J. Myanmar Acad. Arts Sci. 2026 **Vol. XXIII. No.4**

ASSESSMENT ON THE STABILITY OF SPILLWAY SLOPE CUTTING AT THE THA-HTAY HYDROPOWER PROJECT, THANDWE TOWNSHIP, RAKHINE STATE

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Abstract

The present research is carried out slope geology, geotechnical characteristics of rocks and slope stability analysis of spillway slope cutting at the Tha-Htay Hydropower Project, Thandwe Township, Rakhine State. This area is tectonically situated at the Central part of the Rakhine Coastal Belt. The rocks comprise the medium to thick bedded, indurated and moderately jointed sandstone intercalated with thinly laminated, fissile, partly carbonaceous shale and mudstone of Ngapali Formation (Middle Eocene). Most of the rock units are trending nearly NW-SE in direction. The fracture system shows as closely spaced and moderately to highly jointed nature in the map of lineament analysis. According to geotechnical investigation, the rocks exposed along the spillway slope cutting site govern fair, poor and very poor rock classes respectively where the rock classes display CL and CM rock classes in this spillway slope site. Therefore, the supporting system should be installed with wire-mesh and rock bolt covering together shotcrete and systematic drained pipes. Moreover, some of the slope failures can be observed by kinematic analysis. Slope monitoring systems should be prepared on these slope sites. Hence, the selection of systematic supporting systems should be done on surface geological, geotechnical properties of rocks combined with design modeling.

Keywords: Slope geology, geotechnical investigation, slope stability

Introduction

Tha-Htay Dam is a zoned earth dam which will supply 110 kW in total power of electric current for the country. The rocks in this area are composed of sandstone, siltstone, shale and mudstone of Ngapali Formation (Middle Eocene in Age) with volcanic rocks. This area is tectonically situated at the Central part of the Rakhine Coastal Belt.

Location

The study area is situated at Tha-Htay Chaung, Thandwe Township, Rakhine State. This area bounded between North latitudes, 18º 38' 10" to 18º 38' 50" and East longitudes, 94º 22' 40" to 94º 23' 30" which is shown in Figure (1).

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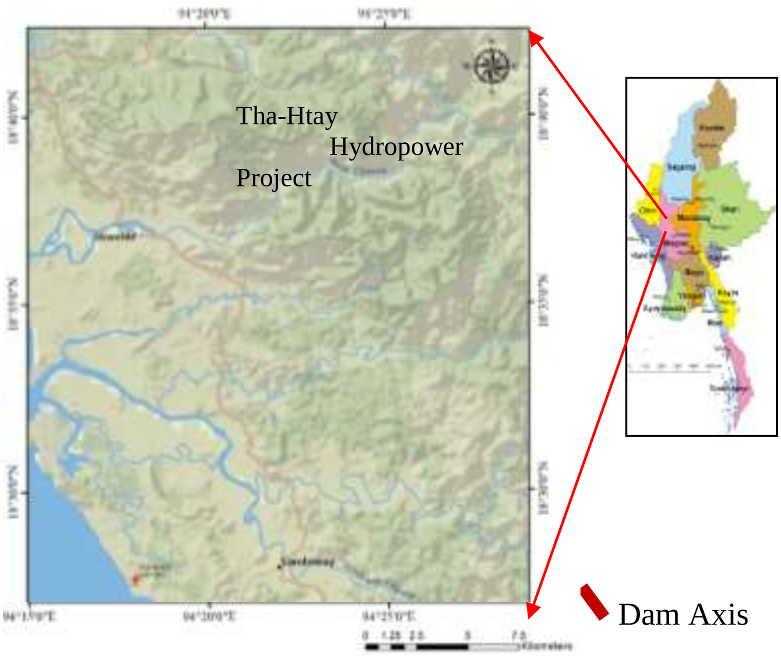


Figure 1. Location map of the study area

Physiography and Drainage

Two drainage patterns such as dendritic pattern and sub-trellis pattern are governed in this area. The dendritic pattern occurred in the Northern and Southern parts of the area. The sub-trellis pattern is mostly governed along the Tha-Htay Chaung which is illustrated in Figure (2). Therefore, the rocks in this area are composed of the alternated units of competent and incompetent rocks. According to the physiographic analysis, there are three physiographic terrains such a highly elevated area, moderately elevated area and flat plain area. Highly elevated area is found in the North-Eastern part and flat plain area occurs in the South-Western part of the area. The study area is occupied in the moderately elevated area which is depicted in Figure (3).

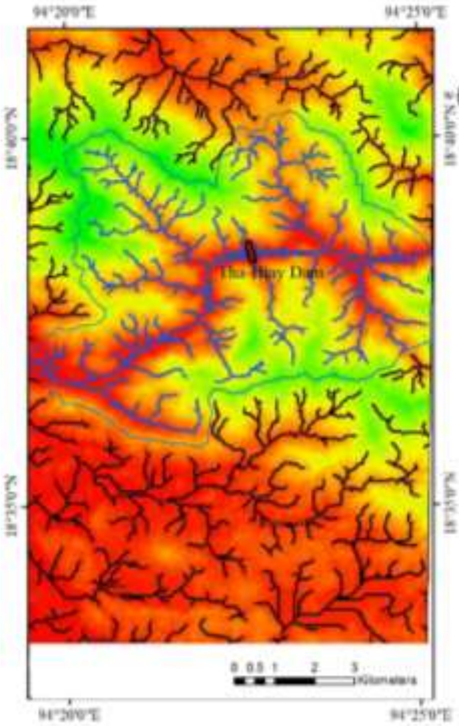


Figure 2. Drainage map of the study area

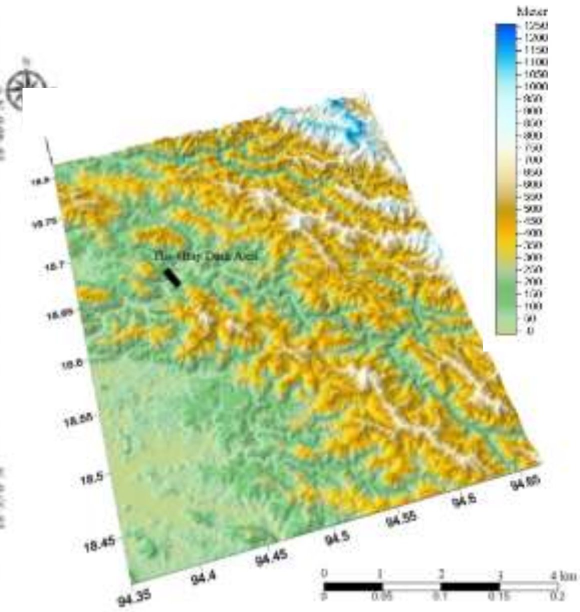


Figure 3. Physiographic map of the study area

Regional Geologic Setting

The research area lies within the Central part of the Rakhine Coastal Plain. The rocks are regionally composed of sandstone, siltstone, shale and mudstone of Ngapali Formation and Gwa Formation with some volcanic rocks.

Gwa Formation (Early Eocene) is mostly found in many places in the main Rakhine Yoma. It is mainly of indurated shale with thin sandstone beds and occasionally alternation sequences are present.

Ngapali Formation (Middle Eocene) is mainly exposed on the Ngapali Beach and in the vicinity of the main Rakhine Yoma. The rocks are composed of sandstone, shale with limestone, conglomerate, mudstone and siltstone occasionally interbedded with thin to medium bedded greywacke. The regional geological map is explained in Figure 4.

Lineament Analysis

Three main structural units are classified on the basis of the structural subdivision, topographic boundaries and distribution of the lineament system.

Structural unit (I) is observed at the North-Eastern part of the research area in the upstream catchment area of Tha-Htay Hydropower project area. This unit is characterized by the NE-SW trending regional pattern and the fracture system is widening in nature. This feature displays poorly to moderately jointed and slightly oblique to regional structural trends.

Structural unit (II) is located in the Central part of the area especially in the dam site area. This unit is characterized by NW-SE and NE-SW, partly randomly E-W trending and the fracture system can be assumed as closely spaced and moderately to highly jointed in nature.

Structural unit (III) is the same as Structural Unit (I) but it occurs in South-Western part of the area. This area is characterized by low topographic terrain which is displayed in Figure 5.

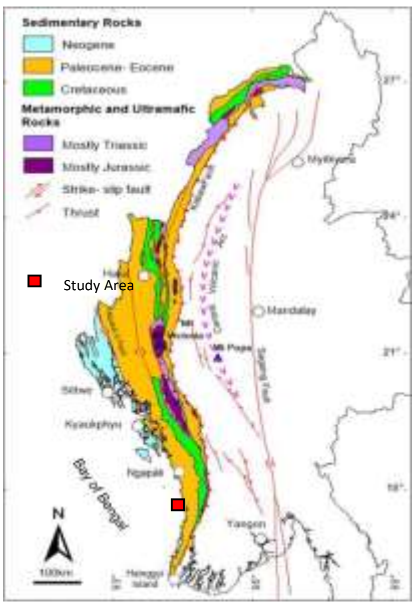


Figure 4 Regional geological map of the study area (After Myanmar Geological Map 2014 in Kyi Khin et al., 2017)

Figure 5. Lineament map of the study area based on satellite image

Aim and Objectives

The research aims to examine the geotechnical characteristics of rocks and slope stabilization of the spillway slope cutting. The objectives are

- To explore geology and fracture systems of the rocks
- To examine the geotechnical properties of rocks
- To evaluate slope stabilization by kinematic analysis
- To select suitable stabilization method

Methodology

Geological and geotechnical investigations are carried out based on the nature of rocks and discontinuities at the spillway slope cutting. Fracture system analysis has been done on the lineament as well as field observation.

The strength of rocks has been measured by a uniaxial compression test. Rock quality designation (RQD) was converted by three-dimensional volumetric joint count in the field which is described by Palmstrom (2005). J(v) formular is $Jv = 1/S1+1/S2+1/S3$ and so on plus $Nr/5$ where Nr is a random joint on outcrop.

Rock mass rating measurements for rock slopes have been made by RMR classification of (Bieniawski, 1989) which is principally composed of six basis parameters such as rock strength, rock quality designation (RQD), spacing of joints, condition of joints, groundwater condition and orientation of discontinuities. The qualification of geological strength Index (Hoek et al., 2013) is calculated on the formula of $GSI=1.5\ Jcond\ (89) + RQD/2$.

Kinematic analysis for rock slope stability is carried out to know failure types of slopes which is described by Goodman (1998), Jeongi and Kulatilake (2001) and Yousif et al. (2013) which is based on relationship of discontinuities of slope, slope inclination and friction angle of rock.

Results and Discussions

In this research, slope geological mapping, volumetric joint count, rock quality designation (RQD), rock mass rating (RMR), geological strength index (GSI) and kinematic analysis of the rocks had been done at the spillway slope.

Layout of the Spillway Slope

The spillway slope cutting dips to the south with 160°-180° in direction and the general slope inclination is nearly 60° facing to the south. The high of a spillway slope is 170 m which is shown in Figure 6A and 6B.

Figure 6. (A) Spillway location on google map (B) layout map of the study slope at the spillway slope cutting

Geological Investigation of the Study Area

The rocks comprise the medium to thick bedded, partly thin to medium bedded, bluish grey to grey, indurated and moderately jointed sandstone intercalated with thinly laminated, fissile, partly carbonaceous shale and mudstone of Ngapali Formation (Middle Eocene). Most of the rock units are trending nearly NW-SE in direction. In the Northern part of the Dam Axis, the rocks are plunging nearly to the North that is remarked by dipping of rock units.

The Ngapali Formation can be divided into three sub-units based on the composition of rock units. Subunit-1 is exposed at the eastern part of the study area and the rocks comprise with light grey to yellowish brown, partly reddish brown, moderately jointed and weathered, thin to medium bedded sandstone intercalated with thinly laminated shale and mudstone which is shown in Figure 7. Subunit-2 is exposed at the Central and South-western parts of the project area and the rocks consist of light grey to grey, partly bluish grey, moderately jointed, thick bedded to massive, turbiditic sandstone intercalated with thinly laminated shale and mudstone which is shown in Figure 8. Subunit-3 is exposed at the Western and Central parts of this area. The rock unit is composed of thinly laminated, dissected, highly friable carbonaceous shale and mudstone interbedded with light grey to grey, thin bedded sandstone which is proved in Figure 9. The geological map is illustrated in Figure 10.

Figure 7. Thin to medium bedded sandstone with shale and mudstone at the Upstream

Figure 8. Thick bedded to massive sandstone with shale and mudstone at the Dam Axis

Figure 9. Thinly laminated, shale and mudstone with sandstone at the downstream

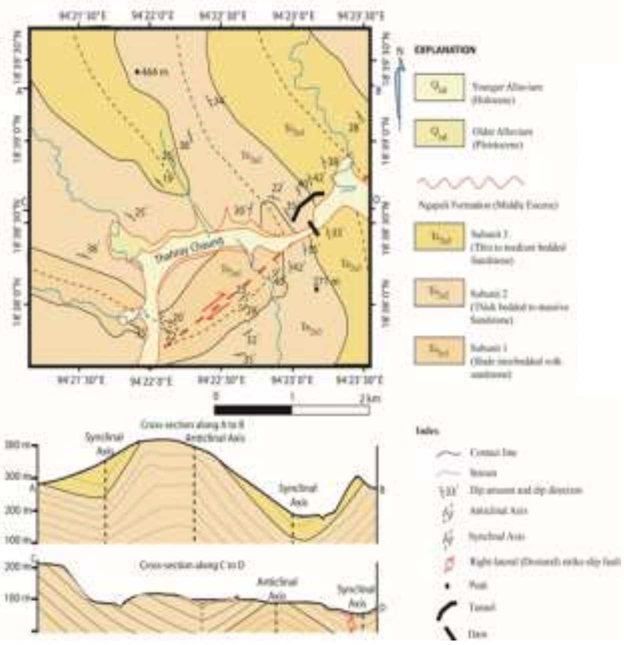


Figure 10. Geological map of the study area

Engineering Properties of the Rock at the Studied Slope Site

Rock Mass Characterization Analysis

The study spillway site is located at the side of left abutment along Dam Axis where the rocks are exposed grey to dark grey colored, partly yellowish-brown colored, medium to thick bedded, highly jointed sandstone intercalated with thinly laminated, soft, shale and mudstone. Most of the rocks are dipping to the North and North-West and z-shaped drag folds occur in the mudstone layers. The rocks exposed on the slope can be divided into three zones as Zone I, Zone II and Zone III based on the natures of rocks as well as rock mass characterizations which are described in (Figure 11) and Table 1.

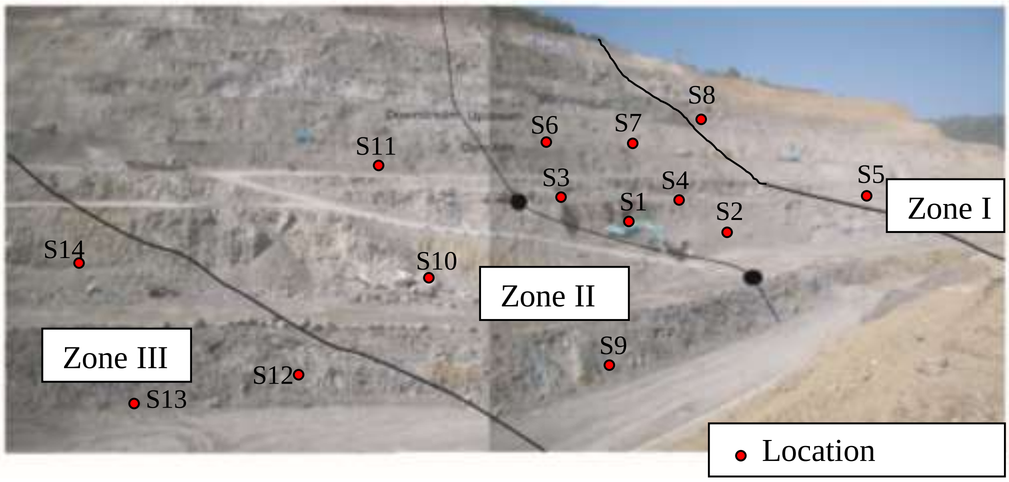


Figure 11. Zonation on rock mass characterization at the spillway slope

Table 1. Rock Mass Characterization of the spillway slope site

No	Jv	RQD (%)	RMR	GSI	Rock Class	ϕ value based on RMR	Possible Failure
S1	16.9	59	60	54	CM	25º to 35º	Plane
S2	21	44	57	51	CM	25º to 35º	Wedge, Topple
S3	19	52	53	50	CM	25º to 35º	Plane, Wedge
S4	19	51	53	50	CM	25º to 35º	Wedge
S5	22	44	48	46	CM	25º to 35º	Wedge, Topple
S6	21	44	57	53	CM	25º to 35º	Plane, Wedge
S7	18	56	57	51	CM	25º to 35º	Wedge
S8	15	64	50	53	CM	25º to 35º	Wedge
S9	19	54	45	44	CM	25º to 35º	Wedge
S10	19	51	57	48	CM	-	-
S11	25	32	24	33	CL	-	-
S12	29	21	48	39	CL	-	-

No	Jv	RQD (%)	RMR	GSI	Rock Class	ϕ value based on RMR	Possible Failure
S13	28	22	21	32	CL	-	-
S14	29	19	21	31	CL	-	-

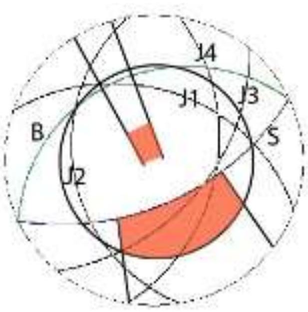
According to rock mass characterization analysis, the rocks exposed at Zone I are fine to medium grained, thin to medium bedded, indurated, moderately to highly jointed, yellowish-brown colored sandstone (8-90 cm in thickness) intercalated with thinly laminated shale and mudstone. In this zone, most of the rocks have fair rock class according to the Rock Mass Rating (RMR) values and CM rock class shows in GSI values.

Zone II occurs at the Central part of the study slope site which is mostly governed with fine to medium grained, medium to thick bedded, moderately to highly jointed, bluish grey to grey colored sandstone intercalated by thinly laminated shale and mudstone. Most of the sandstones are thick bedded in nature and they have moderate to high strength. In this zone, the rocks comprise a fair rock class as RMR value, except two locations where groundwater flows out and most of the rocks are CM rock class in GSI values.

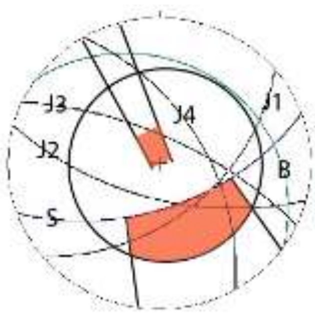
The Westernmost part of the spillway slope site is known as zone III where the rocks are composed of thinly laminated shale and mudstone intercalated with thin to medium bedded, bluish grey to grey colored, highly jointed sandstone. Most of the slope site is covered with mudstone. In this zone, the rocks comprise a poor rock class as RMR value and Most of the rocks are CL rock class in GSI values respectively.

Kinematic Analysis for Slope Stability

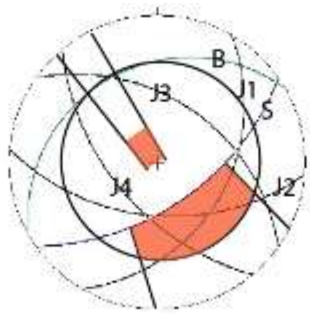
The spillway slope cutting is located at the right side of the Dam Axis which is composed of moderately indurated sandstone with clay and mudstone. Nine slope locations are selected to study the kinematic analysis. According to this study, these slopes can be plane failure, wedge failure and toppling failure which are described in Figure (12).



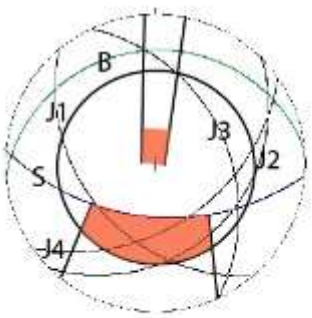
(A) Plane failure at S1



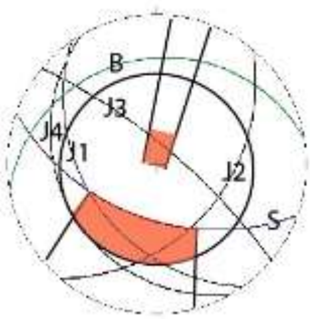
(B)Wedge and Toppling failures at S2



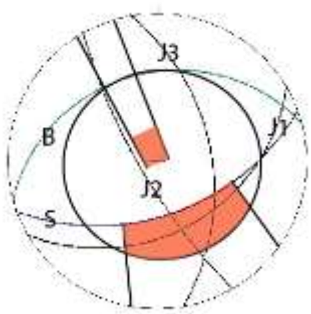
(C) Plane and Wedge failures at S3



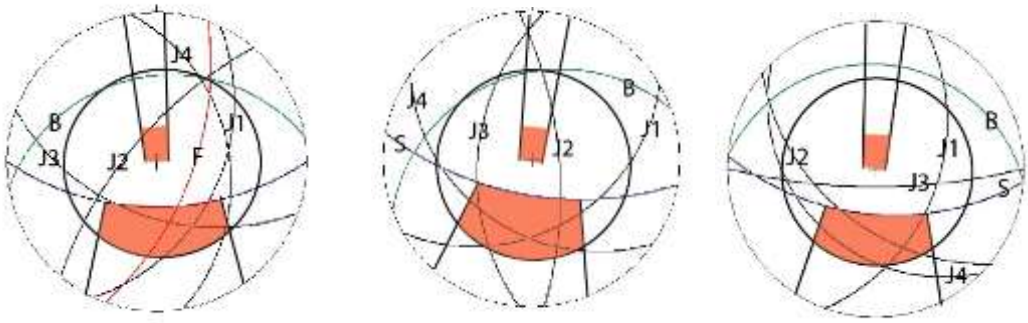
(D) Wedge failure at S4



(E) Wedge and Toppling failures at S5



(F) Plane and Wedge failures at S6



(G) Wedge failure at S7 (H) Wedge failure at S8 (I) Wedge failure at S9

Figure 12 A-I Kinematic analysis of each slope site on the relationship of the discontinuities and slope face parameters

Conclusion and Recommendation

The rocks composed in this area are generally fine to medium grained, medium to thick bedded, partly thin to medium bedded, indurated, moderately to highly jointed sandstone with thinly laminated, dissected, carbonaceous shale and mudstone. Hence, two different strengths of rocks are composed as the alternate layers. This condition is not suitable for slope stability in the rainy season because carbonaceous shale and mudstone are composed of clay minerals which are easily decomposed in rainy water.

The bedding nature of rocks and spillway alignments are generally suitable for this Dam Construction. But the false bedding planes such as discontinuities are unsuitable for slope stability at spillway slope cutting sites. Moreover, two faults occurred in this area and one of the faults, a thrust fault was found in the spillway slope cutting site. Hence, the depth of the failure plane should be confined with the borehole drilling process. Most of the rock bolts should be installed until the rock bolts reach the bottom of the failure plane.

According to Rock Mass Rating (RMR) analysis, the rocks exposed along the spillway slope cutting site govern fair, poor and very poor rock classes. The rock classes display CL and CM rock class in this spillway slope site by the Geological Strength Index analysis. For GSI value based on the structural behavior of rocks, the rocks exposed in this slope should be supported systematically. Therefore, the supporting system should be installed with wire-mesh and rock bolt covering together shotcrete and systematic drained pipes. Furthermore, there were two or more places where groundwater is flowing out continuously. In these places, special treatments should be given with drainage systems and rock bolts where subsurface fracture systems and nature of rocks should be done to explore more detail.

According to kinematic analysis for slope stability, some of the slopes can be failures. Therefore, slope monitoring systems should be prepared on these slope sites. Overall surface geology and engineering properties of the rocks are pointing out the conditions that require a systematic supporting system. Hence, the selection of systematic supporting systems should be done based on surface geological, geotechnical properties of rocks combined with design modeling.

Acknowledgements

The authors would like to acknowledge to Rector Dr Myo Myo, Pro Rectors Dr Tin Tin Yi and Dr Mya Yin Yin Nyein, for their encouragement on this paper.

We also specially thank to Dr Day Wa Aung, Professor and Head of the Geology Department, University of Yangon for his academic encouragement, technical expertise and suggestions.

Finally, the authors also express gratitude to U Ye Win, Assistant Engineer of Tha-Htay Hydropower Project for his kindness and hospitality during the field trip.

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