Background to the methodology in EN 14081

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Introduction

- Calculate the settings on the basis of the machine prediction, rather than the accuracy of the transducers
- Apply the « optimum ranking method » for the determination of the theoretical grade
- Evaluate the difference between actual and theoretical grades on a safety basis
- Minimize the test sample by using special statistical procedures
- Use the same concept for repeatability

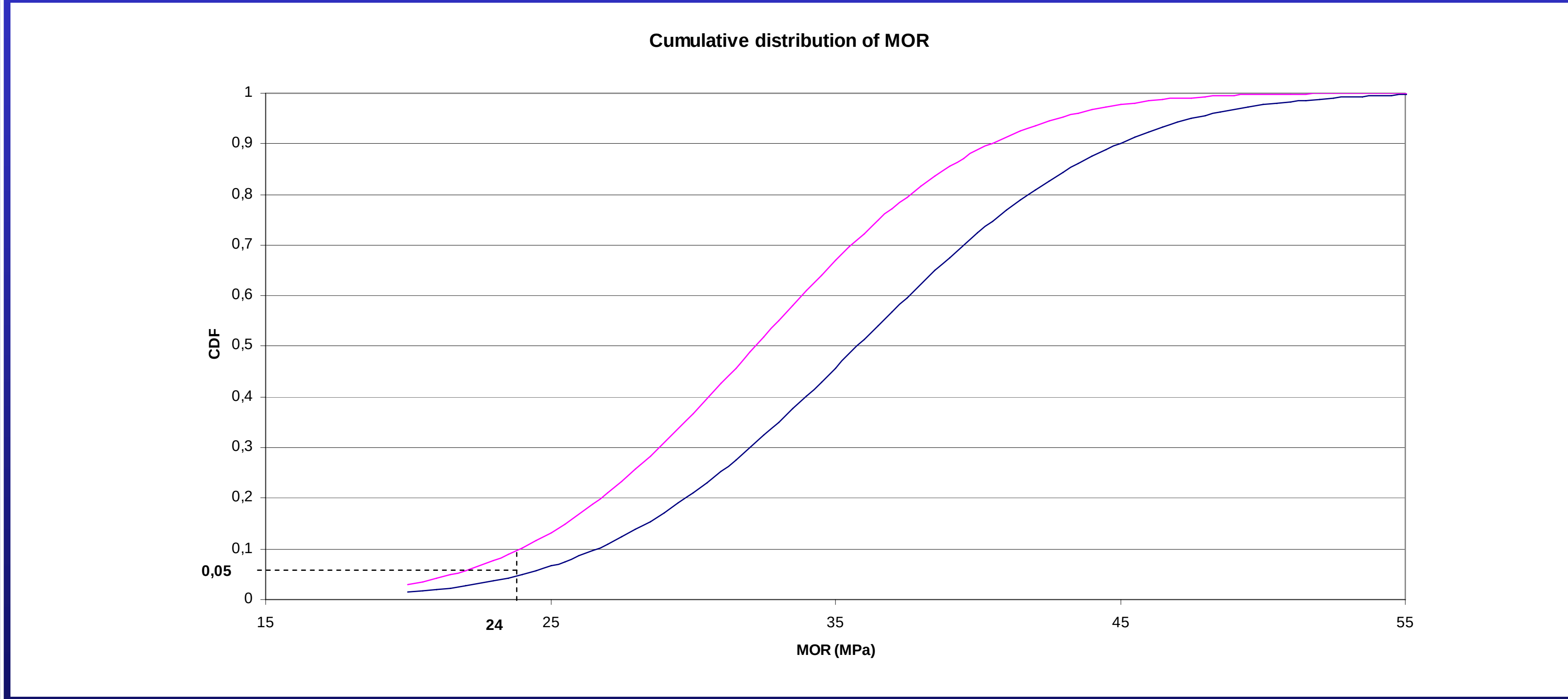
How to estimate the machine prediction

- Do not look at the sensing devices
  - A poor sensing device can be efficient if the required grades are few and low
  - A good sensing device can behave badly if the required grades are numerous and high
- Look at the grade output, which depends on:
  - The machine sensing devices
  - The choice of the grades
  - The statistical method which produces the grade settings
- Give a theoretical prediction of the grade based on the ranking method

Optimal ranking method

- Grades are defined by statistical fractiles
  - Mean MOE
  - 5% MOR and density
  - ➔ work on a sample
- An optimum grade assignment can be made on a individual piece, if this assignment is such that the optimum grade sub sample meets the requirements
- Iterative process for each property and for each grade, FROM THE HIGHEST GRADE

Optimal ranking procedure



Calculations for fractiles

- Compared with an optimum grade (with target characteristic value x_k), a lower quality sample will have a frequency f_k higher than 5%
- To reach the target value, we must take out the n lowest pieces, given by :

$$n = \frac{N}{1-0.05}\left(f_k - 0.05\right)$$

Calculations for mean : iterative

- From j=0 to N

$$\mu(X) = \frac{\sum_{i=1}^{N-j} X_i}{N-j}$$

Examples

	Species					
Strength class	*Spruce & Fir*		*Douglas Fir*		*Maritime Pine*	
	Visual	*Optimum*	*Visual*	*Optimum*	*Visual*	*Optimum*
C30	10	65	10	80	-	60
C24	50	-	10	10	-	15
C18	10	30	20	5	50	5
Reject	30	5	60	5	50	20

Procedure

- Select 900 pieces
- Get their indicating properties (e.g. machine E_{flat})
- Break them (bending or tension)
- Knowing MOR, MOE, density for the pieces, rank them into the target grades, in such a way that fractiles are OK and the yields are maximized for the top grades. For each piece, this grade is called the « optimum grade ».
- Build the regression model and the settings, to get the « assigned grade ».
- If both grades are not the same, use the penalty factors further described.

Penalty for upgrading : loss of reliability level

- If we assume a given grade (the assigned grade), we design according to a target reliability level (3.0)
- If the real grade (the optimum grade) is lower, the real reliability level will be lower
- The penalty is the difference between the safety indexes

Elementary cost matrix : penalty for upgrading

- For a sample, the failure function is :

$$G = f_m - S$$

- Assuming S deterministic, the Cornell safety index is :

$$\beta(f_m) = \frac{\mu_G}{\sigma_G} = \frac{f_{m,mean} - S}{cv.f_{m,mean}}$$

- Assuming $\beta(f_{m,ass})=3$, the cost is given by :

$$Cost = 10\left(3 - \beta\left(f_{m,opt}\right)\right)$$

- The mean values can be calculated from the characteristic values assuming lognormal distributions and cv = 30%

Numerical example

- Optimum grade : C24

$$f_{m,mean,opt} = 41.2\,MPa$$

- Assigned grade : C40

$$f_{m,mean,ass} = 68.6\,MPa \Rightarrow S = 6.86\,MPa$$

- Real safety index :

$$\beta\left(f_{m,opt} \right) = 2.778 \Rightarrow Penalty = 2.22$$

Elementary cost matrix : cost for downgrading is economical loss

$$Penalty = \sqrt[3]{\frac{E_{opt}}{E_{ass}}}$$

since

$$\delta = \frac{\alpha P L^{\beta}}{E b h^{3}}$$

Example :

Opt : C40 ➔ E = 14 and Ass : C24 ➔ C24

Penalty = 0.8

Elementary cost matrix (c_{ij})

Optimum grade	**Assigned grade**											
	C50	C45	C40	C35	C30	C27	C24	C22	C20	C18	C16	C14
C50	0	0,22	0,45	0,72	1,01	1,16	1,33	1,69	1,9	2,11	2,6	3,17
C45	0,37	0	0,23	0,49	0,77	0,92	1,09	1,45	1,64	1,85	2,33	2,89
C40	0,83	0,42	0	0,25	0,53	0,68	0,84	1,19	1,38	1,59	2,05	2,6
C35	1,43	0,95	0,48	0	0,27	0,42	0,57	0,91	1,1	1,3	1,76	2,29
C30	2,22	1,67	1,11	0,56	0	0,14	0,29	0,63	0,81	1,01	1,45	1,97
C27	2,84	2,22	1,6	0,99	0,37	0	0,15	0,48	0,66	0,85	1,29	1,8
C24	3,61	2,92	2,22	1,53	0,83	0,42	0	0,32	0,5	0,69	1,12	1,63
C22	4,24	3,48	2,73	1,97	1,21	0,76	0,3	0	0,17	0,36	0,77	1,26
C20	5	4,17	3,33	2,5	1,67	1,17	0,67	0,33	0	0,18	0,59	1,07
C18	5,93	5	4,07	3,15	2,22	1,67	1,11	0,74	0,37	0	0,4	0,87
C16	7,08	6,04	5	3,96	2,92	2,29	1,67	1,25	0,83	0,42	0	0,46
C14	8,57	7,38	6,19	5	3,81	3,1	2,38	1,9	1,43	0,95	0,48	0

End of the procedure

Size matrix (S_{ij})

Optimum grade	Assigned grade			
	C35	C27	C22	Reject
C35	207	32	16	2
C27	10	168	12	1
C22	4	13	84	2
Reject	0	2	2	24

Global cost matrix (Gij)

Optimum grade	Assigned grade			
	C35	C27	C22	Reject
C35	0	0,06	0,13	0,2
C27	**0,04**	0	0,05	0,08
C22	**0,04**	**0,05**	0	0,13
Reject	**0**	**0,04**	**0,05**	0

$$G_{i,j} = \frac{S_{i,j} c_{i,j}}{\sum_i S_{i,j}} < 0.2 \text{ (magic number!!)}$$

Adaptations to the original method

- If the sample in total meets the lowest grade (ie no reject), include some weak material
- If not possible (the grade is too low), calculate the grade settings as 5% of the sample

Crossed validation method : to reduce the settings

- Stratify the sample into n sub-samples
- Take (n-1) samples to calculate the settings, keep the last one to check it
- Do this n times
- The production settings are the mean values of the n calculations, except if the least conservative sample is less than 15% from this mean, in which case we take it as the production settings

Repeatability : same concepts

- A sample of 100 pieces is selected
- Each piece is passed 5 times
- The grades are fictitious
  - They are as many as the real grades
  - They must divide the sample into equal sub samples
- For each piece, the optimum grade is the most frequent grade
- The assigned grade is the grade of the pass
- Penalty factors of the elementary cost matrix are equal to the number of grades between the assigned and the optimum grade
- In the global cost matrix, no cell value lower than 0,1

Conclusions

- Seems complex, but efficient
- Based on statistical AND engineering concepts
- Has been calibrated

- Questions ?