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THE HONGKONG AND SHANGHAI BANKING CORPORATION HEADQUARTERS - ASPECTS OF BUILDING SERVICES NOISE CONTROL

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1. INTRODUCTION

The 47-storey Headquarters for the Hongkong and Shanghai Banking Corporation was completed in 1985 and has already attracted world-wide interest in its innovative architectural and engineering design. Some of the architectural details and the acoustic performances of the building components have been described in the preceding Paper. The following complementary Paper deals mainly with the engineering designs and their interaction with the acoustical environment within and external to the building.

The main superstructure is comprised of eight masts supporting five double--height truss elements. Each of these trusses supports the weight of the eight floors beneath via slender suspension members. The outer projections of trusses also support the express lift shafts and "containerised" air conditioning plant modules arranged in stacks up the building exterior. In this way a maximum area of unrestricted floor space is achieved in the central zone at each level.

In order to gain the best utilisation of the 5,000m² site (having a maximised plot ratio of the order of 18:1) and to ensure a fast construction programme, many building components were fabricated off site. Much of the building services installation was pre-fabricated and delivered to site in a finished condition. These pre-assembled elements included the floor decks (carrying the air conditioning and electrical supplies), the air conditioning plant and generator modules, and the vertical pipe risers. In this way the required speed of assembly was achieved and the specified quality control (including compliance with all acoustical targets) could be checked before each sub-unit left its assembly site.

The design philosophy required that, wherever practicable, the pre-assembled elements should exhibit economies in weight and compactness of layout. However this frequently meant that control of noise and vibration by the component in question could be compromised unless specific measures were taken to offset any such problems. From the outset of the design programme a collaborative consultancy by Arup Acoustics and Tim Smith Acoustics [1] was engaged to oversee all aspects of the architectural acoustics and control of the noise and vibration environment for the building occupants. This Paper describes aspects of the engineering noise control procedures.

2. ACOUSTIC STRATEGY AND DESIGN SPECIFICATIONS

As the architectural design evolved an acoustic design strategy was developed to provide guidelines for all admissible noise and vibration levels in and around the building. As a result, more than 80 of the sub-contracts issued for the supply of on-site services or components contained specialist clauses specifying the required acoustic performance of each building component when in service. Specifications drafted for the acoustically "passive" elements (such as the partitions, enclosures, suspended floor panels, external glazing and claddings, etc) detailed the required insulation, absorption and vibration-damping performances.

An "Acoustic Strategy" was documented in 1980 by the Acoustic Consultants for the guidance of all members of the Design Team. It established limits for continuous and sporadic noise and vibration in each part of the building together with the anticipated occupational noise levels and/or break-in of external noise to the completed building. The Report set advisory limits for the following:

- maximum constant-level noise spectra from building services.
- advised limits for partial masking noise spectra (where needed).
- noise exposure from external road traffic.
- ground-borne vibration from the new MRTC subway.
- continuous and sporadic structural vibration from internal and external sources.
- target room reverberation time characteristics.

By reference to these noise limits it was possible to determine the maximum admissible noise and vibration generation by "active" sources, including the chillers, air handling plant, lifts, escalators, cranes, piped systems, etc). Acoustic performances were even specified for the refuse disposal equipment, kitchen equipment, document conveyors, floor-mounted services outlets, and for all the emergency services such as the standby generators, smoke extract fans and fire-fighting pumps, refrigeration compressors, etc.

The designs for all services layouts prepared by each Sub-Contractor, and their selections of component materials and products were checked to ensure that flow-induced noise in pipes and ducts (and at dampers, grilles and diffusers) did not exceed advised limits. Similar computations also established the minimum attenuation required from the silencers, vibration isolators, duct walls, equipment enclosures, etc.

3. BASEMENT BUILDING SERVICES

The total building services installations require an installed electrical capacity of 19,500 kVA. The maximum air conditioning load is 12.MW. The cooling (and winter heating) of the building is derived from sea water pumped to heat exchangers via 700mm dia. pipes along a 400m tunnel. Eight centrifugal chiller units (two operated as heat pumps) are installed in a plant hall immediately below the Lower Ground Floor office (a specialist customer services area). The basements also contain all the pumps and control systems for the circulation of chilled and domestic water services. These systems are routed via pre-fabricated vertical pipe risers alongside the stacks of fan plant modules.

Control of noise and vibration transfer from the sub-basement Plant Hall was achieved by careful specification of the mass concrete floor slab of the Lower Banking Hall and by ensuring that no wide-bore piped services were suspended from this slab. All chilled water and condenser water pipework is carried on compliant spring hangers at the second basement level. Each chiller is mounted on specialist coil springs and each pump is carried by a massive inertia base, similarly supported by springs.

In this way the entire pipework system throughout the two basement levels "floats" with reference to the fixed structure. No flexible couplings were required in the high-pressure piping for the purposes of vibration isolation. The first rigid contact between the pipework and the building structure is either at the base of each vertical riser or at the massive plate-type heat exchangers. These contact points are sufficiently remote from the pumps and chillers to ensure that any pipe-borne vibration is reduced by natural attenuation to acceptably low levels at every interface with the structure.

4. UNITARY PLANT MODULES

There are a total of 139 "containerised" plant modules, each 9.4m long, 3.6m wide and 3.9m high. They are arranged in vertical stacks (two on the eastern facade and two on the west) between the suspension hangers outside the structural masts. Many of these modules include the toilet accomodation for the offices; 55 contain air-conditioning plant; three house gas-turbine powered standby generators, and two contain the domestic hot water boilers. Each service module, weighing between 25T and 35T, was designed to be assembled and tested by the supplier before being shipped as a self-contained unit to Hong Kong and then finally craned into position.

The maximum weight of any module was determined by the lifting capacity of the site cranes (about 30T at maximum operating radius). Therefore, in designing for a minimum all-up weight it was very necessary to ensure that the airborne sound insulation provided by their lightweight cladding was not compromised. Furthermore, because of the proximity of the facade of the neighbouring site (less than 4m from the low-level air intake louvres on the western facade), stringent limits were imposed on the admissible external noise transmitted via all the "atmosphere" side fan silencers.

The advised acoustic design targets for the maximum noise and vibration levels measured from any air conditioning module are illustrated in Figure 1. Two such air conditioning modules serve each of the larger office floors. Each contains three axial flow fans handling a total circulating air flow of 6.8 m^3/s at working pressures up to 1.7 kPa. As a result the overall in-duct fan sound power levels can reach 110 dBW. Most modules incorporated a toilet compartment extending for up to 50% of the module's length. This relatively noise-tolerant zone functioned as a sound-lock for the 70 dBA internal noise field, and thereby controlled sound breakout via the access doors to the main office area.

A full-scale mock-up of an air-handling module was fabricated for evaluation of the internal equipment layout by the Design Team. This facility enabled the airway configurations to be studied which, in turn, optimised the silencer locations and dimensions. Later, a prototype air-handling module was built for performance evaluation. Its primary purpose was to enable the structural and air handling performance to be checked. It was also subjected to rigorous acoustic testing to confirm the effectiveness of all the installed noise-control features under all operational conditions. The features to be checked included specialist double-skin external walls, sound-absorbent internal linings, double-walled supply ducts, sound--insulating fan compartments, duct silencers on the job-side and atmosphere side of all fans, and compliant fan mountings and duct connectors.

5. ON-FLOOR SERVICES

The supply and return air is routed at each level of the building within the 700mm deep sub-floor voids (which also contain the on-floor electrical, control and communication services). There is no ductwork at ceiling level. All the 3,200 m^2 office floors up to Level 28 are served by two air conditioning modules located on the western facade. Each contains two high-pressure supply fans - a variable volume system of up to 6.5 m^3/s serving perimeter zones and a constant-volume system of about 2 m^3/s serving the central core.

The high-velocity sub-floor ductwork consists of a densely-packed layout of "flat-elliptical" sections. This serves a distribution of constant-volume (CV) terminal units in the central areas and variable-volume (VAV) units at the room perimeter. Access to the terminal units and to all ducts is achieved by lifting the heavy 1200mm x 1200mm floor panels. The sound-insulating specification drafted for the floor system required that it should provide a weighted sound reduction index of 25 dB to control breakout from the sub--floor noise field. This required sound-insulating performance was ratified by independent laboratory tests.

The perimeter air conditioning is supplied mainly via low-pressure plenum boxes to floor-mounted linear grilles abutting the floor-to-ceiling glazing. In the deep plan areas, each sub-floor terminal unit supplies a low-pressure duct having about eight take-off spigots (allowing for one or two capped-off spare outlets). These are coupled by lengths (averaging about 2m) of 75mm flexible duct to purpose-designed 200mm diameter diffusers set flush with the floor.

The return air from each level is drawn through linear floor-mounted grilles (backed by sound-attenuating plenum boxes) which connect to the negatively pressurised sub-floor void. In certain areas a proportion of the return air is drawn from the ceiling void of the floor below to remove heat generated by the lighting.

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Design limits were specified for the admissible sound power output (both in--duct and radiated from the casing) at each CV and VAV box. These targets were based on the known limiting airborne sound insulation that could be provided by the modular floor panels. The circular air diffusers (spaced at one per 1200 x 1200 floor panel) were of a design especially commissioned for this project and were required to give very efficient mixing and upward diffusion of the supply air (up to 125 l/s per register). However, since they would be very close to the occupants of on-floor work stations, it was equally important that the background sound so generated should be close to the advised speech masking spectrum (PNC 38). By collaboration with the diffuser designers in the UK and at their acoustic laboratories in Germany, a design for the swirl vanes finally evolved which combined the desired aerodynamic performance with optimised acoustic characteristics over the full range of air flow rates.

6. LIFTS AND ESCALATORS

Vertical transportation throughout the building is provided by a combination of lifts and escalators. Twenty-four glass-sided express lifts shuttle the passengers between lift lobbies at every eighth floor (the double-height trussed floors). Access to individual floors is by escalators (70 in all).

The extensive escalator system is a major feature of the building. Since the rush hour involves moving between 4000 and 5000 people (excluding the Bank's customers), nearly double the number of lifts would have been required to achieve the required number of personnel movements. The escalators are designed to "start on demand" whereby the weight of the intending passenger actuates a pressure switch under each approach landing. The escalator then runs for a pre-set time.

The sound output from the escalators contributes a major component of the overall masking sound field in the open-plan offices. Studies of noise and vibration from many working installations were undertaken before the acoustic performance specification was drafted. The limitations on the emitted noise require that 45 dBA should not be exceeded beyond radii of 4m to 5m described about the upper and lower landings. Further limitations were imposed on the transient noise caused by the run-up and braking of the motors during start--stop operations. Detailed sound and vibration studies were made on a prototype escalator at the manufacturer's test site in Germany. As a result, recommendations were made for modified anti-vibration mountings and for procedures needed to minimise sound radiation from the glass-sided trusses.

Acoustic studies were undertaken on the designs for the lift installations to ensure that their noise of operation did not exceed specified limits. Since the lift shafts are set on the building perimeter behind translucent glass, solar heat gain needed to be controlled by vertical air flows assisted by powerful fans at the uppermost levels. Each car carries its own air conditioner unit. Noise from these sources, from "wind-pumping" by the cars, and from structure-borne noise and vibration were all assessed and the appropriate procedures for noise control incorporated into the overall designs.

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7. STANDBY GENERATORS

Three gas turbine standby generator (GTG) modules are located in a vertical stack near the top of the building (Levels 40, 41 and 42). Each alternator is rated at 1.5 MW and powered by a Kongsberg KG2 gas turbine. If unattenuated, the turbines could give rise to sound power outputs of 130 dBA(W) at the inlets and exhausts.

Stringent limits were applied for admissible noise emission from the GTG modules, both to the interior of the building (they are located at the same levels as Executive Suites and the Chairman's apartment) and to the exterior. The noise level within the modules reaches 108 dBA, and nearby noise-critical rooms at the same level (having a noise target of 40 dBA) are separated by the width of a single narrow corridor from the turbine enclosure.

Externally, although the turbine inlets and discharges are some 60m above the roof of the neighbouring building, it was recognised that future developments of that site could bring a new building into very close proximity with the discharge nozzles. Consequently a target of 70 dBA at any adjoining building line was adopted as part of the GTG Technical Specification. As a result their design called for high orders of attenuation of the inlet and discharge noise and for very good airborne sound insulation by the module casings. A further complicating factor was the limitations imposed on the weights and available space for the silencers. Nonetheless a novel hot-gas attenuator design was evolved by the sub-contractor which could be fitted into the available space, and which was shown to achieve the design insertion loss spectrum. Other features included the provision of a high-performance sound-insulating cladding, large splitter silencers for both combustion air and cooling air and attenuated ventilation fans within the modules.

All the GTG modules were tested at the fabrication plant in Japan before shipment. Exhaustive tests of noise emission and structural vibration were undertaken at that time. The targets for noise emission were shown to be achieved, with the exception that a pure tone aerodynamic "whistle" was generated by the airflow through the water-rejection intake louvres. A re-design of this feature resulted in a satisfactory external sound field being achieved.

REFERENCE

[1] T J B Smith and R C Cowell
"The Acoustic Design of the new Headquarters for the Hongkong and Shanghai Banking Corporation, 1 Queens Road Central, Hong Kong. Parts 1 and 2".
Paper presented at Westpac 2, Hong Kong, 1985.

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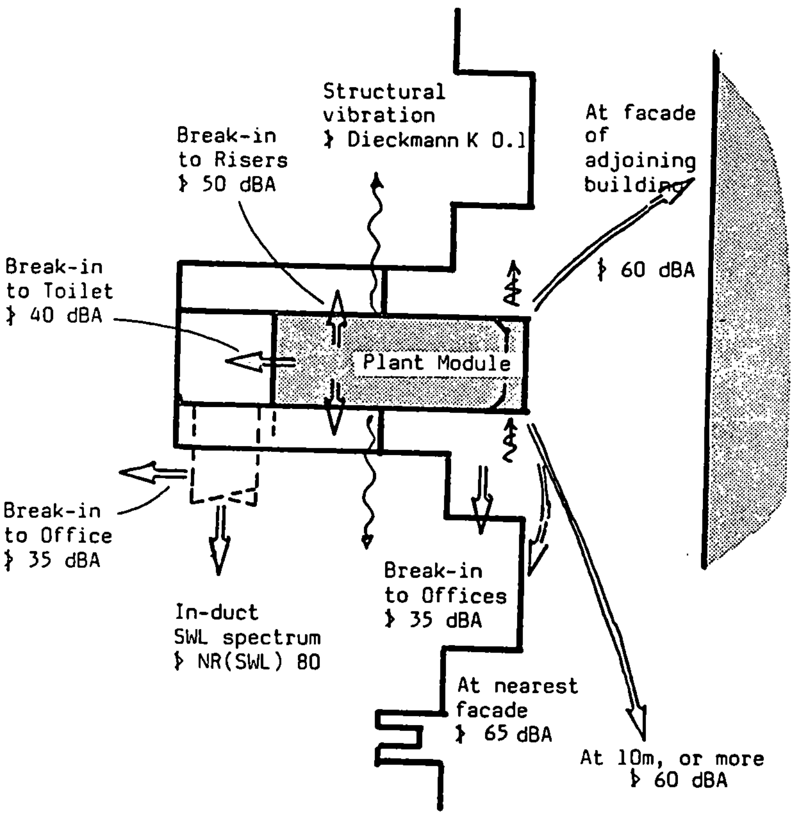

Figure 1. Advised limits for maximum noise and vibration emission from air-handling plant module.