

Highway Engineering Laboratory

ASTM D113

Ductility test |

اختبار قابلية السحب (الاستطالة) للمواد الإسفلتية





Ductility and brittleness

Definitions

□ Ductility

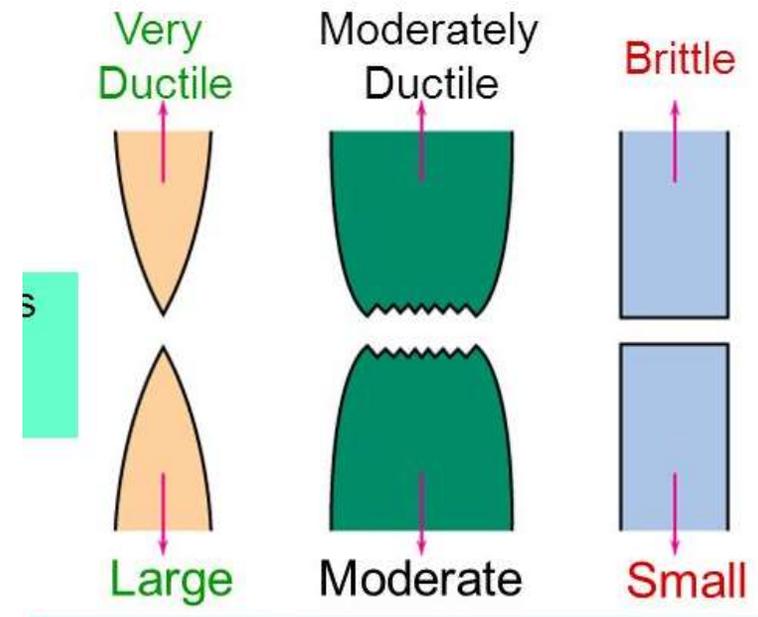
- ❖ is the ability of *a material to undergo a visible enduring deformation through elongation (decreasing of cross section area)*.
- ❖ It expresses *the extent to which the material can be plastically deformed without fracture*.
- ❖ The opposite material behavior is **brittleness**.

□ Typical for a brittle fracture

- ❖ is a very low plastic deformation.

□ The ductility and brittleness depend on

- ❖ *The special cohesive characteristics of the sample.*



Adhesion and Cohesion

❑ Adhesion is defined as

- The attraction process between **unlike** molecules that are brought into contact in such way that the adhesive binds to the applied surface or substrate.

❑ Cohesion is defined as

- The attraction process between **similar** molecules
- Mainly as the result of chemical bonds that are formed between the individual components of the substance.



Test ideal and brittleness

- ❑ The ductility test measures asphalt binder ductility by stretching a standard-sized briquette of asphalt binder to its breaking point.
- ❑ The stretched distance in centimeters at breaking is then reported as ductility.





Designation: D113 – 07

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T51

Standard Test Method for Ductility of Bituminous Materials¹

This standard is issued under the fixed designation D113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

Ductility test

Scope

1. Scope

1.1 This test method describes the procedure for determining the ductility of a bituminous material measured by the distance to which it will elongate before breaking when two ends of a briquet specimen of the material, of the form described in Section 4, are pulled apart at a specified speed and at a specified temperature. Unless otherwise specified, the test shall be made at a temperature of $25 \pm 0.5^{\circ}\text{C}$ and with a speed of $5 \text{ cm/min} \pm 5.0 \%$. At other temperatures the speed should be specified.

1.2 Because of the large number of methods for obtaining test samples, it is impractical to discuss specific products in this test method. Refer to individual product specifications for guidance in obtaining a test sample.

1.3 The values stated in SI units are to be regarded as the standard. Values in parenthesis in inch-pound units are provided for informational purposes only.

Ductility test

Referenced Documents

2. Referenced Documents

2.1 *ASTM Standards:*²

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D5 Test Method for Penetration of Bituminous Materials

D1754 Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)

D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)

E1 Specification for ASTM Liquid-in-Glass Thermometers

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E77 Test Method for Inspection and Verification of Thermometers

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E644 Test Methods for Testing Industrial Resistance Thermometers

Ductility test

Significance and Use

3. Significance and Use

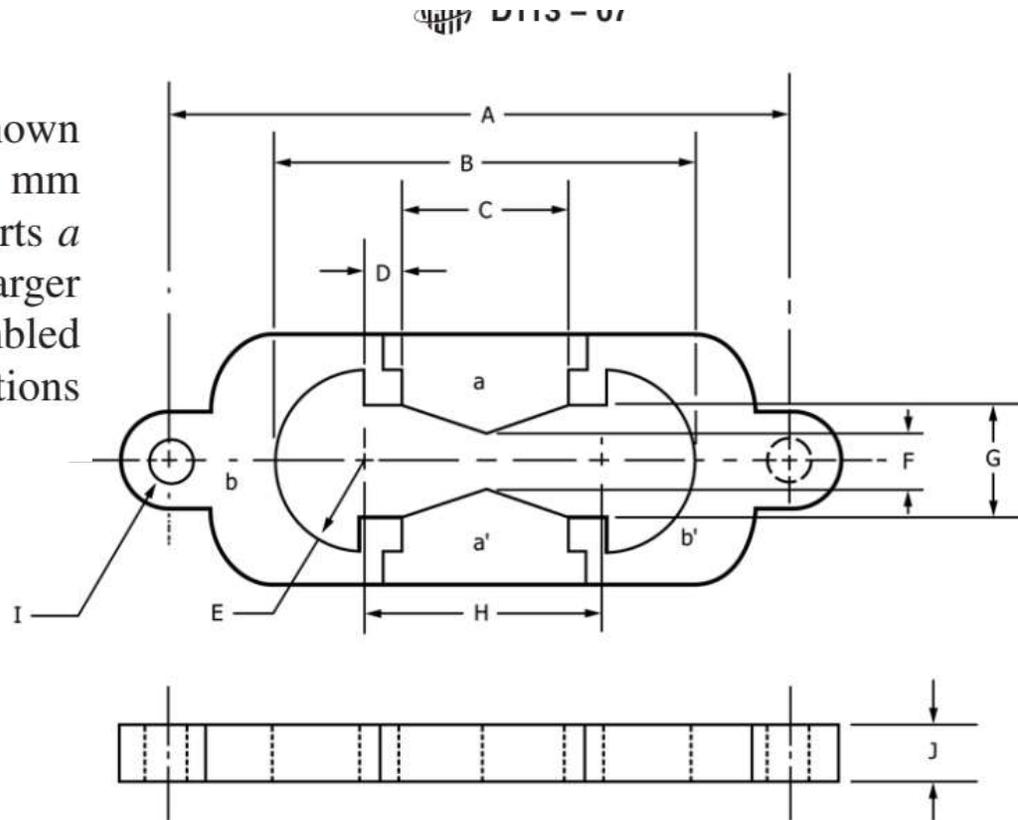
3.1 This test method provides one measure of tensile properties of bituminous materials and may be used to measure ductility for specification requirements.

Ductility test

Apparatus

4. Apparatus

4.1 *Mold*—The mold shall be similar in design to that shown in Fig. 1. The mold shall be made of brass, 10.0 ± 0.1 mm thick, the ends *b* and *b'* being known as clips, and the parts *a* and *a'* as sides of the mold, with a brass base plate that is larger than the assembled mold. The dimensions of the assembled mold shall be as shown in Fig. 1 with the permissible variations indicated.



- A—Distance between centers, 111.5 to 113.5 mm.
- B—Total length of briquet, 74.5 to 75.5 mm.
- C—Distance between clips, 29.7 to 30.3 mm.
- D—Shoulder, 6.8 to 7.2 mm.
- E—Radius, 15.75 to 16.25 mm.
- F—Width at minimum cross section, 9.9 to 10.1 mm.
- G—Width at mouth of clip, 19.8 to 20.2 mm.
- H—Distance between centers of radii, 42.9 to 43.1 mm.
- I—Hole diameter, 6.5 to 6.7 mm.
- J—Thickness, 9.9 to 10.1 mm.

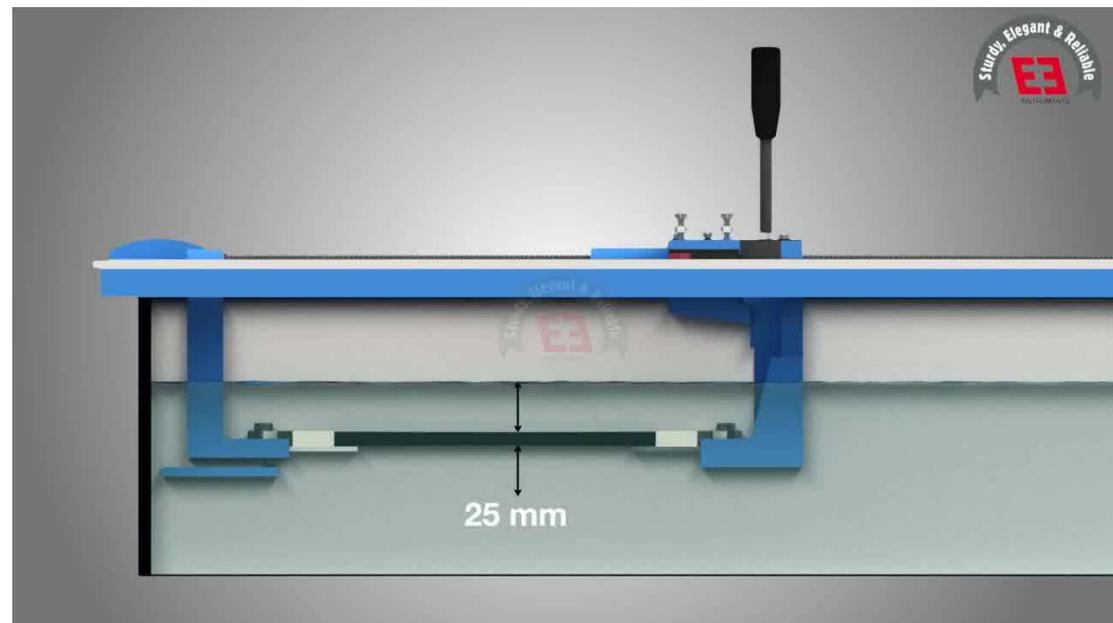
FIG. 1 Mold for Ductility Test Specimen



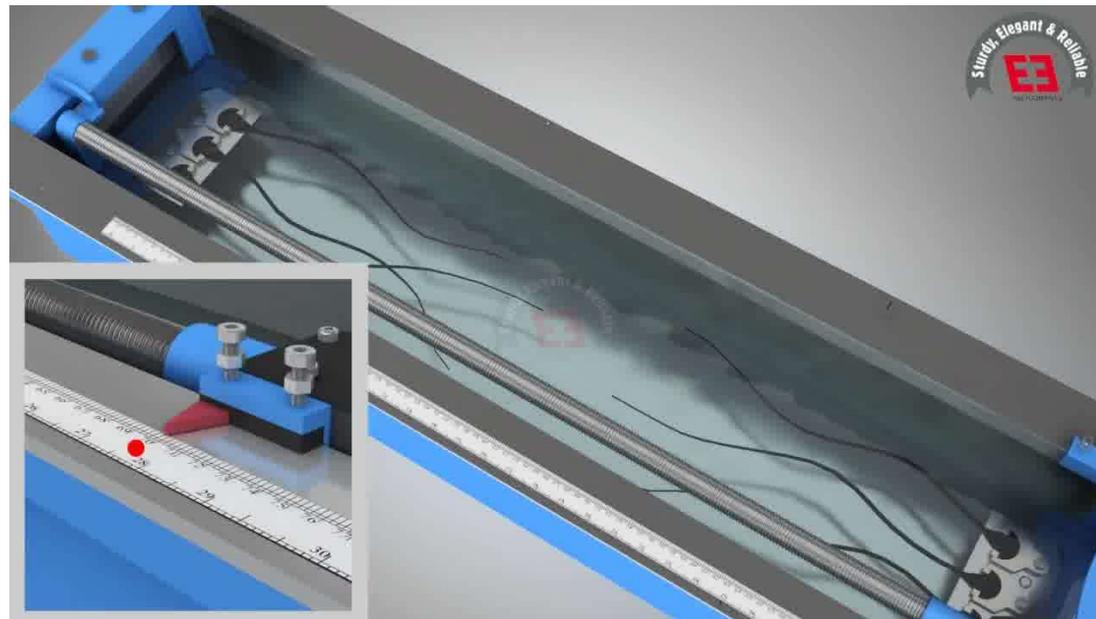
4.3 *Testing Machine*—For pulling the briquet of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously immersed in water, while the two clips are pulled apart at a uniform speed, as specified, without undue vibration. A variation of $\pm 5\%$ is permissible. The water in the tank of the testing machine shall cover the specimen both above and below it by at least 2.5 cm and shall be maintained within $\pm 0.5^\circ\text{C}$ ($\pm 0.9^\circ\text{F}$) of the test temperature. The testing machine shall incorporate a means by which the elongation at the time of rupture can be measured in centimeters.



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(1) at beginning



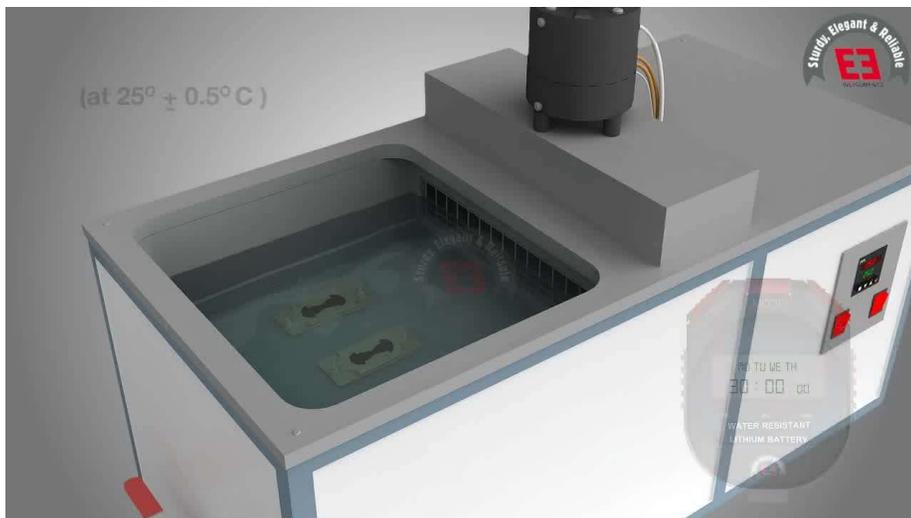
(2) at the yield point



(3) on the stage of failure

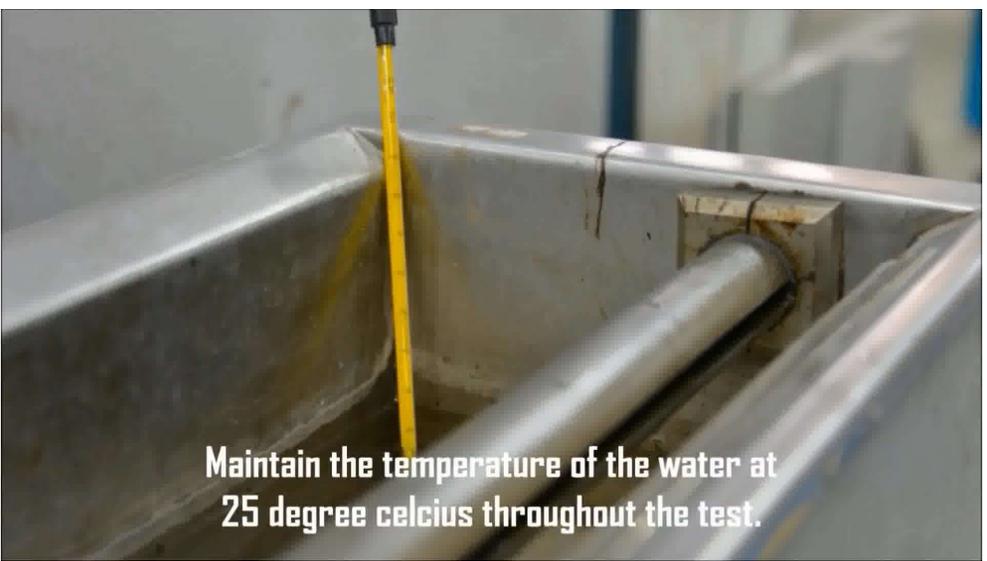


4.2 *Water Bath for Conditioning Specimens*—A water bath capable of maintaining the specified test temperature, varying not more than 0.5°C (0.9°F) from this temperature. The specimen shall be immersed and supported such that it is surrounded by water.



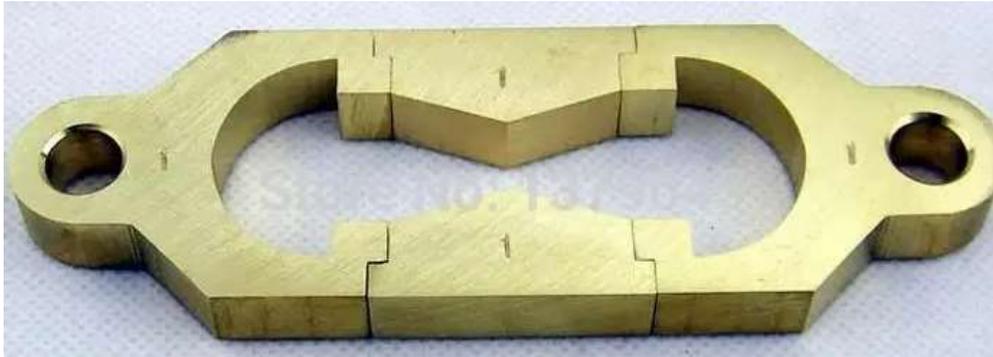
4.4 *Thermometer*—A thermometer having a range shown as follows, and conforming to the requirements in accordance with Specification E1 (Note 1). An equivalent thermometric device that has been calibrated in accordance with Test Method E220 or Test Methods E644 may be used.

Temperature Range	ASTM Thermometer No.
-8 to 32°C	63C
18 to 89°F	63F



Maintain the temperature of the water at 25 degree celcius throughout the test.

4.5 *Release Agent*—A mixture such as glycerin and Dextrin, talc or Kaolin (china clay) or Versamid Resin and mineral oil used to coat the bottom and sides of mold to prevent the specimen from sticking to the mold. Other materials may be used for this purpose if they have been shown not to affect the physical properties of the test specimen.



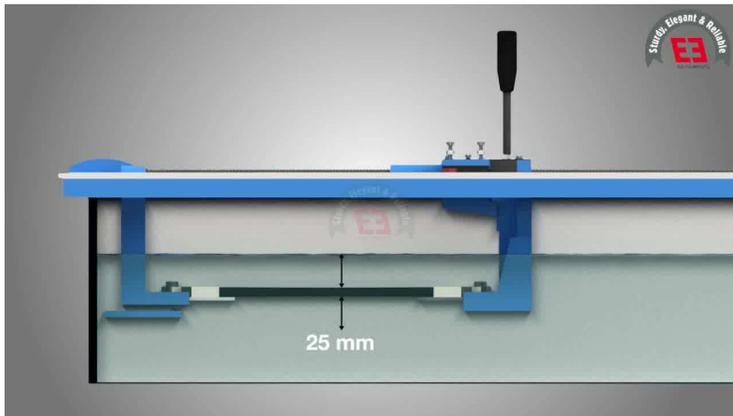
4.6 *Oven*—An oven capable of maintaining within $\pm 5^{\circ}\text{C}$ ($\pm 10^{\circ}\text{F}$) of the temperature required to heat the sample so it is just fluid enough to pour.



4.7 *Trimming Tool*—A straight-edged putty knife or spatula wider than the specimen for trimming.



4.8 *Specific Gravity Additive*—A substance such as methyl alcohol, sodium chloride or ethylene glycol used to adjust the specific gravity of the water bath to prevent specimen from coming to the surface of the water or touching the bottom of the bath. Other additives may be used if they have been shown not to affect the physical properties of the specimen.



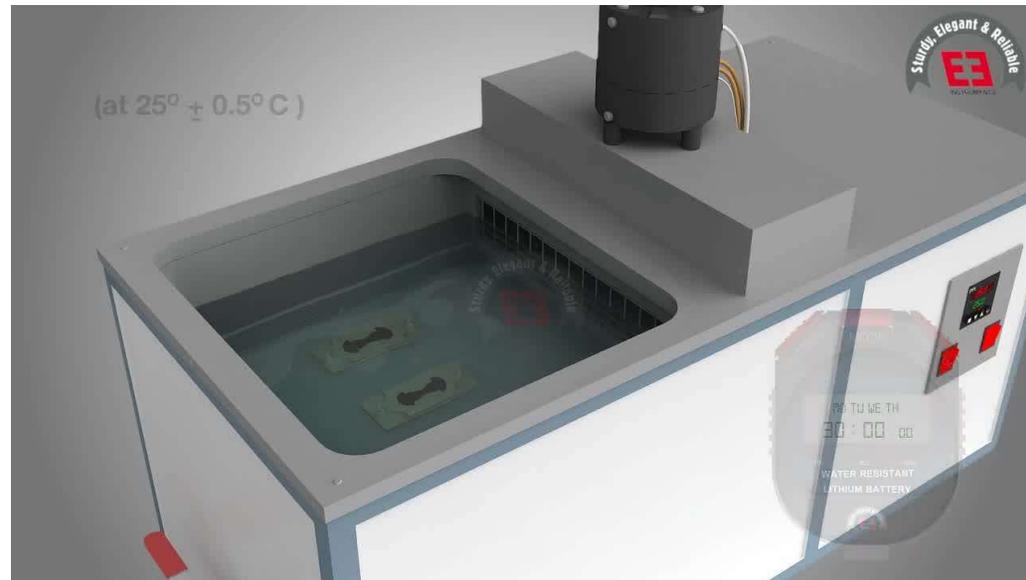
4.3 *Testing Machine*—For pulling the briquet of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously immersed in water, while the two clips are pulled apart at a uniform speed, as specified, without undue vibration. A variation of $\pm 5\%$ is permissible. The water in the tank of the testing machine shall cover the specimen both above and below it by at least 2.5 cm and shall be maintained within $\pm 0.5^\circ\text{C}$ ($\pm 0.9^\circ\text{F}$) of the test temperature. The testing machine shall incorporate a means by which the elongation at the time of rupture can be measured in centimeters.



4.9 Sieves—A 300- μm (No. 50) sieve, in accordance with specification **E11**.



NOTE 1—In those cases where the ductility specimens are conditioned in the standard penetration bath at 25°C, the thermometer or equivalent thermometric as prescribed for Test Method **D5** may be substituted in place of the above.



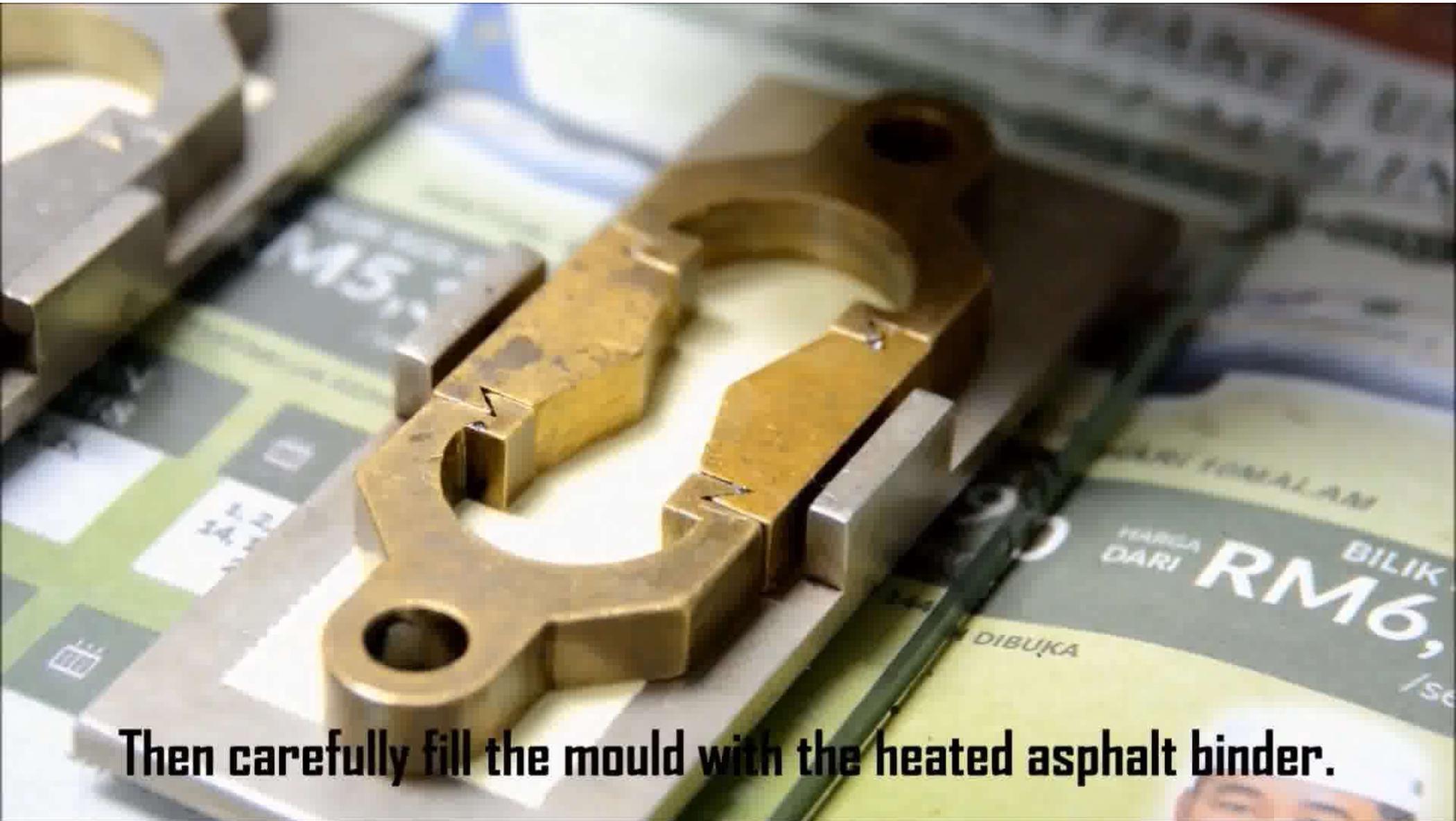
Ductility test

Procedures

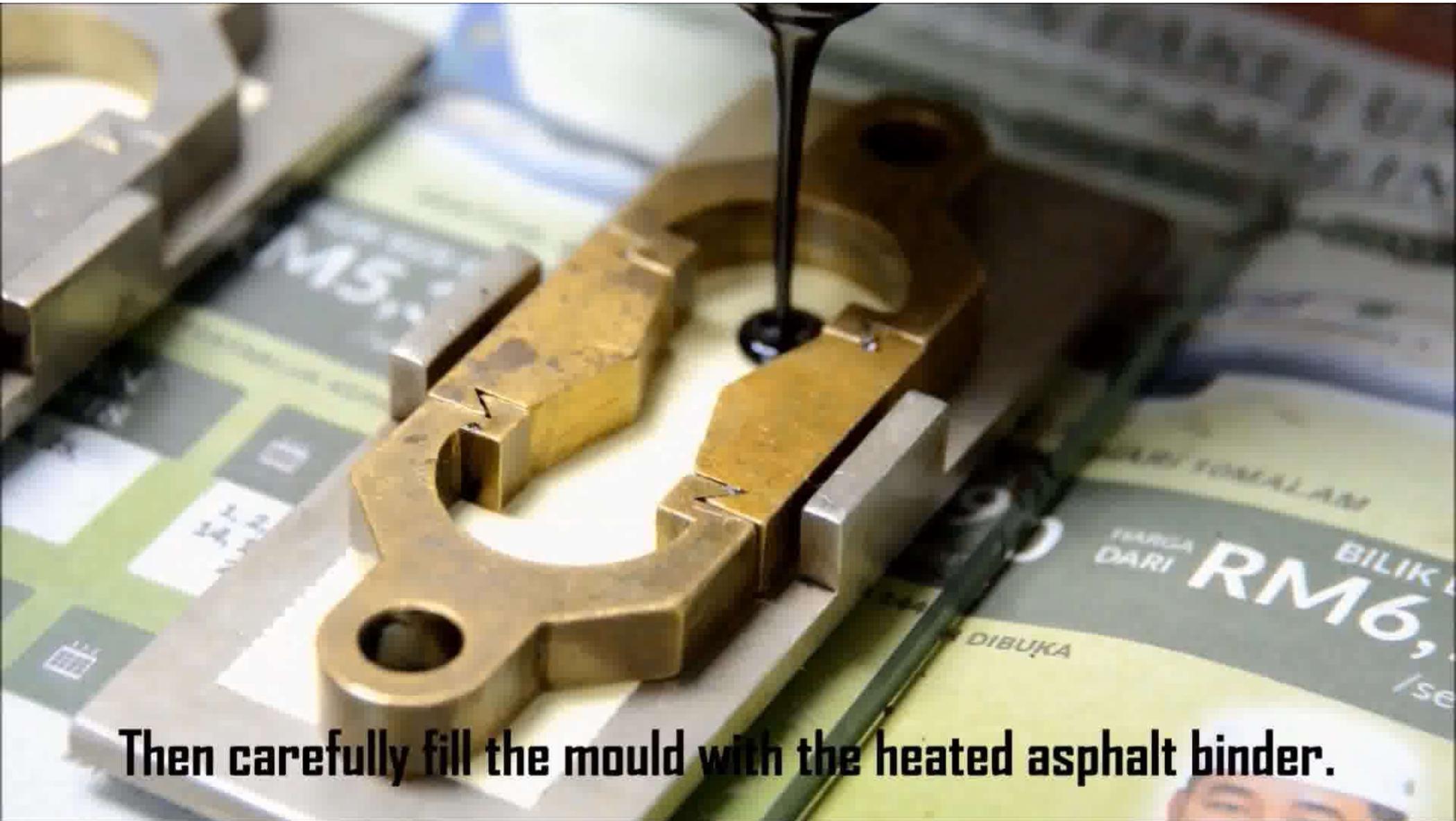
5. Procedure

5.1 Assemble the mold on a brass plate. Coat the surface of the plate and interior surfaces of the sides *a* and *a'*, Fig. 1, of the mold with a thin layer of a mixture of release agent. The plate upon which the mold is placed shall be flat and level so that the bottom surface of the mold will be in contact throughout. Carefully heat the sample to prevent local over-heating until it has become sufficiently fluid to pour. After a thorough stirring, pour it into the mold. In filling the mold, take care not to disarrange the pieces of the mold, thus distorting the specimen shape. Pour the material in a thin stream back and forth from end to end of the mold until the mold is more than level full. Allow the filled mold to cool to room temperature for 35 ± 5 min. Then place it in the water bath at test temperature for 35 ± 5 min. Remove the test specimens from the water bath and immediately trim the excess material with the trimming tool to make the molds just level full.

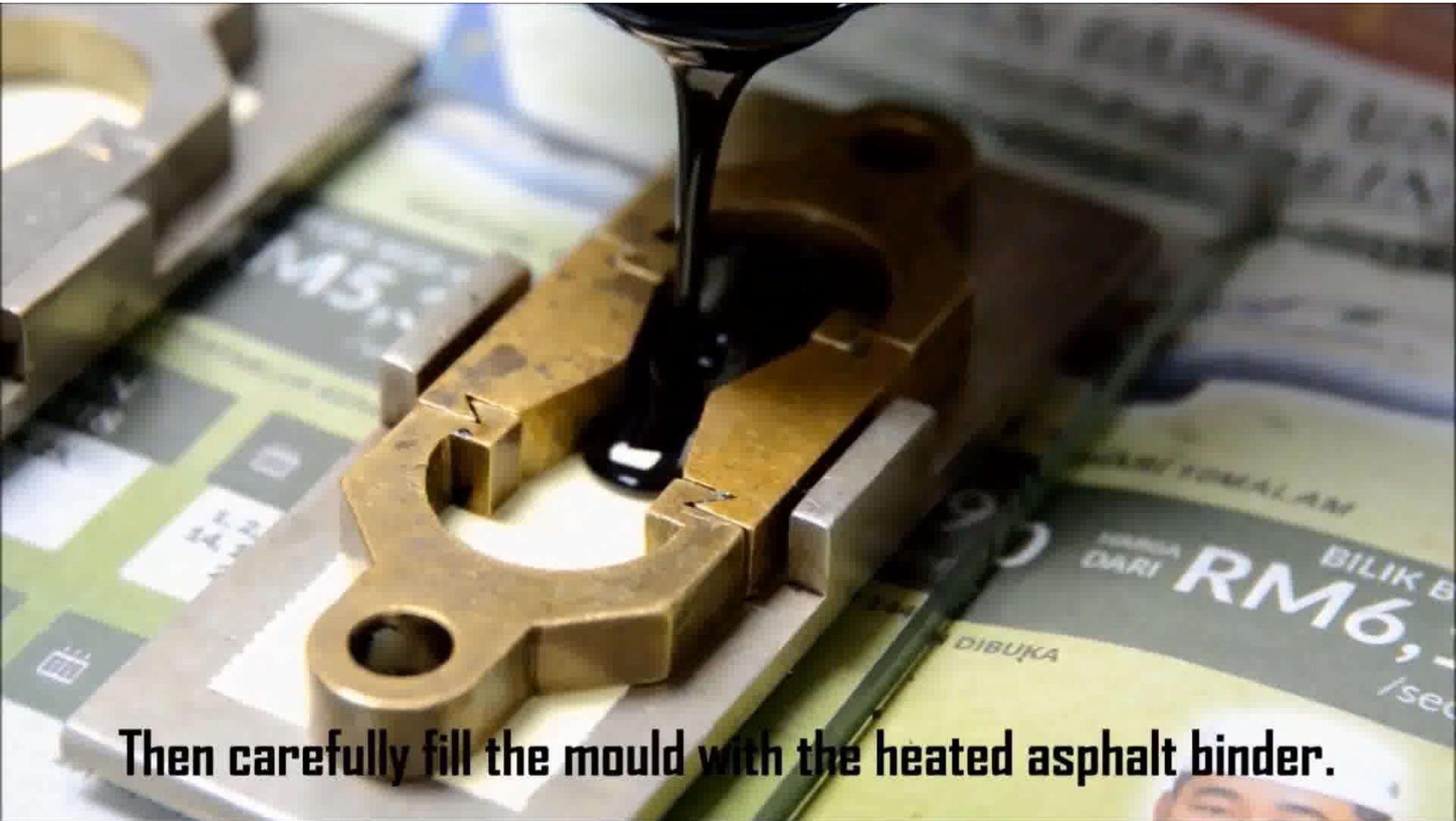




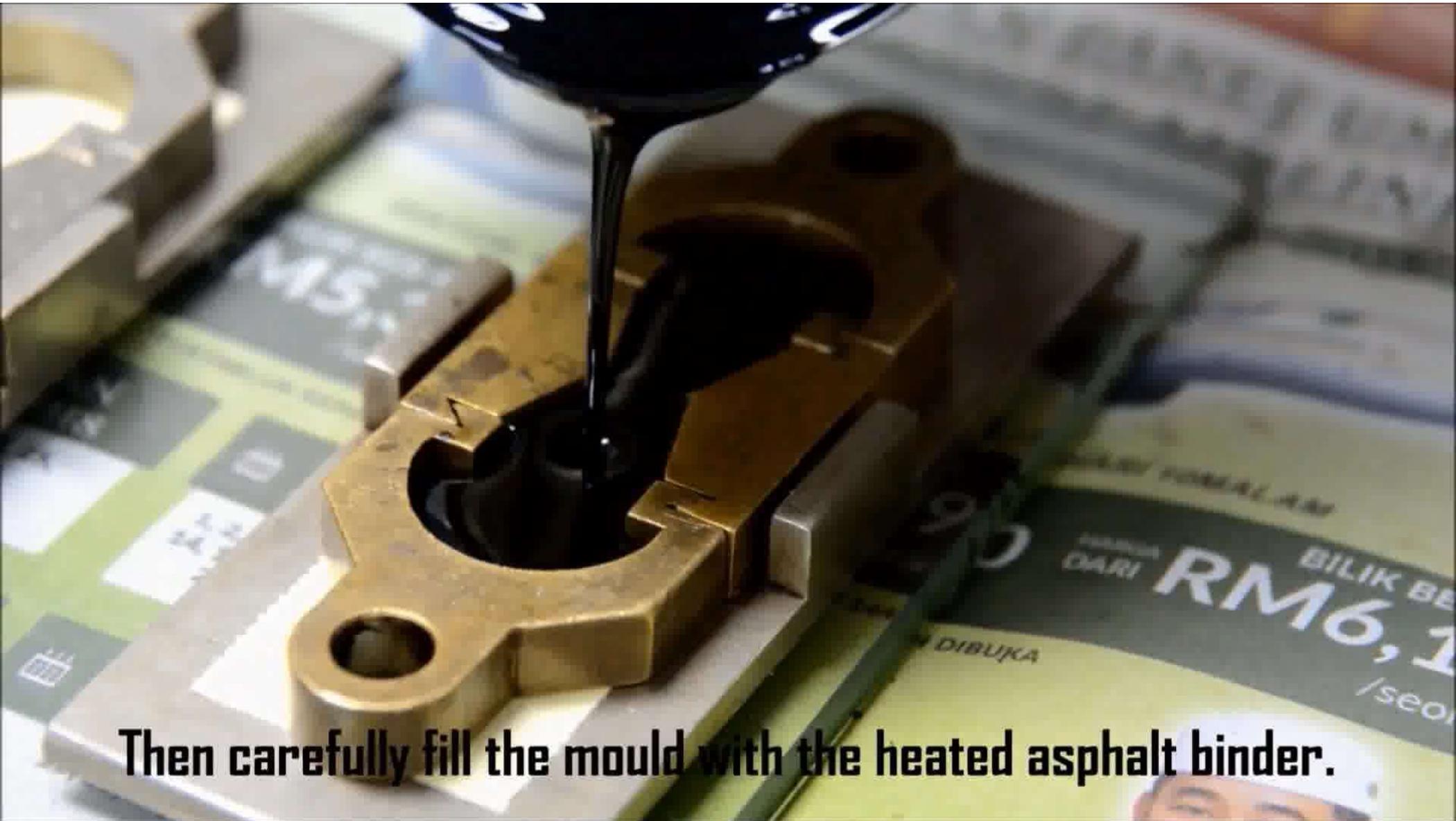
Then carefully fill the mould with the heated asphalt binder.



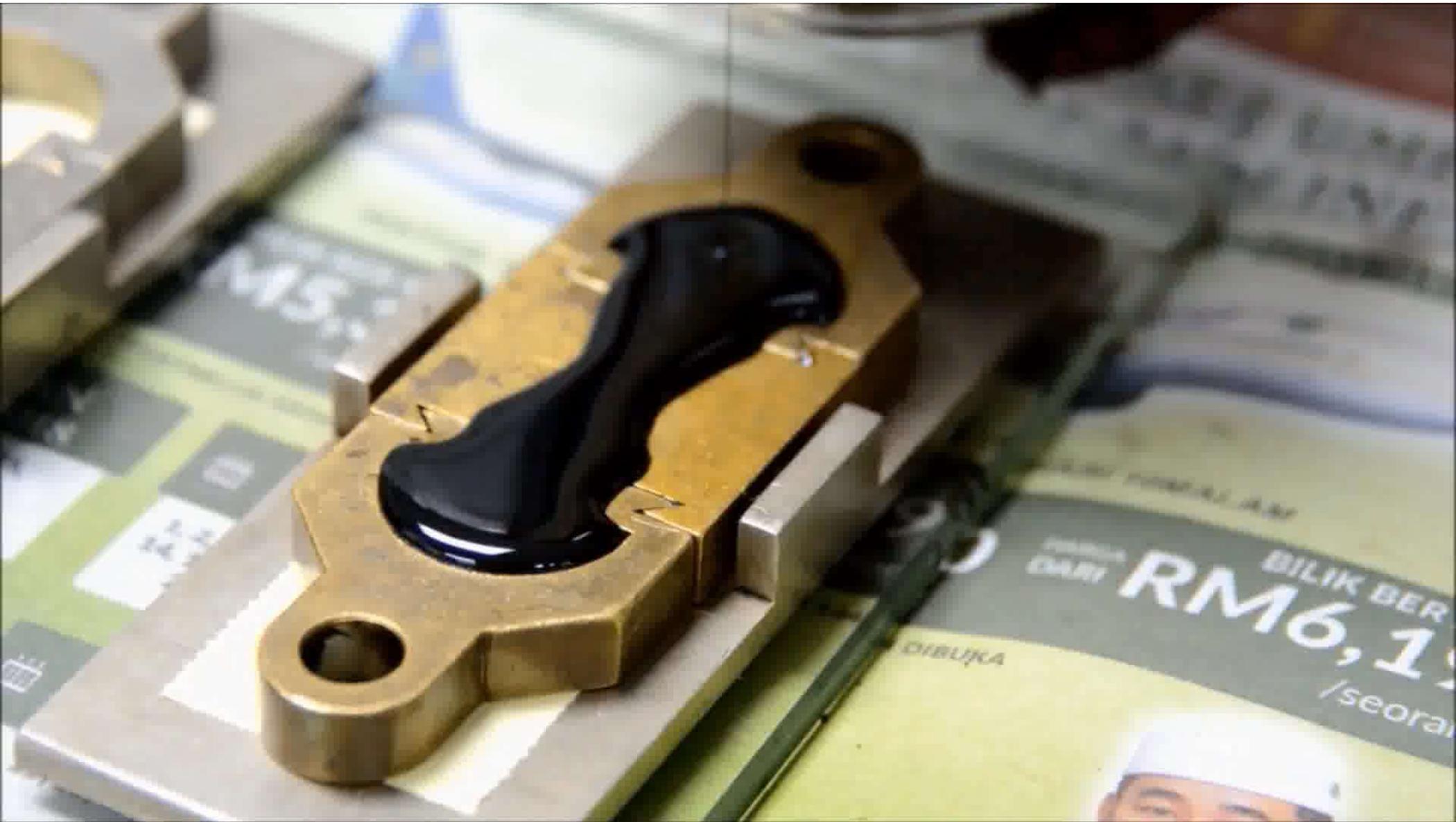
Then carefully fill the mould with the heated asphalt binder.



Then carefully fill the mould with the heated asphalt binder.

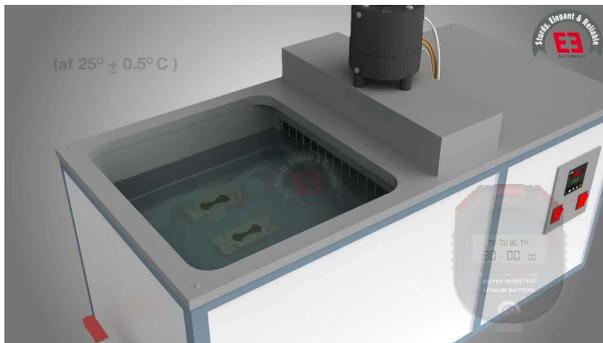


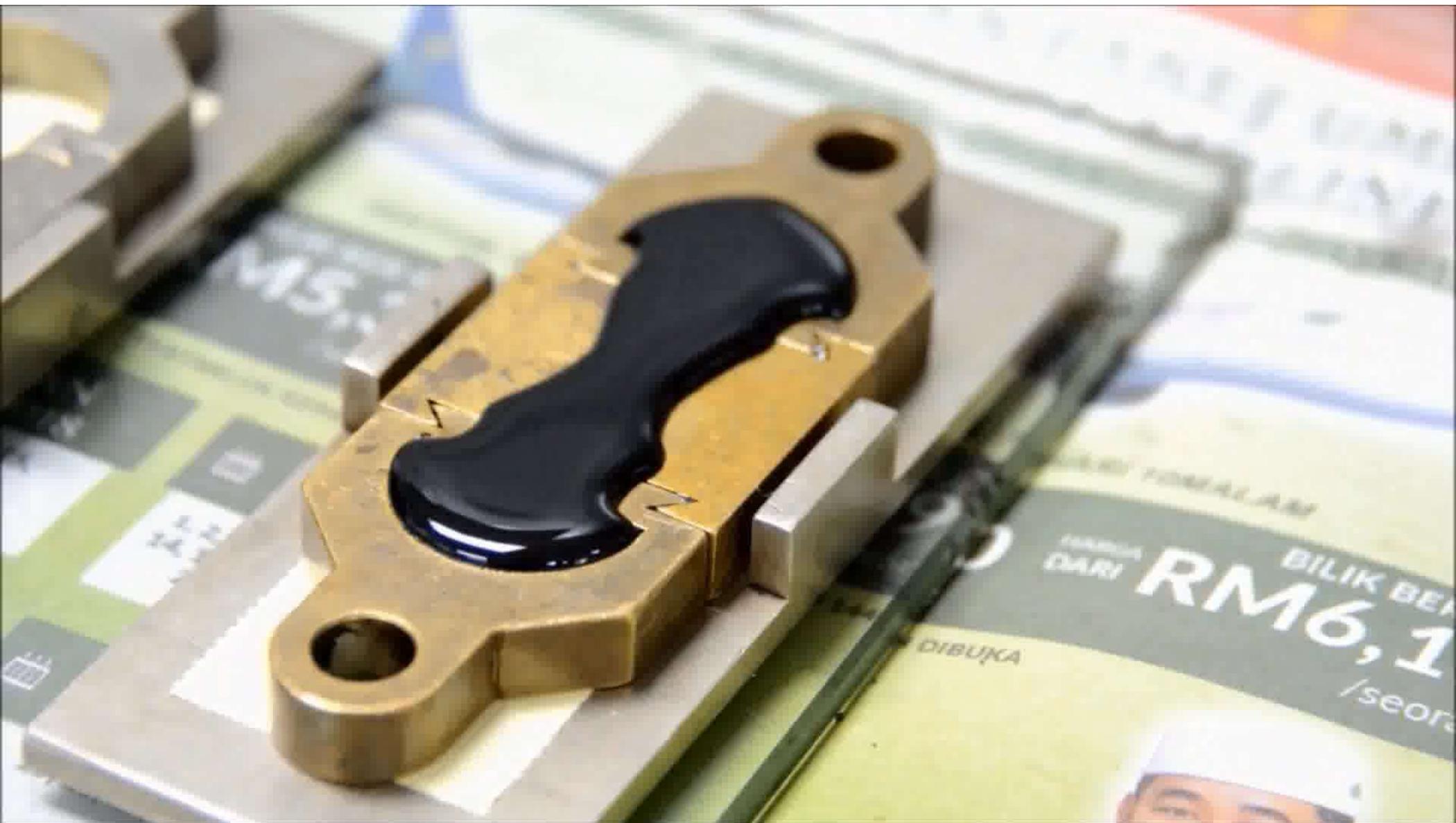
Then carefully fill the mould with the heated asphalt binder.



5. Procedure

5.1 Assemble the mold on a brass plate. Coat the surface of the plate and interior surfaces of the sides *a* and *a'*, Fig. 1, of the mold with a thin layer of a mixture of release agent. The plate upon which the mold is placed shall be flat and level so that the bottom surface of the mold will be in contact throughout. Carefully heat the sample to prevent local overheating until it has become sufficiently fluid to pour. After a thorough stirring, pour it into the mold. In filling the mold, take care not to disarrange the pieces of the mold, thus distorting the specimen shape. Pour the material in a thin stream back and forth from end to end of the mold until the mold is more than level full. Allow the filled mold to cool to room temperature for 35 ± 5 min. Then place it in the water bath at test temperature for 35 ± 5 min. Remove the test specimens from the water bath and immediately trim the excess material with the trimming tool to make the molds just level full.

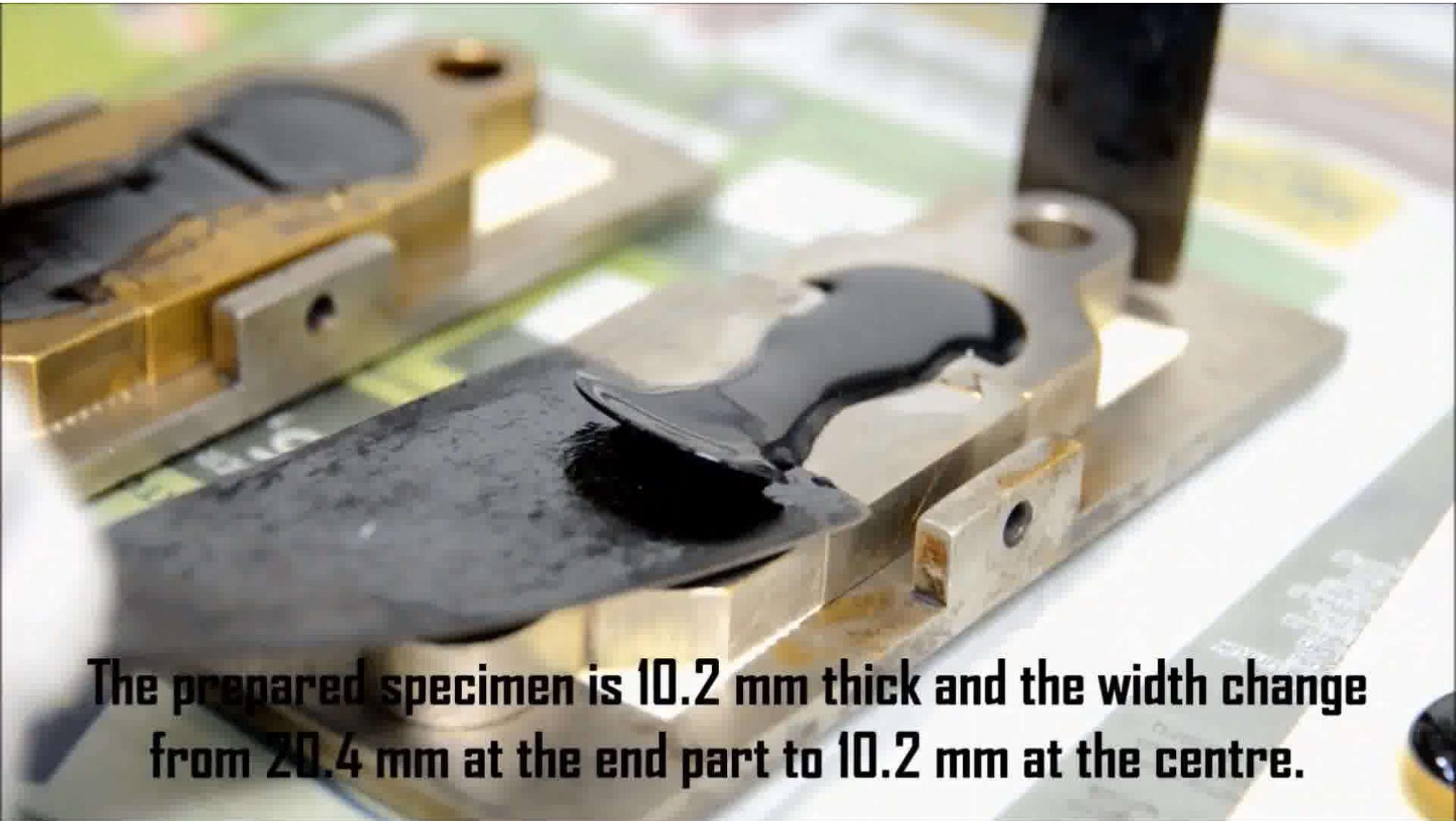




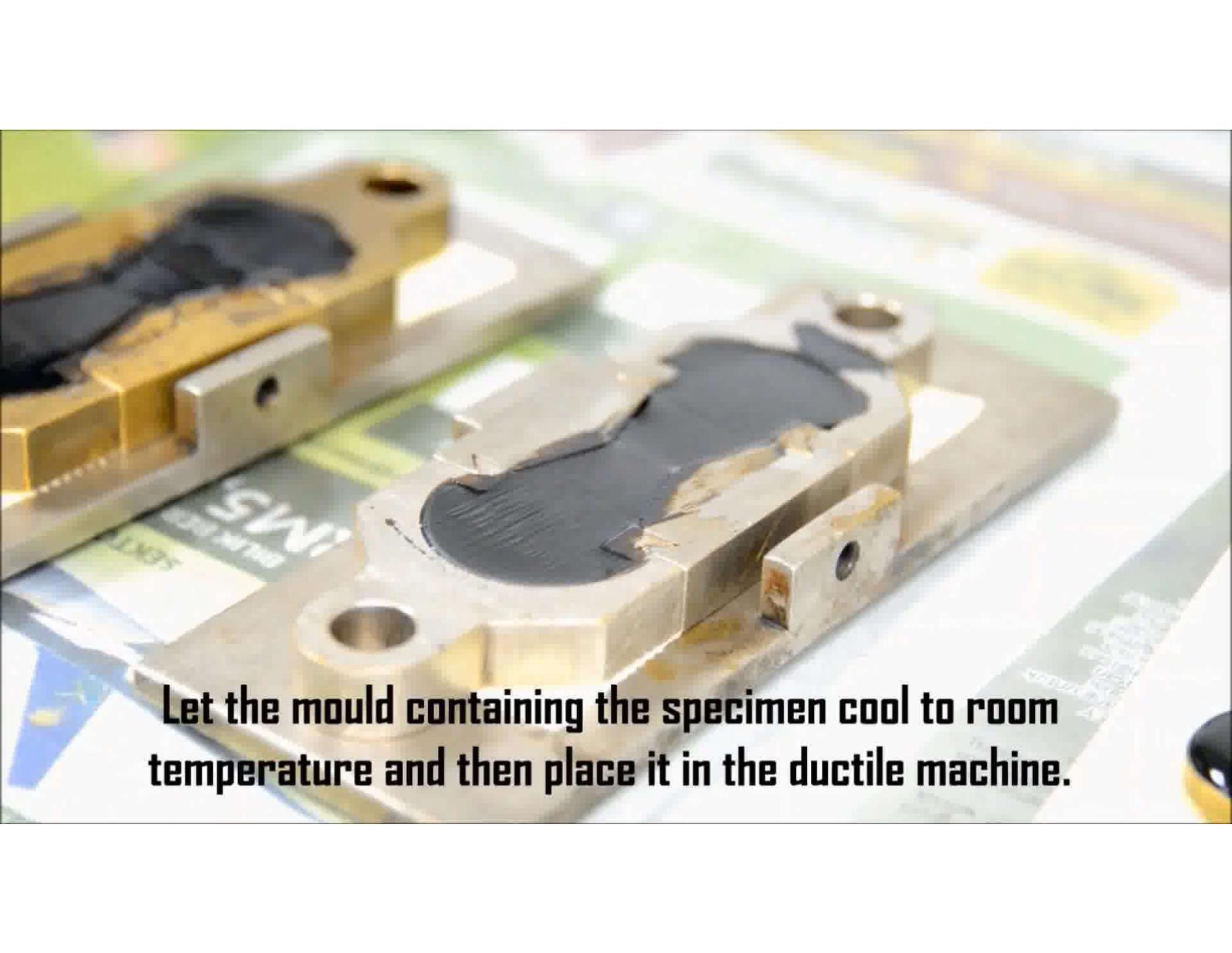




The excess asphalt binder is cut and the surface is levelled using a hot scrapper.



The prepared specimen is 10.2 mm thick and the width change from 20.4 mm at the end part to 10.2 mm at the centre.

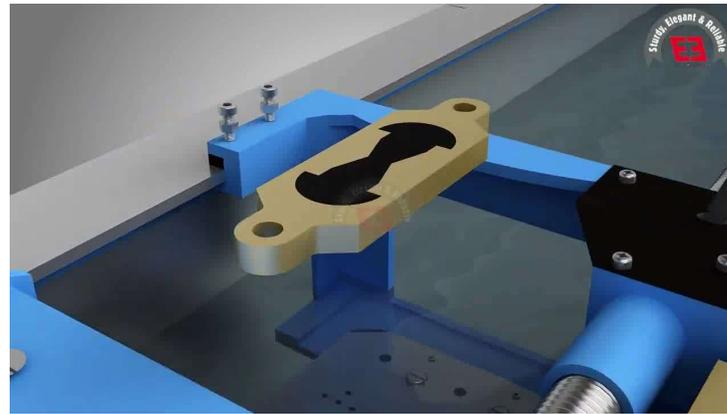
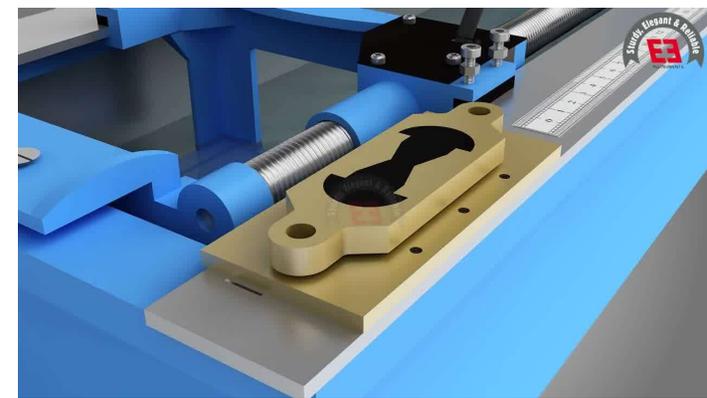


Let the mould containing the specimen cool to room temperature and then place it in the ductile machine.

NOTE 2—It is recommended to the user of this standard that all emulsified asphalt residues and cutback asphalt residues be sieved through a 300 mm (No. 50) screen prior to pouring test specimens. The current distillation procedures subject these materials to temperature conditions that will not be achieved in the field, and particulate matter may develop in the sample residues that may drastically (and negatively) affect the test results. If the material is sieved prior to testing, that notation should be included in the report.



5.2 *Keeping Specimen at Standard Temperature*—Place the trimmed specimen and mold in the water bath at the specified temperature for 90 ± 5 min. Remove the specimen from the plate by a shearing action between specimen and plate, avoiding any bending of the specimen. Remove the side pieces *a* and *a'* being careful not to distort or fracture the specimen.



5.2 *Keeping Specimen at Standard Temperature*—Place the trimmed specimen and mold in the water bath at the specified temperature for 90 ± 5 min. Remove the specimen from the plate by a shearing action between specimen and plate, avoiding any bending of the specimen. Remove the side pieces *a* and *a'* being careful not to distort or fracture the specimen.

5.3 *Testing*—Attach the rings at each end of the clips to the pins or hooks in the testing machine and pull the two clips apart at a uniform speed as specified until the specimen ruptures or reaches the length limitations of the testing machine. Measure the distance in centimetres through which the clips have been pulled to produce rupture or final length.



Ductility test



(1) at beginning



(2) at the yield point



(3) on the stage of failure

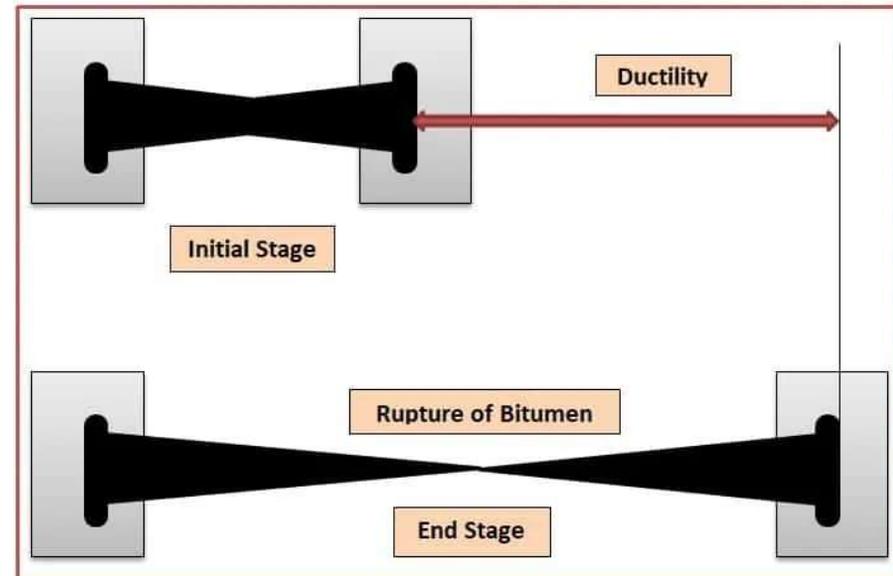
Ductility test

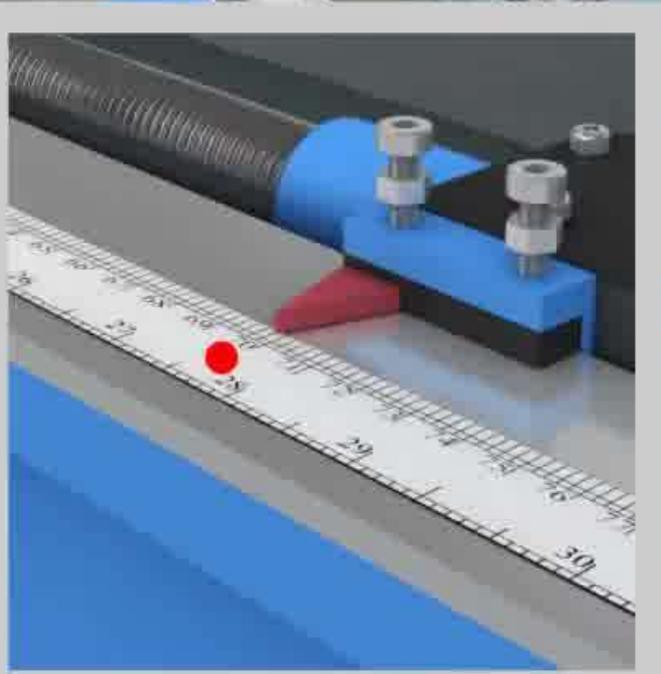
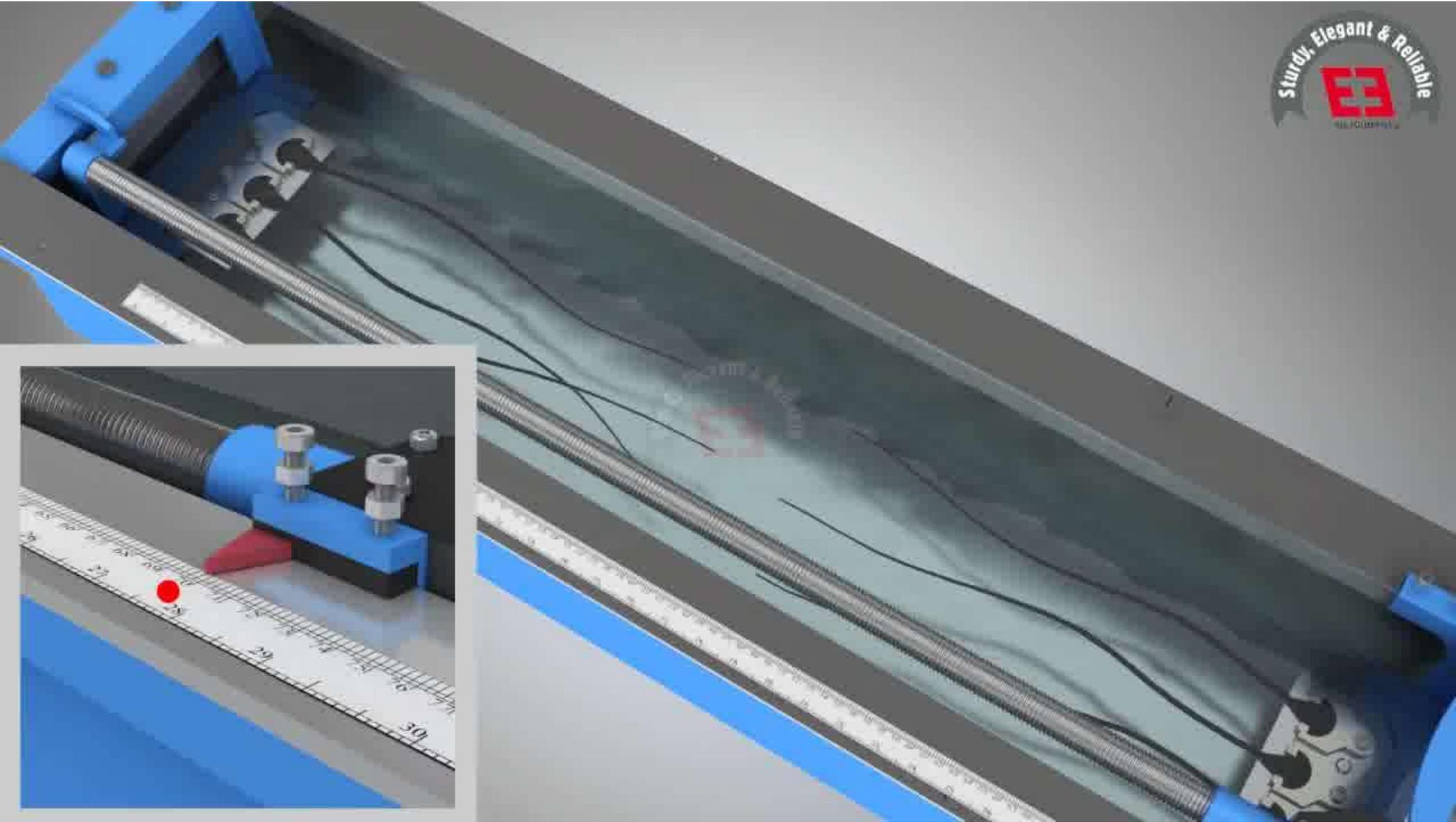
Report

Ductility

Definitions

- ❑ ASTM D113
 - Standard Test Method for Ductility of Bituminous Materials
- ❑ Ductility is defined as
 - The distance in centimeters to which a standard sample may elongate without breaking.



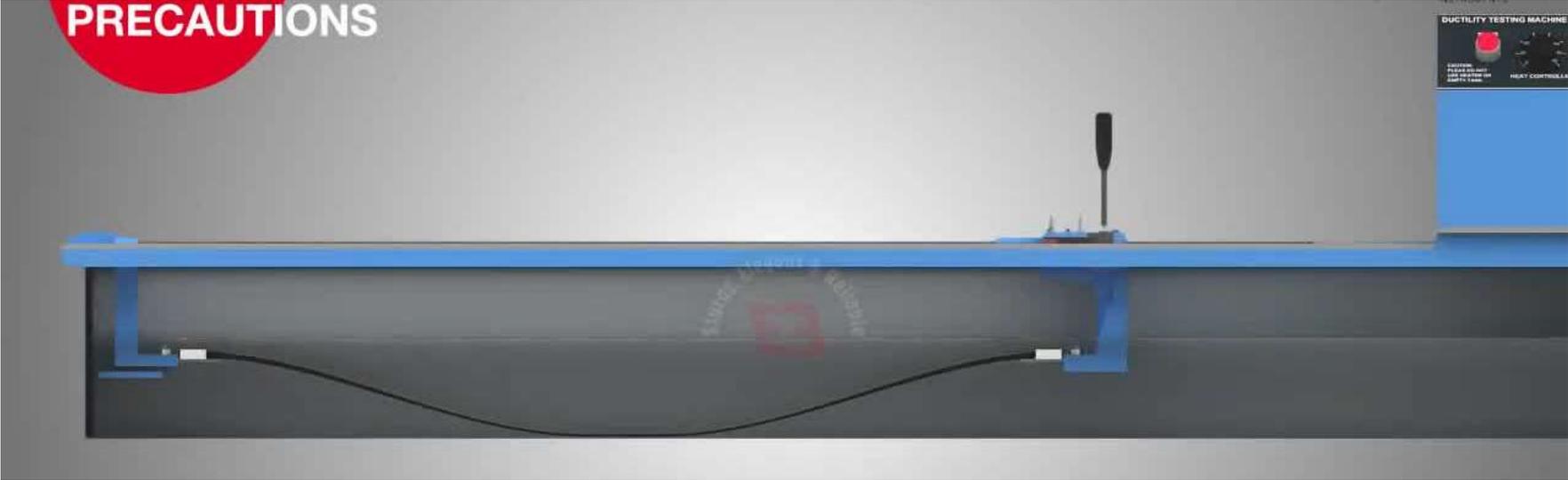


6. Report

6.1 A normal test is one in which the material ruptures near the center of the specimen or reaches the length limitations of the testing machine. A rupture occurring at either clip shall not be considered normal.



6.2 If the bituminous material comes in contact with the surface of the water or the bottom of the bath, the test shall not be considered normal. Adjust the specific gravity of the bath by using a specific gravity additive as described in Section 4.8 so that the test specimen neither comes to the surface of the water, nor touches the bottom of the bath at any time during the test.



NOTE 3—Some additives used to adjust the specific gravity of the water bath are toxic and can cause corrosion of the testing machine. If specific gravity adjustments have been made it is recommended to wear gloves when placing hands in the bath fluid. Frequent bath fluid changes are recommended to prevent damage to the testing machine.



6.3 Report a normal test as the ductility of the sample. If a normal test is not obtainable, report the ductility as being unobtainable under the conditions of the test. If rupture does not occur due to length limitations of the testing machine, report ductility as the length limitation in cm+ (for example, 150 cm+). If this testing is performed on less than three replicates of the same sample due to insufficient material, include the number of replicates used in the test report.



Ductility test

ASTM D113

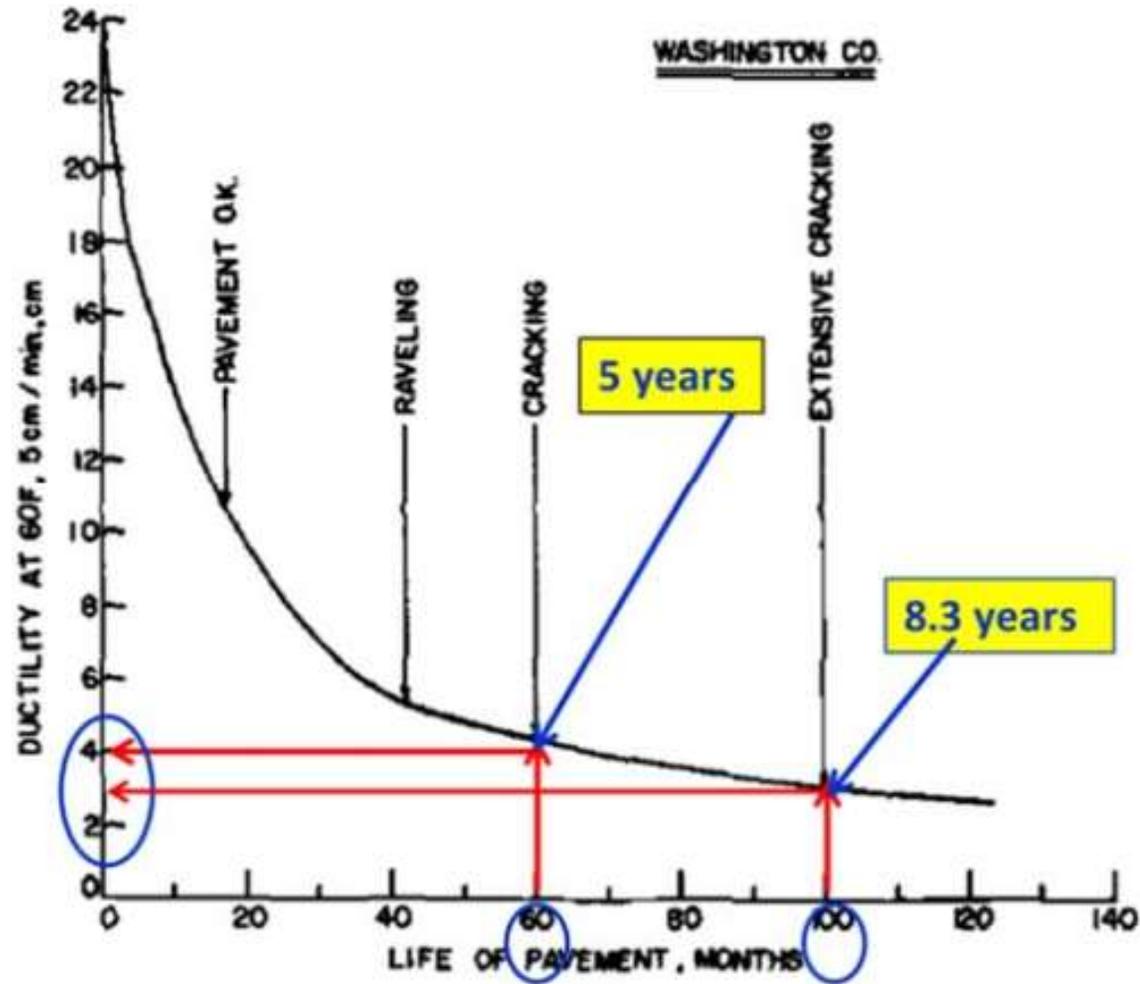


Figure 1 emphasizes that at 5 years of service cracking had occurred at a ductility of 4 cm and at 8.3 years extensive cracking had occurred at approximately 3 cm of ductility. We will show in the course of this report that there are ultimately relationships between ductility at 15°C and rheological parameters more directly related to pavement performance. While Kandhal's work is, by his own admission, empirical it is an important stepping stone on the path towards understanding the drivers of pavement performance. In the conclusion to his 1977 paper Kandhal made the point that "After the penetration of asphalt drops below 30 due to hardening, the pavements containing asphalt with low ductilities are likely to show poorer service than pavements containing asphalts of the same penetration but with high ductilities." Simply stated, not all asphalts are created equally and as we shall see there are more fundamental binder properties available to us today to better articulate that fact than was available to Kandhal in the 1970s.

Ductility test

ASTM D113



Requirements for Penetration Graded Asphalt Cement

ASTM D946

	Penetration Grade									
	40–50		60–70		85–100		120–150		200–300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 25°C [77°F], 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Softening Point, °C [°F]	49 [120]		46 [115]		42 [108]		38 [100]		32 [90]	
Flash point, °C [°F], (Cleveland open cup)	230 [450]	...	230 [450]	...	230 [450]	...	220 [425]	...	175 [350]	...
Ductility at 25°C [77°F], 5 cm/min, cm	100	...	100	...	100	...	100	...	100 ^A	...
Solubility in trichloroethylene, %	99.0	...	99.0	...	99.0	...	99.0	...	99.0	...
Retained penetration after thin-film oven test, %	55 +	...	52 +	...	47 +	...	42 +	...	37 +	...
Ductility at 25°C [77°F], 5 cm/min, cm after thin-film oven test test	50	...	75	...	100	...	100 ^A	...

^AIf ductility at 25°C [77°F] is less than 100 cm, material will be accepted if ductility at 15°C [60°F] is 100 cm minimum at the pull rate of 5 cm/min.