REC2012, BRNO JUNE 13-16, 2012

SIMULTANEOUS LOADS IN STRUCTURAL DESIGN

T. POUTANEN
TAMPERE UNIVERSITY OF TECHNOLOGY
www.tut.fi/rtek/poutanen/en

SUMMARY

1. THE CURRENT THEORY:
   THE ABSTRACTION SIMULTANEOUS LOADS IS MISSING
   LOADS ARE STOCHASTIC AND COMBINED INDEPENDENTLY
   (NOT CONSISTENTLKY APPLIED)

2. LOADS ARE SIMULTANEOUS,
   IF THEY ARE ACTIVE AT THE SAME TIME.
   G – *G* AND *G* – *Q* LOADS ARE SIMULTANEOUS
   Q – *Q*, IF DISTRIBUTIONS ARE DEFINED APPROPRIATELY.

3. SIMULTANEOUS LOADS ARE COMBINED DEPENDENTLY
   10 ARGUMENTS PRESENTED

4. CONCEQUENCES

INCONSISTENCIES

- PERMANENT LOADS *G* + *G* ARE INDEPENDENT
  BUT COMBINED ALWAYS DEPENDETLY

- PERMANENDT AND VARIABLE LOAD *G* + *Q*
  COMBINED DEPENDENTLY OR INDEPENDENTLY
  - Rule 6.10 of Eurocode is dependent
  - Rules 6.10a,b and 6.10a,mod are independent
  - The serviceability combination is made dependently

- VARIABLE LOADS *Q* + *Q* COMBINED SEMI-DEPENDENTLY OR DEPENDENTLY

SIMULTANEOUS LOADS

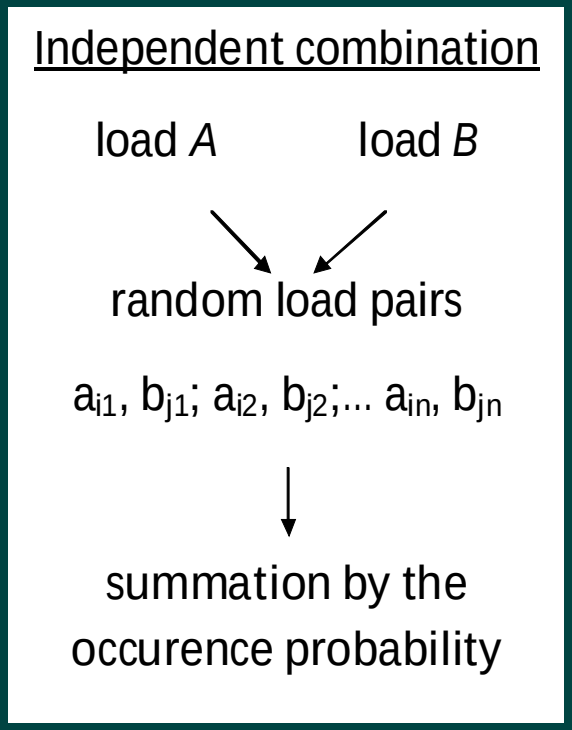
- TWO LOADS ARE SIMULTANEOUS IF THEY ARE ACTIVE WITH ONE ON THE OTHER AT THE REFERENCE TIME
- *G* – *G* and *G* – *Q* ARE ALWAYS SIMULTANEOUS
- *Q* + *Q* ARE SIMULTANEOUS IF THE DISTRIBUTIONS ARE DEFINED APPROPRIATELY
- LOADS ARE ALWAYS COMBINED DEPENDENTLY

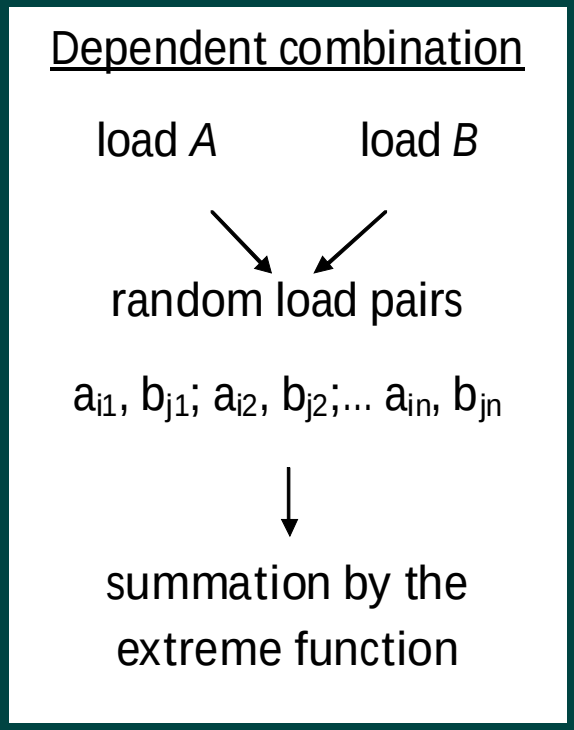
REASONS FOR DEPENDENT COMBINATION

1. EXTREME DISTRIBUTION
2. EQUALITY EQUATION
3. *G* AND *Q* ARE DEPENDENT IN 50 YEARS
4. LINEARITY AND HOOK'S LAW
5. LOAD VANISH
6. EVEN RELIABILITY
7. LOADS ACT INDEPENDENTLY
8. MANY LOADS
9. PROPORTIONS OF ANOTHER LOAD
10. DEPENDENT COMBINATION IS CONSISTEND IN ALL CASES

EXTREME DISTRIBUTION

- DISTRIBUTIONS MUST BE THE EXTREME DISTRIBUTIONS
- INDEPENDENT DISTRIBUTION IS A PROBABLE SUM OF LOADS





EQUALITY EQUATION

- THE BASIC DESIGN EQUATION IS

$$\gamma_G \cdot G + \gamma_Q \cdot Q \leq \frac{M}{\gamma_M}$$

- THE EQUALITY EQUATION MAKES A FULL CORRELATION AND DEPENDENCE BETWEEN *G* AND *Q* AS *M* IS CONSTANT

LINEARITY, HOOK'S LAW

- "ACTION – EFECT RELATION IS LINEAR"
- RULE 6.10a,mod: LOAD INCREASES WITHOUT EFFECT

load case	loads		CDI [%]	
	G	*Q*	dependent	independent
1	1	0	100	100
2	0	1	100	100
3	0.4	0	40	40
4	0	0.4	40	40
5	0.2	0.2	40	37.28

- THE INDEPENDENT COMBINATION CONTRADICTS LINEARITY AND HOOK'S LAW

LOADS ACT INDEPENDENTLY

- ASSUME $G = Q = 1$ (kN/m^2) RESULT IN EFFECT 1 (N/mm^2) WHEN THE LOADS ACT ALONE
- THE EFFECT IS 2 (N/mm^2) WHEN THE LOADS ACT TOGETHER
- IF THE LOADS ARE COMBINED INDEPENDENTLY THE EFFECT IS CA 1.8 (N/mm^2)

G AND *Q* ARE DEPENDENT IN 50 YEARS

- *G* AND *Q* ARE INDEPENDENT DURING ONE YEAR BUT DEPENDENT DURING 50 YEARS
- ALL *Q* VALUES (< 0.98 FRACTILE) OCCUR IN 50 YEARS
- WHICHEVER THE *G* - VALUE AND ITS THE FRACTILE (< 0.98) IS THERE IS A *Q* - LOAD AT THE SAME FRACTILE.
  THEREFORE THESE LOADS ARE CORRELATED AND MUST BE COMBINED DEPENDENTLY.

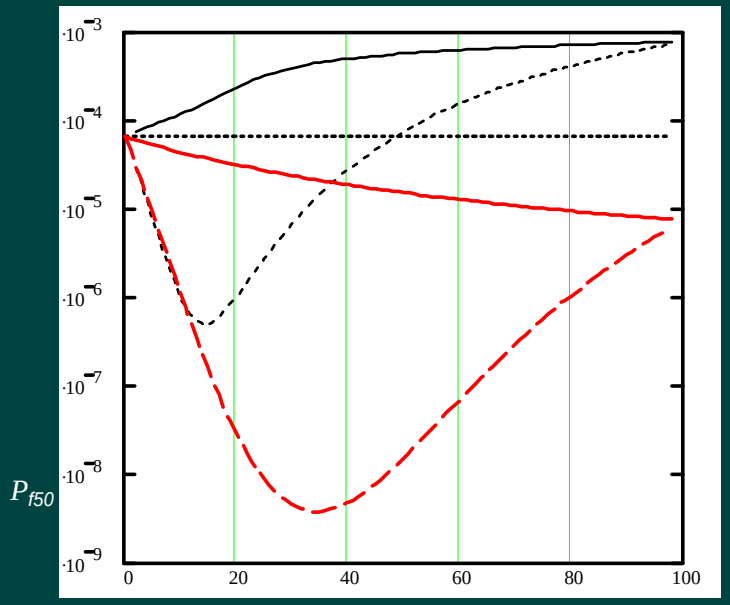
MANY LOADS

- IN THE INDEPENDENT COMBINATION EACH NEW LOAD DECREASES THE TOTAL SAFETY
- IN A MULTY STOREY HOUSE THERE IS VIRTUALLY NO PERMANENT LOAD AND IMPOSED LOAD SAFETY IF THE LOADS ARE COMBINED INDEPENDENTLY

EVEN RELIABILITY

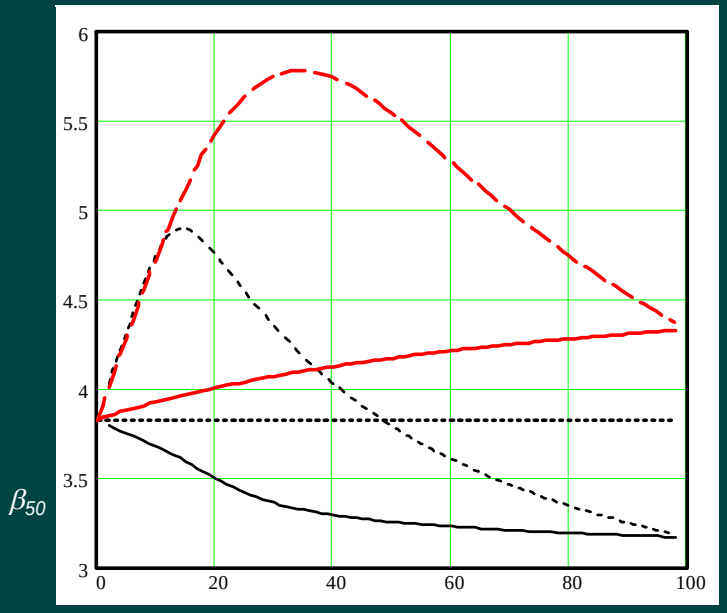
EUROCODE P_f AND β_{50} : γ_G = 1.35, V_G = 0.0915, γ_Q = 1. 5, V_G = 0.4, V_M = 0
SOLID LINES DEPENDENT; DASHED INDEPENDENT

BLACK LINES GUMBEL; RED NORMAL



PERMANENT LOAD

VARIABLE LOAD



PERMANENT LOAD

VARIABLE LOAD

DEPENDENT COMBINATION

- THE DEPENDENT COMBINATION IS CONSISTENT IN ALL CASES

CONCEQUENCES

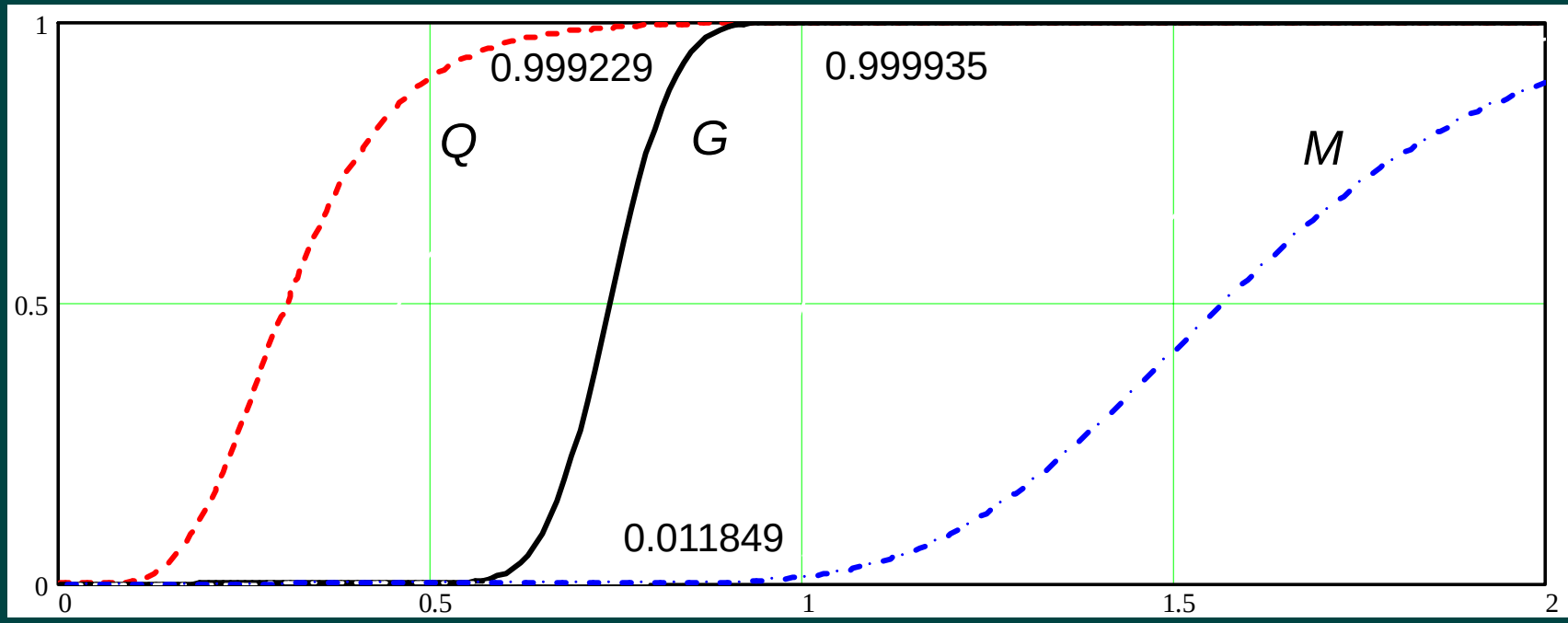
- THE CURRENT RELIABILITY MODEL IS UP TO CA 20 % UNSAFE
- LOAD COMBINATION RULES WITH TWO PERMANENT LOAF FACTORS MUST BE DELETED E.G. 6.10a,b and 6.10a,mod OF EUROCODE
- THE CURRENT PARTIAL SAFETY FACTOR CODES $\gamma_G \neq \gamma_Q \neq 1$ ARE INDUCED FROM THE INDEPENDENT LOAD COMBINATION
  IF $\gamma_G = \gamma_Q = 1$ AN EQUAL RELIABILITY IS OBTAINED
  F $\gamma_G = \gamma_Q = 1$, WITH VARIABLE γ_M ACCURACY IS FAR BETTER
- ψ_0 - FACTORS ARE NORMALLY TOO LOW,
  SNOW AND IMPOSED LOAD $\psi_0 = 1$

THANK YOU FOR YOUR ATTENTION

www.tut.fi/rtek/poutanen/en

Current Eurocode without safety factors

β = 3.83, G 30%, Q 70 %, V_M = 0.2



Eurocode changed to a total safety code

β = 3.83, G 30%, Q 70 %, V_M = 0.2