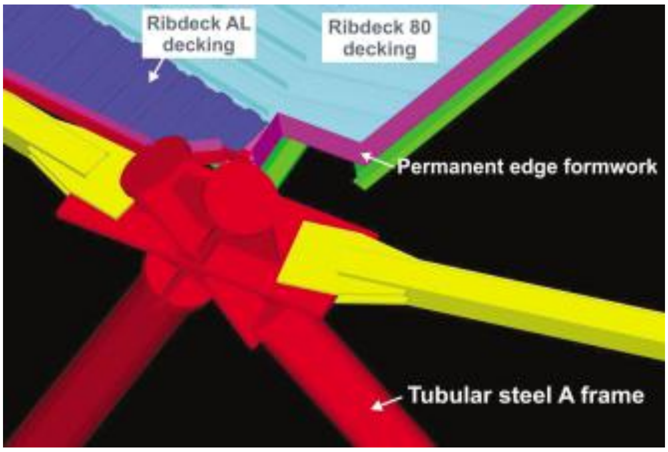


The tapered base reduces the footprint at street level allowing for more public space. This also maximises the external plaza circulation space and opens up the areas in front of the adjacent buildings.

2.3 Foundations

In December 2000, 333 750mm diameter straight-shafted piles where sunk to an average depth of 27 metres into London Clay allowing for the concrete raft to be laid for the steel structure.

2.4 Floor Systems

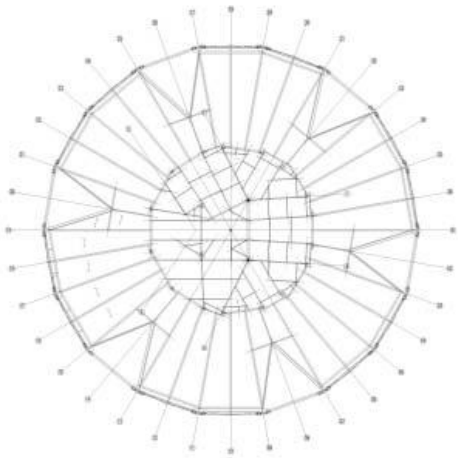


The floor framing system is a concrete slab on profile metal decking of 160mm deep. Floor plates are free from diagonal bracing as the diagrid takes this load. A typical floor plan has a six-leafed (spoke) plan around a circular service core with triangular shaped voids cut out to act like light-wells. Floors are rotated clockwise 5 degrees which every storey, creating six helical or corkscrew voids. These twisting atria are sealed at every sixth floor to prevent fire spread.

The structural requirements of the building allowed Ribdeck 80 to be chosen for its capability of longer span performance in combination with its shallow slab construction. The maximum span of the floor slab is 4.8 metres and a 160mm deep lightweight concrete floor slab was designed to achieve a fire resistance of up to two hours with only light fabric reinforcement in the top.

For flexible and adaptable office space a regular internal planning grid is required. The office floors are organised into six spokes, arranged on a 1.5m grid around a circular service and lift core. (MCRMA) The result is a maximum 14m ‘core to glass’ internal dimension, with all parts of the office fingers within 8.5m of a light-well. The light-wells are offset at each successive floor by 5 degrees.

Left:Structural plan near mid-height of building (showing arrangement of clear-span radial floor beams aligning with perimeter column positions and lightwell edges).



2.5 Wall Structure

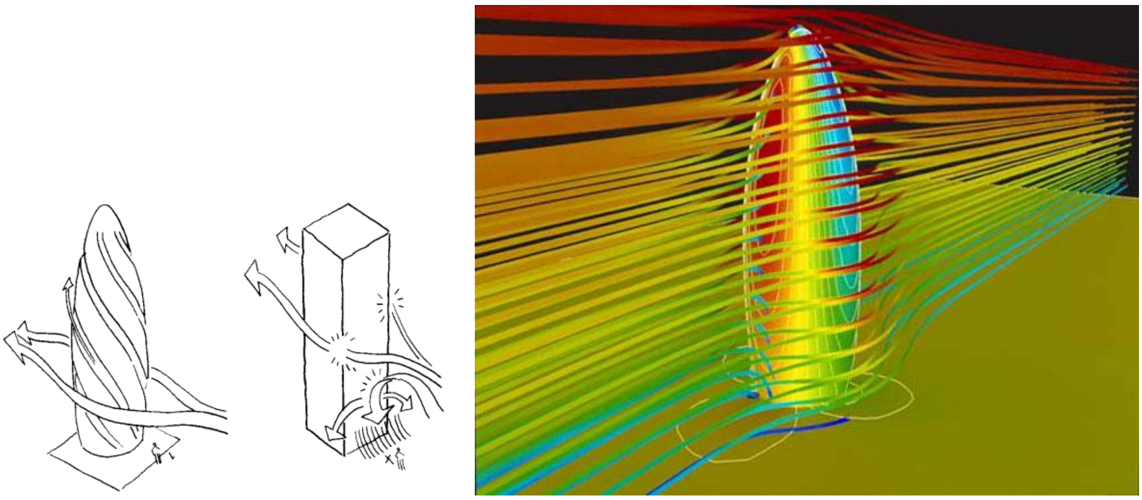
The double-skin energy efficient facade is made of glass, with aluminium profiles and a steel frame. It consists of 24,000 square metres of glass arranged in diamond-shaped panes.
The envelope at the office areas consists of a double-glazed outer layer and a single-glazed inner screen that sandwich a central, ventilated cavity containing solar-control blinds. These cavities reduce the need for mechanical heating and cooling by acting as a buffer zone and are ventilated by exhaust air drawn from the offices.

The elements of the facade include; perforated aluminium louvers, facade frame of extruded aluminium, open able glass screen and a column casing of aluminium. The air conditioning system is increased with the assistance of natural ventilation through the windows in the light wells opening automatically. This system allows the building to save energy for up to 40% of the year.

2.6 Beams

The use of wide flanged (European profile) beams minimises the depth of beams required. The beam depth is the most critical in the primary service distribution zone around the core, whilst there is a less critical fit at mid-span. (Munro) This allows adequate clearance for services. The beam spans are much reduced within the cores, allowing the horizontal separation of structural and services zones. The only area where beam web penetrations are required is around the perimeter where supply and exhaust air is ducted via plenum boxes connected to the back of slotted façade transoms.

2.7 Wind Loads



One of the reason for the buildings shape is that a curve vertically as well as horizontal is more aerodynamic and can reduce vortices which can generate strong gusts at the base. This can be seen in the image above. Floors are concrete and share the lateral wind stress with the diagrid. The strength of the diagrid is strong enough that the core does not have to resist wind forces. Therefore the core only has to handle the vertical loads for which steel would be sufficient. The diagrid resists the wind load by transferring the load through the steel perimeter then to the connection and continue to disperse until it reaches the foundation of the building. The total design sway of the building was 50mm over the height of 180m (Munro).

2.8 Bracing

The diagrid responds to the building's curved shape and provides vertical support to the floors thus allowing large internal column free office space. The central core is required only to act under vertical load and is free from diagonal bracing.
The key components of these connections are three steel plates that are welded together at differing angles to deal with the complex geometry of the tower's perimeter structure.

2.9 Dome

The dome is a steel and glass structure 30 metres in diameter and rising 22 metres from its support on the top of the perimeter diagrid. The dome steelwork is a fully welded lattice of intersecting fabricated triangular profiles. The efficiency of this structural arrangement results in very minimal steel elements that are only 110mm x 150mm in section. (Munro)

The top lens of the building is the only curved glass piece on the entire structure. It has a diameter of 2.4 metres and weighs 250 kg.

2.10 Environmental Sustainability

30 St Mary Axe has been fitted with many energy saving devices such as; light level and movement sensors preventing unnecessary lighting. Also blinds which are located within the cavity of the ventilated double skin, which intercepts solar gain before it enters the office environment. The building offers decentralised on-floor plants. These offer flexibility to supply and control mechanical ventilation on a floor-by-floor basis allowing energy consumption to be reduced compared with a central system supplying the whole building.

3. Elemental Costing

The following elemental costs for 30 St Mary Axe are based on:

OFFICE
LETTIBLE HIGH RISE (FULLY SERVICED) – Shell and Core Lettable
Prestige 36 – 50 Storey (Rawlinsons, 2008 p93)

TRADE DISCRIPTION	$/sqm	%	TOTAL $
PRELIMINARIES	1126.75	23.79	73,238,750.00
SUBSTRUCTURE	34.50	0.73	2,242,500.00
SUPERSTRUCTURE			
Steel Columns/ Beams	337.40	7.12	21,931,000.00
Steel Diagrid	171.60	3.62	11,154,000.00
Upper Floors	304.50	6.43	19,792,500.00
Staircases	27.75	0.59	1,803,750.00
External Cladding	573.5	12.11	37,277,500.00
External Doors	4.75	0.10	308,750.00
Internal Walls	136.50	2.88	8,875,500.00
Internal Screens	13.75	0.29	893,750.00
Internal Doors	28.75	0.61	1,868,750.00
FINISHES			
Wall	56.75	1.20	3,688,750.00
Floor	48.00	1.01	3,120,000.00
Ceiling	96.00	0.20	6,240,000.00
FITTINGS			
Fitments	28.50	0.60	1,852,500.00
Special			
SERVICES			
Plumbing	143.00	3.02	9,295,000.00
Mechanical	675.75	14.27	43,923,750.00
Fire	109.00	2.30	7,085,000.00
Electrical	295.75	6.24	19,223,750.00
Transportation	327.25	6.91	21,271,250.00
Special	9.25	0.20	601,240.00
CONTINGENCY	113.25	2.39	7,361,250.00
PARKING (1980m^2)	1445.00	0.93	2,861,100.00

EXTERNAL PLAZA (2000m^2)	1000.00	0.65	2,000,000.00
SUB TOTAL			307,909,340.00
G.S.T (10%)			30,790,934.00
LOCATION (Newcastle +105)			15,395,467.00
TOTAL (including GST)		100.00	**$354,095,741.00**

Resources

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