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Welcome from the editors

The Editorial welcomes all readers to its first issue of *Malaysian Construction Research Journal (MCRJ)*, a journal that disseminates on the latest development of Malaysian Construction technology. Special thanks to all authors who have contributed their papers and also to all reviewers for editing the papers submitted. The first issue of MCRJ highlights seven titles from research and development results and a report on productivity performance on construction.

In this first issue, *Noorzaei et al* examine the semi-loof element as probably one of the most efficient element available for the solution of thin shells of arbitrary geometry. Based on the semi-loof formulations, three dimensional finite element software are developed and its application to complex structures such as curved beam, scordis shell roof, roofing system and cooling tower are investigated.

*Siti Hawa et al* describe experimental and theoretical investigations to determine the effect of butt joint on the structural behaviour of Profiled Steel Sheet Dry Board (PSSDB) load bearing wall with door opening. The samples were subjected to axial compressive load and the results were compared between the two sets of samples and with the theoretical expressions.

*Lee et al* present on the recent development of micronised amorphous biomass silica and the synthesis of nanoparticles. The objective is to develop an economical and environmental-friendly material and process for sustainable concrete construction. The synthesis of biomass silica of particle size ranging 20µm down to 20nm is expected to promote renewed interest in concrete research related to packing efficiency of particles within the concrete matrix for the reduction of water permeability.

*Fayda et al* examine the development and application of two-dimensional finite element software to account for the structural modeling of concrete face rockfill dams (cfrd) during construction phase. The study focuses on the effect of construction sequence on the structural response of the dam with and without concrete slab.

*Othman et al* present the application of knowledge management in the construction industry. This paper reports on the findings of a survey, taking Malaysia contractors as samples, on the level of knowledge management application in the construction organization and area of construction management that can be improved by its application.

*Harimi et al* provide recommendations for the improvement of roofing design under Malaysian climate and also investigated the thermal performance of metallic roof system with sealed and ventilated attic. Their study include the impact of different thickness of fiberglass and foil-aluminium in reducing ceiling temperature on a low cost house that was mainly built from waste oil palm shell (OPS-Concrete) with galvanized steel-roof.
Shahuren reports the statistical analysis of productivity performance on construction sector for year 2003 and 2004 using data available at National Productivity Corporation (NPC). This paper highlights the percentage of performance growth through five (5) selected indicators representing residential, non-residential and civil engineering sub-sectors. The report compares the percentage achieved in 2003 and 2004. Although the statistic shows the decline on overall productivity performance, the paper examines the area of improvement based on 8th Malaysia Plan (RMK-8)

Syed Alwee examines the validity of claim through an analysis of an IT-led construction tendering initiative soon to be implemented in Malaysia. This paper highlights the need for good governance. The focus area of the paper is the examination on how legal, business and process protocol combine and integrate in e- tendering. It also looks on the universal trends in a unified tendering protocol and formal control for projects tendered electronically across borders.

Editorial Committee
CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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Abstract
Finite element analysis of thin shells received considerable attention during recent years and a number of finite elements for thin shell analyses have been derived. Among these, the semi-loof element occupies a special place owing to its generality, type of formulation and performance. At present the semi-loof element is probably one of the most efficient elements available for the solution of thin shells of arbitrary geometry. Based on the semi-loof formulations, the present study deals with development of three dimensional finite element software and its application to complex structures such as curved beam, scordis shell roof, roofing system and cooling tower.

Keywords: Cooling tower; Finite element code; Folded plate; Idealisation; Scordis Roof; Semiloof shell; Semiloof beam.

INTRODUCTION
Shell problems are difficult especially when the shell is very thin and in addition, one of the principal curvatures is positive and the other negative or zero. To model these types of structures, several shell elements are available in the literature Zienkiewicz (1993), Bathe (1996) and Cook (2002). Among the shell elements, the semi-loof shell element is probably one of the most efficient elements. It is particularly suitable to modal complex civil engineering structures such as cooling tower including staging columns and ring beams, flooring or roofing systems. The finite element formulation semi-loof beam, plate and shell are presented by Iron and Ahmad (1980), Owen and Martin (1981) Martin and Oliveira (1988a & 1988b) but with limited computer coding and application. A simple hybrid semi-loof plate bending element where no slave degree of freedom is involved, was presented by Sze (1994).

In this investigation, based on semi-loof formulations presented by Martin and Oliveira (1988a & 1988b), an attempt has been made to develop a three dimensional finite element software (Wong, 2004). The application of the software is shown extensively in the analysis of several civil engineering structures.

SEMI-LOOF SHELL ELEMENT
Figure 1a shows a quadrilateral semi-loof shell element referred to a system of global axes (x,y,z). Three types of nodes are shown: corner and midside nodes at which the displacements $u^i, v^i$ and $w^i$ along respectively the axes x,y and z are taken as parameters: loof nodes at which the parameters are $\theta^i_{xz}$ (rotation in a plane perpendicular to the element side) and $\theta^i_{yz}$ (rotation in a plane tangent to the element side); central node combining two types of parameters, displacements $\delta^e_i (u^0, v^0, w^0)$ and rotation $\theta^0_{xz}$ and $\theta^0_{yz}$ along the local axes.
The initial 45 degrees of freedom (dof) of the element will be arranged in three vectors as follows:

\[
\{ \mathbf{\sigma}^e \} = \{ u^1, v^1, w^1, \ldots, u^9, v^9, w^9 \} \\
\{ \mathbf{\rho}^e_{XZ} \}_{1 \times 9} = \{ \theta^1_{XZ}, \ldots, \theta^9_{XZ} \}^T \\
\{ \mathbf{\rho}^e_{YZ} \}_{1 \times 9} = \{ \theta^1_{YZ}, \ldots, \theta^9_{YZ} \}^T
\] (1)

After eliminating all the dof at the center node and all the local rotations along the element sides, the final dof of the element will be 32 (Figure 1b).

The coordinates of a point \( P(x, y, z) \) on the element midsurface are interpolated using shape functions. The shape functions for defining the variation of displacements at the corner and the mid-side nodes are given by:

\[
N^1 = \frac{1}{4} \left( -1 + \xi^2 + \xi \eta + \eta^2 - \xi^2 \eta \right) \\
N^2 = \frac{1}{2} \left( 1 - \eta - \xi^2 + \xi^2 \eta \right) \\
N^3 = \frac{1}{4} \left( -1 + \xi^2 - \xi \eta + \eta^2 + \xi^2 \eta \right) \\
N^4 = \frac{1}{2} \left( 1 + \xi - \eta^2 - \xi \eta^2 \right) \\
N^5 = \frac{1}{4} \left( -1 + \xi^2 + \xi \eta + \eta^2 + \xi^2 \eta \right) \\
N^6 = \frac{1}{2} \left( 1 + \eta - \xi^2 - \xi \eta \right) \\
N^7 = \frac{1}{4} \left( -1 + \xi^2 - \xi \eta + \eta^2 - \xi \eta^2 + \xi^2 \eta \right) \\
N^8 = \frac{1}{2} \left( 1 - \xi - \eta^2 + \xi \eta^2 \right)
\] (4)

The shape function for defining the variation of displacements at the central node is given by:

\[
N^9 = \left( 1 - \xi^2 \right) \left( 1 - \eta^2 \right)
\] (5)

The shape functions for the interpolation of rotations at the loof nodes are given by:
The shape function for the interpolation of rotation at the central node is given by:

\[ L^9 = 1 - \frac{3}{4} \left( \xi^2 + \eta^2 \right) \]  

(7)

Now, a relationship between the Cartesian coordinates of any of the shell elements and the curvilinear coordinates is written as:

\[ x = \sum_{i=1}^{8} N^i x^i \quad ; \quad y = \sum_{i=1}^{8} N^i y^i \quad ; \quad z = \sum_{i=1}^{8} N^i z^i \]  

(8)

The displacements along the local axes \( \hat{X}, \hat{Y} \) and \( \hat{Z} \) will be denoted respectively by \( U, V \) and \( W \) and can be obtained as projections of \( u, v \) and \( w \), i.e.:

\[ U = \{X\}^T \{d\} \]  

(9)

\[ V = \{Y\}^T \{d\} \]  

(10)

\[ W = \{Z\}^T \{d\} \]  

(11)
Considering Equation (10) these displacements are obtained in terms of shape functions and nodal parameters as:

\[
U = \{X\}^T [N] \{\delta e\} \\
V = \{Y\}^T [N] \{\theta e\} \\
W = \{Z\}^T [N] \{\phi e\}
\]

(13)

At each point of the element the rotations \(\theta_{xz}\) and \(\theta_{yz}\) are interpolated by means of loof and central node shape functions \(L^j (j = 1,9)\) and the corresponding nodal values \(\theta_{xz}^j\) and \(\theta_{yz}^j\).

The stiffness matrix is formed by the usual finite element procedure, i.e.:

\[
[K^e] = \int [B]^T [D] [B] \, dV 
\]

where

\[
[D] = \begin{bmatrix}
D^p & \vdots & 0 \\
\vdots & \ddots & \vdots \\
0 & \vdots & D^b
\end{bmatrix}
\]

(15)

and

\[
[D^p] = \frac{Et^2}{1 - \nu^2} \begin{bmatrix}
1 & \nu & 0 \\
\nu & 1 & 0 \\
0 & 0 & \frac{1-\nu}{2}
\end{bmatrix} \quad \text{or} \quad [D^b] = \frac{Et^3}{12(1-\nu^2)} \begin{bmatrix}
1 & \nu & 0 \\
\nu & 1 & 0 \\
0 & 0 & \frac{1-\nu}{2}
\end{bmatrix}
\]

(16)

The element strain matrix \([B]\) is composed of two parts, one corresponding to the plane (membrane) behaviour and the other to the bending behaviour. Defining the strains by:

\[
\{\varepsilon\} = \{\varepsilon^p : \varepsilon^b\}^T \\
\quad = \{\varepsilon_X^p, \varepsilon_Y^p, \gamma_{XY}^p : \varepsilon_X^b, \varepsilon_Y^b, \gamma_{XY}^b\}^T \\
\quad = \left\{\frac{\partial U}{\partial X}, \frac{\partial V}{\partial Y}, \left(\frac{\partial U}{\partial Y} + \frac{\partial V}{\partial X}\right), -\frac{\partial^2 U}{\partial X \partial Z}, -\frac{\partial^2 V}{\partial Y \partial Z}, \left(-\frac{\partial^2 U}{\partial Y \partial Z} + \frac{\partial^2 V}{\partial X \partial Z}\right)\right\}^T
\]

(17)

Kirchhoff’s shear constrains are applied by stipulating the transverse shear at loof nodes to be zero so as to eliminate rotation parallel to the side of the nodes. The variables at the central nodes are also eliminated and constrained version has only 32 degrees of freedom per element including 24 translational degrees of freedom at the corner and the midside nodes and 8 rotations at the loof node (Figure 1b).
SEMI-LOOF BEAM ELEMENT

The beam element (Figure 2a) possess, before constraining, the following degrees of freedom:

(i) displacement \((u^i, v^i, w^i)\) along the global axes \((x, y, z)\) at node 1, 2 and 3
(ii) rotation \((\theta^i_x, \theta^i_y, \theta^i_z)\) along the axes at nodes 1 and 3
(iii) rotations \((\theta^i_Y, \theta^i_Z)\) along the local axes at loof nodes 4 and 5

Of these 21 dof, the local rotations \(\theta_Y\) and \(\theta_Z\) along the axes \(\hat{Y}\) and \(\hat{Z}\) at node 4 and 5 are conveniently constrained, the final configuration of the element having therefore 17 dof (Figure 2b). For later reference the following vectors of parameters are defined:

\[
\{\phi^e\} = \begin{bmatrix} \phi^1_x & v^1 & w^1 & u^2 & v^2 & w^2 & u^3 & v^3 & w^3 \end{bmatrix}^T
\]

(18)

\[
\{\varphi^i\} = \begin{bmatrix} \varphi^1_x & \varphi^1_y & \varphi^1_z & \varphi^2_x & \varphi^2_y & \varphi^2_z & \varphi^3_x & \varphi^3_y & \varphi^3_z \end{bmatrix}^T
\]

(19)

Note that nodes and variables are defined in order to match the configuration of the shell element, and that each beam conforms with the neighbouring beams in both slope and deflection.

The coordinates of a generic point \(P(x, y, z)\) belonging to the element axis are interpolated using coordinates of the edge and midside nodes 1, 2 and 3 and shape functions \(N^i\) as follow:

\[
x = \sum_{i=1}^{3} N^i x^i; \quad y = \sum_{i=1}^{3} N^i y^i; \quad z = \sum_{i=1}^{3} N^i z^i
\]

(20)

where the shape function \(N^i\) are obtained through the following polynomial basis

\[
\left(1, \xi, \xi^2\right)
\]

(21)

The displacement along the global axes of a generic point \(P(x, y,z)\)

\[
\{d\} = \{u, v, w\}^T
\]

(22)

are interpolated using the corresponding displacements of nodes (1,2,3) and shape functions, \(N^i\) defined by Equation (23).

These shape functions are given by:

\[
N^i = \frac{1}{2} \left\{\xi^2 - \xi \right\}
\]
\[ N^2 = \left( 1 - \xi^2 \right) \]
\[ N^3 = \frac{1}{2} \left( \xi^2 + \xi \right) \] (23)

Therefore,
\[
\{d\} = [N]\{\xi^r\} \quad \text{(24)}
\]
\[
[N] = \begin{bmatrix}
N^1 & 0 & 0 & N^2 & 0 & 0 & N^3 & 0 & 0 \\
0 & N^1 & 0 & 0 & N^2 & 0 & 0 & N^3 & 0 \\
0 & 0 & N^1 & 0 & 0 & N^2 & 0 & 0 & N^3
\end{bmatrix} \quad \text{(25)}
\]

The rotations at a generic point, P (x,y,z)
\[
\{\theta\} = \{\theta_x, \theta_y, \theta_z\}^T \quad \text{(26)}
\]

are obtained using the global rotations at nodes (1,4,5,3) and shape functions \(L^j\) \((j = 1,4,5,3)\), i.e
\[
\{\theta\} = [L]\{\theta^e\} \quad \text{(27)}
\]

The shape functions \(L^j\) are defined using the following polynomial basis:
\[
\{1, \xi, \xi^2, \xi^3\} \quad \text{(28)}
\]

These shape functions are presented in Equation (29). The matrix \([L]\) is defined in a same way as Equation (25).

\[
L^1 = \frac{1}{4} \left( -1 + \xi + 3\xi^2 - 3\xi^3 \right)
\]
\[
L^2 = \frac{1}{4} \left( -1 - \xi + 3\xi^2 - 3\xi^3 \right)
\]
\[
L^3 = \frac{3}{4} \left( 1 - \sqrt{3}\xi - \xi^2 + \sqrt{3}\xi^3 \right)
\]
\[
L^4 = \frac{3}{4} \left( 1 + \sqrt{3}\xi - \xi^2 - \sqrt{3}\xi^3 \right) \quad \text{(29)}
\]

The stiffness matrix is segmented in usual way:
\[
[K] = \int [B]^T [D][B] \, dv \quad \text{(30)}
\]
The strain displacement matrix \([B]\) is defined as:

\[
[B] = \left\{ \begin{array}{c}
\frac{\partial U}{\partial X}, \frac{\partial V}{\partial X} - \theta_z, \frac{\partial U}{\partial X} + \theta_y, \frac{\partial \theta_y}{\partial X}, \frac{\partial \theta_z}{\partial X}, \frac{\partial \theta_x}{\partial X}
\end{array} \right\}^T
\]  

The elasticity matrix \([D]\), is:

\[
[D] = \begin{bmatrix}
EA & 0 & 0 & 0 & 0 & 0 \\
0 & GA & 0 & 0 & 0 & 0 \\
0 & 0 & GA & 0 & 0 & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
0 & 0 & 0 & EI_{yy} & 0 & 0 \\
0 & 0 & 0 & 0 & EI_{zz} & 0 \\
0 & 0 & 0 & 0 & 0 & GI_{xy}
\end{bmatrix}
\]  

The two local rotations, \(\theta_y\) and \(\theta_z\) at loof nodes were eliminated by imposing the shear constrains, i.e \(\gamma_x = 0.0\) and \(\gamma_{y,z} = 0.0\) at nodes 4 and 5.

**COMPUTER PROGRAMMING**

At initial stage of this study, the subroutines SLSTIF and BMSTIF published by earlier investigator such as Iron et al. (1980) and Martin et al. (1988a &1988b) are implemented under Fortran environment. These subroutines are concerned with generation of stiffness, mass and load matrices. Then pre-processor (Noorzaei, 1991), solution routine (modified frontal technique) developed by Godbole et al. (1991) and post-processor (Noorzaei, 1991) are added under a master main. The flowchart of the complete program is shown in Figure 3.

The calibration of this upgraded semi-loof computer code has been well established by analysing some benchmark problems, for which the analytical solutions are available in the literature. These benchmark problems include curved beam, clamped circular plate and scordis roof. Furthermore an attempt has been to analyse some structures such as roofing system and cooling tower using semi-loof elements and the three dimensional finite element software packages is compatible with Fortran 90 power station computer.

The program further strengthens by adding few standard elements such as brick elements and infinite elements. The program is multi-element in nature and can deal with concentrated, pressure and gravity loadings (i.e only static loading). Besides that, there is compatibility between the shell element and beam element. At present the software application is limited to linear analysis.

**CALIBRATION AND APPLICATION**

In order to explore the capabilities of the semi-loof elements some benchmark structures such as beams, plates and shells have been selected for the purpose of verification,
calibration and application of the finite element code developed in the present investigation.

**Numerical example 1: Behaviour of curved beam**

In order to ascertain the generality of the semi-loof beam element the curved beam shown in Figure 4 is considered. The finite element idealisation of the beam is presented in this figure. The solution obtained via the present idealisation is very close to the solution reported by Robinson (1973) (Table 1). As it should be, the value of displacement at node 3 and 7 are the same in magnitude but opposite in direction.

**Numerical example 2: Clamp circular plate under uniform loading**

As an illustration for modeling of curved boundary this type of problem has been chosen. The finite element mesh of the plate including the material and loading are shown in Figure 5. It is clear from Figure 6 that there is a good agreement between the result evaluated by present modeling and the other investigators.

**Numerical Example 3: Analysis of Scordis roof with semi-loof shell element**

This is a cylindrical shell roof under self weight and has been modeled using semi-loof shell element. The geometry and property of roof problem and the finite element mesh is shown in Figure 7. This example was also solved by many investigators such as Zienkiewicz (1979) and Krishnamoorthy (1988).

The comparison of vertical and axial displacement at different sections of the shell roof is shown in Figures 8 and 9 respectively which shows a good agreement between the results. The comparison of force $N_x$ and moment $M_x$ along the midspan are shown in Figures 10 to 11 respectively. It is clear from these plots that variation of the moment and force for the present study and all other investigators are almost identical.

**Numerical Example 4: Umbrella-Shaped Folded Plate Roof**

The idea of an umbrella-shaped roof for pavilions is based on the article presented by Li (1991). The V-section precast panels are assembled into umbrella shape with joints formed and cast-in-place to fully integrate the structure. Umbrella-shaped folded plate roofs are supported by beams and columns. Figure 12 shows the roof plan and elevation along with material and geometrical properties. Figure 13 shows a plan and section of a tapered V-plate.

Here the roof are represented by means of the semi-loof shell elements while the beam and column is idealised using the semi-loof beam elements. The structure is subjected to gravity type of loading. Figure 14 shows the finite element mesh of the structure.

The variation of displacement at section A-A, B-B and C-C (Figure 15) are shown in Figure 16. Since the section line is symmetrical only half of the section is plotted. As can be seen from Figure 16, variation of vertical displacement reduces as it goes along the length of Section A-A because the location of column situated at length 5.25 m from the ring beam.
Similar trend of behaviour is observed for both Sections B-B and C-C which they have maximum displacement at free end and minimum near the ring beam.

The variation of membrane forces $N_x$, $N_y$ and $N_{xy}$ for all the sections are exhibited in Figure 17 (a,b,c). While the profiles of moments $M_x$, $M_y$ and $M_{xy}$ are illustrated in Figure 18 (a,b,c). The forces $N_x$ and $N_y$ are increasing at the location of near to the column while moments $M_x$ and $M_y$ is decrease near the upper ring beam.

**Numerical example 5: Analysing a hyperbolic cooling tower**

The modeling of a cooling tower including ring beam at the staging level and also without ring beam has been shown using semi-loof beam and shell elements. The geometry is shown in Figure 19 and finite element idealisation of the cooling tower is presented in Figure 20. The material properties of the cooling tower and ring beam at level ($Z=-232.1275$) are shown in Tables 2 and 3 respectively (Karissiddappa et al., 1995).

**MESHING**

Due to symmetric of tower only half of it was considered and boundary condition applied on nodes along symmetric axis. Total number of semi-loof shell element was 72 and 9 beam elements (Noorzaei et al., 2003).

**Behaviour of Tower**

**Vertical Deflection**

The variation of vertical displacement along the height of the cooling tower for $\theta = 90^\circ$ is shown in Figure 21. It is clear from this plot that vertical displacements decrease toward zero at bottom of tower and has a maximum displacement about 0.0175 ft at the top of tower. Similar behaviour has been noted in the tower when the ring beam is included in the model. This indicates that the ring beam has no effect on the vertical displacement, as expected.

**Radial Displacement**

Radial displacement along height of the cooling tower at $\theta = 90^\circ$ shown in Figure 22. It is seen from this figure that the ring beam has a significant influence on the radial displacements and lead to inward displacements of the tower near the mid-height of the tower.

**CONCLUSION**

Based on this investigation, the following conclusions can be drawn:

i. Based on the semi-loof formulation presented by earlier investigators, a three dimensional finite element software package has been written.

ii. The validity of the finite element software has been well established.

iii. The complex structures as roofing and cooling tower has been analysed by using
semi-loof shell elements which show the application of this element in predicting perfect behaviour of these structures.

iv. Semi-loof beam element is suitable for representing the straight curved and its combination with semi-loof shell element has been clearly worked out.

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REFERENCES


EFFECT OF BUTT JOINT ON PSSDB WALL PANEL WITH DOOR OPENING UNDER AXIAL LOAD

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Abstract
Profiled Steel Sheet Dry Board (PSSDB) system as a load bearing wall is structurally efficient and economical in transferring loads to the foundation. This paper describes experimental and theoretical investigations to determine the effect of butt joint on the structural behaviour of PSSDB load bearing wall with door opening. PSSDB wall panels formed from proprietary profiled steel sheet, Bondek II (0.75 mm thick), sandwiched by two skins of Cemboards (12 mm thick), via self-drilling, self-tapping screws, were used for the tests. The samples tested were three (3) PSSDB walls with door opening and butt joint between the Cemboards, and three (3) PSSDB walls with door opening but without butt joint on the Cemboard. The samples were subjected to axial compressive load and the results were compared between the two sets of samples and with the theoretical expressions. The average value of the ultimate load capacity for PSSDB load bearing door panels with butt joint was found to be 328 kN, while that for the samples without butt joint was 322 kN. The average maximum lateral deflections at first cracks for both types of PSSDB panels were 4.1 mm and 5.0 mm respectively. The final failure mode was a combined crushing and lateral buckling.

INTRODUCTION

Profiled Steel Sheet Dry Board or PSSDB system is a new and innovative composite construction system with a potential to be extended in application as an alternative to flooring, wall unit and roofing system. The idea was originally conceived by Wright and Evans (1986) in the United Kingdom. At present, further research works are being conducted extensively at Universiti Kebangsaan Malaysia. The panel system consists of profiled steel sheeting compositely connected to dry boards (plywood, Cement boards or particle boards) by mechanical or self-tapping screws to form panel that has far better features and attributes in comparison to the materials in their original forms separately (Wan Hamidon, et. al, 1996). The research done previously was concerned with PSSDB system as flooring, roofing units and wall without opening. The present study focused on the effect of butt joint in the dry boards on the behaviour of PSSDB system as walling. Therefore, the PSSDB system can be said to have an unlimited potential. It is also very light and therefore easily transportable, and can be erected quickly. PSSDB serves as an alternative and a more practical solution to existing traditional forms of construction.

PSSDB system gives superior bending stiffness, higher load bearing and higher resistance to buckling failure compared to using profiled steel sheet (PSS) alone (Ehsan et al 2000). Furthermore, the depth of floor or wall can be designed much lesser than the traditional design to carry the same loading, thus a saving in cost and space. Various tests were carried out on the system including fire resistance, sound proofing, water resistance and others. In exploiting its usage further so as not to concentrate purely as a flooring structure, various studies were carried out as to its ability and behaviour as wall and roof structures (Mengesha 1992, Benayoune 1998, Ehsan et al. 2000, Suzaimy 2000, Mohd. Zahri 2000, Benayoune & Wan Hamidon 2000, Ehsan et al. 2002, Yong C.B. et al. 2002, Siti Hawa et al. 2003a, Siti Hawa et al. 2003b, Wan Hamidon et al. 2003a, Wan Hamidon et
al. 2003b, Siti Hawa et al. 2004a, Siti Hawa et al. 2004b).

THEORETICAL ANALYSIS

The theoretical investigation of the load bearing capacity of the PSSDB wall panels using a different PSS called PEVA 45 was proposed by Benayoune and Wan Hamidon (2000). The ultimate load capacity of the panel is the ultimate load in which the composite panel would fail under applied axial load. It is based on the concept that the capacity is derived from individual components, namely the PSS and the Cemboard, and the interaction between them. They have proposed a semi-empirical equation to evaluate the crushing load for short wall panel. This equation takes into account of the effective width and the local buckling (BS5950 Part 6) by introducing a reduction factor $k$:

$$P_u = (A_n + nkA_0)k\sigma_y$$  \hspace{1cm} (1)

where

- $P_u$ Ultimate load
- $A_n$ Cross-sectional area of PSS
- $A_0$ Cross-sectional area of Cemboard
- $n$ $E_p/E_c = 1/45.6$
- $k' = 0.14$ for partial interaction
- $k$ Reduction factor
- $\sigma_y$ Yield stress of PSS

As the height of the wall increases the failure may be due to overall buckling. Euler formula is used to evaluate the PSSDB panel elastic buckling load.

$$P_{cr} = \frac{\pi^2EIL}{(KH)^2}$$  \hspace{1cm} (2)

where

- $P_{cr}$ Euler buckling load
- $E_p$ Modulus of elasticity of PSS
- $I_c$ Moment of inertia of composite section
- $K = 1.5$ for wall one end fixed and the other end partially restrained in direction
- $H$ Height of wall

EXPERIMENTAL STUDY ON PSSDB WITH DOOR OPENING

In this section, the experimental study on the PSSDB is described. The aims of the experimental work are to gain an understanding of the behaviour of PSSDB as load bearing wall panels with door opening, and to study the effect of the butt joint in dry board on the structural capacity of the PSSDB panel due to compressive axial load.
PSSDB Wall Panel

The PSSDB load bearing wall system consists of two skins of dry boards (Cemboards) attached to PSS (Bondek II) as the main core of the panel, using mechanical connectors (selfdrilling and self-tapping screws). Bondek II of 0.75 mm thick (the dimensions of Bondek II may be obtained from the web site listed in the reference) and Cemboard of 12 mm thick were adopted in this study. The size of each sample is 1000 mm high x 1320 mm wide x 78 mm thick with door opening of size 700 mm x 300 mm x 78 mm. These dimensions represent 1/3 the actual size of a wall. The thickness of the panel however is not reduced. The connectors were fixed at a 100 mm and 200 mm centre to centre in the longitudinal and transverse directions respectively. There were 46 screws on the front panel and 63 screws on the back panel. Butt joint is formed by putting two pieces of Cemboard side by side without adhesive being applied. Butt joint is necessary for a full size wall because a standard size Cemboard has 1220 mm width. A typical cut-out for the opening in PSSDB and the screw positions are as shown in Figure 1.

![Figure 1. Schematic view of PSSDB with butt joint](image-url)
Experimental Set-up

The test rig consisted of a support beam at the lower end, and a movable loading frame on the upper end. In addition, to allow for equal distribution of the load, the upper C-channel was put on rollers. PSSDB wall sample was placed vertically on C-channel, which was clamped to the bottom beam. The samples were tested under in plane axial load delivered by means of hydraulic jack connected to a load cell having a capacity of 1000 kN placed at the upper end of the sample. Displacement transducers to measure deflections perpendicular (lateral) to the height of the wall panels were placed at various locations as shown in Figure 2. Transducers T1 – T4 were located in a vertical line so that the deflection profile can be obtained. Transducer T5 was placed above the door opening. The load cell and transducers were connected to a portable digital electronic data logger. The initial values for deflection and load were zeroed on the measuring device once the sample, the loading system and the transducers had been assembled in position on the supporting and specimen frames. This condition was considered to represent the initial unloaded state of the panel.

Loads were then applied incrementally. The loads at initiation and propagation of cracks in different locations were observed and noted. The loading and the corresponding deflection were also recorded. Readings were recorded at interval of 0.2 kN. After the loading had peak and then decreased significantly the test was stopped. The load and the corresponding deflection measurements taken from the experiment were then used to investigate the crack patterns and the behaviour of the PSSDB wall panels. The experimental set-up is shown in Figure 3.

RESULTS AND DISCUSSION

Load-Deflection Response and Ultimate Load Capacity
Table 1. Lateral displacement at ultimate load

<table>
<thead>
<tr>
<th>Sample</th>
<th>PSSDB with butt joint (ODB)</th>
<th>PSSDB without butt joint (OD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ultimate load capacity (kN)</td>
<td>Max. lateral deflection (mm)</td>
</tr>
<tr>
<td>1</td>
<td>393</td>
<td>16.1</td>
</tr>
<tr>
<td>2</td>
<td>312</td>
<td>7.2</td>
</tr>
<tr>
<td>3</td>
<td>279</td>
<td>11.6</td>
</tr>
<tr>
<td>Average</td>
<td>328</td>
<td>11.6</td>
</tr>
</tbody>
</table>

All the six samples showed quite similar characteristics in load-deflection. The load-lateral deflection responses of the samples exhibited approximately linear relationships. The linear relationship persisted until the maximum load of each sample. After the maximum load was exceeded, the deflection increased significantly as the load decreased rapidly. This is an indication of the beginning of lateral buckling before failure. A typical load-deflection is as shown in Figure 4.

The deformation profiles of samples with butt joint (ODB 1, ODB 2 and ODB 3) obtained from transducers T1-T4 showed that maximum lateral deflection occurred at about the same position, located at a height of about 700 mm. Stress concentration occurred at this location due to the fact that the cross-sectional area is reduced. The deformation profiles for the samples are as shown in Figure 5. ODB 1 had the lowest lateral deflection and showed slightly double curvature. On the other hand, ODB 2 and ODB 3 exhibited single curvature. The maximum lateral displacements at ultimate load were 16.1 mm, 7.2 mm and 11.6 mm respectively (see Table 1). Similarly, maximum lateral displacement of samples without butt joint (OD 1, OD 2 and OD 3) also occurred at about the same height as shown in Figure 6.

Figure 4. Typical load against lateral displacement
The corresponding maximum lateral displacements were 20.1 mm, 6.7 mm and 11.1 mm respectively.

The ultimate load is the maximum load achieved before the load decreased when the wall panel started to undergo an overall buckling. The ultimate loads recorded for ODB samples ranged from 279 kN to 393 kN and for OD samples, they ranged from 286 kN to 370 kN. The scattering results may due to the difficulty in obtaining a perfectly level surface at the ends of the panel. This was expected when the cutting was done by hand. The results showed that the PSSDB wall with butt joint has similar average strength compared to PSSDB wall without butt joint. The theoretical ultimate load calculated using equation (1) gave $Pu = 375 \text{kN}$, based on a coefficient of reduction $= 0.6$ and the cross-sectional area of the two ‘legs’ of the panel. The reduction takes account on the reduction of strength due to effective width. From Table 1, the average experimental ultimate load is about 13% less than that based on equation (1). This might be due to the present of eccentricity of axial load and in-plane bending. The elastic buckling load using equation (2) against the wall height is as shown in Figure 7. It can be seen that up to about 1.7 m, the buckling load is higher than the theoretical crushing load. It can be said that the buckling load is not likely to happen for domestic loading (Benayoune and Wan Hamidon 2000).
It was observed that the loads at which first crack appeared on the samples were only about 40% to 55% of the ultimate loads as shown in Table 2. Therefore, it is significant to determine the lateral deflections at that loads. The maximum lateral deflections at 40% ultimate load are also given in Table 2. The transducer where the deflection was obtained is given in the parenthesis. The average deflection value for ODB samples was 4.1 mm whilst that for OD samples was 5.0 mm. This showed that the two samples have no significant difference in stiffness. As it can be seen, the two sets of samples had only 30% of the height differed in its configuration, which is the butt joint in the ODB samples. However it is worth to note that the butt joint exhibits hinge reaction at the upper section of the opening. This contributes to flexural stress release at this joint for samples with butt joint.

**Table 2. First crack load and lateral displacement at 40% ultimate load**

<table>
<thead>
<tr>
<th>Sample</th>
<th>PSSDB with butt joint (ODB)</th>
<th>PSSDB without butt joint (OD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load at first crack (kN)</td>
<td>Ratio of crack load/ ultimate load</td>
</tr>
<tr>
<td>1</td>
<td>192</td>
<td>0.49</td>
</tr>
<tr>
<td>2</td>
<td>123</td>
<td>0.39</td>
</tr>
<tr>
<td>3</td>
<td>109</td>
<td>0.39</td>
</tr>
<tr>
<td>Average</td>
<td>4.1</td>
<td></td>
</tr>
</tbody>
</table>

**Crack and Failure Mode**

Similar crack patterns were observed for all ODB samples. A typical crack pattern of PSSDB ODB samples is as shown in Figure 8. The crack started on the sides of the door opening at the upper corners that were considered as high stress areas because of the sudden
decreased in the cross-sectional area. Similar crack patterns are also exhibited on OD samples. A typical crack pattern of OD samples is shown in Figure 9. The difference between the two crack patterns was that there was a crack under flexural at upper middle portion of opening in the OD samples. The butt joints in the Cemboard act as predetermined cracks in ODB. Some cracks were observed to pass through screw positions. The final failure mode for both type of PSSDB was a combined crushing and lateral buckling on the sides of the samples at a height of about 700 mm (Figure 10).

**Figure 8.** Typical crack pattern for ODB

**Figure 9.** Typical crack pattern for OD
CONCLUSION

The experimental study dealt with the behaviour of PSSDB wall under compressive axial load. It can be concluded that the ultimate load capacity for PSSDB walls with butt joint (ODB) was about the same as that without butt joint (OD). The average loads were 328 kN and 322 kN respectively. The proposed theoretical crushing load was compared to the experimental results. It was found that the average load was 13% less than that obtained from the proposed expression. The average deflection value obtained at 40% ultimate load for ODB was 4.1 mm whilst that for OD was 5.0 mm. The lateral displacements for the samples were small and the ultimate load capacity were high indicating that the PSSDB wall panels could be recommended for load bearing wall in domestic building construction. Nevertheless, a full-size investigation is recommended.

ACKNOWLEDGEMENT

The authors wish to express their sincere thanks to Universiti Teknologi MARA, Universiti Kebangsaan Malaysia, Bluescope Steel Sdn Bhd, Hume Cemboard Sdn Bhd, Mohd Rashid Ya’acob and Muhammad Zihan Kisson for making this study possible.

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MICRONIZED BIOMASS SILICA AND NANOPARTICLES SYNTHESIS – RECENT DEVELOPMENT

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Abstract
This paper reports some recent development on micronised amorphous biomass silica and the synthesis of nanoparticles. The objective is to develop an economical and environmentally-friendly material and process for sustainable concrete construction. The experimentation focused on the synthesis of off-white biomass silica. Rice husk experimented in a controlled incineration temperature regime of 500°C within an hour has produced encouraging findings. The biomass silica thus produced was amorphous when examined with XRD. Particle size reduction was conducted with jar mill, Los Angeles abrasion equipment and the opposed jet mill. The smallest average particle size produced was 5.25 μm in the form of dry powder. Research into nanoparticles synthesis with ultrasonic technique revealed the potential of producing particle size of around 90nm in the form of colloidal silica. The synthesis of biomass silica of particle size ranging from 20 μm down to 20 nm is expected to promote renewed interest in concrete research related to packing efficiency of particles within the concrete matrix for the reduction of water permeability.

Keywords: Micronised silica, nanoparticles, colloidal silica, opposed jet mill, water permeability

INTRODUCTION

The natural process of materials synthesis has inspired the human race to learn and explore beyond the frontiers of knowledge. Huang et al (1997) reviewed the assessment of chloride diffusion in high strength concrete using the accelerated ionic migration test. To improve the quality of clinker, Singh et al. (1997) studied the addition of 3% boiler-fired rice husk ash to the black meal of a vertical shaft kiln. Amer et al. (1997) studied blended cements made from rice husk ash fired at 450 °C and portland cement. Water demand was increased with the increase of rice husk ash content. Lin and Hwang (1997) described the hydration mechanism of rice husk ash with calcium hydroxide which starts by the release of the water absorbed in the porous silica structure of the ash. This enables the quick reaction of silica with calcium hydroxide to form growing calcium silicate hydrate (CSH gel). Sugita et al. (1997) designed a semi-industrial prototype furnace to produce a highly reactive and homogeneous rice husk ash. By controlling the burning temperature and grinding, the concrete strength, resistance to acid attack, chloride penetration and carbonation have been improved.

The pozzolanic properties of palm oil fuel ash (POFA), a waste material obtained on burning of palm oil husk and shell, was studied by Hussin et al. (1997). Compressive strength test with Portland cement substitution levels between 10-60% indicate the possibility of replacing 40% ash without affecting concrete strength. A maximum strength gain at the 30% level was achieved. Awal et al. (1997) utilized POFA to reduce the expansion of mortar bars containing tuff as a reactive aggregate. According to the results,
POFA has a good potential in suppressing alkali-silica reaction expansions. El-Hosiny et al. (1997) used Nitrogen adsorption to measure the surface properties portland cement/rice husk ash pastes. The rice husk ash was obtained at three firing temperatures of 450, 700 and 1000 °C. Higher surface areas were obtained for pastes made from rice husks fired at 450 and 700 °C. The surface area and pore volume results were related to the pore structure of the silica produced in the rice husk ash. A controlled incineration method at temperature between 450 to 550 °C is being experimented to produce highly reactive amorphous rice husk ash with a high pozzolan activity and a low unburnt carbon content. Kearsley, E.P. and Wainwright (2000 & 2002) reported various factors affecting the engineering performance of foamed concrete containing fly ash.

Research into nano-structured building materials is progressing at an astonishing speed (Qing et al. 2005). If the nanoparticles are integrated with cement-based building materials the new materials could lead us to the development of materials with increased durability. Extended or improved performance materials are suitable for the construction of super high-rise, long-span or intelligent civil infrastructure systems (Hui, et al. 2004 & Tio, 2005). Nanoparticle synthesis has attracted considerable scientific interest recently due to the new potential uses of particles in nanometer (10^{-9} m) scale. Nanoparticles has good potential to be utilized in Portland cement composite (Balaguru, 2005). Novel exploitation of the properties and phenomena at nano-scale could lead to new business opportunities. The use of nanoparticles can result in dramatic improved properties from conventional grain-size materials of the same chemical composition (Jo et al. 2006).

However the present applications are limited to produce antigen, antiseptic, purified air composite paint or other ecological building materials using nano-TiO\(_2\), nano-SiO\(_2\) or nano-FeO\(_3\) (Hui, et al. 2004). It is important to have strong fundamental understanding of cement chemistry and the resulting hydration products is necessary before any attempt to improve cement and concrete in nano-scale (Corr & Shah, 2005). Nanosilica particles with an average size of 10nm helps to improve the porosity of the hydrated cement paste by filling the voids left in the spaces between larger particles. Nanosilica could also reduce the cement requirement for concrete, thus reducing the heat generation and shrinkage problems associated with high cement contents (Corr & Shah, 2005). Attempt is made to develop suitable methods to produce micronised and nanoparticles of biomass silica to promote advanced materials research.

**RICE HUSK**

Rice husk constitutes one-fifth by weight of paddy harvested. Its average density is around 100 kg/m\(^3\). The rice milling process in Malaysia generates about 3.41 million cubic meter of rice husk annually (Lee et al. 2002). Although rice husk has its traditional uses, it is mostly causing disposal problem in most countries. Due to growing environmental concerns and the need to conserve energy and resources, alternatives have been developed to dispose this biomass. Innovative application is crucial to avoid environmental pollution and the waste of energy.
MICRONISED BIOMASS SILICA AND NANOPARTICLES

Micronised Biomass Silica

It is known that amorphous silica (SiO$_2$) will react with calcium hydroxide to form calcium silicate hydrate (CSH). CSH crystal contributes to compressive strength and will grow with time resulting in pore refinement in the microstructure. The water permeability in cementitious composition is thus reduced. Therefore biomass silica ash with high content of SiO$_2$ is suitable for use in cementitious composition. Reactivity of SiO$_2$ depends on the morphology and particle size. Amorphous (non-crystalline) silica is found to be highly reactive if micronised to the region of 5µm. Thus, the off-white biomass silica ash have to be produced in such a way that it is amorphous, low impurity with less than 15% by weight of carbon content.

Colloidal Silica

Colloidal silica is a watery dispersoid of silicon dioxide. Its molecular formula can be mSiO$_2$ - nH$_2$O. It has many industrial productions, such as investment casting, vacuum-formed fibrous shapes, refractory materials, inorganic coatings, stool and mould coatings, textile industry, paper and film making, hot-top insulating boards, catalyst binders and supports, treatment of carbon products, and the production of enhanced foamed rubber. It has also been used as water-purifying agent, clarification agent, polishes, reinforcing agent and molecular sieves. The potential of developing high purity colloidal silica in concentration from 15% to 40%, with or without alkali, and particle size varying from 5nm to 120nm is being explored.

PROCESS DEVELOPMENT

A rotary reactor furnace is designed to be equipped with controlled opening for introduction of air aiding complete combustion to produce a low carbon content, off-white amorphous biomass silica ash. The first step of production is to put in the raw materials in the furnace (Figure 1). The off-white amorphous biomass silica ash (Figure 2) is falling through the perforated trays into a collecting funnel at the bottom by gravity. The process takes an hour for the raw material to become off-white biomass silica. Different temperature ranging from 300°C to 600°C has been experimented to determine the optimum temperature to produce amorphous biomass silica with low carbon content (Figure 3). The biomass silica ash obtained from the furnace is then subjected to the particle size reduction process. Four methods have been experimented, namely: Los Angeles abrasion equipment, jar mill, opposed jet mill and ultrasonic method. The mean diameter of the particle size were measured and tabulated in Table 1.
Figure 1. Rotary Reactor Furnace to produce Biomass Silica

Figure 2. Unprocessed Biomass Silica
TEST RESULTS

Table 1 shows the colour of ash at different incineration temperature for an hour in the rotary reactor furnace. It shows that organic constituents of the biomass are not decomposed to an adequate extent if the temperature is below 450 °C. Above 550°C, heating-up is spontaneous and the ash is grey. If the temperature is increased beyond 600°C, there is no improvement in the purity of the end product, compared with incineration temperature of 450°C to 550°C. The greatest loss of weight occurs during spontaneous heating at approximately 500°C. Therefore, the test results indicated that the quality of the ash progressively decreases above and below 500°C. The off-white biomass silica is found to be amorphous as shown in the XRD test result in Figure 3.

Table 1. Loss of weight and colour of biomass silica

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Weight loss</th>
<th>Colour of ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 °C</td>
<td>29.8%</td>
<td>Black</td>
</tr>
<tr>
<td>400 °C</td>
<td>66.8%</td>
<td>Grey</td>
</tr>
<tr>
<td>500 °C</td>
<td>77.1%</td>
<td>Off-White</td>
</tr>
<tr>
<td>600 °C</td>
<td>74.7%</td>
<td>Grey</td>
</tr>
</tbody>
</table>

![Figure 3. XRD for Biomass Silica produced at 500°C](image)

Table 2 shows the particle size distributions of biomass silica with different methods of processing. Figure 4 shows the SEM micrograph of micronized biomass silica. The mean diameter of the unprocessed biomass silica was around 142.08µm. The methods used to reduce the particles sizes were the Los Angeles Abrasion Machine using steel rod and steel ball, jar mill, opposed jet mill and ultrasonic. The jar mill process was experimented for every 3, 6, 12, 24, 48, 60 minutes. The particle sizes reduction experiment showed that the mean particle size for Los Angeles Abrasion with steel ball was two times smaller than using steel rod with 1000 rotation. The smallest particle size achieved was using the ultrasonic method with mean diameter of 92 nm. The test report is included as Appendix A.
Table 2. Particle size reduction with different processing methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Rotation</th>
<th>Time Minute</th>
<th>Mean Diameter, ( \mu m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>142.08</td>
</tr>
<tr>
<td>Los Angeles Abrasion Machine (Steel Rod)</td>
<td>1000</td>
<td>18</td>
<td>64.77</td>
</tr>
<tr>
<td>Los Angeles Abrasion Machine (Steel Ball)</td>
<td>1000</td>
<td>18</td>
<td>35.12</td>
</tr>
<tr>
<td>Jar Mill</td>
<td>-</td>
<td>3</td>
<td>55.50</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>6</td>
<td>36.78</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>12</td>
<td>30.18</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>24</td>
<td>24.35</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>48</td>
<td>19.12</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>60</td>
<td>17.61</td>
</tr>
<tr>
<td>Opposed Jet Mill</td>
<td>-</td>
<td>15</td>
<td>5.25</td>
</tr>
<tr>
<td>Ultrasonic Method</td>
<td>-</td>
<td>-</td>
<td>0.93</td>
</tr>
</tbody>
</table>

![Figure 4. SEM Micrograph of Micronized Biomass Silica](image)

CONCLUSION

The optimum temperature to produce off-white amorphous biomass silica with the rotary reactor furnace is 500°C. Particle size reduction with the opposed jet mill produced micronised silica of particle size around 5\( \mu m \) in the shortest time compared with the other methods. The synthesis of nanoparticles from biomass silica is possible in the form of colloidal silica with the ultrasonic method.

Controlled permeability cementitious composites and protective coatings have been experimented with encouraging findings. Specification for controlled density foamed
Micronized Biomass Silica and Nanoparticles Synthesis – Recent Development

Concrete products have been prepared for the ready-mix concrete industry in Malaysia. Cementitious composites derived from the innovative exploitation of micronised biomass silica have been identified for use in the experimental construction of wall for low-cost housing. The synthesis of off-white amorphous silica from controlled incineration of biomass particularly rice ash has attracted much research interest in undergraduate and postgraduate studies.

A method of soft soil stabilisation with micronised silica is therefore proposed for a postgraduate programme. The material is proposed to be experimented with innovative formulation for rural and plantation road system. Precast lightweight concrete pile containing micronised silica is also proposed to provide cost-effective geotechnical solutions for construction on soft soil.

The development of blended cement for waterproofing applications and specialty coatings will be expedited with the support of industrial collaborators. The opposed jet mill available in the Civil Engineering Materials Laboratory of KUiTTHO is for consistent particle size reduction of biomass silica. It is envisaged that successful pre-commercialisation could lead to the establishment of research centres focused on renewable energy, advanced materials, construction and manufacturing. It has potential to expedite the physical development of the university and the surrounding industries.

ACKNOWLEDGEMENT


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Appendix A

Size Distribution Report by Intensity

Sample Details

Sample Name: Dr. Lee nanosilica  
SOP Name: Manual measurement settings  
General Notes:

<table>
<thead>
<tr>
<th>File Name</th>
<th>Dispersant Name: Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Number</td>
<td>Dispersant RI: 1.33</td>
</tr>
<tr>
<td>Material RI: 1.59</td>
<td>Viscosity (cP): 0.8872</td>
</tr>
</tbody>
</table>
| Material Absorption: 0.01 | Measurement Date and Time: Tuesday, July 04, 2006 1:11:...

System

<table>
<thead>
<tr>
<th>Temperature (°C): 25.0</th>
<th>Duration Used (s): 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count Rate (kcps): 139</td>
<td>Measurement Position (mm): 0.45</td>
</tr>
<tr>
<td>Cell Description: Low volume disposable sizing...</td>
<td>Attenuation: 3</td>
</tr>
</tbody>
</table>

Results

<table>
<thead>
<tr>
<th>Z-Average (nm): 1008</th>
<th>Diam. (nm)</th>
<th>% Intensity</th>
<th>Width (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak 1: 1133</td>
<td>87.19</td>
<td>197.4</td>
<td></td>
</tr>
<tr>
<td>Peak 2: 92.43</td>
<td>12.61</td>
<td>9.762</td>
<td></td>
</tr>
<tr>
<td>Peak 3: 0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Intercept: 0.9327
STRUCTURAL BEHAVIOUR OF BAKUN CONCRETE FACED ROCKFILL DAM DURING CONSTRUCTION

Fayda A. Al-Obaidi, J. Noorzaei, Thamir S. Younis, M.S. Jaafar, and W.A. Thanoon
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Abstract
This study covers the development and application of two dimensional finite element software, to account for the structural modeling of concrete face rockfill dams (CFRD), during construction phase. Dead, Birth and Ghost element technique has been adjusted in the physical modeling. Bakun concrete slab rockfill dam which is currently under construction at Malaysia has been modeled using different types of finite elements to simulate different dam zones along with concrete faces. The study focuses on the effect of construction sequence on the structural response of the dam with and without concrete slab. The structural responses in terms of deformations characteristic, stress distributions have been highlighted. The results indicate that concrete slab has an effect that reduces the displacements and stresses on the body of dam.

INTRODUCTION

Concrete-faced compacted rockfill dams become popular for the last three decades as a result of their good performance and low cost compared to other types of dams. They show high level of safety, and the stability compared to other type of dams, due to the large mass of the rockfill embankment. However, the concrete face is the critical part in this type of dam due to the possibility of cracking and leakage of water. Cracking are occurred due to differential settlement of the underlying rock stratum.

Recently the analyses for rockfill dams are carried out using finite element method to identify the various factors affecting the distribution of stresses and strains in the face slab and the body of the dam. Furthermore, most embankments are constructed by incremental process and the loading is accumulated gradually during the construction stages. For realistic assessment of the dam, the analysis should provide the effect of the load being applied in incremental rather than being applied in one stage. The application of finite element method was demonstrated by Clough et al. (1967) for the analysis of earth dam. Boughton (1970) noted that the design of concrete face is largely empirical; modification to design practice was made in the light of the performance of new dams. Finite element method was adopted in the analysis of 36m high Wilmot rockfill dam using triangular elements.

Modeling of slippage between the concrete slab and body of the dam was ignored in the analysis; Khalid et.al (1990) used finite element method to simulate the prototype behavior of various component of a rock fill dam. The analysis includes the effects of sequential construction and the nonlinearity behavior of the materials.

This study is a continuation of author previous work Noorzaei et.al. (1999) and Fayda et al. (2003) where Birth, Dead, and Ghost element technique was used to study the effect of construction sequence in the concrete faced rockfill dams. Moreover, this study focuses on the effect of the concrete slab on the displacements and the distribution of the stresses developed due to gravity load.
In this study the paper focuses on the effect of construction sequences on the structural response of the dam with and without concrete slab for Bakun dam, using 2-D finite element program in the analysis.

**ALGORITHMS FOR SIMULATION SEQUENCE OF CONSTRUCTION**

In order to simulate the sequences of dam construction in this study, the Death-Birth-Ghost element technique was implemented. The finite element discrimination of the dam body is same as to that used under single shot loading. In this algorithm the physical discretization of the dam body is defined completely, while the mechanical properties of the dam body will depends on whether the layer is previously loaded or currently loaded or yet to be loaded. Sequence of construction schedule and accordingly three cases of loading is defined namely:

1. (Dead layer). Previously loaded layers
2. (Birth layer). Current loading layer
3. (Ghost layer) is the layer not yet exist

Figure-1 showing the layers of the dam in each step of analysis the Birth elements are assigned with the material properties of the dam while, the Dead elements are assigned with the material properties of the dame with zero density. The Ghost layers are assigned very small young modulus and passion ratio.

![Figure 1. Sequence of construction](image)

**FINITE ELEMENT MODELLING**

The following elements are used to idealize the cross section of the Bakun dam.

1. Eight noded isoparametric elements to represent the dam body.
2. Six nodded isoparametric element to model the concrete slab.
3. Interface element to model the contact behavior between the concrete face slab and dam body
The finite element formulations of elements in (i) and (ii) are well established and are available in finite element text book, Cook et al. (2002), Zeinkiewics, O.C. (1979). However, a brief description is presented here for the formulation of interface element.

A typical curved parabolic interface element which is sandwiched between two continua are as shown in Fig-2, the pair of nodes 1-1, 2-2, 3-3 and the middle line nodes a, b, c are defined by the same coordinates respectively. Brief descriptions on the formulation of interface element are presented herein:

\[
\begin{align*}
  x &= \sum N_i x_i, \quad y = \sum N_i y_i \\
  u &= \sum N_i u_i, \quad v = \sum N_i v_i \\
  N_a &= \frac{1}{2} \xi (\xi - 1), \quad N_b = (1 - \xi^2), \quad N_c = \frac{1}{2} (\xi + 1)
\end{align*}
\]

Where \(N_a, N_b, N_c\) are the shape function at nodes and

\[
\begin{align*}
  \Delta u_a &= u_1^T - u_1^B, \quad \text{and} \quad \Delta v_a = v_1^T - v_1^B \\
  \Delta u_b &= u_2^T - u_2^B \quad \text{and} \quad \Delta v_b = v_2^T - v_2^B \\
  \Delta u_c &= u_3^T - u_3^B \quad \text{and} \quad \Delta v_c = v_3^T - v_3^B
\end{align*}
\]

\(u_1^T, u_1^B, v_1^T, v_1^B, u_2^T \cdots \text{etc}\), are the nodal displacements in \(x\) and \(y\) directions, and the indices \(T\) and \(B\) indicates top & bottom continuum respectively. The above relationship can be expressed as.

\[
\{\Delta \delta_a\} = \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix} \begin{bmatrix} u_1^T \\ v_1^T \\ u_1^B \\ v_1^B \end{bmatrix} = [T] \{\delta\}
\]
Similar expression can be written for $\Delta_b$, $\Delta_c$

$$\{\Delta\} = \{\Delta_a\ \Delta_b\ \Delta_c\}^T = [T]_{n+12} \{\delta\}_{12+1}$$

(6)

here again $[T]$ is transfer matrix.

As in the case of isoparametric elements, the relative displacement

$$\begin{pmatrix} \Delta u \\ \Delta v \end{pmatrix} = \begin{bmatrix} N_a & 0 & N_b & 0 & N_c & 0 \\ 0 & N_a & 0 & N_b & 0 & N_c \end{bmatrix} \begin{pmatrix} \Delta u_a \\ \Delta v_a \\ \Delta u_b \\ \Delta v_b \\ \Delta u_c \\ \Delta v_c \end{pmatrix}$$

(7)

By substituting equation (6) into Equation (8) to get the following equation:

$$\begin{pmatrix} \Delta u \\ \Delta v \end{pmatrix} = [N]_{2\times6} \{\Delta\}_{6+1}$$

(8)

The strain at any point in the joint defined by local coordinate system

$$\begin{pmatrix} \epsilon_t \\ \epsilon_n \end{pmatrix} = \frac{1}{t} \begin{pmatrix} \Delta u \\ \Delta v \end{pmatrix} = \frac{1}{t} [R][N_{\delta}][\delta] = [B_i][\delta]$$

(10)

where $\Delta u'$, and $\Delta v'$ are the displacement in local co-ordinate $\xi$ and $\eta$ directions respectively.

$\epsilon_t$ and $\epsilon_n$ are the tangential and normal strains respectively at the point. $[R]$ is a rotation matrix and transfers global strains to local strains, ($t$) is the thickness of the element and $[B]$ is the strain –displacement matrix of the joint.

The stiffness matrix of the interface element can be written as:

$$[K] = \int [B_i]^T [D_i] B_i \, ds$$

(11)

Where $[B_i]$ is the strain displacement matrix $[D_i]$ is the elasticity matrix for the joint, and $ds$ is a small length of the joint and
\[
\begin{bmatrix}
\sigma \\
\tau \\
\sigma_n
\end{bmatrix} = \left[D_i\right] \begin{bmatrix}
\varepsilon \\
\varepsilon_n
\end{bmatrix} \tag{12}
\]

\[
[D] = \begin{bmatrix}
K_{ss} & 0 \\
0 & K_{nn}
\end{bmatrix} \tag{13}
\]

Where $K_{ss}$, and $K_{nn}$ are the shear and normal stiffness respectively.

**BAKUN DAM MODELLING**

Bakun dam is a hydropower projects is located in BAULI river of Sarawak in Malaysia, 37 km downstream from the nearest Town of Belaga and 180km away from the seaport city called Mindulu in the east of Malaysia.

The project is mainly composed of three parts: concrete rockfill dam, power generating system and water release system. The project has a maximum dam height of 205m with total installed capacity of 2400MW (the first stage installed capacity of 900MW) and concrete consumption for the main project of 1,100,000 m³. The dam consists of different zones as shown in Figure 3.

![Figure 3. Cross section showing zones of dam](image)

The details of these zones are summarized below:

- Concrete slab with variable thickness reduced with the height.
- Zones (1A, 1B) at the upstream zone, over the lower deck of perimeter joint.
- Zone 2A, a well compacted of processed fine filter having low.
- Zone 2B, well graded processed filter, this zone be immediately behind the face slab.
- Zone 3A, transition zone placed adjacent to zone 2B with maximum size of 0.3 meters.
- Zone 3B, the upstream zone forming approximately 50-60% of the embankment including the integrated cofferdam.
- Zone 3C, a zone within the downstream placed and compacted in layers about 1 meter thick.
• Zone 3D, placed and compacted in layers up to 2 meters thick and dozed to downstream face of the dam to serve as slope protection, also used within the valley bottom to serve a high-capacity under drain.

PHASE OF DAM EMBANKMENT

The construction of Bakun dam is planned to be in four different phases as follows:

Phase I- Cofferdam ending at July 2004
Phase II- Consist of four layers expected time to finish at Nov. 2004
Phase III- Consist of six layers and expected to finish at Jan. 2006
Phase IV- Consist of One layer, finish at Mar. 2007

FINITE ELEMENT MESH

The finite element idealization of the whole dam section is illustrated in figure 4 along with total No. of elements, total number of nodes, total numbers No. of layers and different types elements. This finite element mesh illustrates two models namely:

(a) With slab (shown in Fig. 4a).
(b) Without slab (shown in Fig. 4b).

The proposed finite element model, take into consideration different material properties at different zones of the dam, and the sequence of construction described above.
In this paper only the loading due to the sequence of construction has been taken into the consideration.

RESULTS AND DISUSSION

The structural behavior of the dam has been studied with respect to displacement and stress developed in the body of the dam.

Figures 5, 6, 7, and 8 indicate the vertical displacements across the width of dam at elevation 9.4, 52.5, 110.16, and 170 respectively. Each figure shows the displacements for both finite element models; with and without slab. It is clear from these plots that the concrete slabs reduces the deformations in the body of the dam and increase the displacements nearby the region of the concrete slab.

![Figure 5. Vertical displacements at level 9](image)

![Figure 6. Vertical displacements at level 52.5](image)
The maximum vertical displacement occurred at elevation 110.16 as shown in Figure 7, and their values are, 91.1 and 100 cm, (for the dam with and without concrete slab respectively). This elevation represents approximately the mid height of the where the maximum displacements occur as shown in Figure-9.

When analysing the dam in single shot (ignoring the effect of construction sequence), the maximum displacement calculated found to be larger at the top and lower in the middle part of the dam. The contours of the vertical displacements are shown in figure 10 and 11 for the two models with and without slab respectively.

Results obtained considering the gradual lifting of the dam reflects that the construction sequences are important and have to be considered in the analysis.
Fig.12, 13 shows normal stresses $\sigma_x, \sigma_y$, plotted across the width of the dam, at elevation of 52.5. It can be seen that the maximum vertical stresses occurred at the mid width of the dam. Moreover, the presence of concrete slab reduces the stresses on the body of the dam, and increases the stresses nearby the concrete slab.
Normal stresses \( \sigma_{y} \) at level 52.5 due to sequence of construction:

- **Without slab**:
  - \(-4000\) to \(0\) KN/m²

- **With slab**:
  - \(-3000\) to \(-500\) KN/m²

**Figure 13.** Normal stresses \( \sigma_{y} \) at level 52.5 for different stage of construction

**CONCLUSION**

The paper describes the finite element analysis of Bakun concrete rock fill dam under gravity load. The effects of construction stages and the presence of concrete face slab on the deformations and stresses distribution in the dam have been covered. It is concluded that, the Dead-Birth, and Ghost element technique is very useful as far as the data preparation for the finite element analysis is concerned since only one mesh is required to simulate all the stages of construction. The concrete slab has a significant effect on the deformation and stresses distribution. The high stiffness of the concrete faced slab will alter the distribution of the stresses leading to lower values of stresses in the body of the dam and higher values in the concrete faced slab. Maximum value of settlement occurs in the mid height of the dam for both models, with and without slab.

**ACKNOWLEDGMENT**

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EVALUATION OF THE THERMAL PERFORMANCE OF METAL ROOFING UNDER TROPICAL CLIMATIC CONDITIONS

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Abstract
The assessment of the thermal performance was carried out on a low cost house mainly built from waste oil palm shell (OPS-Concrete) with galvanized steel -roof. It was noticed that reasonable thermal comfort took place during the night for the roof without ceiling and without insulation, and during the day at a peak temperature of a highly ventilated attic area. For such situation, it was recommended to install insulating horizontal plated surface under the roof, which should be turned into a vertical position during the night. Other alternatives may be creating small adjustable openings around building envelope just under the ceiling or making an open roof-ceiling system. This technique will reduce the heat flux from insulated ceiling by the flow of the cooling air at night, but the impact of surrounding microclimate on human thermal comfort should be considered. The mathematical model used to predict the attic temperature for a lightweight roof system was obtained by correlation, which can be used for a quick inspection. Insulation materials of 50 mm fibreglass and foil-aluminium were used with sealed attic, and found the ceiling temperature reduced by about 3 °C and 2 °C respectively. For the case of fibreglass of thickness beyond 50 mm, the reduction of ceiling temperature was recorded less than ½ °C, really not attractive.

Keywords: thermal performance, metal roofing, attic temperature, sealed attic, ventilated attic, insulation

INTRODUCTION

Kota Kinabalu city (the capital of the Sabah state of Malaysia) experiences a typical equatorial humid climate with heavy rainfall usually in the afternoon time, where the temperatures are uniformly high and extremely invariable throughout the year. A good thermal performance of any house in Kota Kinabalu has to have an indoor temperature between 25 °C and 28 °C (comfort range). The analysis of bio-climatic chart indicated that the ventilation should be considered for this type of climatic conditions. The utilization of active cooling system seems to be the only solution during the peak air temperature when no passive strategies could minimize the effect of radiation and air temperature to the acceptable indoor comfort range.

Metal roofing in Kota Kinabalu practically became the norm for low-cost houses, considerably contributing to heat gain and increasing the indoor temperature. A such roof system requires particular attention, since it is the most envelope building part exposed to solar radiation. Berdahl et. al. (1997) and Miller et. al. (2004) have studied the effect of roof colour in minimizing surface temperature, and found that high solar reflectance and infrared emittance of roofs surface reduce heat gain and also the UV radiation received by roofs. The utilisation of lighter colour is very highly recommended under Malaysia climate due to their high solar reflectivity, but it is less diffused and not well accepted by the population. Several solutions are possible to minimize the ceiling temperature such as the insulation of roof,
attic ventilation, selection of roofing materials more suitable under warm humid conditions, the realisation of high-pitched roof, and may be other suitable and practical techniques.

The objective of the present study is to provide recommendations for the improvement of roofing design under Malaysia climate. Therefore, the assessment of the thermal performance of metallic roof system with sealed and ventilated attic will be considered. In addition to that, the impact of different thickness of fibreglass and foil-aluminium in reducing ceiling temperature will be studied. The model house used in this research is the low cost house built inside the campus of the Universiti Malaysia Sabah (5.93°N, 116.05°-about 2.3 m above sea level) using waste oil palm shells “OPS” as aggregate for the realization of walls, whereas the roof is made from galvanized steel.

EXPERIMENTAL PROCEDURES

Description of the OPS House

The low-cost house used as a case study is a single story detached one family house which is considered as model house utilizing agricultural solid waste namely oil palm shell “OPS” in an innovative light weight concrete mix, based on financial and environmental design factors. This has double advantage of reduction in the cost of construction materials and solves the disposal of waste products generated at the palm oil mills. Mannan et. al. (2001, 2004) reported that the trend of behaviours of OPS concrete and control concrete is very similar construction and building materials. It was established that OPS performs as aggregate in concrete and possesses the potential of being used in building construction. The OPS concrete is also considered environmentally sustainable building materials, friendly product and does not have any health hazard since it is covered with cement paste and no deterioration is taking place. The model-house realised with the OPS concrete is considered socially acceptable for the low-income families. The roof system was built with red pre-painted galvanised steel sheet, and with ordinary plywood 6 mm in thickness used as ceiling without insulation, for all rooms. Table 1 describes the OPS building materials used and figure 1 shows the plan view of the house.

<table>
<thead>
<tr>
<th>Description of material</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPS concrete (G20)</strong></td>
<td>Lean concrete, ground beam, Ground slab, Lintel, Roof capping beam.</td>
</tr>
<tr>
<td>- Density = 1850 kg/m³</td>
<td></td>
</tr>
<tr>
<td><strong>OPS hollow block</strong></td>
<td>Walls- Attic ventilation.</td>
</tr>
<tr>
<td>- Size = 420 mm (L) × 125 mm (W) × 190 mm (H)</td>
<td></td>
</tr>
<tr>
<td>- Void/block = 32%</td>
<td></td>
</tr>
<tr>
<td>- Weight/block = 12 kg</td>
<td></td>
</tr>
</tbody>
</table>
The building consists as shown in figure 1, of one living dining room, kitchen, shower, study room and two bedrooms, with floor to ceiling heights of 3.1 m, occupying an area of 58.68 m². The walls are constructed with small windows opening in most exterior walls except on the west-south side, which represents around 7.59% of the surface building envelope. These openings were covered with single plane glazing 6 mm, but no kind of sun shading was used for the openings. Solar radiation reaches the interior of the living and bedroom 2 during the sunrise and the kitchen during the sunset, which produces direct and immediate heating effect. The roof was built with narrow overhang of 0.9 m giving a little protection to the walls. The attic space is well ventilated as it appears clearly in figure 2. The external walls colours are beige and the house is located in an open area without landscaping. The vertical distance between the inlet and the outlet of the vent area facilitate the increase of the ventilation rate in attic space. However, the outlet vent area in this attic is less than the inlet vent area, which in turn minimizes airflow through the attic. The net free ventilating area in the attic space was about 1/13, which is higher than the minimum recommended of most codes at least a 1/150.
Data Monitoring

The field test includes mainly measurements of air temperature with the utilisation of data-loggers HOBO thermometer during two series of measurements, ventilated and sealed attic. The data-loggers were positioned in the centre of the house, outside the house, and at the centre of the attic space. The daily average monthly radiation was estimated on possible sunshine hours, nearly the same during these two periods about 20.22 MJ/m² from 8 July until 8 August 2004, and 20.77 MJ/m² from 21 October 2004 until 22 December 2004. The assessment of different ceiling configurations was evaluated with sealed attic and summarized in Table 2.

Table 2. Thermal Properties of the Evaluated Ceiling Configurations

<table>
<thead>
<tr>
<th>Component</th>
<th>U Ceiling component (W/m².K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mm plywood</td>
<td>0.99</td>
</tr>
<tr>
<td>Foil-aluminium + air space + 6mm plywood.</td>
<td>0.86</td>
</tr>
<tr>
<td>50 mm fibre glass + 6mm plywood</td>
<td>0.41</td>
</tr>
<tr>
<td>100 mm fibre glass + 6mm plywood</td>
<td>0.26</td>
</tr>
<tr>
<td>150 mm fibre glass + 6mm plywood</td>
<td>0.19</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Temperature Prediction of Ventilated and Sealed Attic

Data reported in figure 3 shows a sequence of the indoor, mid attic and outdoor temperature from 8 July 2004 until 4 August 2004 with ventilated attic. The indoor temperature was recorded 1.5m above the floor.

Figure 3. Indoor air, mid attic, and outdoor temperature

The thermal mass of the OPS house brought the maximum indoor temperature which is below the maximum daily outdoor temperature. The thermal capacity of walls has the effect of delaying the impact of external conditions on the interior of the building. The low thermal mass roof system, which is simply red galvanized steel and plywood for the ceiling, shows the tendency of similarity between the outdoor and attic temperature with slight variation during the daytime. This could be due to the roof surface temperature raised by absorption of solar radiation. The system of ventilation was judiciously chosen for this house in
reducing the heat transfer through roofing materials. The hourly evolution of attic temperature for one hot sunny day’s variation recorded on 25\textsuperscript{th} July 2004 was slightly similar to the outdoor temperature, while the maximum indoor temperature was lower by about 4.58 °C below the maximum outdoor temperature. Note that the variation of attic air temperature during the night was lower than the indoor air temperature by about 3.16 °C. The outdoor temperature range (difference between maximum and minimum) recorded was about 10.14 °C. This means the utilisation of thermal mass under Malaysia climate to reduce the indoor temperature by about 7 °C or at least 4 °C during the peak indoor temperature could be quite acceptable. The correlation between hourly attic and outdoor temperature is shown in figure 4.

An analysis of the hourly attic temperature was plotted versus outdoor air temperature. The daily maximum attic temperature was best predicted on the basis of the mean daily outdoor temperature as shown in figure 5, yielding good correlation between measured and calculated maxima.

![Figure 4. Correlation between hourly attic and outdoor temperatures with ventilated attic](image1)

![Figure 5. Correlation between max. attic and mean daily outdoor temperatures with ventilated attic](image2)
The best curve fitting correlations for hourly and maximum daily attic temperature prediction, are as follows:

\[ T_{h-\text{attic}} = 1.542 T_{h-out}^{0.8741} \]  
(1)

\[ T_{d,max-\text{attic}} = 38.416 \ln(T_{d,\text{Mean-out}}) - 96.21 \]  
(2)

Where;

- \( T_{h-\text{attic}} \): Predicted hourly attic temperature.  
- \( T_{h-out} \): Recorded hourly outdoor temperature.  
- \( T_{d,max-\text{attic}} \): Predicted daily maximum attic temperature.  
- \( T_{d,\text{Mean-out}} \): Recorded daily mean outdoor temperature.

Figure 6 shows the measured and the computed maximum ventilated attic temperature based on Eq. (2), which are quite similar in terms of temperature. The difference between them was found statistically not significant using t-test (t-test = 0.04206) with total degree of freedom equals to 52, for the 2 samples (measured and computed), and each one contains 27-recorded data of temperature.

![Figure 6. Comparison between computed and measured maximum attic temperature.](image)

After the attic was sealed, the correlation between daily maximum attic temperature and maximum outdoor temperature was less predictable, conversely to the hourly prediction of attic temperatures plotted in figure 7.
The predicted hourly attic temperature with sealed attic is expressed by the following formula:

\[ T_{h-\text{attic}} = 0.9073T_{h-\text{out}}^{1.0468} \]

(3)

The predicted hourly attic temperature with ventilated and sealed attic for a possible outdoor temperature variation from 24 °C to 35 °C were computed using Eq. (1) and Eq. (3) respectively, and plotted in figure 8.
It is clear that the effect of ventilation in reducing attic temperature was more noticed with the increased outdoor temperature, and the difference between ventilated and sealed attic reached about 3 °C when the outdoor temperature attained 35 °C. The temperature with ventilated attic was always lower than the sealed one, and the difference between them becomes more significant when the outdoor temperature increases.

**Thermal Performance of Metal Roofing and OPS Concrete Walls**

The interior surface temperature of the OPS concrete wall as well as the temperature under metal roofing and the ceiling surface temperature were recorded and plotted against outdoor temperature as illustrated in figure 9. Inspection of figure 9 shown that the OPS concrete walls was always lower than the outdoor temperature, generally from 10 am to 15 pm. The OPS concrete wall rose after that and reached its maximum usually before 20 pm. The main issue of any building components particularly realised with concrete or bricks under tropical humid conditions, are the heat storage released during the early evening or before the outdoor temperature reaches its minimum. As for the case of the traditional building materials made with lightweight materials such as wooden, bamboo or thatched walls, used since the past in Malay architecture, are considered suitable under Malaysia climate, but could be warmer than concrete walls during the daytime since they follow greatly the outdoor temperatures. These traditional building materials are more suitable when the microclimate surrounding the building is modified with the plantation of trees or simply when the house is located in the jungle. Moreover, walls in traditional houses permit air to pass through gaps, which decreases the thermal sensation of the effect of temperature on human body. The problem of overheating was rather solved in the traditional houses in terms of human thermal comfort and not limited on building thermal performance. The designer under warm humid conditions should take into consideration not only the characteristic and the thermal performance of building materials but also the impact of surrounding microclimate on human thermal comfort.

![Figure 9. Hourly outdoor, ceiling, roof, and wall temperature](image-url)
It is evident from figure 10 when the roof surface temperature reaches its maximum limit the radiation attains its maximum level. This is not the case with the relative humidity, since the relative humidity increases when the outdoor temperature decreases which occurs during the nighttime. These results could be also encouraging for possible utilisation of evaporative cooling even under warm humid climate during the peak outdoor temperature when the relative humidity attains its minimum (Harimi et. al., 2005).

**Thermal Performance of Insulation Materials**

Thermal insulation is an important factor in minimizing the effect of heat absorbed and transmitted by metal roofing materials. When solar radiations as well as the roof surface temperature reach their maximum level, the radiant temperature from warm ceiling causes the greatest discomfort and increases the physiological heat stress as reported by Vecchia (2001). This could be reduced with the installation of insulation above the ceiling or just under the roof, and it may well reduce the energy consumption, which lowers utility bills in residential buildings under active cooling system. The role of fibreglass is to minimize conduction and convection, thereby decreasing the ceiling temperature, whereas, the principal function of reflective insulator (radiant barrier) is to reflect radiant heat rays and acts also as vapour barriers. Its capacity to insulate could be lost after a few years. The reflective insulation material is installed in general on a ceiling for more effectiveness. Figure 11 shows the variation of ceiling temperatures without insulation, and with different characteristics of insulation materials.
As it was expected, the fibreglass has more effect in reducing ceiling temperature in comparison to foil-aluminium. This is due to the low emissivity of metal roofing, which has the ability to minimize considerably the emitted radiation into attic before reaching the foil-aluminium. The efficiency of foil-aluminium could be more significant for a roof system made of concrete or clay tile with a ventilated attic space. The temperature difference between insulated ceiling with fibreglass and plywood ceiling could attain 3 °C; while the maximum difference recorded using foil-aluminium was about 2 °C. The increase of insulation thickness beyond 50 mm was not appreciated, because the maximum temperature reduction was found less than 0.5 °C. Table 3 summarize the ceiling surface temperature with different thickness insulation materials that was recorded on the second February 2005.

<table>
<thead>
<tr>
<th>Surface Temperature</th>
<th>Ceiling</th>
<th>Ceiling + Foil Aluminium</th>
<th>Ceiling + Fibreglass 50 mm</th>
<th>Ceiling + Fibre Glass 100 mm</th>
<th>Ceiling + Fibre Glass 150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>33.1</td>
<td>31.1</td>
<td>30.4</td>
<td>30.2</td>
<td>30.1</td>
</tr>
<tr>
<td>Min</td>
<td>26.2</td>
<td>26.9</td>
<td>27.6</td>
<td>27.6</td>
<td>27.6</td>
</tr>
<tr>
<td>Average</td>
<td>29.25</td>
<td>29.03</td>
<td>29.11</td>
<td>29</td>
<td>28.97</td>
</tr>
</tbody>
</table>

It comes into view from table 3, that the minimum surface ceiling temperature recorded during the night was always higher than the ceiling temperature without insulation. The ceiling insulated with fibreglass recorded the highest temperature. Givoni (1994), has recommended in such situation the installation of hinged interior insulating horizontal plated surface under the roof, and should be turned into a vertical position during the night. This special roofing design recommended by Givoni (1994) is more detailed in page 120 of his book and could be very useful under Malaysia climate particularly for low-cost houses. However, the application of such technique needs some improvements in the area of aesthetic and psychological side. Other possibilities could be simply making small adjustable openings all around building envelope and just under the ceiling to reduce the heat flux from insulated ceiling with the cooling air during the night, or by the realisation of an open roof-ceiling system as shown in figure 12.
The overhang design should be large enough to protect the penetration of rain into ceiling floor and at the same time should allow the winds to penetrate easily in this area, which in turn can be slightly inclined to avoid the stagnation of rainwater in case.

CONCLUSIONS

From the thermal assessment of the OPS house, many observations have been recorded. It was noticed that during the night, roof without ceiling and without insulation performs thermally better than any roof system under tropical climate conditions. When the outdoor temperature reaches its maximum, the low-mass corrugated metal roof cools down rather quickly than the ceiling temperature, whereas, the highly ventilated attic area performs thermally better than the sealed attic area. This system is highly recommended under Malaysia climate with no additional cost, but the designer should take into consideration not only the characteristic and the thermal performance of building materials but also the impact of surrounding microclimate on human thermal comfort.

The prediction of attic temperature with lightweight roof system is possible and has been well established using a mathematical model correlation, which can be applied in the future for a quick inspection. The use of 50 mm fibreglass with sealed attic significantly lowers the ceiling temperature by about 3 °C, while for the case of foil-aluminium, ceiling temperature decreases by about 2 °C. It should be highlighted, that the advantage gained by increasing insulation thickness of fibreglass beyond 50 mm does not decrease ceiling temperature significantly, and the maximum temperature reduction was recorded less than ½ °C.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of CIDB Malaysia for funding this project under grant N0 02-002. Also a special thank to Prof. Dr. Eduardo I. Kruger-CEET-PR, Brazil, for his advice and useful suggestions.
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PRODUCTIVITY PERFORMANCE OF THE CONSTRUCTION SECTOR

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National Productivity Corporation

INTRODUCTION

The construction sector had been affected by rapidly changing economic environment, the privatisation of public utilities and the internationalisation of production. The construction sector is sensitive to changes in the economic environment, and needs to adapt its business strategies accordingly. The construction of industrial and commercial buildings and infrastructure will contribute to the growth of construction related activities. The Construction Sector is a catalyst for economic growth as it stimulates development in other sectors.

In 2005, the construction sector contributed 2.7% share to Gross Domestic Product (GDP), with a value of RM7,168 million as compared to RM7,248 million in 2004. The decline of 1.1% in growth was due to the completion of mega projects that were planned during the 8th Malaysia Plan. The sector recorded a 0.6% growth in employment. The positive growth in construction employment was partly attributable to the improved business condition in the residential sub-sector and the implementation of new and on-going major infrastructure projects in 2005, such as the Stormwater Management and Road Tunnelling (SMART). The employment of the sector is expecting to be sustained with the completion of current and new projects including the second phase of the East Coast Expressway and the upgrading and replacing of the existing water pipe system.

Productivity of the sector registered a decline of 0.7%. The decline was due to lower civil engineering activities with the completion of major projects and the reduction in value and number of infrastructure contracts awarded. However, it was partially mitigated by higher demand in the residential and non-residential sub-sector. The demand for houses, especially affordable houses in prime locations with good accessibility as well as office and retail space supported the performance of the construction sector.

The adoption of Industrialised Building System (IBS) is a move to enhance productivity and quality of the sector. This system can assist construction companies in their cash flow, labour efficiency, better safety and health and faster execution of construction projects. It will also reduce the dependency on unskilled foreign labour.

PRODUCTIVITY PERFORMANCE OF SELECTED CONSTRUCTION SUB-SECTORS IN 2004

The construction sector comprises the residential construction of houses and condominiums, the non-residential construction of commercial and industrial buildings, and the infrastructure construction or "civil engineering" of physical amenities and facilities for transportation. Infrastructure construction for transportation includes highways, urban and rural roads, bridges, railways, ports, airports and light rail transit system. The infrastructure
construction for physical amenities in telecommunication includes the fibre-optic cables, submarine cables and earth stations and in utilities includes sewerage and power plants.

In 2004, the construction sector contributed to 2.9% share of GDP, accounting for a value of RM7,248 million. The sector recorded a declining growth of 1.5% due to the lower Government spending on new large infrastructure projects. The slow performance of the construction sector was cushioned by the higher construction activity in residential and non-residential sub-sector. Strong economic and business activities with higher demand for office and retail space supported the performance of the non-residential sub-sector. Furthermore, residential sub sector continued to be sustained by stable demand for residential property especially affordable houses in prime locations with good accessibility.

In 2004, the construction sector registered 1.5% growth in productivity to RM92,279. The sector also registered 1.0% growth in Added Value per Employee due to the increase in demand for residential properties especially affordable houses in favourable locations. The performance was also supported by the expansion in business activities and resilient economic environment in the residential sub-sector during the year (Figure 7.1).

Figure 7.1. Productivity Indicators for the Construction Sector (Growth %)

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added Value per Employee</td>
<td>0.68</td>
<td>1.04</td>
</tr>
<tr>
<td>Total Output per Employee</td>
<td>1.36</td>
<td>1.49</td>
</tr>
<tr>
<td>Added Value per Labour Cost</td>
<td>0.72</td>
<td>-1.36</td>
</tr>
<tr>
<td>Labour Cost per Employee</td>
<td>-0.04</td>
<td>2.44</td>
</tr>
<tr>
<td>Unit Labour Cost</td>
<td>-1.38</td>
<td>0.94</td>
</tr>
<tr>
<td>Fixed Assets per Employee</td>
<td>0.48</td>
<td>-0.77</td>
</tr>
<tr>
<td>Added Value per Fixed Assets</td>
<td>0.20</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Competitiveness in terms of labour cost indicates the comparability of the sector in giving the services at the lowest possible labour cost. There are three competitiveness ratios, namely Added Value per Labour Cost, Labour Cost per Employee and Unit Labour Cost.

The competitiveness of the construction sector was sustained in 2004 with a marginal increase of 0.9% in Unit Labour Cost. Added Value per Labour Cost declined by 1.4% while Labour Cost per Employee grew by 2.4%.
Added Value per Fixed Asset measures the degree of utilization of fixed assets and it is defined as added value generated per RM of fixed assets. In 2004, Added Value per Fixed Assets grew by 1.8% from 2.50 to 2.55. The performance was attributed to the improvement in demand for residential and non-residential properties. The construction sector can improve their Capital Productivity performance by embarking on the efficient utilization of assets in construction activity and enhancing the capability of their management system.

Capital Intensity indicates the amount of fixed assets allocated to each employee. This ratio is used to measure whether an industry is relatively capital-intensive or labor-intensive. Less investment in fixed assets were made in 2004 due to the slow performance in the sector and the completion of several projects especially in civil engineering sub-sector during the year. Fixed Assets per Employee declined by 0.8%.

Residential Sub-sector

Residential sub-sector includes the construction of entire dwellings such as houses, flats and apartments. In 2004 the residential sub-sector accounted for RM10.4 million or 29.0% of the share to total output of the construction sector. This sub-sector also contributed 29.1% and 31.1% in terms of added value and employment respectively (Table 7.1).

<table>
<thead>
<tr>
<th>Table 7.1. Total Output, Added Value and Employment of the Residential Sub-sector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value Level</strong>*</td>
</tr>
<tr>
<td>Total Output</td>
</tr>
<tr>
<td>Added Value</td>
</tr>
<tr>
<td>Employment</td>
</tr>
</tbody>
</table>

* Value Level for Total Output and Added Value are in RM Million

Source: National Productivity Corporation, Malaysia
Computed from: Department of Statistics, Malaysia

In 2004, Added Value per Employee of the residential sub-sector increased by 2.0% while Total Output per Employee increased by 3.4% (Figure 7.2). The stimulus package introduced by the Government to encourage the purchase of residential properties led to increase demand and thus enhance sales.
In 2004, labour cost competitiveness of the sub-sector sector was sustained as shown by a marginal increase in Unit Labour Cost by 1.0%. Added Value per Labour Cost decline by 0.4% while Labour Cost per Employee grew by 2.4%.

Fixed Assets per Employee for the residential sub-sector recorded a growth of 0.3% in 2004 to RM9,807 from RM9,774 in 2003 while Added Value per Fixed Assets grew by 1.7%. The performances were attributed by the continuous investment in fixed assets in the sub-sector. The increased of housing approvals, advertising permit and new sales also supported the good performance of the respective indicators.

**Non-residential Sub-sector**

The non-residential sub-sector includes the construction of offices and/or commercial buildings, stores and other public and utility buildings, farm buildings, etc. In 2004, the non-residential sub-sector accounted for RM9.3 million or 25.8% of the share to total output. The sub-sector registered added value and employment of 26.6% and 31.4% respectively (Table 7.2).
Table 7.2. Total Output, Added Value and Employment of the Non-residential Sub-sector

<table>
<thead>
<tr>
<th></th>
<th>Value Level*</th>
<th>% Share to the Construction Sector</th>
<th>Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Output</td>
<td>9,422</td>
<td>9,267</td>
<td>26.29</td>
</tr>
<tr>
<td>Added Value</td>
<td>3,435</td>
<td>3,354</td>
<td>27.12</td>
</tr>
<tr>
<td>Employment</td>
<td>125,118</td>
<td>121,888</td>
<td>31.74</td>
</tr>
</tbody>
</table>

* Value Level for Total Output and Added Value are in RM Million

Source: National Productivity Corporation, Malaysia
Computed from: Department of Statistics, Malaysia

The non-residential sub-sector recorded a moderate growth in Added Value per Employee of 0.2% and Total Output per Employee of 1.3% in the year 2004. The growth is attributable by the sustained demand for office and retail space that supported the performance of the non-residential sub-sector (Figure 7.3).

Figure 7.3. Productivity Indicators for the Non-residential Sub-sector (Growth %)

Labour cost competitiveness of the sub-sector sector was sustained in 2004 as shown by a marginal increase of 0.8% in Unit Labour Cost. Added Value per Labour Cost grew by 1.8% while Labour Cost per Employee grew by 2.1%.

Fixed Assets per Employee for the non-residential sub-sector recorded a growth of 5.1% in 2004 as investments were made and new machines and equipment were set up for new projects. However, Added Value per Fixed Assets decline at 4.7% due to the gestation period that occurred and the equipment that not fully utilized.
Civil Engineering Sub-sector

The civil engineering sub-sector includes construction of roads, bridges, tunnels, viaducts highways, elevated highways, railways, airfield, harbours, dam irrigation system, drainage and sewage system, pipelines and other water projects, communication and power lines, sports facilities such as stadium and golf course and other civil engineering projects.

In 2004, the civil engineering remained the largest contributor to total output, added value and employment of the construction sector. This sub-sector constituted 45.2% to total output share, 44.4% in terms of added value share and 37.5% in employment share (Table 7.3).

Table 7.3. Total Output, Added Value and Employment of the Civil Engineering Sub-sector

<table>
<thead>
<tr>
<th></th>
<th>Value Level*</th>
<th>% Share to the Construction Sector</th>
<th>Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Output</td>
<td>16,216</td>
<td>16,215</td>
<td>45.25</td>
</tr>
<tr>
<td>Added Value</td>
<td>5,634</td>
<td>5,602</td>
<td>44.47</td>
</tr>
<tr>
<td>Employment</td>
<td>148,016</td>
<td>145,915</td>
<td>37.55</td>
</tr>
</tbody>
</table>

* Value Level for Total Output and Added Value are in RM Million

Source: National Productivity Corporation, Malaysia
Computed from: Department of Statistics, Malaysia

The sub-sector registered a moderate growth in Added Value per Employee of 0.9% valued at RM38,392 and also recorded a growth in Total Output per Employee of 3.9% (Figure 7.4). The increased was due to the implementation of new and on-going infrastructure projects.

The civil engineering sub-sector registered an improved performance in labour cost competitiveness as shown by a decline of 1.2% in Unit Labour Cost. Added Value per Labour Cost declined by 1.7% while Labour Cost per Employee grew by 2.6%.

Capital intensity or Fixed Assets per Employee recorded a decline of 4.6% in 2004. This shows that the sub-sector still depends on the labour-intensive methods. However, Added Value per Fixed Assets grew by 5.7% that was due to the completion of construction projects that highly utilized the existing fixed assets.
Figure 7.4. Productivity Indicators for the Civil Engineering Sub-sector (Growth %)

<table>
<thead>
<tr>
<th>Year</th>
<th>Added Value per Employee</th>
<th>Total Output per Employee</th>
<th>Added Value per Labour Cost</th>
<th>Labour Cost per Employee</th>
<th>Unit Labour Cost</th>
<th>Fixed Assets per Employee</th>
<th>Added Value per Fixed Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>0.45</td>
<td>0.87</td>
<td>0.43</td>
<td>0.02</td>
<td>-0.84</td>
<td>0.41</td>
<td>0.03</td>
</tr>
<tr>
<td>2004</td>
<td>0.87</td>
<td>3.88</td>
<td>-1.70</td>
<td>2.62</td>
<td>-1.21</td>
<td>-4.57</td>
<td>5.70</td>
</tr>
</tbody>
</table>

CONCLUSION

The performance of the construction sector is expected to improve in 2006. The sector is expected to benefit from the development of the housing sector as outlined in 9th Malaysia Plan, under Thrust Four (Chapter 21): Providing Quality Houses and Urban Services. The housing sector will continue to focus on the provision of adequate, affordable and quality houses for all Malaysians. Emphasis will continue be given to the development of low- and low-medium cost houses at suitable locations provided with adequate public amenities to meet the needs of low income group. The strategic thrusts of housing development during the Plan period will be as follows:

- Providing adequate, affordable and quality houses, particularly to meet the needs of the low-income group, with greater emphasis on appropriate locations and conducive living environment;
- Reviewing laws and regulations to ensure proper development of the housing sector;
- Encouraging private sector participation in the construction of low- and low-medium-cost houses; and
- Improving the efficiency and capability of local authorities.

In the 2006 Budget as announced by the Hon. Prime Minister, under the Fourth Strategy: Enhancing The Well-Being and Quality of Life of the Rakyat – Providing Comfortable Homes, the Government proposed that capital expenditure on moulds to manufacture IBS components be given accelerated capital allowance to be claimed for 3 years. This measure will reduce the cost of building components such as pillars, beams, walls and floors. The Government will ensure that the IBS components meet the Malaysia Standard MS 1064. The adoption of the standard will ensure quality and control of construction costs.
To improve the productivity and competitiveness, the sector needs to embark on the following initiatives:

- The competitive cost of doing business that can be achieved by improving the capacity and capability of the company;
- Less dependency on foreign labour and develop high skilled local manpower for the industry;
- Developing competent and productive workers and professionals by providing the comprehensive training and continual learning;
- Maintaining professionalism of company through accreditation and registration;
- Enhancing the implementation of IBS and standardization of materials in infrastructure and development projects;
- The aspect of risk management that must be effectively manageable through a practical fiscal policy and increase exports;
- Nurturing an innovative mindset in carrying out R&D and adopting benchmark and best practices.
TENDERING ON-LINE OR ON-THE-LINE – DOES IT MATTER? A MALAYSIAN CASE STUDY AND REVIEW OF THE LATEST DEVELOPMENTS IN TECHNOLOGY, LAW AND IMPLEMENTATION OF ELECTRONIC TENDERING FOR THE CONSTRUCTION INDUSTRY

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CIDB E-Construct Services, Malaysia

Abstract
This paper examines the validity of the claim through an analysis of an IT-led construction tendering initiative soon to be implemented in Malaysia. The National ETendering Imperative (NETi) is a national initiative that integrates and bridges every process and component of the entire construction tendering supply chain onto an electronic or digital medium in the hope that it can then transcend geographical, time, economical and people-based error and inefficiency barriers, making it faster, more efficient and more profitable for all the players in the industry. Online or e-tendering is a good test subject for validating the IT/Business connection, because it has met with a mix of responses in real-life implementation recently like in the USA, UK, Japan, Singapore, Hong Kong and other countries. In some, like in Hong Kong, the programme itself had changed fundamentally after strong industry consensus, in others like with the CALSEC program (Japan), it has been touted as a new patch for inter-country collaboration with the introduction of new standards and protocols. Some had been industry/contractor driven (Singapore), others client driven (e.g. Tesco – UK). Professional associations has not been quiet either, like their outright rejection of new reverse auctions systems in Canada and the UK or applauding budding new collaborative units like in Japan, Hong Kong and Malaysia (NeTI) or for others, close-knit communities of contractor-suppliers (USA). By highlighting the need for good governance, one of the focus areas of the paper is the examination of how the legal, business and process protocols combine and integrate in e-tendering. It examines whether there area any universal trends in a unified tendering protocol and formal control if projects are tendered electronically across borders.

Keywords: I.T. in Construction, Tendering, Ecommerce, Tendering Laws

INTRODUCTION

“IT Solutions For Your Business Problems”. A common tagline for IT providers, vendors, and even government authorities in touting for a move towards more automation and so-called collaboration opportunities that can be brought in the IT era. Sounds evangelistic? Well, not quite. For some, this has been proven true as new and streamlined work processes starts to increase productivity and accuracy in day-to-day work. For many though, the purchase of expensive “systems solutions” has not generated value to their organization, changes in works has instead garnered dissatisfaction and distrust within users, all at the detriment of its sole cause – the business. So is IT a real solution to all business ills? This paper examines the validity of the claim through an analysis of an IT-led construction tendering initiative soon to be implemented in Malaysia. Online or e-tendering is a good test subject for validating the IT/Business connection, because it has met with a mix of responses in real-life implementation recently like in the USA, UK, Japan, Singapore, Hong Kong and other countries. In some, like in Hong Kong, the programme itself had changed fundamentally after strong industry consensus, in others like with the CALSEC programme (Japan), it has been touted as a new patch for inter-country collaboration with
the introduction of new standards and protocols. Some had been industry/contractor driven (Singapore), others client driven (e.g. Tesco – UK). Professional associations has not been quiet either, like their outright rejection of new reverse auctions systems in Canada and the UK or applauding budding new collaborative units like in Japan, Hong Kong and Malaysia (NeTI) or for others, close knit communities of contractor-suppliers (USA). Quite an array of responses, not even mentioning new calls for a review of the tendering process itself - its laws, policies and standards, in light of a new-found awareness of the possibilities of increased transparency, efficiency and value-selections in the construction procurement process made possible with IT. Perhaps after all, we have found a new elixir – or have we really?

**INDUSTRY BACKGROUND**

Now is a good time as any for a revival of enhanced levels of transparency, efficiency and collaboration in construction. There is beginning to be a gradual liberation of global trade in this industry brought out by the new developments in the General Agreement on Tariffs and Trade (GATT) and the General Agreement of Trade in Services (GATS) from 1993 onwards. There have also been new developments in easing trade restrictions like a reform in construction procurement by over 20 countries agreeing towards a “Government Procurement Agreement” initiative which came into force in 1996. Nevertheless, the objectives of the tender system in construction even in the global context remains unchanged, that is to devise a most efficient framework to select capable contractors who can complete the construction project within set parameters of time, money and quality.

Within this changing environment, construction procurement needs to be modernised to face its new challenges. The usual way of choosing, selecting and appointing a contractor through a tendering process, (that is simply the acceptance of an offer of price along some prescribed project conditions) must be streamlined. Also termed as “bidding” or “bid process”, the common process is that contractors will be invited to place their offer after reviewing the details of the project (drawings, specifications, requirements, etc.) and conditions attached (time, security, performance, etc.). The employer will then be in a position to choose between the contractors’ bids, in turn accepting the tender offered to him.

**Understanding Legacy Problems In Tendering Facing The Malaysian Construction Industry**

Preparing tendering documentation and conducting tenders for employers and obtaining, processing and submitting tenders for contractors are costly. For contractors, the costs associated with preparing and submitting a tender will go to waste if their tenders are rejected. Studies conducted by Holt, etc. (1996) and Pasquire and Collins (1996) further showed that contractors would have invested their own resources in preparing and submitting items like brochures, presentation materials, estimating resources, administration and clerical assistance. These can be significant. They would put an extra strain against contractors’ finances, especially on those whom already would have to cut down their profit margins when tendering competitively for a project (Williamson (1981), Alsagoff (1996), Walker and Chau (1999), Bridge (1999)). Sometimes, in order to ensure selection in the face of the risks of abortive tender costs, some contractors may even go as far as conducting

For employers, factors other than tendering costs may be important. Apart from the employer’s belief that the lowest prices can be only obtained through a competitive process, there are other aspects that must be considered in selecting a contractor for his project. For some employers, especially those linked with government authorities or large corporations, accountability may be paramount. If tenders are assessed through negotiations only, it is difficult for the employer’s agents or his employees to show that the negotiations have been conducted purely objectively and that the best package has been secured through this process. Transparency becomes more important in situations where the contract has been substituted or novated, or where there are further requirements to show that the employer has discharged an unprejudiced selection of replacement contractors (see circumstances in Government Of The State Of Selangor v. Central Lorry Service & Construction Ltd.)

In addition to these legacies, there have great difficulties to restrict uncompetitive tactics practised by contractors themselves. For contractors, the submission of a cover price and bid peddling is as much a norm as it is a strategic manoeuvre. An industry study in Australia conducted by Ray et. al (1999) concluded that a majority of employers considers bid peddling as important to obtain a competitive price from a preferred contractor. In another study in the UK, Pasquire and Collins (1997) found a similar majority showing support for cover pricing practices and concluded that this majority felt that it was necessary to avoid “offending” the employer or prejudice the contractors’ future opportunities.

Understanding Specific Problems And Issues Related To The Tendering Process For in Malaysia

The Malaysian Statistics reported (MER, 200) that there are over 100,000 dependent businesses in the Malaysian construction industry. Even so, construction-based competitive based improvements are not relegated to these businesses – it affects directly the competitiveness of the nation. It has often been said that pushing demand from the construction sector directly benefits other sectors. Some statistics come to support this contention. For example, there is a correlation between the value added generated by the construction industry and the competitiveness index of a nation. Data from the World Economic Report 1999, the International Institute for Management Development, Switzerland (IMD) and the World Economic Forum (WEF) shows (Table 1):

<table>
<thead>
<tr>
<th>Table 1. WEF Economics Report (1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
</tr>
<tr>
<td>Construction Volume (RM billion) 1977</td>
</tr>
<tr>
<td>As a percentage of GDP 1977</td>
</tr>
<tr>
<td>Total Value Added (RM billion) 1977</td>
</tr>
<tr>
<td>Percentage Value added per Volume</td>
</tr>
<tr>
<td>Value added per employment (RM)</td>
</tr>
<tr>
<td>World Competitiveness Ranking 2002 (IMD)</td>
</tr>
<tr>
<td>Growth Competitiveness Indicator 2002 (WEF)</td>
</tr>
</tbody>
</table>
Basing itself on this premise, for Malaysia, in OPP3 (“Rancangan Malaysia ke-8” – RM8), a strategic economic plan tabled for the formation of a “Dasar Wawasan Negara” (National Strategy), the Malaysian government highlighted the need to increase the competitiveness of national industries. According to OPP3, such improvements can be implemented by the use of high technology that generates higher value added and productivity, promoting the awareness for a knowledge-driven society and to stimulate more demand for industries, both locally and internationally.

THE NEED FOR AN COMMON PLATFORM FOR AN INTEGRATED CONSTRUCTION TENDER VALUE CHAIN

Tendering, although appearing elementary at first, has had its share of implementation problems. In Malaysia, over 90% of the total number of projects awarded during the past 10 years are for those valued under RM20 million. These projects often become the target of unethical bid practices in the construction industry. It is a truism as evidenced in numerous industry researches that for contractors, the submission of a cover price and bid peddling is as much a norm as it is a strategic manoeuvre. An industry study in Australia conducted by Ray et. al (1999) concluded that a majority of employers considers bid peddling as important to obtain a competitive price from a preferred contractor. In another study in the UK, Pasquire and Collins (1997) found a similar majority showing support for cover pricing practices and concluded that this majority felt that it was necessary to maintain an amicable relationship with the employer otherwise prejudice the contractors’ future opportunities. Malaysia, as is many other countries, is not immune to these problems. The effect of these practices, just taking an approximate calculation could cost taxpayers close to RM200 million per year even if there is a 1% artificial wastage in the tender process.

In response to these problems, in a sitting of the 29th August 2001, the Malaysian Cabinet highlighted an immediate need to enhance efficiency in managing construction projects that had systematically resulted in procedural delays and late implementation of capital injection into the economy. Further to this, the Cabinet called for a study of contractors in a Cabinet letter ref. PM(R)11880/A/94 Jld. 2 dated 9th September 2001. Subsequently, in this study, the Ministry of Finance has highlighted the underlying cause of the problems lies in the lack of specific integration policies in the tendering value chain in the Malaysian construction industry. It then called for a need for a different approach to overcome fundamental problems in the production, posting, retrieval, submission and analysis of tender documents that must be addressed by the Malaysian construction industry as one step towards promoting better integration into what is considered a “fragmented” sector of the general economy.

The Malaysian Construction Industry: Enabling Conditions for IT Facilitated Paradigm Shift

During 1980-85 the construction industry contributed 4.9% to the nation’s GDP, in 1986-90 this reduced to 3.5% before recovering to 4.4% in 1996-98. The average annual growth was 2.9% in 1980-85, 4.7% during 1986-90 and increased to 13.0% during 1991-95 before declining at 8.3% during 1996-98. At the peak of the economic crisis, the construction industry contracted by more than 20% (MER, 2000).
Although the sector's share of the GDP contribution was small in terms of value-added over, it supported extensive upstream and downstream linkages. Demand for construction was driven by increasing demand for capacity and efficiency as is evident in the share of employment the construction sector. In 1991-95, the sector's employment enjoyed a growth of 11.2% before declining by 2.9% in 1991-95. The sector therefore accounted for 7.6% share of total employment in 1991-95 and 9.5% share in 1996-98. In term of productivity, the GDP per employee grew at 1.6% in 1991-95 before declining by 5.6% in 1996-98 (MER, 2000).

Even so, the added value per employee for the construction sector was calculated to be at 10.6% in 1988-93 which is considered to be relatively low. An increase of 12.2% fixed asset per employee during the same period indicated a shift from being labour-intensive to capital-intensive construction operations. This means that there is a capacity for inducing capital to be spent in investments like IT to increase productivity per worker from these low levels to those comparable with other sectors.

With a clear potential for economic improvement in the sector, coupled with a general drive for IT related knowledge intensive government policy, it is easy therefore to mount a nationwide call for the Malaysian government to inject a vision of IT for the construction industry. The advances that are forecast by this vision is for Information Technology (IT) to provide for significant improvements through dramatic reductions in cost and speed, increases in performance and functionality of such magnitude as to provide opportunities that cannot be fully conceived at this time. This is similar to the ways how the telephone made possible new ways to run organisations that were not foreseen at the time it was first introduced; it is claimed.

TECHNOLOGY AND A NEED FOR A MALAYSIAN AFFIRMATIVE ACTION

Technology adoption and utilization in construction for Malaysia is evolving from the infancy stage and poised to enter the ‘growth’ stage in the coming years. According to an IT Masterplan for Malaysia (ISIS, 2002), as the Malaysia government progress to the new phase of ICT deployment, it is focusing more and more on the systematic alignment of people, policies, processes and technology. The technology investment constitute only the small portion of the total investment in the initiative, as more resources and time are needed for the soft elements e.g. policies, skills, culture, governance. Due to the magnitude and interest in ICT as a key driver and differentiator in the Malaysian ICT Agenda Context over the last 5 years, as evidenced in the examples of successes like the MSC Project, Broadband and ADSL penetration, ICT has emerged as a popular and reliable business enabler and transformer. However, many have yet to feel the impact of various eGovernment initiatives. A survey conducted by the government, (SIRIM, 2003) found that the majority of the respondents are not aware of ongoing eGovernment initiatives such as eSPKB, PMS2 (SPP2) and ePerolehan. This comes with a realization that it is important for educating and sensitizing organizational members on the initiatives to better prepare them to leverage the eGovernment initiatives.

The next phase is to enhance inter-departments and inter-teams collaboration, communication and coordination. To achieve this, the industry needs to link the existing islands of information and form a collective knowledgebase. The information stored
represents the intellectual capital of the organization and its value is significantly increased if it is easily accessible organization-wide (information at the fingertips of the right people at the right time). Paperwork can be reduced further if staff can access share information digitally. Staff can enter the data/information once and can be accessible many times across the organizations. Also, research and information gathering can be done with ease as the repository of information can be accessed and retrieved with greater efficiency and effectiveness.

Therefore we are left with policy, process, people and technology variables in the hunt for the three main objectives of construction tendering (Diagram 2). IT “solutions” typically focus on the process (Workflow re-engineering) and Technology (security, architecture, etc.) but not the qualitative measures of Policy (laws, regulations, standards, etc) and the People (users, knowledge implementation, trust factor, etc.)

Besides technological integration, construction needs to relook at its processes and practices. IT investment alone will not make the industry more efficient and effective in facing challenges in the emerging global, digital economy. The investment needs to be complemented by investment in time, sustained efforts and creativity in changing redundant processes. As noted by Professor Brynjolfsson of MIT Sloan School of Management (Brynjolfsson, 2004), “[t]he biggest investments go toward developing business processes that can reap technology’s benefits.” It is the intangibles such as the rethinking of value chain, customer service, incentive systems and product offerings that determine whether productivity can be achieved with IT. The successful interplay of competent organizational members, digital technologies and redefined business processes provide the necessary ingredients to thrive in the emerging global, digital economy. All these provide room for growth, progress and sometimes new opportunities to emerge. Historical processes become future opportunities and information becomes new knowledge. ICT can help the industry manage these opportunities and take advantage of them.
There have been some initiatives worldwide for e-Tendering in construction, as illustrated in Table 2. Some have been successful while others have fallen prey to poor implementation results. For Malaysia, it is no different. Whist there have been many private-based initiatives but nevertheless, the implementation of information and communication technologies by businesses in the construction industry has been very slow relative to other industries. Statistics show (MERC, 2000) that the construction sector have not improved its capitalisation of such new technologies to bring about more productive outputs. For the moment the capital-to-output ratio had risen from 3.0 in 1988 to 6.5 in 1997, suggesting that the use of capital, including I.T. related spending has been increasingly less efficient. There has been little implementation of I.T. related cutting-edge advances in design and manufacturing systems locally.

Table 2. International Comparison of Government Electronic Construction Procurement Systems
(Adapted from Liao, et. al 2002)

<table>
<thead>
<tr>
<th>Country</th>
<th>Government electronic procurement system</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>FACNET</td>
<td>• Announcing governmental procurement opportunities</td>
</tr>
<tr>
<td></td>
<td>FACNET applies to open procurement processes if simplified procurement process requirement is met</td>
<td>• Providing related governmental procurement information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Accepting bidding electronically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Processing online payment towards contractors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Collecting related governmental procurement information</td>
</tr>
<tr>
<td>Canada</td>
<td>MERX</td>
<td>• With built-in procurement matching system, contractors can be informed immediately with appropriate procurement cases and receiving related information</td>
</tr>
<tr>
<td></td>
<td>MERX applies to open procurement processes and some limited procurement processes</td>
<td>• Accepting bidding electronically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Providing documents to contractors, confirming orders online and inquiring buyers' ordering history</td>
</tr>
<tr>
<td>Australia</td>
<td>Transigo</td>
<td>Providing online procurement information, bidding processing, government procurement handbook and application from government procurement contractor registration</td>
</tr>
<tr>
<td>Singapore</td>
<td>GITIS</td>
<td>Providing online procurement information accessing and bidding submitting services, including open, selected and limited procurement processes</td>
</tr>
<tr>
<td>Japan</td>
<td>JETRO</td>
<td>Supplying information such as government procurement announcement, item category, construction category, procurement institution and location announcement publication date, application deadline, bidding winner announcement dates and procurement dates</td>
</tr>
<tr>
<td>R.O.C (Taiwan)</td>
<td>Electronic tendering system</td>
<td>Electronic tendering system: digitalising procurement and bidding submission documents, which can be retrieved and submitted online</td>
</tr>
</tbody>
</table>
Moreover, despite a doubling of computer ownership in the last five years, studies have showed (SIRIM, 2003) that local contractors had simply used IT to automate existing processes. Perhaps in the fragmented nature of the construction industry at present, no single organisation can dictate and therefore be responsible for establishing and maintaining the necessary communication networks for a construction project. Consequently, this industry sector is faced with ineffective communication and information processes, which have inadvertently contributed to project cost and time overruns.

Why? One answer, which came to light during a national survey commissioned by the Malaysian Economic Planning Unit (SIRIM, 2003) was that although over 80% of the construction industry had said that they “cannot manage without IT” and that “IT contributed significantly to their operations”, over 90% of respondents wanted the Malaysian Government to take the lead in strategic directions and applications. A “Top-Down” implementation policy was also favoured by the respondents in the Malaysian construction sector.


Instead, the Malaysian study has given the government an affirmative action to lead the construction industry in IT adoption. It enables the government to feel the pulse of the industry and hence becoming more responsive to industry shifts. There seems to be an underlying awareness that today’s IT enables the industry to become more networked by providing the possibilities to communicate, coordinate and collaborate with external stakeholders with greater efficiency.

**NeTI as a Government Led Initiative**

Following the needs of the industry, a clear direction, for instance the issue of A GOVERNMENT DIRECTIVE from the government is necessary. For its successful implementation, initiatives shall then take the micro-projects approach as a strategy, to
leverage on an implement-via-use and produce a quick benefit return model. This not only ensures support, ownership and relevance, but also produces maximized and immediate returns for the effort.

With these objectives, a taskforce under patronage by the Ministry of Works (MoW or “KKR”) Malaysia conceived an initiative for e-tendering or NeTI (National ETendering Initiative). Taking stock of the industry’s needs and national aspirations and armed with case studies from similar government backed initiatives, the National eTender initiative (NeTI) promises to integrate and greatly improve on the tedious and multi-faceted tendering process into a streamlined, progressive and ‘intelligent’ one by use of procedural streamlining and technology empowerment. A key business driver, the eTender initiative will not only serve to consolidate and strengthen the industry and defrayments its value, but also to provide a sound and manageable basis for standardization, accreditation and knowledge-based recognition.

With the Construction Industry Development Board (CIDB) and the Public Works Department (JKR) as its key players, NeTI is a product of the principals of prioritised projects under the MoW as its mission for

- The development of a Knowledge Management Portal
- Internal agency application systems to support the agency’s operational needs
- Integration of the latest technology in electronic device for security, communication and collaboration.

Diagram 2. NeTI as an Inter-Agency Collaborative Government Effort
The intensification and upgrading of telecommunications infrastructure and skills, prerequisites for IT development, will be emphasised with the government playing a proactive role in providing an environment for IT advancement, to invest in IT-related programmes and projects. The most important issue in the implementation of IT, which distinguishes construction from other sectors, will be the integration problems; that is how to exchange the information among different the participants involved in the construction process. The introduction of a common platform as a foundation for building integrated databases is among the solutions to the industry at present and remains the primary focus of all major construction IT initiatives world-wide.

What distinguishes NeTi from her other international counterparts is that it is designed to integrate with the Malaysian eGovernment Flagship as a 2nd tier infrastructure to line up and interface with all other agencies for construction procurement and tenders as well as project management. By doing this, as illustrated in Diagram 3, NeTi will synthesize all aspects of pre, during and post tender processing for government projects as well as private-based projects; providing not only integration but also streamlined processing of all data and payment directly by the Auditor General Department.
Implementing E-Tendering: Ongoing Issues on Transparency, Tendering Abuses and the Malaysian Law

IT should be strategically used to enable the Malaysian construction industry to become more responsive to industry shifts and market trends. In the increasingly dynamic knowledge-based economy, it is by being agile that defines competitive advantage. IT needs to enhance processes and make them more efficient by reducing redundancy. IT needs to enable the workforce to become more creative and innovative to thrive successfully in the emerging knowledge-based economy. It is only through the creative and innovative utilization of IT that will determine success.

Is IT the sole and definitive solution for tendering efficiency in Malaysia? Many have claimed that efficiency generated vis-à-vis IT/electronic tendering, for some, coining a “paradigm shift” in tendering automation will automatically be an elixir to the ills of the construction tendering process. Perhaps. Or perhaps not; it is argued that the notion of IT as a cure-all for tendering is a funnelled utopian vision. Considering that automation will bring about some improvements, the legacy system of tendering must be re-examined in a new way if indeed the vision for efficiency can be realised. Transparency and the legal process cannot be overlooked. Instead, it is suggested here that efficiency in tendering is first and foremost linked to transparency of the process itself. “Transparency” or “Ethics” has many interpretations. It has been described as “rules of conduct”, “moral principles or values” or “principles of right conduct”. In tendering, what is viewed as “efficiency” in a process must also embody sub-elements of trust, acceptance and adaptability as suggested by Love, et. al (2001) to infuse some form accepted ethical codes of conduct governing both the employers and the contractors. These codes should not only be recognised in law but more practically goes beyond that. They are conditions upon which individuals and organisation and trusted and respected by those they deal with. Only with trust established can efficiency be tackled successfully.

No doubt, by and large, tendering ethics are based on the principles of good faith and good professional practice (C.U.P., 1997, De George, 1995, Donaldson and Werhane, 1996). At times, they may border into those acts that are otherwise enforceable by law for example against tendering fraud or corrupt practices. It is clear therefore that the principle means of incorporating duties of fairness, and hence efficiency, in Malaysia has to be by express provisions in the contract or under certain government legislation eg. in Chew Chee Sun v. Public Prosecutor, 1975. Nevertheless, construction tendering is not all in disarray though. It can just be fundamentally “uncontrollable”. Take the extreme point – tender corruption and fraud for instance. While it is true to say that corrupt practices and proven frauds are actionable by law; the treatment for opportunistic tendering tactics is not that straightforward. There will always be debates on what is considered “transparent”, “ethical” and what is considered as “lawful”. In law, some guidelines in Richardson v. Silvester (1873) have been offered as a cornerstone where it has been shown that if an employer has no intention of letting the contract to the person invited to tender, or to one of a number so invited, the invitation is clearly fraudulent and an action will lie to recover any tendering expenses by incurred by the contractor. In short, the tender can be both unethical and unlawful. Making the process on-line (with IT) does not change it one bit.
Does IT make tendering “transparent” enough that any fraudulent act can be nipped at the bud? For any tender to be unlawful per se, fraud must be proven. This is constantly a moot point as evidence of clear fraud in law is always circumspect in most legal jurisdictions. Otherwise, clear of fraud, “unethical” conducts although to some may arguably be “transparent” may be better described as an abuse of the competitive tendering process, opportunistic manoeuvres or sometimes as “anti-competitive tactics”. There are many examples of these in the day-to-day practice in the construction industry, both by the employers and also by the contractors like “Dutch auctioning”, repeated tendering and “negotiated” reductions to name a few. IT, with its penchant for instantaneous inter-location communication may have made matters worst – at least a revival of reverse or Dutch auctions. A variant of the system has been used in a few major projects in Malaysia like in the Westport project (New Straits Times, 2002). While the response from Malaysia is lukewarm, elsewhere, Dutch auctions in e-tendering has been met with strong opposition and views across some construction industries (for example in the UK reported by Wood, 2002 and Pearman, 2002). For others, it may just be another cost-cutting avenue – albeit rightly or wrongly.

There is some reprieve if (some say opportunistic) manoeuvres like Dutch auctions in construction tendering are carried out too far, though. The law do intervene to aid contractors by limiting post-tender, “forced pricing” negotiations. In Ben Bruinsma & Son Ltd. v. The Corporation of the City of Chatam et. al, the Canadian courts refused to permit an employer to manipulate a conforming tender by deleting items from the work. By an action brought on by one of the tenderers, the employers have had to discard all of the tenders and start again with the new requirements. This point has also been discussed by Dorter (1996) and Bailey (1999) and further demonstrated in other jurisdictions as well like in Australia in Hunter Bros v. Brisbane City Council concerning post-tender readjustments for project manning levels for a refuse collection contract.

Despite a trend for a move towards a stricter legal control of unethical tendering practices, the Commonwealth and accordingly the Malaysian courts have been reluctant to imply an straightforward obligation for good faith or good practice outside those in fiduciary relationships (principal/agent, employer/employee) or where there is an implication of full disclosure (ubberimae fidae) for instance in insurance contracts. Even so, case law has some examples where the courts have decided on other means to imply good practice. In Ooi Kiah Inn Charles & Anor v. Kukuh Maju Industries Sdn. Bhd., the courts have considered the implications to public policy when deciding on the conducts of the contracting parties. The courts have also have been referred to issues on non diligence in conduct where performance was delayed in Kuala Lumpur Landmark Sdn. Bhd. v. Standard Chartered Bank and have had to decided on common law guidelines for frustration (if not breach for the evasion of the spirit of the deal). Similarly, in Polygram Records Sdn. Bhd. v. Search & Anor, the Malaysian courts have considered but rejected arguments that there are grounds for a covenant of restraint to trade in recording contracts.

All support the line of argument that as the need for transparency is fulfilled, the law, technology and efficiency will automatically follow.
CONCLUSION

Have we found the elusive elixir for construction business ills in e-tendering? Is it in IT? Well perhaps it is more of a dichotomy of solutions. On the one hand, IT will truly improve communication and make work more efficient and most importantly make people collaborate more, judging from the implementation across and within countries recently, whether it has been a success or not. One outlook is apparent though, the industry is more and more aware of the need for group effort within itself over and above the “fragmented” label it used to carry as participants scour for more business across blurring country borders. Along these lines, as tendering protocols seems to be merging, what is also clear is that there is a governing universal trend in a unification of tendering contract standards in its laws and formal control across countries. Transparency, efficiency and good governance will follow, in due time of course. On the other hand, there are and always be opportunists. They come in many guises. For some, they are the rogue clients, as when e-tender means a bigger catchment’s net of willing contractors who will undercut each other’s margins for their benefit. Reverse auctions or not. For others, they are the insatiable IT vendors, with their superfluously complex tendering “solutions, profiteering from the ever willing customers. For Malaysia though, having recognized and learnt from others, it is more of implementing a pathway to better collaboration and more knowledge intensive communities with the government as catalyst. IT is one but not exclusive source of transparency, efficiency and value. Perhaps we were looking at the wrong tier solution. IT is a 2nd tier solution as it is a mere catalyst to 1st tier solutions of better standards, improved communication and more acceptable laws – those are the true elixirs to business problems, it is submitted.

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The Malaysian Construction Research Journal (MCRJ) is the journal dedicated to the documentation of R&D achievements and technological development relevant to the construction industry within Malaysia and elsewhere in the world. It is a collation of research papers and other academic publications produced by researchers, practitioners, industrialists, academicians, and all those involved in the construction industry. The papers cover a wide spectrum encompassing building technology, materials science, information technology, environment, quality, economics and many relevant disciplines that can contribute to the enhancement of knowledge in the construction field. The MCRJ aspire to become the premier communication media amongst knowledge professionals in the construction industry and shall hopefully, breach the knowledge gap currently prevalent between and amongst the knowledge producers and the construction practitioners.

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES
Author’s name (full name): Arial Bold, 9pt. should follow below the title.

Jamalodin Noorzaei¹, Mohd. Saleh Jaafar, Abdul Waleed Thanoon, Wong Jern Nee

Affiliation (including post codes): Arial, 9pt. Use numbers to indicate affiliations.

¹Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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Heading 3: Arial Italic + Lower Case, 11pt.

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Figures caption: Arial Bold + Arial, 9pt. should be written below the figures.

![Figure 8. Computed attic temperature with sealed and ventilated attic](image-url)
Tables: Arial, 8pt. Table should be incorporated in the text.

Table caption: Arial Bold + Arial, 9pt. Caption should be written above the table.

Table Line: .5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw Water Quality</th>
<th>Drinking Water Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform (MPN/100ml)</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>1000</td>
<td>5</td>
</tr>
<tr>
<td>Color (Hazen)</td>
<td>300</td>
<td>15</td>
</tr>
<tr>
<td>pH</td>
<td>5.5-9.0</td>
<td>6.5-9.0</td>
</tr>
</tbody>
</table>

(Source: Twort et al. 1985; MWA,1994)

Reference: Times New Roman, 11pt. Left indent .25 inch, first line left indent – .25 inch. Reference should be cited in the text as follows: “Berdahl and Bretz (1997) found…” or “(Bower et al. 1998)”. References should be listed in alphabetical order, on separate sheets from the text. In the list of References, the titles of periodicals should be given in full, while for books should state the title, place of publication, name of publisher, and indication of edition.

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