Reflective Pavement Markers (RPMs)

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SPE Blow Molding Competition

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Contents

Introduction

This product is an extrusion blow molded reflective pavement marker (RPM) that is designed to be less expensive to manufacture. The most prevalent issue with current reflective pavement markers is that they are dislodged or destroyed by various causes. The leading cause of RPM failure in application is by far snowplow impact. Snowplows catch the edge of the marker and either scrape it off the road or completely shatter it. Efforts consisting of recessing RPMs into the asphalt or framing the markers in metal have been employed to create snowplow-able markers. However, these efforts have proved to be unsuccessful because plow trucks eventually wear down the markers in a short period of time. In addition to snowplow damage, RPMs are commonly destroyed by regular vehicle impact. Specifically, heavy trucks with trailers can shear off or crush RPMs, and high-speed impacts (>70 mph) can generate enough force to knock RPMs off the road.

Figure 1: Current design for reflective pavement markers (RPMs)

The goal of this project is to manufacture a reflective pavement marker that is designed to be easily manufactured and replaceable. This product will be extrusion blow molded out of high-density polyethylene to reduce both material and production costs to mitigate financial losses due to road carnage. Essentially, there is no way to design around snowplow impact. Regardless of the impact strength of the material, a snowplow will still be able to either shear off or destroy the RPM. However, RPMs can be manufactured inexpensively so that this destruction will not have as significant of a financial impact. This RPM will be designed to withstand the force of a semitruck traveling 70 mph, but it will break when impacted by a snowplow. Specific force specifications will be discussed later.

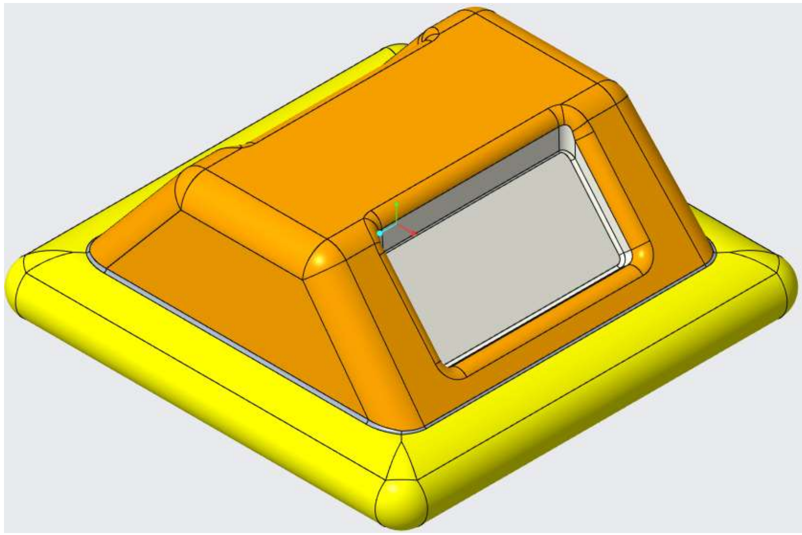
Blow Molding Application

Extrusion blow molding is believed to be a more suitable process for manufacturing an inexpensive reflective pavement marker than injection molding. It enables the creation of a one-piece, hollow structure in a single continuous cycle, which drastically reduces the number of manufacturing steps. This also minimizes assembly labor and simplifies tooling complexity.

In an extrusion blow molded (EBM) reflective pavement marker design, the part can be engineered so that the reflective surface is either integrated during molding or attached in-line immediately after molding. Therefore, the need for a lengthy and expensive secondary operation to assemble the reflective surface is eliminated. This is possible because the blow molding process allows the formation of features such as recessed pockets into the part. Part geometry can be strategically placed to capture a pre-positioned reflective insert during the blow cycle or to receive a pre-cut reflective film or tape immediately after molding. In contrast, traditional injection molded RPMs require the body and reflectors to be molded separately. After molding, each reflector must be manually or semi-automatically assembled into the body, which increases labor costs, cycle time, and tooling complexity. With EBM, that entire post-molding assembly step can be minimized, significantly streamlining production and reducing manufacturing costs.

Extrusion blow molding also allows manufacturers to use lower-cost, high-melt-strength resins such as high-density polyethylene (HDPE), which helps drive down material expenses. The process offers faster cycle times compared to injection molding and enables lightweight but durable parts to be produced more efficiently. These advantages make EBM an ideal method for producing reflective pavement markers at a fraction of the cost of traditional multi-part, injection-molded assemblies.

Finally, extrusion blow molding is a less expensive process overall because it requires lower clamping forces, simpler mold designs, shorter cycle times, and fewer secondary operations. These factors collectively lead to reduced equipment wear, lower energy consumption, and significantly decreased production overhead when compared to injection molding.



Design Details

Material Selection

High density polyethylene was chosen as the most suitable material to manufacture an extrusion blow molded reflective pavement marker due to the qualities described table 2 below. The most important factors that influenced this decision include material cost, melt strength, and impact resistance. Other important factors were UV resistance, chemical resistance, and durability. All of these factors were chosen because they most directly reflect the circumstances an RPM will face in application. Other material candidates included polycarbonate (PC) and polyvinyl chloride (PVC). These materials were chosen as initial candidates because they are both able to be extrusion blow molded while satisfying other criteria like chemical and UV resistance. However, PC was determined to be too expensive despite it having the highest impact resistance.

Table 1: 1-5 scoring system for the material selection matrix

Scoring Scale	0-5
5	Excellent
4	Good
3	Moderate
2	Poor
1	Very Poor
0	Unacceptable

Table 2: Material selection matrix used to determine that HDPE was the most appropriate material for the reflective pavement marker. All scores were determined using MatWeb Data

Property	Weight (%)	HDPE	PC	PVC
Material Cost	20	5	1	4
Melt Strength	15	5	3	4
Impact Resistance	15	4	5	3
UV Resistance	10	4	5	5
Chemical Resistance	5	5	4	4
Processability	10	5	3	4
Durability	10	4	5	3
Weight (density)	5	5	2	3
Surface Finish	5	3	5	3
Recyclability	5	5	3	4

Ultimately, the total scores were 455 points, 360 points, and 357 points respectively

Critical Parameters

HDPE is a highly suitable material for RPM bodies due to its excellent combination of impact resistance, flexibility, chemical inertness, and cost-effectiveness. While many traditional markers are made from polycarbonate or ABS, HDPE offers comparable toughness and fatigue resistance, particularly under dynamic loading from vehicle tires. It performs reliably across a wide temperature range –20°F to 110°F, but will see slightly reduced mechanical properties at temperatures above 150°F. When stabilized with UV inhibitors or 2–3% carbon black, HDPE exhibits long term durability in outdoor conditions, including resistance to sunlight and moisture. In high traffic roadway applications where impact absorption and resistance to cracking are essential, HDPE's inherent ductility and toughness provide a clear performance advantage over more brittle thermoplastics.

The dimensions of raised pavement markers are standardized to ensure visibility and durability while minimizing disruption to vehicle movement. Most RPMs are approximately 4 inches wide and either square or rectangular in shape. The marker height should range from 0.5 to 0.8 inches above the road surface to ensure nighttime visibility without becoming a hazard to passing vehicles. The base may incorporate anchoring features or a textured surface to improve adhesive bonding and prevent dislodgment under shear loads. This blow molded design consists of a 3.8in X 3.8in square with a .5in base to be held under the road surface. The reflective surface extends roughly 1in above the road and has a wall thickness of .2in.

Raised pavement markers must meet strict mechanical durability requirements to ensure safe and long-lasting performance under repeated loads. According to ASTM D4280, each marker must be capable of supporting a 6000 lb static load without breakage or significant deformation, where significant deformation is defined as exceeding 0.13 inches. To validate that the design could hold up to this standard, a linear finite element analysis was conducted in

ANSYS on the HDPE marker body design. The results showed a maximum deformation of 0.00031 inches, which is well below the ASTM deformation threshold. Additionally, the maximum internal stress reached 6161.7 psi, remaining safely below the yield strength of HDPE (6300 psi). These results demonstrate that the design not only meets but substantially exceeds the mechanical load-bearing requirements set forth in ASTM D4280-18.

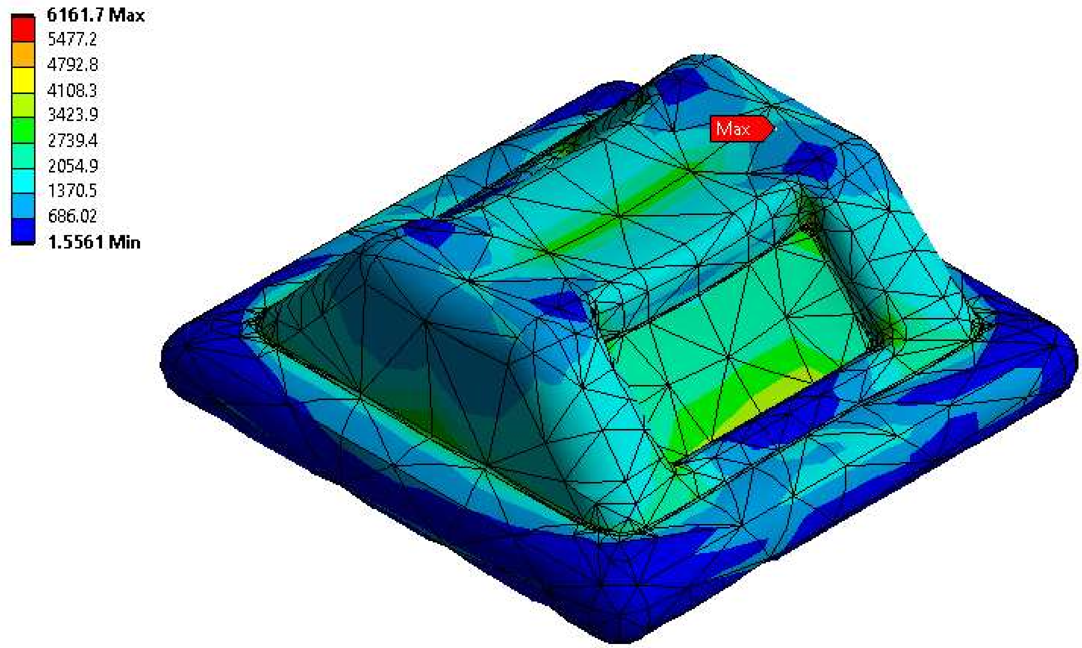


Figure 2 Von Mises Stress of the RPM under 6000lbs static load (psi)

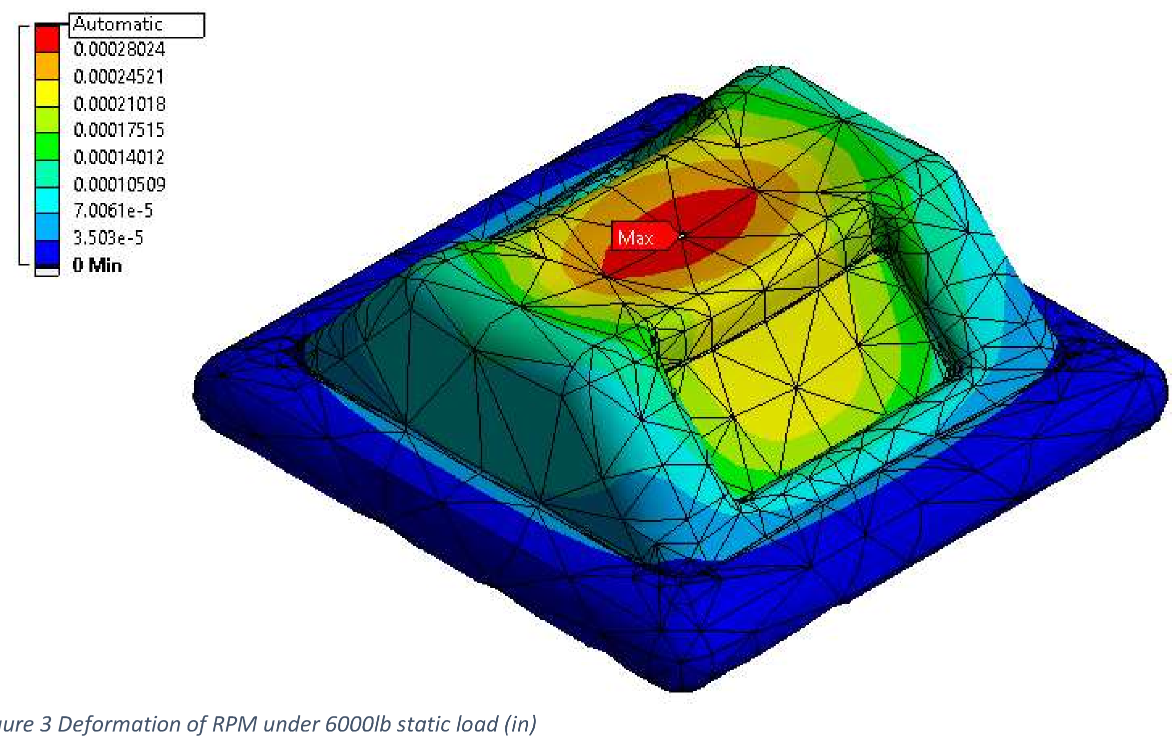


Figure 3 Deformation of RPM under 6000lb static load (in)

Blow Ratio and Cost per Part

In order to determine an accurate blow ratio and cost per part, the parison needs to be analyzed instead of just the part itself. This is because there is a considerable amount of pinch off flash that accompanies eat shot. Therefore, calculations showing the blow ratio for the RPM and the cost per RPM are as follows in figure X.

Parison and Cost per Part

Part Geometry

Overal Length, $l := 4\ in$

Overal Width, $w := 4\ in$

Overal Height, $h := 1.5\ in$

Wall Thickness, $t_{wall} := 0.2\ in$

Mold Geometry

Cavity, $SA_{cavity} := 247.278\ in^2$

Core, $SA_{core} := 16\ in^2$

Parison Geometry

Parison Circumfrence, $C_{parison} := 2 \cdot w = 8\ in$

Parison Diameter, $D_{parison} := \frac{C_{parison}}{\pi} = 2.546\ in$

Blow Ratio, $BR := \frac{(SA_{cavity} + SA_{core})}{C_{parison} \cdot l} = 8.227$

Parison Thickness, $t_{parison} := t_{wall} \cdot BR = 1.645\ in$

Parison Cross Sectional Area,

$$A_{cross} := \frac{\pi}{4}\left(D_{parison}^{\ 2} - \left(D_{parison} - \left(2 \cdot t_{parison}\right)\right)^2\right) = 4.658\ in^2$$

Parison Volume per Part, $V_{parison} := A_{cross} \cdot (l + 1\ in) = 23.288\ in^3$

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Cost per Part

HDPE Density $\rho := 0.035\ \frac{lb}{in^3}$

Cost, $cost := 0.65\ \frac{\$}{lb}$

Cost per Part, $PartCost := V_{parison} \cdot \rho \cdot cost = 0.53\ \$$

Figure 4: Calculations for determining the blow ratio and cost per part when using HDPE to manufacture the extrusion blow molded reflective pavement marker

Mold & Tooling Details

The aluminum mold designed for the HDPE reflective pavement marker will incorporate a total of six water cooling lines to ensure efficient and uniform temperature control during the molding process. The core half of the mold will contain two cooling lines, positioned symmetrically to manage heat near the base of the part. The cavity half of the mold will include four cooling lines, with two lines placed near the top surface and one line on each side, strategically located near the reflective recesses to mitigate hot spots and localized shrinkage. All cooling channels will have a diameter of 3/8 inches, optimized for effective flow and rapid heat transfer in aluminum. Each water line will terminate with a quick-fit connector to facilitate rapid setup and integration with standard process water systems. Additionally, the singular blow pin will be located at the parting line of the mold to introduce pressurized air, enabling proper cavity formation within the part while ensuring balanced wall thickness and reliable part release.

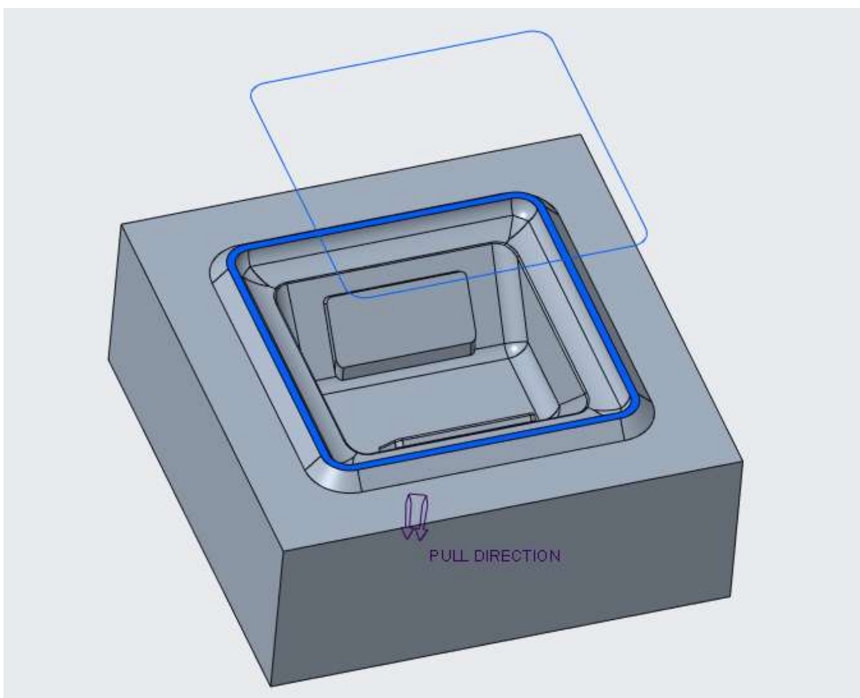

Figure 5: Cavity side (A half) of the mold for the reflective pavement marker

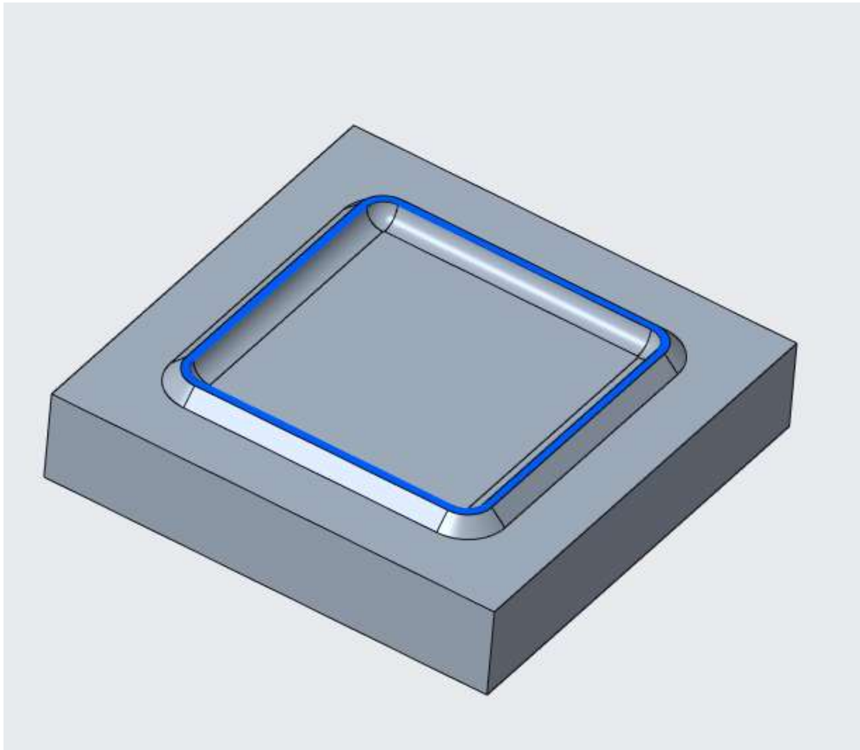

Figure 6: Core side (B half) of the mold for the reflective pavement marker

Manufacturing Details

The reflective pavement marker will be produced using the extrusion blow molding (EBM) process, which is particularly well-suited for creating hollow, durable plastic parts with minimal assembly. To ensure consistent quality and dimensional accuracy, parison programming will be used. This allows the thickness of the parison to be varied along its length, compensating for areas of the mold that would otherwise receive thinner walls due to stretching. For example, sections of the marker subject to frequent tire impacts can be thickened by adjusting the parison profile, ensuring greater durability and crack resistance.

One of the unique features of EBM that will be leveraged in this design is the ability to form integrated features such as recessed pockets or raised mounting surfaces for reflective elements. These can be molded directly into the body without requiring post-processing. This eliminates a secondary assembly step common in injection molded markers, where reflectors are inserted separately. To further simplify manufacturing, draft angles of 2-3 degrees will be incorporated into vertical walls to facilitate mold release, and corner radii will be added to reduce stress concentrations and improve parison conformity.

Potential technical issues in this process include uneven wall thickness, especially in areas with deep draws or sharp transitions. This can lead to weak spots that reduce impact resistance. Additionally, if the parison is not properly centered or if air pressure is inconsistent, blow-outs or non-uniform inflation could occur, resulting in scrap. Material shrinkage (approximately 2–3% for HDPE) will also be accounted for in the mold design to ensure accurate final dimensions.

To ensure a robust manufacturing process, cooling channels will be designed into the mold to promote uniform part cooling and minimize warpage. If reflective film or inserts are to be applied immediately after molding, the production line can be equipped with in-line application stations that bond the reflective element to the still-warm plastic surface, ensuring strong adhesion without requiring separate labor-intensive steps.

Overall, extrusion blow molding provides a fast, cost-effective, and durable manufacturing method for this application, with the added advantage of enabling integrated features that simplify the production process.

Design Drawings

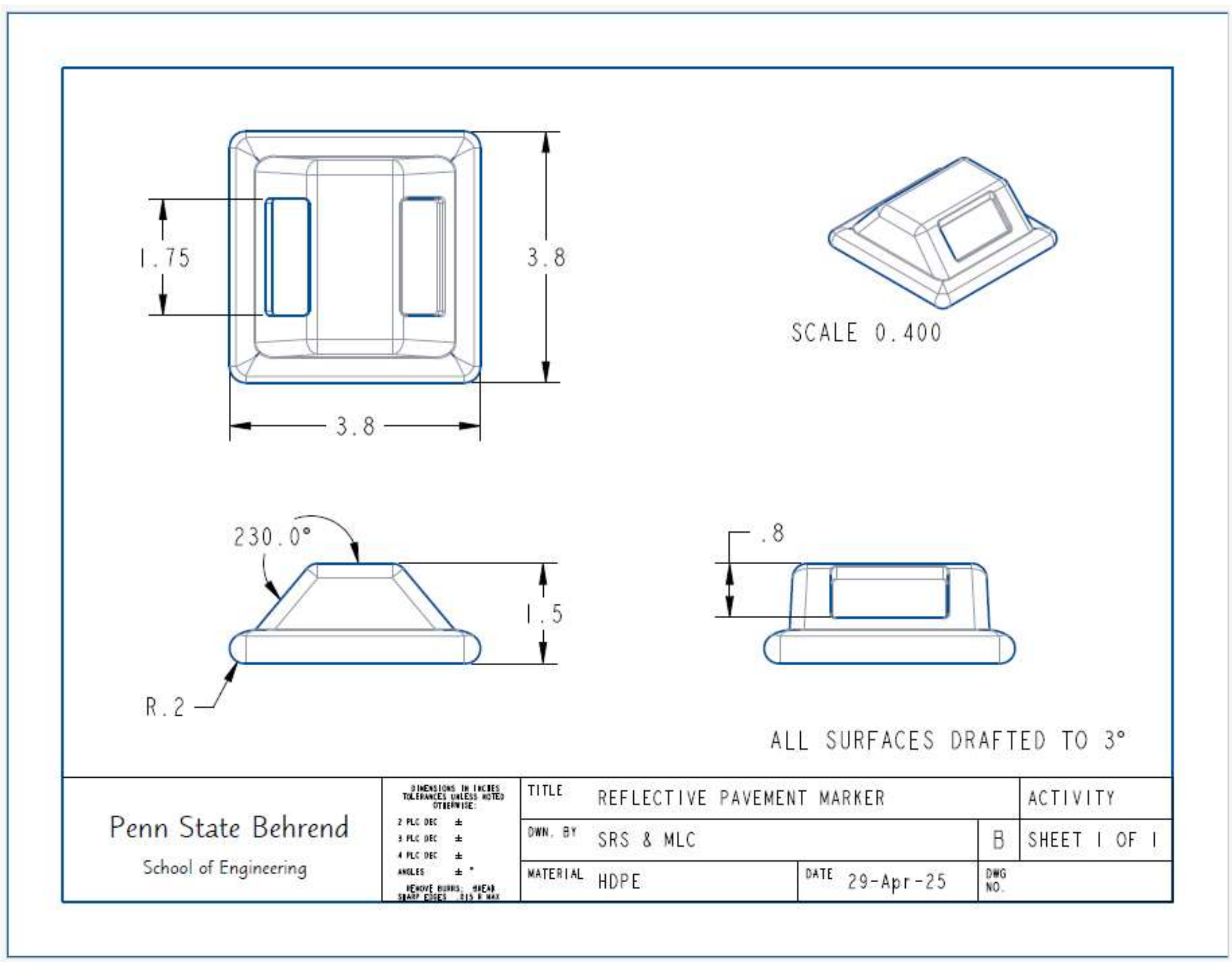

Figure 7: Detailed drawing of the reflective pavement marker

References

[1] ASTM International, Standard Specification for In-Place Thermoplastic Pavement Marking Material, ASTM D4280-18, 2018. [Online]. Available: https://www.astm.org/d4280-18.html

[2] M. Berins (Ed.), Plastics Engineering Handbook of the Society of the Plastics Industry, 5th ed. New York, NY, USA: Springer, 1991.

[3] MatWeb Material Property Data, "High Density Polyethylene (HDPE)," [Online]. Available: https://www.matweb.com/search/datasheet.aspx?matguid=bf453082c50f4a548fc4eaf7596dbf4e

[4] T. Osswald and G. Menges, Materials Science of Polymers for Engineers, 3rd ed. Munich, Germany: Hanser Publications, 2012.

[5] R. Malloy, Plastic Part Design for Injection Molding: An Introduction, 2nd ed. Munich, Germany: Hanser Publications, 2010.