UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006
2nd. Semester Examination
2005/2006 Academic Session

April / Mei 2006

EAS 454/4 – Kejuruteraan Struktur Lanjutan

EAS 454/4 – Advanced Structural Engineering

Masa : 3 jam
Duration: 3 hours

Arahan Kepada calon:
Instructions To Candidates:

1. Sila pastikan kertas peperiksaan ini mengandungi **DUA PULUH (20)** muka surat bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.
*Ensure that this paper contains **TWENTY (20)** printed pages including appendices before you start your examination.*

2. Kertas ini mengandungi **ENAM (6)** soalan. Jawab **LIMA (5)** soalan sahaja. Markah hanya akan dikira bagi **LIMA (5)** jawapan **PERTAMA** yang dimasukkan di dalam buku mengikut susunan dan bukannya **LIMA (5)** jawapan terbaik.
*This paper contains **SIX (6)** questions. Answer **FIVE (5)** questions only. Marks will be given to the **FIRST FIVE (5)** questions put in order on the answer script and **NOT** the **BEST FIVE (5)**.*

3. Semua soalan boleh dijawab dalam Bahasa Inggeris atau Bahasa Malaysia ataupun kombinasi kedua-dua bahasa.
*All questions **CAN BE** answered in English or Bahasa Malaysia or combination of both languages.*

4. Tiap-tiap jawapan **MESTILAH** dimulakan pada muka surat yang baru.
*Each question **MUST BE** answered on a new sheet.*

5. Tuliskan nombor soalan yang dijawab di luar kulit buku jawapan anda.
Write the answered question numbers on the cover sheet of the answer script.

1. (a) Nyatakan kesesuaian penggunaan kaedah **'Analogi Kekuda'** dan **'Teori Rasuk'** untuk merekabentuk tetopi cerucuk.

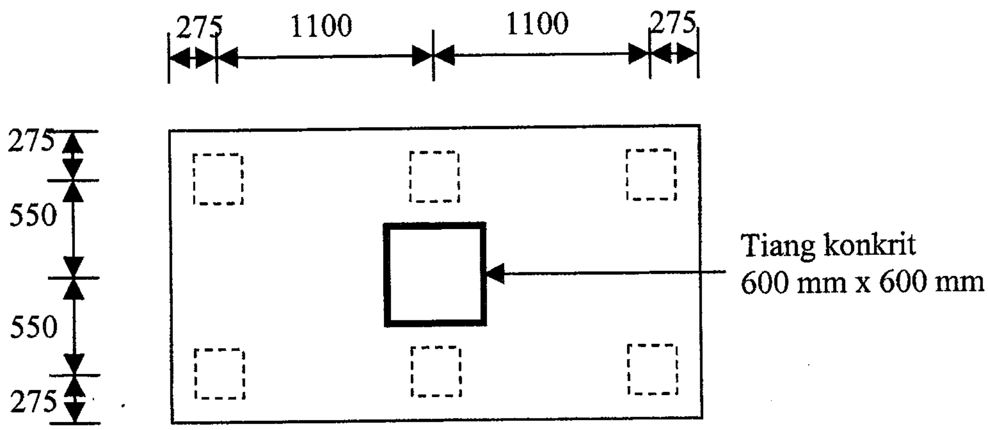
(2 markah)

*States the suitability of using **Truss Analogy** method and the **Beam Theory** method for designing a pile cap.*

(b) Rekabentuk dan lakar perincian tetopi enam (6) kumpulan cerucuk yang menanggung beban rekabentuk had muktamad tiang sebanyak 4000 kN seperti di Rajah 1. Cerucuk yang dicadangkan adalah cerucuk konkrit pratuang segiempat sama bersaiz 350mm x 350mm. Abaikan berat sendiri tetopi cerucuk. Anggap kekuatan ciri konkrit 30 N/mm^2, kedalaman (h) tetopi cerucuk 1000 mm, penutup konkrit 50 mm dan cerucuk terbenam 75mm ke dalam tetopi cerucuk. Rujuk Lampiran 1 dan 2 untuk semakan ricih mengikut BS 8110 : Part 1 : 1997.

(12 markah)

Design and sketch the detail of a pile cap for six (6) pile groups experiencing column load at the ultimate limit state of 4000 kN as shown in Figure 1. The recommended pile is 350 mm x 350 mm pre-cast concrete square pile. Neglect the selfweight of the pile cap. Assume that the characteristic strength for concrete is 30 N/mm^2, overall depth (h) 1000 mm, concrete cover 50 mm and pile embedment into pile cap is 75 mm. Refer Attachment 1 and 2 for shear requirement as per BS 8110 : Part 1 : 1997.

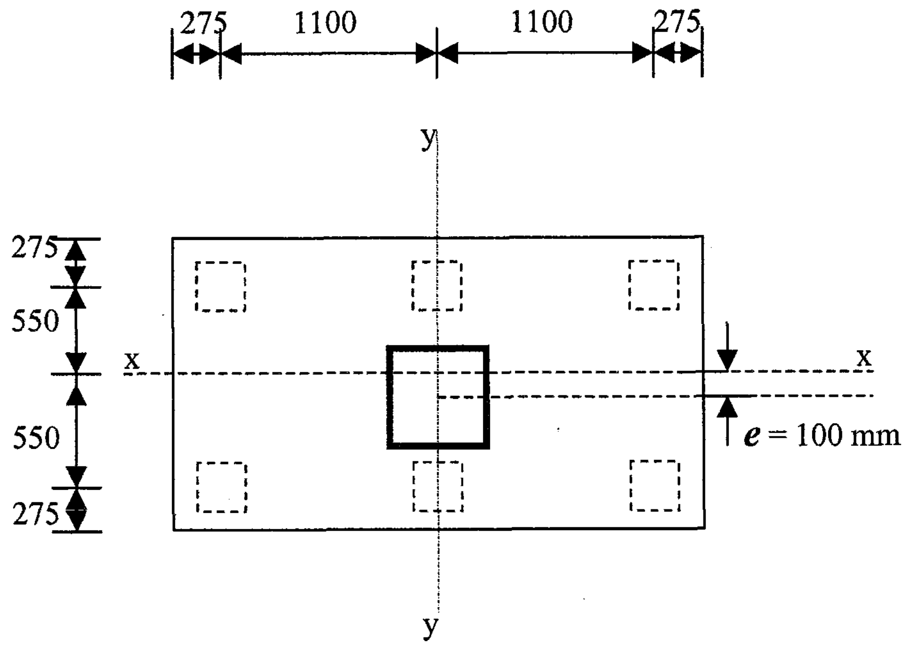


Rajah 1 : Pelan Tetopi Cerucuk

1. (c) Setelah kerja-kerja cerucuk dilakukan, semakan jurutera mendapati posisi tiang telah silap ditandakan dan mengakibatkan kesipian tiang, ***e*** sebanyak 100 mm dari sentroid ke paksi x seperti di Rajah 2. Jika beban tiang had kebolehkhidmatan adalah 2500 kN dan berat sendiri tetopi cerucuk adalah 100 kN, berikan ulasan terhadap keupayaan setiap cerucuk disebabkan kesipian jika keupayaan sebenar rekabentuk setiap cerucuk adalah 450 kN.

(6 markah)

*Upon completion of the piling exercise, the engineer realized that the column position was wrongly marked, resulting in a column eccentricity, **e** of 100 mm from centroid of x-axis as shown in Figure 2. If the column load under serviceability is 2500 kN and the selfweight of pile cap is 100 kN, comment the capacity of each pile due to eccentricity if the allowable capacity of each pile is 450 kN.*



Rajah 2 : Kesipian tiang, *e*

2. (a) Dengan bantuan lakaran-lakaran yang sesuai, jelaskan **TIGA (3)** bentuk struktur bagi bangunan tinggi.

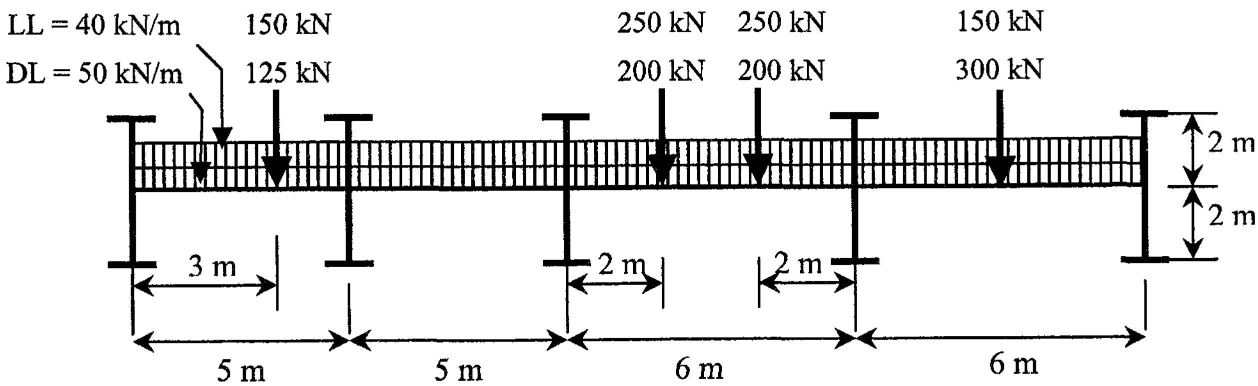
(9 markah)

With the assistance of appropriate sketches, explain ***THREE (3)*** *structural forms of tall buildings.*

(b) Rajah 3 menunjukkan subkerangka bagi bangunan tinggi dengan daya tindakan ke atasnya. Tentukan momen anggota subkerangka dengan menggunakan kaedah Agihan Momen 2 Kitaran (Lampiran 3).

(11 markah)

Figure 3 shows a sub-frame of a tall building with the loading exerted on it. Determine the member moments for the sub-frame by using 2 Cycle Moment Distribution Method (Appendix 3).



DL = Dead Load LL = Live Load
Beams 300 x 450 (D) Columns 300 x 300

Rajah 3

3. (a) Bincang secara ringkas mengenai proses pendiskretan dalam pemodelan kaedah elemen terhingga untuk tajuk berikut:
   i. Pemudah menggunakan simetri (paksi, satah, berkitar dan pengulangan)
   ii. Saiz dan jumlah elemen
   iii. Bentuk elemen dan herotan

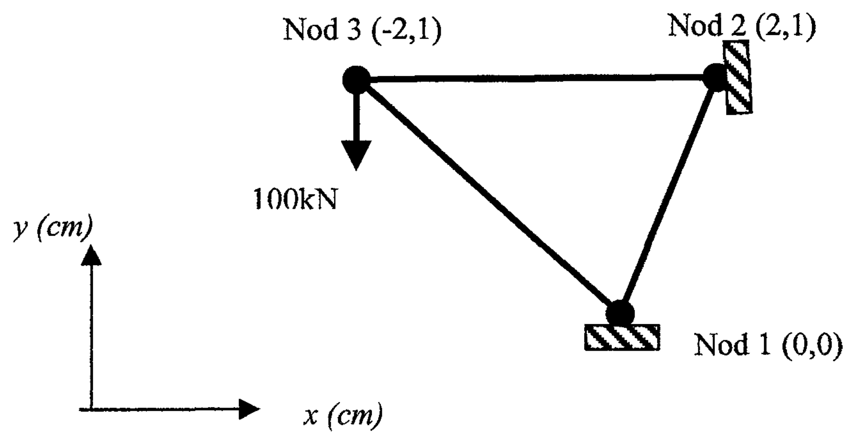
(10 markah)

Discuss briefly the assumption made in the process of discretization of finite element modeling in the following topics:
   i. Simplification through symmetry (axial, planar, cyclic and repetitive)
   ii. Size and number of elements
   iii. Element shape and distortion

3. (b) Terdapat tujuh langkah dalam proses penerbitan matriks elemen $[K]^e$ untuk satu elemen segitiga yang mengalami tegasan satah seperti yang ditunjukkan dalam Rajah 4. Tunjukkan dengan jelas Langkah 1 hingga 5 dalam terma umum (tidak perlu disongsangkan matriks [A]). Diberi daya kenaan pada nod 3 dalam arah y sebanyak 100kN. Anggap nilai $E = 200$ GN/m^2, $\nu = 0.3$ dan $t = 2$ cm.

(10 markah)

There are 7 steps involved in the development process of a stiffness matrix, $[K]^e$, for a triangular element in a state of plane stress as shown in Figure 4. Show clearly Step 1 to 5, in general term (no need an inversion of matrix [A]). Given the applied load of 100kN at node 3 in y direction. Assuming that, value of $E =$ 200 GN/m^2, $\nu = 0.3$ and $t = 2$ cm.



Rajah 4

4. (a) Sebuah bangunan industri perabot akan dibina di Ipoh (Zon II) dalam kategori rupa bumi 2 dengan beban angin asas sebanyak 32.5 m/s^2 seperti yang ditunjukkan dalam Rajah 5. Ia dibina menggunakan kerangka portal keluli. Untuk tujuan rekebentuk, anda dikehendaki mengira nilai tekanan angin rekabentuk (dalam bentuk jadual) di permukaan W (arah angin), L (lindung angin), S (dinding sisi), U (angin menaik) dan D (angin menurun). Seterusnya lakarkan nilai tekanan angin rekabentuk bersih di setiap permukaan bangunan.

(12 markah)

An industrial furniture building will be built at Ipoh (Zone II) in the terrain category 2 with the basic wind speed of 32.5 m/s^2 as shown in Figure 5. It is made of steel portal frame. For the design purposes, you are required to calculate the value of design wind pressure (tabulated form) on the W (windward), L (leeward), S (sidewall), U (upwind) and D (downwind) surfaces. Then, sketch the net design wind pressure for each surface.

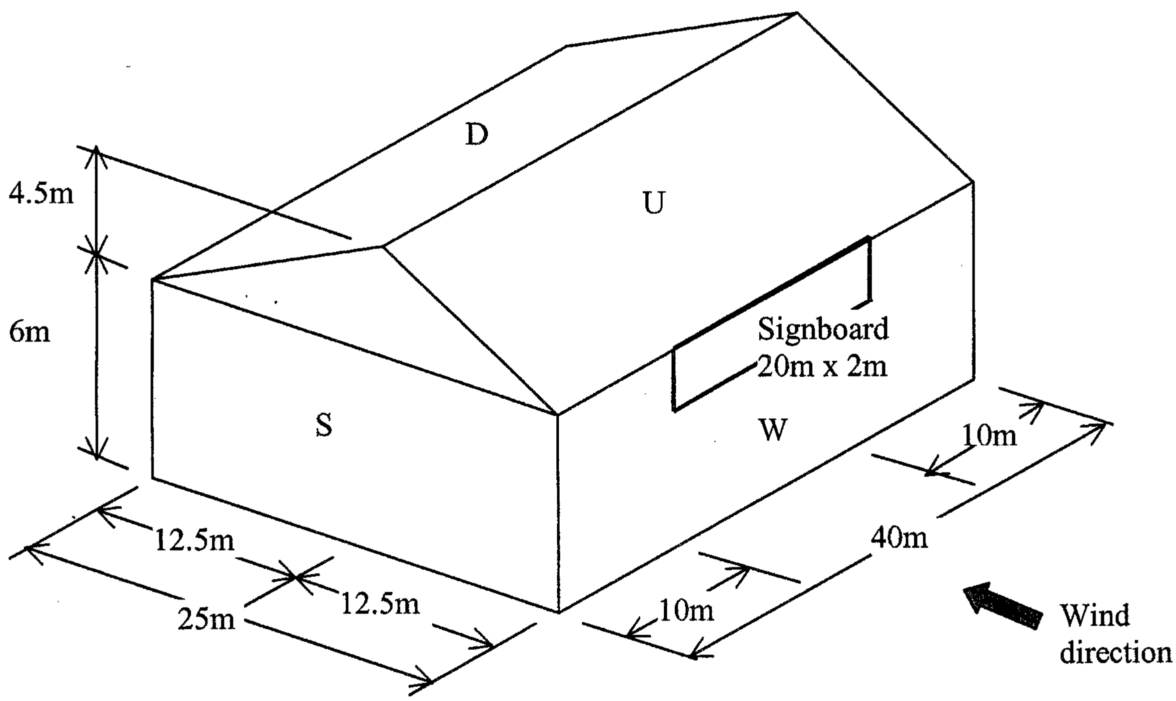
4. (b) Bangunan industri tersebut juga dilengkapi dengan papan iklan bersaiz 10m x 2m di bahagian atas permukaan W (arah angin) seperti dalam Rajah 5 . Anggap papan iklan adalah struktur pelapisan, kira nilai tekanan maksima yang dialami olehnya.

Data rekabentuk dari MS1553 (2002) di Lampiran 4.

(8 markah)

The industrial building is also equipped with a signboard of 10m x 2m on windward surface as shown in Figure 5. Assuming that the signboard is a non-structural element, calculate the maximum pressure experienced by the signboard.

Design data extracted from MS1553 (2002) is given in Appendix 4.

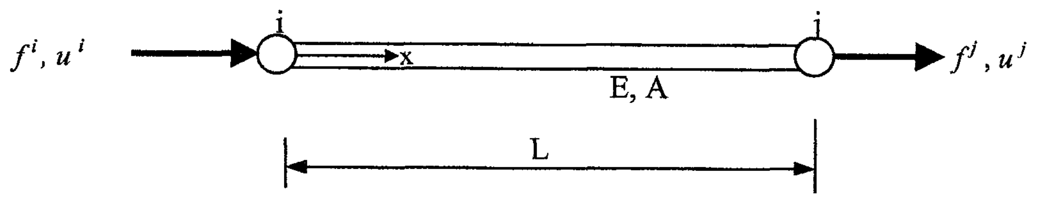


Rajah 5

5. (a) Rajah 6 menunjukkan satu elemen bar di bawah tindakan daya paksi, iaitu f^i, f^j : daya nod pada nod i dan nod j, E : modulus keanjalan bahan bar, A : luas keratan bar, L : panjang asal elemen bar dan u^i, u^j : anjakan nod pada nod i dan nod j. Terbitkan persamaan kekukuhan elemen. Nyatakan dengan jelas dalam proses penerbitan anda hubungan asas dalam bidang mekanik struktur yang digunakan.

(6 markah)

Figure 6 shows an axially loaded element where f^i, f^j : nodal forces at node i and node j, respectively, E : modulus of elasticity of the bar material, A : cross-sectional area of the bar, L : original length of the bar and u^i, u^j : nodal displacement of node i and node j, respectively. Derive the element stiffness equation. State clearly in your derivation which basic equations in structural mechanics have been used.



Rajah 6

5. (b) Rajah 7 menunjukkan satu rasuk dengan momen sifatekun 2EI untuk bahagian 1-2 dan EI untuk bahagian 2-3. Penyokong pada kedua-dua hujung di nod 1 dan 3 adalah jenis tegar. Satu pegas dengan nilai pemalar pegas k bersambung dengan rasuk pada nod 2. Satu beban tertumpu P bertindak pada nod 2 dan satu beban teragih seragam bertindak di bahagian 2-3 rasuk.

Dengan menggunakan kaedah matriks:

i. Bina matrik kekukuhan struktur **K**. Nyatakan dengan jelas saiz **K**.
ii. Dapatkan vektor beban global **F**.

Gunakan data penyambungan elemen seperti yang diberikan dalam Jadual 1.

Sekiranya keadaan sokongan rasuk diubahsuai dalam cara seperti yang ditunjukkan dalam Rajah 8 di mana pegas pada nod 2 telah digantikan dengan satu penyokong jenis guling, dapatkan persamaan untuk daya tindakbalas pada penyokong 1 dan 3.

(14 markah)

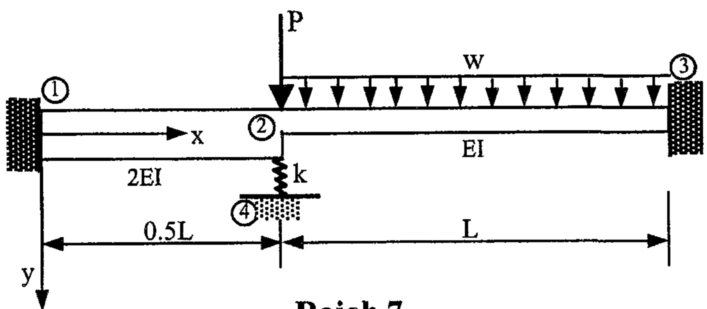
5. (b) *Figure 7 shows a step beam with moment of inertias of 2EI and EI for portions 1-2 and 2-3, respectively. Both end supports at node 1 and 3 are of fixed types. A spring with spring constant k is attached to the beam at node 2. The beam is loaded with a concentrated load at node 2 and a uniformly distributed load along portion 2-3.*

Using matrix method of analysis:

i. *Assemble the structure stiffness matrix* ***K****. Indicate clearly the size of* ***K****.*
ii. *Obtain the global load vector* ***F****.*

Use element connectivity data as given in Table 1.

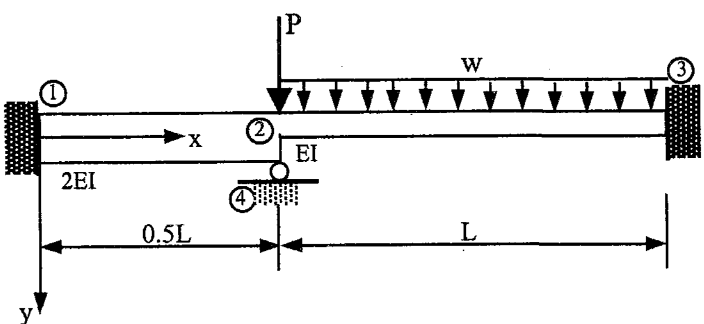
If the support condition of the beam is modified as shown in Figure 8 where the spring at node 2 has been replaced with a roller support, obtain the corresponding reaction forces at support 1 and 3.



Rajah 7

Jadual 1

Element	node i	node j
<1>	1	2
<2>	2	3
<3>	2	4

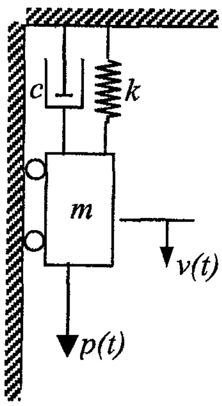


Rajah 8

6. (a) Untuk model jisim-pegas SDOF seperti yang ditunjukkan dalam Rajah 9, terbitkan persamaan gerakan yang berkenaan. Diberi bahawa k : kekukuhan sistem, m : jisim sistem, p(t) : daya luar bertindak yang berubah dengan masa dan v(t) : anjakan sistem yang diukur daripada kedudukan keseimbangan statik.

(6 markah)

For the SDOF model shown in Figure 9, derive the equation of motion. Given k : stiffness of the system, c : viscous damping coefficient of the system, m ; mass of the system, p(t) : time varying external load acting on the system and v(t) : displacement of the system with respect to static equilibrium position.



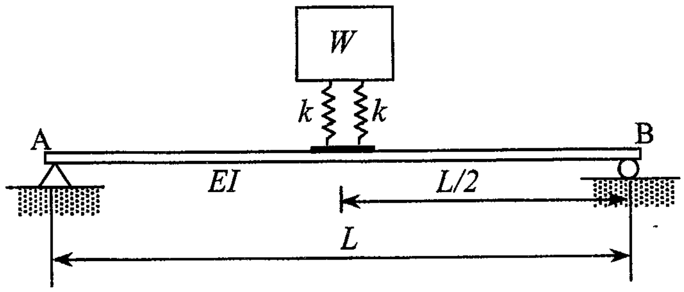
Rajah 9

(b) Satu rasuk mudah dengan rentang L dan ketegaran lenturan EI direkabentuk untuk menanggung satu mesin dengan berat W pada kedudukan pertengahan rentang seperti yang ditunjukkan dalam Rajah 10. Mesin berkenaan tidak diletakkan terus ke atas rasuk. Ia disokong oleh dua pegas dengan nilai pemalar pegas k. Kedua-dua pegas kemudiannya disambung ke atas satu plat tegar yang terikat kukuh kepada rasuk. Dengan mempertimbangkan sistem seperti yang ditunjukkan dalam Rajah 10 sebagai satu sistem SDOF, terbitkan persamaan untuk kekukuhan setara sistem. Abaikan berat sendiri tiang dan juga plat tegar. Diberi bahawa satu daya *P* yang bertindak ke atas satu rasuk mudah pada pertengahan rentang akan menghasilkan pesongan pugak bersamaan dengan $PL^3/48EI$ pada pertengahan rentang.

(6 markah)

A simply supported beam with span L and flexural rigidity EI is designed to carry a heavy machine with weight W at its mid-span as shown in Figure 10. The machine does not sit directly on the beam but is instead supported by two vertical springs with spring constant k. The two springs are rigidly attached to a rigid plate which is firmly attached to the beam. By considering the system as shown in Figure 10 as a SDOF system, derive the expression for the equivalent stiffness of the system. Neglect the self-weight of the beam and also the rigid plate. Given a load P acting at the mid-span of a simply supported beam will produce a deflection of $PL^3/48EI$.

...10/-



Rajah 10

(c) Rajah 11 menunjukkan satu kerangka tegar untuk analisis dinamik. Satu ujian getaran bebas telah dijalankan ke atas kerangka berkenaan. Didapati daripada hasil ujian bahawa apabila nilai daya sisi dari "jack" sebanyak 100kN dikenakan ke atas galang kerangka, anjakan sisi yang terhasil adalah sebesar 20mm. Apabila galang dilepaskan dari kedudukan asal di atas, didapati bahawa masa yang diperlukan untuk kerangka melengkapkan empat kitaran adalah 6s dan amplitud getaran selepas empat kitaran adalah sebesar 5mm.

Berdasarkan kepada data yang diberikan di atas, kirakan:

(i) Jisim berkesan m galang.
(ii) Frekuensi getaran f dalam Hertz.
(iii) Nisbah redaman ζ.
(iv) Masa yang diperlukan untuk amplitud getaran berkurangan sehingga 10% daripada amplitud asal.

(8 markah)

A rigid frame where dynamic analysis is to be carried out is shown in Figure 11. A free vibration test has been carried out on the frame. It is found that when a lateral jacking force of 100kN is applied on to the girder, the lateral displacement produced is 20mm. When the girder is instantaneously released from this initial position, it is observed that the time recorded for the frame to complete four cycles is 6s and the amplitude of vibration after four cycles is 5mm. Based on the data given above and neglecting the mass of the two supporting columns, compute:

(i) Effective mass m of the girder.
(ii) Frequency of vibration f in Hertz.
(iii) Damping ratio ζ.
(iv) Time taken for the amplitude of vibration to decrease to 10% of the initial amplitude.

h thickness of pad footing or pile cap.

l_c half the spacing between column centres (if more than one) or the distance to the edge of the pad (whichever is the greater).

l_x length of the longer side of a base.

l_y length of the shorter side of a base.

v design shear stress at a section.

v_c design concrete shear stress (see table 3.8).

φ diameter of a circular pile or of a circle inscribed in the plan form of a pile of other shape.

3.11.2 Assumptions in the design of pad footings and pile caps

3.11.2.1 ***General***

Except where the reactions to the applied loads and moments are derived by more accurate methods, e.g. an elastic analysis of a pile group or the application of established principles of soil mechanics, the following assumptions should be made.

a) When a base or a pile cap is axially loaded, the reactions to design ultimate loads may be assumed to be uniformly distributed (i.e. load per unit area or per pile).

b) When a base or a pile cap is eccentrically loaded, the reactions may be assumed to vary linearly across the base or across the pile system.

3.11.2.2 ***Critical section in design of an isolated pad footing***

The critical section in design of an isolated pad footing may be taken as that at the face of the column or wall supported.

3.11.2.3 ***Pockets for precast members***

Account should be taken of pockets for precast members in calculating section resistances, unless grouted up with a cement mortar not weaker than the concrete in the base.

3.11.3 Design of pad footings

3.11.3.1 ***Design moment on a vertical section taken completely across a pad footing***

The design moment on a vertical section taken completely across a pad footing should be taken as that due to all external design ultimate loads and reactions on one side of that section. No redistribution of moments should be made.

3.11.3.2 ***Distribution of reinforcement***

For the purposes of this sub-clause the reinforcement considered is that at right angles to the section. Where l_c exceeds $(3c/4 + 9d/4)$, two-thirds of the required reinforcement should be concentrated within a zone from the centre-line of the column to a distance $1.5d$ from the face of the column; otherwise the reinforcement should be uniformly distributed over l_c.

3.11.3.3 ***Design shear***

The design shear is the algebraic sum of all design ultimate vertical loads acting on one side of or outside the periphery of the critical section (see **3.5.5** and **3.5.6**).

3.11.3.4 ***Design shear strength near concentrated loads***

Design shear strength near concentrated loads is governed by the more severe of the following two conditions.

a) *Shear along a vertical section extending across the full width of a base.* See **3.5.5.2** and **3.5.5.3** (which deal with the design shear resistance of slabs).

b) *Punching shear around the loaded area.* Use **3.7.6** except that no shear reinforcement is needed when $v < v_c$.

3.11.4 Design of pile caps

3.11.4.1 ***General***

Pile caps are designed either by bending theory or by truss analogy; if the latter is used the truss should be of triangulated form, with a node at the centre of loaded area. The lower nodes of the truss lie at the intersections of the centre-lines of the piles with the tensile reinforcement.

3.11.4.2 ***Truss method***

Where the truss method is used with widely spaced piles (spacing exceeding three times the pile diameter), only the reinforcement within 1.5 times the pile diameter from the centre of a pile should be considered to constitute a tension member of the truss.

3.11.4.3 ***Shear forces***

The design shear strength of a pile cap is normally governed by the shear along a vertical section extending across the full width of the cap. Critical sections for the shear should be assumed to be located 20 % of the diameter of the pile inside the face of the pile, as indicated in figure 3.23. The whole of the force from the piles with centres lying outside this line should be considered to be applied outside this line.

3.11.4.4 ***Design shear resistance***

The design shear resistance of pile caps may be determined in accordance with **3.5.5** and **3.5.6**, subject to the following limitations.

a) In applying these provisions, a_v is the distance from the face of the column to the critical section as defined in **3.11.4.3**.

b) Where the spacing of the piles is less than or equal to 3φ, the enhancement may be applied over the whole of the critical section. Where the spacing is greater, the enhancement may only be applied to strips of width equal to 3φ, centred on each pile. Minimum stirrups are not required in pile caps where $v < v_c$ (enhanced if appropriate).

c) The tension reinforcement should be provided with a full anchorage in accordance with **3.12.8**.

3.11.4.5 ***Punching shear***

A check should be made to ensure that the design shear stress calculated at the perimeter of the column does not exceed $0.8\sqrt{f_{cu}}$ N/mm^2 or 5 N/mm^2, whichever is the lesser. The maximum shear capacity may also be limited by the provisions of **3.7.7.5**. In addition, if the spacing of the piles is greater than 3φ, punching shear should be checked in accordance with **3.7.7** on a perimeter as indicated in figure 3.23.

3.12 Considerations affecting design details

NOTE. Section **6** gives guidance on workmanship.

3.12.1 Permissible deviations

3.12.1.1 ***General***

The effect of permissible deviations on design and detailing is given in **3.12.1.2** to **3.12.1.5** (see also **6.2.8** for dimensional deviations).

3.12.1.2 ***Permissible deviations on member sizes***

In the selection of member sizes allowance should be made for inaccuracy of construction. BS 5606 gives guidance on accuracy and permissible deviations. The degree of permissible deviation specified should be consistent with the structure's fitness for its purpose.

The partial safety factors will, on a design based on nominal dimensions, provide for all normal permissible deviations. When large permissible deviations are allowed for small highly-stressed members, it may be necessary to base the design on net dimensions after allowance for the maximum specified permissible deviation; this would occur rarely.

3.12.1.3 ***Position of reinforcement***

Normally the design may assume that the reinforcement is in its nominal position. However, when reinforcement is located in relation to more than one face of a member, e.g. a link in a beam in which the nominal cover for all sides is given, the actual concrete cover on one side may be greater and can be derived from consideration of certain other permissible deviations. These are:

a) dimensions and spacing of cover blocks, spacers and/or chairs (including the compressibility of these items and the surfaces they bear on);

b) stiffness, straightness, and accuracy of cutting, bending and fixing of bars or reinforcement cage;

c) accuracy of formwork both in dimension and plane (this includes permanent forms, such as blinding or brickwork);

d) the size of the structural part and the relative size of bars or reinforcement cage.

3.12.1.4 ***Permissible deviations on reinforcement fitting between two concrete faces***

The overall dimension on the bending schedule should be determined for this reinforcement as the nominal dimension of the concrete less the nominal cover on each face and less the deduction for permissible deviation on member size and on bending given in table 3.24.

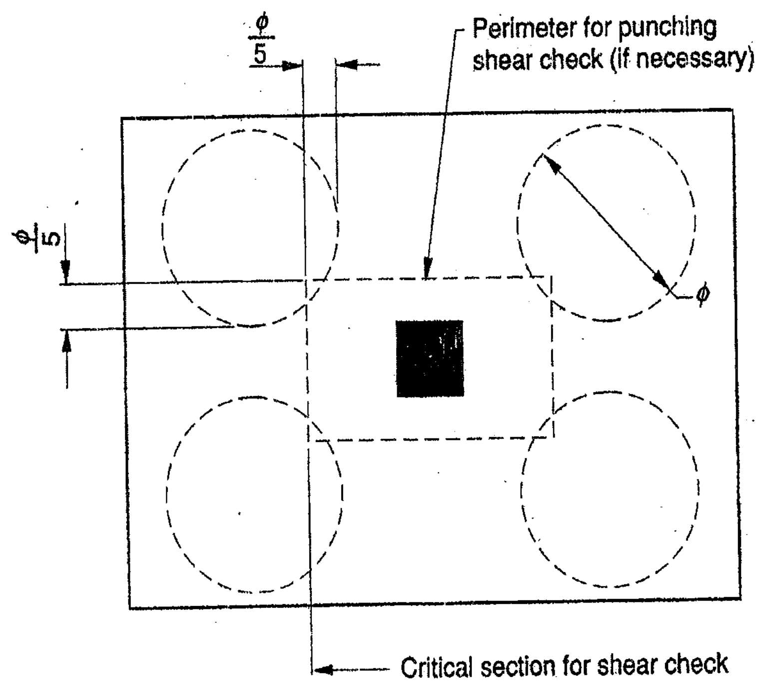
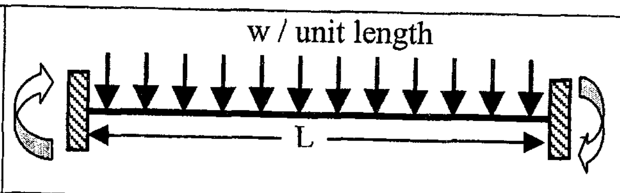
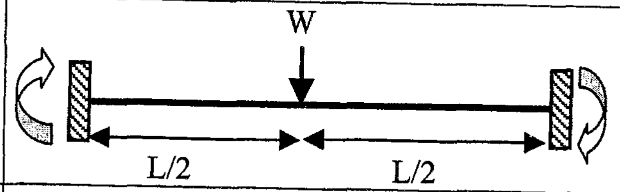
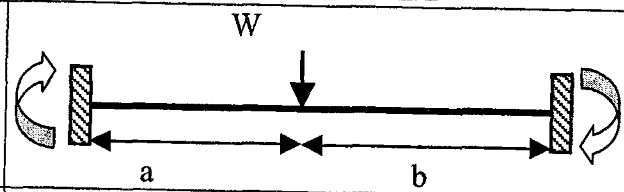
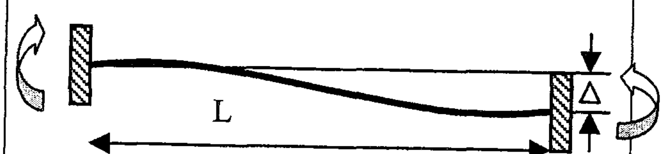
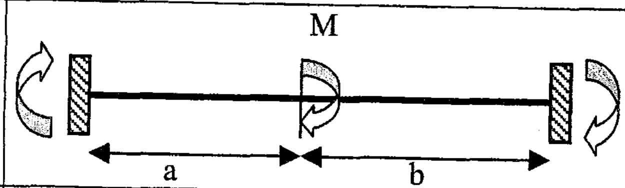
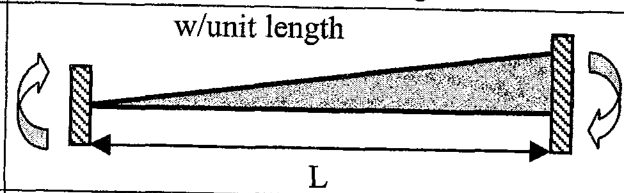
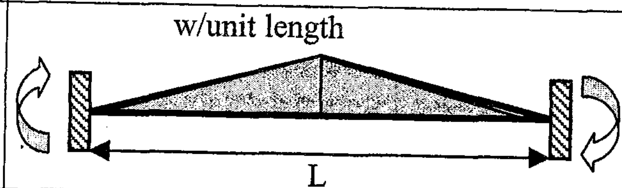
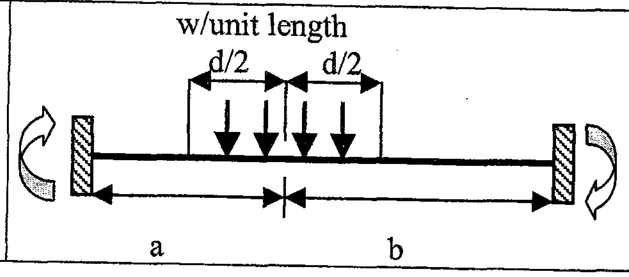


Figure 3.23 Critical section for shear check in a pile cap

LAMPIRAN 3

Fixed End Moment

$-\frac{wL^2}{12}$		$\frac{wL^2}{12}$
$-\frac{WL}{8}$		$\frac{WL}{8}$
$-\frac{Wab^2}{L^2}$		$\frac{Wba^2}{L^2}$
$-\frac{6EI\Delta}{L^2}$		$\frac{6EI\Delta}{L^2}$
$-\frac{Mb(2a-b)}{L^2}$		$\frac{Mb(2b-a)}{L^2}$
$-\frac{wL^2}{30}$		$\frac{wL^2}{20}$
$-\frac{5wL^2}{96}$		$\frac{5wL^2}{96}$
$-\frac{wd}{L^2}\left(ab^2+\frac{(a-2b)d^2}{12}\right)$		$\frac{wd}{L^2}\left(a^2b+\frac{(b-2a)d^2}{12}\right)$

Appendix A
(normative)

Simplified Procedure

A1. Limitations

The simplified procedure of analysis shall be applied to the design of cladding and main structural system of building structures, which meet all of the following criteria:

a) the buildings are rectangular in plan, or a combination of rectangular units;

b) the average roof height of a structure, h, is not greater than 15.0 m;

c) the ratio of the average roof height to the least horizontal dimension does not exceed 3;

d) the location of structure is not at unusually exposed locations such as hill-crest or at headland; and

e) the following types of building are not considered in this section:

   i) buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area;

   ii) essential buildings and structures;

   iii) hospital and medical facilities;

   iv) fire and police stations;

   v) structures and equipment in civil defense;

   vi) communication centres and facilities for emergency response;

   vii) power stations and other emergency utilities; and

   viii) defense shelter.

A2. Procedures

A2.1 The design wind pressures, p in Pa, shall be taken as:

a) $p = 0.613\,(V_s)^2(M_{z,cat})^2(C_{pe}K_l - C_{pi})$ for cladding,

b) $p = 0.613(V_s)^2(M_{z,cat})^2(C_{pe} - C_{pi})$ for structural system,

where,

V_s 33.5 m/s and 32.5 m/s for Zone I and Zone II respectively (see Figure A1)

$(M_{z,cat})$ terrain/height multiplier as given in Table A1

C_{pe} external pressure coefficients for surfaces of enclosed building as given in A2.3 and A2.4

C_{pi} internal pressure coefficients for surfaces of enclosed buildings which shall be taken as +0.6 or −0.3. The two cases shall be considered to determine the critical load requirements for the appropriate condition.

K_l Local pressure factor as given in Table A7 and Figure A2

A2.2 The design wind pressure used in the design of cladding and main structural system shall not be less than 0.65 kN/m^2.

Table A1. Terrain height multiplier, $M_{z,cat}$

Height, z (m)	$M_{z,cat}$			
	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
≤3	0.99	0.85	0.75	0.75
5	1.05	0.91	0.75	0.75
10	1.12	1.00	0.83	0.75
15	1.16	1.05	0.89	0.75

NOTE. Terrain categories definitions:

a) Category 1 : Exposed open terrain with few or no obstructions.

b) Category 2 : Water surfaces, open terrain, grassland with few well scattered obstructions having height generally from 1.5 m to 10.0 m.

c) Category 3 : Terrain with numerous closely spaced obstructions 3.0 m to 5.0 m high such as areas of suburban housing.

d) Category 4 : Terrain with numerous large, high (10.0 m to 30.0 m high) and closely spaced obstructions such as large city centres and well developed industrial complexes.

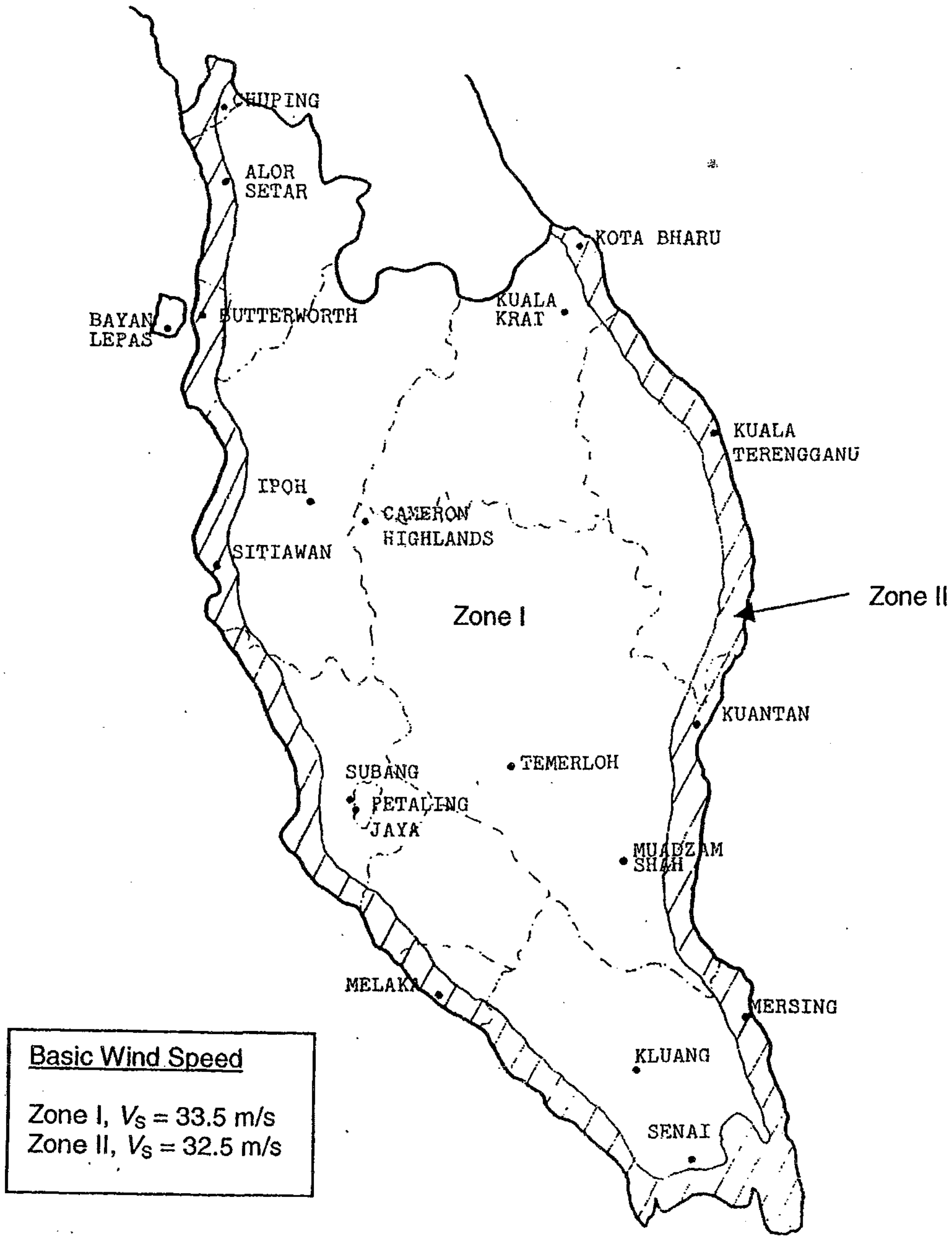


Figure 3.1 Peninsular Malaysia

NOTE. Zone map for East Malaysia has not been provided due to on going research.

A2.3 The external pressure coefficients, $C_{p,e}$, for windward wall shall be taken as 0.8. $C_{p,e}$ for leeward and side wall shall be as per Tables A2 and A3 respectively.

Table A2. External pressure coefficients $C_{p,e}$, for leeward wall

α*	d/b*	$C_{p,e}$
≤10°	≤1 2 ≥4	-0.5 -0.3 -0.2
15° 20° ≥25°	All values	-0.3 -0.4 -0.5

* For intermediate values of d/b and α, use linear interpolation.

Table A3. External pressure coefficients $C_{p,e}$, for side walls

Horizontal distance from windward edge	$C_{p,e}$
0 to 2h >2h	-0.65 -0.30

A2.4 The external pressure coefficients, C_{pe}, for roofs shall be as per Tables A4, A5 and A6.

Table A4. For up-wind slope, U and down-wind slope, D for α<10° and R for gable roofs

Roof type and slope		Horizontal distance from windward edge	External pressure coefficient, $C_{p,e}$	
Cross wind slopes for gable roofs, R	Up-wind slopes, U, Down-wind slope, D		$h/d \leq 0.5$**	$h/d \geq 1.0$**
All α	α < 10°	0 to 1h 1h to 2h > 2h	-0.9, -0.4 -0.5, 0 -0.3, 0.2	-1.3, -0.6 (-0.7)*, (-0.3)*

Table A5. Up-wind slope, U, $\alpha \geq 10°$

Roof type and slope	Ratio h/d	External pressure coefficients, $C_{p,e}$						
Up-wind Slope, U		Roof pitch, α degrees *						
		10	15	20	25	30	35	≥ 45
$\alpha \geq 10°$	≤ 0.25	-0.7, -0.3	-0.5, -0.0	-0.3, -0.2	-0.2, -0.3	-0.2, -0.4	-0.0, 0.5	0, 0.8sinα
	0.5	-0.9, -0.4	-0.7, -0.3	-0.4, -0.0	-0.3, -0.2	-0.2, -0.3	-0.2, 0.4	
	≥ 1.0	-1.3, -0.6	-1.0, -0.5	-0.7, -0.3	-0.5, -0.0	-0.3, -0.2	-0.2, 0.3	

Table A6. Down-wind slope, D, $\alpha \geq 10°$ and R for hip roofs

Roof type and slope		Ratio h/d*	External pressure coefficient, $C_{p,e}$		
Cross-wind slopes for hip roof, R	Down-wind slopes, D		Roof pitch, α degrees*		
			10	15	≥ 20
All α	$\alpha \geq 10°$	≤ 0.25	-0.3	-0.5	- 0.6
		0.5	-0.5	-0.5	-0.6
		≥ 1.0	-0.7	-0.6	-0.6

* Interpolation shall only be carried out on values of the same sign.
* For intermediate values of roof slopes and h/d ratios, use linear interpolation

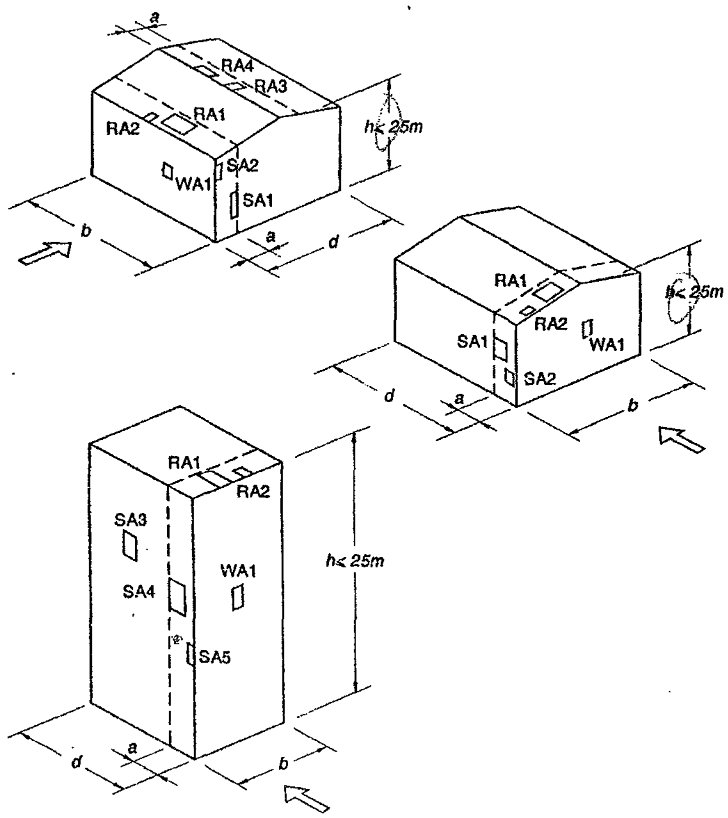
Table A7. Local pressure factor, K_l for claddings

Design case	Figure A2 reference number	h (m)	Area, A	Proximity to edge	K_l
Positive pressures					
Windward wall	WA1	All	$A \leq 0.25a^2$	Anywhere	1.25
All other areas	-	All	-	-	1.0
Negative pressures					
Roof edges	RA1	All	$0.25a^2 < A \leq a^2$	< a	1.5
	RA2	All	$A \leq 0.25a^2$	< 0.5a	2.0
Hips and ridges of roofs With pitch $\geq 10°$	RA3	All	$0.25a^2 < A \leq a^2$	< a	1.5
	RA4	All	$A \leq 0.25a^2$	< 0.5a	2.0

Table A7. Local pressure factor, K_l for claddings (Cont'd)

Design case	Figure A2 reference number	*h* (m)	Area, *A*	Proximity to edge	K_l
Side walls near Windward wall edges	SA1	≤ 25	$0.25a^2 < A \leq a^2$	< a	1.5
	SA2		$A \leq 0.25a^2$	< 0.5a	2.0
	SA3	> 25	$A \leq 0.25a^2$	> a	1.5
	SA4		$0.25a^2 < A \leq a^2$	< a	2.0
	SA5		$A \leq 0.25a^2$	< 0.5a	3.0
All other areas	-	All	-	-	1.0

NOTES:
1. The dimension, a, and the Figure reference numbers are defined in Figure A2.
2. Design cases attracting K_l = 1.5 or 3.0 are alternative cases and need not be applied simultaneously.
3. The areas for local pressure factor are not necessarily square.



NOTE. The value of the dimension *a*, is the minimum of 0.2*b*, 0.2*d* and *h*

Figure A2. Local pressure factors (K_l)