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EXPERIMENTAL SET-UP FOR TESTING MECHANICAL PROPERTIES OF SOFT MATERIAL

Swapan Kumar Palit[1] and M. Mazumdar[2]

ABSTRACT: The characterization of conventional mechanical properties of a material like bitumen mainly includes penetration, softening point, ductility and viscosity, etc. These tests are empirical in nature, in that the load associated with the deformation of soft material sample is not recorded. So an attempt has been made in this paper to present an experimental set up for determining the mechanical properties of such soft materials. This experimental set-up is capable of pulling the sample at a constant rate with the provision of subsequent recording of load and elongation. The load can be read from a tension-proving ring and deformations are taken from a scale for corresponding load with the help of a pointer. Some tests have been conducted for bitumen and modified bituminous sample at a temperature of 30°C in terms of toughness and tenacity. It has also been found that the mechanical properties can be found out by constructing load-deformation curve.

KEY WORDS: Direct tension test, Mechanical properties, Bitumen.

INTRODUCTION

Some soft materials like bitumen, bituminous material, tar, asphalt etc. are used as a binder allover the world in flexible pavement construction. These soft materials are characterized generally by the indirect test method for using in the practical field. The determination of the mechanical properties of metals generally includes a direct tension test in a conventional Universal Testing Machine, represented by a force-elongation curve. But for soft materials, this method cannot be applied, since these soft materials are too soft to produce meaningful results. The problem was first overcome by Benson (1955).

The strength of a paving mix mainly depends on the strength of the binder besides other factors at a particular temperature. This paper presents the results of an investigation aimed at determining "Toughness and Tenacity" properties at a temperature of 30°C. But these properties being not a routine one in normal, the equipment is not manufactured in our region and is not readily available. Hence an equipment has been fabricated for conducting direct tensile test from which toughness and tenacity can be found out.

The objectives of this present work are: (i) to develop a set-up for direct tension test, and (ii) to study mechanical properties of soft materials like bitumen with this set-up.

[1] Department of Civil Engineering, Bangladesh Institute of Technology, Chittagong-4349, Bangladesh.

[2] Department of Civil Engineering, Indian Institute of Technology, Kharagpur-721303, India.

TOUGHNESS AND TENACITY

Toughness is defined as a measure of the energy or strength of a bitumen and is a function of cohesive force as well as elastomeric properties, while Tenacity is a measure of its capacity for delaying failure or break after it has yielded. These two properties are measured from the load-deformation diagram for a typical bituminous material as shown in Fig. 1 (Robinson et al., 1991). In this figure, toughness is given by the total area under the PQRM, while Tenacity is given by the area under the curve RNM, which is bounded by the curve at high elongation. The point N is determined by the projection of the force-elongation curve directly from the initial peak to the zero force line.

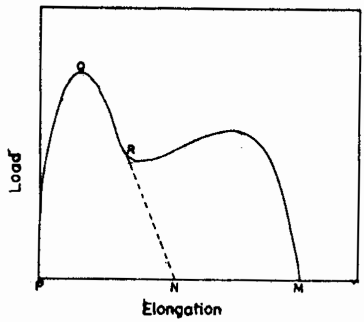


Fig 1. Typical Load-Elongation curve of a bituminous sample

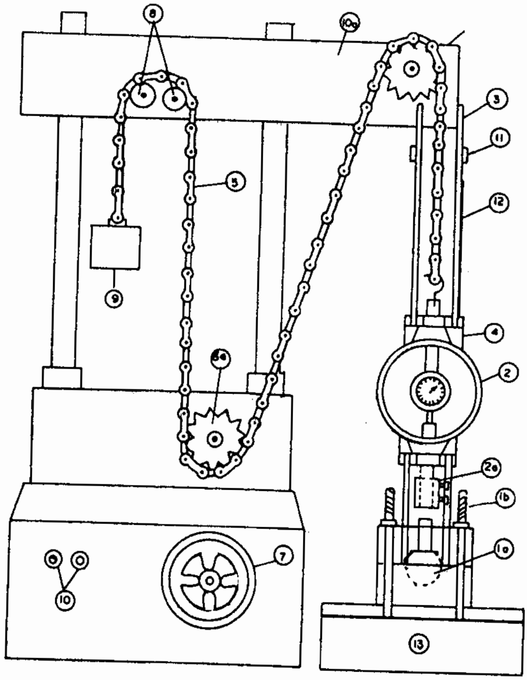
DESCRIPTION OF TEST SET-UP

Since direct tension machine for testing soft materials is not commercially available in our region, the paper presents a study to develop a machine with minimum cost but not sacrificing the quality of the test, providing a slower speed of cross head and a low capacity load cell as suggested by Robinson et al. (1991)

There may be various types of tensile testing machine but the tensile testing machine used for the present study may be considered as a special purpose equipment for testing soft materials like bitumen or bituminous materials.

Components of the Direct Tensile Testing Machine

The machine by Palit (1993) is an assembly of the following functional components and the details are described below. The respective parts are indicated in Fig. 2 by a number, which is mentioned within bracket while describing the part. The functional components include; (i) Load producing mechanism, (ii) Load transmitting mechanism, (iii) Measuring device, and (iv) Controlling mechanism.



1a: Probe, 1b: Specimen holder, 1:Bitumen container with probe assembly, 2: Tension proving ring, 2a: Connector, 3: Horizontal guide, 4: Front and back guide, 5: Chain, 6: Sproket with bearing, 6a: Sproket fitted with the gear spindle, 7: Gear arrangement for speed selection, 8: Chain roller, 9: Weight, 10: On/off switch, 10a: Main frame, 11: Vertical stopper, 12: Steel scale, 13: Masonry foundation.

Fig 2. Toughness and Tenacity Test Set-up.

Load producing mechanism

The requirement of the equipment is to apply a tensile load on bituminous sample through a probe (1a). The motor is that of a CBR testing machine, which drives a crankshaft through a system of gears.

Gear arrangement: For this, the arrangement of an existing CBR testing machine (7) has been used. Several gear arrangements are available in the machine for speed selection. The motor is operated by 220 volts, 15-ampere power supply through an on/off switch (10). A spindle, which projects out of the gear box, revolves at different speeds, which is transmitted to the set- up through a sprocket (6a) attachment to this spindle.

Balancing mechanism: This is provided to balance chain (5) passing over the sprocket. By rotation of this sprocket, the chain moves linearly. One end of the chain is passed over two-chain rollers (8) and a load (9) hanging from that end of the chain. It keeps the chain at stretched position and during testing operation, it goes down slowly so that the chain is kept in stretched condition. The chain rollers are pulleys on which the chain can move easily either in clockwise or anti-clockwise direction.

Load transmitting mechanism

The rotating movement of the spindle is converted to linear movement by means of a chain with the help of two sprockets.

Chain (5): As mentioned earlier, one end of the chain is attached with a load (9), other end is passed over another sprocket (6) and supports an arrangement by which a tensile proving ring (2) is provided. The movement of the chain at a specified speed gives the applied tensile load to the specimen, indicating load in the tension-proving ring.

Sprocket (6, 6a): One sprocket (6a) rotates at the same speed as of the spindle since it is finnly attached to the spindle (crankshaft). During rotation, chain is pulled by sprocket which gives linear movement i.e. rate of pulling. In the present investigation rate of pulling is 50 mm!min. as slower rate of pulling is suggested by Robinson et al2 who used a speed as high as 1000 mm/min. Sprocket (6) with bearing is free to rotate in either clockwise or anti-clockwise direction. This sprocket is supported from the main frame (l0a) by means of a nut and bolts arrangement.

Probe (la and in Fig. 6): It is made of brass and hemispherical (20mm dia.) in shape at the bottom and conical in shape at the top, which is extended as stem. The stem has a groove at the top for placing a screw in the groove through a connector (2a and Fig. 4). The probe is used for immersion in the sample.

Measuring devices

The objective of any strength test is generally to measure load and displacement in the materials. In the present set-up these are achieved in the following ways:

Load measuring device: Load is measured by means of a tension-proving ring (2) depending upon the material to be tested, different types of proving ring can be used. For the present work, a 5kN capacity proving is used as lower capacity load cell is suggested by Robinson et al. (1991) who used a load cell of 10kN capacity. The calibration factor of the proving ring for one small division is 0.439 kg. The proving ring is connected with the chain at the top and a screw with extension at the bottom. Bottom screw is connected with the probe by means of a bush type connector (2a).

Displacement measuring device: Displacement is measured by means of a steel scale (12), which is vertically attached with the horizontal guide (3). The scale indicates distances in centimeters as well as in inches. During operation, the scale gives the elongation. An indicator is placed with the front and back guide (4) for noting the scale reading.

Controlling mechanism

These are necessary for (i) Maintaining vertical movement of the probe, (ii) Preventing any horizontal movement and (iii) Minimizing disturbances to the sample during testing throughout the experiment. It includes the following guides and is shown in Fig. 3

a) Horizontal Guides (3 and 1 in Fig. 3): These guides prevent horizontal movement of the chain and the proving ring during testing operation.

b) Front and Back guide (4 and 2 in Fig. 3): These guides prevent front and back movement of the chain and the proving ring during testing operation.

c) Vertical stopper (11 and 3 in Fig. 3): These stoppers help the chain for not moving downward during gear adjustment, changing from neutral position before testing operation and, thus, the specimen is free from pre-compression

d) Connector (2a and in Fig. 4): It is a bush type connector, which is used for connecting the screw (at the bottom of the proving ring) and the probe. Hence the specimen is free from any kind of twisting during specimen set-up for testing operation.

e) Specimen holder (lb and in Fig. 5): The materials are kept in an aluminum container of capacity 200ml and 5 cm diameter. To prevent movement of the container, the same is fixed with the help of nuts and bolts with a masonry foundation (13). The later also helps in holding the horizontal guides and some components of the testing arrangement.

EXPERIMENTAL INVESTIGATIONS

Materials Used

The materials used include: (i) 80/100 penetration grade bitumen, (ii) 80/100 penetration grade bitumen modified by polyethylene (PE), and (iii) 80/100 penetration grade bitumen modified by Ethylene Vinyl Acetate (EVA).

Preparation of Sample

4OO gm of 80/100-grade bitumen is heated up to 1 70^{0}C. Then the required quantity of polymer is added and mixed manually for two minutes. The mixture is then agitated by a ¼ hp mechanical stirrer, for a minimum of 20 minutes. Blending has been done with 2.5% (by wt. of bitumen) of polymer in the bitumen. The probe is then placed in a 200ml aluminum container at a fixed depth and .central position and heated sample is poured into the container up to the top of the hemisphere, with the help of a mark at the semicircular region. After casting, the sample is cured for 24 hours at room temperature.

Testing Procedure

All the three controlling guides are checked after holding the sample on the testing base. Minimum three tests are conducted to get appropriate load-displacement data. The loads are recorded from the tension proving ring and the corresponding displacements are noted from the steel scale during pulling. The pulling rate is maintained at 50 mm/min and a test temperature of 30°C.

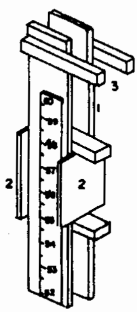


Fig 3. Guides (Isometric view)

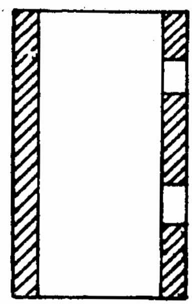


Fig 4. Connector

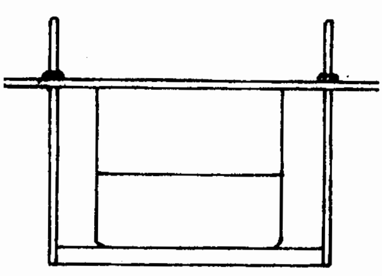


Fig 5. Specimen holder (side-view)

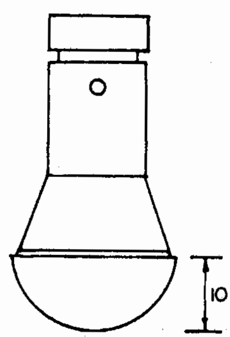


Fig 6. Probe

RESULTS AND DISCUSSION

The results of experimental investigations relating to the above mentioned properties for different samples are presented in Table 1 and the load-displacement curves are shown in Fig. 7. From the table and the figure, it is clear that the shape of the load-displacement curve of the bituminous materials is similar to the shape of the typical sample (Fig.1).

Thus for the tested samples, it can be concluded that (i) There is only one peak point, and (ii) Samples give longer elongation.

Table 1. Experimental Results

Bituminous Sample	Maximum Tensile Load (kg)	Toughness (kg-mm)	Tenacity (kg-mm)
80/100	1.32	41.67	16.67
2.5 PE	1.87	55.00	28.33
2.5 EVA	2.20	73.33	31.67

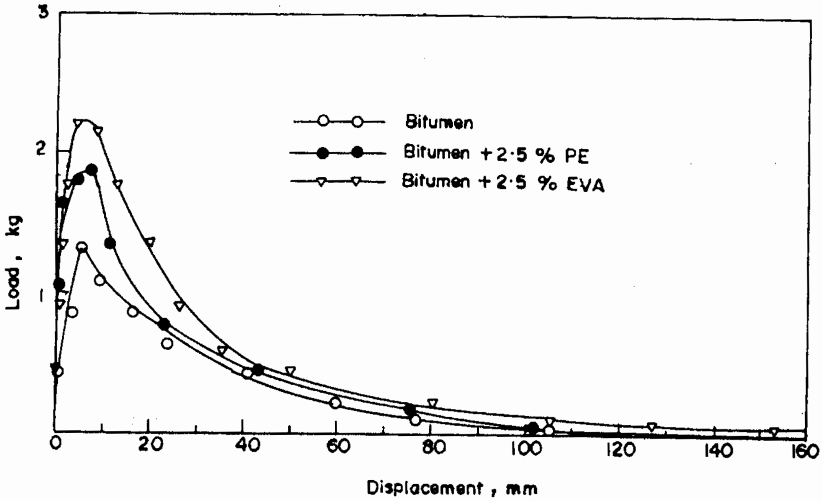


Fig 7. Load-displacement diagram for bitumen and polymer modified bitumen at 30°C

CONCLUSION

In order that highway laboratories keep abreast of the developments taking place rapidly in the new technologies adapted for the characterization of bituminous materials, it is essential that testing equipment that are capable of evaluating necessary inputs to those approaches be available in sufficient number at low cost. However, the prohibitive cost of a number of imported equipment is proving to be a stumbling block in the faster development of pavement research in Bangladesh. If equipment that can perform similar functions can be fabricated in Bangladesh at a cost affordable by a larger cross-section of the educational, research, and consultancy organizations, it can provide much-needed relief to the pavement researchers. The experimental set-up for testing mechanical properties of soft materials as presented in this paper can be suitably used by the road construction industry.

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