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Performance of fire resistant sealant under live power and intense flame

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Abstract

This paper deals with the chemical composition, evaluation of its physica characteristics, fire performance and applications of fire resistant sealant. Fou PVC cable fire stop barrier specimens have been prepared using fire resistan sealant as heat penetration sealing material and their fire performance unde live power supply evaluated by employing standard test methods. Fire resistan sealant is quite effective in preventing the heat penetration from exposed surfa to another side of the specimens. Electric circuit failure time of the specimens i also enhanced by the use of fire resistant sealant.

Introduction

THE large amount of organic material contained in many modern power cables presents a series potential fire risk. Many power plants and industries have various incidents in which power cables have spread the fire over considerable distances. At the same time, so much black dense smoke and corrosive fumes are produced that makes the fire fighting and rescue operations very difficult. Consequently, many equipments, machinery and structures get damaged extensively. Fire occurs in these power cables either from external source or from internal heating due to over loading or poor insulation. In the event of fire, cable insulation melts and conductor of cables comes in contact with each other, generating sparks resulting in the flame spreading very fast through these cables. During such a fire, the cable's PVC burns and undergoes pyrolysis and combustion to produce copious amounts of carbon monoxide, carbon dioxide, hydrogen chloride and carbonyl chloride gases [1-3]. Hydrogen chloride formed during pyrolysis reacts with atmospheric humidity to form corrosive hydrochloric acid, which severely affects the metals and metal finishes, including those with cadmium or zinc plating [4]. Similarly, hydrochloric acid reacts with cement and lime plasters to form calcium chloride on it, and since this is a hygroscopic salt, the penetration is of a self-perpetuating character. Critical harmful concentrations of calcium chloride show that pre-stressed concrete is 40 times as vulnerable as the most porous conventional reinforced concrete. Further, calcium chloride reacts with the iron of the reinforcing bar to corrode them. In the corrosion process, the chloride ion is not used up. The corrosion process requires only iron and moisture to continue[5].

The physiological effect of pyrolysis and combustion products of PVC on human beings is most important. The main pyrolysis and combustion products of PVC are carbonyl chloride, hydrogen chloride and carbon monoxide, in which carbonyl chloride (phosgene gas) is more lethal than hydrogen chloride and carbon monoxide. Hydrogen chloride is an irritant even at low concentrations and affects the eyes and respiratory tract. Carbon monoxide is colorless and odorless and not detectable at all by the senses. The toxicity of carbon monoxide is due mainly to its affinity for haemoglobin. Haemoglobin has 200-300 times more affinity for carbon monoxide than for oxygen. Carbon monoxide, when breathed in along with air, is absorbed by the blood, depriving it of its oxygen carrying capacity. Hence carbon monoxide readily reacts with haemoglobin to form carboxy haemoglobin, a stable compound, resulting anoximia or oxygen deficiency in the body tissues and causing headache, dizziness, weakness in the limbs, mental dullness, tightness in the chest and finally unconsciousness, which leads to death [9]. Thus fire in power cables of all types of plants and industrial units is a matter of great concern today because these fires are highly vulnerable and catastrophic from the point of view life and property. It is, therefore, imperative that effective and concrete measures are taken for fire protection of power cables. The spread of fire in the power cables is apparently assisted by the presence of air in the cavities/gaps within structural elements and cables. Different methods and suggestions are made for the fire protection of cable installations by designing the cable trays, fire stop walls and using different kinds of heat insulating materials [7-8]. Fire resistant sealant is an adequate heat penetration seal material under fire exposure conditions in fire stop walls and floors. Sealants are comprised of pigmented or unpigmented synthetic elastomeric polymers, which in the non-cured state constitute pourable or easily extrudable putty-like mastics. Various sealants such as silicone, urethane, polysulphide, chlorosulphonated, polyethylene, acrylic, polychloroprene, butyl and related solvent release sealants etc. have been studied by many workers for various applications [9]. However, little attention has been paid towards the fire protection of power cables using a suitable sealant, which does resist upon heating. Therefore, there is ample scope to develop a fire resistant sealant for the fire protection of power cables. In order to reducing such spread of fire in the ceramic cavity blocks wall which segregate the groups of cable [10] or fire stop walls [11], there is a need to seal the cavities/gaps between cables and cable trays, cable trays and fire stops wall by the application of fire resistant sealant. Fire resistant sealant prevents the spread of fire from one side to other side of the fire stops wall. On exposure to heat the sealant intumescizes immediately and seals the joints, gaps, cavities, voids, crevices, openings, etc. and does not allow the hot vapours, gases and smoke to penetrate through the cables to the other side of the fire stop wall. This paper is concerned with the development and evaluation of fire resistant sealant under live power and intense flame.

Experiments

Sealant is a putty like mastic elastomeric polymer which is composed of high temperature resistant pigmented metal oxide, flame retardant elastomers and is non-drying, non-sagging, self supporting and pressure sensitive having thixotropic characteristics. The stoichiometric ratio between all the ingredients was established depending upon their fire resistant property, workability, compatibility and adhesiveness etc. Fire resistant sealant was prepared by mixing the following main ingredients:

- Carbonaceous agent
- Dehydrating agent
- Spumific or blowing agent
- Flame retardant halogenated elastomer
- Flame retardant plasticizers
- Flame retardant thermoplastic resin
- Flame retardant halogenated hydrocarbon
- High temperature resistant inorganic oxide
- Glow retardant agent
- Inorganic fillers
- High temperature resistant cera wool

The sealant was prepared by r ing dry ingredients of 325-400 m size with requisite amount of drying, non-flammable binder w consists the of appropriate quant of halogenated elastomer, halogena hydrocarbon, plasticizers and therr plastic resin in a manually opera triturating machine in order to obt a homogenous thick paste.

The fire resistant sealant thus p pared is applied on the PVC insula group of power cables of fire st barriers of different diameters. In der to obtain an effective fire prote tion of groups of cables of fire stc barriers, these were sealed with di ferent quantities and thickness of fir resistant sealant. The effect of diffe ent sealant quantities and thicknes on fire performance of group of cable of different fire stop barriers is dete mined.

Evaluation of sealant

Physical characteristics of fire resistant sealant such as specific gravity, slump, heating loss, consistency, workability, shelf life, effect of heat, adhesion, water absorption, etc. were evaluated as per JIS and ASTM standard procedures [12-14] and are summarized in *Table 1*.

TABLE 1: PHYSICAL PROPERTIES OF FIRE RESISTANT SEALANT

Properties	Standard followed	Performance data
Specific gravity	JIS: A5752-1975	1.60
Slump test	JIS: A5752-1975	No vertical downward movement after 144 hours
Heating loss	JIS:A5752-1975	Class-II putty, non-hardening
Consistency	JIS: A5752-1975	6.3mm, low degree of penetration
Workability	JIS: A5752-1975	satisfactory, no peeling, crumbling, cracking
Shelf life	-	12-15 years anticipated
Effect of heat	ASTM C-792-75-1980	Weight loss = 0.48, durable, no chalking, no cracking, no sagging and no dripping at 70°C in vertical position
Adhesion	JIS: A5752-1975	Tension load = 120 N, excellent adhesion
Water adsorption	ASTM C-1016(84)-1980	> 0.02 grams/cm³, class-I

TABLE 2: COMPARATIVE FIRE RATING OF SPECIMENS

Specimens	Exposure time (minutes)	Exposed surface temperature (°C)	Unexposed surface temperature (°C)	Fire rating time (minutes)
Unprotected	11	900	900	11
Specimen-I	80	900	237	80
Specimen-II	70	900	109	70
Specimen-III	85	900	260	85
Specimen-IV	120	900	120	120

Preparation of fire stop barrier specimens

To evaluate the fire performance of sealant, four fire stop barrier specimens using different kinds of heat resistive materials with sealant were prepared adopting the standard procedure [15]:

I. Sealant with chemically treated and coated fire retardant intumescent jute canvas.
II. Sealant with high temperature resistant ceramic wool and chemically treated and coated fire retardant intumescent jute canvas.
III. Sealant with chemically treated and coated fire retardant intumescent jute canvas and fired clay pipes.
IV. Sealant with high temperature resistant ceramic wool, chemically treated and coated fire retardant intumescent jute canvas and stoneware pipes.

A group of three PVC insulated four core aluminum conductor armoured cable specimens of length 1200 mm and of outer diameter 37mm were taken separately for each fire stop barriers.

Specimen - I

Sealant was applied around the armoured cable specimen in 12mm thickness and 600mm in length to seal the cavities, gaps and voids between the cables. Chemically treated and coated fire retardant jute canvas was wrapped around the sealant.

Specimen - II

On the armoured cable specimen two fire stops having 100mm distance from one another and 250mm each in length were prepared. Sealant was applied on each full-length fire stop in 12mm thickness to seal the cavities, gaps and voids, etc. between the cables. High temperature resistant ceramic wool of 20mm thickness was wrapped around the full-length sealant on each fire stop and supported with chemically treated and coated fire retardant intumescent jute canvas.

Specimen - III

This specimen was prepared similar to specimen-I, except that two fired clay pipes were plac around the specimen-I such a manner that the e of one clay pipe prope overlaps to the end of a other clay pipe and is su ported with high tempe ture resistant clamps.

Specimen - IV

Two fire stops were pr pared around the armour cable specimen similar to specimen by using sealant, high temperatu resistant ceramic wool and fire reta dant intumescent jute canvas. Pr pared fire stops were placed insi the stoneware pipes of 100mm diar eter in such a manner that 100m space remains empty inside the ston ware pipes on the exposed surface o fire stops. These 100mm empty space were filled with sealant in 20mm thick ness to seal the cavities, gaps, void etc. between the cables.

Chromel-alumel thermocouple were mounted at different points all the four fire stop barrier specime

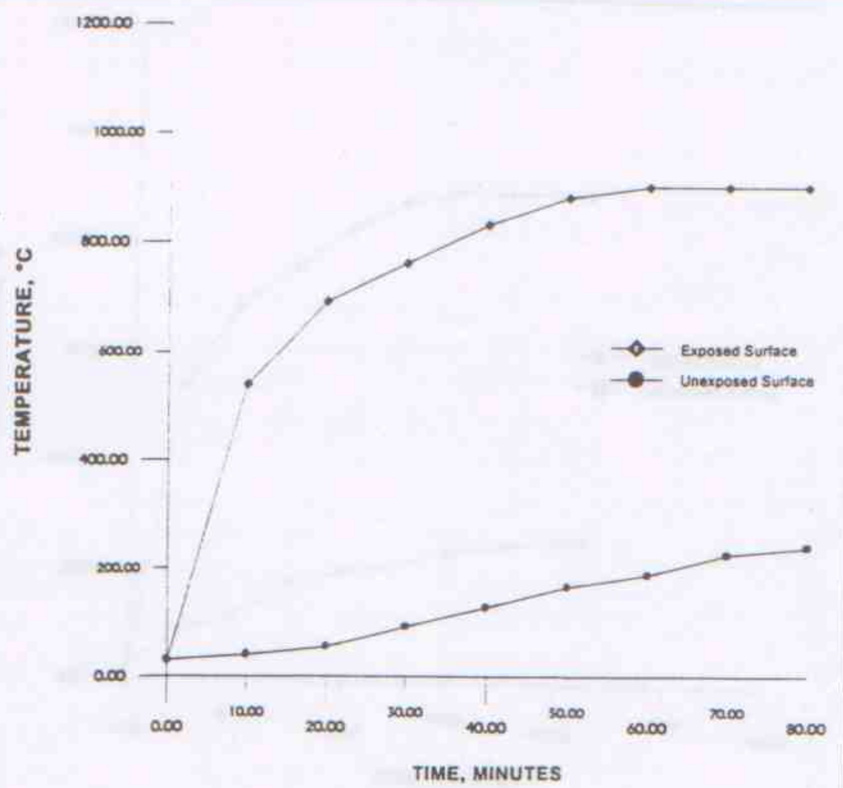

Fig. 1: Fire performance under live power of Specimen - I

depending upon their resistance till the electric circuit failed. The comparative rating of the four specimens is shown in *Table 2* and the observations made during the evaluation are illustrated in *Figures 1, 2, 3, & 4*.

Result and discussion

It is evident from the Table-2 that fire resistant sealant is very effective to prevent the heat penetration from exposed surface to unexposed surface. Minimum heat transfer was observed in the specimens sealed with fire resistant sealant during exposure. Electric circuit break time was also increased significantly in the specimens III & I sealed with fire resistant sealant. After 6-8 minutes exposure, the sealant intumescises on the exposed surface in specimens II &VI and completely covered the 100mm gap between two fire stops and sealed the penetration of hot gases, smoke, vapors etc. to the other side of the fire stop barriers. Besides the sealant, ceramic wool and chemically treated and coated intumescent jute canvas are quite effective to enhance the circuit failure time and reduced the heat penetration. Ceramic wool was not decomposed up to a temperature of 1400°C, while chemically treated and coated intumescent jute canvas decomposed to form an insulating cellular mass and does not burn at all. Thus it is quite clear from the *Figures 1-4* that there is a vast difference in the temperature on the exposed and unexposed surfaces.

The main ingredients of the sealant which are responsible for its enhance fire properties are dehydrating, cabonific, spumific agents and binder. When the sealant is exposed to fire, carbonific agent dehydrated in the presence of an acid evolved by dehydrating agent and formed a large volume of carbonaceous char. This carbonaceous char produced a non-combustible barrier which has excellent heat insulating properties so that the substrate does not readily reach a temperature at which it evolves inflammable gases. At the same time, spumific agent releases non-combustible gases which are trapped inside the carbonaceous char to produce a

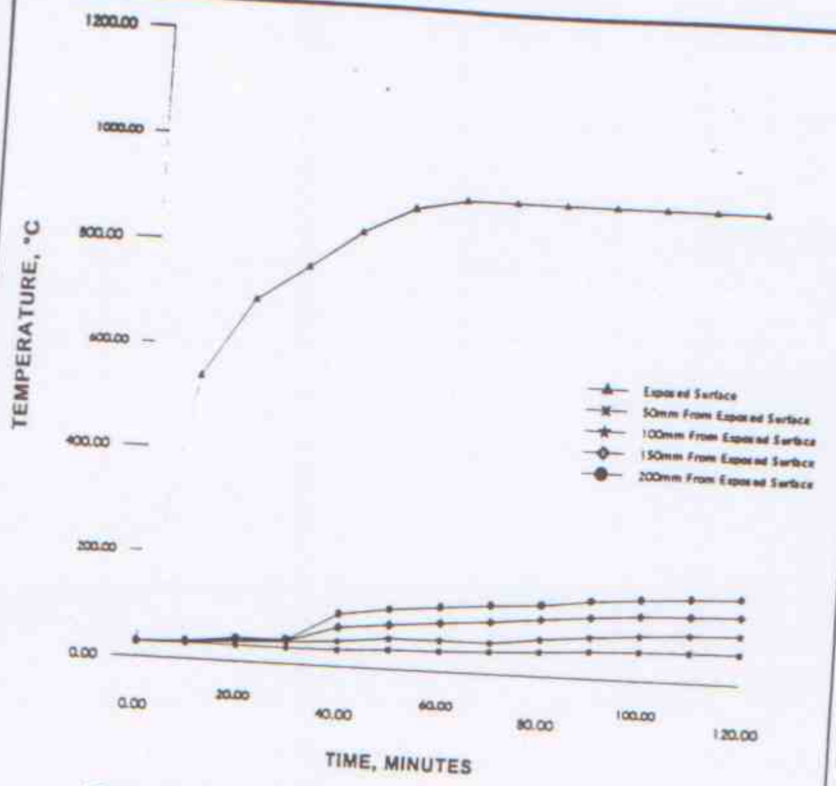

Fig. 4: Fire performance under live power of Specimen - IV

honeycomb blanket, resulting in highly effective insulation. The binder on softening forms an expandable skin over the carbonaceous char to resist the escape of gases produced by spumific agent [16-17]. On exposure the above said chemical reactions take place in the sealant; therefore the specimens are well protected from the heat.

Conclusion

Fire resistant sealant used, as sealing material for fire stop barriers is found quite effective in preventing the penetration of heat from exposed surface to the other side of the specimens. The specific characteristics of the fire resistant sealant is that, on exposure to flame, it intumescises immediately to approximately 10 times its original volume and seals the gaps, voids, cavities, openings, etc. between the cables and does not allow heat penetration. Electric circuit failure time is also increased in the fire stop barriers sealed with fire resistant sealant. After complete exposure of specimens to fire, the unexposed surface was found unaffected by the intense flame. Thus, by the use of fire resistant sealant in power cable fire stop barriers of various plants and industries, power break down can be prevented and consequently financial losses will be minimised.

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