MINISTER FOR MANPOWER
SINGAPORE

13th September 2004

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Mr Richard Magnus
Chairman, Committee of Inquiry

A/P Teh Cee Ing
Assessor, Committee of Inquiry

Er. Lau Joo Ming
Assessor, Committee of Inquiry

Dear Chairman and Members of the Committee of Inquiry

INTERIM REPORT OF THE COMMITTEE OF INQUIRY (COI) INTO THE CAUSE OF THE INCIDENT AT THE MRT CIRCLE LINE WORKSITE THAT LED TO THE COLLAPSE OF THE NICOLL HIGHWAY ON 20 APRIL 2004

Thank you for your letter dated 3 September 2004, enclosing your Interim Report. I note your concerns that the shortcomings uncovered by the COI in the execution of C824 of the Circle Line Project do not 'adversely affect' the ongoing deep excavation projects currently under the purview of the Land Transport Authority.

2 I have circulated the report to the relevant agencies to make certain that these work sites under their purview are safe and to take actions to improve construction safety where necessary. The COI's interim report will be made public.

DR NG ENG HEN
MINISTER FOR MANPOWER

3 September 2004

Dr Ng Eng Hen
Minister for Manpower
Ministry of Manpower

Dear Minister,

INTERIM REPORT OF THE COMMITTEE OF INQUIRY INTO THE CAUSE OF THE INCIDENT AT THE MRT CIRCLE LINE WORKSITE THAT LED TO THE COLLAPSE OF THE NICOLL HIGHWAY ON 20 APRIL 2004

We have the honour to submit an Interim Report of the Committee of Inquiry (COI) into the Incident at the MRT Circle Line Worksite that led to the collapse of Nicoll Highway on 20 April 2004.

2. The COI has completed its 20th day of hearing and has considered evidence from 103 out of 155 witnesses. The areas covered at the Inquiry, to date, are set out in paragraph 10 of the Interim Report. The eighteen Experts engaged by the main parties in this Inquiry are in conference from 1 to 3 September 2004. Pursuant to the COI's directions, these Experts will attempt to narrow issues and reach a common understanding, if possible, in respect of the design and technical aspects pertaining to the cause of the Incident. The COI will resume its hearing on 6 September 2004.

3. The COI has, thus far, seen glaring and critical shortcomings in the execution of C824 of the Circle Line project. These appear, on the evidence, to be common in the construction industry. Some of these deficiencies have contributed directly to the collapse of the retaining wall system in C824.

4. We are concerned that these shortcomings do not adversely affect the execution of subsisting contracts which involve deep excavation not dissimilar to C824. We understand that there are 18 such ongoing projects under LTA's purview. It is important and urgent to address similar deficiencies, where applicable, in these and other projects. Appreciation of these shortfalls and their corrective measures need not wait for the conclusion of the COI's final report. Hence, this Interim Report. The recommendations are set out in paragraphs 11-41 of the Interim Report.

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5. The Interim Report accordingly makes interim recommendations in the following areas:

i) Design Review,
ii) Review of Factors of Safety for Temporary Works,
iii) Enhancing the Safety Culture,
iv) Clarity in respect of Trigger, Design and Allowable Levels,
v) Professionalism and Competence of Sub-Contractors, and
vi) Ownership and Resolution of Design and Site Problems.

RICHARD MAGNUS
CHAIRMAN
COMMITTEE OF INQUIRY

ASSOCIATE PROFESSOR TEH CEE ING
ASSESSOR

Er. LAU YOO MING
ASSESSOR

THE INCIDENT AT THE MRT CIRCLE LINE WORKSITE THAT LED TO THE COLLAPSE OF THE NICOLL HIGHWAY ON 20 APRIL 2004

An interim report on the investigations by the Committee of Inquiry into the collapse of Nicoll Highway on 20 April 2004

THE INCIDENT AT THE MRT CIRCLE LINE WORKSITE THAT LED TO THE COLLAPSE OF THE NICOLL HIGHWAY ON 20 APRIL 2004

An interim report on the investigations by the Committee of Inquiry into the collapse of Nicoll Highway on 20 April 2004

INTERIM REPORT ON

THE INCIDENT AT THE MRT CIRCLE LINE WORKSITE THAT LED TO THE COLLAPSE OF THE NICOLL HIGHWAY ON 20 APRIL 2004

by

THE COMMITTEE OF INQUIRY

Chairman

Richard R Magnus
Senior District Judge
Subordinate Courts

Assessors

Associate Professor Teh Cee Ing

Head
Division of Geotechnical & Transportation Engineering
School of Civil & Environmental Engineering
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Er. Lau Joo Ming

Director
Building Technology Department
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Appointed under Section 54 of the Factories Act (Chapter 104) by

The Honourable Minister for Manpower

1 THE INCIDENT

1.1 The Collapse

1. At about 3.30pm on 20 April 2004, the temporary retaining wall system for a deep excavation adjacent to the Nicoll Highway collapsed. The braced excavation was being made within the temporary retaining wall system to construct a cut and cover tunnel for the Mass Rapid Transit (MRT) Circle Line project C824 by the Land Transport Authority (LTA). The temporary works were designed and constructed by Nishimatsu-Lum Chang Joint Venture (NLCJV). The parties involved in the construction are set out in Appendix A.

2. This 33 metre deep excavation is the deepest excavation in marine clay in Singapore. Numerous workers were working in and around the excavation pit at the time of the collapse. Among them, four persons died (including an LTA technical officer), and several others were injured in the accident. The particulars of the deceased persons are Mr Tan Lock Yong (LTA officer), Mr Heng Yeow Pheow, Mr Liu Rong Quan, Mr Vadivil s/o Nadeson.

1.2 Consequences of the Collapse

3. The failure of the retaining wall system resulted in a massive cave-in on both sides of the braced excavation including a stretch of road along Nicoll Highway. The retaining wall system comprised the following components:

   (a) Reinforced Concrete Diaphragm Wall

   (b) Structural Steel Strutting System

   (c) Two Layers of Jet Grout Pile (JGP) Slabs

4. The collapse resulted in the loss of some 110 metres length of the braced excavation, which was between 15 metres to 20 metres wide and about 30 metres deep at the time of failure. The area of the collapsed zone was approximately 100 metres by 130 metres. The entire strutting system and the diaphragm wall collapsed. Two container site offices, three crawler cranes, a truck, a cement mixer and other equipment which were on the surface of the worksite fell into the cave-in.

5. The accident damaged a gas service line, which resulted in an explosion and fire. Three 66kV power cables which ran across the excavation site were also severed, causing a 15-minute blackout in the Esplanade, Suntec City and Marina Square areas. At the material time, no motorists were within the impacted area. After the incident, the surrounding buildings and structures were assessed and found to be structurally safe.

1.3 Rescue Efforts

6. A search and rescue operation was immediately activated by the Singapore Home Team, comprising the Singapore Police Force (SPF) and the Singapore Civil Defence Force (SCDF). The Home Team managed to recover only three bodies. The fourth person, Heng Yeow Pheow, could not be recovered and remained buried at the excavation site.

7. At the same time, a section 49(1) Factories Act (Chapter 104) Stop Work Order (SWO) was issued and implemented by the Chief Inspector of Factories to NLCJV.

2 THE COMMITTEE OF INQUIRY

2.1 Appointment of the Committee of Inquiry

8. On 22 April 2004, the Acting Minister for Manpower appointed a Committee of Inquiry (COI) under Section 54 of the Factories Act (Chapter 104), to inquire into the cause of the incident at the MRT Circle Line worksite that led to the collapse of the Nicoll Highway on 20th April 2004.

2.2 Inquiry Proceedings

9. The Inquiry commenced on 2 August 2004. A statement of facts agreed to by all parties was tendered to the COI. As of 30 August 2004, after 20 days of hearing, 103 out of 155 witnesses of fact have given evidence. A total of 18 experts have been engaged by the State, LTA, NLCJV, Maunsell Consultants (S) Pte Ltd (Maunsell), L&M Geotechnic Pte Ltd (L&M), and Aviva Ltd (Aviva).

10. The evidence given thus far has been in respect of:

(a) The eyewitness accounts of the incident

(b) The rescue efforts

(c) The roles and responsibilities

i. The role and duty of care of LTA, NLCJV and the sub-contractors

ii. The appreciation of the implied legal, ethical and professional obligations of specialists

iii. The competency, experience, role, responsibilities and accountability of front end supervisory officers and workers from the

LTA, NLCJV and the sub-contractors, the involvement of senior managers

(d) The design and build contract

i. The tender process and the value for money evaluation, and the award of C824 to NLCJV

ii. Some elements of the impact of the non-conventional design and build contract, in particular the control of risks by the owner and the builder

(e) The design

i. Design review

ii. Compliance with local and international industry standards

iii. The differentiation and significance between temporary and permanent works in terms of factor of safety and quality of works and materials

(f) The construction

i. The overall construction sequence and processes in C824

ii. The need for rigorous understanding and assessment of new or unfamiliar technologies before they are adopted. In this case they pertain to the floating cofferdam concept and system and the use of JGP at depths not reached previously

iii. The construction of the diaphragm walls

iv. The construction of the JGP slabs

v. The excavation of the area

vi. The strutting works

vii. The need to balance progress and quality

viii. The standards of workmanship, work practices and quality controls and assessments

(g) Instrumentation and monitoring

i. The types and installation of monitoring instruments, the application and integration of the information for the structured review of quality and reliability

ii. The appreciation and significance of pre-determined review levels of the monitoring instruments and the timely implementation of pre-planned risk based action that should be taken when these levels are breached

iii. The appreciation of the most vital monitoring instruments with regard to the stability of the retaining wall system

iv. The right judgment call by the appropriate senior managers to ensure that work should not be continued until the risks have been reduced

v. The fundamental misunderstanding of back analysis in place of a comprehensive and proper engineering review

(h) Deficiencies and rectification

i. The construction deficiencies and corrective actions taken by NLCJV and LTA in other worksites at Nicoll Highway Station, Boulevard Siding and Launch Shaft 2, as well as at Type K and L at the Cross-over Box along Nicoll Highway

ii. The need to analyse, understand and record in a ‘defect register’ the causes of the previous critical and frequent construction deficiencies and the efficacy of the corrective actions

iii. The mechanistic adoption of these corrective measures to the problems at the incident site without regard to the differentiating wall and soil conditions

(i) The post-collapse investigation and testing

i. Testing of recovered weldments and JGP cores

ii. Post-collapse soil investigation

(j) The safety culture

i. The need to recognise the potential for major accidents by all parties and the effective use of a system of hazard identification, risk assessment, risk avoidance and reduction strategies and contingency management of residual risks

ii. The commitment, culture, competence, co-ordination and consultation in health and safety management systems to secure the effective control of risk and the safe conclusion of work by all parties

iii. The adequacy of contingency and emergency procedures; the need for key decisions to be made at the right level and at the right time; and the need for crucial information to be brought to the attention of senior managers

iv. The balance between production pressures and defensive precautionary systems

v. The recognition that projects carried out in close proximity to the public with the potential to cause significant harm to them require particular plans and review

vi. The overall organisational weaknesses in respect of the entire system to execute the safe construction and successful completion of this project

vii. The ownership of the problems on the work site.

3 INTERIM RECOMMENDATIONS

3.1 Design Review

11. There should be a comprehensive engineering review of the design and safety measures of all on-going projects particularly where deep excavations are being carried out.

12. In the monitoring of the structural performance of the retaining wall system, a proper review of the design and its assumptions should be conducted when any element of works has exceeded the design level.

13. There should be a more rigorous review and inspection regime when unfamiliar technologies are used, or when a known technology is extended beyond the normal range of application. In particular, such a review is necessary for the floating cofferdam system proposed for the Nicoll Highway Station. As grouting is very much an art calling for good engineering appreciation of its effectiveness, the installation and use of JGP in deep excavation needs to be similarly reviewed, supervised and tested in accordance with accepted international practice (British Standard BS EN 12716: 2001 – Execution of Special Geotechnical Works – Jet Grouting is one such standard).

3.2 Review of Factor of Safety for Temporary Works

14. The elements of temporary works must generally comply with the same code and regulations for permanent works (Handbook of Temporary Structures in Construction, First Edition 1985, edited by Robert T. Ratay).

15. Temporary structures should be designed to accommodate all calculable loads with an adequate safety factor that is not less than that for permanent works and the calculations should take full account of the tolerances adopted. The selection of a suitable factor of safety should take into account the soil characteristics, extreme soil conditions, the need to restrict deflection, the consequence of failure, and the conservatism of the design criteria.

16. The factor of safety should be increased when the design or the equipment used has novel features or when there are special uncertainties about the loads encountered in practice or when novel methods of erection are used.

17. It is important that a thorough check is carried out on the design of temporary works by a competent designer, particularly where a major work may involve the assembly of several parts designed independently. A temporary works co-ordinator must be appointed to ensure that all the procedures and checks have been carried out and that the works are constructed in accordance with the design.

18. Such considerations in the determination of the appropriate factor of safety for temporary works in C824 were unclear and seem to be a reflection of the industry's practice. There is a need to establish an industry standard on these aspects of temporary works.

3.3 Enhancing the Safety Culture

19. A good safety management system is no accident. Safety is an attitude of mind and those responsible for the safe operation of any construction works should not only be conversant with the relevant legislation but should be actively committed to a safe approach in any operation. Major hazards are manifested in construction works that have a low probability of occurrence. The potentiality of these hazards is sufficiently infrequent that their occurrences tend to be easily overlooked. The fact that accidents have not happened in previous works does not mean that major accidents will not take place. Sometimes this is due to poor engineering execution and insufficient attention being paid to temporary retaining works as in the execution of C824. When these hazards take place, there is usually a high risk to persons and properties.

20. Safety management system and plans for each construction phase must be present. Overall safety must be integrated into the design phase as well as into construction, trials and execution of works.

21. In deep excavation works, a fortiori, major hazards and the potential consequences must be identified as a first step in the commissioning, planning, designing and construction of the works. These should include an effective framework of risk assessment, risk avoidance and risk reduction strategies.

22. Projects carried out in close proximity to the public and structures with the potential to cause significant harm or damage to them require particular safety plans and review.

23. There should be a greater emphasis to secure the commitment, culture, competence, co-ordination and consultation in health and safety management plans and performance by all parties led by the top management, in addition to the current worksite practice safety briefings.

24. A risk based system of contingency plans and emergency procedures must be put in place that will ensure that key decisions are made at the right level and at the right time. Senior managers must identify and be concerned with the crucial information and take leadership. This calls for the establishment of a clear communication channel.

25. There must be a balance between the pressures of production and contract deadlines with practical and effective precautionary measures that secure work site, people and public safety.

26. Safety Officers engaged in complex construction projects should have familiarity and knowledge of the design function and construction practices, in addition to their current prescribed safety qualifications as a registered safety officer with MOM. The Singapore Standard CP79: 1999 - Code of Practice for Safety Management for Construction Worksites does not refer to such complex construction projects and should be reviewed for all complex construction projects irrespective of their contract value. The British Construction (Design and Management) Regulations 1994 and BS 8800: 1996 (Guide to Occupational Health and Safety Management Systems) can provide a reference framework.

27. Specific to deep excavation works where there is a large number of workers, a review must be carried out of the adequacy of access and escape facilities such as gangways and stairs. Currently there is no Singapore Standard on Excavations. It is timely that such a Code of Practice be developed. Reference can be made to the Code of Practice Excavation (31 March 2000) New South Wales.

28. All in all, the Safety Management System (SMS) must be made more effective. One way to achieve this is to integrate the SMS into the design, construction trials, execution of works and maintenance phases. An industry-wide review is necessary.

3.4 Clarity in Respect of Trigger, Design and Allowable Levels

3.4.1 Reliability and Accuracy of Monitoring Data

29. (i) Instrument-based performance monitoring systems must be effective, adequately resourced and maintained unlike in C824.

(ii) There is a need to integrate information from the various instruments and to relate the crucial information to what is happening on the worksite, as well as the quality of each of the elements in the construction.

These two requirements must be present in all relevant projects.

30. A consistent supply and collation of up-to-date and accurate monitoring information is essential. There is a need to ensure this. Its correct and timely interpretation, including comparisons between predicted and actual values, is crucial for safety. Monitoring at critical locations as construction progresses is important. This will allow adverse trends to be detected early.

31. Skilled personnel must be engaged for the interpretation of instrumentation data. In order to reduce possible human errors in interpretation, peer review must be equally skilled and must involve senior managers who have responsibility for the safe completion of the project.

32. Personnel engaged in specialist function should have the minimum knowledge, qualification and experience. At the COI, it was found that the personnel who were engaged as specialists did not have the basic knowledge and experience. The strut load readings provided by one of the 'specialist' personnel were critical to the safety monitoring of the retaining wall system. These were relied on extensively by the main contractor and LTA, but were subsequently found to be erroneous at the COI.

33. These senior managers must be experienced enough to make the right judgement call either to suspend or to stop the work when instrumentation data exceed the pre-determined risk levels. They are to ensure that work should not continue until risks have been reduced. In addition the owner as well as the contractor must have ownership of this responsibility.

34. While we can and should learn from construction deficiencies and the effective corrective actions taken by LTA and NLCJV in other locations and projects, there should not be a mechanistic adoption and application of these corrective measures to the problems at the incident site without regard to the differentiating conditions and parameters.

35. In essence, there must be a high standard of reliability and accuracy in monitoring data.

3.5 Professionalism and Competence of Sub-contractors

36. There should be a minimum standard for sub-contracting works, particularly for specialised construction works. The evidence at the COI shows sub-standard workmanship and quality. Even the specialist subcontractors do not have an adequate self-regulating system. It is therefore timely to review the construction methods, work quality of the sub-contractors and the technical skills of their personnel. In this regard, paragraphs 20 to 22 on "Maintaining Professionalism of Firms through Accreditation and Registration" of Construction 21 Steering Committee Report would be a useful starting reference.

37. Personnel engaged in specialist functions should have the minimum knowledge, qualification and experience. At the COI, it was found that the personnel who were engaged as specialists did not have the basic knowledge and experience as can be seen in paragraph 32 above on the erroneous strut readings.

38. As part of their professionalism, specialist subcontractors must be told to go beyond mere contractual compliance and alert the employer of any deficiency in design, drawing and methods of construction which impacts safety.

39. A review should be done on all JGP works in terms of their field trials, control and supervision of installation, and the quality assurance process. The COI has revealed the inadequacy of the JGP works in C824 even though the works were undertaken by a well-established and experienced sub-contractor. In this regard, BS EN 12716: 2001 British Standards for the Execution of Special Geotechnical Works - Jet Grouting, which was not known to the sub-contractor as well as to the builder and the employer, will be relevant.

40. Sub-contractors are essential partners in the team. They are the ones who execute the work. This group deserves greater attention and encouragement.

3.6 Ownership and Resolution of Design and Site Problems

41. As the other witnesses from LTA and NLCJV are in the process of being heard, the COI would reserve its recommendations; but make an observation. We note the complex relationship among the different parties as set out in Appendix A. LTA as an Authority and Developer of this project, took upon both the roles of QP (Supervision) and Building Control Unit. NLCJV is a design and build contractor and therefore has control over worksite risks. And again, NLCJV has engaged Maunsell as the consultants for the permanent works as well as certain elements of the temporary works. This complicated relationship inevitably led to conflicts in the ownership and resolution of problems in C824. This critical decision-making gap adversely affected judgment calls necessary to deal with the crisis and had caused uncertainty at the worksite.

APPENDIX A

The relationship of parties involved in this Incident.