

# Use of Average Least Dimension in Surface Dressing



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# Overview

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- Background to Average Least Dimension
  - Methods for Determining ALD
  - Research Study and Results
  - Summary and Findings
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**Background**



# Background - 1

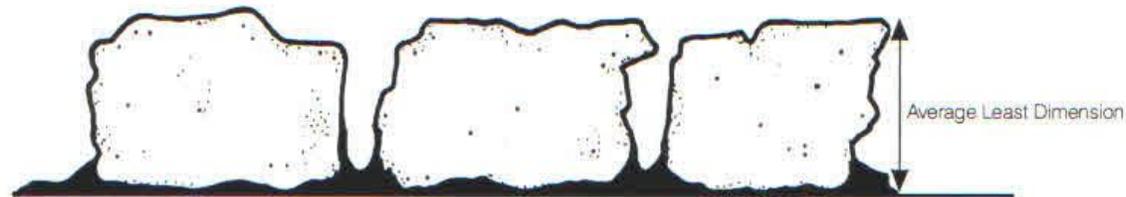
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- Surface dressing is the application of a thin layer of bituminous binder and single-sized aggregate chippings to the surface of a road, in one or more layers.
  - The procedure has become increasingly important since the introduction of standards for skidding resistance on National roads as set out in NRA HD28/11.
  - TII (NRA) are developing a new analytical design approach for surface dressing on National roads.
  - Based on best practice in other countries, an essential parameter used in the analytical design of surface dressing is the **Average Least Dimension (ALD)** of the aggregates used.
  - The ALD is essential to determine the optimum rates of spray of binder and rates of spread of chippings for surface dressing.
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# Background - 2

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- Hanson (1935, New Zealand) developed an engineering approach to the selection of optimum rates of spread of binder and chippings for surface dressing.
- The procedure considered the volume of voids between the chippings after spreading and rolling, and the orientation the chippings adopt after trafficking.
- Hanson found that after construction and trafficking compaction, chippings adopt a position whereby their least dimension is vertical – hence giving rise to the concept of **Average Least Dimension (ALD)**.
- The volume of voids in the covering aggregate, which will be partially filled with binder, is controlled by the ALD of the aggregate chips being used.

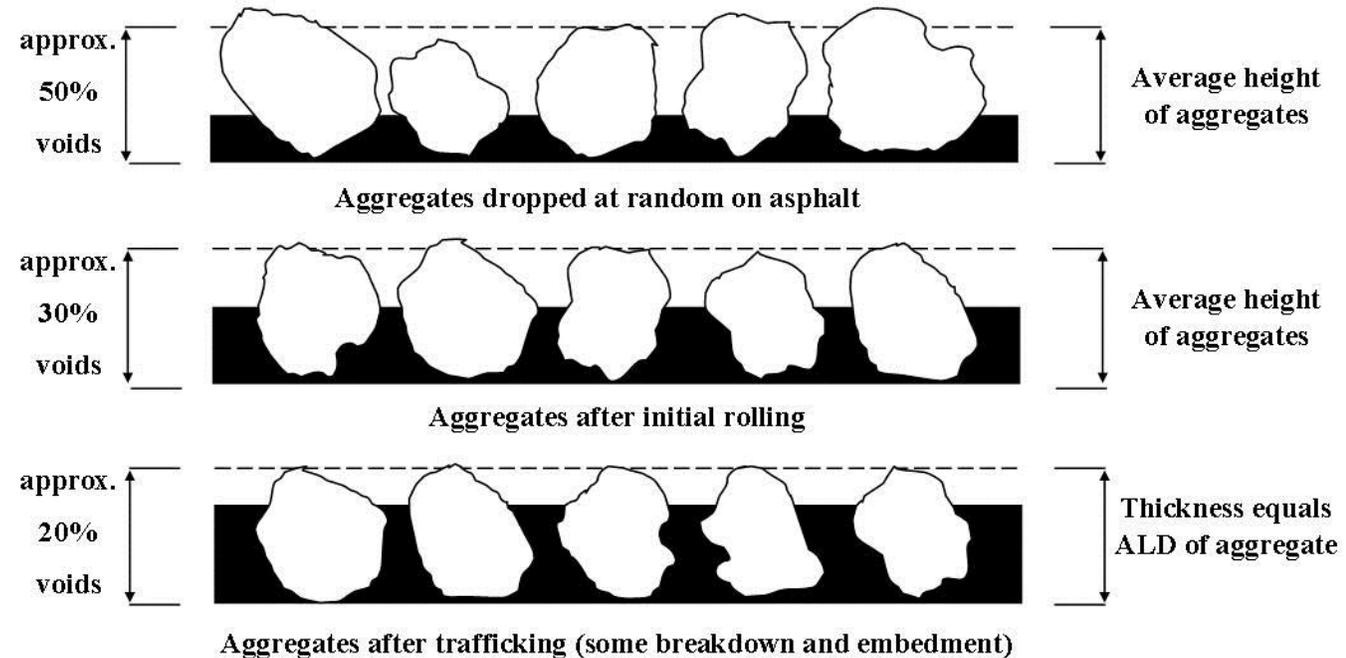


Orientation of Chippings After Trafficking (Shell Bitumen Handbook, 5<sup>th</sup> ed.)

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# Background - 3

- Hanson found
  - that in a loose single layer of chippings for surface dressing that the percentage of voids are initially about 50%, decreasing to around 30% after construction rolling, and to 20% under the action of traffic.
  - The amount of binder to be used is related to the volume of voids between the aggregate. The quantity should be such that between 65 and 70 % of the voids in the final compacted layer should be filled with binder.
  - The average depth of the layer of chippings, after construction and trafficking compaction, is approximately equal to the Average Least Dimension (ALD) of the chippings used.



# What is ALD?

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- The least dimension of an aggregate particle is the smallest perpendicular distance between two parallel plates through which the particle will just pass.
- The **Average Least Dimension (ALD)** is the arithmetic mean of all the measured least dimensions of the aggregate particles measured.
- **By Direct Measurement:** The ALD of an aggregate sample can be determined by measuring the least dimension of every particle in a 200 chip representative sample, and dividing the total of the least dimensions by the number of particles measured.
- **By Computation:** ALD can be determined using computational methods based on the Particle Size Distribution (Grading analysis) and the Flakiness Index.
- There is significant overlap with the Flakiness Index, used for many years as an aggregate characteristic in surface dressing design in Ireland, but international practice has shown that the Flakiness Index alone does not fully capture the shape properties required.



# Methods for Determining ALD

# Methods for Determining ALD

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- PMS were commissioned to conduct a **Research Study** to determine the most appropriate way of calculating the ALD using surface dressing aggregates from Irish quarry sources.
  - A total of **five different methods** were examined, two direct measurement methods and three computational methods.
  - The direct measurement methods are slow and time-consuming, and provide a baseline with which other faster methods of ALD computation can be compared.
  - Therefore, it is preferable to have a computational method where the ALD can be accurately calculated using test data available from normal test methods for surfacing aggregates (i.e. grading and flakiness index).
  - **Objectives:**
  - To assess the range of ALD values for Irish quarry sources.
  - To compare the three computational methods of estimating ALD against the direct measurement methods.
  - To recommend a computational method for calculating ALD.
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# Methods for Determining ALD

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- **Method 1 – Physical Measurement**

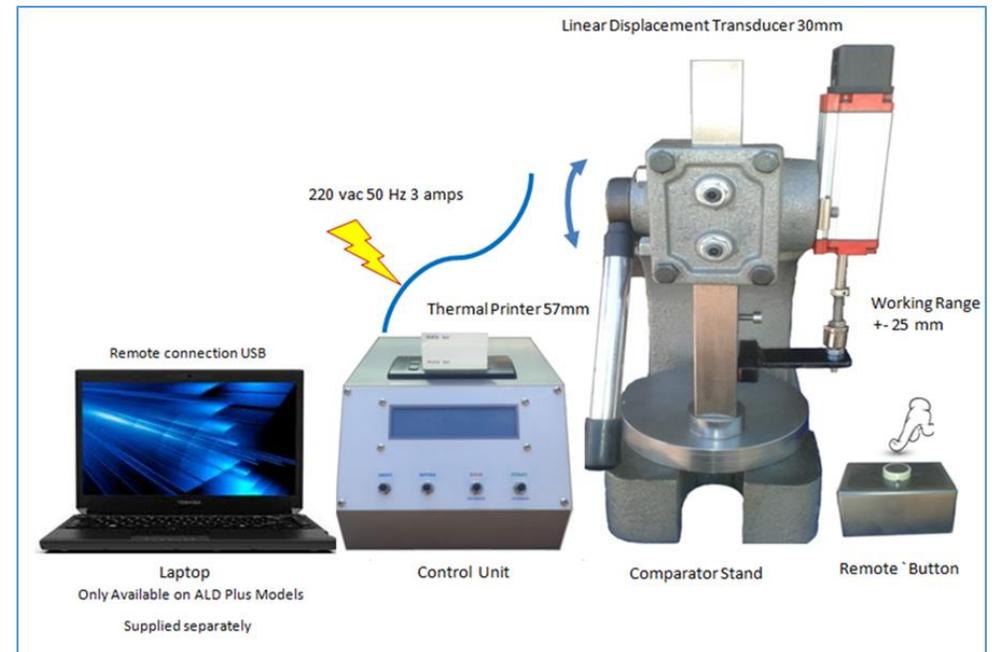
- Determined directly by physically measuring the least dimension of 200 representative chippings using a Vernier calipers.
- Extremely slow, tedious and time-consuming.



# Methods for Determining ALD

- **Method 2 – ALD Machine Measurement**

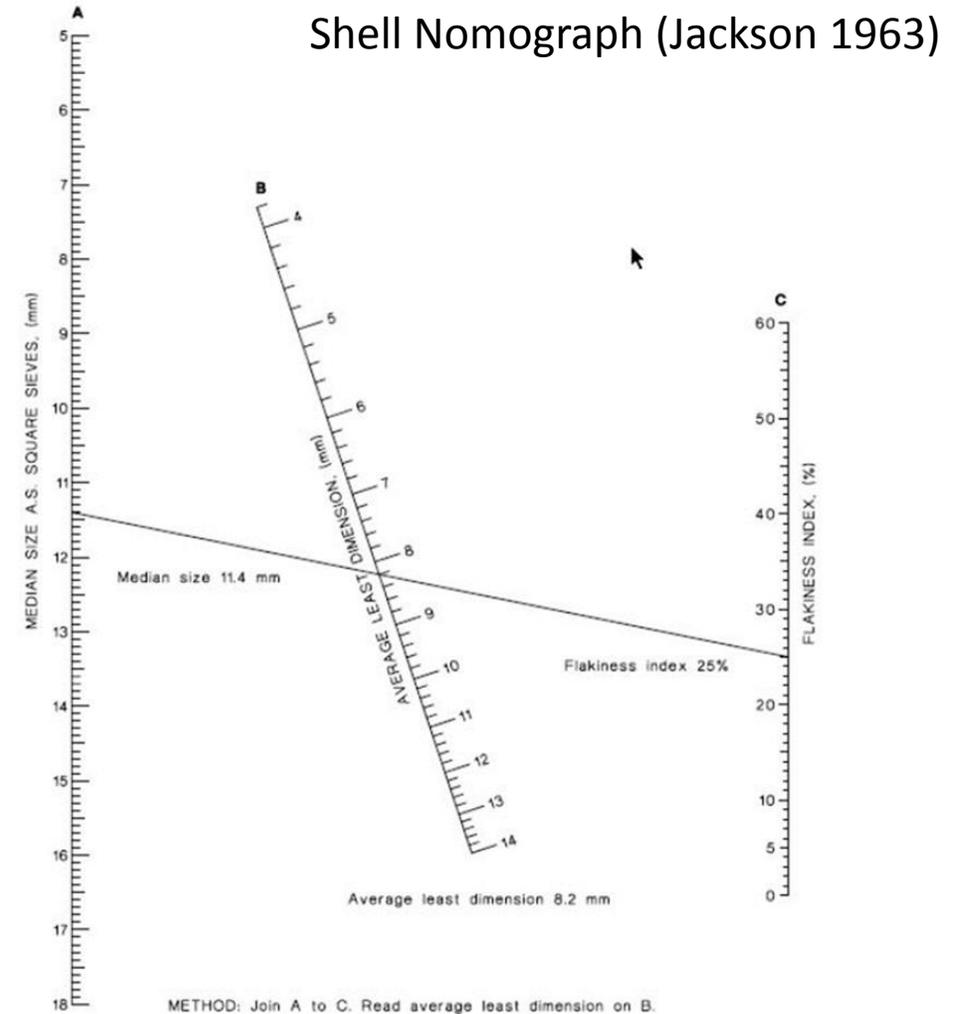
- Second method is a variation on the first, using a device developed in South Africa to automatically taking dimension measurements of the 200 representative chippings.
- Operated using a PC, ALD software and Control unit with the ALD value automatically calculated.
- Significantly faster than the Vernier calipers measurement, but still much too time-consuming for routine measurement of ALD.



# Methods for Determining ALD

- **Method 3 - Nomograph**

- Using a Nomograph (Shell 1963)
- Two key input parameters: Median Particle size and Flakiness Index (FI).
- The Median Particle size of aggregate is defined as the sieve size that 50% of the sample will pass through, and is determined by interpolation from a grading analysis.
- Grading analysis and FI determined from laboratory testing.



# Methods for Determining ALD

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- **Method 4 – Nomograph Equation**

- A computational equation developed to replicate the results obtained from the Nomograph.
- Again calculated using the input parameters of Median Particle Size and Flakiness Index.
- $ALD = (\text{Median Particle Size, mm}) / (1.139285 + (0.11506 \times \text{Flakiness Index}))$  (Source: NCHRP)
- In the Nomograph and Nomograph equation methods, the median is the only variable which describes the particle size distribution of the aggregate.

# Methods for Determining ALD

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- **Method 5 – DUMAS Equation**

- A new and more complex computational method developed by Dumas in South Africa in 2004.
  - The underlying principle of the Dumas method is that the median on its own cannot fully reflect the characteristics of the particle size distribution. Hence, more information is required besides the median.
  - The approach taken is to characterise the particle size distribution based on Percentage Passing and Percentage Retained on five sieves, rather than the single interpolated sieve used to define Median Particle size.
  - The Dumas approach is based on examination of the Percentage Retained (PR) from the gradation analysis for 5 different PR values, 10%, 25%, 50%, 75% and 90%.
  - The calculation process described by Dumas is quite complex, but can be replicated in an Excel spreadsheet, with the calculated ALD values derived from the full Gradation analysis and Flakiness Index results.
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# Research Study & Results

# Research Study

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- Sampling and Laboratory testing of 6mm, 10mm, 14mm and 20mm size chips.
  - From 8 Quarry Sources nationwide.
  - Total of 29 aggregate samples.
  - Grading and Flakiness Index were carried out on the aggregate samples from each source.
    - Grading: IS EN 933 Part 1
    - Flakiness Index: IS EN 933 Part 3
  - Direct (baseline) measurements of Average Least Dimension were carried out on the aggregate samples from each source.
  - Grading analysis and FI results were used to calculate the estimated ALD using the three computational methods: Nomograph, Nomograph equation and Dumas equation.
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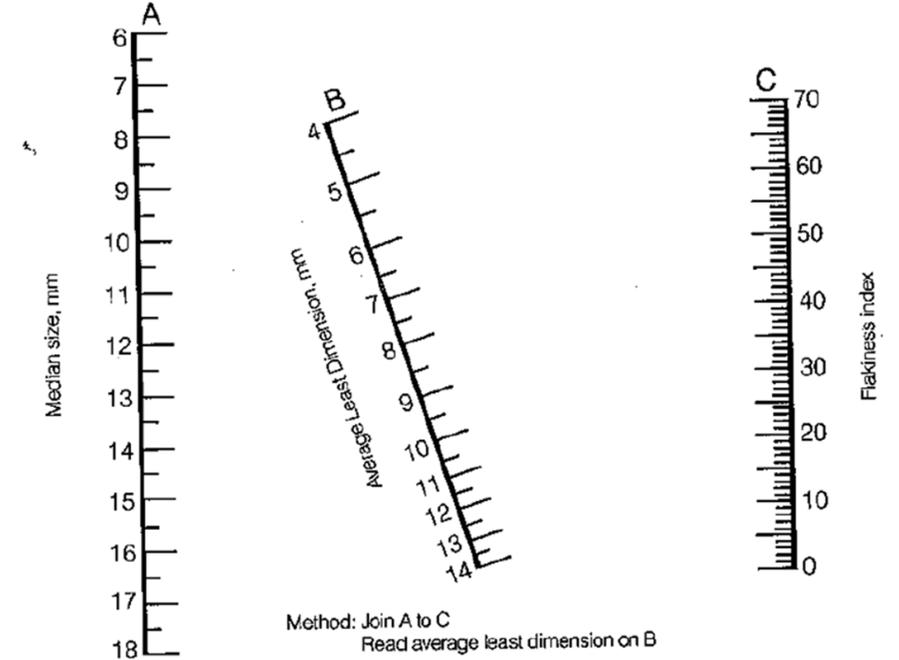
# Results of Study

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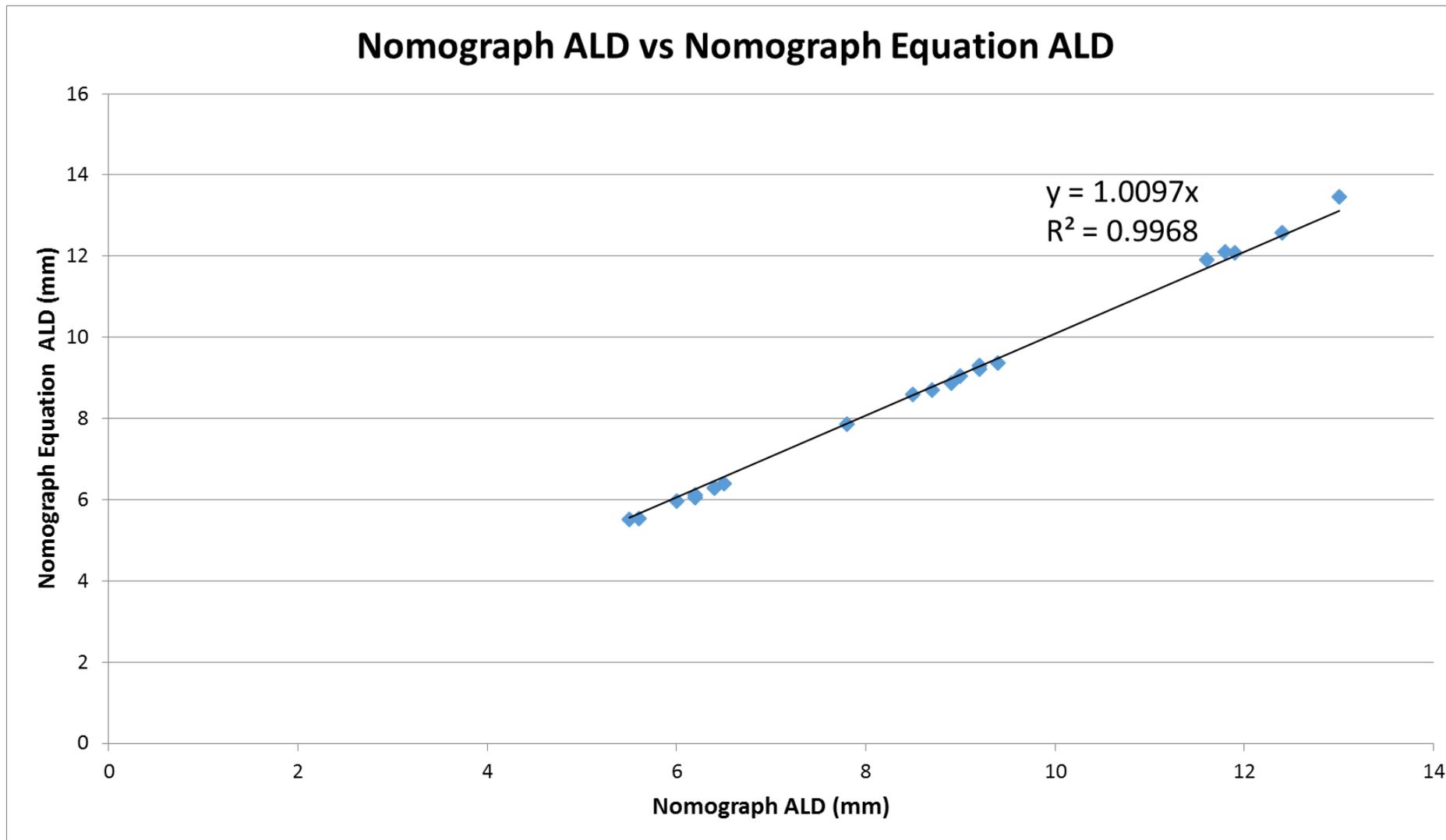
- ALD output results for the aggregate samples from all 8 sources included:
    - Machine measured ALD (Baseline)
    - Nomograph ALD
    - Nomograph equation ALD
    - Dumas equation ALD
  - The ALD values from the various methods were compared.
  - ALD measurements were made using the Vernier calipers (manual) for comparison with the ALD machine method using four different samples of aggregate.
  - Excellent agreement was obtained between the Manual measurement and ALD Machine measurement.
  - As the machine measured ALD approach is considerably faster than the manual measurement, the machine measurement approach was used for the remainder of the baseline measurements.
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# Results of Study

- ALD values for Irish Quarries ranged from 2 to 14.
- Values are in the range cover by the Nomograph.
- Range of values are similar to values calculated and used in New Zealand and South Africa.

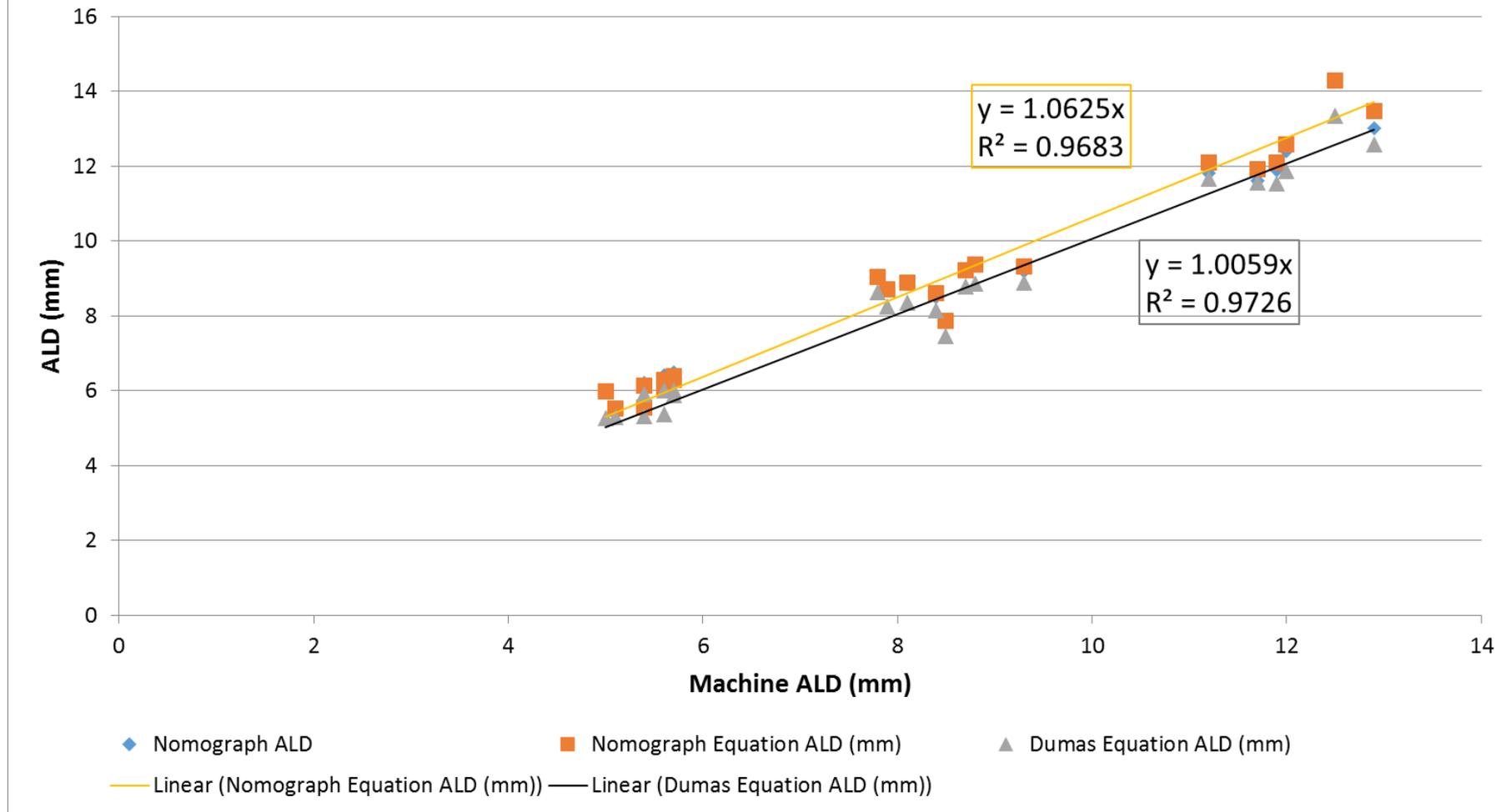


## Nomograph ALD vs Nomograph Equation ALD



- Very good agreement between the Nomograph ALD and Nomograph Equation ALD.
- Slope of almost 1, and  $R^2$  of 99.7%.
- It is much quicker and more efficient to use the equation rather than the Nomograph.

## Machine ALD vs Nomograph Equation & Dumas Equation ALD



- Dumas computed ALD yields an almost 1:1 relationship with the machine measured ALD - (Slope of 1.0059,  $R^2$  of 97.3%).
- Slightly poorer correlation between the Nomograph equation ALD and the machine ALD.
- Dumas equation gives a better relationship to the actual measured ALD.

ALD can be calculated from the standard Grading and FI data.

**ALD Calculator**

Reference No:

Flakiness Index (%):

Input the % Passing through each sieve below:

E.N. Sieve Size (mm)	% Passing
25	100.0
20	100.0
16	99.6
14	88.8
12.5	71.0
10	22.9
8	6.1
6.3	3.3
5	2.6
4	2.4
2	2.2
1	2.1
0.5	2.0
0.425	1.9
0.25	1.7
0.15	1.3
0.125	1.2
0.063	0.7
< 0.063	0.6

PR	SL	SU
10	8	10
25	10	12.5
50	10	12.5
75	12.5	14
90	14	16

PR = % Retained

SL = Sieve size where % passing is < PR

SU = Sieve size where % passing is > PR

The Median Particle size is: 11.4

The Nominal Particle size is: 14

Fr is: 3.3

ALD Nomograph Formula Value:

**ALD Dumas Equation Value:**

# Summary and Findings

# Summary

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- TII are developing a new analytical design approach for Surface Dressing on National roads.
  - The Average Least Dimension (ALD) of the chippings used is an essential parameter in the analytical design procedure.
  - ALD can be determined by direct measurement or by computational methods.
  - Research study conducted to determine the most appropriate way of calculating the ALD for Irish conditions.
  - Five different ALD methods were examined: two direct measurement methods and three computational methods.
  - A new device developed in South Africa to automatically measure ALD was used in the study.
  - Three computational methods examined: Nomograph, Nomograph equation and Dumas equation.
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# Findings

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- ALD values for Irish Quarries were in the range covered by the Nomograph and similar to those found in other countries.
  - The Nomograph equation ALD and the Dumas equation ALD both showed good agreement with the machine measured ALD, with the Dumas equation showing a better overall relationship.
  - It is recommended that the **Dumas approach should be used to determine the computed ALD** as it more fully reflects the characteristics of the particle size distribution of the aggregates, and its gives a better relationship to the actual measured ALD.
  - Using the Dumas computational method, ALD can be accurately calculated using test results from normal test methods for surfacing aggregates (i.e. grading and flakiness index).
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# Site Trials

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- New Analytical Design procedure being developed using the ALD concept to determine optimum rates of spread of binder and chippings for surface dressing.
- Other factors also included in the design procedure including traffic volume, condition of existing surface (texture, hardness), binder type, type of chip and type of site.
- **Surface dressing trials** have been carried out on 12 sites in 6 LA's.
  - Clare, Cork, Donegal, Kerry, Offaly, Wexford
- Outcomes of testing and monitoring of trials will be used to finalise the **Surface Dressing Analytical Design** procedure.
- This design approach will be incorporated in a forthcoming revision of **HD300/15: “Design of Bituminous Mixtures, Surface Treatments, and Miscellaneous Products and Processes”**.



**Thank You.**