A New Method for Consolidating Wall Paintings Based on Dispersions of Lime in Alcohol

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A NEW METHOD FOR CONSOLIDATING WALL PAINTINGS BASED ON DISPERSIONS OF LIME IN ALCOHOL

Rodorico Giorgi, Luigi Dei and Piero Baglioni

Summary—*Dispersions of calcium hydroxide, $Ca(OH)_2$, in short–chain aliphatic alcohols were studied with the aim of establishing a new pre–consolidation and consolidation methodology for wall paintings. The choice of lime (a paste comprising calcium hydroxide plus water) as the consolidant was suggested by physicochemical compatibility criteria, as lime is the original binder in the wall paintings treated. Many problems are encountered when trying to apply calcium hydroxide to wall paintings. Saturated solutions are too weak to act as consolidant, due to the low solubility ($1{\cdot}7 gl^{-1}$) of $Ca(OH)_2$ in water. In addition, suspensions of $Ca(OH)_2$ in water are too unstable to be applied to unprotected painting surfaces. The use of $Ca(OH)_2$ dispersions in propan–1–ol is proposed; these dispersions were characterized, and their kinetic stability investigated, by ultraviolet/visible spectrophotometry. The alcohol dispersions were found to be much more stable than suspensions in water. The second part of the study evaluated the consolidating power of alcohol dispersions on specimens that simulate different degrees of decohesion. These were examined using X–ray diffractometry and Fourier transform infrared spectroscopy. Their surface properties were characterized by studying capillary rise, water permeability and mercury porosity. The mechanical properties of the specimens were determined using sclerometric resistance and the 'Scotch Tape test'. All the results indicated that the lime/alcohol dispersions produced excellent consolidation. Finally, the paper reports the positive results of tests using the lime/alcohol dispersion on wall paintings by Andrea da Firenze in the Cappellone degli Spagnoli, Chiostro Verde of Santa Maria Novella, Florence.*

Introduction

Consolidation and pre–consolidation are critical steps in wall painting conservation treatments [1]. Consolidation is usually performed to reduce, as far as possible, flaking and/or powdering of both the paint layers and the *intonaco* of a wall painting. Generally speaking, five different types of consolidation can be performed on a wall painting:

1. re–adhesion of the paint layer to the support, to stop flaking
2. internal re–cohesion of a paint layer that has become powdery as a result of the loss of binder
3. smoothing of the painted surfaces to minimize scattering effects that opacify the colours
4. *intonaco* consolidation at the *intonaco*/*arriccio* interface
5. pre–consolidation of the paint layer

The last of these is required for the cleaning of highly sulphated regions, or to prepare wall paintings for detachment. During such interventions, many chemical substances, organic and inorganic, are normally used. Two rules of thumb must be respected in any conservation treatment: high durability and physicochemical compatibility with the original materials [2]. Moreover, consolidation must not dramatically alter the structural properties of the original materials, such as porosity and total surface area, which would affect the flow of gases and liquids through the wall surface.

The compounds used in the consolidation process are often called fixatives [1]. This term indicates the mixture of the consolidating agent with a dispersing medium necessary for its application. To achieve good consolidation, the fixative must be able to penetrate to a depth of at least two to three millimetres, thus avoiding the formation of surface films or the accumulation of material in the external layers. An appropriate consolidation procedure should take into account the following points:

- due to their particle size, dispersions penetrate less easily than homogeneous solutions
- due to weaker electrostatic attractions with the polar wall painting matrices, non–polar fixatives penetrate deeper than polar fixatives
- fixatives containing less volatile dispersing agents are more effective than those using volatile solvents, since they remain on the surface longer
- dispersing agents with low surface tension and low viscosity perform better
- fixatives should be colourless, transparent,

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non–toxic, and resistant to atmospheric agents and biological degradation

Sometimes it is necessary to apply fixatives to a wet wall surface. Under these circumstances, organic solvents with low polarity and surface tension can be used to avoid too deep a penetration of the fixative into the painted layer [3, 4].

Both organic and inorganic fixatives have been used for consolidation of works of art including, in the last 30 years, many artificial (acrylic and vinylic) polymeric resins. However, irreversibility of the treatment, poor durability, drastic change of the structural properties of a wall painting, and poor physicochemical compatibility with the substrate are often associated with treatments performed using these organic materials [5, 6].

Inorganic–based consolidants have the great advantage of good durability and, from a physicochemical point of view, are usually highly compatible with the wall painting matrix. The most common, and simplest, inorganic consolidants are solutions of limewater or barium hydroxide in water. Barium hydroxide solutions have been used for many years with very positive results [7–9]. However, barium hydroxide cannot be considered totally compatible with the wall painting matrix, because small amounts of barium (as barium carbonate or sulphate) are introduced into the calcium carbonate matrix.

The best consolidant would be calcium hydroxide, $Ca(OH)_2$, which formed the original binder. Unfortunately, the poor solubility of calcium hydroxide in water ($1{\cdot}7 gl^{-1}$ at 20°C [10]) has prevented an extensive use of limewater as a wall painting consolidant [11]. The only way to increase the $Ca(OH)_2$ concentration in limewater is to use a lime dispersion in water, sometimes in the presence of micronized sand. Lime dispersions are not widely used; their sole uses are for micro–stuccoing or internal injections [12, 13]. Moreover, lime dispersions in water are not stable as they have a very fast sedimentation rate. This precludes their use as wall painting consolidants, because they form a white film on the surfaces to be consolidated. It is these limitations in the use of inorganic consolidants which have favoured the inappropriate use of those polymeric compounds that have often produced damage to wall paintings.

This study investigated the stability and consolidation properties of some calcium hydroxide dispersions recently formulated in our laboratory. Their use in the consolidation of wall paintings by Andrea da Firenze in the Cappellone degli Spagnoli in the Chiostro Verde of the church of Santa Maria Novella in Florence produced excellent results. These new calcium hydroxide dispersions might be regarded as a first choice for consolidating wall paintings and are an innovation in consolidation treatments for the conservation of wall paintings.

Experimental section

The materials used in the experimental work were: slaked lime (calcium hydroxide, $Ca(OH)_2$, 45% and water 55% w/w); calcium hydroxide (powder), purity >99·5%; propan–1–ol, purity >99·5%; quartz, SiO_2, 40–100 mesh, purity >99%. The water used was HPLC–grade (resistance $>18 M\Omega.cm$), obtained from a Milli–RO6 plus Milli–Q–Water System (Organex). All these materials were used without further purification. The characteristics of the $Ca(OH)_2$ particles in the powder and slaked lime are reported in Table 1.

The stability of the dispersions was determined as follows. The dispersions were prepared by vigorously stirring 0·25g of $Ca(OH)_2$ (powder or slaked lime) in 40ml of the dispersing medium (water or propan–1–ol) at room temperature. The absorbance, A, was measured at 600nm, using a Lambda 5 Perkin–Elmer ultraviolet/visible spectrophotometer, immediately after the preparation of the dispersion (time, t = 0) and as a function of time for up to 16 hours. The relative kinetic stability of the dispersions was determined as the ξ–parameter, calculated using equation (1) [14]:

$$\xi = \{1 - [(A_{t=0} - A_t)/A_{t=0}]\} \times 100 \qquad (1)$$

The mortar samples (size 50 × 50 × 10mm) on which the calcium hydroxide dispersions were tested were prepared as follows. Slaked lime and pure quartz (particle size 40–100 mesh) in various ratios (1:2, 1:3, 1:5, 1:8 and 1:10 v/v, slaked lime/quartz) were mixed in sufficient distilled water to obtain a paste. The ratios 1:2 and 1:3 are representative of ordinary mortar for *intonaco* to be painted *a fresco*, while the ratios 1:5, 1:8 and 1:10 were chosen to produce mortars lacking in binder (slaked lime) to simulate decohesion. These pastes were put into wooden moulds on bricks covered by filter papers, to avoid adhesion of the sample to the bricks. In order to achieve a high degree of carbonation of the calcium

Table 1 Characteristics of $Ca(OH)_2$ powder and slaked lime particles

Parameter	*Powder*	*Slaked lime*
BET surface area (m^2g^{-1})	1–14	25–30
Average particles diameter (μm)	6–8	3–4

hydroxide, the mortar was left to set properly in air for two months. To test the efficacy of the consolidants, the calcium hydroxide dispersions were brushed onto these samples, protecting the surface with Japanese paper sheets. The lime/propan-1-ol dispersion used as pre-consolidant in the restoration of a small region of the wall paintings in the Cappellone degli Spagnoli was treated in a Branson B-12 ultrasonic bath for six minutes to reduce the particle size further.

The consolidant efficacy was ascertained by checking both the chemical (degree of carbonation) and physical-structural properties (capillary rise, water permeability, total porosity, sclerometric resistance and surface cohesion) of five samples of each type of mortar. Capillary rise curves and water vapour permeabilities were determined using the procedures reported in the literature [15, 16]. The degree of carbonation of powder samples was checked by X-ray diffractometry (XRD) using a Philips PW 3710 diffractometer equipped with a CuKα tube; data were recorded as 2θ values between 5 and 65 degrees. The degree of carbonation was also determined by calcimetry using the Dietrich-Frühling method. Porosity measurements (total porosity) were performed using a Ruska 1060-800 picnometer, while the resistance to surface abrasion (sclerometric scratch test) was measured using a Durimet Leitz microdurometer (for metal hardness) by making 30mm-long scratches with a weight of 300g on the punch. The surface cohesion parameter κ (in m^{-1}) was defined as the reciprocal of the average scratch width. Surface cohesion was also measured by the 'Scotch Tape test' (STT) [1, 2].

Results and discussion

Two different sets of dispersions each containing 0·625g of $Ca(OH)_2$ in 100ml of solvent were prepared, that is, dispersions of $Ca(OH)_2$ powder in water, slaked lime in water, $Ca(OH)_2$ powder in propan-1-ol, and slaked lime in propan-1-ol. The stability of these dispersions was monitored by following absorbance as a function of time. The stability of slaked lime in propan-1-ol, $Ca(OH)_2$ powder in propan-1-ol, and slaked lime in pure water are shown in Figure 1. $Ca(OH)_2$ powder in water (not shown in Figure 1) behaves in the same manner as slaked lime in water. Figure 1 shows that water dispersions are unstable, while the dispersions in alcohol possess quite good stability. In particular, the slaked lime dispersions are more stable than those of $Ca(OH)_2$ powder, in agreement with their lower average particle diameter (see Table 1). Quantitative information on the stability of the dispersions was

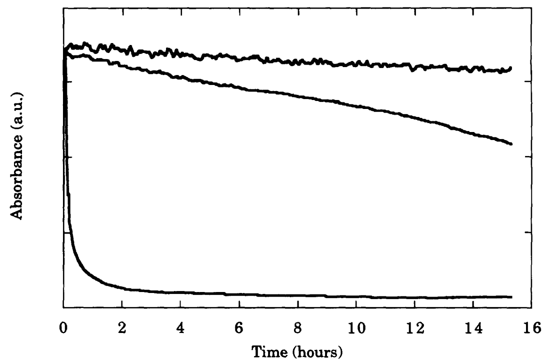

Figure 1 Absorbance at 600nm as a function of time for three $Ca(OH)_2$ dispersions. From top to bottom: slaked lime in propan-1-ol, $Ca(OH)_2$ powder in propan-1-ol, slaked lime in water.

obtained from the ξ-parameter calculated as a function of time. The stability parameter for water dispersions is about 10% 30 minutes after the preparation of the dispersion, indicating that most of the suspension has already settled. Alcohol dispersions are much more stable; after 16 hours the stability parameters were 63 and 86% for powder and slaked lime, respectively. Of interest was that the extremely good stability of the alcohol dispersions cannot be attributed solely to the hydrodynamic forces that oppose gravity. If the sedimentation velocity is calculated from equation (2) [17]:

$$V_o = 2a^2(\rho - \rho_o)g/9\eta_o \qquad (2)$$

where a is the particle radius, ρ the density of $Ca(OH)_2$, ρ_o the density of the dispersing medium, g the acceleration due to gravity and η_o the viscosity of the dispersing phase, values in the range 1-10cm per hour are obtained for both water and alcohol. These values are high enough that complete sedimentation from the propan-1-ol suspension might be predicted to occur in a few hours, as found for the systems in water. Therefore, the enhanced stability detected with propan-1-ol as dispersing medium must be due to the combination of electrostatic and hydrophobic interactions that prevent both sedimentation and particle aggregation.

Once the stability of these dispersions had been established, their use as consolidants in wall painting conservation was studied. They were applied to the surface of mortar specimens prepared as described in the experimental section. Due to the very low lime/sand ratio, these specimens simulate decohesion of wall paintings; in particular, when the lime/sand ratio is 1:8 or 1:10, the surface is powdery to the touch. Before consolidation treatment, the mortar samples were characterized by capillary rise absorp-

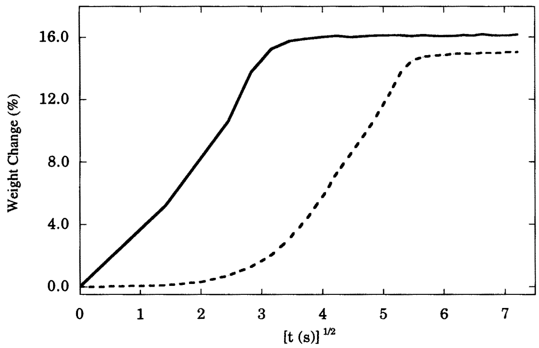

Figure 2 Capillary rise for mortar samples comprising sand and lime in a ratio of 8:1 by volume. Solid line: untreated sample. Dotted line: sample treated with the lime/propan–1–ol dispersion.

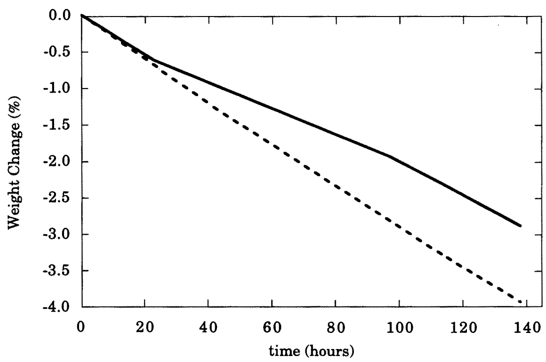

Figure 3 Water vapour permeability for mortar samples comprising sand and lime in a ratio of 8:1 by volume. Solid line: untreated sample. Dotted line: sample treated with the lime/propan–1–ol dispersion.

tion, water permeability, mercury porosity, sclerometric resistance and surface cohesion. The mortar surfaces were protected with Japanese paper sheets and treated three or four times with the dispersions. Three or four minutes after the last application (sufficient for complete penetration of the dispersion into the mortar samples) the Japanese paper was removed. It was noticed that the dispersions were highly fluid, their viscosity being almost identical to pure propan–1–ol. Depending on the thermohygrometric conditions, the time required for the propan–1–ol to evaporate completely was up to 12 hours. This left $Ca(OH)_2$ particles entrapped in the wall matrix to be consolidated and the samples were allowed to set properly for one month. After this time the effectiveness of the consolidation treatment was assessed.

Figure 2 shows the capillary rise behaviour for two mortar samples (ratio of sand to lime 8:1 by volume) before and after treatment with the lime/propan–1–ol dispersion. It is evident that water absorption at the treated surface is less pronounced than at the untreated surface of the 'blank' (reference sample), implying that the treatment has made the surface more compact and less permeable to water. Furthermore, the treatment has changed the shape of the absorption curve from an exponential to a sigmoid type, indicating a partial induction time for water absorption by the surface. Figure 3 shows the water vapour permeability as a function of time [16]. Consolidation by the lime/propan–1–ol dispersion produced a decrease in the water vapour permeability, confirming the efficacy of the method [18]; a good consolidant should produce a more compact material, which will be less permeable to water vapour. On the other hand, the decrease in water vapour permeability can be attributed either to bulk (whole sample) consolidation, or to consolidation of only the first few microns at the surface. To discriminate between these two different mechanisms, total porosity measurements were carried out. Figure 4 shows the total porosity of various mortar samples treated with lime/propan–1–ol dispersions. It is evident that only the surface layers were consolidated, since an appreciable decrease of total porosity (associated with pore occlusion by $Ca(OH)_2$ particles) would otherwise have been detected. This method did not produce any drastic reduction of porosity, suggesting that it is a suitable consolidation procedure, in that it does not dramatically alter the structural properties of the original materials.

Table 2 summarizes the physicochemical properties of the mortar samples before and after treatment

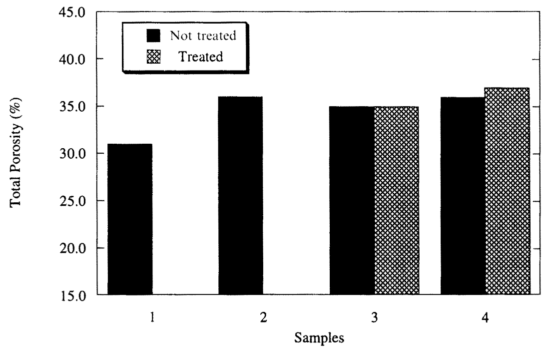

Figure 4 Total porosity for mortar samples with different sand to lime ratios before and after treatment with a lime/propan–1–ol dispersion. Samples 1 to 4 have lime to sand ratios of 1:2, 1:3, 1:5 and 1:8 respectively. The solid bars show porosity before treatment, the hatched bars porosity after treatment.

*Table 2 Capillary absorption coefficients (CA), surface cohesion parameter (κ) and loss of material by Scotch Tape test (STT) for various mortar samples before and after the treatment with lime/propan–1–ol dispersions**

Sand to lime ratio (volume:volume)	*CA* $(g.cm^{-2}.s^{-1/2})$	*κ* (m^{-1})	*Loss of material by STT* $(mg.cm^{-2})$
2:1	0·56	1111	0
3:1	0·48	625	0
8:1	0·64	312	5·19
8:1 treated	0·35	556	1·37
10:1	0·72	227	7·12
10:1 treated	0·42	417	4·12

*The values are averages of measurements made on five mortar samples; the uncertainty is about ±10%.

with the lime/propan–1–ol dispersion. These data clearly show the improvement in capillary absorption coefficient, surface cohesion parameter (by durimeter) and SST results, indicating a consistent increase in cohesion after the application of the lime/propan–1–ol dispersion to those mortar samples that previously exhibited poor cohesion.

As the laboratory experiments produced very positive results, the technique was applied to wall paintings by Andrea da Firenze in the Cappellone degli Spagnoli in the Chiostro Verde in Santa Maria Novella, Florence. Figure 5 shows a portion of the painting containing a geometric decoration, before and after treatment. The deterioration was mainly due to flaking and powdering of the paint layer, which required a pre–consolidation. Normally, this would be achieved by using a mixture of lime and casein, but this mixture introduces an incompatible material (casein) into the wall painting structure. Our aim was to substitute this mixture with the lime/propan–1–ol dispersion, which is totally compatible with the inorganic wall matrix.

The dispersion was applied using a brush, while protecting 30 × 30cm patches of the wall surface with Japanese paper sheets. The Japanese paper allowed the dispersion to be applied without damage to the painted surface by mechanical removal of pigment powder and/or fragments. The pore size distribution of the Japanese paper was selected so that all the $Ca(OH)_2$ particles in the lime/alcohol dispersion would penetrate into the wall without leaving any residue on the paper surface. First, the wall was treated with 100ml of a dispersion containing 0·5g of $Ca(OH)_2$ per 100ml of propan–1–ol and allowed to set for a week. This dispersion was slightly less concentrated than those tested in the laboratory (0·625g per 100ml), as a precaution against the risk of leaving a white film on the surface of the wall painting. A second application of 70ml of the same dispersion was carried out using the same procedure, and allowed to set for 10 days. After this pre–consolida-

Figure 5 Portion of one of the wall paintings by Andrea da Firenze in the Cappellone degli Spagnoli in the Chiostro Verde in Santa Maria Novella, Florence, before (top) and after (bottom) the restoration carried out using pre–consolidation with a lime/propan–1–ol dispersion.

tion, the wall painting was conserved using the methods presented by Ferroni and Dini [7–9, 19–21]. The final appearance after restoration is illustrated in Figure 5. The results are basically the same as those obtained by using the 'casein technique', but with the important difference that no organic material was permanently introduced into the wall painting structure which might produce damaging effects due to possible proliferation of microorganisms, or to the different physicochemical properties of the organic material.

Conclusions

This study has shown that it is possible to obtain stable lime/alcohol dispersions that can be used in wall painting conservation. These dispersions contain about three times more $Ca(OH)_2$ than saturated aqueous lime solutions and their stability is of the order of many hours; this stability is particularly important for their possible application to wall painting surfaces. The high kinetic stability of the dispersions is fundamental in avoiding lime deposition on the painted surfaces and consequent irreversible white glazing.

A lime/propan-1-ol dispersion was tested in the laboratory as a consolidant for mortar samples that simulated severe decohesion due to low binder concentration. All the parameters measured confirmed that the dispersion provided good consolidation without any glazing on the surfaces. In particular, the resistance to tangential scratches (sclerometric measurements with the durimeter) and to the surface abrasion test (STT) indicated high re-cohesion of the upper paint layers.

The dispersion was also used in the restoration of wall paintings by Andrea da Firenze in the Cappellone degli Spagnoli, with excellent results. It should be stressed that this method should not be used, or used only with extreme caution, in the presence of pigments that are sensitive to alkaline solutions or are executed *a secco*. The authors suggest that the technique can be used without drawbacks in all cases where it would be appropriate to use limewater. Finally, the key feature of this new methodology is its complete physicochemical compatibility with the materials in the original work of art.

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Suppliers of materials

Calcium hydroxide (powder) and propan-1-ol: Merck, Darmstadt, Germany.
Quartz, 40–100 mesh: Fluka, Buchs, Switzerland.
Slaked lime (calcium hydroxide plus water) as 'lime cream': Ceprovip, Medolago (BG), Italy.
Japanese paper sheets: Zecchi, Florence, Italy.
Milli-RO6 and Milli-Q-Water System (Organex): Millipore SA, France.

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Résumé—*On a étudié les dispersions d'hydroxyde de calcium $Ca(OH)_2$ dans des alcools aliphatiques à courte chaîene dans le but de mettre au point une nouvelle méthodologie de pré-consolidation et de consolidation pour les peintures murales. Le choix de la chaux (une pâte d'hydroxyde de calcium et d'eau) comme consolidant a été suggéré par des critères physiques de compatibilité, puisque la chaux est le liant originel dans les peintures murales traitées. Plusieurs problèmes sont apparus lors des essais d'application de l'hydroxyde de calcium aux peintures murales. Les solutions saturées sont trop faibles pour agir en tant que consolidant, en raison de la faible solubilité du $Ca(OH)_2$ dans l'eau (1.7 gl^{-1}). Par ailleurs, les suspensions de $Ca(OH)_2$ dans l'eau sont trop instables pour pouvoir être appliquées sur des surfaces peintes non protégées. On suggère donc l'utilisation de $Ca(OH)_2$ en dispersion dans le propan-1-ol. Ce type de dispersion a été caractérisé, et leur stabilité cinétique étudiée par spectrométrie UV/visible. Les dispersions dans l'alcool se sont avéré es plus stables que les suspensions en milieu aqueux. La deuxième phase a consisté à évaluer le pouvoir consolidant des dispersions dans l'alcool sur des échantillons reproduisant différents degrés de désagré gation. Ceux-ci ont été examinés par diffractométrie des rayons X et par spectroscopie IRTF. Leur propriétés de surface ont été étudiées par mesure de tension capillaire, de perméabilité, ainsi que par porosimétrie à mercure. Leur propriétés mécaniques ont été déterminées par la résistance sclérométrique et le test d'arrachement de ruban Scotch. Tous les tests concourent à indiquer que que les dispersions chaux/alcool produisent une très bonne consolidation. Finalement, l'article relate les résultats positifs des tests de type de dispersion sur les peintures murales d'Andrea da Firenze dans la chapelle Cappellone degli Spagnoli, Chiostro Verde de Santa Maria Novella, à Florence.*

Zusammenfassung—*Dispersionen von Calciumhydroxid ($Ca(OH)_2$) in kurzkettigen, aliphatischen Alkoholen wurden untersucht, um sie möglichenfalls als neues Vorfestigungs-oder Festigungsmittel für Wandmalerei zu verwenden. Die Wahl von Kalk (eine Calciumhydroxid und Wasser bestehende Paste) als Festigungsmittel wurde wegen seiner physiochemischen Ähnlichkeit zum originalen Bindemittel der Wandmalereien vorgeschlagen. Bei dem Versuch Calciumhydroxid anzuwenden, traten viele Probleme auf: Wegen der geringen Löslichkeit von Calciumhydroxid (1.7 gl^{-1}) sind gesättigte Lösungen zu schwach als Festigungsmittel. Darüber hinaus sind die Lösungen zu instabil, um sie auf ungeschützte Wandmalereien zu applizieren. Daher wird die Verwendung von Dispersionen des $Ca(OH)_2$ in Propan-1-ol vorgeschlagen. Durch UV/VIS-Spektroskopie wurden diese Dispersionen charakterisiert und ihre kinetische Stabilität untersucht. Die Dispersionen in Alkohol waren viel stabiler als die Suspensionen in Wasser. Der zweite Teil der Untersuchungen beschäftigte sich mit der Festigungsstärke der Alkohol-Dispersionen an Proben, die einen jeweils verschiedenen Grad der Ablösung simulierten. Diese wurden durch Röntgendiffraktometrie und Fouriertransforminfrarotspektroskopie untersucht. Die Oberflächeneigenschaften wurden durch Bestimmung der Kapillarkräfte, der Wasserbeständigkeit und der Quecksilberdurchlässigkeit getestet. Für die Untersuchung der mechanischen Eigenschaften wurde der Sclerometrische Widerstand bestimmt und der 'Scotch-Tape-Test' durchgeführt. Alle Ergebnisse zeigen, daß die Kalk/Alkohol Dispersionen exzellente Festigungsmittel sind. Abschließend wird in der vorliegenden Studie über Test mit Kalk/Alkohol Dispersionen an Gemälden von Andrea da Fierenze in der Cappelone degli Spagnoli. Chiostro Verde von Santa Maria Novella in Florenz berichtet.*

Resumen—*Las dispersiones de hidróxido de calcio, $Ca(OH)_2$, en alcoholes alifáticos de cadena corta fueron estudiadas con el fin de establecer nuevas metodologías de pre-consolidación y consolidación en pinturas murales. La elección de aguadas de cal (una pasta incluyendo hidróxido de calcio, $Ca(OH)_2$, y agua) como consolidante fue indicada por criterios de compatibilidad fisico-quimica, ya que la cal era el aglutinante original de las pinturas al fresco tratadas. Se encuentran numerosos problemas a la hora de aplicar las aguadas de cal a las pinturas murales: las disoluciones saturadas son demasiado débiles para actuar con efecto consolidante, debido a la baja solubilidad (1.7 gl^{-1}) del $Ca(OH)_2$ en agua. Además de esto, las suspensiones de $Ca(OH)_2$ en agua son demasiado inestables para ser aplicadas en pinturas desprotegidas. Se propone el uso de dispersiones de $Ca(OH)_2$ en propan-1-ol; estas disperciones se caracterizaron, y su estabilidad cinética fue investigada por medio de espectrofotometría visible/ultravioleta. Las dispersiones de alcohol se mostraron mucho más estables que las suspensiones en agua. La segunda parte del estudio evaluó el poder consolidante de las dispersiones alcohólicas en muestras que simulan los distintos niveles de descohesión. Estas fueron examinadas usando difractometría de rayos X y espectrometría trasformada de Fourier. Sus propiedades superficiales se caracterizaron estudiando la infiltración capilar, la permeabilidad al agua y la porosidad al mercurio. Las propiedades mecánicas de las muestras se determinaron mediante la resistencia esclerométrica y la 'prueba de la cinta adhesiva Scotch'. Todos los resultados indicaron que las dispersiones cal/alcohol producían excelentes consolidaciones. Finalmente el artículo señala los resultados positivos de las pruebas usando dispersiones cal/alcohol en las pinturas murales de Andrea da Firenze en la Capellone degli Spagnoli, Claustro Verde de Santa María Novella, Florencia.*