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Digitalization-Based Geometric Design of Open Pit Mining Blast Using Visual Block Programming Method

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ABSTRACT

Gilgal Batu Alam Lestari (PT. GILBAL) is a company specializing in granodiorite rock mining. In its mining operations, PT. GILBAL employs blasting to break down materials, simplifying the loading and processing stages. The design of blast hole geometry requires precise calculations to achieve an optimal configuration, ensuring that blast fragmentation aligns with operational needs. To facilitate the blast hole geometry calculations, an application is needed that delivers accurate results and can be accessed anytime, anywhere. One approach to developing this application is through visual block programming using the Kodular tool. The research aims to design a system programming concept for an application capable of processing calculations for both blast geometry design and blast fragmentation outcomes, implementing this application program for actual blasting operations in the field, and achieving high accuracy in the application design's performance when applied in real-world field conditions. Application testing for blast hole geometry calculations demonstrated that the R.L. Ash method achieved an average accuracy of 97.39%, the C.J. Konya method reached 98.49%, the Anderson method achieved 99.93%, and the Langefors method reached 99.95%. In terms of calculating blast fragmentation, the R.L. Ash method attained an average accuracy of 89.57%, the C.J. Konya method 93.49%, the Anderson method 86.50%, and the Langefors method 99.81%.

Keywords: *Blast Hole Geometry; Blast Fragmentation; Application; Kodular.*

INTRODUCTION

In the mining industry, rocks with relatively high hardness are often encountered. To break these rocks, blasting is necessary to make excavation and loading into transport equipment easier, enabling mining operations to proceed effectively and efficiently [1]. One key indicator of successful blasting is fragmentation, where the resulting fragment size affects the excavation and loading processes of blasted rock or ore [2].

In planning blasting activities for open-pit mines, several factors must be considered, including the type of material, drilling precision, geometric patterns, and the explosives used [3]. Calculating blasting geometry requires a high degree of accuracy, and manual calculations are often time-consuming. Therefore, a system is needed to streamline and expedite the calculation process while improving the accuracy of the results.

Previous research on the "Design of a Mobile-Based Open-Pit Mining Blast Geometry Application Using Android Studio Programming" produced a mobile application for blasting geometry calculations using the C.J. Konya and R.L. Ash methods, as well as blast fragmentation analysis using the Kuz-Ram method [4]. The application's outputs include blast hole geometry data (such as burden, spacing, stemming, subdrilling, power factor, etc.) and a fragmentation analysis with a line graph. However, the application still has limitations, including the lack of a database for storing calculation results.

In this research, the aim is to enhance the application or software by adding several features. These features include four options for blast geometry calculation methods (R.L. Ash, C.J. Konya, Anderson, and Langefors), illustrated images of calculated geometry results, fragmentation calculation of the blasting outcomes, a database system for storing calculation data, and a reporting feature related to blasting activities.

METHODS

Research Stages

1. **Field Observation1**
   The purpose of field observation is to examine the actual conditions of blasting activities in the field, particularly those related to the design and calculation of blasting geometry.
2. **Literature Review**
   The literature review aims to establish a theoretical foundation based on references such as journals, books, and previous studies related to the research problem.
3. **Data Collection and Acquisition**
   The data required for this study includes primary and secondary data that will support the development of the blast geometry calculation system application design. The data collected will consist of supporting data for application system design and data to test the accuracy level of the designed application system. Secondary data needed for this research includes, for example, the Mining Permit (IUP) of PT. Gilbal and explosive specifications. Additionally, data necessary for the parameters used in the geometry and fragmentation calculations for developing the system application design are as follows:

Table 1. Calculation Parameter Data

Primary	Secondary
Blast Geometry Calculation Parameters	
Hole Diameter	Rock Specific Gravity (SG)
Bench Height	Standard Rock Specific Gravity
Blasting Method	Explosive Specific Gravity
Ore Condition	Standard Explosive Specific Gravity
	Explosive Velocity of Detonation (VOD)
	Standard Explosive VOD
	Target Volume
	Hole Diameter
	Spacing Ratio (Ks)
	Stemming Ratio (Kt)
	Depth Ratio (Kh)
	Subdrilling Ratio (Kj)
	Bench Height
	Rock Mass Description (RMD)
	Joint Plane Spacing (JPS)
	Joint Plane Orientation (JPO)
	Specific Gravity Influence (SGI)

4. **Design**
5. **Programming the Prototype**
6. **Prototype Testing**
7. **Prototype Testing Analysis**
8. **Blast Geometry Calculation Application**
9. **Conclusion and Recommendations**

Prototype Design of Application System Program

Once all data has been gathered, the next step is to design a prototype for the application system program, which includes creating a conceptual layout of the planned application system. This concept includes a sketch of the user interface, the features to be incorporated along with their functions, and a list of requirements necessary to implement these features within the application system design. The conceptual design of the application system prototype is illustrated in the following figure.

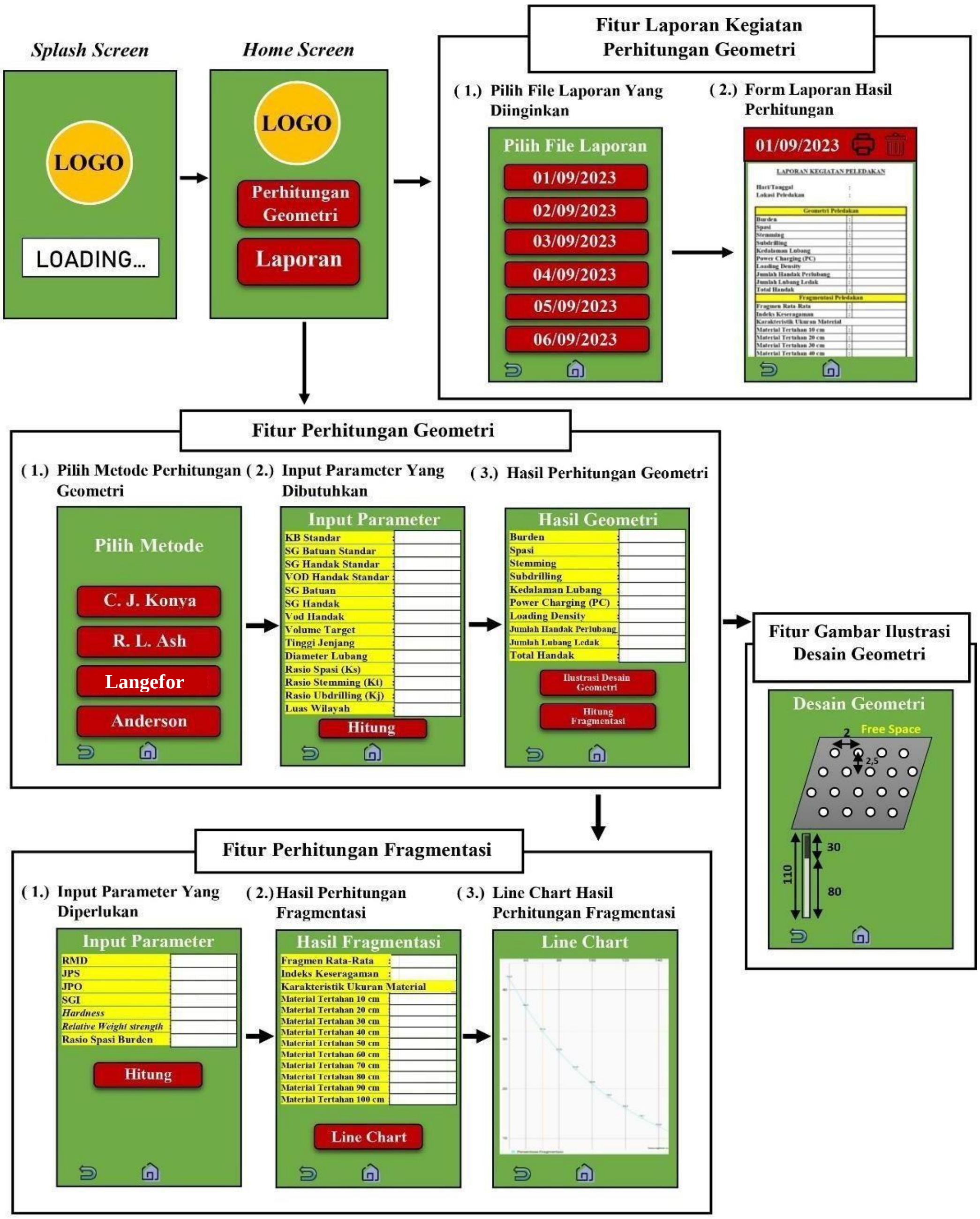

Figure 1. Application Design Concept

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RESULTS AND DISCUSSION

Calculation Methods Used by PT. GILBAL

PT. GILBAL employs the R.L. Ash method for calculating blast hole geometry, while fragmentation calculations for blasted materials are based on the number of truckloads (ritase) transported by dump trucks carrying blasted rock material. To facilitate these calculations, PT. GILBAL uses Microsoft Excel as the computational tool.

Supporting Data for Blast Hole Geometry Calculations

The following data is required to support testing the accuracy and error rate in the blast hole geometry calculations for the developed prototype system:

Table 2. Blast Hole Geometry Calculation Parameter Data

No.	Parameter	Value	Unit
1	Explosive SG (SG Handak)	0.8	g/cc
2	Standard Explosive SG (SG Handak Standar)	1.2	g/cc
3	Rock SG (SG Batuan)	2.5	ton/m³
4	Standard Rock SG (SG Batuan Standar)	2.6	ton/m³
5	Explosive VOD (VOD Handak)	3400	m/s
6	Standard Explosive VOD (VOD Handak Standar)	3660	m/s
7	Hole Diameter	3	inches
8	Bench Height (Tinggi Jenjang)	5	m
9	Spacing Ratio (Ks)	1.2	-
10	Stemming Ratio (Kt)	0.7	-
11	Subdrilling Ratio (Kj)	0.3	-
12	Depth Ratio (Kh)	3	-
13	Target Blast Volume	5000	m³
14	Blasting Method (Metode Peledakan)	Delay	-
15	Material Condition (Kondisi Material)	Layered	-

Table 3. Fragmentation Calculation Parameters for Blasting Results

No.	Parameter	Value
1	Rock Mass Description (RMD)	50
2	Joint Plane Spacing (JPS)	20
3	Joint Plane Orientation (JPO)	40
4	Specific Gravity Influence (SGI)	16.5
5	Hardness (H)	4.40
6	Relative Weight Strength of Explosive	100

Discussion of the Designed Application

The application development process used in this research follows a prototyping method, where the prototype design of the application is iteratively developed before reaching its final version. Kodular was employed as the programming platform to create this application. The stages involved in designing the prototype until it becomes the final application are outlined as follows:

Application Specifications

The specifications of the developed application include:

1. A calculation feature for blast hole geometry using the C.J. Konya method

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2. A calculation feature for blast hole geometry using the R.L. Ash method
3. A calculation feature for blast hole geometry using the Lungefors method
4. A calculation feature for blast hole geometry using the Anderson method
5. An illustration feature for visualizing blast hole geometry designs
6. A calculation feature for fragmentation analysis of blasting results
7. A line chart feature displaying fragmentation material data from blasting results
8. A report file feature to document the calculation activities
9. The application must request access permissions for the device’s internet network

Application User Interface

Each screen in the application includes specific assets and components. The **splash screen** features background imagery, the application logo, the application name, and a loading animation. The **home screen** contains a background image, the logo, the application name, and buttons for accessing the blast hole geometry calculation features and calculation report.

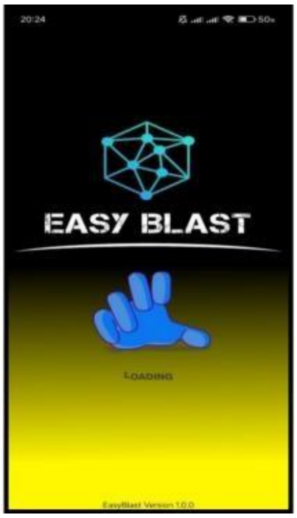

Figure 2. Splash Screen

Figure 3. Home Screen

Figure 4. Calculation Method Selection

Figure 5. Blast Geometry Calculation Input

Figure 6. Blast Geometry Calculation Results

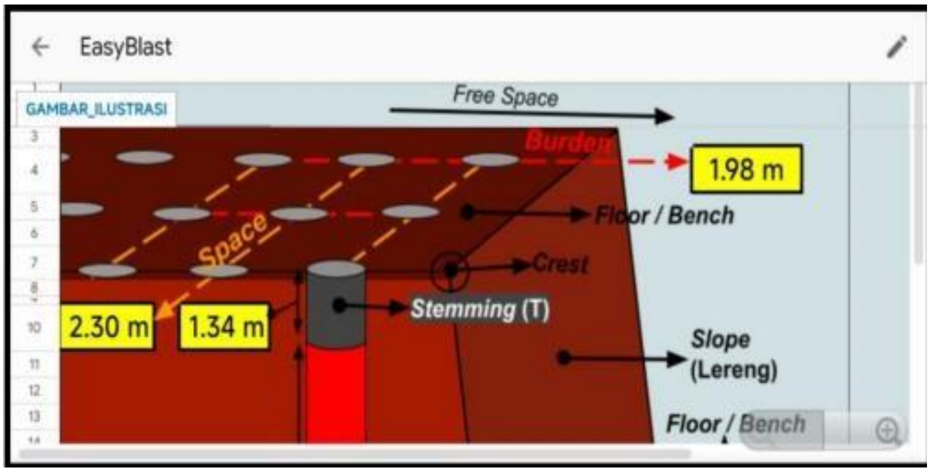

Figure 7. Blast Geometry Design Illustration

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Figure 8. Fragmentation Calculation Input

Figure 9. Fragmentation Calculation Results

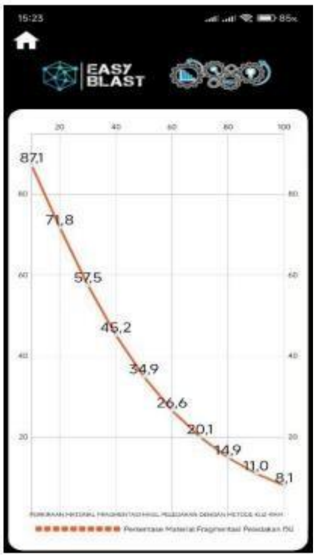

Figure 10. Fragmentation Line Chart Graph

Figure 11. *Calculation Report Selection*

Figure 12. Save Calculation Results Report

Figure 13. Report Form

Figure 14. Delete Report

Figure 15. *Print Report*

Calculation Accuracy Testing

The calculation accuracy testing results for the application are as follows:

Table 4. Accuracy and Error Testing of Blast Hole Geometry Calculations Using the R.L. Ash Method

No.	Calculation Parameter	Calculation Result		Difference	Error (%)	Accuracy (%)
		Application	Testing			
1	Burden (m)	1.930	1.930	0.000	0.000	100.000
2	Spacing (m)	2.316	2.316	0.000	0.000	100.000
3	Stemming (m)	1.351	1.351	0.000	0.000	100.000
4	Subdrilling (m)	0.579	0.579	0.000	0.000	100.000
5	Hole Depth (m)	5.790	5.790	0.000	0.000	100.000
6	Powder Column (m)	4.439	4.439	0.000	0.000	100.000
7	Loading Density (kg/m)	3.658	3.658	0.000	0.000	100.000
8	Explosive Charge per Hole (kg)	16.238	16.238	0.000	0.000	100.000

9	Number of Holes	194.000	194.000	0.000	0.000	100.000
10	Total Explosive (kg)	3150.172	3150.172	0.000	0.000	100.000
11	Powder Factor (m)	0.,627	0.,627	0.000	0.000	100.000
12	Average Fragmentation (Xm)	20.,002	20.,002	0.000	0.000	100.000
13	Fragmentation Size Characteristic (Xc)	24.762	24.762	0.000	0.000	100.000
14	% Material Retained on 10 cm Sieve	81.061	81.061	0.000	0.000	100.000
15	% Material Retained on 20 cm Sieve	50.120	50.120	0.000	0.000	100.000
16	% Material Retained on 30 cm Sieve	25.001	25.001	0.000	0.000	100.000
17	% Material Retained on 40 cm Sieve	10.306	10.306	0.000	0.000	100.000
18	% Material Retained on 50 cm Sieve	3.565	3.565	0.000	0.000	100.000
19	% Material Retained on 60 cm Sieve	1.046	1.046	0.000	0.000	100.000
20	% Material Retained on 70 cm Sieve	0.262	0.262	0.000	0.000	100.000
21	% Material Retained on 80 cm Sieve	0.057	0.057	0.000	0.000	100.000
22	% Material Retained on 90 cm Sieve	0.011	0.011	0.000	0.000	100.000
23	% Material Retained on 100 cm Sieve	0.002	0.002	0.000	0.000	100.000
Accuracy (%)					0.000	
Average Accuracy (%)					100.000	

Table 5. Accuracy and Error Testing of Blast Hole Geometry Calculations Using the C.J. Konya Method

No.	**Calculation Parameter**	**Calculation Result**		**Difference**	**Error (%)**	**Accuracy (%)**
		Application	**Testing**			
1	Burden (m)	1.978	1.978	0.000	0.000	100.000
2	Spacing (m)	2.318	2.318	0.000	0.000	100.000
3	Stemming (m)	1.352	1.352	0.000	0.000	100.000
4	Subdrilling (m)	0.593	0.593	0.000	0.000	100.000
5	Hole Depth (m)	5.593	5.593	0.000	0.000	100.000
6	Powder Column (m)	4.241	4.241	0.000	0.000	100.000
7	Loading Density (kg/m)	3.646	3.646	0.000	0.000	100.000
8	Explosive Charge per Hole (kg)	15.463	15.463	0.000	0.000	100.000
9	Number of Holes	196.000	196.000	0.000	0.000	100.000
10	Total Explosive (kg)	3030.748	3030.748	0.000	0.000	100.000
11	Powder Factor (m)	0.603	0.603	0.000	0.000	100.000
12	Average Fragmentation (Xm)	20.470	20.470	0.000	0.000	100.000
13	Fragmentation Size Characteristic (Xc)	25.670	25.670	0.000	0.000	100.000
14	% Material Retained on 10 cm Sieve	80.540	80.540	0.000	0.000	100.000
15	% Material Retained on 20 cm Sieve	51.410	51.410	0.000	0.000	100.000
16	% Material Retained on 30 cm Sieve	27.710	27.710	0.000	0.000	100.000
17	% Material Retained on 40 cm Sieve	12.940	12.940	0.000	0.000	100.000
18	% Material Retained on 50 cm Sieve	5.310	5.310	0.000	0.000	100.000
19	% Material Retained on 60 cm Sieve	1.940	1.940	0.000	0.000	100.000
20	% Material Retained on 70 cm Sieve	0.630	0.630	0.000	0.000	100.000
21	% Material Retained on 80 cm Sieve	0.190	0.190	0.000	0.000	100.000
22	% Material Retained on 90 cm Sieve	0.050	0.050	0.000	0.000	100.000
23	% Material Retained on 100 cm Sieve	0.010	0.010	0.000	0.000	100.000
Accuracy (%)					0.000	
Average Accuracy (%)					100.000	

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Table 6. Accuracy and Error Testing of Blast Hole Geometry Calculations Using the Anderson Method

No.	Calculation Parameter	Calculation Result		Difference	Error (%)	Accuracy (%)
		Application	Testing			
1	Burden (m)	1.837	1.837	0.000	0.000	100.000
2	Spacing (m)	2.204	2.204	0.000	0.000	100.000
3	Stemming (m)	1.286	1.286	0.000	0.000	100.000
4	Subdrilling (m)	0.551	0.551	0.000	0.000	100.000
5	Hole Depth (m)	5.511	5.511	0.000	0.000	100.000
6	Powder Column (m)	4.225	4.225	0.000	0.000	100.000
7	Loading Density (kg/m)	3.658	3.658	0.000	0.000	100.000
8	Explosive Charge per Hole (kg)	15.455	15.455	0.000	0.000	100.000
9	Number of Holes	225.000	225.000	0.000	0.000	100.000
10	Total Explosive (kg)	3477.375	3477.375	0.000	0.000	100.000
11	Powder Factor (m)	0.693	0.693	0.000	0.000	100.000
12	Average Fragmentation (Xm)	18.326	18.326	0.000	0.000	100.000
13	Fragmentation Size Characteristic (Xc)	22.884	22.884	0.000	0.000	100.000
14	% Material Retained on 10 cm Sieve	77.558	77.558	0.000	0.000	100.000
15	% Material Retained on 20 cm Sieve	45.016	45.016	0.000	0.000	100.000
16	% Material Retained on 30 cm Sieve	21.037	21.037	0.000	0.000	100.000
17	% Material Retained on 40 cm Sieve	8.154	8.154	0.000	0.000	100.000
18	% Material Retained on 50 cm Sieve	2.670	2.670	0.000	0.000	100.000
19	% Material Retained on 60 cm Sieve	0.748	0.748	0.000	0.000	100.000
20	% Material Retained on 70 cm Sieve	0.181	0.181	0.000	0.000	100.000
21	% Material Retained on 80 cm Sieve	0.038	0.038	0.000	0.000	100.000
22	% Material Retained on 90 cm Sieve	0.007	0.007	0.000	0.000	100.000
23	% Material Retained on 100 cm Sieve	0.001	0.001	0.000	0.000	100.000
Accuracy (%)					0.000	
Average Accuracy (%)					100.000	

Table 7. Accuracy and Error Testing of Blast Hole Geometry Calculations Using the Langefors Method

No.	Calculation Parameter	Calculation Result		Difference	Error (%)	Accuracy (%)
		Application	Testing			
1	Burden (m)	2.385	2.385	0.000	0.000	100.000
2	Spacing (m)	2.981	2.981	0.000	0.000	100.000
3	Stemming (m)	2.385	2.385	0.000	0.000	100.000
4	Subdrilling (m)	0.779	0.779	0.000	0.000	100.000
5	Hole Depth (m)	6.068	6.068	0.000	0.000	100.000
6	Powder Column (m)	3.376	3.376	0.000	0.000	100.000
7	Loading Density (kg/m)	3.646	3.646	0.000	0.000	100.000
8	Explosive Charge per Hole (kg)	12.309	12.309	0.000	0.000	100.000
9	Number of Holes	117.000	117.000	0.000	0.000	100.000
10	Total Explosive (kg)	1440.153	1440.153	0.000	0.000	100.000
11	Powder Factor (m)	0.285	0.285	0.000	0.000	100.000
12	Average Fragmentation (Xm)	35.843	35.843	0.000	0.000	100.000
13	Fragmentation Size Characteristic (Xc)	47.930	47.930	0.000	0.000	100.000
14	% Material Retained on 10 cm Sieve	87.114	87.114	0.000	0.000	100.000
15	% Material Retained on 20 cm Sieve	71.830	71.830	0.000	0.000	100.000
16	% Material Retained on 30 cm Sieve	57.550	57.550	0.000	0.000	100.000
17	% Material Retained on 40 cm Sieve	45.210	45.210	0.000	0.000	100.000

18	% Material Retained on 50 cm Sieve	34.940	34.940	0.000	0.000	100.000
19	% Material Retained on 60 cm Sieve	26.630	26.630	0.000	0.000	100.000
20	% Material Retained on 70 cm Sieve	20.060	20.060	0.000	0.000	100.000
21	% Material Retained on 80 cm Sieve	14.940	14.940	0.000	0.000	100.000
22	% Material Retained on 90 cm Sieve	11.020	11.020	0.000	0.000	100.000
23	% Material Retained on 100 cm Sieve	8.060	8.060	0.000	0.000	100.000
Accuracy (%)					0.000	
Average Accuracy (%)					100.000	

Application Testing Analysis

The analysis of the prototype system testing results is as follows:

1. **Black-box Testing**
   After conducting black-box testing, users did not encounter any functional issues or errors in any features within the prototype. Based on these results, it can be concluded that the tested prototype is functioning well.
2. **Calculation Accuracy Testing**
   The accuracy results, detailed in Tables 4, 5, 6, and 7, indicate that the calculations meet the company's (PT. GILBAL) error margin standard of 95%. The blast hole geometry calculations (including burden, spacing, stemming, subdrilling, hole depth, powder column, loading density, explosive charge per hole, number of blast holes, total explosive, and powder factor) for each calculation method (R.L. Ash, C.J. Konya, Anderson, and Langefors) achieved an error percentage of 0% and an accuracy percentage of 100%. Additionally, the fragmentation calculations based on blast hole geometry for each method also showed 0% error and 100% accuracy. Therefore, the application's calculation accuracy meets PT. GILBAL's company standards as defined by the specified error margin.

CONCLUSION

Based on the functional testing results using the black-box method, all system activities, including features, buttons, parameter input fields, calculation result fields, and application pages, have operated correctly and as expected, with no errors or bugs identified. According to the error rate and accuracy percentage test results for the application's calculations, the blast hole geometry calculations using the R.L. Ash, C.J. Konya, Anderson, and Langefors methods have achieved a 0% error rate and 100% accuracy. The blast hole geometry calculations performed by the application meet the error margin standard set by the company (PT. GILBAL), with the application achieving a calculation accuracy of 95%.

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