IDENTIFICATION OF HARD ROCK BASED ON SHALLOW SEISMIC INTERPRETATION AND SPT TEST FOR FOUNDATION OF BRIDGE AT BALANG ISLAND, BALIKPAPAN BAY, EAST KALIMANTAN

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(Manuscript received 2-September-2010)

ABSTRACT

The study area is located in Balikpapan Bay, the connecting waters between Pancur village at the southwest and Balang Island at the northeast. The objective of study is to know the engineering properties of rock as a foundation groundwork of bridge. Result of seismic reflection interpretation profiles in the survey area indicates that the seismic sequences can be divided into two sequences, those are sequence A and B. Sequence A lies at the upper part, which is characterized by concordance, parallel, wavy and hummocky reflectors. Sequence B is characterized by mounded, chaotic and free reflectors.

Sediment thickness obtained from seismic profiles show that Quaternary sediment is about 1.56 to 4.89 meters, while harder substrate thickness ranging between 7.03 and 21.60 meters. While, based on core drilling data, hard rock started to appear between 3 and 4 meters below seafloor with Standard Penetration Test (SPT) between 32 and 34 blows as Tertiary sediments.

Based on field observation and correlated with geological map of Balang Island, Balikpapan Sheet, the hard rock proposed for base of bridge foundation is Balang Island Formation (Middle Miocene) that consist of claystone, sandstone and coal layers that have been deformated and start to form fold as anticline. The seismic record show that, the hard rock is interpreted as B sequence that underlain by Quaternary sediments.

Key words: seismic, drilling, Quaternary sediment, hard rock, bridge foundation, Balang Island

SARI

Daerah penelitian terletak di Teluk Balikpapan, merupakan perairan penghubung antara desa Pancur di bagian baratdaya dan Pulau Balang di bagian timurlaut. Tujuan penelitian in untuk mengetahui sifat keteknikan batuan keras sebagai tapak jembatan. Hasil interpretasi rekaman seismik di lokasi penelitian menunjukkan bahwa sekuen sedimen dapat dibagi menjadi dua yaitu Sekuen A dan B. Sekuen A terletak di bagian atas dengan ciri reflektor selaras, sejajar, bergelombang terputus-putus dan perlapisan terputus-putus. Bagian paling bawah adalah Sekuen B dicirikan oleh bentuk reflektor

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berbukit-bukit kecil, berbintik-bintik kacau tidak beraturan dan makin ke bawah dicirikan oleh bebas pantul.

Hasil perhitungan ketebalan sedimen pada penampang seismik diperoleh ketebalan sedimen Kuarter antara 1,56 - 4,89 meter dan kedalaman batuan keras berkisar antara 7,03 – 21,60 meter. Sedangkan berdasarkan data pemboran, batuan keras mulai muncul pada kedalaman 3 - 4 meter di bawah dasar laut dengan SPT antara 32 – 34 sebagai sedimen Tersier.

Berdasarkan pengamatan di lapangan dan dikorelasikan dengan peta geologi P. Balang, Lembar Balikpapan, batuan keras yang diusulkan sebagai dasar tapak jembatan adalah Formasi Pulau Balang (Miosen Tengah) yang terdiri atas batulempung, batupasir and batubara yang sudah mengalami deformasi dan mulai terlipat membentuk antiklin. Pada penampang seismik, batuan keras tersebut adalah Sekuen B yang ditutupi oleh sedimen Kuarter.

Kata kunci: seismik, pemboran, sedimen Kuarter, batuan keras, tapak jembatan, Pulau Balang.

INTRODUCTION

Study area is located in Balikpapan Bay, East Kalimantan Province. In this region, it will be developed a bridge that connect Balang Island and mainland of Panajam Regency. For this purpose, its required sub surface geological data especially Quaternary sediment and stable layer by using seismic survey and core drilling.

Administratively, the study area is located at Balang Island - Pancur village, Panajam District, Panajam Regency, East Kalimantan Province. Geographically, the location in coordinates between 116.67^{o} – 116.85^{o} N and 1.08^{o} – 1.28^{o} E (Figure 1).

Geologically, region of Balang Island waters and its surrounding is composed by Tertiary sediment formed since Oligocene to Miocene (Hidayat and Umar, 1994). According to these authors, rocks at Balang Island are dominated by quartz sandstone layers, sandstone and claystone with marl and coal bed with thickness achieved 900 meters. The top layer is soft sediment as a result of weathering from lands to fill base of river. The soft sediment is usually characterized by reddish yellow, and at river edge rather grayish and contained organic matters.

Outcrop of rocks at Balang Island belongs to only Pulau Balang Formation, while other formation has been closed at the top by alluvium sediment (Hidayat and Umar, 1994). Pulau Balang Formation consists of quartz sandstone, sandstone and claystone with intercallation marl and coal, contain fossils of *Lepidocyclina sp*., *Miogypsina*, *Miogypsinoides* and *Fusculinella borneoensis* of Middle Miosen. The depositional environment is shallow sub-littoral sea and the thickness of this formation reached to 900 meters with strike 45^{o} and dip 10^{o}. At the main land of East Kalimantan, Pulau Balang Formation covered by Pemaluan Formation and Balikpapan Formation. Type location of Pulau Balang Formation is located in Balang Island, Balikpapan Bay.

Pemaluan Formation (1500 - 2500 meter thick) is consisted of claystone and marl, sandstone and limestone, contained *Lepidocyclina* sp., *Miogypsinoides* sp., *Cycloclipeous* sp., and *Operculina* sp. This formation is underlain of Pulau Balang Formation. It is also found the planktonic fossils of *Globigerina venezuela* HEDBERG that show Early Oligosen – Middle Miocene and deposited as deepsea environment. The type location of this is found at the Pemaluan Village, that is situated around 30 km from NNW of Balikpapan direction.

While at Balang Island, Pulau Balang Formation is also found and covered by alluvium deposit, but Balikpapan Formation is not found. The bridge site plan at Pancur village is characterized by greyish to blackish alluvium that consists of soft organic matter. In

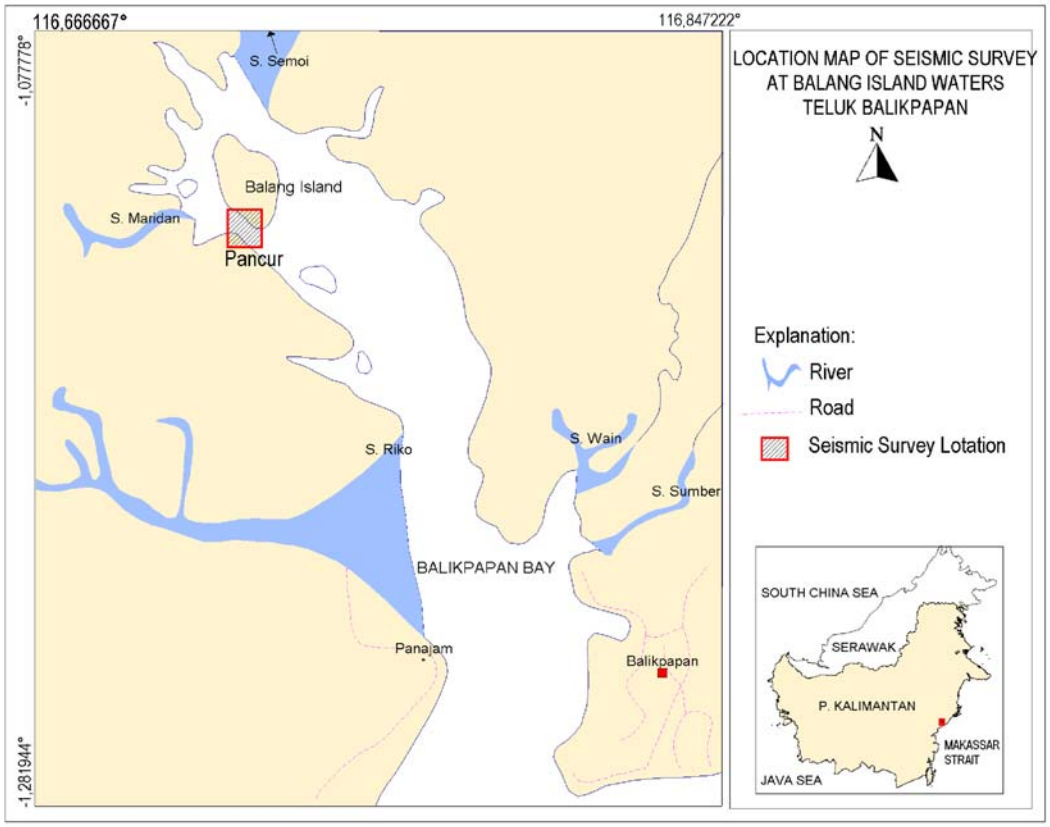

Figure 1. Map of the study area

the other hand, organic matter at Balang Island is more thicker than Pancur side. Structure geology around the Balang Island is not found because covered by alluvium deposit.

In this study, it is important to understand the existence of alluvium and hard rock layer. Therefore, it required the description of bearing capacity rock related to bridge construction such as Standard Penetration Test (SPT) that correlated with seismic data.

METHODS

To get the sub bottom data is used single channel high resolution shallow seismic reflection and core drilling methods. This method aims to know the thickness and profile of the sub surface sediment of the study area. The principle of shallow seismic reflection is to use underwater sound wave, where the sound wave on medium will be reflected by sediment layer between alluvium as the unconsolidated sediment and hard rock as the consolidated sediment (acoustic impedance). The sound wave will be received by hydrophone. The energy source of seismic method is boomer (Photo 1).

Interpretation of seismic data is based on the stratigraphical seismic principles to identification of reflector characteristics and limit of sediment sequence (include the internal reflector) each seismic units (Priyono, 2000). Furthermore, identification and seismic reflector nomenclature, it can describe

Photo 1. Energy source (boomer) and hydrophone.

reflection character difference every sediment sequence that passed by seismic wave.

In this survey is used the sweep 0,25 sec. and firing rate 1 sec. The total of seismic sweep 250 mS in two way traveltime (twt) or 125 mS in one way traveltime (owt). The sediment thickness is counted based on speed of sound wave on waters that is 1500 m/S and in sediment 1600 m/S (Hubral and Krey, 1980).

The separation of Quaternary sediment and hard rock base on seismic characters according to Ringis (1993). The Quaternary sediment character in seismic usually divided two are recent marine deposits (sea sediment resent) with soft sediment size and coarse fluvial deposits (sediment fluvial coarse granulous) with sand – gravel size. Recent marine deposits in seismic profile is typed by reflector form according to concordance and parallel lamination), and coarse fluvial deposits is typed by wavy, hummocky, and sometimes to fill the base valley basin (channel fill) (Figure 3). Hard rock as a bedrock is typed by mounded, sometimes chaotic form, and free reflection at the bottom and the above as an erosional truncation line (Ringis, 1993).

To get the soft rock and hard rock as a base in construction pillar of bridge is done with Standards Penetration Test (SPT). This data besides to detect rock condition also to

Table 1. The SPT connection, soil character and bearing capacity (qu) according to Terzaghi and Peck (1967) and Hardiyatmo (2002).

No.	N-SPT	Soil Condition	Qu (Kg/Cm^2)
1	< 2	Very Soft	< 0,25
2	2 – 4	Soft	0,25 – 0,50
3	5 – 8	Medium	0,50 – 1
4	9 – 15	Stiff	1 – 2
5	16 – 30	Very Stiff	2 – 4
6	> 30	Hard	> 4

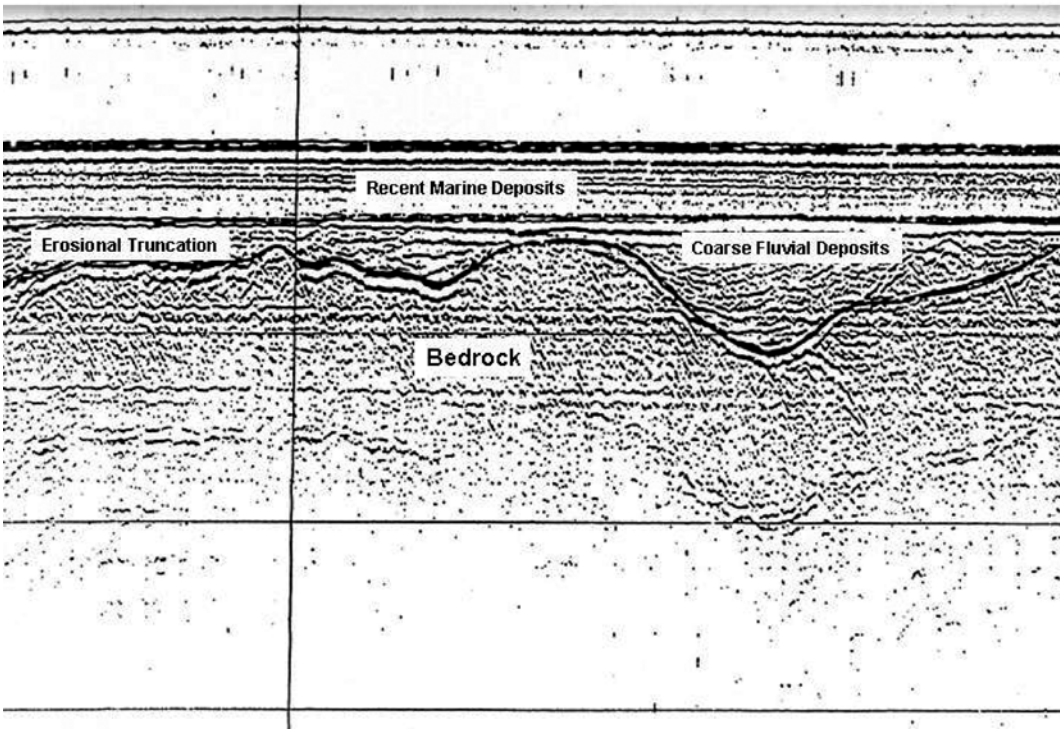

Figure 2. The model of hard rock identification (bedrock) and Quaternary sediment (Ringis, 1993).

help in interpretation and correlation in seismic recording data. In dredging activity around 7 meters depth from sea floor and 16,71 meters depth from sea surface. Dredging location at track L-3, so that simplify in interpretation and rock correlation in seismic. While, to detect the connection between SPT, soil character and power supports soil threatens in Zaghi and Peck (1967) and Hardiyatmo (2002) (Table 1).

SURVEY RESULT

Seismic Trackline

Seismic trackline is done to get description about Quaternary sediment thickness and hard rock depth as a base of bridge foundation at Balang Island. The total of seismic tracklines about 12 tracklines; and each 7 tracklines is parallel with the bridge axis, 2 crosslines and 3 tracklines is parallel with coastline. The total seismic tracklines about 3,561.8 meter long or around 3.56 km (Figure 3).

The main seismic tracklines around the center of bridge line crossing of the river body with direction from southwest - northeast. The strong river current and narrow channel widely around 350 meters, so that causes the tracklines can not true around bridge axis. The tracklines around bridge axis are L-3 and L-4 (Figure 4).

Interpretation of Seismic Profile

Based on interpretation of seismic profile shows that the characteristic of seismic reflector are difference. The seismic profile at the survey area can be divided in two parts,

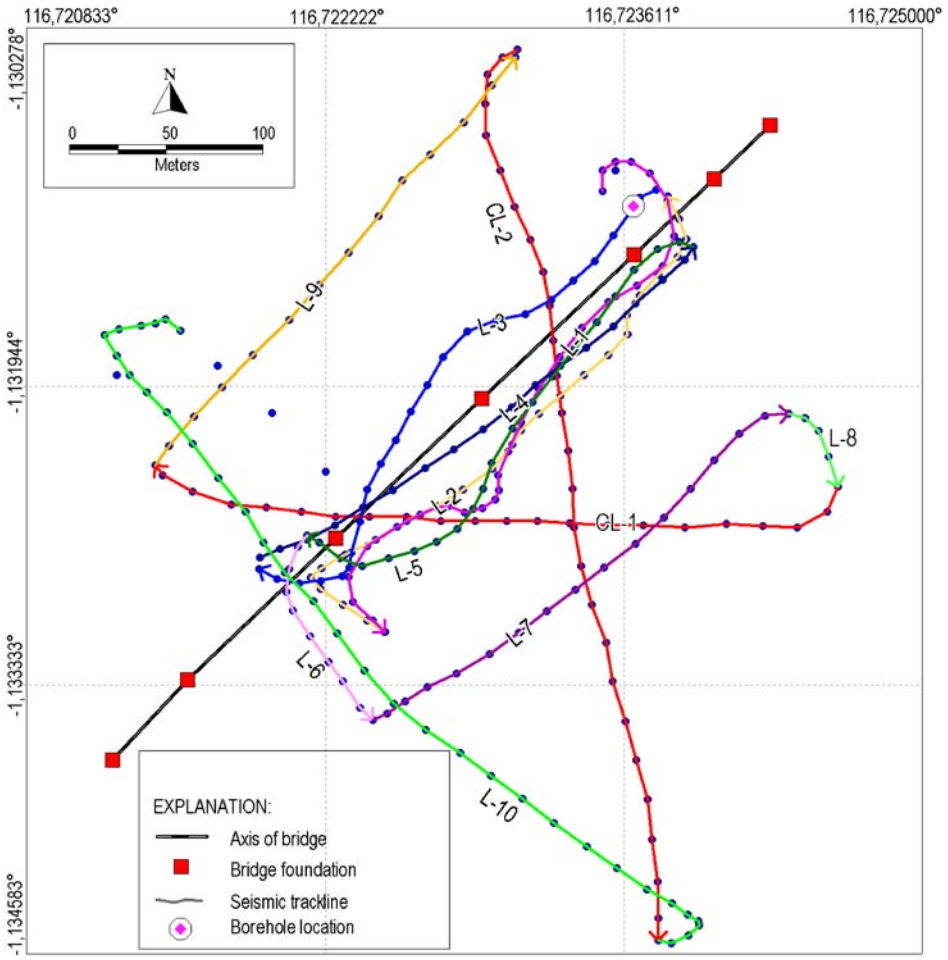

Figure 3. Seismic trackline map around bridge line at Balang Island, Panajam Sub-regency, East Kalimantan.

that is sequence A as a Quaternary sediment and sequence B as a basement acoustic.

Sequence A: generally shown by reflector form the concordance and parallel lamination, locally is wavy and hummocky type, and follow the sea floor surface morphology at Balang Island Waters.

Based on reflector characteristic, outcrop observation (at the Balang Island and Pancur Village), lithology from bore hole and SPT value, it can be interpreted if the Sequebce A, so can be interpreted that sequence A is Quaternary sediment not yet consolidation. Based on outcrop observation and dredging data, this Quaternary sediment are the mixture between mud, shells and plant remainder as a soft sediment. Furthermore, according to Ringis (1993), sequence A interpreted as youngest marine sediment (or beach sediment) as a unconsolidated sediment is called the recent marine deposits.

Sequence B: located in the bottom part of sequence A to form some layer is characterized by chaotic reflector, wavy and

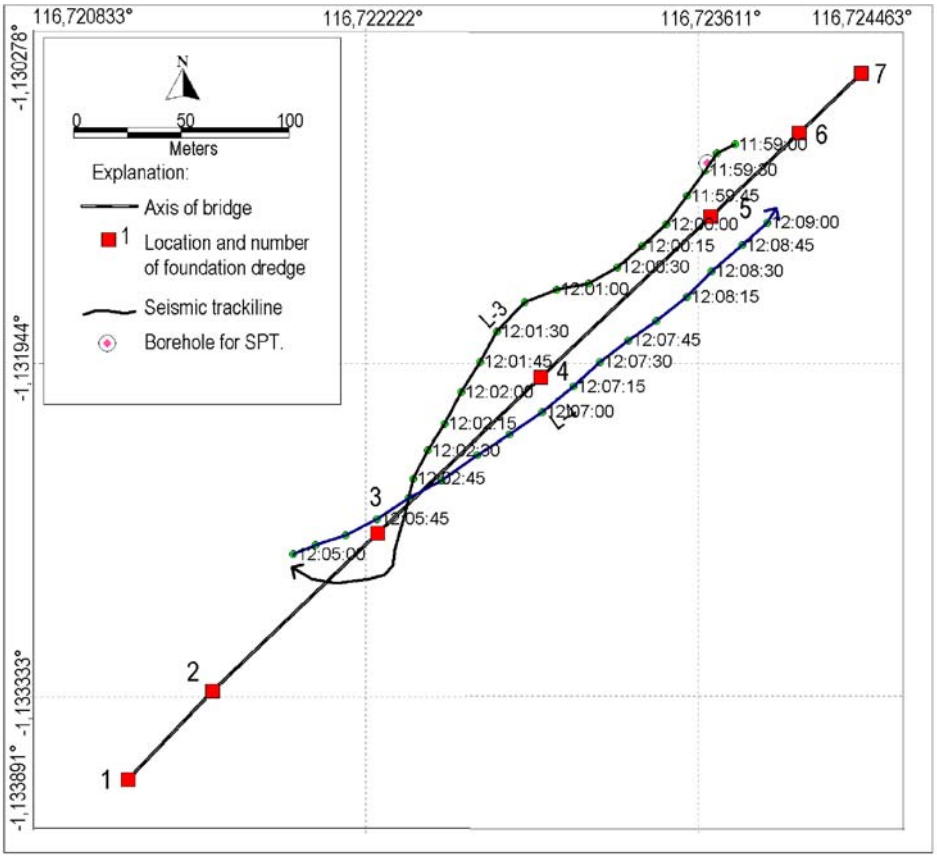

Figure 4. Map of seismic trackline (L-3 dan L-4) at the foundation and axis of bridge.

free reflector. Sequence B is the sediment rock that be covering of Quaternary sediment on the top. Based on seismic profile, the sequence B to form the sloping area, and based on regional geology map is estimated that the Tertiary sediment from the Balang Island Formation with layer position (strike) 45° and dip 10° (Hidayat and Umar, 1994). Balang Island Formation consists of quartz sandstone, sandstone and claystone interlaying marl and coal.

At southwestern of trackline L-4 to form highly that can be interpreted as an anticline. In the trackline profile of L-4 in sequence B found form little highly with reflector pattern form mounded (little hilly). The reflector with feature mounded can be interpreted as limestone lens or reef lens (Priyono, 2000). The lenses form existence as a reefs, if correlated with geology map of Balikpapan Sheet are the part of Pemaluan Formation that consist of claystone and shard interlayer marl, sandstone and limestone, containing the plankton fossil of Globigerina venezuela HEDBERG shows that early oligocene – middle miocene age (Hidayat and Umar, 1994). The hilly form also met in another seismic profile in trackline CL-1, L-5, L-9 and L-10 (Figure 7).

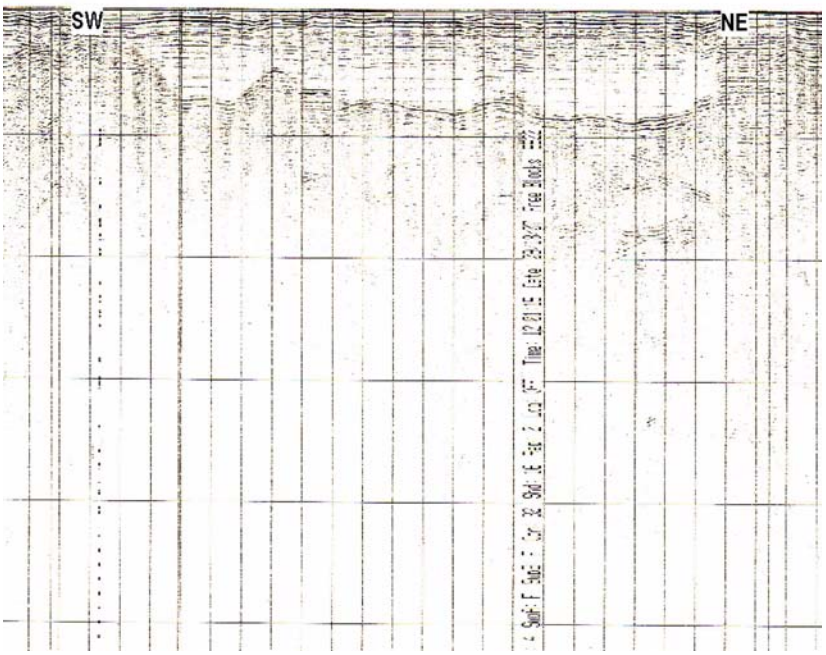

Figure 5a. Seismic profile of L-3 with SW – NE direction.

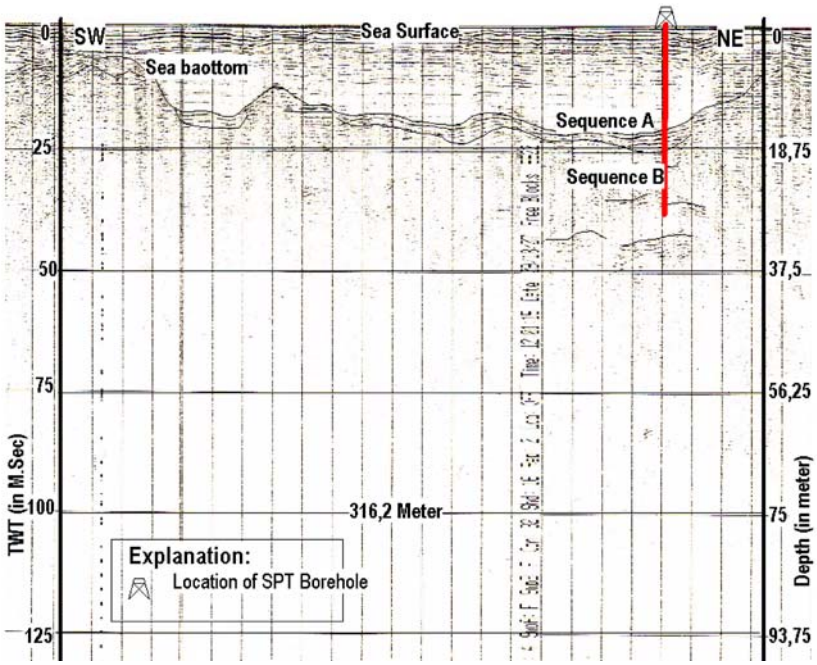

Figure 5b. Result of seismic profile interpretation at L-3 with southwest – northeast direction (thickness in meter).

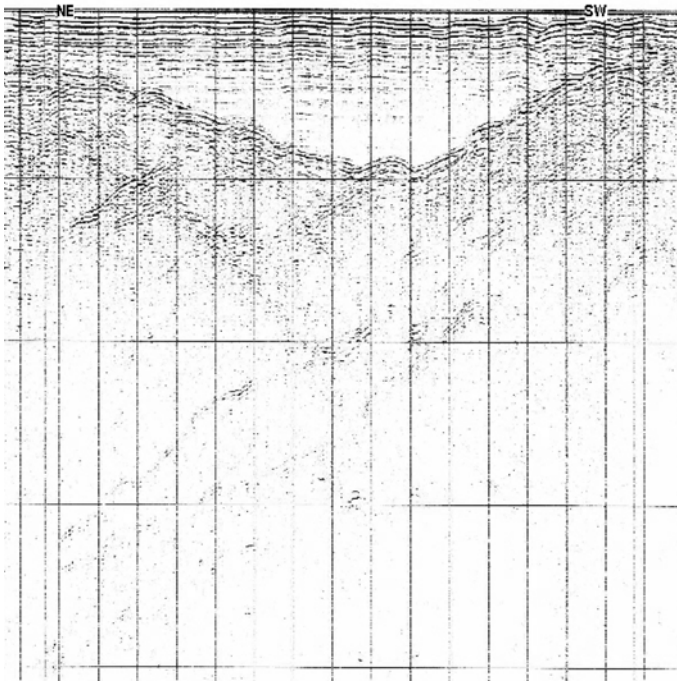

Figure 6a. Seismic profile of L-4 with SW – NE direction.

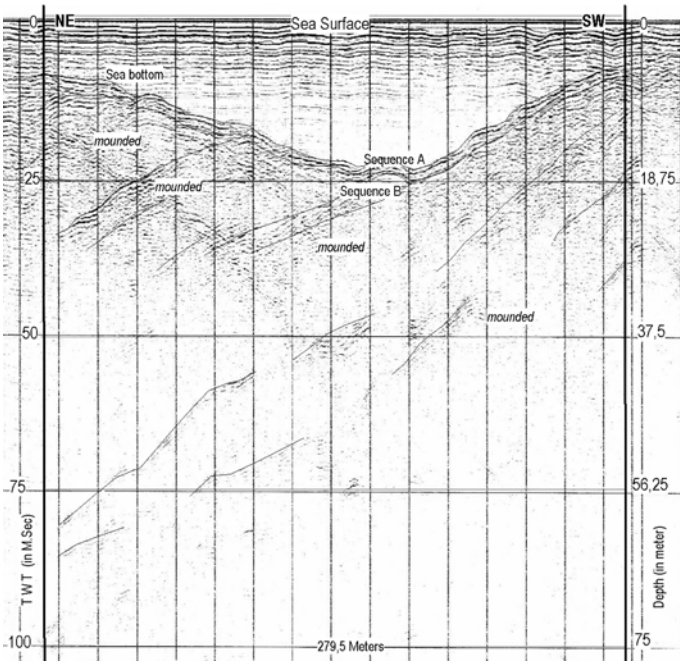

Figure 6b. Result of seismic profile interpretation at L-4 with southwest – northeast direction (thickness in meter).

Table 2. Sediment thickness around Pillar 3, 4 and 5 with seismic trackline (L-3 and L-4).

Trackline	No. Of Pillar	Time	Water Depth (in meter)	Thickness (in meter)	Hard rock Depth (in meter)
L-3	4	12:01:30	13,86	2,45	16,31
	4	12:01:45	17,12	4,08	21,20
	5	11:59:45	16,71	4,89	21,60
	5	12:00:00	15,49	2,85	18,34
L-4	3	12:05:30	5,47	1,56	7,03
	3	12:05:45	6,25	1,56	7,81
	4	12:07:00	16,40	1,95	18,35
	4	12:07:15	16,80	1,56	18,36
	5	12:08:45	7,81	1,95	9,76

Table 3. Measurement result of N-SPT and megascopic of sediment example at Balang Island waters, Balikpapan Bay.

Water Depth (in meter	Sediment Depth (in meter)	N-SPT	Soil Type	Description
16,71	0	6	Soft	Grey colour, contain wood and leaf, and unconsolidated sediment.
17,71	1	8	Medium	Grey and blackness colour, contain wood and leaf and black sediment layer.
18,71	2	18	Very Stiff	Grey and blackness, contain wood, leaf, yellowness grain, shell, reef materials and black sediment layer.
19,71	3	32	Hard	Yellowness colour, contain coal and peat, shell and reef materials, blacksediment layer.
20,71	4	34	Hard	Yellowness colour sediment, contain coal and peat, lithic and reef material, and stringent.
21,71	5	44	Very Hard	I t e m
22,71	6	55	Very Hard	I t e m
23,71	7	60	Very Hard	I t e m

Photo 2. Lithology condition at Pancur Village side shows that the grey colour as a Tertiary sediment.

Photo 3. Borehole location for SPT measurement at Balang Island shows the alluvium and Tertiary sediment.

The Hard Rock Depth as a Base of Bridge Foundation

To get the soft sediment thickness and hard rock depth to pole location foundation bridge at Balang Island, the borehole location be side in the North-east of L-3. Interpretation result and sediment layer thickness calculation in seismic profile shows the variation thickness and generally the soft sediment layer follows the sea floor morphology pattern (Table 1).

In the profile trackline of L-3 the Quaternary sediment thickness with range from 2,45 to 4,89 meters and waters depth between 13,86 and 17,12 meters. The hard rock depth in pillar location 4 between 16,31 and 21,20 meters and in pillar location 5 between 18,34 and 21,60 meters. In the profile trackline of L-4 the sediment thickness of Quaternary with range from 1,56 to 1,95 meters and waters depth between 5,47 and 16,80 meters. Hard rock depth in pillar location 3 between 7,03 and 7,81 meters, hard rock depth in pillar location 4 between 18,35 and 18,36 meters and hard rock depth in pillar location 5 are 9,76 meters. Furthermore borehole data got the SPT and megascopic rock as table 2.

Based on borehole data can be divided two sediment units, that is soft rock with SPT between 6 and 18 and hard rock with SPT above 30. Result of borehole at obtain the soft rock with SPT less than 18 on sediment depth between 0 and 2 meters. Under 2 meters depth of sediment with SPT above 30. In sediment depth under 3 meters is got SPT higher that is 36. If sediment thickness Quaternary comparison with seismic profile is 4,89 meters, so in borehole data in depth around 4 - 5 with SPT between 34 and 44 as a hard – very hard. Existence of hard rock in depth around 4 - 5 meters is Tertiary rock from aged Balam Island Formation is oligo-miocene age (Hidayat and Umar, 1994). The Tertiary sediment it grey coloured, consist of interlaying siltstone, quartz sandstone and inserted coal (Photo 2).

Furthermore, based on observation at field of outcrop, alluvium sediment at the coast of Pancur Village that shows the intensive of weathered process existence with thickness with ranges from 5 to 10 meters. Under alluvium found the sediment layer with soft layer as Tertiary sediment to form the anticline structure with axis line of SW – NE direction. This rock at the land, formed by some faults structure to form the parallel direction with axis line of anticline (Weerd and Armin, 1992).

Observation done around the foundation of bridge at Balang Island. The rock condition much the same with rock beside Pancur Village, but at Balang Island most solid and not yet deformation forms fold, to form interlayer between sandstone and siltstone and coal (Photo 3).

The alluvium sediment at the others location around the bridge line found beside left and right of river characterized by grey colour, rather smell and contain organic materials. This sediment existence is necessary gets attention, because the existence to part middle river. This type of sediment necessary guarded, because not yet compact and less strong to support the overload of material above the bridge pillar.

DISCUSSIONS

At survey area, result of seismic interpretation and calculation of Quaternary sediment thickness calculation with range from 1,56 to 4,89 meters and waters depth between 5,47 and 17,12 meters. The depth of hard rock with ranges from 7,03 to 21,60 meters, and the position of hard rock depth more shallow found in pillar location 3 is 7,03 meters and more deep at location 5 is 21,80 meters. Based on the condition, so long of pillar at location 3 is 7,81 meters, at the pillar 4 is 21,20 meters and at the pillar 5 is 21,60

meters. The part more deep from hard rock located in around pillar location 4 that resides in middle river, while the pillar location 3 and 5 to edge to form the shallow water.

Based on observation at field and correlation with regional geology map at Balang Island, Balikpapan sheet (Hidayat and Umar, 1994), hard rock as base of bridge at Balang Island formation. At the seismic profile, sequence B can interpretation as Balang Island Formation. The existence of anticline structure in the eastern side of Balang Island and reef lens like seen in trackline L-4 (see Fig. 6b). Based on regional geology map, estimated the reef as a part of limestone layer in Pemaluan Formation.

Alluvium sediment at the sub-surface necessary get attention because mixing between organic and unconsolidated sediment, so that high risk to power of foundation bridge. The Tertiary rock that is proposed to be base of bridge foundation, but at the top it experienced the weathering process. At several appearances at the left and right location of bridge, the weathering process is influences the crack and changing forms the soft layer

CONCLUSIONS

The interpretation of seismic records show that there are two sequences in the study area : sequence A and sequence B. Sequence A located in above of seismic with reflector characteristic according to concordance, parallel lamination, wavy, hummocky, and channel fill. Based on seismic interpretation, Quaternary sediments consist of silt, clay, organic material and coarse sand. In the bottom of seismic profile is Sequence C as an acoustic basement is characterized by mounded, little hilly reflector, and base of bottom more downwards with type is free reflector.

Based on reflector feature identification and correlated with sediment rock around survey area, the Sequence B interpreted as the Tertiary sediment that is consists of claystone, sandstone, marl and interlayer with coal that experiences the deformation has formed the anticline. Hard rock depth ranges from 7,03 to 21,60 meters, in the top at location 3 that is 7,03 meters and in the bottom at the location 5 that is 21,60 meters. The long of pillar foundation to reach hard rock at location 3 that is 7,81 meters, at pillar 4 that is 21,20 meters and at pillar 5 that is 21,60 meters. The part necessary is needed in location 4 because hard rock to maximum depth if compared with the other pillar, so that needs the deeper and longer of pillar.

To support of seismic interpretation data; it correlated with borehole data got hard rock depth between 4 and 5 and SPT between 34 and 44 as hard rock. The existence of hard rock is Tertiary sediment from Balang Island Formation with oligo-miocene age, and grey coloured feature, consist of interlayer between claystone, quartz sandstone and inserted of coal.

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