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3M™ Connected Roads All Weather Elements

Product Bulletin CR AWE
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1 Description

3M Connected Roads All Weather Elements ("**Elements**") have been designed for use on roadways and highways, primarily as long line pavement markings. They can be used in either new marking applications or as parts of maintenance marking applications. Elements, when used with compatible binders, form markings that are highly visible, day and night, under both dry and wet weather conditions.

Table 1. 3M Connected Roads All Weather Elements product family.

Series Names			
Dry White	50	90	Wet White
Dry Yellow	51	91	Wet Yellow
Dry M White	50M	70M	Wet M White
Dry M Yellow	51M	71M	Wet M Yellow
Dry E White	50E	70E	Wet E White
Dry E Yellow	51E	71E	Wet E Yellow

2 Composite Optic Construction

Elements consist of an outer layer of microcrystalline ceramic beads partially embedded into composite cores to provide optimal performance under dry and/or wet conditions.

3 Specifications

3.1 Retroreflectivity

Elements, when tested according to the methods below, shall have the minimum wet and dry cup brightness values presented in Table 2.

Table 2. Minimum initial coefficients of retroreflection [cd/lx/m^2].

Property/test method	Series Dry, Dry E, Dry M	Series 50, 50E, 50M	Series 90, 70E, 70M	Series Wet, Wet E, Wet M
Dry Cup Brightness R_A, cd/lx/m^2	White: 18.6 Yellow: 11.5	White: 7.4 Yellow: 4.6	White: 1.8 Yellow: 1.1	N/A
Wet Cup Brightness R_A, cd/lx/m^2	N/A	White: 2.4 Yellow: 1.2	White: 4.2 Yellow: 2.1	White: 6.0 Yellow: 3.0

3.2 Retroreflectivity Measurements

3.2.1 Equipment and Supplies

- 8 to 24 ounce (200–800 mL) glass jar and lid
- No. 30 US mesh 8" (200 mm) sieve or close equivalent
- Sieve pan
- Sieve lid
- 400 mL glass beaker
- Glass stir rod or metal spatula
- Large glass or plastic funnel (greater than 5" / 130 mm top opening)
- Balance, accurate to 0.1 gram
- Metal or plastic sample weighing pans
- Concentrated Simple Green® All Purpose Cleaner
- Drying oven, set to 150 °F (65 °C)
- Sample cups - Glass petri dishes, approximately 2–4" (50–100 mm) diameter and at least ½" (12 mm) high
- RoadVista® 932 retroreflectometer or equivalent conforming to CIE Publication 054.2–2001 and/or ASTM E1709, capable of pointing nearly vertically down onto a sample resting on a horizontal surface with -4.0° entrance angle and 0.2° observation angle
- Wash bottle with water and soap solution - 200:1 water to pH neutral household dish-washing detergent (5 g/L)

3.2.2 Sample Preparation

1. Collect a representative sample of Elements.
2. Measure out 100 grams of sample using balance.
3. Place 100 grams sample of Elements in clean glass jar and screw on lid.
4. Shake vigorously by hand for one minute to remove fines.
5. Attach sieve pan to bottom of sieve.
6. Empty jar contents onto the sieve.
7. Place lid on sieve, then swirl and shake sieve and contents for 30 seconds.
8. Remove sieve pan and lid and discard pan contents.
9. Transfer sieve contents into a clean 400 mL glass beaker, using funnel if necessary.
10. Pour or spray Simple Green® over the Elements until Elements are barely submerged.
11. Swiftly stir submerged Elements with glass rod or spatula for 20 seconds and let stand for 20 minutes. Fill the beaker to at least half way with clean water, then stir for 20 seconds.

12. Decant as much liquid from the beaker as possible without pouring out Elements.
13. Refill beaker containing Elements to at least half way with clean water, stir for 20 seconds, then decant as much liquid as possible. Repeat until rinse water is clean and clear (3–5 times).
14. Pour the Elements from the beaker onto the sieve, to remove any excess water, and spread them out evenly on the sieve screen to form a thin layer. Rinse the Elements in the sieve tray with clean water to remove any remaining debris and cleaning solution. Tilt the sieve slightly to allow excess retained water to run out of the sieve.
15. Place the sieve with Elements in the 150 °F (65 °C) drying oven and leave until thoroughly dry (allow at least 30 minutes).
16. Remove sieve and Elements from the oven and allow to cool to room temperature.
17. Transfer enough of the cooled Elements from the sieve to a glass petri dish, using a funnel if necessary, to form an even layer of Elements about ¼" (6 mm) deep.

3.2.3 Dry Cup Brightness Test Procedure

1. Calibrate retroreflectometer according to manufacturer's recommendations.
2. Use manufacturer-supplied stabilizing devices to ensure proper alignment of retroreflectometer with the sample in the petri dish.
3. Set the retroreflectometer to take measurements using -4.0° entrance angle and 0.2° observation angle.
4. Place the dish and sample on a flat, level surface.
5. Carefully rest the instrument on the rim of the petri dish with its measurement area positioned over the Elements.
6. Take a measurement and record the R_A value in cd/lx/m^2.
7. Repeat the procedure for 2 more samples from each batch or lot and report values as the averages of the three samples.

3.2.4 Wet Cup Brightness Test Procedure

1. Calibrate retroreflectometer according to manufacturer's recommendations.
2. Use manufacturer-supplied stabilizing devices to ensure proper alignment of retroreflectometer with the sample in the petri dish.
3. Set the retroreflectometer to take measurements using -4.0° entrance angle and 0.2° observation angle.
4. Place the dish and sample on a flat, level surface.
5. Using the wash bottle, gently flood and cover the Elements in the petri dish with the soap and water solution. Manually press down any Elements that float to ensure a smooth, even liquid surface above the Elements, across the entire petri dish.
6. Carefully rest the instrument on the rim of the petri dish with its measurement area positioned over the Elements.
7. Take a measurement and record the R_A value in cd/lx/m^2.
8. Repeat the procedure for 2 more samples from each batch or lot and report values as the averages of the three samples.

3.3 Gradation

The gradation of Elements shall meet or be within the limits in Table 3.

Table 3. Element gradation.

US Mesh	Micron	Mass Percent of Elements Passing ASTM D1921
10	2000	95–100
14	1410	0–40
20	850	0–5

4 Elements Use and Binder Compatibility

Table 4 presents the general compatibilities of Elements with several common pavement marking binders.

Table 4. General compatibilities of 3M Connected Roads All Weather Elements.

Binder	Target Thickness, final dry/cured (mils, 0.001")	Elements series for high dry reflectivity	Elements series for balanced wet and dry reflectivity	Elements series for high wet reflectivity	Elements series for all wet reflectivity
High build water-borne paint	18–25+	Dry	50	90	Wet
Thermoplastic	≥90	Dry	50	90	Wet
3M LPM 5000	18–25+	Dry	50	90	Wet
Epoxy and Polyurea (excluding 3M LPM 5000)	18–25+	Dry E	50E	70E	Wet E
Methyl Methacrylate (MMA)	20–150+	Dry M	50M	70M	Wet M

4.1 Reflective Elements for High Build Waterborne Paint

Elements Series Dry, 50, 90, and Wet are generally compatible with paints formulated with Dow® FASTRACK™ HD21-A binder. Since formulations may vary, users should test for ultimate compatibility and performance. Markings should be applied at a target wet thickness of at least 25 mils (0.025 inches).

4.2 Reflective Elements for Thermoplastic Markings

Elements Series Dry, 50, 90, and Wet are generally compatible with formulations based on alkyd and hydrocarbon binders with a target thickness greater than 90 mils. At a minimum, these materials should meet AASHTO M249 specifications. Since formulations may vary, users should test for ultimate compatibility and performance.

4.3 Reflective Elements for Epoxy and Polyurea Markings

Elements Series Dry E, 50E, 70E, and Wet E are generally compatible with formulations of epoxy and polyurea pavement markings. Since formulations may vary, users should test for ultimate compatibility and performance.

4.4 Reflective Elements for 3M LPM 5000 Markings

Elements Series Dry, 50, 90, and Wet are compatible with 3M LPM 5000 markings. Please see 3M Product Bulletin 3M LPM 5000 for further information.

4.5 Reflective Elements for Methyl Methacrylate (MMA) Markings

Elements Series Dry M, 50M, 70M, and Wet M are generally compatible with MMA pavement markings. Since formulations may vary, users should test for ultimate compatibility and performance.

5 Installation

5.1 Weather and Pavement Conditions

Elements should be applied according to the manufacturers' application guidelines for the appropriate binders.

5.2 Installation Equipment

Elements must be installed using a double-drop Element/bead delivery system. The Elements must be installed as the first drop of the two drop system and at a truck speed of no greater than 8 mph to minimize loss, prevent rolling, and ensure adequate sink. Contact 3M Technical Service/Application Engineering at 1-800-553-1380 for additional information on modifying existing equipment.

5.3 Binder Thickness

Elements should be applied at target binder thicknesses according to the guidelines presented in Table 4. Contact 3M Technical Service/Application Engineering for product recommendations and additional application information and restrictions.

5.4 Placement of Elements and Beads

Elements and accompanying second drop beads should be applied to pavement marking binders such that the Elements and beads do not roll, thus ensuring that their exposed portions are free of binder material. Elements and beads should be embedded (sunk) into binders to a depth of approximately 50% of their diameter. Under-sinking the Elements and beads will result in their premature loss and the optical failure of the marking. Over-sinking the Elements will result in low dry and wet brightnesses.

5.5 Typical Properties

Typical average initial retroreflectance values are shown in Table 5. Some variance should be expected across applications, and all values represent initial properties unless otherwise noted.

Table 5. Typical average initial coefficients of retroreflected luminance[a] [mcd/m^2/lx].

Property/test method	Series Dry, Dry E, Dry M	Series 50, 50E, 50M	Series 90, 70E, 70M	Series Wet, Wet E, Wet M
Retroreflectivity, Dry Average ASTM E1710	White: 1250 Yellow: 900	White: 700 Yellow: 525	White: 500 Yellow: 375	N/A
Retroreflectivity, Wet Recovery Average ASTM E2177	N/A	White: 275 Yellow: 225	White: 375 Yellow: 300	White: 400 Yellow: 325
Retroreflectivity, Wet Continuous Average ASTM E2832	N/A	White: 200 Yellow: 150	White: 275 Yellow: 225	White: 300 Yellow: 250

a. Typical retroreflectivity results represent average performance for smooth pavement surfaces. Results may vary due to differences in pavement type and surface roughness. Initial readings taken of “M” or “E” Elements must be performed after the treatment has been cleaned off of the Elements. Increased Elements drop rate may be necessary to compensate for increased surface area characteristic of rough pavement surfaces. Wet retroreflectivity testing of markings applied in grooved or recessed surfaces is difficult since water pools in recesses. In such cases, consider installing sections of pavement markings for testing on either a smooth section of the pavement surface, or on rigid panels (50 mil aluminum). If markings are applied to panels, allow them to cure, then move them carefully for retroreflectivity testing - make sure to protect the optics when transporting.

The term “wetting” describes a liquid's ability to form a uniform continuous layer on a solid surface when the two are in intimate contact. When a liquid forms a uniform continuous layer on a solid surface, it has “wet” the solid surface. The term “hydrophobicity” describes a solid surface's tendency to repel water. Hydrophobicity causes water to form discrete droplets, with dry areas between them, on a solid surface instead of wetting the surface to form a uniform continuous layer. Common examples of hydrophobic surfaces include rain jackets and freshly waxed car finishes.

Similarly, water is unable to wet hydrophobic pavement markings. Instead, when water is placed in intimate contact with a hydrophobic pavement marking, it forms droplets on the marking's surface, leaving dry regions between the water droplets. Retroreflectivity measurements taken on hydrophobic pavement markings under wet conditions give false high values, which result from the dry regions between water droplets.

Pavement marking hydrophobicity is reduced through exposure to traffic and the environment. Therefore, newly installed pavement markings must be exposed to traffic and the environment for a period of time to avoid false high readings.

The testing procedures of ASTM E2832 and ASTM E2177 also recommend that retroreflectivity measurements taken under wet conditions be performed only after newly installed pavement markings have been exposed to traffic for a period of time sufficient to minimize the effects of hydrophobicity. 3M recommends exposing all new pavement markings to traffic for a period of time proportional to the road's lane annual average daily traffic ("**Lane AADT**") prior to taking initial retroreflectivity measurements, as described in Table 6.

Table 6. Recommended traffic exposure time as a function of Lane AADT.

Lane AADT	Initial Reading Period (weeks of traffic exposure)
<5000	3–4
5000–15000	2–3
>15000	1–2

Since pavement marking panels prepared for laboratory measurements are typically not exposed to traffic, they are usually hydrophobic. When taking laboratory measurements on pavement markings installed on panels, particular care must be taken to avoid hydrophobic conditions. The use of surfactants in the water used for testing retroreflectivity under wet conditions has been observed to create microscopic foaming and bubbles, resulting in unacceptable measurement variability. More testing is needed before a specific surfactant and method of use can be recommended.

Elements with "E" and "M" designations have been treated to prevent them from over-sinking into the binder and to slow the wicking of the binder onto the Elements. This treatment causes a temporary reduction in retroreflectivity that is regained after exposure to weather and vehicle traffic. Retroreflectivity recovery may take up to 5 weeks, depending on the weather and vehicle traffic levels. Data presented in Table 5 were, therefore, taken after the treatment was cleaned off. Similarly, users should take initial retroreflectivity readings on E and M type Elements after the treatment has been cleaned off by exposure to weather and vehicle traffic. However, if spot checks are required for markings containing "E" or "M" Elements at the time of application, they should only be performed upon fully hardened markings and after the treatment has been manually cleaned off of the Elements. To remove the treatment, soak the line section to be measured with Concentrated Simple Green® All Purpose Cleaner. Let stand for 2 minutes, then rinse clean with water. Blot the line with a clean, dry cotton towel to remove excess water and allow to dry completely before performing dry or wet retroreflectivity tests.

Table 7 shows typical properties for markings made with Elements.

Table 7. Other typical properties of 3M Connected Roads All Weather Elements.

Property	Test Method	Expected Result
Index of refraction of ceramic beads	ASTM E1967-98	1.89 for Dry, 2.4 for Wet
Acid resistance of glass	24-hr exposure of microcrystalline ceramic beads to 1% solution (by weight) sulfuric acid	No more than 15% of beads showing distinct opaque surface upon microscopic examination

5.6 Traffic Marking Binder Material

The marking binder shall be of quality and type as designated by governing agency. The quality binder shall be thoroughly mixed, homogeneous, and applied to the road surface per manufacturer's specifications.

5.7 3M Connected Roads All Weather Elements

The Element type must be selected based on marking binder type, according to the criteria described in Table 4, and the Elements be the same color as the binder. The Elements must be installed using the double-drop Element/bead delivery system, with Elements being the first drop. Contact 3M Technical Service/Application Engineering for additional installation questions.

5.8 3M Connected Roads All Weather Elements Application Rates

Minimum Elements application rates for smooth or densely-packed pavement surfaces are presented in Table 8. The application rates stated provide good initial retroreflectivity and match the longevity, or restripe frequency, of most pavement marking binder systems to which the Elements are installed. More heavily traveled roads will require greater quantities of Elements to achieve similar longevities.

Rough pavement surfaces (open-graded mixes, large stone mixes, etc.) can have up to 50% more surface area than smooth surfaces. As a result, rough pavement surfaces require greater quantities of marking materials (binder, Elements, and beads) than smooth surfaces to achieve similar coverages.

Table 8. 3M Connected Roads All Weather Elements application rates.

Units	Minimum for Durable Markings on Smooth Surface	Minimum for Temporary Markings on Smooth Surface
Pounds per 4-inch lineal foot	0.018	0.009
Pounds per mile, 4-inch width	93	46.5
Grams per 4-inch lineal foot	8	4
Grams per square foot	24	12
Grams per square meter	260	130
Pounds per gallon - 20 mils ~240 ft/gal	4.2	2.1
Pounds per gallon - 25 mils ~ 190 ft/gal	3.4	1.7
Pounds/100 Sq ft	5.3	2.6
Element count per square inch, average	35–40	18–20

5.9 Second Drop Glass Beads

A second drop of glass beads is necessary to improve physical characteristics, durabilities of finished markings, and assure expected track-free times. Glass beads usually provide some measure of increased visibility during dry conditions as well.

Many different glass bead gradations are currently used for pavement markings. Table 9 presents glass bead gradations appropriate for temporary and durable applications to paint, polyurea, epoxy, 3M LPM 5000, MMA, and thermoplastic. The gradation of the second drop must meet or be within the limits in Table 9.

Table 9. Typical gradations of second drop glass beads.

Common bead types with liquid pavement markings Bead gradations - mass percent passing (ASTM D1214)					
US Mesh	Microns	Temporary Pavement Markings		Durable Pavement Markings	
		AASHTO M247 Type 1	Missouri Specification Type P[a]	FP03 718.19 Type 3	18/50 (Utah) Performance Specification
12	1700			100	
14	1410			95–100	
16	1180	100		80–95	
18	1000			10–40	65–80
20	850	95–100	90–97	0–5	
25	710			0–2	
30	600	75–95	60–87		0–30
40	425				
50	300	15–35	0–15		0–5
70	212		0–5		
80	180				
100	150	0–5			

a. A minimum of 15% of the total weight shall be from direct melt glass. All +30 US mesh beads shall be 85% minimum rounds and have a minimum crush strength of 30 lbs. in accordance with ASTM D1213.

Typical glass bead application rate ranges are shown in Table 10.

Table 10. Typical glass bead application rates.

Binder Type Units	High Build Waterborne Paint	Polyurea / 3M LPM 5000	Epoxy[a]	MMA	Thermoplastic
Pounds per 4" lineal foot	0.026–0.053	0.033–0.053	0.05–0.0917	0.033–0.053	0.033–0.053
Grams per 4" lineal foot	12–24	15–24	22.7–41.6	15–24	15–24
Pounds per gallon - 20 mils ~240 ft/gal	6.4–12.8	8.0–12.8	12–22		
Pounds per gallon - 25 mils ~ 190 ft/gal	5.1–10.2	6.4–10.2	9.5–17.4		
Pounds/100 Sq ft	7.94–15.87	9.92–15.87	15–27.5	9.92–15.87	9.92–15.87
Preferred bead type	Missouri Type P or 18/50 (Utah)			18/50 (Utah) or FP -3 #718.19 Type 3	

a. Bead drop rate may be adjusted to achieve adequate track-free time.

5.10 Quality of Second Drop Glass Beads

The required glass beads shall have an index of refraction of 1.5 when tested by the immersion method at 25 °C (77 °F). The glass beads shall be surface treated for optimal performance with the liquid binder traffic marking. The glass beads shall have a minimum of 70% rounds as measured according to ASTM D1155. The surfaces of the glass beads shall be free of pits and scratches. The glass beads retained on a #40 U.S. mesh sieve (425 microns) shall have a minimum crush strength of 30 pounds, in accordance with ASTM D1213.

6 Storage

For best results, store Elements, covered and off the ground, in a cool (40–100 °F, 4–38 °C), dry area, indoors or outdoors. Use Elements within one year from date of manufacture. Follow binder and glass bead manufacturers' instructions for storage.

7 Health and Safety Information

Read all health hazard, precautionary, and first aid statements found in the Safety Data Sheet ("**SDS**") and/or product labels of chemicals prior to handling or use. Refer to SDSs for information regarding volatile organic compound ("**VOC**") contents of chemical products. Consult local regulations and authorities for possible restrictions on product VOC content and/or VOC emissions.

8 Warranty Information

8.1 3M Standard Warranty

3M has no control over application methods or the quality of the surface to which materials are applied. Therefore, 3M's warranty for Elements shall be limited to the quality of materials supplied.

Elements are warranted ("**3M Standard Warranty**") to be free of defects in materials and manufacture at the time of shipment and meet the specifications stated in this product bulletin. If Elements are proven not to have met the 3M Standard Warranty on their shipment date, then a buyer's exclusive remedy, and 3M's sole obligation, at 3M's option, will be refund or replacement of the Elements.

8.2 Disclaimer

THE 3M WARRANTY IS MADE IN LIEU OF ALL OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE, OR ANY IMPLIED WARRANTY ARISING OUT OF A COURSE OF DEALING OR OF PERFORMANCE, CUSTOM, OR USAGE OF TRADE.

8.3 Limitation of Liability

Except for the limited remedy stated above, and except where prohibited by law, 3M will not be liable for any loss or damage arising from the use of or the inability to use the Elements or any 3M product, whether direct, indirect, special, incidental, or consequential damages (including but not limited to lost profits, business, or revenue in any way), regardless of the legal theory asserted including warranty, contract, negligence, or strict liability. Before using, the user shall determine the suitability of Elements for his/her intended use and the user assumes all risk and liability whatsoever in connection therewith.

3M assumes no responsibility for any injury, loss, or damage arising out of the use of a product that is not of our manufacture. Where reference is made in our literature to a commercially available product made by another manufacturer (for example, application equipment), it shall be the user's responsibility to ascertain its effectiveness and to take any precautionary measures required for its use, as outlined by the product's manufacturer.

9 Other Product Information

Always confirm that you have the most current version of the applicable product bulletin, information folder, or other product information from 3M's Website at http://www.3M.com/roadsafety.

10 Literature References

3M IF 5.18	Application Guidelines for Pavement Markings in Grooved Pavement Surfaces
3M IF 5.22	All Weather Paint Application Guidelines for Elements and Glass Beads on a High-Build Waterborne Traffic Marking Paint
3M IF 5.23	3M™ Connected Roads All Weather Elements Application Guidelines for 3M Connected Roads All Weather Elements
3M IF 5.24	3M™ All Weather Thermoplastic Pavement Markings Application Guidelines
3M IF 5.28	Liquid Pavement Marking Application Guidelines Series 5000
3M PB AWP	All Weather Paint
3M PB AWT	All Weather Thermoplastic
3M PB LPM 5000	3M™ Liquid Pavement Marking Series 5000

ASTM Test Methods are available from ASTM International, West Conshohocken, PA.

For Information or Assistance
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1-800-3M HELPS
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