BREAKTROUGH IN NEW ROAD TECHNOLOGY THAT OPENS ISOLATED AND ABANDONED AREA

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Abstract

The growth of economic live within Centers for Development Region must be followed by the growth of infrastructure. The quality and capacity of connecting road between those Centers should be increase. Industrial development has grown rapidly and reduced the existing productive agriculture land. This condition will influence to the supply and demand of agriculture product. Due to the limited of productive agriculture land especially in archipelago countries, a new farmland must be developed in selected marginal land. A breakthrough in road and open channel technology must be adopted to support of opening a new productive farmland. Fire attack during dry season has destroyed thousand of hectares of forest and peat area and cause great flood to the neighboring village during next rainy season. An action must be taken to save infrastructure and nature resources in selected area from fire hazard that comes periodically. This paper is deal with a new system of road and road-channel for soft soil and deep peat area, which is called "Multiple Spans Structural Cable Road and Road-Channel System P.951100". A brief concept of Integrated Plan Patterning is also presented in concerning with Infrastructure, Fire Fighting System and Opening New Farmland in extremely sensitive zone.

Key worlds: road, open channel, new technology, soft and swampy soil, peat, fire assault.

1.INTRODUCTION

The economic fast growing of Centers for Development Region must be followed by the extension of infrastructure. Road that connects those potential places must posses sufficient traffics capacity and loads bearing capability. The road alignment should be shorter than existing condition that is circling around untouchable area. To keep continuing of this prospected economic growth, bypass roads must be developed

For time being road planners can not afford to develop road construction on deep swampy and deep peat soil unless by utilizing bridge system. New road technology is required to put these soil road body alignments protrude into weak load bearing zones like isolated and abandoned land.

The expansion of industrial area has reduce productive agriculture land and as consequences new land replacement must be prepared to keep food supply and demand in balance condition with the growth of population. New open channel technology must be developed to change the selected marginal land into new productive agriculture land.

Fire attack in some tropical rain forest had destroyed thousands hectare of forest and peat area in long dry season and followed by sudden great flood to the neighboring village in the next rainy season. The wildfires had also destroyed service road connection on this burning peat environment that had disadvantage effect to the domestic daily live activity.

An integrated plan patterning of Infrastructure Development, Fire Assault Defense System and New Agriculture Land Replacement Program (Figure 1) must be adopted to reach human being wealth and prosperity in the near future.

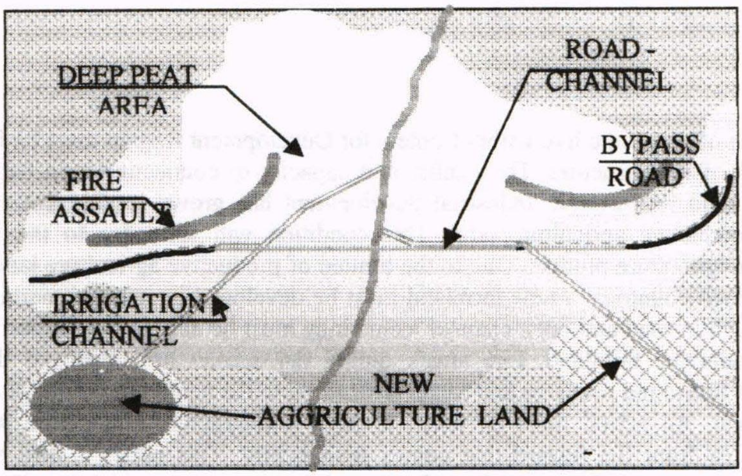


Figure 1. Integrated Site Plan

2.EXISTING ROAD TECHNOLOGY

2.1 Constraint of Road Development

The physical environment that limits in infrastructure development on peat soil and swampy area are field topography, physical soil bearing condition and the climate.

Depression zones will be filled by rain water or incoming run-off water during rainy season and afterward will be drained out along dry season. This rhythmic change in climate will influence to the pore water pressure of compressible peat. Soil fills road body that exists at this area become unstable.

Peat layers become very sensitive to fire expose in long dry season. Wildfires caused by uncontrollable land clearing or by nature's phenomena can grow bigger and deeper in peat layers. Road soil fills that rests on top of this burning peat ashes will destroyed.

Non uniform bearing layers of soft soil cause local failure or irregular settlements to the compacted road soil fills both in transverse and longitudinal sections. The road sections displace each other and show up as road waving, road tilting and section sinking.

Those peat nature characteristics that have been identified should be taken into account in preparing new road plan on peat zone including the sensitiveness to fire expose.

2.2 Road Structure in Soft Soil.

Road engineers are familiar with road design and construction on shallow soft bearing soil or peat layer but not for deep soft bearing stratum with sensitive environment. In very urgent condition, road planners have two choices design alternative, first is by applying bridge system and second is by sand force displacement method.

The sand in the second alternative had spread uncontrollable and disintegrated into surrounding deep soft soil. The construction cost had been estimated would become very high at the completion of project. For very soft and deep bearing stratum, the implementation of bridge system was competitive.

Road soil fill body or dikes of open channel can be built directly on top of stiff bearing soil by placing and compacting the soil fill in layers as specified. For fewer stiffs bearing layer condition the application of reinforcement fabrics on contact area are required. These fabric sheets spread out both dead and live load on this weak sub grade to increase the stability of compacted soil fill.

Up until now most of road construction on shallow soft soil likes swampy land has been done by soil displacement method. Bulldozer blades push and displace new selected road soil fills into the bearing sub grade by its own weight. The compacted submerge soil fill will support the rest of upper road body and structural bearing pavement.

The soil displace method can not be applied even on shallow peat layer. In place, soil fill compacting with fabric sheets in contact area is the only relevant existing solution but has consequences of long continuing settlement. This road construction method needs extensive road maintenance up until secondary settlement finalized.

Soil fill compacting that are reinforced by pile wood mat system are also being used now for shallow swampy land and peat soil bearing stratum Figure 2a. During its service live time, road settlements grow smoothly and can change progressively due to increase of traffic loads and traffic frequency. Periodical maintenance must be commenced by heightened and reshaping the road body and pavement with new selected materials to keep road in serviceability condition.

Elevated concrete pile slab road structures have been introduced in 1996 for deep soft soil with run-off water on topsoil elevation Figure 2b to replace the sand fill forced method that had canceled. These bridge structures are consisting of concrete slabs that are supported by piles in row.

At Grade, concrete pile slab structure is applied for soft soil with no run-off water condition Figure 2c. The slab is rested on top elevation of bearing soil and is supported by piles in a formatted pattern.

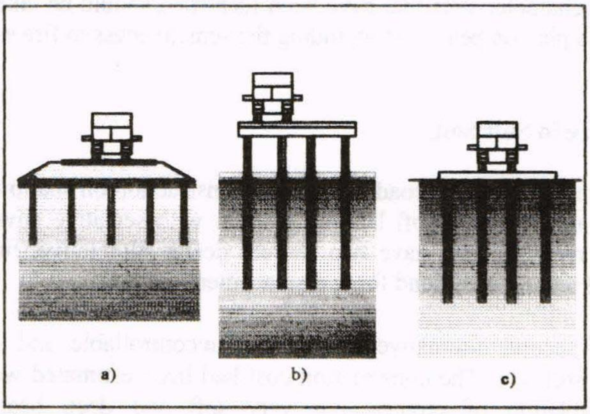


Figure 2. Road Cross Section on Soft Soil
a) Pile Wood Mat, b) Pile Slab and c) At Grade Slab

3.NEW ROAD TECHNOLOGY

3.1 Road Structure

The newest solution in road engineering for soft deep soil is "Multiple Span Structural Cable System", which is based on composite soil – reinforcing material. This new road technology adopts the composite section concept that had been implemented successfully in servicing logistic road alignment on soft soil in 1970-1971. The reinforcing material consists of wooden polygonal arrangement that supported wooden mat as soil reinforcement components.

This composite action of road section is required to support the execution of new transmission foundation experimentation "Chicken Foot Foundation System" on soft soil. This project was under Riam Kanan Project Otority – Department of Public Work and Energy and was executed by P.N. Wijaya Karya General Contractor Riam Kanan branch.

This breakthrough in road plan and construction will open new perspective in utilizing isolated and abandoned lands that are most of them dominated by deep swampy and thick peat soil conditions. Through this new technology, the development of single soil road or in combination with open channel that is passing over deep swampy or thick peat area is possible Figure 3.

This new road and road-channel structure consists of road soil fills that are supported by laterally continuos fabric sheet. The fabric sheets are attached perpendicular to the fix end exterior structural cables, and along the lateral span are supported by continuos interior structural cables. These fabric materials will keep the soil fill body of being breakdown and disintegrates into the surrounding bearing soft soil.

The structural fabrics sustain reduce external load and transmit it into the structural cable. The reduction of external loads is caused by soil bearing reaction and arching phenomena on the system. The structural cable lines will support the overall external load minus soil bearing reaction. In other statement, the structural cable will absorb reduced external load that fall into cable plus vertical reaction from fabrics.

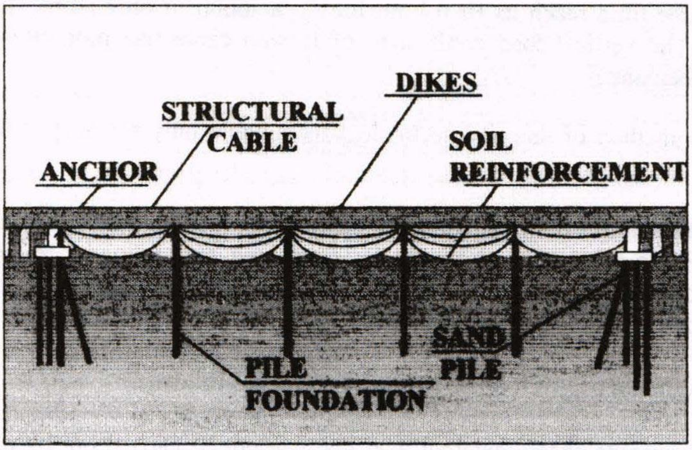


Figure 3. Multiple Span Structural Cable System
Side Few

The vertical loads are transferred into deep bearing strata through deep foundations. Negative skin friction on deep pile must also be considered if any. Under the balancing load condition the soil body would be in equilibrium system, the vertical displacement and the rotational movement of the cross section are controllable.

At the beginning stage of embankment on swampy land, the fill materials will expand the fabric sheets rapidly Figure 3. Due to soil interaction which is proportional to the soil bearing capacity, the expansion speed of soil fill will decrease and terminated at its final cross section form.

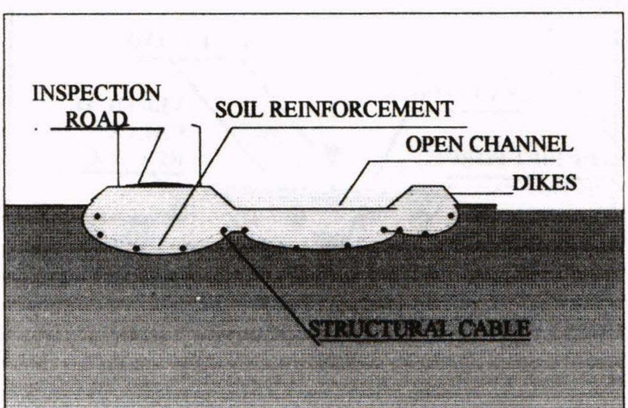


Figure 4. CROSS SECTION of ROAD-CHANNEL

The soil volume changes performance indicates that the fabric sheets and structural cables are still relaxing and the working external force are fully anticipated by surrounding bearing soil.

The structural cable lines reach its final limit form (parabola), if only fabric sheets have fully tensioned. The vertical load component of tension cable rise proportionally with height of soil embankment

The construction method of this new technology is suitable only for deep soft swampy environment.

The implementation of this new technology in peat environment is different from that soft swampy land. Pre-trenching ahead should be conducted and followed by soil filling progress. This construction method will decrease or delete the settlement duration time as much as has planned (refer to section 3.5).

Special attention should be given into two main concepts as follow:

- Fabric sheet transmits excess external load that can not be carried out by natural soil bearing capacity.

- The arching phenomena (Terzaghi and Peck, 1967) cause the external working load will divert most into supporting stretch tension cables and the rest into the spanning fabric sheets. As the consequences of this phenomena, the fabric sheets will receive reduced external load and again it is deducted by actual soil bearing capacity reaction, so that the tension force in the fabric sheets itself will be much decrease.

3.2 Vertical Stability Consideration

Free body structure equilibrium can be focused separately into partial section as well as inspection road dikes, water lane section and dike section Figure 5.

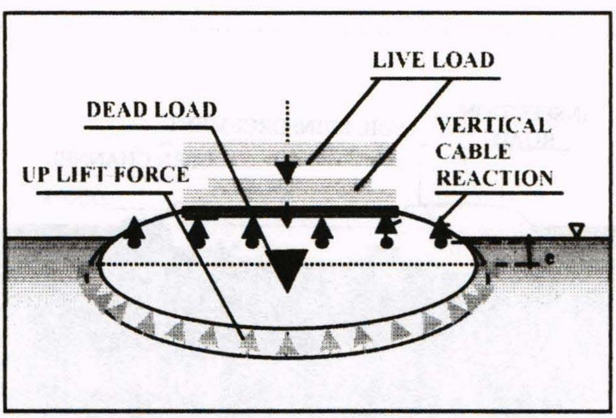


Figure 5. Inspection road dikes equilibrium

Stability analyses of road inspection dike are as follows:

External load that absorb by the bearing soil:

$$R = b\, q_a \text{ [kg/m]} \quad (1)$$

Total working load on cable:

$$q = Y A - b\, q_a + Q_{ll} \text{ [kg/m]} \quad (2)$$

Tension force in structural cable line:

$$T = q L^2 \sqrt{(1 + 16f^2/L^2)} \text{ [kg]} \quad (3)$$

Structural cable elastic elongation:

$$\delta_L = T L / (E A) \text{ [m]} \quad (4)$$

Vertical load on pile cap:

$$V = T \sin \alpha \text{ [kg]} \quad (5)$$

where b: effective width of soil fill, q_a: soil bearing capacity, Y: soil fill unit weight, Q_{ll}: live load, f: structural cable parabolic sag, E: modulus of elasticity, A: cross section area of structural cable and α: cable angle at support.

3.3 Rotational Section Stability

Field observation has shown that conventional road structure in soft soil almost unstable. Road fill body failure beginning from edge in the form of shear failure will cause road body become waving. Rotational section instability causes road body section become tilting. This could happen because the soil bearing capabilities along the road transverse section is not well distributed as well as in longitudinal direction.

Multiple Span Structural Cable System has introduced a pair of periphery longitudinal cable that is fixed and terminated at each pile cap. These structural cables will react also against undistributed soft soil bearing capacity by contributing contra rotational couple:

$$M_t = R \times l \quad (6)$$

where: R = reaction load on exterior structural cable, l = effective width of soil fill.

Because the existence of fabric sheets that are supported by exterior and interior longitudinal bearing cables, the sections become rigid and solid. The road sections are in equilibrium condition both vertical and rotational displacement.

3.4 Structural Vibration Response

The new road technology should poses sufficient safety driving services and comfort to the road users. Beside road geometric factor, the vibration damping response must be well considered to get the most promising road serviceability

The damping factors that influence to the Multiple Span Structural Cable System:

- Soil resistance surrounding the soil road body.
- Elastic elongation and sag of the structural cables.
- Dead load at main span and sub spans, as well as dead load at next spans and so fort.
- Vacuum effect due to the displacement of reinforced soil body mass.
- Shear displacement between structural cable and its protecting cover if any.
- Shear displacement between structural cables and support.
- Internal shear force within reinforced embankment body.

The influence of damping effect (viscous damping) causes dissipation of vibration energy so that the structural cable system will be almost in stable condition.

The Natural Frequency of simple supported cable is given be the equation:

$$W_n = (n \pi / l) \sqrt{(T g / q)} \quad (7)$$

where n = 1, 2, 3., fundamental mode at n = 1, g = gravitational acceleration, T = time period and q = distributed load.

The ratio between external pulses and natural frequency of the road system is given by W_e/W_n Figure. And to get good structural performance against vibration, the ratio must be in the range of $1{,}5 < W_e / W_n < 0{,}5$ (Purushotama, 1995).

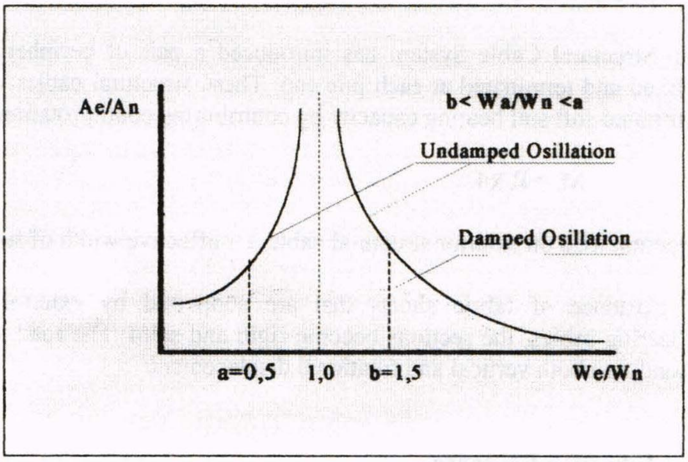


Figure 6. Correlation between Amplitude Ratio Vs Frequency Ratio

3.5 Settlement Characteristic of Peat Soil

Peat stratum has own specific settlement characteristic that is not found in inorganic soil. Elastic settlement that is caused by external load acts on the surface of peat layer is followed by consolidation settlement. Consolidation settlement consists of primary consolidation and secondary settlement.

The conduction of primary consolidation is caused by releasing of pore water under sustain external load. Due to decrement of pore pressure, the effective pressure increases gradually. The secondary consolidation is caused by slippage and reorientation of soil particle under sustained load.

Limited road settlement had occurred in shallow peat strata as seen in road embankment Figure 7. This road body should be reshaped by adding new road fill and new paving improvement up until the secondary settlement terminated, that cause expensive road maintenance.

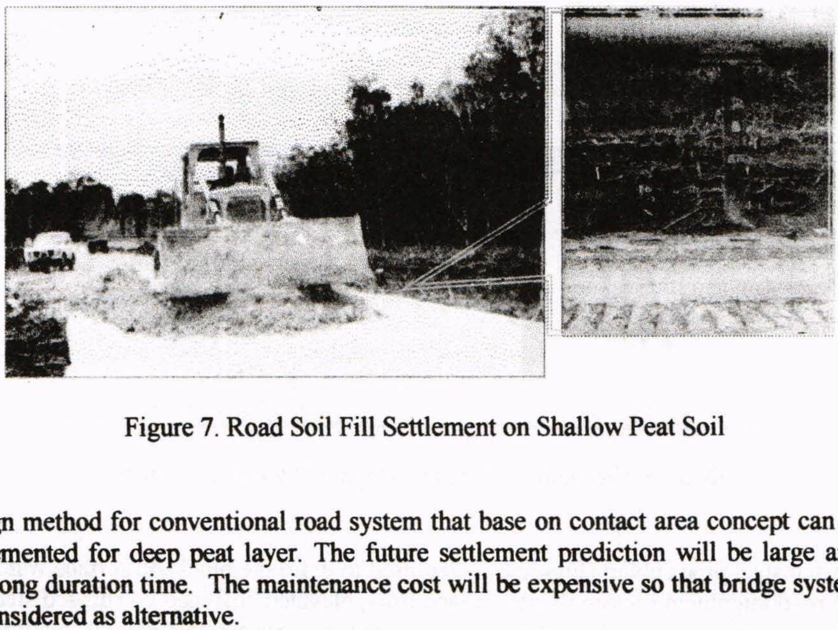


Figure 7. Road Soil Fill Settlement on Shallow Peat Soil

Design method for conventional road system that base on contact area concept can not be implemented for deep peat layer. The future settlement prediction will be large and can take long duration time. The maintenance cost will be expensive so that bridge system can be considered as alternative.

New road technology adopts semi floating design concept. Soil bearing capability and settlement characteristic of peat layer is not becoming dominant. The settlements that caused by road compaction soil fill and elongation's of structural cables are small. The rest of potential settlement is depending on pile groups resistance to vertical displacement that is controllable.

No detrimental repair will happen that cause by soil bearing over stress or overall settlement in the road span. The overall road stability is finalized by stiffness and settlement resistances of supporting pile groups, which depends on pile diameters and pile depth.

Primary consolidation in very soft inorganic clays are more significant in wide and very deep soft soil, the conventional road settlement will become uncontrollable and unlimited if present in this zone.

3.6 Temporary Run-off Water that Influences the Road Body.

Road alignment that crosses soft depression zone should also consider against the influence of incoming run-off water. Rainfall in this area as well as in adjacent zone could cause sudden flood.

The retained run-off water causes accumulation of water behind road body. This water pounding will increase the lateral pressure into road body and at least over flow. Since the road body of soil compacted fill is rigid and reinforced, it could resist the water pressure but frequent of over flow could damage the road pavement.

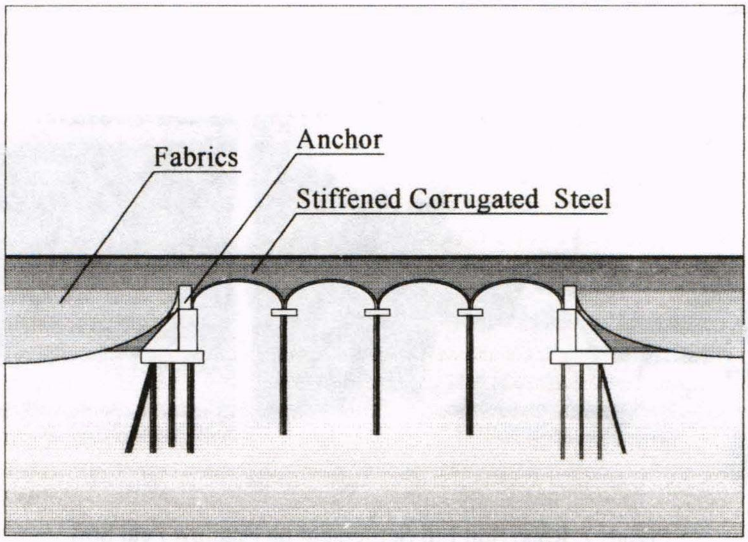


Figure 8. Elevated Stiffened Corrugated Steel Pile System

Corrugated steel pipe culvert (Figure 8) is required to drain the blockade surface water. In case of road alignment crossing wide surface flow, elevated stiffened corrugated steel pile system or elevated concrete pile slab system is needed. This supporting road facility must be positioned and well distributed in accordance with hydrological analysis and evaluation for this area.

3.7 Structural Corrosion Consideration

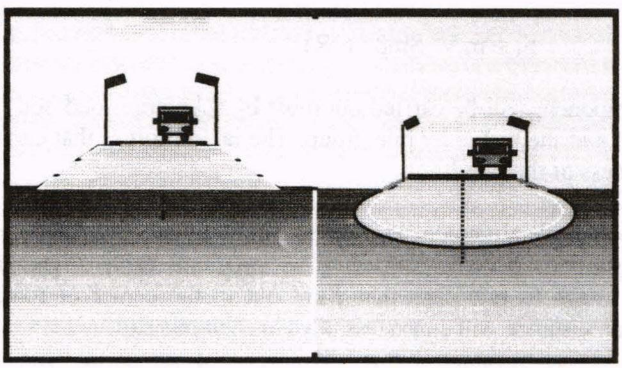
The structural cables that are selected for this new road system is galvanized wire rope type that should conform to building materials specification. The wire rope is painted with tar epoxy and zinc rich epoxy of resin paint to increase the corrosion resistance.

Covering the structural cable with bitumen and placing it in flexible polyethylene sleeve is an alternative way to protect against corrosion. These extra protections will lessen the structural cable from physical damage and keeping it long lives.

3.8 Soil Reinforcement.

Fabric sheet is widely used in road construction; most of it function as soil reinforcement. This material is placed between prepared sub grade and compacted soil fill.

For high compacted soil fill, the slope of soil fill must also be reinforced to keep from soil fill sliding. The slope reinforcements are applied in pieces separately in conformity with soil fill layered, to get perfect fixation. The comparison between soil reinforcement shape of existing road and new road technology is presented in Figure 9.



a) b)

Figure 9. Soil Reinforcement Shape
a) Existing road, b) new road technology

The soil reinforcement curve is idealized into the form of circle plane (Fluet. *at al*, 1986. Impe.V, 1989) and copied by (Law, B.K. *et al*, 1994) with radius of R, perimeter angle 2θ and the curved height t.

External working load into soil reinforcement:

$$p_o = (c_s - t\,M / D) \qquad (8)$$

Tension force in soil reinforcement:

$$T = K_g\, e_g \qquad (9)$$

where: K_g: tension stiffness, e_g: axial strain of fabric soil reinforcement, M: modulus of elasticity, D: depth of soil strata below.

The vertical component of T on both reinforcement adjacent span are carried out by deep foundation via the structural cable.

3.9 Road Geometric

Road curve alignment required fillet expansion and angle of super elevation to keep the passengers feel comfortable and the road traffic running in its lane. Symmetric cross sectional slope in straight alignment and one way slope due to super elevation angle are needed as specified, to free the road surface from water pounding.

Centrifugal force acting on the road surface:

$$S = m V^2 / (2R) \tag{10}$$

The force will cause additional load both on structural cable and deep foundation This load has two consecutive component value working in horizontal direction and in vertical direction:

$$S_h = m V^2 \cos\beta / (2R) \tag{11}$$

$$S_v = m V^2 \sin\beta / (2R) \tag{12}$$

Horizontal component will be carried out most by submerge road body wall that contacts on bearing soil and the rest is by pile group. The lateral forces that carried by pile depend on lateral stiffness of the pile.

The smooth road curve alignment as planned can be found only if the consecutive distance between pile supports become shorter. The structural cable alignments divert in fillet locations and attach to pile caps that point out to the center of road curve alignment. Reduced in span distance will cause less piles in each pile cap.

3.10 Construction Method

Road foundation that is build spreads out along its path needs specific construction method and equipment for each different soil condition. New construction method is required for soil fill compaction work on soft and compressible bearing stratum.

It has been proved that road construction system as seen in Figure 7 needs intensive road maintenance due to the presence of secondary settlement on bearing layer.

If new road technology is implemented for this project site, first by preparing road trench along road alignment, the structural cable is laid along this trench. Fabric sheets are attached into this relaxing structural cable. Trench cross sectional should be smaller than that of road cross section plan, to get full contact force area. This action is taken to shorten duration period for elastic, primary consolidation and secondary settlement of the peat stratum.

Soil fills are placed in layers as specified in filling and compacting road material procedure. After road fill reach its final elevation, the structural cables become in full stretching condition like also the fabric sheet each with tension stress below its permission stress. All new external loads that act on road body will increase both tension stresses of fabric sheets and structural cables without increasing contact pressure on the bearing soil. The total final load is absorb by structural cable and transmitted to deep foundation via pile caps.

Road soil filled on very soft inorganic soil at swampy land is done by force displace method but without applying pre trenching method (refer to paragraph 5 in section 3.1).

Figure 10. Construction Method for New Road Technology
On Deep Peat Soil (Simulation of Figure 6)

3.11 Road Lane Extension

In targeted year plan before the traffic volume has reached its peak capacity, the road must be extended by adding new lane, between proposed plan stations. New road extension can be constructed side by side with the existing road or in one side only.

New piles are positioned in the same existing pile row, and new pile cap will be required. Exterior structural cable available in each new lane or half of this amount if road extension takes in one side.

The new exterior cable should be position coincides with the existing exterior structural cable and both cables became interior cables in this new extended road section.

4. CONTRIBUTION OF ROAD-CHANNEL SYSTEM IN OPENING NEW FARM LAND

Multiple cable structural system can be implemented to single road or channel and also to joint section road-channel that crossing deep swampy or deep peat zone. This construction system can be design also for unstable ground water table condition that is caused by weather changes influence. Drop in water table will rise the structural cable tension and in reverse condition can decrease the stress force in the cable.

Fresh rain waters from the catch area or from adjacent river if any can be connected into the proposed irrigation network in the selected new farmland in that zone. The elevation of water in the channel is higher than that of surrounding acid run off water at this peat environment, so that fresh water contamination could be much eliminated.

This new type of irrigation channel could support the development of new agriculture modernization system in selected marginal land, to raise agriculture production.

5. THE CONTRIBUTION OF ROAD-CHANNEL SYSTEM INTO REGIONAL FIRE CONTROL EFFORT

In long dry season peat layers become very sensitive to fires expose. Wildfires attack due to uncontrollable land clearing by shifting cultivators or by natural causes had destroyed all object in this area.

The hazardous smoke has blown away crossing the border and cause severe effects to health and human activities in both domestic and international. The perish forest vegetation can not retain anymore against rainfall that cause runoff water flush down into natural trenches. Water elevation of the rivers in this rainfall-cached area has risen. This water had swept away adjacent villages and flooded cities that are divert by river.

Water bombing method from Transall aircraft C-160 of 8@10 tons water capacity into this burning peat areas had failed to put out the fire and shown up ineffective. This instantaneous shock water therapy cannot reach underneath fire head instead of change the water into water steam and black ash smoke. Field observations have indicated that only long and continuing rainfall not less than a week can totally stop this deep burned dry peat.

Fire assault forecasting pattern must be first identified to anticipate this periodical natural hazard, base on the past forest and peat fire attack. The potential and important site to be protected at the first priority should be recognized and decided. The basic fire assault defense line can than be adopted Figure 11.

The road-channel alignment should enter this proposed fire zone and minimally should coincide with this fire defense line. This macro road-channel system must have flow access to the existing selected natural field trenches network. Man made open trenches is also required to make perfect connection with nodal natural trenches.

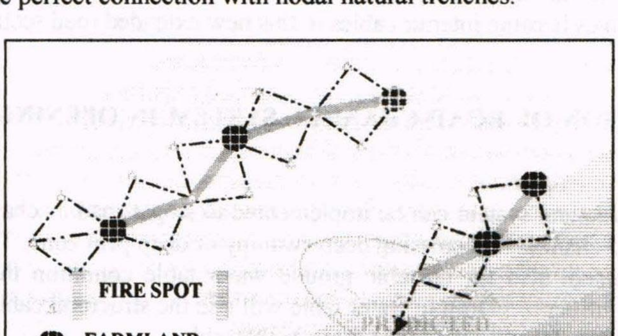


Figure 11. Nature Fire Control Concept

If the first fire alert is detected, the water from road-channel must be flushed down into selected natural trenches network under the water gate control in the dikes. The flushing water outbreak deep into the danger sector under certain speed below erosion limit. Nature barriers as well as man made barriers at certain critical spots are enabling to direct the flush water into precise targeted fire spot under control.

Those stands by facility will support the forest fire fighting units in putting out the fire. This fire control system should be one of the most promising wildfire anticipation concepts in natural way and utilizing permanent nature facilities.

6.INTEGRATED PLAN PATTERNING

Fire hazard could have serious disadvantage impact into the community that lives in this fire sensitive zone. This nature phenomenon is also influence into the economic live of adjacent Center for Regional Development.

The most efficient and economical solution must be created soon to anticipate those worst possible conditions. Integrated plan patterning must be adopted. Road-Channel in combination plan with Forestry Regional Fire Protection Plan or also in combination with New Farmland Development Plan must be created simultaneously if exist in those sensitive area.

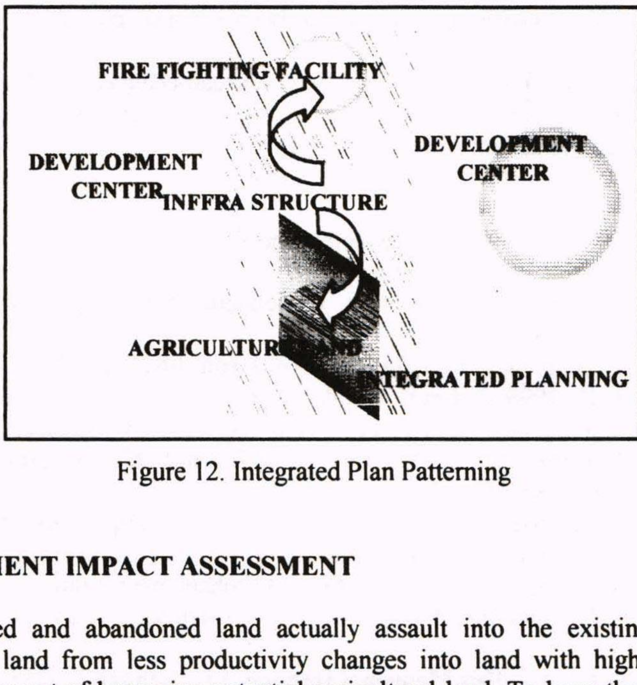


Figure 12. Integrated Plan Patterning

7. ENVIRONMENT IMPACT ASSESSMENT

Opening isolated and abandoned land actually assault into the existing environment equilibrium. A land from less productivity changes into land with higher quality that posses good prospect of becoming potential agricultural land. To keep the environmental in balance condition, identification of all potential impact factor must be well consider such as follow:

- The influences of changing in ground and surface water management due to the development of road and road-channel system in the area.

- The way to anticipate and extinguish the fire attack in the most seriously threatened sector by flushing water into natural trench network.
- The blockade of animal migration due to the existence of road or road-channel in their natural habitat.

Environmental impacts assessment study should be includes in the feasibility study and be done before the commencing of the project.

8. DISCUSSION

Multiple Span Structural Cable System is quite different from Suspension Bridge System. This new road technology is free from bridge structural components like stiffened flooring system, main girder, and tower.

Road sections rigidity is created from surrounding earth passive pressure; air does not contribute any rigidity to bridge structures.

No external vibration damper will act on bridge system, except from air medium that is very small in comparison with surrounding soil damper in multiple cable road system.

Controllable standby interconnection chain between road-channel or channel and selected natural trenches or agriculture land will promote awareness that may lessen tragic consequences when fire assault strike again.

Reference

Fukuoka, M. (1991) Negative Skin Friction of Foundation Steel Pipe Piles. **Proceedings, 91-9 ECD**, HATI, Indonesia, 1991.
JISEA (1991) Steel Seminar,**Proceedings,** Tokyo, Japan, 14-25, October 1991.
Kadarisman, B. *at al.* (1998) Sistim Konstruksi Diatas Tanah Lunak. **Proceedings VI-11-18 Geo Millennium 3 PAU ITB-HATTI**, ITB, Indonesia, 14-15, January 1998.
Low, *at al.* (1994) Arching In Piled Embankments, **Journal Of Geotechnical Engineering Vol. 120,** No 11.
Linson, T. (1995) Foundation Design And Construction. Longman Publisher, Singapore.
Purushotama, R.(1995) **Geotechnical Engineering**. Tata Mc Graw-Hill, New Delhi.
Rehau, (1996) Project Information Rehau Raugrid Embankment Reinforcement, Germany.
Sayed, A. *et al.* (1994) **Soil Steel Bridges Design Construction**. Mc Graw-Hill, NewYork.
Soemarwoto, O.(1997) **Analisis Mengenai Dampak Lingkungan**.UGM Press, Yogyakarta.
Soepandji, B.S. *et al.* (1996) Physical Behaviours of Peat Soils from Sumatera and Kalimantan. **Seminar UI-HATTI-HAGI-PU**, Jakarta.
Terzaghi, K and Peck, R.B.(1960) **Soil Mechanic In Engineering Practice**,WileyTuttle Tokyo.
Raoof,. (1994) Estimation of Spiral Strand Bending Fatigue Life. **7th Proceedings International Conference on Behaviour of Offshore Structures**, Oxford 1994.