A New Breakthrough – Application of Control Modulus Column for Settlement and Stability Control under Soft Soil and High Embankment Load at Pemalang-Batang Toll Road

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ABSTRACT:

Pemalang-Batang (Pematang) Toll Road as a part of Trans Jawa Toll Road is currently being constructed. The Pematang Toll Road which has 39.2 km length with 13 embankments before bridges (bridges approach / oprit) will be constructed above very soft river sedimentation soil. The construction of embankment on the soft soil leads to excessive settlement and high susceptibility toward slope stability failure. Ground improvement using Controlled Modulus Columns (CMC) is adopted to reinforce the soil, increase the strength thus reduce the settlement and stabilize the embankment. The application of CMC at Pemalang-Batang Toll Road is indeed a breakthrough in history of toll road construction as a new construction technology in Indonesia, where majority the settlement/stability issue commonly solved by structural or conventional solution such as: slab on pile, cerucuk matras beton, PVD/Vacuum Preloading etc. Control Modulus Column is one of ground improvement technique installed by forming a regular grid of semi-rigid inclusion to enhance global stiffness of soil mass so that the problem such as: settlement, bearing capacity can be controlled. The installation of CMC itself performed using special design auger element that is able to force the soil displace laterally induce volumetric expansion resulted a lateral compaction of surrounding soil. In Indonesia, Menard has been successfully implementing CMC in several projects for different sector. The CMC's design technology makes them uniquely efficient for the immediate support of road for public transport, large liquid or bulk solid storage tanks warehouse, and other infrastructures building or facilities. This paper gives a brief description of application of CMC for supporting embankment to achieve settlement criteria, special design concept, and recommendation are briefly discussed.

Keywords: control modulus column, very soft soil, ground improvement, embankment, toll road

1. INTRODUCTION

Human has found ways of dealing with poor soil conditions using simple techniques such laying wooden log, conventional dynamic compaction using human power. Significant efforts have been made in developing variety and more advanced ground improvement methods. The developments took advantage of comprehensive research, innovative technology in equipment, advanced methods, sophisticated instrument to provide faster execution and reliable results.

It is rather common available large area with reasonable investment required for road, airport, and port facilities are located at unpleasant location where significant weak soils such as peat, very soft clay, organic soil, loose sand is present. Often, in many industrial practices when the time becomes a major constraint, two methods are usually adopted; either installing piles to bypass the weak soil; or performing engineering soil modification.

Ground improvement techniques are commonly categorized into two categories; ground improvement without addition of material such as consolidation and compaction method; ground improvement with addition material such as stone column method, soil mixing, controlled modulus columns, etc. Preliminary studies therefore are conducted to determine the most adequate technique with several considerations such as loading, ground condition, design criteria to be achieved, project location, construction period.

In the beginning of 1990s, Menard patented the technology of Controlled Modulus Columns (CMC). CMC is very common in many countries in Europe, and it is either newly introduced or yet to be widely used in Southeast Asia. Certain countries e.g. Malaysia have about more than 15 years of history of using CMC. In Indonesia, Menard has been successfully implementing CMC in several projects in different sectors. CMC are vertical inclusions installed in the treated ground to form a mass of semi rigid inclusion column. The composite mass (soil-CMC) has greater stiffness than the initial untreated ground reducing global deformability, hence reducing settlements induced by the weight of the structure to within allowable ranges.

Rather than transferring the load directly, the CMC utilizes a well compacted granular fill with typical thickness varying from 0.4 to 1.0m which serves as Load Transfer Platform (LTP). **Figure 1** illustrates the load transfer mechanism of ground improvement using CMC as semi rigid inclusion in comparison with piling system. The CMC are suitable for structures with distributed loads to large surface areas (reservoir, warehouse, highway embankment) underlain with soft to medium soil.

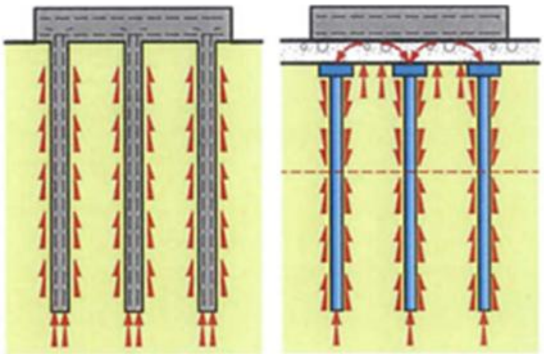


Figure 1. Comparison of Load Transfer Mechanism between Pile (left) and CMC (right) (Asiri National Project, 2012)

Some features of the CMC technology are:

- Installation is performed using auger. In this manner, the installation is quiet, vibration free and generates minimum spoil.
- Elasticity modulus of the CMC elements is typically 50-3,000 times that of the soil (weakest stratum)
- A load transfer platform of generally granular fill (LTP) is placed over the CMC reinforced ground.
- In granular soils, densification due to lateral displacement may occur between the columns by virtue of the displacement drilling process.

2. CMC INSTALLATION METHOD

CMC are installed using a specially designed displacement auger. Unlike the conventional auger which excavate the soil material and produces large spoil and create disposal problem. This special auger displaces the soil laterally and densifies surrounding soil, increases load bearing capacity and produces minimum spoil during installation.

When the auger reaches the designed depth, grout is pumped through the hollow stem of the auger and into the soil bore as the auger is retracted with calibrated pre-defined rate to avoid necking. Quality control of CMC is conducted with real time monitoring of the following installation parameters:

- Speed of rotation
- Rate of penetration and retraction of the auger
- Torque
- Depth of CMC
- Installation time
- Grout pressure
- Volume of cement mixture with function of depth.

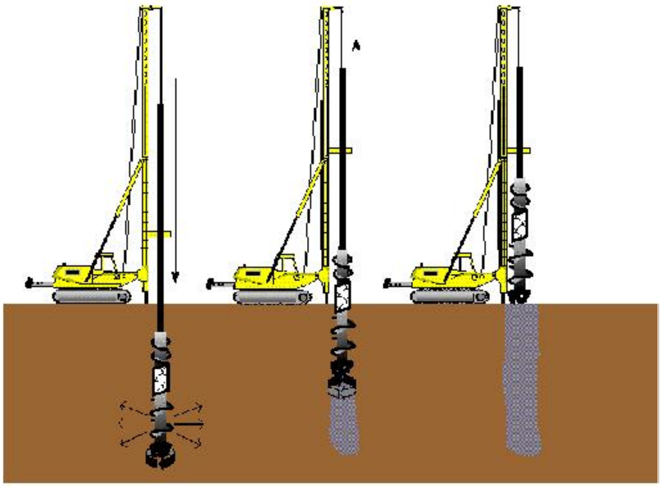
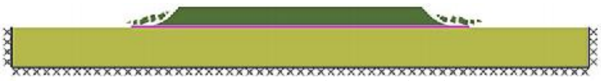


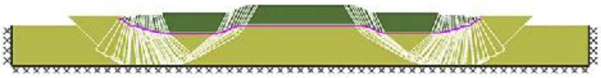
Figure 2. Installation of CMC by Displacement Method (Plomteux,. et al., 2000)

3. DESIGN CONCEPT CMC FOR HIGH EMBANKMENT

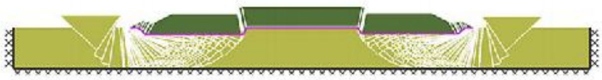
Placing embankment above soft layer shall be performed with slow increment within long time to let the soil release the excess pore water pressure and increase bearing capacity gradually. In case the embankment was built recklessly, the low bearing capacity soil will generate excessive settlement at the center and lateral deformation at the slope due to slope failure as illustrated at figure below:



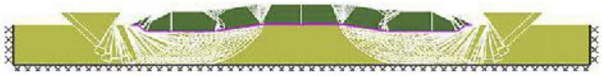
(a) Lateral sliding failure (surface failure)



(b) Deep seated global failure



(c) Lower layer extrusion with sinking



(d) Lower layer extrusion with 'snapping'

Figure 3. Typical Failure of Embankment (Smith et al., 2016)

The application of CMC was intended to increase soil bearing capacity thus reducing displacement into several limits and prevent slope bearing capacity failure. High embankment generates axial forces (self-weight and traffic weight) and lateral forces. While the CMC is commonly used for supporting axial load, due to its material behavior. Therefore, additional material such as geosynthetic, wiremesh, CMC with reinforced steel will be probably required. **Figure 4** below illustrated the forces of CMC below embankment. The following section briefly describe technical aspect and design concept for CMC to support high embankment:

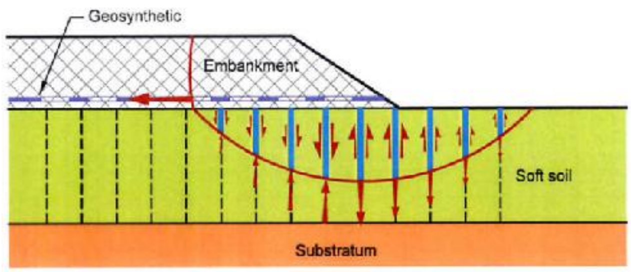


Figure 4. Typical Cross Section of CMC (Asiri National Project, 2012)

3.1 Force Equilibrium

The CMC has a different load transfer mechanism compared to pile foundation. It does not transfer the load directly to the structures but it utilizes some well compacted granular material as a load transfer platform. The dimensions, spacing, and material of the CMC are based upon the development of an optimal combination. The detailed explanation of CMC's load transfer mechanism due to structural load are described below (Combarieu, 1988):

1. The imposed load is transferred to the CMC through LTP. The vertical displacement of the soil occurs due to consolidation.
2. With the consolidation of the soil, vertical displacement of surrounding soil is larger than CMC, therefore generating negative skin friction along the CMC.
3. Vertical displacement of soil decreases gradually until equal to CMC (neutral plane), below neutral plane the vertical displacement of the soil is less than CMC at the certain depth, thus CMC are able to generate positive skin friction.

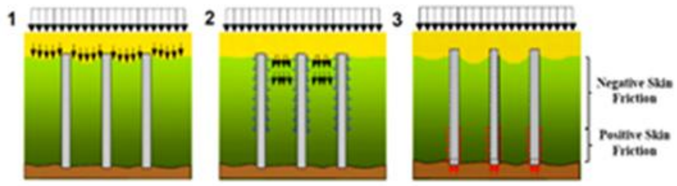


Figure 5. Load Transfer Mechanism (Plomteux,. et al., 2000)

The design concept of CMC should satisfy the principle of an equilibrium state of load distribution over the full length of CMC inclusions with the main components of acting forces:

1. The vertical load (Q) at the top of the CMC.
2. The negative skin friction (F_n) acting on the upper zone of the CMC.
3. The positive skin friction (F_p) acting on the lower zone.
4. The vertical reaction at the tip (Q_p).

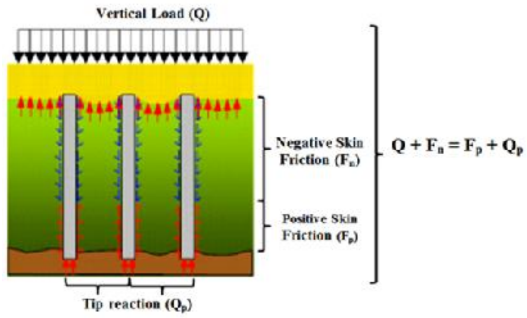


Figure 6. Force Equilibrium of CMC (Abuhuroyroh,. Et al 2014)

3.2 Load Transfer Platform (LTP)

Load Transfer Platform (LTP) is a well compacted clean granular fill placed over the CMC column to distribute the load from structural load to the CMC column. Another purpose is to provide stable working platform for rig movement during CMC installation. **Figure 7** describes typical cross section of CMC system.

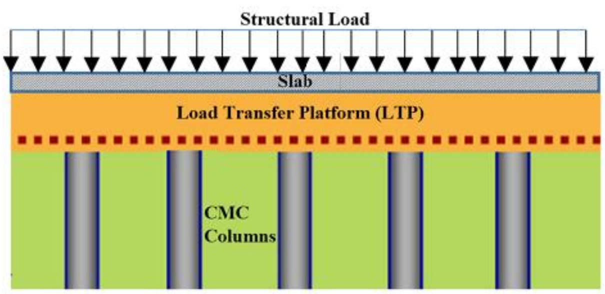


Figure 7. Typical Cross Section of CMC System (Abuhuroyroh,. Et al 2014)

The thickness of LTP shall be designed to transfer the load efficiently. The load transfer's efficiency is increasing with the thickness until optimum thickness. If the optimum thickness is exceeded, the thickness will become additional load. The efficiency is also influenced by the spacing between CMC and shear strength characteristic of LTP material (elastic modulus and friction angle). Typical thickness of LTP is commonly ranged from 0.3m to 1.0m. **Figure 8** illustrates load distribution mechanism within LTP.

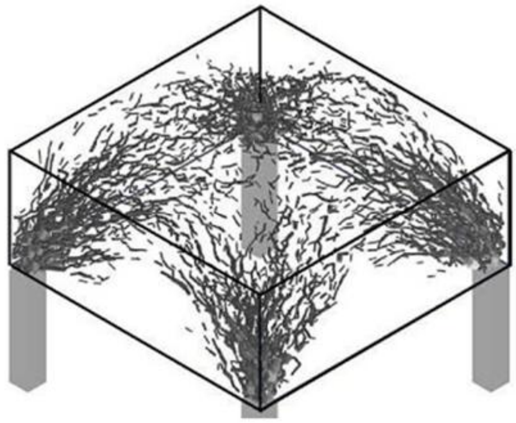


Figure 8. Load Distribution Mechanism with LTP (Asiri National Project, 2012)

3.3 Wiremesh

If horizontal forces caused by the active earth forces of an embankment are not fully dissipated, it is necessary to install a horizontal reinforcement at the embankment base, for additional safety measures. This reinforcement (usually in the form of geosynthetic or rebar-mesh) might also serve to limit lateral soil displacements and therefore any displacement of the inclusions.

ASIRI provide a guideline to compute the lateral forces of the embankment reinforcement (as illustrated in figure below). The maximum tensile force $T_{d;thrust;max}$ mobilized in the geosynthetic by the embankment lateral active forces is calculated below the embankment crest:

$$T_{d;thrust;max} = 0.5K_a(\gamma_\gamma . \gamma_r . H_R + 2\,\gamma_G . g + 2\,\gamma_Q . q).H$$

Where:

H_R: embankment height above the geosynthetic,
Ka: coefficient of active earth pressure of the embankment:
γ_r: unit weight of the embankment;
g: permanent excess vertical load;
q: variable excess load;
γ_γ: partial factor on the soil unit weight;
γ_G: partial factor on the permanent actions;
γ_Q: partial factor on the variable actions.

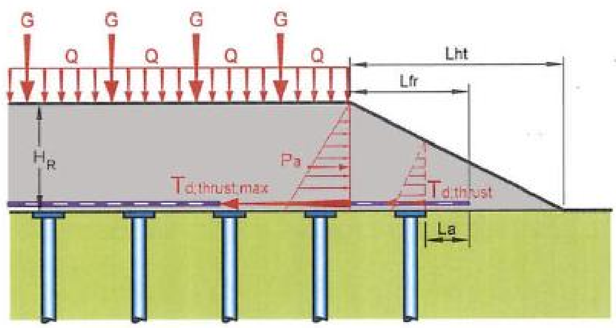


Figure 9. Configuration examined at the edge of the embankment (Asiri National Project, 2012)

Beneath the embankment slopes, the tensile force $T_{d;thrust}$ mobilized in the geosynthetic by the embankment lateral active pressure decreases with distance from the slope crest; this force may be calculated at any point based on the embankment slope and thickness above this given point.

It is also important to note that this configuration may also induce lateral displacements of the compressible soil capable of creating bending moments in the inclusions that also require verification.

3.4 CMC with Reinforcement

In cases where the force is large enough compared to the resistance capability of the CMC column to the lateral force, reinforcement needs to be added to the CMC column. The lateral force is normally found in is CMC near to the toe of the embankment slope.

An analysis of the calculation of resistance capabilities of the CMC column on lateral loads can be done with the following steps referring to BS EN 1992-1-1.2004 12:

1. Calculate the axial design load and design moment that work with the following equation

$$N_{ed} = N_{plaxis} \times spacing \times \gamma_G$$

$$M_{ed} = M_{plaxis} \times spacing \times \gamma_G$$

Where:

N_{ed}, M_{ed}	: axial and moment acting on CMC
N_{PLAXIS}, M_{PLAXIS}	: axial and moment obtained from Plaxis
Spacing	: Spacing of CMC
γ_G	: safety factor; 1.2 - 1.4

The axial load and bending moment are obtained from inner forces for every CMC columns as described at chapter 5.4

2. Calculate resistance CMC (N_{rd}):
   a. Eccentricity (e) with following equation $e = \frac{M_{ed}}{N_{ed}}$, illustrated as below:

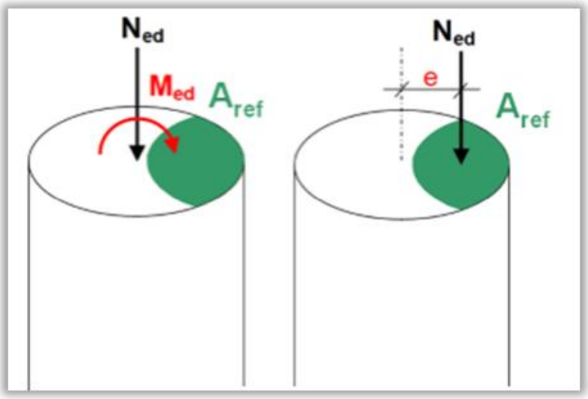


Figure 10. Illustration of Eccentrical Load Distance

   b. Calculate resistance area (A_{ref}) with following equation:

$$A_{ref} = R^2 \cdot (2\theta - \sin 2\theta)$$

$$\theta = \arccos\left(e/R\right)$$

Where:

e	: load eccentricity (m)
R	: radius of CMC column (m)

   c. Calculate resistance area (A_{ref}) with following equation:

$$N_{rd} = A_{ref} \cdot f_{cd}$$

where:

A_{ref}	: area resistance (m^2)
f_{cd}	: concrete strength, e.g. 20MPa

3. Check if reinforcement required:
   - If $N_{rd} > N_{ed}$, reinforcement not required
   - If $N_{rd} < N_{ed}$, reinforcement required
4. If reinforcement is required, then the CMC's reinforcement need to be designed using M_{ed}.

4. PROJECT CASE STUDY: UP BOJONG

4.1 Project Description

Pemalang-Batang Toll Road with 39.2-kilometer highway connects Pemalang with Batang Area, located in Central Java Province, Indonesia (**Figure 13**). The toll road is part of Trans-Java Expressway (**Figure 14** that connect Merak Port to Banyuwangi. The Pemalang-Batang Toll Road has 13 bridge approach, embankment near bridge with height ±6.0m, where 7 bridge approach is treated with CMC. One of the bridge approach treated using CMC methods are located at UP Bojong (STA 354+870) with estimated area 4,200 m^2.

The Pemalang-Batang Toll Road is planned to be used during Eid Al-Fitr, hence the construction of embankment need to be accelerated using CMC method. The design criteria to be achieved for ground improvement are listed below:

- The maximum allowable residual settlement shall be 100 mm after the 10 years of ground improvement
- The factor of safety against slope failure shall be equal or more than 1.5 static condition.
- The loading component shall be calculated from fill embankment soil from existing ground level to the final platform plus the 15 kPa traffic loading.

The following figure shows site condition prior installation of CMC:

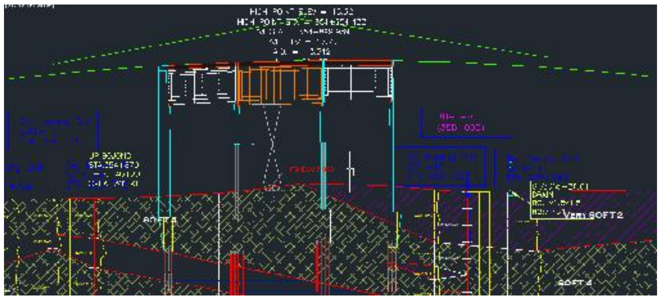


Figure 11. Section of Bridge and Embankment UP Bojong

Figure 12. East Area of UP Bojong

Figure 13. Indicative Location of Pemalang-Batang

Figure 14. Layout of Trans-Java Toll Road

4.2 Soil Condition

Additional soil investigation campaign consist of two boreholes and one CPT was conducted in 2017 by Menard to verify data consistency and provide more detail information for design purposes. **Figure 15** shows the location of additional soil investigation.

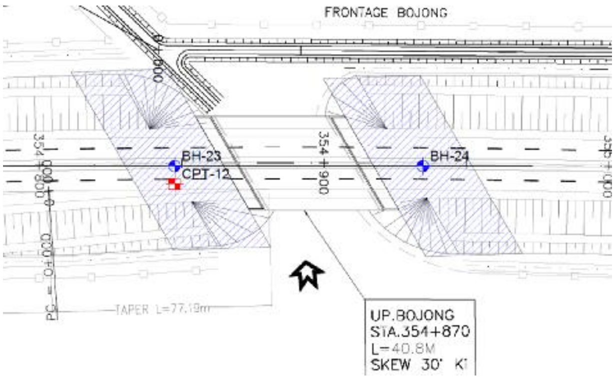


Figure 15. Location of Additional Soil Investigation.

The following table briefly summarized the elevation reference and ground water level for design purposes. For design, 8.0m fill thickness was used, while ground water level was conservatively assumed at 1.0m below existing level.

Table 1. Elevation Reference of UP Bojong

In situ test	Elevation EGL (+m)	Elevation FPL (+m)	Fill thickness to FPL (m)
BH-23	+7.2	+15.2	± 8.0 m
BH-24	+7.0	+15.0	± 8.0 m
CPT-07	N/A	N/A	N/A

Table 2. Ground Water Level of UP Bojong

In situ test	Elevation EGL (m)	Depth of GWL (m)	Elevation GWL (+m)
BH-23	+7.2	3.95	+3.25
BH-24	+7.0	5.6	+1.4
CPT-07	N/A	N/A	N/A

According to soil investigation results, a soft silt layer was observed at 6.0m depth from existing level; while stiff silt layer was found at ± 20.0m depth. The NSPT result, soil layering are shown below figure:

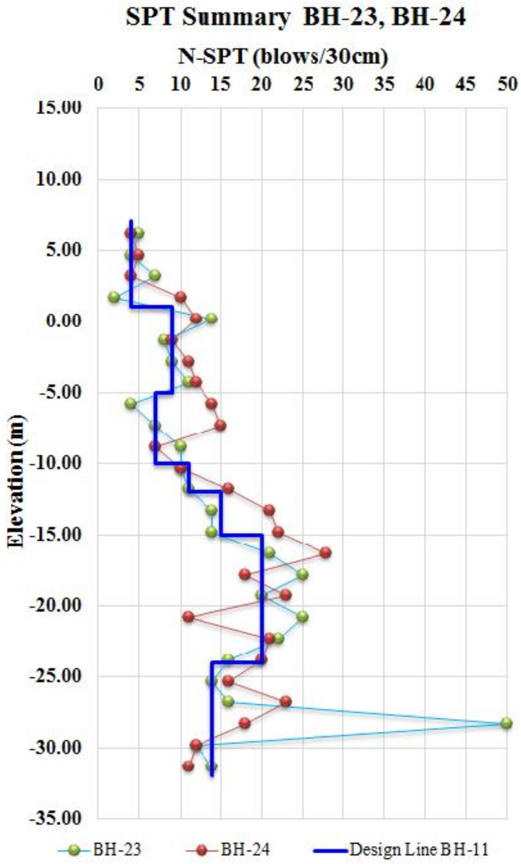


Figure 16. Combine Plot NSPT UP Bojong

Figure 17. Soil Stratification of UP Bojong

5. GROUND IMPROVEMENT SOLUTION

As described previously, CMC combined with additional wiremesh, and CMC reinforced steel was decided to support the high embankment. The material parameter used for analysis is summarized below:

Table 3. Parameter Design for UP Bojong (1)

No	SOIL TYPE	k (m/day)	¥ (kN/m³)	c' (kPa)	¤ ‘
1	LTP (Sirtu)	8.64×10^{-1}	19	1	35
2	SILT NSPT= 4	8.64×10^{-4}	16	5	20
3	SILT NSPT = 9	8.64×10^{-4}	17	5	20
4	SILT NSPT = 7	8.64×10^{-4}	17	5	20
5	SILT NSPT = 11	8.64×10^{-4}	17	7	21
6	SILT NSPT = 15	8.64×10^{-4}	17	7	21
7	SILT NSPT = 20	8.64×10^{-3}	17	7	21
8	SILT NSPT = 14	8.64×10^{-3}	17	7	21
9	Sand NSPT = 14	8.64×10^{-2}	17	2	30
10	SILT NSPT = 14	8.64×10^{-3}	17	7	21
11	Backfill				

Table 4. Parameter Design for UP Bojong (2)

No	SOIL TYPE	C_u (kPa)	E_{50} (kPa)	E_{oed} (kPa)	E_{ur} (kPa)
1	LTP (Sirtu)		35,000		
2	SILT NSPT= 4	20	3,000	2,400	9,000
3	SILT NSPT = 9	45	6,750	5,400	20,250
4	SILT NSPT = 7	35	5,250	4,200	15,750
5	SILT NSPT = 11	55	8,250	6,600	24,750
6	SILT NSPT = 15	75	11,250	9,000	33,750
7	SILT NSPT = 20	100	15,000	12,000	45,000
8	SILT NSPT = 14	70	10,500	8,400	31,500
9	Sand NSPT = 14	-	12,600	10,080	37,800
10	SILT NSPT = 14	70	10,500	8,400	31,500
11	Backfill				

The concrete strength used for CMC were 20 Mpa. While for material design used in PLAXIS calculate using following equation and summarized in table below:

$$E_{ref}(E_{50}) = 2700 \sqrt[3]{f28}$$

Where:
$E_{ref}(E50)$ = modulus elasticity of CMC, kPa
F_{28} = grout srength after 28 days, MPa

Table 5. Parameter Design for UP Bojong (2)

Steps	Analysis	Unit
Concrete quality	20	MPa
Modulus of CMC, E_y	7,329	MPa
E_y used for design	7,000	MPa

5.1 Ground Improvement Design Steps

The elevation reference and loading calculation is shown in **Figure 18**. The calculation was started from settlement analysis without ground improvement due to design load using Settle3D software. In this condition, the settlement due to embankment and traffic load exceed 100 mm. Ground improvement was required at bridge approach area, hence first step of CMC analysis shall be performed using Finite Element Method-axisymmetric to predict CMC single column behavior such as settlement and verification of compression capacity of CMC.

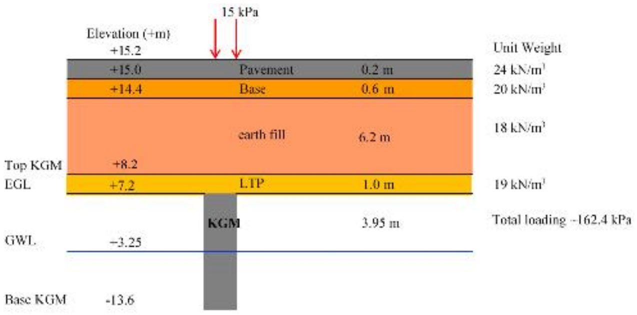


Figure 18. Cross Section of Embankment

The axisymmetric analysis serving as guideline to prepare further rigorous analysis using plane strain model. The finite element software, PLAXIS was used to analyze on plane strain condition with purposes to obtain settlement, factor of safety at slope, tensile forces acting along wiremesh, and inner forces within CMC columns. All the input from plane strain analysis let the designer to design wiremesh and cmc with reinforced steel. All the calculation procedure is summarized in following table:

Table 6. Calculation Procedure of CMC for High Embankment

Steps	Analysis	Method	Purposes
1.	Settlement Without ground improvement	Elastic Method-Software Settle3d	1. Settlement
2.	Settlement With ground improvement	FEM-Axisymmetric – PLAXIS 2D	1. Settlement 2. Stress acting in CMC
3.	Slope stability	FEM- Plane Strain – PLAXIS 2D CMC – using Embedded Pile Row	1. Settlement 2. Factor of safety against failure. 3. Tensile load on wiremesh 4. Inner force in CMC
4.	Wiremesh design	FEM- Plane Strain – PLAXIS 2D Wiremesh equation checking	Wiremesh configuration (Chapter 3.3)
5.	CMC with rebar design	FEM- Plane Strain – PLAXIS 2D Rebar equation checking	Rebar configuration (Chapter 3.4)

5.2 Settlement Analysis-Without Ground Improvement

Analysis Settle3D analysis was performed using information from **Figure 18** and parameter from **Table 3** and Table 4. The settlement of bridge approach due to embankment load and traffic load without ground improvement ranged from 600 to 800 mm which exceed settlement criteria 100 mm. The analysis result is illustrated at below figure:

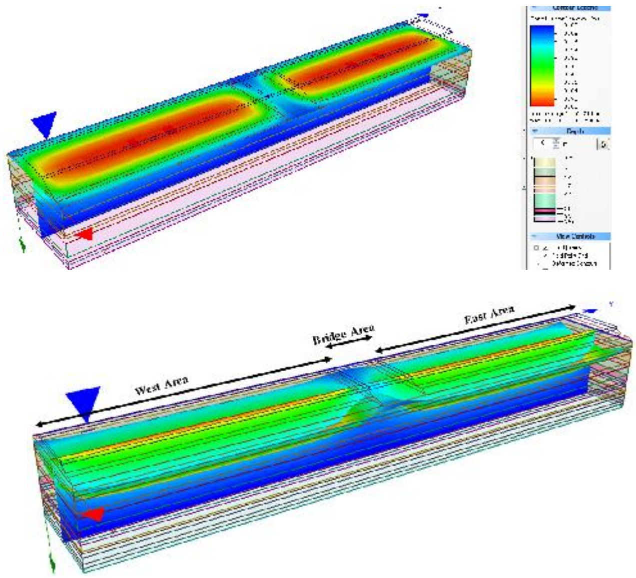


Figure 19. Settle3D Model

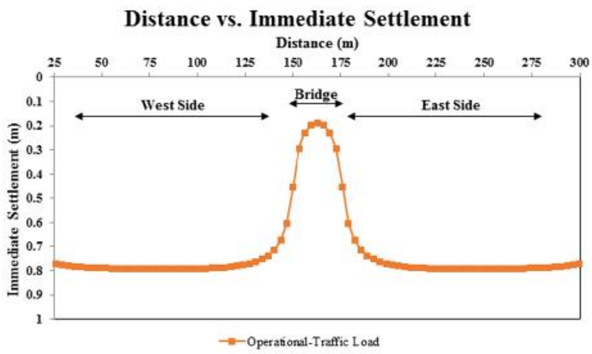


Figure 20. Settlement Curve- Without Ground Improvement

5.3 Axisymmetric Model

Where the settlement of bridge approach without ground improvement were exceeding 100 mm, the CMC was planned to increase soil stiffness, thus reducing the settlement below 100 mm. Construction sequence for axisymmetric analysis are listed as below. The construction period at FEM analysis was determined conservatively, the actual construction process require longer period than analysis.

1. Initial phase
2. CMC installation – 7 days
3. LTP Installation using sirtu with additional rebar – 7 days
4. Backfilling process to embankment final level – 30 days
5. Applying of operational load – 10 years of service period.

The settlement obtained using axisymmetric model was 99 mm, less than 100 mm (**Figure 21**). It should be noted that settlement obtain using axisymmetric model are conservative due to all loading on the top is fully distributed to the bottom of model. The compression stress acting within CMC column was 5.2 MPa. ASIRI, 2012 limited the compression stress on CMC shall be column shall be less than 7 MPa.

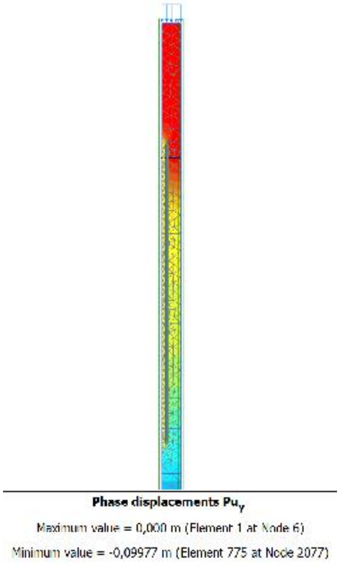


Figure 21. Settlement Result – Axisymmetric Model

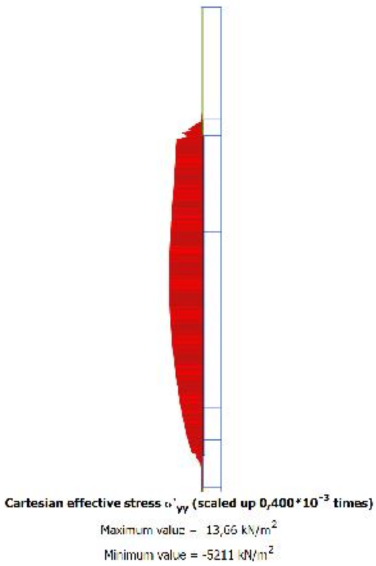


Figure 22. Compression Stress on CMC Column

5.4 Plane Strain Model

The main purpose of plane strain model is simulating global behavior of embankment supporting by CMC. Therefore, analysis output such as settlement and compression stress acting within CMC column shall be compared with axisymmetric model.

After several trial and error, the maximum settlement obtained from plane strain analysis was 95 mm, which closed to axisymmetric model, 99 mm. For compression stress checking, the maximum axial forces acting on CMC column was 337.9 kN/m (**Figure 25**) that generated pressure 5.367 MPa, which is close to axisymmetric model output. The safety factor against slope failure was analyzed for short term and long term; 1.543 and 1.703, more than minimum value of 1.5 (**Figure 26** and **Figure 27**).

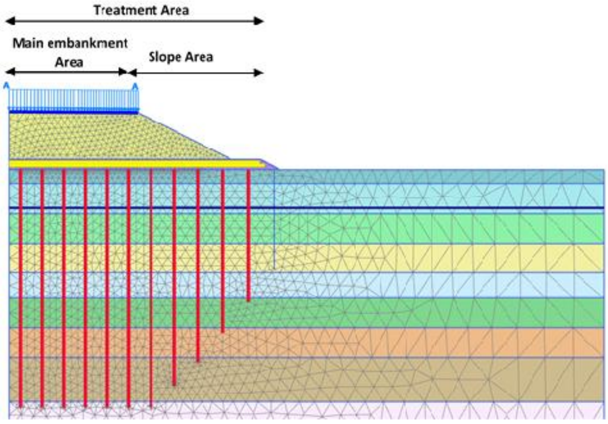


Figure 23. Typical Plane Strain Model

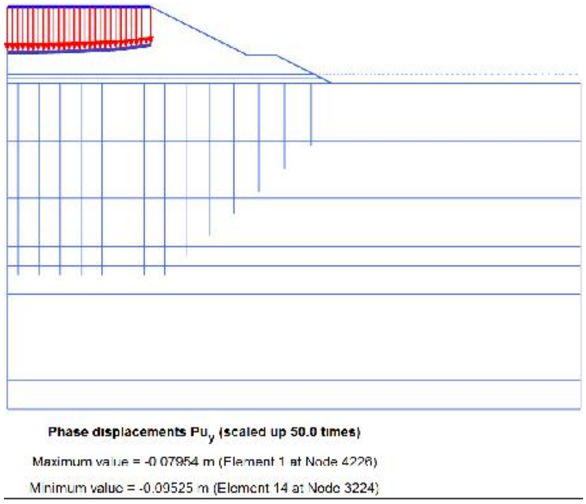


Figure 24. Settlement Result – Plane Strain Model

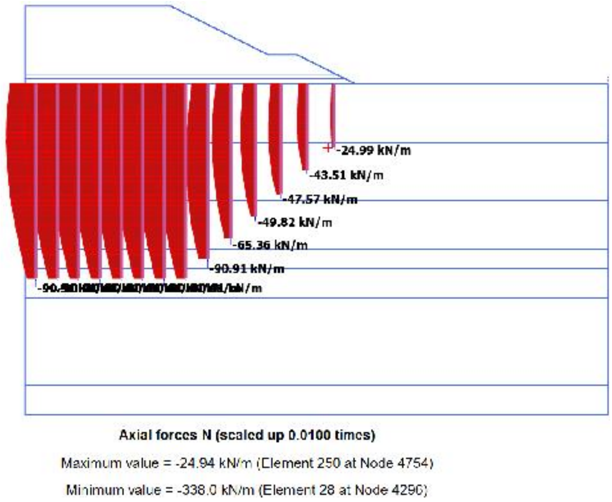


Figure 25. Axial Forces CMC Column

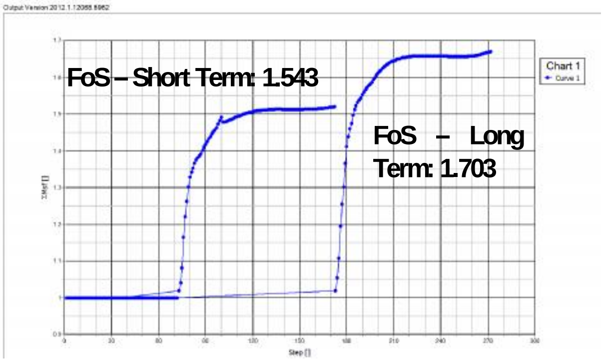


Figure 26. Factor of Safety Against Slope Failure

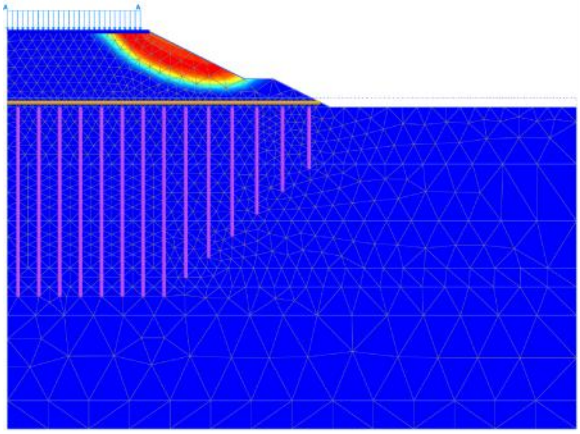


Figure 27. Location of Slope Failure

5.5 Wire Mesh Design

Designing wire mesh was conducted in plane strain model, where wire mesh was simulated using geogrid model. From the analysi, maximum tensile forces acting along wire mesh was 241 kN/m (**Figure 28**). Therefore, the configuration of required wire mesh was determined using equation below:

$$R_{tT} = \frac{f_e}{\beta} . n . \frac{\pi . d_y^2}{4}$$

Where:
f_e = stress yield stress, kPa
n = number of steel bars per meter
dy = bar diameter in longitudinal section, m = 0.008m
spacing = 0.15m

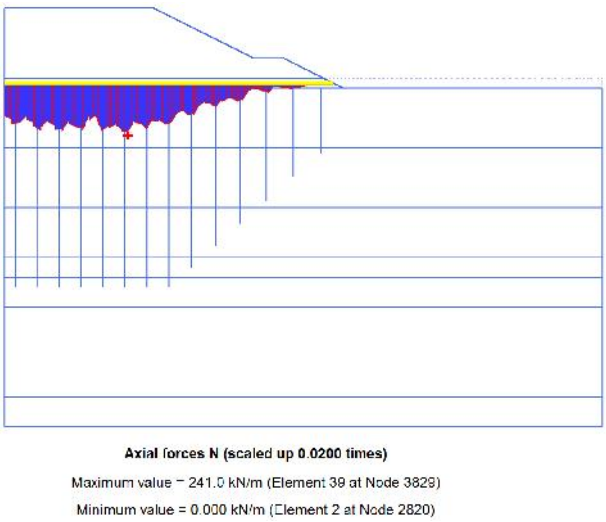


Figure 28. Tensile Forces Acting along Wire Mesh

5.6 Checking CMC Required Reinforced Steel

The bending moment and axial force inside the KGM is limited to certain value to ensure limited strain envelope inside the CMC. The procedure to check limit of axial and bending is using BS EN 1992-1-1:2004 §12. The axial forces and bending moment forces for each CMC column were obtained from FEM model (**Figure 25** and **Figure 29**).

From the rebar checking, we conclude that rebar is required to be placed inside the CMC for two outer most CMC columns.

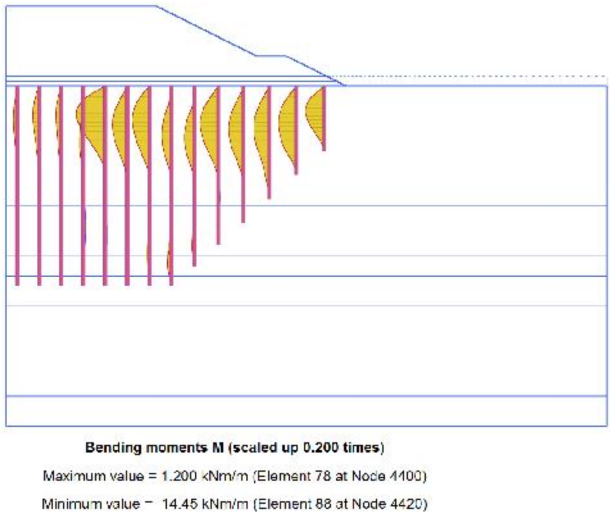


Figure 29. Bending Moment Forces Acting on CMC Column

5.7 Configuration of CMC

After conducted all the analysis, the optimum design configuration for CMC at UP Bojong are illustrated and summarized below figure:

- Diameter: 42 cm
- Length KGM 6 to 11 are 20m, KGM 1 to 4 varies from 8.5m to 20m
- 2 layer of Steel wire mesh 8mm diameter with grid 15cm x 30cm
- Compacted gravel sand (sirtu) 1m thick

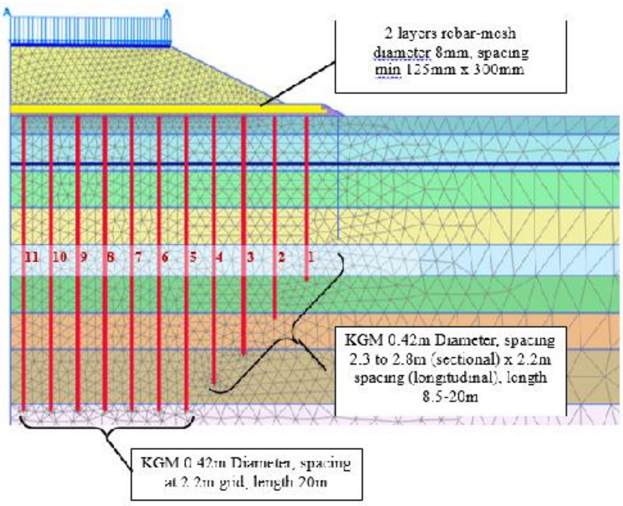


Figure 30. CMC Design for UP Bojong

6. QUALITY CONTROL

Several quality control program was conducted to ensure material and installation quality consist of:

1. Prior installation of CMC
   - Workability criteria: using flow table test, with concrete after 3 hours to ensure pumability of the grout during injenction.
   - Strength criteria: using compressive test after 28 days.
2. During installation of CMC
   - On board quality systems to monitor pumping pressure, drill pressure, installation depth, date of installation, etc.

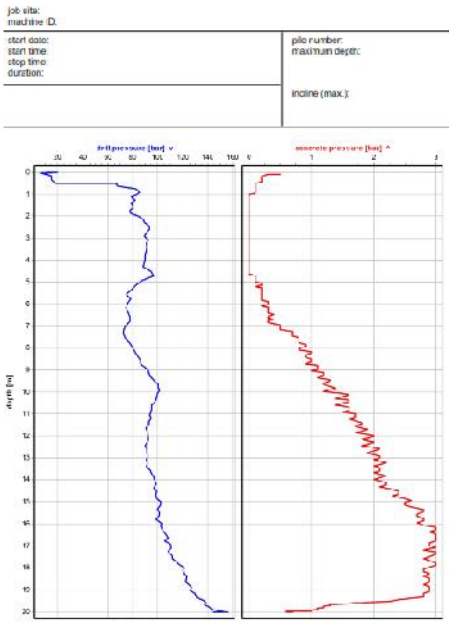


Figure 31. Example of On Board Quality System Output

3. After installation
   - Vertical Plate Loading Test (PLT) is perfomed with several purposes:
     - Verification design assumption: soil condition, parameter design
     - Verification construction procedure: drilling pressure, penetration speed, etc
     - Confirmation the achievement of design criteria

   The typical setting up of PLT and testing result of Bojong are illustrated at following Figures 32 and Figures 33. The settlement obtained during 100% load is 16 mm, less than 100 mm. This value indicated the soil condition, parameter design, concrete quality, construction procedure such as drilling pressure, penetration speed is appropriate to be applied in this area.

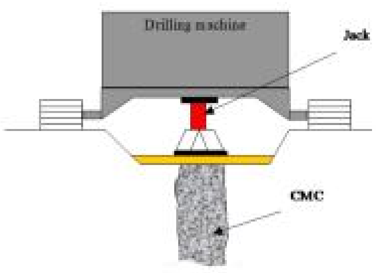


Figure 32. Setting Up of PLT / Vertical Plate Loading Test

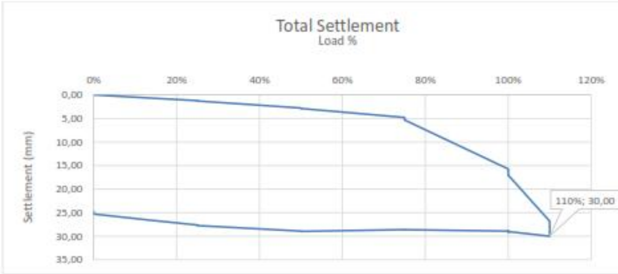


Figure 33. Settlement Vs Load for PLT Test at UP Bojong

7. CONCLUSION

- Ground improvement using CMC was installed to increase global stiffness of the soil, thus reducing the settlement to acceptance limit.
- The application of CMC on toll road project is first time in Indonesia.
- Quality control programs was perfomed in CMC project to ensure the installation quality.
- The design concept and analysis procedure are briefly described in this paper.

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