CASE STUDY OF DISTRESSED ROAD CULS-DE-SAC IN A NEW RESIDENTIAL ESTATE

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ABSTRACT

This case study summarises the analysis of two cul-de-sac pavements located in the north-west of Sydney. The study was undertaken by the Concrete Masonry Association of Australia at the request of the Council Engineer. The pavement was analysed by site examination and computer. The key points of the study are: (1) when segmental pavements are being examined, computer analysis can highlight areas which merit scrutiny before on-site investigations take place; (2) proof-rolling, whilst being a useful quality checking technique, cannot replace regular monitoring of the quality, depth and compaction of the basecourse material; (3) an assessment of the level of skills present amongst the paviors is desirable before laying commences; and (4) close liaison between the client and the paving unit supervisor can help enhance job quality.

BACKGROUND

The Concrete Masonry Association of Australia (CMAA) was contacted about a number of problems a Council was encountering with two concrete segmental cul-de-sac pavements. The problems were:

(a) chipping of units at the edge;

(b) rotation of edge restraints;

(c) ingress and egress of water through the paving;

(d) rutting; and

(e) areas of localised subsidence.

SITES EXAMINED

Four sites were examined in a new large residential development area. Two sites were subsequently examined in detail (see Fig. 1):

(1) a cul-de-sac, approximately two years old, serving six housing sites (hereinafter referred to as Site One).

(2) a cul-de-sac, approximately two years old, serving eight house sites (hereinafter referred to as Site Two).

OBSERVATIONS ON SITE ONE

This site exhibited rutting of approximately 25-40 mm. It was believed that this deformation had taken place as a result of the heavy construction traffic which had used the cul-de-sac during the building of the houses surrounding the short access road.

Because of this rutting, the units had rotated and edge spalling had occurred as a result of edge contact. The joint widths between the units appeared to be within normally-acceptable tolerances, but there were large areas where joint filling sand was not present.

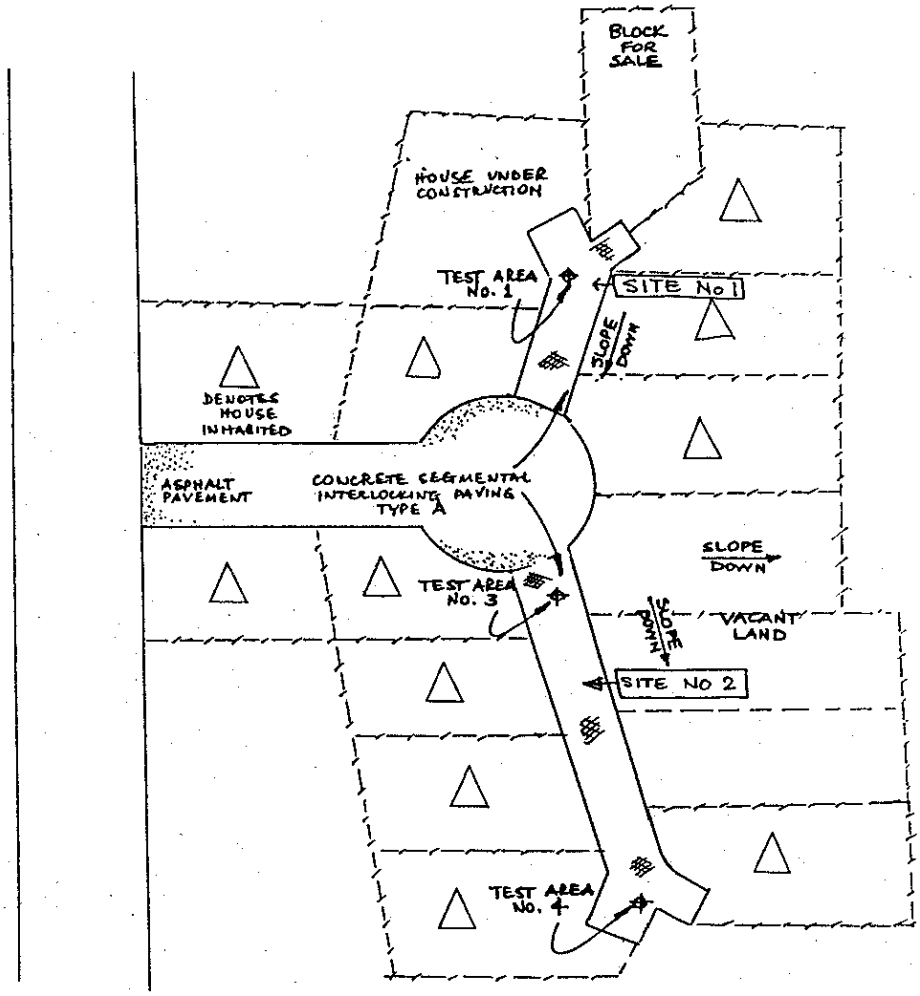


Fig. 1 - Sketch plan of test sites

There was a localised depression around a gulley pit and a kerb adjacent to the pit had rotated, permitting horizontal displacement and settlement of the pavement.

The Council engineer indicated that the design had been carried out using information derived from the Cement and Concrete Association of Australia's (CACA) TN40 (Hodgkinson and Morrish 1982), which has since been superceded. The pavers used were 60 mm type A, and the design called for 40 mm of bedding sand and 160 mm of A grade fine crushed rock. (The design subgrade CBR was later advised to be 3 per cent.)

OBSERVATIONS ON SITE TWO

Site Two exhibited similar characteristics to Site One but there was an absence of filling sand and evidence of water penetration from what is believed to be an underground spring. Rutting such as would be caused by heavy vehicles on an under-strength pavement was observed, with a rut depth up to 30 mm and some 90 per cent of the surface area could be rotated by foot.

Several paving units were removed from the pavement for testing. The bedding sand was observed to be moist but not saturated.

Council provided a large road grader which was driven over the cul-de-sac and the resulting movement in the pavement surface was observed. Under each wheel of the grader the pavement deformed some 5 to 10 mm, then recovered its original position. The absence of jointing sand permitted rotation of the paving units when this load was applied, confirming the likely cause of edge chipping elsewhere.

The bedding sand appeared to be of a suitable quality and had been correctly laid, but the absence of a suitable jointing sand had permitted the underlying layers to become saturated, and this had exacerbated

the rutting. In all cases the severest rutting occurred in areas where garbage trucks had turned around.

The design subgrade CBR was later advised to have been 4 per cent. The basecourse was specified as 135 mm of A grade fine crushed rock.

ACTIONS

ACTION REQUESTED

The Council engineer requested comment from CMAA on the following points.

(a) Was the design in line with current practice for roads of this nature?

(b) Was a 60 mm thick paver appropriate for this type of road?

(c) If the design appeared to be deficient in basecourse thickness, would the removal of 60 mm pavers and the replacement of them with 80 mm units be an advantage?

(d) What would be the effect of removing the pavers and cement stabilising the basecourse and bedding sand, and then replacing the pavers?

(e) Were the pavers themselves of a good quality?

(f) What further action would CMAA recommend?

ACTION TAKEN

CMAA took the information supplied by the Council and carried out a computer analysis in order to determine the effect of various loads, basecourse thicknesses and soil CBR's in order to reply to the Council's questions. The results of this analysis are given in Tables 1 to 4, with the differences in input circled.

This analysis allowed CMAA to reply to the Council's questions as follows.

(a) The designs were in line with current recommendations for roads of this nature.

(b) The 60 mm thick pavers were appropriate for this class of road and the design used was consistent with this thickness of paver.

(c) Changing the thickness of paver from 60 to 80 mm would have little difference on the depth of basecourse required (due to the fact that the computer program takes into account only limited stiffening of the layer of paving units in new residential estate roads).

(d) Generally there was insufficient material existing on the site to stabilise. (The computer analysis compares the design thickness for both bound and unbound basecourses.)

(e) Testing of the pavers removed from the site by the manufacturer revealed that they had a characteristic compressive strength of 54 MPa when tested in accordance with CMAA (1980) (since superceded), and a characteristic transverse strength of 5.75 MPa. These were above the minimum quality required to successfully perform under the load conditions.

(f) From the information obtained from the computer, CMAA concluded that the distress being exhibited by the pavement was unlikely to be caused by the pavers or pavement design and that a site examination to check the in situ CBR and the details of the pavement as constructed needed to be carried out.

FOLLOW-UP INVESTIGATION

Areas exhibiting distress were re-examined and three areas of the pavement were selected for testing (numbered 1, 3 and 4 in Fig. 1). Measurements were made of surface rutting, sand bedding thickness and basecourse thickness. Readings of the subgrade CBR, using a dynamic cone penetrometer (DCP), were taken after the removal of approximately ten pavers at each site, i.e. about 0.25 square metres area.

A summary of the results of testing and observations is given in Table 5.

SUBGRADE

The subgrade immediately below the pavements consisted of a medium-soft grey- to orange-coloured clay. It had a high degree of plasticity and could be kneaded by hand. In test locations 1 and 4 the clay was apparently saturated.

TABLE 1

DESIGN OF A CONCRETE BLOCK ROAD PAVEMENT

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

JOB NAME: HOUSING ESTATE

CLIENT: SHIRE ENGINEER

SIZE OF JOB: 500 sq m

Details entered by

DATE: 01-01-1980 TIME: 00:15:22

(a) PAVEMENT DESIGN ASSUMPTIONS:

LAYER No.	THICKNESS (mm)	E (MPa)	MU	MATERIAL TYPE	COSTS $	UNITS
1	60	3200	.3	BLOCKS	0	sp m
2	?	0<E<350	.35	CRUSHED ROCK	0	cu m
2	?	2300	.35	STABILISED COARSE-GRAINED MTL	0	cu m
3	SEMI INF	E=F(CBR)	.4	SUBGRADE	0	sq m

(b) TRAFFIC DATA:

ROAD CLASS: MINOR
AVERAGE DAILY TRAFFIC: (200)
GROWTH RATE = 0% pa
DESIGN PERIOD = 20 YEARS
PROPORTION OF TRUCKS > 3 tonnes = 1.6%
Road is a new development serving (20) houses
There are (2) garbage collections/week

(c) PAVEMENT DESIGN COMPRISES:

SURFACE: (60) mm BLOCKS
SAND: 30 mm of BEDDING SAND
BASE: UNBOUND OR STABILISED CRUSHED ROCK
SUBGRADE: See TABLE below for CBR values

CBR %	THICKNESS OF UNBOUND LAYER mm	THICKNESS OF STABILISED LAYER mm
1	230	260
2	190	235
4	145	215
6	125	200

TABLE 2

DESIGN OF A CONCRETE BLOCK ROAD PAVEMENT

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

JOB NAME:

CLIENT:

SIZE OF JOB: 500 sq m

Details entered by

DATE: 01-01-1980 TIME: 02:37:24

(a) PAVEMENT DESIGN ASSUMPTIONS:

LAYER No.	THICKNESS (mm)	E (MPa)	MU	MATERIAL TYPE	COSTS $	UNITS
1	80	3200	.3	BLOCKS	0	sp m
2	?	0<E<350	.35	CRUSHED ROCK	0	cu m
2	?	2300	.35	STABILISED COARSE-GRAINED MTL	0	cu m
3	SEMI INF	E=F(CBR)	.4	SUBGRADE	0	sq m

(b) TRAFFIC DATA:

ROAD CLASS: LOCAL
AVERAGE DAILY TRAFFIC: (200)
GROWTH RATE = 1% pa
DESIGN PERIOD = 20 YEARS
PROPORTION OF TRUCKS > 3 tonnes = 1.6%
Road is a new development serving (20) houses
There are (2) garbage collections/week

(c) PAVEMENT DESIGN COMPRISES:

SURFACE: (80) mm BLOCKS
SAND: 30 mm of BEDDING SAND
BASE: UNBOUND OR STABILISED CRUSHED ROCK
SUBGRADE: See TABLE below for CBR values

CBR %	THICKNESS OF UNBOUND LAYER mm	THICKNESS OF STABILISED LAYER mm
1	200	240
2	180	215
4	145	195
6	125	185

TABLE 3

DESIGN OF A CONCRETE BLOCK ROAD PAVEMENT

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

JOB NAME: HOUSING ESTATE

CLIENT:

SIZE OF JOB: 500 sq m

Details entered by Concrete Masonry Assoc.

DATE: 04-04-1985 TIME: 00:15:47

(a) PAVEMENT DESIGN ASSUMPTIONS:

LAYER No.	THICKNESS (mm)	E (MPa)	MU	MATERIAL TYPE	COSTS $	UNITS
1	60	3200	.3	BLOCKS	0	sp m
2	?	0<E<350	.35	CRUSHED ROCK	0	cu m
2	?	2300	.35	STABILISED COARSE-GRAINED MTL	0	cu m
3	SEMI INF	E=F(CBR)	.4	SUBGRADE	0	sq m

(b) TRAFFIC DATA:

AVERAGE DAILY TRAFFIC: 100
GROWTH RATE = 1% pa
DESIGN PERIOD = 20 YEARS
PROPORTION OF TRUCKS > 3 tonnes = 1.6%
Road is a new development serving 10 houses
There are 2 garbage collections/week

(c) PAVEMENT DESIGN COMPRISES:

SURFACE: 60 mm BLOCKS
SAND: 30 mm of BEDDING SAND
BASE: UNBOUND OR STABILISED CRUSHED ROCK
SUBGRADE: See TABLE below for CBR values

CBR %	THICKNESS OF UNBOUND LAYER mm	THICKNESS OF STABILISED LAYER mm
1	215	260
2	180	235
4	145	215
6	125	200

TABLE 4

DESIGN OF A CONCRETE BLOCK ROAD PAVEMENT

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

JOB NAME: HOUSING ESTATE

CLIENT:

SIZE OF JOB: 500 sq m

Details entered by Concrete Masonry Assoc.

DATE: 04-04-1985 TIME: 00:24:32

(a) PAVEMENT DESIGN ASSUMPTIONS:

LAYER No.	THICKNESS (mm)	E (MPa)	MU	MATERIAL TYPE	COSTS $	UNITS
1	80	3200	.3	BLOCKS	0	sp m
2	?	0<E<350	.35	CRUSHED ROCK	0	cu m
2	?	2300	.35	STABILISED COARSE-GRAINED MTL	0	cu m
3	SEMI INF	E=F(CBR)	.4	SUBGRADE	0	sq m

(b) TRAFFIC DATA:

AVERAGE DAILY TRAFFIC: 100
GROWTH RATE = 1% pa
DESIGN PERIOD = 20 YEARS
PROPORTION OF TRUCKS > 3 tonnes = 1.6%
Road is a new development serving 10 houses
There are 2 garbage collections/week

(c) PAVEMENT DESIGN COMPRISES:

SURFACE: 80 mm BLOCKS
SAND: 30 mm of BEDDING SAND
BASE: UNBOUND OR STABILISED CRUSHED ROCK
SUBGRADE: See TABLE below for CBR values

CBR %	THICKNESS OF UNBOUND LAYER mm	THICKNESS OF STABILISED LAYER mm
1	200	240
2	180	215
4	145	195
6	125	185

TABLE 5

SUMMARY OF TEST RESULTS AND OBSERVATIONS

TEST NO.	PAVER SPALLING	RUTTING	JOINT CONDITION	SAND BED THICKNESS (mm)	F.C.R. BASECOURSE THICKNESS (mm)	SUBGRADE CONDITION	PENETROMETER MEASUREMENTS (5 drops)	SUBGRADE C.B.R. (DERIVED VALUE)
1	Severe	25 mm over 750 mm circular diameter	No Jointing sand	20 - 25	50 - 60 well compacted	saturated	803 mm to 483 mm = 64 mm average/ drop	2.5
3	minimal	Not apparent	30 mm depth of jointing sand and wide joints	30 - 35	75 - 85 well compacted	partially saturated	779 mm to 552 mm = 45 mm average/ drop	4.0
4	Severe -	30 mm over 500 mm circular diameter	No jointing sand	25	65 - 75 well compacted	saturated	890 mm to 682 mm = 42 mm average/ drop	4.0

NOTE: Relationships between soaked CBR values and penetrometer readings have been shown to exhibit a large degree of variation in some instances. The derived CBR readings should be taken as an indication only. The graph used to derive the tabulated relationship is shown on Fig. 2.

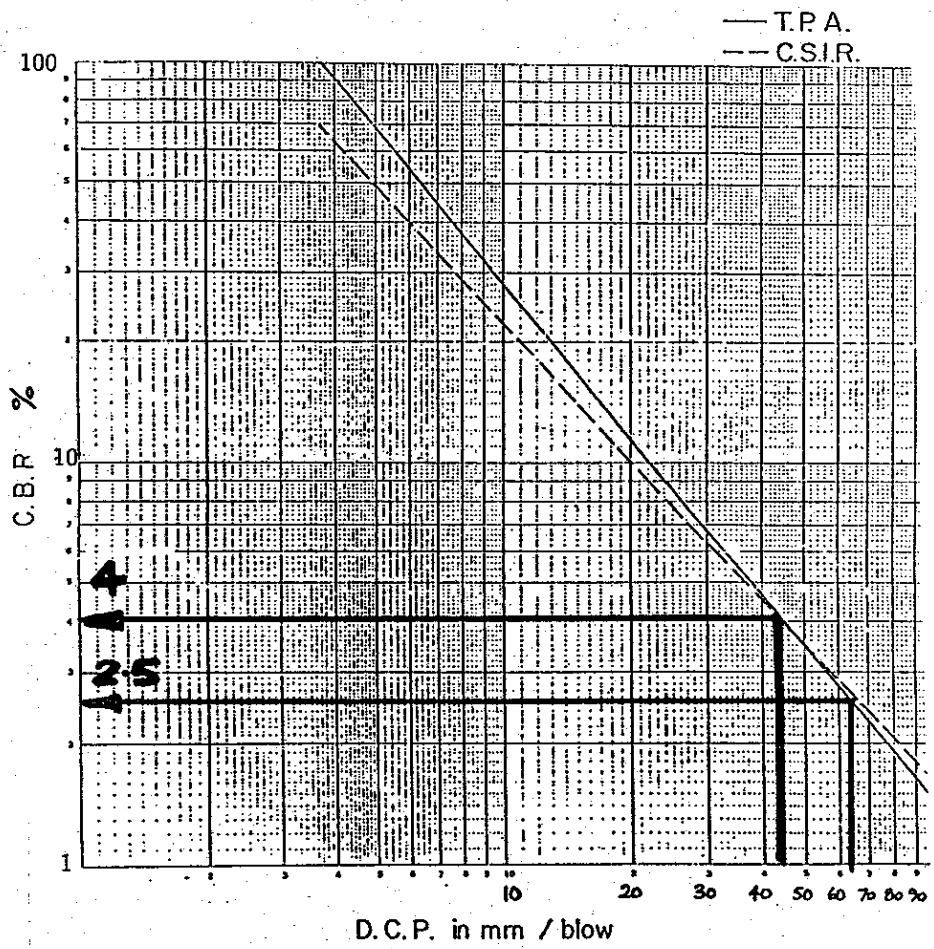


Fig. 2 - Relationship between subgrade DCP CBR and imputed CBR

The relationship between the DCP CBR and the imputed CBR is shown in Fig. 2.

BASECOURSE

The basecourse consisted of a well-graded crushed rock, dark in colour, and resembling dolerite. The maximum aggregate size was approximately 10 mm.

The basecourse appeared to be well compacted (it was difficult to excavate), and no mixing of the clay subgrade with the basecourse was observed. There were instances where the clay had intruded through 'cracks' in the basecourse which corresponded with the above paver joints. This form of intrusion occurred in test areas 1 and 3 in Fig. 1.

BEDDING SAND

The grading of the bedding sand appeared to be 'typical'.

PAVERS AND JOINTING MATERIAL

The segmental concrete pavers were of shape type A, 60 mm thick, pink to orange in colour, and generally sound. Very little jointing sand was present and, where it existed, it appeared to have a maximum aggregate size of 2 mm. Considerable movement of the pavement (10-20 mm) was observed under garbage truck wheel loads. Spalling of the paver arrises had occurred in localised areas throughout the pavement and in other areas the joint widths were greater than 5 mm.

CONCLUSION

The investigation showed that the most likely cause of failure was the difference between the thickness of the basecourse as specified and as laid (160 mm and 135 mm specified - 50 mm to 86 mm observed at points where the investigation was carried out).

Recommended designs for Sites One and Two for a range of subgrade CBR's are shown in Table 6.

OBSERVATIONS ON THIS PROJECT

(a) The Council stated that the pavement was regularly inspected and that proof-rolling was carried out on the basecourse material prior to the placement of the bedding sand and blocks. It is understood that this proof-rolling took place after a dry period and, given the clayey nature of the subgrade, this could account for the apparent lack of basecourse thickness not being detected.

This demonstrates that basecourse material, particularly when placed on reactive soils, should always be checked for quality, thickness and compaction and that proof-rolling alone is not necessarily an indicator of compliance with the specification.

(b) Although poor workmanship in block laying did not appear to be the prime cause of the failure, it was noticeable that the quality of laying, and attention to detail, was of a lower order on the latter sections of the work than those which were achieved on the initial stages of the project.

It is understood that, on this project - which was put out to tender on a cul-de-sac by cul-de-sac basis - contractor 'A', who completed the first section successfully, employed 'B' amongest his workers. When section two was out to tender, 'B' (who had the experience of one job) submitted a lower tender than 'A' and was awarded the work. Subcontractor 'B' than employed worker 'C' for stage two who, in turn, won stage three; a process of diminishing standards (albiet with cost savings) was thus established.

Whilst not wishing to critise the tender system, the client should ensure that the layer has a level of competence commensurate with the level of competence which would be expected from operatives in other areas of the construction industry. The apparent ease with which pavers can appear to be laid sometimes leads people to believe that 'any fool can do that' and masks the techniques which are required to successfully and attractively lay paving at edges, kerbs and gullies.

This is not to say that segmental paving demands a very high level of skill to lay; rather that the acceptance of the lowest tender, accompanied by minimum skills, often requires a level of supervision which makes the overall costs greater than those which could have been achieved by accepting a price from a more experienced layer, even though it may not be the lowest tender.

(c) Close liaison between the client and the supplier can often overcome the situation described in the previous paragraphs. It is interesting to note that the pavements

TABLE 6

DESIGN OF A CONCRETE BLOCK ROAD PAVEMENT

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA

JOB NAME: RESIDENTIAL PAVING

CLIENT:

SIZE OF JOB: 500 sq m

Details entered by Concrete Masonry Assoc.

DATE: 01-01-1980 TIME: 00:33:27

(a) PAVEMENT DESIGN ASSUMPTIONS:

LAYER No.	THICKNESS (mm)	E (MPa)	MU	MATERIAL TYPE	COSTS $	UNITS
1	60	3200	.3	BLOCKS	0	sp m
2	?	0<E<350	.35	CRUSHED ROCK	0	cu m
2	?	2300	.35	STABILISED COARSE-GRAINED MTL	0	cu m
3	SEMI INF	E=F(CBR)	.4	SUBGRADE	0	sq m

(b) TRAFFIC DATA:

ROAD CLASS: MINOR
AVERAGE DAILY TRAFFIC: 100
GROWTH RATE = 0% pa
DESIGN PERIOD = 20 YEARS
PROPORTION OF TRUCKS > 3 tonnes = 1.6%
Road is a new development serving 10 houses
There are 2 garbage collections/week

(c) PAVEMENT DESIGN COMPRISES:

SURFACE: 60 mm BLOCKS
SAND: 30 mm of BEDDING SAND
BASE: UNBOUND OR STABILISED CRUSHED ROCK
SUBGRADE: See TABLE below for CBR values

CBR %	THICKNESS OF UNBOUND LAYER mm	THICKNESS OF STABILISED LAYER mm
1	210	260
2	180	235
3	160	220
4	145	215
5	135	205
6	125	200

Note: The Table to the left tabulates the thickness recommended for both both bound and unbound layers of basecourse. In the sites examined only unbound basecourses were examined.

on this estate which were placed in close association with the paving supplier are performing satisfactorily.

REFERENCES

CONCRETE MASONRY ASSOCIATION OF AUSTRALIA (1980). Interim specification for interlocking concrete paving units. MA15.

HODGKINSON, J.R. and MORRISH, C.F. (1982). Design of interlocking concrete pavements for road traffic. Cement Conc. Assoc. Aust. Tech. Note TN40, March.



John Rourke is an architect and a graduate of the University of Sydney. He has had extensive European experience, having completed post-graduate courses at the Universite de Besancon, the Centre Scientifique et Technique du Batiment in Paris and the School of Advanced Architectural Studies in York. He was, for the five years prior to its completion, the co-ordinating architect on the Sydney Opera House. From that time until 1982 he was the Principal of a Sydney-based architectural practice. in 1982 he joined the Cement and Concrete Association of Australia and in 1984 was appointed Executive Officer of the Concrete Masonry Association of Australia.