Durability of Building and Construction Sealants and Adhesives

2nd Volume

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Editor

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Foreword

This publication, *Durability of Building and Construction Sealants and Adhesives*, contains papers presented at the second symposium of the same name held in Reno, Nevada, on 15-16 June, 2005. The symposium was sponsored by the ASTM International Committee C24 on Building Seals and Sealants. The symposium chairman was Andreas T. Wolf of Dow Corning GmbH, Wiesbaden, Germany.

Contents

Overview

Introduction

The Second ASTM Symposium on Durability of Building and Construction Sealants and Adhesives (2005-DBCSA) was held on June 15-16, 2005 in Reno, Nevada. The symposium brought together architects, engineers, scientists – researchers and practitioners. Their aim was to transfer new ideas, gained from laboratory research and field work, to the study of sealant and adhesive durability and the development of new products and test methods.

Nineteen papers were presented at the symposium. This book contains a selection of twelve symposium papers published by the Journal of ASTM International (JAI) prior to February 2007. JAI is an online, peer-reviewed journal for the international scientific and engineering community. Publication in JAI allows rapid dissemination of the papers as soon as they become available, while publication in this Special Technical Publication (STP) is intended to provide easy access to the condensed information in a single volume for future reference.

Since the commercial introduction of the first elastomeric sealants and adhesives about fifty years ago, major advancements have been made in our understanding of their durability and the factors governing it. The progress of sealant and adhesive technology in building and construction structures has brought with it many new materials, products, systems, designs and concepts. It has also brought an awareness of new or formerly unrealized problems relating to the durability of building and construction sealants, which ASTM C 24 Committee on Buildings Seals and Sealants is addressing.

Against a background of national and international efforts to harmonize testing and approval of building materials and structures, ASTM C 24 Committee has been looking for ways of bringing together the experience of international experts gathered in the application and testing of building and construction sealants.

The current series of ASTM symposia on Durability of Building and Construction Sealants and Adhesives is a continuation of tri-annual symposia which were inaugurated by the RILEM Technical Committee 139-DBS Durability of Building Sealants in 1994. Today, this continuing series of symposia provides the best scientific forum globally in the building and construction industry for peer-reviewed papers on all aspects of sealant and adhesive durability.

As with most scientific disciplines, substantial advances often occur through a series of small steps, rather than in giant leaps. This is also the case for the papers presented at the ASTM Symposium on Durability of Building and Construction Sealants and Adhesives (2005-DBCSA). Many of the papers reflect progress reports on on-going research.

This volume contains twelve contributions reflecting the wide spectrum of current state-of-the-art research into sealant and adhesive durability. The symposium papers cover the following topics:

- Factors Influencing the Durability of Sealed Joints and Adhesive Fixations
- Durability Studies of Sealants and Adhesives
- Development of New Test Methods and Performance Based Specifications

Below is a short overview of the papers which were published in JAI in the above three categories.

Factors Influencing the Durability of Sealed Joints and Adhesive Fixations

While our understanding of the factors influencing the durability of sealed joints and adhesive fixations has progressed substantially over the past decades, there is still much to learn. A number of papers therefore focus on this topic.

The modulus of a sealant is a key property influencing the durability of weatherproofing joints that undergo movement. For sealants subjected to cyclic movements, formulation changes resulting in a reduction in modulus will provide higher durability, if sealant fatigue and other performance properties, such as adhesion, are not simultaneously degraded. J. M. Klosowski and J. E. Plott show the utility of a melamine resin additive in reducing the modulus of polyurethane and silicon-curable polyether sealants. The authors demonstrate that addition of relative small amounts of the melamine resin results in modulus reduction and improved adhesion in the specific sealants studied. However, the short-term nature of the study does not allow a sound assessment of the long-term durability of these sealants, since potential negative effects of the additive on the long-term behavior of physical properties were not studied.

Differential thermal movement between the spacer frame and the glass panes is a key contributor to the aging of the insulating glass edge seal and of the insulating glass unit (IGU) itself. Using finite element analysis, J. E. Stewart, W. R. O'Brien, and A. T. Wolf model the thermal movements occurring in the edge seal of a large IGU as a result of temperature variations (-30°C to +60°C) for three commercially available spacer bars of different material (aluminum, galvanized steel, and stainless steel) and corner design (corner keys or bent corners). As expected, at the low temperature, the corners are pulled inward, resulting in a bending angle >90°; while at the high temperature, the corners are pushed outwards, resulting in a bending angle <90°. Monitoring the changes occurring in the thickness of the polyisobutylene primary seal along the circumference of the IGU, the authors find that the stainless steel spacer has, by far, the least effect on the change in the cross-sectional area, while the aluminum spacer has the most substantial effect. This finding is in keeping with the expected performance based on the difference in thermal expansion coefficients between spacer material and float glass. Thus, changes in the effective cross-sectional area of the primary seal available for diffusion that arise from differential thermal movements are likely to account for the observed performance differences of IGUs manufactured with different spacer materials.

Any material, that is an effective catalyst for an equilibrium reaction, catalyzes both the straight reaction as well as the reversion of the reaction. This much can be gleaned from any basic chemistry textbook. What makes predicting the durability of sealants and adhesives complicated is the fact that under weathering exposure in general several reactions occur simultaneously. Y. Cai in his paper studies the effect of tin and aminosilane – both well-known silicone condensation catalysts – on the durability of a silicone elastomeric coating. The author shows that the tin catalyst has the strongest influence on detrimental changes in elastomeric properties and on chalking, but that the aminosilane also contributes to these changes.

Durability Studies of Sealants and Adhesives

The intent of this section is to present recent studies of the durability of sealant and adhesive materials and systems.

Customers increasingly challenge sealant formulators to develop high weatherability construction sealants with ever-higher performance. The trend towards higher service-life sealants is most visible in Japan and has led there to a gradual substitution of conventional sealants, such as polyurethanes, by higher performance sealants, such as silane curable organic sealants. Building on experience gained in Japan, C. Urban, T. Matsumoto, S. Tomari, and F. Adeleu in their paper discuss some of the factors that influence weatherability and durability of one-component sealants, such as binder, pigments, stabilizers, and catalysts. The authors compare conventional polyurethane sealants to silane curable sealants based on polypropylene oxide or polyacrylate backbones and mixtures of these two backbones. As expected, binder and stabilizer have the most notable influence on weathering resistance; however, catalyst, titanium dioxide, and plasticizer also affect the weathering behavior. For optimum weathering performance, all raw materials influences need to be carefully tested. Combinations of raw materials, especially in the case of stabilizers, may have synergistic effects, but may also reduce the weathering resistance. The authors also highlight the fact that a minimum of 1500–2000 hours of accelerated weathering should be used to assess the durability of construction sealants, and that for more demanding applications, 5000 hours, 10 000 hours, or an even longer duration of accelerated weathering may be required.

The second paper by Y. Masaoka, Y. Nakagawa, T. Hasegawa, and H. Ando also deals with the durability of silane curable organic sealants. In this paper, the authors discuss the durability and performance of sealants based on a novel telechelic silane curable acrylate polymer in contact with photocatalytic self-cleaning glass. Conventional sealants, when used in this application, often lack sufficient weatherability or involve the risk of hydrophobic staining of the self-cleaning glass. Sealants based on the novel telechelic silane curable acrylate polymer retain good adhesion to the self-cleaning glass even after more than 10 000 hours of exposure to UV irradiation in a super-accelerated xenon-arc weathering machine. Based on outdoor exposure of the test samples for two months and measurement of contact angles before and after exposure the authors conclude that these novel sealants have very low staining potential on photocatalytic coatings.

Since its introduction nearly four decades ago, structural silicone glazing (SSG) has become a popular glazing method for curtain wall construction. The major difference between SSG systems and the more widely used 'dry-glazed' systems is that glass lights or panels in SSG systems are adhered to the supporting glazing frame with structural silicone sealant along either two edges of the glass panel or all four edges. It is generally believed that SSG systems perform well in seismic regions due to the 'resilient attachment' of glass to the glazing frame. This notion has merits in four-sided SSG systems, but has not been previously substantiated for two-sided systems, wherein the top and bottom edges are typically captured in metal glazing pockets. The research presented by A. M. Memari, X. Chen, P. A. Kremer, and R. A. Behr in their paper therefore is aimed at characterizing the serviceability and ultimate behavior of two-sided SSG curtain walls under cyclic racking displacements. Serviceability drift capacities corresponding to damage states such as gasket distortion, weather-seal and structural seal failures leading to air leakage and glass cracking are identified. Based on the results obtained in this study and comparisons with data collected during comparable studies on dry-glazed curtain walls, the authors conclude that serviceability and ultimate drift capacities of two-sided SSG systems under seismic conditions are significantly higher than their dry-glazed counterparts.

Development of New Test Methods and Performance Based Specifications

The final section of the collated symposium papers reviews attempts at developing new test methods for assessing the durability of sealants and adhesives, and, at reaching the ultimate goal, the development of performance-based specifications.

Structural silicone sealants are used to attach glass or other panels to curtainwall framing systems. These sealants must possess sufficient structural strength to carry the wind-loads but must also have sufficient movement capability to resist the fatigue caused by cyclic shear movement. Cyclic shear movement is induced in the structural sealant by differences in the thermal expansion between the glazing panel and the curtainwall substructure undergoing variations in temperature. Temperature variations occur in response to changes in atmospheric conditions (clouds, rain, etc.), as well as diurnal or seasonal climate changes. Assuming the occurrence of a cyclic shear exposure event twice a day, a structural sealant is exposed to 36 525 cycles over a period of 50 years. In their paper, L. D. Carbary, E. D. Bull, and S. S. Mishra expose nine silicone sealants with rated movement capabilities of 12.5%, 20%, 25% and 50% to at least 36 000 cycles of cyclic shear movement with 15% strain at a rate of five cycles per minute. It should be noted that realistically, thermal movement displacements for in-service curtainwalls will rarely approach strains of 15%. Products with a movement capability of 12.5% have been performing without failure for many years lending credence to this point. While the tested structural silicone sealants experience degradation as a result of the cyclic shear exposure, the degradation is small enough not to induce rupture, if the sealants are not strained beyond their movement capability. The sealants with higher movement capability show less susceptibility to degradation than sealants with lower movement capability. The authors suggest that this test method can provide a basis and a model from which to further study fatigue and to provide some guidelines and understanding of how the structural silicone sealants react to repetitive loading. They also speculate that further development of this method may result in its inclusion in the ASTM C1184 Specification for Structural Silicone Sealants.

The expectations of building owners for waterproofing systems are simple. Waterproofing must prevent the passage of water (impermeability), must be capable of successful installation under typical construction conditions (constructability), and must continue to provide waterproofing for the life of the structure (durability). The realization of these expectations is thwarted, in part, by a lack of consensus on how these features are defined, tested, and compared to performance-based criteria. J. C. Strong, J. R. Kovach, and V. S. Eng in the first part of their paper investigate important properties of waterproofing materials commonly used on plazas and below-grade walls and review the acceptance criteria of ASTM International, Canadian General Standards Board (CGSB), and International Code Council (ICC) Evaluation Services (ES) standards for waterproofing systems. In order to overcome the discrepancies between these standards, the authors recommend an open dialogue between the groups responsible for waterproofing material specifications in ASTM, CGSB, and the ICC ES. In the second part of their paper, the authors contribute two exploratory studies on the initial leakage resistance of bentonite waterproofing and the water absorption in cold liquid-applied waterproofing. Based on this testing, the authors suggest specific improvements in the relevant standards.

In November 2000, the Architectural Institute of Japan (AIJ) established a subcommittee chartered with developing an accelerated weathering test method suitable for assessing the durability of sealants. In their paper, N. Enomoto, A. Ito, I. Shimizu, T. Matsumura, Y. Takane, and K. Tanaka report interim results obtained with the proposed test method. In this method, the weatherability of sealants is studied using newly developed test specimens, which enable exposure of the cured sealants to simultaneous compression and extension in a single test specimen. The study comprises twenty-four sealants of seven chemical types commercially available in Japan. Interim results are reported after twelve months of natural outdoor weathering at three exposure sites in Japan (north: Hokkaido, central: Chiba, and south: Okinawa) and 3500 hours of artificial accelerated weathering with xenon lamp and carbon flame weathering devices. The interim results confirm that the surface degradation of sealants is accelerated by the additional movement cycles, and that the differences in the degradation among the sealants are becoming observable after the current exposure durations.

In their paper, H. Miyauchi and K. Tanaka propose a new design and service life assessment method for sealed joints exposed to seismic events. The paper is the culmination of several years of research by the two authors. In this research, the fatigue resistance of sealed joints to relative story displacement movements caused by earthquakes was studied experimentally and analytically. The authors now propose a new joint design method, which provides adequate sealed joint performance over the joint's service life. The design method is based on three criteria, i.e., type of sealant, effect of cross-sectional size and shape of the sealed joint, and fatigue resistance of the sealant at intersectional zones of sealed joints to the sliding and rocking motions of curtain wall panels. The process of sealed joint design considers the relationship between the number of cyclic movements to which the sealed joint is exposed during its service life and the number of cycles to crack initiation in the sealed joint as observed in the fatigue test method developed by the authors. Finally, the approach suggested by the authors allows the calculation of the accumulated damage level and the expected service life of a sealed joint.

In their paper, A. T. Wolf, S. Sugiyama, and F. Lee report on the use of an optical imaging and image analysis system in the assessment of surface changes induced in sealants by outdoor weathering. The method allows quantification of four distinct surface defects in the samples, namely cracking (crazing), visual color change, spatial uniformity of deterioration (due to dirt pick-up and uneven color change, or both), and overall surface texture. Chalking and dirt pick-up, as rated visually prior to the evaluation, cannot be accurately assessed with the digital imaging technique employed. The analysis shows that surface cracking and crazing generally can be well characterized using the automated image analysis system. While this study represents a step in the right direction, the authors suggest that further investigations are needed to develop an automated surface characterization method for sealants.

With current expectations for building exteriors to prevent all air and water entry into the building interior, the need for a near perfect seal of weatherproofing sealant joints has reached new levels of intensity. The need for better field tests has increased accordingly. To reach these goals, ASTM C-1521-02a Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints has been developed and adopted. The practice outlines a nondestructive procedure. The advantage of this methodology is that it allows an unlimited amount of testing to be conducted. While the procedure does not specify a specific instrument to induce the strain on the sealant/substrate bond-line, a device able to accomplish this procedure in a uniform, controlled, and calibrated fashion has been developed. The paper by D. Huff outlines a description of the device and its capabilities. The paper also provides a discussion of the use of statistical sampling when the option of complete testing is not feasible or required.

Closure

As we publish this volume, I look forward to the next Symposium on Durability of Building and Construction Sealants and Adhesives (2008-DBCSA) and the associated flurry of papers in this dynamic industry. I encourage all readers to participate in the work of ASTM C24 committee, to attend the future symposia and to contribute new papers. Your participation and feedback help to advance the industry and, as a result, we will all benefit from improvements to our built environment.

In closing, I would like to gratefully acknowledge the outstanding quality of the contributions made by the authors as well as the dedicated efforts of the 2005 session chairpersons, the peer reviewers, and the staff of ASTM and AIP, who all helped to make the 2005 symposium and the publication of the associated papers possible.

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