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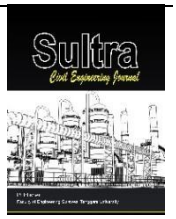

Revolutionizing Onsite Management Using a Cutting-Edge App

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ABSTRACT

Due to lack of adequate material management systems, construction projects often suffer material wastes, delays and other related problems. In order to address the issue of construction material mismanagement, it is envisaged to develop an android application using innovative technologies such as Java, Dart, YAML, Kotlin and Flutter 2.x with Economic Order Quantity (EOQ) and flat fees method as the logical framework. Features such as material list, stock management, purchase records along with supplier information, material issuance records and due amount information is conceived to a part of this versatile tool, capable of overcoming a multitude of challenges, including tracking and managing issued materials on site, maintaining up-to-date stock records, financial tracking, managing supplier information, ensuring accurate and detailed information on material quantities to name a few. Thus, a potential savings of up to 12-15% in material management cost is estimated through the employment of this application on construction projects.

1. Pendahuluan

Material management is a crucial aspect of construction projects, as it accounts for a significant portion of overall construction costs. Materials typically make up around 55%-60% of the total construction expenses (Kumar et al., 2018; Song, 2005; and Nasir, 2008). Material management has changed drastically over time and is often customized by project stakeholders to accommodate the growing complexity of construction projects.

Due to lack of an effective material management system, a construction project incurs significant time and cost overruns. Without precise inventory monitoring, there is a chance of ordering excessive materials, which cause problems with on-site storage, take up precious space, and result in higher expenses; unused supplies are also wasted, therefore increasing the cost of the entire project. On the other hand, ordering less than required material leads to significant opportunity loss due to material not being available when needed. Planning materials well definitely cuts down labor costs, eliminates human error, and speeds up project completion time. Poor activity planning and disorganized inventory purchases result in higher costs due to both understocking and overstocking of commodities as well as improper management of material distribution on construction sites. As a result, the construction sector encounters issues like restricted capital or lost chances brought on by material shortage & wastes.

Due to the complex nature of construction projects, there is always an opportunity for improvisation in a traditional/conventional material management system. Developing a mobile application (app) for construction material management offers numerous benefits, including improved efficiency, better cost control, and greater collaboration [Caldas *et. al*., 2015]. The main goals of developing a material management app in the construction sector are to increase productivity, remove data errors, and effectively mitigate bottlenecks commonly associated with quantities and outstanding dues. A construction material management app will assist in organizing tasks, saving expenses, increasing productivity, and improving safety, all of which contribute to more successful projects.

2. Literature Review

Stakeholder opposition to change and inadequate anticipation of material requirements are prime obstacles in construction material management [Akintoye, 1995]. Better planning, monitoring, and control of material usage were the areas that needed improvement in construction material management [Ayegba, 2013]. Effective stakeholder coordination, communication, and tried and tested procurement practices in material management are essential for ensuring materials are available precisely when needed [Thomas *et al.,* 2005]. The significance of an efficient material management system in construction projects was discussed and various strategies for implementation of a material management plan, effective stakeholder communication, and the utilization of suitable storage facilities were discussed [Patel & Vyas, 2013].

An extensive examination of the procurement practices used in the construction sector revealed that many firms have historically depended on techniques that may not have been best suited to the particular requirements of the sector. The crucial need of using sustainable material management strategies, such as resource recycling and resource reuse, as well as waste minimization through enhanced planning and design, was emphasized [Caldas *et al.,* 2015]. Perishable inventory management methods were thoroughly investigated, with a focus on evaluating the environmental effects of both the First-In-First-Out (FIFO) and Last-In-First-Out (LIFO) policies. These methods revealed important information on how to manage inventories effectively while adhering to environmental rules [Murmu *et al.,* 2023]. Always Better Control (ABC) analysis was used to improve resource management for the construction of residential buildings, providing useful advice for improving resource management and lowering project costs [Mahagaonkar & Kelkar, 2017]. The use of Just in time (JIT) materials management systems in developing countries was investigated, with an emphasis on the possible advantages and drawbacks [Kasim *et. al.,* 2012]. The ABC analysis, S-curve analysis, JIT inventory management, and lean construction methods were all important aspects that should form a based for any material management model [Polat & Arditi, 2005].

A decision model for selecting building material suppliers depending on criteria was studied, which showed how multi-criteria decision-making models might enhance the supplier selection process in the construction industry [Patil & Pataskar, 2013]. In choosing a material management model, a number of elements need to be taken into account, including the project's breadth and complexity, the degree of integration needed, and the organization's openness to using new technology. Thus, electronic models have the potential to improve material management in the building sector by improving the management of construction materials [Castro-Lacouture & Skibniewski, 2003].

The awareness of the information and communication technology (ICT) for materials management in construction projects was studied and it was found that experts in the construction industry had a relatively low degree of familiarity with ICT deployment in materials management [Kasim & Ern, 2011]. The difficulties associated with managing materials in decentralized supply chains, where numerous organizations were involved in the production

and delivery of products were discussed. The need for a combination of managerial, organizational, and technological advancements for effective material management in such supply chains was stressed [Lee & Billington, 1993]. A case study from a building project in India, illustrated the advantages of efficient inventory control, including increased material availability and waste reduction [RathinaKumar *et al.,* 2018]. The practical implementation of an automated materials tracking system in a case study was found to be quite effective [Girme, 2017]. A web-based material management system including an access portal for clients, server, database and various modules for material list, activity list, supplier list, inventory page, requirement page, etc. was found to be quite effective in construction material management [Kazi & Parkar, 2021].

An Internet-Based Agent System (IBAS), which used mobile agents in construction material management, benefited from quicker procurement time-frames, better stakeholder communication, and decreased human error [Hadikusumo *et al.,* 2005]. A Material Management System (MMS), which was developed to track the entire material management process, from ordering to delivery at construction sites, was found to be quite effective in controlling the flow of construction materials for various processes, saving considerable costs [Tavakoli & Kakalia, 1993]. A framework that could alleviate problems with materials tracking and enhance inventory control in building projects was developed, which boasted of a communication protocol with regular updates and a centralized platform with definite step-by-step procedure for monitoring items using barcodes and Radio Frequency Identity (RFID) tags, employing mobile devices, Global Positioning System (GPS) tracking, and cloud-based platforms to improve accuracy and efficiency [Kasim *et al.,* 2012]. The use of multi-sensor data fusion techniques for on-site material tracking in construction projects was investigated and a framework for doing so was tested. This included monitoring materials in real-time using a variety of sensors, including RFID tags, barcodes, and GPS devices [Razavi, & Haas, 2010]. The development and implementation of a prototype cloud-based materials tracking system integrated with RFID tagging technology were successfully demonstrated, and the potential benefits due to real-time updates regarding the status and precise location of supplies was elaborated [Koo *et al.,* 2016]. Building material allocation techniques were studied using a simulated optimization methodology, and the suggested method was seen as a potentially useful tool for construction project managers looking to optimize construction material allocation processes [Lu *et al.,* 2018]. The adaptation of ICT to the management of construction materials revealed that the MMS reduced waste, lowered the danger of stock-outs, and improved the effectiveness of material management; RFID technology improved inventory data accuracy and decreased material handling time [Kasim, 2011]. For large-scale projects, a MMS's benefits significantly outweigh its costs [Bell & Stukhart, 1987]. An efficient MMS has the ability to save costs, increase productivity, and boost overall quality [Kasim, 2008]. A system for managing and controlling materials automatically in construction projects was developed, which had the ability to decrease material waste, enhance project schedule and cost performance, and improve productivity [Navon & Berkovich, 2005]. The development and the implementation of an e-commerce system for the purchase of construction materials and technologies increased the efficiency and decreased the cost of the procurement process by enabling real-time information exchange and price negotiation between suppliers and contractors [Kong *et al.,* 2001].

A material integration analysis of the construction industry from 1800 to 2000 was done using historical and socio-technological data for a region, which seamlessly allowed for incorporation of new materials into construction techniques [Verbong & Vleuten, 2004]. A GIS-based approach was created with the goal of improving material management practices on construction sites, with a special focus on building restoration projects. In order to demonstrate the tool's potential for speeding material handling activities and improving material arrangement, an application case study of the tool being used during a building restoration project was demonstrated [Su *et al.,* 2012].

3. Methods

Traditionally, a lot of material management methods are followed on construction sites, out of which two are detailed below.

a) Economic Order Quantity (EOQ) Analysis

A mathematical model used in inventory management to find the optimal order quantity for a specific product is known as Economic Order Quantity (EOQ) Analysis. The purpose of EOQ analysis is to reduce overall inventory costs, which include both ordering and holding expenses. Analysis involves balancing the cost of ordering more inventory (which includes costs such as setup, transportation, and paperwork) with the cost of holding inventory (which includes costs such as storage, obsolescence, and damage) [RathinaKumar *et. al.,* 2018 & Kazi & Parkar, 2021].

b) Flat Fees Method

Regardless of the product's worth or volume, the flat fee method entails charging a predefined fixed sum for it. Because the charge is fixed regardless of consumption, it offers certainty. Flat costs are just because they treat every client equally, regardless of the magnitude or frequency of their activities. For example, a labor may charge a flat fee of ₹500 for a one-day work, regardless of the actual hours he worked [Lindberg, 2009].

3.1 Research Methodology

It is identified that certain material management techniques, such as the EOQ Analysis, Flat Fees Methods are critical in developing the logical framework of a material management system. The proper calculation of these inputs, obtained from inventory analysis and taking into account future on-site actions, considerably improves material management efficiency. Figure 1 shows a detailed logic for developing a construction material management app.

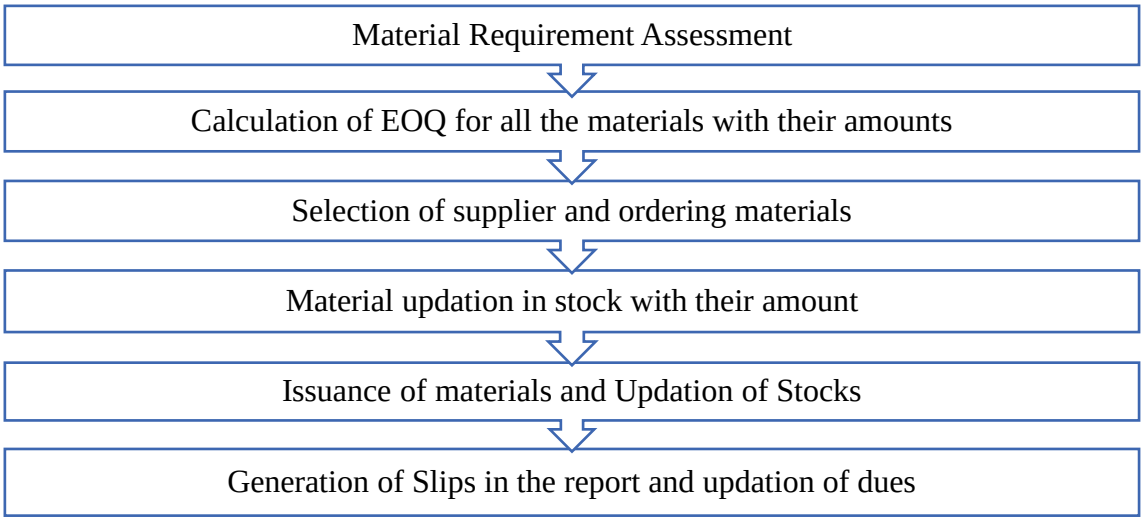


Figure 1. Logic framework of material management app.

Thus, as seen from figure 1, it is clear that 'Economic Ordering Quantity', 'Stock Quantity', 'Issued Quantity', 'Required Quantity', and 'To Be Ordered Quantity' of Materials with their amounts are important input parameters for building the logic framework. These inputs are essential for figuring out the ideal inventory levels and supporting effective on-site material management. The entire material management process may be greatly enhanced by precisely calculating these amounts and including them in the framework. This logical construction guarantees that resources are managed more effectively, therefore increasing productivity and streamlining construction processes.

Following are the terms along with their nomenclature,

EOQ = Economic Ordering Quantity of a material

Stock Quantity = Quantity of material available in stock
Issued Quantity = Quantity of materials that are issued.
Required Quantity = Actual quantity of material required on the site for a given period
To Be Ordered Quantity = Quantity of material that is to be ordered from supplier
IF: Stock Quantity + Issued Quantity ≥ Required Quantity
THEN: To Be Ordered Quantity = 0
ELSE IF: Required Quantity > Stock Quantity + Issued Quantity
THEN:
Case I - IF: EOQ ≥ Required Quantity
THEN: To Be Ordered Quantity = EOQ
Case II - ELSE IF: Required Quantity > EOQ
THEN: To Be Ordered Quantity = Required Quantity

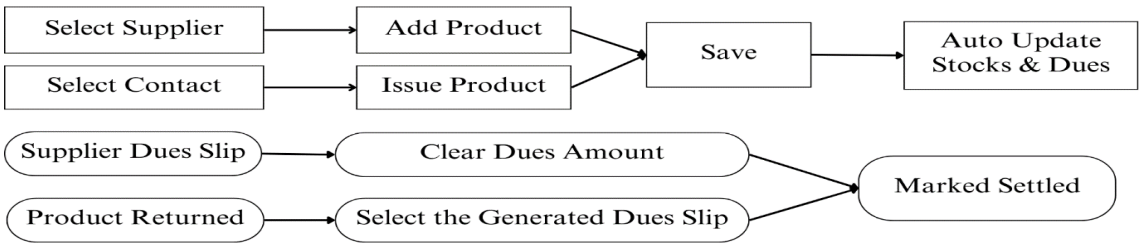


Figure 2. Basic working design of the app.

The app contains a number of different components such as user interface (UI), front-end development, back-end development, and compatibility with the latest Android operating systems. Programming languages and technologies used in the development process include Java, Dart, YAML, Kotlin, and Flutter 2.x. Notably, the app has the option to print invoices utilizing Bluetooth Thermal Printers, guaranteeing smooth slip production. Additionally, it offers a quick and fluid user experience with 60 frames per second (FPS) support that is optimized for Android devices. Picture 2 shows the home interface of the app.

App Interface

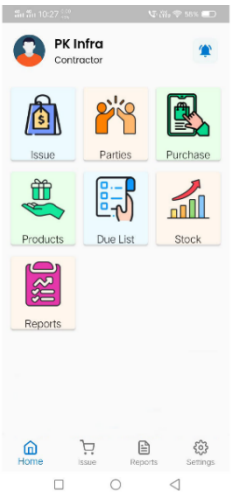


Figure 3. Home interface of the app.

As seen in Figure 3, this is the home screen of the app. It includes icons titled, 'Issue,' 'Parties,' 'Purchase,' 'Product,' 'Due list,' 'Stock,' and 'Reports'.

4. Results And Discussions

The proposed method serves as the framework for an app that promises to greatly increase material management effectiveness. Because of its adaptability, all overdue transactions may be integrated seamlessly, giving the billing manager or material management team more control over material operations. Additionally, the app enhances the accuracy of dues record-keeping and enables accurate tracking of material movement on-site. Processes are streamlined, and

whenever any data is needed, it is simple to get through digital searches, resulting in the elimination of the burden of physical paperwork and hence reducing mismanagement of materials.

The on-site use of this app is successful and makes tracking simple. This app can manage tracking of materials, the amount owing to contractors, or the amount owed to client by the supplier. Further it contains all the supplier and material information along their appropriate due amounts and makes ordering items from suppliers easier. It also maintains track of every contact person that is added to the list. For controlling inventories, this app will be extremely useful. It is simple to use, offers reliable data, and minimises human error. Figure 4, 5 shows the inner section of 'Issue', 'Purchase', 'Purchase' 'Products', 'Due', 'Stock' and 'Reports' screen of the app.

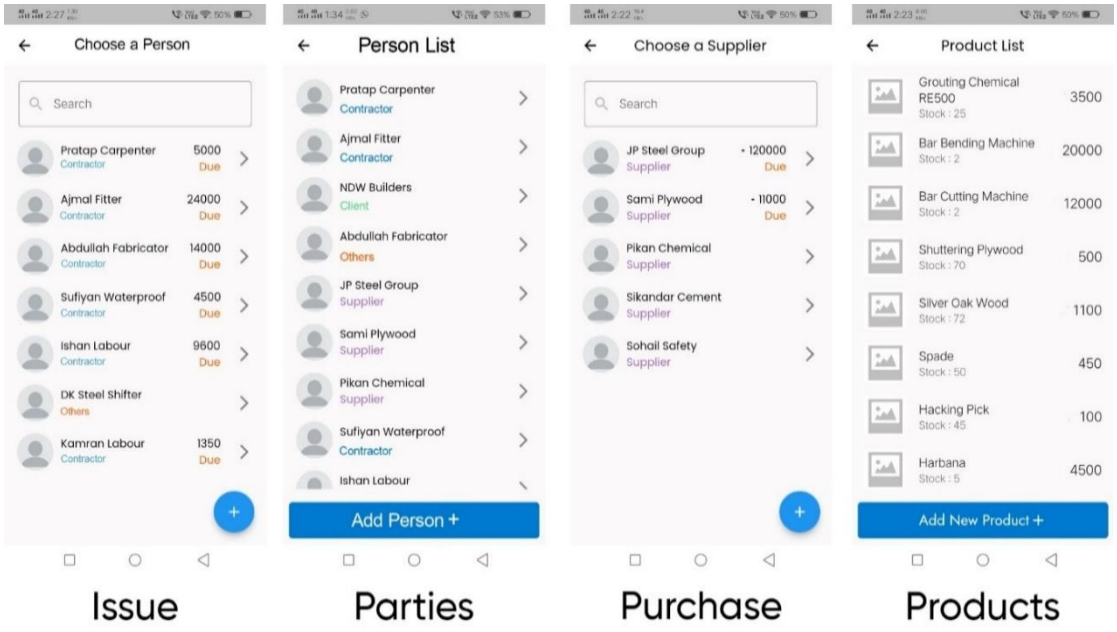
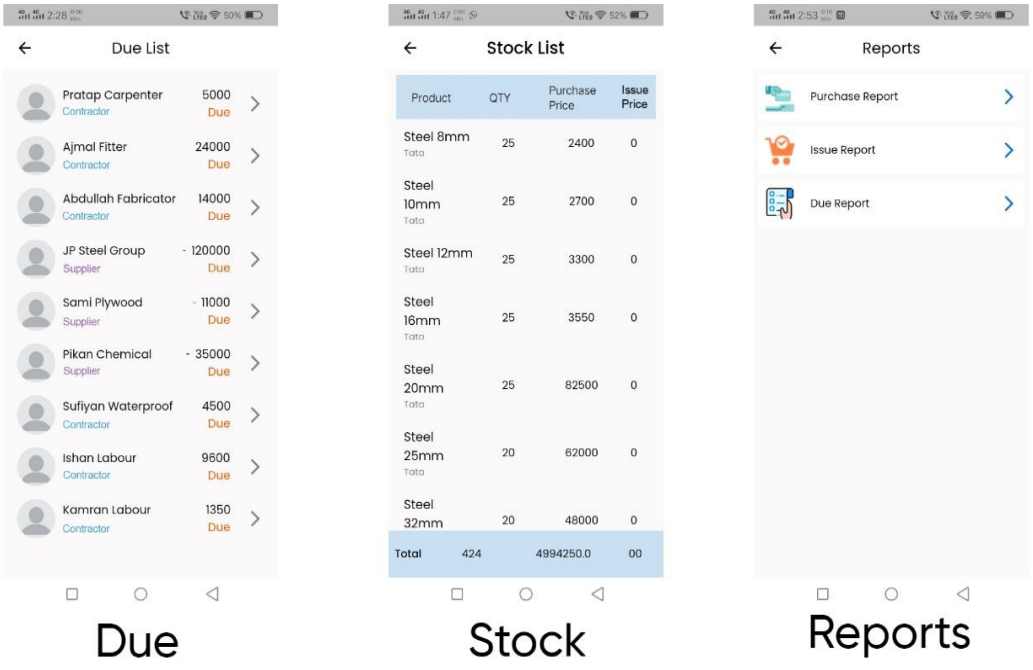


Figure 4. Detail view of (Issue, Parties, Purchase & Product) section.



Picture 5. Detailed view of (Due, Stock, Reports) section.

As seen in Figures 4 & 5, the "Issue" section contains a list of all the materials that have been issued. The "Parties" section includes contact information of all the parties that have been added. The "Purchase" section includes all the purchases made. The "Product" section includes details about different products. The "Due" Section includes all the due amount records. The "Stock" section shows the current quantity of materials available, and the "Reports" section includes detailed reports on Purchase, Issue, and Due.

5. Conclusion

This research focuses on the development of an 'app' dedicated to construction inventory management. The aim is to establish a logical framework that effectively connects various material management techniques so that practical hindrances are also accounted for.

The data was collected on the materials issued in April 2023 from the NDW Altima site in Mumbai, India. it discovered over the course of our analysis that a sizable amount of additional items had been issued without any proper issuance slips being given to subcontractors. Due to the missing records, materials were issued without approval, which have caused existing materials to be misused. Additionally, there was no on-site material pricing calculation and pricing issance slips in the name of subcontractors, which made it challenging to keep track on and stop subcontractor from wasting and misusing materials.

According to the data, each month, around 15.5% of the total amount of materials is issued in excess. To overcome this an application was created for tracking material issuance and keeping updates on their costs in order to handle this problem. This application will enable us to determine whether materials have been returned or not, ultimately reducing waste and preventing material misuse. The materials issued on the site in April 2023 are included in the table that is provided in the end. This emphasises the need for a more structured and effective approach for managing and issuing materials on construction sites.

After thorough consideration, effective material management practices are carefully selected to establish a robust foundation for developing a versatile material and inventory management system. By combining the defined logic and database into a android app, a framework for effective material management is successfully devised. This app assists in easily adding materials to stock, automatically collecting and saving data related to dues, and generating payment slips for those dues. For easy identification, contact information of suppliers, contractors, clients, and other individuals is also saved. Once the data of material is entered, it automatically updates the stock lists and due reports in the app. The app includes a low inventory level indicator that indicates a warning when a material's inventory falls below a specified threshold inventory level.

By using this app it is estimated that a construction project may cut down on 12-15% of the expenses due to faulty material management practices. When tested for a construction project, this app is found to meet the demands of the industry and is designed for quick integration into construction sites.

6. Future Scope

To enhance functionality of the material management app, a notification system can be seamlessly integrated into the framework. This system shall be designed to proactively send notifications to users at regular intervals or during critical moments, keeping them informed about stock levels and requirements. This ensures that timely actions are taken without the need for users to manually check the app. Additionally, the app can be integrated with other project management software such as Microsoft Projects (MSP), Primavera P6, and similar platforms. This integration would allow for better overall material management within project environments. Further features such as the time-based performance for material delivery,

discounts on bulk purchases, payment reminder for outstanding dues, etc. can be added to increase the competitiveness of the construction management app.

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Appendix

Data of material issue on site (Unwal Infra Pvt. Ltd.) (April-2023)								
Material list	**Issue date**	**Quantity required**		**Quantity used**		**Unit**	**Total cost of material required**	**Total cost of material used**
Helmet	01-04-2023	8	Piece	8	Piece	₹ 300.0	₹ 2,400.0	₹ 2,400.0
Name to whom it issued		NO DATA		**Returned/ not returned**			No data of return	
Shoes	01-04-2023	8	Piece	8	Piece	₹ 800.0	₹ 6,400.0	₹ 6,400.0
Name to whom it issued		NO DATA		**Returned/ not returned**			No data of return	
Jacket	01-04-2023	8	Piece	8	Piece	₹ 300.0	₹ 2,400.0	₹ 2,400.0
Name to whom it issued		NO DATA		**Returned/ not returned**			No data of return	
Shuttering ply	04-04-2023	10	Piece	11	Piece	₹ 1,000.0	₹ 10,000.0	₹ 11,000.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
Nails	04-04-2023	3	Kg	4	Kg	₹ 65.0	₹ 195.0	₹ 260.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
Wooden sections	04-04-2023	4	Bundle	5	Bundle	₹ 320.0	₹ 1,280.0	₹ 1,600.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
Ledger & Vertical	04-04-2023	120	Piece	125	Piece	₹ 350.0	₹ 42,000.0	₹ 43,750.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
Shuttering oil	05-04-2023	3	Litre	4	Litre	₹ 82.0	₹ 246.0	₹ 328.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	

C-channels	06-04-2023	5	Piece	5	Piece	₹ 280.0	₹ 1,400.0	₹ 1,400.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
I-beam	06-04-2023	2	Piece	2	Piece	₹ 1,750.0	₹ 3,500.0	₹ 3,500.0
Name to whom it issued		NO DATA		**Returned/ not returned**			Non-returnable material	
Square tubes	06-04-2023	8	Piece	8	Piece	₹ 140.0	₹ 1,120.0	₹ 1,120.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Walers	06-04-2023	8	Piece	10	Piece	₹ 1,800.0	₹ 14,400.0	₹ 18,000.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Hilti RE500 grouting chemical	08-04-2023	2	Pack	2	Pack	₹ 5,500.0	₹ 11,000.0	₹ 11,000.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Wing nuts	11-04-2023	10	Piece	12	Piece	₹ 40.0	₹ 400.0	₹ 480.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Jack munda	12-04-2023	8	Piece	8	Piece	₹ 740.0	₹ 5,920.0	₹ 5,920.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Helmet	13-04-2023	7	Piece	7	Piece	₹ 300.0	₹ 2,100.0	₹ 2,100.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Shoes	13-04-2023	7	Piece	7	Piece	₹ 800.0	₹ 5,600.0	₹ 5,600.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Jackets	13-04-2023	7	Piece	7	Piece	₹ 300.0	₹ 2,100.0	₹ 2,100.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	

Tie rods	13-04-2023	4	Piece	6	Piece	₹ 270.0	₹ 1,080.0	₹ 1,620.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Ledgers and verticals	14-04-2023	100	Piece	105	Piece	₹ 350.0	₹ 35,000.0	₹ 36,750.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Wall tie	15-04-2023	60	Piece	75	Piece	₹ 15.0	₹ 900.0	₹ 1,125.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Nails	17-04-2023	2	Kg	3	Kg	₹ 65.0	₹ 130.0	₹ 195.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Shuttering ply	17-04-2023	5	Piece	6	Piece	₹ 1,000.0	₹ 5,000.0	₹ 6,000.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Shuttering oil	17-04-2023	2	Litre	3	Litre	₹ 82.0	₹ 164.0	₹ 246.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Wooden sections	17-04-2023	2	Bundle	2	Bundle	₹ 320.0	₹ 640.0	₹ 640.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Wooden battens	17-04-2023	11	Piece	11	Piece	₹ 185.0	₹ 2,035.0	₹ 2,035.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Mason hammer	19-04-2023	2	Piece	4	Piece	₹ 150.0	₹ 300.0	₹ 600.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
RCC covers	19-04-2023	350	Piece	370	Piece	₹ 4.0	₹ 1,400.0	₹ 1,480.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	

Cement bags	20-04-2023	18	Bags	20	Bags	₹ 420.0	₹ 7,560.0	₹ 8,400.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Grouting chemical powder	20-04-2023	5	Bags	8	Bags	₹ 600.0	₹ 3,000.0	₹ 4,800.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Red bricks	20-04-2023	420	Piece	430	Piece	₹ 6.0	₹ 2,520.0	₹ 2,580.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Helmet	24-04-2023	10	Piece	10	Piece	₹ 300.0	₹ 3,000.0	₹ 3,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Shoes	24-04-2023	10	Piece	10	Piece	₹ 800.0	₹ 8,000.0	₹ 8,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Jackets	24-04-2023	10	Piece	10	Piece	₹ 300.0	₹ 3,000.0	₹ 3,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Grinder machine	24-04-2023	2	Piece	2	Piece	₹ 1,500.0	₹ 3,000.0	₹ 3,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Steel cutting blade, ply cutting blade, polishing blade	24-04-2023	6	Piece	8	Piece	₹ 250.0	₹ 1,500.0	₹ 2,000.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Drill machine	26-04-2023	2	Piece	2	Piece	₹ 1,500.0	₹ 3,000.0	₹ 3,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Drill bit	26-04-2023	8	Piece	9	Piece	₹ 250.0	₹ 2,000.0	₹ 2,250.0

Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Breaker machine	27-04-2023	2	Piece	3	Piece	₹ 35,000.0	₹ 70,000.0	₹ 1,05,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Breaker bit	27-04-2023	2	Piece	4	Piece	₹ 350.0	₹ 700.0	₹ 1,400.0
Name to whom it issued		No data		**Returned/ not returned**			Non-returnable material	
Harbana	28-04-2023	4	Piece	4	Piece	₹ 3,000.0	₹ 12,000.0	₹ 12,000.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Cube mould	28-04-2023	12	Piece	14	Piece	₹ 800.0	₹ 9,600.0	₹ 11,200.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	
Wrench, screw, drivers, Spanners	29-04-2023	14	Piece	14	Piece	₹ 250.0	₹ 3,500.0	₹ 3,500.0
Name to whom it issued		No data		**Returned/ not returned**			No data of return	

Total	**₹ 2,80,290.0**	**₹ 3,31,979.0**
Difference	**₹ 51,689.00**	
% Waste	**15.57%**	