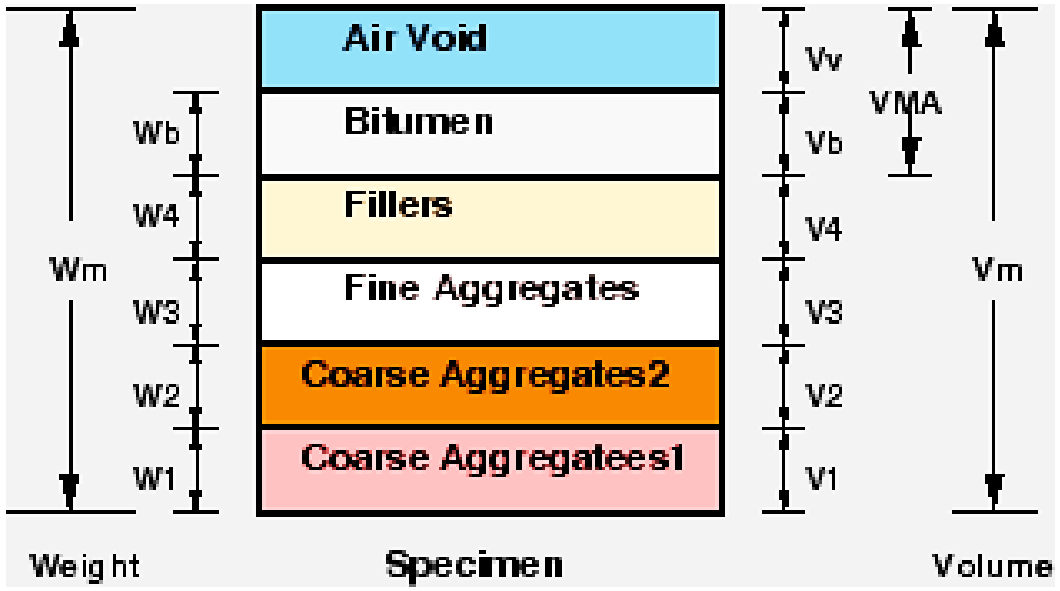
Republic of Iraq
Ministry of Higher Education & Scientific Research
Al-Mustaqbal University College
Building & Construction Engineering Technology Department

"HIGHWAY ENGINEERING" 3rd Stage

((Analysis of Marshall Specimen "Mass-Volume Relationship" تحليل عينة مارشال))



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Analysis of Mixture (Mass-Volume Relationship)

Va = volume of air voids in total mix

Vs_1 = volume of effective asphalt

Vs_2 = volume of absorbed asphalt

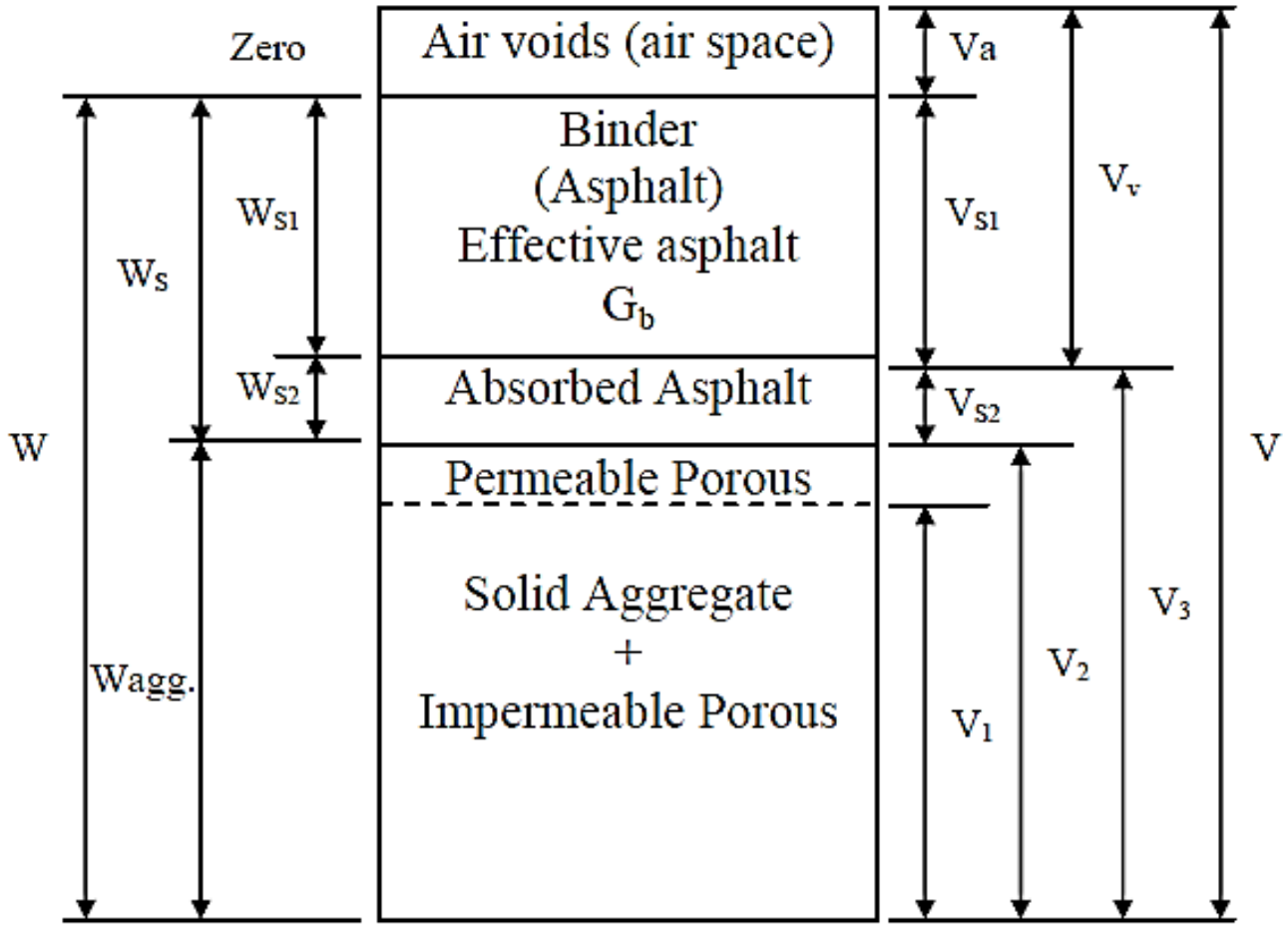
V_1 = apparent volume of aggregate

V_2 = effective volume of aggregate

V_3 = bulk volume of aggregate

V = total volume of mixture

Vv = voids of aggregate (Voids in mineral aggregate)



Bulk G_A = bulk specific gravity of combined aggregate

Gs
الوزن النوعي

$$\text{Bulk } G_A = \frac{100}{\frac{\%\text{course}}{Gs(\text{course})} + \frac{\%\text{fine}}{Gs(\text{file})} + \frac{\%\text{filler}}{Gs(\text{filler})}} \quad (1)$$

$$P_S + P_A = 100\% \rightarrow P_A = 100 - P_S \quad (2)$$

P_S = total % of asphalt (by wt. of total mix)

P_A = % of aggregate (by wt. of total mix)

$$\text{Effective } G_A = \frac{100 - P_S}{\frac{100}{Gm} - \frac{P_S}{Gs}} \quad (3)$$

Max Gm: max. theoretical sp. gr. of mix

Effective G_A : effective sp. gr. of mix

$$\text{Calculated max. Gm} = \frac{W}{V - Va} = \frac{100}{\frac{P_s}{Gs} + \frac{100 - P_s}{\text{effective}\,G_A}} \qquad (4)$$

$$\text{Actual Gm} = \frac{W}{V} = \frac{W_{air}}{W_{air} - W_{water}} \qquad (5)$$

$$\%\ \text{air voids (in total mix)} = \frac{Va}{V} * 100\% = \frac{\text{max.Gm} - \text{actual Gm}}{\text{max.Gm}} * 100\% \qquad (6)$$

$$\%\ \text{voids in mineral aggregate (V.M.A.\%)} = \frac{V_V}{V} * 100\% = 100 - \frac{\text{actual Gm} * P_A}{\text{bulk}\,G_A} \qquad (7)$$

$$\text{Absorbed asphalt (\% by wt. of agg.)} = P'_{S2} = \left[\frac{1}{\text{bulk } G_A} - \frac{1}{\text{effective } G_A}\right] * Gs * 100\% \quad (8)$$

$$\text{Effective asphalt (\% by wt. of total mix)} = P_{S1} = P_S - \frac{P'_{S2} * P_A}{100} = P_S - P_{S2} \quad (9)$$

Where: P_{S2} = absorbed asphalt (% by wt. of total mix)

$$\text{\% voids filled with asphalt} = \frac{\text{actual } Gm * P_{S1}}{\text{actual } Gm * P_{S1} + Gs * \text{\% air voids}} * 100\% \quad (10)$$

For surface course (wearing):

- % of asphalt (usually effective asphalt) = 4.5 – 6.5 % by wt. of total mix
- Stability at 60°C & 75 blows/end ≥ 800 kg
- Flow = 2 – 4 mm
- % air voids in total mix = 3 – 5 %
- % voids filled with asphalt = 70 – 85 %
- % voids in mineral aggregate V. M. A.% (min. =15%)
- Filler / Asphalt (max. = 1.4)
- Index of retained strength = $\frac{\text{comp.st.(Immersion)}}{\text{comp.st.(Dry)}} * 100\% \geq 70\%$
- Relative compaction = $\frac{\text{Field density}}{\text{Lab. density}} * 100\% \geq 96\%$

Ex.: To prepare asphalt mixture as surface course, it is found the following:

a) For aggregate:

Sieve size:	1"	No. 4	No. 200
% passing:	100	45	5

For course agg. Gs = 2.64

For fine agg. Gs = 2.67

For filler Gs = 3.10

b) For asphalt (40-50) → Gs = 1.04

c) For asphalt concrete contains 5% asphalt → max. Gm = 2.49

If the same above materials used to construct asphalt concrete layer with 5.7% asphalt. The core from layer has W_{air} = 1200gm, & W_{water} = 692gm. Check this layer?

Sol.: Check: % air voids (3-5), V.M.A. = min. 15,

asphalt voids (70-85), effective asphalt (4.5-6.5)%

$$\%\ \text{air voids (in total mix)} = \frac{Va}{V} * 100\% = \frac{\max.Gm - \text{actual}\,Gm}{\max.Gm} * 100\%$$

$$\%\ \text{voids in mineral aggregate (V.M.A.\%)} = \frac{Vv}{V} * 100\% = 100 - \frac{\text{actual}\,Gm * P_A}{\text{bulk}\,G_A}$$

$$\%\ \text{voids filled with asphalt} = \frac{\text{actual}\,Gm * P_{S1}}{\text{actual}\,Gm * P_{S1} + Gs * \%\,\text{air voids}} * 100\%$$

$$\text{Effective asphalt (\% by wt. of total mix)} = P_{S1} = P_S - \frac{P'_{S2} * P_A}{100} = P_S - P_{S2}$$

Bulk GA = يمكن حسابة

Ps = 5%

Max Gm = 2.49

Ps new = 5.7%

Wair = 1200gm

Wwater = 692gm

% air voids = ?

V.M.A. = ?

V.F.A. = ?

P_{S1} = ?

$$\text{Bulk } G_A = \frac{100}{\frac{\%course}{Gs(course)} + \frac{\%fine}{Gs(file)} + \frac{\%filler}{Gs(filler)}} = \frac{100}{\frac{55}{2.64} + \frac{40}{2.67} + \frac{5}{3.1}} = 2.672$$

$$\text{Effective } G_A = \frac{100 - P_s}{\frac{100}{Gm} - \frac{P_s}{Gs}} = \frac{100 - 5}{\frac{100}{2.49} - \frac{5}{1.04}} = 2.687$$ (مقدرا ثابت بتغير نسبة الاسفلت)

For the layer with asphalt = 5.7%

$$\text{Actual } Gm = \frac{W}{V} = \frac{W_{air}}{W_{air} - W_{water}} = \frac{1200}{1200 - 692} = 2.362$$

$$\text{Calculated max. Gm} = \frac{W}{V - Va} = \frac{100}{\frac{P_s}{Gs} + \frac{100 - P_s}{\text{effective}\,G_A}} = \frac{100}{\frac{5.7}{1.04} + \frac{100 - 5.7}{2.687}} = 2.464$$

$$\text{Absorbed asphalt (\% by wt. of agg.)} = P'_{S2} = \left[\frac{1}{\text{bulk}\,G_A} - \frac{1}{\text{effective}\,G_A}\right] * Gs * 100\%$$

$$= \left[\frac{1}{2.672} - \frac{1}{2.687}\right] * 1.04 * 100\% = 0.23\%$$

$$\therefore \text{ effective asphalt concrete} = P_{S1} = 5.7 - \frac{0.23 * 94.3}{100} = 5.48\%\ (4.5\text{-}6.5)\%\ \therefore \text{OK}$$

$$\%\ \text{V. M. A.} = 100 - \frac{2.362 * 94.3}{2.672} = 16.6\% \geq 15\%\ \therefore \text{OK}$$

$$\%\ \text{air voids} = \frac{2.464 - 2.362}{2.464} * 100\% = 4.1\%\ (3 - 5)\%\ \therefore \text{OK}$$

% voids filled with asphalt

$$= \frac{2.362 * 5.48}{2.362 * 5.48 + 1.04 * 4.1} * 100\% = 75.2\% \ (70 - 85)\% \ \therefore \text{OK}$$