Chapter V Tin Chung Court - Verification of piling design

5.1 As pointed out by HD and HYA, no matter what number or length of piles was proposed, the Contractor must justify its design. Since the piling design of TCC was based on the use of friction piles instead of founding on bedrock, verification of the design methods and parameters became an important step in ensuring that the product was in compliance with HD's acceptance criteria stated in the Specification. There were two major "results" which the piling design should achieve: that the piles could withstand the maximum working load with a safety factor of two, and that the differential settlement of piles at the working load between any two adjacent piles within the same building/structure should not exceed 1/300 times the distance between the centre lines of the piles.

5.2 Since the TCC Contract was a design-and-build contract, Franki (B+B) had the responsibility to justify and verify its piling design; HYA had the responsibility to check the design, with HYA's own structural team to verify the ultimate load bearing capacity of piles with input from JMK; and JMK to verify the settlement analysis.

Verifying the safe load bearing capacity of piles

5.3 The maximum working load of piles for TCC was based on the loading schedule of standard Concord blocks. On the basis of Franki (B+B)'s estimate of 1,882 piles for the domestic blocks in the project, each pile should be capable of carrying 2,700 kN. With a safety factor of not less than two, the safe load bearing capacity of each pile should be 5,400 kN.

5.4 To achieve the required embedded length of the piles in the bearing stratum, Franki (B+B) should base its pile design, in addition to the dynamic formula, on static formula by using one of the given references in the Specification. The overall length of each pile should be the one whichever was the greater derived by either the dynamic formula or the static formula.

Dynamic formula

5.5 Pile driving formulae relate the ultimate bearing capacity of driven piles to the final set (i.e. penetration per blow) [24]. The final set process was inspected by the site staff and the final set records should be checked by ACW/TCC to ensure the proper carrying out of the works. The final set records show that all driven piles for TCC were found to have achieved the required final set. Questions were raised by some witnesses in the geotechnical field on the likelihood of piles in Block 1 to be founded at 22 m below ground, as the SPT N-value of the soil stratum at that depth was definitely well below 80 to 100. Notwithstanding the arguments put forward by HYA to substantiate the viability of founding at such a depth, the results of the investigation commissioned by JSM during November 2000 to November 2001 show that 30 piles of the 32 piles in Blocks 1 and 2 drilled to their founding depths were shorter than the as-built records (see Appendix 5). In some piles, the shortfall was small, but the majority demonstrated a significant discrepancy of up to 7.5 m. In the circumstances, the Select Committee has reason to doubt how far the piles in Blocks 1 and 2 really achieved final set.

5.6 The doubt of the Select Committee in the preceding paragraph is supported by a prosecution expert witness who testified before the Court that the piles at their recorded levels could not have been driven to final set [25], not to mention those piles which were shorter than their recorded levels. As shown from the interview records of ICAC, the two WSs/TCC who inspected the final set process for the majority of piles were not even aware of the areas that could be tampered with, such as the positioning of the pencil on the reference beam for plotting the final set graphs. It was only after explanations by the ICAC officers that the two WSs/TCC became aware of the problems in the final set graphs of some piles which had been certified by them to be in order [26]. The "co-operative" attitude adopted by ACW/TCC in accepting

[24] GEO Publication No. 1/96 on "Pile Design and Construction" (Page 47)
[25] See pages 55 and 92 of the transcript of the summing-up of the trial
[26] See pages 6507 to 6542 of the transcript of the video interview conducted by ICAC with WSI/TCC, and pages 7300 to 7315 of the transcript of the video interview conducted by ICAC with WSII/TCC

submitted final set records without query rendered the checking process unable to achieve its intended purpose [27].

Static formula

5.7 The installation of preliminary piles is a means to obtain data for static formula calculations. Static formula calculates the pile bearing capacity which is taken as the sum of skin friction and base resistance. In HA's Specification, piles must be installed to a depth not shallower than that determined by a static formula. However, the Contractor was allowed to justify skin friction or base resistance of values higher than those determined by the static formula using preliminary pile testing.

5.8 The parameters derived from loading tests of preliminary piles were used to assess whether the as-built driven piles for the relevant blocks could achieve the required bearing capacity. The Select Committee has therefore examined the way test results of the preliminary piles were used to verify the design. As early as the design stage, Franki (B+B) had never intended to drive the piles to bedrock. The estimated pile length was calculated solely by static formula. Franki (B+B) estimated that by using static formula, it was unlikely that the founding depth of piles would reach the level at which hard pans were present. It is obvious that Franki (B+B)'s design had aimed to be aggressive. As the lengths of the as-built piles were found to be too short on the basis of the results of PP1 and PP2, Franki (B+B) had to find more favourable data to substantiate the designed pile length. While the Contractor was permitted under the Specification to install additional preliminary piles, HD and HYA should not be unaware of the implications of such a standard provision which enabled the Contractor to use data from additional preliminary piles.

5.9 The Select Committee notes from the evidence submitted to the Court that PSE/TCC did point out anomalies at various stages of the piling and take follow-up actions to resolve them. However, his efforts did not appear to

[27] See pages 6286 to 6305 of the transcript of the video interview conducted by ICAC with ACW/TCC.

be effective. He considered that the data from PP1 and PP2 should not be ignored and the piles should be driven deeper. Yet, he was aware that Franki (B+B) was against re-driving the piles because of the tight construction schedule and hefty daily liquidated damages. He then agreed to the proposal of Franki (B+B) to use the linear regression method to combine the data of the preliminary and additional preliminary piles which supported a shorter pile length [28]. Being the leader of Structural Sub-consultancy Team, PSD/TCC should have involved himself in making technical decisions. However, he claimed not to even know the installation of additional preliminary piles. It seems to the Select Committee that despite PSE/TCC's lack of experience in PPC piles, he was not given sufficient assistance to enable his effective discharge of duties.

Static load tests

5.10 The load bearing capacity of piles was verified by the static load tests. As mentioned in paragraph 4.31, of the 297 piles for Block 1 and 294 piles for Block 2, only three piles were selected for static load tests for each Block.

5.11 In this respect, the Select Committee also finds that in fact the JMK Report dated September 1996 recommended that driven piles from each wing and core of the building blocks should be selected for load test and preferably two load tests should be carried out for each wing and core of the blocks. The positions of the piles selected for load test did not accord with the recommendation in the JMK Report. The Select Committee doubts the purpose and the usefulness of compiling the JMK Report if it was not intended to be followed. The Select Committee has doubt on whether the data so obtained from the load tests were able to provide a representative picture of the load bearing capacity of the driven piles.

[28] See pages 31, 33, 34, 39, 42, 43, 54, 66, 82, 83, 88 and 105 of the transcript of the summing-up of the trial

Differential settlement

5.12 Assessment of differential settlement in the case of TCC was carried out:

(a) when the RSE submitted the full set of settlement calculations in the RSE Report after the completion of the piling works; and

(b) after installing settlement markers for monitoring settlement readings when the superstructure had been built to the sixth floor.

5.13 JMK was responsible for all geotechnical matters including those relating to settlement calculations. All settlement calculations were made available to JMK for comment. Franki (B+B) calculated the group settlement of each of the four wings and the central core of the block (See **Appendix 15** for example) by making reference to the soil properties of the representative boreholes relevant to the wing or the central core. The net length of the pile adjacent to the representative borehole, i.e. the reference pile, was taken as the general pile length of the group. Settlement so calculated was assumed to develop at the locations of the reference piles. The relative settlement between any two reference piles was then calculated. Such relative settlement divided by the distance between the two reference piles was taken as the ratio for compliance checking against the standard of 1/300.

5.14 The RSE Report shows the numbers of the reference piles of the boreholes for all blocks except Block 1. Under the circumstances, the Select Committee has no information about the lengths of the reference piles used for calculating settlement in Block 1. According to the findings of CMW, borehole A31-75, where the most serious settlement was found, was not used in the settlement calculations for Block 1. Franki (B+B) used instead the data of two confirmatory boreholes HY21 and HY22, drilled in May 1997 after the piling works had been completed, in the settlement analysis.

5.15 The Select Committee has obtained conflicting evidence on the events leading to the sinking of HY21 and HY22. According to one version, the sinking of these two additional boreholes was to address the concern raised by LSE2/TCC about the poor ground conditions of A31-75, which was very close to the footprint of Block 1. The locations of HY21 and HY22 were determined by the Project Geotechnical Engineer of JMK with input from LSE2/TCC. LSE2/TCC, however, denied that he had ever been involved in the determination of the locations of these two boreholes.

5.16 According to another version given by JMK, its Project Geotechnical Engineer attended a meeting to discuss the sinking of four additional boreholes HY21 to HY24 at the request of PSE/TCC. The meeting was attended by representatives from Franki (B+B). The purpose of sinking the additional boreholes was to confirm whether the data indicated by previous boreholes were representative and whether any local weak layers were present in the vicinity. At that meeting, Franki (B+B) proposed to sink HY21 and HY22 to provide more information on the soil near A31-75. JMK could not object to the proposal because the installation of additional boreholes to substantiate the piling design of Franki (B+B) was permissible under GS 19.05(4). JMK had considered the locations of HY21 and HY22 and found them suitable because they were closer to the footprint of Block 1 than A31-75. JMK was aware of the unfavourable ground conditions of A31-75, but considered that the borehole, outside the footprint of Block 1, was not useful for calculating differential settlement between the four wings and the central core. In JMK's view, the calculation of differential settlement between any two representative piles should be based on the boreholes within the footprint of the block.

5.17 Noting the significance of boreholes selected for settlement calculations, the Select Committee has asked various witnesses on any principles agreed and adopted by the geotechnical profession for such purpose. While some witnesses, including GE/TCC, considered that factors such as the borehole's distance from a pile should be considered, other witnesses, including CMW, opined that all borehole data should be used in settlement calculations.

5.18 The Select Committee notes from evidence submitted to the Court that Franki (B+B) had once included A31-75 in calculating the differential settlement for Block 1, which showed that the differential settlement was around 1 in 250, exceeding the permissible ratio of 1 in 300. Franki (B+B) therefore deliberately discarded A31-73 and A31-75 in settlement calculations. Apart from excluding the unfavourable data from these two boreholes, the Select Committee further notes from evidence submitted to the Court that Franki (B+B) also wrongly used the pile cap area instead of the pile group area for the centre group of piles in settlement calculations. Should the pile group area have been used, the differential settlement for Block 1 would be between 1 in 250 to 270 [29], exceeding the permissible ratio of 1 in 300 [30].

5.19 A comparison of the settlement calculations shown in the RSE Report dated July 1997 and in the CMW Report dated December 1999 is set out in Chart 5.1.

Chart 5.1: Comparison of the projected long-term uneven settlement shown in the RSE Report dated July 1997 and in the CMW Report dated December 1999

Block	Projected Long-term Uneven Settlement	
	as estimated in the RSE Report dated 7/1997	as estimated in the CMW Report dated 12/1999
1	1:329	1:200
2	1:323	1:353
3	1:319	1:623
4	1:315	1:388
5	1:316	1:1200
6	1:301	1:819

[29] See pages 43, 44, 54 and 58 of the transcript of the summing-up of the trial
[30] PS 19.23(1)

5.20 According to CMW, the possible reasons for the significant differences in the two sets of figures shown above are as follows:

(a) The two estimations were based on entirely different approaches in that Franki (B+B)'s estimation was based on theoretical calculations using the equivalent raft method allowed under the PS, whereas CMW used the actual settlement data recorded on site during building construction;

(b) The geology of land stretching across the blocks varied greatly. Franki (B+B) only compared the settlement at a limited number of borehole locations across the block, which might not be representative enough. CMW's estimation, which was based on the actual performance of the block, took into account the geological variations; and

(c) There were some anomalies in Franki (B+B)'s estimation of settlement. Apart from omitting two critical boreholes for Block 1, namely, A31-73 and A31-75 for each layer of soil where settlement was calculated, in many cases the highest rather than the average of the SPT N-values for the layer of soil was adopted. Both anomalies would result in under-estimation of settlement.

5.21 Despite the allowable limit of 1/300 for differential settlement between any adjacent piles under the Specification, the Select Committee notes that the 1/301 reading for Block 6 did not raise the concern of HD's Liaison Team, HYA or JMK. JMK pointed out to the Select Committee that since 1/300 was the allowable limit under the Specification, and many assumptions had been made in settlement calculations, even if the limit was exceeded, that did not necessarily mean non-compliance with the safety requirements.

5.22 The Select Committee notes that serious doubts were raised by a prosecution expert witness testifying before the Court about the possibility of the piles achieving final set at the recorded levels. A defence expert witness

also expressed the view that, unless all the piles had been driven to final set, all the settlement calculations would be meaningless and were simply undertaken to comply with the contractual requirements [31].

Monitoring readings

5.23 According to the Specification, settlement markers must be installed by the contractor of the superstructure about 1 m above the ground floor level on the columns and walls when the superstructure was built to the sixth floor. Records show that despite repeated reminders from HYA, the contractor of the superstructure failed to install the markers in time. It was not until mid-April 1998 when the superstructure was built to the 17th floor were the markers installed. It took another week for HD to come to the site and take the initial reading. By that time, the superstructure was built to the 18th floor.

5.24 The Select Committee notes that long-term settlement took time to develop but settlement markers would provide useful reference to track the performance of blocks in relative settlement. The delayed installation of the settlement markers was certainly not conducive to early detection of uneven settlement of the superstructures.

[31] See pages 55 and 92 of the transcript of the summing-up of the trial