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LA DURABILITÀ DEI COMPONENTI EDILIZI

THE DURABILITY OF BUILDING COMPONENTS

ediTecnica

La presente pubblicazione riporta i risultati di una ricerca scientifica nazionale (PRIN-2003) su "*Metodologie di progettazione e di valutazione della durabilità dei componenti edilizi in processi di produzione sostenibili, finalizzate alla programmazione della manutenzione degli edifici*" cui hanno partecipato sei unità di ricerca di università italiane: il Politecnico di Milano, il Politecnico di Torino, l'Università degli Studi di Napoli Federico II, l'Università degli Studi di Palermo, l'Università degli Studi di Catania, l'Università degli Studi di Brescia.
La ricerca è condotta in coerenza con quanto si sta sviluppando a livello internazionale nell'ambito dell'International Council for Research and Innovation in Building and Construction (CIB), in particolare nella Commissione CIB W80 Prediction of Service Life of Building Materials and Components, nonché nei correlati lavori dell'ISO TC 59 SC14 per l'elaborazione delle varie parti della norma ISO 15686 "*Service life planning*".
Il lavoro ha portato nel 2006 alla uscita della norma UNI 11156 "*Valutazione della durabilità dei componenti edilizi*" articolata in tre parti: "*Terminologia e definizione dei parametri di valutazione*", "*Metodi per la valutazione della propensione all'affidabilità*", "*Metodi per la valutazione della durata*".
I risultati finora acquisiti costituiscono già un significativo riferimento per gli operatori di committenza pubblica e privata in interventi edilizi di nuova costruzione al fine di organizzare una manutenzione programmata atta ad assicurare nel tempo il mantenimento di un livello di qualità tecnologica adeguato, con benefico effetto di riduzione dei costi di gestione degli edifici.
Ciò potrà essere perseguito attraverso la conoscenza della qualità tecnologica utile dei componenti edilizi, che i progettisti, attraverso le specifiche di durabilità, possono richiedere nei capitolati speciali d'appalto tenendo conto dei dettami della sopra citata norma UNI 11156.
I controlli dei livelli di durabilità dei componenti edilizi utilizzati nel progetto dell'edificio sono fin d'ora eseguibili presso i laboratori tecnologici delle sedi delle unità di ricerca della rete nazionale che hanno partecipato al programma trattato nella presente pubblicazione.

The present publication shows the results of a national scientific research program (PRIN-2003) about "*Methodologies for evaluating durability of building components in sustainable processes of production for buildings' planned maintenance*". This national research program had the participation of six research units of as many Italian universities of engineering: the Politecnico di Milano, the Politecnico di Torino, the University of Naples "Federico II" and the Universities of Palermo, Catania and Brescia.
The research were undertaken in coherence with the developments at international level within the International Council for Research and Innovation in Building and Construction (CIB), in particular in the CIB W80 Committee – "*Prediction of Service Life of Building Materials and Components*", as well as in the correlated jobs of ISO TC 59 SC14 for the elaboration of the standard code ISO 15686 "*Service life planning*".
This work brought in 2006 to the publication of the Italian standard code UNI 11156 "*Valutazione della durabilità dei componenti edilizi*" (*Evaluation of durability of building components*) divided into three parts: "*Terminology and definition of the evaluation parameters*", "*Evaluation methods for the reliability propensity*", "*Evaluation methods for Service Life*".
The obtained results already constitute a meaningful reference for public and private customers in new buildings' construction works with the aim to allow a planned maintenance able to assure suitable levels of technological quality. This brings as a consequence to the reduction of buildings' overheads.
This can directly be pursued thanks to the knowledge of durability of building components, which can be required through the performance specifications of the contract according to the above quoted national standard code UNI 11156.
The controls of the durability's levels of the used building components can be already executed in the technological laboratories of the research units belonging to the national network involved in the program described in the present publication.

ISBN 978-88-7454-045-7

9 788874 540457

Prezzo € 15,00

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The durability of building components

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Prima edizione: Marzo 2008

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DURABILITY OF CONTINUOUS ROOFING
by Maurizio Nicolella

1 Service life problems in continuous roofing

As part of the national research project on durability, the Naples research unit - made up by Alba De Pascale, Patrizia Desiderio and Maria Gabriella Russo - addressed roofing subsystems. Roofing is one of the most complex components of the external covering of buildings, insofar as normally comprised of numerous materials and usually presents many problems in the maintenance. It is also the one which presents most variety across, and within, its different contexts of application.

Another – but certainly not the last – problem which needs to be addressed is "quality of execution", a particularly sensitive issue, and in fact roofing are one of the few remaining building trades still generally entrusted to specialized firms, without whose expertise the results in terms of performance often leaves much to be desired.

In the course of our analysis of the state of the art in the durability of continuous roofing – which included both scientific literature and an examination of Italian and international standards for laboratory testing – it became apparent that, as with so many other building components, while indications on individual products are in plentiful supply (e.g. bituminous membrane), there is something of a black hole when it comes to the built-up roof itself. It is, instead, particularly interesting to research on roofing, as it is in the variety of materials which comprise them, and the diversity of the ways in which they're combined, that lies the reasons for the problems which can often lead to sudden performance decay and anticipated end of the service life.

The fact is, here as in other parts of building, we have to acknowledge that the physical changes undergone by roofing materials during and after their application are decisive for their performance evaluation. Returning to the example of prefabricated bituminous membrane (a good example after all, since in a sense it's a crucial component in the appraisal of the performance of the roofing assembly as a whole), this is a material which as prescribed in the standards is tested in such a way as to ignore the changes it undergoes subsequent to its application at temperature using propane gas; likewise ignored are the differences which manifest themselves over time in accordance with the different protection systems currently used in the country: nowadays acrylic paint instead of slate granules.

There are, moreover, other important factors: the articulation of the different layers of the built-up roofing, the presence or absence of an insulating layer, the nature of this layer: these are all of major significance in the evaluation of roofing service life.

We therefore felt that it would be useful to go a little beyond the strictures of standard prescriptions. Although standards are an obligatory point of reference for a whole range of conditions, they were of little use when it came to designing the samples to be subjected to accelerated ageing if the ultimate goal of laboratory testing is re-scaling to real conditions.

In other words, in agreement with the other units, a research approach driven by accelerated ageing testing on the different materials ultimately leads to re-scaling due to externally-sourced sampling. So if this had to compare to real buildings, i.e. the behaviour of the elements undergoing testing as part of a complex as well as individually, to design samples capable of reproducing as faithfully as possible the situations and conditions of the same materials in real buildings were considered suitable.

2 Technical characteristics of the samples

In the light of the above, we decided to work on test pieces made in exactly the same way as for roofing used in real buildings.

This meant we first had to compile a systematic inventory of all the possible roofing technical solutions, on the basis of field research and in the light of the solutions adopted by the designers, without influence of local building traditions. We then examined each of these solutions so we could select those which were most interesting for purposes of research.

So we decided to limit our work to a restricted number of samples, the idea being to conduct a number of tests on each sample so we could determine its performance over the artificial ageing cycle.

This selection process resulted in four different roofing solutions, layered as shown below (from top to bottom):

a	slate-surfaced membrane
	cement and coarse calcareous sand screed
	expanded clay lightweight cement mortar slope layer
	reinforced concrete and hollow tiles mixed floor

b	slate-surfaced membrane
	bitumen-precoated polyurethane insulation roll
	cement and coarse calcareous sand screed
	expanded clay lightweight cement mortar slope layer
	reinforced concrete and hollow tiles mixed floor

c	membrane with acrylic paint protection
	cement and coarse calcareous sand screed
	expanded clay lightweight cement mortar slope layer
	reinforced concrete and hollow tiles mixed floor

d	membrane with acrylic paint protection
	bitumen-precoated polyurethane insulation panel
	cement and coarse calcareous sand screed
	expanded clay lightweight cement mortar slope layer
	reinforced concrete and hollow tiles mixed floor

We should point out that in making these choices we did take into account the fact that one of the most interesting aspects of research is the deterioration of the uppermost layers (since protective coating of membrane), a phenomenon which invariably triggers deterioration in the layers immediately below.

3 Morphological characteristics of the samples

In view of the comments of paragraph 1, the samples were designed according to criteria partially different from those indicated in national and international standards, so that they could be laid exactly as they are in real buildings, i.e. as shown in the layer diagrams in 2 for the roofing solutions selected.

From the morphological point of view, the samples constructed – which we also subjected to puddling tests, given the specific natures of the components under review – have the following characteristics (cf. figure 1):

- footprint dimensions 52 x 52 cm;
- total height 28 cm;
- bearing structure of steel sections L 30 x 60 x 5 mm tensing a plane comprising two hollow brick tiles (3 x 25 x 50 cm) on the base and vertical sides.

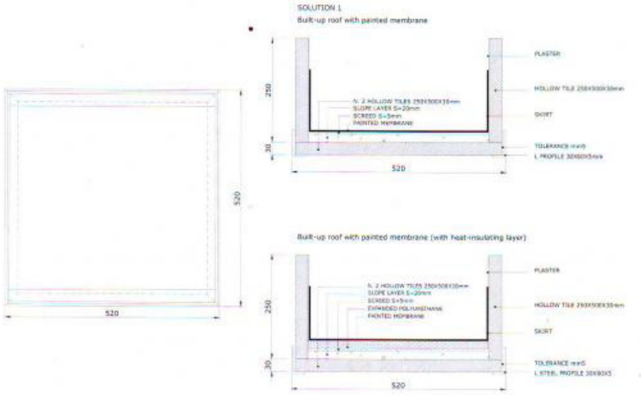
This arrangement was also designed to take into account the fact that in practice many of the maintenance problems associated with continuous coverings are located in the perimeter flashing, and therefore we devised a configuration which not only allowed us to perform puddling tests but also enabled us to carry out waterproofing tests on vertical surfaces connected to horizontal surfaces.

Obviously, the samples differed in terms of the solutions they represented, though all included the slope layer and cement screed.

The samples exposed outdoors were positioned in exactly the same fashion, since it made no sense to position them at pitches which would accelerate ageing in assemblies which are most commonly used on the horizontal plane.

Puddling, evidently, was not induced as in laboratory testing but occurred as per the natural course of events.

Fig. 1 - Morphological characteristics of the samples



4 Correlation between properties, functional characteristics and performance thresholds

The need to describe the "states" which the samples pass through during induced ageing, and to classify those to which a certain condition of degradation – and therefore a certain approach to repair – is to be associated meant that it was essential to itemize the properties of the various elements of the assembly, and its performance specifications.

There were two objectives here:

- to describe performance decay in terms of a curve (and not simply as a line linking two points corresponding to the "birth" and the "death" of the element) which is as close a representation of reality as possible and which – even if by extrapolation – allowed us to plot future deterioration, repair schedules and a design approach which is truly maintenance oriented;
- to create a dynamic checklist allowing us systematically to associate a given objective condition (conventionally coded performance) to a time threshold, so that both in turn can be assigned a maintenance typology.

Our analysis was conducted on the basis of national and international standards, recommendations in the manufacturers' manuals, and experience from real building contexts.

We therefore ensured that everything essential for the study was in place as required, defining where possible performance thresholds which on the one hand could provide a quick view of the component's life cycle and on the other would make it possible to determine a certain typology of maintenance.

We carried out a preliminary evaluation designed to individually identify, for each layer in the roofing assembly, the types of tests required under applicable standards relative to the "well-being" need, taking into account for each layer the requirement class/requirement subclass/expected requirements/test methods employed in determining performance, as shown in the table below:

CLASS OF REQUIREMENT	**FUNCTIONAL LAYER**	**REQUIREMENT SUBCLASS**	**EXPECTED REQUIREMENT**	**TEST METHODS FOR DETERMINING PERFORMANCE**
Water resistance *ability to prevent surface water from penetrating roofing*	resistance element	Resistance to mechanical action	behaviour under traction impact resistance static load resistance ripping resistance resistance to penetration of roots interply bond uplift resistance	UNI EN 12311-1:2002 UNI EN 12691:2002 UNI EN 12730:2002 UNI EN 12310-1:2001 UNI EN 13948: 2001 ASTM E 907 – 96
		Resistance to thermal action	cold flexibility dimensional stability dimensional stability in cyclical temperature conditions slippage when hot stability of form when hot differential dilation linear thermal dilatation coefficient pliability at low temperatures	UNI EN 1109:2002 UNI EN 1107-1:2002 UNI EN 1108:2002 UNI EN 1110: UNI 8202-18 UNI 8202-19 UNI 8202-20 UNI EN 495-5:2002

	prot.		adhesion of mineral surfacing adhesion of granules	UNI 8202-35 UNI EN 12039:2001
Control of heat transmission *To prevent heat exchange indoor-outdoor*	Heat insulating element	Resistance to mechanical action	behaviour under deflection behaviour when cut behaviour under spot load behaviour under cyclical load	UNI EN 12089:1999 UNI EN 12090:1999 UNI EN 12430:2000 UNI EN 13793:2004
		Resistance to thermal action	dimensional stability deformation in specific compression load and temperature conditions	UNI EN 1604: 1999 UNI EN 1605: 1999
		Resistance to various actions	transmission of water vapour immersion absorbance of water diffusion absorbance of water frost-defrost resistance	UNI EN 12086: 1999 UNI EN 12087: 1999 UNI EN 12088: 1999 UNI EN 12091: 1999
	sep. and/or slippage	Resistance to thermal action	dimensional stability deformation in specific compression load and temperature conditions	UNI EN 1604: 1999 UNI EN 1605: 1999
Control of inter-ply condensation *Preventing condensation of water vapour within the roofing system by containing vapour diffusion and convection*	vapour barrier	Resistance to various actions	thermal ageing in water transmission of water vapour acceptance limits type BPP	UNI 8202-27: 1988 UNI EN 1931:2002 UNI 9380-1
	vapour screen	Resistance to various actions	thermal ageing in water transmission of water vapour acceptability limits type BPP	UNI8202-27 UNI EN 1931:2002 UNI 9380-2
	diffusion and/or equalization of vapour pressure	Resistance to various actions	thermal ageing in water transmission of water vapour acceptability limits type BPP	UNI 8202-27 UNI EN 1931:2002 UNI 9380-2

Another preliminary definition regarded the classification of problems, to which a out of order status could be defined and the need for maintenance determined.

To allow us to devise a program of tests to be carried out on the samples before, during and after application, an exhaustive survey of detected anomalies were conducted and, using standard ASTM E 632 as our reference, these faults as defects and/or faults which can be detected visually and defects and/or faults which can only be detected using instruments were classified, as shown in the table below (which also gives the applicable standards for each test).

VISIBLE ANOMALY	PROPERTY TESTED FOR DETECTING PERFORMANCE DECAY	MEASUREMENT METHOD	STANDARD
Change in colour	UV resistance of protective layer	sight microphotography	
	UV resistance of membrane	instrumental	UNI EN 1297
Surface alteration	scrape resistance of membrane	sight microphotography	
	adhesion of granules (for mineral-coated membranes)	instrumental	UNI EN 12039 UNI 8202-35
	chemical resistance in contact with common substances/ resistance to chemical agents	instrumental	
Cracking / wrinkling	dimensional stability of membrane	instrumental	UNI EN 1107-1
	dimensional stability of membrane in cyclical temperature conditions	instrumental	UNI EN 1108
	flexibility of membrane when cold	instrumental	UNI EN 1109
	pliability at low temperatures	instrumental	UNI EN 495-5
	dimensional instability of insulation panel	instrumental	UNI EN 1604
	incorrect application (excess of bitumen, incorrect adhesion of membrane, irregularities in application surface etc.)	instrumental / sight	ASTM D 3617-2
Detachment of membrane	dimensional stability of membrane	instrumental	UNI EN 1107-1
	dimensional stability of membrane in cyclical temperature conditions	instrumental	UNI EN 1108
	flexibility of membrane when cold	instrumental	UNI EN 1109
	pliability at low temperatures	instrumental	UNI EN 495-5
	dimensional instability of insulation panel	instrumental	
	incorrect application (incorrect gluing of membrane, continuity of membrane between horizontal and vertical element etc.)	instrumental / sight	ASTM D 3617-2
	interply bond	instrumental	ASTM E 907 -96
Detachment of side and end laps	resistance of joints to traction	instrumental	UNI EN 12316
	detachment resistance of joints	instrumental	UNI EN 12317
	adhesion between layers	instrumental	
	uplift resistance	instrumental	ASTM E 907 -96
Splitting	resistance to traction	instrumental	UNI EN 12311
	resistance to ripping	instrumental	UNI EN 12310
	impact resistance	instrumental	UNI EN 12691
	resistance to penetration of roots	instrumental	UNI EN 13948
Incisions	resistance to ripping	instrumental	UNI EN 12310
	resistance to static loads	instrumental	UNI EN 12730
	resistance to penetration of roots	instrumental	UNI EN 13948
Interply condensation	flexibility of vapour barrier when cold	instrumental	UNI EN 1109
	resistance to traction	instrumental	UNI EN 12311
	transmission of water vapour in water barrier	instrumental	UNI EN 1931
	thermal ageing of vapour barrier in water	instrumental	UNI8202-27
	incorrect application (absence of vapour layer barrier, presence of trapped water etc.)	instrumental / sight	ASTM D 3617-2
Presence of water where no fissures / detachment exist	water resistance of membrane	instrumental	UNI EN 1928
	water resistance after low-temperature traction of membrane	instrumental	UNI EN 13897
	transmission of membrane water vapour	instrumental	UNI EN 1931
	hail resistance of membrane	instrumental	UNI EN 13583

Given the complexity of the elements tested and the considerable number of tests which would be necessary for an exhaustive description of the performance decay of the individual layers in the roofing assembly, we decided to simplify the process by classifying anomalies into three "macrogroups":

1. surface alterations (including changes in colour);
2. detachment (including: detachment of membrane from underlayer; interply detachment; detachments along joints, cracking and/or wrinkling, uplifting and/or rippling);
3. cracking (including: "alligatoring", incisions, tears etc.).

Note that we have not included surface vegetation as we decided to exclude from laboratory tests the agents which normally trigger the appearance of this pathology.

Surface alterations, therefore, are detected using microphotography; detachments using thermography followed by pull-off; and cracking by sight.

To plot the following time/performance curves:

1. efficiency of protective layer over time;
2. adhesion between layers and to underlayer over time;
3. water resistance over time,

the instruments and test methods having been analyzed, we established a test table as shown below:

TEST	**REQUIREMENT**	**ELEMENT TESTED**	**MEASUREMENT METHOD**
pull-off	adherence	membrane	instrumental
microphotography	protection	protective layer	sight
UNI EN 12086 (heat insulation) UNI 8202 and 8223 (membrane) tests	water vapour permeability μ	entire assembly	instrumental
ISO 8301 test	heat insulation	entire assembly	instrumental

As an example, we provide below some images of samples before testing, accompanied by their thermographic images, showing the areas of detachment during and after the test cycle.

INFRARED VIDEOTHERMOGRAPHY INSPECTION CHECKLIST

TYPE 1 SAMPLE

Time and date of inspection

13:16:08 27.06.2006

Working conditions

Ambient T (sensor): 37.9 °C

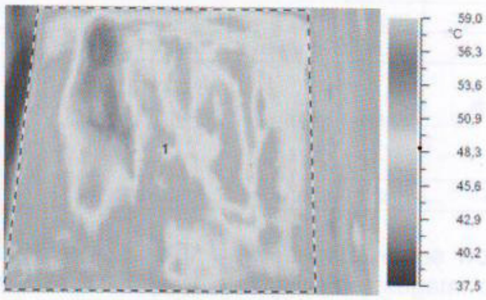
Notes

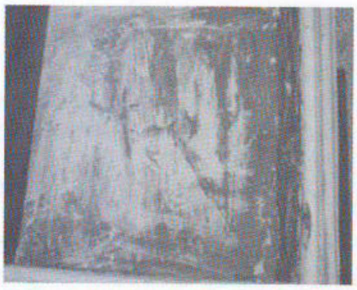
A sunny, very hot day.

Description: membrane with protective coating of acrylic paint – screed with cement and coarse calcareous sand dosed at 300 kg – cement mortar slope layer dosed at 200 kg with expanded clay – underlayer

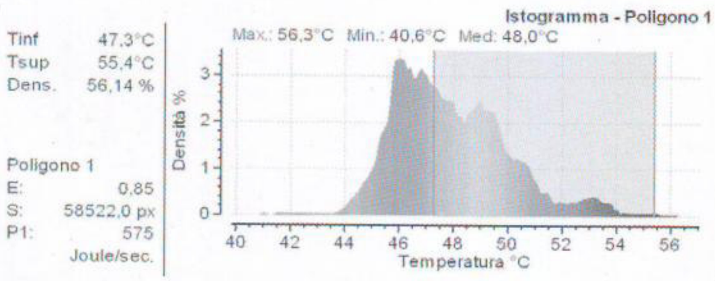
Image description

Bottom surface





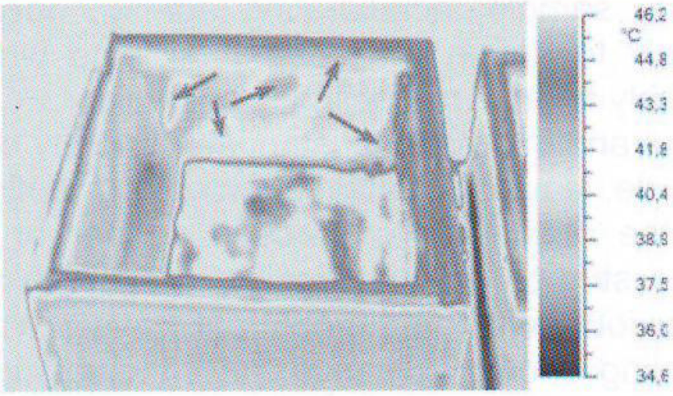
Extent of detachment area

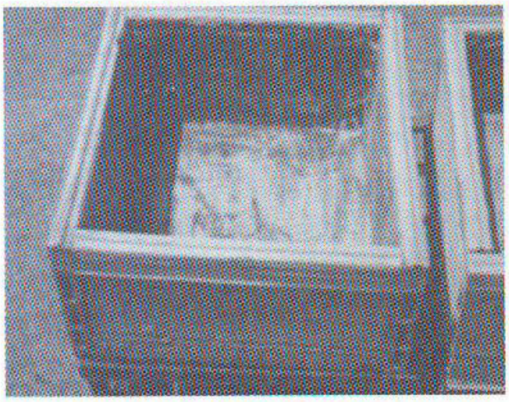


Outcome: detachment of 56.14% from bottom surface (yellow-orange-red areas); the protective layer has deteriorated by around 50%.

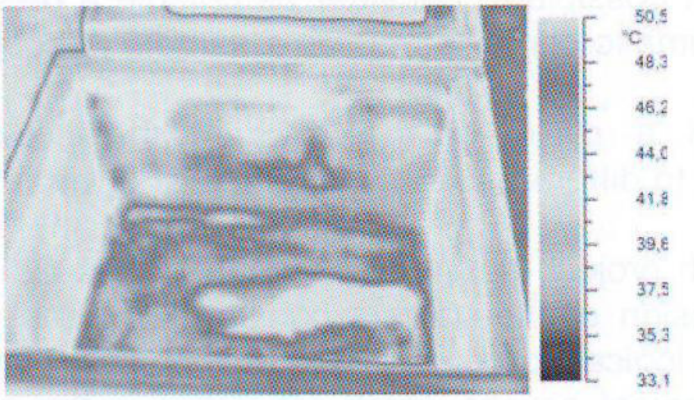
Examination of cap sheet skirts

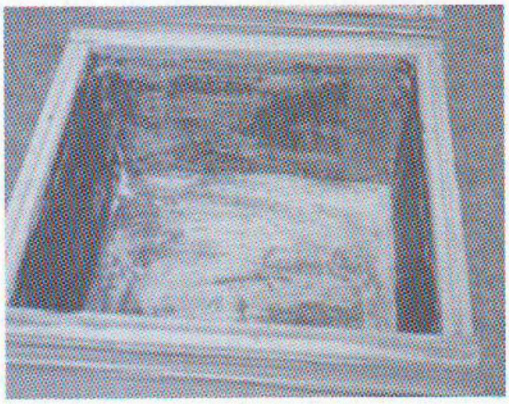
Skirt 1A



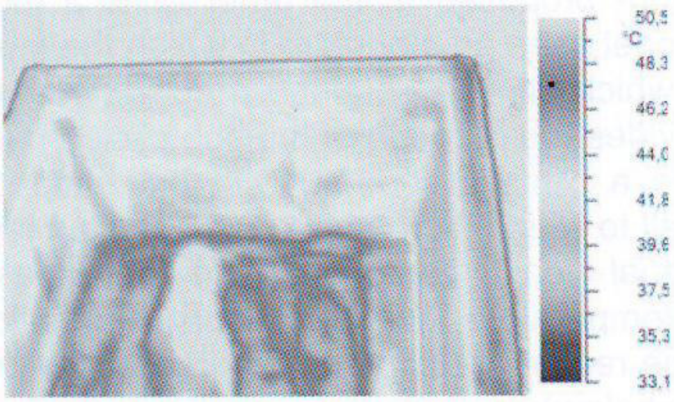


Skirt 1B

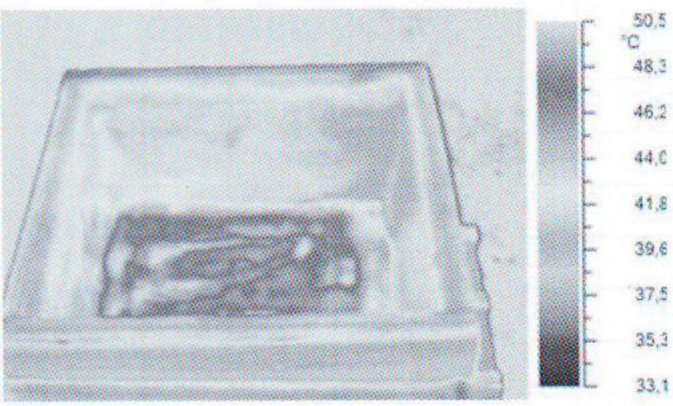




Skirt 1C



Skirt 1D



Outcome: areas of non-adhesion of cap sheet to under layer along the skirts; the protective paint is for the most part visibly absent

5 Ageing cycle determination

A methodological approach which determines the service life of a building component by comparing an artificial ageing test conducted in the laboratory with a natural weathering test on the same sample, accelerating ageing, necessarily raises the problem of how accurately to define the ageing cycle to which the sample is subjected so that a reasonably reliable re-scaling is possible.

As mentioned above, both national and international standards merely outline a series of criteria for determining this cycle, leaving a certain leeway for its definition.

We feel, on the contrary, that the obligation to proceed sooner or later – otherwise only comparative tests and studies will be possible, via which we can determine analogous patterns of behaviour between the different ways in which the same element is used – to a re-scaling should influence the conditioning cycle, which must necessarily be differentiated by the diverse contexts for which re-scaling is to occur.

In other words: it does not seem possible to consider as reliable a re-scaling performed in significantly different climatic contexts, where a sample is subject to same artificial action.

Therefore, we tried to design a cycle which provides an accelerated reproduction of what actually occurs, to different extents, in different environmental contexts.

As part of the Prin 2003 research project the various research units examined problems and phenomena in the design of the various components used in the external “enclosures” of buildings: the logical approach in this project was to attempt to simulate, in the laboratory, the ambient actions which are active in the various climatic contexts, differentiating them for purposes of customized re-scaling.

The Naples research unit therefore proposed to the other units a model for determining the ageing cycle. This model uses an algorithm in which the input data comprises a series of climatic data which can be obtained from various sources (principally, air force). The output provides the duration of the sub cycles (each one of which represents, and reproduces a climatic season) with the temperatures, humidity, sunlight radiation, and rainfall to which the sample has been subjected. In this way, we obtain a kind of “virtual year”, comprising the four seasons in succession, with different values for temperature, humidity, sunlight radiation, and rainfall, with the values inserted for the region and time of year that represents the season in question (as shown in table below):

SUBCYCLE	ACTION	VALUE INSERTED
FREEZE	TEMPERATURE	absolute minimum
	HUMIDITY	mean
	SUNLIGHT RAD.	-
	RAINFALL	-
HOT / DRY	TEMPERATURE	highest among means
	HUMIDITY	mean
	SUNLIGHT RAD.	xenon lamp lights
	RAINFALL	-

HOT / HUMID	TEMPERATURE	absolute maximum
	HUMIDITY	95%
	SUNLIGHT RAD.	xenon lamp lights
	RAINFALL	-
RAINY	TEMPERATURE	lowest among means
	HUMIDITY	mean
	SUNLIGHT RAD.	-
	RAINFALL	splash or puddling

Climatic data was collected in advance from various official sources, covering a period no longer than the last 5 years, on account of the extreme variability in recent times. The values necessary for implementing the proposed model together with related definitions are given in table below:

ACTION	VALUE INSERTED	DEFINITION
Rainfall	number of rainy days in one year	value obtained from mean annual value
	intensity of rainfall	value obtained from mean annual value
Temperature	absolute minimum	value obtained from mean absolute minimum value
	mean minimum	value obtained from mean monthly value, calculated as daily mean minimum value, taking lowest value into account
	absolute maximum	value obtained from mean absolute maximum value
	mean maximum	value obtained from monthly mean value, calculated as daily mean maximum value, taking highest value into account
Humidity	relative humidity	value obtained from monthly mean for work for each year
Sunlight radiation	number of sunny days in one year	value obtained from annual mean value
	sunlight radiation hours trend	value obtained from annual mean value

It is interesting to note that across the different climate zones in Italy there is little difference between the absolute values for many of the environmental actions.

Two examples suffice to illustrate this point:

- where absolute maximum temperature is concerned, there is no significant difference between Milan and Palermo. What distinguishes the two contexts is the *number* of days per year in which they reach high temperatures;

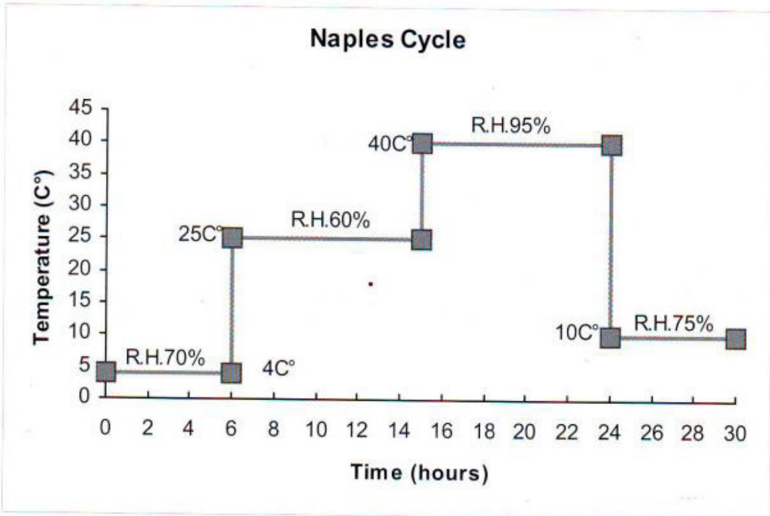
* the intensity of rainfall recorded in Naples in the last five years exceeds, to a considerable extent, that of Milan in some winter months.

It so happens that for contexts and climates which differ significantly, the seasonal sub cycles determined have (for example) similar temperatures. It is the length of the segment, or the combined effect of the other environmental actions, which characterizes each context.

The final output generated by special simulation software providing the values for Naples are shown in table below:

SUBCYCLE	DUR.	TEMP.	HUM.	SUN RAD.	RAINFALL
FREEZE	6 hrs	4 C°	70%	No	No
HOT / DRY	9 hrs	25 C°	60%	Yes	No
HOT / HUMID	9 hrs	40 C°	95%	Yes	No
RAINY	6 hrs	10 C°	75%	No	Yes

These figure is represented in graph form below.



6 Composition of the cycles for any climatic context

By adopting the criteria previously described, one can develop – as was done for Naples – a simulated cycle for any environment. A schematization has been provided with the options to be exercised by the operator with regard, not only to specifically climatic data (temperature and humidity) but, also, the lamp activation mode in the two heat segments, and, above all, the duration of the various segments in which the sub cycles are contained. Therefore, the process should first be conducted for the individual sub cycles, and then, used as a direct indicator for the selection of climatic data and durations by the user wishing to compile and customize the cycle for the local climatic context.

Note that the length of the segments is not only established in relation to climatic data in terms of temperature and humidity, but is also evaluated, as mentioned above, in terms of the longevity of the season in relation to the annual climate. For example, maximum temperatures recorded in the hottest months in Milan are as much as those in Palermo, regardless of the fact that these two locations belong to climatically diverse contexts. What is important is the duration of elevated temperatures, indeed, and the effect on the climatic trend for the entire year. Such periods of oppressive heat in which temperature peaks occur, can vary significantly from location to location.

To assist in the schematization of this process, the Italian National Zoning Plan (Italian directive 412/93) has been used, based on the number of degree-days[1] recorded for the different districts. This directive provides information on the delineation of Italy into 6 subdivisions[2]. For the present purposes, given the similarities of performance between pairs of subdivisions, they were examined two by two; hence the observed subdivisions include zones A and B, C and D, and E and F. By crossing the climatic data (absolute or mean values) with the impact percentage of the reference climatic season for the trend of the climatic year (here illustrated by zones A to F, as determined by the legislation), we will be able to correctly estimate the duration for which the season in question must be schematized in the reference sub cycle.

In light of the above considerations, the following schematizations are proposed:

Subcycle A – FREEZE: Definition of climate conditions		
Parameter	**Instruction**	**Value**
Temperature	Enter absolute zone minimum value recorded in period of the year represented by the season in question	X C°
Humidity	Enter zone mean value for the season in question	Y %
Sunlight radiation	Keep lamp switched off from now on	---
Rainfall	Switch off water	---
Climate zone	Establish zone	Zones A/B/C/D/E/F

Subcycle A – FREEZE: Definition of length of segments	
Climate zone	**Value**
Zones A/B	4 hrs
Zones C/D	6 hrs
Zones E/F	9 hrs

[1] The "degree-days" of a designated district are the sum, for all the days in a conventional annual warm period, with the daily positive differences between ambient temperature, conventionally set at 20 degrees centigrade, and the daily mean outdoor temperature; the unit of measurement used is the degree-day (DD).

[2] The Italian territory is divided into six climate zones according to their degree-days, regardless of their geographic location:
Zone A: districts with degree-days less than 600; Zone B: districts with degree-days between 600 and 900; Zone C: districts with degree-days between 900 and 1,400; Zone D: districts with degree-days between 1,400 and 2,100; Zone E: districts with degree-days between 2,100 and 3,000; Zone F: districts with degree-days greater than 3.000.

Subcycle B – HOT / DRY: Definition of climate conditions		
Parameter	**Instruction**	**Value**
Temperature	Enter the absolute zone mean maximum value recorded in the period of the year represented by the season in question	25 C°
Humidity	Enter the zone mean value for the season in question	Y %
Sunlight radiation	Light lamp for zones A/B/C	Maximum value
Rain	Switch off water	---
Climate zone	Establish zone	Zones A/B/C/D/E/F

Subcycle B – HOT / DRY: Definition of length of segments	
Climate zone	**Value**
Zones A/B/C	9 hrs
Zone D	6 hrs
Zones E/F	4 hrs

Subcycle C – HOT / HUMID: Definition of climate conditions		
Parameter	**Instruction**	**Value**
Temperature	Enter the absolute zone maximum value recorded in the period of the year represented by the season in question	X C°
Humidity	Enter a fixed value	95 %
Sunlight radiation	Keep lamp switched on always	Maximum value
Rain	Switch off water	---
Climate zone	Establish zone	Zones A/B/C/D/E/F

Subcycle C - HOT / HUMID: Definition of length of segments	
Climate zone	**.Value**
Zones A/B/C	9 hrs
Zone D	6 hrs
Zones E/F	4 hrs

Subcycle D – RAINY: Definition of climate conditions		
Parameter	**Instruction**	**Value**
Temperature	Enter the mean zone minimum value recorded in the period of the year represented by the season in question	X C°
Humidity	Enter the zone mean value for the season in question	Y %
Sunlight radiation	Keep lamp switched off from now on	---
Rain	Water	30 mm of water
Climate zone	Establish zone	Zones A/B/C/D/E/F

Subcycle D - RAINY: Definition of length of segments	
Rainfall band	**Value**
Band 1: less than 50 days/year	4 hrs
Band 2: 50 – 90 days/year	6 hrs
Band 3: over 90 days/year	9 hrs

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