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Comparison of Tunnel Construction Cycle Time with NTNU Model: A Case Study of Siddhababa Road Tunnel, Palpa, Nepal

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Abstract

This research investigates factors contributing to extended construction cycle times in tunnel projects within the geologically challenging Siwaliks region of the Nepal Himalaya, characterized by interbedded sandstone and mudstone. Focusing on the 1126 meters long Siddhababa Tunnel with 110 square meters cross sectional area constructed using the conventional Drill and Blast Method, the study analyzes the impact of local geology on construction efficiency. Findings indicate that weak rock classes, specifically MS-IV-A, significantly increase the construction cycle time, demanding careful management of dummy holes and explosives. The paper then contrasts these practices with the NTNU model, highlighting its superior efficiency. The NTNU model offers advantages primarily because it utilizes drilling jumbos instead of manual drilling, a single ventilation phase per cycle compared to dual requirement for heading and benching, and increased mucking efficiency due to larger truck sizes. The study concludes that adopting NTNU methods offers a significant potential to reduce cycle times and improve overall tunneling efficiency for future projects undertaken in similar geological conditions and construction practices.

Keywords: *Siwaliks, Siddhababa, Construction Cycle Time, NATM, NTNU Model.*

1. Introduction

A key element of modern infrastructure is tunneling, which makes it possible for utilities to pass through difficult terrain and for efficient transportation. In Nepal, road tunnel construction is a relatively recent development, especially in the geologically complex Himalayan region. The Siwaliks range which is the part of five major tectonic zones of Nepal, poses significant challenges for tunneling due to intense jointing, faulting, folding, weathering, and the presence of shear zones (Panthi, 2006). These conditions demand careful geological assessment and tailored construction techniques.

Despite offering benefits such as reduced surface disruption, faster transit, and environmental preservation (Balasubramanian, 2014), tunnel projects often face delays due to unforeseen geological obstacles, high costs, and technical demands. This study focuses on a road tunnel in the Siwaliks, constructed using New Austrian Tunneling Method (NATM). It aims to analyze how geological conditions affect the construction cycle and to compare the efficiency of NATM with the Norwegian University of Science and Technology (NTNU) model, offering practical insights to improve planning and reduce delays in future tunnel projects in similar geological condition.

2. Study Area and Geology

Siddhababa Road Tunnel is located in Palpa district of Lumbini Province at the Tinau River Corridor in Siddhartha Highway. Its south portal is located at 27°43’47” N, 83°28’09” E and north portal is located at 27°44’11” N, 83°27’57” E coordinates. This project entails constructing a road tunnel through the Siwaliks to offer a safer and more dependable route for travelers. The Siddhababa-Dovan Road plays a vital role in linking more than a dozen districts across both the plains and hilly regions, including Palpa, Gulmi, Arghakhanchi, Syangja, Kaski, Parbat, and Baglung. Young sedimentary rocks sandstone, siltstone, and mudstone are the three main types of rocks in this area. Every year during monsoon and dry season along the Siddhartha Highway rock falls and mud flow problems can be seen along the road alignment. On an average, 20 people are injured, and 10 lose their lives each year due to falling rock masses and debris (Bhandari and Dhakal, 2021).

Geologically, the proposed tunnel alignment passes through the rocks of the Siwaliks of the Nepal Himalaya. The Project area is composed of sandstone and mudstone. When there is presence of water, the distinct weathering patterns of hard rock sandstone and soft rock mudstone shows distinct characteristics that cause the sandstone to overhang (Pokhrel et al, 2022).

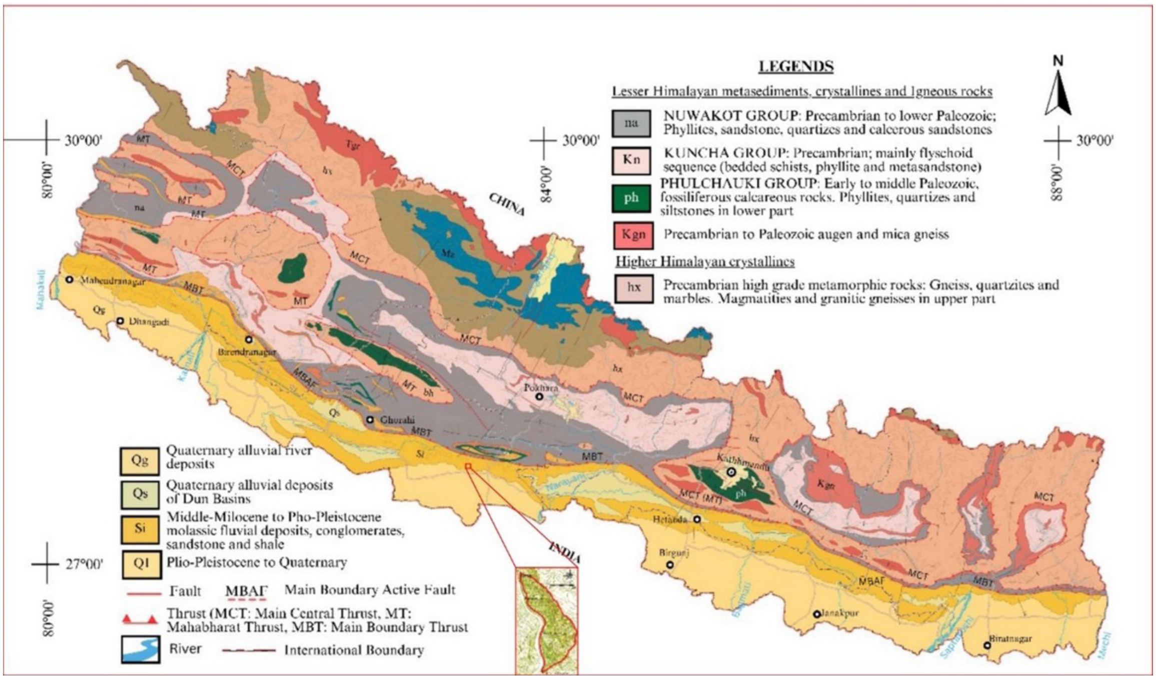

Figure 1: Geological Map of Nepal Showing Study Area(Panthi et al, 2025)

3. Research Methodology

The research follows a systematic flow, as shown in Figure 2. The process begins with a desk study, where existing information and data are collected, followed by a literature review to explore previous research, and findings relevant to the study. Similarly, engineering geological field mapping is conducted to gather on-site data about the rock masses. Using these data, the estimation of rock mass parameters is carried out. Additionally, the tunnel construction cycle is studied to understand the methods and processes involved in the tunneling project. The findings are then compared with the NTNU model. Finally, all findings are arranged in the analysis of results for conclusions and recommendations.

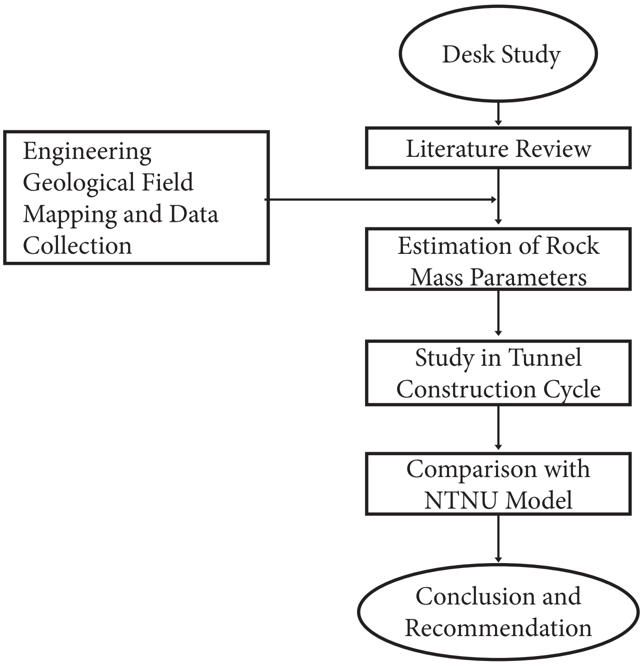

Figure 2: Graphical Methodology for Research

4. Results and Discussion

Rock mass is a combination of intact rock, discontinuities, stresses, and groundwater. (Deere et al, 1972) introduced the Rock Quality Designation (RQD) concept to estimate rock mass from drill core logs. If drill cores are unavailable, RQD can be calculated using (Palmstrom, 1982) method, which relies on the number of discontinuities per unit volume. Rock mass classification systems, such as the Rock Mass Rating (RMR) and the Q-system, are commonly used to evaluate and categorize the quality of the rock mass. The characteristics of rock mass vary significantly due to its inhomogeneity, weathering, strength, in situ stresses, and anisotropy. Data collected from the tunnel construction project focusing on key operational aspects are analyzed. It covers details from explosive used, specific charge along with the number of dummy and total holes, construction cycle time and a comparison between tunneling methods.

4.1 Explosives and Drill Holes with respect to Rock Class

The Table 1: shows the details of explosives used in kg, specific charge, along with the number of dummy and total holes drilled across different rock classes.

Table 1: Explosive, Specific Charge, Dummy Holes, Total Holes and Pull Length in Different Rock Class

S. N.	Rock Class	Explosive (kg)	Specific Charge (kg/m3)	Dummy Hole (Number)	Total Hole (Number)	Pull Length (m)
1	MS-III-A	250	0.829	6	155	3.5
2	MS-IV-A	200	0.739	16	165	3.5
3	MS-IV-B	250	0.997	8	157	3.3
4	MW-III-A	250	0.861	12	158	3.5
5	MW-III-B	250	2.003	12	160	3.5
6	MW-IV-B	250	0.829	8	157	3.5

4.2 Construction Cycle Time

The process of tunneling involves a series of cyclical and repetitive tasks, including mucking, excavation and application of support (Shrestha et al, 2023). Time required in minutes for various activities in construction of Siddhababa Road Tunnel by NATM Method under different rock classes are presented in Table 2.

Table 2: Observed Time in Minutes for Different Activities in Siddhababa Tunnel

S.N.	Description	Rock Class MS-IV-A	Rock Class MS-IV-B	Rock Class MS-III-B	Rock Class MW-IV-B	Rock Class MW-III-A
1.	Instrument checkup for face drilling	21	23	15	23	15
2.	Drilling	299	309	302	304	287
3.	Explosive Loading	56	57	55	58	58
4.	Blasting	29	26	27	27	27
5.	Ventilation	58	58	58	58	58
6.	Mucking	385	387	377	407	401
7.	Scaling	65	71	67	76	72
8.	Survey and Marking	56	56	56	56	56
9.	Face Mapping	26	26	26	26	26
10.	Steel Ribs Installation	247	222	233	223	232
11.	Rock Bolts Installation	155	126	157	138	159
12.	Shotcrete	302	300	235	299	242
	Total	1699 min (28.31 hrs)	1661 min (27.68 hrs)	1608 min (26.8 hrs)	1695 min (28.25 hrs)	1633 min (27.21 hrs)

The summarized form of observed cycle time for different rock classes is listed in Table 3.

Table 3: Construction Cycle Time for Different Type of Rock Class

S. N.	Rock Class	Heading (min)	Benching (min)	Total (min)
1	MS-IV-A	1106	593	1699
2	MS-IV-B	1073	588	1661
3	MS-III-B	1039	569	1608
4	MW-IV-B	1097	598	1695
5	MW-III-A	1068	565	1633

4.3 Estimated Tunnel Excavation Time Using NTNU Model

Estimated cycle time for each activity of tunnel excavation using NTNU Model (Bruland and Zare, 2006) for different rock classes are presented in Table 4.

Table 4: Estimated Tunnel Excavation Cycle Time using NTNU Model Rock Class

S.N.	Activities	MS-IV-A	MS-IV-B	MS-III-B	MW-IV-B	MW-III-A
1.	Drilling	167.6	167.6	167.6	167.6	167.6
2.	Charging	52	52	52	52	52
3.	Ventilation	27	27	27	27	27
4.	Mucking	193.8	193.8	193.8	193.8	193.8
5.	Scaling	51	51	51	51	51
6.	Survey and Marking	56	56	56	56	56
7.	Rock Bolt Installation	130	102	100	100	100
8.	Shotcrete	302	300	235	299	242
	Total(minutes)	979.4	949.4	882.4	946.4	889.4
	Total (hours) (Inc. 5% incidental loss)	16.32	15.82	14.70	15.77	14.82

Comparing between Siddhababa Tunnel and NTNU Model, significant time could be saved in NTNU Model. During the calculation, incidental time loss was not added as an overall 5%. It is assumed that marking time of drilling to be overlap within surveying time. Scaling time is calculated with the help of the NTNU model. Similarly, the Shotcrete time is observed time in Siddhababa Tunnel. Furthermore, the rock bolting time is adopted from the NTNU Model.

4.4 Advance Rate

For the tunnel cross section of 110 sq. m. the NTNU model suggests the wheel loader and dump truck for mucking and 4 drilling hammers, for which advance in tunnel can be achieved up to 56 meters per week. Also, the fact to be considered is working time in Norway is 5 days per week 2 shifts 10 hours per shifts. In Siddhababa Tunnel, advance rate is 34.5 meters per week. Working time in Siddhababa is 7 days per week 2 shifts 12 hours.

4.5 Proposed Blasting Pattern

The proposed drilling pattern for Siddhababa tunnel has been designed based on (Bruland and Zare, 2006). Two large empty holes of 127 mm diameter have been used. Burden are maintained between 0.8 - 1 meter and spacing are maintained between 0.8 - 1.1 meter which is shown in Figure 3.

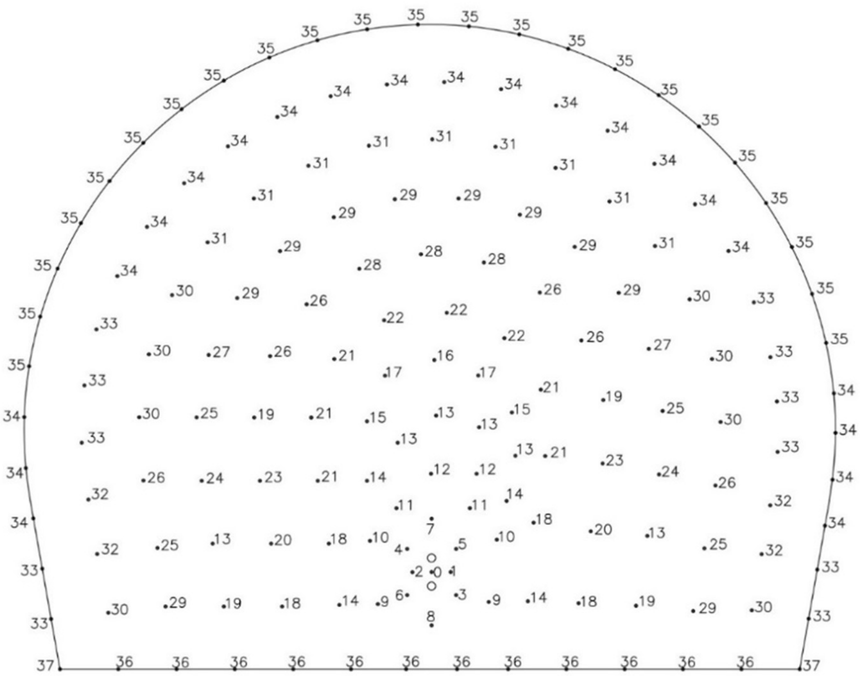

Figure 3: Proposed blast pattern by NTNU Model

5. Conclusions

- The study has accurately assessed the duration of each activity in the tunneling cycle in different rock mass conditions. The cycle time for each activity is calculated.
- Detailed assessment of cycle times across various rock classes revealed that weaker formations, particularly MS-IV-A which significantly increased the construction duration by increasing dummy holes for controlled blasting requirements.
- Comparison with the NTNU model demonstrated its superior efficiency in similar geological conditions. Mechanized drilling, optimized ventilation, and higher capacity mucking systems contributed to reduced cycle times by approximately 40% in drilling and 50% in mucking.

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