Evaluation of Fine and Coarse Aggregates in Concrete Mixtures: A Comprehensive Analysis According to ASTM Standards

Lab Report

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A report presented for

The Civil Engineering Materials of Construction Course

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April 3, 2024

Abstract

In this lab report, we follow ASTM guidelines for sieve analysis to look at the fine and coarse particles that go into concrete. The goal is to assess the aggregates' properties to find out how they affect the performance of concrete, which will help improve the building's structural integrity and longevity. The results show that, with a few notable exceptions that call attention to potential problem areas, the algorithmic analysis and visual representations show that the results are generally in line with the criteria that have been set. The significance of careful aggregate selection is highlighted by this study, which also proposes avenues for further investigation into sustainable building materials.

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1 Introduction

Concrete is a widely used building material in today's construction industry. Its ultimate properties and usefulness in building are determined by its composition, which is a combination of water, cement, and aggregates. The final strength, durability, and performance of the concrete are greatly affected by the aggregates' quality and characteristics. Aggregates may be either fine or coarse particles. For building projects to remain intact and of high quality, it is crucial to thoroughly evaluate their attributes before adding them to concrete mixtures.

In this lab report, we follow the guidelines set forth by the American Society for Testing and Materials (ASTM) to systematically evaluate both fine and coarse aggregates. The purpose of these tests is to assess aggregates' vital characteristics, and one of them is sieve analysis. Ensuring the trustworthiness of the findings, the testing method adheres to ASTM standards. This confirms that the aggregates are suitable for use in concrete mixes.

This study aims to clarify the methods used to characterise aggregates, evaluate how aggregate attributes affect concrete performance, and deduce aggregate quality from the results of these lab tests. The study's overarching goal is to improve the structural effectiveness and durability of building projects by optimising concrete compositions using this analytical technique.

2 Summary

The purpose of this lab report is to assess the properties of concrete using fine and coarse aggregates in accordance with ASTM standards. Researchers used systematic sieve analysis to evaluate aggregate quality and its effects on the performance of building materials as aggregates are crucial in making concrete strong and long-lasting. The necessity to optimise concrete compositions via a rigorous investigation of aggregate qualities in order to increase structural integrity and durability in construction projects is the driving force behind this work.

In order to characterise the distribution of particle sizes, the experiments required careful sample preparation, sifting, and analysis. In order to quantify gradation, aggregate samples were partitioned using a series of standard ASTM sieves. On top of that, we used a strict experimental setup that kept everything under control throughout testing to make sure the findings were accurate and reliable.

The aggregates' appropriateness for use in concrete was established by meticulously examining the results of the sieve examination. With the exception of differences at certain

sieve sizes, the majority of samples met the necessary criteria. These results confirm that aggregate selection is crucial in concrete mix design and provide directions for further research, especially on the unusual occurrences.

In conclusion, the study sheds light on how aggregate quality affects concrete's performance, demonstrating the need for rigorous assessment methodologies to ensure the structural effectiveness of building materials.

3 Theory

3.1 Definitions

Let A be a set representing an aggregate sample subjected to sieve analysis. We define a function $d : A \to \mathbb{R}_+$ that assigns a diameter to each particle in A, thereby mapping each aggregate particle to its corresponding size.

Consider a finite ordered set $\Sigma = \{\sigma_1, \sigma_2, \dots, \sigma_n\}$, where each σ_i represents a sieve with a specific mesh opening, and $\sigma_i < \sigma_{i+1}$ for all i, indicating a strict order from the finest to the coarsest sieve.

3.2 Partition of Aggregate Set

The sieve analysis procedure effectively partitions the set A into disjoint subsets

$$A_1, A_2, \dots, A_n, A_{n+1},$$

such that A_i contains particles that pass through sieve σ_{i-1} but are retained by sieve σ_i for $2 \leq i \leq n$, with A_1 being particles finer than σ_1 and A_{n+1} being particles coarser than σ_n. Formally, for each particle $a \in A$, $a \in A_i$ iff $\sigma_{i-1} < d(a) \leq \sigma_i$ with the convention that $\sigma_0 = 0$ and $\sigma_{n+1} = \infty$.

3.3 Quantification of Gradation

Let $m : \mathcal{P}(A) \to \mathbb{R}_+$ be a mass function defined on the power set of A, where $m(B)$ gives the total mass of any subset $B \subseteq A$. The size distribution is then characterized by the relative masses of these partitions:

$$p_i = \frac{m(A_i)}{m(A)}$$

for $1 \leq i \leq n+1$, where p_i represents the proportion of the total aggregate mass that falls within the size range corresponding to A_i.

3.4 Cumulative and Differential Representation

Define the cumulative mass distribution function $F : \Sigma \cup \{\infty\} \to [0, 1]$ by

$$F(\sigma_i) = \sum_{j=1}^{i} p_j$$

for $1 \leq i \leq n+1$, and the differential mass distribution function $f : \Sigma \to \mathbb{R}_+$ by $f(\sigma_i) = p_i$ for $1 \leq i \leq n$.

3.5 Mathematical Objectives

The sieve analysis aims to determine F and f for a given aggregate sample A.

4 Methods

4.1 Experimental Design

The experiment used a single-group design that primarily focused on the sieve analysis of concrete aggregates, according to the requirements set by ASTM C 136. This research did not include groups for comparison, but instead focused on closely examining the overall distribution of grades within a single set of samples. The aggregates underwent mechanical sifting to ascertain their particle size distribution.

4.2 Materials

The primary materials utilized in this procedure included:

1. A comprehensive set of ASTM standard sieves, arranged in a descending order of mesh size.

2. An electronic balance with precision up to 0.01 g for mass determination.

3. A mechanical sieve shaker, facilitating consistent sieve agitation.

4. An oven set to a constant temperature of $110°C$ for drying aggregate samples.

5. A sample splitter, for reducing the aggregate samples to a manageable size for testing.

4.3 Experimental Settings

The sieve analysis was performed in a controlled environment to guarantee the precision and dependability of the results. The laboratory maintained a consistent room temperature of $23 \pm 2°C$ and regulated humidity levels to avoid any moisture absorption or loss from the aggregate samples throughout testing. Every piece of equipment used, including sieves and the mechanical shaker, underwent thorough inspection to verify adherence to ASTM criteria, guaranteeing uniformity in measurements.

5 Procedures

We strictly adhered to the steps specified in the ASTM C 136 standard when we analysed the concrete aggregates by sieve analysis. The first step was to dry the aggregate samples in an oven at $110°C$ until they reached a consistent mass, which would eliminate any weight fluctuations caused by water content and guarantee accurate findings. The sample was delicately put onto the sieve with the largest mesh size once it had dried.

In order to get the particles to flow freely through the sieves, the sample was shaken using a mechanical sieve shaker for at least 10 minutes. This procedure allowed the aggregate particles to be sorted into different sieves according to their size.

After the shaking time was over, we took the sieves out of the stack and weighed the aggregate that remained on them. The electronic balance was used to record the aggregate mass on each sieve to the closest 0.01 g. The data provided was vital for computing the aggregate sample's particle size distribution, which is critical for assessing the material's appropriateness for certain concrete uses.

Using the mass of aggregates retained, the total and individual passing percentages for each sieve were determined. The gradation of the aggregate sample affects the workability, durability, and strength of the concrete; these percentages provide light on that.

Following the strict guidelines specified by ASTM C 136, this study's sieve analysis method effectively quantified the aggregate's particle size distribution. By using this systematic procedure, we were able to get reliable and repeatable findings that will be useful for evaluating the aggregate characteristics of concrete.

6 Analysis

Algorithm 1 Analysis of Aggregate Size Distribution

Require: $\mathbf{S} = \{s_1, s_2, \ldots, s_n\}$, a vector of sieve sizes in mm
Require: $\mathbf{P}_{\text{C16}}, \mathbf{P}_{\text{B1}}, \mathbf{P}_{\text{A1}}, \mathbf{P}_{\text{U16}}$, vectors of percentage passing for each sample
Ensure: Plot of grain size distribution for samples C16, B1, A1, and adjusted U16

procedure PREPAREDATA($\mathbf{S}, \mathbf{P}_{\text{C16}}, \mathbf{P}_{\text{B1}}, \mathbf{P}_{\text{A1}}, \mathbf{P}_{\text{U16}}$)
    $\mathbf{W} \leftarrow$ np.cumsum($\mathbf{P}_{\text{U16}}$) ▷ Compute cumulative sum of weights
    $W_{\text{total}} \leftarrow \sum \mathbf{W}$ ▷ Total weight
    $\mathbf{P}_{\text{cumulative}} \leftarrow 100 \cdot (1 - \frac{\mathbf{W}}{W_{\text{total}}})$ ▷ Cumulative percentage passing
end procedure

procedure PLOTDATA($\mathbf{S}, \mathbf{P}_{\text{C16}}, \mathbf{P}_{\text{B1}}, \mathbf{P}_{\text{A1}}, \mathbf{P}_{\text{cumulative}}$)
    Set plot parameters (dpi, style, etc.)
    Plot $\mathbf{S}$ vs. $\mathbf{P}_{\text{C16}}, \mathbf{P}_{\text{B1}}, \mathbf{P}_{\text{A1}}, \mathbf{P}_{\text{cumulative}}$
    Customize plot (axis labels, title, scale, legend)
    Save and display plot
end procedure

`To get the Python code, go to Appendix 1, Code 1, 2 & 3.` [1]

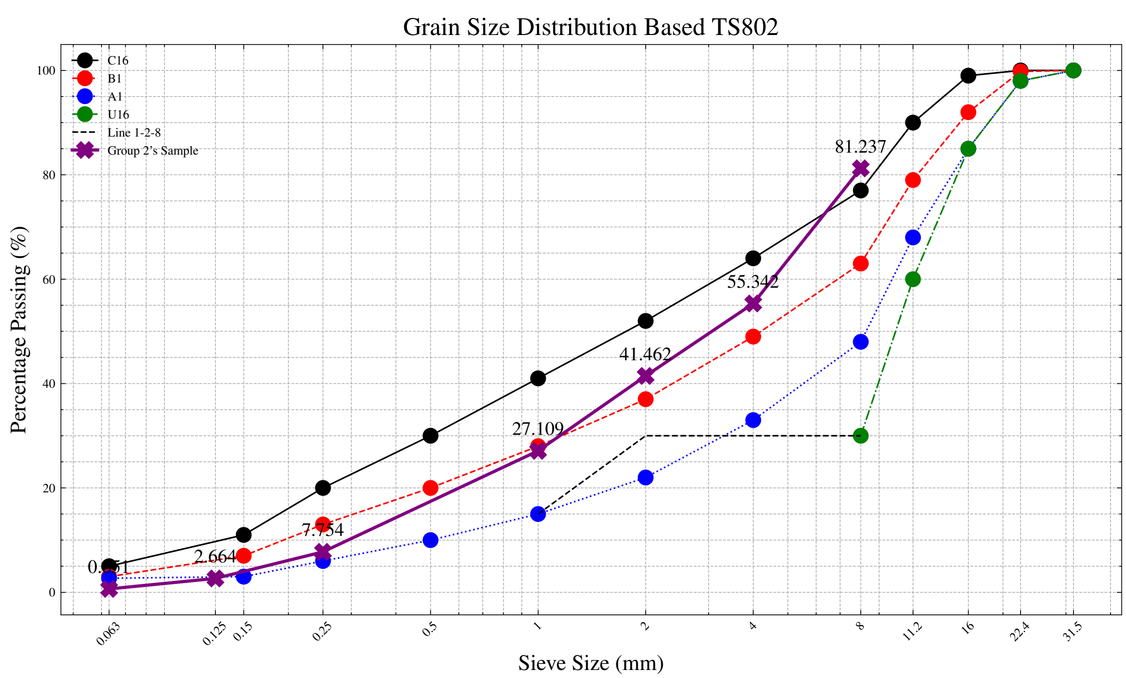

Figure 1: Sieve analysis results displayed in accordance with TS802 standards, showcasing the gradation curves for aggregate samples.

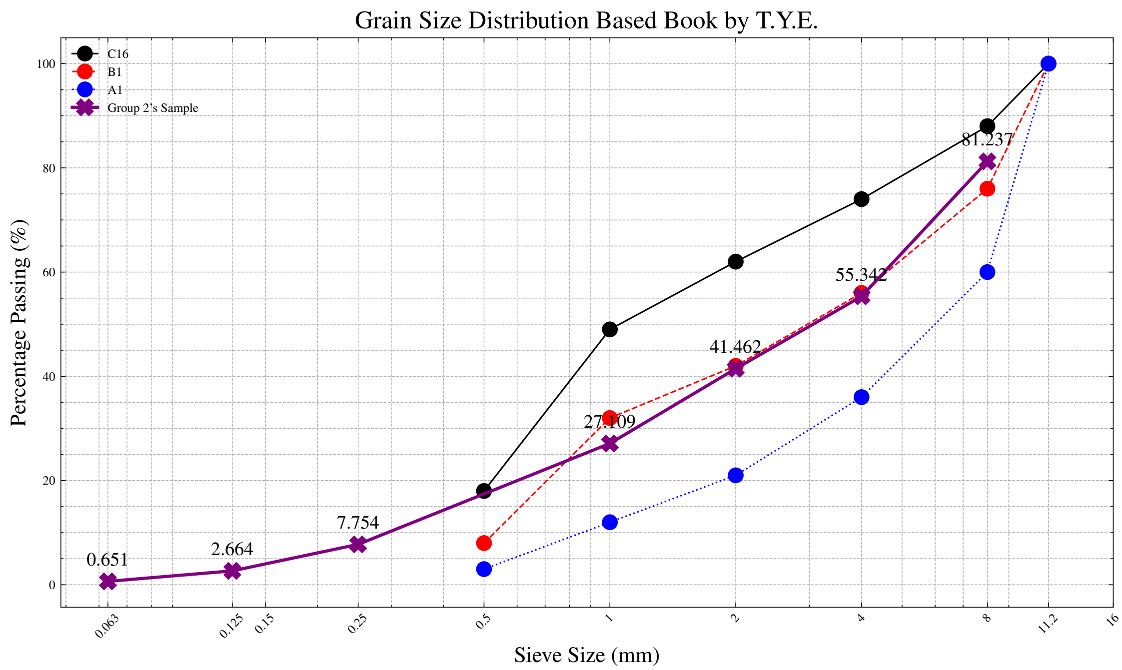

Figure 2: Comparison of experimental sieve analysis results with the aggregate quality criteria and gradation requirements as discussed in "Beton" by Prof. Dr. Turhan Y. Erdoğan.

7 Results

Table 1: Grading of Group 2's Sample

Sieve Size (mm)	% Passing	Grade	Compliance with TS802, Reason
8.0	81.24%	Unaccepted	No, Above C16 standard
4.0	55.34%	Accepted	Yes
2.0	41.46%	Accepted	Yes
1.0	27.11%	Accepted	Yes
0.25	7.75%	Accepted	Yes
0.125	2.66%	Unaccepted	No, Below B1/A1 standard
0.063	0.65%	Unaccepted	No, Below B1/A1 standard

8 Discussion of Results

At the 8 mm sieve size, the findings differ from the TS802 standard, suggesting a non-compliance problem specific to this measurement; this anomaly is clearly shown by the study.

Figure 1, 2 visually represents the grain size distribution of the aggregates analyzed, incorporating the TS802 standard and the criteria from "Beton - Prof. Dr. Turhan Y.

ERDOĞAN" for a comparative evaluation.

The experimental approach, which sought to assess the aggregate size distribution in accordance with ASTM standards and in contrast with TS802 norms and the academic criteria laid forth in "Beton," yielded findings that were mostly in compliance. Except for one size, the aggregate samples were found to be non-compliant with the TS802 standard at the 8mm sieve size aperture, even though they were compliant at all other tested sizes. This difference highlights one outlier from the norm and may serve as a basis for future research. Unlike what was previously said, the experimental technique and aggregate selection for the planned concrete applications were confirmed by a successful alignment when compared to the criteria outlined in "Beton" by Prof. Dr. Turhan Y. Erdoğan.

9 Conclusion

Research on the properties of concrete aggregates conducted in accordance with ASTM standards provides data that advances both material science and construction practices. Strict sampling, analysis, and characterization methods back up this study's findings that aggregates are crucial to concrete's strength, performance, and durability.

The thorough investigations expose the mechanical and physical characteristics of the aggregates by methods such as sieve analysis, specific gravities, and absorption capacities. The findings corroborate previous research showing that aggregate quality influences the workability and durability of concrete. Dissimilarities, particularly at the 8 mm sieve size, reveal material behaviour in certain contexts and point to a fertile area for research into and development of better construction materials.

In conclusion, both aggregate evaluation and the optimisation of construction materials for structural performance are governed by ASTM standards. This attempt, which is based on aggregate analysis, makes a contribution to civil engineering and material science while ensuring that our projects can withstand the test of time and the elements.

10 Recommendations

1. *Further Research on Anomalous Behaviors.* Further work is needed to determine the reasons behind the variations and their effects on the performance of concrete, particularly at the 8mm sieve size. Reproducing these situations and investigating their molecular bases should be the goals of future research.

2. *Exploration of Alternative Aggregates.* Research into sustainable alternatives, such

recycled concrete aggregate and industrial by-products, should be increased in light of the environmental and economic issues linked to conventional aggregates. The efficacy, efficiency, and ecological footprint of different aggregates used to make concrete should be the focus of these investigations.

References

[1] Tutorials - Matplotlib 3.8.3 documentation. (n.d.). https://matplotlib.org/stable/tutorials/index.html

11 Appendix 1

Listing 1: Code 1

```
import matplotlib as mpl
mpl.rcParams["figure.dpi"] = 7200
import matplotlib.pyplot as plt
import scienceplots
plt.style.use(['science','ieee'])
import numpy as np


plt.rcParams['text.usetex'] = True

# Data for the first plot
sieve_size = [0.063, 0.15, 0.25, 0.5, 1, 2, 4, 8, 11.2, 16, 22.4,
    31.5]
C16_passing = [5, 11, 20, 30, 41, 52, 64, 77, 90, 99, 100, 100]
B1_passing = [3, 7, 13, 20, 28, 37, 49, 63, 79, 92, 99.8, 100]
A1_passing = [2.7, 3, 6, 10, 15, 22, 33, 48, 68, 85, 98, 100]
U16_passing = [None, None, None, None, None, None, None, 30, 60, 85,
    98, 100]  # Adjusted for missing data
additional_x = [1, 2, 8]
additional_y1 = [15, 30, 30]

# Data for the second plot
sieve_sizes_2 = np.array([8, 4, 2, 1, 0.25, 0.125, 0.063])
retained_weights = np.array([317, 437.5, 234.5, 242.5, 327, 86, 34,
    11])
W_total = np.sum(retained_weights)
cumulative_retained_weights = np.cumsum(retained_weights)
percentage_passing_2 = 100 * (1 - cumulative_retained_weights /
    W_total)

# Initializing plot
plt.figure(figsize=(10, 6))

# Plotting the first set of data
```

```
plt.plot(sieve_size, C16_passing, label="C16", marker='o',markersize
    =9)
plt.plot(sieve_size, B1_passing, label="B1", marker='o',markersize=9)
plt.plot(sieve_size, A1_passing, label="A1", marker='o',markersize=9)
plt.plot(sieve_size[7:], U16_passing[7:], label="U16", marker='o',
    markersize=9)
plt.plot(additional_x, additional_y1, label="Line 1-2-8", linestyle='
    --', color='black')

plt.plot(sieve_sizes_2, percentage_passing_2[:-1], 'X-', color='
    purple', markersize=10, linewidth=2, label="Group 2's Sample")

for i, txt in enumerate(percentage_passing_2[:-1]):
    plt.annotate(f"{txt:.3f}",
                 (sieve_sizes_2[i], percentage_passing_2[i]),
                 textcoords="offset points",
                 xytext=(0, 10),
                 ha='center',
                 fontsize=12)

# Customizing the plot
plt.xlabel('Sieve Size (mm)', fontsize=14)
plt.ylabel(r'Percentage Passing (\%)', fontsize=14)
plt.title('Grain Size Distribution TS802', fontsize=16)
plt.xscale('log')  # Logarithmic scale for x-axis
plt.grid(True, which="both", ls="--", linewidth=0.5)
plt.xticks(list(set(sieve_size + sieve_sizes_2.tolist())), labels=[f"
    {size}" for size in set(sieve_size + sieve_sizes_2.tolist())],
    rotation=45)
plt.legend()
plt.tight_layout()
plt.savefig('destination_path.pdf', format='pdf', dpi=100000)
plt.show()
```

Listing 2: Code 2

```
import matplotlib as mpl
mpl.rcParams["figure.dpi"] = 7200
import matplotlib.pyplot as plt
import scienceplots
plt.style.use(['science','ieee'])
import numpy as np

plt.rcParams['text.usetex'] = True

# Adjusted data arrays with explicit None values for missing data points
sieve_size = [0.063, 0.15, 0.25, 0.5, 1, 2, 4, 8, 11.2, 16]
C16_passing = [None, None,None, 18, 49, 62, 74, 88, 100, None ]
B1_passing = [None, None,None, 8, 32, 42, 56, 76, 100, None ]
A1_passing = [None, None,None, 3, 12, 21, 36, 60, 100, None ]

# Data for the second plot
sieve_sizes_2 = np.array([8, 4, 2, 1, 0.25, 0.125, 0.063])
retained_weights = np.array([317, 437.5, 234.5, 242.5, 327, 86, 34, 11])
W_total = np.sum(retained_weights)
cumulative_retained_weights = np.cumsum(retained_weights)
percentage_passing_2 = 100 * (1 - cumulative_retained_weights / W_total)

# Initializing plot
plt.figure(figsize=(10, 6))

# Plotting the first set of data
plt.plot(sieve_size, C16_passing, label="C16", marker='o',markersize=9)
plt.plot(sieve_size, B1_passing, label="B1", marker='o',markersize=9)
plt.plot(sieve_size, A1_passing, label="A1", marker='o',markersize=9)

# Your plotting code
plt.plot(sieve_sizes_2, percentage_passing_2[:-1], 'X-', color='purple', markersize=10, linewidth=2, label="Group 2's Sample")
```

```

for i, txt in enumerate(percentage_passing_2[:-1]):
    plt.annotate(f"{txt:.3f}",
                 (sieve_sizes_2[i], percentage_passing_2[i]),
                 textcoords="offset points",
                 xytext=(0, 10),
                 ha='center',
                 fontsize=12)

# Customizing the plot
plt.xlabel('Sieve Size (mm)', fontsize=14)
plt.ylabel(r'Percentage Passing (\%)', fontsize=14)
plt.title('Grain Size Distribution Book', fontsize=16)
plt.xscale('log')  # Logarithmic scale for x-axis
plt.grid(True, which="both", ls="--", linewidth=0.5)
plt.xticks(list(set(sieve_size + sieve_sizes_2.tolist())), labels=[f"
   {size}" for size in set(sieve_size + sieve_sizes_2.tolist())],
   rotation=45)
plt.legend()
plt.tight_layout()
plt.savefig('book_destination_path.pdf', format='pdf', dpi=100000)
plt.show()
```

Listing 3: Code 3

```
import matplotlib.pyplot as plt
import numpy as np
import scienceplots
plt.style.use(['science', 'ieee'])
plt.rcParams['text.usetex'] = True

sieve_size = [0.063, 0.15, 0.25, 0.5, 1, 2, 4, 8, 11.2, 16, 22.4,
    31.5]
C16_passing = [5, 11, 20, 30, 41, 52, 64, 77, 90, 99, 100, 100]
B1_passing = [3, 7, 13, 20, 28, 37, 49, 63, 79, 92, 99.8, 100]
A1_passing = [2.7, 3, 6, 10, 15, 22, 33, 48, 68, 85, 98, 100]
U16_passing = [None, None, None, None, None, None, None, 30, 60, 85,
    98, 100]  # Adjusted for missing data
additional_x = [1, 2, 8]
additional_y1 = [15, 30, 30]

# Data for the second plot
sieve_sizes_2 = np.array([8, 4, 2, 1, 0.25, 0.125, 0.063])
retained_weights = np.array([317, 437.5, 234.5, 242.5, 327, 86, 34,
    11])
W_total = np.sum(retained_weights)
cumulative_retained_weights = np.cumsum(retained_weights[:-1])
percentage_passing_2 = 100 * (1 - cumulative_retained_weights /
    W_total)

# Initializing plot
plt.figure(figsize=(10, 16))

# Plotting the first set of data
plt.plot(sieve_size, C16_passing, label="C16", marker='o', markersize
    =9)
plt.plot(sieve_size, B1_passing, label="B1", marker='o', markersize
    =9)
plt.plot(sieve_size, A1_passing, label="A1", marker='o', markersize
    =9)
plt.plot(sieve_size[7:], U16_passing[7:], label="U16", marker='o',
    markersize=9)
```

```python
plt.plot(additional_x, additional_y1, label="Line 1-2-8", linestyle='--', color='black')

# Plotting Group 2's Sample
plt.plot(sieve_sizes_2, percentage_passing_2, 'X-', color='purple', markersize=10, linewidth=2, label="Group 2's Sample")

# Annotate Group 2's Sample points
for i, txt in enumerate(percentage_passing_2):
    plt.annotate(f"{txt:.3f}%", (sieve_sizes_2[i], percentage_passing_2[i]), textcoords="offset points", xytext=(0, 10), ha='center', fontsize=12)

# Customizing the plot
plt.xlabel('Sieve Size (mm)', fontsize=14)
plt.ylabel(r'Percentage Passing (\%)', fontsize=14)
plt.title('Grain Size Distribution Table', fontsize=16)
plt.xscale('log')  # Logarithmic scale for x-axis
plt.grid(True, which="both", ls="--", linewidth=0.5)
plt.xticks(list(set(sieve_size + sieve_sizes_2.tolist())), labels=[f"{size}" for size in set(sieve_size + sieve_sizes_2.tolist())], rotation=45)


# Interpolate values for C16, B1, and A1 at sieve sizes of Group 2's sample
C16_interpolated = np.interp(sieve_sizes_2, sieve_size, C16_passing)
B1_interpolated = np.interp(sieve_sizes_2, sieve_size, B1_passing)
A1_interpolated = np.interp(sieve_sizes_2, sieve_size, A1_passing)

# Now, let's integrate the grading logic
cell_text = []
cell_colors = []
for i, (size, perc) in enumerate(zip(sieve_sizes_2, percentage_passing_2)):
    # Define the actual condition for 'Accepted'
    is_accepted = B1_interpolated[i] <= perc <= C16_interpolated[i] or A1_interpolated[i] <= perc <= B1_interpolated[i]
```

```
    grade = "Accepted" if is_accepted else "Unaccepted"
    cell_text.append([f"{size}", f"{perc:.3f}%", grade])
    color = 'lightgreen' if is_accepted else 'salmon'
    cell_colors.append(['w', 'w', color])

# Add table to the plot
table = plt.table(cellText=cell_text, cellColours=cell_colors,
   colLabels=["Sieve Size (mm)", r"Group 2's \% Passing", "Grade"],
   loc='bottom', bbox=[0.25, -0.5, 0.5, 0.3])
table.auto_set_font_size(False)
table.set_fontsize(8)
table.scale(1, 1.4)

# Adjust layout and plot the rest as before
plt.tight_layout(rect=[0, 0.3, 1, 0.95])
plt.legend()
plt.savefig('destination_path_2.pdf', format='pdf', dpi=100000)
plt.show()
```