Behavior of Decontaminable Coatings prior to and after Exposure to Ionizing Radiation

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Abstract

Coatings applied on floors, walls and ceilings as well as on inserts of nuclear facilities were examined for their decontaminability, color, gloss, resistance to chemicals both before and after exposure to ionizing radiation (absorbed dose 0.3 MGy).

It has been confirmed that reproducible results are obtained if during specimen irradiation sufficient air ventilation is provided.

As a consequence, in the revised version of DIN 53781 only gamma irradiation under defined conditions of air supply at 25 ± 10°C and absorbed dose rates $\leq$ 1000 Gy/h (10^5 rad/h) is permissible for the examination of coatings in nuclear facilities relevant to practical application (DIN 55991). Although the high absorbed dose rate exceeds application relevant absorbed dose rates by several orders of magnitude, it is reasonable for use in examinations optimized in terms of costs.

Verhalten von dekontaminierbaren Beschichtungen vor und nach Belastung mit ionisierender Strahlung

Kurzfassung

Beschichtungen, die in kerntechnischen Anlagen auf Böden, Wänden und Decken sowie Einbauteilem verwendet werden, wurden vor und nach Belastung mit ionisierender Strahlung (Energiedosis 0,3 MGy) auf Dekontaminierbarkeit, Farbe, Glanz, Chemikalienbeständigkeit untersucht. Es hat sich bestätigt, daß reproduzierbare Ergebnisse erhalten werden, wenn während der Bestrahlung der Proben ein ausreichender Luftwechsel vorhanden ist. In der Neufassung der DIN 53781 sind daher für die praxisbezogene Bestrahlungsprüfung von Beschichtungen für Kerntechnische Anlagen (DIN 55991) nur die Gammabestrahlung unter definiertem Luftzutritt bei 25 ± 10 °C und Energiedosisleistungen von $\leq$ 1000 Gy/h (10^5 rad/h) zulässig. Diese hohe Energiedosisleistung übersteigt anwendungsrelevante Energiedosisleistungen zwar um mehrere Größenordnungen, ist aber für kostenoptimierte Prüfungen sinnvoll.

Contents

1.   General Remarks

If coatings produced on the basis of epoxide, polyurethane, etc. ,as currently used in conventional applications, are exposed solely to natural ambient radiation (light), the damage caused to the coating depends primarily on the temperature and on the physical and chemical impacts.

If ionizing radiation, as may occur in nuclear facilities, is effective in addition, this will speed up curing of the coatings [1-5]. Due to the absorption of this high energy radiation, free radicals are formed in the coatings which readily enter into reactions. The resulting changes in physical and chemical properties of the coatings are attributable to

> progressing crosslinking, degradation, partly by release of gaseous products, and reactions with the ambient media (e.g. oxygen).

Progressing crosslinking and degradation frequently take place at the same time. However, in most cases one of the two reactions dominates which then accounts for the change in properties.

During irradiation the medium next to the coating is of high importance. Ogygen reacts readily with the radicals to give peroxides. Consequently, in some cases degradation takes place at a more or less fast rate because crosslinking reactions are inhibited. Therefore, irradiations in the presence of oxygen will give rise to more severe damage of coatings than in the absence of oxygen.

The degree of damage to a coating depends in the first line on the absorbed energy of radiation, the so-called absorbed dose. However, irradiations at low dose rates mostly produce less favorable effects over extended periods of time, due to the longer impact of oxygen, than short-term irradiation at high dose rates do. In nuclear power plants electron, gamma and neutron radiation occurs. The latter radiation is limited in the majority of cases to the immediate environment of the reactor core. Beyond that zone, above all beta and gamma radiation has to be anticipated. As beta radiation covers but a small range, it contributes to the radiation exposure of coatings only if these coatings are adjacent to the radiation source, with the resulting bremsstrahlung (X-radiation) to be taken into account. In that case, however, the dose rate may be very high.

The wall and floor coatings as well as the coatings of the inserts of the reactor buildings are exposed almost exclusively to gamma irradiation.

Dose rate relevant radionuclides occurring in nuclear power plants, such as Co-60 of 1.17/1.33 MeV and Cs-137 of 0.66 MeV, have mean gamma energies on the order of 1 MeV. Therefore, in order to simulate the irradiation of surface coatings in nuclear power plants, radiation sources emitting gamma energies in that range should be preferred.

As during normal operation of a nuclear power plant operations are carried out in the presence of air, the dose rates are low, the temperatures are normally below 40°C and the service lives of the coatings are long. The examinations relating to resistance to ionizing radiation according to DIN 53781 as well as the subsequent examination for decontaminability according to DIN 25415, Part 1, are performed with the conditions above largely taken into account. The search for a defined dependence of the absorbed dose rate and the resulting effects is the subject of current activities.

2. Composition and Application of the Coating Materials

2.1 Composition - Field of Application

To be able to judge the coatings prior to and after irradiation exposure, coating materials were used which are proven in the various fields of application in nuclear facilities, i.e. ceilings, walls, inserts, floors.

In the floor coatings (systems 3 - 8) different low molecular epoxy resins and polyamine adducts were incorporated in addition in the formulations in order to be able to assess their influence on the capability to tolerate radiation.

The expoxide/dispersion base coating indicated for system 9 was applied as a thin surface coating (50 µm) onto an epoxide coating of 1 mm thickness (system 7), a currently used practice for so-called as-delivery or repair floor coatings.

As to system 10, a thin colorless coating on the basis of polyurethane was applied in addition to a grey epoxide coating (system 7) in order to be able to make a comparison under radiation exposure conditions.

The composition of the coating materials used as final coating of the systems which was directly exposed to radiation and the testing media, respectively, is evident from Table 1.

2.2 Application

The specimen carriers used were asbestos cement plates, 100 x 70 x 5 mm
and steel sheets 100 x 70 x 1 mm.

The coating materials were applied under normal climatic conditions and the thickness of the coating was the same as in current practice.

System 1	1 x epoxide primary coating	10/40 µm
	1 x epoxide 1st surface coating	50 µm
	1 x epoxide 2nd surface coating	50 µm
System 2	1 x epoxide primary coating	10/40 µm
	3 x silicone rubber coating	400 µm
Systems 3-8	1 x epoxide primary coating	10/40 µm
	1 x epoxide coating	1000 µm

System 9	1 x system 7	1000 µm
	1 x expoxide/dispersion surface coating	50 µm
System 10	1 x system 7	1000 µm
	1 x polyurethane surface coating	50 µm

The coatings were cured in normal climate.

3. Loading of the Coatings by Gamma Radiation prior to Contamination

After curing of four weeks duration under normal climatic conditions (DIN 50014) the coatings were exposed to ionizing radiation.

The examination was performed in conformity with DIN 53781 (issue 1979) up to an absorbed dose of 0.3 MGy (3×10^7 rad) and gamma irradiation in air. The specimens to be irradiated were 100 mm x 70 mm in size. The carrier materials of the specimens were steel sheet and asbestos cement, respectively.

3.1 Irradiation with a Co-60 Source

The irradiation was carried out at Gammaster, Munich, in rooms (ca. 150 m³) with permanent air ventilation (up to 10,000 m³/h). The distance of the Co-60 radiation source from the specimen plates was chosen to be of such order that the absorbed dose rate was 1 KGy/h. The ozone content of the air was monitored and attained approx 0.5 ppm (Table 2).

3.2 Irradiation with Spent Fuel Elements from the Annulus of a Material Testing Reactor (MTR)

The fuel elements from the MTR annulus emit radiation whose spectrum corresponds to that of a complete fission product mixture. This irradiation was carried out at KFA Jülich in air atmosphere in a closed container placed in the decay storage pool. The specimens were ventilated with air for 30 minutes at least once every day during two weeks of irradiation (Table 2).

4.   Judging the Coatings on the Basis of the Paints Used

4.1   Changes of Colors of the Coatings

Before exposure to gamma irradiation the color shading of all coatings was measured with a diffraction spectrophotometer.

The colometric measures (DIN 5033), L = brightness and a, b = variegation of colors, were stored in a computer and referred to as standards for measurement of the color shading after exposure to gamma irradiation of 0.3 MGy (3×10^7 rad). Moreover, the so-called color difference (DE) was calculated using the CIELAB formula (DIN 6174). As appears from Table 3, gamma irradiation causes slight to very marked changes in color for the various systems.

The coatings produced on the basis of silicone rubber (system 2) and epoxide/polyamine adduct (system 4) undergo the greatest changes in color with DE-values of 6.7 and 7.18, respectively.

System 1, epoxy resin/aliphatic polyamine adduct, and system 9, epoxy resin/dispersive paint, change the color shading but slightly (DE 2.02 and 1.56, resp.) whereas systems 3, 5, 6, 7, 8, expoy resins/cycloaliphatic polyamine adducts, exhibit medium (distinct) discoloration with DE-values of 3.21 to 4.48.

Also the result obtained for system 10 is of interest, where a colorless polyurethane surface layer of 50 μm thickness was applied onto a grey coating based on epoxide/cycloaliphatic polyamine adduct (system 7). After exposure to gamma irradiation system 7 exhibits medium (distinct) discoloration, whereas system 10 undergoes but slight discoloration.

Except for system 3, more conspicuous changes in color appeared for the coatings after gamma irradiation at Jülich than after irradiation at Gammaster, Munich.

For details refer to Table 3.

4.2 Change in Brilliancy of the Coatings

The brilliancy of the coatings was measured according to DIN 67530 prior to and after exposure to 0.3 MGy (3×10^5 rad) gamma radiation using a reflectometer.

Different from the standard, all measurements were made at the same angle of measurement of 60° in order to improve comparison among the various coatings.

As appears from the values in Table 4, radiation exposure causes only minor reduction in brilliancy in all systems.

4.3 Resistance to the Action of Solvents and Chemical Solutions

To be able to evaluate possible modifications resulting from radiation exposure, the liquids ethanol, acetone, toluene, tetrachlorethylene, 1 molar nitric acid, 1 molar caustic soda solution, listed in DIN 25415, Part 1, item 9.1, were applied to the coating surface. The changes in coating were evaluated immediately after the reaction time as well as 24 hours later.

The coatings exposed to 0.3 MGy (3×10^7 rad) radiation dose, like the non-exposed coatings, do not exhibit any or only minor changes resulting from the action of the liquids mentioned above. In the evaluations the index 1 (change of trace) according to DIN 53230 was not surpassed in any of the systems as regards the change in color, shading and brilliancy. No other changes such as swelling, bubble formation and the like have been observed.

4.4 Evaluation of the Mechanical Stability

The coatings, systems 1 and 2 (ceiling, wall, inserts) were evaluated by means of cross cutting according to DIN 53151. Prior to and after exposure to 0.3 MGy (3×10^7 rad) gamma irradiation values of GT 0-1 were attained (0 = best value, 5 = poorest value).

The coatings, systems 3 - 10 (floors) were examined on the steel sheets by means of adhesive strength testing according to DIN ISO 4624. In all cases cohesive fracture occurred in the epoxide primary coating prior to and after radiation exposure at values of 2.8 to 4.0 N/mm^2. Therefore, the strength of the floor coating was not amenable to evaluation, but it is obvious that gamma irradiation did not produce a severe change.

Further subjective examinations such as cutting with an erasing knife, pressure loading, etc. have not produced different results for all systems examined regarding non-exposed and exposed specimens.

5. Results of Decontamination

Within the framework of the activities described here which extended over several years, it was found that ventilation during irradiation is very important in terms of decontaminability of coatings. It has been known for quite a long time that in the course of irradiation ventilation exerts an influence on the changes in organic substances.

If there is no or inadequate ventilation in the specimen containers, the compounds produced during irradiation such as nitric acid, ozone, etc. are only insufficiently removed and cause additional damage to the coatings.

This type of testing yields only little reproducible results which is attributable to time dependent effects, e.g. oxygen consumption or the formation of end products of radiolysis such as ozone.

The findings accumulated in this context will be incorporated in the revision of DIN 53781 where a specified ventilation will be described.

In Table 5 the results of decontamination of coatings have been entered for walls and floors on various beddings without previous irradiation and after gamma irradiation and sufficient air ventilation (see Section 3).

The decontamination tests were performed in conformity with DIN 25415, Part 1 (October 1980). Only three specimens were tested instead of the five specimens prescribed in the standard.

5.1 Results Obtained in the Absence of Previous Irradiation

As is evident from Table 5, all ten coatings (based on high or low molecular epoxides such as polyurethane and silicone rubber) on asbestos as bedding are very well decontaminable. However, a coating made on the basis of low molecular epoxy resins (system 4) on a steel bedding is only well decontaminable.

5.2 Results Obtained after Gamma Irradiation

The decontamination factors measured after gamma irradiation (except for system 4) are lower compared with those measured before gamma irradiation. However, all results are within the grading "very good." By gamma irradiation up to 0.3 MGy (3×10^7 rad) the coating based on low molecular epoxy resins (system 4) on a steel bedding was improved from the mark "well decontaminable" to "very

well decontaminable." Consequently, all coatings on asbestos and, in some cases, steel beddings which were examined after gamma irradiation are very well decontaminable.

5.3 Results Obtained after Irradiation with Electrons

Also experiments were performed with electron radiation at the linear accelerator of Bundesanstalt für Ernährung located on the premises of the Karlsruhe Nuclear Research Center. At the time of the irradiation tests the mean absorbed dose rate was 10^6 Gy/s (10^8 rad/s). By the intermittent mode of irradiation the ratio of time of irradiation to time without irradiation within the whole period of irradiation was reduced to a mean absorbed dose rate of 10^5Gy/h (10^7 rad/h). Due to this high absorbed dose rate it was necessary to irradiate the specimens in water so as to avoid an intolerable temperature loading of the coatings.

Coatings irradiated in that way exhibited better results of decontamination than specimens exposed to gamma radiation in air.

The absorbed dose rate which was 200 times higher than that of gamma irradiation is still further distant from the rate encountered in practice. Therefore, no electron irradiation is applied in the tests of coatings to be used in nuclear facilities; DIN 55991.

6.   Summary

Of the ten systems examined which were based on low molecular and high molecular epoxy resins with different curing agents such as polyurethane and silicone rubber, all were very well decontaminable after exposure to gamma radiation of 0.3 MGy (3×10^7 rad) at an absorbed dose rate $\leq$ 1000 Gy/h (10^5 rad/h) with a defined rate of air supply at 20 - 30°C.

Adverse changes concerning the mechanical stability and resistance to chemicals as well as visible changes such as cracking, bubble formation and the like have not been observed. Dependent on the system, the change in color was minor to distinct.

The decontaminability is influenced in a negative way if in the course of irradiation air ventilation is inadequate, because in those cases the compounds formed during irradiation such as ozone and its daughter products, e.g. nitric acid, etc., cannot be removed and cause additional damage to the coating.

The results of decontamination obtained after irradiation with electrons at very high absorbed dose rate which had to be performed in water in order to avoid inadmissible temperature loading of the coatings are better than the results obtained after gamma irradiation at clearly lower dose rate, performed in air.

Tests with gamma radiation were performed at KFA Jülich and at Gammaster, Munich. In the subsequent examinations the results of decontamination obtained were very well comparable; by contrast, distinct differences were found in the changes in color of the coatings.

7. References

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Table 1: Composition of the Coating Materials

System No.	Application in Nuclear Facilities	Base of Bonding Agent	Pigments	Solid [wt. %]
1	Ceilings Walls Inserts	High molecular epoxy resins/aliphathic polyamine adduct	Titanium dioxide Extenders Coloring pigments	65
2	Ceilings Walls Inserts	Silicone rubber	Titanium dioxide Extenders	70
3[1]	Floors	Low molecular epoxide resins/cycloaliphatic polyamine adduct	Titanium dioxide Coloring agents Quartz mixture	100
4[1]	Floors	Low molecular epoxy resins/aliphatic polyamine adduct	Titanium dioxide Coloring agents Quartz mixture	100
5[1]	Floors	Low molecular epoxy resins/cycloaliphatic polyamine adduct	Titanium dioxide Coloring agents Quartz mixtures	100
6[1]	Floors	Low molecular epoxy resins/cycloaliphatic poliamine adduct	Titanium dioxide Coloring agents Quartz mixture	100
7[2]	Floors	Low molecular epoxy resins/cycloaliphatic polyamine adduct	Titanium dioxide Coloring agents Quartz mixtures	100
8[2]	Floors	Low molecular epoxy resins/cycloaliphatic polyamine adduct	Titanium dioxide Coloring agents Quartz mixtures	100
9	Floors	Expoxy resin/polyamine amide dispersive paint (water)	Titanium dioxide/ Extenders	60
10	Floors	One-compound polyurethane, humidity curing, aliphatic polyisocyanate	None	40

Moreover, special additives are contained which exert a positive effect on the formation of non-porous homogeneous layers.

[1]   Similar epoxy resins: variation of the curing compounds.

[2]   Similar curing agents: variation of the epoxy resins.

Table 2: Gamma Irradiation of Coating Materials

	Gammaster, Munich Irradiation in an Open Space	KFA Jülich Irradiation in a Container
Source of radiation .	Co-60 radiation source	Spent fuel elements from an MTR annulus; approx. 45% burnup in the decay storage basin
Mean quantum energy [MeV]	1.17 / 1.33	0.8
Homogeneity of the radiation field [%]	± 10	± 10
Mean energy dose rate [KGy/h]	1 *	0.4 to 2.4
Absorbed dose [KGy]	300	300
Measurement of absorbed dose	Red-acrylic and alanine	Glass dosemeter
Irradiation container [l]	150.000	8 to 270
Specimen	50 mm x 50 mm x 1 to 5 mm	50 mm x 50 mm x 1 to 5 mm
Ambient atmosphere	Air, relative humidity 30 to 70%	Air, relative humidity 50 to 70%
Ozone content during irradiation	~ 0.5 ppm	Not measured
Pressure built up in the container due to radiochemical reactions	--	Not observed
Temperature of the specimens during irradiation [°C]	20 to 30	Approx. 30
Air ventilation during irradiation	Permanent	Flushing with air for 30 minutes every day

*in that special case

Table 3: Determination of the Color Shading of the Coatings and Changes in Color after Exposure to Irradiation

			Measurement with a Diffraction Spectrophotometer (Spectrogard)												
			Color Measurement			Change in Color (D = delta)				Change in Color (D = delta)			
System	Base of Surface Coating	Grading	Prior to Irradiation			After Irradiation with 3x10^7 rad (300 KGy) Irradiation in an Open Space, Gammaster, Munich				After Irradiation with 3x10^7 rad (300 KGy) Irradiation in Container, KFA Jülich			
			L	a	b	DL	Da	Db	DE	DL	Da	Db	DE
1	High molecular epoxy resins / aliphatic polyamine adduct	Ivory colored	85.09	-1,40	9.25	-1.28	0.42	1.51	2.02	-1.60	0.56	1.89	2.54
2	Silicone rubber	White	93.90	-0.86	2.33	-0.87	-1.85	6.34	6.70				
3	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	66.29	-1.97	6.95	-2.14	-0.10	3.93	4.48	-2.08	0.40	3.66	3.66
4	Low molecular epoxy resins / aliphatic polyamine adduct	Grey	65.48	-2.04	7.30	-2.23	-1.06	6.74	7.18	-3.38	-0.80	8.93	9.58
5	Low molecular epoxy resins/ cycloaliphatic polyamine	Grey	67.25	-1.99	6.75	-1.93	0.26	3.34	3.86				
6	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	67.26	-1.97	6.71	-1.94	0.13	3.39	3.91				
7	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	65.57	-1.95	7.07	-1.25	-0.04	2.96	3.21	-2.65	0.11	5.03	5.69
8	Low molecular epoxy resins/ cycloaliphatic polyamine adduct	Grey	65.08	-1.95	6.92	-1.67	-0.23	3.46	3.85				
9	Epoxy resin/polyamine amide dispersive paint (water)	Grey	67.64	-2.26	8.81	-1.49	0.36	0.31	1.56				
10	Polyurethane on grey coating, system 7	Colorless on grey	65.52	-2.01	7.04	-0.40	-0.29	0.86	0.99	-0.49	-0.52	1.42	1.59

DE = color difference, calculated according to the CIELAB formula (DIN 6174)

Table 4: Brilliancy of the Coatings prior to and after Exposure to Irradiation

System	Base of Surface Coating	Shading	Measurement of Brilliancy with Reflectometer 60° [1]		
			Prior to Irradiation	After Irradiation with 3×10^7 rad (300 KGy) Irradiation in an Open Space Gammaster, Munich	After irradiation with 3×10^7 rad (300 KGy) Irradiation in Container KFA Jülich
1	High molecular epoxy resins / aliphatic polyamine adduct	Ivory colored	61	56	58
2	Silicone rubber	White	14	13	
3	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	98	96	95
4	Low molecular expoy resins / aliphatic polyamine adduct	Grey	97	94	94
5	Low molecular epoxy resins/ cycloaliphatic polyamine	Grey	99	94	93
6	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	99	93	
7	Low molecular expoy resins / cycloaliphatic polyamine adduct	Grey	95	93	94
8	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	99	97	
9	Epoxy resin/polyamine amide dispersive paint (water)	Grey	63	61	
10	Polyurethane on grey coating, system 7	Colorless on grey	94	91	92

[1] In order to allow a direct comparison of the specimens to be made, all the measurements were performed at an angle of 60°.

Table 5: Results of Decontamination of Coatings prior to and after Gamma Irradiation

System	Base of Surface Coating	Color Shading	Specimen Bedding	Results of decontamination according to DIN 25 415, Part 1 (Oct. 1980) DF_h ± standard deviation in %								
				Prior to Irradiation			After Irradiation with 3x10^7 rad (300 KGy) Irradiation in an Open Space, Gammaster, Munich			After Irradiation 3x10^7 rad (300 KGy) Irradiation in Container KFA Jülich		
				H$_2$O	Tenside	Acid	H$_2$O	Tenside	Acid	H$_2$O	Tenside	Acid
1	High molecular epoxy resins / aliphatic polyamine adduct	Ivory colored	Steel	1640±5.4	3480±7.3	11340±10.4 very good	360±4.9	1000±3.0	4760±4.8 very good	630±11.3	1380±14.1	5630±13.2 very good
			Asbestos cement	760±6.0	1710±6.0	5460±9.1 very good	610±7.8	1330±5.6	4320±10.5 very good			
2	Silicone rubber	White	Asbestos cement	1740±5.9	3390±8.8	5440±8.2 very good	3.90±7.5	1070±5.8	4060±10.0 very good			
3	Low molecular expoxy resins / cycloaliphatic polyamine adduct	Grey	Steel	1500±6.7	3540±7.5	15410±14.0 very good	770±5.5	1990±8.3	11330±11.0 very good			
			Asbestos cement	2040±6.0	5460±9.4	15610±10.2 very good	860±5.1	1870±5.3	11680±8.1 very good	590±12.4	1530±7.1	4920±15.6 very good
4	Low molecular epoxy resins / aliphatic polyamine adduct	Grey	Steel	290±13.7	570±11.9	1510±7.1 good	250±9.7	620±4.4	3180±6.5 very good	530±11.2	1010±12.3 very good	3910±7.5 very good
			Asbestos cement	490±8.6	1040±6.9	2750±7.9 very good	340±8.5	840±6.2	5430±7.9 very good	400±4.5	930±7.7	3010±6.9 very good
5	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	Asbestos cement	1840±4.5	4490±8.0	15270±10.6 very good	1060±5.4	2750±8.3	9740±6.8 very good			
6	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	Asbestos cement	860±7.2	3080±9.5	9520±6.0 very good	590±5.8	1120±7.3	2160±4.0 very good			
7	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	Steel	660±7.7	1970±5.8	9720±7.6 very good	390±6.6	1280±3.7	5280±6.3 very good	1140±13.9	2670±10.2	7650±13.1 very good
			Asbestos cement	750±7.9	1930±4.5	8800±6.1 very good	280±4.4	800±5.8	2470±4.1 very good	570±14.9	1540±5.5	7460±14.2 very good
8	Low molecular epoxy resins / cycloaliphatic polyamine adduct	Grey	Asbestos cement	960±6.2	2270±9.3	15640±15.3 very good	450±8.6	1140±5.3	6760±11.8 very good			
9	Epoxy resin/polyamine amide dispersive paint (water)	Grey	Asbestos cement	2580±9.8	6270±10.8	18180±9.8 very good	790±5.1	1570±5.2	8250±11.9 very good			
10	Polyurethane	Colorless on grey	Asbestos cement	3340±9.2	7540±7.8	22740±9.0 very good	1060±4.6	3470±7.5	9860±7.1 very good	1220±27.6	4640±26.5	12270±24.1 very good