

# **New Materials for Safeguarding Cultural Heritage**

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## **1. Introduction**

As my expertise is based on practical field work as an engineer and architect, working as a consultant and liberal professional for the conception and direction of architectural conservation and restoration projects, I shall report on “new materials and techniques” the way they are applied today on building sites. For this reason, my vision on the ‘state of the art’ regarding the subject of this meeting, might not always correspond with what is going on in research laboratories or with the ideas of people from industry or from administrative bodies. I also regret not having inquired all involved Belgian institutes and/or organisations; so, please, accept my apologies for not being complete on what is going on in our country!

During last twenty years, we have seen great changes on the restoration building sites in Belgium and Europe: up to 1970, conservation and restoration of ancient buildings and historic monuments was in hands of some very few experts, mainly motivated and concerned about the historic aspects of the buildings and operating according to the traditional techniques and materials. Since 1970, the general interest in conservation and restoration “exploded” up to unknown dimensions, what demanded for new approaches, new methodologies and new techniques. (Only one example: in 1970, there were +/- 250 protected buildings in Belgium; today they are more than 10.000!). Between the many changes as a result of this “inflation” of the number of monuments and of the much greater variety of involved people, one of the most interfering ones certainly has been the introduction of applied sciences and advanced technologies within this very traditional discipline. Especially the impact of different types of new building CHEMICALS has created many new uncertainties. Several materials and technologies are developed, and after application, we find sometimes they are excellent, sometimes they are not completely fulfilling their promises, or in other cases, they even seem to be inadequate or negative after certain time.

Regarding the “new materials for safeguarding cultural heritage”, we must admit that for many of them, we still have the same UNCERTAINTY as we have with ancient structures: with ancient materials we are uncertain while we do not know their technical characteristics nor their specific production processes. With modern materials, we know quite well their technical characteristics and production process, but we know only very approximate things (from laboratory testing) about their behaviour on the long term! For this reason it is extremely important to study and evaluate the behaviour of the ancient applications of those “new materials” such as hydrofobes, consolidants, repair mortars,... (of which some also have been applied since 50 years!).

Of course, absolute certainty will never exist, as we can not know what will happen in future – when architects at the end of XIX° and beginning of XX° century choose Euville limestone as a substitute for the local Ledische or Gobertange stone, they could not know about the air pollution and acid rains of the 1950’s and 1960’s who damaged completely this Euville stone!

## **2. New materials for conservation and restoration of stone and other porous materials**

On the building site of a normal conservation/restoration project, we have to consider following interventions:

- a. cleaning

- b. repair for structural improvement (visible or non visible reinforcements)
- c. repair for aesthetical improvement (reconstruction of missing parts)
- d. protection and prevention of future damage
  - d.1 surface consolidation
  - d.2 protection against water (surface water = hydrofobation / rising groundwater / condensation damp)
  - d.3 painting and other decorations (polychromie, goldleaf, ...)
  - d.4 anti-algae and anti-graffiti

Each of them implies specific technologies and specific products, and the type of intervention to choose depends also in great extend on the 'philosophy' of the project (e.g. authenticity of historic materials, conservation of 'patina', relation with modern architecture,...) ! I report on some new materials in this field.

## 2.1 Cleaning

For applications in cleaning of great facades, the most recent techniques to apply are:

- improved water cleaning with rotating water jet (type 'Jos' technique)
- improved dry cleaning by 'gumming' i.e. blasting of very fine and soft granulates within a movable special cabin in permanent underpressure (to Hoover the dust)
- laser applications (limited to small surfaces or delicate decorations because of the very high costs of equipment and time)
- several new chemical products (pastes or liquids) (all types : neutral ones, acid or alcalic ones, organic ones, ...)

Interesting to mention is the recent development of a new type of '**DRY cleaning paste**', specially for application in **interior spaces** (Commercial names: a.o. Monuclear (Rewah), Arte Mundit (FTB), ...). They are, what the producers call 'third generation' cleaning pastes , i.e. combination of natural latex and clay-complexes as a dirt-absorbent filler, combining in this way the adhesive capacity of the latex and the absorbing capacity of the clay. (Because of this clay, the colour of the fresh product is slightly brown – it darkens during hardening). Depending on the application, there is the one 'without any chemical' (sic !) i.e. a single combination of natural latex and clay minerals which guarantees against any risk on salts or decolouration on the long term, and those with few 'chemicals' (acids or alcalic salts ?? ) with faster and more aggressive cleaning properties. The first one doesn't need any treatment after application as no residues are left after peeling off the cleaning layer, the second one needs rinsing with abundance of water as a preventive protection (this last type is used for more industrial cleaning purposes).

This 'latex and clay' paste is sprayed (or with brush) on the surface to create a film of 0,5 to 1 mm thick and peeled off after 1 day (in normal conditions) or even after 2 or 3 hours when heat is added.

Sometimes it can be necessary to repeat the treatment, depending on the 'cleaning level' one likes to realise! (Cleaning with laser can go much 'further' as all dust particles are 'burned' up to deep in the pores)

Possible problems:

- when the layer is sprayed too thin, peeling off can give problems
- when the layer is kept too long on the surface (e.g. 1 week), vulcanisation of latex reduces effectiveness

This product is un-effective for exterior applications in our country (climate is too variable, and/or too humid)

(N.B.1: first generation paste cleaner = latex with different (neutral and other) supplements to apply with brush, second generation = idem to apply with air jet.

N.B.2 : also for outside surface, more types of cleaning-pastes can be useful e.g. Alkutex, Aquafin, (Remmers) These are powder mixtures, applied with brush, and rinsed down with water; most of them contain acids and require special precautions ! )

## **2.2 Structural improvements of stone work**

During last twenty years, there has been great developments in this field. It is impossible to enter in all details within this short report. Damaged single stones or stonework in general can be improved by:

- full exchange of the old material by a new 'identical' one (as identical as possible)
- partly exchange : i.e. only the very damaged part is substituted – problem of connection of the new with the old (anchoring, gluing, special cutting of the stone section, ...)
- parallel or interior reinforcement systems (anchors, injections, lateral supports, ...)
- (needle anchors, injections with limecaseïne, lime mortar, cement, micro-cement, resins, ...)
- advanced strengthening techniques are offered with the use of externally bonded steel plates or carbon laminates (=carbon fibre reinforced polymers) parallel to the existing structures. (\*)
- special metal suspending and fixation materials have been developed for application in seismic zones by so called SMADs = Shape Memory Alloy Devices (e.g. San Francesco Basilica in Assisi). (\*\*)

## **2.3 Repair mortars for stone, brick or concrete.**

Especially in restoration business, these products as 'ersatz'-substitutes for natural stone, have become very successful while traditional stone substitution became extremely expensive, and in most cases, the original stone quarries are not in exploitation any more, so it becomes very difficult to find a satisfying substitute.

Similar techniques are used for concrete repair (to repair so called 'concrete-rot'), motivated also by evident economic reasons.

Many firms prepare "stone repair mortars"! They compose new mixtures or improve existing ones, based on site experience. These new products are offered on the market with suggestive names such as Monulit, Articon, Lithos Arte, ... joining the already existing ones of Lafarge, Mineros, Jahn, Tubag, Amonit, Euroquartz, Resilith, ... All of them are mortar mixtures using specific powders and granulates of different calibres similar to those of the original material they have to substitute + binding material. Usually they are available in 10 to 20 standard mixtures (based on colour), but it is also possible to prepare them "ad hoc" for specific applications. According to the binding material, they can be divided into three types:

- 'mineral' mortars = using lime or cement (1 component + water)
- 'chemical' mortars = using zinc oxide (powder) and zinc chloride (liquid) as a hardener (2 component system)
- 'resin-based' mortars = with epoxy resins or other polymers ( 2 component system)
- Each of them do have specific characteristics and applications (see 'Annex 1')

Most of them also use special anchoring (stainless steel or copper) and do have specific operational techniques (e.g. preparation of the surface, previous impregnation or consolidation of the bearing surface, ...)

The most important goal is to obtain a end result that approaches the original stone, brick or concrete as identical as possible (colour, texture, elasticity, porosity, dilatation and shrinkage, ...) and to limit possible future side effects (chemical or mechanical). Selection of which type to use, will depend on:

- compatibility of both materials (the existing stone and the repair-mortar) in all regards ;
- 'treatability' of the work (geometrical or formal complex ) and the workability of the mortar (= hardening period / level of plasticity, ... )
- work and climate conditions (inside, outside, warm, humidity, ....)

Recent example from practice : before the restoration of the renaissance façade of the Courts Office in Bruges in 2000, the contractor tested two families of standard available mortars on a experimental zone : three types (with different granulate distribution) of hydraulic lime mortars (from Lafarge : Parthena – Mortier Pierre) and a zincchloride mortar (from FTB : Lithos Arte 2000). The lime mortars were found excellent, easy to apply, and they got the preference because the hardening process is much slower and so it was easier for the operator to correct his sculpture-work during a longer period, and obtain a more satisfying result.

Also the zincchloride mortar was especially developed in order to avoid the often happening efflorescence of calciumchloride salts after the binding proces (while the remaining chloride atoms - after having bound the oxides – are reacting with the calcium to calciumchloride). For this reason, the mixture of this 'Lithos 2000' was specially balanced not to generate such zincchloride residues! Normally, the efflorescence of calciumchloride salts is not such a great problem, as they can brushed away, or disappear with the rain. In this case, any efflorescence, even for a short period, was not acceptable as the stones had to receive finishing with polychromy and gold leave.

Given this specific conditions, the contractor optioned to use hydraulic lime mortar for all the decorative work to avoid any salt-risk and because of because of the longer plasticity time of the mortar (= 2 to 3 hours). Zincchloride mortar (plasticity during 15 to 30 minutes = working much faster!) was used for the architectural (= simple geometric surfaces) work without any colour finishing!

## **2.4 Surface consolidation**

Different types are on the market. The experiences during last decades have sufficiently proved that only the 'ethyl-ortho-silicate' based product can guarantee sufficient effectiveness. This resin is available in 75 % up to 100 % (= solvent free) concentration. One of the most determinative characteristics is given by the penetration depth of the liquid into the stone surface (and of course the porosity of the stone material)

To obtain better and deeper penetration, one suggest 'spray-flow' technique (i.e. repeated flow down of the liquid up to full saturation of the stone surface).

## **2.5 Hydrofobes (= surface water repellent products)**

Many surface water-repellent products are available. Many manufacturers produce different types of products, and it is very difficult to select good from bad products! Regular systematic testing is going on in our

"Institute for Artistic Heritage – Brussels" and

"Scientific and Technical Centre for Building Industry – Brussels"

Mostly their effectiveness is of short duration because of their sensibility to U.V. radiation, or the poor penetration within the stone material.

Available products are based on oligomer siloxans (8 % to 10% concentration, dissolved in hydrocarbon with slow evaporation) or watersolved silanes.

This products can be used as protection against atmospheric water and against condensation water but in the case of condensation, it might be more effective to look after solutions by improving ventilation and/or thermal insulation!

To complete the 'damp and humidity' interventions, I just mention the available systems against rising damp in porous constructions:

- mechanical systems = introduction of separation layer by cutting or vibration (metal, bitumen ...)
- physical system = ventilation pipes : poor and ineffective
- electrical system = electro-osmosis / electro-foresis ...: unreliable !
- chemical systems = injection of chemicals (different techniques and products) : mostly very good results

Interesting new products within this context are the '*Sanierungs-putz*'

= self sacrificing lime mortar-mixture, applied as a render, and consisting of a specific granulation in which the unavoidable salt crystals migrating in ancient walls, are absorbed. When the render (2 à 4 cm) is saturated with salt, it is moved away and substituted by a new 'fresh' one.

Other products such as active 'salt extracting mortars' are in research (\*)

## 2.6 Paints

Because of the problems with synthetic paint in old buildings (a.o. rising damp creating bubbles or blisters and cracks, salt accumulation, insufficient damp diffusion, ...) one is looking after paint layers without any 'tension' or so-called pure mineral paints (i.e. without any organic component). Last years, many new materials have been proposed and some of them work excellent – they are all based on traditional LIME with natural pigments. The traditional "Lime wash" still gives the best results – it is very effective and easy to maintain and to repair ! But 'lime' is a quite capricious product (while the hydraulic character is determinate by the lime stone, which is so variable in nature), and for this reason, the production needs constant control and a perfect know how ! (\*\*\*)

## 3. Materials for WOOD conservation/restoration

In the early 1970's, the first applications for structural wood repair with epoxyresins were realised. Very little has changed in this field as it is an excellent technique with 'pro' (easy, economic,..) and 'contra' (stiffness, fire risk, ...) . Today we see a greater preference for using iron bar armaments (in stead of the earlier glass fibre) because of their better mechanical properties (glasfibre has a nominal tension resistance which is about 1/3 lower than iron and application is limited because of the lower plasticity border).

Another consideration is related to the consistency of the epoxymortar: it is recommended to work with so-called 'self-levelling' mortars (i.e. high liquidity of the mixture), otherwise there is a risk for holes (possible air bulbs) in the timber substitute and not full contact with the armament bars. This limits effectiveness of the armament and reduces the stress resistance of the section.

#### 4. Materials for METAL conservation/restoration

see Annex 2 :

A. DE NAEYER : "Restoration of historic iron structures using epoxy bound laminates", in L. VERHOEF (Ed.) Proceedings of international congress on urban heritage and building maintenance – 'Iron & Steel' – oct. 27th, 1999, COST C5 and Delft University, Delft, 1999 pp.91-98 (\*\*\*\*)

(\*) Detailed information about some of the mentioned new materials and techniques (and many other topics) can be found in the 'International Journal for Restoration of Buildings and Monuments – Internationale Zeitschrift für Bauinstandsetzen und Baudenkmalpflege', Aedificatio Verlag GMBH, Zürich

and

WTA Publications (Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege e.v.), Zürich.

(\*\*) European Commission – DG XII - ISTECH Project : "Development of innovative techniques for the improvement of stability of cultural heritage, in particular seismic protection", Research report nr 13, Brussels 2001 pp.64.

(\*\*\*) E.U. COST C5 'Urban Heritage – Building Maintenance 1997-2000' – Working Group 5 "Lime and his applications" - Final report in preparation. (Brussels)

(\*\*\*\*) VERHOEF L., WITTMANN F. (Ed.) : E.U. COST C5 "Urban Heritage, Building Maintenance" – Proceedings of international congresses in Delft (oct.27th, 1999) and Zürich (sep.01, 2000) (8 vol.)