Determination No. 2004/39

Land retention system adjacent to a boundary

1 THE MATTER TO BE DETERMINED

1.1 The matter before the Authority is a dispute about the adequacy of a land retention system ("the system") associated with a building constructed adjacent to a boundary.

1.2 The applicant submitted that the original intention, for which a building consent had been issued, was that the space between the excavated bank retained by the system and the completed building would be backfilled so that the bank would then be retained by the building itself. The system was to have been temporary, but had now become permanent, with the intended backfilling having been abandoned. Accordingly, the applicant asked the Authority to determine:

(a) Various matters related to the territorial authority's issuing of, or failure to issue, building consents for the original proposal and for what is now completed.

(b) Whether the system as completed complied with the provisions of the building code, and

(c) Whether the territorial authority must refuse a code compliance certificate for the completed system.

1.3 For the reasons set out in 4 below, the Authority takes the view that it is being asked to determine, under section 17 of the Building Act 1991 ("the Act"), whether the system as installed complies with clauses B1 Structure and B2 Durability of the building code (the First Schedule to the Building Regulations 1992).

1.4 In making its determination the Authority has not considered any other aspects of the Act or of the building code.

2 THE PARTIES

2.1 The applicant is the owner of the land being supported by the system, acting through a firm of solicitors. The applicant has the status of a party in terms of section 16(d) of the Act because the system has the purpose of protecting the applicant's land.

2.2 The other parties are the owner of the building, acting through a firm of construction managers, and the territorial authority.

3 THE SYSTEM

3.1 General

3.1.1 The system is building work done for and in connection with the construction of a building close to the boundary between the owner's property and that of the applicant. The building has eight floor levels including a partial basement. The sloping site has been excavated up to 18 m to form a building platform. The system supports the excavated face, which is on the owner's side of the boundary.

3.1.2 The excavated land consists of schist bedrock with an overburden of up to approximately 6 m of beach gravels overlying lake sediments. The bedrock is jointed, with joints dipping out of the face of the cutting. There are some major shears with breccia and silt infill of several centimetres.

3.1.3 The relevant parts of the building are completed, but a code compliance certificate has not been issued.

3.2 Retention of the bedrock

3.2.1 The fractured bedrock is stabilised by approximately 50 epoxy-grouted steel members[1], at least 80% of them galvanised (the non-galvanised ones were used for stability during construction only, and are regarded as temporary). The members were tensioned to 50 kN by torque wrench. None of the steel members extend beyond the boundary.

3.2.2 The upper part of the rock excavation is covered with sprayed concrete ("shotcrete") with embedded mesh to a nominal thickness of 100 mm, installed after the steel members had been installed. Where the rock has been shotcreted, an additional plate and nut were placed on the outer end of each affected steel member while the shotcrete was still fresh to allow the plate to bed in.

3.2.3 A highly foliated section of the bedrock is also supported by an in situ reinforced concrete beam about half-way between the base and the elemental wall described in 3.3 below.

3.2.4 Site investigation was undertaken and rock stabilisation was designed by a firm of consulting geotechnical engineers ("the geotechnical designer") aided by a consulting geologist. That geologist was also responsible for the logging of the rock mass and of the stabilising steel members. Another specialist ("the rock bolting consultant") observed and advised during the insertion of the steel members into bedrock.

[1] The term "steel members" is used rather than "ground anchors", "rock bolts" or "rock dowels" so as to avoid prejudging the nature and function of those members.

3.3 Retention of the overburden

3.3.1 The overburden above the bedrock is supported by a retaining wall ("the elemental wall") designed by the firm of consulting structural engineers ("the structural designer").

3.3.2 As shown in Figure 1, the elemental wall consist of steel sheet piling driven down to bedrock and supported by a reinforced concrete frame infilled with rock-filled galvanised-wire gabion baskets.

Figure 1: The elemental wall

The elemental wall originally cantilevered from reinforcing steel grouted into the bedrock. Subsequently, as shown in Figure 2, the upper floors of the building were stepped out to the line of the elemental wall. Thus the elemental wall now carries some vertical load from those floors, which prop it at the top against horizontal loads from the overburden.

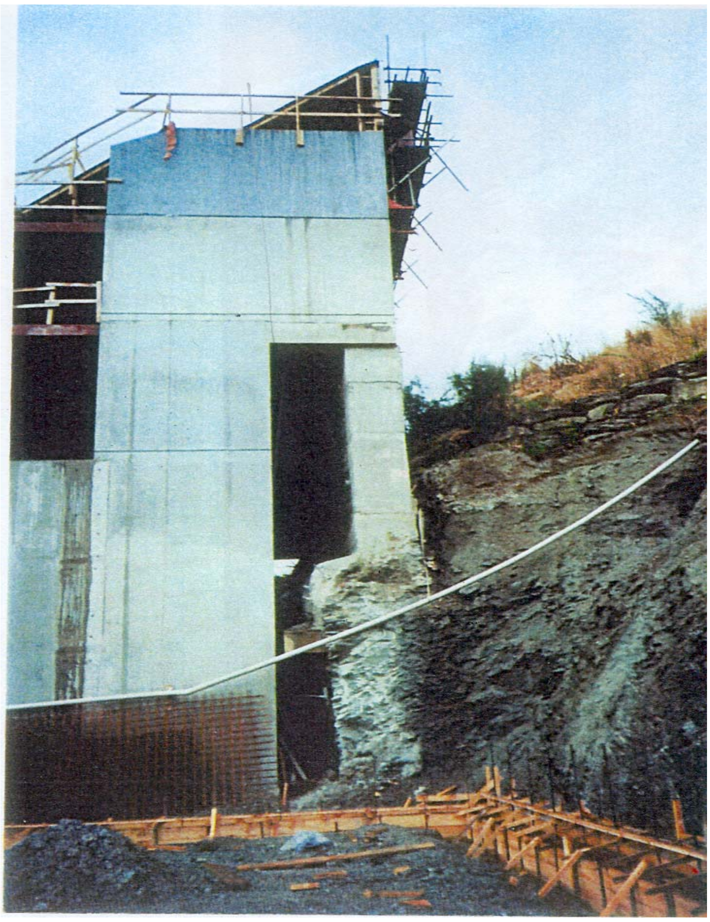

Figure 2: The building in relation to the elemental wall

3.4 Backfilling

3.4.1 The applicant advised that the original intention had been to backfill for the full height between the completed building and the face of the excavation, so that the land would be retained by the building itself. However, that intention was changed when the system was installed.

3.4.2 Nevertheless, the geotechnical designer has recommended that backfill to RL 315 m should be provided in the gap between the building and the bedrock (see Figure 2). The Authority has not been informed as to whether the owner currently intends to follow the geotechnical designer's recommendation.

3.4.3 This matter is discussed in 6.5 below.

4. THE RELEVANT LEGISLATION AND THE AUTHORITY'S JURISDICTION

4.1 Legislation

4.1.1 The relevant provisions of the Building Act are:

(a) Section 18:

> An application to the Authority under section 17 of this Act shall be limited to whether or not, or to what extent, particular building work or proposed building work (including any actual or proposed demolition) complies with all of the provisions, or with any particular provision, of the building code . . .

with "building work" and "sitework" being defined in section 2 as:

> "Building work" means work for or in connection with the construction, alteration, demolition, or removal of a building, and includes sitework
>
> "Sitework" means work on a building site, including earthworks, preparatory to or associated with the construction, alteration, demolition, or removal of a building:

(b) Section 20:

> A determination by the Authority . . . may incorporate waivers or modifications and conditions that a territorial authority is empowered to grant or impose and shall—
>
> (a) Confirm, reverse, or modify the disputed decision to which it relates or determine the matter which is in doubt

4.1.2 The relevant provisions of the building code are:

(a) Clause B1 Structure:

> **B1.3.1** Buildings, building elements and sitework shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives.
>
> **B1.3.3** Account shall be taken of all physical conditions likely to affect the stability of buildings, building elements and sitework . . .
>
> **B1.3.4** Due allowance shall be made for:
>
> (a) The consequences of failure,
>
> (b) The intended use of the building,
>
> (c) Effects of uncertainties resulting from construction activities, or the sequence in which construction activities occur,
>
> (d) Variation in the properties of materials and the characteristics of the site, and
>
> (e) Accuracy limitations inherent in the methods used to predict the stability of buildings.
>
> **B1.3.6** Sitework, where necessary, shall be carried out to:
>
> (a) Provide stability for construction on the site, and
>
> (b) Avoid the likelihood of damage to other property.

> **B1.3.7** Any sitework and associated supports shall take account of the effects of:
>
> (a) Changes in ground water level,
>
> (b) Water, weather and vegetation, and
>
> (c) Ground loss and slumping.

with "building element" being defined in clause A2 as:

> **Building element** Any structural or non-structural component and assembly incorporated into or associated with a building. Included are fixtures, services, drains, permanent mechanical installations for access, glazing, partitions, ceilings and temporary supports.

(b) Clause B2 Durability:

> **B2.3.1** Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building, if stated or:
>
> (a) The life of the building, being not less than 50 years, if:
>
> (i) Those building elements (including floors, walls, and fixings) provide structural stability to the building, or
>
> (ii) Those building elements are difficult to access or replace, or
>
> (iii) Failure of those building elements to comply with the building code would go undetected during both normal use and maintenance of the building.

4.2 The Authority's jurisdiction

4.2.1 Of the matters that the applicant asked the Authority to determine (see 1.2 above), the Authority takes the view that under section 18 of the Act:

(a) It has no jurisdiction to determine whether or not the territorial authority ought to have issued or refused to issue building consents in respect of the system.

(b) It does have jurisdiction to determine whether the completed system complies with the building code.

(c) Whether the territorial authority must refuse a code compliance certificate for the completed system depends on whether or not it complies with the building code, which will depend on the outcome of the determination.

4.2.2 The owner questioned whether the Authority had jurisdiction to determine questions relating to the steel members grouted into the bedrock, saying:

" . . . a bolted rockface is not strictly a retaining wall and would not normally come under the terms of the Building Act."

4.2.3 The Authority takes the view that the installation of the steel members into bedrock comes within the definition of "sitework" (and therefore within the definition of "building work") in section 2 of the Act, so that the Authority does have jurisdiction to determine whether those members, together with the rest of the system, comply with the building code.

5 THE SUBMISSIONS

5.1 The applicant

5.1.1 The applicant submitted a report from a consulting geotechnical engineer ("the applicant's consultant") to the effect that the completed system did not comply with the building code because of the following concerns about corrosion protection, factors of safety, and design parameters:

"The corrosion protection provided to the gabion baskets is inappropriate to their use as permanent retention in the concrete wall system. . . .

"The corrosion protection applied to the ground anchors and rock bolts is inappropriate for permanent anchors, with respect to the modern standards required in the industry.

"It is unclear whether the factor of safety of the rock bolted support beneath the columns of the concrete elemental wall is sufficient. . . .

"British Standard 8081:1989 provides construction requirements associated with installation of ground anchors. The applicant submits that during installation of the anchors, the standards of care set out in clause 10 of those Standards [*sic*] to ensure the corrosion protection measures are not damaged were not met.

"The rock bolts over the fixed length may be stressed at greater than allowable minimum values and the length of the rock bolts is less than the minimum normally recommended.

"The temporary retention system (which is now to be used as the permanent retention system) appears to have been designed on the basis of soil and rock strength parameters which may not be appropriate to the site conditions encountered. Some of the strength parameters should have been verified by in situ site testing.

"There is no double protection system for the ground anchors beneath the concrete wall or for the rock bolts and therefore they do not meet the corrosion protection required for permanent anchors. . . .

5.1.2 The applicant also submitted extensive correspondence arising out of the efforts of its consultant to satisfy itself that the applicant's land would be properly protected by the system. Much of that correspondence concerned matters that have not been submitted for determination. The matters for determination may be summarised as being:

(a) Compliance with clause B1 Structure of the building code, in particular whether, without backfilling:

(i) The bedrock is adequately stabilised by the steel members grouted into it; and

(ii) The overburden is adequately retained by the elemental wall propped by the upper floor connection.

(b) Compliance with clause B2 Durability of the building code, in particular whether there is adequate corrosion protection for:

(i) The steel members grouted into the bedrock; and

(ii) The steel members associated with the elemental wall, being the sheet piling, the gabion baskets, and the reinforcing bars grouted into the bedrock.

5.1.3 The applicant subsequently submitted responses to the submissions made by the owner and the territorial authority as described below. In particular, the applicant said:

"Fundamental to this application is that what was initially designed and constructed as a temporary retaining structure [is now proposed to be a] permanent structure. . . The critical decision under review in this application is accordingly the decision to dispense with backfilling the void between the retaining wall and the building. . . ."

5.2 The owner

5.2.1 The owner submitted:

(a) A report from the geotechnical designer responding to the report from the applicant's consultant,

(b) An appraisal of the retaining wall loads by the structural designer,

(c) A report on the expected life of the sheet piling from the rock bolting consultant, and

(d) Comments by the rock bolting consultant responding to the report from the applicant's consultant.

5.3 The territorial authority

5.3.1 The territorial authority provided copies of all documents that it considered to be relevant to this determination, including correspondence and building consents, held by the territorial authority or by the firm engaged to undertake building control functions on the territorial authority's behalf.

5.3.2 The territorial authority also made submissions in respect of its issuing of building consents, which are not considered in this determination, see 4.2 above.

5.3.3 The territorial authority subsequently submitted the information about the gabion baskets that is mentioned in 6.4.3 below.

5.4 The Authority's consultant

5.4.1 The Authority obtained a report on the matter from a rock engineering consultant ("the Authority's consultant") which was copied to the parties.

5.4.2 The report, which is discussed in more detail in 6 below, concluded that the system as installed appeared to be satisfactory with respect to loads and durability.

5.4.3 On the subject of the design and supervision, the report said:

> "Although it is not strictly a technical issue, the professional input to the excavation design is a relevant matter in the appraisal of the suitability of the work. Apart from the two consulting firms [the geotechnical designer and the structural designer], additional specialist input was obtained for geological mapping and rock dowel installation from professionals with considerable experience in these areas."

5.5 Responses to the Authority's consultant's report

5.5.1 The applicant's consultant accepted that the design methodology for the stabilisation of the bedrock followed sound engineering practice and that adequate capacity was provided by the steel members. However, three questions still needed to be answered:

- "Was the British Standard [BS 8081] intended to apply to rock anchors as installed at this site?"

  That query is addressed in 6.1.3 and 6.4.1.3 below.

- "Do the anchors beneath the elemental retaining wall meet the requirements of durability for even single corrosion protection?"

  That query is addressed in 6.4.4 below.

- "Has the additional protection required for the gabions been installed? If not then this should be required as part of the determination."

  That query is addressed in 6.4.3 below.

5.5.2 Neither the owner nor the territorial authority commented on the report, but both commented on the applicant's subsequent queries.

6 DISCUSSION

6.1 General

6.1.1 The Authority's consultant proposed, and none of the parties objected to, the following definitions, as being consistent with BS 8081:1989 *Code of Practice for Ground Anchorages* ("BS 8081").

- *Ground anchor* is the generic name for an installation capable of transmitting an applied tensile load to a load bearing stratum. The installation consists of an anchor head, free anchor length and fixed anchor. (The term is most commonly applied to an installation which consists of relatively long, multistrand tendons tensioned to a significant load.)

- *Rock bolt* is a specific form of ground anchorage tensioned during installation, where a single steel bar is fixed in rock. These act by increasing the normal force across defects (and hence increasing the frictional resistance) as well as by shear.

- *Rock dowel* is a specific form of untensioned ground anchorage where a single steel bar is fixed in rock. This element acts primarily in shear.

That terminology is used from here on.

6.1.2 The Authority's consultant justified his conclusions in terms of BS 8081, certain publications issued by the Geotechnical Office, Civil Engineering Department, Hong Kong Public Works Department ("GEO"), and certain papers published in peer-reviewed technical journals.

6.1.3 None of the parties queried the use of those publications, except that, as mentioned in 5.5.1 above, the applicant's consultant questioned whether BS 8081 was intended to apply to the steel members used to retain the bedrock. The Authority accepts its consultant's approach of treating those members as "rock dowels" for the purposes of BS 8081, noting that they act mainly in shear and carry only nominal pre-tension.

6.1.4 Accordingly, the Authority accepts all of the documents relied on by the Authority's consultant as providing appropriate guidance to the current state of knowledge and accepted good practice for ground retention.

6.1.5 The Authority considers that the level of safety achieved by current good practice for ground anchorage in the UK, Hong Kong, and similar developed economies is at least as high as that required by clause B1 Structure of the building code. For the purposes of this determination, therefore, the Authority considers that compliance with that current good practice may be accepted as establishing compliance with clause B1. The Authority notes that clause B1.3.4(a) requires due allowance to be made for the consequences of failure at any time during the life of the building.

6.1.6 The Authority also considers that the durability that is achieved by current good practice in the UK, Hong Kong, and similar developed economies is at least as great as that required by clause B2 Durability of the building code. The Authority notes that the general requirement is not for the 50 year life mentioned in some of the correspondence, but for an indefinite life exceeding 50 years. If the intended life of a proposed building is 50 years or less, then the building consent for that building must be issued subject to the conditions specified in section 39 of the Act.

6.1.7 Accordingly, the question is whether the system complies with current good practice in developed economies and will therefore comply with clauses B1 and B2 of the building code.

6.2 Retention of the bedrock

6.2.1 The Authority's consultant carried out a design check on the stabilisation and concluded that:

(a) The grouted steel members cross the defects at angles greater than 45° and therefore act mainly in shear as rock dowels.

(b) For rock dowels, the 1981 version of the GEO manual[2] uses formulae based on work by Bjurstrom[3]. With the uniaxial compressive strength of the bedrock taken as typically 40 MPa and a characteristic steel yield stress of 500 MPa, that method gives a dowel shear resistance of 96 kN for the 32 mm rock dowels.

(c) A more recent method by Spang and Egger[4] calculates the friction and dowel effect of the bar taking into account both the defect and the rock properties. Using that method for the rock dowels concerned gives a working load resistance of the joint due to the dowel exceeding 150 to 180 kN respectively for pessimistic assumptions of rock strength (40 MPa) and the likely ranges of defect friction angles (45 and 20°).

(d) The values used by the geotechnical designer are about 80% of those predicted by Spang & Egger and are therefore reasonable design values.

(e) The dynamic factors of safety (allowing for loads transmitted to the rock by the building) calculated by the geotechnical designer for various locations varied from 1.24 to 2.89. Those factors were considered to be acceptable based on GEO guidelines and for the following reasons:

- A factor of safety greater than 1.4 is generally considered acceptable for rock slopes provided that there is a factor of safety greater than or equal to 1.1 for extreme conditions.
- The geological structure does not form simple two-dimensional wedges [as conservatively assumed for the design] and extra resistance would arise from three-dimensional wedge effects, lateral resistance and lack of continuity of defects.

(The term "dynamic factors of safety" refers to factors of safety under seismic ground acceleration conditions.)

6.2.2 The Authority accepts its consultant's conclusions and accordingly considers that the system complies with clause B1 of the building code as regards the stabilisation of the bedrock.

6.3 Retention of the overburden

---

[2] *Geotechnical Control Office. Geotechnical manual for slopes.* Public Works Department, Hong Kong, 1981

[3] Bjurstrom S. Shear strength of hard rock joints reinforced by grouted untensioned bolts. *Proc 3rd Congr Int Soc Rock Mech*, Denver, 1974

[4] Spang K and Eggar P, Action of fully grouted bolts in jointed rock and factors of influence *Rock Mech & Rock Eng*, 1990.

6.3.1 There was no dispute as to the structural designer's assessments of the loads on the elemental wall nor that the elemental wall was capable of resisting those loads.

6.3.2 The Authority accordingly considers that the elemental wall complies with clause B1 of the building code.

6.4 Corrosion protection

6.4.1 The rock dowels

6.4.1.1 The applicant's consultant pointed out that BS 8081 requires double corrosion protection of permanent ground anchors, single protection being, for example, galvanising, epoxy coating, or a grease-filled sheath. The applicant's consultant also cited a decision tree for corrosion protection in a paper by Nierlich and Bruce[5]. Applying that decision tree indicated that the corrosion protection of the members concerned, while appropriate for a temporary situation (less than 2 years) was inappropriate for a permanent situation.

6.4.1.2 The Authority's consultant cited a recent paper by Baxter[6] as stating that BS 8081:

"is for highly stressed anchorages which are primary supporting elements but it does refer to rockbolts in several instances. . . . Based on overseas standards and practices for rock anchorages, the minimum corrosion protection required for long design life (>50 years) is one physical barrier, e.g. galvanising or epoxy coating."

6.4.1.3 The applicant's consultant disagreed as to the applicability of BS 8081, saying that advice as to "whether BS 8081 is intended to apply to 'Rock Anchors'" should be sought from the British Standards Institution. The Authority does not favour that approach, believing that the actual words of BS 8081 are preferable to someone's opinion as to what the responsible committee intended in 1989, and that in any case the real test is currently accepted good practice.

6.4.1.4 As to the paper by Nierlich and Bruce, the Authority's consultant said that he had raised the matter orally with one of the authors, who had said that the paper applied to highly stressed primary anchorages (as its title indicates) rather than small passive dowels (as is the case here).

6.4.1.5 The Authority's consultant quoted the GEO requirements for corrosion protection of rock bolts and dowels:

"For mild and high-yield steel dowels, the maximum stress should be limited to 50% of the guaranteed ultimate tensile strength. An allowance of 2mm sacrificial thickness on the radius should be made for corrosion, and an annulus of grout of 6mm minimum thickness should be provided around the bar. . . .

"Single corrosion protection is considered adequate for high-yield or mild steel bars, providing an allowance for generalised corrosion of 2mm on the radius is made. For

---

[5] Nierlich H and Bruce D A *A review of the Post-Tensioning Institute's revised recommendations for prestressed rock and soil anchors*.

[6] Baxter D A, Rockbolt corrosion under scrutiny *Tunnels & Tunnelling International*, July 1997.

permanent bolts, single corrosion protection for the free length should consist of grout, a grease-filled sheath, or other suitable protection system.”

6.4.1.6 The Authority’s consultant listed the corrosion protection provided on a number of projects in New Zealand and overseas, and concluded that:

“The rock support [concerned] is in accordance with general civil engineering practice, both nationally and internationally.”

6.4.1.7 The Authority accepts that conclusion and accordingly considers that the rock dowels comply with clause B2 of the building code.

6.4.2 The sheet piling

6.4.2.1 The sheet piling in effect serves as 10.5 mm thick sacrificial protection to the outer sides of the gabion baskets. The Authority concludes that the fact that the sheet piling itself is not protected against corrosion is irrelevant provided the gabion baskets have the required durability.

6.4.3 The gabion baskets

6.4.3.1 The gabion baskets are made of plain galvanised wire. That is clearly inadequate. The Authority accordingly considers that the gabion baskets as originally installed do not have adequate protection against corrosion.

6.4.3.2 However, the territorial authority advised that it had approved:

“ . . . the face-fixing [to the gabions] of a . . . zinc-aluminium coated wire mesh system. This has been assessed to provide in excess of the 50 year durability requirements of the NZ Building Code, and will be a requirement to be installed prior to a Code Compliance Certificate being issued . . .”

6.4.3.3 The Authority notes that the new face-fixed mesh will act differently than the original wrapped-round mesh. However, none of the parties disputed that decision by the territorial authority, so that the Authority is not required to determine whether the new mesh will ensure that the gabion baskets comply with clause B2 of the building code.

6.4.4 The reinforcing bars

6.4.4.1 The elemental wall relies on the shear resistance of non-galvanised reinforcing bars from the columns and the bottom beams of the frame that are grouted into bedrock with cementitious grout. The applicant’s consultant asked whether those rods “meet the requirements of durability for even single corrosion protection”.

6.4.4.2 The Authority’s consultant responded:

“ . . . Single protection is defined as one physical barrier against corrosion provided for the tendon prior to installation. Grout injected in situ to bond the tendon to the ground does not constitute a part of the protective system because the grout quality and integrity cannot be assured.

"The writer has not seen any details of the anchors used to tie back the columns to the rock, apart from the fact that these are 32Ø and 28Ø bars cement grouted 3.5m and 1m respectively into rock. The anchors are understood to be ungalvanised reinforcing bars. These would not comply with the requirements for single corrosion protection for steel tendons used for ground anchorages."

6.4.4.3 The applicant's consultant responded:

"[The Authority's consultant] agrees that the durability of these anchors do not meet the requirements for corrosion protection of these critical elements. As this wall forms a critical part of the support of the upper 5-6m of the slope retention system we consider this alone should be grounds for additional support to be provided."

6.4.4.4 The structural designer replied that, on a conservative basis and taking into account only certain of the reinforcing bars ("steel dowels"):

"The stress in the steel dowels is very low with ample capacity for sacrificial corrosion should that occur. . . .

"Before any allowance for corrosion, the clamping stress in the bars . . . averages 30MPa which is only 7% of the yield strength . . ."

"If we make a conservative nominal allowance of 3mm corrosion to the perimeter of all the reinforcement then the steel stress increases to 44MPa which is still only 10% of the yield strength . . ."

6.4.4.5 In a different context, the geotechnical designer cited the following typical rates of corrosion for structural steels in contact with water as being appropriate for "rock bolts embedded in a rock mass":

Below seabed or riverbed level	0.01 mm/year
Continuous fresh water immersion zone	0.05 mm/year

The Authority accepts that, for the situation concerned, those rates are conservative.

6.4.4.6 Applying those rates of corrosion, it would take approximately 200 to 1,000 years of continuous corrosion for the cross-sectional area of the reinforcing bars to be reduced to 10% of its current value, still well in excess of the 7% required. The Authority recognises that the 7% relates to shear stress only, and that the bars could also experience some flexural tension. However, any such stress can be expected to reduce over time due to creep effects and rock relaxation. Furthermore, in arriving at the 7% the structural designer made a series of conservative assumptions, including not taking account of all of the bars that would in fact contribute. The Authority accepts the structural designer's opinion that the "conservative assumptions [in the design of the elemental wall] more than compensate for the non-conservative aspects of this assessment".

6.4.4.7 Nevertheless, the life of the building is required to be indefinite, so that it is possible that during the life of the building the bars might corrode to the point where the elemental wall could no longer retain the excavated face. Therefore, the Authority is willing to accept that the reinforcing bars comply with clause B2 subject to verification that failure of the elemental wall will not result in the collapse of the building's upper floors.

6.5 Backfilling

6.5.1 As mentioned in 3.4 above, the geotechnical designer recommended that the space between the building and the excavated rock face should be backfilled to RL 315 m (approximately 5 m depth of backfill) for various reasons, including:

(a) "Whilst I believe that there is no obvious mechanism for a large scale rock failure on the back face, there will always be some risk that we have not detected such a mechanism under some circumstances (eg raised groundwater pressures, freezing in rock defects, creep along silt filled defects). . . ."

(b) "The existing bolts are not long enough to give the usual factor of safety against earthquake load [which should be] negligible but there is a risk that unforeseen conditions may control."

(c) "[In certain locations] there are now evident the conditions suggesting classic wedge or block sliding mechanisms . . ."

(d) "Backfill between building and rock serves to provide additional safety factor against large movements. Should there be a tendency for movement, the backfill would absorb energy without imposing significant loads or impact on the building."

6.5.2 The geotechnical designer admitted that:

"This [RL 315 m] is somewhat arbitrary and based on judgment but derives from observations . . ."

and noted:

"My understanding is that the building has been designed for the backfill to at least RL 315 m."

6.5.3 As noted in 5.3.4 above, the Authority's consultant recognised the relevance of specialist input into the design of the system.

6.5.4 The Authority agrees, and considers that it would be unwise to ignore a recommendation from the specialist geotechnical designer. Accordingly, the Authority concludes that the recommendation is to be followed.

7 CONCLUSION

7.1 The Authority concludes that the system, with backfill provided to RL 315 m complies with the building code, but subject to verification that:

(a) Failure of the elemental wall will not result in the collapse of the building's upper floors, and

(b) The building has been designed for the backfill to at least RL 315 m.

8 THE AUTHORITY'S DECISION

8.1 In accordance with section 20 of the Building Act, the Authority hereby determines that the system, supplemented by backfill to RL 315 m, complies with the building code subject to verification, to the satisfaction of the territorial authority, that:

(a) Failure of the elemental wall will not result in the collapse of the building's upper floors; and

(b) The building has been designed for backfill to at least RL 315 m.

Signed for and on behalf of the **Building Industry Authority** the 16th day of August 2004.

John Ryan
Chief Executive