 DOI: 10.34049/bcc.53.D.27

Comparison of particle size distribution estimated by Rosin-Rammler equation *vs* Malvern particle size analyzer for different brands of PPC cement

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Received: November 17, 2021; Revised: February 05, 2022

In modern science precision and accuracy play a vital role towards accomplishing good quality final products. Precision and accuracy are very much inevitable either for raw materials, intermediates or semifinal / final products. In current scientific scenario, lot of instruments, gadgets and equipments are being developed, imbibing high technologies, which were considered to be expensive. Equipment by name Malvern is also considered as an expensive gadget to measure particle size distribution of μm size particles. This paper deals with the established particle size distribution by a simple and manual method using an empirical equation called Rosin-Rammler equation. Cements of different brands and different grades were procured from local market and tested for particle size distribution. The results obtained were compared with the results of Malvern particle size analyzer and the deviation is found to be 10% as maximum. The results depict that manual analysis by using the empirical Rosin-Rammler equation is very much matching with the standard particle size analyzer. Therefore, manual analysis of particle size distribution using Rosin-Rammler equation can be adopted in experimental analysis/research.

Keywords: Cement, Particle size distribution, Rosin-Rammler equation, Malvern particle size analyzer

INTRODUCTION

Cement is a binding substance usually inorganic in nature used for construction purpose, which sets when dries and hardens to adhere to other materials, by way of fixing with them together. Generally, cement is used on its own, but rather found to be binding with sand and gravel. Cement is used with fine sand and gravel mixture inaggregate for making mortar for masonry use like bricklaying and stuccos to produceconcrete [1]. Cement used in construction is inorganic in nature as it contains lime and calcium silicate which shows the characteristic features of hydraulic or non-hydraulic ability which depends on the cement to set in the presence of water. The cement which sets when it dries reacting with carbon dioxide in the air is very resistant to attack by chemicals after setting; the cement which will not set in wet conditions or under water is set to be non-hydraulic cement [2]. The particle size distribution of cement is very important to understand the response of its physical and chemical nature, since it is a matter which is important in understanding its physical and chemical properties, since it directly affects the strength and load bearing properties. It also affects the nature of reactions and needs to be closely monitored in production operations. Particle size distribution may be represented as the "range" analysis, where the amount of each size range is listed in a particular order. It may also be represented in "cumulative" form, in which the total mixture of all sizes "retained" or "passed" by a single notional "sieve" is represented for a range of sizes [3]. Range analysis will fetch, when a particular size is desired. The particle size affects the properties of powder in multiple ways. It affects i) the setting time of cement, ii) the hiding powder of pigments present in it, iii) the activity of chemical catalysts, iv) the taste of food, v) the potency of drug and sintering shrinkage of powders. Therefore, for quality control of the final product, it is very much essential to maintain particle size distribution of any powder [4].

In the process of cement production, the fine product is analyzed and characterized by 95% below the 90 μm mesh usually recommended or based on the Blaine value. Particle size is a critical property and is used to characterize powders. It is possible to get high strength with lower Blaine (surface area) number. This is possible only when attempt is made to analyze the size distribution of the powder. As far as particle size distribution is concerned, the maximum usage of particle size distributions data may be generated if the data were represented by a mathematical expression. Such

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mathematical function permits ready graphical/ analytical representation and produces maximum opportunities for interpretations, extrapolations, and comparative analysis of different particle size distributions [5]. Different measurement techniques are in place to produce different results while measuring non-spherical particles. The techniques or instruments used for particle size analysis need to generate data in a form relevant to the process, reliable to the method and simple to understand. Laser diffraction is commonly used for particle size measurement and it is said to be a standard method which many industries follow for characterization and control. In this method a laser beam is scattered directly related to their size by particle size analyzer [6]. When the particle size decreases the scattering increases logarithmically observed in laser diffraction [7], intensity of beam is subjected to particle size, decrease is subjected to particle volume. Laser diffraction ranges from 0.2 to 2000 μm [8].

Dynamic light scattering is known as an accurate, reliable and repeatable technique which measures the size of molecules in the subμm region and it gives results in particle hydrodynamic diameter [9]. This method is non-invasive and is also called photon correlation spectroscopy. Sedimentation is a traditional method which gives large errors for particles of large aspect ratio [10]. This equipment is used in paint and ceramic industries and is simple to use, as well as complex to determine as particles function setting of viscosity [11,12], in which density of material is needed, this method is not good for emulsions where the material settles too quickly. Ultrasound is used instead of light to collect information of the particles in the fluid disperse [13]. Sound waves similar to light absorb the particles disperse and scattered in a fluid system and measure the particle size distribution at very high concentration in this acoustic spectroscopy [14]. The distribution of particle size using Rosin-Rammler distribution parameters has been used to explain the particle size distribution of powders of different types and sizes [15-17]. These distribution parameters are in general suited to representing powders made by crushing, grinding and milling operations [18-20].

MATERIALS AND METHODS

Standard sieves of BIS had been used to assess particle size distribution [21] of 90, 75, 63 and 45 μm in size. Power sieve shaker is used to vibrate the powder for half an hour and particle size distribution has been estimated. Based on the values obtained in manual sieving, further distribution was carried out by using Rosin-Rammler equation [15-17]. Furthermore, the values of particle size distribution are generated in Rosin-Rammler equation have been compared with standard Malvern particle size analyzer results.

Empirical equation for the particle size distribution is given by:

$$Q_3(x) = 1 - e^{\left[-(x/x_d)^n\right]} \quad (1)$$

where x = particle size (μm), x_d = constant related particle size, n = constant indicating the width of the distribution, $Q_3(x)$ = cumulative percentage undersize (%).

Estimation of parameters of different samples in Rosin-Rammler equation

Five different brands of Pozzolona Portland Cement (PPC) cement were procured from the local market, then subjected to sieving with sieves of 90, 75, 63 and 45 μm in size used in screening and from the retained weight of each sieve from the weighing balance, with the obtained data of mesh size to particles retained,a graph between Q3 (x) and x is plotted. From the graph, using the values of slope and intercept 'xd' and 'n' were evaluated. These values were embedded in Rosin-Rammler equation (1) to produce the entire particle size distribution.

RESULTS AND DISCUSSION

Manual Sieving

Standard sieves of 90, 75, 63 and 45 μm were taken to analyze cement particle size distribution by using a vibrator [21]. Coarser size, i.e. 90 μm was kept on the top and finer size, i.e. 45 μm was kept in bottom, below which the last container pan was kept to collect very fine particles. Particles retained on each sieve were weighed and accordingly cumulative mass weight was estimated.

Generation of X_d and n values of Rosin-Rammler equation

Based on the values of Table 1, a graph was plotted between ln (particle size) *vs* Ln[-ln(1-cumulative undersize/100)], and the slope line was drawn, from which 'xd' and 'n' values were estimated based on which, 'n' and 'c' values were obtained from the equation y = 1.372x - 4.786. 'xd' was obtained by exp. (c/n) where 'c' value is directly taken from the equation. Rosin-Rammler constants xd, and n, i.e. xd =32.73 and n =1.3, were incorporated in the equation from Fig. 1.

Table 1. Particle size distribution of cement obtained by manual sieving.

Sieve size (µm)	Powder retained weight (g)	Cumulative powder mass weight (g)	Cumulative undersize (%)
90	1.24	1.24	98.76
75	3.68	4.92	95.08
63	6.49	11.41	88.59
45	7.39	18.80	81.20

Values of xd and n were incorporated in Rosin-Rammler equation, and the particle size distribution was generated for five samples, i.e S1, S2, S3, S4 and S5, similarly particle size distribution was estimated in Malvern Analyzer. The distribution of both methods is projected in graphs. RS1, RS2, RS3, RS4, RS5 depict particle size distribution values of samples 1-5 using Rosin- Rammler equation, while MS1, MS2, MS3,MS4, MS5 depict particle size distribution of samples 1-5 using Malvern analyzer.

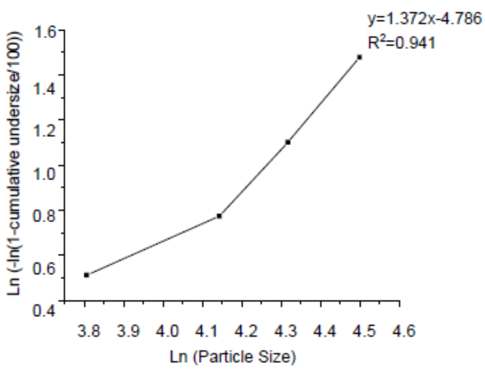

Fig. 1. Graph depicts Ln (particle size) vs Ln (-ln (1-cumulative undersize/100))

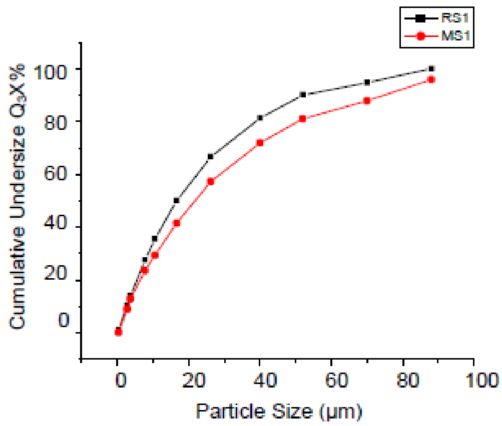

Fig. 2. Particle size distribution of sample 1 by Malvern and Rosin-Rammler

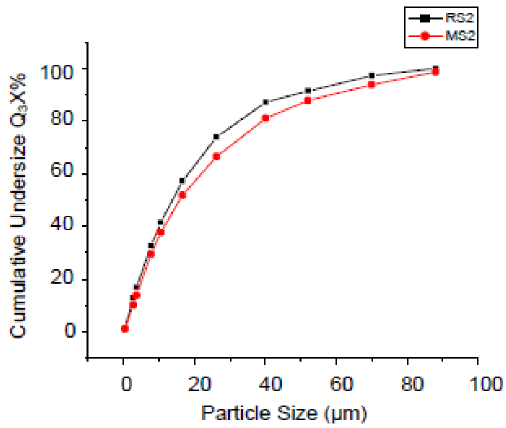

Fig. 3. Particle size distribution of sample 2 by Malvern and Rosin Rammler

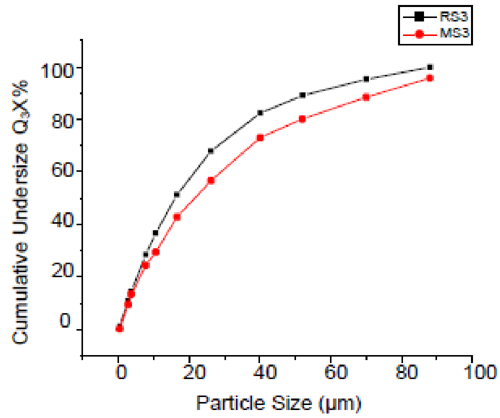

Fig. 4. Particle size distribution of sample 3 by Malvern and Rosin-Rammler

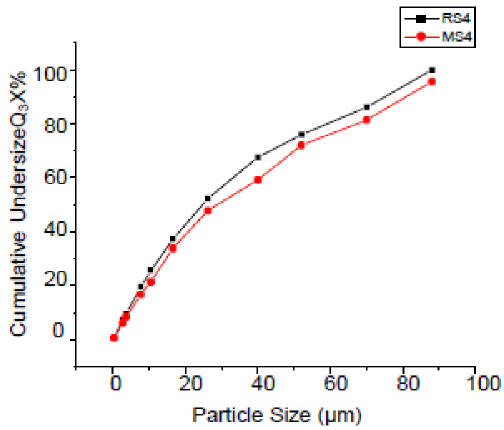

Fig. 5. Particle size distribution of sample 4 by Malvern and Rosin-Rammler

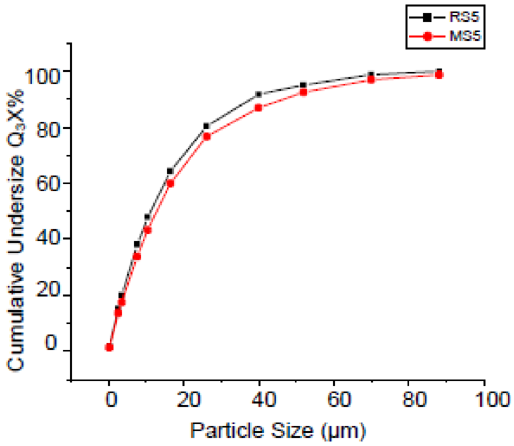

Fig. 6. Particle size distribution of sample 5 by Malvern and Rosin-Rammler

Figs. 2 to 6 show a comparison of particle size distribution of sample 1 to 5 by Malvern analyzer and Rosin Rammler distribution method. It can be clearly seen that percentage deviation between two methods, i.e. Rosin-Rammler distribution and Malvern analyzer is almost negligible, for all five samples.

CONCLUSION

With the series of cement analysis/particle size distribution by using Rosin-Rammler equation, it was observed that the results are very much close to those of Malvern particle size analyzer. Different brands of cement / grades were used to estimate the particle size distribution. A deviation of approximately 10% was noticed which is in a well - accepted range. The size of the cement particles according to Rosin Rammler equation estimation is in the range of 1 µm to 100 µm, which is very much matching with the established Malvern Particle analyzer. Therefore, it can be concluded that particle size distribution measurement using Rosin Rammler equation is almost accurate in line with conventional Malvern particle size distribution for analyzing PPC cement samples.

Acknowledgements: *To be presented in International Chemical Engineering Conference on "100 Glorious Years of Chemical Engineering & Technology" from September 17 to 19, 2021, organized by Department of Chemical Engineering at Dr. B. R. Ambedkar NIT Jalandhar, Punjab, India (Organizing Chairman: Dr. Raj Kumar Arya & Organizing secretary: Dr. Anurag Kumar Tiwari).*

The authors express deep sense of gratitude to the management of Anjani Powder Research Centre, where part of research has been done. The authors also express thanks to National Academy of Construction, Gachibowli, Hyderabad. The authors are also thankful to Prof. Pitchumani Balakrishnan for his constant cooperation and help. The authors are thankful to the management of Lords Institute of Engineering & Technology, Hyderabad for their encouragement and support.

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