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EFFECT OF CROSS-SECTIONAL SHAPES OF POLYSULFIDE SEALANT ON SHEAR FATIGUE RESISTANCE TO SLIDING JOINT MOVEMENT

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ABSTRACT: The effect of cross-sectional shapes of polysulfide sealing beads on shear fatigue resistance to sliding joint movement was studied experimentally and analytically. Six kinds of sealing beads that were different in the depth of their concavity were repeatedly deformed by shear joint movement. Cracks appeared in surface near substrates or in the middle of surfaces in some specimens, and developed in parallel to substrates or in X-shape. The time to cracking became shorter for the specimen with deeper concave shape. To learn the reason for these results, the surface stresses of the beads were studied using a finite element method. It was concluded from both experimental and analytical results that a durable cross-section of a sealing bead to shear joint movement is rectangular or slightly concave shapes.

KEYWORDS: sealant, polysulfide, shear fatigue, shear joint movement, sealing bead, cross-sectional shape, concave surface, cyclic test

The most important aspect in the design process of sealing joints is to determine dimension of cross-section of sealing beads. Their sizes have been designed with the assumption that their cross-sectional shapes might be rectangular [1]. However, most sealing beads in joints of actual buildings do not have completely flat surfaces, but slightly concave surfaces. It is because front surfaces of beads are usually finished into concave shapes by a flexible finishing knife after injection, and bottom surfaces are, on the contrary, formed off into concave shapes by back-up materials attached behind sealants, and sometimes volatile constituents in sealants, might leave concave surfaces by their volatilization during cure.

There has been concern over issue of surface shape of a bead. In the previous paper [2], we studied on its effect on fatigue of polysulfide sealant repeatedly subjected to extension and contraction movement. However, we have had little interest in the subject for shear movement, because the width of sealing beads obtained from the calculation to extension and contraction movement is larger than that to shear movement, and the dimension of sealing beads are, thereby, determined for former joint movement, not for shear movements in most joints.

The Hyougokenn-Nannbu earthquake 1995 made us realize again the importance of shear fatigue resistance of sealants. At the earthquake, some sealing beads were ruptured by the shear movement of joints between panels of curtain walls. In addition to the movement by an earthquake, wind also induces shear movement of joint between panels, in particular curtain walls of tall buildings, and the number of buildings that we should consider shear joint movement by wind at design stage increases in our country.

These circumstances have furthermore urged us basic studies on shear fatigue of sealants by sliding joint movement, in addition to the previous detailed papers on the subject [3-5]. In this paper, we focused on cross-sectional shapes of a sealing bead, and intend to clarify its effect on shear fatigue resistance to sliding joint movement.

SHEAR FATIGUE TESTS OF SEALING JOINTS WITH VARIOUS SURFACE SHAPES

Specimen

A sealant is injected into the gap between two panels and a back-up material as shown in Fig.1. Hence it was modeled into the specimen as shown in Fig.2; a back-up material was removed off for inspection of a bottom surface of a bead during fatigue tests. A polysulfide sealant was injected into the space between two aluminum bars of 280mm long fixed at 20mm in the gap, and at the bottom of which epoxy resin bars of various shapes were installed instead of back-up materials. After injection, their faces were formed into various concave shapes by specially shaped plates. The specimens were cured at room temperature for two weeks and kept in a chamber controlled at 50℃ for two more weeks.

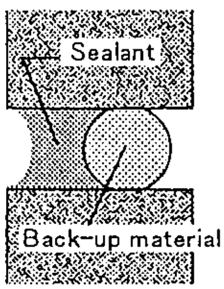

FIG.1—Cross section of sealed joint

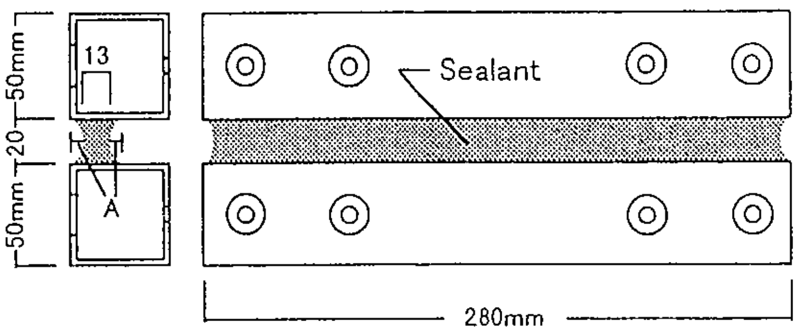

FIG.2—Test specimen

Surface shapes of Sealing Beads

Among sealing beads designed for use in buildings, the 20mm wide and 13mm deep (Shape factor, Depth/Width, is 2/3) was selected for the specimens. As for the surface shape of beads, various elliptical curves that are given by the elliptic function ($X^2/A^2+Y^2/(10mm)^2=1$, where A is a length of semiminor axis of the ellipse) were used, because the depth of concave surface is able to change mathematically through the function. The six levels of specimens in depth of concave surface were prepared for the study, as shown in Fig.3.

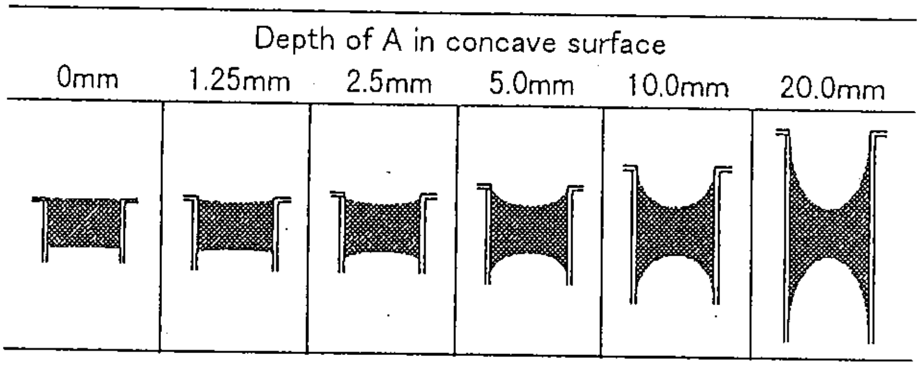

FIG.3—Cross-sectional shape of specimen

Fatigue Tests

Two specimens for each cross-sectional shape were attached to the fatigue test equipment. They were subjected repeatedly shear movement of joint according to three loci of sine curve, amplitude of which are ±60%, ±80% and ±100% of the joint width (that is, ±12mm, ±16mm and ±20mm respectively) and a period of 10 seconds. The front and bottom surfaces of specimens were periodically inspected directly with the naked eye for front surfaces, and through a fiberscope for bottom surfaces. The numbers of repetition of crack initiation, and the patterns of cracks were observed. Fatigue tests were stopped at one hundred thousand cycles unless any defects were observed in the sealing beads.

Results of Fatigue Test and Discussion

Fine cracks appeared on the surfaces of the specimens and gradually developed during shear fatigue operation. Three cracking patterns due to shear movements were observed as shown in Fig.4; Cracks start first in a bead near to substrate bars and gradually develop along them(a). A crack starts in the middle of the arc of a bead and develops in X shape(b-1). A crack starts also in the middle of the arc of a bead and develops in parallel to substrate bars(b-2).
The results of the shear fatigue test are shown in Fig.5.
(1) Influence of amplitude of shear movement to fatigue

The level of amplitude of shear movement directly affects the fatigue resistance of sealing beads. The larger amplitude accelerated fatigue failure of the specimens.

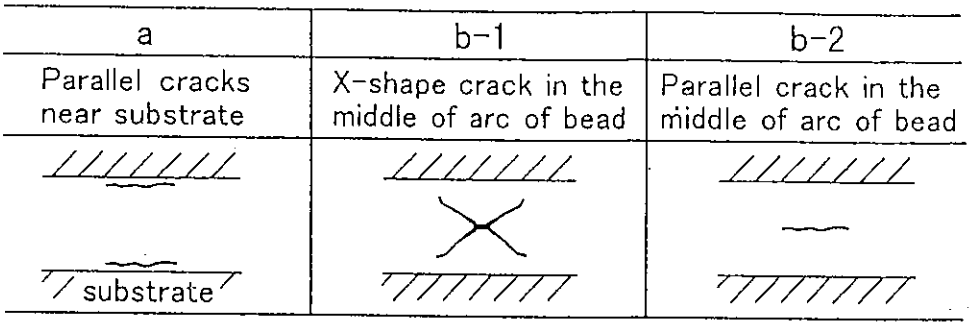

FIG.4—Cracking patterns

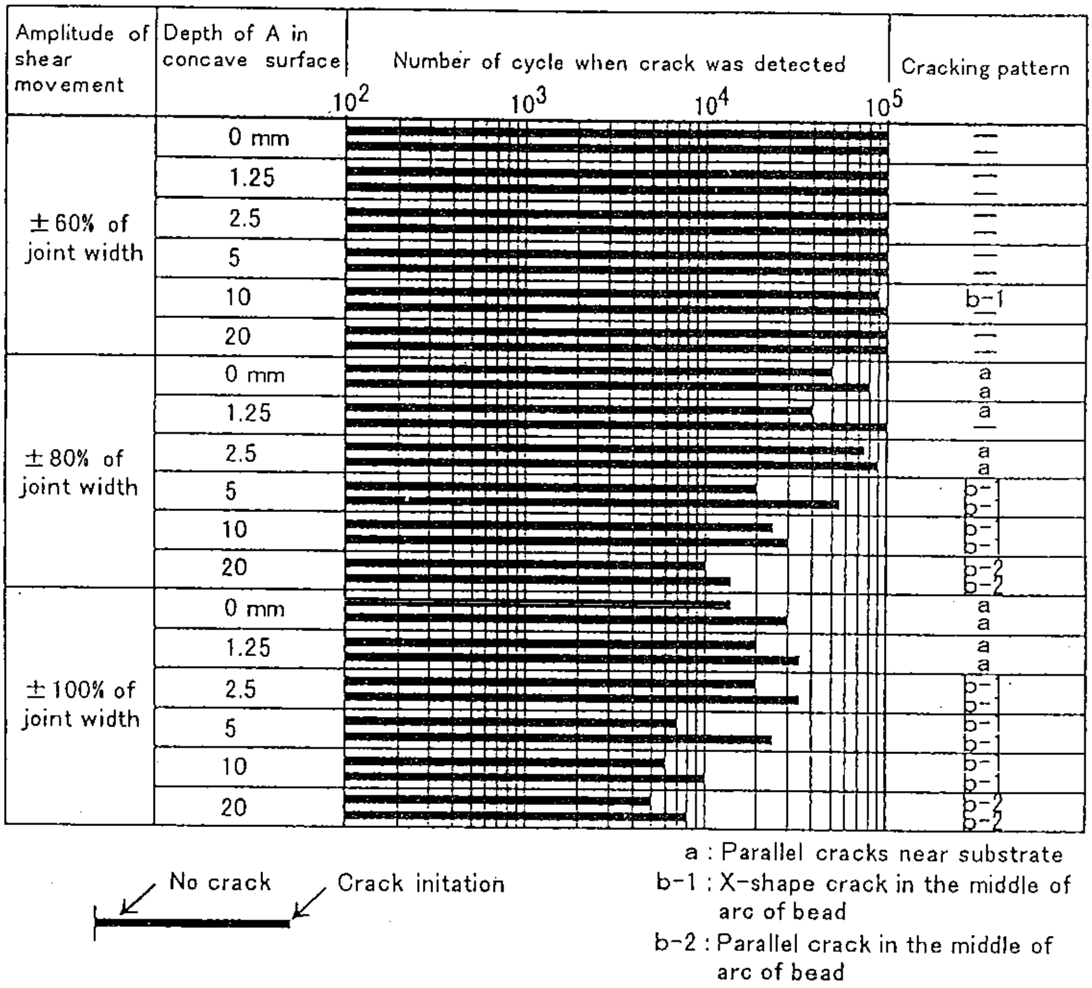

FIG.5—Results of shear fatigue test

(2) Influence of concave surface shape to shear fatigue

From the shear fatigue test results, Fig.6 was drawn, which shows the relationship between the depth of concave-surface bead shapes and the number of cycles of crack initiation. The patterns of cracks are also shown in the same figure by the symbols a, b-1 and b-2. It is obvious that shear fatigue resistance becomes lower when the depth of concave shape becomes too deep.

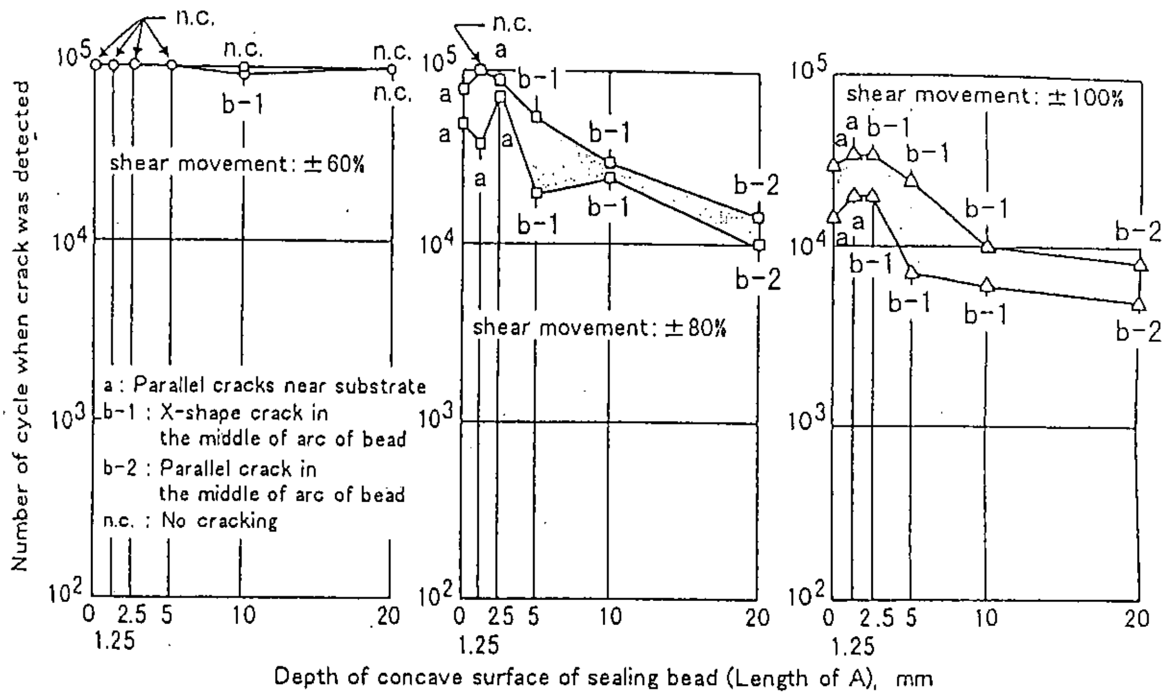

FIG.6—Relationship between depth of concave surface bead shapes and number of cycles of crack initiation

(3) Relation between cracking pattern and depth of concave surface shape

Cracks started from the location in surface near substrates for the beads with a straight surface and slightly concave surfaces, and gradually developed along substrates. For the beads with deep concave surface, a crack started from in the middle of the arc of beads, and developed in X-shape. For the bead with the deepest concave shape, a crack started in the middle of the arc of beads and developed in parallel to substrates.

STRESS OF BEAD BEING DEFORMED IN SHEAR

As seen from the fatigue tests, the shear fatigue resistance of sealing beads reduced as concave shape becomes deep. It is obvious that the results depend on the stresses of beads, in particular their surface stresses, because cracks occurred in the surface of beads. Hence, stresses and their distributions were further studied using a FEM computer program.

Outline of Analysis

A sealing bead is replaced in a three-dimensional model as shown in Fig.7. On the basis of the study on the accuracy of the results obtained through the preliminary calculations, the models of 120 elements were used. Calculation was carried out for six figures of cross-sectional shapes of which the length of A is changed from zero to 20mm. Most sealants show visco-elastic behavior in actual moving joints. However, the purpose of this analysis is to know the outline of stress distributions of sealing beads of

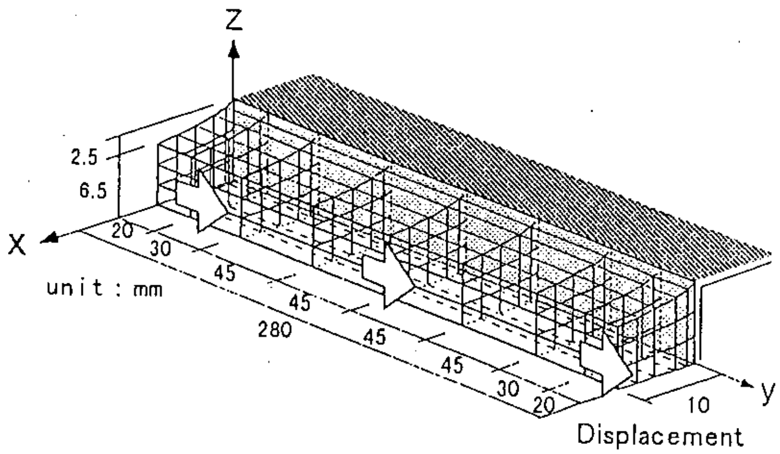

FIG.7—Analytic Model(modeled a quarter of the specimen in the case of A=2.5mm)

being shear deformed, and hence their stresses were obtained on the assumption of elasticity. For calculations, secant modulus of elasticity of 0.30MPa, 0.27MPa and 0.25MPa for shear deformation rate of 0.6, 0.8 and 1.0 respectively obtained from the shear test, and 0.48 of Poisson's ratio was adopted for the polysulfide sealant used here.

Results and Discussion

Fig.8 shows calculated principal stress distributions along the bead surfaces at shear deformation rate of 60, 80, 100%. The distributions are shown the stresses at the center of the specimen length. The stresses are not uniform along their surfaces, and the levels of stresses become higher according to an increase of shear deformation.

(1) Relation between stress and depth of concave surface shape

The principal surface stress is equal all over the surface for a rectangular cross-sectional shape bead. As for beads with concave shape, the stress at the corner of a bead is lower than the other area of a bead. The highest stress position moves to the middle of a bead and the higher stress area is concentrated into the middle area of a bead. as the concave shape becomes deep. The level of the highest stress appeared in a bead, rises according to an increase of depth of concave shape.

(2) Relation between stress distribution and cracking pattern

Three cracking patterns are presented in Fig.8 by the same symbol as Fig.4. They seem to be related to the stress distribution in a bead. The cracking pattern a, cracks started near substrates and developed parallel to substrates, is observed for the beads with flat and slightly concave surfaces. This might be for greater change of stress near substrates shown in 1.25mm and 2.5mm of A, or restraint effect of substrate that was not estimated by the elastic analysis. The pattern b-1, a crack stared in the middle of a bead and developed in X-shape, is observed for the cross section with moderate concave surfaces such as 2.5mm(at 100% shear movement),5mm and 10mm deep. The higher stress is distributed in the area of several millimeters from the middle of a bead for these cross sections. The pattern b-2, a crack started in the middle of a bead and

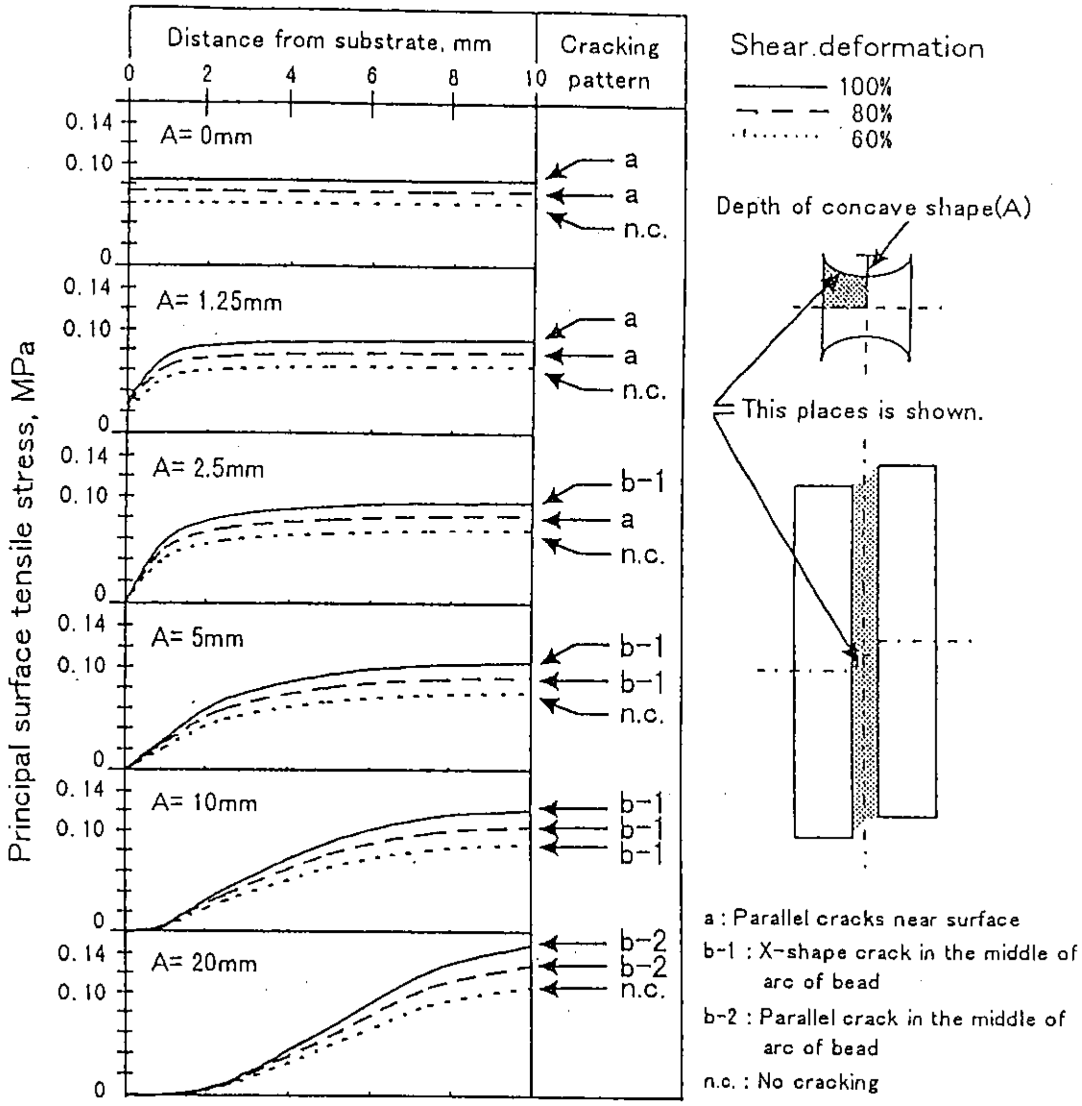

FIG.8—Stress distribution along surface of bead at shear deformed
(Stress at the center of a specimen length is shown.)

developed in parallel to substrates, is only observed for the bead of the deepest concave surface of 20mm deep. This is because the stress in the middle of surface is prominently higher than the other area.

DURABLE CROSS-SECTIONAL SHAPE OF BEAD TO SHEAR JOINT MOVEMENT

Good fatigue resistance of a bead to shear joint movement is theoretically expected when the levels of the stress are well balanced. From this point, a flat surface is deemed to be desirable. However, the restraint effect is not sufficiently expressed in the elastic analysis carried out here. Considering the restraint effect, slightly concave surface bead is also considered to be desirable. In the fatigue test result, good fatigue resistance was shown for the specimens of a rectangular shape and concave shapes of 1.25 and 2.5mm deep. Therefore, rectangular and slightly concave shapes are recommended as durable cross-sectional shape of a bead to shear joint movement.

CONCLUSION

The effect of cross-sectional shapes of polysulfide sealing bead, in particular surface shapes, on their shear fatigue resistance by shear joint movement was studied experimentally and analytically. The results thus obtained are concluded as follows.
(1) Cracks appeared and developed in a bead by shear joint movement, and they roughly divided into the three patterns. They are related to fatigue resistance of a bead in shear.
(2) Durable cross-sectional shape of a bead to shear movement is considered to be rectangular or slightly concave shapes.

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Feasibility Study on Recycling of Asphalt of Aged Built-up Roofing Membrane

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Keywords: Recycle, Asphalt, Built-up membrane, Performance of membrane, Hot press, Process oil

Abstract

No aged built-up membranes have been recycled yet, though they occupy more than half of about 90 million square meters in area of the waterproofing membranes newly applied every year in Japan. This paper describes the feasibility of recycling of aged asphalt obtained from built-up membranes that are over service life. First, we tried to develop the method to squeeze aged asphalt from an old roofing membrane, and could successfully obtain asphalt of 50-70% in weight from 13 years old membrane by hot press technique at about 100°C. Reductions of resins, aromatics and saturated hydrocarbons in the aged asphalt, compared to original one, were found out by a component analysis. Then, process oil was added to make the property of it recover. Penetration, softening point and slippage length of it was measured, and it was found out that the former two reached to the original level and the latter did not. Therefore, the mixing of some volume of new asphalt to it was further attempted to improve the slippage resistance. The compound of 45% of the aged asphalt, 5% of process oil and 50% of new asphalt was finally considered to be available as asphalt for built-up roofing membranes.

Durchführbarkeitsuntersuchung über das Recycling von Asphalt von gealterten zusammengesetzten Dachelementen

Bisher war das Recycling von gealterten zusammengesetzten Dachelementen noch nicht üblich trotz der Tatsache, daß solche Elemente mehr als die Hälfte der ca. 90 Mio. Quadratmeter Fläche an Dachabdichtungelementen ausmachen, die jährlich in Japan verbaut werden. Die vorliegende Abhandlung beschreibt die Durchführbarkeit des Recyclings von gealtertem Asphalt, der von zusammengesetzten Dachelementen stammt, die ihre Nutzungsdauer überschritten haben. Zunächst wurde versucht, eine Methode zum Herausdrücken des gealterten Asphalts aus alten Dachelementen zu entwickeln; dabei konnten mit Hilfe eines Warmpreßverfahrens bei 100°C aus 13 Jahre alten Dachelementen 50 bis 70% des Gewichts an Asphalt wiedergewonnen werden. Der verminderte Gehalt an Harzen, Aromaten und gesättigen Kohlenwasserstoffen des gealterten