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Polyurethane elastomeric sealants in building applications

Building construction activity is rapidly increasing in India requiring more and more materials for diverse and specific applications. Polymer consumption in various forms like plastic products, coatings, adhesives and sealants is also increasing.

Rain water gains entry into buildings through cracks and joints. Traditional jointing and sealing materials like mortar, putty and bituminous mastics do not prevent entry of water and moisture effectively mainly due to their high shrinkage characteristics. The problem becomes more acute in prefabricated construction as a result of using large size panels and slabs involving larger thermal and moisture movements. Mortar and putty become hard on setting, often lose bond with adjacent wall or roof panels and develop cracks. Bituminous compositions become brittle on ageing and deteriorate under the influence of sunlight.

A wide range of modern elastomeric sealants based on neoprene, butyl rubber, silicones, sulphochlorinated polyethylene, acrylics, polysulphides and polyurethanes are in use in industrially advanced countries. These sealants are employed in buildings in different forms such as viscous liquid, pastes, caulks, putties, tapes and gaskets to prevent the passage of moisture, air, dust, heat etc, through all joints and slabs in RCC structures. These sealants exhibit negligible shrinkage and possess excellent elastomeric properties. Polyurethane sealants put a perfect barrier between the substrate and the environment.

Sealants are classified[1,2] in the construction industry according to the movement of joints in structures as shown in Table 1. The detailed performance of different types of sealants is shown in Table 2. Polyurethanes are good candidates for sealants because of a number of outstanding properties such as abrasion, oil resistance, low temperature flexibility, resistance to bio-deterioration etc. A very wide choice of the raw materials, diisocyanates and various polyols such as polyesters, polyethers, castor oil and polybutadienes allows polyurethanes to be designed with desired properties for specific applications. Sealants based on polyurethanes have not penetrated the construction sector in a big way in India although they are known in industrially advanced countries.

National Chemical Laboratory (NCL), Pune, and Central Building Research Institute (CBRI), Roorkee have developed a two pack polyurethane sealant for use in the construction industry. The sealant is predominantly based on raw materials available in India. The process steps consist of preparing isocyanate resin with controlled reactivity and it is crosslinked by hydroxy polyols having fillers. The sealant has been extensively evaluated and results are reported in this paper.

Table 1. Sealant classification

Type of sealant	Maximum tolerable movement as % of joint width	Character after cure	Recovery	Typical uses
Oil and resin base	5-10	Plastic	Poor/fair	Pointing around window and door frames
Bituminious and rubber/ bituminious	10	-do-	-do-	In contact with bituminous materials
Butyl rubber	10	-do-	Poor	Pointing and bedding
Acrylic (solvent)	12.5	Plasto-elastic	Fair	Pointing, eg around timber frames treated with exterior wood stains etc.
Acrylic (emulsion)	10	-do-	Poor/fair	Internal pointing
Chloro sulphonated polyethylene	12.5	-do-	Fair	Pointing
One part polysulphide	15-20	Elasto-plastic	Fair	Movement joints in heavy structures
Two part polysulphide	25	-do-	Fair/good	Fast moving joints in light weight structures and slow moving joints in large heavy structures
One part polyurethane	25	Elastic	Good	Movement joints in light components
Two part polyurethane	25	-do-	Excellent	Fast moving joints in light weight structures and slow moving joints in heavy structures
Silicon (structural high modulus)	20-25	-do-	-do-	Sanitary ware, fast moving joints.
Silicon low modulus	40-50	-do-	Good	Joints between plastic and metal components

Test methods

The devising of test methods is a most demanding and challenging contribution that applied scientists and engineers are called upon to make. The ultimate objective of most testing is to assist in selection and use of materials, components and systems which will perform as desired or as required.

Test methods for sealants may be broadly classified on the basis of requirements relating to application, compatibility and performance. For assessing the requirements relating to the application extrudability or pourability, slump test or ability to flow, non toxic, cure characteristics, replaceability and maintenance tests are important. Tests related to compatibility — adhesion to relevant surfaces, non adhesion to back up materials, non staining to surfaces, non migration of oily or other separable mobile components over building surfaces. Performance tests required for sealants, involve many factors or variables as well as very complex and often imperfectly known functional relationships.

Performance of the sealants may be assessed by movement accommodation (ie maintenance of adhesion to appropriate joint surfaces and of cohesive integrity of joint sealant to ensure sealing function despite movement of the joint) and durability (maintenance of salient physical properties throughout the intended life of the products while exposed simultaneously to weather). There are two methods for evaluating the durability of the sealants:

(i) Simulation of service conditions i.e. assessment of adhesion and cohesion when product subjected to extension and compression with simultaneous or continuous exposure to specified factors causing degradation in service.

(ii) Measurement of properties having influence on performance before and after exposure to degradating factors, ie high, & low temperature, water and humidity, UV radiations etc.

For assessing the suitability of developed tow component self levelling grade polyurethane sealant for building applications its hardness, loss of mass after heat ageing, application life, cure time, rheological properties, shrinkage were determined as per the relevant test methods[3,4]. For assessing compatibility and performance,

Table 2. Performance of sealants

Generic type	Parts	Maximum movement capability	Joint limits W × D(in.)	Expected life (y)	Weight shrinkage (%)	Resistance to UV	Resistance to Ozone	Resistance to Heat ageing
Oil and resin base	1	±5%	½ × ½	10+	10	fair	fair	hardens
Butyl—mastics	1	±5%	⅜ × ⅜	10+	5 to 20	fair	fair	stays soft
Butyl—curable	1	±10%	½ × ⅜	10+	5 to 20	fair	fair	good
Butyl/polyisobutylene	1	±10%	tapes	20+	0	super	super	stays soft
Polyisobutylene	1	±10%	thin beads	20+	0	super	super	stays soft
Emulsion acrylic	1	±7.5%	½ × ½	10+	15	poor	poor	hardens
Solvent acrylic	1	±12.5%	¾ × ⅜	20+	10	good	good	toughens
Chlorosulfonated polyethylene	1	±12.5%	⅜ × ½	20	10	good	good	toughens
One-part polysulfide	1	±12.5%	½ × ½	20	10	crazes	crazes	toughens
Two-part polysulfide	2	±25%	¾ × ½	20	10	crazes	crazes	toughens
One-part urethane	1	±25%	1¼ × ⅜	20	10	good	good	good
Multipart urethane		±25%	2 × ½	20+	4 to 10	super	super	super
Silicon-structural	1	±25%	¾ × ⅜	20+	4	super	super	super
Silicon-low modulus	1	over±25%	¾ × ⅜	20	1	super	super	super

Precautions: Contact sealant manufacturer for priming instructions to various surfaces. The above capabilities are based on superior sealants meeting ASTM or federal specifications. Users should require certification from qualified laboratories. All joint depths to be controlled by back-up rod.

Table 3. Physical properties

Test	Method followed	Results
Hardness (Shore A)	I.S.3400	25-35
Tensile strength (kg/cm^2)	-do-	12-17
Elongation at break (%)	-do-	300-350
Plastic deformation (%)	I.S.12118 Pt.2)	2.0
Loss of mass after heat ageing (% by weight)	-do-	1.29
Application life (h)	-do-	8.0
Rheological properties	-do-	Self levelling No bubbling
Tack free time (h)	ASTM C-679	24.0
Shrinkage (% by volume)	B.S. 3712	Accl.- 2.90 R.T. 2.08
Paintability	-do-	No discoloration
Seepage test	-do-	Seepage depth two filter papers, seepage spread nil.

Table 4. Adhesion and tensile modulus

Name of substrate	Conditioning before test	Tensile forces at 30mm extension (N)	Remarks	Results
Concrete	15 days at 27+2°C	100	No	Passes
	7 days at 70+2°C	110	adhesion	
	7 days in water at 27+2°C	98	failure	
Aluminium	15 days at 27+2°C	106	No	Passes
	7 days at 70+2°C	118	adhesion	
	7 days in water at 27+2°C	96	failure	
Glass	15 days at 27+2°C	100	No	Passes
	7 days at 70+2°C	114	adhesion	
	7 days in water at 27+2°C	100	failure	

Table 5. Adhesion in peel

Substrate	Conditioning before test	Tensile force after 1 min. extension (N)	Remarks	Results
Concrete	15 days at 27+2°C followed by 7 days in water	60	Adhesion failure in less than 25%	Passes
Aluminium	-do-	58	-do-	Passes

paintability, seepage test, adhesion and tensile modulus, peel strength, tensile strength, elongation, plastic deformation were measured as per the relevant standard test procedures. The results are reported in Tables 3,4 and 5.

Results and discussions

Hardness of sealant around 30±5 (Shore A) is an ideal hardness. Hardness more than 40 (Shore A) is generally too stiff to have sufficient compliance to accommodate building movement. As per ASTM C-661-83 hardness[5] should not be less than 15 and more than 50. It is evident from the results of tensile strength, elongation (%) and plastic deformation tests that the developed sealant is suitable for building applications, because tensile strength is around 15±2 kg/cm^2 and plastic deformation is only 2% which shows that the sealant has very good recovery and strength values, elongation is 300-500% which passes the usual requirement to accommodate building movement[6]. Loss of mass after heat ageing is of the order of 1.29% by weight and there was no cracking in the sealant which shows the sealant is durable. The maximum permissible limit of loss of weight after heat ageing is 10% and 12%[7,8]. Shrinkage (% by volume) of the developed sealant is quite low ie 2.90% in accelerated conditions and 2.08% at 27±2°C. The sealant also passes the requirement tests such as application life, rheological properties, tackfree time, paintability, seepage tests etc., for building sealants.

The adhesive strength of the sealant (with different substrates) was determined measuring the adhesion and tensile modulus and peel strength test. In tensile adhesion tests, tensile force at 30mm extension are 96-118 N with all the substrates under study. There was neither adhesion failure nor cohesive failure. Peel strength test gives good indication of adhesive strength of a sealant in shear. The developed sealant passes both the above mentioned tests. The requirement for adhesion and tensile modulus[7] is that the adhesion failure area is less than 100mm^2 and force should be between 25 N to 270 N at 30mm extension and in case of peel strength adhesion failure is less than 25% and force should be more than 25 Newton.

Assessment of movement capability of sealant in joint and accelerated weathering tests are in progress.

Areas of application

The main areas or urethane sealant application are architectural construction, clay sewer pipes, airports and highways, marine aerospace-cryogenic electrical and automotive fields.

Thixotropic non sagging sealants are employed in various vertical joints. Self-levelling sealants are recommended for horizontal road expansion or contraction joints, side walks, parking areas, concrete slabs, where vehicle or foot traffic is quite heavy.

The urethanes have good cohesive strength and excellent recovery, they are good for highway and airport runway expansion joint sealants. Since urethane sealants have good dimensional stability, they resist cold flow under their own weight or under small loads. Thus they are able to prevent the penetration of stone and foreign matter, and show excellent resistance to the abrasion action of high speed traffic.

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