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Properties o framing Materials

Case Study: Barbican Estate

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1. Introduction

The Barbican Estate is one of the most important residential complexes constructed in reinforced concrete in Europe. It is located in the city of London. The project was conceived and developed after the destruction caused by the bombings of the Second World War during The Blitz, and it emerged as a strategy to bring people back to the city through this housing development. (Cantelon, 1969)

Construction began in 1965 and most of the complex was completed in 1976. It was designed by the architectural practice Chamberlin, Powell and Bon. Although at the time the design included influences from Modernist, Mediterranean, Roman and medieval architecture, it is more widely recognised for its Brutalist style. (BAAS, 2025)

From a structural point of view, the Barbican Estate is mainly constructed using reinforced concrete structural frames, which include columns, beams, slabs and structural walls. This material was selected due to its mechanical properties, especially its high compressive strength, durability and fire resistance (Atkins, 2022)

The aim of this report is to analyse the structural properties of the framing material used in the Barbican Estate, evaluating its mechanical behaviour, durability, environmental impact, and other aspects related to concrete production.



Figure 1: Photograph of the Barbican Estate showing the concrete towers. (RICS, 2026)

2. Analysis of the Framing Material (Concrete)

The structural system of the Barbican Estate is based on reinforced concrete frames. These frames include robust vertical columns that support the loads from elements such as slabs and beams, as well as gravitational loads coming from the self-weight of the structure and the occupants, which are also distributed through the beams of the building.

The residential buildings are supported on a large podium structure, which elevates the housing blocks above ground level. This design allows the separation of pedestrian circulation from vehicular circulation.

The vertical loads of the building include:

- self-weight of the structure
- occupancy loads
- services loads

These loads are transferred from the slabs to the beams, then to the columns, and finally to the foundations.

Concrete is particularly suitable for resisting compressive stresses, which makes it ideal for columns and structural walls in high-rise buildings.

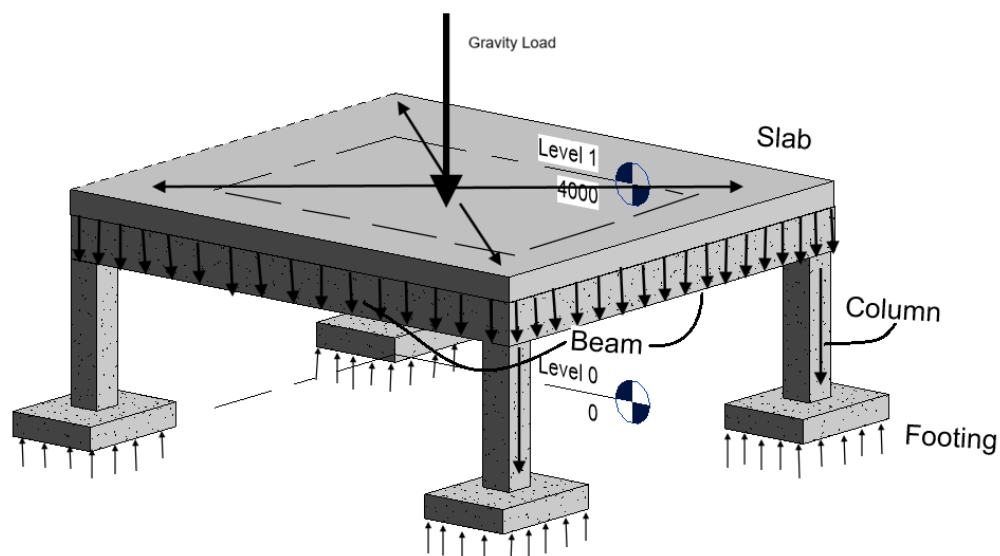


Figure 2: Load transfer diagram in a reinforced concrete structure showing the path of gravity loads from slab to beam, column and foundation (Author's own sketch, 2026).

This section analyses the structural behaviour of reinforced concrete, which is based on the combination of two materials with different properties: concrete and reinforcement steel.

Concrete has high compressive strength but low tensile strength. For this reason, reinforcement steel is incorporated within the concrete.

When a reinforced concrete beam is subjected to loading, different types of stresses are produced:

- compression at the top
- tension at the bottom
- shear stresses near the supports

The reinforcement steel is placed in the zones where tensile stresses are generated.

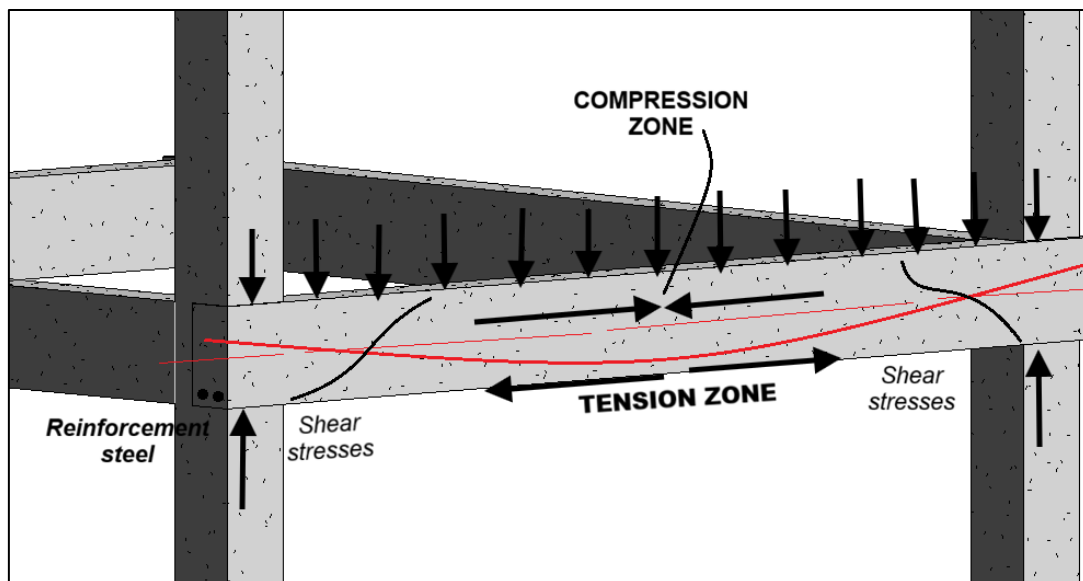


Figure 3: Diagram of a beam with compressive stresses develop in the upper portion of the beam while tensile stresses develop in the lower portion. (Author's own sketch, 2026).

The relationship between the applied force and the area is expressed by the stress equation: $\sigma = A/F$

Where:

σ = stress

F= Force

A= cross-sectional area

Shear forces also develop within beams, particularly near supports. Shear stresses can lead to diagonal cracking if not properly controlled. In reinforced concrete beams, shear reinforcement is typically provided using stirrups or links. The shear stress is calculated as:

$$\tau = \frac{V}{A}$$

Where:

V = shear force

A = shear area

In large reinforced concrete buildings such as the Barbican Estate, shear walls are also used to resist lateral loads including wind forces.

The repetitive use of reinforced concrete columns in the Barbican Estate serves both structural and spatial purposes. Structurally, the columns support the elevated podium and transfer loads from slabs and beams down to the foundations, allowing large spans and open spaces at ground level. Architecturally, this system elevates the buildings above the ground, creating visual continuity, permeability, and a sense of openness, reducing the feeling of enclosure despite the mass of the concrete structures.

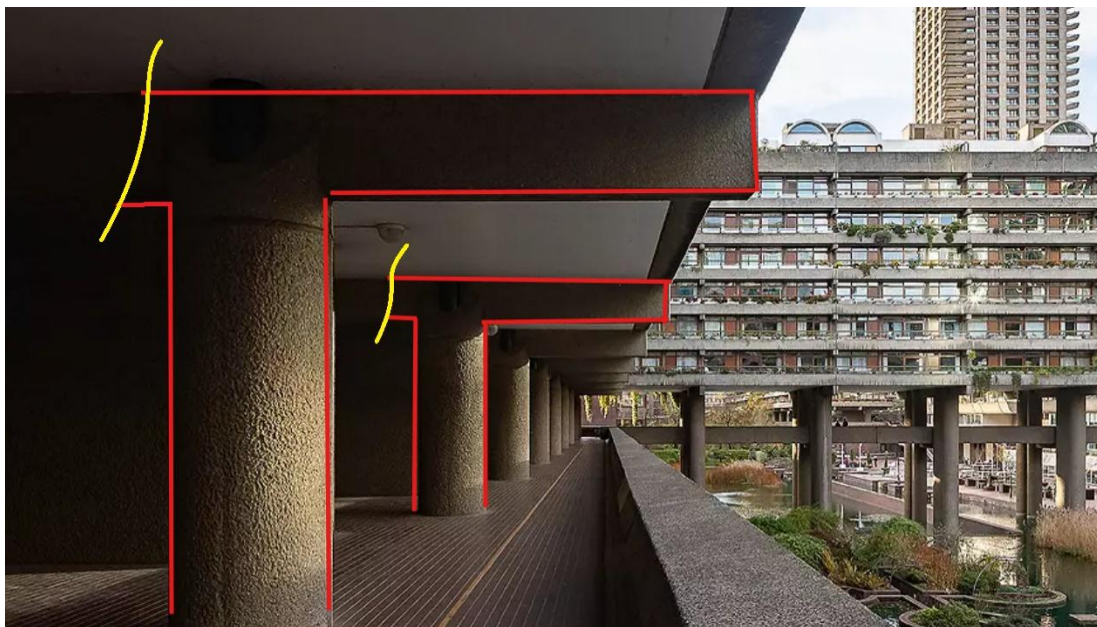


Figure 4: Photograph of the Barbican Estate showing the concrete columns and beams. (RICS, 2026)

The supports are represented as simple supports for analysis purposes, although the beam-column connections are semi-rigid due to monolithic reinforced concrete construction.

The beam can be idealised locally as a cantilever projecting from the column. Under a uniformly distributed load (UDL), the maximum bending moment occurs at the column connection and can be expressed as $M = wL^2 / 2$, while the moment at the free end is zero.

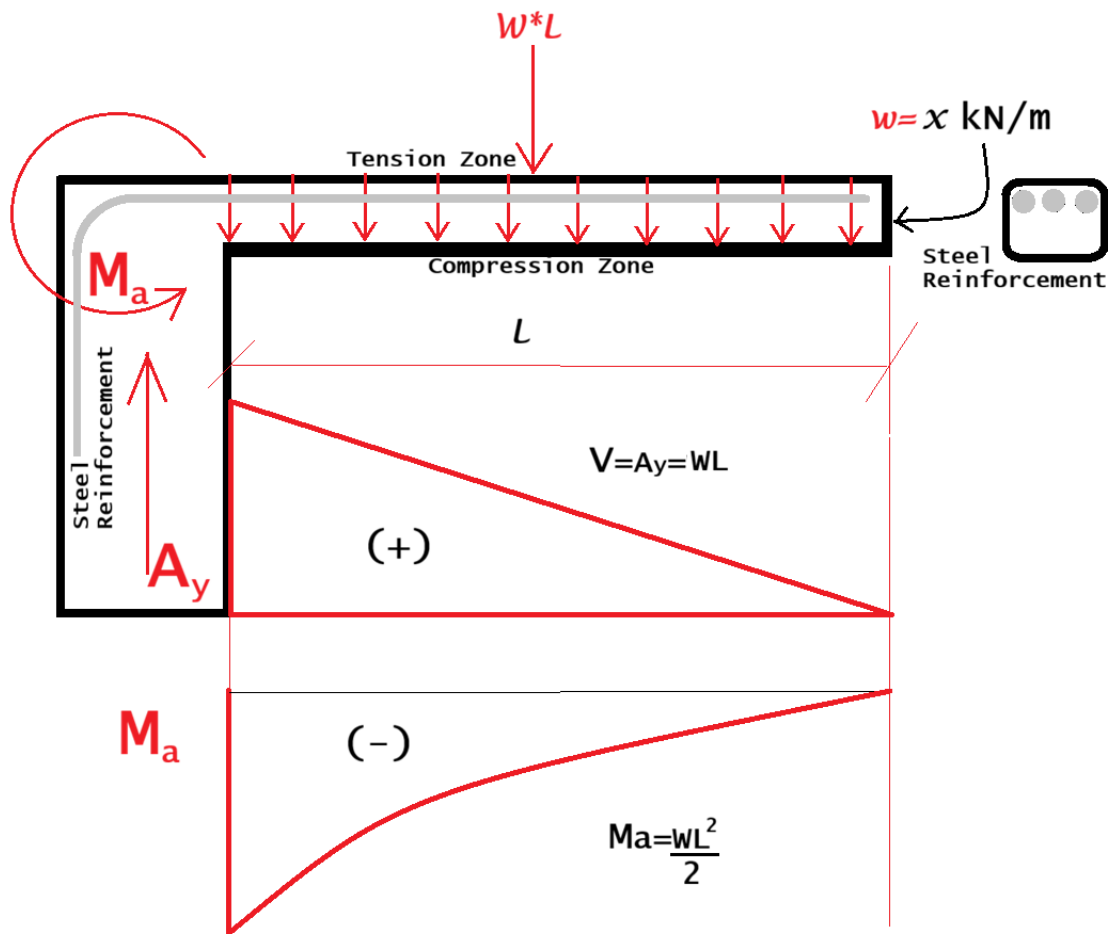


Figure 5. Structural idealisation of a cantilever beam subjected to a uniformly distributed load (w), showing the resulting shear force diagram (V) and bending moment diagram (M). *Source: Author's own work.*

2.1. Strength, Durability and Climatic Resistance

Strength refers to the load-carrying capacity of concrete, while durability refers to its ability to resist environmental conditions over time. Although quality control systems at the time were not as advanced as those used today, the Barbican

Estate did include basic control measures. These involved cube strength testing at 28 days, classification of concrete grades, and controlled batching and mixing processes carried out on site.

These measures helped to ensure that the concrete achieved the required structural strength, while material selection and construction methods contributed to its long-term durability:

The concrete throughout the estate was made with Pen Lee crushed granite, which Nikolaus Pevsner in “The Buildings of England” described as “used in tough masculine forms on a mighty scale”. Two grades of structural concrete were used with 28-day cube strengths of 34 N/mm² and 42 N/mm². For the most part, all batching and mixing of concrete was carried out on site.

(‘Structure of buildings in the Barbican Estate’, 2015)

(Barbican Living, n.d.).

Durability is a key property of reinforced concrete structures. The Barbican Estate was designed to resist the environmental conditions of central London, including rainfall, temperature changes and air pollution.

Concrete provides protection to reinforcement bars by limiting exposure to oxygen and moisture, which reduces the risk of corrosion. In addition, the alkaline nature of concrete helps to protect the steel reinforcement.

However, over time, exposure to environmental conditions can lead to deterioration mechanisms such as carbonation and water ingress. Carbonation occurs when carbon dioxide penetrates the concrete and reduces its alkalinity, which may allow corrosion of the reinforcement. Maintenance and refurbishment works at the Barbican have included improvements to waterproofing systems and drainage in order to reduce water penetration into structural elements.

2.2. Time, Labour, Programme and Cost Compared to Steel Framing

From a construction management perspective, reinforced concrete construction requires more time and labour due to the need for formwork, reinforcement placement and curing.

Unlike steel structures, which can be prefabricated and quickly assembled on site, reinforced concrete is usually cast in situ. This process involves placing concrete into temporary formwork, where it hardens and gains strength over time.

The hydration process of cement generates heat and contributes to the hardening of the concrete. Proper curing is necessary to ensure adequate strength development and to avoid early cracking.

Despite longer construction times, reinforced concrete offers important advantages such as durability, fire resistance and long-term structural performance. These factors contributed to its selection for the Barbican Estate.

2.3. Ease of Assembly and Adaptability of the Frame

The reinforced concrete frame of the Barbican Estate allowed a relatively efficient construction process through the use of repetitive formwork and in-situ casting techniques. The use of load-bearing cross-walls simplified the structural system and reduced construction complexity.

However, although this system provides strength and stability, it limits flexibility for future modifications. Load-bearing walls restrict internal changes, making it more difficult to adapt the layout or change the use of the building over time.

2.4. Integration of Services and Associated Challenges

The integration of building services within the Barbican Estate presented several challenges due to the use of reinforced concrete and load-bearing cross-wall construction. The solid nature of the concrete structure limited the ability to introduce service routes after construction, making it difficult to install or modify systems such as plumbing, electrical and ventilation services.

To overcome these challenges, services were carefully planned and integrated during the design stage. Dedicated service shafts and designated zones were incorporated to allow vertical and horizontal distribution of services without compromising the structural integrity of the building. This approach ensured that essential services could be accommodated while maintaining the strength and stability of the concrete frame.

2.5. End-of-Life and Demolition Challenges

One of the main challenges of reinforced concrete buildings is the difficulty of demolition and structural modification. The Barbican Estate is a listed building, which means that major changes require approval from heritage authorities.

Reinforced concrete is more difficult to dismantle than steel structures due to the composite nature of the material. Demolition usually requires mechanical crushing or cutting techniques.

3. The negative impact of the concrete production process, in terms of community and the environment

The production of concrete has significant impacts on both the environment and local communities. One of the main environmental concerns is the high level of carbon dioxide emissions associated with cement production, which contributes to global greenhouse gas emissions.

In addition, the extraction of raw materials such as sand and gravel can lead to environmental damage, including habitat loss and reduced biodiversity. The process also requires large amounts of water and energy, increasing its environmental impact.

From a community perspective, concrete production and construction activities generate noise, dust and traffic, which can affect the health and wellbeing of nearby residents. Therefore, although concrete is an essential construction material, its production presents important sustainability challenges.

4. Particle Size Distribution Analysis

The following particle size distribution was obtained from a sieve analysis on an 'all-in' aggregate used for concrete production.

The original sample size was 1250g.

The percentage passing is calculated as:

$$\% \text{ Passing} = \frac{\text{Total mass} - \text{retained mass}}{\text{Total mass}} \times 100$$

4.1. Sieve Analysis Results

Table 1: Particle size distribution results of the aggregate sample (1250 g).

Sample: 1250			
Sieve Size	Mass (gr)	% on sieve	% Passing
125	0	0	100
75	0	0	100
63	0	0	100
37.5	120	9.6	90.4
20	137	11.0	79.4
10	143	11.4	68.0
6.3	105	8.4	59.6
3.35	45	3.6	56.0
2	130	10.4	45.6
1.18	63	5.0	40.6
0.6	105	8.4	32.2
0.3	102	8.2	24.0
0.212	109	8.7	15.3
0.15	98	7.8	7.4
0.063	55	4.4	3.0
Total retained on sieves		97%	
% passing through the last sieve		3%	
Total of the sample		100%	

Source: Author's own work.

4.2. Particle Size Distribution Curve

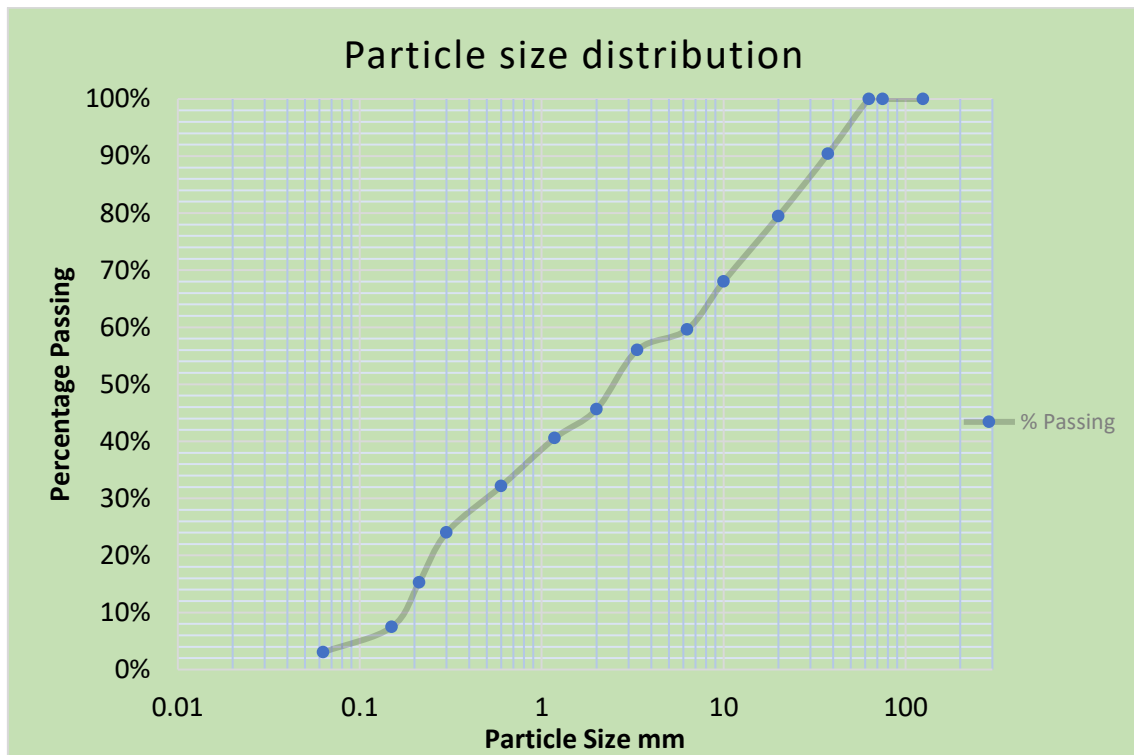


Figure 6: Particle size distribution curve (Author's own, 2026).

A 'coarse aggregate' is defined as having a particle size greater than 4.7mm diameter, and a fine aggregate less than 4.7 mm

From the sieve analyse we have:

3.35 mm (56% passing)

6.30 mm (59.6% passing)

4.7 mm is located in the middle of these values.

The percentage passing at 4.7 mm was estimated by interpolating between the 6.3 mm and 3.35 mm sieve values:

$$\frac{59.6 - 56}{6.3 - 3.35} = \frac{x - 56}{4.7 - 3.35}$$
$$\frac{3.6}{2.95} = \frac{x - 56}{1.35}$$
$$x = 57.65\%$$

Therefore:

Fine aggregate (less than 4.7 mm) = 57.65%

Coarse aggregate (Greater than 4.7 mm) = $100 - 57.65\% = 42.35\%$

Silt (less than 0.063 mm) = 3%

4.3. Aggregate Classification

The particle size distribution is shown in Figure 3, with the original hand-plotted graph included in Appendix A.

The sample can be classified as a well-graded all-in aggregate, consisting of both fine and coarse particles. The fine fraction (57.65%) is mainly composed of medium to coarse sand, while the coarse fraction (42.35%) falls within the medium gravel range. The silt content is low (approximately 3%), indicating good quality material suitable for concrete production.

Although the aggregate sample is well-graded and suitable for concrete production, the proportion of coarse aggregate (42.35%) is lower than the typical range recommended for structural concrete (55–60%). The higher proportion of fine material (57.65%) may improve workability but could lead to reduced strength and increased cement demand. Therefore, while the material may still be used in concrete, it may not be optimal for structural applications without further adjustment of the mix design.

5. Conclusion

- a. In conclusion, the Barbican Estate demonstrates the effective use of reinforced concrete as a primary structural material, providing both strength and durability through its load-bearing system and in-situ construction methods. The structural design reflects the architectural intentions of the time, giving priority to robustness and monumentality; however, this comes with some limitations in terms of flexibility and ease of adaptation over the building's life cycle. The fact that the Barbican Estate is still in use today highlights the durability and long-term performance of its reinforced concrete structure.
- b. However, this analysis also highlights the significant environmental impact associated with concrete production, particularly in terms of carbon emissions, extraction of raw materials and its effects on local communities.

This shows the importance of considering sustainability in current construction practices.

- c. The particle size distribution analysis also supports this study by showing the importance of material properties in concrete performance. The analysed sample was classified as a well-graded all-in aggregate, with a balanced proportion of fine and coarse particles and a low silt content. This indicates that it is suitable for concrete production, contributing to good workability, strength and durability.
- d. Overall, this assignment highlights the relationship between structural design, material selection and environmental responsibility within the built environment.

6. References

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BS 1377-2:1990 Uncontrolled Copy: Giorgio Cavaliere, ALSTOM, 7-Feb-01, Uncontrolled Copy. © BSI

Particle size distribution chart

Form 2.N

Location		Soil description		Job ref.		Sample no.	
Test method		BS 1377-2:1990:9.2/9.3/9.4/9.5*		Borehole/Pit no.		Depth	
						Date	
						m	

CLAY				SILT				SAND				GRAVEL				COBBLES		BOULDERS	
Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	Operator	Checked	Approved		

*Delete as appropriate

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Figure A1: The particle size distribution with the original hand-plotted graph