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DEVELOPING AN ANDROID PROTOTYPE APPLICATION TO PREDICT ROCK FRAGMENTATION FROM BLASTING IN SURFACE MINING

Hendra Harisman[1]*, Nurul Aflah[1], Pocut Nurul Alam[1], Muchlis[1], Febi Mutia[1]

[1]Mining Engineering Department, Faculty of Engineering, Universitas Syiah Kuala, 23111, Indonesia
Email: hendra.harisman@usk.ac.id

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ABSTRACT

Blasting plays an important role in surface mining operations because it directly affects rock fragmentation, which is a key factor in optimizing mining performance. However, fragmentation prediction is commonly conducted using complex mathematical calculations on computers or laptops, making the process less practical and time-consuming. This study aims to develop an Android-based application to facilitate the prediction of blasting fragmentation results in a more efficient and accessible manner. The research employed a research and development (R&D) methodology consisting of application design, development, and testing stages. The results show that the developed Android application can assist mining professionals in predicting rock fragmentation practically through smartphone devices. The application improves the efficiency and accessibility of fragmentation prediction and demonstrates the implementation of digital technology in mining practices within the Industry 4.0 era.

Key words: blasting, surface mining, fragmentation prediction, mining optimization, digital technology.

INTRODUCTION

Surface mining plays a pivotal role in meeting the global demand for essential minerals and raw materials. Central to the success of surface mining operations is the process of blasting, which fractures rock materials and prepares them for extraction. The efficiency and precision of these blasting activities have a direct impact on the resulting fragmentation of rock: reduction of mining costs and increase in production efficiency (Kanchibotla et al., 1998; Michaux & Djordjevic, 2005; Monjezi et al., 2008, 2009). The size of the obtained fragmentation significantly impacts downstream operations, including the hauling system and secondary crushing. These aspects have been thoroughly studied by various researchers (Scott & McKee, 1994; Smith et al., 1994; Kojovic et al., 1995; Nielsen & Kristiansen, 1995; Kahraman & Kilic, 2020). Therefore, making accurate prediction of utmost importance in optimizing mining operations.

In general, there are two methods that have been introduced to predict rock fragmentation, which are uncontrollable methods that dependent on physical and mechanical characteristics of rocks, and controllable methods which based on design parameters, including measurement of fragmented rocks and size distribution prediction, as outlined by Singh and Narendrula (2010). Controllable methods are categorized into direct and indirect methods. The direct method relies on sieve analysis to compute fragmentation content, offering high accuracy; however, its application has waned in recent times due to associated costs and time constraints (Sudhakar et al., 2006). In contrast, indirect techniques, such as empirical, visual, and image analysis methods, present a compromise between test accuracy and the associated time and cost. Visual methods provide a lower accuracy in predicting the particle size distribution (PSD). Various experimental methods introduce distinct equations for forecasting the PSD of fragmented rocks. Figure 1 summarizes the direct and indirect methods to predict the PSD.

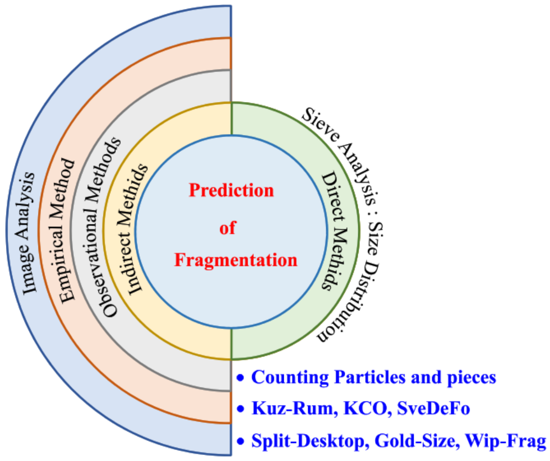


Figure 1. Main Methods of Rock Fragmentation Prediction (Hosseini, et al., 2022)

This research used indirect method to predict the PSD, particularly the empirical method. Traditionally, predicting fragmentation outcomes by using empirical method has been a laborious task, involving the application of intricate mathematical equations and relying on the computational power of computers or laptops. This method, while effective, comes with the drawbacks of time-consuming calculations and limited accessibility in the field. However, we now find ourselves in the era of Industry 4.0, characterized by the convergence of digital technologies and the advent of smartphones with powerful computational capabilities. This transformative development presents an opportunity to redefine the way we approach mining practices.

This research sets out to address the challenges posed by traditional fragmentation prediction methods by leveraging the potential of smartphone technology. By adopting a research and development approach, this research aim to design and implement an Android application that will enable mining professionals to efficiently and accessibly predict fragmentation results from blasting activities. This transition from computer-based calculations to a smartphone application promises not only to streamline the prediction process but also to enhance its accessibility, ultimately contributing to the optimization of surface mining operations.

In the course of this research, an Android app for predicting fragmentation results from blasting has been successfully created, marking a significant step towards harnessing modern technology for the mining industry and advancing mining practices in the digital age.

MATERIALS AND METHODS

Blasting geometry data crucial for this research were obtained from PT Semen Padang, located in Indarung, West Sumatra. The dataset comprised a total of 18 data points, with 11 data entries sourced from Pit PNBP and 7 data entries from Pit PLB. For the specific focus of this study, only the blasting geometry data from Pit PNBP were utilized. The acquired data encompassed essential parameters, including burden (B), spacing (S), diameter (D), Hole Length (H), bench height (L), stemming (T), and length of charge (PC). These data will be utilized as input in the Android application developed for predicting fragmentation outcomes from blasting activities.

The primary tool employed for the development of the Android application is Android Studio Giraffe. This integrated development environment (IDE) is specifically tailored for Android app creation, offering a comprehensive set of features for efficient coding, testing, and debugging. The application is programmed using the Java programming language, harnessing its versatility and compatibility with Android development. The Android app is designed to run on smartphones with a minimum Android version of 5.1 (Lollipop), ensuring broad compatibility and accessibility across a range of devices.

The research and development (R&D) methodology employed in this study adhered to a systematic approach aimed at creating a robust Android application for predicting fragmentation outcomes from blasting activities. The initial phase encompassed a comprehensive literature review and detailed requirement analysis, providing a solid foundation for subsequent development. The Android application underwent key stages, including design, coding, testing, and debugging. Rigorous testing procedures were implemented, involving simulations of blasting scenarios and validation with real-world data. This iterative process of development and testing ensured the reliability and accuracy of the final Android application.

Empirical functions to predict rock fragmentation

The development of the Android application for predicting rock fragmentation involves the implementation of specific functions that play a pivotal role in the prediction process. Drawing inspiration from prior research, several studies have sought to predict fragment size distribution based on the parameters used in blast design, resulting in empirical prediction models. Notably, the Kuz–Ram model stands out as one of the most commonly employed models, providing valuable insights for informing the functions integrated into our application. Given its widespread use and established reliability, this research will adopt the Kuz–Ram model as a fundamental component, leveraging its predictive capabilities to enhance the accuracy of the fragmentation predictions generated by our Android application.

The Kuz–Ram model comprises three main components: a modified version of the Kuznetsov equation, the Rossin–Rammler equation, and the Cunningham uniformity index. The parameters outlined by these equations form the output of the prediction model (Jethro, et al., 2018). Specifically, the Kuznetsov equation, originally proposed by Kuznetsov, serves to predict the mean fragment size (X50). The original formulation of the Kuznetsov equation is expressed as (Kuznetsov, 1973):

$$X_{50} = A\left(\frac{V}{Q}\right)^{0.8} Q^{0.167} \tag{1}$$

In Equation (1), X_{50} represents the average fragment size (cm); A denotes the rock factor (7 for medium hard rocks, 10 for hard but highly fissured rocks, 13 for very hard, weakly fissured rocks); V indicates the rock volume (m^3); and Q stands for the weight of TNT (kg) equivalent to the energy released by the explosive charge in a single borehole. An inherent limitation of this equation is the broad categorization of rock mass, necessitating a more refined level of precision (Kulatilake, et al., 2010). To address this limitation, Cunningham, in 1983, presented a modified version of the equation:

$$X_{50} = AK^{-0.8}\, Q^{\frac{1}{6}}\left(\frac{115}{RWS}\right)^{\frac{19}{30}} \tag{2}$$

Where, A is the rock factor; K is the powder factor, defined as the weight of explosive, in kg per cubic meter of rock; Q is the mass, in kg, of the explosive in the hole; and RWS is the relative weight strength relative to ANFO (ANFO = 100). A is calculated by multiplying 0.12 with blastability index (BI):

$$A = 0.12\, x\, BI \tag{3}$$

The Blastability Index, as proposed by Lily (1986), utilizes in-situ characteristics of the rock mass to anticipate the specific charge required for blasting in open-pit mines. Additionally, it serves as a tool for characterizing the ease of blasting and subsequent rock fragmentation. Equation (4) is used to calculate the BI (Cunningham, 1987), and this computation is supported by the parameters presented in Table 1 (Hustrulid, 1999).

$$BI = 0.5\,(RMD + JPS + JPO + SGI + H) \qquad (4)$$

Where, RMD is the rock mass description, JPS is the joint plane spacing, JPO is the joint plane orientation, SGI is the specific gravity influence, H is hardness (in Mohs scale).

Tabel 1. Ratings for blastability index parameters

Parameters	Score
Rock Mass Description	
Powdery/friable	10
Blocky	20
Totally massive	50
Joint Plane Spacing	
Close (< 0.1 m)	10
Intermediate (0.1 - 1 m)	20
Wide (> 1 m)	50
Joint Plane Orientation	
Horizontal	10
Dip out of face	20
Strike normal to face	30
Dip into face	40
Specific Gravity Influence	25 x SG rock - 50
Hardness	1 - 10

The Rosin-Rammler equation is to predict the overall fragmentation distribution. When provided with a particular mesh size or screen opening denoted as X, the equation can estimate the proportion of retained fragments. The formulation of the Rossin-Rammler equation is expressed as:

$$R(x) = e^{-\left(\frac{X}{Xc}\right)^n} \qquad (5)$$

Where, X is the dimension of the sieve, n is the index of uniformity, R(x) is the ratio of the material retained on the sieve, and Xc is the specific size. The specific size functions as a straightforward scaling index, representing the sieve size through which 63.2% of the fragmented material passes (Kadijani et al., 2018). Xc can be calculated using equation (6):

$$Xc = \frac{X_{50}}{0.693^{\frac{1}{n}}} \qquad (6)$$

The uniformity index, n, is developed by Cunningham through several investigations which involved consideration of the effects of blast geometry, hole diameter, burden, spacing, hole length, and drilling accuracy (Adebole et al., 2016). The index of uniformity can be estimated using equation (7) as shown below:

$$n = \left[2.2 - 14\left(\frac{B}{D}\right)\right]\left[0.5\left(1 + \frac{S}{B}\right)\right]^{0.5}\left[1 - \frac{W}{B}\right]\left[\frac{L}{H}\right] \qquad (7)$$

Where; B is the burden (m), S is the spacing (m), D is the hole diameter (mm), W is the standard deviation of drilling accuracy (m), L is the total length of drilled hole (m) and H is the bench height (m).

Application Development

To develop the rock fragmentation distribution prediction app, the ADDIE model is applied. The ADDIE model is a well-known instructional design framework used for the systematic planning and development of educational or training programs. The acronym ADDIE stands for Analysis, Design, Development, Implementation, and Evaluation (Yusoff & Romli, 2018). Therefore, there are five key phases derived from the ADDIE model involved in the development process of this android application.

Analysis phase

The primary aim of this Android app is to provide a reliable and user-friendly tool for predicting rock fragmentation resulting from blasting activities in surface mining. The app seeks to enhance the efficiency of mining operations by offering accurate and timely predictions, enabling miners to optimize blasting parameters and downstream processes. The target audience for this app includes mining engineers, geologists, and other professionals involved in surface mining operations. By catering to the specific needs of these professionals, the app aims to facilitate better decision-making in blast design, leading to improved rock fragmentation outcomes. To fulfill its predictive capabilities, the app require relevant data such as blasting geometry parameters (burden, spacing, diameter, etc.), geological characteristics, and estimated fragmentation data. The blasting geometry data obtained is shown in Table 2. The app leverages established algorithms, the Kuz–Ram model, to perform predictive calculations.

Tabel 2. Blasting Geometry Parameters in Pit PNBP

Number of blasthole	B (m)	S (m)	D (Inch)	H (m)	L (m)	T (m)
75	3	4	5	10.4	9.0	4.16
60	4	5	5	9.8	9.0	3.92
67	4	4	5	9.5	8.8	3.80
60	4	4	5	9.7	8.5	3.88
51	4	5	5	9.1	8.4	3.64
60	3	3	5	8.1	7.5	3.24
39	3	3	4	6.6	7.0	2.64
92	3	3	4	5.4	6.0	2.16
120	4	5	5	9.3	9.0	3.72
69	4	5	5	9.1	8.7	3.64
36	4	5	5	8.0	7.5	3.20
47	4	5	5	9.9	9.0	3.96
60	4	5	5	9.5	8.5	3.80
48	4	5	5	9.7	8.8	3.88

Design phase

In this phase the key features and app functionalities that the app will offer are specified (Figure 2). Based on these identified features, the requisite input parameters for predicting rock fragmentation outcomes are meticulously defined. After defining the necessary input parameters, the subsequent step in the interface design process involves the creation of wireframes and mockups. This critical stage is dedicated to visualizing the app's structure and layout before development begins. These visual representations serve as blueprints, providing a tangible framework for the user interface's structure and guiding the subsequent development stages. The placement of input fields, navigation elements, and visual representations of fragmentation predictions are also considered. This intentional visualization ensures that the final interface not only meets the functional requirements but also to enhance user experience, ensuring efficient and intuitive data entry.

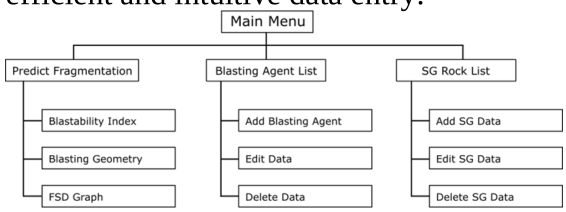


Figure 2. Predicting Rock Fragmentation Application Module

Based on the conceptual scheme illustrated in Figure 2, the wireframes and mockups were developed so that intricately align with the established scheme. In Figure 3, the predict fragmentation activity wireframe shows the user interface layout designed for inputting blasting geometry parameters, harmonizing seamlessly with the conceptual structure depicted in Figure 2. Additionally, Figure 3b and 3c show the blasting agent database activity and SG database activity wireframes which share the same design, respectively, mirroring the envisioned interfaces for accessing and managing blasting agent data and SG data. The blasting agent database activity and SG database activity modules were specifically created to facilitate the efficient management of databases for blasting agents and SG. Users have the flexibility to add custom blasting agents and SG that may not be pre-included in the app, empowering them with a customizable and adaptable tool for their unique needs.

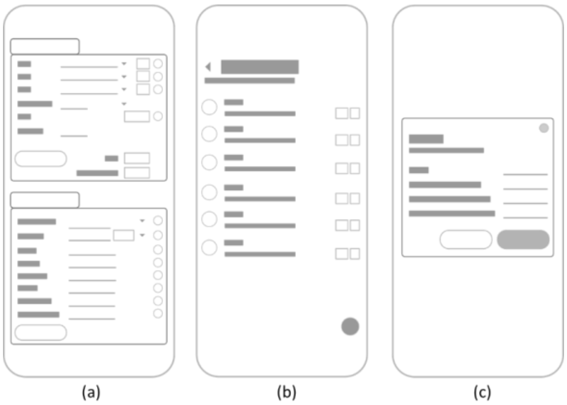


Figure 3. Wireframes of the Application Activity

Development Phase

After creating wireframes for each activity, the subsequent step is to transform these wireframes into the actual layout of the user interface. This crucial process is accomplished through the use of XML (eXtensible Markup Language), a versatile markup language widely employed in Android app development for defining the structure and appearance of user interfaces. The XML code serves as the blueprint for the visual components, specifying the arrangement, properties, and interactions of the elements within each activity. The android layout user interfaces, transformed from the wireframes depicted in Figures 3(a), 3(b), and 3(c) and defined through XML, are shown in Figure 4:

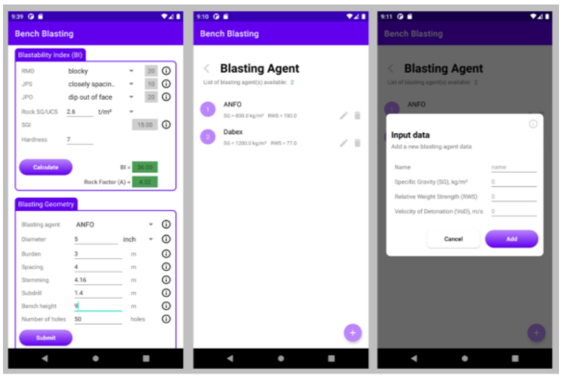
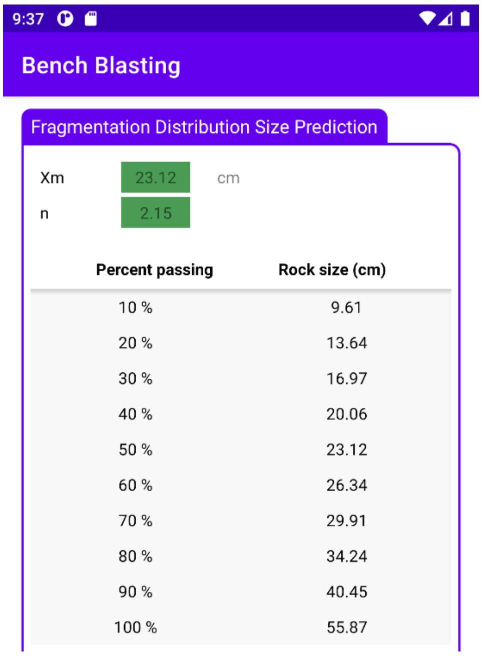


Figure 4. Application Interface Design in XML

As the layout of each activity has been established, the next stage is to implement the functionality and logic that power the app. This is done by crafting the necessary code to manage user inputs, process data, establish seamless communication with databases, and execute other vital operations. The initial code for this app involves creating model data for blasting agents and SG, as depicted in Figure 5a and 5b.

Figure 5. Blasting Agent Code (a) and SG Handler Code (b)

Now that the blasting agent data and SG data are available, the subsequent step is algorithm integration. The Kuz–Ram model is incorporated into the app's functionality. This involves translating the mathematical expressions from Equation (2) to Equation (7) into Java programming language. Equation (5) is iteratively applied ten times with intervals of 10 to calculate the percentage of material retained, spanning from 10 to 100 percent. The Kuz-Ram prediction model produces a fragmentation distribution size presented as a list of percent passing and corresponding fragment sizes. The generated list is displayed in tabular form, presenting the fragmentation distribution size in terms of percent passing and corresponding fragment sizes (Figure 6).



Percent passing	Rock size (cm)
10 %	9.61
20 %	13.64
30 %	16.97
40 %	20.06
50 %	23.12
60 %	26.34
70 %	29.91
80 %	34.24
90 %	40.45
100 %	55.87

Figure 6. Percent Passing and Rock Fragmentation Size Prediction

The distribution size is further illustrated through a graphical representation, with a curve depicting percent passing on the y-axis and fragment size on the x-axis (Figure 7). The graphical representation is generated using the MP Android Chart library, a robust open-source tool designed for creating powerful chart views and graph displays on Android. Implementing graphical representation of fragmentation outcomes allow users to interpret and analyze predictions easily.

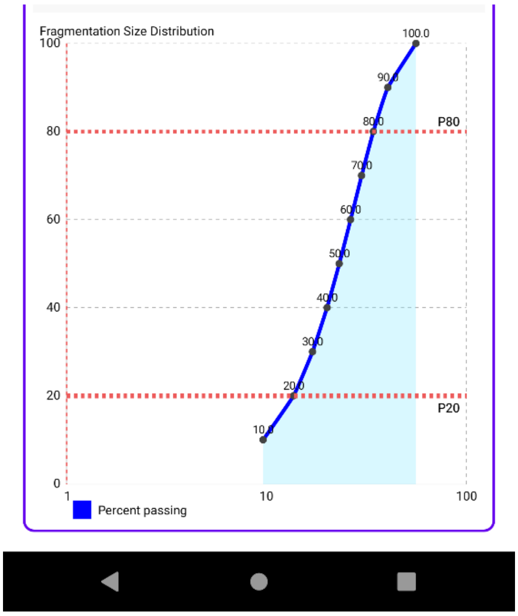


Figure 7. Graphical Representation of Rock Fragmentation Size Prediction

Evaluation phase

During the evaluation phase, this Android application developed for rock fragmentation size distribution prediction, integrating the Kuz-Ram method, underwent a meticulous comparison to validate its predictive accuracy. A comprehensive assessment was conducted by comparing the application-generated predictions against manual calculations performed using Microsoft Excel. The results consistently demonstrated a high degree of concordance between the predictions generated by the application and the manually derived results. This affirmed the precision and reliability of the computational model employed in the application. Simultaneously, a robust monitoring protocol was implemented to detect and address potential software bugs or issues within the application. The monitoring process extended to the identification of scenarios that might induce app instability and force closures.

RESULTS AND DISCUSSION

The evolution of technology has led to the development of mobile applications. This is also prevalent in the mining engineering field. The current study developed a mobile fragmentation size distribution prediction application using the ADDIE model. As the result, the android app to predict fragmentation distribution size from blasting activity in surface mining has successfully been created. To use the app properly, the user must first check the available blasting agent and specific gravity provided by the app. If the blasting agent or SG of the rock in the user field is available then he might continue to predict PSD based on blasting geometry he used, otherwise he must add the blasting agent or SG data that match his blasting field area by pressing the '+' button located in the bottom right corner of the page (Figure 4b). To do the prediction of PSD, the user must input the geological characteristics data in the blastability index tab. The data needed are RMD, JPS, JPO, to be blasted rock SG, and rock hardness. For RMD, JPS, and JPO, user only need to choose one option from the dropdown menu that match his blasting environment. The next required input data is the blasting geometry data. The user must first select the blasting agent used to blast the bench (ANFO, Dabex, etc) from the dropdown menu. The blasting agent list that appear is match with the list of available blasting agent data. Afterwards, the user must fill the diameter of blast hole, burden, spacing, stemming, subdrill, and bench height. By pressing the submit button, the developed app will then predict the PSD.

In this study, the blastability index data acquired from the blasting site is used. The RMD, JPS, JPO, rock SG, and hardness are blocky (20), widely spacing (50), dip out of face (20), 2.6 ton/m3, and 7.5, respectively. Whereas the blasting geometry data used to do the prediction come from the blasting geometry data in Table 2. The PSD prediction from the first two blasting geometry is shown in Figure 8.

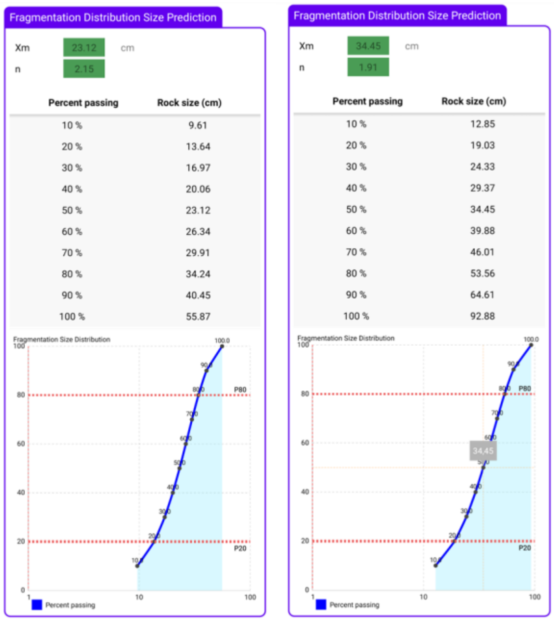


Figure 8. PSD Prediction Based on Blasting Geometry on 21st and 24th March

By following the same step as described before, the complete PSD for the entire blasting geometry data in Table 2 is shown in the following table:

Tabel 3. PSD Prediction Using Bench Blasting App

Date	Location	Particle Size (mm) Percent Passing		
		20%	50%	80%
21-Mar-22	PNBP 6	136.4	231.2	342.4
24-Mar-22	PNBP 4	190.3	344.5	535.6
25-Mar-22	PNBP 4	152	286.7	459.7
29-Mar-22	PNBP 8	187.4	340.3	530.2
31-Mar-22	PNBP 8	95.7	176.2	277.3
04-Apr-22	PNBP 4	182.7	341.6	543.7
05-Apr-22	PNBP 5	183.5	340.3	538.7
23-Apr-22	PNBP 7	181.7	333.1	522.5
24-Apr-22	PNBP 6	191.8	345.1	534.1
25-	PNBP	192.3	342.8	526.8

Apr-22	6			
26-Apr-22	PNBP 4	191.4	344	531.8
Average		171.38	311.44	485.71

CONCLUSION

Based on the results, this app efficiently performs calculations for obtaining fragmentation size distribution predictions across ten percent passing intervals with ease and minimal time requirements. The user will only need to provide 12 (twelve) data in the input fields. From those twelve, four of them are choose from dropdown available menu that suit user blasting environment. This app can further develop to simplify it so it will take only six input data from user. This will be able to achieved by creating a model regarding the blastability index. The blastability index data then can be saved like blasting agent and SG data. As long as the geological characteristics of rock to be blasted is the same, the user do not need to change BI data. Only six data input from user and the app will do the rest.

This app surely make the PSD prediction become faster, more effective, and more efficient. However, as this app employed empirical method to predict the fragmentation size distribution, the accuracy of the prediction must be compared with the actual fragmentation outcomes from mining blast result to get the error of the empirical prediction. As mentioned by Sudakhar (2013), the direct method that relies on sieve analysis to compute fragmentation content (offering high accuracy) is the best comparison for the prediction made by any other indirect methods.

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