

PROPERTIES OF FRAMING MATERIALS

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Introduction

Hong Kong is an international port and a major global financial center. It is also one of the most densely populated cities in the world, with a skyline defined by an exceptionally high concentration of skyscrapers.

This assignment focuses on Central Plaza, a 374 m, 78 stories skyscraper located at 18 Harbour Road, Wan Chai, Hong Kong. Completed in 1992, it was the world's tallest reinforced concrete building at the time and remained the tallest building in Asia until 1996 (Skyscraper Center, no date).



Figure 1: Central Plaza gleaming under daylight



Figure 2: Central Plaza illuminated against the harbour skyline

Part 1: Original Design and Construction Method

Original Design Element

Central Plaza's floor plan is triangular in form, with the three corners chamfered to provide better internal office spaces and improve usable floor area (Hui, 2001; ICE, 2026). The triangular form was chosen to maximize the number of harbour-facing offices, providing approximately 20% more floor area with harbour views compared to a square or rectangular building (Hui, 2001). The shape also proved effective in managing the high wind loads characteristic of Hong Kong's typhoon-prone climate, which was a key structural design constraint (Ayres and MacArthur, 1993, p. 16). The exterior curtain wall is clad with gold and silver coated reflective glass, arranged in a vertical and horizontal pattern to give the tower its distinctive appearance (Hui, 2001; Vollers and Geometries, 2005). The facade also incorporates 720 tonnes of granite, covering an area of 40,060 m² (ICE, 2026). Moreover, the tower is divided into three vertical zones: a 30.5m base entrance lobby and podium, a 235.4m tower body containing 57 office floors, and a sky lobby at Level 46, capped by a 102m mast at the tower top. The structural system consists of reinforced concrete core walls combined with perimeter columns at 4.6m centers and 1.1m deep edge beams, with the core providing primary lateral stability. Deep bored caissons founded on bedrock support the structure, while top-down basement construction allowed superstructure work to proceed simultaneously, keeping the programme on track (Ayres and MacArthur, 1993, pp. 16–17).

Construction Method

The construction relied on two formwork systems to maintain a rapid programme.

To begin with, the climbing formwork was used for reinforced concrete core walls. It is a self-climbing hydraulic system that requires no crane assistance, hence reducing crane dependency and accelerating the core cycle. Secondly, the table form was adopted for the floor slabs, with large pre-assembled panels lifted floor to floor. It significantly reducing labour and shortening the floor cycle to an average of four days per floor at peak (Ayres and MacArthur, 1993, pp. 18–19). This is a remarkable achievement for a building on this scale. High-strength Grade 60 concrete was pumped to height throughout the tower, pioneering its use in Hong Kong’s private sector and enabling more slender column sections without sacrificing load capacity.

The overall construction programme ran from 1989 to 1992, with topping-out completed on 9 April 1992. Notably, the first tenants occupied the lower floors while upper-floor concreting was still ongoing, a phased occupation strategy that allowed early revenue generation without delaying structural completion (ICE, 2026).

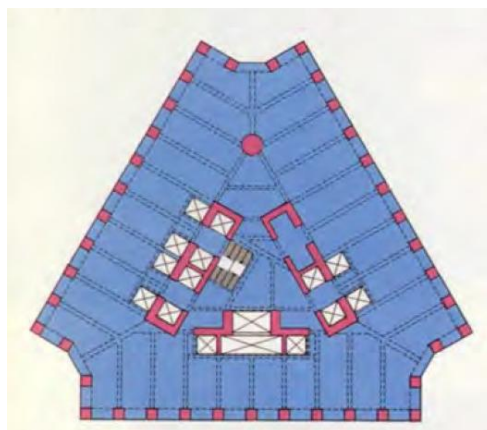


Figure 3: Typical plan of lower zone up to Level 26 (Ayres and MacArthur, 1993, p. 19)

Part 2: Framing Material Analysis

2.1 Strength, Durability and Climatic Resistance

Strength Performance

Central Plaza required concrete significantly stronger than the Hong Kong Building Authority's standard limit of 45 N/mm². Approval was sought and granted for Grade 60 concrete, with a 28-day cube strength of 60 N/mm², which was considered achievable using locally available materials (Ayres and MacArthur, 1993, p. 19). Rigorous quality control measures were enforced, including cube sampling from every concrete delivery truck. In addition, to manage the heat generated by the high-cement-content mixes in large-diameter columns, cooling measures were initially introduced. Later, pulverized fuel-ash (PFA) was used as a cement replacement, ending the need for active cooling entirely (Ayres and MacArthur, 1993, p. 19).



Figure 4: Foundations from the air, showing the very large diameter main caissons. (Ayres and MacArthur, 1993, p. 19)

Durability in Coastal Environment

Central Plaza's reinforced concrete frame faces significant durability challenges due to its coastal waterfront location on reclaimed land, with a water table just 2–3m below ground level (Ayres and MacArthur, 1993, p. 18). Carbonation gradually lowers concrete pH, compromising the passive layer protecting embedded reinforcement, while chloride ions from the nearby harbour can penetrate the concrete cover and accelerate rebar corrosion. These risks are mitigated through the specification of Grade 60 high-strength concrete, producing a dense, low-permeability mix resistant to ion ingress (Ayres and MacArthur, 1993, p. 19). Below-grade water ingress subsequently required remediation using a crystalline waterproofing treatment (Kryton, 2016). Also, the inherent non-combustibility of concrete also provides maintenance-free fire resistance throughout the building.

Climate Resistance

Wind resistance was a primary structural consideration for Central Plaza given Hong Kong's typhoon-prone climate. Above the tower base, lateral stability is provided by the tube nature of the external façade frames, comprising columns at 4.6m centers and 1.1m deep edge beams, while the reinforced concrete core transfers the full wind shear to the foundations at the lower levels (Ayres and MacArthur, 1993, p. 18). To validate performance, a detailed wind tunnel study was conducted by Professor Alan Davenport at the Boundary Layer Wind Tunnel in University of Western Ontario. The study uses a design wind speed of 64 m/s based on a 50-year, three-second gust. The analysis predicted a maximum sway of approximately 400mm at the 75th floor, with peak accelerations of less than 20 milli-g (Ayres and MacArthur, 1993, p. 19).

2.2 Time, Labour, Programme and Cost Compared to Steel Framing

Construction Speed, Labour Consideration, Programme Advantages

The original steel scheme had envisioned an externally cross-braced framed tube with a steelwork core designed to carry vertical load only (Hui, 2001). By switching to reinforced concrete, the use of climbing and table formwork enabled a four-day floor cycle at peak, meaning the reinforced concrete frame took no longer than the original steel scheme (Ayres and MacArthur, 1993, p. 21). Moreover, this approach allowed a temporary occupation permit for the lowest 27 floors was granted in October 1991, with the first tenants moving in by January 1992 while upper floors were still under construction (Ayres and MacArthur, 1993, p. 21). Therefore, it maximized early rental revenue without compromising the overall programme.

Cost Analysis

The switch from the original steel scheme to reinforced concrete resulted in substantial cost savings for building developers. The reinforced concrete structure was estimated to save HK\$230 million compared to the equivalent steel scheme, a decisive factor in the developer's financial review (Hui, 2001; Ayres and MacArthur, 1993, p. 17). Also, further savings were achieved by reducing the floor-to-floor height to 3.6 meters. Every additional meter of building height would have increased structural costs by over HK\$1 million. This reduction saved approximately HK\$30 million across the 58 office floors (Hui, 2001). The total construction cost of the completed tower was HK\$1,100 million, equivalent to HK\$6,300 per square meter (Hui, 2001).

2.3 Ease of Assembly and Adaptation Within Building Life Cycle

Assembly Efficiency and Adaptability to Building Shape

The repetition of identical floor plates at Central Plaza allowed climbing and table formwork systems to be reused across successive floors, directly enabling the four-day floor cycle achieved at peak construction (Ayres and MacArthur, 1993, p. 21). Moreover, reinforced concrete's cast-in-place nature also offered significant geometric flexibility. The triangular plan of the building with truncated corners could be executed without the complex fabrication and connection detailing that a steel frame would have required (Ayres and MacArthur, 1993, p. 18; Hui, 2001). This adaptability to irregular geometry is a key advantage of concrete in architecturally complex high-rise construction.

Adaptability to Different Uses and Life Cycle

Central Plaza's structural system delivers column-free office floors with clear spans of 9-13.4m from core to perimeter, achieving an overall usable floor area efficiency of 81% (Hui, 2001). This open-plan flexibility allows tenant layouts to be reconfigured without structural intervention, supporting long-term commercial viability. The building has maintained its primary office use for over 30 years since completion in 1992 (ICE, no date). This demonstrates that when the initial structural design closely matches the intended use, the need for major adaptation is limited. Also, this must be weighed against the general limitation that concrete structures are more intrusive to modify than steel-framed buildings.

2.4 Integration of Services Provision: Problems and Solutions

Problem 1: Horizontal Service Distribution and Floor-Ceiling Void

Reinforced concrete construction inherently limits space for horizontal service distribution. Unlike steel frames with open-web joists through which services can pass freely, the 1.1m deep perimeter edge beams at Central Plaza restricted how ducts, conduits, and pipework could run around the building perimeter (Ayres and MacArthur, 1993, p. 18). Furthermore, the floor-to-floor height of only 3.6 meters, resulting that there are only a 1m ceiling void to accommodate all building services (Hui, 2001). To overcome this, the structural and mechanical and electrical engineers coordinated closely to concentrate vertical risers within and around the reinforced concrete core. By minimizing the length of horizontal service runs on each floor, congestion within the limited ceiling void can be alleviated (Hui, 2001).

Problem 2: Core Penetrations and Vertical Distribution Strategy

A further challenge arose from the solid reinforced concrete core walls, through which all penetrations for ductwork, pipework, and conduits had to be pre-formed during casting. Post-drilling reinforced concrete for missed sleeves is both structurally compromising and practically disruptive (Hui, 2001, section 2.1). To manage this, the design team employed precise traditional drawing coordination to pre-sleeve all penetrations accurately before casting. Vertically, the solution relied on eleven dedicated mechanical plant floors. It acts as distribution of hubs at regular intervals throughout the building's height. This approach minimized the length of horizontal service runs on typical office floors, compensating effectively for the inherent rigidity of the reinforced concrete structure (Hui, 2001, sections 1.4, 4.2).

2.5 Challenges at End of Life: Demolition Considerations

At end of life, the reinforced concrete structure poses significant challenges. Unlike steel-framed buildings, where bolted connections permit selective deconstruction and material recovery, reinforced concrete is monolithic and must be physically broken apart (Hugo Cox, 2021). This process would generate enormous volumes of concrete rubble from a structure spanning 173,000 m² of total floor area (Hui, 2001). The building's height of 378.4 meters, combined with its location in a highly built-up area of Wan Chai surrounded by busy roads and neighbouring buildings, would make any future demolition extremely complex, requiring strict management of vibration, dust, and traffic (Hui, 2001). While the resulting concrete rubble can be processed into recycled concrete aggregate, its reuse in Hong Kong is stringently restricted to non-structural applications (Poon and Chan, 2006).

Part 3: Negative Impact of Concrete Production – Community and Environment

The concrete used in Central Plaza's construction carried significant environmental and community costs at the production stage. Cement manufacturing alone accounts for approximately 6–8% of global CO₂ emissions, with each ton of cement releasing around 0.8–0.9 tons of CO₂, through the calcination of limestone in kilns operating at approximately 1450°C. This chemical process releases CO₂ regardless of the fuel source used (Bărbulescu and Hosen, 2025). Beyond greenhouse gas emissions, cement plants discharge particulate matter, nitrogen oxides, and sulphur dioxide. These toxic gases are directly linked to respiratory disorders and cardiovascular diseases. Additionally, noise levels at cement facilities commonly exceed 80 dB(A), causing hearing loss among workers and significantly disrupting nearby residents (Bărbulescu and Hosen, 2025).

Part 4: Sieve Analysis

4.1 Sieve Table Calculation

Sieve Size (mm)	Mass (g)	% on sieve	% Passing
125	0	0	100
75	0	0	100
63	0	0	100
37.5	120	9.6	90.4
20	137	10.96	79.44
10	143	11.44	68
6.3	105	8.4	59.6
3.35	45	3.6	56
2	130	10.4	45.6
1.18	63	5.04	40.56
0.6	105	8.4	32.16
0.3	102	8.16	24
0.212	109	8.72	15.28
0.15	98	7.84	7.44
0.063	55	4.4	3.04

4.2 Sieve Calculations

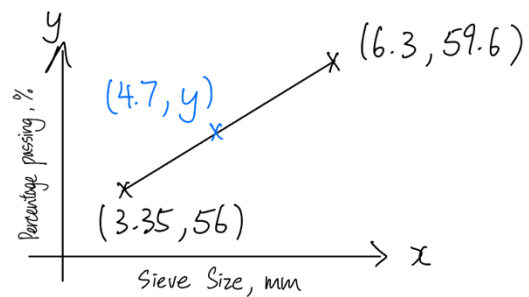
% of fine aggregate = 59.6%

% of coarse aggregate = 40.4%

For more precise calculations, by using particle size greater than 4.7mm is coarse aggregate, and particle size less than 4.7mm is fine aggregate,

$$\frac{59.6 - 56}{6.3 - 3.35} = \frac{59.6 - y}{6.3 - 4.7}$$

$$y = 57.65 \text{ (cor. to 2 sig. fig.)}$$



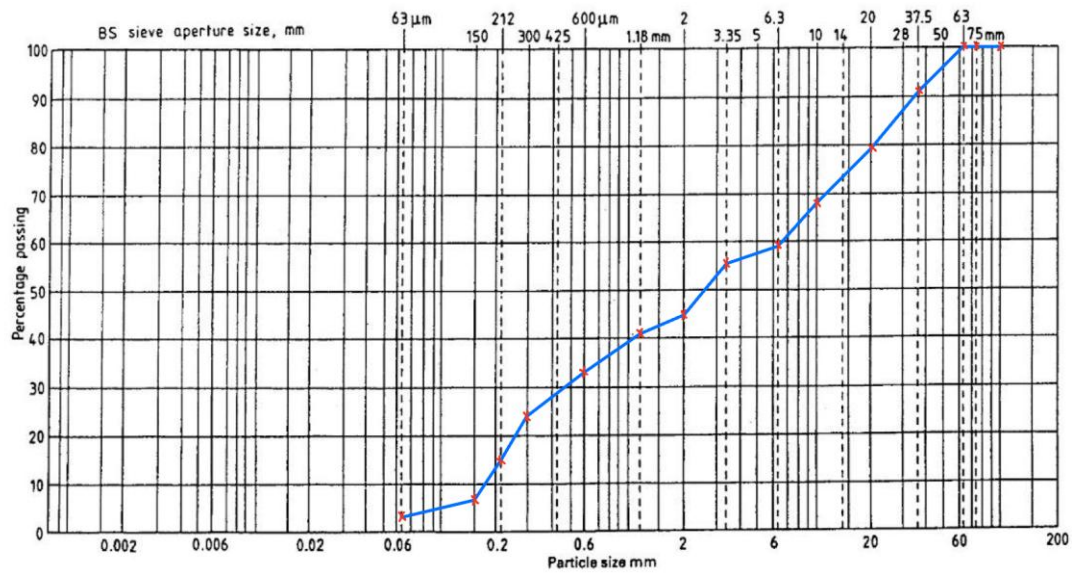
Using two-point form, 57.65% is the approximate % in 4.7mm sieve.

Hence,

% of fine aggregate $\approx$ 57.65%

% of coarse aggregate $\approx$ 42.35%

4.3 Particle Size Distribution Chart



4.4 Comment about the result

The sieve analysis shows that it is a well-graded aggregate. There is no significant gap in sizes, around 57.65% fine and 42.35% coarse aggregate. Resulting a higher proportion of fine aggregate than coarse aggregate. It is desirable for making concrete, as the space between larger particles is effectively filled by smaller particles to produce a well-packed structure.

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Figure 1: Central Plaza gleaming under daylight.

Figure 2: Central Plaza illuminated against the harbour skyline.

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