STRUCTURAL SAFETY
Course code: 72785

Lesson 14: Structural Reliability Assessment

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Reliability Assessment

Uncertainties in Reliability Assessment

- Phenomenological uncertainty
- Decision uncertainty
- Modelling uncertainty
- Prediction uncertainty
- Physical uncertainty
- Statistical uncertainty
- Uncertainties due to human factors

From Melchers

Human error

Error type	Human variability V	Human error E	Gross human error G
Failure process	In a mode of behaviour against which the structure was designed		In a mode of behaviour against which the structure was *not* designed
Mechanism of error	One or more errors during design, documentation, construction and/or use of the structure		Engineer's ignorance or oversight of fundamental behaviour. Profession's ignorance of fundamental behaviour
Possibility of analytic representation	High	Medium	Low

From Melchers

Human error

Cause	%
Inadequate appreciation of loading conditions or structural behaviour	43
Mistakes in drawings or calculations	7
Inadequate information in contract documents or instructions	4
Contravention of requirements in contract documents or instructions	9
Inadequate execution of erection procedure	13
Unforeseeable misuse, abuse and/or sabotage, catastrophe, deterioration	7
Random variation in loading, structure, materials, workmanship etc.	10
Others	7

From Melchers

Human error

Factor	%
Ignorance, carelessness, negligence	35
Forgetfulness, errors, mistakes	9
Reliance upon others without sufficient control	6
Underestimation of influences	13
Insufficient knowledge	25
Objectively unknown situations (unimaginable?)	4
Remaining	8

Adapted from Matousek and Schneider (1976)

From Melchers

Modelling of human error and intervention

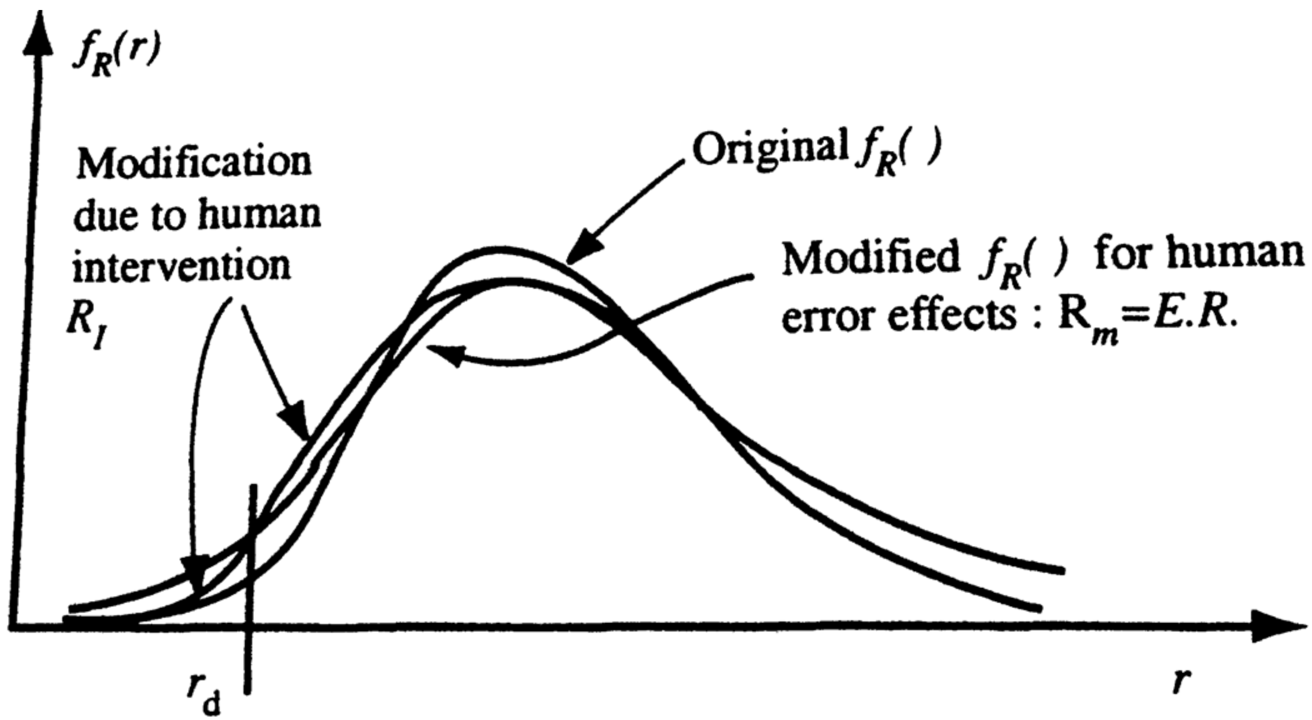


Figure 2.5 Modification of resistance probability density function for human error and human intervention effects.

From Melchers

Criteria for Risk Acceptability

Table 2.5 Selected risks in society (indicative)

Activity	Approximate death rate[a] (× 10^{-9} deaths/h exposure)	Typical exposure[b] (h/year)	Typical risk of death (× 10^{-6} /year) (rounded)
Alpine climbing	30 000–40 000	50	1500–2000
Boating	1500	80	120
Swimming	3500	50	170
Cigarette smoking	2500	400	1000
Air travel	1200	20	24
Car travel	700	300	200
Train travel	80	200	15
Coal mining (UK)	210	1500	300
Construction work	70–200	2200	150–440
Manufacturing	20	2000	40
Building fires[c]	1–3	8000	8–24
Structural failures[c]	0.02	6000	0.1

From Melchers

Criteria for Risk Acceptability

Table 2.6 Broad indicators of tolerable risks

Risk of death per person per year.	Characteristic response
10^{-3}	uncommon accidents; immediate action is taken to reduce the hazard
10^{-4}	people spend money, especially public money to control the hazard (e.g. traffic signs, police, laws);
10^{-5}	mothers warn their children of the hazard (e.g. fire, drowning, firearms, poisons), also air travel avoidance
10^{-6}	not of great concern to average person; aware of hazard, but not of personal nature; act of God.

From Melchers

Criteria for Risk Acceptability

Table 2.7 Typical 'collapse' failure rates for building structures

Structure type	Data cover	Number of structures (estimated)	Average life (years)	Estimated lifetime p_f
Apartment floors	Denmark	5×10^6	30	3×10^{-7}
Mixed housing	the Netherlands (1967–1968)	2.5×10^6	-	5×10^{-4}
Controlled domestic housing	Australia (New South Wales)	145 500	-	10^{-5}
Mixed housing	Canada	5×10^6	50	10^{-3}
Engineered structures	Canada	-	-	10^{-4}

Sources: Allen, 1981a; Ingles, 1979; Melchers, 1979.

From Melchers

Criteria for Risk Acceptability

Table 2.8 Typical 'collapse' failure rates for bridges

Bridge type	Data cover	Number of structures (estimated)	Average life (years)	Estimated lifetime p_f
Steel railway	USA (<1900)	-	40	10^{-3}
Large suspension	World (1900-1960)	55	40	3×10^{-3}
Cantilever and suspended span	USA	-	-	1.5×10^{-3}
Bridges	USA	-	-	10^{-3}
Bridges	Australia	-	-	10^{-2}

Sources: Pugsley, 1962; Ingles, 1979.

From Melchers

Load and Load Effect Modelling

Wind loading

- The typical average values and the correlated characteristic ones are taken from annual maximum means or 50-years maximum means

Table 7.1 Typical average values of mean hourly wind speed data

	Annual maximum			50 - year maximum		
	Mean speed (m/s)	(miles/h)	Coefficient of variation	Mean speed (m/s)	(miles/h)	Coefficient of variation
USA[a]	15.5	(34.7)	0.12–0.17	24.1	(18.6)	0.11–0.14
Australia[b]	14.9	(33.3)	0.12	24.7	(55.2)	0.12
Cardington, UK[c]	15.5	(34.7)	0.24	23	(≈52)	0.12

[a]Converted from 'fastest-mile' wind records [Simiu and Filliben, 1980].
[b]Converted from '3-sec.' wind records [Pham *et al.*, 1983].
[c]Converted from '3-sec.' wind records [Shellard, 1958]
Mean hourly speeds ≈ 0.77 x fastest-mile speeds
Mean hourly speeds ≈ (1/1.55–1/1.7) × 3-sec. gust speeds.

From Melchers

Floor loading

- Live loading on floors must be modelled, since long-term records are not available, and since there are many possible parameters which may influence it.
- Originally, data used in design consisted of estimates of dense crowd loading.
- For multi-storey buildings it is unlikely that all floors will be subjected to crowd loading at the same time in corresponding locations.

From Melchers

Floor loading: area dependence effect

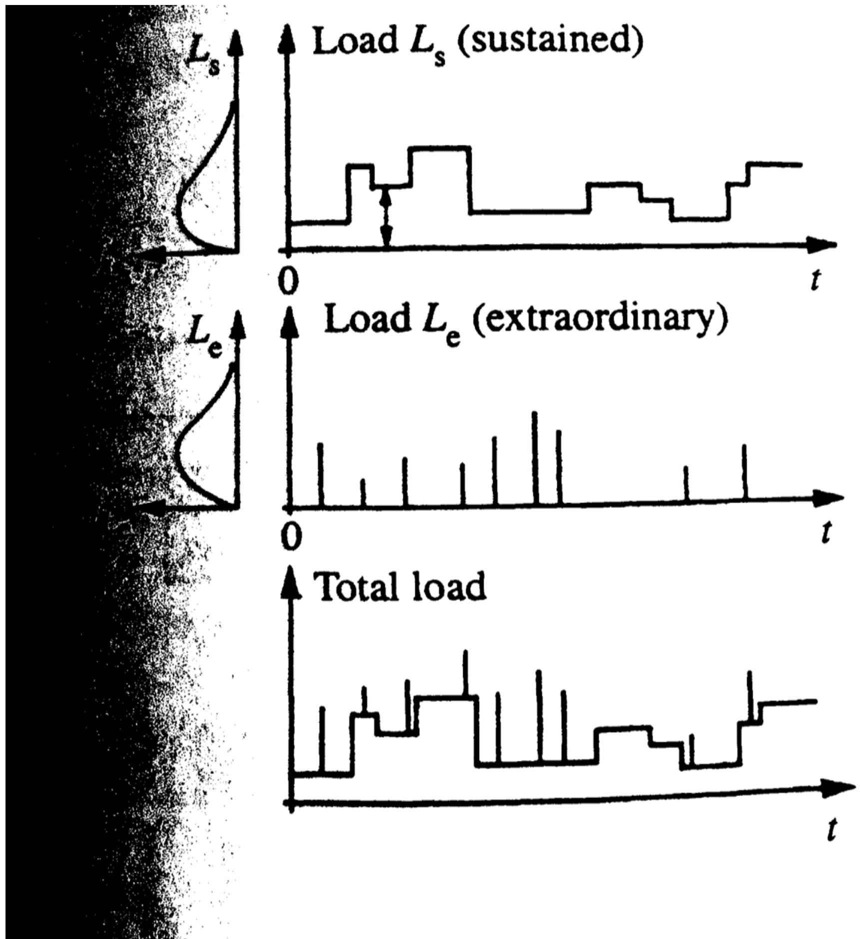


Figure 7.3 Time histories of typical live loads.

From Melchers

Floor loading: area dependence effect

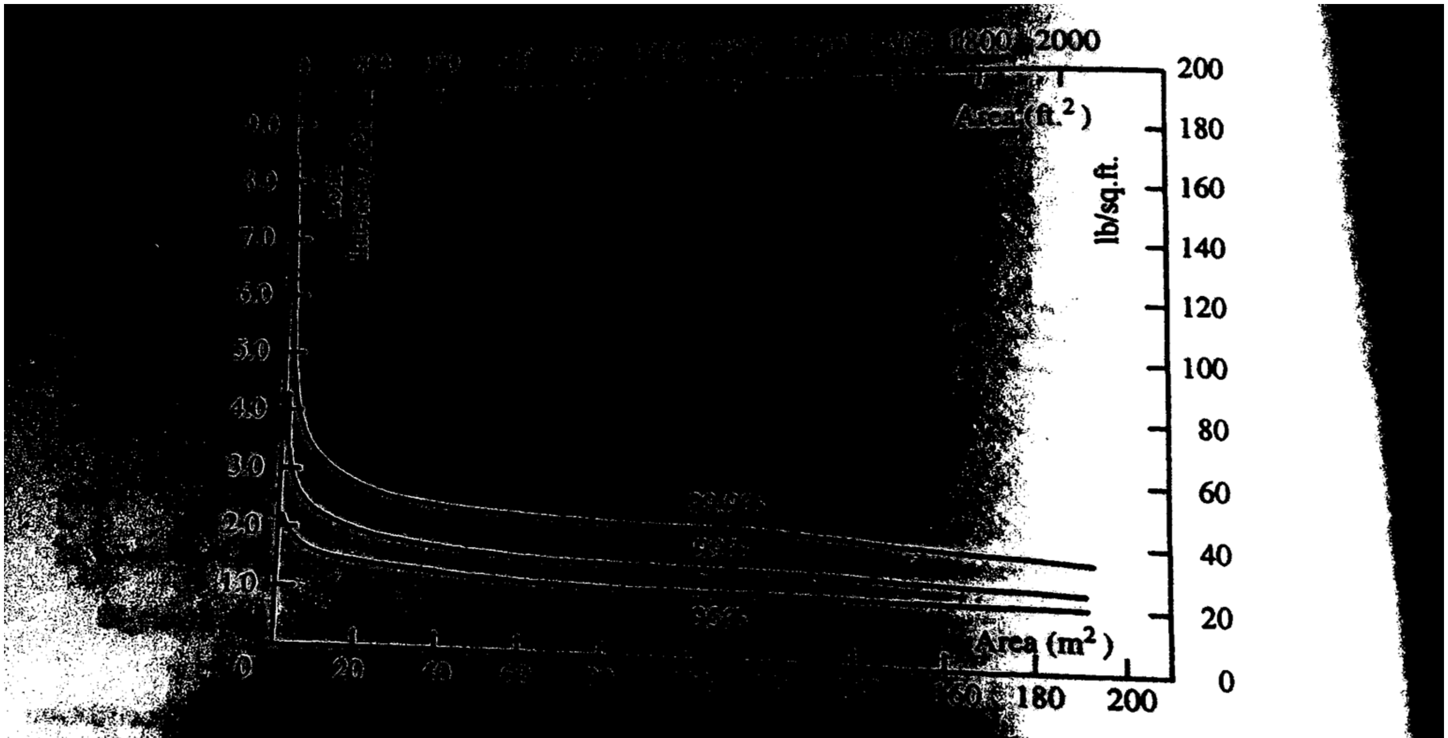
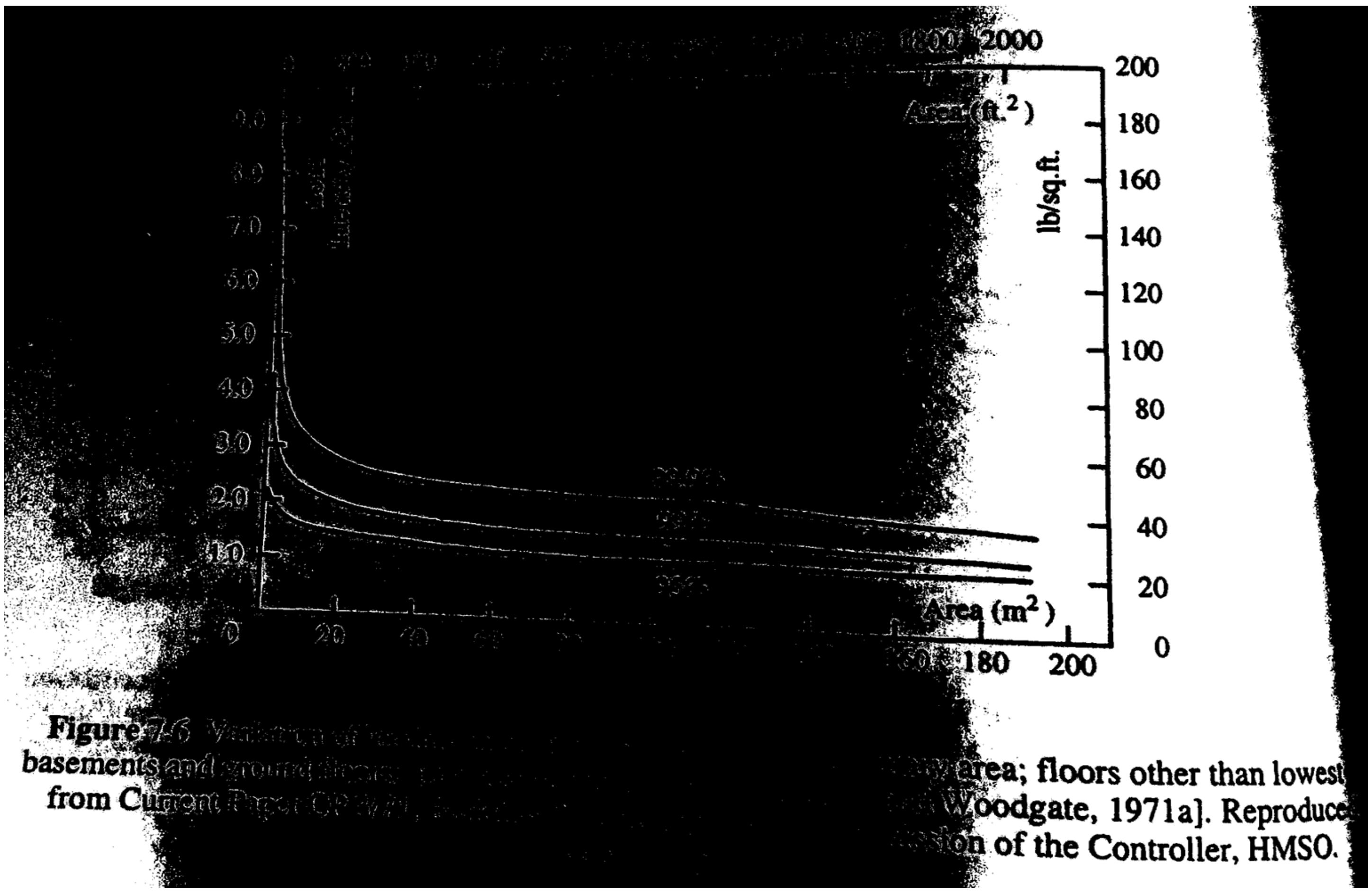


Figure 7-6 [illegible] basements and ground floors [illegible] area; floors other than lowest from Current Paper [illegible] Woodgate, 1971a]. Reproduce[illegible] [illegible] of the Controller, HMSO.

From Melchers

Floor loading: area dependence effect



From Melchers

Floor loading: area dependence effect

Distribution of equivalent uniformly distributed load

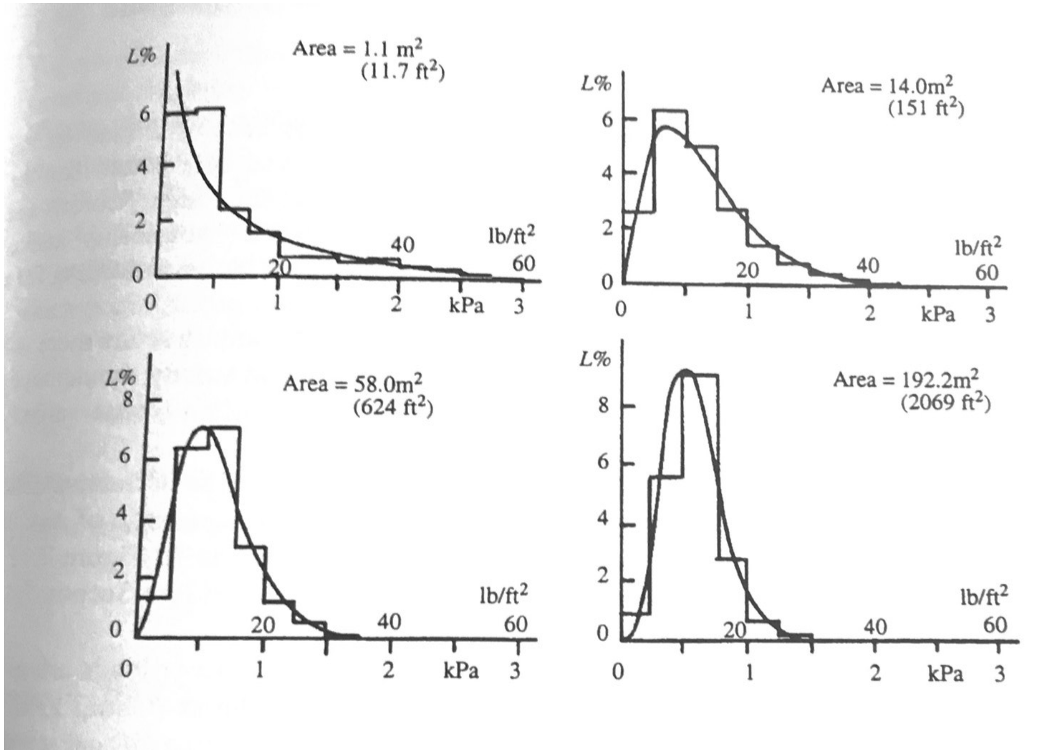


Figure 7.10 Histograms of floor load intensity as modelled by distribution functions [Reproduced from Pier and Cornell (1973) by permission of the American Society of Civil Engineers].

From Melchers

Floor loading: area dependence effect

Table 7.5 Typical basic loads, modelling parameters and load combinations for office floor loadings for $A_I = 18.6\,\mathrm{m}^2$ floor area [Reproduced in part from Corotis and Doshi, 1977; Chalk and Corotis, 1980; and Harris *et al.*, 1981 by permission of the American Society of Civil Engineers]

Basic data			
• Typical influence area	A_I	18.6 m^2	(200 ft^2)
• Typical design life	T	50 years	
Instantaneous uniformly distributed sustained load (arbitrary-point-in-time load)	L		
• Mean	μ_L	0.53 kPa	(10.9 $\mathrm{lbf/ft}^2$)
• Standard deviation	σ_L	0.37 kPa	(7.6 $\mathrm{lbf/ftt}^2$)
• Average number of occupancy changes per year	ν_o	0.125	
• Expected occupancy duration (years)	$E(\tau) = 1/\nu_o$	8	
Instantaneous uniformly distributed extraordinary live load	L_{e1}		
• Mean	μ_{e1}	0.39 kPa	(8 $\mathrm{lbf/ft}^2$)
• Standard deviation	σ_{e1}	0.40 kPa	(8.2 $\mathrm{lbf/ft}^2$)
• Average number of extraordinary live load occurrences per year	ν_e	1	
*Theoretically derived values**			
Maximum sustained load	L_S		
• Mean	μ_{L_S}	1.21 kPa	(24.9 $\mathrm{lbf/ft}^2$)
• Standard deviation	σ_{L_S}	0.33 kPa	(6.9 $\mathrm{lbf/ft}^2$)
Lifetime maximum extraordinary load	L_e		
• Mean	μ_{L_e}	1.79 kPa	(36.7 $\mathrm{lbf/ft}^2$)
• Standard deviation	σ_{L_e}	0.41 kPa	(8.4 $\mathrm{lbf/ft}^2$)
Simulated values for combinations			
• Case I $L_S + L_{e1}$ (occurrence rate, 30%)	Mean	2.50 kPa	(51.2 $\mathrm{lbf/ft}^2$)
• Case II $L + L_e$ (occurrence rate, 41%)	Mean	2.40 kPa	(49.1 $\mathrm{lbf/ft}^2$)
• Case III $L_S + L_e$ (occurrence rate, 17%)	Mean	2.79 kPa	(57.2 $\mathrm{lbf/ft}^2$)
• Other (occurrence rate, 12%)	Mean	2.15 kPa	(44.2 $\mathrm{lbf/ft}^2$)

$1\,\mathrm{kPa} \equiv 1\,\mathrm{kN/m}^2 \approx 20.5\,\mathrm{lbf/ft}^2$.

* simulated values agree reasonably closely.

From Melchers