journal homepage: www.pktm.my

International Journal of Technical Vocational and Engineering Technology

e-SSN2710-7094, Vol. 5, No. 1 (2024)

Development Of Elongation Index Test Kit 2.0

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ARTICLE INFO

Article History:
Received 31 January 2024
Revised 29 April 2024
Accepted 1 June 2024

Keywords:
Highway Engineering,
Aggregates Testing,
Elongation Index Test,
Innovation,
Elongation Test Kit,
Applications

ABSTRACT

This research discusses elongation index test gauges that have been developed into elongation index test kit phase 2 (ETK 2.0). Existing elongation index test have is time consuming as it involves repetitive measuring and weighing procedure. The limited number of elongation gauge available in the laboratory also only exacerbated the problem. ETK was innovated and put to the test to evaluate its accuracy and practicality throughout the elongation index test procedure and the calculation process. ETK 2.0 was designed according to British Standard (BS 812 - 105.2: 1990) with additions of the drawer for collecting the measured aggregates, a balancing weighing scale and with an application which will contains of elongation index test lab manual and automated data calculations. The materials used for ETK 2.0 main structures is mild steel. With 93.54% accuracy, ETK 2.0 practicality has been able to reduce the elongation index test procedure time by 28.9%. Meanwhile ETK 2.0 applications showed a practicality of 50.54% for time differences with 100% accuracy when compared to manual computations. In summary, ETK 2.0 has effectively accomplished its objectives. ETK 2.0 has demonstrated the ability to reduce computation time and expedite the elongation test procedure. Furthermore, accuracy of more than 90% demonstrates that ETK 2.0 is a valuable output in addition to being optimal. It is also respectable and reasonable.

1.0 Introduction

Aggregate plays an important role in pavement construction. Aggregates influence, to a great extent, the load transfer capability of pavements. Therefore, it is imperative that they undergo extensive testing prior to being utilized in construction. Not only that aggregates should be strong and durable, they should also possess proper shape and size to make the pavement act monolithically. Strength, toughness, hardness, shape, and water absorption are all assessed in aggregates. The following tests, such as the crushing, abrasion, impact, soundness, shape, and others, are performed to determine whether the aggregate is suitable for use in pavement construction (Padhi, 2015).

The percentage of flaky and elongated aggregate present in the entire aggregate sample is determined by aggregate shape tests like the Elongation and Flakiness Index Test, which are crucial and need to done on aggregates in the laboratory (Mahajan, 2020). The use of flaky, elongated aggregates in construction should be discouraged since their flat and elongated shape makes them prone to breaking, either during pavement building or later under traffic (Carlos, 2022).

The elongation index test also been conducted at Highway Laboratory, Merlimau Polytechnic for educational purposes. Based on studies and interviews, numerous issues have been discovered while conducting this test. These issues include the gauge's existing physical parts, the repeated procedure during testing and computations, and the availability of testing apparatus in the laboratory.

The existing elongation gauge does not have a component for gathering the aggregates that are being tested. Every step for every sieve size requires the tester to gather the tested aggregates, arrange them in multiple basins or trays by the size of the sieve, and repeatedly weigh them. The aggregates also prone to get mix easily and will slow down the process of the test (Faizul, 2020).

Elongation Index Test requires are time-consuming since it need repetitive process of testing each individual aggregate particle of a particular sieve size using the existing gauge, collecting the aggregates, weighing them, recording the results, and computing the data accordingly. The physical components of the current gauge are extremely basic and have limited functionality, which makes the testing process more repetitious and takes longer time (Mustafa, 2022).

There aren't many elongation index test machines in the lab, so users have to share and wait their turn to use one. The waiting and testing times are extended by sharing the equipment, which includes trays, weighing scales, and the elongation gauge itself. Exacerbate the situation if the current equipment is outdated (Jama'on, 2022).

As to address the issues that have been discovered, there is a need to produce elongation index test gauge that is innovative and meets the established standards (accuracy and practicality) as to make it beneficial to educators, students, and other relevant stakeholders in the civil engineering sector.

The innovation needs to incorporate new components by altering the product's design, adding innovative elements and Fourth Industrial Revolution (IR 4.0) concepts. Nonetheless, the initial elongation gauge sieve size measurements will remain the same as on British Standard, BS 812: 105.2: 1990.

As a result, the Elongation Index Test Kit 1.0 (ETK 1.0) was developed and evaluated. Since the data obtained reveals ETK 1.0 shortcomings, hence the findings will serve as a guide for ETK 2.0 development. Therefore ETK 2.0 will also be designed as a toolbox that includes a weighing balance scale as a new feature to weigh the measured aggregates, larger size drawers to hold the measured aggregates, and a new interface of ETK applications that consists of a laboratory manual and calculator for computing the test data via QR Code. Mild steel was selected as the material of choice for the main body structures because of its excellent strength, resistance to corrosion, durability, superior workability, good ductility, ease of formability and fabrication, and minimal maintenance requirements.

ETK 2.0 will be evaluate and compared with the existing elongation gauge and ETK 1.0 as to assess its practicality and accuracy. The error rate of the aggregate weight measured for each sieve size will be recorded to determine the accuracy of ETK 2.0. Besides that, the error rate of data calculated using the application and calculated manually will also be evaluated. Time will be tracked, both during the testing and calculation phases to assess the practicality of the ETK 2.0. By comparing the existing gauge and ETK 1.0 to ETK 2.0, it will show the accuracy percentage along with the practicality percentage of time that can be speed up while using ETK 2.0 in laboratory.

2.0 Literature review

Aggregate is a collective term for the mineral materials such as sand, gravel, and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as bituminous concrete and Portland cement concrete). Aggregate typically contributes up 92% to 96% of the volume of bituminous concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. As they comprise the majority of pavement volume. Therefore, knowledge of aggregate properties is crucial in designing a high-quality pavement (Mathew, 2010).

The performance of the pavement is directly and significantly impacted by the aggregate's characteristics. Studies have indicated that aggregate properties including size, shape, and texture affect how well pavement performs and how long will it last (Brown et al. 1989).

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Figure 1: Shape of Aggregates

Proper compaction, deformation resistance, and workability are dependent on the shape and surface texture of the aggregate particles (Figure 1). It is not desirable for HMA mixtures to contain an excessive amount of flaky and elongated aggregate particles since these particles tend to break down during production and construction, which affecting the durability of pavement (Kandhal and Parker, 1998). Meanwhile according to Shiuh (2005), cubical aggregate demonstrated the best resistance to rutting, while flaky and/or elongated displayed lower compatibility and greater breakage.

Particles having a rough surface texture and a cubic angular shape work best as aggregates in pavement construction because they interlock to provide strength and rigidity. Better workability and easier compaction are provided by rounded particles since they cause less interlocking between the particles than angular particles. Less interlock in the pavement is generally a disadvantage as rounded aggregate will continue to compact, shove and rut after construction. Thus, angular particles are desirable for Hot Mix Asphalt (HMA) (despite their poorer workability), while rounded particles are not desirable (PCA, 1988).

Since aggregates are the main component of mixtures for bituminous concrete. When aggregates are chosen and used improperly, pavement distress such as rutting, stripping, surface pop outs, and insufficient surface frictional resistance might be directly linked. Undoubtedly, aggregate selection based on the results of proper aggregate tests is necessary for attaining desired performance (Privithi S. Kandhal, 1997).

2.1 Elongation Index Test

For determining elongation index. Particle is consider elongated when its length (longest dimension) is more than 1.8 of the midsize of the sieve fraction. Aggregate to be classified is separated into seven sieve fractions from 63 to 6.3mm, and each fraction is examined separately. Six labelled openings between pairs of metal pins measure particle from each of the six sieve cuts below 50mm. The mass of all elongated particles (failing to pass between pins) as percent of the sample is the elongation index (BS Technical Committee, 1990).

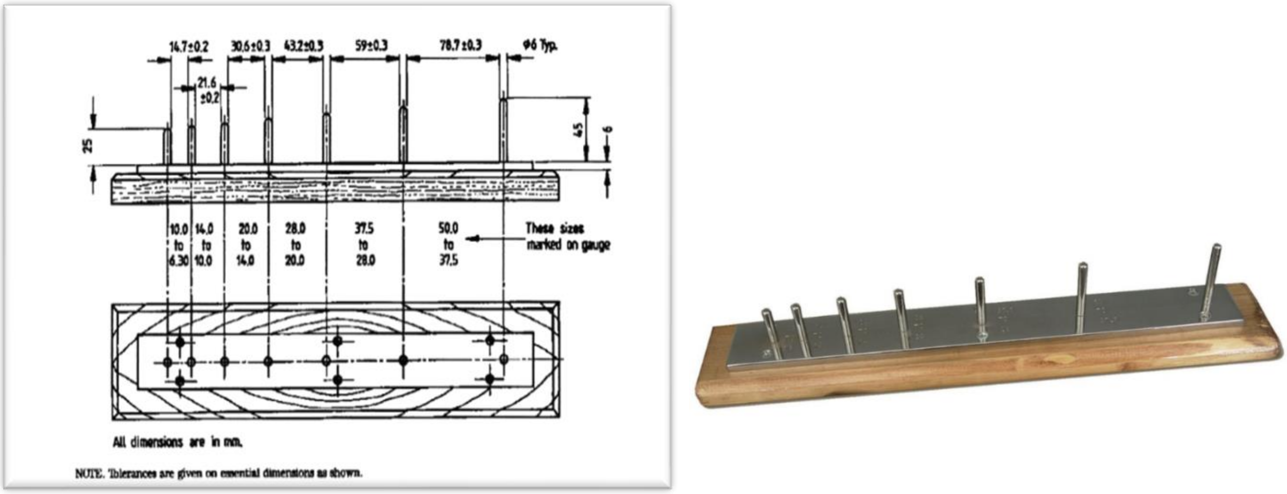

Figure 2: Elongation Gauge

2.1.1 Apparatus

i. A sample divider, of size appropriate to the maximum particle size to be handled or alternatively a flat shovel and a clean, flat, hard horizontal surface, e.g. a metal tray for use in quartering.

ii. A ventilated oven, thermostatically controlled to maintain a temperature of 105 ± 5°C.

iii. A balance, or balances, of suitable capacity accurate to 0.1 % of the mass of the test portion.

iv. Test sieves, of the sizes and apertures appropriate to the specification of the material being tested, complying with BS 410 for square hole perforated plate and with the appropriate sizes of lids and receivers.

v. A mechanical sieve shaker (optional)

vi. Trays, of suitable size, which can be heated in the ventilated oven (5.2) without damage or change in mass

vii. Metal length gauge/elongation gauge as shown in Figure 2.

2.1.2 Procedure

i. Carry out a sieve analysis. Discard all the aggregate retained on the 50 mm test sieve and all the aggregate passing the 6.30 mm test sieve.

ii. Weigh each of the individual size fractions retained on the test sieves, other than the 50.0 mm test sieve, and store them in separate trays with their size marked on the trays.

iii. From the sums of the masses of the fractions in the trays (M1) calculate the individual percentage retained on each of the various test sieves. Discard any fraction whose mass is 5% or less of mass M1. Record the mass remaining (M2).

iv. Gauge each fraction as follows. Select the length gauge appropriate to the size fraction under test and gauge each particle separately by hand. Elongated particles are those whose greatest dimension prevents them from passing through the gauge, and these are placed to one side.

v. Combine and weigh all the elongated particles (M3).

2.1.3 Calculation and expression of the results

The value of the elongation index is calculated from the expression:

$$\text{Elongation Index} = (M3 / M2) \times 100$$

where: -

M2 is the sum of the masses of fractions that have a mass greater than 5 % of the total mass.

M3 is the mass of all the elongated particles. Express the elongation index to the nearest whole number.

3.0 Methodology

The ETK 2.0 development process consists of multiple steps, including design of the product, preparation of the material, production, and testing; all of these are grounded from the problems statement and the predefined objectives as shown in Figure 3. ETK 2.0 was divided into two sections: one for the main body structure and one for the application.

ETK 2.0 body structures were produced in workshops. Thunkable Apps, a free application, was selected to be utilized. Once the ETK 2.0 produced, it will be compared to the current elongation gauge and ETK 1.0 as to evaluate the accuracy and practicality of the structures and applications.

ETK 2.0 accuracy will be determined by comparing the Elongation Index Test data of each size fraction during testing (BS 812: 105.2: 1990) and data result during computation (application). As for practicality, the duration of time spent during testing and computation (application) while using ETK 2.0 and the current elongation gauge and ETK 1.0 will be recorded and compared. The collected data then will be analysed, summarized, and recommendations will be made in accordance with the objectives.

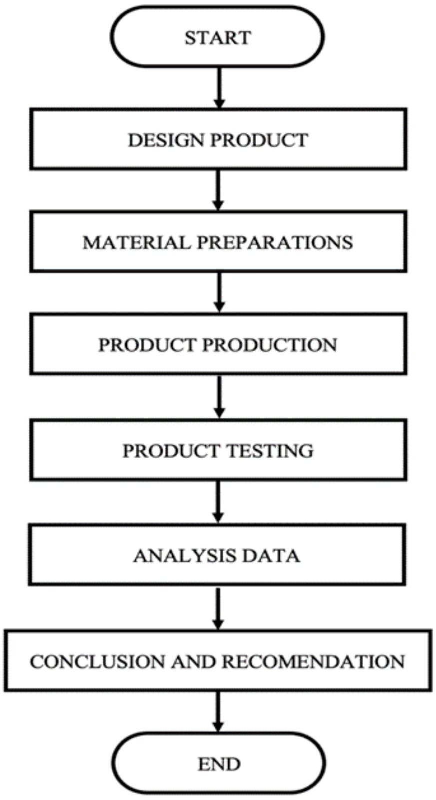

Figure 3: Methodology Flowchart

4.0 Discussion of analysis and findings

Based on the objectives to be achieved, scope and methodology that had been constructed, data analysis will be presented by objective accordingly.

4.1 Innovative Elongation Index Test Kit 2.0 (ETK 2.0)

The ETK 2.0 was designed as a toolbox that includes an elongation index test gauge that is in accordance with British Standard BS 812: 105.2: 1990, drawers to hold the measured aggregates, a balance weighing scale and an ETK applications which has laboratory manual and calculator for computing the test data via QR code and a balance weighing scale, as shown in Figure 4.

Figure 4: Elongation Test Kit 2.0 (ETK 2.0)

Materials used for the main body structures is mild steel as the material are high strength, corrosion resistance, durable, better workability, good ductility, easy formability and fabrication and low maintenance. Table 1 show the specification of the ETK 2.0 compared to existing elongation gauge compared and ETK 1.0.

Table 1: The Elongation Gauge vs Elongation Test Kit Specification

Specification	 **Elongation Gauge**	 **ETK 1.0**	 **ETK 2.0**
Weight,	1.00kg	6.09kg	6.5 kg
Size, mm (w x l x h)	70 x 370 x 70	300 x 360 x 140	215 x 295x 140
Materials	Base: Cengal Wood Measuring gauge: Stainless steel rod and plate	Main structures: Waterproof Plywood Measuring gauge: Stainless steel and mild steel flat bar Drawer: Stainless steel sheets	Main structures: Mild steel
Elements	Base Measuring gauge	Main structure toolbox Measuring plate Storage drawer per fraction size Application	Main structure toolbox Measuring plate Storage Drawers Weighing scale Application

As expected the ETK 2.0 toolbox-like form makes it convenient to carry and store in addition to being appropriate for the adding elements. In the meantime, the elements drawer which have been designed bigger then ETK 1.0, alongside with the new additional of balance weighing scale built in elements do helps to simplify and fasten the test procedure step by able to collect and weigh the measured aggregates without additional apparatus needed.

Even after considering and taking into account the ETK 1.0 shortcoming when designed ETK 2.0, there are still drawbacks with ETK 2.0. The primary drawback in the design is that the ETK 2.0 weighs more than the other two dues to the modifications in size, composition, larger drawer components, and the addition of a balancing weighing scale. Besides that, the placement of balance weighing scale in the toolbox need to be reconsidered as it unable to weigh the measured aggregates directly.

The QR code that is affixed to the ETK 2.0 is shown in Figure 5. Scanning the code will take the user immediately to the ETK applications, which include a calculator for calculating the test results and a laboratory handbook. Regarding the IR 4.0 components, the ETK application has been coded correctly and provides the required result. The only drawback is that iOS users are unable to utilize this application.

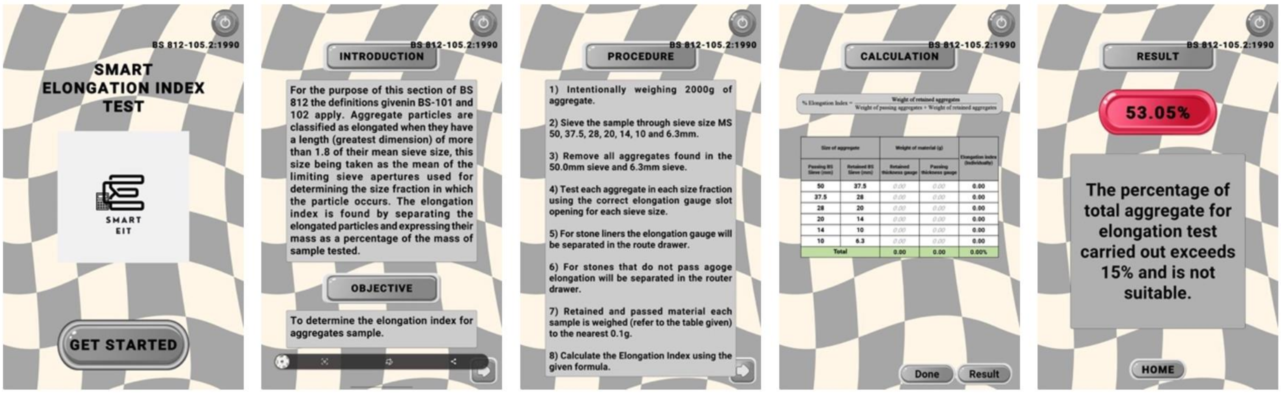

Figure 5: ETK 2.0 Application

4.2 Accuracy of Elongation Index Test Kit (ETK)

The accuracy percentage of ETK compared to existing gauge test procedure shown in Table 2 and Table 3.

Table 2: Data of Accuracy during Elongation Test Procedure

Tester	ETK 1.0 Accuracy Percentage		ETK 2.0 Accuracy Percentage	
	Passing	Retained	Passing	Retained
1	80.93	81.92	97.67	93.34
2	80.88	79.84	91.83	96.26
3	79.96	73.29	91.55	90.65
Average	80.59%	78.35%	93.68%	93.41%
	79.47%		93.54%	

Accuracy for test procedure using ETK 2.0 is 93.54% compared to ETK 1.0 which only 79.47% as shown in Table 2 above. The 6.46% of error rates of ETK 2.0 test measurement were occur at sizes 20, 14 and 6.3mm by tester no.2 and no.3. These errors were caused by the repetitive process of small size aggregates physical measurement which even at the utmost of care it's still unavoidable even been conducted using the same aggregates sample and same tester as a control measure.

Table 3: Data of Accuracy during using ETK Application

Tester	Elongation Index (%)			Error Rate	Accuracy
	Manual Calculation	ETK 1.0 Apps Calculation	ETK 2.0 Apps Calculation		
1	22.61 %	22.61 %	22.61 %	0 %	100 %
2	24.81 %	24.81 %	24.81 %	0 %	100 %
3	23.59 %	23.59 %	23.59 %	0 %	100 %
			Average	0 %	100 %

Meanwhile for ETK application accuracy, the same data from the testing either from ETK or existing gauge will be calculated manually and by using the application. With 0% of error rate, hence the application gives 100% of accuracy for the calculations procedure as shown in Table 3. According to Barkved (2023), accuracy ranging from 70% to 90% indicates that the product is not only excellent but also respectable, practical, and a value output. This indicates that ETK 2.0, which has accuracy above 90%, is a legitimate innovation that can be employed in a laboratory.

4.3 Practicality of Elongation Index Test Kit 2.0 (ETK 2.0)

Practically of the product will be evaluated by comparing time taken by using the ETK 2.0, ETK 1.0 and existing gauge during the test procedure and during the calculating procedure.

Table 4: Data of Time Taken during Elongation Test Procedure

Tester	Test Procedure Time (second, s)			Percentage Of Time Difference (%)	
	Elongation Gauge	ETK 1.0	ETK 2.0	ETK 1.0	ETK 2.0
1	2200	2085	1500	5.23	31.82
2	1620	1542	1220	4.81	18.52
3	1980	1871	1260	5.51	36.36
Average Percentage of Time Difference, %				5.18 %	28.9 %

Table 4 shows the recorded amount of time spent on the test procedure. The statistics indicates that the ETK 2.0 can save 28.9% compared to ETK 1.0 which can save only 5.18% percent of time. Even though the percentage is small, the inclusion of the balance weighing scale and the sizing up of the collecting drawers can nevertheless speed up the operation by 23.72% when compared to ETK 1.0. The observations indicate that the process is slowed down by the placement of the balance weighing scale, which is unable to immediately weigh the measured aggregates. Therefore, it is definitely possible to raise the practicality percentage with a small change to balance the placement of the weighing scale.

Table 5: Data of Time Taken during the Elongation Test Calculation Process

Tester	Calculation Procedure Time (second, s)			Percentage of Time Difference, %	
	Manual Calculation	ETK 1.0 Apps Calculation	ETK 2.0 Apps Calculation	ETK 1.0	ETK 2.0
1	120	60	60	50.00	50.00
2	123	61	60	50.41	51.22
3	121	60	60	50.00	50.41
Average Percentage of Time Difference				50.14%	50.54%

In contrast to manual calculation, Table 5 shows how the ETK 2.0 application's practicality can save or speed up computation times by 50.54% and ETK 1.0 by 50.14%. The average percentage remains consistent since ETK 2.0 was coded precisely like ETK 1.0 application, which were precise and error-free when it was coded in the past. As anticipated, the automation of the computations using IR 4.0 does increase productivity, efficiency, and flexibility.

5.0 Conclusion and future research

The Elongation Test Kit 2.0 (ETK 2.0) has been developed in a productive manner, and the study's goals have been met. In general, ETK 2.0 is creative, functional, and practically capable of streamlining the process. It has been demonstrated that ETK 2.0 may expedite the elongation test process and calculation in real-world scenarios. Given that the accuracy range exceeds 90%, ETK 2.0 appears to be the best option as well as a dependable and a practical solution.

As for recommendations, redesigning the ETK 2.0's main body structures to make it more lightweight and compact is suggested. Additionally, in order to speed up the testing procedure, balancing weighing scales must be positioned right beneath the drawers so that the aggregates may be measured immediately. In the interim, the apps must be user-friendly, available to iOS users, and provide up-to-date material.

Furthermore, it is important to reduce the variables that affect ETK 2.0 accuracy and practicality. Human error is the main reason why this study was not able to reach 100% accuracy. Measurements of the elongation index can also vary due to human error. As a result, it is suggested that the tester possess knowledge and expertise in order to generate accurate and trustworthy results for accuracy as well as practicality. The fundamental goal of ETK 2.0 innovations can still be achieved by keeping up the development and enhancement of ETK 2.0 inefficiencies.

Acknowledgements

Grateful acknowledgment is made to lecturers, technicians and students at the Department of Civil Engineering, Merlimau Polytechnic's, in Malacca, Malaysia, for their assistance with this research.

Author Contributions

Nurfazilah Mat Salleh: Conceptualization, Methodology, Software, Writing- Original Draft Preparation, Validation; Azah Abas: Supervision, Project Adminstration, Writing-Reviewing; Nurul Saidatul Fitri binti Mohd Zamri: Resources, Investigation, **Siti Nurain Norizal:** Software, Writing-Reviewing and Editing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its Submission and declare no conflict of interest in the manuscript.

6.0 References

BS Technical Committee, C. (1990). Bristish Standard, BS 812-105.2: 1990. London: BSi 12-1998.

Carlos. (2022). LegitCivil. Retrieved from https://legitcivil.com/how-do-you-calculate-elongation-index/

Faizul, F. N. (2020, August). Civil Engineering Student. (N. S. Zamri, Interviewer)

Jama'on, J. b. (2022, August). Civil Engineering Lecturer. (A. b. Abas, Interviewer)

Kandhal, P. S., and Parker, F. J. (1998). Aggregate Tests Related to Asphalt Concrete Performance in Pavements, National Cooperative Highway Research Program Report 405, Transportation Research Board, National Research Council, Washington, D.C.

Mahajan, B. (2020). Civiconcepts. Retrieved from https://civiconcepts.com/blog/flakiness-and-elongation-index

Mathew, P. T. (2010). Transportation System Engineering: Pavement Materials : Aggregates. Retrieved from https://www.civil.iitb.ac.in/tvm/1100_LnTse/404_lnTse/plain/plain.html

Mustafa, S. H. (2022, August). Civil Engineering Student. (N. S. Zamri, Interviewer)

Padhi, S. (2015). CivilBlog.Org. Retrieved from https://civilblog.org/2015/09/12/7-lab-tests-on-aggregate-to-check-quality-for-use-in-road-work/

Pavement Interactive. (2022). Retrieved from https://pavementinteractive.org/reference-desk/testing/aggregate-tests/flat-and-elongated-particles/

Portland Cement Association (PCA). (1988). Design and Control of Concrete Mixtures. Portland Cement Association. Skokie, IL

Privithi S. Kandhal, F. P. (1997). Aggregate Test for Hot-Mix Asphalt, State of the Practice. Washington, D.C: Transportation Research Circular.