The Walsh method of beam-on-mound design from inception to current practice*

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ABSTRACT: This paper reviews the original Walsh design method used for designing slabs on expansive soil and describes how the method has been implemented from its earliest use in the 1970s up to current practice. The focus of the paper is solely on the Walsh design method and, because the Walsh design method has been the instrument for the deemed-to-comply solutions for raft slab designs within the Australian Standard AS 2870, no comparison is made with alternative approaches used either within or outside Australia for designing residential footings. The paper presents previously unpublished changes to the original the Walsh method made as part of its inclusion in the two most recent editions of the Australian Standard AS 2870 and broadly discusses some of the impacts of these changes. A new adaptation of the Walsh method, written by the first named author, is introduced in which new parameters have been adopted to model more accurately the soil-footing interaction than previous adaptations. These changes still achieve residential footing designs comparable to those obtained using existing versions of the Walsh design method and are in keeping with the spirit of the Standard and Walsh’s original intentions for the implementation of his program.

KEYWORDS: Walsh design method; residential footings; soil-footing interaction; expansive clays; AS 2870; computer design.


1 INTRODUCTION

Lytton (1970) was the first to publish a detailed mathematical approach to the design of residential footings on expansive clay soils. He assumed that the critical design case could be approximated satisfactorily by modelling the effects of a doming soil mound beneath an infinitely-stiff concrete footing and designing the footing beams for the resulting bending moments in the concrete.

The conventional “Winkler spring” representation of the soil, in which all supporting springs are assumed to behave independently, was modified by assuming that adjacent support springs could interact with one another through shear coupling, so “coupling springs” were included in the soil model.

Lytton proposed that, in general terms, the patterns of soil movement, bending moments, shear and beam deflections for both centre heave and edge heave could be assumed, at least for design purposes, to be similar to the patterns shown in figure 2. Both the edge and centre heave mounds were assumed to have a polynomial shape in an unloaded condition, where the mound equation took the general form:

\[ y = cx^m \]  

(1)

where \( y \) is the distance below the highest point of the mound, \( x \) is the distance along the beam, \( m \) is an integer exponent, and \( c \) is a constant.
Figure 1: Lytton beam on mound model.

Figure 2: Lytton’s proposed patterns of moments, shear, deflection and soil pressure.
The beam on mound equation adopted for the Lytton Method was:

\[
\frac{d^2}{dx^2} \left( EI \frac{d^2 w}{dx^2} \right) - \frac{d}{dx} \left( G h B \frac{d}{dx} (w - y) \right) + kB (w - y) = q
\]

(2)

where \( EI \) = the beam flexural stiffness; \( B \) = effective width within which soil support for the beam is mobilised; \( G \) = effective shear modulus for the soil; \( h \) = effective depth within which soil shear resistance is mobilised; and \( q \) = the uniformly distributed load on the beam.

The first term in equation (2) represents the relationship between beam curvature, beam stiffness and the applied loads, the second term represents the behaviour of the “coupling springs” shown in figure 1, and the third term is the mathematical representation of the “swelling” Winkler springs.

Lytton reported that the solution of the beam on mound equation required a “trial and error procedure” and was best carried out using computer-based numerical methods such as finite differences to represent the beam component of the model which could quickly determine the points at which the beam would lift off the foundation. Lytton’s computer program, which assumed that the concrete beam was infinitely stiff, could solve “28 problems in 2 minutes” when run on CSIRO’s CDC 3200 computer. This level of computing technology was not available to practitioners at that time and so Lytton’s method was not adopted in general practice.

In the early 1970s, Walsh extended Lytton’s model by replacing the infinitely-stiff concrete footing beam with a mathematical representation of the reinforced concrete beam using the finite element method of analysis. Walsh called his FORTRAN computer program “DUBAL”, a play on words related to the “double stiffness” soil mound used in his model. In 1974, DUBAL could only be run on a mainframe computer and very few engineering practitioners had access to this kind of resource.

Figures 3(a) and 3(b) show the assumed mound shapes for “centre heave” and “edge heave” in DUBAL with the footing beam unloaded and weightless, and also indicate how Walsh proposed the “double mound”, soft and hard, could be modelled in the analysis using two independent sets of spring elements.

![Figure 3](image)

*Figure 3:* Walsh idealised soil mound shapes with footing beam unloaded and weightless – (a) centre heave and (b) edge heave.
For the centre heave mode, Walsh assumed that the top of the mound was flat and that the shape of the surface at each end of the mound over edge distance, \( e \), could be represented as a parabola. For the edge heave mode, the centre portion of the soil surface was assumed to be flat and, again, the shape of the surface at each end of the mound over edge distance, \( e \), could be represented as a parabola. In Walsh’s original version of DUBAL (Pitt, 1982), the edge distance for edge heave design was assumed to be equal to \( L/2 \), that is, the parabolic mound shapes of the soil were assumed to meet at the mid-span of the beam, similar to the mound shape assumed by Lytton.

The design differential movement of the soil mound was taken as \( y_m \). For centre design heave, the edge distance, \( e \), over which the differential movement occurred, was based on observations from instrumented covers and slabs constructed at two experimental research sites in Melbourne (Holland, 1981). Table 1 shows the recommended values of edge distance for centre heave design. Estimates of mound differential movement are also given in the table.

Based on observations on non-basaltic clays studied in Melbourne, Walsh (1978) proposed that, typically, the hard and soft swell mounds for a swelling soil could be related by differential mound height, \( y_m \), and swell stiffness, \( k_s \):

\[
y_m^s = 8y_m^h
\]

(3)

\[
k_s^h = 30k_s^s
\]

(4)

In equations (3) and (4), the superscript \( s \) refers to the soft swell mound and the superscript \( h \) refers to the hard swell mound.

Swell stiffness is defined as the pressure required to suppress a metre of heave and is expressed in units of kPa/m. Walsh studied swell-stiffness curves and concluded that these curves could be adequately represented by bi-linear plots, representing an initially soft response at low applied pressures, which stiffened to a hard response with further loading. Figure 4 shows a typical representation of Walsh’s swell-stiffness curve for a swelling clay soil. The slopes of the lines represent swell stiffness.

In order to make the functionality of DUBAL generally available to designers of footings, Walsh used DUBAL to publish tabulated values of two parameters \( C_1 \) and \( C_2 \) which were functions of footing geometry and measurable soil properties. The design tables assumed that the loads applied by a typical residential superstructure comprised the following three load types:

- an edge line load applied by the external walls, including the loads from the roof at the edge of the building
- a uniform slab load, including domestic live load
- a central line load applied across the building, again including wall and roof loads.

Walsh assumed the loading distribution could be represented as shown in figure 5, in which \( W \) is derived from total load applied to the footing, expressed as an equivalent uniform load applied over the entire footing length.

A suitable footing could then be designed using the following equations:

### Table 1: Estimates of mound parameters for Melbourne soil types (centre heave design).

<table>
<thead>
<tr>
<th>Soil type</th>
<th>( y_m^s ) [mm]</th>
<th>( e ) [mm]</th>
<th>( k ) [kPa/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary basaltic</td>
<td>30(^a)</td>
<td>2400</td>
<td>400 to 800</td>
</tr>
<tr>
<td>Uniform cracking clay at Sunshine</td>
<td>45(^b)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Tertiary sedimentary duplex clay at Waverley</td>
<td>15</td>
<td>2400</td>
<td>1000</td>
</tr>
</tbody>
</table>

\(^a\) Constructed in initially-wet conditions; \(^b\) constructed in initially-dry conditions
The Walsh method of beam-on-mound design from inception to current ...

The design of raft footings was introduced in the 1970s by Walsh and Payne. The Walsh method, which was developed in the early 1980s, was based on a table-based approach to the design of residential raft footings. The method did not allow a designer to model the actual load distribution applied to the soil foundation by the superstructure in cases where the loading distribution was significantly different from Walsh’s assumed loading distribution.

In 1984, following a technical review of the Walsh Method by Payne (1983a) as part of a research project sponsored by Peter Koukourou and Partners Pty Ltd, Walsh extended his method by developing DUBAL further into the computer program CORD (Code-oriented Raft Design). CORD was specifically intended for engineering practitioners to run on a desktop micro-computer.

In a submission by Payne (1983b) to the Footing Guidelines Panel of Engineers Australia, South Australian Division, the following equations were suggested as being appropriate for calculating edge distances for centre heave and edge heave in the Walsh method.

For centre heave,

\[ e = (0.5 + y_m/36) \text{ [m]} \]

where \( y_m \) = 0.7\( y_s \) [mm].

For edge heave,

\[ e = 0.2L \text{ and } y_m = 0.3y_s \text{ [mm]} \]

Payne developed equations (7) and (8) by back-calculating against experimental data published by Holland (1981) and earlier work published at CSIRO by Aitchison & Woodburn (1969). As part of the development of program CORD, Walsh agreed to trial equations (7) and (8).

Between 1984 and 1986, Walsh tested CORD for a range of footing configurations, residential building loads and soil types likely to be encountered across Australia and slightly modified equations (7) and (8) for edge distance calculation to those which appeared in the first version of AS 2870-1986, Residential Slabs and Footings (Standards Australia, 1986), and subsequently in AS 2870.2-1990, Residential Slabs and Footings – Part 2: Guide to Design by Engineering Principles (Standards Australia, 1990).

Considerations of prevailing climate and its impact on mound shape were introduced in the 1996 revision of the standard. In the “informative” Appendix F of AS 2870-1996 (Standards Australia, 1996), it was suggested that the edge distance, \( e \), for use in the Walsh method could be appropriately calculated using modified forms of equations (7) and (8) as follows.

For centre heave,

\[ e = H_s/8 + y_m/36 \]

where \( H_s \) is the depth of surface cracking in the soil [m], and \( y_m = 0.7y_s \) [mm].

For edge heave,

\[ e = \text{min}(0.2L, (0.6 + y_m/25)) \]

where \( L \) is expressed in metres and \( y_m = 0.5y_s \) [mm].

AS 2870-1986 recommended that the soil swell stiffness should be assumed to be 400 kPa/m for basaltic clays in the Melbourne area and 1000 kPa/m for other soils. For beams in contact with the soil, the soil swell stiffness should be taken as 100\( q \) kPa/m, where \( q \) is the average loading pressure acting on the soil foundation from the superstructure, including the weight of the footing, measured in kPa. Later versions of AS 2870 modified these recommendations slightly.

Practical experience with CORD post-1986 was generally reported as being satisfactory, except that occasionally footing sizes calculated for the edge heave condition appeared to be conservative. In response to this feedback from practitioners and based on some research work carried out in Melbourne by Washusen (1977), Walsh changed the mound shape for edge heave in CORD to that shown in figure 6. The mound consisted of a central flat portion bounded at each end by two parabolae with their origins at A and C. The parabolae met at point B, where the gradients were compatible. Point B was defined by the mound shape factor, \( W_f \), a design input parameter. Initially Walsh recommended a value for \( W_f \) of zero, resulting in a convex mound for edge heave design as in figure 3(b).
After further feedback from design office experience with CORD, and during Walsh’s overseeing of the commercialisation of program CORD during the late 1980s, it was found that the convex mound shape occasionally produced excessively conservative designs. The mound shape factor $W_f$ was changed again and was eventually chosen to have a constant value of 0.75, which produced, for edge heave design, an S-shaped edge mound with a supportive perimeter edge (figure 6).

Based on further practical experience with the design program, the value of $W_f$ eventually became a variable input parameter for the design method, calculated using Figure F2 in both AS 2870-1996 and AS 2870-2011 (Standards Australia, 2011) (figure 7). Therefore, in the subsequent CORD version of the Walsh method, the value of $W_f$ depended on two factors, being the characteristic surface movement, $y_s$, and the depth of design suction change for the site, $H_s$; a “normal profile” applied for $H_s$ less than 3 m, while a “deep-seated profile” applied for a site with value for $H_s$ greater than or equal to 3 m.

It is important to recognise that the shape of the edge heave mound has been the subject of ongoing debate and change since AS 2870 was first released in 1986. Specifically, the factor $W_f$ has not been published outside AS 2870 and, within that context, is referred to only in an “informative” Appendix of the standard.

In an attempt to model more closely potential torsional bending effects close to the corners of raft footings, Walsh & Walsh (1987) updated DUBAL into a separate program intended to model the three-dimensional actions of a stiffened raft footing. Their program, called “Grid On Mound”, or GOM, was used to check the torsion moments in a grid of beams, which theoretically could occur at the corners of structures subjected to the effects of moisture change in reactive soils. Program GOM did not gain general acceptance as a routine footing design aid.

2 A NEW ADAPTATION OF THE WALSH METHOD

In preparation for changes foreseen in AS 2870-2011, in which the impact of the influence of trees on residential footings was expected to be significant in many design cases, the first named author in 2009 undertook to develop a version of the Walsh method for TMK Consulting Engineers, which would run in Microsoft Excel. The Excel program is based on the first author’s 1986 translation of Walsh’s program DUBAL, originally written in FORTRAN, and published as an Appendix to a Master of Engineering thesis submitted by Pitt (1982) to the Swinburne Institute of Technology, Melbourne, Australia.

The second named author was asked to test the software against the provisions of AS 2870-2011 to check that the program could be used for routine footing design. As part of the development process, a testing regime was required to include an investigation into the effects of trees to the extent required by AS 2870-2011.

Several key features have been added to or modified within the design spreadsheet in order to comply with AS 2870-2011 and to reflect practical experience gained from observing real raft footings over the past 30 years or so, as described in the following sections.

In this new adaptation, the programming language and structure of the 1986 translation of DUBAL was initially altered to suit Excel’s Visual Basic for Applications (VBA) environment and several additional, peripheral software modules were written to create a suitable software interface between the translation of DUBAL and Excel’s input and output worksheets. In the final version of the program, the converted DUBAL module was implemented as a dynamic link library compiled in Microsoft’s .NET environment and made available to Excel using Microsoft’s Common Object Model.
(COM) technology. Based on a parametric study carried out by the first named author while testing the 1986 version of DUBAL and also on results obtained while testing the current Excel version, the .NET compiled version of DUBAL uses 100 finite element units to represent one half of the design beam span. This number of elements is required to properly represent the interaction of the soil mound and the footing beam, particularly for the edge heave design case where the length of beam support can be short for values of \( y_s \) greater than 60 mm or so.

### 2.1 Edge heave mound shape

A new feature of this adaptation is the way in which the edge heave mound is represented. Based on practical experience gained over many years and by studying the results obtained by using the method of calculating \( W_f \) suggested in Appendix F of AS 2870-2011, the new adaptation uses equation (11) to calculate \( W_f \):

\[
W_f = \begin{cases} 
0 & \text{for } y_s \leq 90 \text{ mm} \\
0.0125y_s - 1.125 & \text{for } 90 < y_s \leq 150 \text{ mm} \\
0.75 & \text{for } y_s > 150 \text{ mm}
\end{cases} \tag{11}
\]

Figure 7 shows how equation (11) compares with the relationship suggested in AS 2870-2011. In essence the original and conservative convex mound shape of Walsh is adopted until the design site surface movement of 90 mm is reached and then it is moderated gradually to a less severe shape as \( y_s \) increases to 150 mm. The maximum value of \( W_f \) is 0.75, the value adopted in the early development of CORD for all values of \( y_s \). So, in summary, the relationship between design ground movement and mound shape in edge heave adopted in the new version of the Walsh method is more conservative than that recommended by the standard.

### 2.2 Swell stiffness

The original DUBAL program assumed that \( k_s^h = 30k_s^e \). An investigation carried out by the second named author as part of the testing of the TMK spreadsheet indicated that the current version of CORD does not include the hard mound in the mathematical model. Li (1996) had previously reported this to be the case. The removal of the hard mound from the model does not appear to be consistent with the philosophy behind the Walsh method. As a result, this new adaptation of DUBAL reintroduces the hard mound into the model. Initially, equation (4) was implemented.

### 3 TESTING OF THE NEW ADAPTATION OF THE WALSH METHOD

The program was “beta-tested” by the second author at The University of South Australia (UniSA) between January and April 2012 to check for compliance with the requirements of AS 2870-2011. The testing program involved running the spreadsheet more than one thousand times, principally related to a 20 m long by 8 m wide stiffened raft footing, rectangular in plan, with three stiffening beams parallel to the long direction and six stiffening beams parallel to the short direction.

For articulated masonry veneer (AMV) walls, both single and double storey, the design site surface characteristic movement, \( y_s \), was taken to be between 30 mm and 150 mm, incremented in steps of 10 mm. For articulated full masonry (AFM) construction, the upper limit of \( y_s \) was set at 110 mm.

The testing was carried out in three distinct stages. The first stage of beta-testing provided comparisons between the outputs from the original version of the Excel spreadsheet and Walsh’s program CORD. Input variables included the wall types, wall height, roof construction (conventional rafter or truss) and number of storeys up to two-storey residential buildings. Double storey construction was investigated only for AMV houses.

The second stage investigated the influence of additional soil drying due to trees. Single-storey construction was tested in both AMV and articulated full veneer, and with a conventional rafter and tiled roof. Broadly in line with the requirements of AS 2870-2011, the additional soil movement due to the drying effects of a tree was taken to be 40% of \( y_s \).

Figures 8 and 9 show typical results obtained for single-storey AMV construction from the two programs for the flexural requirement per unit width of slab. The original version of the TMK spreadsheet used to produce these figures adopted a shape factor, \( W_o \), of zero. In addition, equation (4) was applied to determine the support of a footing at mid span when subjected to edge heave (refer “TMK edge heave” curve in the figures).

It was found that the effect of such high values for the mound hard swell stiffness in edge heave limits the theoretical interaction of the footing beam with the central zone of the supporting soil to insignificance. As a consequence, the limiting beam deflection is quite readily reached. In order to account for this unwanted effect, a modified version of the spreadsheet was developed, which incorporated a reduced hard mound swell stiffness for edge heave, given by:

\[
k_s^h = 5k_s^e \tag{12}
\]

Equation (12) is more consistent with the intent of AS 2870-2011, which suggests that the elastic stiffness of a drying, or dried, soil can be taken as being 5000 kPa/m. This value for the elastic stiffness is approximately five times the value of the swell stiffness of a wetting soil suggested by AS 2870-2011 and earlier versions. The earlier Walsh proposal
The reasons for recommending the use of equation (12) over Walsh’s original equation (4) are clearly demonstrated in the figures 8 and 9, which compare the TMK edge heave curves with the modified TMK edge heave curves. Although the flexural requirements in edge heave increased, the requirements remained substantially less than the corresponding requirements of program CORD.

It should also be noted that the modified version also implemented the variation of the shape factor as expressed by equation (11). As a result, the increase in design requirements from the original version has been moderated by adopting a shape factor \( W_f \) which increases as \( y_s \) increases, although at a slower rate than in CORD.

Following the testing program carried out at UniSA, the test report (Cameron, 2012) recommended that the modified TMK design spreadsheet be adopted for routine footing design provided that the soft mound stiffness is set to 100\( q \) or 1000 kPa/m, whichever is less.

The TMK spreadsheet, as originally developed and beta-tested, relied on the vigilance of the designer to set an appropriate value of the swell stiffness. During beta-testing of the TMK spreadsheet, care was taken to adopt the value of swell stiffness used by CORD. In April 2012, TMK adopted all the recommendations arising from the beta-test program. TMK also elected to modify the minimum mound soft swell stiffness...
3.1 Performance of the final TMK design spreadsheet

Tables 2 and 3 summarise comparisons made between CORD and the final modified TMK adaptation of the Walsh Method in terms of the footing beams obtained using the two methods for single-storey construction.

In the comparisons, the site characteristic swell, $y_s$, was assumed to be between 40 and 120 mm, generally. All widths of beams were taken as 300 mm for single-storey AMV construction and the slab mesh was assumed to be SL82. All beams were assumed to be reinforced with two bars in the top face and three bars in the bottom face. For AFM construction (single-storey), the external beam was widened to 400 mm and an extra reinforcement bar was provided top and bottom of the edge beam. Design beam depths were rounded up to the nearest 50 mm. Controlling factors for the overall design are noted in the tables although in some instances the controlling factor may have been just marginally ahead of another factor. The abbreviations CH and EH represent centre heave and edge heave, respectively.

In comparing outputs it should be noted that CORD adopts the design strategy of “smearing” the stiffness and flexural requirements over the slab and its beams by considering a “lumped” beam design, whereas the TMK approach distributes stiffness and flexural requirements equally between all beams, meaning that the edge and internal beams are designed separately in the TMK approach. The edge beams, which have smaller flange widths, will often control the design. In addition, the TMK design method always adopts the maximum beam depth for all beams. Consequently, the TMK design approach is an inherently more conservative design procedure than that embraced by CORD. Flange widths were compatible between the two design methods.

It can be seen that centre heave controlled most of the nine TMK designs, while edge heave was a little more dominant in the CORD designs. Edge heave tended to dominate CORD designs for AMV construction once $y_s$ values exceeded 70 mm, while the turning point for the TMK designs was closer to 90 mm. The TMK designs were slightly more conservative than the CORD designs for AMV construction.

The heavier loads from AFM construction resulted in centre heave dominating the designs at higher values of $y_s$ than observed for the designs for AMV. The TMK designs were significantly more conservative up to a $y_s$ value of 80 mm, past which point edge heave began to control the CORD designs.

3.2 Final results for AMV and AFM construction: CORD compared with the TMK spreadsheet

Figures 10 and 11 show results obtained from CORD and the final version of the TMK spreadsheet for the overall flexural requirement per unit width of

Table 2: Comparison of footing designs from CORD and TMK adaptation of Walsh Method (AMV).

<table>
<thead>
<tr>
<th>$y_s$ [mm]</th>
<th>CORD</th>
<th>TMK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam depth [mm]</td>
<td>Bar diameter [mm]</td>
<td>Controlling factor</td>
</tr>
<tr>
<td>40</td>
<td>300</td>
<td>12</td>
</tr>
<tr>
<td>60</td>
<td>400</td>
<td>12</td>
</tr>
<tr>
<td>80</td>
<td>500</td>
<td>16</td>
</tr>
<tr>
<td>100</td>
<td>800</td>
<td>16</td>
</tr>
<tr>
<td>120</td>
<td>1000</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 3: Comparison of footing designs from CORD and TMK adaptation of Walsh Method (AFM).

<table>
<thead>
<tr>
<th>$y_s$ [mm]</th>
<th>CORD</th>
<th>TMK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam depth [mm]</td>
<td>Bar diameter [mm]</td>
<td>Controlling factor</td>
</tr>
<tr>
<td>40</td>
<td>550</td>
<td>12</td>
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<td>60</td>
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<td>80</td>
<td>950</td>
<td>16</td>
</tr>
<tr>
<td>100</td>
<td>1550</td>
<td>20</td>
</tr>
</tbody>
</table>
slab. It is evident that the agreement between the two programs was much improved by the changes implemented in the TMK spreadsheet.

4 CONCLUSIONS

The Walsh design method evolved from work published by Lytton in 1970 and first appeared as a computer program written in FORTRAN suitable for operating on a mainframe computer. The theory behind the model has withstood the test of time, but in its original form, the mathematical model was found to be wanting due to gaps in the knowledge concerning key design parameters such as soil heave and mound edge distance. In addition, the effects of trees were not included in the original version of the program.

The shape of the edge heave mound has been the subject of ongoing debate and change. Unfortunately, these changes have generally not been well documented, nor the reasons for making them clearly explained. This paper has presented much of the relevant history surrounding the development of the Walsh Method from 1978 to the present.

Walsh’s program CORD has been a key component of Australian residential footing design since the release of the first design Standard in 1986. TMK Consulting Engineers have upgraded Walsh’s theory to reflect the development of slab on ground design since then and have produced a version of Walsh’s DUBAL program which is linked to Microsoft Excel.

The TMK program has been tested by the second author at the University of South Australia. The test report has concluded that, with the inclusion of the changes to Walsh’s DUBAL program described in this paper, the TMK design spreadsheet can be adopted for routine footing design.

ACKNOWLEDGEMENTS

Both authors wish to acknowledge the significant financial contribution made by TMK Consulting Engineers, Adelaide, to enable the development of the Excel design spreadsheet, including its testing. An acknowledgement must also be made to Paul Francis Walsh, for his lasting contribution to the design of raft slabs. Paul passed away in 2011.

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DAVID PAYNE

David Payne graduated from the University of Adelaide in 1974 and worked for the consulting firm, Peter S Koukourou Pty Ltd, as a structural designer until 1977 when he returned to the University of Adelaide as a post-graduate student. He completed his doctorate on load bearing masonry in 1982 and returned to Koukourou and Partners to work on the development of the waffle pod domestic footing system. In 1984 he joined Kinhill Stearns as a structural design engineer and also worked in the civil and geotechnical fields on several major projects including the O-Bahn Busway and the State Bank Centre in Adelaide. In 1994 he started his own consulting practice, OffTech Computing Pty Ltd, specialising in the design and development of software, mainly related to business quality management; he also designed and created software used in project and costing control in the manufacturing industry. While working with several Adelaide-based manufacturers as a government-sponsored management consultant, David completed his Master of Business Administration degree from Charles Sturt University in 2002. Since 2003, he has been designing and developing custom software in the fields of civil and structural engineering for clients wanting to move their businesses into computer-based design, including the use of remote access using the Internet. David is currently a senior engineering design, business management and computing consultant to TMK Consulting Engineers in Adelaide.

DON CAMERON

Don Cameron conducted research at CSIRO in Melbourne and later at UniSA in Adelaide. His research has included expansive clays, laboratory testing, design of footings for small buildings and the influence of trees on soil drying. Collapsing soils are a continuing interest. Pavement engineering has become a strong research interest and includes sustainable aggregates from recycled C&D waste for pavement construction, and the influence of soil suction both on subgrades below rail and on unbound granular materials in roads.