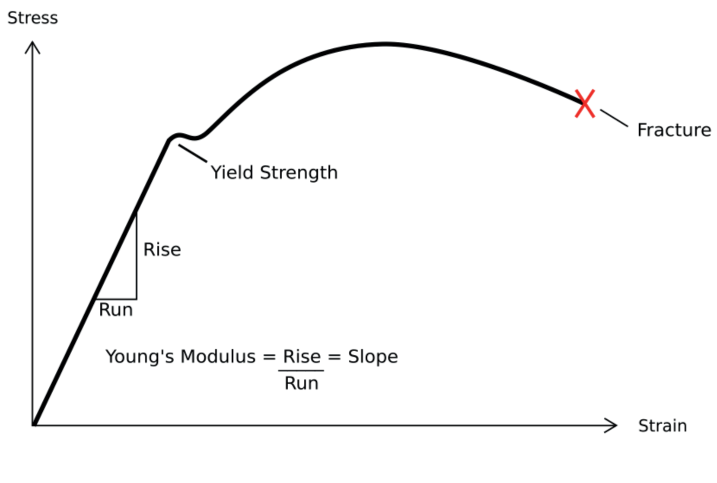
Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon

The working group WG2 of the Technical Committee TC139 of CEN (European Committee for Standardization) is working on the final adjustments to a new standard that describes a test method for the determination of the tensile properties of free coating films.
From the films produced with the application of the coatings, specific specimens (with a "bone" shape) are obtained which are then tested to determine the mechanical properties of the film.
From the analysis of the results obtained with a series of tests carried out on different coating samples, a lack of univocity in the interpretation of the data seems to emerge. This article is intended to present some considerations derived from the experience carried out at our Institute.

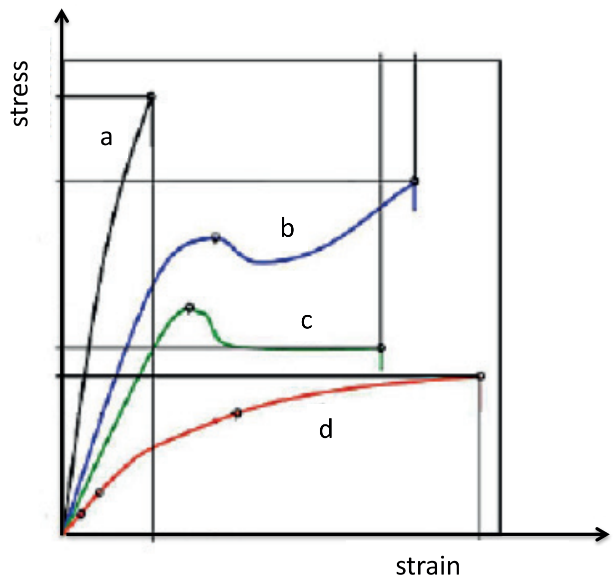
For a long time, CATAS together with the German laboratory WKI of Braunschweig, has developed and applied a common product certification for the coating systems for wood elements for exterior use. Such certification contains, rules, testing methods and requirements that are shared by the two institutes.
The two bodies have interestingly share their knowledge to organize and propose this certification to the market, and among the methods proposed by the WKI, there was also the evaluation of the coating film extensibility based on an internal procedure.
Despite some technical aspects of the method to be improved and the difficult interpretation of the results, the method had been included in the certification rules. Given the use over time of this procedure and the constant assessment of its potential and critical parts, the method has been also considered by CEN (European Committee for Standardization). Today the document is in its final version and consequently everything concerning the procedure can be considered already established even if the discussion about the interpretation of the results seems to persist.
Before analysing in detail some aspects of this method, it is useful to give a few hints about the tensile test theory.



Graph 1.

Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon



Graph 2.

The mechanical characteristics of every material can be evaluated through a stress/strain curve.
A material subjected to tensile test can provide a different curve depending on its ductility.
Graph 1 represents a typical situation of deformable material which can be, for example, a polymer.
Graph 2 compares different materials: the curve "a" represents, for example, a rigid material (e.g.: ceramic, glass), the curves "b" and "c" can represent plastic materials; the curve "d" is typical of elastomers.

With regard to coatings, a distinction must be made between the assessment of elasticity and the fracture point. The fracture point is normally considered the final result of the test, (see graph 1), but on our opinion it does not really represent the elasticity of a coating film.
By definition elasticity is, in fact, the property of the material to come back to its original dimensions after the stress ceases.
This property, in the graphs proposed here, can be determined only in the initial part of the stress/strain curve.
The elasticity modulus or Young's modulus, represents the relationship between the stress and the deformation in this section of the curve (the slope) and is expressed in MPa.

Considering that we are dealing with wood coatings, every assessment and consideration on their deformation should be done in combination with the movements of wood which represents the substrate on which they are applied.
Let's then consider the following (severe) example:
A wood element (100 mm wide), produced with a tangential cut, undergoes a variation of its moisture content of 10%.
Considering a coefficient of variation equal to 0.4% for each moisture point absorbed or released by wood, we obtain a global movement of 4 % which represents a deformation of 4 mm.

Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon

It seems consequently that a doubt arises regarding the choice to consider the elongation at break as a result of the tensile test. Why should we consider the last part of the curve, where, speaking about waterborne paints, the deformation normally reaches and exceeds 100% and why not focus our attention on the first part of the curve?

So, after such consideration, should we need to re-consider the requirements of the test? Probably yes. In fact, what the standardization group would like to presumably study and keep under control is the phenomenon of film breaking, which may occur over time, to try to limit and prevent it.
If this is the goal, we would also need to age the film, to evaluate the differences between the initial state and its differences suffered after weathering.
In our Institute we have addressed this issue, given the importance that the definition of requirements has for our certification.
Table 1 shows the results of various exterior top coatings: semi-transparent and opaque (all white top coats).
The results of the modulus of elasticity and the elongation at break were compared, both before and after an artificial ageing trial carried out with UV lamps.
Ageing was performed by exposing the films to two 168-hour cycles according to EN 927-6.

Sample	Elongation at break (% difference)	Initial elongation at break (%)	Final elongation at break (%)		Young modulus (% difference)	Initial Young modulus (MPa)	Final Young modulus (MPa)	
1	-27	142	103	decreases	34	224	332	increases
2	26	44	55	increases	-25,9	610	452	decreases
3	58	124	197	increases	-38,0	450	279	decreases
4	31	160	210	increases	-22,8	404	312	decreases
5	6	182	194	increases	-27,3	326	237	decreases
6	-9	182	166	decreases	11,5	374	417	increases
7	-4	153	147	decreases	19,1	288	343	increases
8	4	131	137	increases	36,5	197	269	increases
9	-8	233	215	decreases	20,1	227	273	increases
10	-23	131	101	decreases	7,7	386	416	increases
11	-25	117	88	decreases	45	196	285	increases
12	-3,0	101	98	decreases	-9,8	337	304	decreases
13	-36	148	94	decreases	75,6	318	558	increases
14	-2	66	65	decreases	-7,4	386	358	decreases
15	-8	122	112	decreases	-7,5	322	298	decreases
16	15	13	16	increases	-3,2	948	917	decreases
17	16	197	228	increases	-35,0	749	487	decreases
18	-50	134	68	decreases	51,5	365	553	increases

Table 1. Extract of the tensile tests on exterior coating films before and after ageing.

Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon

First of all, a distinction was made between opaque and semi-transparent coating. The opaque paints are identified with the blue colour in the graph.
Starting from the principle that" the higher the percentage elongation at break, the more resistant is the film" and" the higher the Young's modulus, the more rigid is the film", it is interesting to consider that not always ageing causes the stiffening of the film (see samples: 2, 3, 4, 5, 16, 17). In fact, in such cases, the Young's modulus decreases with ageing rather than increasing and, at the same time, the elongation at break increases.
An opposite behaviour was observed for coatings 8, 12 and 14, where both elongation and modulus of elasticity increase while for coatings, 12 and 14 they decrease.
From these data, we could derive that the two-week artificial ageing was not sufficient to properly age the films and that, we would have to continue the exposure, to be able to significantly weather the samples.

Sample	Elongation at break (% difference)	Initial elongation at break (%)	Final elongation at break (%)	Young modulus (% difference)	Initial Young modulus (MPa)	Final Young modulus (MPa)
1	-27	142	103	34	224	332
6	-9	182	166	11,5	374	417
7	-4	153	147	19,1	288	343
9	-8	233	215	20,1	227	273
10	-23	131	101	7,7	386	416
11	-25	117	88	45	196	285
13	-36	148	94	75,6	318	558
18	-50	134	68	51,5	365	553

Table 2. Extract of useful results.

Extrapolating the results useful to us for this activity let's evaluate table 2.
Here, we can immediately derive that the white paints are more sensitive to ageing, because the changes in their mechanical properties are consistent, both in the elastic modulus and in the fracture point.
Considering the semi-transparent coating, we find that samples 1 and 11 are those whose elastic modulus undergoes a greater increase after ageing, which is confirmed by the significant reduction of the fracture point.
Such trends, however, are not confirmed by the other samples (e.g. coatings 10 and 7).

In Table 3, we have summarized all coating tested and we can note that the samples with the highest initial elastic modulus show an elongation at break below the 100% (see, for example, coatings 2, 14 and 16).
Samples 8 and 11 demonstrate a higher elastic behaviour (lower initial Young modules), but their elongation break initially exceeds in both cases the 100%.
Coating 8 loses considerably its initial elasticity after ageing (initial Young's modulus <final), but one could say that it is maintained in terms of elongation at break.

Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon

Sample	Elongation at break (% difference)	Initial elongation at break (%)	Final elongation at break (%)	Young modulus (% difference)	Initial Young modulus (MPa)	Final Young modulus (MPa)
1	-27	142	103	34	224	332
*2	26	44	55	-25,9	610	452
3	58	124	197	-38,0	450	279
4	31	160	210	-22,8	404	312
5	6	182	194	-27,3	326	237
6	-9	182	166	11,5	374	417
7	-4	153	147	19,1	288	343
**8	4	131	137	36,5	197	269
9	-8	233	215	20,1	227	273
10	-23	131	101	7,7	386	416
**11	-25	117	88	45	196	285
12	-3,0	101	98	-9,8	337	304
13	-36	148	94	75,6	318	558
*14	-2	66	65	-7,4	386	358
15	-8	122	112	-7,5	322	298
*16	15	13	16	-3,2	948	917
17	16	197	228	-35,0	749	487
18	-50	134	68	51,5	365	553

Table 3. Data comparison.

Also, the observation of the specimens after the test, besides the graph, can help us to understand the behaviour of the tensile test.
The following photos are explanatory of the tensile properties of films.

In conclusion, the tensile test of coating films is a test whose data must certainly be individually studied.
In this work the comparison between different coatings was useful and this should always be.
At the moment, in my opinion, it is not possible to classify a coating for a single aspect, be it the percentage elongation at break, or the modulus of elasticity, but both must be taken into consideration.
From our study it is also evident that two weeks of artificial ageing are not sufficient to age the film enough permit to evaluate a reduction in elastic performance. Surely, however, when there is a significant stiffening following two weeks post-ageing, the coatings could be classified less lending than others.

Tensile test of free coating films. How to evaluate the test results and which are the limitations of the procedure.

Alessia Matellon

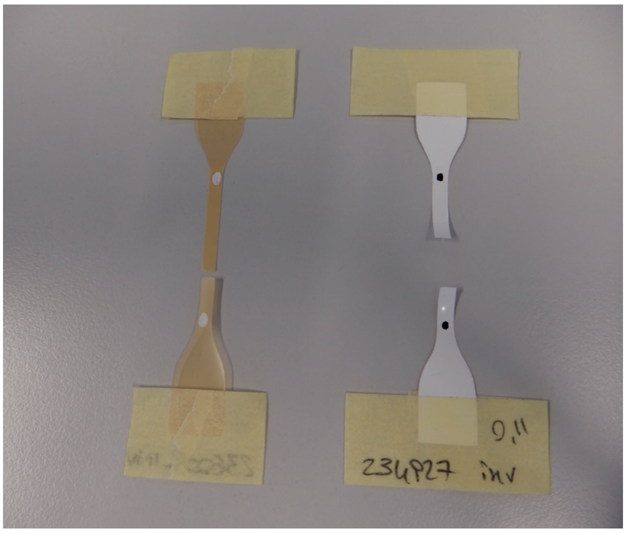


Photo 1. Example of samples with rigid behaviour.

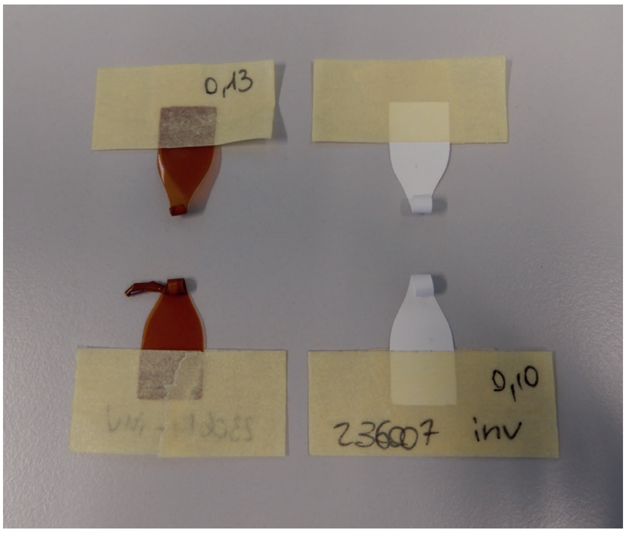


Photo 2. Example of samples with elastic behaviour.

The evaluation of the loss of mechanical performance after ageing, at that point may take longer and become more expensive.

For what concerns the method, moreover, I consider that some aspects of the test cannot be fixed: the speed of test plays fundamental role for the definition of the modulus of elasticity. It cannot be a fixed datum and must be modulated according to preliminary tests on the coating to be tested in order to obtain repeatable data.

At the moment Catas is considering a re-evaluation of the requirements for the elasticity of free films in the certification of outdoor coating systems and has consequently temporarily suspended this feature in the certification rules.

For info:
Alessia Matellon
+39 0432 747232
matellon@catas.com