(d) **Subgrade Stabilization:**

Physical Property	Test Method	Requirements
Tensile Strength @ 20% elongation	ASTM D4595	80 lbs./lin inch (Min.)
Apparent Opening Size (AOS)	ASTM D4751	Equal to or smaller than 0.85 mm
Secant Modulus @10% Strain	ASTM D4595	500 lbs./lin inch (Min.)
*Soil Fabric Friction Angle	ASTM D5321	24 deg. (Min.)
Tear Strength	ASTM D4533	75 lbs. (Min.)
Puncture Strength	ASTM D4833	75 lbs. (Min.)

*For test, use Ottowa Sand that passes the No. 20 sieve but can be retained on the No. 30 sieve. Use normal loads of 0.5 ton/sq ft, 1.0 ton/sq ft and 2.0 ton/sq ft.

(e) **Geotextile for Embankment Stabilization up to 6 feet in height:**

Physical Property	Test Method	Requirements
Tensile Strength (Ultimate)	ASTM D4595	200 lbs./lin inch (Min.)
Apparent Opening Size (AOS)	ASTM D4751	Equal to or smaller than 0.85 mm
Secant Modulus @10% Strain	ASTM D4595	1700 lbs./lin inch (Min.)
*Soil Fabric Friction Angle	ASTM D5321	24 deg. (Min.)
Tear Strength	ASTM D4533	75 lbs. (Min.)
Puncture Strength	ASTM D4833	75 lbs. (Min.)

*For test, use Ottowa Sand that passes the No. 20 sieve but can be retained on the No. 30 sieve. Use normal loads of 0.5 ton/sq. ft., 1.0 ton/sq ft and 2.0 ton/sq ft.

SECTION 246—PAVEMENT MARKING

246.01—Description.

These specifications cover material for use in the various retroreflective pavement-marking applications.

246.02—Detail Requirements.

Materials that must be heated for application shall not exude fumes that are toxic or injurious to persons or property when heated to the application temperature.

Materials shall withstand air and roadway temperature variations from 0 degrees F to 140 degrees F without deforming, bleeding, staining, or discoloring and shall

maintain their original dimensions and placement without chipping, spalling, or cracking. Material shall not deteriorate because of contact with sodium chloride, calcium chloride, mild alkalies and acids, or other ice control materials; oil in the pavement material; or oil and gasoline drippings from vehicles.

(a) **White and Yellow Pavement Marking Material:** White pavement marking material shall be equal to Federal Standard Color No. 595-17886, and yellow pavement marking material shall be equal to Federal Standard Color No. 595-33538.

Color determination will be made for markings and the diffuse daytime color of the markings shall conform to the below CIE Chromaticity coordinate limits. Color determination for liquid marking materials will be made without drop on beads at least 24 hours after application. Color determination for thermoplastic will be made in accordance with the requirements of AASHTO T 250.

Cie Chromaticity Coordinate Limits (Initial without drop-on beads)

	1		2		3		4		Daytime Luminance Factor Y (%)	
Color	**x**	**y**	**x**	**y**	**x**	**y**	**x**	**y**	**Min.**	**Max.**
White (Types A; B– Classes I, II & III; & F)	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375	80.0	—
Yellow (Types A; B– Classes II & III; & F – except thermoplastic)	0.493	0.473	0.518	0.464	0.486	0.428	0.469	0.452	50.0	60.0
Yellow (Types B – Class I; & F – if thermoplastic)	0.499	0.466	0.545	0.455	0.518	0.432	0.485	0.454	40.0	60.0

Color readings will be determined in accordance with the requirements of ASTM E1349 using CIE 1931 2 degrees standard observer and CIE standard Illuminant D65.

Retained daytime color of markings shall conform to the following CIE Chromaticity coordinate limits when measured on a beaded marking after a period of ninety days for construction pavement markings and one year for all other markings:

Cie Chromaticity Coordinate Limits (Retained)

	1		2		3		4	
Color	**x**	**y**	**x**	**y**	**x**	**y**	**x**	**y**
White	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375
Yellow	0.560	0.440	0.490	0.510	0.420	0.440	0.460	0.400

Retained color readings will be determined using a 0 degrees /45 degrees Hunter Labminiscan Spectro-Colorimeter or equal in accordance with the requirements of ASTM E 1349 using CIE 1931 2 degrees standard observer and CIE standard Illuminant D65.

Initial nighttime color of thermoplastic pavement marking material shall conform to the following CIE chromaticity coordinate requirements when tested in accordance with VTM 111.

Cie Chromaticity Coordinate Limits (initial with drop-on beads)

	1		2		3		4	
Color	**x**	**y**	**x**	**y**	**x**	**y**	**x**	**y**
Yellow	0.486	0.439	0.520	0.480	0.560	0.440	0.498	0.426

The marking material shall not be formulated with any compounds of the heavy metals listed in 40 CFR 261.24 Table 1 except that barium sulfate is allowed. Total heavy metal levels, with the exception of barium sulfate, shall not exceed 20 times the specified regulatory limits.

The amount and type of yellow pigment and inert filler for yellow material shall be at the option of the manufacturer provided the material complies with all other requirements of this specification.

(b) **Paint Pavement Marking Material (Type A):** Paint material shall be a fast drying water based, nonleaded, acrylic resin paint suitable for use on both asphalt and hydraulic cement concrete surfaces. Paint shall be selected from the Department's approved list. Paint products will be included on the approved list after the Department determines conformance to the specifications on both asphalt and hydraulic cement concrete roadways. Determination of conformance will include, but will not be limited to, the evaluation of test data from AASHTO's National Transportation Product Evaluation Program (NTPEP) or other Department approved facilities.

1. **Hiding Power:** Paint shall show a dry hiding quality that will give a contrast ratio of at least 0.96 at 0.38 mm (15 mil) wet film thickness.

2. **Settling Properties:** Settling shall be no less than a rating of 8 when tested in accordance with ASTM D869.

3. **Freeze-Thaw and Heat Stability:** Paint shall show no coagulation or change in viscosity greater than +/- 5 KU.

4. **Water Resistance:** Paint shall show no blistering, peeling or wrinkling, softening or loss of adhesion.

5. **VOC: The Volatile Organic Compound** content shall be no greater than 150 grams/liter when tested in accordance with EPA Method 24.

6. **Flash Point:** Paint shall have a flash point of at least 140 degrees F when tested in accordance with ASTM D93, Pensky-Martens Closed Cup.

7. **No-Track Time:** Paint shall have a 60-second maximum vehicle no-track time when measured in accordance with the NTPEP Field Test Procedures.

8. **Maintained Retroreflectivity and Durability:** Maintained retroreflectivity and durability shall conform to the following requirements after being installed on the test deck for 1 year:

   a. **Maintained Retroreflectivity:** Photometric quantity to be measured is coefficient of retroreflected luminance (R_L) in accordance with the requirements of ASTM E 1743 for 15 meter geometry and ASTM E1710 for 30 meter geometry. R_L shall be expressed in millicandelas per square foot per foot-candle and shall be at least either 150 for 15 meter or 100 for 30 meter when measured in the skipline or centerline areas.

   b. **Durability:** Paint shall have a durability rating of at least 4 when determined in the wheel path area.

(c) **Thermoplastic Pavement Marking Material (Type B, Class I)**: Thermoplastic material shall be suitable for use on asphalt concrete surfaces and yellow thermoplastic shall be selected from the Department's approved list. Yellow thermoplastic products will be included on the approved list after the Department determines conformance to the specifications. Thermoplastic material shall have the pigment, beads, and filler well dispersed in the resin and shall be free from skins, dirt, and foreign objects.

1. **Composition:**

Component	White (Percent by Weight)	Yellow (Percent by Weight)
Binder	18.0 min	18.0 min
Glass Beads	25.0 min	25.0 min
Titanium Dioxide	8.0 min	—
Calcium Carbonate & Inert Fillers	49.0 max	—

The binder shall be either alkyd or hydrocarbon. If an alkyd thermoplastic is used, the binder shall consist of synthetic resins, at least one of which is solid at room temperature, and high-boiling plasticizers. At least 1/2 of the binder composition shall be a maleic-modified glycerol ester of resin and shall be at least 10 percent by weight of the entire material formulation.

2. **Physical requirements:**

a. **Water absorption:** Materials shall not have more than 0.5 percent retained water by weight when tested in accordance with the requirements of ASTM D570, Procedure A.

b. **Softening point:** Materials shall have a softening point of at least 194 degrees F as determined in accordance with the requirements of ASTM E28.

c. **Specific gravity:** The specific gravity of the thermoplastic compound at 77 degrees F shall be from 1.7 to 2.2.

d. **Impact resistance:** Impact resistance shall be at least 10 inch-pounds at 77 degrees F after material has been heated for 4 hours at 400 degrees F and cast into bars of 1 inch cross-sectional area, 3 inches long and placed with 1 inch extending above the vise in a cantilever beam, Izod-type tester, conforming to the requirements of ASTM D256, using the 25 inch-pound scale.

e. **Drying time:** Material shall set to bear traffic in not more than 2 minutes when the road temperature is 50 degrees F or above.

f. **Durability and wear resistance:** Material shall be designed to provide a life expectancy of at least 3 years under an average daily traffic count per lane of approximately 9,000 vehicles.

g. **Glass beads:** Glass beads shall conform to the requirements of Section 234.

h. **Flashpoint:** The material flashpoint shall be no less than 500 degrees F when tested in accordance with the requirements of ASTM D92.

(d) **Polyester-Resin Pavement Marking Material (Type B, Class II):** Polyester-resin is a two-component pavement marking material suitable for use on hydraulic cement concrete surfaces.

1. **Composition (uncatalyzed material):**

	Min.	Max.
Pigment	36.0	40.0
Acrylic monomer	8.5	—
Polyester resin	—	55.5

2 **Physical requirements (uncatalyzed material):**

a. **Viscosity:** Viscosity (25 degrees C), ASTM D562, shall be 80 to 90 Kreb units.

b. **Weight per gallon:** Weight per gallon shall be at least 11.5 pounds.

c. **Drying time:** The catalyst/resin ratio shall be adjusted by the operator so that the applied line shall dry to a no-tracking condition in 15 minutes or less when applied at an application temperature of 77 degrees F to 100 degrees F, a substrate temperature of at least 60 degrees F, a wet thickness of 15 to 25 mils, and with 10 to 15 pounds of glass beads, conforming to the requirements of Section 234, applied per gallon. No-track time shall be determined by passing over the line with a passenger car or pickup truck at a speed of 25 to 35 miles per hour (mph) in a simulated passing maneuver. A line showing no visual deposition of the material to the pavement surface when viewed from a distance of 50 feet shall be considered as showing “no-track” and conforming for time to “no-track”.

d. **Catalyst:** The catalytic component of the system shall be a commercially available type recommended by the manufacturer of the polyester. The peroxide shall not be exposed to any form of heat, such as direct sunlight, radiators, open flame, or sparks. Heat may cause the organic peroxide to decompose violently or burn if ignited. The peroxide shall not come into contact with easily oxidized metals, such as copper, brass, or mild steel or galvanized steel as this can also initiate a violent reaction.

e. **Weight loss:** Beaded catalyzed material shall not have a weight loss of more than 125 milligrams after 1,000 revolutions when abraded according to Federal Test Method Standard No. 141b, Method 6192, using CS-17 wheels with a 1,000-gram load on each wheel.

f. **Shelf life:** The shelf life of uncatalyzed material shall be at least 6 months when stored in a cool area below 85 degrees F.

g. **Durability and wear resistance:** Material shall be designed to provide a life expectancy of at least 3 years under an average daily traffic count per lane of approximately 9,000 vehicles.

h. **Hiding:** The marking shall show a dry hiding quality that will give a contrast ratio of at least 0.96 with the Morest Black and White Power Chart, Form 03B when drawn down at a fifteen (15) mil wet film thickness. Readings will be determined in accordance with the requirements of ASTM E 1349 using CIE 1931 2 degrees standard observer and CIE standard Illuminant D65.

(e) **Epoxy-Resin Pavement Marking Material (Type B, Class III)**: Epoxy-resin is a two-component pavement marking material suitable for use on both asphalt and hydraulic cement concrete surfaces. Pigment, beads, and filler shall be well dispersed in the resin. Material shall be free from skins, dirt, and foreign objects and shall conform to the following:

1. **Composition**

Component	ASTM	White	Yellow
Epoxy resins	D1652	Max. 82%	Max. 77%
Titanium dioxide	D476 Type IV	Min. 18%	—
Pigments	—	—	Min. 23%

2. **Physical requirements**:

a. **Hardness:** Hardness, Shore D, ASTM D2240, shall be 75 to 100.

b. **Tensile strength:** Tensile strength, ASTM D638, shall be at least 6,000 pounds per square inch after the material has cured for 72 hours at 73 ± 4 degrees F.

c. **Compression strength:** Compression strength, ASTM D695, shall be at least 12,000 pounds per square inch after the material has cured for 72 hours at 73 ± 4 degrees F.

d. **Adhesion to concrete:** Adhesion, ACI 503, shall be at 100 percent concrete failure after the material has cured for 72 hours at 73 ± 4 degrees F. Concrete used for the test shall have a tensile strength of at least 300 pounds per square inch and shall be 90 degrees F when the material is applied.

e. **Drying time:** Material shall dry to a “no-track” condition in 15 minutes or less at pavement temperatures from 50 degrees F to 120 degrees F and under all humidity conditions, providing the pavement is dry. No-track time shall be determined by passing

over the line with a passenger car or pickup truck at a speed of 25 to 35 mph in a simulated passing maneuver. A line showing no visual deposition of the material to the pavement surface when viewed from a distance of 50 feet shall be considered as showing “no-track” and conforming for time to “no-track”.

f. **Weight per epoxy equivalent:** Weight per epoxy equivalent of Part A of the epoxy pavement marking material shall be within ±50 of the target value provided by the manufacturer when tested in accordance with the requirements of ASTM D1652.

g. **Total amine value:** Total amine value of Part B of the epoxy pavement marking material shall be within ±50 of the target value provided by the manufacturer when tested in accordance with the requirements of ASTM D2074.

h. **Durability and wear resistance:** Material shall be designed to provide a life expectancy of at least 3 years under an average daily traffic count per lane of approximately 9,000 vehicles.

i. **Abrasion resistance:** Wear index shall be no greater than 80 when abrasion resistance is tested in accordance with the requirements of ASTM D4060.

j. **Hiding:** The marking shall show a dry hiding quality that will give a contrast ratio of at least 0.96 with the Morest Black and White Power Chart, Form 03B when drawn down at a fifteen (15) mil wet film thickness. Readings will be determined in accordance with the requirements of ASTM E 1349 using CIE 1931 2 degrees standard observer and CIE standard Illuminant D65.

(f) **Plastic-Backed Preformed Tape Pavement Marking Material (Type B, Class IV):** Plastic-backed preformed tape shall conform to the requirements of ASTM D4505 for a Type I or VI, Grade B, C, D or E material and any additions and/or exceptions indicated herein. Tape shall be suitable for use on both asphalt and hydraulic cement concrete surfaces and shall be capable of being applied to previously applied marking material of the same composition under normal conditions of use. Tape shall be selected from the Department’s approved list. Tape products will be included on the approved list after the Department determines conformance to the specifications on both asphalt and hydraulic cement concrete roadways. Determination of conformance will include, but will not be limited to, the evaluation of test data from AASHTO’s National Transportation Product Evaluation Program (NTPEP) or other Department approved facilities.

1. **Thickness (No Adhesive):** Thickness shall be at least 60 mils and no more than 90 mils.

2. **Skid Resistance:** Skid resistance requirements for a Type I material shall be the same as required for a Type VI material.

3. **Initial Retroreflectivity:** Initial retroreflectivity requirements for a Type VI material shall be the same as required for a Type I material.

4. **Maintained Retroreflectivity, Durability and Adhesion:** Maintained retroreflectivity, durability and adhesion shall conform to the following requirements after being installed on the test deck for 1 year:

   a. **Maintained Retroreflectivity:** Photometric quantity to be measured is coefficient of retroreflected luminance (R_L) in accordance with the requirements of ASTM E 1743 for 15 meter geometry and ASTM E1710 for 30 meter geometry. R_L shall be expressed in millicandelas per square foot per foot-candle and shall be at least either 150 for 15 meter or 100 for 30 meter when measured in the skipline or centerline areas.

   b. **Durability:** Tape shall have a durability rating of at least 4 when determined in the wheel path area.

   c. **Adhesion:** No line shall have walked nor shall it be torn or missing.

(g) **Construction Pavement Marking Materials:** Construction pavement markings shall consist of removable tape, non-retroreflective black removable tape and temporary pavement marking material. Construction pavement marking materials shall be selected from the Department's approved list. Products will be included on the approved list after the Department determines conformance to the specifications on both asphalt and hydraulic cement concrete roadways and the manufacturer has supplied information to the Department indicating conformance to the below warranty requirements for the tape products except Type E material will only be evaluated for asphalt concrete roadways. Determination of conformance will include, but will not be limited to, the evaluation of test data from AASHTO's National Transportation Product Evaluation Program (NTPEP) or other Department approved facilities.

1. Removable Tape (Type D, Class I and II): Removable tape shall be suitable for use on both asphalt and hydraulic cement concrete surfaces and shall conform to the following requirements:

   a. **Initial Skid Resistance:** Initial skid resistance value shall be at least 45 BPN.

   b. **Warranty:** The manufacturer shall provide a full manufacturer's warranty on their product that shall cover the retroreflectivity, removability and adhesiveness. The warranty period shall

be no less than 90 days, beginning on the date of installation and shall include all material and labor costs when installed in accordance with the manufacturer's recommendations.

c. **Maintained Retroreflectivity, Removability and Adhesion:** Maintained retroreflectivity, removability and adhesion shall conform to the following requirements after being installed on the test deck for 90 days:

(1) **Maintained Retroreflectivity:** Photometric quantity to be measured is coefficient of retroreflected luminance (R_L) in accordance with the requirements of ASTM E 1743 for 15 meter geometry and ASTM E1710 for 30 meter geometry. R_L shall be expressed in millicandelas per square foot per foot-candle and shall be at least the following values for either 15 meter or 30 meter when measured in the wheel path area.

Coefficient of Retroreflected Luminance (R_L)

Color	Type D, Class I (15 meter)	Type D, Class I (30 meter)	Type D, Class II (15 meter)	Type D, Class II (30 meter)
White	150	100	500	335
Yellow	100	65	335	225

(2) **Removability:** Removability value shall be at least 8 for materials submitted to NTPEP prior to the year 1998. For materials submitted to NTPEP in the year 1998 and later, the internal tape strength value shall be no greater than 3, and the adhesive bond value shall be no greater than 7. Values shall be the average of the three monthly readings for the transverse line.

(3) **Adhesion:** No line shall have walked nor shall it be torn or missing.

2. **Non-retroreflective Black Removable Tape (Type E):** Non-retroreflective black removable tape shall be suitable for use on asphalt concrete surfaces and shall conform to the following:

a. **Initial Skid Resistance:** Initial skid resistance value shall be at least 45 BPN.

b. **Warranty:** The manufacturer shall provide a full manufacturer's warranty on their product that shall cover the removability and adhesiveness. The warranty period shall be no less than

90 days, beginning on the date of installation and shall include all material and labor costs when installed in accordance with the manufacturer's recommendations.

c. **Removability and Adhesion:** Removability and adhesion shall conform to the following requirements after being installed on the test deck for 90 days:

(1) **Removability:** Removability value shall be at least 8 for materials submitted to NTPEP prior to the year 1998. For materials submitted to NTPEP in the year 1998 and later, the internal tape strength value shall be no greater than 3, and the adhesive bond value shall be no greater than 7. Values shall be the average of the three monthly readings for the transverse line.

(2) **Adhesion:** No line shall have walked nor shall it be torn or missing.

3. **Temporary Pavement Marking Material (Type F, Class I and II):** Temporary pavement marking material shall be suitable for use on asphalt and hydraulic cement concrete surfaces and shall conform to the following:

a. **Paint Products**

(1) **Settling Properties:** Settling rating shall be at least 8 when tested in accordance with ASTM D869.

(2) **Freeze-Thaw and Heat Stability:** Paint shall show no coagulation or change in viscosity greater than ±5 KU when tested in accordance with the NTPEP test procedure.

(3) **Water Resistance:** Paint shall show no blistering, peeling, wrinkling, softening or loss of adhesion when tested in accordance with the NTPEP test procedure.

(4) **VOC:** The Volatile Organic Compound content shall be no greater than 150 grams/liter when tested in accordance with EPA Method 24.

b. **Tape Products**

(1) **Initial Skid Resistance:** Initial skid resistance value shall be at least 45 BPN.

(2) **Warranty:** The manufacturer shall provide a full manufacturer's warranty on their product that shall cover the

retroreflectivity, removability and adhesiveness. The warranty period shall be no less than 90 days, beginning on the date of installation and shall include all material and labor costs when installed in accordance with the manufacturer's recommendations.

(3) **Adhesion:** No line shall have walked nor shall it be torn or missing after being installed on the test deck for 90 days.

c. **All Products (including paint and tape products)**

(1) **Thickness:** Thickness shall be no greater than 40 mils.

(2) **Maintained Retroreflectivity and Durability:** Maintained retroreflectivity and durability shall conform to the following requirements after being installed on the test deck for 90 days:

a) **Maintained Retroreflectivity:** Photometric quantity to be measured is coefficient of retroreflected luminance (R_L) in accordance with the requirements of ASTM E 1743 for 15 meter geometry and ASTM E1710 for 30 meter geometry. R_L shall be expressed in millicandelas per square foot per foot-candle and shall be at least the following values for either 15 meter or 30 meter when measured in the wheel path area.

Coefficient of Retroreflected Luminance (R_L)

Color	Type F, Class I (15 meter)	Type F, Class I (30 meter)	Type F, Class II (15 meter)	Type F, Class II (30 meter)
White	150	100	290	190
Yellow	100	65	190	125

b) **Durability:** Marking material shall have a durability rating of at least 4 when determined in the wheel path area.

SECTION 247—REFLECTIVE SHEETING

247.01—Description.

This specification covers reflective sheeting used on traffic control devices to provide a retroreflective surface or message. Color of the reflective sheeting shall be as