# Highway & Traffic Engineering

## MARSHALL MIX DESIGN METHOD

by

**Dr. Intan Suhana bt Mohd Razelan**
**Puan Azlina Ismail**
**Faculty of Civil Engineering & Earth Resources**
**intan@ump.edu.my**

# Chapter Description

- Aims
  - Understand the steps, principles and theory behind the design of flexible pavement using Marshall mix design method.
- Expected Outcomes
  - Students should be able to understand basic criteria for pavement mix design
  - Students should be able to elaborate different type of tests involved in pavement design
  - Students will be able to design the pavement design using Marshall mix design method
- References
  - http://www.pavementinteractive.org/marshall-mix-design/
  - Images are taken from other related websites as stated.

# Asphalt Mixture

- Asphalt concrete consist of asphalt cement, aggregate and air.
- Relative amounts of each component is important in determining pavement properties.
- The mass/volume relationship of a compacted asphalt paving mix must be accurately calculated.

# History

- The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army.
- Currently, the Marshall method is used in some capacity by about 38 states.

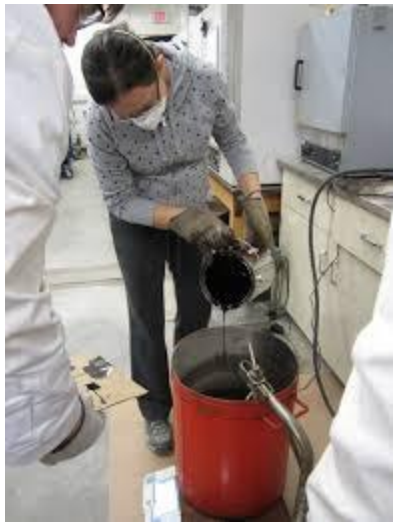
# Fundamental Design Concept

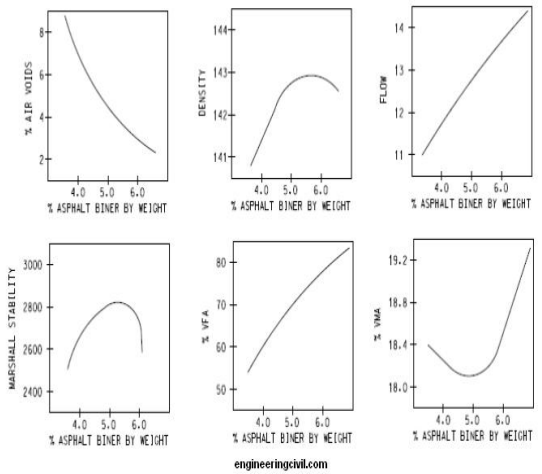
- Design of Marshall or other flexible pavements design are typically includes :-
  - Best blend aggregate (Aggregate Blending)
  - Asphalt Binder Selection (Within range 3-5)
  - Optimum Asphalt Content Determination (OAC)

# Mix Design Steps

http://www.alaliengineering.net/sabeareadymix.php

https://www.concretenetwork.com/aggregate/






Design graphs for Marshall Mix Design

http://www.engineeringcivil.com/what-is-marshall-mix-design-for-bituminous-materials.html

# Marshall Testing Apparatus

# Sample Testing in Marshall Mix Method

- Stability and Flow Test → to check the performance of the designed samples whether it meets the Marshall specifications requirements or not.
- Stability Test → will determine the maximum load that can be sustained by the designed samples.
- Flow Test → Records the potential of flow in a sample during loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time the maximum load is recorded.

# Density – Voids Analysis

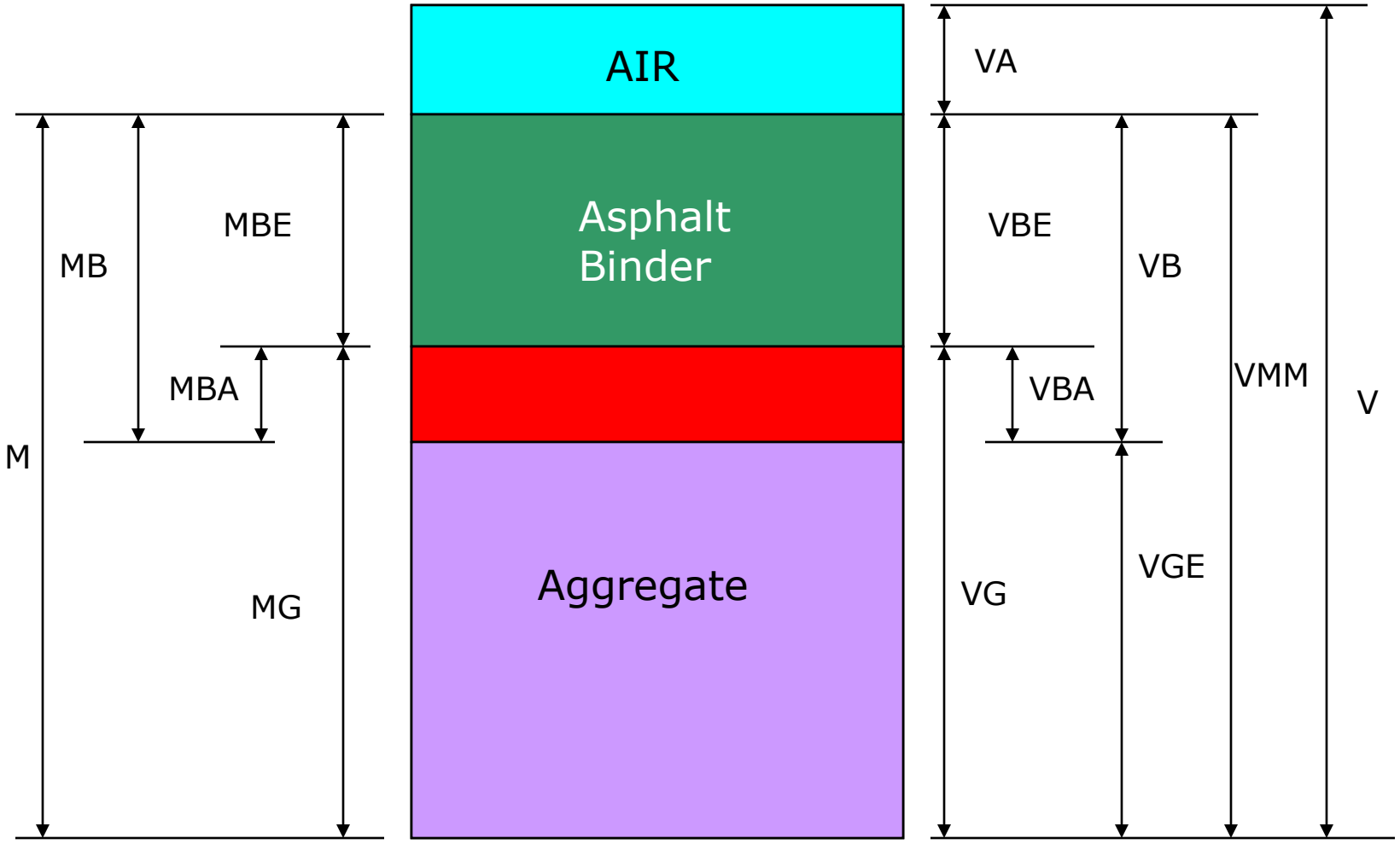
- Density Voids analysis starts with determination of relative density of compacted mixture.
  - Weight of specimen in air
  - Weight of specimen in water
  - Weight of Saturated Surface Dry (SSD).
- Relative density of aggregate, $RD_{agg}$.
- Percentage of asphalt absorbed in aggregate, $V_{ba}/P_{ba}$.
- Percentage of effective asphalt content in mix, $V_{be}/P_{be}$.

# Density – Voids Analysis

- Percentage of Voids in Mineral Aggregate, % VMA.
- Percentage of Air Voids, %AV.
- Percentage of Voids Filled with Asphalt, % VFA.

http://www.pavementinteractive.org/article/hma-weight-volume-terms-and-relationships/

# Mass/Volume Relationship in Asphalt Mixes.



# Selection of Asphalt Binder

- Asphalt binder were selected based on the typical estimated asphalt binder (taken from design criteria) which is between 3 to 5 percent with 4% is typically taken as median (first trial).
- The best blend mix which include one of those will be selected as the optimum value of asphalt content if all requirements were met.

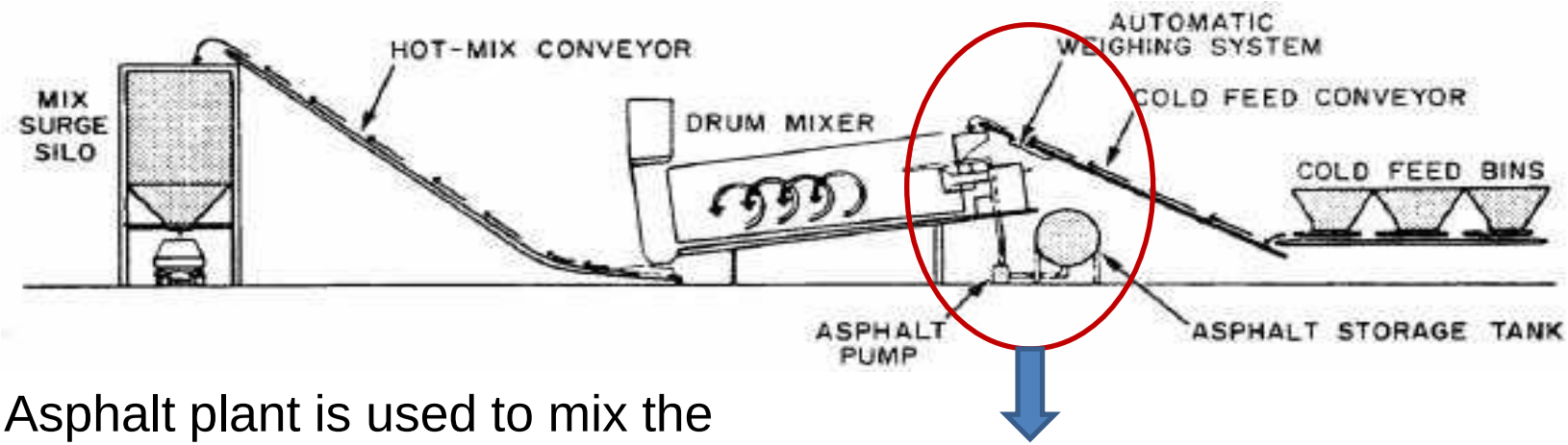
| Type of Asphalt Concrete (AC) | Range of Bitumen Content (%) |
|---|---|
| AC 10 – Wearing Course | 5.0 – 7.0 |
| AC 14 – Wearing Course | 4.0 – 6.0 |
| AC 28 – Binder Course | 3.5 – 5.5 |

Extracted from : JKR/SPJ/2008-S4, JKR 20403 0003 07

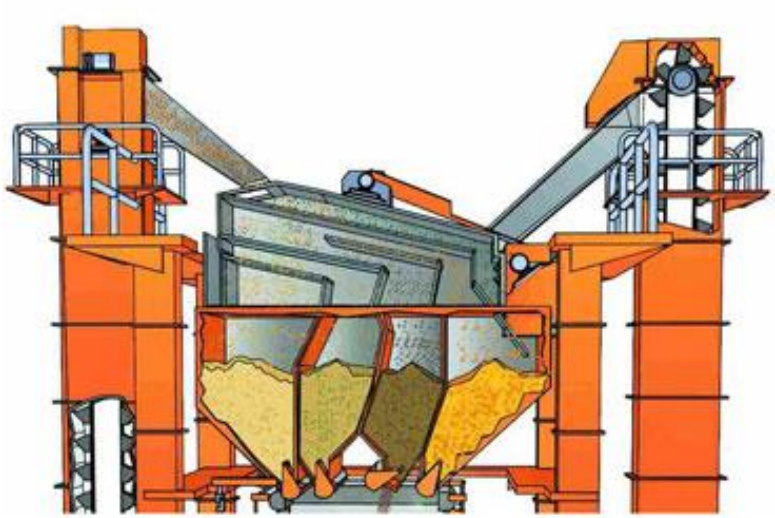
# Determinations of % of Asphalt Content

- Several trial aggregate-asphalt binder blends (typically 5 blends with 3 samples each for a total of 15 specimens, 0.5% increment in each blend), each with a different asphalt binder content were prepared spanning from expected asphalt content.
- Asphalt and aggregate are heated separately and then mixed.
- The trial blends must contain a range of asphalt contents both above and below the optimum asphalt content.

# Drum Mix Plant / Hot Mix Plant



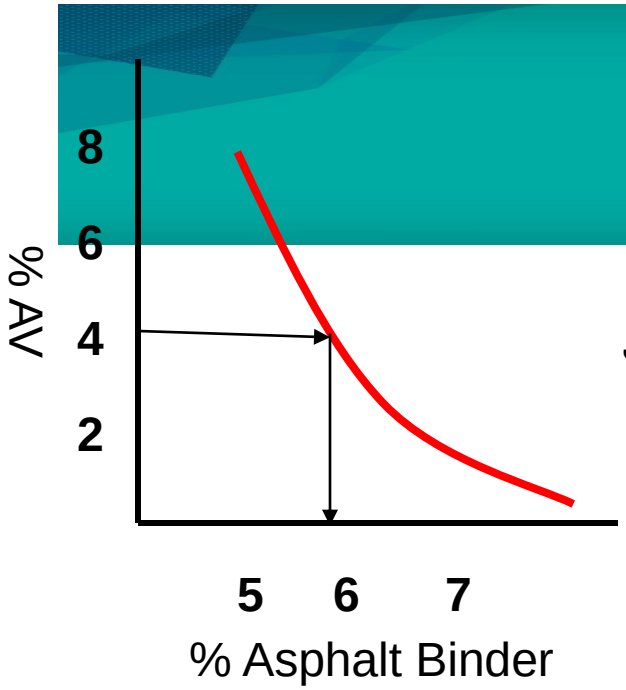

Asphalt plant is used to mix the aggregate and asphalt together before the HMA can be transported to site. Engineer will submit the mix design form which includes the calculation of aggregate blending and OAC so that plant can produce the HMA according to client's need.

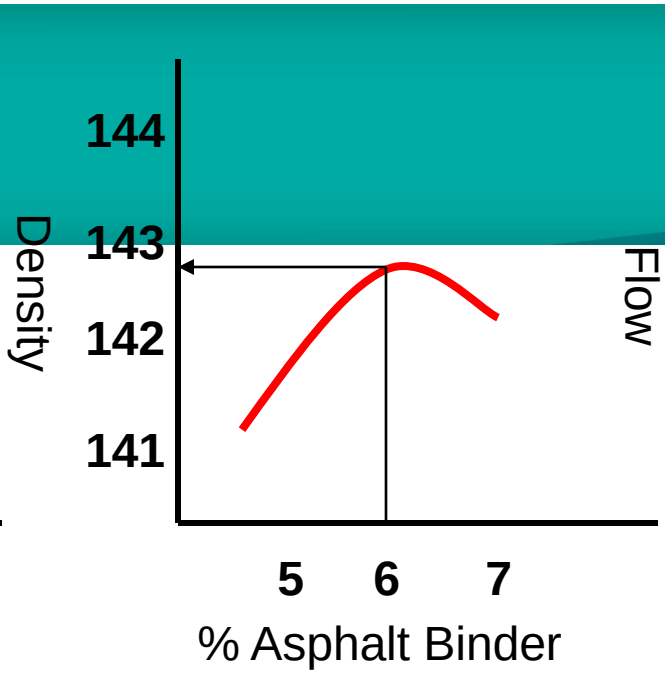


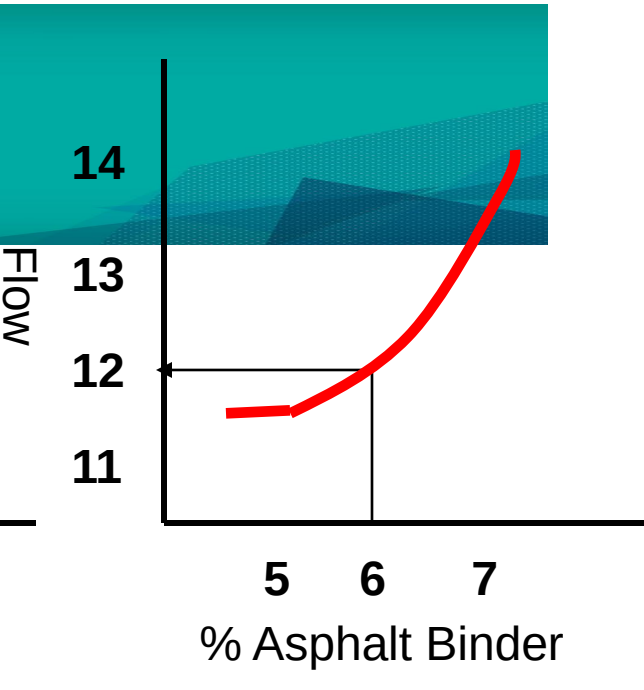
Images from http://enginemechanics.tpub.com/14080/css/Drum-Mix-Asphalt-Plant-180.htm

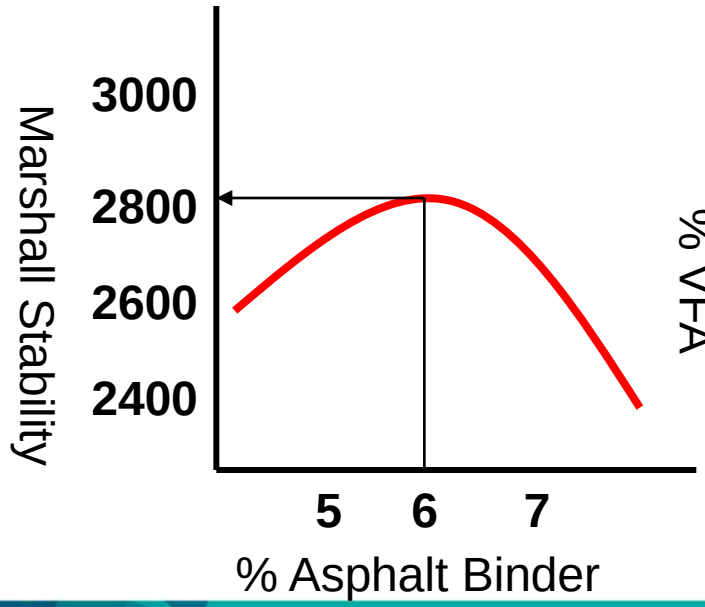
# Suggested criteria for Asphalt Concrete Design by Marshall.

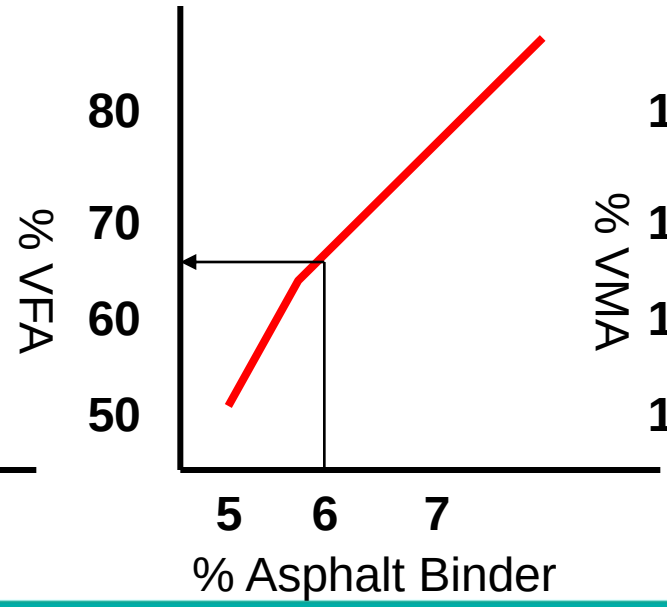
| Marshall method mix criteria | Light Traffic | | Medium Traffic | | Heavy Traffic | |
|---|---|---|---|---|---|---|
| | Surface | Base | Surface | Base | Surface | Base |
| | Min | Max | Min | Max | Min | Max |
| Compaction -blows | 35 | | 50 | | 75 | |
| Stability - N | 3336 | - | 5338 | - | 8006 | - |
| Flow, 0.25mm | 8 | 18 | 8 | 16 | 8 | 14 |
| % Air Voids | 3 | 5 | 3 | 5 | 3 | 5 |
| %VFA | 70 | 80 | 65 | 78 | 65 | 75 |

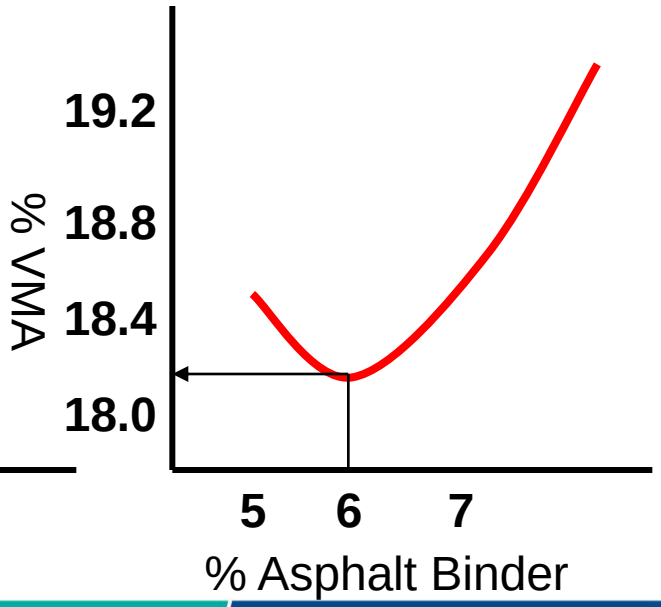


- Asphalt binder content vs. density.
  - Density will generally increase with increasing asphalt content, reach a maximum, then decrease. Peak density usually occurs at a higher asphalt binder content.
- Asphalt binder content vs. Marshall stability. This should follow one of two trends:
  - Stability increases with increasing asphalt binder content, reaches a peak, then decreases.
  - Stability decreases with increasing asphalt binder content and does not show a peak. This curve is common for some recycled HMA mixtures.

- Asphalt binder content vs. flow.
  - Asphalt binder content vs. air voids. Percent air voids should decrease with increasing asphalt binder content.
- Asphalt binder content vs. VMA.
  - Percent VMA should decrease with increasing asphalt binder content, reach a minimum, then increase.
- Asphalt binder content vs. VFA.
  - Percent VFA increases with increasing asphalt binder content.

# Optimum Asphalt Content

- According to Asphalt Institute Procedure:

- $$OAC = \frac{AC\ (Max.\ Density) + AC\ (Max.\ Stability) + AC\ (4\%\ AV)}{3}$$

From OAC, find values of stability, flow and VFA.

Compare the value with design criteria.

# Determinations of OAC

- Another method to calculate OAC (US Department of Transportations procedure)
- Find OAC from 4% air voids
- Find stability, flow and VFA from OAC
- Compare with design criteria.

# Example 1

- From the determination of preliminary asphalt content, below results were calculated:-
- Determine IF the results meet the design criteria for heavy traffic area.

| | | Design Criteria | |
|---|---|---|---|
| | | Min. | Max. |
| Asp.cont. | 4.7 | - | - |
| Stability | 10.1 | 8 | - |
| Flow(0.01 in) | 9 | 8 | 14 |
| VMA (%) | 14 | 12 | - |
| VFA(%) | 68 | 65 | 75 |

1. Determine the asphalt binder content that corresponds to the specifications median air voids content (typically this is 4 percent).
2. Optimum asphalt binder content at 4% of air voids were determine.
3. The other mix properties for a percents air voids of 4% are determined and compared to previous table.
4. Otherwise, if any of these properties is outside the specification range the mixture should be redesigned.

# Example 2

- The results of a Marshall test for 5 specimens were given below, find the optimum asphalt content and check whether the suggested AC using Asphalt Institute method meets the design criteria for medium traffic.

| Specimens | Stability (kg) | Flow (Units) | AV (%) | VFA (%) |
|---|---|---|---|---|
| 1 | 499.4 | 9 | 10.0 | 34 |
| 2 | 717.3 | 9.6 | 7.2 | 65 |
| 3 | 812.7 | 12 | 3.9 | 84 |
| 4 | 767.3 | 14.8 | 2.4 | 91 |
| 5 | 662.8 | 19.5 | 1.9 | 93 |

# Conclusion of The Chapter

- Conclusion #1
  - There 3 main criteria in pavements design i.e. best blend, binder selection and OAC
- Conclusion #2
  - Steps and calculation of specific items in Marshall is a very important in producing best blend mix.
- Conclusion #3
  - OAC will be achieved by producing a series of graph between 6 design criteria and bitumen content.
- Conclusions #4
  - The design of pavement is in accordance with types of road that will be built as different road with traffic loads gives different design criteria.

# Author Information

Dr. Intan Suhana bt Mohd Razelan
Puan Azlina Ismail