DTLR Framework Report: Proposed Revised Guidance on meeting Compliance with the requirements of building Regulation A3: Revision of Allot and Lomax proposal

Project report number: 205966

EXECUTIVE SUMMARY

The Building Regulations and guidance given in Approved Document A are being revised by a Working Group comprising members of the Building Regulations Advisory Committee (BRAC), Departmental officials, expert consultants and other officials.

BRE was commissioned under the Framework Agreement via a call-off contract to support the Working Group and its Secretariat by contributing, on request, to specific technical issues.

The first technical issue for which BRE was tasked was a calibration of Allott and Lomax's[1] proposed revised guidance on meeting compliance with the requirements of Building Regulation A3. It became evident that there could be ambiguous interpretation of some of the parameter values and that some negative values for Risk and Consequence factors could be determined. These findings were reported to DETR in BRE Report 200682 in June 2000. Consequently, DETR invited BRE to submit a proposal for a further task under this contract to address the issues raised in that report and to include a calibration for grandstand structures. This report details the findings of this task and presents a revised proposal for consideration by the BRAC Part A Working Group.

Revised expressions for the Risk and Consequence factors, and for the category lines on the chart, have been determined to eliminate the occurrence of negative values. A calibration process using the building types specified in the earlier task has been performed using these new expressions. The results agree with the results determined during the earlier task. Therefore it is suggested that the revised expressions given in this report should replace the earlier expressions, as they eliminate the possibility of negative values.

To eliminate the ambiguity of some of the parameter definitions, alternative text has been suggested. However no alterations have been made to the parameter values.

[1] Now Babtie, Allott and Lomax

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INTRODUCTION

The Building Regulations and guidance given in Approved Document A are being revised by a Working Group comprising members of the Building Regulations Advisory Committee (BRAC), Departmental officials, expert consultants and other officials.

BRE was commissioned under the Framework Agreement to support the Working Group and its Secretariat by contributing, on request, to specific technical issues.

The first technical issue for which BRE was tasked was a calibration of Allott and Lomax's[1] proposed revised guidance on meeting compliance with the requirements of Building Regulation A3. This calibration was aimed at determining whether the proposed categorisation arrangement provided a sensible level of safety for a variable population of building types without attracting diseconomy. DETR specified the buildings that the calibration should encompass.

During that task it became evident that there could be ambiguous interpretation of some of the parameter values in the determination of the resulting risk and consequence factors for some of these building types. The result was that some of the resulting risk categories determined initially were inconsistent and, in some cases, inappropriate. Following discussion with Allott and Lomax and DETR it was agreed that the calibration should proceed on the basis of an interpretation more on Allott and Lomax's intention rather than the actual report and that BRE would identify those parts of the proposal that were unclear or needed some revision.

The results of that task were reported to DETR in BRE Report 200682 in June 2000. Consequently, DETR invited BRE to submit a proposal for a further task under this contract to address the issues raised in that report and to include grandstand structures in the calibration. This proposal was accepted by DETR at the end of June.

This report details the findings of this task and presents a revised proposal for consideration by the BRAC Part A Working Group.

DESCRIPTION OF THE PROJECT

The aims of the task were:

- to remove apparent anomalies identified during the review and calibration of the Allott and Lomax proposal,
- to ensure that parameter definition and interpretation is consistent and unambiguous in use, and
- to assess the proposal against current European guidance.

These aims were translated into the following outline programme of work:

1. **Negative Consequences and Risk Values:** Examine the reasons why such values occur for some of the parameter combinations in the calibrations study. Propose alternative mathematical formulation and repeat spreadsheet calculations of the previous combinations to ensure that the resulting categorisation is satisfactory.

2. **Load Parameter C:** Examine background to the available value choices for this parameter. The calibration study suggested that these values were related more to

[1] Now Babtie, Allott and Lomax

specific identifiable events than to general unspecific events. Provide illustrative examples of parameter selection to aid implementation by end-user.

3. **Societal Parameter S:** Re-appraise the definition of this parameter in order to assign an appropriate value to single value dwellings irrespective of storey height.

4. **Environment Parameter E:** Clarify and provide appropriate guidance on the choice of environment parameter for structures with underground elements e.g. basements, car parks

5. **Structural Parameter D:** Examine rationale behind type of material behaviour being included in parameter definition, explore alternative proposal based on need to include degree of warning associated with failure response. Prepare illustrative examples to aid consistent interpretation of any revised parameter definition.

6. **Harmonisation with Europe:** Examine the provisions in the proposal with those for each risk category in ENV 1991-2-7 and develop appropriate amendments to work towards harmonisation with Europe.

7. **Revised Proposal:** Prepare revised proposal for submission to BRAC Working Party

FINDINGS

Negative Consequences and Risk Values:

The original Allott and Lomax proposal required the calculation of a **Risk** and **Consequence** for the building in order to determine, from a categorisation chart, a **Risk Factor** which is then used to categorise the guidance given currently in Requirement A3.

For some of the parameter combinations in the calibration study negative consequence and risk values resulted even though the resulting risk factor was positive. No physical meaning could be associated with these negative values. Moreover, the risk factor regions were only defined in the first graphical quadrant (i.e. for positive values of both risk and consequence), thus no categorisation could be made for any negative values.

Following examination of the derivation given in Chapter 5.0 of Allott and Lomax's report, it was evident that constants had been added to the basic definitions of Risk and Consequence intended to ensure that all Risk and Consequence values would lie in the positive quadrant.

By considering all parameter combinations, the following expressions for Consequence and Risk respectively always result in a positive value:

$$\textbf{Consequence} = N + E + S - 1.6$$

$$\textbf{Risk} = 3.5 - C - D$$

The justification for this is given in Annex A.

Using the spreadsheet developed for the previous calibration study, the new values of risk and consequence were determined for the various parameter combinations. However because the **Risk Factor** was independent of the added constants this remained unchanged. When these values were plotted on the original Allott and Lomax categorisation chart, it was found that the majority of the combinations fell into higher risk factor categories than before. Therefore, the category boundary lines needed to be changed. This in essence was achieved by translating the boundary lines by the changes in the constants values used in the Risk and Consequence expressions. The mathematical derivation of this is given in Annex A.

In Appendix 2 of the Allott and Lomax report Risk Factor limits are given for the different categories. However, since inequality only limits are specified, it is not clear in which category a Risk Factor lies when its value equalled one of these limits. From consideration of the earlier analyses, the following limits were determined:

Category	**Risk Factor**
Exempt	Risk Factor $\leq$ 0.7
Category 1	0.7 $<$ Risk Factor $\leq$ 2.0
Category 2	2.0 $<$ Risk Factor $\leq$ 4.0
Category 3	4.0 $<$ Risk Factor

The categories of the combinations determined using both the original Allott and Lomax and the new chart were compared with the categories determined from the Risk Factors. For the Allott and Lomax chart all the points within the positive quadrant lie within the correct category; however some of the points that lie in the negative area fall into a higher category than that determined from the Risk Factor. For the new chart all but one point fall with the same category as those determined using the Risk Factor.

The cause of these points lying within other categories on the charts was investigated. It was found that due to the curving of the ends of the category lines in the original categorisation chart, points were being 'pushed' into the category above. Therefore, it was decided to investigate the possibility of keeping the boundary lines straight.

By comparing the boundary line values at the axes (given in Annex A) with Risk and Consequence combination values it was found that no points will fall on the lines - the combination values are determined using parameters defined to only one decimal place compared with two decimal places that define the lines. Therefore the boundary lines can be kept straight and the points which previously fell into a higher (and inappropriate) category now lie within the same category as that determined using the Risk Factor.

The revised chart needed to be checked to ensure that all Risk factors and categories were consistent. This was done by evaluation of all possible parameter combinations. The process is described in Annex A and confirmed the consistency.

Finally the calibration of the previously specified buildings was repeated to ensure that the process still resulted in satisfactory classification of the risk factors and categories associated with them. The table and chart produced during this calibration are given in Annex B. In addition, following a request from the Working Party, a calibration of grandstand structures was undertaken using the revised chart. This calibration is given in Annex C.

Load Parameter C:

In the previous study, we reported that the term **Human Live Load** was misleading and that the other type of load required some prior knowledge of the accidental event and its likelihood of occurrence.

Since the intention is to assess the likelihood of the number of people within a structure at the time that the load will occur, a better term might be **Human Occupancy.** This could be interpreted to give some indication of both numbers of people and their duration of stay.

However this also supposes that we have some understanding of the time at which the load event is going to occur.

For instance, it may be reasonable to assume that the chances of a gas explosion are greatly increased during the time that cooking or heating of premises is on going. Hence the assumption that this correlates with significant occupancy would seem valid. However, what about impact loads from a falling object from the sky, e.g. ice from a passing plane, this can be ascribed any time (unless night flying is prohibited).

The original headings chosen were: FULL, NORMAL and NONE. These can be retained but suggest that an attempt to provide some form of quantitative guidance is given such as:

FULL Building significantly occupied for more than say 18 hours a day,
NORMAL Building significantly occupied between 6 and 18 hours a day
NONE Building significantly occupied for less than, say, 6 hours a day

The following are given as examples:

FULL	NORMAL	NONE
Institutional Buildings e.g. hospitals, residential nursing homes/hospices	Offices	Storage buildings
Multi-storey Flats	Hypermarkets	Car Parks

In the Allott and Lomax proposal the value of C for accidental load types may be increased by 0.3, where the structure does not contain piped gas or is protected from impacts. However from evidence reported in Ellis and Currie's paper [1], canister gas in a single room can cause significant explosion effects on the structure. Hence it is suggested that this qualification be removed.

Societal Parameter S:

This parameter is intended to reflect the perception of society of the impact of an accidental or unforeseen action occurring in different buildings. Clearly events which affect large gatherings of people in circumstances that are not unusual are likely to be perceived far more seriously, i.e. with a high consequence, than those which affect a small minority in rare or unusual circumstances.

The principal problem with the original definition was the qualification on the first two values of S for **family/domestic dwellings less than 3 storeys.** This meant that multi-occupancy domestic dwellings of three stories and above were automatically assigned the public assembly value of 3.0. This meant that the societal risk of an event on three storey flats or three storey single family dwellings, of which there is estimated to be a significant population in the country, would not be dissimilar with that for public assembly buildings and would be greater than that associated with offices. This seemed inconsistent.

It was also noted that the parameter values for S quoted in the Allott & Lomax proposal from CIRIA Report No 63 included 2.0 for all domestic situations, as well as offices and industry.

From discussion with Allott and Lomax their intention was to reflect the difference in perceived risk between a single family and multi-occupancy family dwellings. They did this by introducing an additional, but lower, value of 1.6 for single family dwellings. However their reasoning for introducing the qualification is not known. To retain the spirit of the intention we suggest the following:

$S = 1.6$ for single family dwellings not more than 3 storeys

S = 2.0	for all other domestic dwellings not more than 3 storeys, offices, trade and industry
S = 3.0	for domestic dwellings of more than 3 storeys and public assembly buildings

It is noted that the qualification of not more than three storeys is used in Section 1C of Approved Document Part A.

Environment Parameter E:

The intention of this parameter is to reflect the number of people at risk in the proximity of a building at the time of an accidental load event. The original proposal used the height of the structure, and its location, as a broad indication of the area adjacent to the structure that may be subject to collateral damage. This seems a reasonable proposition.

The location was described originally by one of: Domestic, Suburban and City Centre. These were taken to indicate areas of different building density as well as broad indicators of the number of people who may be in the area adjacent to a particular building. For semantic reasons, Residential is preferred to Domestic, but the other two are sufficiently descriptive to indicate the intended distinction. Some thought was given to trying to quantify the building density to aid interpretation e.g. number of buildings per hectare, or floor area per hectare, but so far, a meaningful quantity remains to be identified.

The second area of concern identified in the calibration review were those structures with underground elements e.g. basements and car parks. Such structures are referenced in the current limits of application on Requirement A3 in Approved Document Part A where the designation is made by storeys.

Since this parameter is intended to reflect the area around the structure, and not the structure itself, then the presence of underground elements in such a structure are unlikely to have little additional influence, if any, on the extent of any collateral damage resulting from the superstructure. Thus height should be interpreted as height of the structure above ground level rather than height of the structure relative to the basement level. It is acknowledged that the provision of underground storeys will probably result in a greater number of people being in the structure, particularly if the structure is one of public assembly, but that factor should be taken account of in the **People at Risk Parameter, N.**

Structural Parameter D:

This parameter is intended to reflect the degree of load redistribution available within the structure, the ability of the structure to accommodate large strains and the degree of visual warning that an event is occurring, or has occurred. The principal concern we had in the previous review was the inclusion of a material type, our opinion was that individual material behaviour was less important than overall structural response.

For instance consider a steel frame, a material which by common agreement would be regarded as ductile, at least under normal temperatures and conditions. The performance of the overall frame will be influenced by the connections between the frame members. If their performance is brittle then overall the behaviour will be brittle. Of course, if the frame depends solely on the connection, and there are no alternative load paths, then this would be reflected in the choice of **Single Element** as the **Structural Type.**

Notes: Better to classify the material type as System type – ie could we make use of these terms to reflect the overall response. What about buckling?

The qualification whereby for structures which are not visible the values are reduced is perhaps the wrong way round. Most structures are going to have hidden components or elements and therefore that situation should be the default. Hence the reverse is recommended.

Harmonisation with Europe:

The requirements for robustness given in the Allott and Lomax report (taken from the Building Regulations, plus additional categories) and the European Prestandard 'Accidental actions due to impacts and explosions' [2] are given in the following table. The differences / similarities are between the documents are summarised below:

Exempt – this category is included in the Building Regulations, however such a category is not given in the European Prestandard.

Category 1 – the Building Regulations specify the use of effective horizontal ties following the recommendations given in the British Codes and Standards. For gas explosions the European Prestandard specifies compliance with the rules for connections and interaction between components given in the material Eurocodes. The guidance given in the material Eurocodes has not been checked against that given by the British Standards.

Category 2 – the use of horizontal and vertical ties following the recommendations given in the British Standards is specified by the Building Regulations. Where vertical ties are not feasible the structure should be checked for 'bridging' of elements, or key elements should be used in the design. In the European Prestandard prescriptive design/detailing rules may be applied. However for gas explosions key elements must be designed to withstand a given pressure.

Category 3 – both the Building Regulations and European Prestandard specify the use a full dynamic analysis of the structure. This approach in our opinion is not a viable option.

Category	Building Regulations	European Prestandard
Exempt	No specific requirements are required.	This category is not included in the European Standard.
1	Provide effective horizontal ties in accordance with the recommendations given in the Codes and Standards.	• No specific consideration is necessary with regard to accidental actions. • For gas explosions compliance with the rules for connections and interaction between components provided in the Eurocodes.
2	• Provide effective horizontal and vertical ties in accordance with the recommendations given in the Codes and Standards. • If effective horizontal ties are provided and it is not feasible to provide vertical ties, then each untied member should be considered to be notionally removed, one at a time, to ensure that the structure is capable of 'bridging' over the missing member. • If it is not possible to 'bridge' over the missing member, that member should be designed as a protected member (key element).	• Prescriptive design/detailing rules may be applied. • Simplified analyses using representative static loads may be applied to the structure when considering vehicular impacts. • For gas explosions key elements of the structure shall be designed to resist actions using analysis based upon equivalent static models. The accidental static pressure design value can be taken as [20 kN/m^2][2], or determined using the given expression. This action is applied in any direction to the key element.
3	The use of dynamic analysis as described in Appendix B of ENV 1991-2-7.	• The use of a more extensive study is recommended. • Simplified analyses using representative static loads may be applied to the structure when considering vehicular impacts. • Also advanced design for impacts may included one or several of the following aspects: - Dynamic effects - Non-linear material behaviour - Probabilistic aspects - Analysis of consequences - Economic optimisation of mitigating measures. • Advanced design for explosions may include one or several of the following aspects: - Explosion pressure calculations, including the effects of confinements and breaking panels - Dynamic non-linear structural calculations - Probabilistic aspects and analysis of consequences - Economic optimisation of mitigating measures.

[2] This value is only indicative and an alternative value may be given for use in national application.

Draft Revised Proposal: .The draft revised proposal for consideration by the Working Group is given in Annex D.

CONCLUSIONS

Following previous work on the calibration of the Allot & Lomax's proposed revised guidance on meeting compliance with the requirements of Building Regulation A3, reported to DETR in BRE Report 200682 in June 2000, DETR invited BRE to submit a proposal for a further task under this contract to address the issues raised in that report and to include a calibration for grandstand structures. This report details the findings of this task and presents a revised proposal for consideration by the BRAC Part A Working Group.

Revised expressions for the Risk and Consequence factors, and for the category lines on the chart, have been determined to eliminate the occurrence of negative values. A calibration process using the building types specified in the earlier task has been performed using these new expressions. The results agree with the results determined during the earlier task. Therefore it is suggested that the revised expressions given in this report should replace the earlier expressions, as they eliminate the possibility of negative values.

To eliminate the ambiguity of some of the parameter definitions, alternative text has been suggested. However no alterations have been made to the parameter values.

The revised guidance has been used to carry out an additional calibration of grandstand structures. This showed that the majority of cases considered resulted in risk category two, however a small number fell in to risk category 3.

A draft revised proposal has been prepared for consideration by the Working Party. That draft includes, as an Appendix, a description of the calculation procedure.

REFERENCES

1. ELLIS, B R & CURRIE, D M. Gas explosions in buildings in the UK: regulation and risk. The Structural Engineer, Vol. 76/No 19, 6 October 1998.

2. CEN, ENV 1991-2-7: Accidental actions due to impacts and explosions, CEN Central Secretariat, Brussels. Final Draft June 1998.

ANNEX A - ROBUSTNESS CHART – ELIMINATING NEGATIVE VALUES

1. Determine new factors for the Risk and Consequence expressions

All possible mathematical combinations of the parameters were considered, irrespective of whether the combinations would be chosen during a robustness check. This insured that all possible combinations that may be chosen would result in positive values of Risk and Consequence.

Consequence

Expression given in Allott and Lomax report; Consequence = N + E + S – 2

Considering the parameters N, E and S the lowest value obtained using the above expression is:

Minimum values for the parameters are, N = 0, E = 0 and S = 1.6.

Therefore the minimum value for Consequence = 0 + 0 + 1.6 – 2 = <u>-0.4</u>

Altering the factor value to 1.6 from 2 would eliminate the negative values determined for Consequence. The following equation is suggested as a replacement to that given above:

Consequence = N + E + S – 1.6

Risk

Expression given in Allott and Lomax report; Risk = 2.25 – C – D

Considering the parameters C and D the lowest value obtained using the above expression is:

Maximum values for the parameters are, C = 2.5 and D = 1.0.

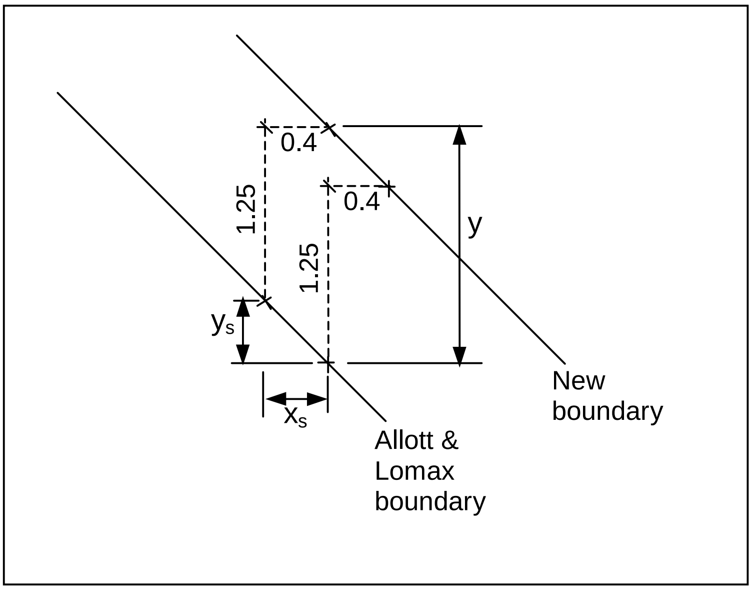
Therefore the minimum value for Risk is 2.25 – 2.5 – 1 = <u>-1.25</u>

Altering the factor value from 2.25 to 3.5 would eliminate the negative values determined for Risk. The following equation is suggested as a replacement to that given above:

Risk = 3.5 – C – D

2. Determine the new equations for the category boundaries

The keep the categories the same the boundary lines will have to move along the axes as follows, x-axis 0.4 and y-axis 1.25. The equations representing the category boundaries were determined as follows:



Determine the vertical 'shift' in the boundary line y.

$y = 1.25 + y_s$

Slope of line = 1 $\Rightarrow y_s = x_s = 0.4$

$\therefore y = 1.25 + 0.4 = 1.65$

General equation of Allott and Lomax boundary line $y = x_a + b_a$

Therefore general equation of New Boundary line is:

$$\mathbf{y = x_a + b_a + 1.65}$$

where b_a is determined for each boundary line.

3. Removing the curve at the ends of the boundary lines

The co-ordinates of the lines were determined as follows:

Exempt / category 1	x = 0, y = 2.65	y = 0 2, x = 2.65
Category 1 / category 2	x = 0, y = 3.95	y = 0 2, x = 3.95
Category 2 / category 3	x = 0, y = 5.95	y = 0 2, x = 5.95

Where: x = Consequence = N + E + S – 1.6
y = Risk = 3.5 – C – D

4. Calibrate new chart using all possible combinations

To calibrate the new chart and boundary lines it was decided to determine all the possible mathematical combinations of the parameters. These combinations included those which were considered unrealistic in practice. The combinations were determined as follows:

Consequence

All possible mathematical combinations of E, N and S were determined.

Case	E ‘Height’			N ‘People at Risk’			S ‘Societal Criteria’		
	<10m	10-30m	>30 m	Dom-estic	Office & flats	Public asse-mbly	Single family dwell-ings	Office, trade etc.	Public asse-mbly
1	✓			✓			✓		
2	✓				✓		✓		
3	✓				✓			✓	
4	✓					✓		✓	
5	✓					✓			✓
6		✓				✓			✓
7		✓			✓				✓
8		✓			✓			✓	
9		✓		✓				✓	
10		✓		✓			✓		
11			✓	✓			✓		
12			✓		✓		✓		
13			✓		✓			✓	
14			✓			✓		✓	
15			✓			✓			✓
16	✓					✓	✓		
17	✓			✓				✓	
18	✓			✓					✓
19		✓			✓		✓		
20		✓				✓		✓	
21			✓			✓	✓		
22			✓		✓				✓
23			✓	✓					✓
24		✓		✓					✓
25	✓				✓				✓
26		✓				✓	✓		
27			✓	✓				✓	

Each of the above combinations were considered in turn with the following combinations to determine all possible values of Consequence.

Case	E ‘Location’			N	S
	Domestic	Suburban	City Centre		
1	✓			✓	✓
2		✓		✓	✓
3			✓	✓	✓

A total of 81 combinations for Consequence were determined using the above tables. From these combination 23 different values of Consequence were determined.

Risk

All possible mathematical combinations of parameters C and D were determined.

Case	C 'Human Live Load'			D 'Material type'		
	Full	Normal	None	Brittle	Normal	Ductile
1	✔			✔		
2	✔				✔	
3	✔					✔
4		✔			✔	
5		✔		✔		
6		✔				✔
7			✔			✔
8			✔		✔	
9			✔	✔		

Each of the above combinations were considered in turn with each of the following combinations to determine all the possible values for Risk.

Case	C 'Load Type'		D 'Structural Type'	
	Accidental	Other	Single Element	With Redundancy
1	✔		✔	
2	✔			✔
3		✔		✔
4		✔	✔	

The possibility of the accidental values being increased by 0.3 and the redundancy values being decreased by 0.3 were also considered. C and D parameters were combined for cases where no alterations were made, where only accidental values were altered, where only redundancy values were altered and where both were altered.

144 different combinations were determined for Risk. From these combinations 25 different values of Risk were obtained.

Each different value of Consequence was combined in turn with each value of Risk. A total of 552 combinations for Risk and Consequence values were determined, Risk Factors were determined for each combination. Each combination was plotted on the new chart. The category determined using the new chart was compared to the category determined by the Risk Factor. It was found that all the categories were the same.

ANNEX B – RE-CALIBRATION OF BUILDINGS SPECIFIED IN PREVIOUS BRE REVIEW

B1: Current Robustness requirements given by British Standards

B2: Chart - Proposed Categorisation New Expressions and New Category lines

B3: Excel Spreadsheet – Results of calibration process performed for the new expressions and new category lines.

B1: Current Robustness requirements given by British Standards

Steel BS5950: Part 1: 1990

1. All buildings

Sway stability e.g. braced frames, joint rigidity, staircases, lift cores and shear walls.
Building frame tied together at each principal floor and roof level.
All columns restrained in two perpendicular directions at each principal floor or roof which they support. Beams or ties can be used in a continuous line to restrain columns.

2. Tall Multi-storey buildings

As above plus additional requirements given below.
Sway resistance evenly distributed through buildings, so that a substantial part of the building is not reliant on a single plane of bracing.
Column splices should be able to withstand given tensile force.
Columns should be carried through at each column/beam connection.
Floor units should be anchored in the direction of their span.
Design elements as key elements where their removal will cause damage outside of the local area.

Concrete BS8110: Part 1: 1997

1. All buildings

Resist notional horizontal load acting at every floor and roof level simultaneously.
Effective horizontal ties at each floor and roof level in two perpendicular directions.
Design key elements to 'bridge' over areas where the removal of a vertical load-bearing element causes damage outside of the local area.
Continuous vertical ties for each column/wall carrying vertical load from the lowest to the highest level.

Masonry BS5628: Part 1: 1992

1. Category 1 – 4 storeys and below

No additional detailed recommendations are given for ties.

2. Category 2 – 5 storeys and above

Three design options.

2.1. No horizontal or vertical ties if it can be proved that each element, unless protected, can be removed one at a time without causing collapse.

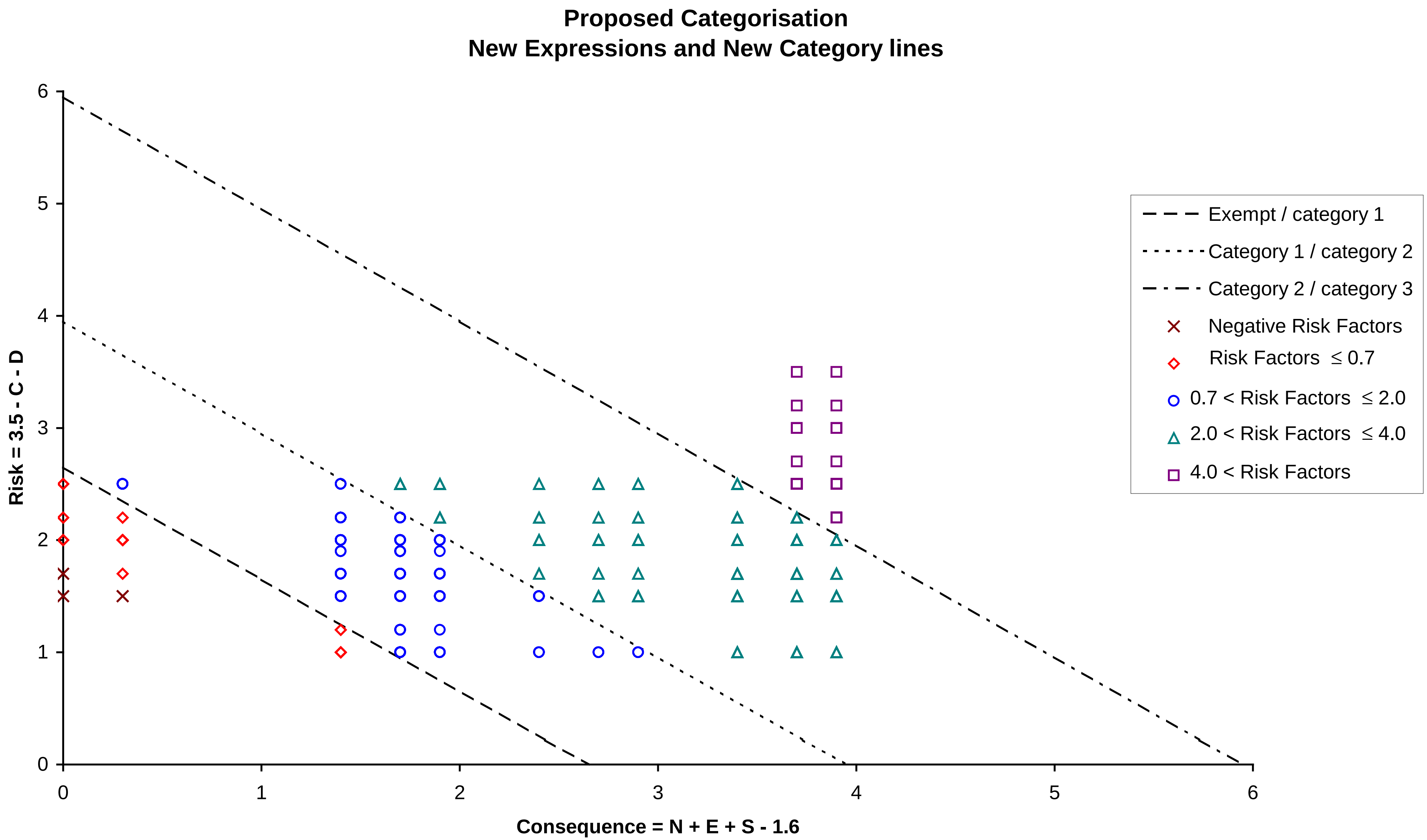
2.2. Horizontal ties at each floor and roof level.
Vertical elements, unless protected, proved removable, one at a time without causing collapse.

2.3. Horizontal ties at each floor and roof level.
Floor/roof units should be anchored in the direction of their span either to each other over a support or directly to their supports.
Vertical ties extending from roof level to the foundation or to a level at and below which the relevant members of the structure are protected.

Timber BS 5268

1. Low Rise buildings

No specific guidance is given on robustness in the Standard on Timber. However following standard design for low rise buildings tying is present within the structural system.



Proposed Categorisation
New Expressions and New Category lines
Risk = 3.5 - C - D
Consequence = N + E + S - 1.6
0
1
2
3
4
5
6
Exempt / category 1
Category 1 / category 2
Category 2 / category 3
Negative Risk Factors
Risk Factors ≤ 0.7
0.7 < Risk Factors ≤ 2.0
2.0 < Risk Factors ≤ 4.0
4.0 < Risk Factors

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Houses - 2 storey	Masonry															
- Case 1	(Brittle)	1		0		0		0	1.6	2.5	0	0.6	*	Exempt	M1	FALSE
- Case 2		1			0.3	0		0	1.6	2.2	0	0.3	*	Exempt	M1	FALSE
- Case 3		1			0.3		0.3	0	1.6	2.2	0.3	0.6	*	Exempt	M1	FALSE
- Case 4		1		0			0.3	0	1.6	2.5	0.3	0.9	*	1	M1	FALSE
- Case 5			1.5		0.3		0.3	0	1.6	1.7	0.3	0.1	*	Exempt	M1	FALSE
- Case 6			1.5	0			0.3	0	1.6	2	0.3	0.4	*	Exempt	M1	FALSE
- Case 7			1.5	0		0		0	1.6	2	0	0.1	*	Exempt	M1	FALSE
- Case 8			1.5		0.3	0		0	1.6	1.7	0	-0.2	*	Exempt	M1	FALSE
Houses - 2 storey	Timber															
- Case 1	(Normal)	1		0		0		0	1.6	2.5	0	0.6	*	Exempt	T1	FALSE
- Case 2		1			0.5	0		0	1.6	2	0	0.1	*	Exempt	T1	FALSE
- Case 3		1			0.5		0.3	0	1.6	2	0.3	0.4	*	Exempt	T1	FALSE
- Case 4		1		0			0.3	0	1.6	2.5	0.3	0.9	*	1	T1	FALSE
- Case 5			1.5		0.5		0.3	0	1.6	1.5	0.3	-0.1	*	Exempt	T1	FALSE
- Case 6			1.5	0			0.3	0	1.6	2	0.3	0.4	*	Exempt	T1	FALSE
- Case 7			1.5	0		0		0	1.6	2	0	0.1	*	Exempt	T1	FALSE
- Case 8			1.5		0.5	0		0	1.6	1.5	0	-0.4	*	Exempt	T1	FALSE
Houses - 3 storey	Masonry															
- Case 1	(Brittle)	1		0		0		0	1.6	2.5	0	0.6	*	Exempt	M1	FALSE
- Case 2		1			0.3	0		0	1.6	2.2	0	0.3	*	Exempt	M1	FALSE
- Case 3		1			0.3		0.3	0	1.6	2.2	0.3	0.6	*	Exempt	M1	FALSE
- Case 4		1		0			0.3	0	1.6	2.5	0.3	0.9	*	1	M1	FALSE
- Case 5			1.5		0.3		0.3	0	1.6	1.7	0.3	0.1	*	Exempt	M1	FALSE
- Case 6			1.5	0			0.3	0	1.6	2	0.3	0.4	*	Exempt	M1	FALSE
- Case 7			1.5	0		0		0	1.6	2	0	0.1	*	Exempt	M1	FALSE
- Case 8			1.5		0.3	0		0	1.6	1.7	0	-0.2	*	Exempt	M1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Houses - 3 storey	Timber															
- Case 1	(Normal)	1		0		0		0	1.6	2.5	0	0.6	*	Exempt	T1	FALSE
- Case 2		1			0.5	0		0	1.6	2	0	0.1	*	Exempt	T1	FALSE
- Case 3		1			0.5		0.3	0	1.6	2	0.3	0.4	*	Exempt	T1	FALSE
- Case 4		1		0			0.3	0	1.6	2.5	0.3	0.9	*	1	T1	FALSE
- Case 5			1.5		0.5		0.3	0	1.6	1.5	0.3	-0.1	*	Exempt	T1	FALSE
- Case 6			1.5	0			0.3	0	1.6	2	0.3	0.4	*	Exempt	T1	FALSE
- Case 7			1.5	0		0		0	1.6	2	0	0.1	*	Exempt	T1	FALSE
- Case 8			1.5		0.5	0		0	1.6	1.5	0	-0.4	*	Exempt	T1	FALSE
Flats - 4 storey (<10m)	Reinforced															
- Case 1	Concrete	1		0		0		1	3	2.5	2.4	3	2	2	C1	TRUE
- Case 2	Or Timber	1			0.5	0		1	3	2	2.4	2.5	2	2	C1	TRUE
- Case 3	(Normal)	1			0.5		0.3	1	3	2	2.7	2.8	2	2	C1	TRUE
- Case 4		1		0			0.3	1	3	2.5	2.7	3.3	2	2	C1	TRUE
- Case 5			1.5		0.5		0.3	1	3	1.5	2.7	2.3	2	2	C1	TRUE
- Case 6			1.5	0			0.3	1	3	2	2.7	2.8	2	2	C1	TRUE
- Case 7			1.5	0		0		1	3	2	2.4	2.5	2	2	C1	TRUE
- Case 8			1.5		0.5	0		1	3	1.5	2.4	2	1	1	C1	TRUE
Flats - 4 storey (<10m)	Steel															
- Case 1	(Ductile)	1		0.3		0		1	3	2.2	2.4	2.7	**2**	2	S1	TRUE
- Case 2		1			1	0		1	3	1.5	2.4	2	1	1	S1	TRUE
- Case 3		1			1		0.3	1	3	1.5	2.7	2.3	**2**	2	S1	TRUE
- Case 4		1		0.3			0.3	1	3	2.2	2.7	3	**2**	2	S1	TRUE
- Case 5			1.5		1		0.3	1	3	1	2.7	1.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	3	1.7	2.7	2.5	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0		1	3	1.7	2.4	2.2	**2**	2	S1	TRUE
- Case 8			1.5		1	0		1	3	1	2.4	1.5	*	1	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Flats - 10 storey (<30m)	Reinforced															
- Case 1	Concrete	1		0		0.3		1	3	2.5	2.7	3.3	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		1	3	2	2.7	2.8	2	2	C1	TRUE
- Case 3		1			0.5		0.5	1	3	2	2.9	3	2	2	C1	TRUE
- Case 4		1		0			0.5	1	3	2.5	2.9	3.5	2	2	C1	TRUE
- Case 5			1.5		0.5		0.5	1	3	1.5	2.9	2.5	2	2	C1	TRUE
- Case 6			1.5	0			0.5	1	3	2	2.9	3	2	2	C1	TRUE
- Case 7			1.5	0		0.3		1	3	2	2.7	2.8	2	2	C1	TRUE
- Case 8			1.5		0.5	0.3		1	3	1.5	2.7	2.3	2	2	C1	TRUE
Flats - 10 storey (<30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.3		1	3	2.2	2.7	3	2	2	S2	TRUE
- Case 2		1			1	0.3		1	3	1.5	2.7	2.3	2	2	S2	TRUE
- Case 3		1			1		0.5	1	3	1.5	2.9	2.5	2	2	S2	TRUE
- Case 4		1		0.3			0.5	1	3	2.2	2.9	3.2	2	2	S2	TRUE
- Case 5			1.5		1		0.5	1	3	1	2.9	2	*	1	S2	FALSE
- Case 6			1.5	0.3			0.5	1	3	1.7	2.9	2.7	2	2	S2	TRUE
- Case 7			1.5	0.3		0.3		1	3	1.7	2.7	2.5	2	2	S2	TRUE
- Case 8			1.5		1	0.3		1	3	1	2.7	1.8	*	1	S2	FALSE
Flats - 25 storey (>30m)	Reinforced															
- Case 1	Concrete	1		0		0.5		1	3	2.5	2.9	3.5	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0.5		1	3	2	2.9	3	2	2	C1	TRUE
- Case 3		1			0.5		1	1	3	2	3.4	3.5	2	2	C1	TRUE
- Case 4		1		0			1	1	3	2.5	3.4	4	2	2	C1	TRUE
- Case 5			1.5		0.5		1	1	3	1.5	3.4	3	2	2	C1	TRUE
- Case 6			1.5	0			1	1	3	2	3.4	3.5	2	2	C1	TRUE
- Case 7			1.5	0		0.5		1	3	2	2.9	3	2	2	C1	TRUE
- Case 8			1.5		0.5	0.5		1	3	1.5	2.9	2.5	2	2	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Flats - 25 storey (>30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.5		1	3	2.2	2.9	3.2	2	2	S2	TRUE
- Case 2		1			1	0.5		1	3	1.5	2.9	2.5	2	2	S2	TRUE
- Case 3		1			1		1	1	3	1.5	3.4	3	2	2	S2	TRUE
- Case 4		1		0.3			1	1	3	2.2	3.4	3.7	2	2	S2	TRUE
- Case 5			1.5		1		1	1	3	1	3.4	2.5	*	2	S2	FALSE
- Case 6			1.5	0.3			1	1	3	1.7	3.4	3.2	2	2	S2	TRUE
- Case 7			1.5	0.3		0.5		1	3	1.7	2.9	2.7	2	2	S2	TRUE
- Case 8			1.5		1	0.5		1	3	1	2.9	2	*	1	S2	FALSE
Offices - 4 storey (<10m)	Reinforced															
- Case 1	Concrete	1		0		0		1	2	2.5	1.4	2	**1**	1	C1	TRUE
- Case 2	(Normal)	1			0.5	0		1	2	2	1.4	1.5	**1**	1	C1	TRUE
- Case 3		1			0.5		0.3	1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 4		1		0			0.3	1	2	2.5	1.7	2.3	2	2	C1	TRUE
- Case 5			1.5		0.5		0.3	1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
- Case 6			1.5	0			0.3	1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 7			1.5	0		0		1	2	2	1.4	1.5	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0		1	2	1.5	1.4	1	**1**	1	C1	TRUE
Offices - 4 storey (<10m)	Steel															
- Case 1	(Ductile)	1		0.3		0		1	2	2.2	1.4	1.7	1	1	S1	TRUE
- Case 2		1			1	0		1	2	1.5	1.4	1	1	1	S1	TRUE
- Case 3		1			1		0.3	1	2	1.5	1.7	1.3	1	1	S1	TRUE
- Case 4		1		0.3			0.3	1	2	2.2	1.7	2	1	1	S1	TRUE
- Case 5			1.5		1		0.3	1	2	1	1.7	0.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	2	1.7	1.7	1.5	1	1	S1	TRUE
- Case 7			1.5	0.3		0		1	2	1.7	1.4	1.2	1	1	S1	TRUE
- Case 8			1.5		1	0		1	2	1	1.4	0.5	*	Exempt	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Offices - 10 storey (<30m)	Reinforced															
- Case 1	Concrete	1		0		0.3		1	2	2.5	1.7	2.3	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 3		1			0.5		0.5	1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 4		1		0			0.5	1	2	2.5	1.9	2.5	2	2	C1	TRUE
- Case 5			1.5		0.5		0.5	1	2	1.5	1.9	1.5	**1**	1	C1	TRUE
- Case 6			1.5	0			0.5	1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 7			1.5	0		0.3		1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0.3		1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
Offices - 10 storey (<30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.3		1	2	2.2	1.7	2	**1**	1	S2	TRUE
- Case 2		1			1	0.3		1	2	1.5	1.7	1.3	**1**	1	S2	TRUE
- Case 3		1			1		0.5	1	2	1.5	1.9	1.5	**1**	1	S2	TRUE
- Case 4		1		0.3			0.5	1	2	2.2	1.9	2.2	2	2	S2	TRUE
- Case 5			1.5		1		0.5	1	2	1	1.9	1	*	1	S2	FALSE
- Case 6			1.5	0.3			0.5	1	2	1.7	1.9	1.7	**1**	1	S2	TRUE
- Case 7			1.5	0.3		0.3		1	2	1.7	1.7	1.5	**1**	1	S2	TRUE
- Case 8			1.5		1	0.3		1	2	1	1.7	0.8	*	1	S2	FALSE
Offices - 25 storey (>30m)	Reinforced															
- Case 1	Concrete	1		0		0.5		1	2	2.5	1.9	2.5	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0.5		1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 3		1			0.5		1	1	2	2	2.4	2.5	2	2	C1	TRUE
- Case 4		1		0			1	1	2	2.5	2.4	3	2	2	C1	TRUE
- Case 5			1.5		0.5		1	1	2	1.5	2.4	2	**1**	1	C1	TRUE
- Case 6			1.5	0			1	1	2	2	2.4	2.5	2	2	C1	TRUE
- Case 7			1.5	0		0.5		1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0.5		1	2	1.5	1.9	1.5	**1**	1	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Offices - 25 storey (>30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.5		1	2	2.2	1.9	2.2	2	2	S2	TRUE
- Case 2		1			1	0.5		1	2	1.5	1.9	1.5	**1**	1	S2	TRUE
- Case 3		1			1		1	1	2	1.5	2.4	2	**1**	1	S2	TRUE
- Case 4		1		0.3			1	1	2	2.2	2.4	2.7	**2**	2	S2	TRUE
- Case 5			1.5		1		1	1	2	1	2.4	1.5	*	1	S2	FALSE
- Case 6			1.5	0.3			1	1	2	1.7	2.4	2.2	2	2	S2	TRUE
- Case 7			1.5	0.3		0.5		1	2	1.7	1.9	1.7	**1**	1	S2	TRUE
- Case 8			1.5		1	0.5		1	2	1	1.9	1	*	1	S2	FALSE
Department Stores 4 storey(<10m)	Reinforced															
- Case 1	Concrete	1		0		0		2	3	2.5	3.4	4	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 3		1			0.5		0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 4		1		0			0.3	2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.3	2	3	1.5	3.7	3.3	2	2	C1	TRUE
- Case 6			1.5	0			0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 7			1.5	0		0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 8			1.5		0.5	0		2	3	1.5	3.4	3	2	2	C1	TRUE
Department Stores 4 storey(<10m)	Steel															
- Case 1	(Ductile)	1		0.3		0		2	3	2.2	3.4	3.7	**2**	2	S1	TRUE
- Case 2		1			1	0		2	3	1.5	3.4	3	**2**	2	S1	TRUE
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	*	2	S1	FALSE
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	**2**	2	S1	TRUE
- Case 8			1.5		1	0		2	3	1	3.4	2.5	*	2	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Department Stores 6 storey(<30m)	Reinforced															
- Case 1	Concrete	1		0		0.3		2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 3		1			0.5		0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 4		1		0			0.5	2	3	2.5	3.9	4.5	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.5	2	3	1.5	3.9	3.5	2	2	C1	TRUE
- Case 6			1.5	0			0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 7			1.5	0		0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 8			1.5		0.5	0.3		2	3	1.5	3.7	3.3	2	2	C1	TRUE
Department Stores 6 storey(<30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.3		2	3	2.2	3.7	4	2	2	S2	TRUE
- Case 2		1			1	0.3		2	3	1.5	3.7	3.3	2	2	S2	TRUE
- Case 3		1			1		0.5	2	3	1.5	3.9	3.5	2	2	S2	TRUE
- Case 4		1		0.3			0.5	2	3	2.2	3.9	4.2	**3**	3	S2	TRUE
- Case 5			1.5		1		0.5	2	3	1	3.9	3	*	2	S2	FALSE
- Case 6			1.5	0.3			0.5	2	3	1.7	3.9	3.7	2	2	S2	TRUE
- Case 7			1.5	0.3		0.3		2	3	1.7	3.7	3.5	2	2	S2	TRUE
- Case 8			1.5		1	0.3		2	3	1	3.7	2.8	*	2	S2	FALSE
Department Stores 4 storey(<10m)	Reinforced															
+ 3 storey underground parking	Concrete															
- Case 1	(Normal)	1		0		0		2	3	2.5	3.4	4	2	2	C1	TRUE
- Case 2		1			0.5	0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 3		1			0.5		0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 4		1		0			0.3	2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.3	2	3	1.5	3.7	3.3	2	2	C1	TRUE
- Case 6			1.5	0			0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 7			1.5	0		0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 8			1.5		0.5	0		2	3	1.5	3.4	3	2	2	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Department Stores 4 storey(<10m)	Steel															
+ 3 storey underground parking	(Ductile)															
- Case 1		1		0.3		0		2	3	2.2	3.4	3.7	2	2	S2	TRUE
- Case 2		1			1	0		2	3	1.5	3.4	3	2	2	S2	TRUE
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	2	2	S2	TRUE
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	2	2	S2	TRUE
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	*	2	S2	FALSE
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	2	2	S2	TRUE
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	2	2	S2	TRUE
- Case 8			1.5		1	0		2	3	1	3.4	2.5	*	2	S2	FALSE
Department Stores 6 storey(<30m)	Reinforced															
+ 3 storey underground parking	Concrete															
- Case 1	(Normal)	1		0		0.3		2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 2		1			0.5	0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 3		1			0.5		0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 4		1		0			0.5	2	3	2.5	3.9	4.5	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.5	2	3	1.5	3.9	3.5	2	2	C1	TRUE
- Case 6			1.5	0			0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 7			1.5	0		0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 8			1.5		0.5	0.3		2	3	1.5	3.7	3.3	2	2	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Department Stores 6 storey(<30m)	Steel															
+ 3 storey underground parking	(Ductile)															
- Case 1		1		0.3		0.3		2	3	2.2	3.7	4	2	2	S2	TRUE
- Case 2		1			1	0.3		2	3	1.5	3.7	3.3	2	2	S2	TRUE
- Case 3		1			1		0.5	2	3	1.5	3.9	3.5	2	2	S2	TRUE
- Case 4		1		0.3			0.5	2	3	2.2	3.9	4.2	**3**	3	S2	TRUE
- Case 5			1.5		1		0.5	2	3	1	3.9	3	*	2	S2	FALSE
- Case 6			1.5	0.3			0.5	2	3	1.7	3.9	3.7	2	2	S2	TRUE
- Case 7			1.5	0.3		0.3		2	3	1.7	3.7	3.5	2	2	S2	TRUE
- Case 8			1.5		1	0.3		2	3	1	3.7	2.8	*	2	S2	FALSE
Multi-storey car park 4 storey(<10m)	Reinforced															
- Case 1	Concrete	1		0		0		1	2	2.5	1.4	2	**1**	1	C1	TRUE
- Case 2	(Normal)	1			0.5	0		1	2	2	1.4	1.5	**1**	1	C1	TRUE
- Case 3		1			0.5		0.3	1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 4		1		0			0.3	1	2	2.5	1.7	2.3	2	2	C1	TRUE
- Case 5			1.5		0.5		0.3	1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
- Case 6			1.5	0			0.3	1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 7			1.5	0		0		1	2	2	1.4	1.5	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0		1	2	1.5	1.4	1	**1**	1	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Multi-storey car park 4 storey(<10m)	Reinforced		Assumed that no piped gas will be present in building													
- Case 1	Concrete	1.3		0		0		1	2	2.2	1.4	1.7	**1**	1	C1	TRUE
- Case 2	(Normal)	1.3			0.5	0		1	2	1.7	1.4	1.2	**1**	1	C1	TRUE
- Case 3		1.3			0.5		0.3	1	2	1.7	1.7	1.5	**1**	1	C1	TRUE
- Case 4		1.3		0			0.3	1	2	2.2	1.7	2	**1**	1	C1	TRUE
- Case 5			1.5		0.5		0.3	1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
- Case 6			1.5	0			0.3	1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 7			1.5	0		0		1	2	2	1.4	1.5	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0		1	2	1.5	1.4	1	**1**	1	C1	TRUE
Multi-storey car park 4 storey(<10m)	Steel															
- Case 1	(Ductile)	1		0.3		0		1	2	2.2	1.4	1.7	1	1	S1	TRUE
- Case 2		1			1	0		1	2	1.5	1.4	1	1	1	S1	TRUE
- Case 3		1			1		0.3	1	2	1.5	1.7	1.3	1	1	S1	TRUE
- Case 4		1		0.3			0.3	1	2	2.2	1.7	2	1	1	S1	TRUE
- Case 5			1.5		1		0.3	1	2	1	1.7	0.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	2	1.7	1.7	1.5	1	1	S1	TRUE
- Case 7			1.5	0.3		0		1	2	1.7	1.4	1.2	1	1	S1	TRUE
- Case 8			1.5		1	0		1	2	1	1.4	0.5	*	Exempt	S1	FALSE
Multi-storey car park 4 storey(<10m)	Steel		Assumed that no piped gas will be present in building													
- Case 1	(Ductile)	1.3		0.3		0		1	2	1.9	1.4	1.4	1	1	S1	TRUE
- Case 2		1.3			1	0		1	2	1.2	1.4	0.7	*	Exempt	S1	FALSE
- Case 3		1.3			1		0.3	1	2	1.2	1.7	1	*	1	S1	FALSE
- Case 4		1.3		0.3			0.3	1	2	1.9	1.7	1.7	1	1	S1	TRUE
- Case 5			1.5		1		0.3	1	2	1	1.7	0.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	2	1.7	1.7	1.5	1	1	S1	TRUE
- Case 7			1.5	0.3		0		1	2	1.7	1.4	1.2	1	1	S1	TRUE
- Case 8			1.5		1	0		1	2	1	1.4	0.5	*	Exempt	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Multi-storey car park 6 storey(<30m)	Reinforced															
- Case 1	Concrete	1		0		0.3		1	2	2.5	1.7	2.3	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 3		1			0.5		0.5	1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 4		1		0			0.5	1	2	2.5	1.9	2.5	2	2	C1	TRUE
- Case 5			1.5		0.5		0.5	1	2	1.5	1.9	1.5	**1**	1	C1	TRUE
- Case 6			1.5	0			0.5	1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 7			1.5	0		0.3		1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0.3		1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
Multi-storey car park 6 storey(<30m)	Reinforced		Assumed that no piped gas will be present in building													
- Case 1	Concrete	1.3		0		0.3		1	2	2.2	1.7	2	**1**	1	C1	TRUE
- Case 2	(Normal)	1.3			0.5	0.3		1	2	1.7	1.7	1.5	**1**	1	C1	TRUE
- Case 3		1.3			0.5		0.5	1	2	1.7	1.9	1.7	**1**	1	C1	TRUE
- Case 4		1.3		0			0.5	1	2	2.2	1.9	2.2	2	2	C1	TRUE
- Case 5			1.5		0.5		0.5	1	2	1.5	1.9	1.5	**1**	1	C1	TRUE
- Case 6			1.5	0			0.5	1	2	2	1.9	2	**1**	1	C1	TRUE
- Case 7			1.5	0		0.3		1	2	2	1.7	1.8	**1**	1	C1	TRUE
- Case 8			1.5		0.5	0.3		1	2	1.5	1.7	1.3	**1**	1	C1	TRUE
Multi-storey car park 6 storey(<30m)	Steel															
- Case 1	(Ductile)	1		0.3		0.3		1	2	2.2	1.7	2	**1**	1	S2	TRUE
- Case 2		1			1	0.3		1	2	1.5	1.7	1.3	**1**	1	S2	TRUE
- Case 3		1			1		0.5	1	2	1.5	1.9	1.5	**1**	1	S2	TRUE
- Case 4		1		0.3			0.5	1	2	2.2	1.9	2.2	2	2	S2	TRUE
- Case 5			1.5		1		0.5	1	2	1	1.9	1	*	1	S2	FALSE
- Case 6			1.5	0.3			0.5	1	2	1.7	1.9	1.7	**1**	1	S2	TRUE
- Case 7			1.5	0.3		0.3		1	2	1.7	1.7	1.5	**1**	1	S2	TRUE
- Case 8			1.5		1	0.3		1	2	1	1.7	0.8	*	1	S2	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Multi-storey car park 6 storey(<30m)	Steel		Assumed that no piped gas will be present in building													
- Case 1	(Ductile)	1.3		0.3		0.3		1	2	1.9	1.7	1.7	**1**	1	S2	TRUE
- Case 2		1.3			1	0.3		1	2	1.2	1.7	1	*	1	S2	FALSE
- Case 3		1.3			1		0.5	1	2	1.2	1.9	1.2	*	1	S2	FALSE
- Case 4		1.3		0.3			0.5	1	2	1.9	1.9	1.9	**1**	1	S2	TRUE
- Case 5			1.5		1		0.5	1	2	1	1.9	1	*	1	S2	FALSE
- Case 6			1.5	0.3			0.5	1	2	1.7	1.9	1.7	**1**	1	S2	TRUE
- Case 7			1.5	0.3		0.3		1	2	1.7	1.7	1.5	**1**	1	S2	TRUE
- Case 8			1.5		1	0.3		1	2	1	1.7	0.8	*	1	S2	FALSE
Theatres	Reinforced															
- Case 1	Concrete	1		0		0.3		2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 3		1			0.5		0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 4		1		0			0.5	2	3	2.5	3.9	4.5	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.5	2	3	1.5	3.9	3.5	2	2	C1	TRUE
- Case 6			1.5	0			0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 7			1.5	0		0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 8			1.5		0.5	0.3		2	3	1.5	3.7	3.3	2	2	C1	TRUE
Theatres	Steel															
- Case 1	(Ductile)	1		0.3		0.3		2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 2		1			1	0.3		2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 3		1			1		0.5	2	3	1.5	3.9	3.5	**2**	2	S1	TRUE
- Case 4		1		0.3			0.5	2	3	2.2	3.9	4.2	**3**	3	S1	TRUE
- Case 5			1.5		1		0.5	2	3	1	3.9	3	*	2	S1	FALSE
- Case 6			1.5	0.3			0.5	2	3	1.7	3.9	3.7	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0.3		2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 8			1.5		1	0.3		2	3	1	3.7	2.8	*	2	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	**Other**	**Single**	**Redun-dancy**	**Subu-rban**	**City Centre**									
Hypermarkets - single storey	Steel															
- Case 1	(Ductile)	1		0.3		0		2	3	2.2	3.4	3.7	**2**	2	S1	TRUE
- Case 2		1			1	0		2	3	1.5	3.4	3	**2**	2	S1	TRUE
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	*	2	S1	FALSE
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	**2**	2	S1	TRUE
- Case 8			1.5		1	0		2	3	1	3.4	2.5	*	2	S1	FALSE
Hypermarkets - single storey	Steel															
+ single storey underground parking	(Ductile)															
- Case 1		1		0.3		0		2	3	2.2	3.4	3.7	**2**	2	S1	TRUE
- Case 2		1			1	0		2	3	1.5	3.4	3	**2**	2	S1	TRUE
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	*	2	S1	FALSE
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	**2**	2	S1	TRUE
- Case 8			1.5		1	0		2	3	1	3.4	2.5	*	2	S1	FALSE
Schools - single storey	Reinforced															
- Case 1	Concrete	1		0		0		2	3	2.5	3.4	4	2	2	C1	TRUE
- Case 2	(Normal)	1			0.5	0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 3		1			0.5		0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 4		1		0			0.3	2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.3	2	3	1.5	3.7	3.3	2	2	C1	TRUE
- Case 6			1.5	0			0.3	2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 7			1.5	0		0		2	3	2	3.4	3.5	2	2	C1	TRUE
- Case 8			1.5		0.5	0		2	3	1.5	3.4	3	2	2	C1	TRUE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Schools - single storey	Steel															
- Case 1	(Ductile)	1		0.3		0		2	3	2.2	3.4	3.7	**2**	2	S1	TRUE
- Case 2		1			1	0		2	3	1.5	3.4	3	**2**	2	S1	TRUE
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	*	2	S1	FALSE
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	**2**	2	S1	TRUE
- Case 8			1.5		1	0		2	3	1	3.4	2.5	*	2	S1	FALSE
Colleges - 4 storey (>10m)	Reinforced															
- Case 1	Concrete	1		0		0.3		2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
- Case 2	(Normal)	1			0.5	0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 3		1			0.5		0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 4		1		0			0.5	2	3	2.5	3.9	4.5	**3**	3	C1	TRUE
- Case 5			1.5		0.5		0.5	2	3	1.5	3.9	3.5	2	2	C1	TRUE
- Case 6			1.5	0			0.5	2	3	2	3.9	4	2	2	C1	TRUE
- Case 7			1.5	0		0.3		2	3	2	3.7	3.8	2	2	C1	TRUE
- Case 8			1.5		0.5	0.3		2	3	1.5	3.7	3.3	2	2	C1	TRUE
Colleges - 4 storey (>10m)	Steel															
- Case 1	(Ductile)	1		0.3		0.3		2	3	2.2	3.7	4	**2**	2	S1	TRUE
- Case 2		1			1	0.3		2	3	1.5	3.7	3.3	**2**	2	S1	TRUE
- Case 3		1			1		0.5	2	3	1.5	3.9	3.5	**2**	2	S1	TRUE
- Case 4		1		0.3			0.5	2	3	2.2	3.9	4.2	**3**	3	S1	TRUE
- Case 5			1.5		1		0.5	2	3	1	3.9	3	*	2	S1	FALSE
- Case 6			1.5	0.3			0.5	2	3	1.7	3.9	3.7	**2**	2	S1	TRUE
- Case 7			1.5	0.3		0.3		2	3	1.7	3.7	3.5	**2**	2	S1	TRUE
- Case 8			1.5		1	0.3		2	3	1	3.7	2.8	*	2	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Hospitals - 6 storey (<30m)	Reinforced															
- Case 1	Concrete	0		0		0.3		2	3	3.5	3.7	5.3	**3**	3	C1	TRUE
- Case 2	(Normal)	0			0.5	0.3		2	3	3	3.7	4.8	**3**	3	C1	TRUE
- Case 3		0			0.5		0.5	2	3	3	3.9	5	**3**	3	C1	TRUE
- Case 4		0		0			0.5	2	3	3.5	3.9	5.5	**3**	3	C1	TRUE
- Case 5			0.5		0.5		0.5	2	3	2.5	3.9	4.5	**3**	3	C1	TRUE
- Case 6			0.5	0			0.5	2	3	3	3.9	5	**3**	3	C1	TRUE
- Case 7			0.5	0		0.3		2	3	3	3.7	4.8	**3**	3	C1	TRUE
- Case 8			0.5		0.5	0.3		2	3	2.5	3.7	4.3	**3**	3	C1	TRUE
Hospitals - 6 storey (<30m)	Steel															
- Case 1	(Ductile)	0		0.3		0.3		2	3	3.2	3.7	5	**3**	3	S2	TRUE
- Case 2		0			1	0.3		2	3	2.5	3.7	4.3	**3**	3	S2	TRUE
- Case 3		0			1		0.5	2	3	2.5	3.9	4.5	**3**	3	S2	TRUE
- Case 4		0		0.3			0.5	2	3	3.2	3.9	5.2	**3**	3	S2	TRUE
- Case 5			0.5		1		0.5	2	3	2	3.9	4	2	2	S2	TRUE
- Case 6			0.5	0.3			0.5	2	3	2.7	3.9	4.7	**3**	3	S2	TRUE
- Case 7			0.5	0.3		0.3		2	3	2.7	3.7	4.5	**3**	3	S2	TRUE
- Case 8			0.5		1	0.3		2	3	2	3.7	3.8	2	2	S2	TRUE
Factory workshops - single storey	Steel															
- Case 1	(Ductile)	1		0.3		0		1	2	2.2	1.4	1.7	1	1	S1	TRUE
- Case 2		1			1	0		1	2	1.5	1.4	1	1	1	S1	TRUE
- Case 3		1			1		0.3	1	2	1.5	1.7	1.3	1	1	S1	TRUE
- Case 4		1		0.3			0.3	1	2	2.2	1.7	2	1	1	S1	TRUE
- Case 5			1.5		1		0.3	1	2	1	1.7	0.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	2	1.7	1.7	1.5	1	1	S1	TRUE
- Case 7			1.5	0.3		0		1	2	1.7	1.4	1.2	1	1	S1	TRUE
- Case 8			1.5		1	0		1	2	1	1.4	0.5	*	Exempt	S1	FALSE

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S-C-D	Risk Category Allott& Lomax	Risk Category New with New lines	Risk Category B.S	Allott RC = New RC
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre									
Factory workshops - single storey	Steel		Assumed that no piped gas will be present in building													
- Case 1	(Ductile)	1.3		0.3		0		1	2	1.9	1.4	1.4	1	1	S1	TRUE
- Case 2		1.3			1	0		1	2	1.2	1.4	0.7	*	1	S1	FALSE
- Case 3		1.3			1		0.3	1	2	1.2	1.7	1	*	1	S1	FALSE
- Case 4		1.3		0.3			0.3	1	2	1.9	1.7	1.7	1	1	S1	TRUE
- Case 5			1.5		1		0.3	1	2	1	1.7	0.8	*	1	S1	FALSE
- Case 6			1.5	0.3			0.3	1	2	1.7	1.7	1.5	1	1	S1	TRUE
- Case 7			1.5	0.3		0		1	2	1.7	1.4	1.2	1	1	S1	TRUE
- Case 8			1.5		1	0		1	2	1	1.4	0.5	*	Exempt	S1	FALSE

ANNEX C CALIBRATION OF GRANDSTAND STRUCTURES

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk	Societal Criteria	Risk (New)	Consequence (New)	Risk Factor	Risk Category	Risk Category
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre	N	S	3.5-C-D	N+E+S-1.6	N+E+S-C-D		B.S
Grandstands	Steel	Human occupancy = NONE				H < 10m								
- Case 1	(Ductile)	2		0.3		0		2	3	1.2	3.4	2.7	2	S1
- Case 2		2			1	0		2	3	0.5	3.4	2	1	S1
- Case 3		2			1		0.3	2	3	0.5	3.7	2.3	2	S1
- Case 4		2		0.3			0.3	2	3	1.2	3.7	3	2	S1
- Case 5			2.5		1		0.3	2	3	0	3.7	1.8	1	S1
- Case 6			2.5	0.3			0.3	2	3	0.7	3.7	2.5	2	S1
- Case 7			2.5	0.3		0		2	3	0.7	3.4	2.2	2	S1
- Case 8			2.5		1	0		2	3	0	3.4	1.5	1	S1
Grandstands	Steel	Human occupancy = NONE				10 < H < 30m								
- Case 1	(Ductile)	2		0.3		0.3		2	3	1.2	3.7	3	2	
- Case 2		2			1	0.3		2	3	0.5	3.7	2.3	2	
- Case 3		2			1		0.5	2	3	0.5	3.9	2.5	2	S1 or S2
- Case 4		2		0.3			0.5	2	3	1.2	3.9	3.2	2	Depending
- Case 5			2.5		1		0.5	2	3	0	3.9	2	1	on height
- Case 6			2.5	0.3			0.5	2	3	0.7	3.9	2.7	2	
- Case 7			2.5	0.3		0.3		2	3	0.7	3.7	2.5	2	
- Case 8			2.5		1	0.3		2	3	0	3.7	1.8	1	
Grandstands	Steel	Human occupancy = NONE				30m < H								
- Case 1	(Ductile)	2		0.3		0.5		2	3	1.2	3.9	3.2	2	S2
- Case 2		2			1	0.5		2	3	0.5	3.9	2.5	2	S2
- Case 3		2			1		1	2	3	0.5	4.4	3	2	S2
- Case 4		2		0.3			1	2	3	1.2	4.4	3.7	2	S2
- Case 5			2.5		1		1	2	3	0	4.4	2.5	2	S2
- Case 6			2.5	0.3			1	2	3	0.7	4.4	3.2	2	S2
- Case 7			2.5	0.3		0.5		2	3	0.7	3.9	2.7	2	S2
- Case 8			2.5		1	0.5		2	3	0	3.9	2	1	S2

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category	Risk Category B.S
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre							
Grandstands	Steel	Human occupancy = NORMAL				H < 10m								
- Case 1	(Ductile)	1		0.3		0		2	3	2.2	3.4	3.7	2	S1
- Case 2		1			1	0		2	3	1.5	3.4	3	2	S1
- Case 3		1			1		0.3	2	3	1.5	3.7	3.3	2	S1
- Case 4		1		0.3			0.3	2	3	2.2	3.7	4	2	S1
- Case 5			1.5		1		0.3	2	3	1	3.7	2.8	2	S1
- Case 6			1.5	0.3			0.3	2	3	1.7	3.7	3.5	2	S1
- Case 7			1.5	0.3		0		2	3	1.7	3.4	3.2	2	S1
- Case 8			1.5		1	0		2	3	1	3.4	2.5	2	S1
Grandstands	Steel	Human occupancy = NORMAL				10 < H < 30m								
- Case 1	(Ductile)	1		0.3		0.3		2	3	2.2	3.7	4	2	S1 or S2 Depending on height
- Case 2		1			1	0.3		2	3	1.5	3.7	3.3	2	
- Case 3		1			1		0.5	2	3	1.5	3.9	3.5	2	
- Case 4		1		0.3			0.5	2	3	2.2	3.9	4.2	3	
- Case 5			1.5		1		0.5	2	3	1	3.9	3	2	
- Case 6			1.5	0.3			0.5	2	3	1.7	3.9	3.7	2	
- Case 7			1.5	0.3		0.3		2	3	1.7	3.7	3.5	2	
- Case 8			1.5		1	0.3		2	3	1	3.7	2.8	2	
Grandstands	Steel	Human occupancy = NORMAL				30m < H								
- Case 1	(Ductile)	1		0.3		0.5		2	3	2.2	3.9	4.2	3	S2
- Case 2		1			1	0.5		2	3	1.5	3.9	3.5	2	S2
- Case 3		1			1		1	2	3	1.5	4.4	4	2	S2
- Case 4		1		0.3			1	2	3	2.2	4.4	4.7	3	S2
- Case 5			1.5		1		1	2	3	1	4.4	3.5	2	S2
- Case 6			1.5	0.3			1	2	3	1.7	4.4	4.2	3	S2
- Case 7			1.5	0.3		0.5		2	3	1.7	3.9	3.7	2	S2
- Case 8			1.5		1	0.5		2	3	1	3.9	3	2	S2

Building type	**Building Material**	**Load Parameter C**		**Structural Parameter D**		**Environmental Parameter E**		**People at risk**	**Societal Criteria**	**Risk (New) 3.5-**	**Consequence (New)**	**Risk Factor N+E+S**	**Risk Category**	**Risk Category**
		Accid-ental	**Other**	**Single**	**Redun-dancy**	**Subu-rban**	**City Centre**	**N**	**S**	**C-D**	**N+E+S-1.6**	**-C-D**		**B.S**
Grandstands	Reinforced	Human occupancy = NONE				H < 10m								
- Case 1	Concrete	2		0		0		2	3	1.5	3.4	3	2	C1
- Case 2	(Normal)	2			0.5	0		2	3	1	3.4	2.5	2	C1
- Case 3		2			0.5		0.3	2	3	1	3.7	2.8	2	C1
- Case 4		2		0			0.3	2	3	1.5	3.7	3.3	2	C1
- Case 5			2.5		0.5		0.3	2	3	0.5	3.7	2.3	2	C1
- Case 6			2.5	0			0.3	2	3	1	3.7	2.8	2	C1
- Case 7			2.5	0		0		2	3	1	3.4	2.5	2	C1
- Case 8			2.5		0.5	0		2	3	0.5	3.4	2	1	C1
Grandstands	Reinforced	Human occupancy = NONE				10 < H < 30m								
- Case 1	Concrete	2		0		0.3		2	3	1.5	3.7	3.3	2	C1
- Case 2	(Normal)	2			0.5	0.3		2	3	1	3.7	2.8	2	C1
- Case 3		2			0.5		0.5	2	3	1	3.9	3	2	C1
- Case 4		2		0			0.5	2	3	1.5	3.9	3.5	2	C1
- Case 5			2.5		0.5		0.5	2	3	0.5	3.9	2.5	2	C1
- Case 6			2.5	0			0.5	2	3	1	3.9	3	2	C1
- Case 7			2.5	0		0.3		2	3	1	3.7	2.8	2	C1
- Case 8			2.5		0.5	0.3		2	3	0.5	3.7	2.3	2	C1
Grandstands	Reinforced	Human occupancy = NONE				30m < H								
- Case 1	Concrete	2		0		0.5		2	3	1.5	3.9	3.5	2	C1
- Case 2	(Normal)	2			0.5	0.5		2	3	1	3.9	3	2	C1
- Case 3		2			0.5		1	2	3	1	4.4	3.5	2	C1
- Case 4		2		0			1	2	3	1.5	4.4	4	2	C1
- Case 5			2.5		0.5		1	2	3	0.5	4.4	3	2	C1
- Case 6			2.5	0			1	2	3	1	4.4	3.5	2	C1
- Case 7			2.5	0		0.5		2	3	1	3.9	3	2	C1
- Case 8			2.5		0.5	0.5		2	3	0.5	3.9	2.5	2	C1

Building type	Building Material	Load Parameter C		Structural Parameter D		Environmental Parameter E		People at risk N	Societal Criteria S	Risk (New) 3.5-C-D	Consequence (New) N+E+S-1.6	Risk Factor N+E+S -C-D	Risk Category	Risk Category B.S
		Accid-ental	Other	Single	Redun-dancy	Subu-rban	City Centre							
Grandstands	Reinforced	Human occupancy = NORMAL				H < 10m								
- Case 1	Concrete	1		0		0		2	3	2.5	3.4	4	2	C1
- Case 2	(Normal)	1			0.5	0		2	3	2	3.4	3.5	2	C1
- Case 3		1			0.5		0.3	2	3	2	3.7	3.8	2	C1
- Case 4		1		0			0.3	2	3	2.5	3.7	4.3	3	C1
- Case 5			1.5		0.5		0.3	2	3	1.5	3.7	3.3	2	C1
- Case 6			1.5	0			0.3	2	3	2	3.7	3.8	2	C1
- Case 7			1.5	0		0		2	3	2	3.4	3.5	2	C1
- Case 8			1.5		0.5	0		2	3	1.5	3.4	3	2	C1
Grandstands	Reinforced	Human occupancy = NORMAL				10 < H < 30m								
- Case 1	Concrete	1		0		0.3		2	3	2.5	3.7	4.3	3	C1
- Case 2	(Normal)	1			0.5	0.3		2	3	2	3.7	3.8	2	C1
- Case 3		1			0.5		0.5	2	3	2	3.9	4	2	C1
- Case 4		1		0			0.5	2	3	2.5	3.9	4.5	3	C1
- Case 5			1.5		0.5		0.5	2	3	1.5	3.9	3.5	2	C1
- Case 6			1.5	0			0.5	2	3	2	3.9	4	2	C1
- Case 7			1.5	0		0.3		2	3	2	3.7	3.8	2	C1
- Case 8			1.5		0.5	0.3		2	3	1.5	3.7	3.3	2	C1
Grandstands	Reinforced	Human occupancy = NORMAL				30m < H								
- Case 1	Concrete	1		0		0.5		2	3	2.5	3.9	4.5	3	C1
- Case 2	(Normal)	1			0.5	0.5		2	3	2	3.9	4	2	C1
- Case 3		1			0.5		1	2	3	2	4.4	4.5	3	C1
- Case 4		1		0			1	2	3	2.5	4.4	5	3	C1
- Case 5			1.5		0.5		1	2	3	1.5	4.4	4	2	C1
- Case 6			1.5	0			1	2	3	2	4.4	4.5	2	C1
- Case 7			1.5	0		0.5		2	3	2	3.9	4	2	C1
- Case 8			1.5		0.5	0.5		2	3	1.5	3.9	3.5	2	C1

ANNEX D: MODIFICATION TO APPROVED DOCUMENT PART A REGULATION A3 AND SECTION 5 TEXT

REGULATION A3

The Requirement: The text remains unaltered.

Limits on Application: Either, remove existing text and leave blank, or replace with the following:

Requirement A3 applies to all buildings having a non-exempt Risk Category (i.e. a Risk Factor greater than 0.7) as determined in accordance with Appendix B.

PERFORMANCE

In the Secretary of State’s view the requirement of A3 will be met by an appropriate choice of measures:

1. preventing the action from occurring or reducing to a reasonable level the probability and/or the magnitude of the action.
2. protecting the structure against the effects of an action by reducing the actual loads on the structure (e.g. protective bollards)
3. reducing the sensitivity of the building to disproportionate collapse should an accident occur

Introduction

The guidance in this section deals with the means of reducing the sensitivity of a building to disproportionate collapse in the event of an accident.

REDUCING THE SENSITIVITY OF THE BUILDING TO DISPROPORTIONATE COLLAPSE IN THE EVENT OF AN ACCIDENT

5.1 The requirement will be met by adopting the relevant approach from the following according to the Risk Category and Risk Factor for the building determined in accordance with Appendix B.

Risk Category – Exempt: Risk Factor ≤ 0.7

No specific measures need to be taken.

Risk Category – Category 1: 0.7 < Risk Factor ≤ 2.0

Provide effective horizontal ties in accordance with the recommendations given in the Codes and Standards, listed under paragraph 5.2 below

Risk Category – Category 2: 2.0 < Risk Factor ≤ 4.0

Provide effective horizontal and vertical ties in accordance with the recommendations given in the Codes and Standards, listed under paragraph 5.2 below.

If effective horizontal tying is provided and it is not feasible to provide vertical tying of any of the vertical loadbearing members, then each such untied member should be considered to be notionally removed, one at a time in each storey in turn, to check that its removal would allow the rest of the structure to bridge over the missing member, albeit in a substantially deformed condition.

In considering this option it should be recognised that certain areas of the structure (e.g. cantilevers or simply supported floor panels etc.) will remain vulnerable to collapse. In these instances, the area at risk of collapse of the structure should be limited to that given in paragraph a below.

If it is not possible to bridge over the missing member, that member should be designed as a protected member (see paragraph b below).

a. If it is not feasible to provide effective tying of horizontal and vertical tying of any of the load bearing members, then each support member should be considered to be notionally removed, one at a time in each storey in turn, to check that, on its removal the area at risk of collapse of the structure within the storey and the immediate adjacent storeys is limited to

i. 15% of the area of the storey or

ii. $70m^2$

which ever is the less (see Diagram 25). It should be noted that the area at risk, is the area of the floor at risk of collapse on the removal of the member and, not necessarily, the entire area supported by the member in conjunction with other members.

b. Design of protected members:

The protected members (sometimes called ‘key’ elements) should be designed in accordance with the recommendations given in the appropriate Codes and Standards listed in paragraph 5.2

Alternative approach

5.2 The performance can also be met by following the relevant recommendations given in the clauses of the Codes and Standards listed below:

Structural work of masonry: Clause 37 of BS5628: *Code of practice for use of masonry Part 1: 1978 Structural use of unreinforced masonry*

Structural work of steel: Clause 2.4.5.3 of BS5950: *Structural use of steelwork in building Part 1: 1990 Code of practice for design in simple and continuous construction: hot rolled Sections.* (The accidental loading referred to in clause 2.4.5.5 should be chosen having particular regard to the importance of the key element and the consequences of failure, and the key element should always be capable of withstanding a load of at least $34kN/m^2$ applied from any direction).

Structural work of reinforced, prestressed or plain concrete: Clause 2.2.2.2 of BS8110 *Structural use of concrete.* Part 1: 1985 *Code of practice for design and construction*, and Clause 2.6 of Part 2: 1985 *Code of practice for special circumstances*.

Risk Category – Category 3: Risk Factor ≥ 4.0

A more extensive design analysis to identify load paths and affected areas taking into account appropriate elemental interactions is required. The members should be designed to the recommendations given in the Codes and Standards listed in paragraph 5.2. Consideration should also be given to reducing the affected areas at risk to less than the limits given in Risk Category 2 and to either preventing the actions from occurring and/or protecting the structure against the effects of actions.

{Draft Note: Risk Category 3 provision should be Risk Category 2 plus additional measures. The concern with the more extensive analysis recommended is the appropriate representation of the relevant loading for accidental/other unforeseen actions. This is the reason why the Allott & Lomax proposal 'dynamic analysis to Appendix B of ENV 1991-2-7' has not been included. It may be more appropriate to propose:

The recommendations of Risk Category 2 should be followed with additional consideration given to measures designed either to prevent the actions from occurring or protecting the structure against the effect of these actions}

Appendix B (to the Revised AD) – Method for Determining Risk Categories and Risk Factors for Buildings

To determine the risk category and risk factor applicable to a structure, Risk and Consequence values need to be calculated. From these values, a risk factor is calculated which then determines the relevant Risk Category.

Risk and Consequence should be determined as follows.

RISK

Risk is expressed by the following equation:

Risk = 3.5 – C – D

Where: C = Load Parameter
D = Structural Parameter

The parameter values are determined by considering the type of structure and related factors considered applicable to the building under consideration.

Load Parameter C

This parameter is used to assess the likelihood of the building being occupied at the time of the event, and the type of load that may cause structural damage. The value for C is selected from Table A1 using the Load Type and Human Occupancy that relate to the structure under consideration. These factors are defined as follows:

Human Occupancy

FULL Building significantly occupied for more than 18 hours a day.
NORMAL Building significantly occupied between 6 and 18 hours a day.
NONE Building significantly occupied for less than 6 hours a day.

For Example:

FULL	NORMAL	NONE
Institutional Buildings e.g. hospitals, residential nursing homes/hospices	Offices, Single Family Domestic Dwellings.	Storage buildings
Multi-storey Flats	Hypermarkets	Car Parks

Load Type

ACCIDENT Loads due to gas explosions or vehicle impacts.
OTHER Over loading of structural elements, differential settlement.

Structural Parameter D

This parameter is intended to reflect the degree of load redistribution available within the structure, the ability of the structure to accommodate large strains and the degree of visual warning that an event is occurring, or has occurred. Values of D are given in Table A2 and are determined by considering both the Structural Type and Response. These are defined below:

Structural Type

This defines the ability of the structure to use an alternate load path when the most direct path can not be used due to the loss of an element. Structures which are designed to allow this are defined as **With Redundancy**. Structures which do not have alternative load paths are defined as **Single Element**.

Structural Response

This defines the response of the structure, as a whole, under loading. It reflects the ability of the structure to accommodate large strains by analogy with the ductile and brittle behaviour of materials. Normal behaviour should be assumed if brittle and/or ductile behaviour cannot be assured.

CONSEQUENCE

Consequence is defined by the following expression:

$$\textbf{Consequence} = N + E + S - 1.6$$

Where: N = Number of people at risk.
E = Environmental Parameter.
S = Societal Criteria.

Environmental Parameter E

This parameter reflects the likelihood of surrounding buildings and people in the proximity being affected when the building under consideration is subjected to an accidental event.
The height of the structure above ground level and its location are used to obtain the value of E, the values of which are given in Table A3.

Location of Structure

The Location of the Structure accounts generally for the number of surrounding buildings that may be affected by an event in the structure under consideration. The sub-categories are defined as follows:

Sub-Category	**Description**
RESIDENTIAL	representative of building density associated with 2 or 3 storey domestic housing estates
SUBURBAN	mixture of low and medium storey, single and multi-occupancy domestic housing, commercial buildings and industrial units
CITY CENTRE	multi-storey, multi-purpose commercial and multiple occupancy domestic buildings

Number of People at Risk N

This parameter reflects the number of people considered to be at risk within the structure at the time of an event. The values for N are shown in Table A4.
Societal Criteria S

This parameter reflects the societal perception of the impact of an accidental or unforeseen action occurring in different buildings. The values for S are shown in Table A5.

RISK FACTOR

The Risk Factor is defined by the following expression:

Risk Factor = N + E + S – C – D

Where the parameters are the same as those defined for Risk and Consequence.

The Risk Category is determined using Table A6.

Table A1. Load Parameter C

Human Occupancy	Load Type	
	Accident	Other
Full	0.0	0.5
Normal	1.0	1.5
None	2.0	2.5

Table A2. Structural Parameter D

Structural Response	Structural Type	
	Single Element	With Redundancy *
Brittle	0.0	0.0
Normal	0.0	0.2
Ductile	0.3	0.7

*****The values for structures designed with redundancy should be increased by 0.3 if any parts of the structure are clearly visible and major structural elements requiring maintenance can be easily inspected.

Table A3. Environmental Parameter E

Height above ground level (m)	Location of Structure		
	Residential	Suburban	City Centre
<10m	0.0	0.0	0.3
10 to 30m	0.0	0.3	0.5
>30m	0.3	0.5	1.0

Table A4. Number of People at Risk N

	N
Single Family Dwellings of not more than 3 storeys	0.0
Offices and Flats	1.0
Public Assembly Buildings	2.0

Table A5. Societal Criteria S

	S
Single Family Dwellings of not more than 3 storeys	1.6
All other domestic dwellings of not more than 3 storeys, offices, trade and industry.	2.0
Domestic dwellings of more than 3 storeys and public assembly	3.0

buildings	

Table A6. Risk Categories as defined by Risk Factors

Risk Factor	Risk Category
Risk Factor ≤ 0.7	Exempt
0.7 < Risk Factor ≤ 2.0	1
2.0 < Risk Factor ≤ 4.0	2
Risk Factor > 4.0	3

Summary of Method

1. For the structure under consideration, determine the appropriate values of the parameters C, D, E, N and S from Tables A1, A2, A3, A4 and A5 respectively.

2. Calculate the value of Risk and Consequence from:

$$\text{Risk} = 3.5 - C - D, \text{ and } \text{Consequence} = E + N + S - 1.6$$

3. Calculate the Risk Factor from: Risk Factor = E + N + S – C - D

4. Determine the Risk Category either by,

- locating the point corresponding to the calculated Risk and Consequence values on the Categorisation Chart (Fig A1), or
- obtaining directly from Table A6 corresponding to the range in which the calculated Risk Factor lies.