# Draft Test Procedures for Seal Coat Aggregate-Binder Compatibility

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Project Number 0-4362
Project Title: Develop a Testing and Evaluation Protocol to Assess
Seal Coat Binder-Aggregate Compatibility

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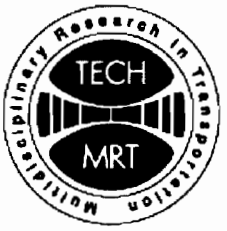


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# 0-4362 P1 – Part 1

## Compatibility Test and Evaluation Protocol for Aggregate and Precoating Hot Asphalt Binder

**Tex-XXX-X Compatibility Test and Evaluation Protocol for Aggregate and Precoating Hot Asphalt Binder**

**Overview:**

This test method is almost identical to "The Net Adsorption Test for Chip Sealing Aggregates and Binders" developed by Walsh et al. (1995). This test method developed by Walsh et al. to evaluate the compatibility between seal coat aggregates and binders was based on a similar method developed for asphalt-aggregate systems in general, by Curtis et al. (1993). Both test methods indicated above include an asphalt *adsorption* phase (on the aggregate surface) from an asphalt-toluene solution and an asphalt *desorption* phase from the aggregate surface in the presence of water (i.e. stripping), which is considered as a measure of the strength of bond between the two materials. It is suggested that the *percent net adsorption* calculated as proposed by Curtis et al. (1993) be used to evaluate the appropriateness of an asphalt to precoat a particular surface treatment aggregate.

**Apparatus:**

1. Mechanical Shaker Table (Figure 1): Equipped with 8 holders for 500 ml Erlenmeyer flasks.
2. Spectrophotometer (Figure 2): Capable of providing a continuous 410 nm wavelength with an accuracy of +/- 2nm, holding standard 10 mm path length cuvettes.
3. Spectrophotometer cuvettes: Capable of 4.5 ml and 10 mm path length.
4. Erlenmeyer flasks with the capacity of 500 ml.
5. Volumetric flasks with capacities of 25 ml and 1000ml.
6. Filter paper: Whatman No. 42, 125 mm in diameter.
7. 250 ml graduated glass cylinder.
8. 10 ml pipettes
9. Analytical balance with precision of up to 0.001 grams.
10. Aggregate drying oven capable of maintaining 135 °C.

**Reagents:**

1. Toluene: UV/Spectroanalyzed grade
2. Distilled water

**Test Procedure:**

The test takes nearly 24 hours to complete and the test procedure can be divided into the seven steps outlined below:

1. Calibration of the Spectrophotometer to Measure Light Absorbance

The spectrophotometer must be calibrated using the procedure recommended by its manufacturer. This procedure should result in a calibration curve for each asphalt binder to be tested.

2. Preparation of Aggregate Samples

For each aggregate-asphalt combination, prepare four 50-gram aggregate samples graded according to the standard grading recommended by the National Roads Association of Ireland (NRA) shown in Table 1. The aggregate must be dried uncovered in an oven for approximately 15 hours at a temperature of 135 °C. The aggregate samples must be removed from the oven at least 15 minutes prior to the beginning of the test.

**Table 1. Recommended Aggregate Gradation for NRA Test Method (Walsh et al. 1995)**

| Sieve Size | Percent Retained | Wt. Retained (g) |
|---|---|---|
| 2.36 mm | 8.0 | 4.3 |
| 1.18 mm | 25.0 | 13.5 |
| 600 μ m | 17.0 | 9.1 |
| 300 μ m | 23.0 | 12.4 |
| 150 μ m | 14.0 | 7.5 |
| 75 μ m | 6.0 | 3.2 |
| | | Total 50 |

3. Preparation of Stock Solution

Measure approximately 0.6-grams (±0.001g) of asphalt binder and dissolve it in 600 ml of toluene in a 1000 ml volumetric flask. This will produce an asphalt-toluene stock solution with an approximate concentration of 1g/liter.

4. Measure Initial Light Absorbance of Stock Solution

Take four milliliters of the stock solution prepared in Step 3. Place this solution sample in a spectrophotometer cuvette and measure the initial light absorbance of the solution using the spectrophotometer at a wavelength of 410 nm. Use the calibration curve(s) developed in Step 1 to obtain the corresponding concentration ($A_1$) of the solution. With some spectrophotometers, the solution may have to be diluted to a known concentration before the measurement can be taken. Use a clean 25 ml volumetric flask for this purpose when needed.

5. Preparation of Test Samples and Control Sample in Erlenmeyer Flasks

Place each of the four aggregate samples in a separate 500 ml Erlenmeyer flask. Of the four Erlenmeyer flasks, three contain test samples and the fourth contains the control sample. Add 140 ml of freshly-prepared asphalt-toluene stock solution to each of the three flasks containing the test samples, and add 140 ml of pure toluene to the flask containing the control sample. Place all four Erlenmeyer flasks on the mechanical shaker.

6. Adsorption Phase

Shake the four flasks for six hours at 300 rpm. At the end of the shaking period, take four milliliters of the solution from each of the four Erlenmeyer flasks. Place this solution sample in a spectrophotometer cuvette and measure the light absorbance of the solution after the adsorption phase using the spectrophotometer at a wavelength of 410 nm. Use the calibration curve to obtain the corresponding concentration ($A_2$) of the solution. With some spectrophotometers, the solution may have to be diluted to a known concentration before the measurement can be taken. Use a clean 25 ml volumetric flask for this purpose when needed.

7. Desorption Phase

Add 2 ml of distilled water to each Erlenmeyer flask and shake for a further 15-17 hours. At the end of this period, take four milliliters of the solution from each of the four Erlenmeyer flasks. Place this solution sample in a spectrophotometer cuvette and measure the light absorbance of the solution after the desorption phase using the spectrophotometer at a wavelength of 410 nm. Use the calibration curve to obtain the corresponding concentration ($A_3$) of the solution. With some spectrophotometers, the solution may have to be diluted to a known concentration before the measurement can be taken. Use a clean 25 ml volumetric flask for this purpose when needed.

**Calculation Procedure**

This proposed calculation procedure is similar to that recommended by Curtis et al. (1995).

Initial Adsorption ($A_i$), i.e. the amount of bitumen initially adsorbed onto the aggregate surface;

$$A_i = VC^*(A_1-A_2)/ (WA_1)$$

Net Adsorption ($A_n$), i.e. the amount of bitumen remaining on the aggregate after water is added;

$$A_n= V_rC (A_1-A_3)/ (WA_1)$$

% Net Adsorption ($\%A_n$), i.e. the percentage of initially adsorbed bitumen remaining on the aggregate after the desorption phase;

$$\%A_n = (A_n / A_i) * 100$$

Where:
$A_i$ = Initial adsorption, mg / g
V = volume of solution in the flask, 140 ml
W = weight of aggregate, in grams
C = Initial concentration of bitumen in solution, 1g / l
$A_1$ = Initial absorbance reading
$A_2$ = Absorbance reading after 6 hours
$A_3$ = Absorbance reading after 16-17 hours
$A_n$ = Net adsorption, mg/g
$V_r$ = Volume of solution in the flask at the time $A_3$ is obtained, 136 ml.

**Evaluation Protocol for Aggregate-Binder Compatibility:**

The criteria selected by SHRP to evaluate the performance of aggregate-binder adhesion based on percent Net Adsorption results ($\%A_n$) are recommended for this test (Table 2).

**Table 2. Evaluation Criteria for Aggregate-Binder Adhesion (based on Walsh et al. 1995)**

| Percent Net Adsorption ($\%A_n$) | Expected Performance of Aggregate-Binder Bond |
|---|---|
| >70 | Good |
| 55-70 | Acceptable |
| <55 | Poor |

**References:**

G. Walsh, I. L. Jamieson and M. O'Mahoney, "The Net Adsorption Test for Chip Sealing Aggregates and Binders", *RC 372*, National Roads Authority, Ireland, November 1995.

C. W. Curtis, K. Ensley and J. Epps, "Fundamental Properties of Asphalt-Aggregate Interactions Including Adhesion and Absorption", *Research Report SHRP-A-341*, Strategic Highway Research Program, National Research Council, Washington, DC, 1993.

Figure 1. Mechanical Shaker

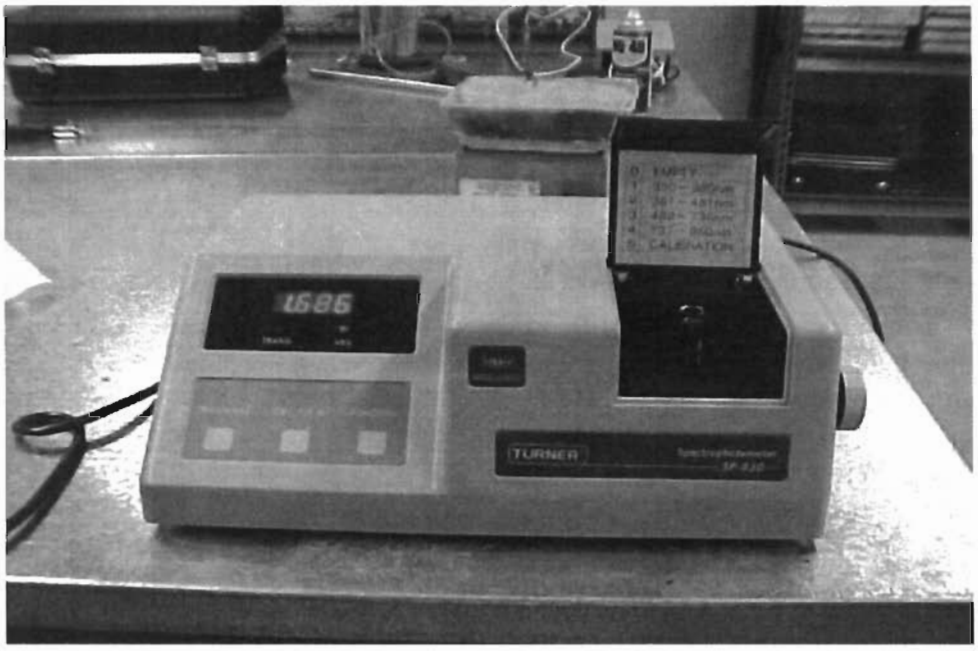



Figure 2. Spectrophotometer

# 0-4362 P1 – Part 2

## Performance-Based Compatibility Test and Evaluation Protocol for Aggregates and Binders used in Seal Coats and Surface Treatments

**Tex-YYY-Y Performance-Based Compatibility Test and Evaluation Protocol for Aggregates and Binders used in Seal Coats and Surface Treatments**

**Overview:**

This test method is recommended to predict the bonding compatibility of aggregate and bituminous binder used in seal coats and surface treatments. This is a performance-based test that incorporates field condition of materials, construction conditions and performance conditions during the first year after the seal coat or surface treatment is applied.

**Apparatus:**

The following apparatus is required:

1. 6 in. x 6 in. x 1/8 in. thick (15 cm x 15 cm x 3 mm thick) Aluminum plates: It is recommended that for each binder-aggregate combination to be tested, a minimum of three replicate specimens be used. Therefore, a sufficient number of Aluminum plates need to be secured. The plates must of uniform thickness and should be free of warping. The thickness of asphalt film could be as little as 1.25 mm, and therefore, the specimen plates must be flat and level to an accuracy of 0.1 mm.
2. 6 in. x 6 in. x ¼ in. thick (15 cm x 15 cm x 6 mm thick) steel plate
3. Asphalt oven capable of maintaining a temperature of up to 200 °C (400 °F)
4. Hot plate capable of maintaining a temperature of up to 65°C (150 °F)
5. Weighing balance readable to 0.1g
6. Adjustable blade and rails to apply the binder film of uniform thickness
7. Automated chip spreader (Figure 1). The aggregate may also be spread by hand.
8. Micro-Deval Test Equipment (ASTM D 6928 o AASHTO T 327) for dust generation in aggregates
9. Water tank to soak laboratory prepared specimens: The size of tank depends on the number of specimens soaked at one time. If several specimens are soaked at the same time, it is recommended that a rack be used to keep specimens in the tank so that they do not rest on each other.
10. Freezer capable of maintaining -25 °C (-13 °F)
11. Modified Proctor hammer used in soil compaction test Tex-113-E
12. Specimen mounting apparatus (Figures 2-5)
13. Steel drum roller padded with ¼ in. thick rubber sheet (Figure 6), and capable of producing a contact pressure of 45 psi on 6 in. wide seal coat specimen, assuming a contact width of 2 inches.
14. Non-contact thermometer: This thermometer must be calibrated according to guidelines given by the manufacturer.
15. Miscellaneous items such as brush, small scoop, small can, heat resistant gloves, etc.

**Materials:**

The following materials are needed for the test.

1. Bituminous binder
2. Aggregate (precoated or uncoated)
3. Antistripping agent (if needed for laboratory precoating of aggregate)

**Specimen Preparation:**

This step consists of the following activities:

- Preparation of aggregate
- Preparation of test specimens

Preparation of Aggregate

1. Secure a representative sample of aggregate (cover stone) for the seal coat.
2. Sieve the aggregate to obtain a sample of Grade 4S or other approved grade.
3. Take 1500 g of aggregate and soak it in water for 6 hours.
4. Wash the aggregate in running water for 5 minutes and oven-dry at 110°C for 24 hours.
5. Put the oven-dried aggregate to the Micro-Deval test machine and operate the machine for 2 minutes without the steel charge (aggregate only). If the aggregate is sampled directly from a field stockpile, it may be used as is, if desired.
6. The aggregate sample is now ready for specimen preparation. If precoating is desired, aggregate can be precoated at this stage using a laboratory mixer.

Preparation of Test Specimens

Follow these steps to prepare material and equipment for this procedure.

1. Place an appropriate quantity of binder into a small can for easy handling.
2. Heat the binder in the oven to the desired seal coat application temperature.
3. Calculate the amount of binder needed for each specimen plate using the following equation:

   For a binder application rate of $B$ gal/yd$^2$,
   The corresponding thickness of the asphalt film $T$, in millimeters, can be calculated by the equation:

   $$T = 4.527 \cdot B \qquad \text{Eq. 1}$$

   The mass of binder $M_B$, in grams, needed for one specimen plate at the application rate of $B$ can be calculated by the equation:

   $$M_B = 105.198 \cdot B\, G_b \qquad \text{Eq. 2}$$

   $G_b$ is the specific gravity of asphalt binder.
4. Adjust the asphalt sweeper blade height to provide the film thickness $T$ calculated using Eq. 1 above.

5. Place sticker tape to the four sides of the specimen plate so that the tape rises to a height of ¼ inch above the specimen plate. This tape will serve as an overflow barrier for asphalt in the specimen plate. Measure the mass of plate and tape and record it as $M_P$.
6. Place the aluminum plate on the hot plate and adjust the hot plate temperature dial until the aluminum plates attain the desired temperature. This temperature is related to the desired pavement temperature at which seal coat is applied in the field.
7. Pour $M_B$ grams of binder to the end of specimen plate and run the sweeper blade across the specimen plate to provide an asphalt film of uniform thickness $T$. Steps 4, 5 and 6 may be replaced by an appropriate binder spray mechanism that is capable of providing an asphalt film of uniform thickness.
8. Weigh the plate with the binder in it and record as $M_{PB}$. If the exact binder content needed to get the desired asphalt rate is used,

   $M_{PB} = M_B + M_P$

9. Measure the temperature of binder in the plate at intervals of 15 seconds using a properly calibrated non-contact thermometer.
10. Place the aggregate to the binder film when the binder cools down to the desired aggregate application temperature. It is recommended that this temperature be set as the temperature of the hot plate. The quantity of aggregate used should be determined based on the aggregate application rate used in the field. This can be calculated using the procedure outlined below:

    If the aggregate application rate is 1:$A$ (i.e. 1yd$^3$ of aggregate used over $A$ yd$^2$ of pavement),

    Loose volume of aggregate needed for one specimen = $0.520833/A$ ft$^3$

    If the unit weight of aggregate is $U$ lb/ft$^3$,

    Mass of aggregate sample needed for one specimen = $(0.520833/A)\ U$

    Do not place any aggregate within ½ inch from the four edges of the plate. The aggregate application may be done either by hand, or by automated means. The total time taken to apply aggregate must be within 15 seconds. It is recommended that aggregate particles be dropped onto the binder from a height of approximately 12 inches from the specimen plate. This may be of particular significance for emulsified asphalt seals.

11. Move the specimen from the hot plate to the rolling area.
12. Measure the temperature of the binder at 15-second intervals using a properly calibrated non-contact thermometer.
13. Roll the seal coat specimen with the roller after the desired time has elapsed between aggregate application and rolling. It is recommended that five roller passes be used to roll the specimen. One forward pass or one backward pass is treated as one roller pass. The roller should have a contact pressure of approximately 45 psi.
14. Count the number of aggregate particles in the specimen and record it as $C_A$.

15. Weigh the plate + binder + aggregate and record as $M_T$. The mass of aggregate ($M_A$) in the specimen can be calculated by,

$$M_A = M_T - M_P - M_B$$

16. Store the specimens under room temperature for 96 hours until specimen conditioning begins.

**Specimen Conditioning:**

Follow these steps for specimen conditioning

1 Once the specimens are cured for 96 hours, soak the specimens in water at room temperature for 16 hours.
2 At the end of 16 hours of soaking, transport the specimens to the freezer and freeze at the desired temperature for 8 hours. The freezing temperature must be selected to represent the coldest temperature experienced in the region.
3 Repeat steps 1 and 2 for two more cycles such that a total of three soak-freeze cycles are achieved.
4 After three soak-freeze cycles, continuously soak the specimen in a water bath at room temperature for 64 hours. This completes the specimen conditioning process.

**Impact Testing:**

The complete testing apparatus used to determine aggregate retention is shown in Figure 7.

1 When the conditioning process is finished, place the inverted specimen (with the aggregate facing down) on the impact testing apparatus as shown in Figure 3. Care should be taken not to have aggregate particles along the boundary where the inverted specimen rests on the impact testing apparatus. This way, the specimen plate is resting on the rubber pads along the perimeter of impact loading apparatus.
2 Place the 6 inches x 6 inches x 1/4 in thick steel plate on to the inverted specimen plate.
3 Drop the modified proctor hammer 3 times onto the ¼ in. thick steel plate over its full drop height of 18 inches.
4 Count the number of aggregates retained on the specimen and record as $C_R$.
5 Weigh the specimen after testing and record as $M_F$.

Table 1 shows the recommended test schedule.

**Table 1. A Recommended Specimen Preparation, Conditioning and Testing Schedule**

| Day of Week | Time | Activity |
|---|---|---|
| Friday | | Prepare specimens |
| Tuesday | 4pm | Begin 16-hour soak |
| Wednesday | 8am | End 16-hour soak and begin 8-hour freeze |
| | 4pm | End 8-hour freeze and begin 16-hour soak |

| | | |
|---|---|---|
| Thursday | 8am | End 16-hour soak and begin 8-hour freeze |
| | 4pm | End 8-hour freeze and begin 16-hour soak |
| Friday | 8am | End 16-hour soak and begin 8-hour freeze |
| | 4pm | End 8-hour freeze and begin 64-hour soak |
| Monday | 8am | End 64-hour soak and specimens ready for impact testing |

**Calculations:**

Use the following calculations to determine percent loss.

If the evaluation is based on aggregate count,

$$\%\ Loss\ by\ Aggregate\ Count = \frac{C_A - C_R}{C_A} x100$$

Where:

$C_A$ = Number of aggregates on the specimen before conditioning starts
$C_R$ = Number of aggregates retained on the specimen after impact loading

If the evaluation is based on weight,

$$\%\ Loss\ by\ Aggregate\ Mass = \frac{M_T - M_F}{M_T - M_{PB}} x100$$

Where:

$M_F$ = Mass of the specimen after impact loading
$M_T$ = Mass of the plate + aggregate + binder before impact testing
$M_{PB}$ = Mass of the plate + binder

**Evaluation:**

| Percent Aggregate Loss Based on Aggregate Count | Compatibility Evaluation |
|---|---|
| 0 to 10 | Very Good |
| 10 to 20 | Good |
| 20 to 30 | Marginally Compatible |
| 30 to 100 | Incompatible |

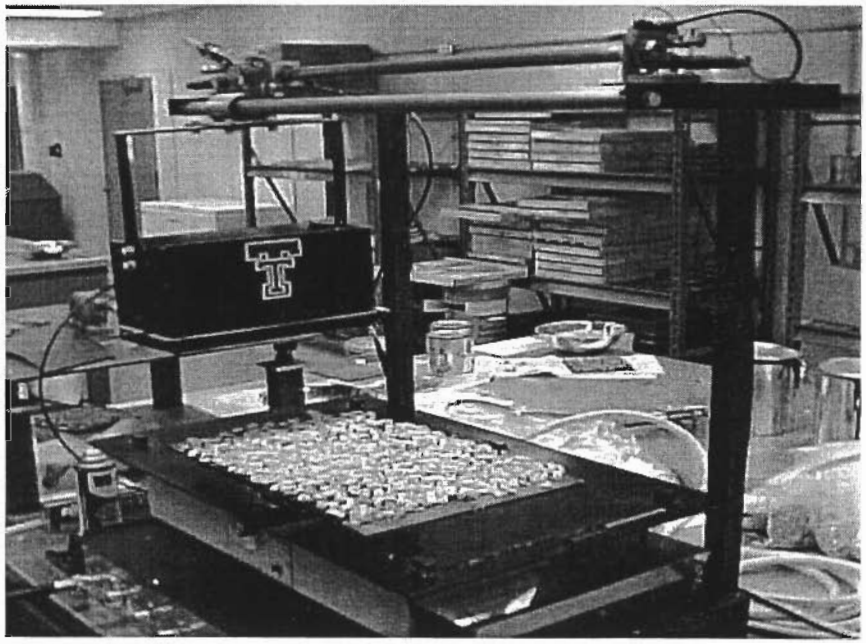


**Figure 1. Automated Chip Spreader used in Research Project 0-4362**

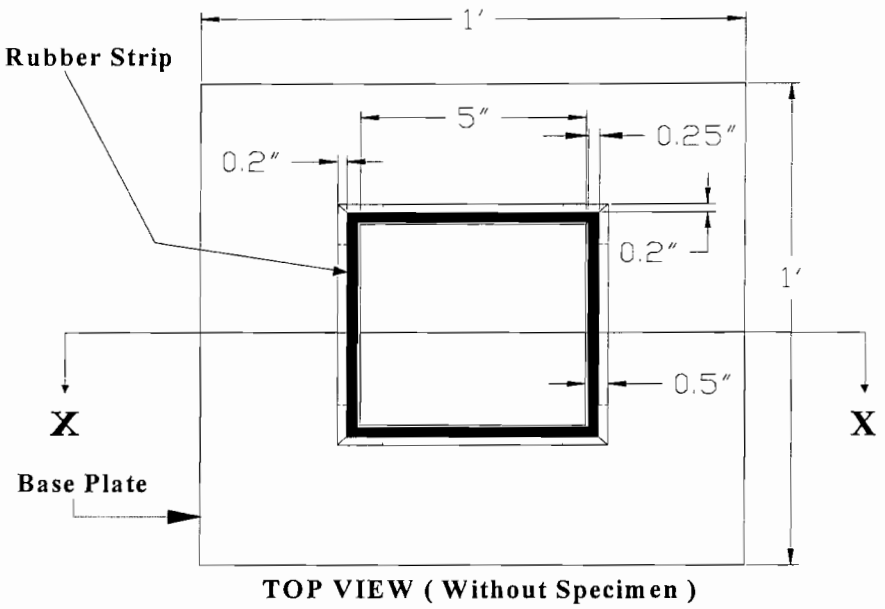



**Figure 2. Top View of Specimen Mounting Unit (without Test Specimen)**

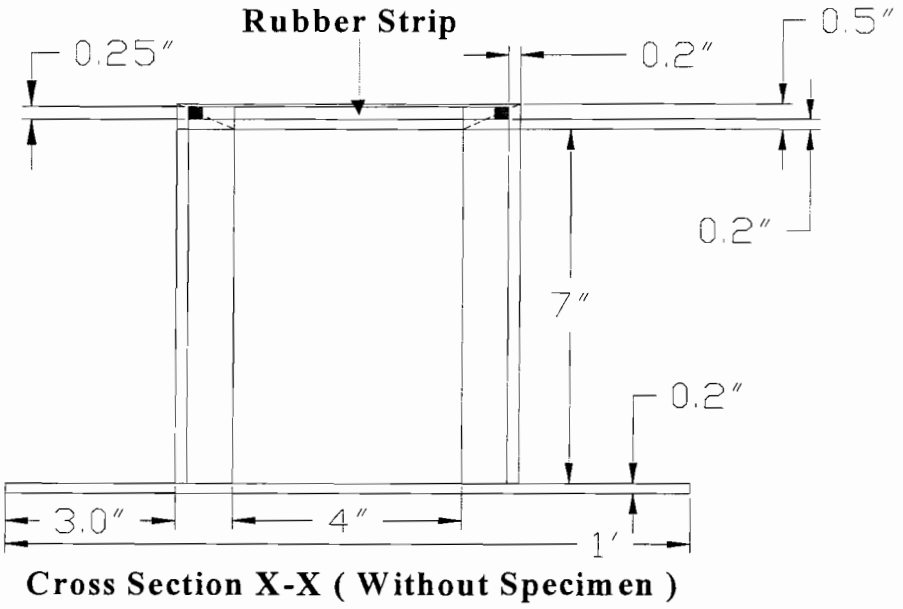



**Figure 3. Cross Section View X-X of the Specimen Mounting Unit (without Test Specimen)**

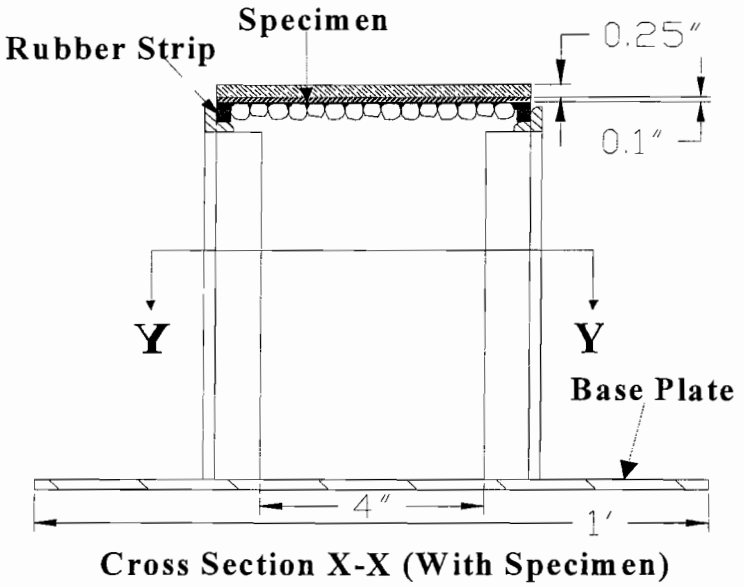



**Figure 4. Cross Section View X-X of the Specimen Mounting Unit (with Test Specimen)**

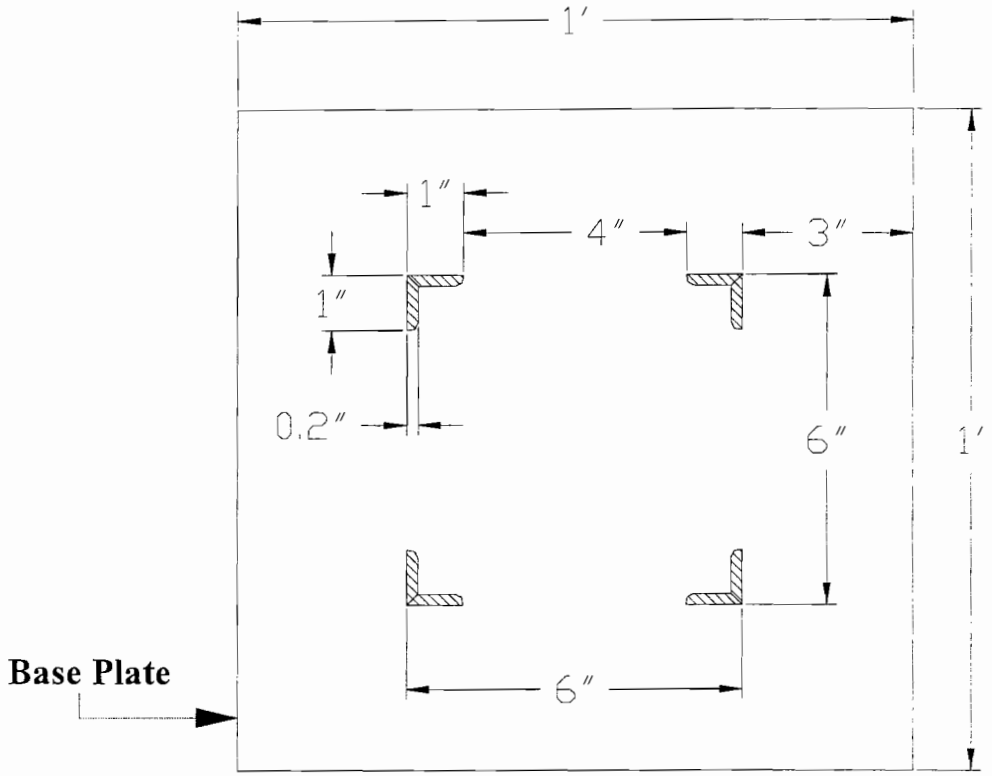
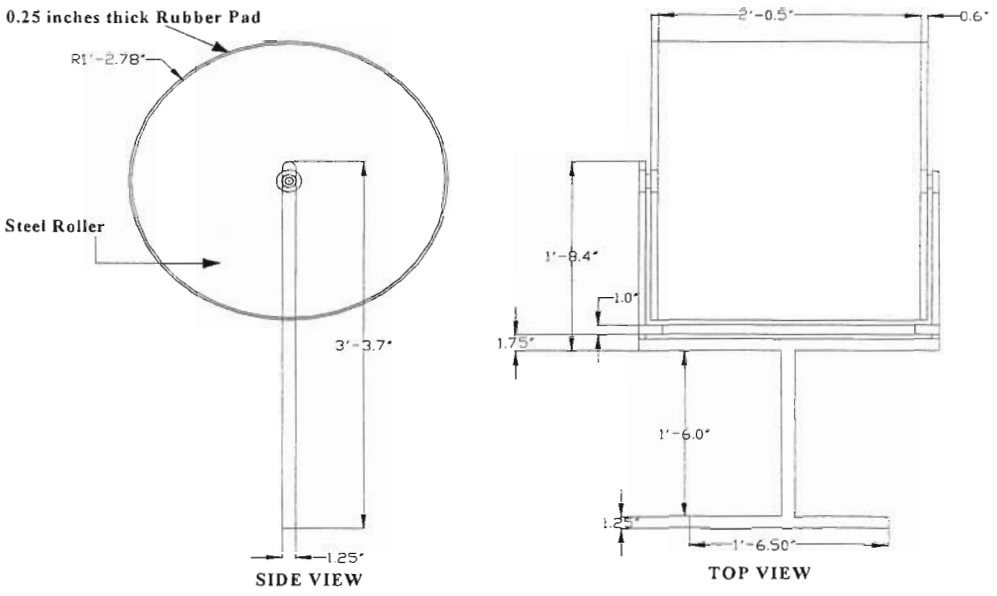
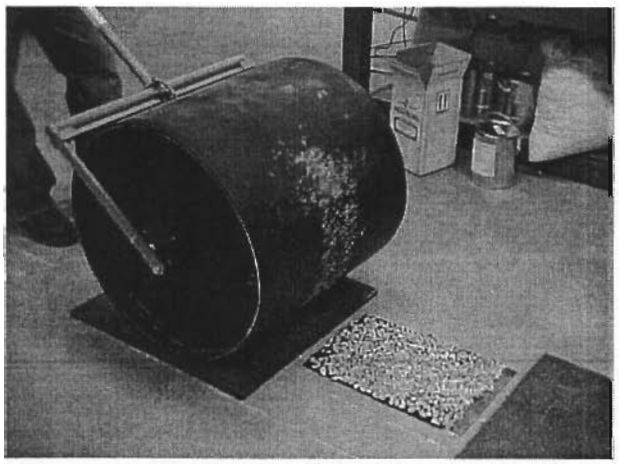



**Figure 5. Cross Section View Y-Y of the Specimen Mounting Unit**




(a)



(b)

**Figure 6. Steel Drum Roller (a) Shop Drawing (b) Roller used in Research Project 0-4362**

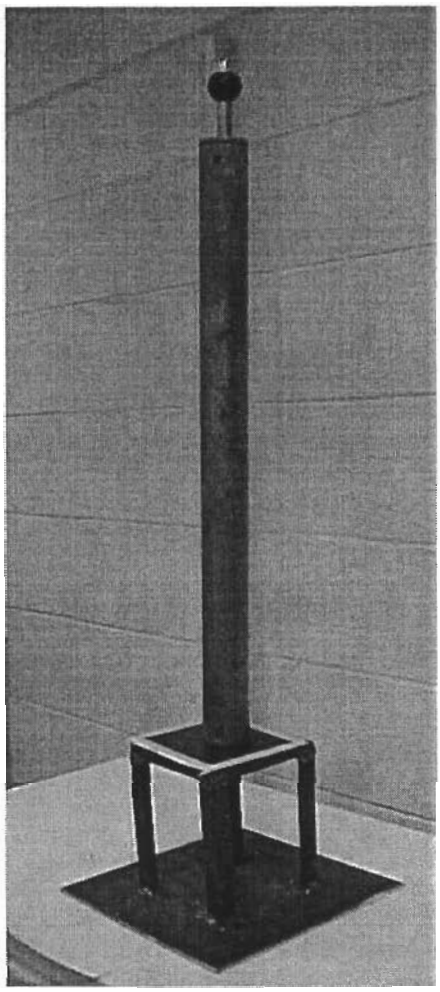


**Figure 7. Aggregate-Binder Compatibility Test Apparatus.**