THE IDENTIFICATION OF ASR IN THE CONCRETE COOLING TOWER INFRASTRUCTURE OF THE TARONG POWER STATION

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Vertical cracking was observed in the precast columns supporting the hot water ponds of the cooling towers in August 1990. These columns were cast in 1981/82 and were approximately 8 years old at the time of the observed distress. The hot, moist environment within the cooling towers of a power station is extremely aggressive regarding alkali-silica reaction (ASR). This analysis confirms the hypothesis that the vertical cracking observed in the cooling tower hot water pond columns is primarily due to ASR.

INTRODUCTION

This investigation was conducted to determine the mechanism causing the observed vertical cracking in the precast columns supporting the hot water ponds of the Tarong Power Station Cooling Towers. It represents the continuation of a broader project previously completed by Carse and Dux (1) investigating Australian concrete structures affected due to ASR. These columns were cast in 1981/82 and were 8 years old at the time of this inspection in August 1990. Tarong Power Station has two cooling towers which were completed in March 1984 and December 1985 respectively. The power station was brought on line in 1986. Fig. 1 shows a general view of cooling tower No. 1 in operation and Fig. 2 shows the hot water at 40°C being delivered to the pond from the power station condenser.

DETAILED ANALYSIS OF DISTRESS

Field Investigation

Crack Survey. The initial part of this analysis required a detailed crack survey to be undertaken to determine the extent of cracking which had occurred in the precast columns. It is important to establish the orientation and maximum width of cracking as these two factors are significantly influenced by the type of mechanism causing the observed distress.

The following data was determined from the crack survey:

(i) The predominant orientation of the cracks was in the vertical direction.

(ii) Approximately 30% of the precast columns were exhibiting vertical cracks varying in width from 0.1 mm to 1.0 mm at an age of 8 years since manufacture.

Selection of Concrete Core Locations. Concrete cores of nominal diameter 70 mm and length 150 mm were extracted from three cooling tower hot water pond columns. The cores were located over zones of maximum cracking and also over uncracked zones. It is important to select cores from sound areas for comparison purposes. Table 1 identifies the location of each core and Fig. 3 shows the detailed measured location for column 2/12.

TABLE 1 - Summary of Core Locations

Tower No.	Unit No.	Column No.	Core No's.
1	1	26	A/B/C
1	2	12	A/B/C
2	3	17	A/B/C

From Fig. 3 it can be seen that the predominant zone of cracking was at the water line and below in the cold water pond at ground level. Cores marked A and B were extracted below the maximum water level and core C above this level. Each cooling tower has an inside and outside circular row of columns supporting the hot water ponds. Each row consists of 54 precast columns and hence, each cooling tower has 108 columns.

Laboratory Investigation

The following testing was conducted on the Cooling Tower No. 1 cores:

(i) Petrographic Analysis

(ii) Electron Microscope Analysis of the thin sections used in the petrographic analysis.

The concrete cores from Cooling Tower No. 2 were kept for future reference.

Petrographic Analysis. Table 2 details the width and extent of cracking observed in the cores. Figure 4 shows a view of the crack in column no. 1/26 and Figure 5 shows the cracking in cores no. 1/26A and 1/26B.

With reference to Table 2, it can be seen that the crack widths at the surface of the columns vary from 0.1 mm to 1.0 mm with corresponding penetrations of 33 mm to 110 mm. Hence, the range of cracking observed in the columns is quite substantial.

The main conclusions of the petrographic analysis are:

(i) The observed cracking mainly traverses the cement paste but there are numerous examples of the fractures cutting coarse aggregate and sand grains.

(ii) Alkali-silica gel and crystalline derivations fill or more commonly line some air bubbles.

(iii) It seems likely that the vertical cracking observed in the columns is due to swelling of the interior concrete as a result of alkali-silica reaction. Electron microscope work should confirm this diagnosis.

(iv) Potential sources of reactive aggregate are:

(a) Coarse aggregate - Chert

(b) Fine Aggregate - Chert, jasper, quartzite

(v) The environment surrounding the columns is aggressive in relation to ASR.

TABLE 2 - Geometry of Observed vertical Cracking in Cores

ITEM	CORE NO.				
	Core 1/26A	Core 1/26B	Core 1/26C	Core 2/12A	Core 2/12B
Width at the surface	0.7mm	1mm	0.1mm	0.5mm	0.3mm
Width at 60 mm depth	0.04mm	0.02mm	-	0.05mm	0.3mm
Depth of penetration	110mm	70mm	33mm	70mm	80mm
Depth to which carbonation has proceeded down the crack	10mm	35mm	13mm	26mm	12mm
Depth at which alkali-silica gel is first encountered in the crack	23mm	43mm	17mm	26mm	38mm

Electron Microscope Analysis. Thin sections from four cores were subjected to electron microscope analysis of reaction products observed during the petrographic report. Table 3 summarises the chemical analysis of the various reaction products.

TABLE 3 - EDX Chemical Analysis of Reaction Products in Cores 1/26A and 1/26B

Thin Section No.	Element % by Mass					
	Na	Si	Cl	K	Ca	Fe
1/26B	6	25	2	5	28	1
1/26B	5	50	2	5	33	4
1/26A	2	5	1	1	83	1
1/26A	4	43	1	1	49	1

From Table 3 it is clear that the predominant reaction product (filling the observed cracks and entrapped air bubbles within the concrete) is a calcium/alkali/silica complex. Fig. 6 shows a view of the reaction product filling an air bubble in core no. 1/26A. This analysis confirms the hypothesis from the petrographic report that the vertical cracking observed in the cooling tower hot water pond columns is primarily due to swelling of the interior concrete due to alkali-silica reaction. The mechanism of ASR is accelerated in areas of high temperature and humidity. The water temperatures that exist in the hot and cold water ponds are summarised in Table 4.

TABLE 4 - Pond Water Temperatures ^{0}C

Pond Type	Winter	Summer
Hot Pond	38	42
Cold Pond	26	31

CONCLUSIONS

This investigation has confirmed that alkali-silica reaction is the mechanism causing the observed vertical cracking in the precast columns of the cooling towers. This reaction is significantly encouraged by the hot moist conditions surrounding the hot water pond columns. At this stage there has been no identified zones of reinforcement corrosion associated with the observed level of cracking. The next phase of this project is to assess the optimum asset management philosophy for the precast columns to ensure they meet their original design life of 30 years.

REFERENCES

1. Carse, A., and Dux, P.F., 1988, "Alkali-Silica Reaction in Concrete Structures", University of Queensland Research Report No. CE88.

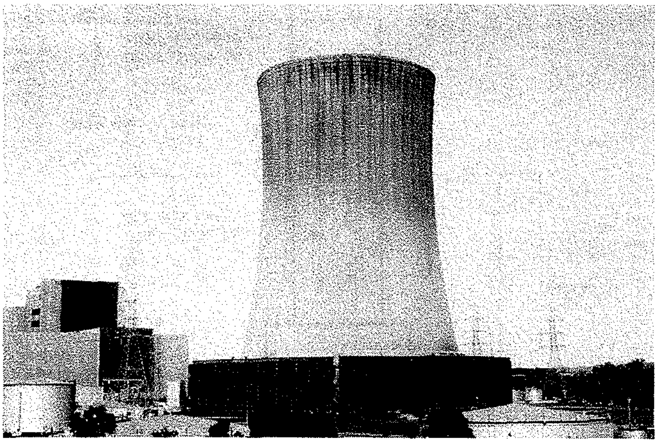

Figure 1 General view of cooling tower no. 1

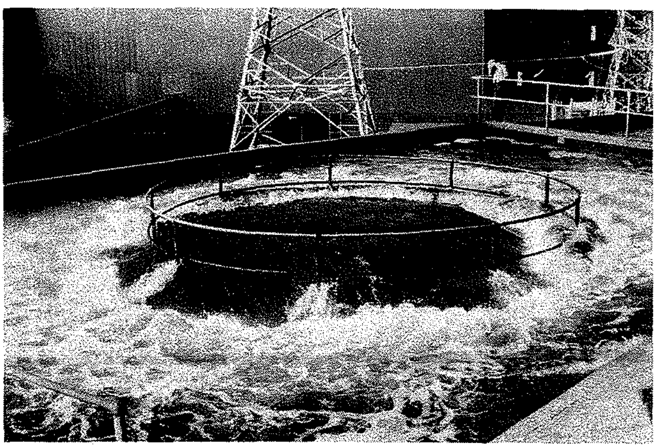

Figure 2 View of hot water (40°C) being delivered to the pond from the power station condenser

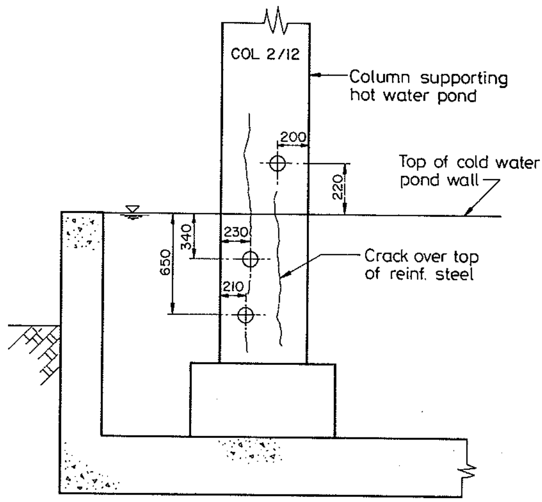

Figure 3 View of concrete core locations at column no. 2/12

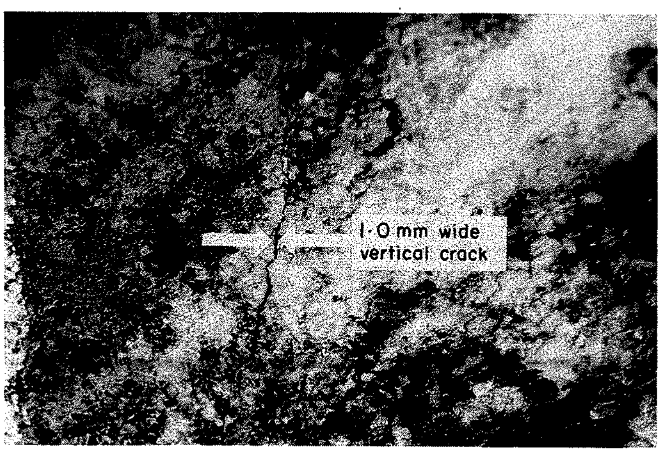

Figure 4 View of the vertical crack in column no. 1/26

Figure 5 View of cracking in cores no. 1/26A and 1/26B

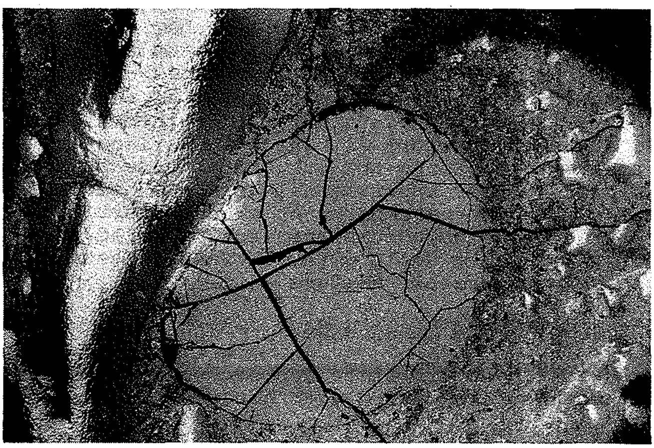

Figure 6 View of alkali-silica gel filling
a 2 mm dia. air bubble in core no. 1/26A