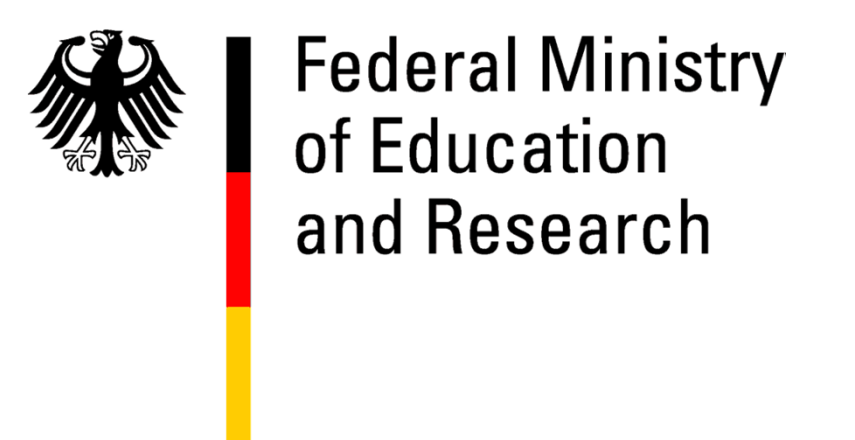


DERIVATION OF QUALITY SPECIFICATIONS OF GLASS BY PROBABILISTIC EVALUATION OF MECHANICAL MODULE RELIABILITY

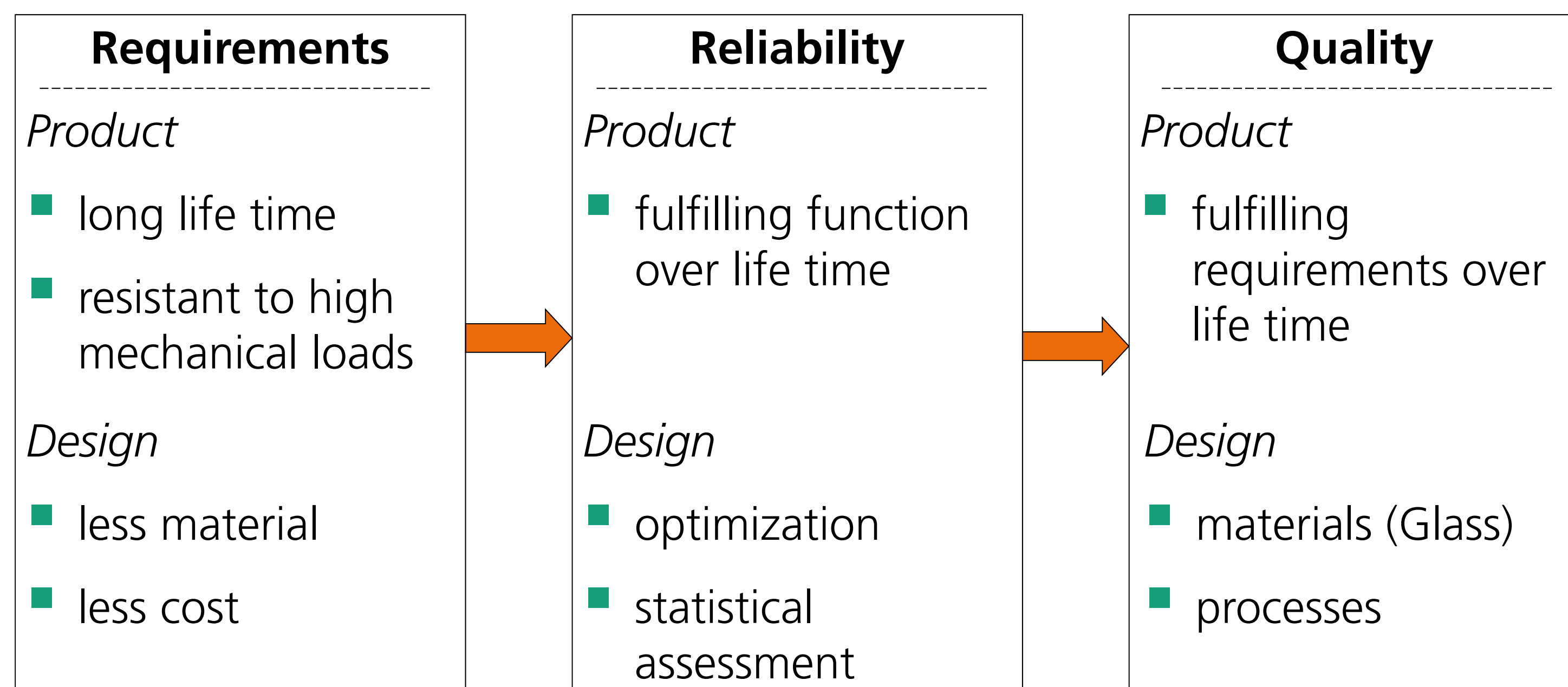
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Motivation



Experiments

- Ring on ring strength test according to DIN 1288-5
 - test of surface (edges excluded)
 - size of specimens 100 x 100 mm²
 - Result: fracture strength
- Weibull statistics for strength evaluation
- Several batches of float glass were tested
- Significant differences of char. strength and scatter
 - Strength values can differ from batch to batch not only from manufacturer to manufacturer

- Questions:
- Influence on module reliability?
 - How to design "on the brink" with lowest material consumption?
 - What quality of glass is required?
 - Safety factor?

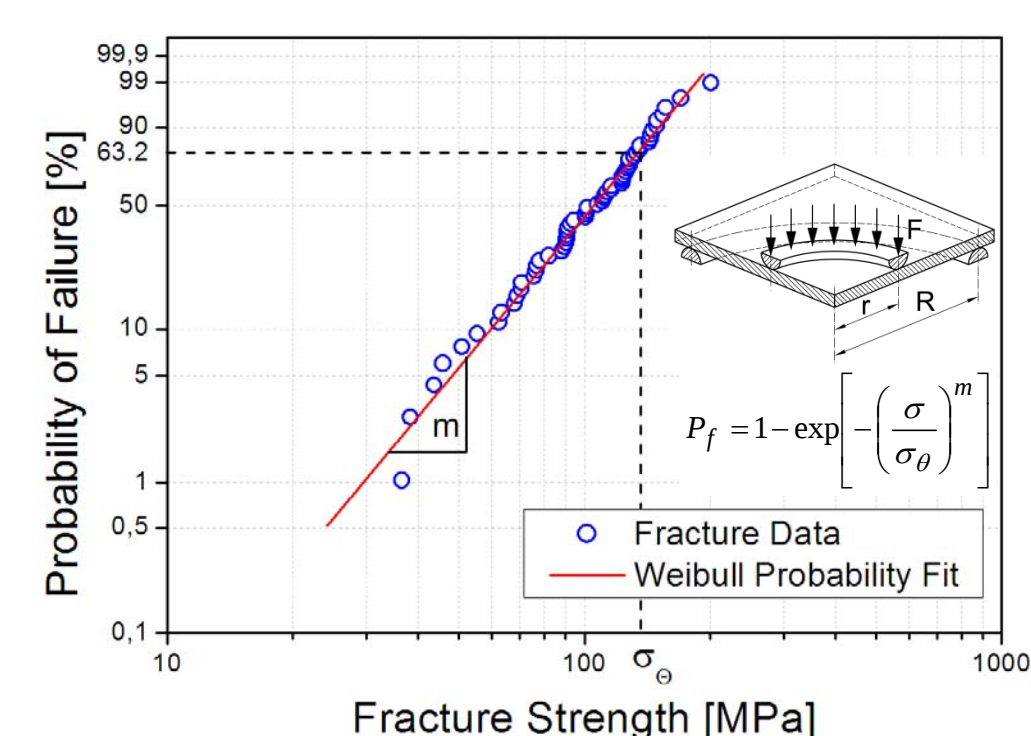


Fig. 1: Weibull probability plot + ring on ring test setup

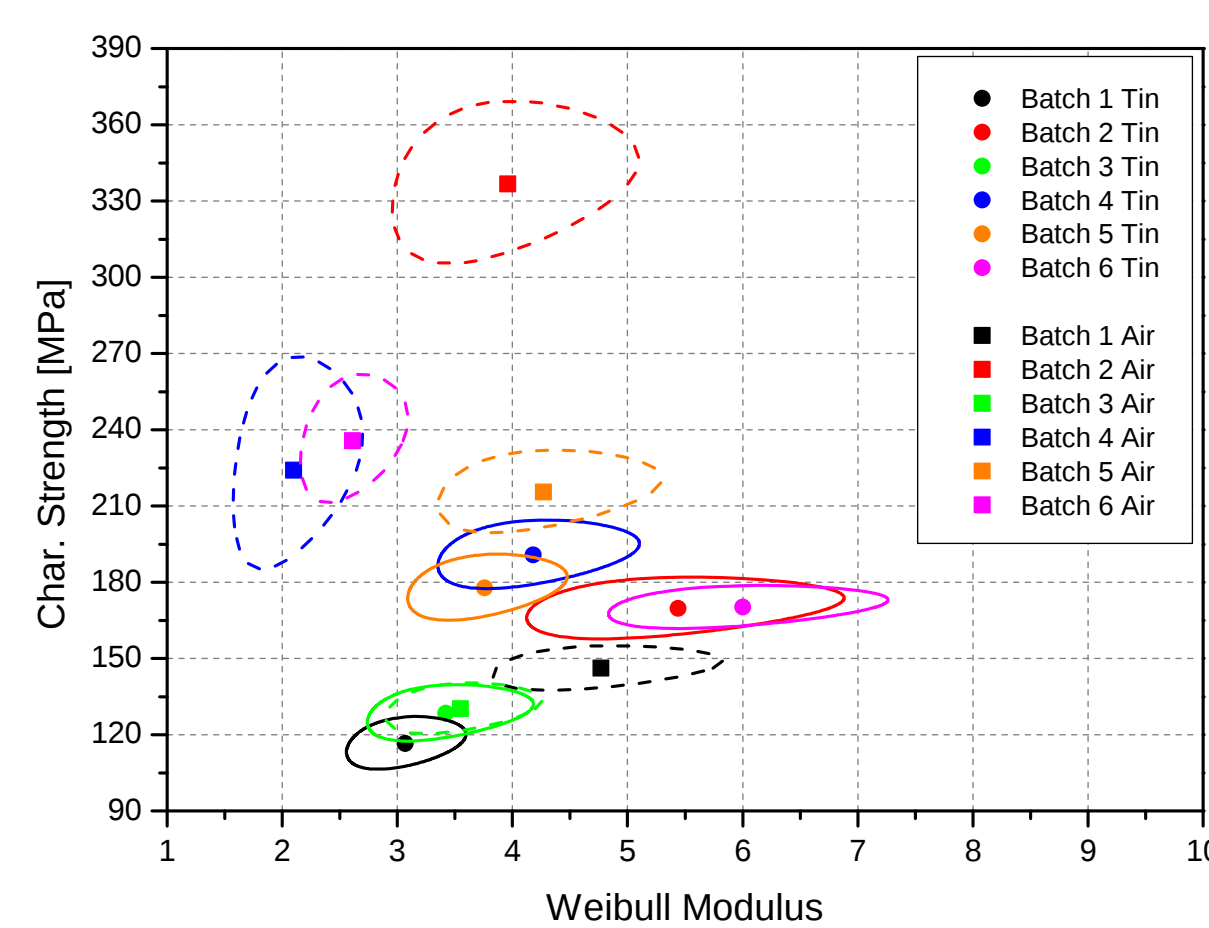


Fig. 2: Strength values and confidence rings for several glass batches (both sides tested)

Numerical Simulations

- Numerical simulation of 2400 Pa static pressure load → principle stress field
- 4 common types of mounting
- size of module: 1200 x 600 mm²
- double glass setup

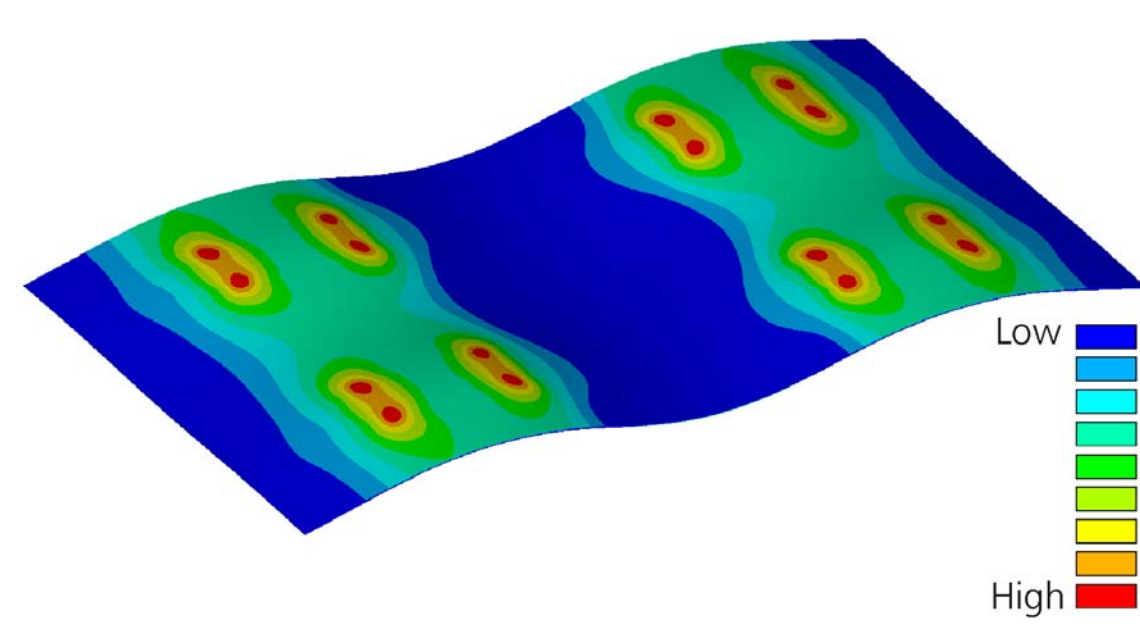


Fig. 3: 1st principle stress for mounting V4 – top view (2400 Pa pressure)

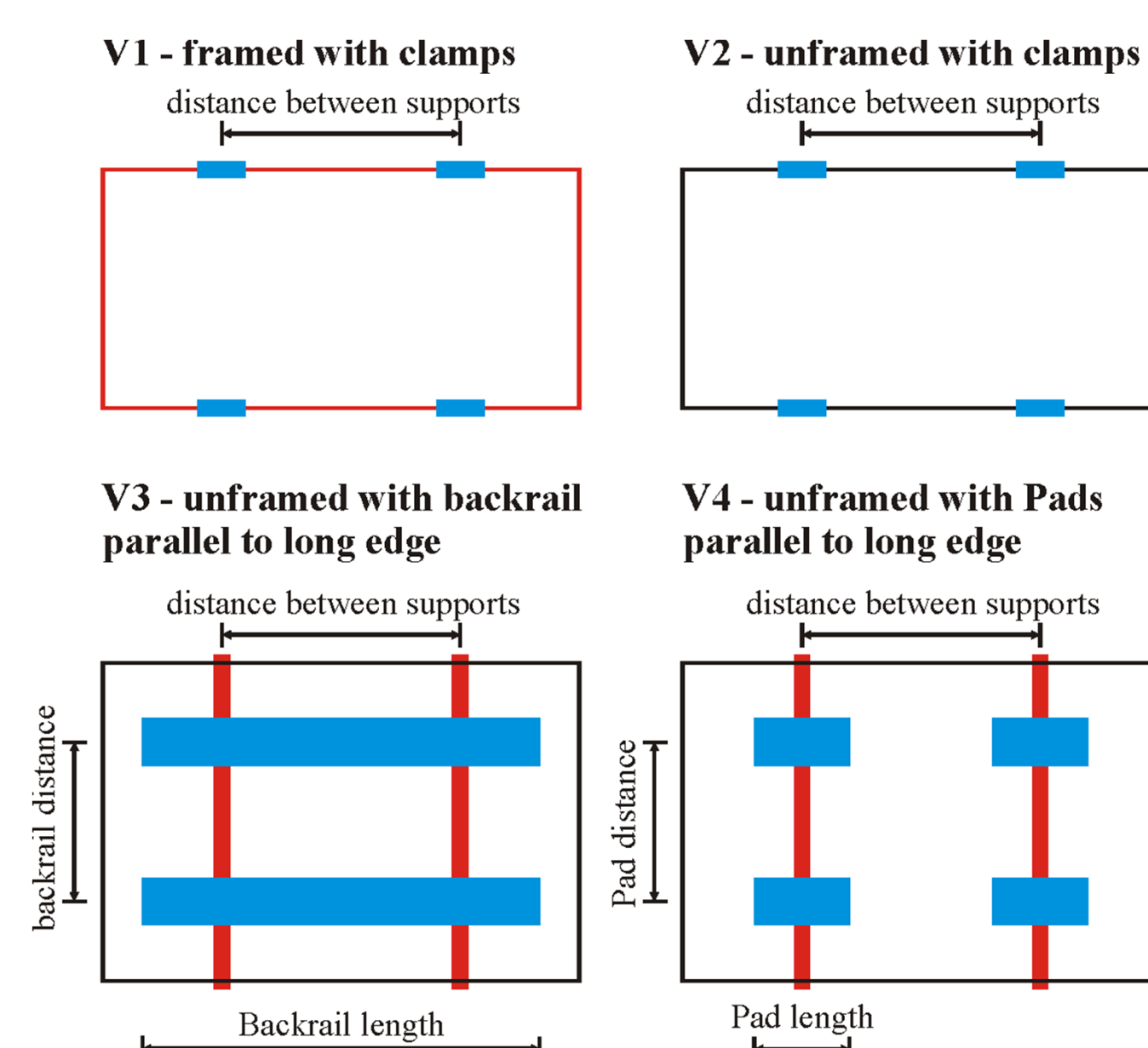
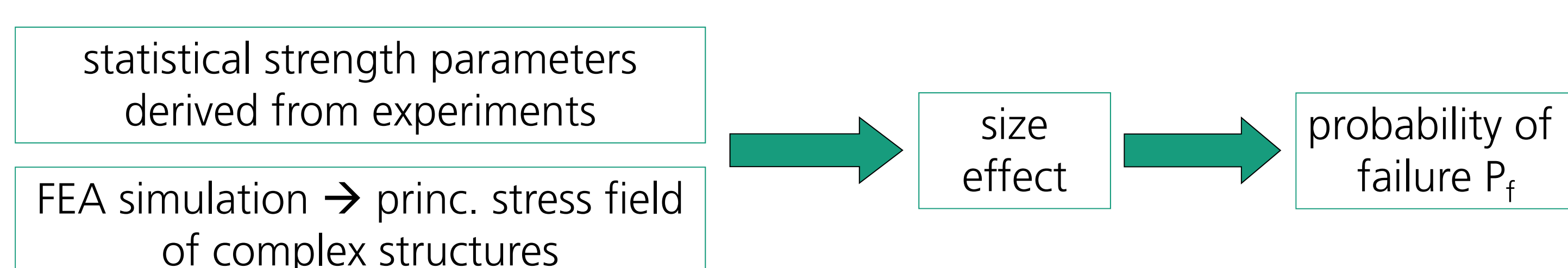


Fig. 4: Mounting concepts for PV modules

Reliability Evaluation



Studies in Module Design

- Evaluation of probability of failure shows magnitude of differences of mounting types

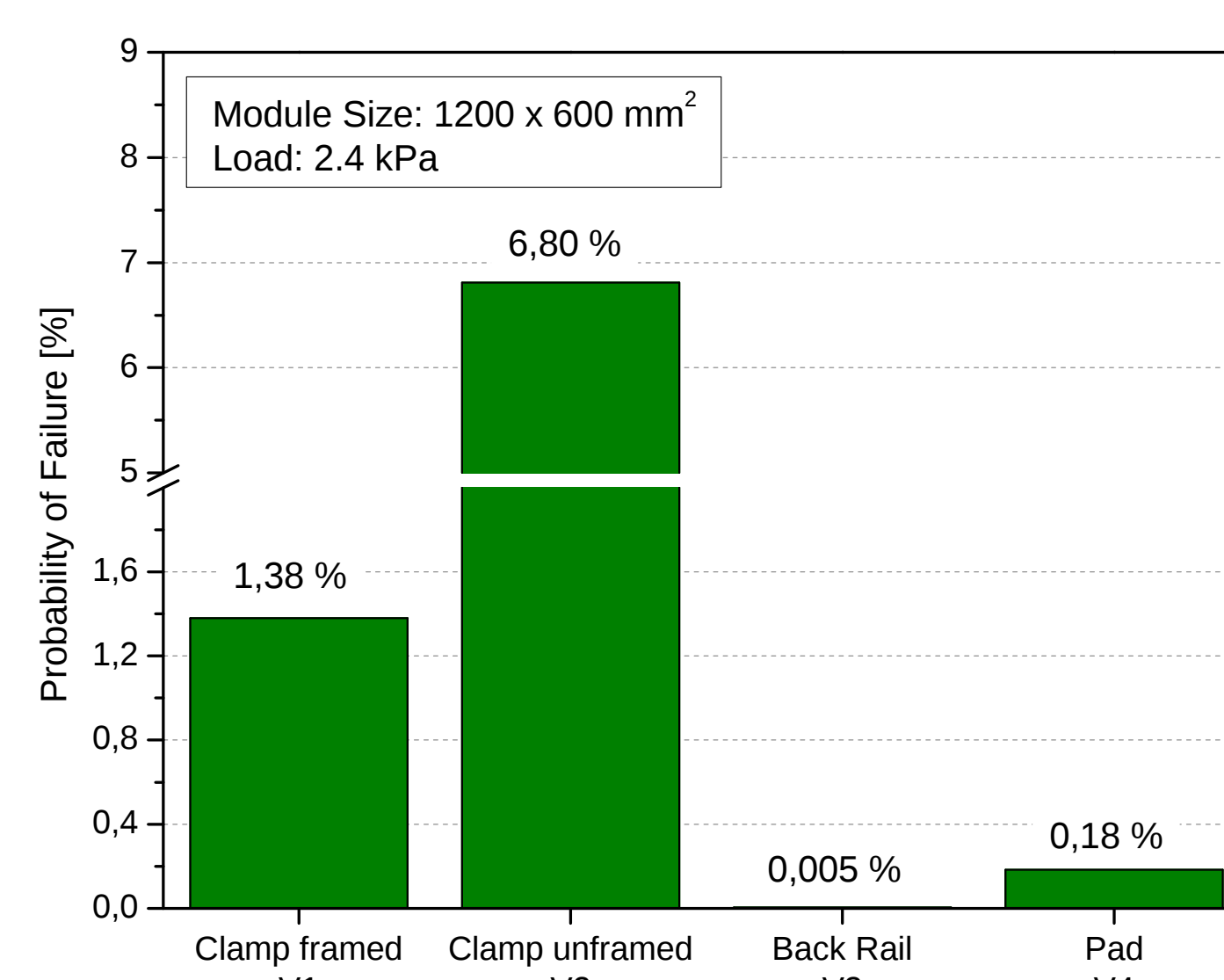


Fig. 5: Probability of Failure for several types of mounting (Batch 5)

- Large influence of material quality on probability of failure

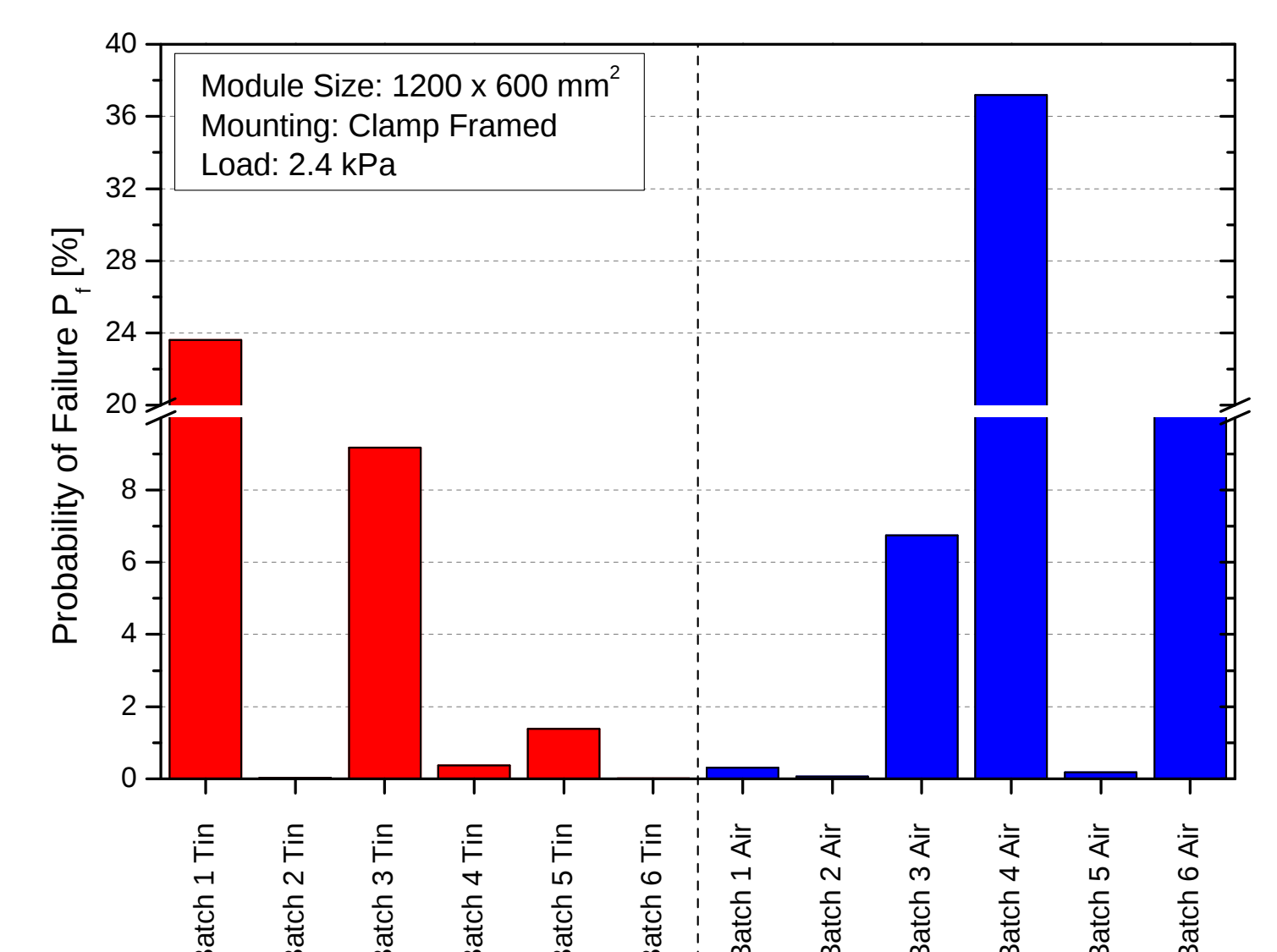


Fig. 6: Probability of Failure of different material strength qualities (mounting V1)

Reliable Design and Quality of Glass Strength

- Large differences between batches of glass lead to uncertain reliability of module designs.
- Module design, mounting and scattering of glass quality should be incorporated in a proper design concept.

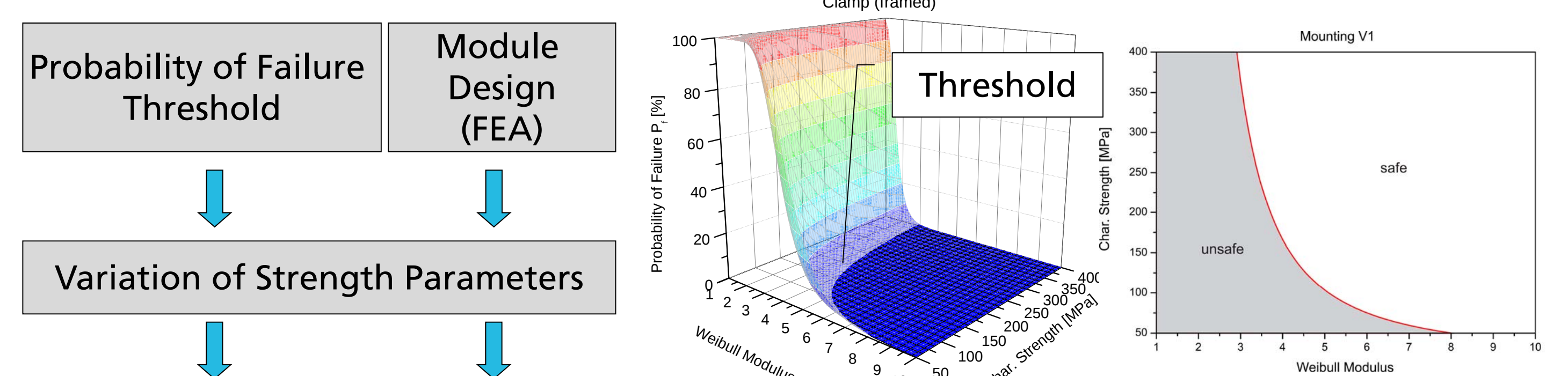
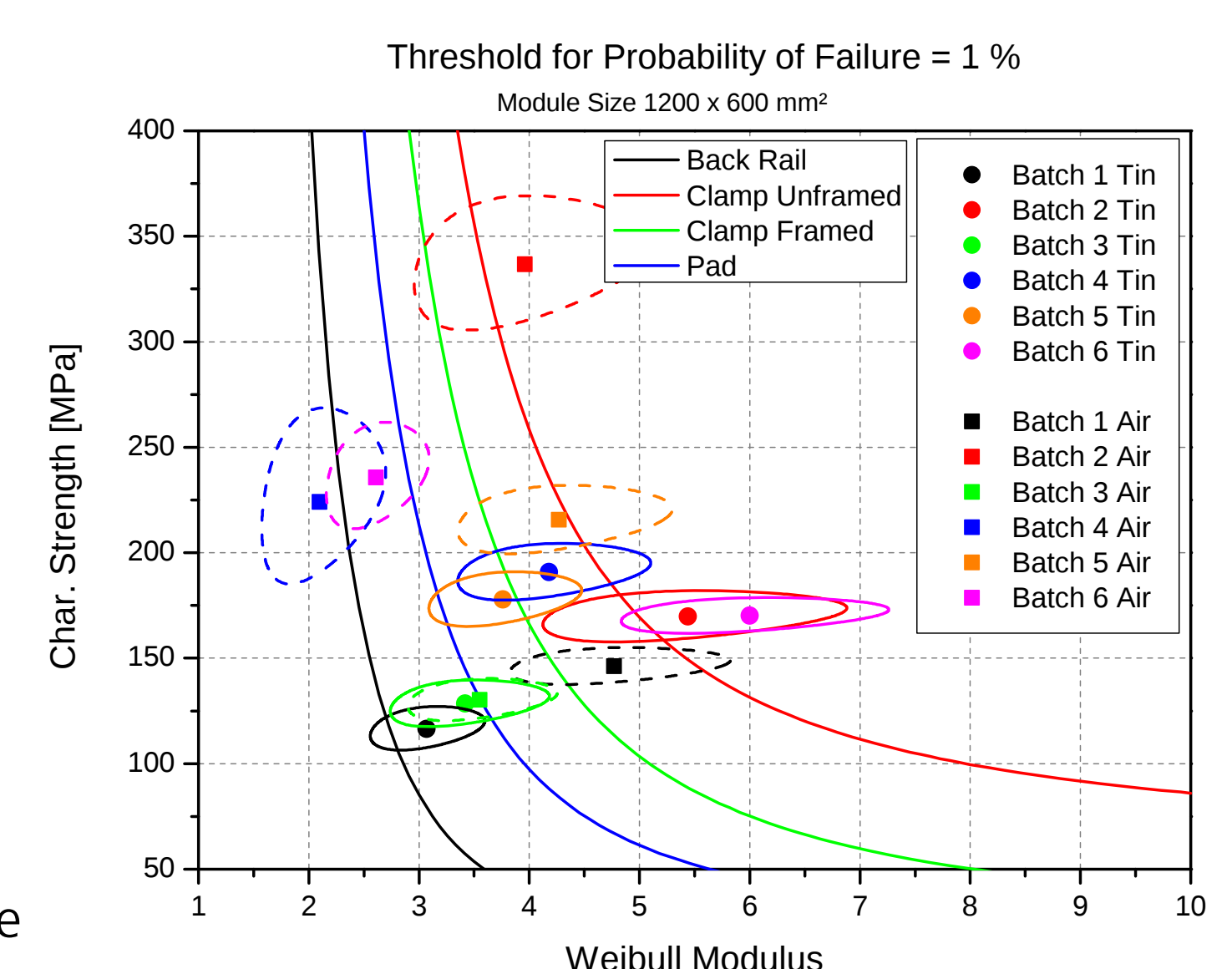


Fig. 7: Surface for probability of failure (P_f) for a variation of strength parameters + setting a threshold value for $P_f = 1\%$ (left); projected curve at $P_f = 1\%$ (right)

- Combination of module design + Finite Element Analysis + variation of strength parameters leads to threshold curve, which can be used as a definition for **glass quality**.
- Different mounting designs lead to different positions of this curve.

Fig. 8: Threshold curves for glass strength at $P_f = 1\%$ for several mounting setups left of curve unsafe, right of curve safe



Conclusion

- Evaluating the mechanical design of PV modules and mounting concepts by a probabilistic approach can give new and exclusive answers on reliability
- Material strength for different batches of glass can differ widely, which leads to shifting reliability of module and mounting designs
- Strength evaluation of glass should be introduced in a QA-system

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