

Joint Sealants for Buildings

S. M. SINGH & L. K. AGGARWAL
Central Building Research Institute, Roorkee

Received 2 May 1976; accepted 15 September 1976

Sealants are used for sealing joints and cracks in buildings. The demand for them has increased considerably with the coming into vogue of prefab construction units. In India, the requirement for sealants is met through the use of bitumen mastic and cement mortar or imported sealants. The formulations, characteristics and methods of application and performance testing techniques for silicone, polysulphide, polyurethane and acrylic based sealants are discussed. Bitumen modified with elastomeric materials, such as rubber latex, is still considered to be a good base for the development of sealants with adequate elastic properties.

IN concrete structures, joints are provided to accommodate the movements caused by variations in temperature and other weather conditions. These are filled with materials which allow expansion and contraction of the structural components and control the ingress of water. These sealing materials are polymeric in nature and are often termed as sealants. They are different from preformed strip sealing tapes and elastic gaskets.

Sealants may be plastic or elastic materials. An elastic sealant exhibits strain reversible properties in the presence of alternating stresses, whereas a plastic sealant is irreversible to strain.

Thermoplastic sealants— Bituminous compounds

Bituminous sealing compounds have been used from ancient times and are still in use. They consist mostly of bitumen, rubber, solvent and extenders. They possess excellent resistance to water, dilute acids and alkalis, but are affected markedly by solar radiation. They are applied by the spatula or the hot pour method over horizontal joints in pavement floors and roofs. Bituminous sealants can accommodate movement up to 25% of the joint width. These are most suitable for joint widths varying from 1 to 3.5 cm and depth from 2 to 3.5 cm¹. They show good adhesion to concrete and fairly good ageing stability under use. However, the life of bituminous

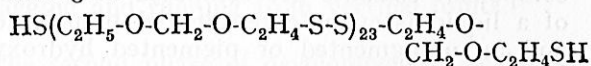
sealants depends largely on the performance of the joint walls.

Elastomeric sealants

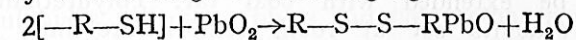
Elastomeric sealants are based on long chain type polymers and cure to a rubbery mass by chemical reaction. These materials can withstand much higher strains than bitumen based sealants. They exhibit good adhesion to concrete and possess good chemical and abrasion resistance. They are highly durable materials. The main elastomeric sealants are polysulphides, silicones, polyurethane and acrylics.

Polysulphide sealants

The polysulphides were the first polymeric type sealants to be used in the building industry. These are room temperature curing rubbers with minimum of shrinkage. They have a distinct and disagreeable odour which, however, disappears in fully cured compounds. The polymer consists of repeating bis (ethyleneoxy) methane groups containing disulphide linkages:



Curing of polysulphide polymers is accomplished by a wide range of oxidizing agents.



Polysulphide sealants are available in one- and two-component systems. The two-com-

ponent compounds are superior to one-component compounds. The first component consists of a polysulphide resin, a plasticizer and extenders, while the other one contains a peroxide and an additional plasticizer. Polysulphides are sensitive to heat and light and are unaffected by dilute alkalis². They possess excellent resistance to sunlight and weathering. For achieving proper adhesion, it is necessary to give a primer coat before the sealant is applied²⁻⁴.

Silicone sealants

Silicone sealants consist mainly of polysiloxanes, monomers, plasticizers, extenders and solvents. The backbone of polysiloxanes is the Si-O-Si linkage. Carbon participates only in organic saturated and unsaturated side chains attached to the main polysiloxanes chain.

The silicone sealant is one-component material in the form of a viscous liquid paste, which reacts with atmospheric moisture to give a smooth elastic material. It accommodates movement through its elastic properties. Silicone sealants adhere to many substrates. However, the use of an appropriate primer greatly helps its adhesion in critical applications⁵. Silicone sealants find limited use for economic reasons. However, for narrow joints requiring small quantities of the sealant and good finish, they find ever-increasing application. They do not sag in the joints even at high temperatures and are resistant to water, heat and oxidation^{6,7}.

Polyurethane sealants

Polyurethane sealants are available as one- and two-component systems. One-component urethane sealants are based on isocyanate terminated prepolymers of moderately high molecular weight. On the other hand, two-component sealants are composed of a blend of a liquid isocyanate terminated prepolymer and an unpigmented or pigmented hydroxyl terminated compound. The two components are blended before application. They may be extended with coal tar. Polyurethane sealants set at room temperature into a rubber-like material, which remains elastic at both low and elevated temperatures.

Polyurethane sealants are cheaper than silicone and polysulphide based sealants. The curing agents are more elastic than polysulphides and their high elasticity imparts fast and complete recovery to moving joints. The elasticity is reduced on ageing. Resistance to abrasion and tear is good. A drawback of urethanes is adhesion failure on immersion in water. As with silicones, the priming system used is very important to obtain optimum adhesion with various substrates.

Acrylic sealants

Acrylic sealants appeared in the late sixties, but the developmental work remained unpublished and highly restricted. Thermoplastic polyacrylics constitute the main binders for acrylic sealants. They set by solvent evaporation and so shrink after application and subsequent ageing. The main advantages of the acrylics are their excellent adhesion, flexibility and extensibility. They are durable and non-staining and require no primer. They are, however, not recommended for joints exposed to contraction and expansion motions.

Sealing tapes

Sealing tapes are recent entrants in the field of sealants. They are based mainly on polybutenes, polyisobutylenes and butyl rubber. They are preformed, semi-solid materials exhibiting pressure sensitive adhesion. Sealing tapes are produced in a variety of shapes, sizes and degrees of softness and strength. Because of their softness and compressibility, sealing tapes ensure continuous, void-free seals despite variations in the tolerances of the joints or materials to be sealed. They allow clean and quick installation without special equipment and skill. They can be applied under adverse conditions and become effective immediately after application.

In building structures, their main application is in the field of large precast concrete panels.

Sealing of the joints

Successful sealing of the joints depends mainly on (i) the geometry of the joints, (ii) surface preparation, and (iii) correct application of the compound. The geometry of the space occupied by the sealant has a marked influence on its performance. It is difficult to

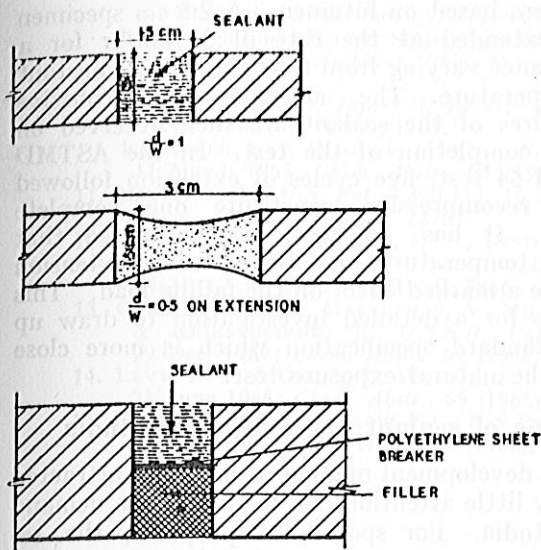


Fig. 1 — Diagrammatic representation of the operation of sealing the joints

obtain a good seal with depth less than 1.5 cm⁸. Narrow deep seals produce high strain in the compound and should be avoided. Best results are obtained if the ratio of sealant depth to sealant width is 1 or less than 1. It should, however, in no case be greater than 2. For deep joints, a suitable backing is provided to control the depth of the seal and to provide a stop, so that adequate pressure build-up takes place in the cavity during filling. It also ensures complete filling without voids. Suitable back-up materials are expansion joint fillers (IS: 1838-1961), foam rubber, fibreboard, etc. A bond breaker, such as polyethylene film, is placed between the substrate and the sealant to prevent stress concentration, which may occur if the sealant adheres to the bottom of the cavity (Fig. 1).

Surface preparation and application of sealants

Masonry, concrete and brick work are prepared by wire brushing followed by blowing out the dust with compressed air. Grit blasting may also be employed to clean the surface. Washing with water is avoided, as it takes a long time for complete drying. Most of these surfaces are porous in nature. The edges of the joints are, therefore, primed with a thin bituminous composition consisting of bitumen, 66 parts; light creosote soil, 14 parts; and mineral turpentine, 20 parts (by wt).

Bituminous sealants may be applied hot or by gun under pressure. Addition of solvent to the sealant which facilitates cold application takes a long time to dry completely. Therefore, it is not generally favoured. For gun application, the material is first filled in cartridges made of cardboard, foiled wrapped paper, a plastic material or metal. The cartridges are loaded into the guns and the sealant is dispensed at the desired place in the proper form under pressure.

Pourable sealing compounds which are fluid at the working temperature find their own level in the cavity and present no special problem. Care is, however, taken to avoid trapping of air in sealing the cavity. On vertical surfaces, pouring application cannot be adopted. It can best be applied by gun, which dispenses the material in the form of beads.

Formulation of sealant materials

Most of the developmental work reported in the literature is covered by patents. In the early sixties, bitumen and rubberized bitumen were used extensively. Investigations aimed at overcoming the deficiencies of bitumen led to the use of many other substitutes. Improved chemical and solvent resistant compositions were obtained with coal tar and isocyanate. Still better products were obtained when polycyclic materials containing active functional groups and polyesters with terminal —OH groups were cured through isocyanates. With the advances made in the field of plastics, more and more new materials, such as styrene, polyacrylates⁹ and acrylonitrile¹⁰ came into use. The products obtained had better weathering properties and were suitable for construction joints and cracks. Many more patents concern the use of plasticizers and hydrophobic agents¹¹ like stearates, abietates and dibutyl and dioctyl phthalates to yield more flexible sealants. Asbestos fibre and aluminium silicates, talc and vegetable fibres were employed to prevent sagging and running from vertical joints.

The second phase of development of sealants was the use of more flexible, chemical resistant and durable elastomeric materials¹² like polysulphides, silicone rubbers and polyurethanes. Polyurethane foams were used in conjunction with tar and asphalt, which gave cellular expansion joint sealers. Bitumen and rubber,

however, did not lose the field completely to modern synthetic elastomers. Many compositions based on the use of hydrogenated butyl rubber¹¹, polychloroprene and butadiene-styrene copolymers¹³ and bitumen were developed.

More stringent requirements of heat, water and chemical resistance in recent years have brought into prominence regular and random block copolymers of ABC type and polyisobutylene¹². Epoxy resin¹⁴ has also been used for the preparation of chemical resistant sealants.

It follows that bitumen and rubber have continued to be the backbone of all sealants. Newer elastomers no doubt gave products with excellent durability and flexibility, but these have inferior adhesive properties, resulting in the revival of bituminous materials with certain modifications. More recently, work has been initiated on the development of hermetically sealed, non-sticky, sprayable, thixotropic and antiseptic sealants to meet the requirements of the modern construction, thiokol and polyisobutylene acrylates¹⁴ and butadiene-styrene rubber were tried. Attention has also been paid to the development of test methods^{17,18}, which were inadequate till recently.

Performance and testing of sealants

The performance of a sealant depends on the physical and chemical properties of the sealant and the movement of the joint. The physical characteristics normally affected are softening, modulus of elasticity, compression, the degree of recovery, hardness and permanent set. Resistance to water, acids and alkalis and oxidation on exposure determines the chemical nature of the sealant. Movement of joints has a marked effect on the elastic and plastic properties of the sealant. A reasonably good sealant in a joint, not subjected to movement, may last indefinitely, provided it has good adhesion to the substrate. However, the sealant is most extended at the lowest temperature and most compressed during the period of high temperature¹⁹⁻²⁰. According to Tons²¹, a high quality joint sealant may be used to seal joints with up to 30% movement; however, the sealant should be capable of complete (or nearly so) recovery after unloading. In case the linear expansion is less than 10%, service should not be greatly affected if recovery of the sealant is not complete. IS:1834-1964, ASTM D 1191 and ASTM D 1850-67 deal with the testing of concrete joint

sealers based on bitumen. A 2.5 cm specimen is extended at the rate of 3 mm/hr for a distance varying from 6 to 2 mm at a constant temperature. The adhesive and cohesive failures of the sealant are then observed on the completion of the test. In the ASTM D 1191-64 test, five cycles of extension followed by recompression constitute one complete test. It has, however, been observed that the temperature and the rate of extension have a marked effect on the failing load. This calls for a detailed investigation to draw up a standard specification which is more close to the natural exposure test.

Stage of sealant development in India

The development of good sealants has attracted very little attention due to their poor demand in India. For specialized purposes, the requirements are met mostly through the use of imported materials. Although a few compositions based on bituminous and non-bituminous materials are commercially available, they find limited application.

A composition based on BNSL and rubber has been reported²² which was found good for sealing lap joints, boilers and railway wagons. Sealants for pressurized cabins and integral tanks of aircrafts have also been reported. There is obvious scope and need for the development of sealant compounds in India to meet the ever-growing demand for them in the construction of prefabricated and other structures.

Acknowledgement

The paper is published with the permission of the Director, Central Building Research Institute, Roorkee.

References

1. MEIKLE, T. A., *Architect Bldg News*, 7 (Oct. 1970), 72.
2. GREATHOUSE, G. A. & KLESSEL, C. J., *Deterioration of materials* (Reinhold Publishing Co., New York), 1954, 557-88.
3. FEBBES, E. M. & JORCZAK, J. S., *Ind. Engng Chem.*, 42 (1950), 2220.
4. GEORGE, D. A., ROTH, F. & STONE, P., *Adhes. Age*, 6 (1963), 35.
5. GAYLORD, N. G., *Polyethers*, Part III (Interscience Publication, New York), 1962, 143.
6. MYLIS, E. S., *Accelerated aging of elastomeric sealants*, Paper presented at Conference on Elastoplastics Technology, Society of Plastics Investigations, Wayne State University, 1965.
7. MARTELLOCK, A. C., *The hydrolytic degradation of silicone polymers*, paper presented at Conference

on Elastoplastic Technology, Society of Plastics Investigations, Wayne State University, 1966.

8. MEIKLE, T. A., *Architect Bldg News*, 5 (Nov. 1970), 62.
9. KIYOZO SHIOMOTO, *Jap. Pat.* 18751, Jan. 1960; *Chem. Abstr.*, 56 (1962), 1161.
10. KRENKLER, K. & WAGNER, F., *Germ. Pat.* 118,807, 11 March 1965; *Chem. Abstr.*, 63 (1965), 5854.
11. BATTLELINE, F., *U.S. Pat.* 3,320,333, 16 May 1967; *Chem. Abstr.*, 67 (1967), 22767.
12. AKUTIN, M. S., ABERMAN, G. S., PESID, I. M. & GURMAN, I. M., *U.S.S.R. Pat.* 160,245, 16 Jan. 1964; *Chem. Abstr.*, 61 (1964), 5866.
13. GARALEVICIUS, R., MARTECKAS, A., MILAKNITE, I. & KRIKSTULIENE, J., *U.S.S.R. Pat.* 208,154, 29 Dec. 1967; *Chem. Abstr.*, 69 (1968), 3549.
14. LEVY, D. F. & GAGLE, D. W., *U.S. Pat.* 3,257,336, 21 June 1966; *Chem. Abstr.*, 65 (1966), 7407.
15. BRAMBLE, L. F. & MORROW, F. C., *U.S. Pat.* 3,379,662, 23 April 1968; *Chem. Abstr.*, 68 (1968), 116233.
16. VASILE, I., ANDRAS, E., IOAN, M. & MIVRA, V., *Rom. Pat.* 48,978, 6 Jan. 1970; *Chem. Abstr.* 73 (1970), 27346; *Rom. Pat.* 52097, 4 Feb. 1970 *Chem. Abstr.*, 73 (1970) 27347.
17. GUREEV, A. T., *Izv. Vyssh. ucheb. Zaved., Stroit. Arkhitekt.*, 13 (8) (1970), 110-12.
18. SCHNEIDER, L. J., *Germ. Pat.* 2,058,700, 15 June 1972; *Chem. Abstr.*, 77 (1972), 90214.
19. PFLAUMER, Y. N., *Sb. Trud. vses. nauchno-issled. Inst. Nov. Stroit. Mater.*, No. 28, (1970), 38-40.
20. YAKUB, O. YU., *Sb. Trud. vses. nauchno-issled. Inst. Nov. Stroit. Mater.*, No. 27, 1970, 65-8.
21. KARPATI, K. K., *J. Paint Technol.*, 44 (1972), 55.
22. KARPATI, K. K., *J. Paint Technol.*, 44 (1972), 58.
23. TONS, E., *Materials and geometry in joint seals*, Paper presented at Plastics Conference, Wayne State University, March 1965.
24. RAMANUJAM, S. & SALUJA, R. V., *Indian Pat.* 80,084, 2 May 1964; *Chem. Abstr.*, 63 (1965), 4516.

PHOSPHOGYPSUM is a waste product of the wet process phosphoric acid industry. For every tonne of P₂O₅ produced as phosphoric acid, 4.5 tonnes of phosphogypsum containing about 20% moisture are obtained. In India, it is available to the extent of about 0.3 million tonnes per annum. Another 2 million tonnes would be available annually from the plants slated to go on stream in the near future.

Disposal of phosphogypsum poses a serious problem, because its inland dumping leads to pollution of ground and river waters and dumping in sea involves large treating expenditure.

Phosphogypsum contains phosphates, fluorides and organic matter in quantities. These impurities affect the hydration of cement if the material is used as an additive to cement clinker during its grinding. They also hinder the hydration and strength development of calcined plaster produced from it. Investigations were taken up to improve the quality of phosphogypsum so as to make it suitable for the above applications.

Experimental procedure

A representative sample of phosphogypsum received from Albright, Moraji and Pandit, Bombay was taken. The sample after drying

or... The sample was... rich in these impurities... The resulting product is suitable for use as an additive... also for making calcined plaster... boards and light weight blocks... partition walls.

of 42T analysis: SiO₂, 6.60; Al₂O₃, 0.86; CaO, 27.78; MgO, 0.2; SO₃, 39.8; P₂O₅, 0.92; Fe₂O₃, 16.0; 17.84; and organic matter, 0.13%.

Microropic examination showed acicular/orthorhombic and lath shaped crystals of gypsum, 3-4 μ powder dip action and that of hematite, of CaSO₄·2H₂O in gypsum. The thermogram showed shifting of transition temperature of CaSO₄(II) to CaSO₄(I) at 360°C for mineral gypsum to 370°C for this material, presumably due to the formation of solid solution of the impurity in gypsum crystal.

A sample was washed and wet slaved. The fractions obtained were dried at 45°C and weighed. Sieve analysis of the sample is given in Table 1.

The above four fractions were tested for impurities. The results given in Table 2 indicate that the concentration of impurities

Table 1—Sieve analysis of different fractions

Fraction No.	% Above	Retention
1	100	100
2	100	100
3	100	100
4	100	100