The Beetham Tower Project:

Planning for Repetitive Activities (A)

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In that late afternoon in June 2003, Mark Connolly, the project manager for the Beetham tower, mulled over using the line-of-balance method[1] vis-à-vis the traditional activity-base network method for planning the delivery of Beetham Tower project. The Beetham tower was the first high-rise ever to be erected in Manchester, a city long renowned for its technological achievements in the industrial revolution (**Exhibit 1**). At planned completion, the massive 47-storey 171m glass tower would be the second tallest building in the UK and the tallest residential building in Europe. Mark needed to include a high-level schedule in the planning application that Beetham wished to submit to the local authority by the end of the month, thereby putting an end to a one-year long design development process in the run up to submit the application.

Mark Connolly worked for the Beetham Organization, a real estate developer leading a trend in the UK towards the mixed-use skyscraper concept that brought together two occupancy types: a deluxe hotel in the lower storeys and high-rise living in the top storeys for well-paid professionals. Mark had spent the morning discussing project planning with two colleagues: Ian Simpson of Ian Simpson Architects, the chief architect for the Beetham tower and Anthony Winch, project manager for another 40-storey residential tower that Beetham was developing in Birmingham. Mark now needed to put together the schedule based on his notes about the activities, resources, and estimated durations.

The question for Mark was whether he could commit to hand over the hotel as a block to Hilton International sometime in February 2006 and to hand over the apartments from May to September 2006. Mark wondered what the risks would be to commit to such timescale. Speeding project delivery was attractive to minimize the impacts of construction work on the surrounding streets, stimulate the apartment sales, and maximize the return on investment. Mark was aware, however, that projects seldom happened as planned: the planning applications could be called in during the 13-week judicial review period, delaying the whole process; the contractors could fail to deliver as fast as planned in; and the soil conditions could turn out different from what they initially anticipated. Wind could also be a major difficulty as strong winds could temporarily disrupt crane operations. Thus, Mark pondered whether he ought to add some contingencies to the project plan, and if so, where and how big the contingencies should be.

[1] The Line of Balance technique was originated by the Goodyear Company in the early 1940's and developed by the U.S. Navy in the early 1950's for the programming and control of both repetitive and non-repetitive projects.

Background: Beetham's Skyscraper Development Business

The escalating costs of well-located plots of land in the late nineties made European real estate developers interested in developing skyscrapers as a means to meet demands for exquisite living and office space in the city centres while maximizing return on the capital investment. Across the UK, for example, more than 80 towers, each higher than 20 storeys, were either being built or planned in 2005, offering in total an estimated 18,840 apartments[2]. One trend emerging was the development of mixed-use skyscrapers with at least 40 storeys bringing together two occupancy types: a deluxe 200 to 300-bed hotel in the lower floors and high-rise apartments for high-paid professionals on the top floors. The proven business model had been pioneered by Donald Trump - the pre-eminent developer in the North American market. Residential skyscrapers could be much slender than traditional office blocks because buildings used for living, rather than working in, did not require more than 3,000m2 area per floor plate. In contrast, office blocks required around 7,000m2 of letable area per floor. Residential skyscrapers suited the limited areas of land plots available in historic city centres, as well as the developers' interest to limit the capital investment on land acquisition. Despite the multi-million pound price of the apartments, they remained attractive to high-earners. Among other reasons, buyers appreciated the breathtaking views, the convenience of living in city centre, and the amenities provided by the deluxe hotel, such as spa and health club with swimming pool, 24-hour concierge services, doormen, world-class restaurant, closed-circuit television, and valet parking in the garage.

Beetham Organization was a family-owned property developer operating in the UK market, making a name for itself as one of the UK's premier skyscraper developer. In 2003, Beetham had a number of skyscrapers under planning or development in Liverpool, Manchester, Birmingham and London. In these projects, Beetham had consistently adopted the mix-used business model, working closely with luxury hoteliers, such as Hilton, Radisson SAS, and Shangri-La. Furthermore, Beetham systematically offered the customers of its apartments the possibility to customize the internal decoration, which helped to sell out most of the apartments before the start of the construction on-site. Unlike the apartments, however, Beetham remained the proprietor of the hotels. The hotelier was granted about 6 weeks to train the staff between the hand over of the completed premises and opening day.

[2] Pickard, J. (2005). "Europe's tallest residential skyscraper planned for London," *Financial Times*, 30th June

The business of developing skyscrapers in city centres was highly controlled by the local authorities. While British authorities had developed a more relaxed approach to high buildings in city centres over time, developers still had to struggle to speedily get planning permission before construction could start. The schedule or time plan for the project was a key document that needed to go into a planning application to inform the local authorities about how long the overall development process would last, and in particular, how long the construction process would impact to the surrounding environment. The schedule needed to realistically represent the main tasks required to complete the project, the sequence by which the tasks would unfold, and the methods of construction involved. Yet, too much detail could make it hard to read for non-planners and ultimately have deleterious effects to the success of the planning application. Speeding up project delivery into short-range timeframes was an essential condition to facilitate the sale of the apartments and cash in earlier.

The Skyscraper Development Process

The lead time to deliver a skyscraper, from the outset through design development until completion of the construction work on-site could take more than 4 years. The early stages of the skyscraper development process prior to submitting the planning application could last about one year. In this initial period, Beetham would put together a team of design consultants led by a design manager, including the architect, specialist engineers in foundations, structures, mechanics, electrics, acoustics, security, and fire safety, as well as environmentalists. This team was responsible for developing a design scheme compatible with the environmental constraints and site restrictions, as well as for ensuring its constructability and economical feasibility. In this period, critical design decisions had to be made about the height and volume of the tower to simultaneously satisfy the commercial and planning requirements. To increase the chances that a planning application would get approved, Beetham would make various presentations of the skyscraper concept to relevant stakeholders, such as the Lord Mayor, English Heritage, CABE[3], and owners of neighbouring properties. Beetham would then use their feedback to make any needed changes.

After submitting the planning application, Beetham had to wait about 13-weeks, the duration of the judicial review period, to receive a response on whether the local authority had approved the planning application. Beetham usually used this interim period to negotiate

[3] The Commission for Architecture and the Built Environment, a public agency taking the role of governor's advisor

construction contracts with the general and specialist contractors to whom Beetham novated the team of design consultants. Beetham tried to have the work starting on site typically within one to two months after receiving the green light from the city authority.

The construction process of skyscrapers had a repetitive nature stemming from the large number of floor plates, and the similarity between the mechanical, electrical, and architectural designs across the various floors. Beetham had a reputation of developing challenging project schedules based upon innovative construction methods and technology. In these schedules, compressing the construction process was key to make the project financially viable. Beetham paid interest on the borrowed capital until reaching positive cash flow through the sales of the apartments. A week off the project construction schedule could save Beetham up to £200,000 in a project. A reliable project plan had to take into account the effects of foreseeable uncertainties, including windy weather conditions; scarcity of skilled labour; as well as local constraints on site accessibility and on blocking streets for off loading materials and equipment. Wind, in particular, was a major factor to consider when developing project schedules for high rises. To increase the project schedule reliability, a contingent period could be added to take into account a number of days when wind speeds would exceed 40 miles per hour (mph) high above the ground. Above this limit, the cranes and hoists necessary to lift materials and workers could not be used. While wind speeds increased exponentially with an increase in the vertical distance to the ground, the only available metrological data records on wind speeds in Manchester suggested that mean wind speeds on the ground were consistently far below 10 mph in Manchester (**Exhibit 2**).

Another uncertainty in terms of construction progress on site was crane availability. Like a jailed animal, skyscraper construction work starved unless a crane constantly fed it with materials and labour. Cranes, however, could break down, or take longer to assemble if the contractor requested a change. For example, a request to change the crane location in relation to the original location agreed in the planning application could easily take a few weeks to get authorization. Further, crane suppliers needed at least 6 to 8 weeks advance notice to make sure they could provide a crane on time.

Risk Managing Approach

Beetham's approach to risk management was a traditional one in building development projects. In essence, it involved specifying upfront the types of foreseeable risks and how they could impact to the project delivery speed and budget. These risks, as well as a budget contingency to cope with their hypothetical occurrence, were spelt out in the contractual agreements to sign in with the main contractor. Chronologically, the process started by Beetham first putting out for tender the set of documents included in the planning application, such as design drawings and specifications, and logistics plan. After receiving a set of bids from contractors interested in taking the job, Beetham interrogated a selected number of contractors about the proposed time estimates and costs to perform the various tasks. If a contractor said that he needed two days to drive a pile, for example, Beetham assessed the extent the contractor was being conservative in its prediction to mitigate the risk of delays. Eventually, Beetham would suggest alternative construction methods to speed delivery, and get the contractor to agree. As far as the weather conditions were concerned, Beetham and the contractors jointly looked to historical data on the average number of days in the year when wind speeds had exceeded the limit above which cranes and hoists would not be able to operate, and accordingly agreed a time extension free of Liquidated Ascertained Damages (LAD).

Further, Beetham 'novated' to the contractor the original team of design consultants in the negotiation phase to reduce the number of contracting parties. Accordingly, the main contractor was contractually committed to employ the team of design consultants involved in the planning stage, and took professional liability for the design. The negotiation process between Beetham and the contractor concluded when they jointly agreed a budget and a timescale to erect the tower, as well as the LAD-free time extensions in the event some foreseeable risks materialized and delayed the project.

Beetham's approach to the relationship with the hotelier was similar. Beetham signed in a contract with the hotelier agreeing to the same set of drawings that Beetham had agreed with the contractor. Before Beetham instructed a change requested by the hotelier to the developing team, it assessed the impacts to the contractors' work and agreed on the additional costs that the contractors would incur. Hospitality technology for the high-end hotel industry, such as communication technology entertainment equipment and mini-bars, evolved very rapidly. As a result, Beetham tended to postpone the detailed design of the hotel rooms fit-out to the late project stages. Beetham also built in the design definition of the hotel rooms fit-out some flexibility to make late changes.

The Beetham Tower Project

The 171m-high Beetham tower would be located at the end of Deansgate Street, one of the most desirable streets in the heart of the Manchester city. The tower consisted of 47 stories, and it would be at completion the second tallest building in the UK, 43m higher than the country's current tallest residential building, the 128m Barbican tower cluster in central London, and 50m taller than its current rival in the Manchester city, the CIS building. The Beetham tower had a slender structural design with an aspect to height ratio of 1:11. The project estimated budget was around £150 mil (2004 prices).

The entire structure of the tower sat on a 3m deep concrete raft (**Exhibits 3 and 4**). The two underground floors were designed to accommodate parking spaces. The ground, first, and second floors of the tower's 47-storeys formed a podium accommodating shops and restaurants open to the public. Floor 3 hosted a plant room dedicated to ventilation, water treatment and air conditioning equipments. Floors 4 to 22 were home to a deluxe hotel with 285 beds to be run by Hilton International, internationally recognised as one of the pre-eminent names in the hospitality industry. On floor 23 there would be a 'sky bar', which would offer residents and guests vertigo-inducing views across Manchester, the Peak District, and towards Liverpool and Snowdonia in Wales. Floor 24 accommodated another plant room similar to floor 3. Floors 25 to 45 were occupied by 219 residential flats and penthouses, and the last two floors were used as an up-scale sumptuous penthouse. The skyscraper also featured a swimming pool jutting out of the second floor on the north face, where there was a large ballroom. From the sky bar upwards, the building jutted out by about four metres on the north face, which "allowed to break up the façade and introduce clarity to mark the transition from hotel accommodation to residential properties" according to Ian Simpson. In 2003, the offered prices for the residential tower started from £100,000 for a studio, £700,000 for a one bedroom apartment, rising to £2.5m for the top floor penthouse. Prospective tenants included: TV stars shooting Coronation Street in the nearby Granada studios, football players of the Manchester United and Manchester City, the two local teams in the premier league, as well as administrators of global businesses with a strong presence in the North West of Great Britain.

Planning the Construction Process

According to the notes taken by Mark in the meeting he had had in the morning with Ian and Anthony, the first activity that needed to be undertaken on site was site preparation. This involved fencing, cleaning, and security — Anthony had mentioned that one week would be enough to get this work done. This needed to be followed by the excavation. Excavation would include knocking down the original railway arches on the site, driving piles into the perimeter of the foundations, and then basically digging a big hole. Anthony had suggested putting down 5 weeks for excavation, assuming the city council would allow Beetham to close the roads adjacent to the site for the whole period.

The next major activity would be filling the foundations with a 3m deep concrete pad, which Anthony estimated that it would last about 3 weeks. This would be followed by pouring the concrete for the vertical elements (columns and lift shaft cores) and slabs. Before concrete pouring, however, Mark recalled Anthony mentioning that they needed to allow half a week for first installing the two hoists and two tower cranes that would be needed to support most of the construction activities quite until the end. The concrete pouring operations would be done by first installing some ‘flying’ or slip forms to receive the concrete, which would be later removed after the concrete had hardened sufficiently. Hence, the sequence of operations would consist of: installing the slip forms; pouring the concrete inside; allow the concrete to cure for a few days; and finally uninstall and move the forms to the next floor above. Anthony estimated the entire sequence would take about one and a half weeks for each floor, assuming they would use the normal C80 concrete.

The Beetham Tower would be covered with glass curtain wall from the outside. Anthony had mentioned that the curtain wall in each floor could be installed immediately after removing the forms for the respective columns and slabs. The installation of the curtain wall per floor could be done as rapidly as in 2 days, assuming the resources were available. However, the execution rate for this task was contingent on the progress of the columns and slabs. Further, Anthony noted that health and safety guidelines suggested keeping a distance of 4 floors between curtain walling and concrete pouring tasks.

Mark also recalled that Anthony had mentioned a problem regarding floors 3 and 24 when discussing the curtain walling. These two floors accommodated the large pieces of equipment that would perform the water treatment and air conditioning of the building. These equipment pieces needed to be loaded into these floors from the different sides of the building with the help of the tower cranes. It mattered to finish all loading operations before curtain walling these floors. Anthony had estimated that it would take about 2 weeks to load the equipment for floor 3 and another 2 weeks for floor 24. However, he advised Mark to schedule this activity early enough so it would not delay the curtain walling activity.

Mark recalled Anthony mentioning one last issue about curtain walling. It could not be done straight away in the northern part of the tower where the hoists would be connected to the building. Instead, that part of the tower could only be curtain walled while the hoists were being dismantled, i.e., the hoist should be dismantled in a top down fashion. The part of the wall which was freed from the hoist installation should be curtain walled before moving to the next lower floor. Anthony estimated that it would take one day to dismantle and disconnect the hoists from each floor plus curtain wall that part of the façade. Unlike the other activities, this activity would start from the last floor and end at the first floor. Of course, the contractor would prefer to have the hoist operational as long as possible since transporting materials and equipment through the interior lifts was very difficult (and actually impossible in the case of most piping materials).

The next activity was the installation of the piping and electrical systems. While these were the most complex and time consuming jobs in the construction process, Anthony observed that "the good thing was that different crews could work on different floors at the same time." Anthony estimated that using an optimum-size crew (the most efficient team size to avoid people running into each other's work), piping and the electrical work for each floor would take 6 weeks. Ian then noted that the bathroom pods he had chosen for the hotel rooms could be installed once the piping and electrical systems were in place. This job required to hoist and off load the pods directly on top of the floor plates, unwrap, and connect them to the building services, a job which the supplier had reportedly told Ian should not take more than one week for each floor.

Mark observed, however, that they were not using packaged bathrooms for the residential units. This meant that the bathrooms of the units would need to be constructed together with other dry walling works in the residential floors. Dry walling (including bathroom construction), with one optimum-size crew, would last about 5 weeks for each residential floor, but only 2.5 weeks for each of the hotel floors. Dry-walling in the hotel floors could start immediately after completing the installation of the bathroom pods; further, dry walling of the first two floors would last about 7 weeks. The designs for the sky bar in floor 23 and the penthouse in floors 48 and 49 were not yet completed. This made it hard to provide a reliable estimate for the duration of the dry walling job in these floors. Ian suggested assuming that they would last the same as the residential floors. He also told Mark he should expect the dry-walling contractor to be interested in levelling the resources throughout the job, or in other words, to vary the number of crews over time.

Ian had also asked Mark to postpone the decoration work for the hotel rooms as late as possible. This, in turn, would allow Ian to postpone design detailing and avoid the otherwise inevitable late requests to change the design documents if the hotelier introduced changes to the 'purple book.' This was the key corporate document specifying the design criteria for hotels operating under the Hilton International brand. The 'purple book' was under constant evolution to catch up with late developments in customer-centric hospitality technology, including internet protocol telephony, door locks, and digital video entertainment equipment. Anthony estimated that the decoration activity of each hotel floor should not last more than 6 weeks, except for the first two floors which were more likely to last 8 weeks. Unlike the hotel, the decoration of the apartments was the responsibility of the owners. Owners could independently schedule the decorating activities to start immediately after the dry-walling of each floor. Mark wondered whether he needed to represent that the decoration activities in the schedule and whether he should give a deadline to the owners to complete the decoration jobs. One possibility was to allow 8-weeks for the apartment owners to do their customizations.

The last activity that ought to go in the schedule was lift installation. Anthony mentioned that the lifts could be installed any time after the concrete pouring of the last floor. However, he suggested that an early installation could be useful to transport some construction materials. The installation of the lifts should take about 6 weeks, and it should be done before starting to dismantle the hoist.

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Mark reviewed his notes and started to scratch a line-of-balance representation. He pondered about the extent he could develop a programme robust enough to cope with a possible delay in getting the application approved or an unusual windy weather. Of course, the design detailing tasks would have to progress in parallel with the construction work onsite. Mark therefore also wondered whether he needed to represent design tasks in the overall programme to submit with the planning application, and how he could do that.

GLOSSARY

Concrete Pouring: the process of causing fresh concrete to flow in a continuous stream into a form or mould.

Concrete Curing: The process of keeping the poured concrete for a period of time under regulated humidity and temperature conditions to encourage the proper hardening until the concrete attains the design strength.

Concrete Slab: The plane of concrete separating each floor in a multi-story concrete structure.

Crane: A temporary tower equipped with cables and pulleys to lift and lower materials and equipments.

Curtain Glass Wall: The exterior wall of the building made of glass and attached to the concrete structure through a metallic frame.

Dry Walling: The construction of the interior walls, interior ceiling and any non-weight bearing structure in a building.

Flying Forms: The mobile steel structures used in high-rise construction that act as a mould and provide a protected environment while the concrete mixture hardens.

Hoist: A temporary device, very similar to an elevator, usually installed as an attachment to a building during the construction process to haul materials, equipments, and people.

Liquidated Ascertained Damages (LAD): Expression used in the law of contracts to describe a contractual term which establishes damages to be paid to one party if the other party should breach the contract.

Exhibit 1 – The Beetham Tower

Exhibit 2 – Wind Speed Information for the last 12 months (annual mean 2.8 mph)

Month	Monthly mean wind speed (mph*)	Monthly maximum gust speed (mph)	Date
January	6.4	62	8
February	3	48	12, 13
March	3	41	16
April	2.5	44	6
May	3.1	41	7
June	2.4	35	4
July	2.1	37	6
August	1.7	37	24
September	1.8	37	28
October	2	44	24
November	2.8	44	3
December	2.4	48	30

** miles per hour*

Exhibit 3 – Cross-section of the Beetham tower

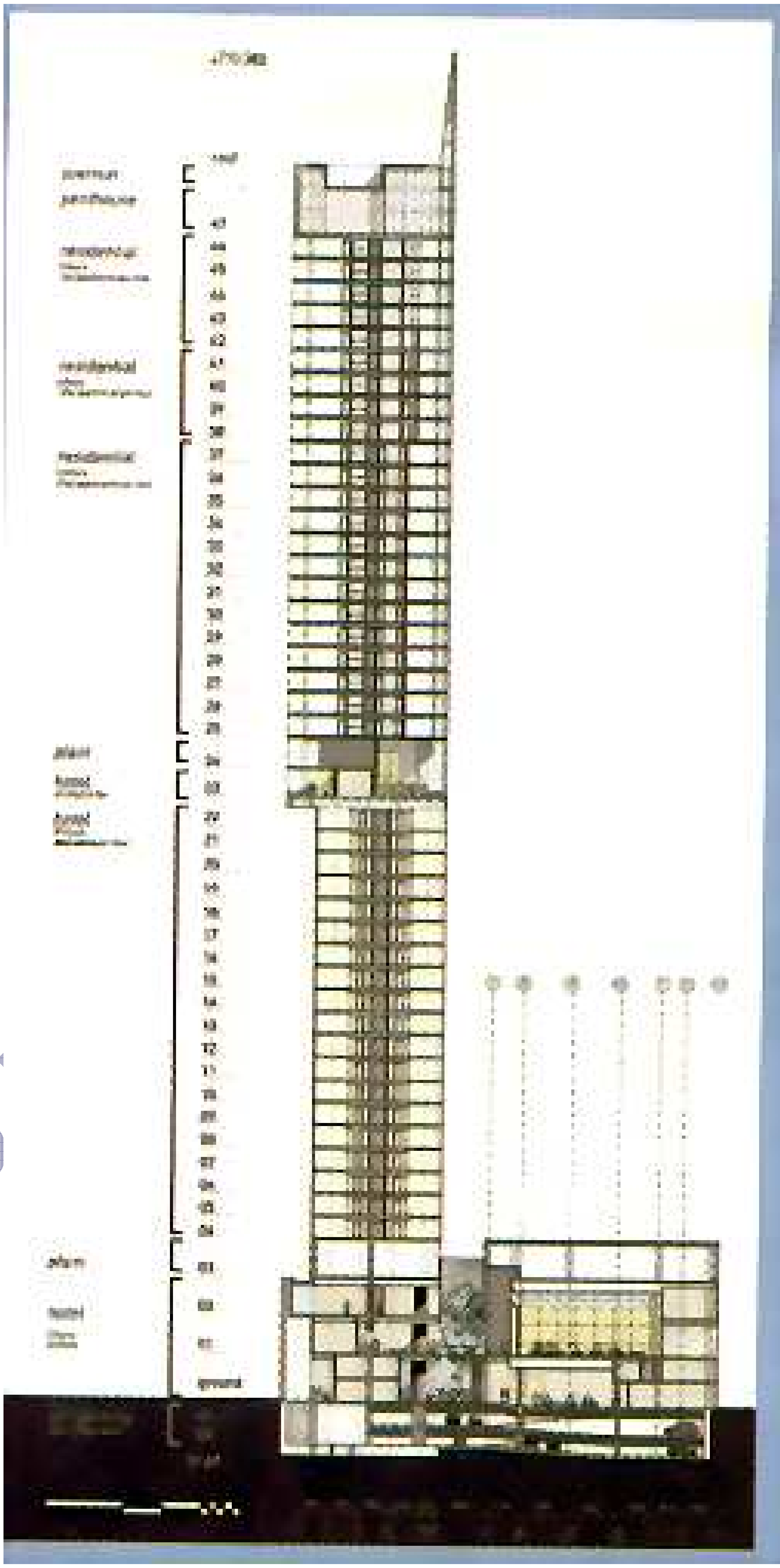

Exhibit 4 – Technical Synopsis of the Beetham tower

The 171m-high tower structure consisted of twin concrete shear cores measuring 8m by 9m and standing 9m apart, with shear walls running from front to back. These walls, supplemented by reinforced concrete columns around the perimeter, supported the glass curtain walling. One core contained lifts, stairs, and services, whereas the other provided purely structural function. The floor plates consisted of post-tension concrete slabs, in which ducts were cast into the concrete with wire tendons within. These tendons were then stressed from the slab edge to achieve greater strength using less concrete. As a result, the floor to floor height was 2.875m whereas traditional construction would require a 3m floor-to-floor height. At the hotel level, the floor plates measured approximately 16m by 40m. At the 23rd floor, the north facing façade cantilevered out by 4m to mark the transition from hotel accommodation to residential properties. To support the eccentric load from the cantilever, concrete columns ran from the shear walls at floor 22, gradually stepping outwards so that by the 28th floor there was a true cantilever of only 2m. Further, the shear walls were positioned near the side of the cantilever. The thickness of the walls reduced 500mm at the base to 300mm at the top as the loads decreased, and the concrete strength also diminished.

The mechanical and electrical design of the building was based on a combined heat and power plant (CHP). A gas supply fed directly from the main into the plant, which acted like a large engine. The movement of this engine was used to spin a generator to produce energy. Heat from the engine was used to produce domestic hot water supply for the hotel and the apartments, plus heating the swimming pool, which made the CHP plant 76% thermally efficient. Further, the plant was used as a standby power source to maintain fire alarms and lifts if the main power failed. In contrast, typical electrical efficiency from a power station to consume was less than 30%.[4] The tower was covered with 4,800 panes of glass, and 2,000 cubic metres of concrete went into the foundations alone. A ventilation system allowed each apartment or room to act as a separate 'fire box.' Hence, in a fire, smoke would be flushed out of the area quickly significantly reducing the risk of fire spreading. To ensure that wind-induced oscillation would not upset the tower's residents, tests of a 1:400 scale model in a wind tunnel confirmed that acceleration would not exceed an acceptable maximum of 0.015m.

[4] Redfern, B. (2004). "Manchester's Record Taker," *New Civil Engineer*, 22, 27/5.