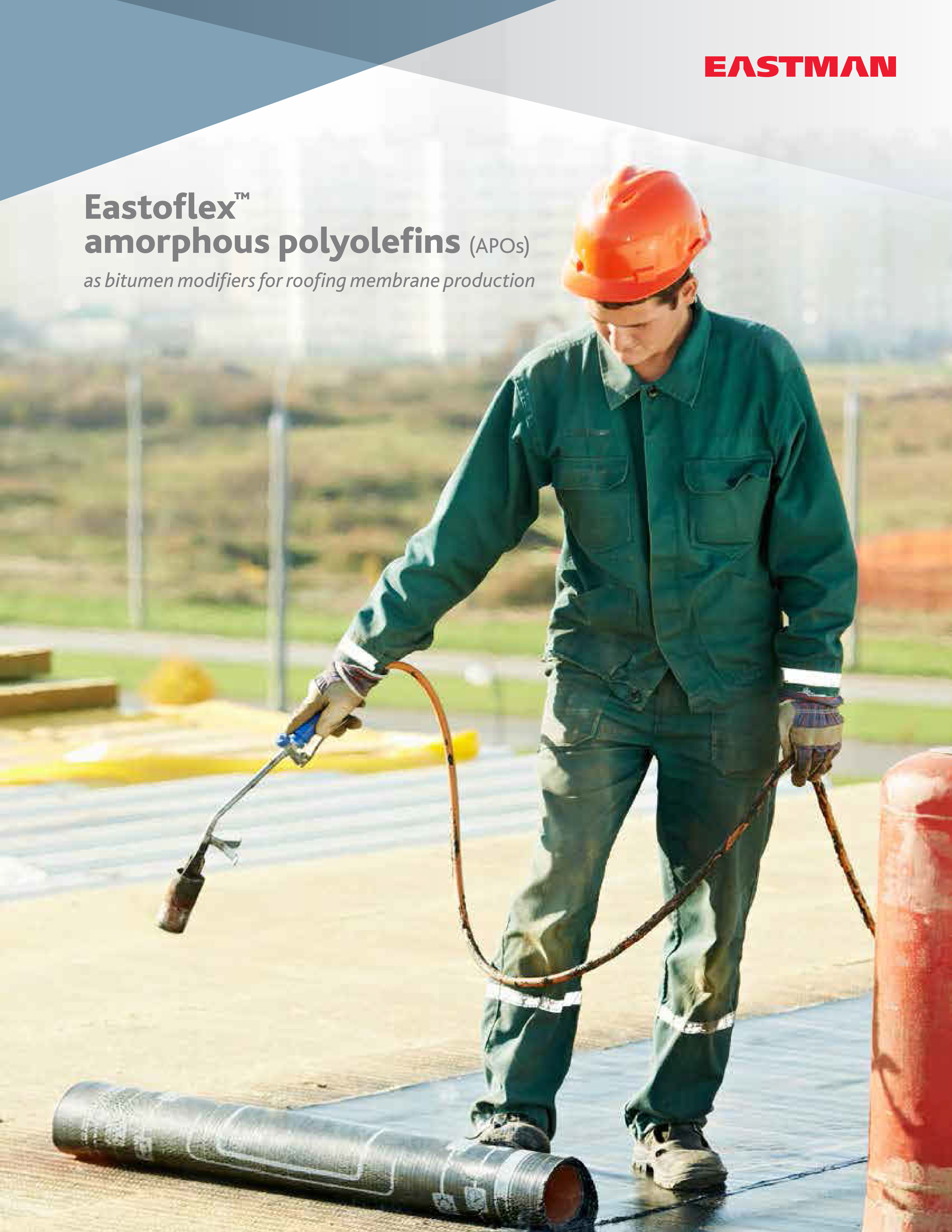
EASTMAN

Eastoflex™ amorphous polyolefins (APOs)

as bitumen modifiers for roofing membrane production



Contents

Eastoflex™ amorphous polyolefins (APOs)

as bitumen modifiers for roofing membrane production

What are amorphous polyolefins?

Eastoflex™ amorphous polyolefins are noncrystalline polymers characterized by low color and odor, resistance to heat and UV light degradation, softness and flexibility, and low melt viscosity. They are compatible with a range of polymers, waxes, tackifying resins, and asphalt. In a roofing membrane application, the use of Eastoflex APO as a bitumen modifier provides improved UV stability, resistance to high temperatures, viscosity control, and low temperature flexibility. Using Eastoflex APO in a roofing membrane reinforces the desirable properties of bitumen in resistance to water and oxidation. Eastoflex APO can be processed in heated, low-shear mixing equipment and does not require high-speed dispersing equipment to incorporate it into bitumen-based compounds.

Eastoflex™ amorphous polyolefins as bitumen modifiers

By itself, bitumen has many desirable properties that suggest its use in roofing materials: high resistance to water and oxidation, easy workability, low cost, and wide availability. The positive aspects of bitumen in roofing are detracted by some undesirable properties: embrittlement at low temperatures, melting within the ambient temperature range, poor resistance to UV, and melt viscosity too low for membrane formation. These negative aspects of bitumen can be overcome by the use of polymeric additives such as Eastoflex amorphous polyolefins. The use of amorphous polyolefin as a bitumen modifier offers the following important property improvements:

- Raise the softening point from 50°C (120°F) for unmodified AC-5 grade bitumen to more than 150°C (300°F).
- Extend minimum flexibility temperature for unmodified AC-5 bitumen from 0°C to as low as −30°C depending on Eastoflex APO grade selection.
- Increase the melt viscosity from less than 500 cps for unmodified AC-5 bitumen at 190°C (302°F) to as high as 2500 cps depending on Eastoflex APO addition level and grade selection.
- Decrease needle penetration from 120 dmm at 25°C (77°F) for unmodified AC-5 bitumen to as low as 30 dmm depending on Eastoflex APO addition level and grade selection.
- Improve the UV stability of bitumen from a minimum flexibility temperature increase of 10°C (50°F) for unmodified AC-5 bitumen to zero change after 1000 hours carbon-arc Weather-O-Meter™ exposure depending on addition level of Eastoflex APO.

Eastoflex APO product range

Eastman employs a unique production facility to make Eastoflex™ amorphous polypropylene (APP) and amorphous propylene-ethylene (APE) copolymers. The typical properties of the five base polymers produced in the Eastman facility located in Longview, Texas, are described in Table 1. The values shown for typical properties in Table 1 and Figures 1 and 2 are included for information only and cannot be used for setting purchase specifications. Eastman will provide manufacturing specifications for any material supplied as well as Certificates of Analysis for any shipment of Eastoflex amorphous polyolefin. However, Eastman makes no representation that the material in any particular shipment will conform exactly to the values shown.

These five grades are maintained in bulk molten form and can be blended in any proportions to produce custom grades on demand. This unique APO blending capability allows great flexibility in the ability to supply Eastoflex amorphous polyolefins with properties that precisely match the requirements of a particular application or fabrication line. For bitumen-based roofing membranes, this means that Eastman has the capability of producing blends customized to a particular recipe, finished product specification, or processing window for a particular membrane fabrication line with very low lead time.

Advanced mixing technology and mathematical modeling systems allow the plant to use these five base polymers in two- or three-component blends. The predicted viscosity vs. softening point and T_g vs. needle penetration relationships across the existing range of blending capabilities are shown in Figures 1 and 2.

Table 1
Typical properties of the five base grades of Eastoflex™ amorphous polyolefins

Product property	ASTM test method	Eastoflex P1010	Eastoflex P1023	Eastoflex E1003	Eastoflex E1060	Eastoflex E1200
Product type		**Propylene homopolymer**		**Propylene-ethylene**		
Brookfield viscosity at 190°C, cps (mPa•s)	D3236	1,000	2,300	300	6,000	20,000
Ring and ball softening point, °C	E28	155	155	120	135	135
Needle penetration, dmm	D5	20	20	100	35	30
Glass transition temperature (T_g), °C	D3418	–10	–10	–33	–23	–22

Figure 1
Viscosity vs. ring and ball softening point blending space bounded by the Eastoflex APO base grades

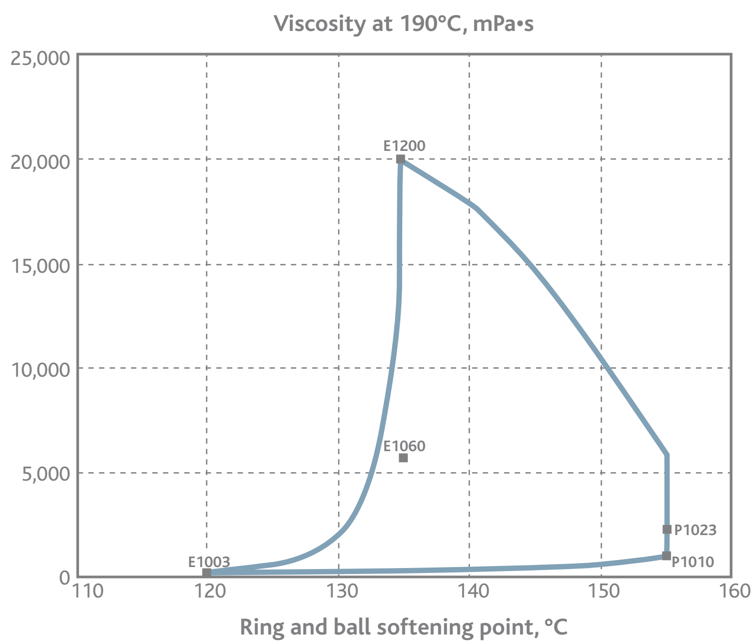
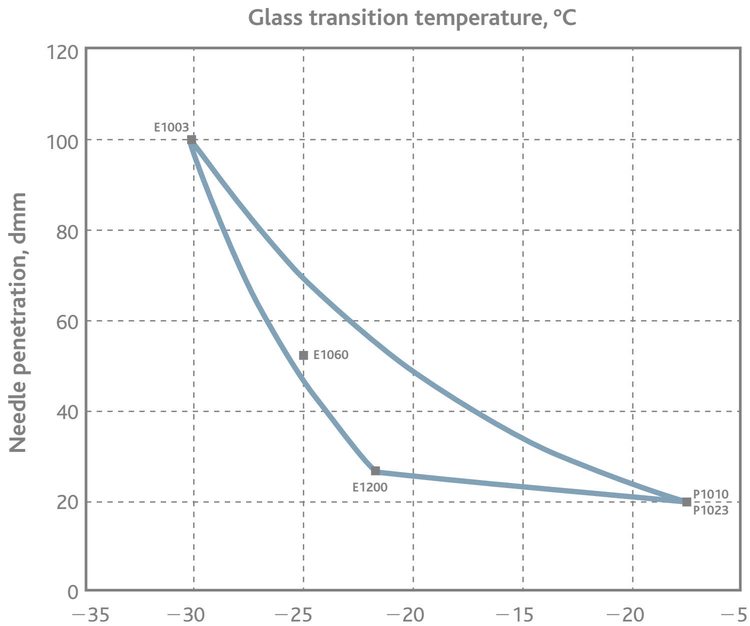


Figure 2

Glass transition temperature vs. needle penetration blending space bounded by the Eastoflex APO base grades



Addition levels for Eastoflex™ amorphous polyolefins in modified bitumen roofing membrane compounds

The first challenge in formulating an acceptable compound for roofing membrane is determining how much Eastoflex APO to add. To demonstrate the effect of adding APO to a bitumen-based compound, the graphs in Figure 3 show the effect of adding between 14% and 24% Eastoflex E1060 to an asphalt-based compound which also includes calcium carbonate and isotactic polypropylene at typical levels for a roofing membrane formula. Eastoflex E1060 amorphous propylene-ethylene (APE) copolymer was chosen because its properties fall in the center of the blending space and is therefore a good representative of typical properties for APO. AC-5 asphalt is a standard grade of bitumen used extensively for road and architectural construction. AC-5 is a general specification for asphalt concrete which refers to its melt viscosity of 500 Pa•s at 60°C (140°F). Asphalt meeting the AC-5 specification is produced by many refiners worldwide and is not specific to a particular refinery or producer. Isotactic polypropylene is used in the compound to impart greater tensile strength and impact resistance. For evaluation purposes, a propylene homopolymer with a melt flow index of 20 grams/10 minutes at 230°C (446°F) with a 2.16 kg load was chosen. Isotatic propylene homopolymers of this type are produced by many global suppliers. A typical product is ExxonMobil™ PP1074KNE1. Powdered calcium carbonate is included to reduce cost, add weight, and improve UV light resistance to a roofing membrane. It is available from many sources, and a typical product used in roofing membrane is Omyacarb™ 3 from Omya Corporation with worldwide production and distribution. The full composition of the test compounds is shown in Table 2.

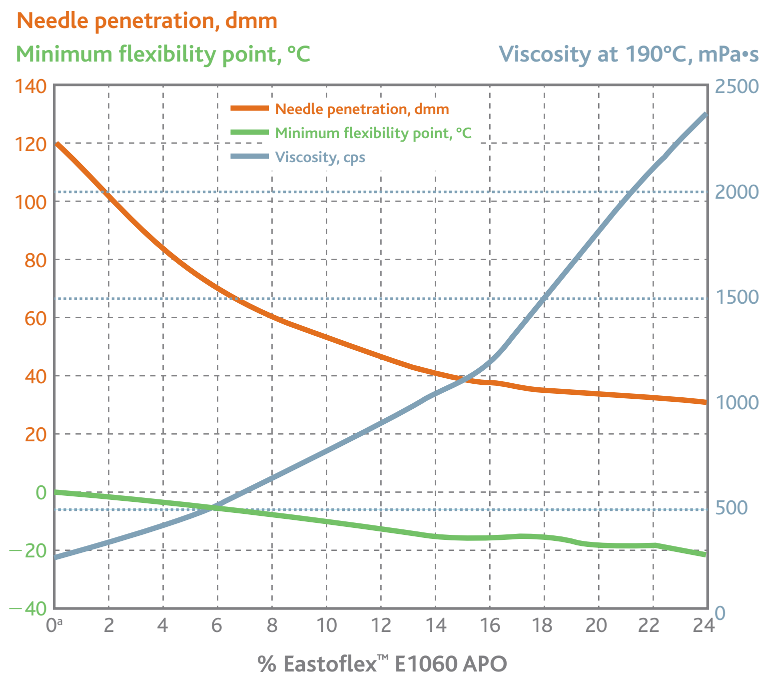
Table 2

Compositions to determine optimum loading of Eastoflex™ E1060 amorphous propylene-ethylene copolymer in a roofing membrane compound

Component	Weight %					
Eastoflex E1060 APO	14	16	18	20	22	24
Isotactic polypropylene, MFI 20	4	4	4	4	4	4
Calcium carbonate	15	15	15	15	15	15
AC-5 asphalt	67	65	63	61	59	57

Figure 3

Compound properties vs. % Eastoflex E1060 APO addition



[a] Zero point is for unmodified AC-5 asphalt, with no added calcium carbonate or isotactic polypropylene.

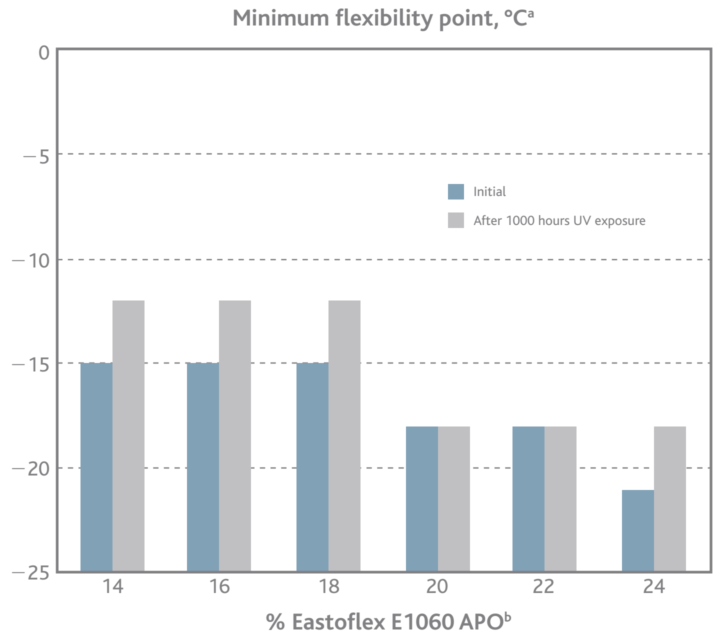
In examining the results of APO addition to the bitumen compound, the needle penetration does not change significantly over the tested range of 14%–24% Eastoflex E1060 APO, although there is a slight downward trend. Any level of APO addition above 16% should attain needle penetration values below 40 dmm. For low temperature flexibility, there again is a slight downward trend with the highest addition levels of 20%–24% APO dropping to near −20°C. This is to be expected since the T_g of Eastoflex E1060 alone is −23°C, so the minimum flexibility point cannot be below the T_g of the APO. These results suggest that the addition level of APO should be at least 20%. For viscosity, the response to APO addition is nearly linear over the range of tested compounds. To allow sufficient buildup of bitumen compound on a production line, the viscosity should be above 1500 mPa•s, which suggests that an addition level of 20% or greater of Eastoflex E1060 is required.

Accelerated weathering study on Eastoflex APO-modified roofing compositions

The sample compounds presented in Table 2 were exposed in a carbon-arc Weather-O-Meter UV light exposure simulator for 1000 hours per ASTM D1499. Each sample was then retested for minimum flexibility point. The minimum flexibility temperature of each of these samples was found to have changed by 3°C (37.4°F) or less as shown in Figure 4. Samples with 20% and 22% Eastoflex E1060 showed no change.

Figure 4

Ultraviolet light stability of bitumen blends with Eastoflex™ E1060 APO



[a]90°, 2-second bend *[b]See Table 2 for formula details.*

Properties of modified bitumen compounds with varying APO composition

The remaining question about the use of APO in modified bitumen roofing membrane compounds is the effect of changing the properties of the APO component. In the previous sections, Eastoflex E1060 amorphous propylene-ethylene copolymer was selected as representing the center of the existing Eastoflex APO blending space. Another set of experiments was done using two of the other available base products, Eastoflex P1023 and E1200. Eastoflex P1010 and E1003 were not selected to study since they are designed for use with a propylene homopolymer; when used with a propylene-ethylene copolymer, their viscosities are too low to produce compounds in the desired viscosity range. In addition, four systems using binary blends of Eastoflex P1023, E1060, and E1200 APOs were made to test representative blends within the Eastoflex APO blending space. The details of the APO compositions used and their respective physical properties are shown in Table 3. The base formula used for all of these tests was 20% Eastoflex APO, 60% AC-5 asphalt, 15% calcium carbonate, and 5% isotactic polypropylene with MFI of 20 from the previously sited sources.

Table 3

Physical properties of APO-modified bitumen roofing membrane compounds

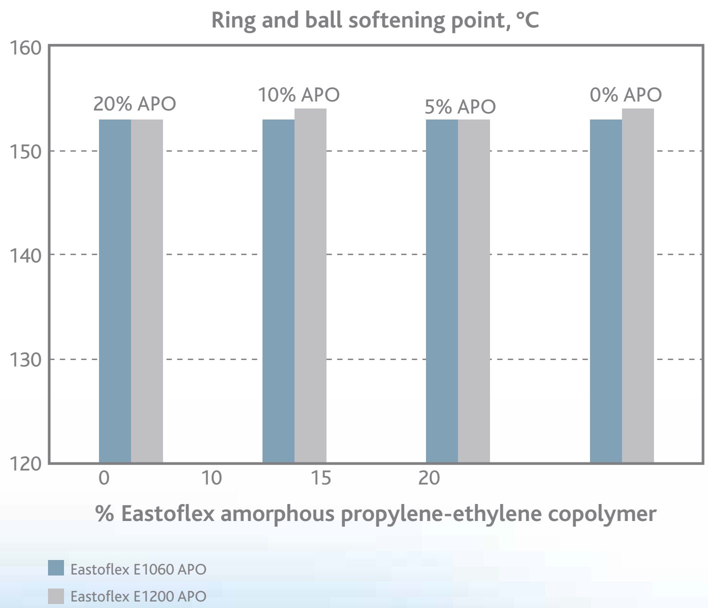
Formula number	APO component	Ring and ball softening point, °C	Needle penetration, dmm	Brookfield viscosity at 190°C, mPa•s	Minimum flexibility point, °C[a]
1	20% Eastoflex E1200 APO	154	25	2,400	–29
2	20% Eastoflex E1060 APO	153	35	1,700	–21
3	20% Eastoflex P1023 APO	153	25	1,200	–9
4	5% Eastoflex P1023, 15% E1060	153	35	1,500	–18
5	10% Eastoflex P1023, 10% E1060	153	30	1,400	–21
6	10% Eastoflex P1023, 10% E1200	154	24	1,900	–21
7	5% Eastoflex P1023, 15% E1200	153	24	2,000	–23

[a]108°, 7-second bend

The first important observation from this experiment is that the ring and ball softening point for all seven compounds are not significantly different, regardless of the APO composition of the material. In this case, the softening point is being driven by the isotactic polypropylene included in the formula and the APO has only minor influence on this property. Figure 5 shows the changes in softening point with the different blends used in the experiments demonstrating that the softening point is independent of the APO composition.

Figure 5

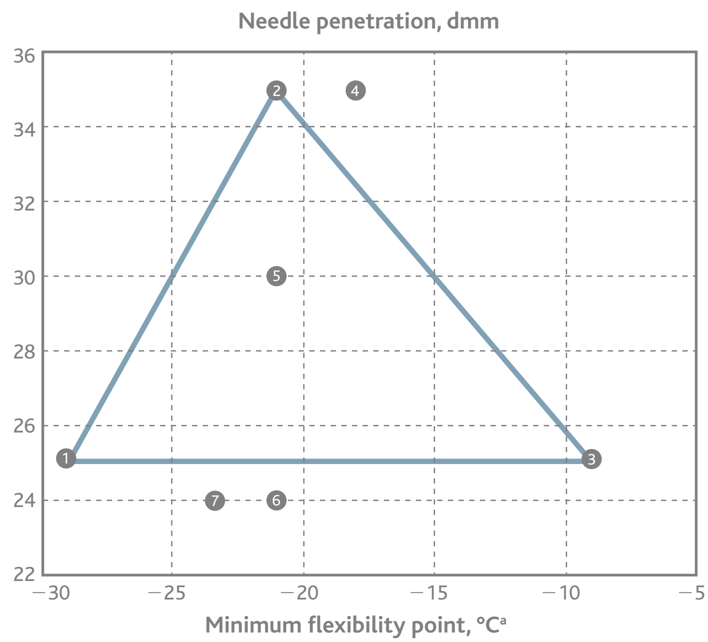
Ring and ball softening point vs. % Eastoflex amorphous propylene-ethylene copolymer in modified bitumen compounds



The needle penetration, minimum flexibility point, and melt viscosity are all properties that are certainly affected by the APO composition in the formula. The APE copolymers used for bitumen modification all have higher needle penetration values and lower glass transition temperatures and are higher in viscosity than propylene homopolymer (APP). The relationship between needle penetration and minimum flexibility point is shown in Figure 6. Note that for most of the two-component blends, the observed properties lie outside the area defined by the three base polymers used. The means that the properties resulting from a particular blend may not be completely predictable from the properties of the base polymers used to make the blend.

Figure 6

Needle penetration vs. minimum flexibility point of Eastoflex APO-modified asphalt blends



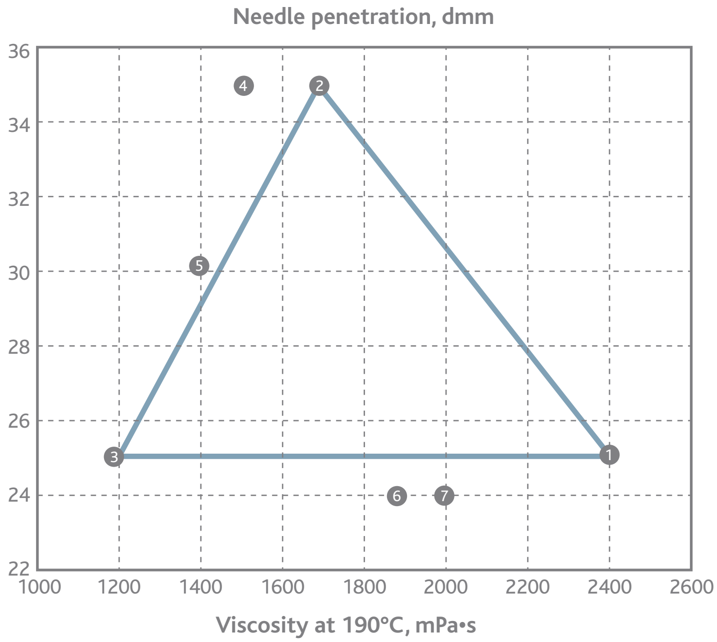
NOTE: Refer to Table 3 for APO component breakdown

[a]*108°, 7-second bend*

A plot of needle penetration versus viscosity at 190°C is shown in Figure 7. Again, the results for the APO blends all fall outside the area bounded by the three base polymers, which illustrates the need to carefully test a new formula before drawing conclusions. This also suggests that it may be necessary to use trinary blends if intermediate properties are required. Arranging the data in another way begins to produce a more predictable model for the performance of APO in a bitumen-based compound. In Figures 8, 9, and 10, the properties of viscosity at 190°C, needle penetration, and minimum flexibility point are plotted against the % APO in the formula with the data from different APO copolymers shown separately. Presented in this manner, it is easier to see the relationships between physical properties of the compound and the composition of the APO portion of the formula.

Figure 7

Needle penetration vs. viscosity at 190°C of Eastoflex APO-modified asphalt blends



NOTE: Refer to Table 3 for APO component breakdown

Figure 8

Viscosity at 190°C vs. % Eastoflex™ APO copolymer in modified bitumen compounds

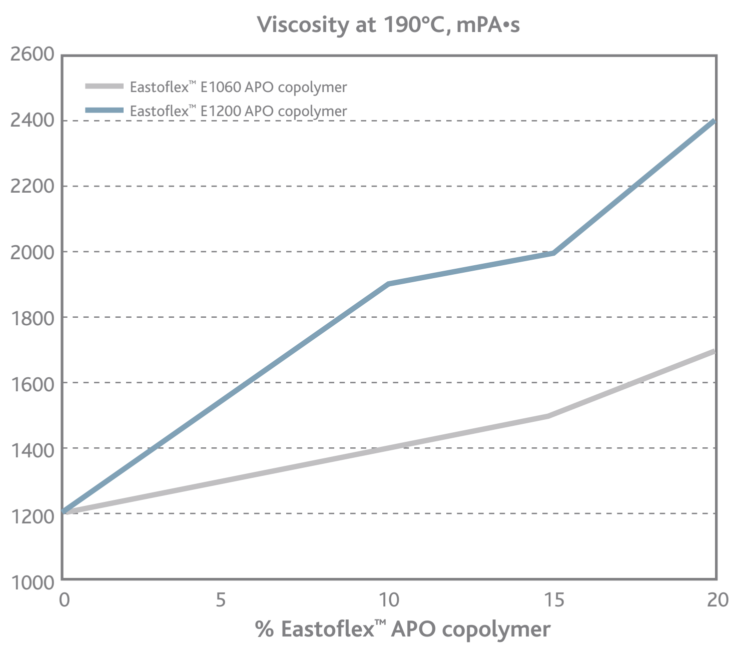


Figure 9

Needle penetration vs. % Eastoflex™ APO copolymer in modified bitumen compounds

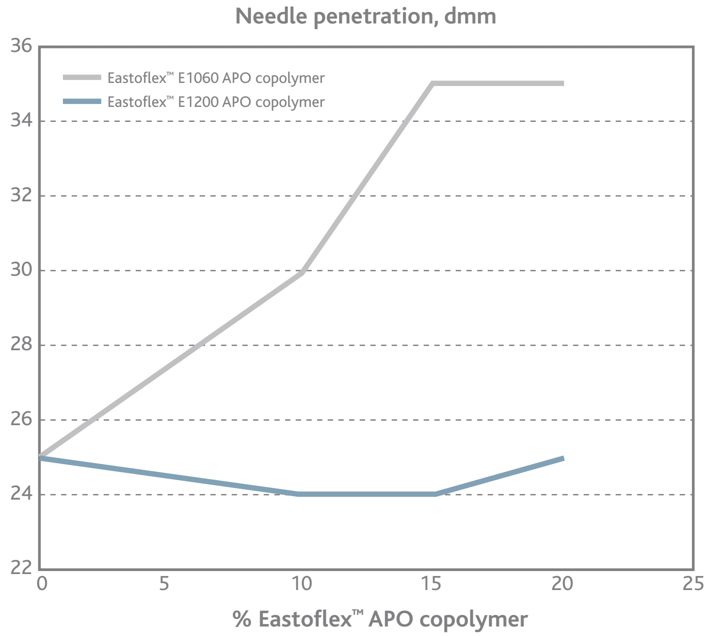
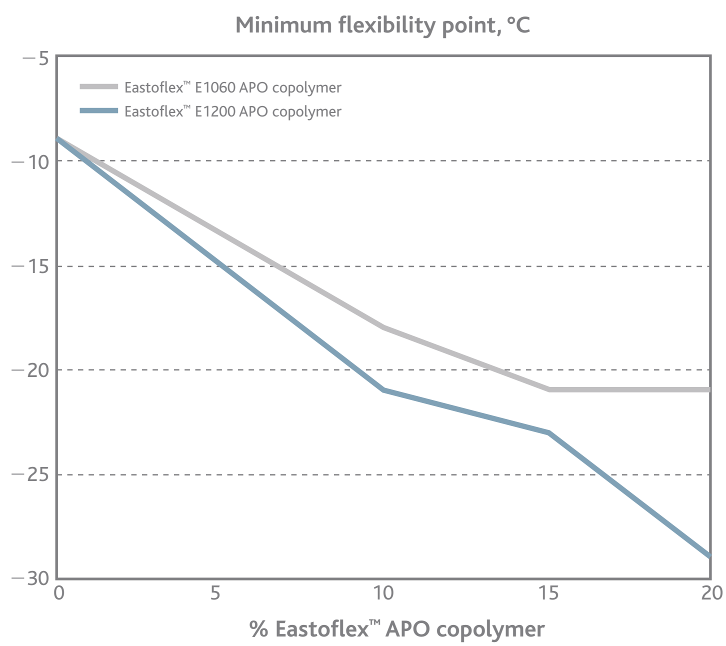


Figure 10

Minimum flexibility point vs. % Eastoflex™ APO copolymer in modified bitumen compounds



Conclusion

Bitumen possesses many attractive properties indicating its use in single-ply roofing membranes. It is highly water resistant, low cost, and easy to apply. Counterbalancing these properties, bitumen has several deficiencies that must be overcome. These include embrittlement at low temperatures, melting at temperatures above 50°C, poor resistance to UV degradation, and low penetration resistance. The use of inorganic fillers and a small amount of isotactic polypropylene can overcome some of these deficiencies, but the use of a polymeric additive can produce a roofing membrane compound with excellent all-around properties. Amorphous polyolefins are one of the principal polymers used to modify bitumen for roofing membrane compounds. Eastoflex APOs from Eastman are well-suited for this application. Eastman supplies amorphous propylene homopolymers and propylene-ethylene copolymers which provide a wide variety of formulation options for bitumen modification. Additionally, Eastman Chemical Company has unique capabilities for blending APOs to custom specification that facilitates the matching of APO properties to the requirements of a given grade of asphalt and membrane production equipment. Eastoflex amorphous polyolefins are available globally and technical support is available for product selection to meet the needs of the modified bitumen roofing membrane industry.

To find out more about Eastoflex™ amorphous polyolefins, contact your Eastman representative or visit www.eastoflex.com.

EASTMAN
The results of **insight**™

Eastman Chemical Company
Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, (1) 423-229-2000
Fax: (1) 423-229-1193

Eastman Chemical Latin America
9155 South Dadeland Blvd.
Suite 1116
Miami, FL 33156 U.S.A.

Telephone: (1) 305-671-2800
Fax: (1) 305-671-2805

Eastman Chemical B.V.
Fascinatio Boulevard 602-614
2909 VA Capelle aan den IJssel
The Netherlands

Telephone: (31) 10 2402 111
Fax: (31) 10 2402 100

Eastman (Shanghai) Chemical Commercial Company, Ltd. Jingan Branch
1206, CITIC Square
No. 1168 Nanjing Road (W)
Shanghai 200041, P.R. China

Telephone: (86) 21 6120-8700
Fax: (86) 21 5213-5255

Eastman Chemical Japan Ltd.
MetLife Aoyama Building 5F
2-11-16 Minami Aoyama
Minato-ku, Tokyo 107-0062 Japan

Telephone: (81) 3-3475-9510
Fax: (81) 3-3475-9515

Eastman Chemical Asia Pacific Pte. Ltd.
#05-04 Winsland House
3 Killiney Road
Singapore 239519

Telephone: (65) 6831-3100
Fax: (65) 6732-4930

www.eastman.com